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VIA ELECTRONIC FILING
Marlene H. Dortch, Secretary
Federal Communications Commission
445 Twelfth Street, S.W.
Washington, DC 20554

RE: In the Matter of
Public Safety Network in the 700 MHz Broadband
PS Docket No. 06-229 / RM-11348
WT Docket Nos. 06-150, 06-169 and 96-86
Ex Parte Presentation

Dear Ms. Dortch:

On behalf of Cyren Call Communications Corporation ("Cyren Call"), and in accordance with Section 1.1206(b) of the Commission's Rules, 47 C.F.R. § 1.1206(b), undersigned counsel hereby submits the instant notice of an *ex parte* presentation.

This will confirm that Cyren Call has provided the attached documents to both John Branscome, Division Chief, Spectrum & Competition Policy Division, Wireless Telecommunications Bureau and Jeff Cohen, Senior Legal Advisor, Public Safety & Homeland Security Bureau.

Kindly refer any questions or correspondence regarding this matter to the undersigned.

Very truly yours,

/s/

Elizabeth R. Sachs
Counsel to Cyren Call
Communications Corporation

Enclosure

cc: John Branscome
Jeff Cohen

ATTACHMENT 1

Determining Traffic Asymmetry of Future Mobile Services

E. M. Healy and T. J. Young

Telecompetition, Inc.

Abstract

This paper discusses an offered traffic model and output that analyzes aggregate traffic results in a multi-service environment. The focus is on future (2010) mobile networks where a single service (voice) will no longer dominant. Instead there will be a mixture of many services and activities. Results include both a composite diurnal traffic distribution and offered traffic asymmetry. This paper demonstrates that, in aggregate, this traffic will be asymmetric to the downlink. This work builds upon a series of market analyses of next generation service opportunities published by the UMTS Forum and Telecompetition, Inc. It uses the service framework used by the UMTS Forum, 3GPP, OMA and other organizations.

Traffic Model

The model uses the UMTS Forum Service Framework that includes six service categories:

- Mobile Intranet/ Extranet Access
- Customized Infotainment
- Multimedia Messaging
- Mobile Internet Access
- Location-Based Services
- Rich and Simple Voice

While actual services offered by mobile operators may bundle a number of capabilities and services, the framework will "force" any individual service under analysis into only one category, thus eliminating the potential for double counting traffic.

The model employs a bounded top-level forecasting methodology. That is, a determination is made of a reasonable maximum level of demand, and all other service forecasts are calculated as a subset of that top-level number. In this manner, all service forecasts are assured of fitting within a reasonable frame of reference.

Each service variable has a number of allowed states. For example, the terminal type might be either high complexity or low complexity. Each state will drive assumptions about the traffic. Only a subset of all the possible service variable states will be practical for the services studied. The service variables and states are shown in Table 1.

Table 1. Allowable states for each service variable in the traffic model.

Location Profile	Cell, city, country, region, worldwide
Subscriber Profile	Urban, suburban, rural
Connectivity Type	Machine to machine, people to people, people to machine
Market Segment	Consumer (by age & income) and Business (19 occupations and 20 industries) plus mobile, Internet and cable penetration, GNP, etc.
Media/Activity Type	Video, image, text, email, gaming, browsing, streaming, etc.
Network Cases	Mobile to mobile, mobile to fixed, fixed to mobile
Contact Type	One to one, one to many
Terminal Type	Low complexity, high complexity
Transmission Mode	One way, two way
Service Level	Restricted, normal

Source: Telecompetition, Inc. and UMTS Forum, Report 33, Nov. 2003.

All of these service states impact uplink and downlink traffic. Most are self-explanatory. The rest are explained below:

Baseline - Location Profile

While the model can use a wide variety of locations, the total traffic presented in this paper is based on the mobile subscribers in San Francisco in the year 2010.

Baseline – Subscriber Profile

The subscriber profile includes primarily dense urban and urban along with some suburban subscribers. No deployment in rural areas is considered.

Media / Activity Types

Traffic varies by the activity or service in use. For example, while gaming and file downloads are both activities that a subscriber can engage in they each have distinct traffic characteristics and therefore the uplink and downlink traffic is calculated independently. Similarly, text and video are two different media types that result in different traffic loads. Thirty-six different Media / Activity types are analyzed in the model.

Network Cases

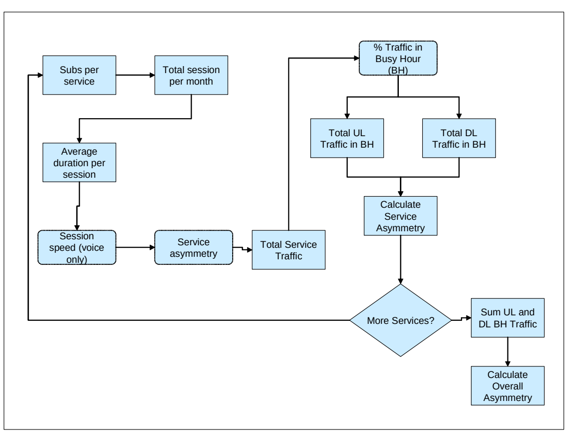
This service variable identifies the originating and termination networks. The network case affects the uplink and downlink traffic.

Service Levels

Carriers may offer premium or restricted services and varying their pricing accordingly. This will influence Quality of Service (QoS) parameters, such as latency, data rate and priority. In turn, this will affect network loading (hence spectrum demand), particularly at the busy hour.

For each service variable and state identified for analysis, busy hour and total traffic per subscription and per session are calculated. The basic calculation flow is shown in Figure 2. This framework is used for the calculations shown in later sections, with some variation for individual service differences. In the framework, monthly sessions or messages are used as subscribers are typically billed on a monthly basis. Daily traffic is estimated based on the number of days per month the service would be used. (Typically, consumer services assume 30 days per month while business services assume 22 days per month in use). The percentage of traffic in the busy hour is calculated based on the assumed percentage of traffic in the busy hour.

Figure 2. Traffic analysis framework.



Service Assumptions

This report analyses all the service categories shown in Table 3. Table 3 provides the specific definitions of each service category.

Table 3. UMTS Forum Service category descriptions.

Service Category	Service Description	Market Segment
Mobile Intranet /Extranet	Secure mobile access to corporate LANs, VPNs, and the Internet.	Business
Customised Infotainment	Access to personalised content via mobile portals.	Consumer
Multimedia Messaging	Non-real-time messaging for user groups and machine-to-machine telemetry.	Consumer and Business
Mobile Internet Access	Mobile access to Internet content.	Consumer
Location-Based Services	Service to find location and contextual info about people, machines, assets and services.	Consumer and Business
Simple and Rich Voice	Real-time voice services including features and operator services. Videoconferencing, voice-activated Internet access, and voice with multimedia content.	Consumer and Business

These service categories have very distinct definitions that are important considerations in analysing traffic. For example, MMS is non-real-time and one-way, while Rich Voice is real-time and two-way.

Mobile Penetration

The mobile traffic forecasts in this report are built upon a foundation of extensive market analysis of mobile service opportunities. The underlying revenue, subscriber, and usage relationships are the starting point for the traffic analysis. The following maximum usage assumptions for the representative geography are the basis for the peak load and busy hour calculations in this report:

– Maximum mobile penetration is 90% of population.
– Maximum advanced service penetration is 60% of mobile subscribers.[I]

Mobile Usage

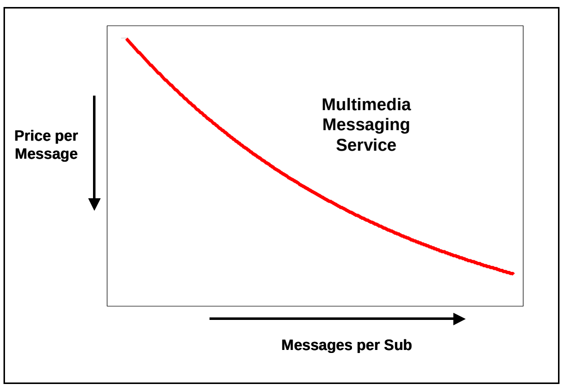
Service adoption and usage volume are highly influenced by service price. Typically the number of subscribers and the usage volume of those subscribers will increase as price decreases. There is, however, a limit on how much subscribers will use a service regardless of the price.

[I] 60% represents the bulk of subscribers that generate traffic on a consistent basis. Also, the "maximum" penetration is less than 100% of mobile subscribers to take into consideration geographic areas that may not be served by 3G networks (e.g., rural areas) and portions of the mobile population that do not use any mobile data services (such as the very old, the very young, or economically disadvantaged people).

Conservative assumptions and reasonability governed the forecast analysis process. At no time was it assumed that premium pricing or above-normal usage is attributed to service adoption. For example, price points used in the forecasts for MMS and Rich Voice represented a reasonable willingness to pay for existing services or substitute services. In general, volume usage for any service category was predicted to increase as per unit prices decreased. Reaching "maximum" penetration and usage levels described above, presumes a relatively low price level for mobile data services relative to current pricing.

Figures 4 and 5 illustrate the shape of the price demand curve for MMS and Rich Voice, and are representative of the analysis conducted for each service category

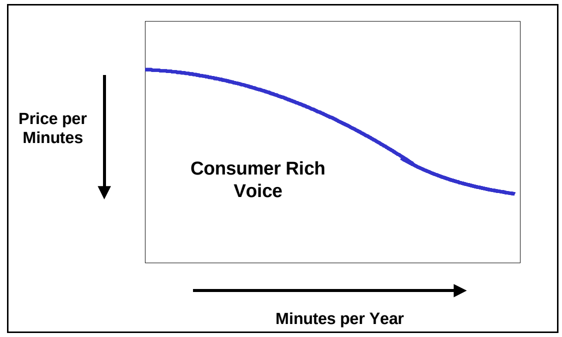
Figure 4. Price demand relationship – Multimedia messaging (MMS).



Source: UMTS Forum, Report 33, Nov. 2003.

Because a full Rich Voice is a higher priced service, not commercially available for a few years, the adoption rate does not reach the same penetration levels as does MMS. Only 25% of users will have subscribed to Rich Voice as apposed to almost 60% subscription levels for MMS. The shape of the curve for Rich Voice also shows service volume is less sensitive to changes in price than is MMS.

Figure 5. Price demand for Rich Voice.



Source: UMTS Forum, Report 33, Nov. 2003.

Simple Voice

There is a long history of analyzing traffic data for both fixed and mobile voice. Mobile voice has tended to be concentrated in commute hours. However, since traffic was modelled in the future where there will be more substitution of mobile phones for landline phone, a traffic distribution with traffic concentrated in the evening hours was used.

Mobile voice traffic for business subscribers is more concentrated in the business hours of 8AM to 6PM. However, there is still business voice traffic through the day.

Multimedia Messaging Service (MMS)

Consumers use MMS more for recreational and personal interaction. Thus, consumer MMS traffic is more concentrated in the evenings than is business traffic.

The traffic distribution does not vary by the type of message, network, or terminal used. Subscribers use the service when they desire, using whatever terminal or network access is available to them at that time. The decision to send a photo or a video clip is based on the personal circumstances or situation of the subscriber, not on the hour of the day.

Rich Voice

Rich Voice can most simply be thought of as videoconferencing. Rich Voice subscribers incorporate the service into routine business processes. Since this service is real-time and either one-to-one or one-to-many, it is assumed only to be used when business users are available during the 8AM to 5PM window.

Consumers use Rich Voice more for recreational and personal interaction. Thus, consumer Rich Voice traffic is more concentrated in the evenings.

The busy hour does not vary by the type of message or network. Subscribers use the service when desired; using whatever terminal or network access is available to them at that time. The type of terminal capabilities and the needs of the situation determine whether the consumer will use a higher or lower resolution service.

Business and consumer Rich Voice subscribers will have the ability to choose a restricted (lower speed) rather than a basic class of service for individual calls.

Mobile Internet Access

As a consumer service, Mobile Internet Access would be used similarly as Simple Voice service, with traffic concentrated in the evening hours.

Mobile Intranet Extranet Access

Businesses use Mobile Intranet Extranet Access during business hours. The percentage of traffic in the busy hour is 8.6%.

Location-Based Services

Location-Based Services are used by both consumer and business subscribers so the traffic is distributed throughout the 24 hour period as shown in Figure 6.

Tracking services such as vehicle tracking are based on periodic polling of the device attached to the person or asset being tracked. Hence, the traffic distribution is flat throughout the day. The volume of data for each polling event is very small.

Diurnal Traffic Distributions by Service Category

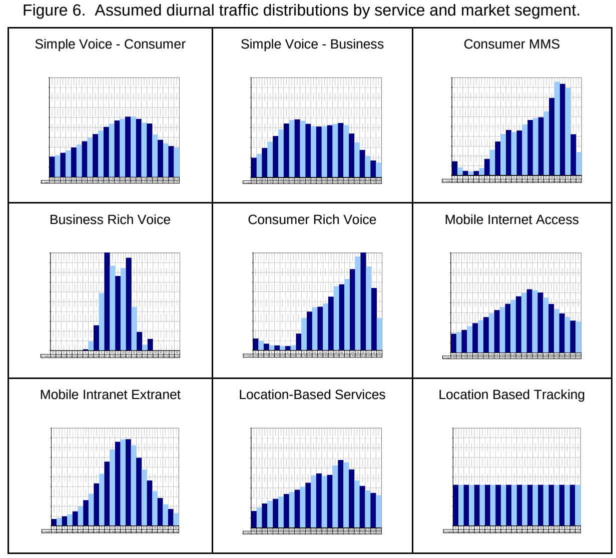
The traffic distributions are based on historic carrier data where available. Assumptions about future usage for services with no historic basis are detailed along with the distribution chart for that service category. In some cases, multiple distributions were required when service with very different media/activity types were calculated.

In all cases, each distribution chart shows traffic by hour in a 24 hour period. Simplifying assumptions were made so that only Business days were considered (Monday through Friday). Traffic on weekends and holidays could vary substantially. Since consumer and business behavior is different, separate distributions were generally used for each market segment. The percentage of the daily traffic in each hour is calculated based on these distributions and the percentage in the busy hour is used to calculate the total busy hour traffic. All traffic for each hour is also calculated allowing an aggregate busy hour to be identified.

The traffic model can vary these traffic distributions based on actual carrier data. These distributions represent an average distribution since the results shown in this paper are for all carriers within a geographic area.

Figure 6 shows selected traffic distributions to provide the reader with insight as to how the overall busy hour traffic and asymmetry was analyzed.

Figure 6. Assumed diurnal traffic distributions by service and market segment.



Source: UMTS Forum, Report 33, Nov. 2003.

Offered Traffic Loads

Based on the San Francisco Bay Area in 2010[II], the following tables show the resultant traffic loads. The total daily and busy hour traffic is the sum of uplink and downlink traffic.

[II] CSMA – Consolidated Statistical Metropolitan Area.

Table. 7. Total daily and busy hour traffic for San Francisco in 2010. [iii]

Service Category	Total Daily (TBytes)	Total Traffic in Service Busy Hour (TBytes)
Multimedia Messaging Service	0.9	0.06
Rich Voice	4.1	0.63
Customised Infotainment	4.0	0.28
Mobile Internet Access	3.5	0.22
Mobile Intranet/Extranet Access	11.4	1.00
Location-Based Services	0.1	0.01
Simple Voice	14.8	0.83
Total	**38.8**	**3.09**

Composite Traffic Distributions

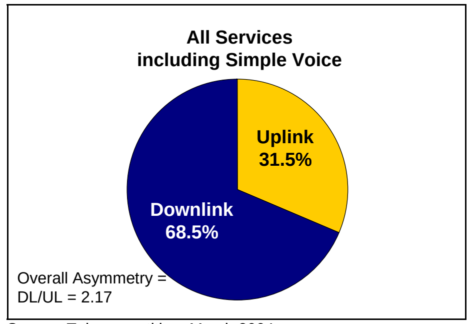
Table 8 shows the sum of service traffic. Here the worst case is presented where the peak traffic for each service falls in the same hour.

Table 8. Total service busy hour traffic.

Total Busy Hour Traffic	Subs	Uplink (TBytes)	Downlink (TBytes)
3G Subscribers (in millions)	3.8		
3G Consumer Subscribers	2.2		
3G Business Subscribers	1.7		
Total Busy Hour Traffic		**0.97**	**2.12**

Most individual services are highly asymmetric, with the exception of Simple/Rich Voice and MMS, which are fairly symmetric. To calculate the aggregate asymmetry over all service categories, the sum of the total downlink traffic in the aggregate busy hour was divided by the total of the uplink traffic in the aggregate busy hour. An asymmetry of 2.17 was calculated when Simple Voice service, which is symmetric, was considered.

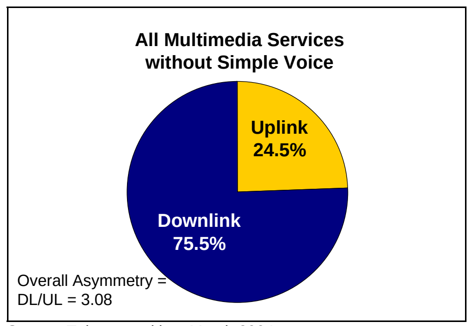
Figure 9. Total offered traffic asymmetry during the aggregate busy hour with voice for San Francisco Bay Area in 2010.



Source: Telecompetition, March 2004.

Since most voice is a symmetric service, it is useful to look at the asymmetry without voice. While the overall asymmetry increases, it does not increase significantly.

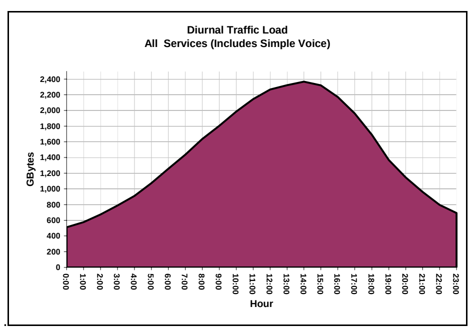
Figure 10. Total offered traffic asymmetry during the aggregate busy hour without voice for San Francisco Bay Area in 2010.



Source: Telecompetition, March 2004.

Figure 11 shows the combined traffic with Simple Voice. The horizontal axis is divided into 24 hours showing the traffic starting at midnight.

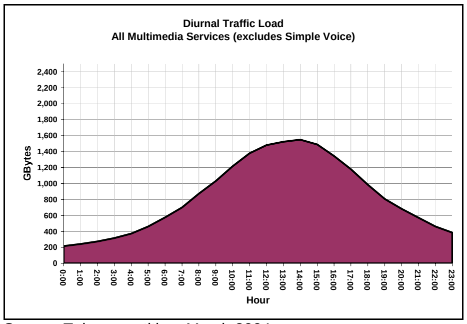
Figure 11. Total diurnal traffic distribution – aggregate busy hour for the San Francisco Bay Area in 2010.



Source: Telecompetition, March 2004.

Similarly, total traffic without voice was analyzed to determine the impact of voice.

Figure 12. Total diurnal offered traffic without voice for the San Francisco Bay Area in 2010.



Source: Telecompetition, March 2004.

As shown in Figures 11 and 12, the overall busy hour takes place in the 1400 hour. The aggregate busy hour is more representative of the actual traffic a network operator will experience.

Conclusions

Traffic engineering in future mobile networks will be complicated by the many multimedia services that will be delivered over a single network. This paper discusses a new offered traffic model and two aspects of these future services: traffic distributions and service asymmetry. At a macro level service asymmetry of between 2 and 3 can be expected. The mix of services in a given geographic area will be an important consideration in traffic engineering. Based on the service asymmetry results presented, the range of service level asymmetry is 1 to 6.7. Each service will contribute its own distinct diurnal traffic distribution and a composite distribution along with each service QoS requirements will need to be considered to engineer efficient public mobile networks.

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Biographies

E. M. Healy is President and CEO of both Healy & Co and its affiliate, Telecompetition, Inc., Eileen combines hands-on creative experience to build network projects that have been some of the company's most successful initiatives. Her experience ranges from engineer to industry analyst at such well-known companies as SBC Pacific Bell and the Gartner Group. Eileen has served as Vice-Chairman of ANSI's committee T1X1 where she successfully worked to reach agreement on SONET / SDH standards. Eileen holds a BSEE degree from U.C. Berkeley.

T.J. Young is VP Marketing for Telecompetition, Inc. and brings a market perspective and re-focuses projects on the realities of customer needs and competitive conditions. Terry has extensive experience in sales and marketing as well as strategic, competitive, and market analysis for large public carriers, specializing in the areas of emerging technology market assessment. The combination of strategic analysis and customer facing sales experience brings real world balance to strategic vision. Terry has an MBA from Arizona State University.

Acknowledgements

Some of the work described in this paper was funded by the UMTS Forum. Experts from the Spectrum Aspects Group of the Forum chaired by Anne T. Leino from Nokia supported this work. More detail along with the full text of Report 33 can be found at the web site www.umts-forum.org.

ATTACHMENT 2

Report No. 33
Report from the UMTS Forum

3G Offered Traffic Characteristics

Final Report

UMTS Forum, November 2003

One of the key issues currently occupying the minds of the UMTS Forum's Spectrum Aspects Group (SAG) is that of the nature of the traffic that will flow across the UMTS networks, and how the characteristics of the expected traffic (especially its uplink/downlink asymmetry) might affect spectrum arrangements. The initial focus of this SAG work is in relation to the possible frequency arrangements for the 2500-2690MHz band. The SAG group has created a sub-group (the Ad-hoc Group on Traffic Characteristics) to gather information on traffic characteristics. This is a challenging task as there is little historical experience of the varied multimedia, content, messaging and internet/intranet services that will be supported by UMTS. To underpin this activity the UMTS Forum has commissioned this study of the likely characteristics of the traffic that might be offered to the UMTS networks. The study, by Telecompetition Inc, was undertaken under the active guidance of the SAG Ad-hoc Group, and the work is based on the six services identified if the earlier UMTS Forum Reports on the revenue opportunities for UMTS (UMTS Forum Reports #9 and #13). This Report is a significant input to the ongoing work of the Spectrum Aspects Group, and it will be used alongside inputs provided by the Forum's members and material from other appropriate sources. However, as it is believed that the topic of traffic characteristics is of general interest to the Forum's members, the document is being issued as a UMTS Forum Report.

This report follows on from other reports which have dealt with: a regulatory framework, and spectrum and technical aspects, impact of licence cost levels, licensing conditions, minimum spectrum requirements, an extended vision, market forecasts, and other issues. Reports on these and other topics are listed in the Bibliography and can be found on the UMTS Forum Web site, www.umts-forum.org/reports.html.

The following UMTS Forum members contributed in the preparation of this report:

The Spectrum Aspects Group (SAG) Ad-hoc Group of Traffic Characteristics:

Tim Hewitt, BT (Ad-hoc Group Chairman)	Krister Bjornsjo, TeliaSonera
Adriaan Brinkerink, ERO	Rauno Ruismaki, Nokia
Christoph Legutko, Siemens	Sabrina Saudai, Bouygues Telecom
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TABLE OF CONTENTS

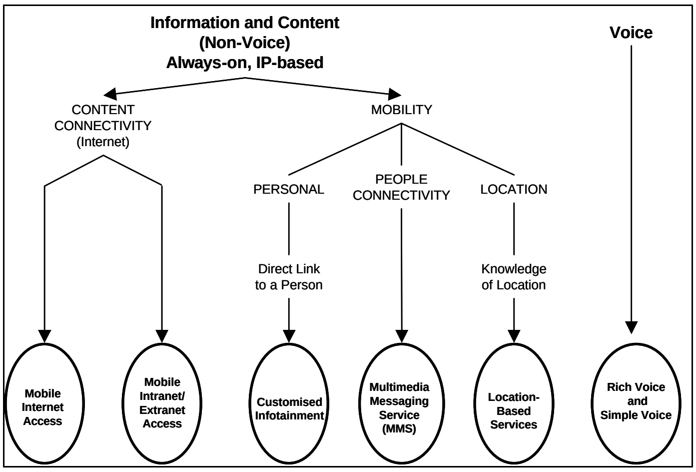
1 Introduction

The purpose of this study is to provide a first estimate of the offered traffic characteristics for UMTS/3G network, in particular how these translate into uplink and downlink requirements. When reviewing all mobile aggregate traffic, 2G traffic, which is outside the scope in this report, should also be taken into account. Whilst there are clearly many unknown factors, this study provides a reasonable picture of the offered traffic of future 3G services.

Most of the mobile services studied do not currently exist. These results are therefore dependent upon the service assumptions made. A sensitivity analysis determined which assumptions had significant impact of the aggregate results. Those assumptions are presented.

This study builds upon previous market analysis work completed by the Forum, using the services category framework shown in Figure 1.1[1]. This framework includes all anticipated possibilities for 3G services. The framework cleanly segments the services by user segment, type of functionality, and connectivity. Its specific design is broad enough to include new individual service concepts while at the same time, eliminate double counting of revenue and subscribers.

Figure 1.1. 3G services framework with its six service categories.



Source: UMTS Forum and Telecompetition, Inc., Report 13, September 2000.

The use of this framework along with the underlying subscription forecasts from previous UMTS Forum market studies prevents double counting of traffic volume and ensures consistency with market forecasts using a representative mix of service types for study.

1.1 Service Traffic Characteristics Defined

Service traffic characteristics describe the unrestrained end user traffic offered to the UMTS/3G network; not considering network imposed asymmetry or other hardware and software limitations or remedies (such as traffic caching). Service traffic characteristics therefore refer to the expected nature of the traffic offered to the network, not the actual traffic characteristics over the air interface. No impediment to the build up of traffic is considered (such as the non-availability of devices or spectrum). The traffic loads are based on forecasted traffic in 2010, after networks have been deployed for more than five years.

Traditionally, the examination of service traffic for the purposes of spectrum calculations has only considered the technical characteristics of a particular application or service. For example, the spectrum requirements for voice have simply considered the speech coder characteristics (i.e. data

[1] The UMTS Forum services category framework was originally presented in Report 9, and used as the basis for service forecasts in Reports 9, 13, and 17.

rate), the spectrum efficiency of the modulation scheme and network and the predicted offered traffic. This was possible in the past, because circuit-switched voice service is symmetric and only the bulk traffic was taken into account.

Mobile multimedia services, however, introduce new challenges, such as traffic asymmetry, driven by the wide variety of multimedia-based activities available to the user. For example, web browsing typically has much more traffic coming to the user (downlink) than from the user (uplink). Telecompetition's *ATIVA Research Tools*, which analyse the "propensity to buy" for any given service enables the determination of unrestrained traffic demand, taking into account a number of variables, which are explained below. Thus, the methodology adopted incorporates this variety of activities and service variables in a way that relates them to their forecasted market demand.

Specifically, in this report, service traffic characteristics includes all traffic that end users would offer the network based upon baseline location and subscriber profiles plus seven service variables and states,[2] shown in Figure 1.2. This is the unconstrained traffic offered to the network. Many other factors may affect the actual network traffic characteristics - both technical (e.g., traffic shaping, required overhead) and market-oriented (e.g., pricing plans).

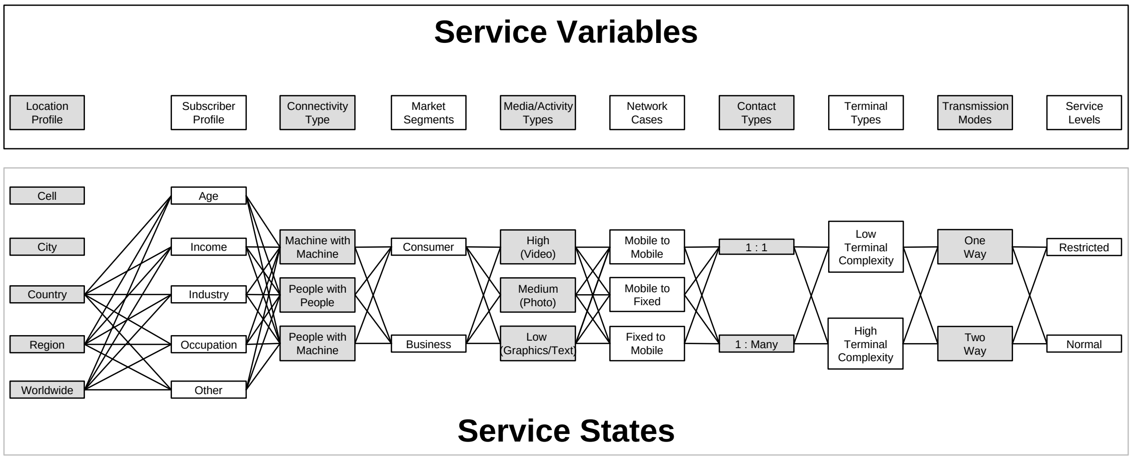
The first step in this study was to develop a structured way to consistently analyse each service category. The structured approach chosen is based on nine service variables and their associated states. These variables capture the most significant attributes of mobile service that impact the traffic loads and asymmetry. The nine service variables are:

- Location profile
- Subscriber profile
- Connectivity Type
- Market segment
- Media / Activity Type
- Network cases
- Contact type
- Terminal type
- Transmission mode
- Service level

These service variables and their states are shown in Figure 1.2 and further described in Section 2.

[2] The volume and proportion of traffic for each of the service variables was determined by using the *ATIVA Research Tools*, which forecasts the propensity to buy (or use) such services, based on large, detailed and well qualified social data, as described in Section 8.

Figure 1.2. Service variables and associated states used to analyse traffic characteristics.



Source: Telecompetition, Inc., prepared for the UMTS Forum, October 2003.

For each of the six service categories, relevant states for each service variable shown in Figure 1.2 are analysed. This analysis resulted in a large number of permutations of the service variable states – each representing a potential individual service. After identifying the permutation that represented reasonable realistic services, related assumptions included the following:

- File sizes for non-real time sessions for the uplink (UL) and downlink (DL).
- Asymmetry of relevant service permutations (UL/DL).
- Data rates – customer expectation of speed over the air interface (UL and DL).
- Session frequency and duration.
- Busy hour characteristics and traffic distribution.
- Subscriber adoption of individual services.

Total offered traffic includes the average aggregate offered traffic over all service categories.

The total offered traffic has to be considered separately for uplink and downlink because it is possible that the traffic asymmetry for one service will be offset by another service.

The volume and proportion of traffic related to the first two service variables (location and subscriber profiles) was determined by using the *ATIVA Research Tools*, which uniquely forecasts the propensity to buy (or use) such services, based on large, detailed and extremely well qualified social data. This is described further in Section 8.

1.2 Study Scope

The study considers the following:

- Six service categories.
- Up to 288 service permutations within each service category.
- Two market segments within each service category.
- Unconstrained offered traffic only based on future market demand (at saturation).
- Average aggregate daily and busy hour traffic.
- Average 3G subscriber demographic profile and service demand in a Western European country.

The study results address:

- Expected asymmetry per service per market segment

- IP session duration
- Busy hour offered traffic, including identification of the busy hour
- Number of subscriptions per service
- Total traffic per subscription (uplink + downlink)
- Total traffic per country and per service category
- Total traffic per 3G subscriber
- IP sessions (“call attempts”) per subscription
- Service level

The following general methodology is used in this study[3]:

- Choose the UMTS Forum service forecasts from a representative Western European country as the baseline for determining subscriber and subscription levels.
- Use the service forecasts for the year 2012 to project the anticipated traffic offered to the network once 3G has reached a mature subscriber penetration level.
- Using location and subscriber profiles, determine service subscription and per-subscription frequency of use and session duration for each service category to develop individual subscriber offered traffic volumes.
- Analyse each service category based on the seven service variables and states. Exclude states that don’t apply.
- Estimate the traffic volume for each service permutation.
- Develop traffic distributions and service asymmetry for each market segment and service category.
- Calculate traffic load, busy hour and aggregate asymmetry.
- Test sensitivity of service assumptions to determine the most critical traffic assumptions.
- Aggregate service level traffic and busy hour loads to determine overall traffic characteristics.

[3] This study analyses traffic characteristics for a representative Western European country. Thus traffic characteristics and estimates are presented on a total country basis and are not analysed in more granular detail, such as by cell site or specific metro area. Because it is recognised that network engineering requires this granular level of detail, the study also provides the data on a per subscription or per subscriber basis.

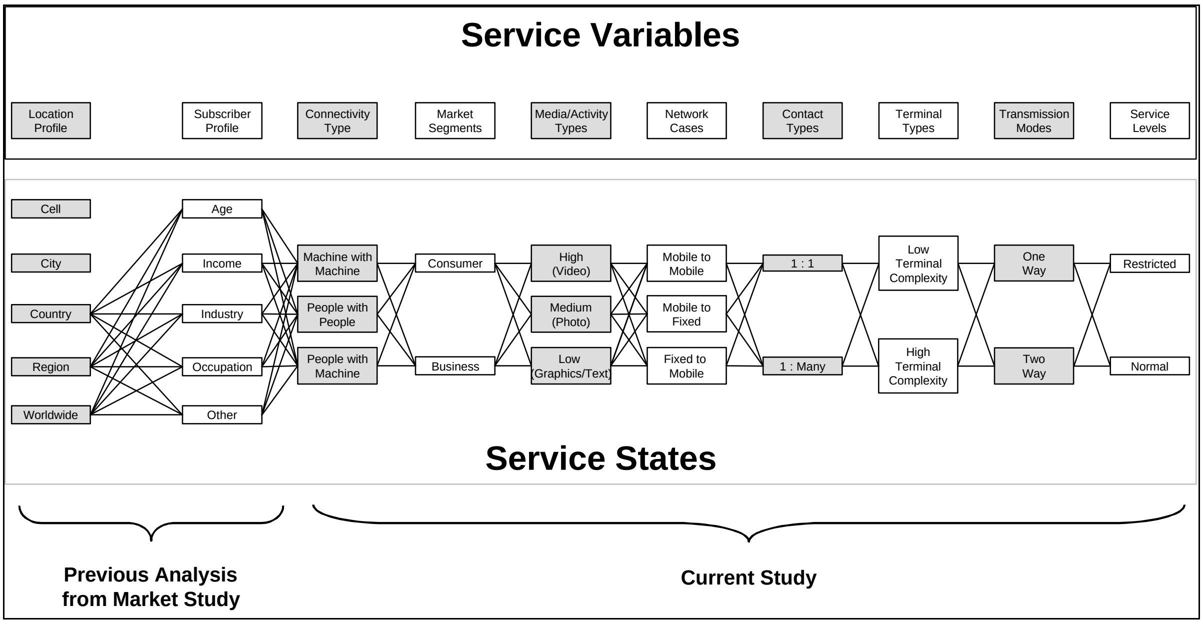
2 Study Approach

This study builds upon previous market analysis work completed by the UMTS Forum, using the services category framework shown previously in Figure 1.1. While actual service offers by mobile operators may bundle a number of capabilities and services, the framework will "force" any individual service under analysis into only one category, thus eliminating the potential for double counting of traffic.

The approach used in previous service forecasts as well as in this report employs a bounded top-level forecast. That is, a determination is made of a reasonable maximum level of demand, and all other service forecasts are calculated as a subset of that top-level number. In this manner, all service forecasts are assured of fitting within a reasonable frame of reference.

As shown in Figure 1.2, a total of nine service variables and their applicable states were considered. Figure 1.2 is repeated as Figure 2.1 below. Also shown in Figure 2.1 are the baseline location and subscriber profile variables considered in determining the subscription level for each service studied. These baseline assumptions are discussed further in Section 2.1.

Figure 2.1. Service analysis variables, variable states, and baseline profiles.



Source: Telecompetition, Inc., prepared for the UMTS Forum, October 2003.

Following are definitions and discussions of each of the baseline profiles, variables, and variable states shown in Figure 2.1.

Baseline - Location Profile

For the traffic modelling in this report, the population and service profile of a representative Western European country was chosen as the baseline network[4]. Geography, demographics and propensity to buy services for a representative western European country were used in this analysis. A more detailed discussion of the location profile is found in Section 2.1.

[4] The demographic data comes from population data compiled by Telecompetition, Inc. from a number of respected and well—known demographic sources. These sources include the International Labour Organisation (ILO), US Census Bureau International Database, Rand McNally, EuroStat, and other country-specific statistical sources.

Baseline – Subscriber Profile

The subscriber profile includes demographic factors such as age, income, occupation, and industry. The population counts by these demographic variables in the representative country help determine the number of subscriptions for each service. A more detailed discussion of the subscriber profile for the representative country is found in Section 2.1.

Connectivity Types

Connectivity types consider whether the communication is between machines (machine-to-machine), people (people-to-people), or between machines and people (people-to-machines or machines-to-people.) The service category definition often includes the connectivity type. (Rich Voice, for example is entirely people-to-people, while Customised Infotainment, Mobile Internet Access, and Mobile Intranet / Extranet Access connect people with content (servers) and are therefore people-with-machines.)

Media / Activity Types

Media and activity types include those services within a service category that have definable and distinct user features or characteristics. Rich Voice and Multimedia Messaging services are more easily defined by the type of media that is being utilised (e.g. text, graphics, photos, video, and audio). For each of the remaining service categories, specific activities were identified and analysed that represented the majority of expected traffic volume. Examples of activity types are web browsing, email, and mobile gaming. These activities differ for each service category. Media and activity types will also differ between market segments within service categories.

Market Segment

Consumer users and business subscribers are the two market segments analysed. In some service categories, consumer and business segments were further split into sub-segments. A business subscriber using media for professional purposes will need higher quality than a consumer user, who is only exchanging pictures for social purposes. For example, a repairperson that needs a photo or diagram of the workings of an appliance will need it at much higher resolution than a consumer user who wants to send a quick holiday picture. The media quality will act as a multiplying factor for both the traffic volume and the asymmetry of a given media type.

Network Cases (Origination and Termination)

This instance describes whether the user is engaged in a mobile-to-mobile[5] call, fixed to mobile or mobile to fixed. Traffic volumes and asymmetry are affected by network cases. For example, in the case of messaging services, if messages are sent from one mobile subscriber to another mobile subscriber then, on average, the number of uplink messages equals the number of downlink messages. However, if for example, a mobile subscriber sends a photo to a network server for later download from a home PC, the mobile traffic is primarily uplink. The propensity to use different network cases is also dependant on the market segment.

The proportion of traffic that stays within mobile networks, between mobile networks (i.e., international roaming) or between fixed and mobile networks is expected to change over time.[6] The deployment of SIP and IMS will enable greater interoperability between fixed and mobile networks, creating greater traffic between fixed and mobile networks.[7] International roaming traffic is growing, but is still less than

[5] Mobile to mobile includes traffic between mobile users or devices regardless of whether the users or devices are in the same or different operator's mobile networks.

[6] Studies by both Oftel (UK) and CTIA (US) indicate increasing percentage of traffic between mobile and fixed networks. Oftel, "Vodafone, O2, Orange T-Mobile Terminating Minutes", December 2002. CTIA, Wireless Industry Indices Report: Mid-Year 2001.

[7] See UMTS Forum Report 20 for more details on the impact of IMS (IP Multimedia Subsystem).

2% of total traffic.[8] From the mobile operator perspective, an international roaming call has the same traffic characteristics as a mobile to fixed call – the “receiver” portion of the call is to an “outside” network. The network case assumptions for each service take into consideration these industry trends, as well as the particular usage patterns for the service.

Contact Types

Contact types mean whether the communication is one-to-one or one to many. This has an impact on spectrum, particularly for certain service categories. Contact types also significantly influence network cases and the market segment. For example, consumers will have a tendency to send messages from mobile-to-mobile. If they are at the same time, one-to many messages (such as might be sent to “buddy lists”), there will be many more downlink messages than uplink messages. On the other hand, if a business user (estate agent) is sending photographs of a property from his camera phone to several offices (in the fixed network), there is only one uplink message and no downlink.

Terminal Types

The study considers two different categories of mobile terminal, which will influence traffic and symmetry. Professionals will tend to use terminals with high-resolution screens (“high complexity” terminals) such as laptops and high end PDAs for multimedia, where the accuracy and detail of the information is crucial. On the other hand, consumer subscribers will have more interest in small lightweight terminals, for which a high-resolution screen is not relevant. However, some exceptions are likely, when, for example, a consumer (with a small device) sends a photo to someone in the fixed network (e.g. as an e-mail attachment). Here, the recipient will have a high-resolution screen and printer and so will want the picture at high resolution. The size and resolution of the screen significantly affects the data volume of the picture or video media intended for it, so this usage factor will act as a multiplying factor for the associated traffic and asymmetry.

Transmission Modes

Transmission modes means whether the communication is predominantly one-way or two-way. Service categories usage will determine the transmission mode. For example, certain types of multimedia communication may allow the transmission mode as an option. For design purposes, asymmetry at a cell level is important. So while subscribers may broadcast Multimedia Messaging Service (MMS) messages to a large number of friends or business associates, a smaller number remains within the same cell. This study has assumed that on average, a “one to many” call will transmit to an average of three other terminals.

Service Levels

The expectation is that in many cases a user will be able to choose between restricted service quality and normal service quality. This will influence Quality of Service (QoS) parameters, such as latency, data rate and priority. In turn, this will affect network loading (hence spectrum demand), particularly at the busy hour. While this report does not explicitly calculate QoS effects, it does consider two levels of service – “normal” and “restricted”

Service expectations for “normal” service levels vary by service and segment, and change over time. If one uses the fixed Internet as an anecdotal example, user expectations for data rate, latency, and priority will increase as usage increases and bandwidth is more available and less expensive. These future expectations of service level are considered in the calculations for this report.

The individual assumptions for the most traffic sensitive service variables are discussed under the respective service categories (Sections 4 and 5). For some services, some variable states were eliminated due to lack of any significant demand or impact on traffic calculation.

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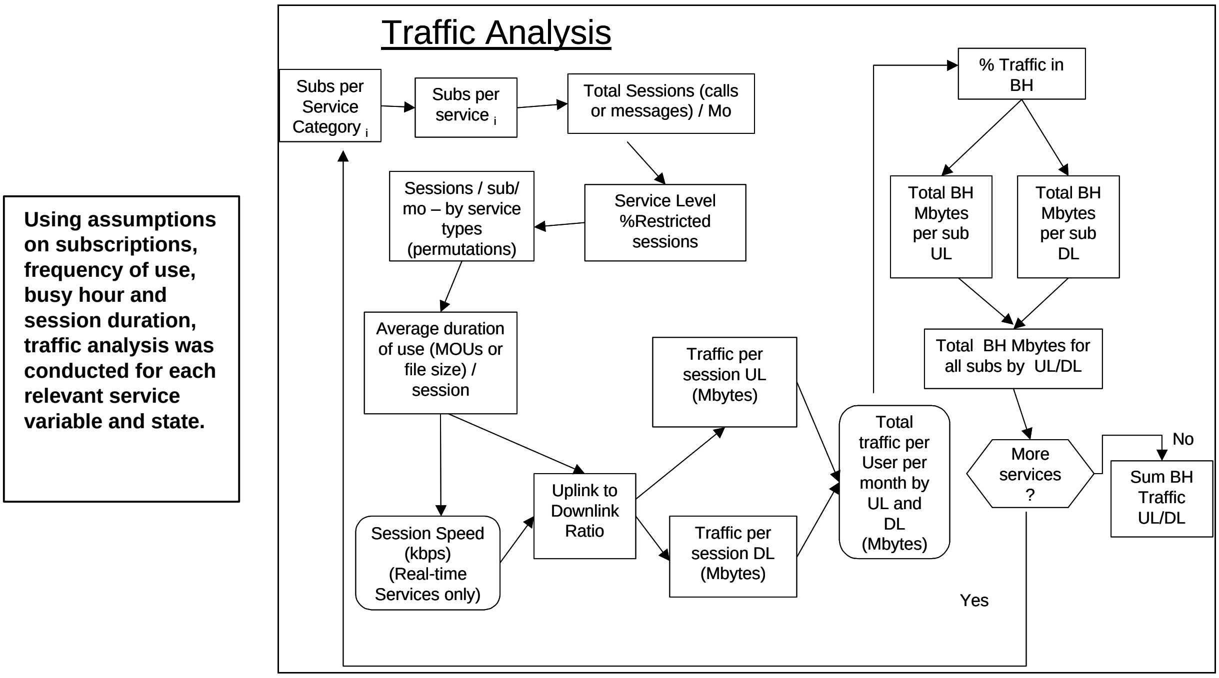
[8] Source: Communications Week and Strategy Analytics, September 1999.

For each service variable and state identified for analysis, busy hour and total traffic per subscription and per session is calculated. The basic calculation flow is shown in Figure 2.2. This framework is used for the calculations shown in later sections, with some variation for individual service differences. In the framework, monthly sessions or messages are used as subscribers are typically billed on a monthly basis. Daily traffic is estimated based on the number of days per month the service would be used. (Typically, consumer services assume 30 days per month while business services assume 22 days per month in use). The percentage of traffic in the busy hour is calculated based on the assumed percentage of traffic in the busy hour found in the traffic distributions in this report (for example Figure 4.9) applied to this daily traffic.

Figure 2.2. Traffic analysis framework.



Source: Telecompetition, Inc., prepared for the UMTS Forum, October 2003.

2.1 Study Assumptions – Location Profile

This section highlights the key parameters of the baseline location profile using the representative country's geography, demographics, and propensity-to-buy demographics.

This country level aggregate view is important to begin to understand the overall offered traffic characteristics and service symmetry. However, practical RF design requires a much smaller geographic analysis, typically starting with a cell. While that type of analysis is not the focus of this study, subscriber traffic loads are presented for consumer and business subscribers to provide the reader with some ability to apply the data to this type of design.

The traffic characteristics and analysis in this report use the service subscription volumes as previously forecast for the chosen representative country in UMTS Forum Report 17 in year 2010. While individual countries will certainly have differences in demographics, the expectation is that the "representative country" will provide an adequate picture of traffic characteristics usable to any developed country. In addition, the traffic model is built in a way that will allow individual operators to use the model and to modify the service concentration or usage they believe more closely represents their individual situations.

The following geographic profile is the basis for the traffic model assumptions:

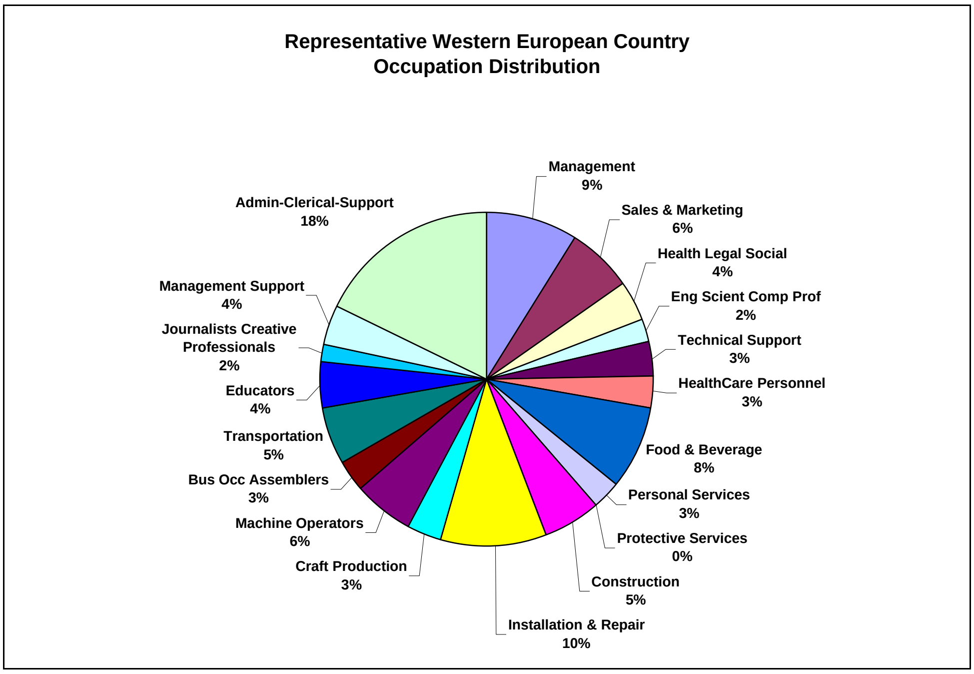
- Urban environment (where the majority of 3G traffic is expected to occur)
- Total Population: 60 Million

- Workforce Population: 30 Million

Demographic Characteristics – Subscriber Profile

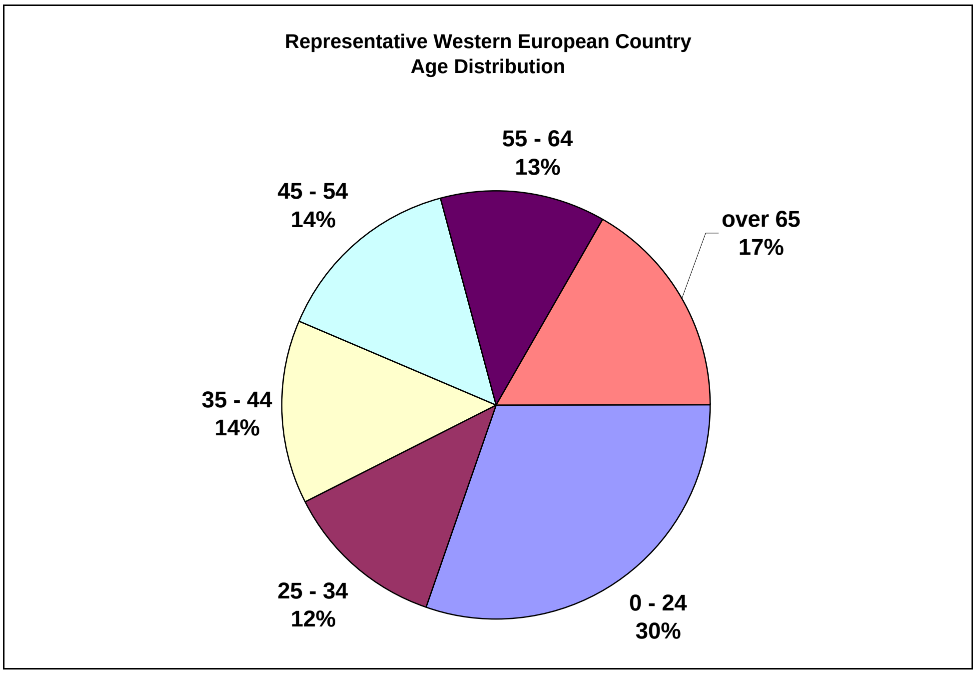
A Telecompetition proprietary forecasting tool that accommodates a wide range of demographic and other geographic variables was used to develop the service subscription forecasts. The tool uses demographic variables as a way to estimate the subscription levels for each country. The demographic population counts by industry, occupation, and income and the propensity-to-buy profiles (Section 3) for each service provide a basis for estimating subscription levels in each country. For example, sales and marketing professionals in an information industry are more likely to use mobile multimedia business conferencing. Therefore, a country that has a higher percentage of its population with those characteristics will have a higher concentration of service subscription. Figure 2.3– 2.6 summarise the representative country demographic profiles used to develop the subscription estimate for each service.

Figure 2.3. Occupational distribution used in service forecasts.



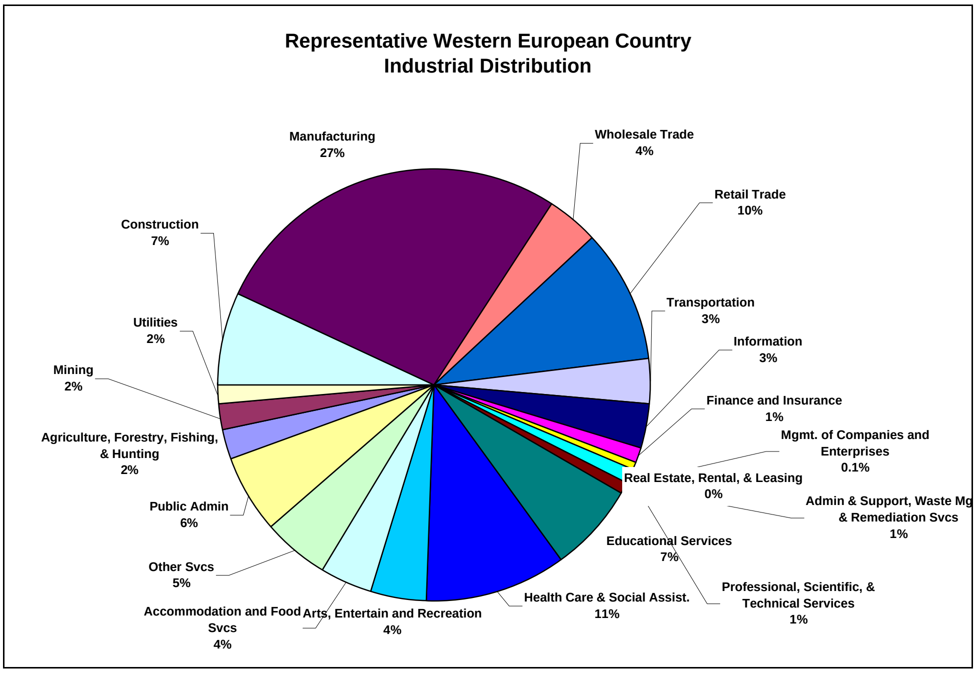
Source: International Labour Organisation

Figure 2.4. Age distribution used in service subscription forecast.



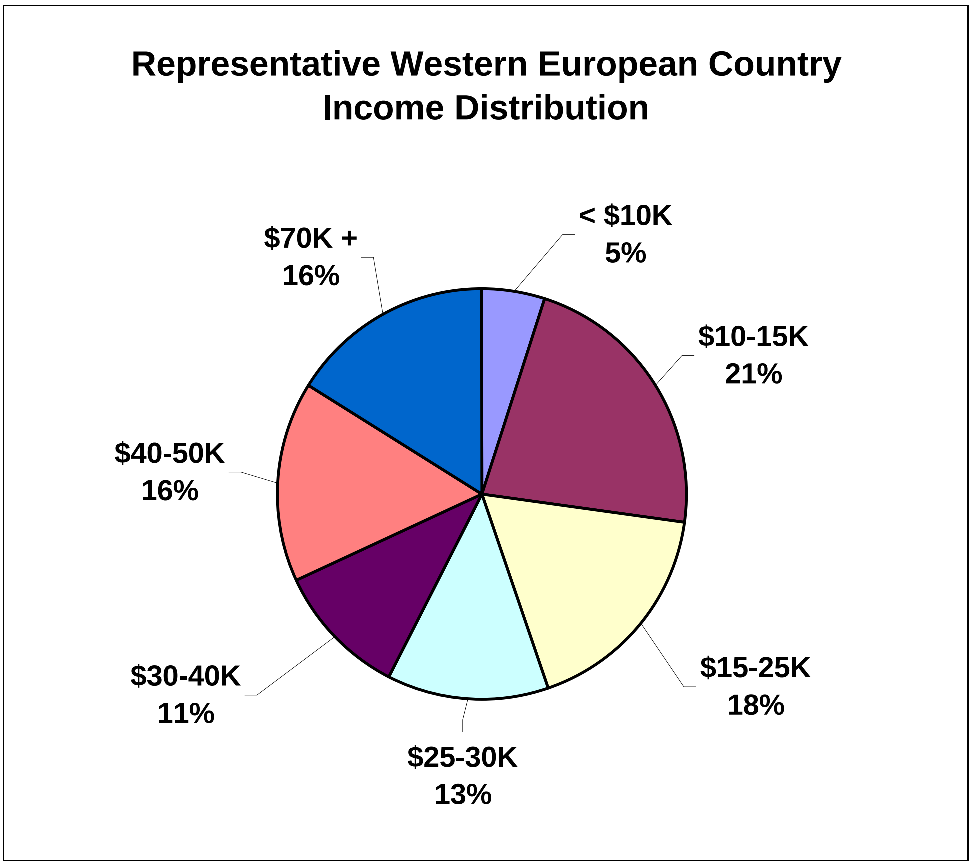
Source: International Labour Organisation

Figure 2.5. Industrial distribution used in service forecast.



Source: International Labour Organisation

Figure 2.6. Income distribution considered in traffic forecast.



Source: National Statistics, Department for Work and Pension, Family Resources Survey, 2000-01.

This demographic profile combined with the following assumptions result in a service forecast that is skewed towards an urban environment:

- Urban environments will have the concentration of 3G traffic.
- Population is concentrated in urban and dense urban environments.
- The propensity to buy profile (Section 3) is skewed towards occupations and industries more concentrated in urban rather than rural areas.

3 Service Assumptions

This report analyses all the service categories shown in Table 3.1. Table 3.1 provides the specific definitions of each service category.

Table 3.1 Service category descriptions.

Service Category	Service Description	Market Segment Analysed
Mobile Intranet/Extranet Access	A business 3G service that provides secure mobile access to corporate Local Area Networks (LANs), Virtual Private Networks (VPNs), and the Internet.	Business
Customised Infotainment	A consumer 3G service that provides device-independent access to personalised content anywhere, anytime via structured-access mechanisms based on mobile portals.	Consumer
Multimedia Messaging Service (MMS)	A consumer or business 3G service, that offers non-real-time, multimedia messaging with always-on capabilities allowing the provision of instant messaging. Targeted at closed user groups that can be services provider- or user-defined. MMS also includes machine-to-machine telemetry services.	Consumer
Mobile Internet Access	A 3G service that offers mobile access to full fixed ISP services with near-wireline transmission quality and functionality. It includes full Web access to the Internet as well as file transfer, email, and streaming video/audio capability.	Consumer
Location-Based Services	A business and consumer 3G service that enables users to find other people, vehicles, resources, services or machines. It also enables others to find users, as well as enabling users to identify their own location via terminal or vehicle identification.	Consumer and Business
Simple Voice and Rich Voice	A 3G service that is real-time and two-way. Simple Voice provides traditional voice services including mobile voice features (such as operator services, directory assistance and roaming). Rich Voice provides advanced voice capabilities (such as voice over IP (VoIP), voice-activated net access, and Web-initiated voice calls, and mobile videophone and voice enriched with multimedia communications.	Consumer and Business

Source: UMTS Forum Report 13

These service categories have very distinct definitions that are important considerations in analysing traffic. For example, MMS is non-real-time and one-way, while Rich Voice is real-time and two-way.

3.1 Mobile Penetration

The mobile traffic forecasts in this report are built upon a foundation of extensive market analysis of 3G service opportunities from UMTS Forum Report 17 and analyses from other reports. The underlying revenue, subscriber, and usage relationships are the starting point for the traffic analysis. The forecasts extend through year 2012, when it is expected that developed countries will have obtained maximum penetration and usage volumes of 3G services. Therefore, the following maximum usage assumptions for the representative country are the basis for the peak load and busy hour calculations in this report:

- Maximum mobile penetration is 90% of population.

- Maximum 3G data penetration is 60% of mobile subscribers.[9]

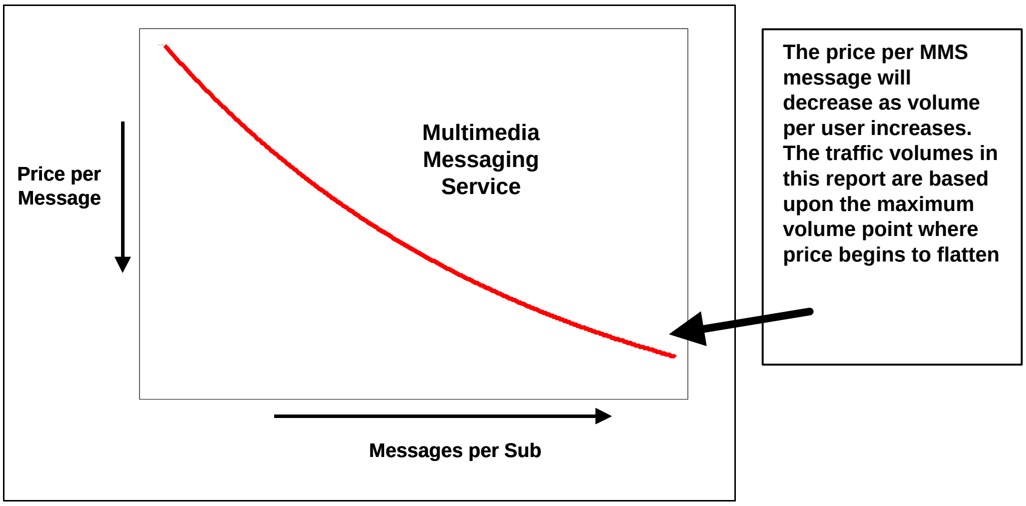
3.2 Mobile Usage

Service adoption and usage volume are highly influenced by service price. Typically the number of subscribers and the usage volume of those subscribers will increase as price decreases. There is, however, a limit on how much subscribers will use a service regardless of the price.

In the UMTS forecast analysis, conservative assumptions and reasonability governed the analysis process. At no time was it assumed that premium pricing or above-normal usage is attributed to 3G subscriptions. For example, price points used in the forecasts for MMS and Rich Voice represented a reasonable willingness to pay for existing services or substitute services. In general, volume usage for any service category was predicted to increase as per unit prices decreased. Reaching "maximum" penetration and usage levels described above, presumes a relatively low price level for mobile data services relative to current pricing.

Figures 3.2 and 3.3 illustrate the shape of the price demand curve for MMS and Rich Voice, and are representative of the analysis conducted for each service category

Figure 3.2. Price demand – MMS.

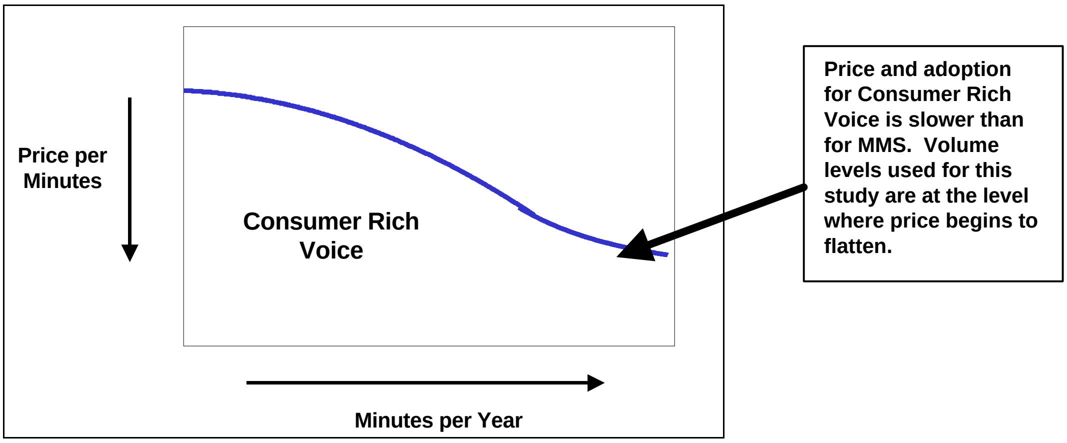


Source: Telecompetition, Inc., prepared for the UMTS Forum, October 2003.

Because a full 3G Rich Voice enabled by IMS is a higher priced service, not commercially available for a few years, the adoption rate does not reach the same penetration levels as does MMS. Only 25% of 3G users will have subscribed to Rich Voice vs. almost 60% subscription levels for MMS. The shape of the curve for Rich Voice also shows service volume is less sensitive to changes in price than is MMS.

[9] 60% represents the bulk of 3G subscribers that generate traffic on a consistent basis. Also, the "maximum" 3G penetration is less than 100% of mobile subscribers to take into consideration geographic areas that may not be served by 3G networks (e.g., rural areas) and portions of the mobile population that do not use any 3G mobile data services (such as the very old, the very young, or economically disadvantaged people).

Figure 3.3. Price demand for Rich Voice.

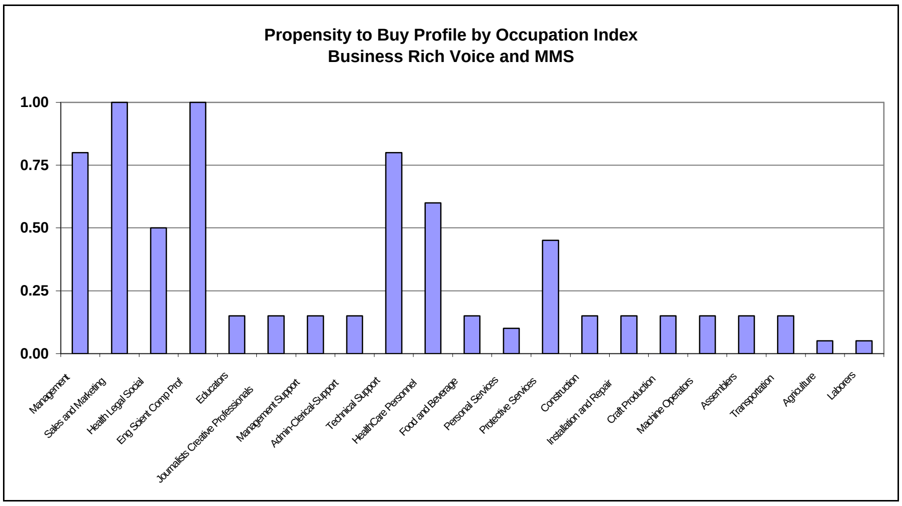


Source: Telecompetition, Inc., prepared for the UMTS Forum, October 2003.

3.3 Propensity to Buy Profiles

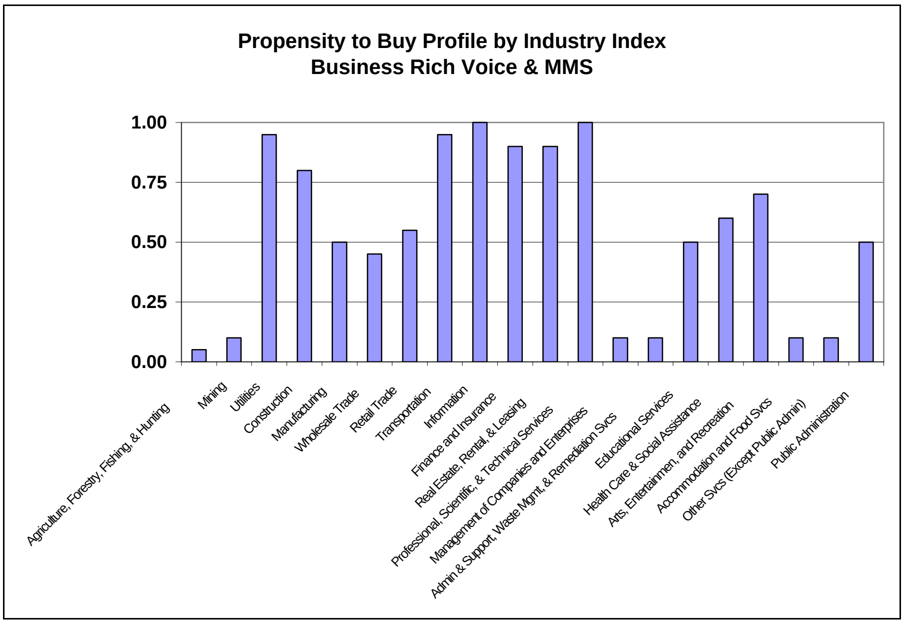
The forecast for each service category used in this analysis is based upon a service category profile that identifies the propensity to buy each service. Figures 3.4-3.7 for Rich Voice and MMS show the profiles as a relative index, are representative of profiles created for each service category. As illustrated in the Figures 3.4 and 3.5, workers in management, sales, marketing, engineering, and technical support occupations are more likely to use business Rich Voice and MMS than are workers in other occupations. Likewise, workers in the information and professional services industries are more likely to use business Rich Voice and MMS services than are workers in other industries. These indices are used as weighting factors against area population demographics to determine the number of subscribers for a service. These types of occupations are typically concentrated in urban rather than rural areas.

Figure 3.4. Relative propensity to buy Index by occupation – business Rich Voice and MMS



Source: Telecompetition, Inc., prepared for the UMTS Forum, October 2003.

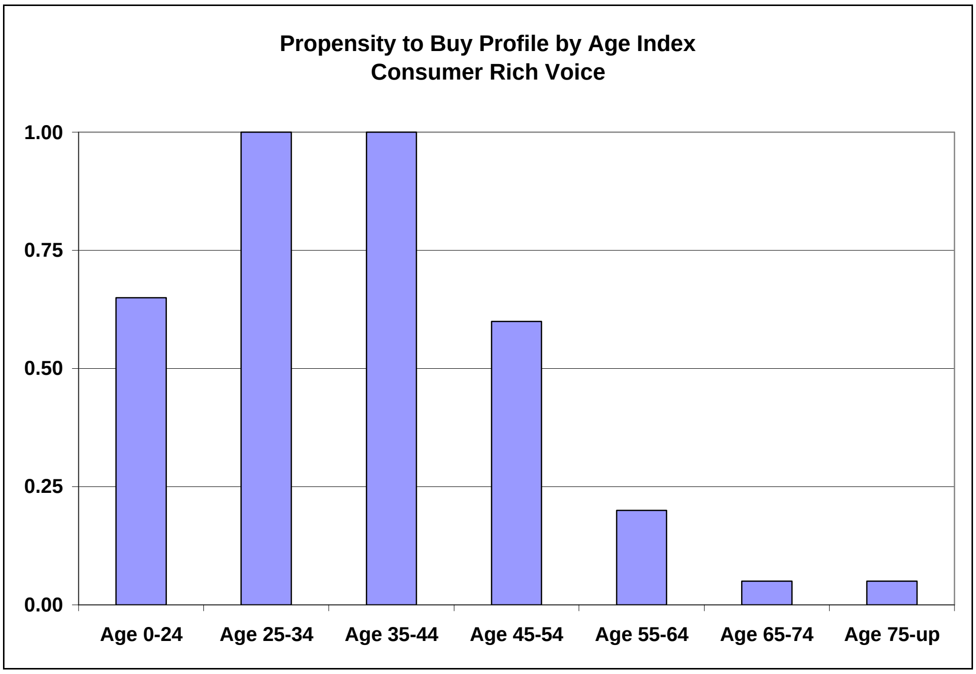
Figure 3.5. Relative propensity to Buy Index by industry – Business MMS and Rich Voice



Source: Telecompetition, Inc., prepared for the UMTS Forum, October 2003.

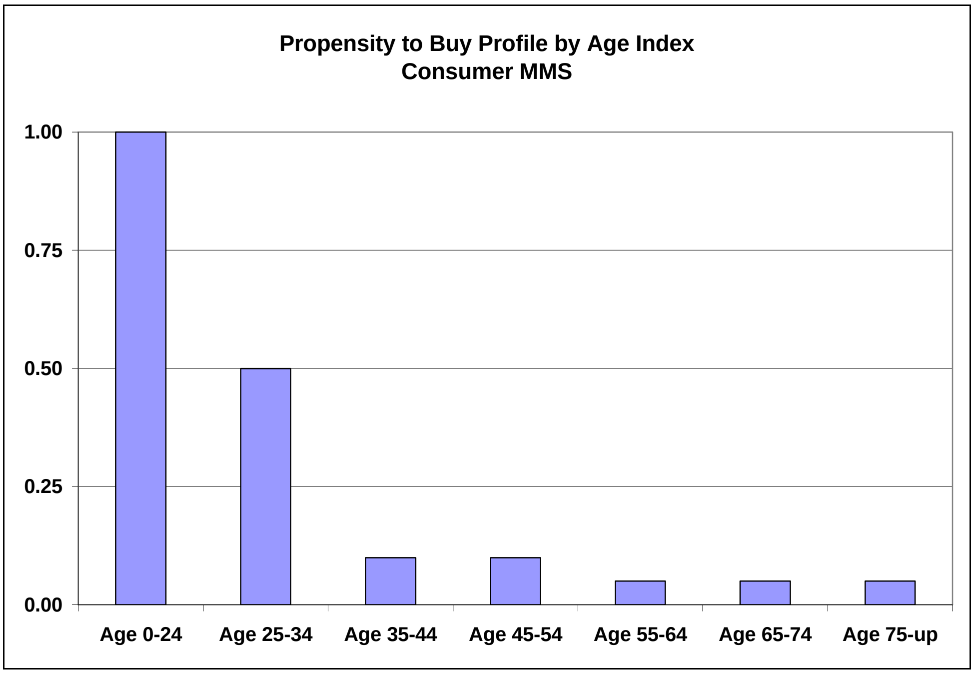
Figures 3.6 and 3.7 show the relative index for propensity to buy by age for consumer MMS and Rich Voice services. Consumer MMS is highly skewed to teenagers and very young adults, while Rich Voice is more skewed towards young adults to middle age.

Figure 3.6. Relative propensity to buy index by age – Consumer Rich Voice.



Source: Telecompetition, Inc., prepared for the UMTS Forum, October 2003.

Figure 3.7. Relative propensity to buy index by age – Consumer MMS.



Source: Telecompetition, Inc., prepared for the UMTS Forum, October 2003.

4 Multimedia Messaging Service Assumptions and Offered Traffic

Analysis of MMS included business and consumer use and considers all the variables shown in Figure 1.2. The definition of MMS is repeated here for reader clarity:

> **Multimedia Messaging Service: A consumer or business 3G service that offers non-real-time, multimedia messaging with always-on capabilities allowing the provision of instant messaging. Targeted at closed user groups or business communities that are services provider- or user-defined. MMS includes messaging between people and also between machines (telemetry).**

For purposes of this analysis, Rich Voice and MMS services have very distinct differences even though both services can involve sending and receiving video and photos. The most important distinguishing difference is that MMS is non-real-time and one-way. In contrast, Rich Voice, (discussed in Section 5) is real-time and generally two-way.

From the end-user perspective, MMS service will look very much like existing SMS services, except that the user can include expanded and new media elements in addition to text. The MMS user will create the message and media (e.g., a mobile phone "camera), store it temporarily in the handset, then "send it" to other people or a network storage service.[10] The originator of the MMS message is either a mobile user or a fixed Internet PC user, sending the message to one or multiple parties. Therefore, MMS can include mobile-to-mobile, mobile to fixed, fixed to mobile as well as one-to-one and one-to-many variable states. Terminal device are a mobile handset, a PC, or a laptop / smart phone. By definition, MMS is one-way only, thus two-way transmission was not calculated. Three media types for both consumer and business are analysed in this report:

- People to People Messaging
  - Short video clips,
  - Photos,
  - Expanded text that may include some low-resolution graphics.

Analysis of MMS also includes business and consumer use of machine-to-machine telemetry services. Telemetry is defined as:
Machine-to-Machine Messaging

- Low bandwidth machine-to-machine initiated communications, monitoring or tracking of stationary objects.
- Telemetry does not include people and machines, (i.e., messaging or files that are transferred between servers, but initiated by people or files uploaded or downloaded by people to servers (e.g., Customised Infotainment)

These service variables are illustrated in Figure 4.1 and 4.2.

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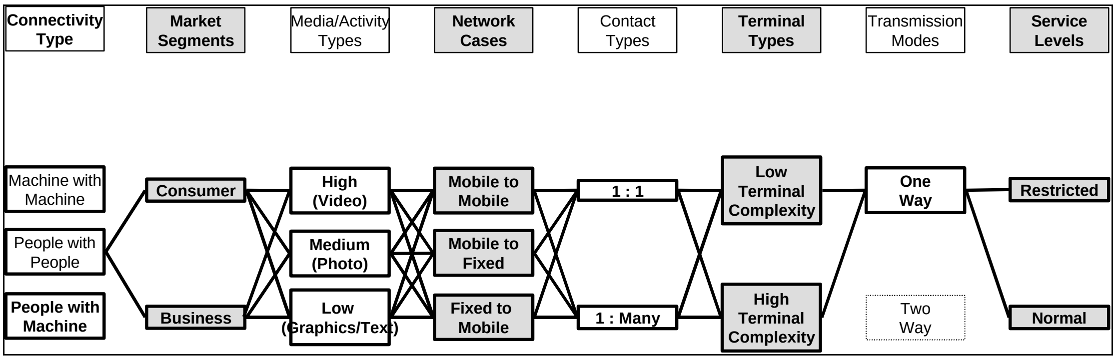
[10] It is also possible that the user could download content from a mobile Internet portal or web site, add a message, and then send it. However, the download portion of that transaction would actually be included under a different service category (e.g., Customised Infotainment)

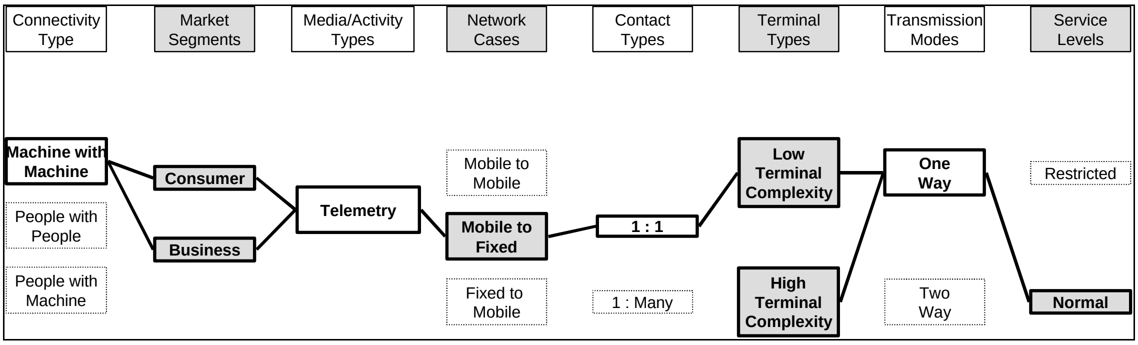
Figure 4.1. Service variables and states used for business and consumer MMS.

In MMS, the "two-way" variable states were eliminated, as MMS, by definition, is one way.



Source: Telecompetition, Inc., prepared for the UMTS Forum, October 2003.

Figure 4.2. Service variables and states used for machine-to-machine telemetry.



Source: Telecompetition, Inc., prepared for the UMTS Forum, October 2003.

4.1 Usage and Traffic Assumptions

The number of MMS subscribers and their frequency and type of use (number of messages and type of media in message) was estimated based upon the representative country described earlier. MMS is viewed as a popular business service, used by nearly all business 3G subscribers as part of their daily activities. In the consumer market, MMS is heavily concentrated among teens and young adults. The analysis assumes that all messages include a text component, and a smaller number include video and or photo media. The major usage assumptions for MMS used in the offered traffic estimates for 2012 are as shown in Table 4.3.

Table 4.3 MMS usage assumptions.

3G Subscribers[11]	▪ 31.9 M 3G Subscribers (53% of population) ▪ 20.4 M Consumer 3G Subscribers ▪ 11.5M Business 3G Subscribers
MMS Subscriptions	• 7.1 million consumer MMS Subscriptions (12% of population) • 11.5 million business MMS Subscriptions (19% of population) • 60 million telemetry subscriptions
Frequency of Use[12]	• Consumer – 11 messages per day • Business – 5 messages per day • Telemetry- 24 messages per day (every hour 24x7)
Media Type	• All MMS messages have text component, • 66%% of messages are text and low graphics only • 24% have a Photo media component, • 10% have a video media component
Network Cases[13], Origination and Termination	• 32% mobile to mobile • 40% mobile to fixed • 28% fixed to mobile • Telemetry is 100% mobile to fixed
Transmission Mode and Contact Type	• 80% one-to-one; 20% one-to-many • All traffic is one-way

Source: Telecompetition, Inc., prepared for the UMTS Forum, October 2003.

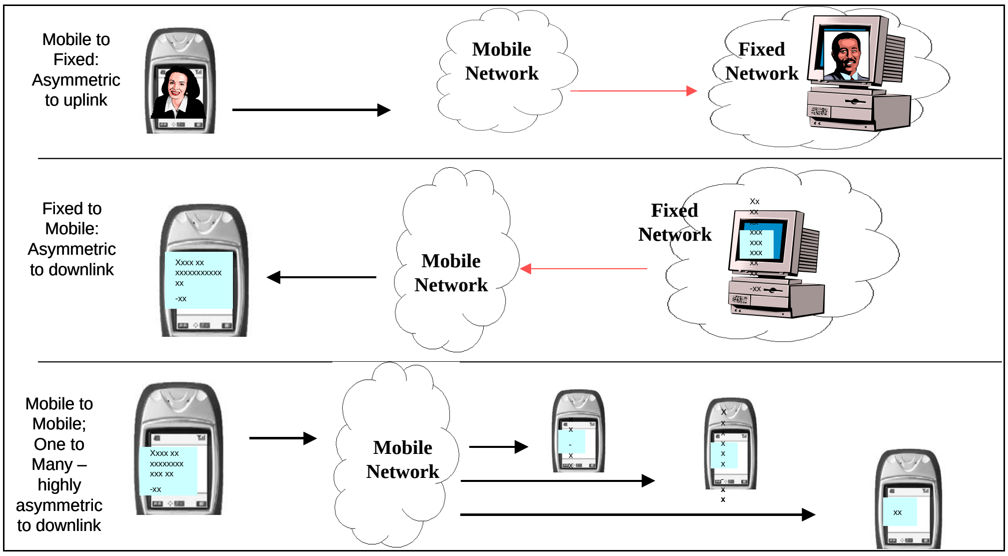
MMS service is one way. Therefore, the traffic symmetry of an individual session is defined by the network case (e.g., mobile-to-fixed) and whether the transmission is one to one or one to many. . The assumed symmetry of MMS is illustrated in Figure 4.4 and Telemetry in Figure 4.5, both further described in Table 4.6.

[11] Estimates of subscribers for 3G and MMS are based on UMTS Forum Report 17.

[12] Telecompetition estimate based on reported SMS messages and projected growth rates reported by GSM Association, IDC, EMC and other industry analysts.

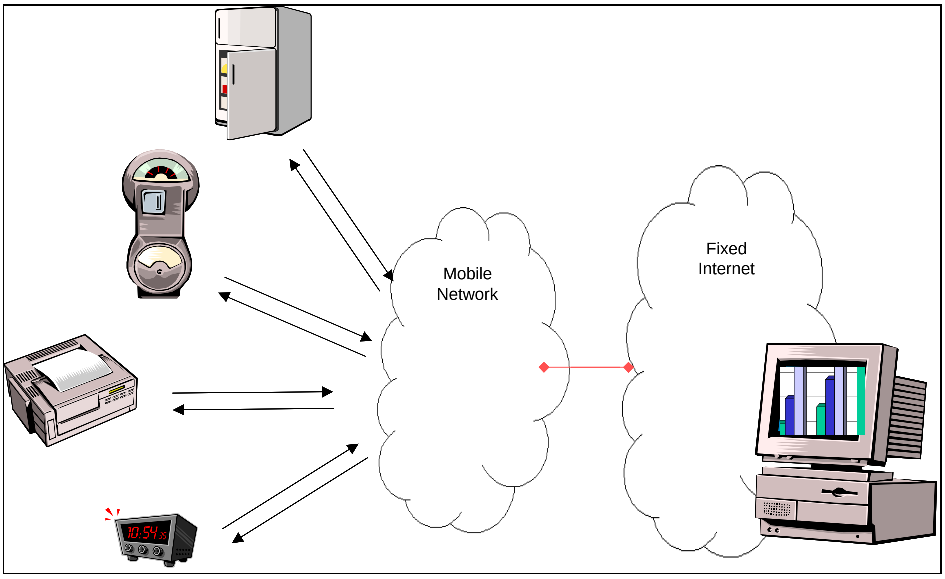
[13] Source: Telecompetition analysis of Oftel report on Vodafone, O2, Orange, and T-Mobile terminating minutes. Although mobile-to-mobile messaging is expected to increase in the future, it is also expected that this will be offset by an increase in messaging between fixed PCs and mobile users. Therefore, the relative proportion of future traffic between mobile and fixed networks is assumed to be similar to what exists today.

Figure 4.4. MMS symmetry for different service variables and states.



Source: Telecompetition, Inc., prepared for the UMTS Forum, October 2003.

Figure 4.5. Telemetry symmetry.



Source: Telecompetition, Inc., prepared for the UMTS Forum, October 2003.

Table 4.6. Assumed asymmetry of personal MMS services by contact type, transmission mode and network case.

Contact Type Transmission Mode	Network Case	Service Symmetry	Ratio UL: DL
One to One: One Way	Mobile to mobile	Symmetric	1:1
	Mobile to Fixed	Asymmetric to Uplink	1:0
	Fixed to Mobile	Asymmetric to Downlink	0:1
One to Many: One-Way	Mobile to mobile	Highly Asymmetric to Downlink	1:3
	Mobile to Fixed	Asymmetric to Uplink	1:0
	Fixed to Mobile	Highly Asymmetric to Downlink	0:3

Source: Telecompetition, Inc., prepared for the UMTS Forum, October 2003.

The type of media used in an MMS message is an important factor in determining the file size. A range of file sizes is possible. The assumed message sizes for MMS in this analysis are summarised in Table 4.7.

Table 4.7 MMS – size of message[14]

Terminal Type	Media / Activity Type	Message Size (kBytes)
Low Complexity Terminals	Text and/or low resolution graphics	10
	Photo	30
	Video	100
High Complexity Terminals	Text and/or low resolution graphics	30
	Photo	100
	Video	150
Low Complexity Terminals	Machine-to-Machine Telemetry	0.01

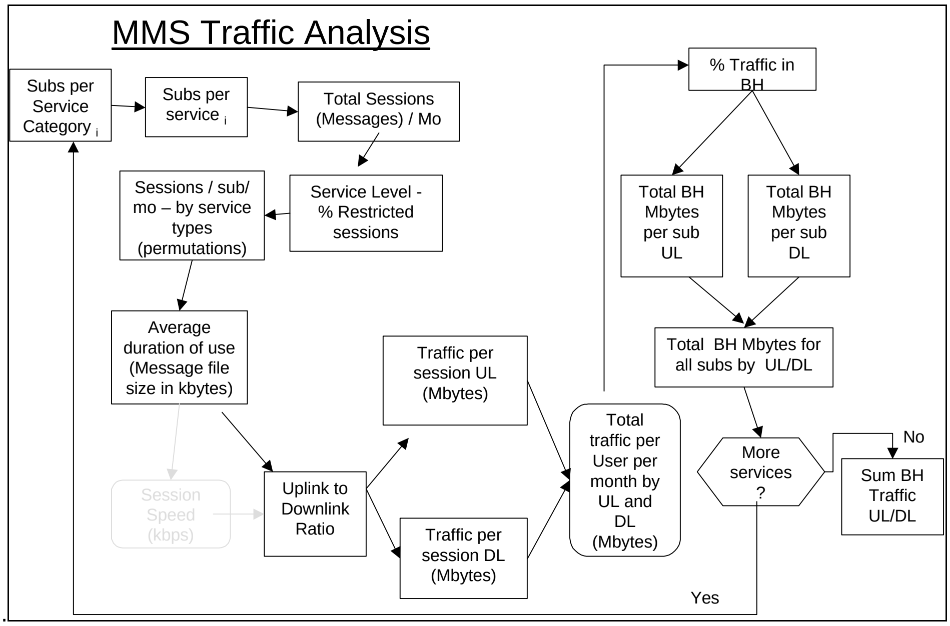
Source: Telecompetition, Inc., prepared for the UMTS Forum, October 2003.

4.2 Traffic Analysis and Results

The framework used for MMS traffic analysis follows the same flow as shown earlier in Figure 2.2. Since MMS is not a real-time service, "duration of use" and "session speed" is replaced by message file size. This is illustrated in Figure 4.8.

[14] Some of the Telecompetition estimates are based on file size capabilities of Nokia 7650, MMS enabled handsets per Nokia web site www.nokia.com.

Figure 4.8. MMS Traffic analysis framework.



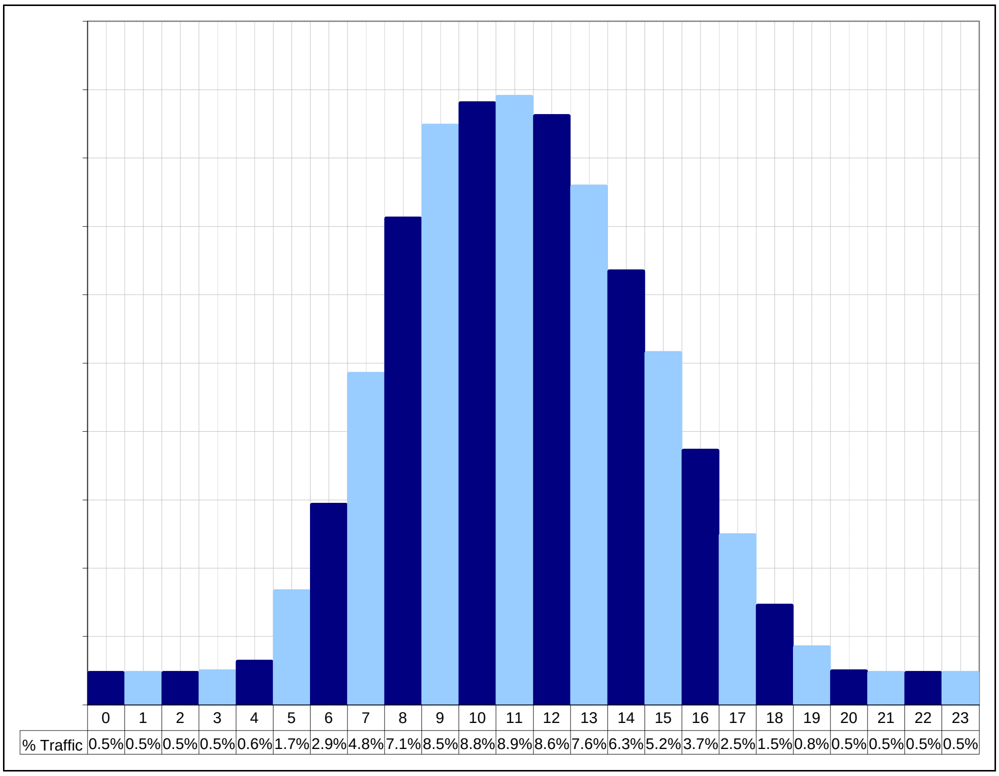
Source: Telecompetition, Inc., prepared for the UMTS Forum, October 2003.

The busy hour distribution is shown in Figures 4.9, 4.10 and 4.11. The percent of traffic that occurs in the busy hour is 9.5% for consumers and 10.7% for business.

The traffic distribution is based on actual messaging traffic data from the UK operator O2 and on the following observations and rationale:

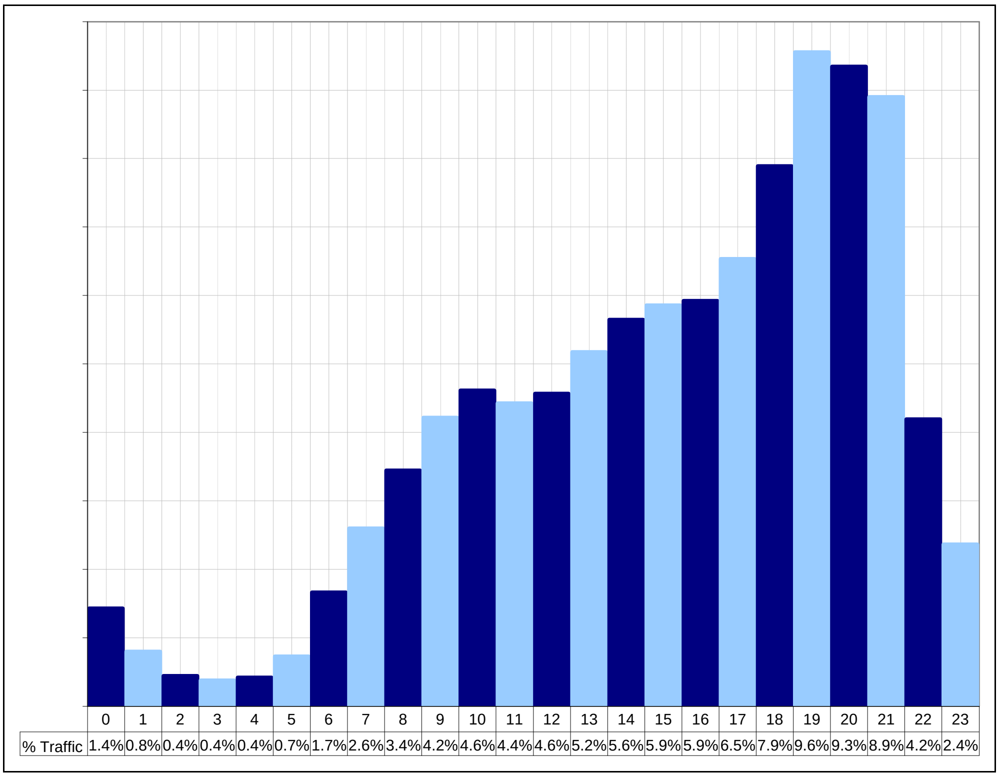
- Business use is concentrated from Monday through Friday, during the working hours of 0800 to 1800 (8 a.m. to 6 p.m.)
- Whilst business mobile voice traffic is often concentrated during commute hours, MMS users incorporate MMS into the routine business processes of a mobile employee so traffic is more evenly distributed throughout the day.
- Consumers use MMS more for recreational and personal interaction. Thus, consumer MMS traffic is more concentrated in the evenings than is business traffic.
- The traffic distribution as used in this study does not vary by the type of message, network, or terminal used. Subscribers use the service when they desire, using whatever terminal or network access is available to them at that time. The decision to send a photo or a video clip is based on the personal circumstances or situation of the subscriber, not on the hour of the day.

Figure 4.9. Diurnal traffic distribution – Business Multimedia Messaging Service.



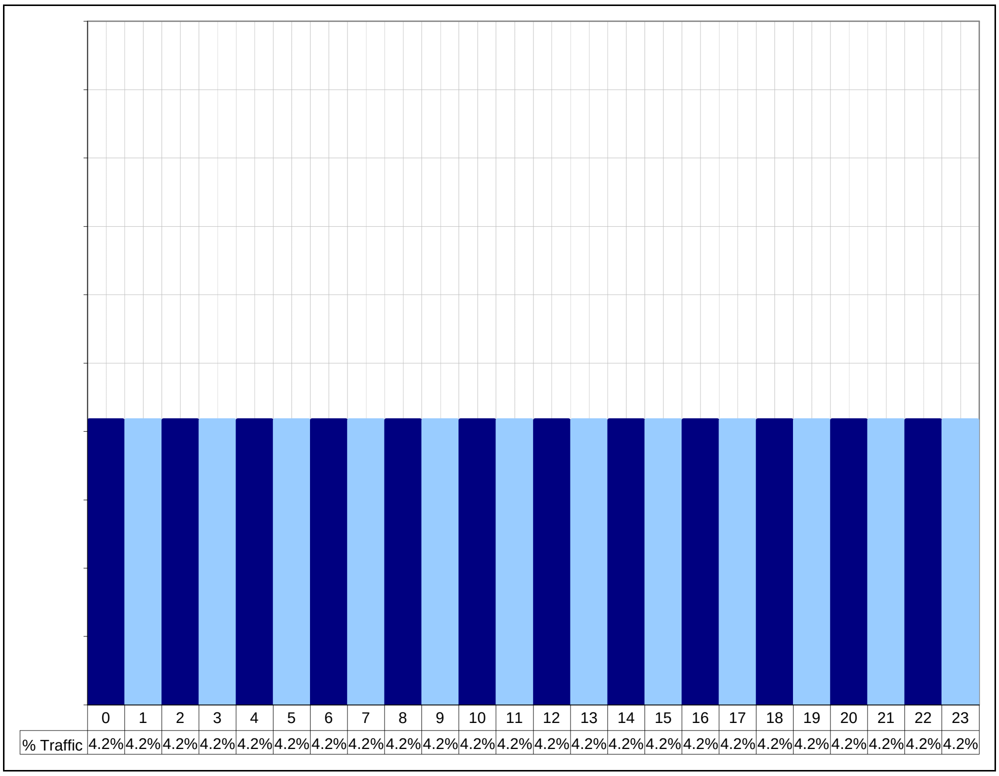
Source: Telecompetition, Inc., prepared for the UMTS Forum, October 2003.

Figure 4.10. Diurnal traffic distribution – Consumer Multimedia Messaging Service.



Source: Telecompetition, Inc., prepared for the UMTS Forum, October 2003.

Figure 4.11. Diurnal traffic distribution – machine-to-machine telemetry.



Source: Telecompetition, Inc., prepared for the UMTS Forum, October 2003.

Based on the assumptions and analysis presented in this section, Table 4.12 and 4.13 summarise the offered traffic and traffic characteristics of MMS. This indicates MMS is slightly asymmetric to the downlink.

Table 4.12 MMS - offered busy hour traffic and asymmetry per country.

Description	Busy Hour Traffic
MMS Offered Traffic per country– Uplink	**0.504 TBytes**
Business	0.323 TBytes
Consumer	0.180 TBytes
Telemetry	0.001 TBytes
MMS Offered Traffic per country – Downlink	**0.511 TBytes**
Business	0.350 TBytes
Consumer	0.160 TBytes
Telemetry	0.001 TBytes
Overall Service Asymmetry - Uplink / Downlink	**0.99**

Source: Telecompetition, Inc., prepared for the UMTS Forum, October 2003.

Table 4.13 MMS – Busy hour offered traffic per subscription.

Description	Busy Hour Traffic
Uplink traffic per MMS subscription	
Per Business Subscription	28.16 kBytes
Per Consumer Subscription	25.17 kBytes
Telemetry	0.02 kBytes
Downlink traffic per MMS subscription	
Per Business Subscription	30.51 kBytes
Per Consumer Subscription	22.46 kBytes
Telemetry	0.02 kBytes

Source: Telecompetition, Inc., prepared for the UMTS Forum, October 2003.

5 Rich Voice Assumptions and Offered Traffic

Analysis of Rich Voice services includes business and consumer usage, and considered all the variables shown in Figure 1.2. The definition of Rich Voice is repeated here for reader clarity:

> **Rich Voice: A 3G service that is real-time and two-way. It provides advanced voice capabilities (such as Voice over IP, voice-activated net access, and Web-initiated voice calls) as well as mobile videophone and multimedia communications.**

Rich Voice services are real-time and always include voice plus a multimedia element.

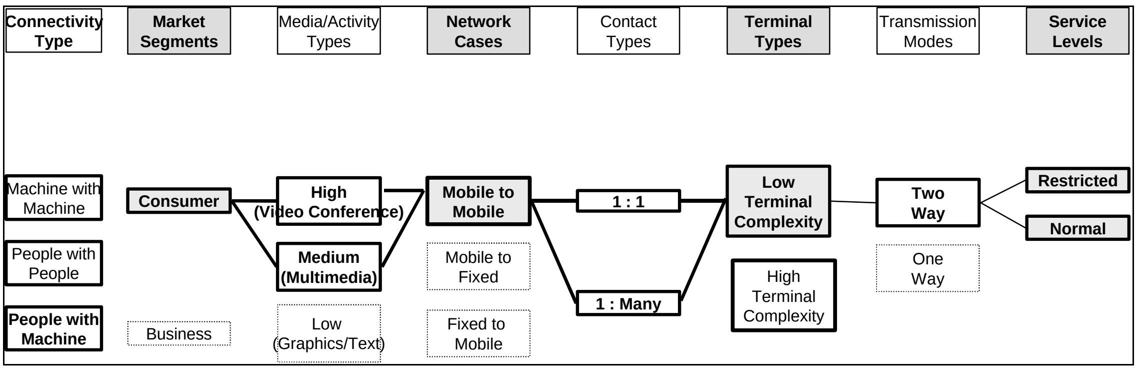
5.1 Usage and Traffic Assumptions

From the end-user perspective, Rich Voice will look much like a mobile substitute for desktop or other video conferencing service and/or a web conference that uses shared "whiteboard" and other multimedia elements (e.g., MS Net meeting). Some of the functionality of Rich Voice - talking while sharing other media - is closely emulated through a MMS message followed by a standard voice call once the message is received. However Rich Voice is a real time service, and as such the expectation is that a smaller number of 3G subscribers will pay a higher price for that real-time capability. Two levels of multimedia were analysed for both consumer and business segments:

- Low Resolution Video or multimedia (consumer)
- Video Only (consumer)
- Video Only (business)
- Multimedia Video Conference (business)

Some simplifying assumptions were made for the Rich Voice analysis. Rich Voice, by definition is real-time, two-way voice plus a real-time multimedia component. Therefore, as long as the communication is two-way, the service is, in aggregate, symmetrical. Although it is technically possible to use Rich Voice service as a one-way service and between fixed and mobile devices, in practical use, it would seem more likely that the service is real-time and used in an interactive conversation, not a one-way transmission. Also transmission of multimedia elements between mobile and fixed devices can occur in ways other than real time (e.g., MMS). The network variations do not make a difference in the symmetry or bandwidth required. Therefore, for consumer Rich Voice, all Rich Voice calls are two-way using low complexity terminals (e.g., mobile handsets). Figure 5.1 illustrates the service variables used for the traffic estimates in the consumer segment. Further discussion on traffic characteristics for consumer Rich Voice is found in Section 5.2.

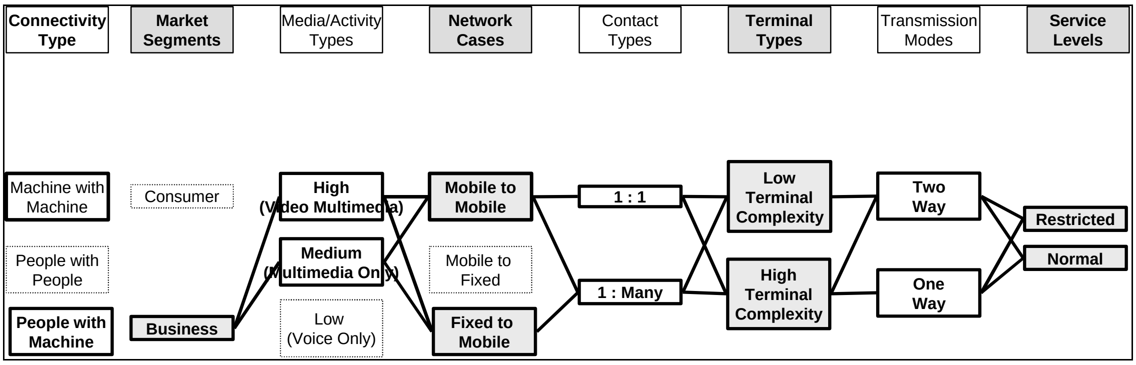
Figure 5.1. Service variables and states used for consumer Rich Voice.



Source: Telecompetition, Inc., prepared for the UMTS Forum, October 2003.

Service variables and states used for business Rich Voice calculations are shown in Figure 5.2. While any type of variation is possible, the analysis assumes that most multimedia conferences are conducted with both parties receiving and sending equal amounts of video or other multimedia real-time content. In most cases, differences in type of media, types of networks interoperating, terminal complexity, or whether the transmission is one to one or one to many change the total bandwidth required, but not the symmetry. The one notable exception is business Rich Voice for hosted video and multimedia conferences where the host is typically a fixed terminal broadcasting video to remote and mobile locations.

Figure 5.2. Service variables and states used for Business Rich Voice.



Source: Telecompetition, Inc., prepared for the UMTS Forum, October 2003.

Table 5.3 summarises the usage assumptions for Rich Voice. It is important to remember that these usage assumptions only apply to the smaller portion of 3G subscribers that actually subscribe to Rich Voice service – not to the entire mobile or 3G-subscriber base. Anyone that subscribes to the service is a relatively heavy user. For example, consumer Rich Voice is envisioned as premium service used mostly for entertainment and personal communications purposes, to share special events (holidays, birthdays, vacations, etc) with other people. Consequently, only 10% of 3G subscribers use the service. Within this small subscriber base, the highest quality video Rich Voice is used infrequently (six times) during the year. More casual, lesser quality video or multimedia calls are made about two times a week for 15 minutes each time.

Compared to consumers, business subscribers of Rich Voice use the service less frequently, but for longer periods of time. Business subscribers of 3G services are expected to have 18 collaborative, mobile “conferences” per year – six of which include video plus multimedia. The remaining calls will look more like a Net Meeting conference with whiteboard and/or files shared and viewed in real-time. Each collaborative conference will last an hour on the average. Business usage includes one-way hosted conferences from a fixed host.

Table 5.3 Rich Voice usage assumptions.

3G Subscribers	• 31.9 M 3G Subscribers (53% of population) • 20.4 M Consumer 3G Subscribers • 11.5M Business 3G Subscribers
Rich Voice Subscriptions[15]	• 5.6M Consumer Subscriptions • 5.9M Business Subscriptions
Frequency of Use	• 100 Consumer calls per year per subscription • 18 Business calls per year per subscription
Media Type	• All Rich Voice calls include voice • 33% of business Rich Voice are for multimedia video conference; 67% for multimedia only • 2% of Consumer Rich Voice calls are video and 98% are for multimedia / Low Resolution Video
Network Case: Origination and Termination	• 100% of consumer Rich voice calls are mobile to mobile • 70% of business Rich Voice calls are mobile to mobile • 30% of business Rich Voice calls are fixed to mobile (hosted conferences)
Session Duration	• Consumer calls are either 5 or 15 minutes • Business calls are either 15 or 60 minutes

Source: Telecompetition, Inc., prepared for the UMTS Forum, October 2003.

Most Rich Voice services are two-way and symmetric – all parties are sending and receiving the same type and quantity of information. Symmetry assumptions used in the analysis are shown in Table 5.4.

Table 5.4 Assumed asymmetry of Rich Voice service by contact type and network case.

Contact Type	Network Case	Service Symmetry – per user	Ratio UL: DL
Two Way	Mobile to mobile	Symmetric	1:1
	Mobile to Fixed	Not Applicable	
	Fixed to Mobile	Not Applicable	
One Way	Mobile to mobile	Not Applicable	1:1
	Mobile to Fixed	Not Applicable	
	Fixed to Mobile	Asymmetric to Downlink (hosted conference)	1:5

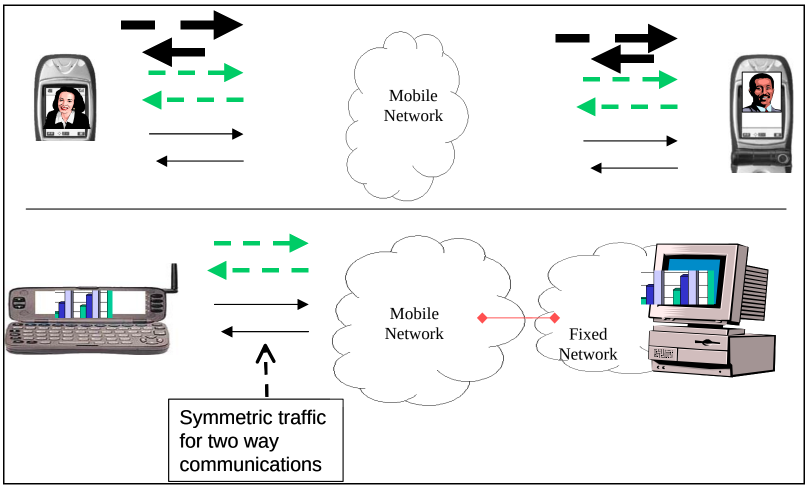
Source: Telecompetition, Inc., prepared for the UMTS Forum, October 2003.

Figure 5.5 further illustrates the symmetry of most Rich Voice services. Regardless of the type of terminal used or whether the transmission is between mobile and/or fixed networks, the real-time Rich Voice services are almost always two-way and symmetric.

[15] Rich Voice subscriptions estimated by Telecompetition Inc. for UMTS Forum Report 17. The estimates considered historic digital camera adoption rates as reported by IDC ("Worldwide Digital Camera Market Forecast and Analysis", 2000) and growth in business conferencing services as reported by Wainhouse Research ("Teleconferencing Markets and Strategies", September 2000).

Figure 5.5. Symmetry of Rich Voice services.

As long as the multimedia transmission is two-way, Rich Voice service is symmetric.

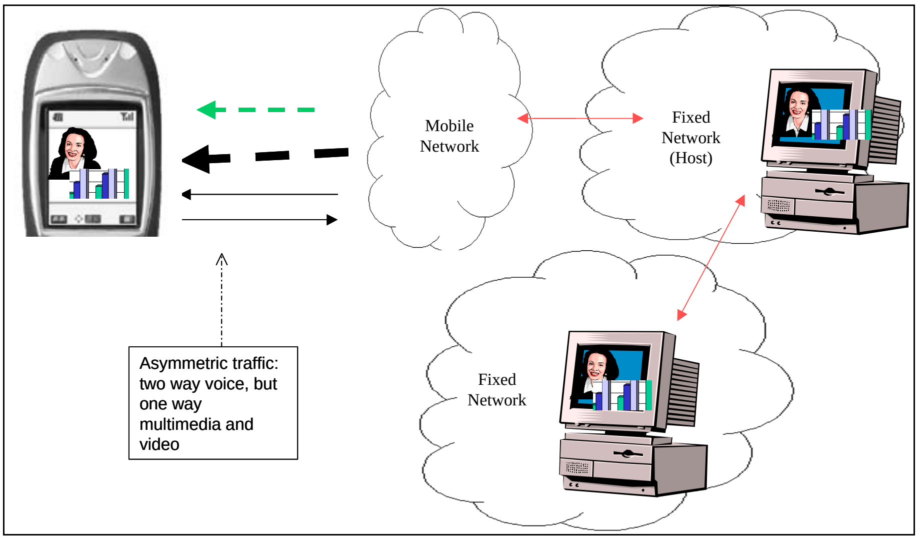


Source: Telecompetition, Inc., prepared for the UMTS Forum, October 2003.

The one clear exception to the Rich Voice symmetry is in the case of a hosted business conference where the host is in the fixed network. This typically would be a web cast, which is primarily one-way. The host transmits video, multimedia and voice, while the mobile participant would send only voice and possibly simple text to ask questions. This is illustrated in Figure 5.6

Figure 5.6. Rich Voice service example - hosted one-way conference for business.

One-way multimedia transmission is possible, but in practical use is most likely limited to business-hosted conferences.

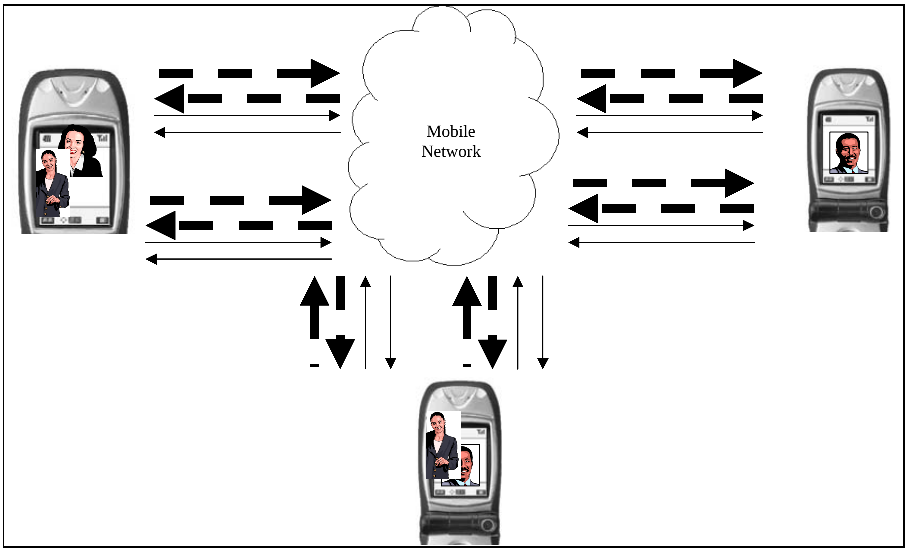


Source: Telecompetition, Inc., prepared for the UMTS Forum, October 2003.

Multi-party conferences between Rich Voice subscribers are included in the calculations for total sessions. As shown in Figure 5.7, multi-party calls are still symmetric and two-way.

Figure 5.7. Rich Voice service example for number of sessions – one to many.

The total number of sessions (calls) made by Rich Voice users is included in the total usage calculation regardless of whether they are calling each other or others on the fixed network. Therefore, a multi-party (one-to-many) call session impacts the traffic load during the busy hour, but not the symmetry.



Source: Telecompetition, Inc., prepared for the UMTS Forum, October 2003.

Session speed and session duration assumptions are shown in Table 5.8. Business Rich Voice calls are longer than consumer calls.

Table 5.8 Range of Rich Voice session speed assumptions based on media type and terminal complexity.

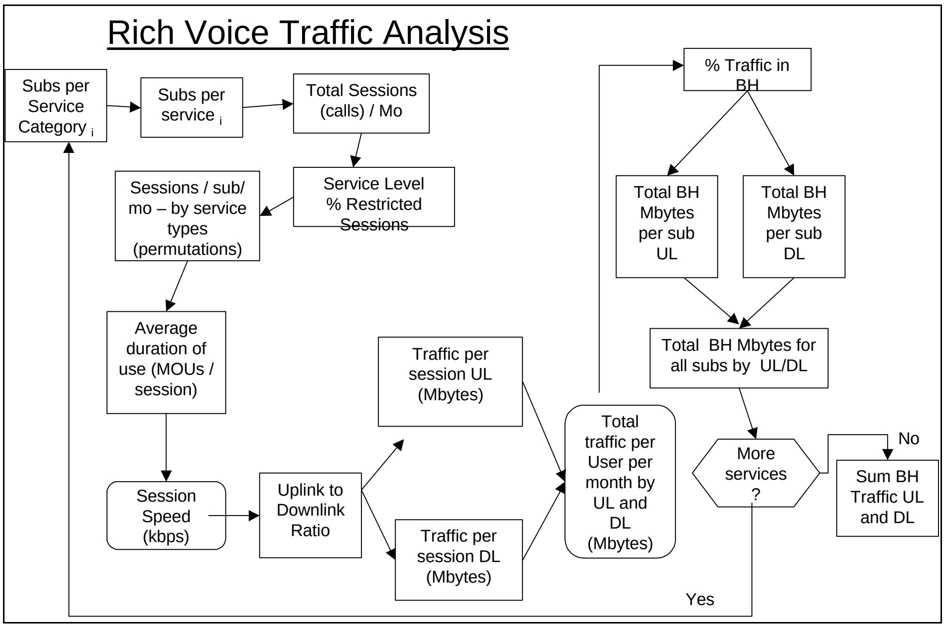
Terminal Complexity	Media Type	Session Data Rate
Low	Voice plus text	8 kbps
High	Voice plus multimedia	38 kbps
High	Voice plus video plus multimedia	192 kbps

Source: Telecompetition, Inc., prepared for the UMTS Forum, October 2003.

5.2 Service Traffic Analysis and Results

The framework used for Rich Voice traffic analysis follows the same flow as shown earlier in Figure 2.2. Because Rich Voice is a real-time service, session speed and average duration of use (MOUs/session) are important variables in the analysis. This is illustrated in Figure 5.9.

Figure 5.9. Rich Voice traffic analysis framework.

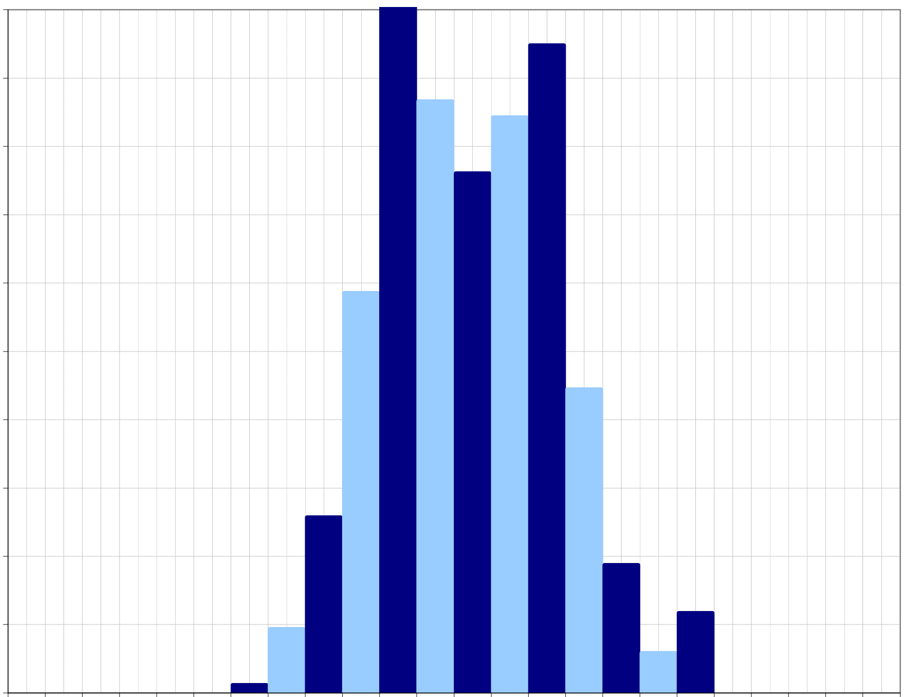


Source: Telecompetition, Inc., prepared for the UMTS Forum, October 2003.

The assumption is that 10.3% consumer and 16.6% business subscribers daily traffic occurs in the busy hour. The traffic distribution is illustrated in Figures 5.10 and 5.11, and is based on the following assumptions:

- Business use is concentrated from Monday through Friday, during the working hours of 0800 to 1800 (8 a.m. to 6 p.m.)
- While business mobile voice traffic is typically concentrated during commute hours, Rich Voice users incorporate Rich Voice into the routine business processes of a mobile employee so traffic is more evenly distributed throughout the day.
- Consumers use Rich Voice more for recreational and personal interaction. Thus, consumer Rich Voice traffic is more concentrated in the evenings.
- The busy hour does not vary by the type of message or network. Subscribers use the service when desired; using whatever terminal or network access is available to them at that time. The type of terminal capabilities and the needs of the situation determine whether the consumer will use a higher or lower resolution service.
- Business and consumer Rich Voice subscribers will have the ability to choose a restricted (lower speed) rather than a basic class of service for individual calls.
- Consumers use the service 30 days a month, while business subscribers use it for 21.2 days a month.

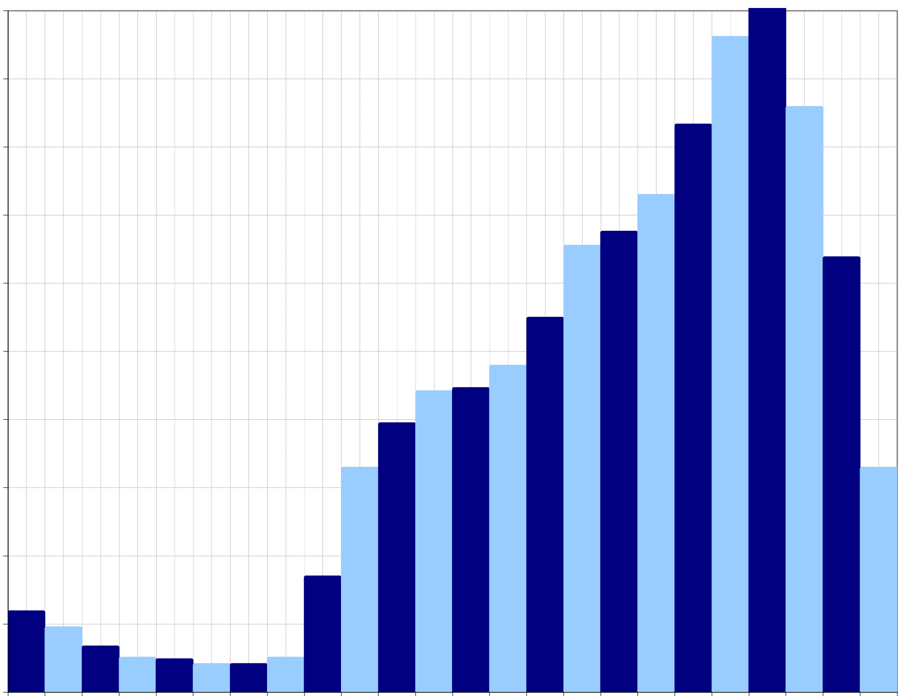
Table 5.10 Assumed diurnal traffic distribution – Business Rich Voice



	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
% Traffic	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.9%	2.6%	5.9%	10.3	8.7%	7.6%	8.4%	9.5%	4.4%	1.9%	0.6%	1.2%	0.0%	0.0%	0.0%	0.0%	0.0%

Source: Telecompetition, Inc., prepared for the UMTS Forum, October 2003.

Table 5.11 Assumed diurnal traffic distribution – Consumer Rich Voice



	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
% Traffic	1.2%	0.9%	0.7%	0.5%	0.5%	0.4%	0.4%	0.5%	1.7%	3.3%	3.9%	4.4%	4.4%	4.8%	5.5%	6.5%	6.7%	7.3%	8.3%	9.6%	10.3	8.6%	6.4%	3.3%

Source: Telecompetition, Inc., prepared for the UMTS Forum, October 2003.

Based on the assumptions and analysis presented in this section, Table 5.12 and Table 5.13 summarises the offered traffic and traffic characteristics of Rich Voice. This indicates Rich Voice is asymmetric to the downlink. The asymmetry of Rich Voice is created by the existence of high bandwidth one-way hosted conferences for business users. All other Rich Voice services are two way and symmetric.

Table 5.12 Rich Voice – offered busy hour traffic and asymmetry per country.

Description	Busy Hour Traffic
Uplink - Rich Voice Offered traffic per country	**2.06 TBytes**
Business	2.03 TBytes
Consumer	0.03 TBytes
Downlink - Rich Voice Offered traffic per country	**2.67 TBytes**
Business	2.64 TBytes
Consumer	0.03 TBytes
Overall Service Asymmetry (UL /DL)	**0.77**

Source: Telecompetition, Inc., prepared for the UMTS Forum, October 2003.

Table 5.13 Rich Voice – Offered busy hour traffic per subscription.

Description	Busy Hour Traffic
Uplink - Rich Voice traffic per Subscription	
Per Business Subscription	345.6 KBytes
Per Consumer Subscription	7.5 KBytes
Downlink - Rich Voice traffic per Subscription	
Per Business Subscription	450.7 KBytes
Per Consumer Subscription	7.5 KBytes

Source: Telecompetition, Inc., prepared for the UMTS Forum, October 2003.

6 Customised Infotainment Assumptions and Offered Traffic

Analysis of Customised Infotainment services includes business and consumer usage, and considered all the variables shown in Figure 1.2. The definition of Customised Infotainment is repeated here for reader clarity:

> **Customised Infotainment: A consumer 3G service that provides device-independent access to personalised content anywhere, anytime via structured-access mechanisms based on mobile portals.**

Customised Infotainment is a mass-market portal service that can include access to a wide variety of content and services. It is defined as a consumer-only service, paid for by an individual and used for entertainment, shopping, email, etc. A Customised Infotainment subscriber could also subscribe to other services such as MMS or Location-Based Services. Customised Infotainment is similar to Mobile Internet Access (Section 7) in the types of activities and segments included. Customised Infotainment differs from Mobile Internet Access in that it is a portal service, typically access via less complex mobile terminals, where the service provider is controlling the content and therefore the bandwidth/ file size available. Customised Infotainment subscribers are not as “Internet centric” as Mobile Internet Access subscribers and therefore access the service less frequently, for shorter periods of time. Personalisation of content and easy access to desired information is relatively more important than access speed.

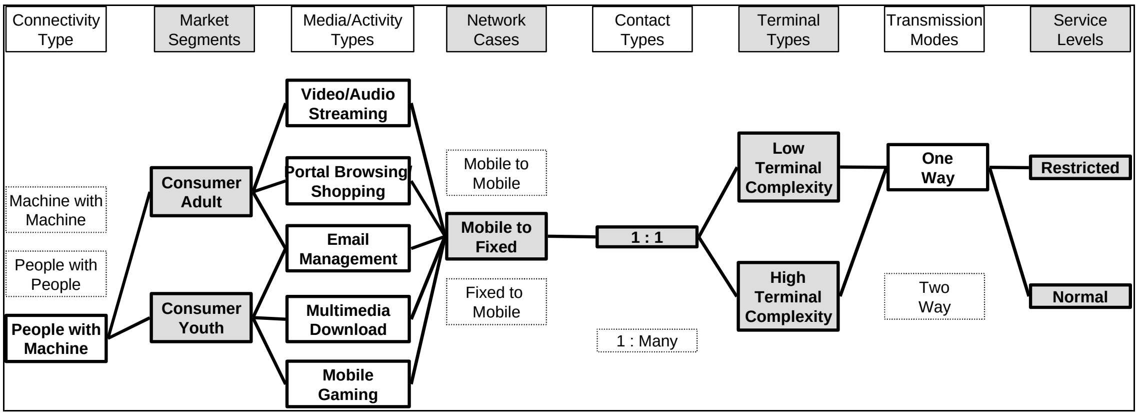
6.1 Usage and Traffic Assumptions

Three activity types were analysed for each of two consumer segments. While there are any number of activities and content that are potentially available through a Customised Infotainment service, the activity types chosen are represent the bulk of traffic volume and services with distinct traffic characteristics. Adult consumers and Youth were analysed separately to capture more accurately the entertainment services with higher usage patterns in a smaller group of subscribers.

- Adult Consumers
  - Email Management (includes both sending and receiving emails)
  - Video/Audio Streaming
  - Portal Browsing / Shopping
- Youth Consumers (teens)
  - Email Management (includes both sending and receiving emails)
  - Multimedia Download (i.e., music or video clips)
  - Mobile Games

The service variables and states for Customised Infotainment are shown in Figure 6.1. By definition, Customised Infotainment includes people accessing content hosted on network servers. (Person-to-person messaging and communications is part of MMS.) Thus all activities are considered one-way, mobile-to-fixed, and one-to-one communication.

Figure 6.1. Service variables and states used for Customised Infotainment.



Source: Telecompetition, Inc., prepared for the UMTS Forum, October 2003.

Subscribers of Customised Infotainment are expected to connect to their portal services once or twice a day and to perform multiple activity sessions each time they connect. For adult subscribers, the most popular activity is portal browsing and shopping (which includes financial transactions) followed by email. For Youth, mobile gaming is the most popular activity along with email. Table 6.2 summarises the specific usage assumptions for Customised Infotainment.

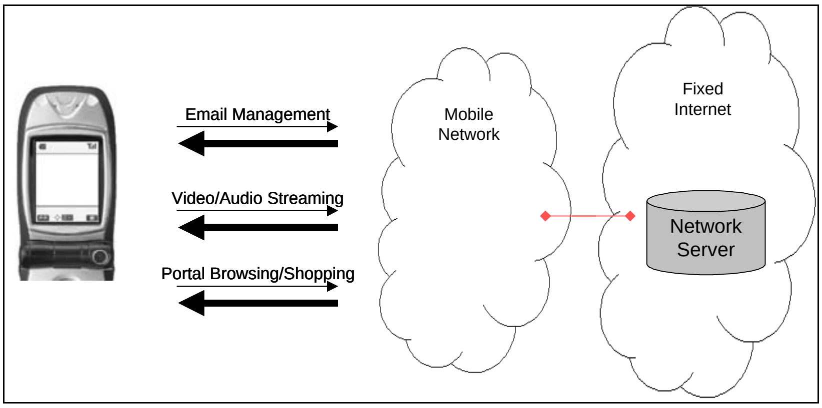
Table 6.2 Customised Infotainment usage assumptions.

3G Subscribers	• 31.9 M 3G Subscribers (53% of population) • 20.4 M Consumer 3G Subscribers
Customised Infotainment Subscriptions	• 18.2 M Customised Infotainment Subscriptions • 2.2 M Youth Subscriptions and 16M Adult Subscriptions
Frequency of Use	• 26 connections per month – combined activity types
Activity Type (sessions per month)	• Email Management: 20 sessions • Video / Audio Streaming: 3 sessions • Portal Browsing, Shopping: 25 sessions • Mobile Gaming (Youth): 13 sessions • Music or Video Download (Youth): 6 sessions
Network Case and Terminal Complexity	• 100% mobile to fixed • 90% Low Complexity Terminals
Transmission Mode and Contact Type	• 100% one way • 100% one-to-one

Source: Telecompetition, Inc., prepared for the UMTS Forum, October 2003.

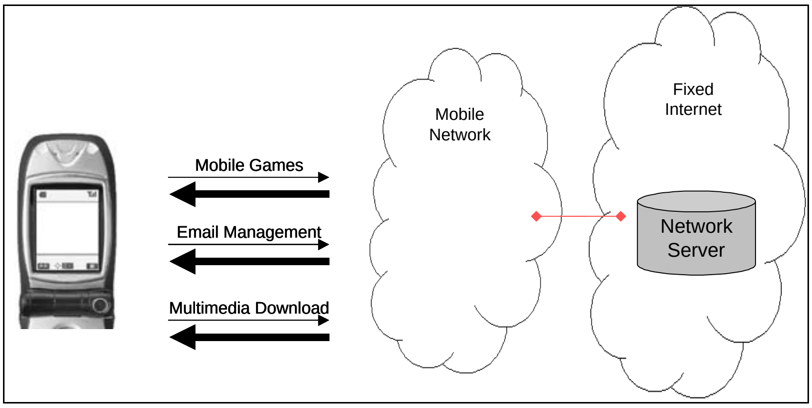
Figure 6.3 and 6.4 further illustrates the symmetry of most Customised Infotainment services.

Figure 6.3. Symmetry of Customised Infotainment - Adult Segment..



Source: Telecompetition, Inc., prepared for the UMTS Forum, October 2003.

Figure 6.4. Customised Infotainment – Youth Segment



Source: Telecompetition, Inc., prepared for the UMTS Forum, October 2003.

File size assumptions for uplink and downlink are shown in Table 6.5. Customised Infotainment services are asymmetric to the downlink.

Table 6.5 Customised Infotainment – UL and DL file size by activity type – low complexity terminals.

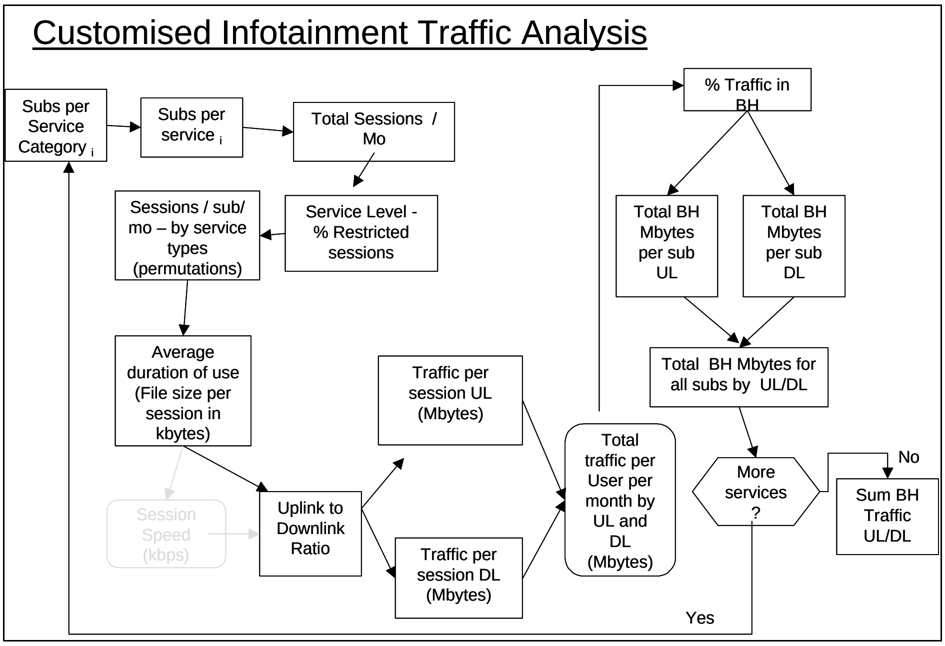
Media / Activity Type	UL File Size (Kbytes)	DL File Size (Kbytes)	UL: DL Ratio
Email Management	208	830	1:4
Video/Audio Streaming	90	2,250	1:25
Portal Browsing / Shopping	216	1,512	1:7
MM Download	90	2,250	1:25
Mobile Games	144	3,600	1:25

Source: Telecompetition, Inc., prepared for the UMTS Forum, October 2003.

6.2 Service Traffic Analysis and Results

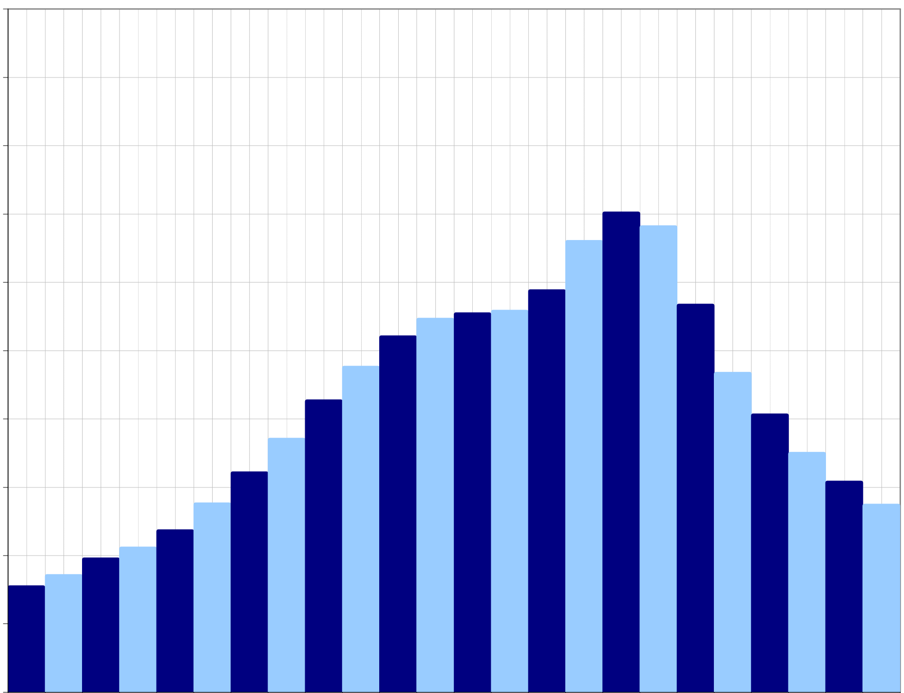
The framework used for Customised Infotainment traffic analysis follows the same flow as shown earlier in Figure 2.2 and is repeated in Figure 6.6. The busy hour distribution is shown in Figures 6.7. The percent of traffic that occurs in the busy hour is 7.0%.

Figure 6.6. Customised Infotainment traffic analysis framework.



Source: Telecompetition, Inc., prepared for the UMTS Forum, October 2003.

Figure 6.7. Assumed diurnal traffic distribution – Customised Infotainment



	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
% Traffic	1.5%	1.7%	1.9%	2.1%	2.4%	2.8%	3.2%	3.7%	4.3%	4.8%	5.2%	5.5%	5.5%	5.6%	5.9%	6.6%	7.0%	6.8%	5.7%	4.7%	4.1%	3.5%	3.1%	2.7%

Source: Telecompetition, Inc., prepared for the UMTS Forum, October 2003.

Based on the assumptions and analysis presented in this section, Table 6.8 and Table 6.9 summarises the offered traffic and traffic characteristics of Customised Infotainment.

Table 6.8 Customised Infotainment – offered busy hour traffic and asymmetry per country.

Description	Busy Hour Traffic
Uplink - Customised Infotainment Offered traffic per country	**0.38 TBytes**
Adult	0.36 TBytes
Youth	0.02 TBytes
Downlink - Customised Infotainment Offered traffic per country	**2.57 TBytes**
Adult	2.22 TBytes
Youth	0.35 TBytes
Overall Service Asymmetry (UL /DL)	**0.15**

Source: Telecompetition, Inc., prepared for the UMTS Forum, October 2003.

Table 6.9 Customised Infotainment – offered busy hour traffic per subscription.

Description	Busy Hour Traffic
Uplink - Customised Infotainment traffic per Subscription	
Adult Subscription	22.4 kBytes
Youth Subscription	10.4 kBytes
Downlink - Customised Infotainment traffic per Subscription	
Adult Subscription	138.3 kBytes
Youth Subscription	159.9 kBytes

Source: Telecompetition, Inc., prepared for the UMTS Forum, October 2003.

7 Mobile Internet Access Assumptions and Offered Traffic

Analysis of Mobile Internet Access services considered all the variables shown in Figure 1.2. The definition of Mobile Internet Access is repeated here for reader clarity:

> **Mobile Internet Access: A 3G consumer-only service that offers mobile access to full fixed ISP services with near-wireline transmission quality and functionality. It includes full Web access to the Internet as well as file transfer, email, and streaming video/audio capability.**

As stated in Section 6, the activity/media types considered for Mobile Internet Access are the same as those for Customised Infotainment. Like Customised Infotainment, Mobile Internet Access is a consumer-only service. However, Mobile internet Access subscribers prefer direct access to Internet services and content rather than using a portal service, go “on line” more frequently, and are more likely to use complex terminals. As a result, the bandwidth / file size requirements for the same activities is higher. Furthermore, Internet content is less likely to be optimised for mobile terminals than mobile portal content, pointing again to larger file sizes.

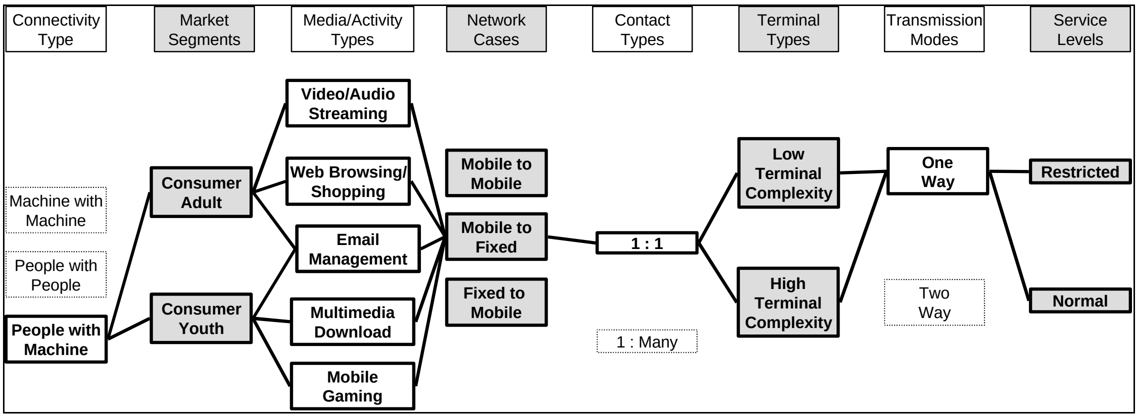
7.1 Usage and Traffic Assumptions

Three activity types were analysed for each of two consumer segments. While there are any number of activities and content that are potentially available through a Mobile Internet Access service, the activity types chosen are represent the bulk of traffic volume and services with distinct traffic characteristics. Adult consumers and Youth were analysed separately to capture more accurately the entertainment services with higher usage patterns in a smaller group of subscribers.

- Adult Consumers
  - Email Management
  - Video/Audio Streaming
  - Web Browsing / Shopping
- Youth (teens) Consumers
  - Email Management
  - Multimedia Download
  - Mobile Games (mobile access to server-based games)

The service variables and states for Mobile Internet Access are shown in Figure 7.1 and are identical to those shown for Customised Infotainment. By definition, Mobile Internet Access includes people accessing content hosted on network servers. (Person-to-person messaging and communications is part of MMS.) Thus all activities are considered one-way, mobile-to-fixed, and one-to-one communication.

Figure 7.1. Service variables and states used for Mobile Internet Access.



Source: Telecompetition, Inc., prepared for the UMTS Forum, October 2003.

Subscribers of Mobile Internet Access service are expected to connect "on-line" two or more times a day and to perform multiple activity sessions each time they connect. For adult subscribers, the most popular activity is portal browsing and shopping (which includes financial transactions) followed by email. For youth, mobile gaming is the most popular activity along with email. Table 7.2 summarises the usage assumptions for Mobile Internet Access.

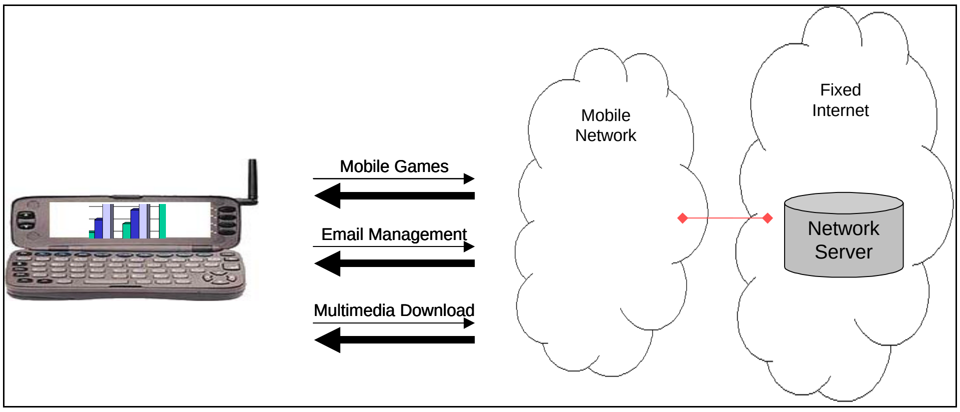
Table 7.2 Mobile Internet Access usage assumptions.

3G Subscribers	• 31.9 M 3G Subscribers (53% of population) • 20.4 M Consumer 3G Subscribers
Mobile Internet Access Subscriptions	• 2.5 M Mobile Internet Access Subscriptions • 0.3 M Youth Subscriptions and 2.2M Adult Subscriptions
Frequency of Use	• 52 connections per month – combined activity types
Activity Type (sessions per month)	• Email Management: 39 sessions • Video / Audio Streaming: 5 sessions • Portal Browsing, Shopping: 49 sessions • Mobile Gaming (Youth): 26 sessions • Music or Video Download (Youth): 12 sessions
Network Case and Terminal Complexity	• 100% mobile to fixed • 70% High Complexity Terminals
Transmission Mode and Contact Type	• 100% one way • 100% one-to-one

Source: Telecompetition, Inc., prepared for the UMTS Forum, October 2003.

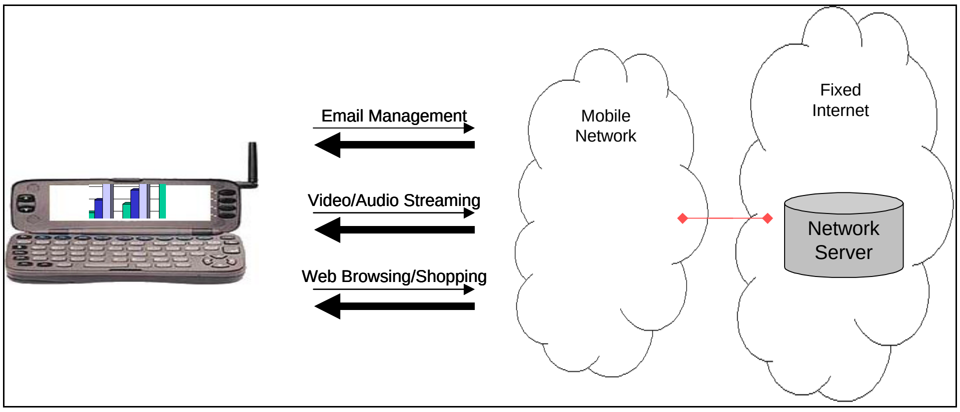
Figure 7.3 and 7.4 further illustrates the symmetry of most Mobile Internet Access services.

Figure 7.3. Mobile Internet Access – Youth Segment.



Source: Telecompetition, Inc., prepared for the UMTS Forum, October 2003.

Figure 7.4. Mobile Internet Access – Adult Segment



Source: Telecompetition, Inc., prepared for the UMTS Forum, October 2003.

File size assumptions for uplink and downlink are shown in Table 7.5. Mobile Internet Access services are asymmetric to the downlink.

Table 7.5 Mobile Internet Access – UL and DL file size by activity type – high complexity terminals.

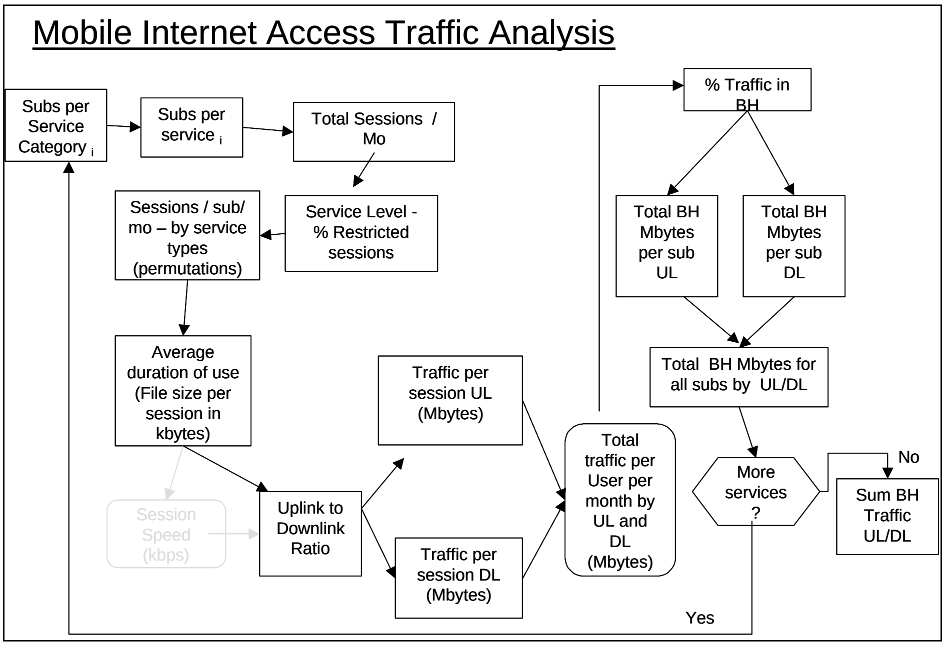
Media / Activity Type	UL File Size (Kbytes)	DL File Size (Kbytes)	UL: DL Ratio
Email Management	436	1,743	1:4
Video/Audio Streaming	189	4,725	1:25
Web Browsing / Shopping	454	3,175	1:7
Multimedia Download	189	4,725	1:25
Mobile Games	288	7,200	1:25

Source: Telecompetition, Inc., prepared for the UMTS Forum, October 2003.

7.2 Service Traffic Analysis and Results

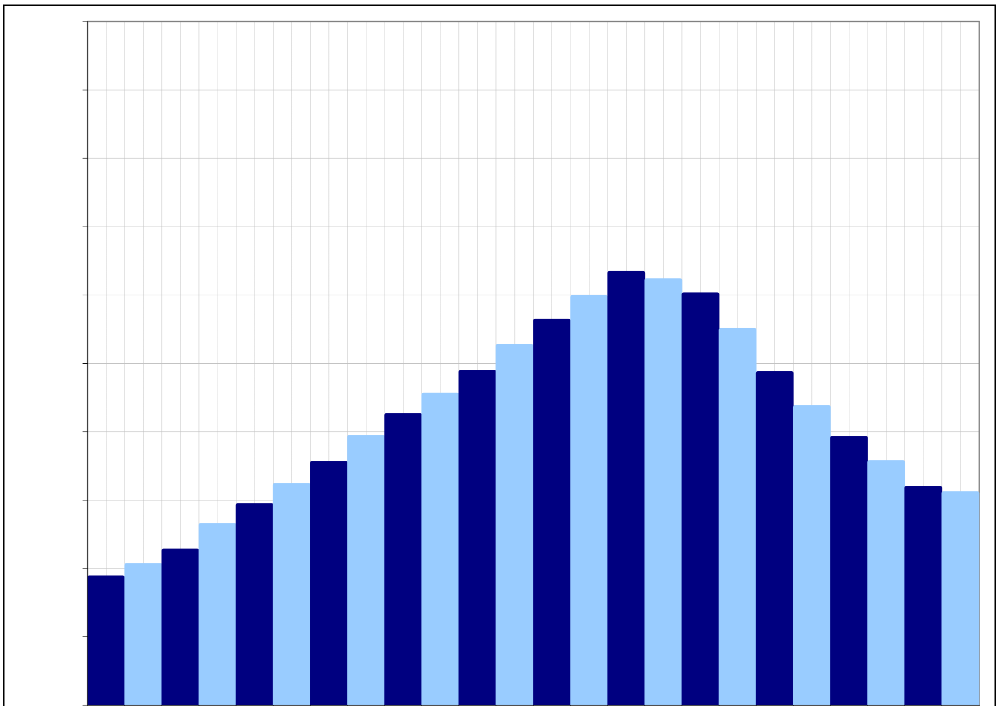
The framework used for Mobile Internet Access traffic analysis follows the same flow as shown earlier in Figure 2.2 and is repeated here in Figure 7.6. The assumed busy hour traffic distribution is illustrated in Figures 7.7. The percent of traffic that occurs in the busy hour is 6.33%.

Figure 7.6. Mobile Internet Access traffic analysis framework.



Source: Telecompetition, Inc., prepared for the UMTS Forum, October 2003.

Table 7.7 Assumed diurnal traffic distribution – Mobile Internet Access



	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
% Traffic	1.9%	2.1%	2.3%	2.6%	2.9%	3.2%	3.5%	3.9%	4.2%	4.5%	4.9%	5.3%	5.6%	6.0%	6.3%	6.2%	6.0%	5.5%	4.9%	4.4%	3.9%	3.6%	3.2%	3.1%

Source: Telecompetition, Inc., prepared for the UMTS Forum, October 2003.

Based on the assumptions and analysis presented in this section, Table 7.8 and Table 7.9 summarises the offered traffic and traffic characteristics of Mobile Internet Access.

Table 7.8 Mobile Internet Access – offered busy hour traffic and asymmetry per country.

Description	Busy Hour Traffic
Uplink - Mobile Internet Access Offered traffic per country	**0.15 TBytes**
Adult	0.14 TBytes
Youth	0.01 TBytes
Downlink - Mobile Internet Access Offered traffic per country	**0.98 TBytes**
Adult	0.87 TBytes
Youth	0.11 TBytes
Overall Service Asymmetry (UL /DL)	**0.15**

Source: Telecompetition, Inc., prepared for the UMTS Forum, October 2003.

Table 7.9. Mobile Internet Access – offered busy hour traffic per subscription.

Description	Busy Hour Traffic
Uplink - Mobile Internet Access traffic	
Per Adult Subscription	72.8 kBytes
Per Youth Subscription	30.0 kBytes
Downlink - Mobile Internet Access traffic	
Per Adult Subscription	449.6 kBytes
Per Youth Subscription	420.1 kBytes

Source: Telecompetition, Inc., prepared for the UMTS Forum, October 2003.

8 Mobile Intranet Extranet Access Assumptions and Offered Traffic

Analysis of Mobile Intranet Extranet Access services considered all the variables shown in Figure 1.2. The definition of Mobile Intranet Extranet Access is repeated here for reader clarity:

> **Mobile Intranet Extranet Access: A business 3G service that provides secure mobile access to corporate Local Area Networks (LANs), Virtual Private Networks (VPNs), and the Internet, including access to all messaging and email services.**

8.1 Usage and Traffic Assumptions

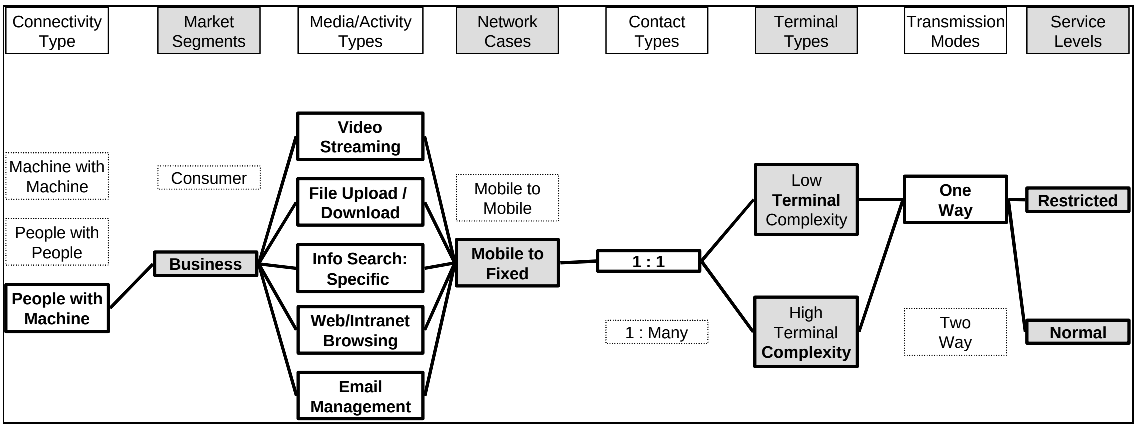
Analysis of Mobile Intranet Extranet Access includes two distinct business subscriber segments. The first segment, "Typically Mobile" includes field sales or technicians who are typically working away from the office and must regularly access corporate infrastructure on a daily basis to send and retrieve information. The second segment, "Occasionally Mobile", includes mobile executives and other professionals that typically work in an office, but must travel or are away from the office about 25% of the time. A total of six activity types were analysed for these two segments. While there are any number of activities and content that are potentially available, the activity types chosen are represent the bulk of traffic volume and services with distinct traffic characteristics or bandwidth requirements.

- Typically Mobile Workers
  - E-Mail Management (sending and receiving emails with attachments)
  - Video / Audio Streaming (e.g., corporate training clips or announcements)
  - Info Search: Specific (e.g., market or sales updates)
- Occasionally Mobile Workers
  - File Download / Upload
  - Intranet, Extranet, or Web Browsing
  - Email Management

Source: Telecompetition, Inc., prepared for the UMTS Forum, October 2003.

Service variables and states used for business Mobile Intranet Extranet Access calculations are shown in Figure 8.1. By definition, Mobile Intranet Extranet Access includes mobile workers accessing content hosted on network servers. (Person-to-person messaging and communications is part of MMS.) Thus all activities are considered one-way, mobile-to-fixed, and one-to-one communication.

Figure 8.1. Service variables and states used for Mobile Intranet Extranet Access.



Source: Telecompetition, Inc., prepared for the UMTS Forum, October 2003.

Typically Mobile Intranet Extranet Access subscribers connect about three times every workday. Occasionally Mobile workers connect about three times a day for the 25% of the work month away from the office. Typically Mobile workers look for specific information, view streaming media (e.g. repair instruction videos) and check email. Occasionally Mobile workers browse for more general information on corporate servers or the Internet, check email, and download files, revise them, then upload. Table 8.2 summarises the usage assumptions for Mobile Intranet Extranet Access.

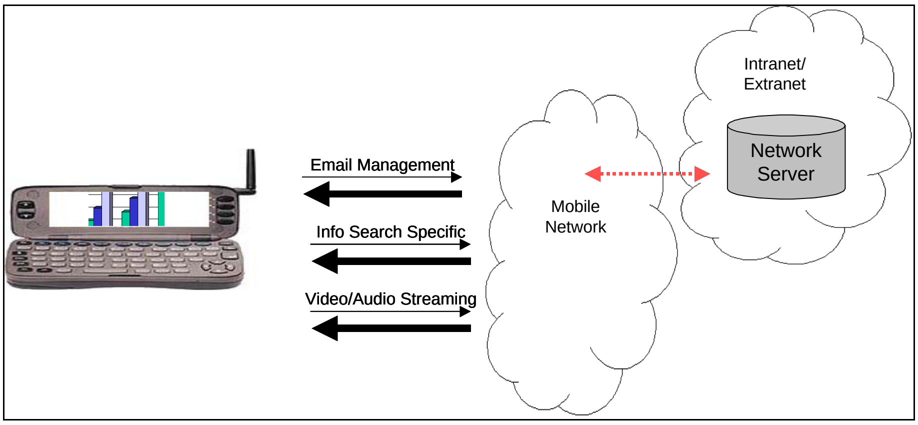
Table 8.2 Mobile Intranet Extranet Access usage assumptions.

3G Subscribers	• 31.9 M 3G Subscribers (53% of population)
Mobile Intranet Extranet Access Subscriptions	• 11.5 M Business Subscriptions • 9.3 M "Typically Mobile" • 1.8 M "Occasionally Mobile"
Frequency of Use	• 66 sessions per month – combined activity types; "Typically Mobile" • 16 sessions per month – "Occasionally Mobile"
Activity Type (sessions / month)	• Email Management: 56 sessions • Video Audio Streaming: 7 sessions • Info Search – Specific: 47 sessions • File Download / Upload: 8 sessions (Occasionally Mobile) • Intra/Extra or Web Browsing: 16 sessions (Occasionally Mobile)
Network Case and Terminal Complexity	• 100% mobile to fixed • 70% High Complexity Terminals
Transmission Mode and Contact Type	• 100% one way • 100% one-to-one

Source: Telecompetition, Inc., prepared for the UMTS Forum, October 2003.

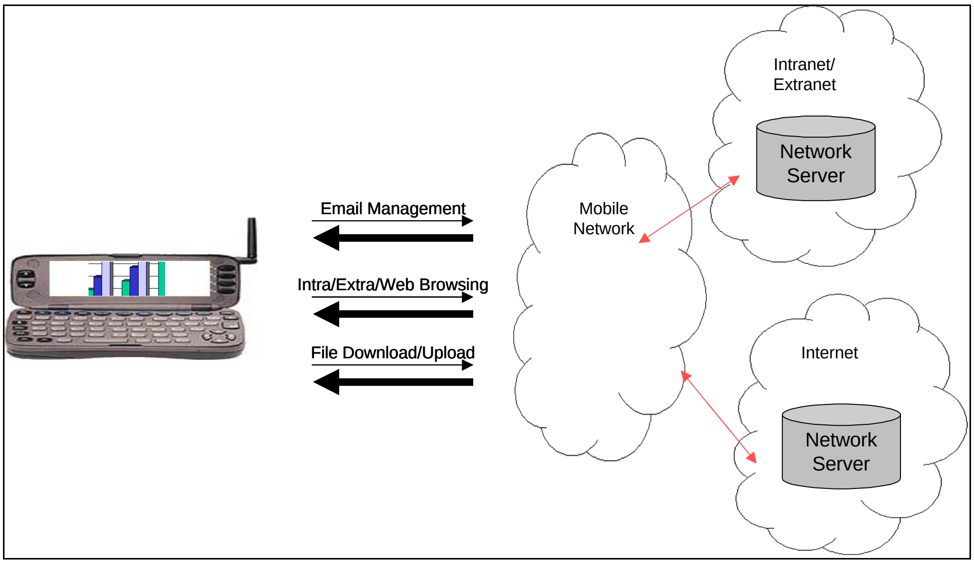
Figure 8.3 and 8.4 further illustrate the symmetry of most Mobile Intranet Extranet Access services.

Figure 8.3. Symmetry of Mobile Intranet Extranet Access – Typically Mobile Worker.



Source: Telecompetition, Inc., prepared for the UMTS Forum, October 2003.

Figure 8.4. Mobile Intranet Extranet Access - Occasionally Mobile Worker.



Source: Telecompetition, Inc., prepared for the UMTS Forum, October 2003.

File size assumptions for uplink and downlink are shown in Table 8.5. Mobile Intranet Extranet Access services are asymmetric to the downlink.

Table 8.5 Mobile Intranet Extranet Access – UL and DL file size by activity type – high complexity terminals.

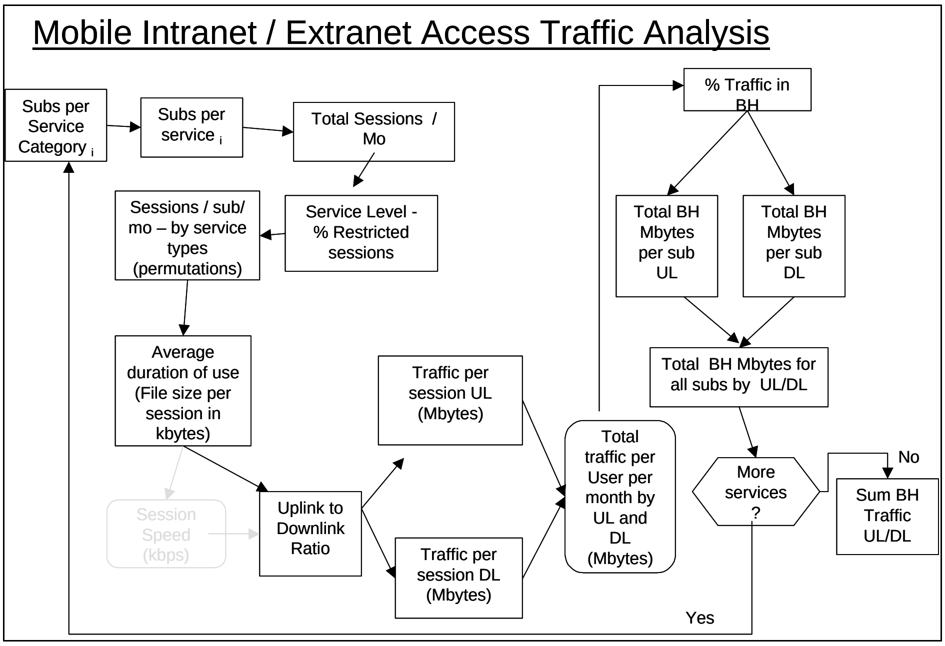
Media / Activity Type	UL File Size (Kbytes)	DL File Size (Kbytes)	UL: DL Ratio
E-Mail Management	436	1,743	1:4
Video / Audio Streaming	189	4,725	1:25
Info Search – Specific	88	617	1:7
File Upload / Download	987	1,036	1:1.1
Intra/Extra or web browsing	454	3,175	1:7

Source: Telecompetition, Inc., prepared for the UMTS Forum, October 2003.

8.2 Service Traffic Analysis and Results

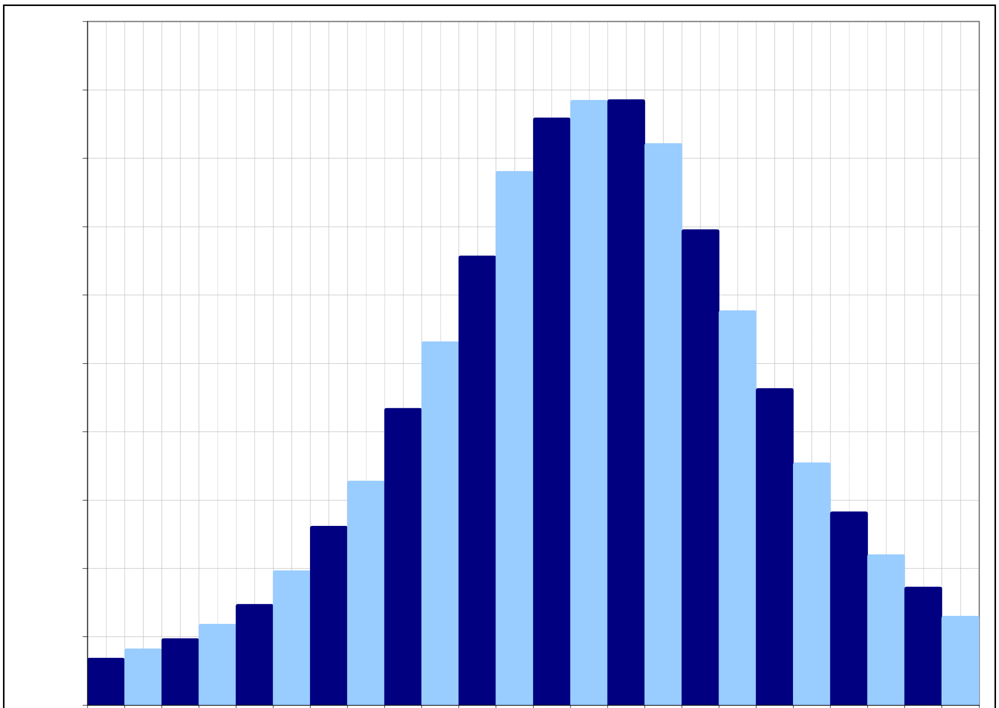
The framework used for Mobile Intranet Extranet Access traffic analysis follows the same flow as shown earlier in Figure 2.2 and repeated in Figure 8.6. The traffic distribution is illustrated in Figures 8.7. The percent of traffic that occurs in the busy hour is 8.57%.

Figure 8.6. Mobile Intranet / Extranet Access traffic analysis framework.



Source: Telecompetition, Inc., prepared for the UMTS Forum, October 2003.

Table 8.7 Assumed diurnal traffic distribution – Mobile Intranet Extranet Access



	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
% Traffic	0.7%	0.8%	1.0%	1.2%	1.5%	1.9%	2.6%	3.3%	4.3%	5.3%	6.6%	7.8%	8.6%	8.8%	8.8%	8.2%	6.9%	5.7%	4.6%	3.5%	2.8%	2.2%	1.7%	1.3%

Source: Telecompetition, Inc., prepared for the UMTS Forum, October 2003.

Based on the assumptions and analysis presented in this section, Table 8.8 and Table 8.9 summarises the offered traffic and traffic characteristics of Mobile Intranet Extranet access.

Table 8.8. Mobile Intranet Extranet Access – offered busy hour traffic per country.

Description	Busy Hour Traffic
Uplink - Mobile Intranet Extranet Access Offered traffic per country	**1.09 TBytes**
Typically Mobile	.96 TBytes
Occasionally Mobile	0.13 TBytes
Downlink - Mobile Intranet Extranet Access Offered traffic per country	**5.61 TBytes**
Typically Mobile	5.10 TBytes
Occasionally Mobile	0.51 TBytes
Overall Service Asymmetry (UL /DL)	**0.20**

Source: Telecompetition, Inc., prepared for the UMTS Forum, October 2003.

Table 8.9. Mobile Intranet Extranet Access – offered busy hour traffic per subscription.

Description	Busy Hour Traffic
Uplink - Mobile Intranet Extranet Access traffic per Subscription	
Typically Mobile	103.2 kBytes
Occasionally Mobile	73.9 kBytes
Downlink - Mobile Intranet Extranet Access traffic per Subscription	
Typically Mobile	546.2 kBytes
Occasionally Mobile	286.1 kBytes

Source: Telecompetition, Inc., prepared for the UMTS Forum, October 2003.

9 Location-Based Services Assumptions and Offered Traffic

Analysis of Location-Based Services includes business and consumer usage, and considered all the variables shown in Figure 2.2. The definition of Location-Based Services is repeated here for reader clarity:

> **Location-Based Services: A business and consumer 3G service that enables users to find other people, vehicles, resources, services or machines. It also enables others to find users, as well as enabling users to identify their own location via terminal or vehicle identification.**

The distinguishing characteristic of Location-based Services is that the service requires data on the current location or position of a mobile object or person. Machine-to-machine devices that monitor stationary objects would be considered telemetry. Services that provide information about a future location (such as travel information) would fall under Customised Infotainment or Mobile Internet Access.

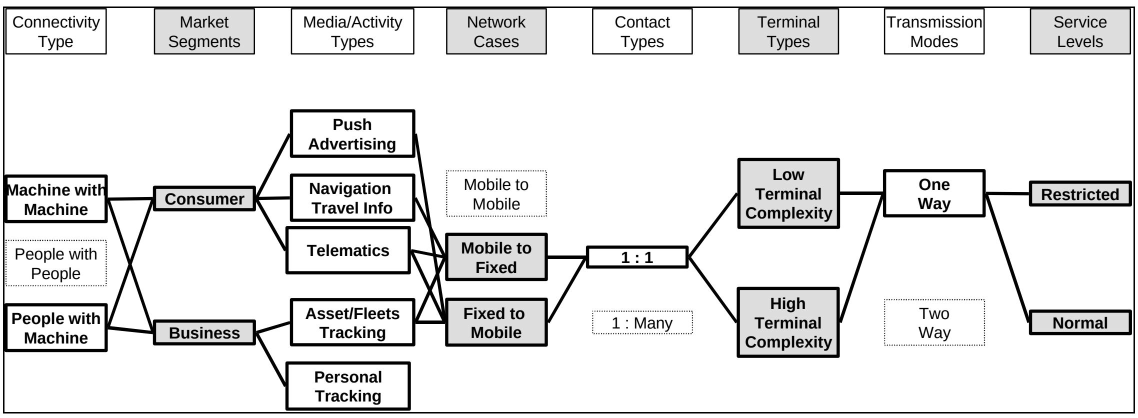
9.1 Usage and Traffic Assumptions

Future Location-based Services could include a wide variety of activities. For purposes of this report, five total activity types within consumer and business segments were analysed:

- Consumer Information Services
  - LBS Push Advertising (“Opt -in” only)
  - Navigation / Travel Information (Directions or area information based on current location of mobile user)
  - Telematics (Personal Vehicle (Navigation and direction information services such as OnStar, delivered via mobile networks.)
- Business Tracking Services
  - Personal Tracking (Continuous tracking of children, elderly, pets, etc.)
  - Fleet / Asset Tracking (Continuous tracking of mobile assets such as fleets or cargo)

Service variables and states used for business Location-Based Services calculations are shown in Figure 9.1

Figure 9.1. Service variables and states used for Location-Based Services.



Source: Telecompetition, Inc., prepared for the UMTS Forum, October 2003.

Location-based services include incremental activities access by 3G subscribers occasionally or by a small portion of users. Table 9.2 summarises the usage assumptions for Location-Based Services.

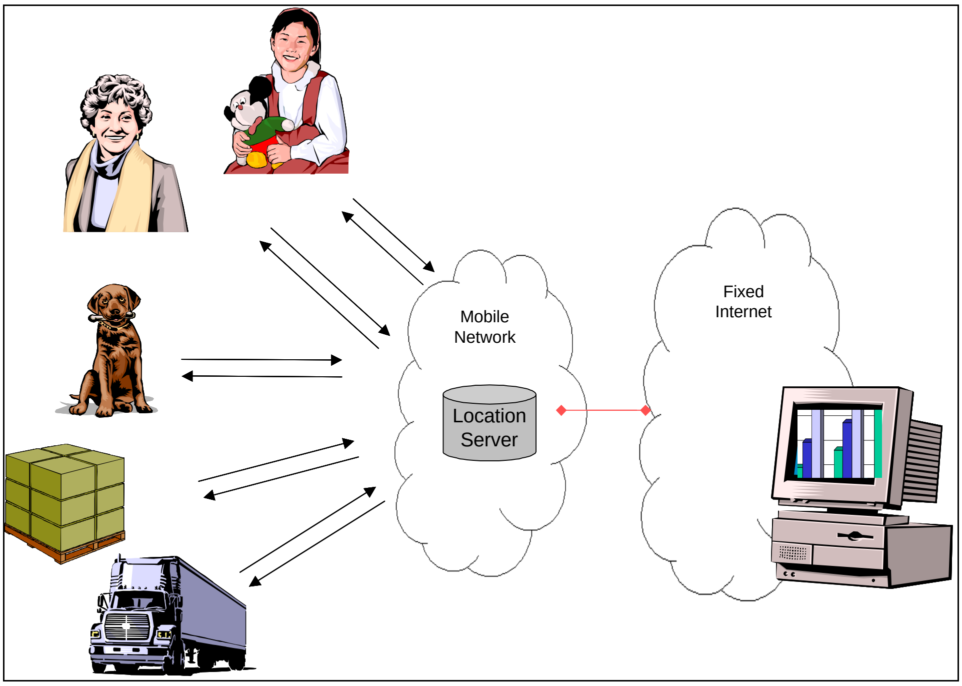
Table 9.2. Location-Based Services usage assumptions.

3G Subscribers	• 31.9 M 3G Subscribers (53% of population) • 20.4 M Consumer 3G Subscribers
Subscriptions and Activity Type (sessions per month)	• LBS advertising: 25% of consumer subs access one session per day • Navigation/Travel: 85% of consumer subs @ 8 sessions/ month • Personal tracking: 1.3 3G subscribers use continuous (24x7) tracking • Telematics: 1.8M 3G subscribers @ 1 session per week • Fleet / Asset Tracking: 0.3M 3G subs with continuous tracking
Network Case and Terminal Complexity	• Mobile to fixed –varies by activity type • 90% Low Complexity Terminals
Transmission Mode and Contact Type	• 100% one way • 100% one-to-one

Source: Telecompetition, Inc., prepared for the UMTS Forum, October 2003.

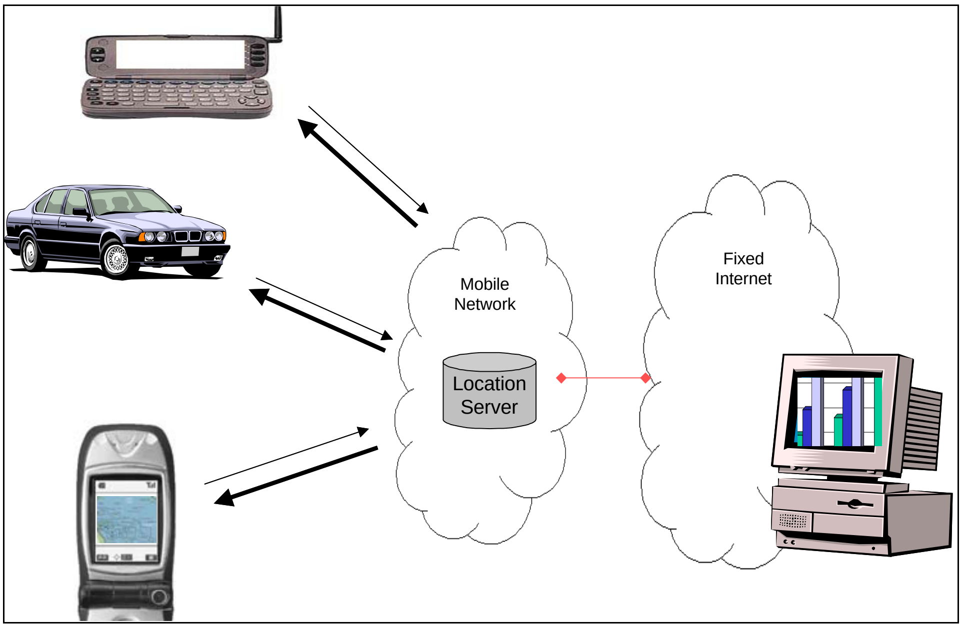
Figure 9.3 and 9.4 further illustrate the symmetry of most Location-Based Services.

Figure 9.3. Location-Based Services - continuous tracking services.



Source: Telecompetition, Inc., prepared for the UMTS Forum, October 2003.

Figure 9.4. Location-Based Services - Consumer.



Source: Telecompetition, Inc., prepared for the UMTS Forum, October 2003.

File size assumptions for uplink and downlink are shown in Table 9.5. Location-Based Services are asymmetric to the downlink.

Table 9.5. Location-Based Services – UL and DL file size by activity type – low complexity terminals.

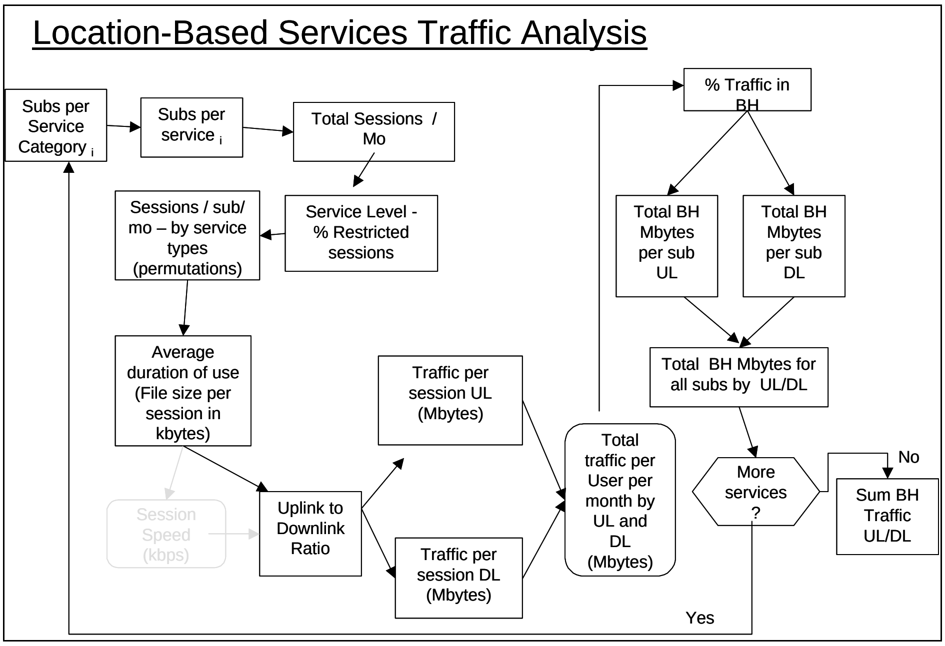
Media / Activity Type	UL File Size (Kbytes)	DL File Size (Kbytes)	UL: DL Ratio
Push Advertising	0	100	0: 1
Navigation / Travel	83	100	1: 1.2
Personal Tracking	.01	.01	1: 1
Asset / Fleet Tracking	.01	.01	1: 1
Telematics	83	166	1:2

Source: Telecompetition, Inc., prepared for the UMTS Forum, October 2003.

9.2 Service Traffic Analysis and Results

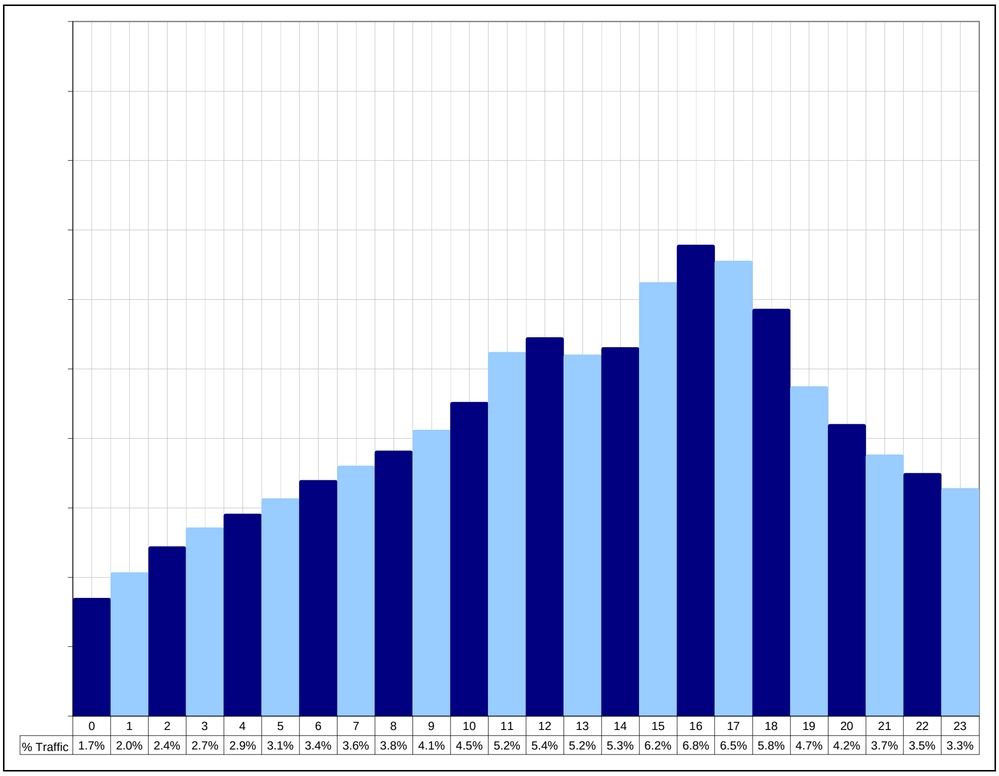
The framework used for Location-Based Services traffic analysis follows the same flow as shown earlier in Figure 2.2 and is repeated in Figure 9.6. The busy hour traffic distribution is illustrated in Figures 9.7 and 9.8. The percent of traffic that occurs in the busy hour is 6.76% for consumer and 4.17% for tracking services.

Figure 9.6. Location-Based Services traffic analysis framework.



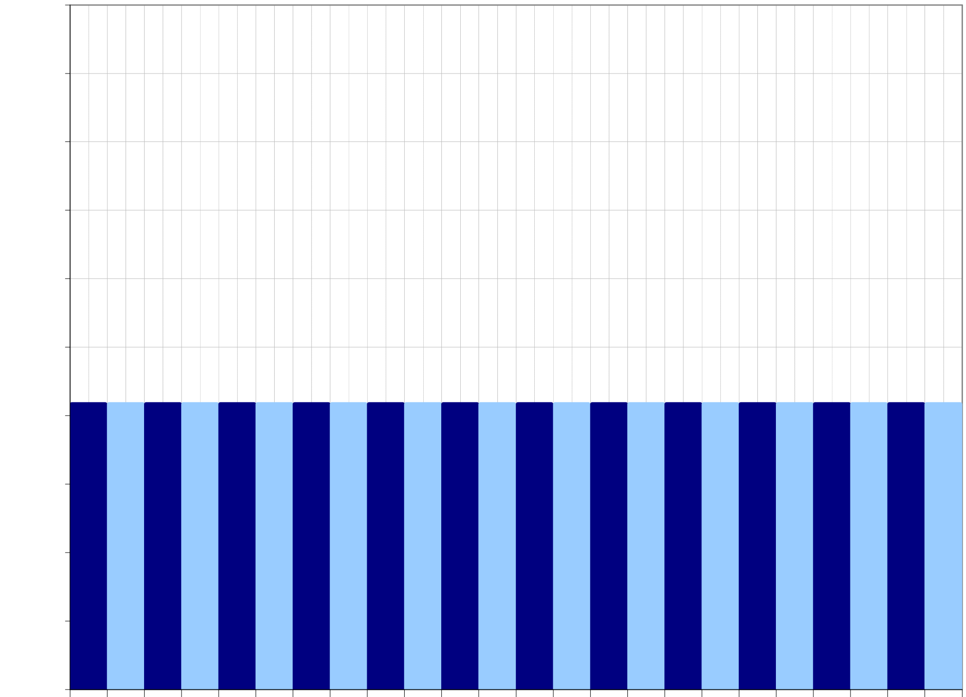
Source: Telecompetition, Inc., prepared for the UMTS Forum, October 2003.

Table 9.7 Assumed diurnal traffic distribution – Location-Based Services



Source: Telecompetition, Inc., prepared for the UMTS Forum, October 2003.

Table 9.8 Assumed diurnal traffic distribution – Location-Based Services - tracking services.



	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
% Traffic	4.2%	4.2%	4.2%	4.2%	4.2%	4.2%	4.2%	4.2%	4.2%	4.2%	4.2%	4.2%	4.2%	4.2%	4.2%	4.2%	4.2%	4.2%	4.2%	4.2%	4.2%	4.2%	4.2%	4.2%

Source: Telecompetition, Inc., prepared for the UMTS Forum, October 2003.

Based on the assumptions and analysis presented in this section, Table 9.9 and Table 9.10 summarises the offered traffic and traffic characteristics of Location-Based services.

Table 9.9. Location-Based Services – offered busy hour traffic and asymmetry per country.

Description	Busy Hour Traffic
Uplink - Location-Based Services Offered traffic per country	**0.024 TBytes**
Consumer	0.023 TBytes
Continuous Tracking	0.001 TBytes
Downlink - Location-Based Services Offered traffic per country	**0.061 TBytes**
Consumer	0.060 TBytes
Continuous Tracking	0.001 TBytes
Overall Service Asymmetry (UL /DL)	**0.402**

Source: Telecompetition, Inc., prepared for the UMTS Forum, October 2003.

Table 9.10. Location-Based Services – offered busy hour traffic per subscription.

Description	Busy Hour Traffic
Uplink - Location-Based Services traffic per Subscription	
Consumer	1.3 kBytes
Continuous Tracking	0.1 kBytes
Downlink - Location-Based Services traffic per Subscription	
Consumer	3.3 kBytes
Continuous Tracking	0.1 kBytes

Source: Telecompetition, Inc., prepared for the UMTS Forum, October 2003.

10 Simple Voice Assumptions and Offered Traffic

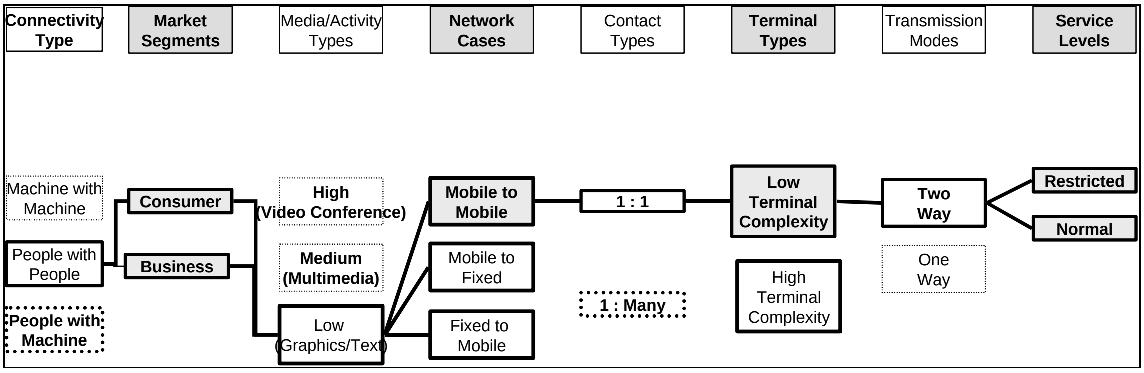
Analysis of Simple Voice includes business and consumer usage, and considered all the variables shown in Figure 2.2. The definition of Simple Voice is repeated here for reader clarity:

Simple Voice: Two way, person-to-person real-time audio

10.1 Usage and Traffic Assumptions

Service variables and states used for business Simple Voice calculations are shown in Figure 10.1

Figure 10.1. Service variables and states used for Simple Voice.



Source: Telecompetition, Inc., prepared for the UMTS Forum, October 2003.

Table 10.2 summarises the usage assumptions for Simple Voice

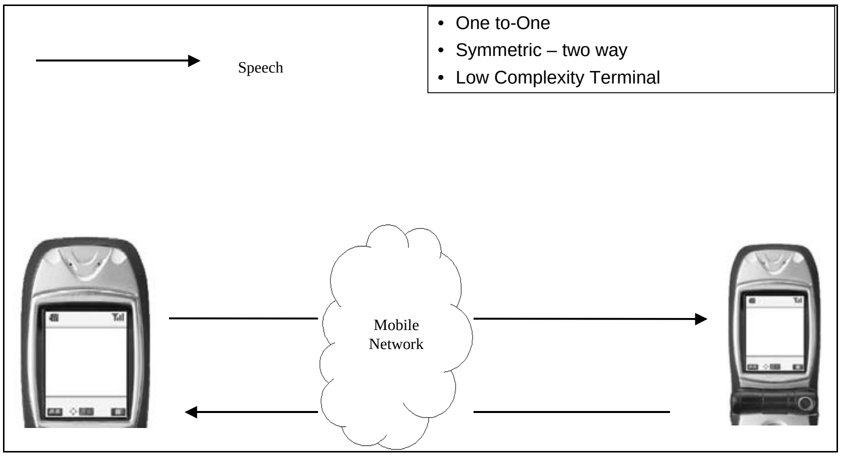
Table 10.2. Simple Voice usage assumptions.

3G Subscribers	• 31.9 M 3G Subscribers (53% of population) • 20.4 M Consumer 3G Subscribers
Subscriptions and Activity Type (calls per month)	• Business Simple Voice: call duration of 3.0 minutes with 400 minutes per month • Consumer Simple Voice: call duration of 3.5 minutes with 600 minutes per month
Network Case and Terminal Complexity	• Mobile to mobile: 32% • Mobile to fixed: 40 % • Fixed to mobile: 28% • 100% Low Complexity Terminals
Transmission Mode and Contact Type	• 100% two way • 100% one-to-one

Source: Telecompetition, Inc., prepared for the UMTS Forum, October 2003.

Figure 10.3 illustrates the symmetry of Simple Voice.

Figure 10.3. Simple Voice symmetry for mobile-to-mobile calls.

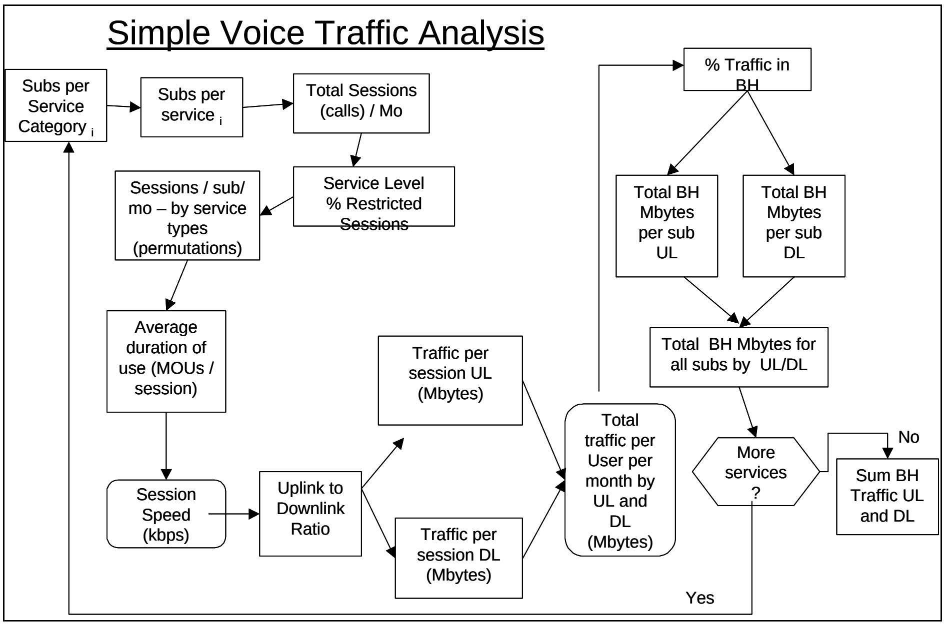


Source: Telecompetition, Inc., prepared for the UMTS Forum, October 2003.

10.2 Service Traffic Analysis and Results

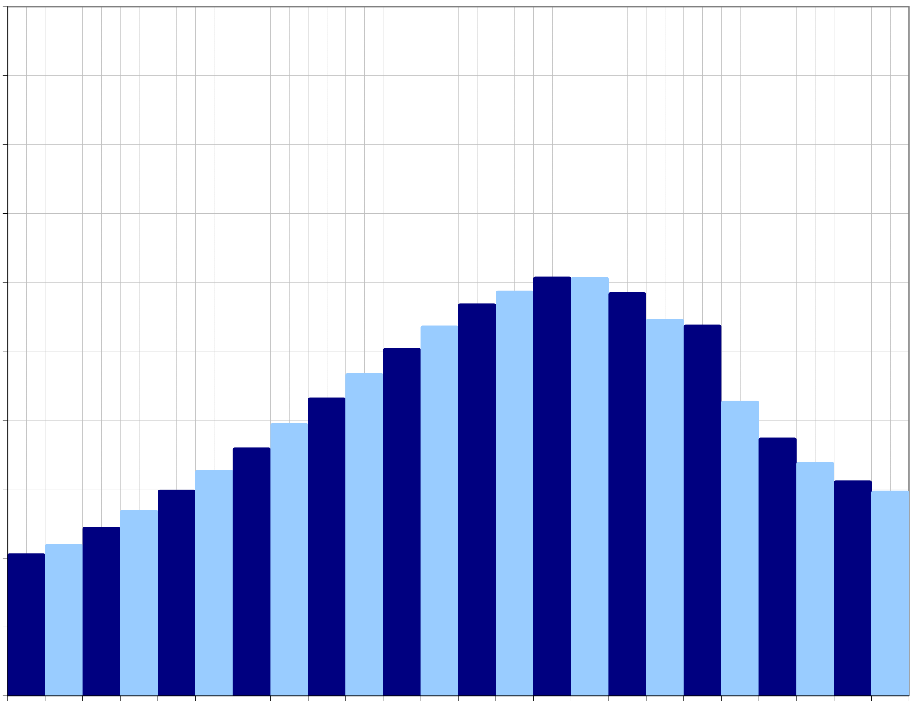
The framework used for Simple Voice traffic analysis follows the same flow as shown earlier in Figure 2.2 and is repeated in Figure 10.4. The busy hour traffic distribution is illustrated in Figures 10.5 and 10.6. The percent of traffic that occurs in the busy hour is 6.1% for consumer and 5.8% for business.

Table 10.4. Simple Voice traffic analysis framework.



Source: Telecompetition, Inc., prepared for the UMTS Forum, October 2003.

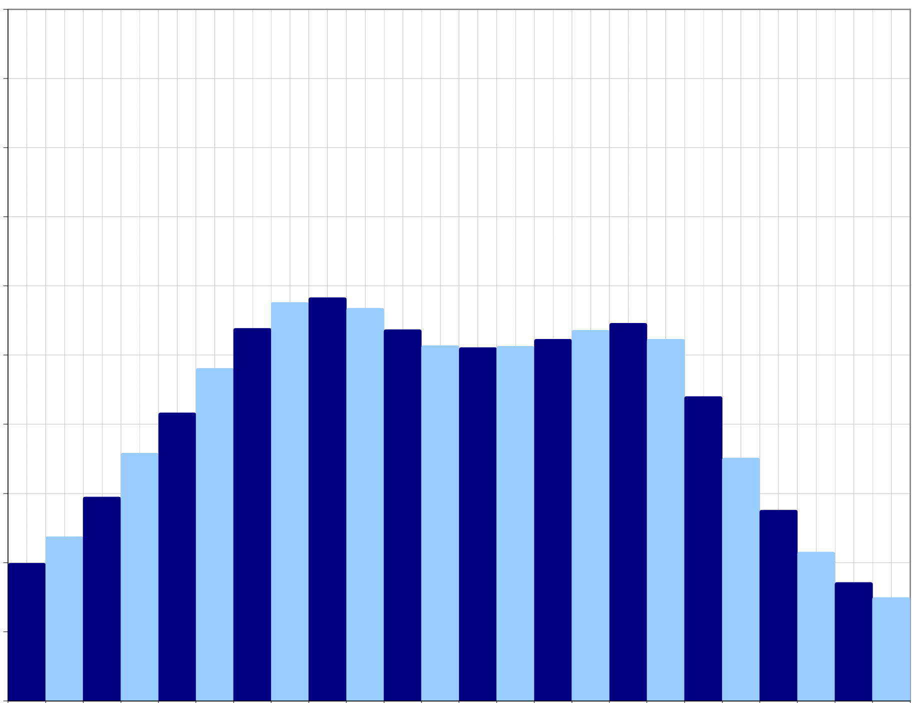
Table 10.5. Assumed diurnal traffic distribution – Simple Voice - Consumer.



	0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00
% Traffic	2.0%	2.2%	2.4%	2.7%	3.0%	3.3%	3.6%	3.9%	4.3%	4.7%	5.0%	5.3%	5.7%	5.9%	6.1%	6.1%	5.8%	5.4%	5.4%	4.3%	3.7%	3.4%	3.1%	2.9%

Source: Telecompetition, Inc., prepared for the UMTS Forum, October 2003.

Table 10.6. Assumed diurnal traffic distribution – Simple Voice – Business.



	0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00
% Traffic	2.0%	2.4%	2.9%	3.6%	4.1%	4.8%	5.4%	5.7%	5.8%	5.7%	5.3%	5.1%	5.1%	5.1%	5.2%	5.3%	5.4%	5.2%	4.4%	3.5%	2.7%	2.1%	1.7%	1.5%

Source: Telecompetition, Inc., prepared for the UMTS Forum, October 2003.

Based on the assumptions and analysis presented in this section, Table 10.7 and Table 10.8 summarises the offered traffic and traffic characteristics of Simple Voice.

Table 10.7. Simple voice – offered busy hour traffic and asymmetry per country

Description	Busy Hour Traffic
Uplink – Simple Voice Offered traffic per country	**2.13 TBytes**
Consumer	1.41 TBytes
Business	.72 TBytes
Downlink - Simple Voice Offered traffic per country	**2.13 TBytes**
Consumer	1.41 TBytes
Business	.72 TBytes
Overall Service Asymmetry (UL /DL)	**1.00**

Source: Telecompetition, Inc., prepared for the UMTS Forum, October 2003.

Table 10.8. Simple Voice – Offered busy hour traffic per subscriber.

Description	Busy Hour Traffic
Uplink – Simple Voice traffic per Subscriber	
Consumer	69.1 kBytes
Business	62.4 kBytes
Downlink – Simple Voice traffic per Subscriber	
Consumer	69.1 kBytes
Business	62.4 kBytes

Source: Telecompetition, Inc., prepared for the UMTS Forum, October 2003.

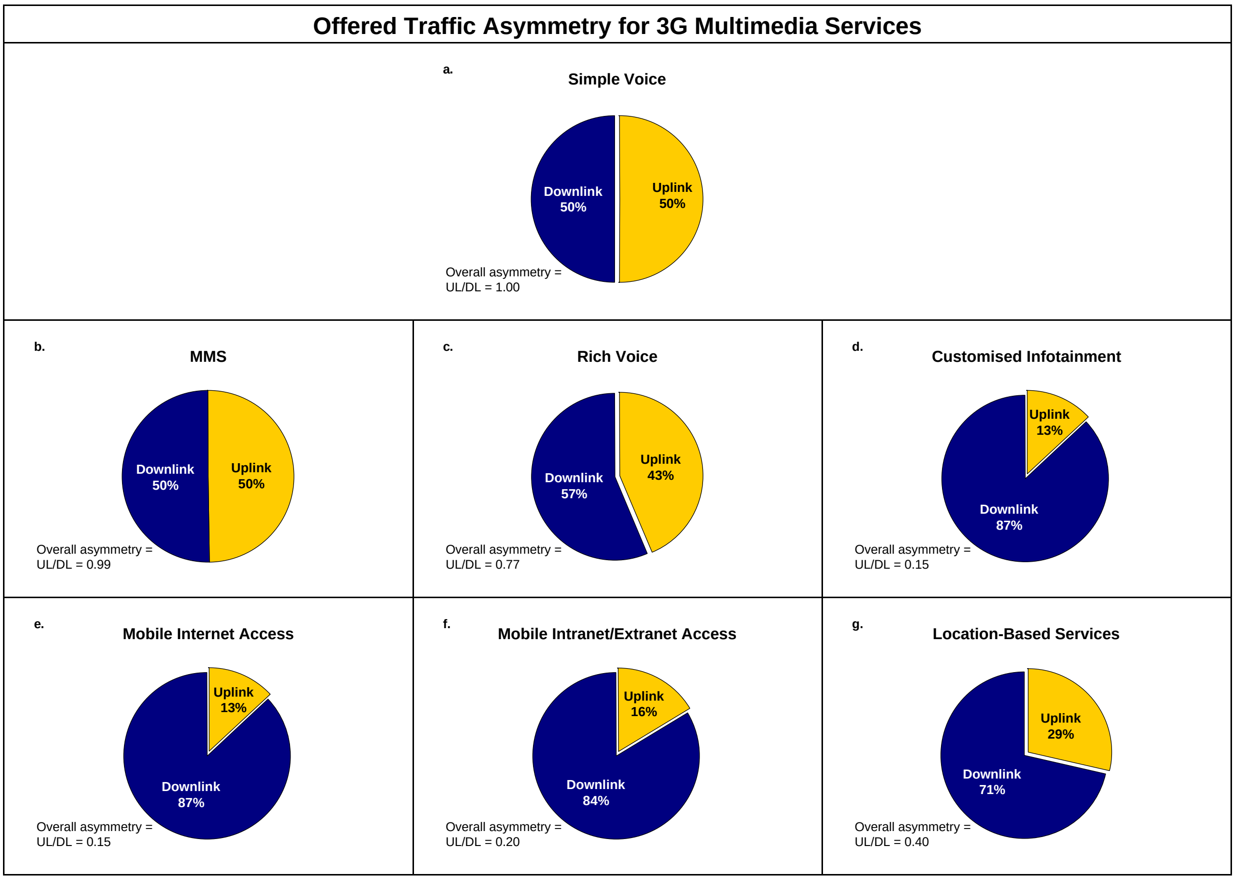
11 Results Summary

This section presents the summary results by Service Category from Sections 4 –10 so the reader can compare the traffic in aggregate and across Service Categories. The results are presented comparing Simple Voice to all other multimedia services. It should be noted that from a spectrum viewpoint, a more meaningful comparison is to compare all real time services to all non-real time services. Both Simple and Rich Voice are real time services and must be given special consideration in any spectrum calculation. Sufficient details about both types of services are contained in this report so that a comparison can be made. This comparison will be presented more fully in a later report.

11.1 Summary by Service Category

Figure 11.1 shows the offered traffic asymmetry for each service category. This asymmetry is calculated by dividing the total Service Category uplink traffic in its busy hour by the total Service Category downlink traffic is its busy hour. [16] The Service Category busy hour comes from the assumed traffic distribution charts found in the sections of this report applicable to each Service Category. For example, the assumed busy hour traffic for Customised Infotainment is shown in Table 6.7 as 0.38 TBytes over the uplink and 2.57 TBytes over the downlink. The resultant asymmetry is 0.38 divided by 2.57 or 0.15. This relationship is shown in Figure 11.1d.

Figure 11.1(a-g). A comparison of offered traffic asymmetry by service category.



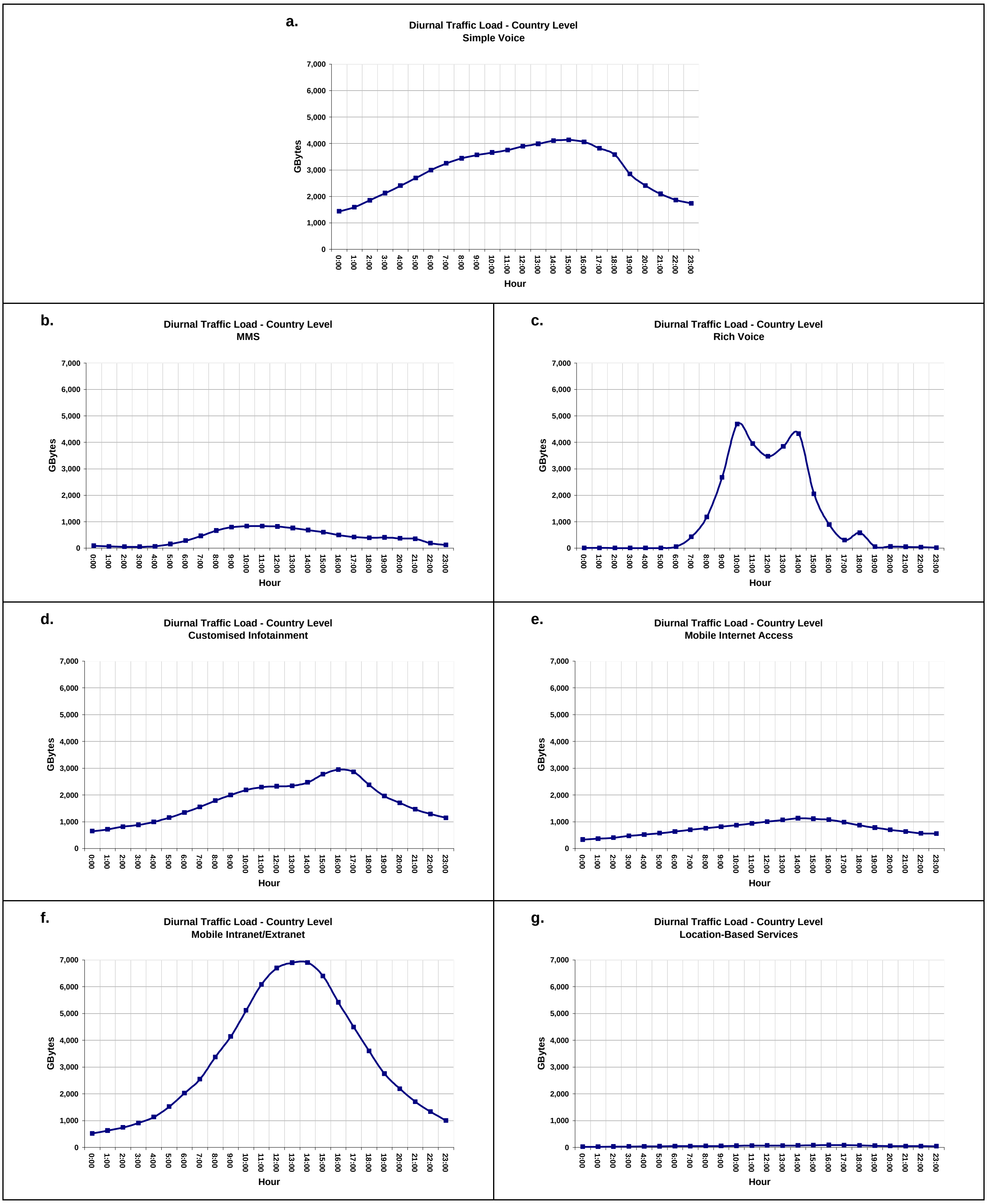
Source: Telecompetition, Inc., prepared for the UMTS Forum, October 2003.

Figure 11.2 shows the aggregate daily traffic load distribution for each Service Category. The distribution includes both uplink and downlink traffic. The vertical scale is the same for each of the charts in the figure, ranging from 0 to 7,000 GBytes. The horizontal axis is divided into 24 hours

[16] Busy hour varies by service category.

showing the traffic starting at midnight (0:00). The centre of each graph is midday (12:00). This figure represents the “typical” daily traffic for each Service Category. It is assumed that business traffic is only significant during business days (21.2 days per month), an assumption that tends to increase the busy hour traffic on business days.

Figure 11.2(a-g). Comparison of total diurnal traffic (UL + DL) by Service Category for representative country.



Source: Telecompetition, Inc., prepared for the UMTS Forum, October 2003.

Whilst Rich voice has a high traffic load during its busy hour, the total daily traffic for other services exceeds Rich Voice as shown in the following summary table.

Table 11.3. Daily total and busy hour traffic by service category.

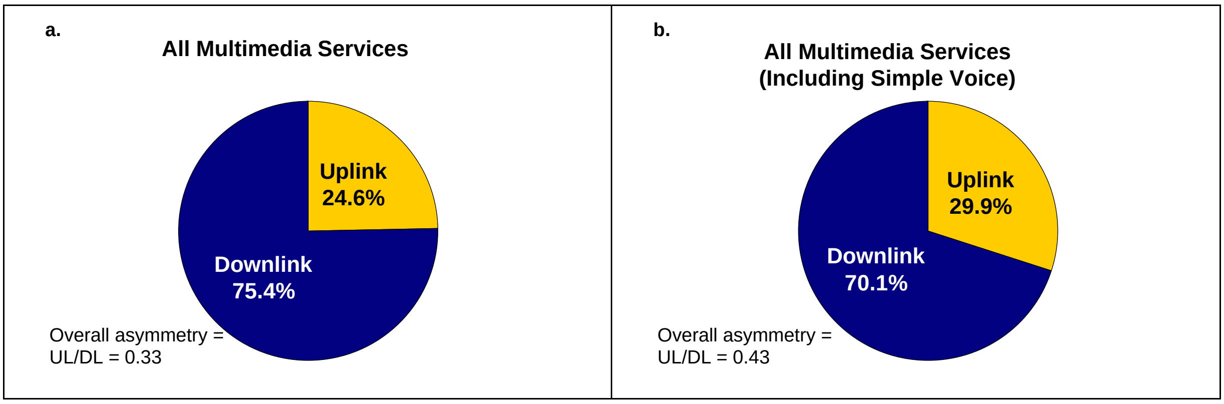
Service Category	Total Daily Traffic for the Representative Country (TBytes)	Total Traffic in Service Category Busy Hour (TBytes)
Multimedia Messaging Service	9.92	1.02
Rich Voice	28.66	4.73
Customised Infotainment	42.04	2.95
Mobile Internet Access	17.87	1.13
Mobile Intranet/Extranet Access	78.14	6.70
Location-Based Services	1.30	0.09
Simple Voice	71.28	4.26
Total	249.21	20.88

Source: Telecompetition, Inc., prepared for the UMTS Forum, October 2003.

11.2 Aggregate Traffic Results

Figure 11.4 shows the sum of the six service categories with and without Simple Voice. Most individual services are highly asymmetry, with the exception of Simple/Rich Voice and MMS, which are fairly symmetric. To calculate the aggregate asymmetry over all service categories, the sum of the total uplink traffic in the overall busy hour was divided by the total of the downlink traffic in the overall busy hour. An asymmetry of .43 was calculated when Simple Voice service, which is symmetric, was considered.

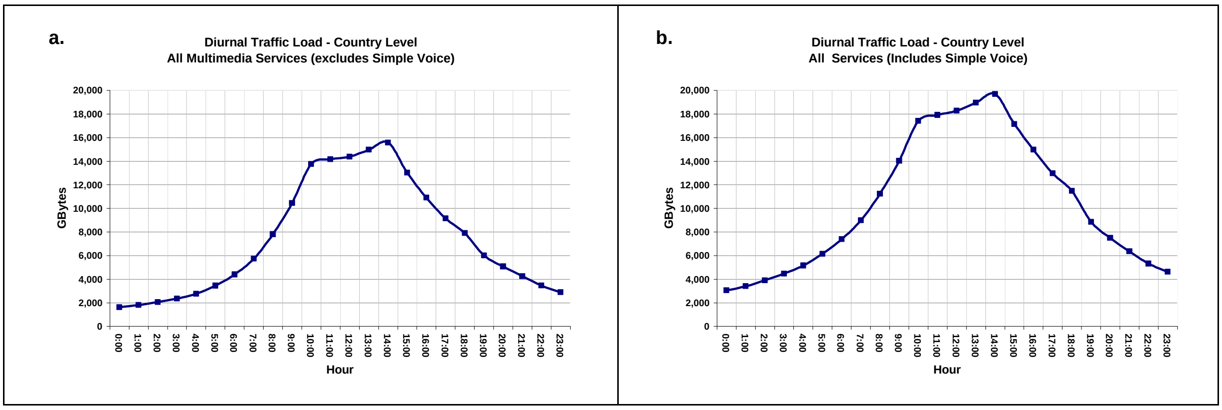
Figure 11.4 (a-b). Total offered traffic asymmetry during the aggregate busy hour.



Source: Telecompetition, Inc., prepared for the UMTS Forum, October 2003.

Figure 11.5 shows the combined traffic distribution with and without Simple Voice. The top of the vertical scale is 20,000 GBytes. As in Figure 11.2, the horizontal axis is divided into 24 hours showing the traffic starting at midnight (0:00).

Figure 11.5 (a-b). Total diurnal traffic distribution – aggregate busy hour.



Source: Telecompetition, Inc., prepared for the UMTS Forum, October 2003.

11.3 Traffic Characteristics – Aggregate Busy Hour

As shown in Figure 11.5, the overall busy hour takes place in the 1400 hour. The aggregate busy hour is more representative of the actual traffic a network operator will experience. For this reason, the aggregate busy data is presented.

For network planning it is sometimes useful to have average traffic numbers that apply to the entire subscriber base served by the network. As not all subscribers in a network use every service such as MMS or Rich Voice, this section shows the busy hour traffic averaged over business or consumer 3G subscribers (not all of whom actually use these specific services) rather than service subscriptions (actual users of the service). This is provided as another aid to network planners in applying the data to their specific situations.

Table 11.6 shows the average busy hour traffic by consumer or business 3G subscribers and by total 3G subscribers. These numbers are different than the "per subscription" numbers presented for each service category, as the denominator is the total number of 3G subscribers, not the specific subscriptions to individual services.

Table 11.6. Total aggregate busy hour offered traffic.

Total Busy Hour Traffic		Uplink	Downlink
3G Subscribers	31.9 M		
3G Consumer Subscribers	20.4 M		
3G Business Subscribers	11.5 M		
Total Busy Hour Traffic – per Country		5.89 TBytes	13.80 TBytes
Business traffic		3.87TBytes	9.11 TBytes
Consumer Traffic		2.02 TBytes	4.70 TBytes
All Busy Hour Traffic – Average per all 3G Subscribers		184.4 kBytes	432.4 kBytes
Business Segment - per Business 3G Subscriber		335.9 kBytes	790.4 kBytes
Consumer Segment - per Consumer 3G Subscriber		98.9 kBytes	230.2 kBytes

Source: Telecompetition, Inc., prepared for the UMTS Forum, October 2003.

11.4 Worst Case Traffic Loads

The service level traffic distributions used in this reports were developed using historic voice and messaging traffic distributions and an assessment of user expectations, service pricing and other factors that may impact traffic patterns. Due to the normal market uncertainties for this type of analysis, a worst-case assessment is presented that shows the peak traffic load as if each service falls within the same exact hour of the day. Table 11.7 shows the country and subscriber level traffic loads under this worst case.

Table 11.7. Worst-case busy hour offered traffic per country – all service categories.

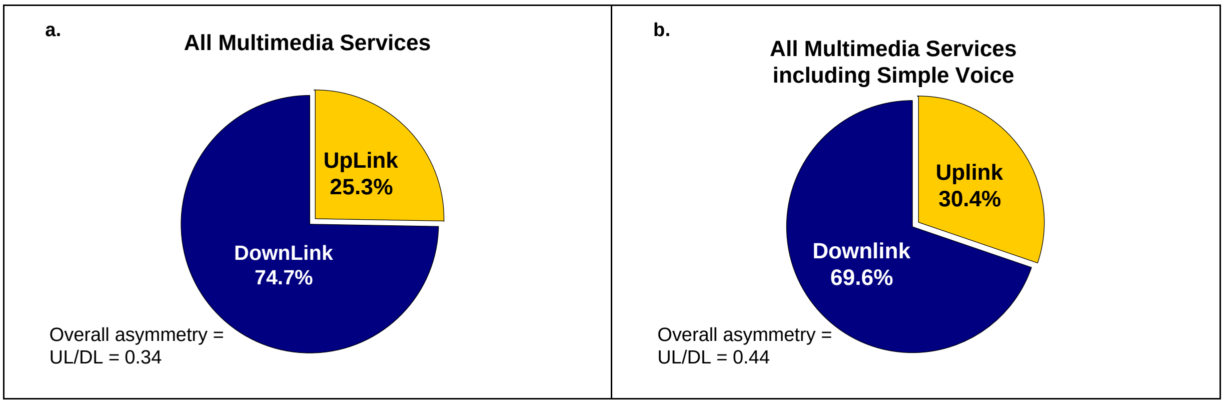
Worst Case Busy Hour Traffic		Uplink	Downlink
3G Subscribers	31.9 M		
3G Consumer Subscribers	20.4 M		
3G Business Subscribers	11.5 M		
Worst Case Busy Hour Traffic – per Country		6.33 TBytes	14.52 TBytes
Business		4.16 TBytes	9.32 TBytes
Consumer		2.17 TBytes	5.20 TBytes
Worst Case Busy Hour - Average per all 3G subscribers		198.4 kBytes	454.9 kBytes
Business Segment – per Business 3B Subscriber		361.4 kBytes	808.7 kBytes
Consumer Segment – per Consumer 3G Subscriber		106.4 kBytes	255.1 kBytes

Source: Telecompetition, Inc., prepared for the UMTS Forum, October 2003.

In this worst case, busy hour traffic is approximately 8% higher than the aggregate busy hour. This is based on a comparison of the total worst-case busy hour traffic of 20.85 TBytes to the aggregate busy traffic (uplink plus downlink) of 19.69 TBytes presented in Table 11.6. These results are highly dependent upon the traffic distributions assumed in this study.

Figure 11.8 shows the offered traffic assuming the worst-case scenario. The asymmetry is slightly different than the aggregate busy hour asymmetry shown in Figure 11.4.

Figure 11.8 (a-b). Worst-case total offered traffic asymmetry during the busy hour.



Source: Telecompetition, Inc., prepared for the UMTS Forum, October 2003.

12 Conclusions

This study presents an assessment of the offered traffic characteristics for future mobile data services based on end user demand. This is the unconstrained traffic offered to a 3G network. 2G and 2.5G traffic is not considered in this analysis, but could be added following the same methodology. Other factors may affect the actual network traffic characteristics – both technical (e.g., traffic shaping) and market-oriented (e.g., pricing plans).

The downlink traffic dominates the busy hour with the overall asymmetry of 0.43. In other words, on average, there is over twice (2.3) as much traffic flowing to the end-user as flows from the end-user back to the network. This overall asymmetry results from the service asymmetry assumptions made during this study. These assumptions are based on a number of field and lab measurements made using similar services on both 2.5G and fixed (wireline) networks. As 3G services develop and further data becomes available, these assumptions should be revisited. In addition, this overall asymmetry is based on a country-level service mix. The service mix in a local area, such as a cell, may vary significantly. The results per subscriber found in this report would then be needed to assess the local asymmetry in, for example, an area that is primarily used for business.

As fixed Internet traffic tends to be very asymmetric to the downlink (downloading content more than uploading), mobile access to Internet content follows the same pattern in this analysis. The possibility exists for mobile operators to change this asymmetric pattern through the pricing plans, traffic shaping and service definition. However, this study analysed the offered traffic based on how users currently prefer to interact.

This analysis represents an important step in better understanding the future traffic patterns for 3G networks. Further analysis should be done. Several additional areas have been identified for further work including:

- Obtaining more traffic distribution data from network operators and service providers.
- Varying the traffic distribution for each service.
- Adding the traffic from 2G and 2.5G services to this analysis.
- Adding traffic associated with network overhead for operations, administration, maintenance and provisioning to these offered traffic results.
- Completing further field measurements to validate the input assumptions made in this study.
- Updating the subscriber and subscription forecasts that are the basis of this analysis.
- Developing traffic scenarios at the cell level that have various mixes of consumer and business customers as an aid in the network planning process.

13 Service Forecasting Tool

The service forecasts that are the basis for this report with developed with a proprietary, adaptive forecasting technology called *ATIVA Research Tools*Ò. This technology performs sophisticated computations on both demand and supply side industry data to produce historic and forecasted revenues and other market size information at the regional, national and sub-national levels.

ATIVA Research Tools® uses algorithms to calculate product revenues to smaller geographic areas. Factors considered in the calculations include demographics, relative use by household income, age, industry characteristics, workforce population, propensity-to-buy profiles, deployment / service availability and other current market and technology drivers.

Figures 13.1 and 13.2 depict the *ATIVA Research Tools*®, system design and calculation process.

Figure 13.1 *ATIVA Research Tools*® system design.

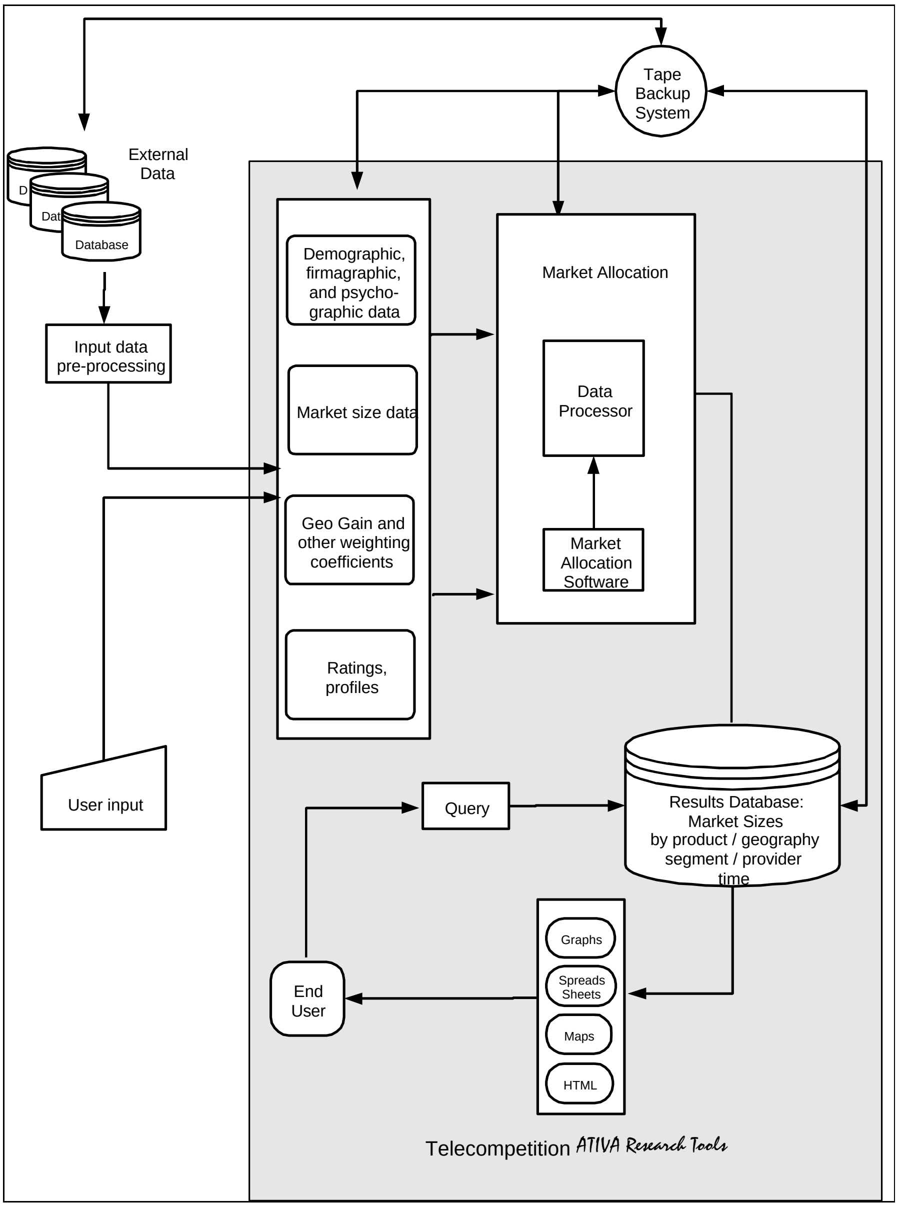
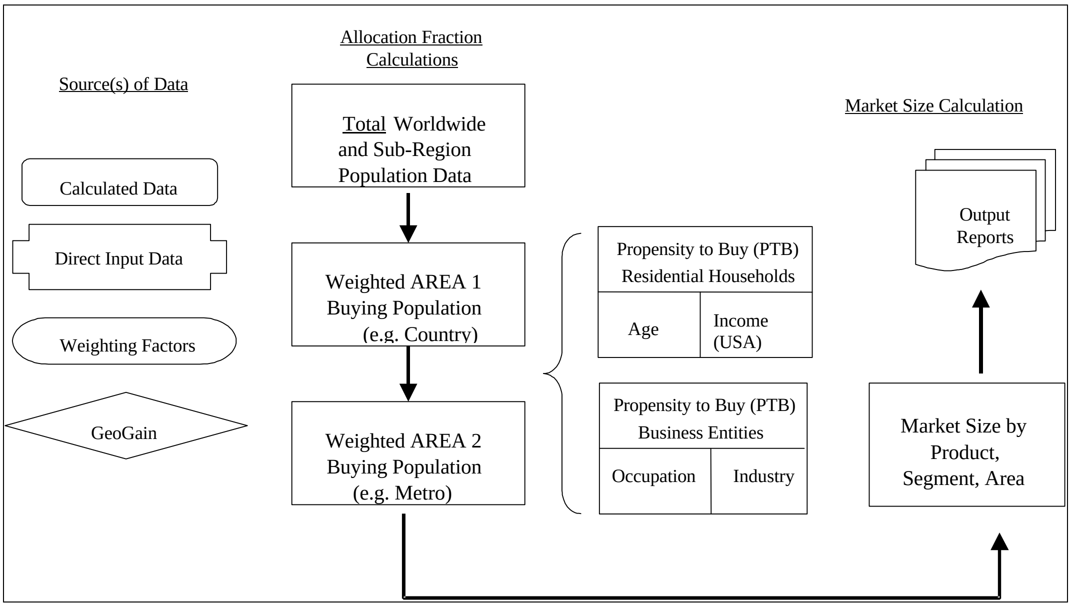


Figure 13.2 *ATIVA Research Tools*® calculation process flow.



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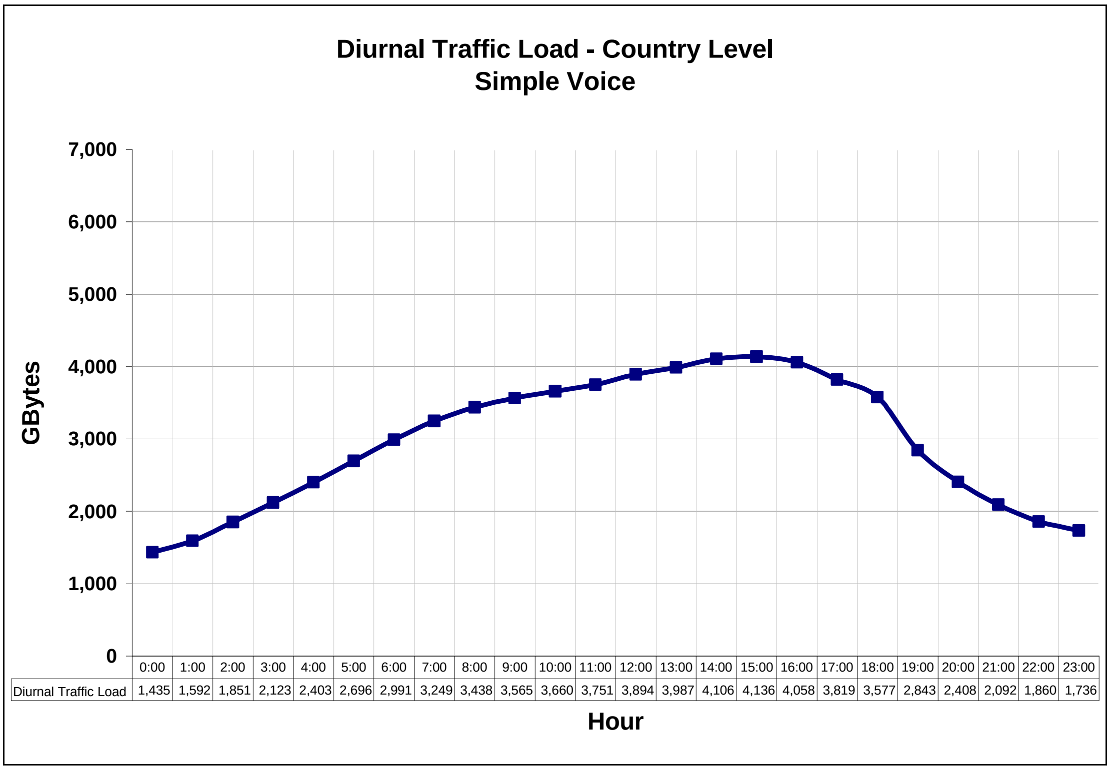
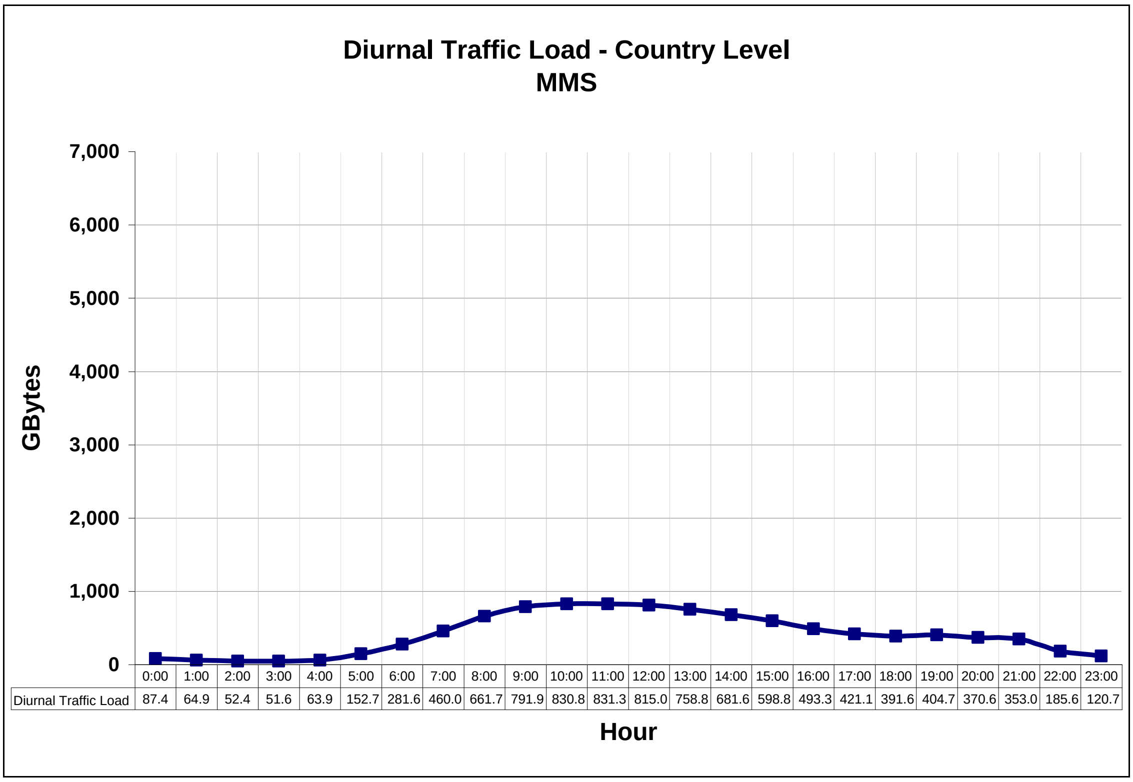
15 Appendix

Figure 15.1 Offered traffic load for Simple Voice.



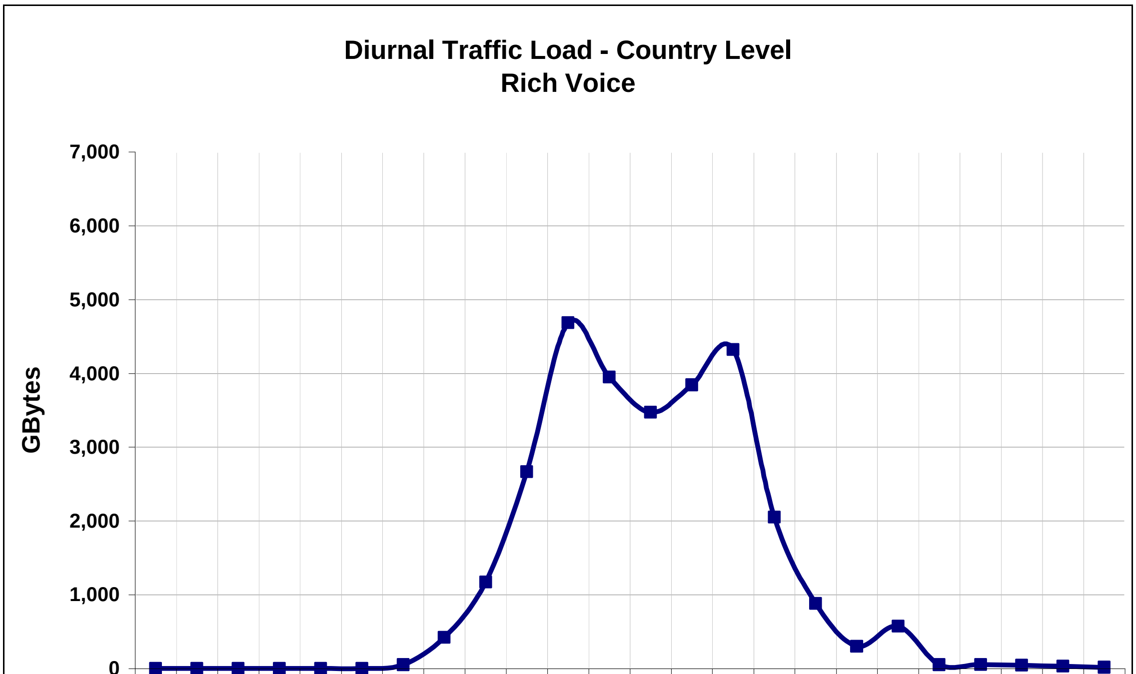
Source: Telecompetition, Inc., prepared for the UMTS Forum, October 2003.

Figure 15.2 Offered traffic load for MMS.



Source: Telecompetition, Inc., prepared for the UMTS Forum, October 2003.

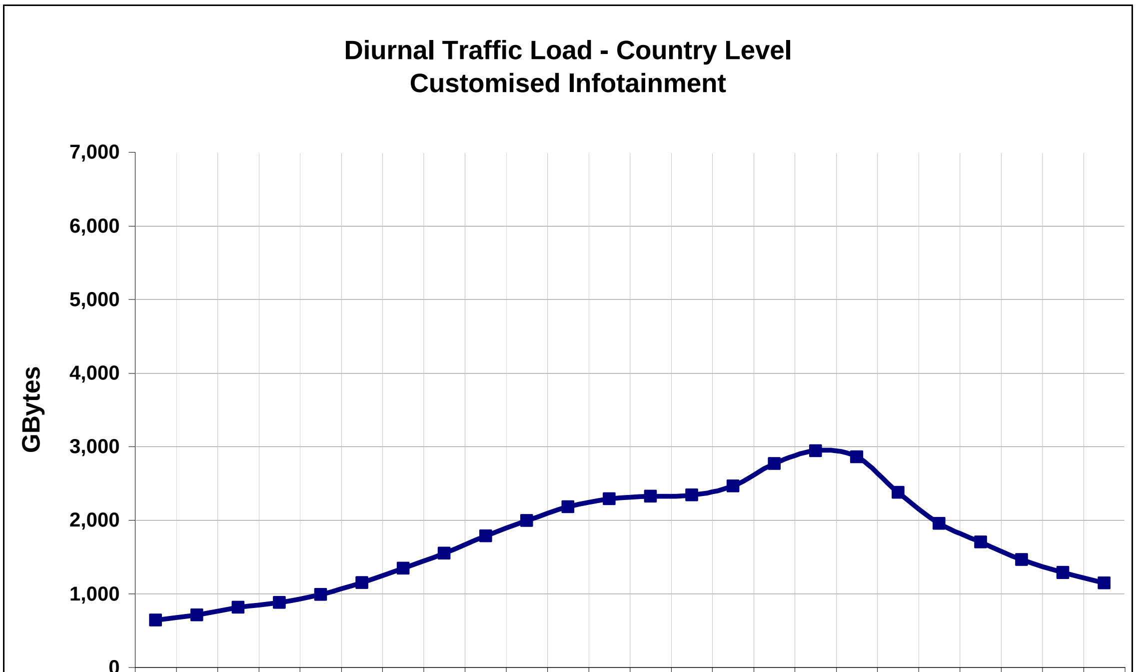
Figure 15.3 Offered traffic load for Rich Voice.



	0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00
Diurnal Traffic Load	6.4	5.1	3.6	2.7	2.6	2.2	55.2	427.0	1,176	2,669	4,689	3,949	3,471	3,845	4,326	2,051	885.6	305.1	575.9	52.6	56.4	46.9	34.9	18.0

Source: Telecompetition, Inc., prepared for the UMTS Forum, October 2003.

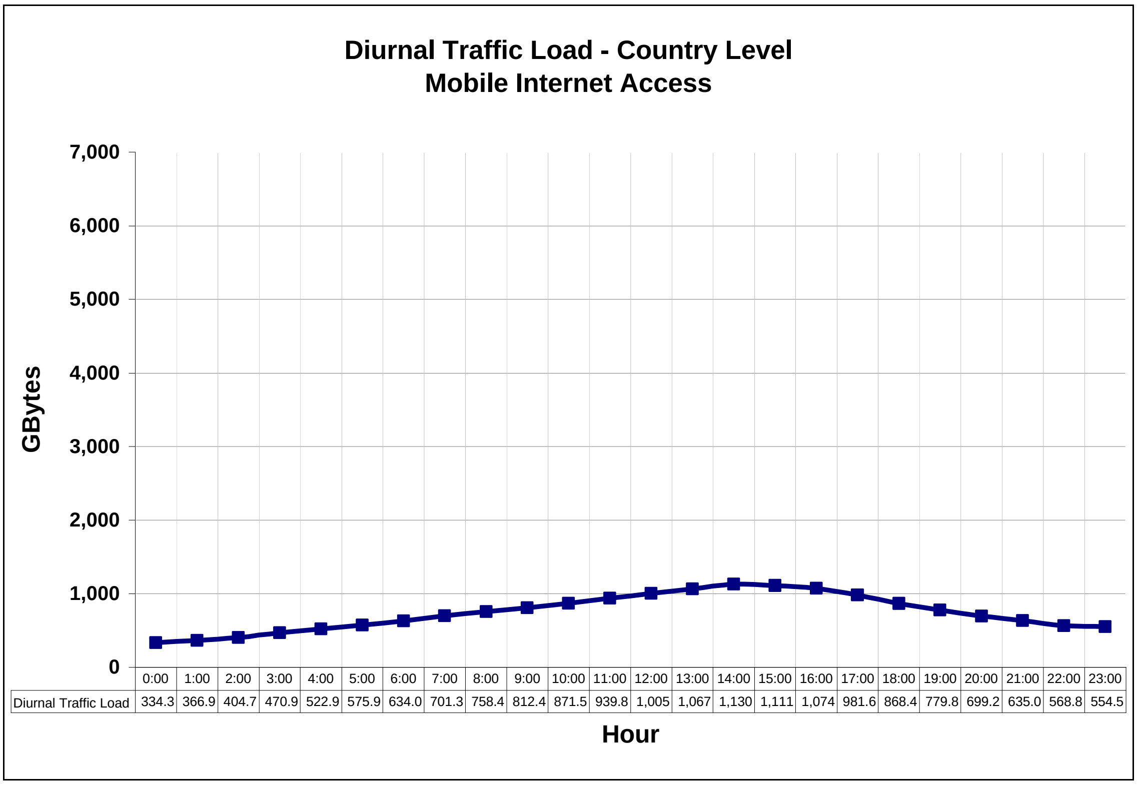
Figure 15.4 Offered traffic load for Customised Infotainment.



	0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00
Diurnal Traffic Load	647.5	714.2	817.0	883.7	992.1	1,156	1,347	1,553	1,789	1,998	2,184	2,292	2,326	2,342	2,467	2,770	2,945	2,862	2,378	1,959	1,703	1,467	1,289	1,147

Source: Telecompetition, Inc., prepared for the UMTS Forum, October 2003.

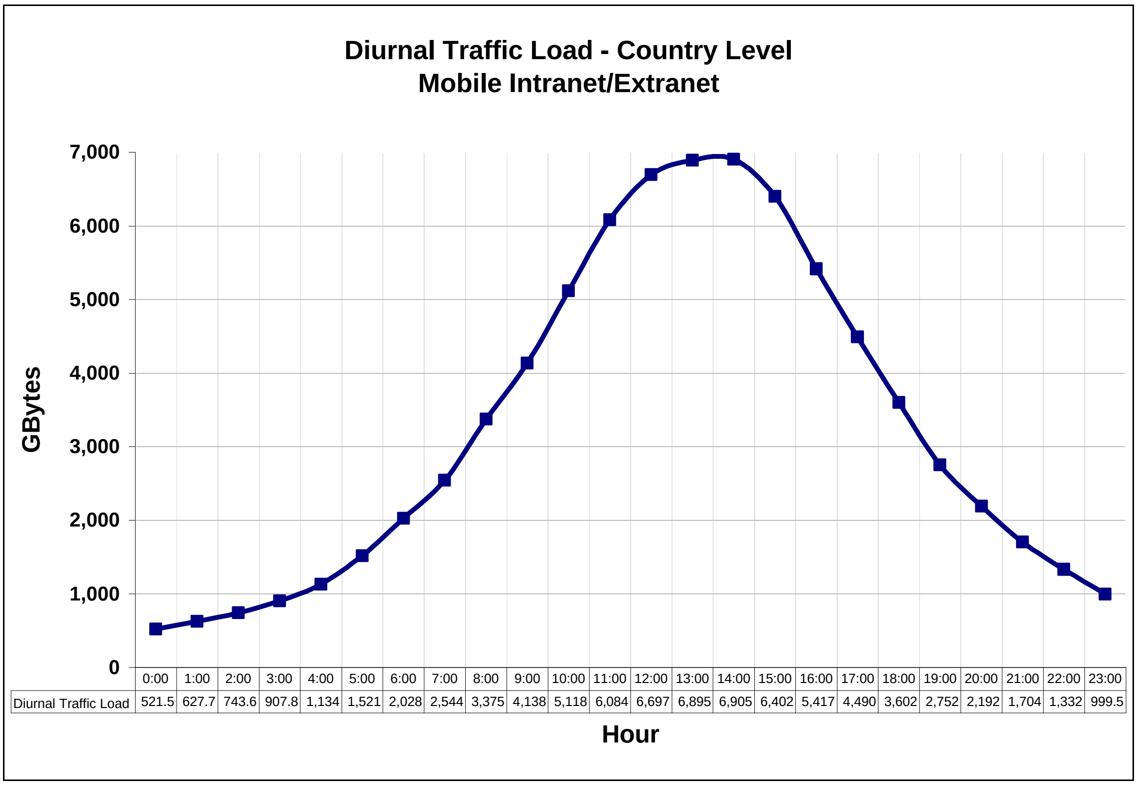
Figure 15.5 Offered traffic load for Mobile Internet Access.



	0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00
Diurnal Traffic Load	334.3	366.9	404.7	470.9	522.9	575.9	634.0	701.3	758.4	812.4	871.5	939.8	1,005	1,067	1,130	1,111	1,074	981.6	868.4	779.8	699.2	635.0	568.8	554.5

Source: Telecompetition, Inc., prepared for the UMTS Forum, October 2003.

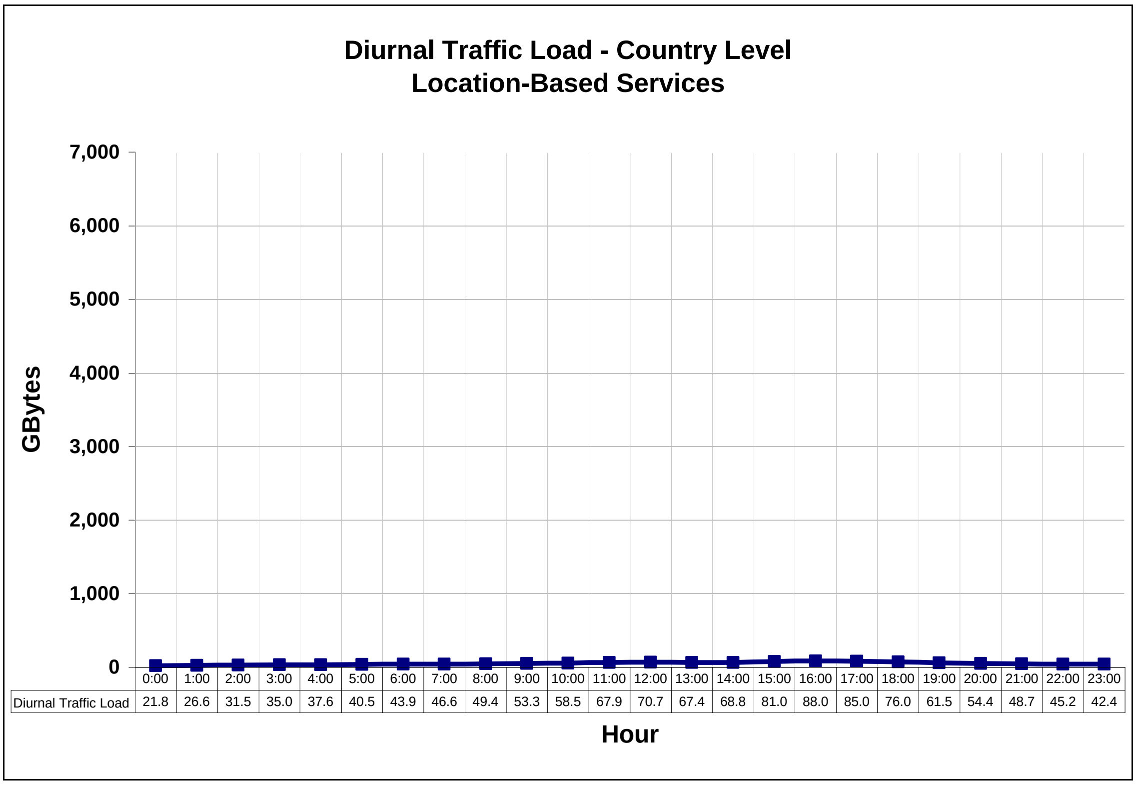
Figure 15.6 Offered traffic load for Mobile Intranet/Extranet.



	0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00
Diurnal Traffic Load	521.5	627.7	743.6	907.8	1,134	1,521	2,028	2,544	3,375	4,138	5,118	6,084	6,697	6,895	6,905	6,402	5,417	4,490	3,602	2,752	2,192	1,704	1,332	999.5

Source: Telecompetition, Inc., prepared for the UMTS Forum, October 2003.

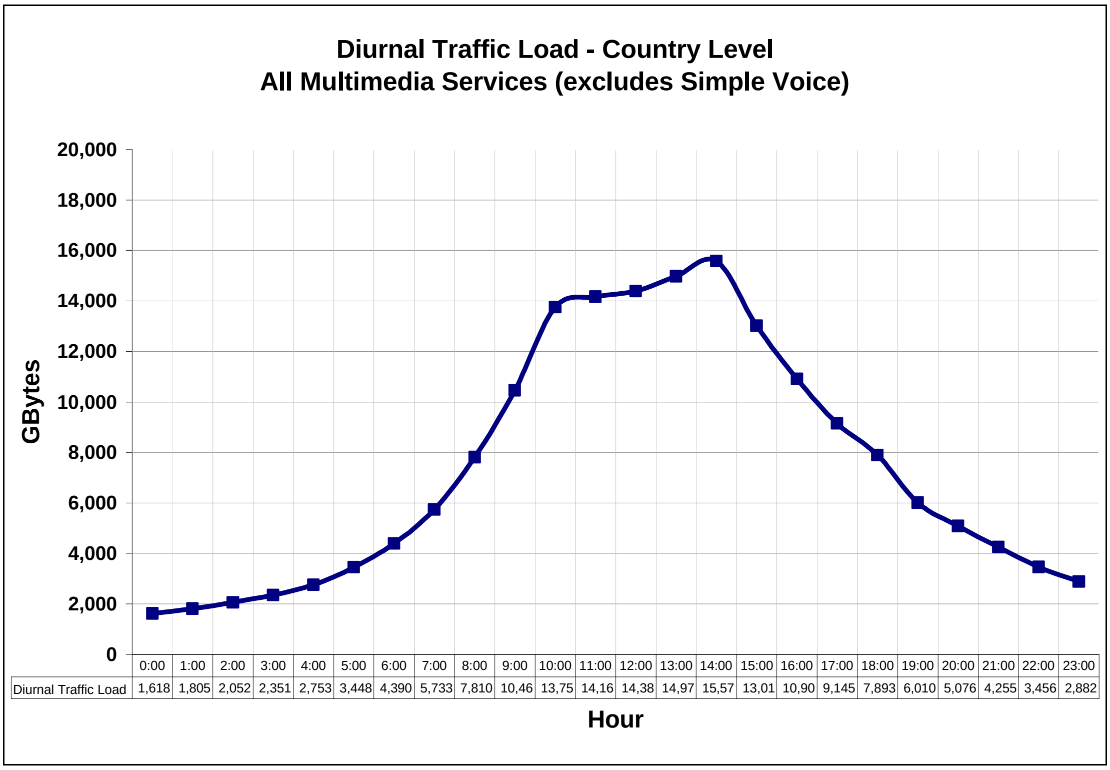
Figure 15.7 Offered traffic load for Location-Based Services.



Hour	0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00
Diurnal Traffic Load	21.8	26.6	31.5	35.0	37.6	40.5	43.9	46.6	49.4	53.3	58.5	67.9	70.7	67.4	68.8	81.0	88.0	85.0	76.0	61.5	54.4	48.7	45.2	42.4

Source: Telecompetition, Inc., prepared for the UMTS Forum, October 2003.

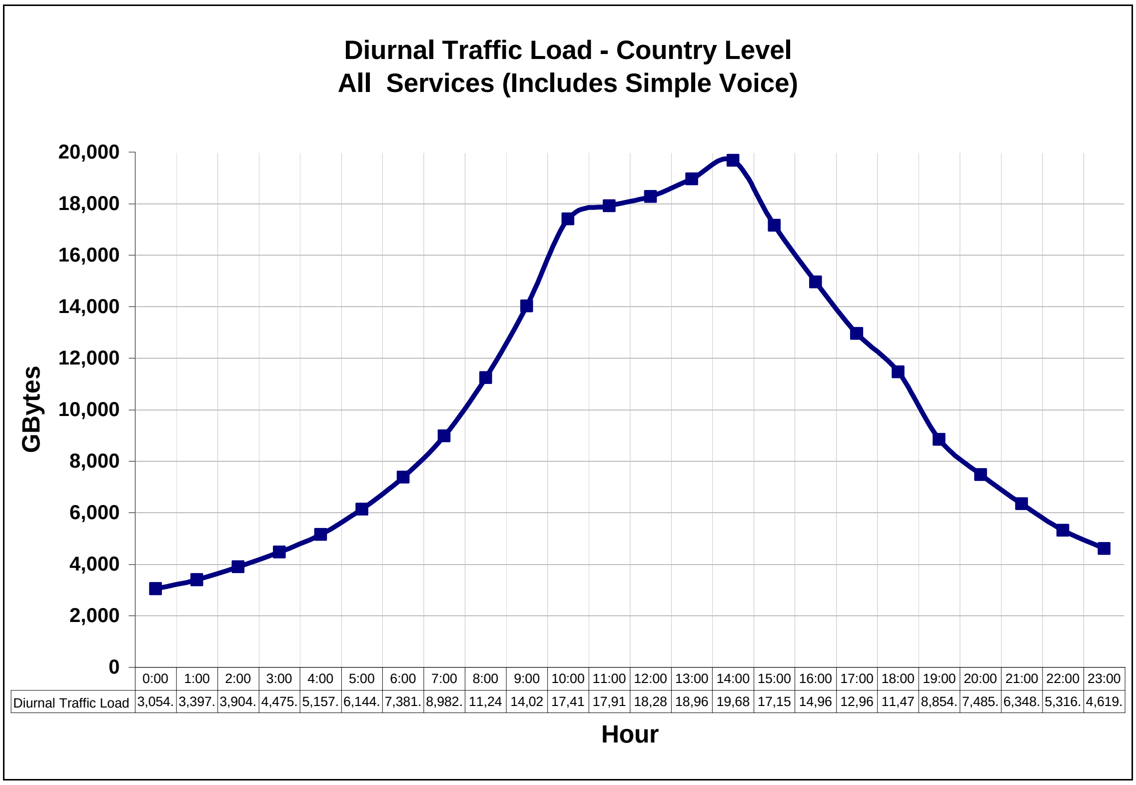
Figure 15.8 Offered traffic load for All Multimedia Services (excludes Simple Voice).



Hour	0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00
Diurnal Traffic Load	1,618	1,805	2,052	2,351	2,753	3,448	4,390	5,733	7,810	10,46	13,75	14,16	14,38	14,97	15,57	13,01	10,90	9,145	7,893	6,010	5,076	4,255	3,456	2,882

Source: Telecompetition, Inc., prepared for the UMTS Forum, October 2003.

Figure 15.9 Offered traffic load for All Services (Includes Simple Voice).



Source: Telecompetition, Inc., prepared for the UMTS Forum, October 2003.

ATTACHMENT 3

Performance Analysis for Data Service in Third Generation Mobile Telecommunication Networks

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Abstract

The data traffic in wireless networks for the third generation (3G) mobile telecommunication systems should take into account a variety of services (voice, data, video) and environments (e.g.: private, outdoors, indoors) as well as the user mobility behavior. A good evaluation of measures of performance can help a system designer to make its strategic decisions concerning cell size and the number of channel frequencies allocated to each cell. In this paper we present an analysis of data services in a third generation mobile telecommunication networks based on simulation. In addition, we illustrate the need for a simulation in order to characterize the mix of several traffic types for capacity and quality of service (QoS) planning. We use the distributions heavy tailed Weibull and Pareto to simulate respectively, the data traffic and the resource occupation time for data service. Finally, we also comment some simulation results of third generation services where we analyze the QoS parameters of a mobile network, such as channel occupation time, handoff, new call blocking probabilities and traffic in Erlangs.

Keywords — *Mobile Networks, Data Services, Third Generation, Quality of Service*

1. Introduction

One of the driving forces of the next generation of wireless communication and computing networks is the promise of high-speed multimedia services. The next generation wireless mobile networks, known as third generation (3G) mobile telecommunication systems, should take into account a variety of services (voice, data, video) and environments (e.g.: private, outdoors, indoors) as well as the user mobility behavior. The great difference between the next and the current networks is their ability to provide higher-rate data service, which are expected to fuel a mobile device of new application. Third generation systems, such as Future Public Land Mobile Telecommunication System (FPLMTS or IMT-2000) and the Universal Mobile Telecommunication System (UMTS), promise to provide multimedia services to mobile and fixed users via wireless access to the global telecommunication infrastructure [25, 27, 32]. The UMTS idea is to enable Mobile Users (MUs) to access differentiated services of *'anywhere'*, and *'anytime'*, using a single telecommunication device.

The evolution of cellular mobile networks, pushed by a rapidly increasing number of subscribers, began in the field of telephony. Nevertheless, the evolution of mobile networks also followed a second path: the packet radio networks for mobile data communication. These networks provide packet oriented data transfer to and from a mobile station. In addition to the integration of speech and data services, the ongoing network evolution progress is directed towards personal communications and mobility. Building integrated services mobile networks can be realized either by improving the service profile offered by existing cellular systems, or by adding air interfaces to existing wired networks.

Traffic modeling in wireless telecommunication system has to deal with two main issues, the Radio Resource Management (RRM) scheme and the effect of the user mobility on the traffic volume per cell [14, 22, 34]. Data traffic in wireless telecommunication networks is emerging like one of aspects more important in third generation networks planning [13, 16, 33, 35]. Thus a mix of several traffic types of different services has required more resources and QoS planning. Therefore, from the telecommunications point of view we can model the different traffic types like voice and data based on their behaviour.

Wireless data applications produce data that may have different characteristics from those of wired data applications and wireless voice data [18]. This article describes the simulation results of data service in mobile (cellular) telecommnunication networks, using the simulator named 'Simula2' [29, 30, 31], which take into account the self-similarity [5, 21, 26] of the network traffic. We use the distributions heavy tailed Weibull and Pareto [17] to simulate the data traffic and the resource occupation time for data service, respectively. The simulation provides simple analytical results regarding the traffic of different services and also provides means to estimate the following parameters:

- telecommunication traffic volume,
- telecommunication traffic intensity,
- handoff blocking probability,
- call blocking probability, and
- channel occupation time.

When a MU wants to communicate with another MU, it must first obtain a channel from one of the base stations that hears depending on signal power. If a channel is available, it is assigned to the user. In the case that all the channels are busy, the new call is blocked. This kind of blocking is called new call blocking and it refers to blocking of new calls. On the other hand, the procedure of moving from one cell to another, while a call is in progress, is called handoff. While performing handoff, the MU requires that the base station of the destination cell will allocate it a channel. If no channel is available in the new cell, the handoff call is blocked. This kind of blocking is called handoff blocking and it refers to blocking of ongoing calls due to the mobility of the users [33]. Basically, the new call and handoff blocking probabilities is that allow to determine the Quality of Service (QoS) in cellular networks.

In addition, the traffic volume and intensity, and channel occupation time are also parameters that will allow to evaluate the system behavior and the resource utility. The time interval that a call is keeping busy a channel or a set of them is called channel occupation time. Then the traffic volume may be defined as the sum of the channel occupation time. The traffic intensity is a measure of the average occupancy of a channel during a specified period of time, normally a busy hour, measured in traffic units (Erlangs[1]). This is a dimensionless quantity and may be used to measured the time utilization of single or multiple channels. The results are obtained by assuming that voice and data service are available, while user moves.

The paper is organized as follows. In Section 2, the simulation organization and simulator characteristics are described. Section 3 reports the data traffic modeling used in the simulator. Simulation results and implications on QoS planning are given in Section 4. Finally, the conclusions and future directions, towards to the third generation systems are presented in Section 5.

2. Simulation Organization

We used the Manhattan Model [4, 23] that perfectly serves ours needs, and because of its simplicity, allows us to track hundreds of thousands of MUs. The square grid has 12.8 Km sides. The streets are spaced every 128 meters, and are numbered 0, 1, 2,...N, with each one accepting traffic in both directions. Speed of the MUs is controlled independently for the inner and the outer streets, typical values being 30 and 50 Km/h respectively. All cells have the same area, are circular and spread having minimum overlapping areas. The program allows us to define several areas within the city, which we call *regions of interest*. For implementation purposes we have limited these areas in:

- Traffic
- Residential

[1] Erlang or Erl corresponds to measured unit that determine the occupation rate of a channel, for example: to use a channel of 1 Erl means that the channel is been used in its maximum capacity all the time.

- Business
- Shopping
- Park/Lake

The information entered can then be stored, allowing us to have several different templates for simulation purposes. Hence it is possible in the simulator to create as many MU categories as needed, and divide the whole population among the categories such as to reflect a real situation.

When the MUs are created within a simulation, the program randomly assigns one Home location and one Work location for each MU. We can also built timetable to schedule the MU's activities, which are used for traffic simulation. These timetables are defined using a simple ASCII editor. A typical example is shown on Figure 1.

In the Figure 1, we have 4 categories of MUs. The originating and the receiving call distributions can be defined by the words CALLDIST and RECDIST respectively. For each category we can also define different services and its connection average. These services can be voice, data or video. Each service has different requiring of bandwidth. To determine the bandwidth that will be used by each service, a different channel amount for each one has been allocated (i.e., two channel to WWW service and four channel to video service). To determine the traffic volume over the area under study, we define that:

- On voice service the call arrival process is assumed to be Poissonian while the call duration is exponentially distributed.
- On data service the call arrival process is assumed to be Pareto while the call duration follow the heavy tailed Weibull distribution.
- On video service the call arrival process is assumed to be Pareto while the call duration is exponentially distributed.

The simulator can also write a ASCII text file in disc. Figure 2 shows a example file.

We define in our simulator five types of events that can be processed by event manager as shown in Table 1.

```
CAT 1  ;24 delivery boy
CALLDIST POISSON 14 5
RECDIST POISSON 10 10
SPEED +10 5
SERVICES
;voice, 1 channel, exponential distrib. w/ mean= 80s, 90% of the connctions
Voice VOICE 1 EXPON 80 90
;www, 2 channels, weibull distrib. w/ mean= 180s, 9% of the connections
WWW DATA 1 WEIBULL, 180 PARETO 1000 9
;video, 4 channels, exponential  distrib. w/ mean= 3600s, 1% of the connections
Video DATA 1 EXPON 3600 PARETO 1000 1
MOVETABLE 0
00:00 24:00 ARnd
;————————————————————————————————————
CAT 2   ;Common worker
CALLDIST POISSON 14 8
RECDIST POISSON 14 10
SPEED 0 10
SERVICES
Voice VOICE 1 EXPON 80 75
WWW DATA 1 WEIBULL 180 PARETO 1000 20
Video DATA 1 EXPON 3600 PARETO 1000 5
MOVETABLE 0
00:00  04:00 Home 98 ARnd 02
04:00  07:00 Home
07:00  12:00 Work
12:00  13:30 Work 75 Busi 20 Shop 05
. . .
;————————————————————————————————————
CAT 3  ;Housekeeper
LIKE 2
SERVICES
Voice  VOICE 1 EXPON  80  80
WWW DATA  1 WEIBULL 180 PARETO 1000 15
Video  DATA 1 EXPON 3600 PARETO 1000 5
MOVETABLE 0
00:00  04:00 Home 98 ARnd 02
04:00  14:00 Home
14:00  18:00 Home 50 Resi 25 Shop 25
. . .
;————————————————————————————————————
CAT 4  ; Taxis
CALLDIST POISSON 18 6
RECVDIST POISSON 13 20
SPEED +5 5
SERVICES
Voice VOICE 1 EXPON 80 80
WWW DATA 1 WEIBULL 180 PARETO 1000 10
Video DATA 1 EXPON 3600 PARETO 1000 10
MOVETABLE 0
00:00  07:00  Home
07:00  08:00  Busi
08:00  09:00  Resi
09:00  10:00  ARnd
. . .
```

Figure 1. ***Timetable*** **with location probability distribution given for 4 different MU categories**

To handle the handoff request we used the Priority II model, defined in [15], that considers handoff queue. In [20, 21] and in numerous other studies [5, 7, 8] network packet traffic appears "similar" when measured over a wide range of time scales. That is, the network traffic looks the same when measured over time intervals ranging [10]. Data traffic of this type is said to be *self-similar* or *fractal* in nature [20, 21]. Self-similar traffic is very different from both conventional telephone traffic and from the currently accepted norm for model of packet traffic.

An important parameter of a self-similar process is the Hurst parameter H. It is a parameter used to describe the degree of self-similarity and it can be esti-

```
RECV   476   3   8:02:59   22   2   Voice  [1]  1
HANG   185   2   8:03:01   48   3   535 535  2  0  1
CALL   986   2   8:03:02   41   1   WWW  [2 3]  2
CALL   504   3   8:03:02   54   3   Voice  [1]  2
HANG   414   3   8:03:04   67   4   186  0  0  1
RECV   461   2   8:03:04   55   3   Voice  [1]  3
HANG   853   2   8:03:11   41   1   17  17   0  0  3
RECV   881   2   8:03:26   66   4   Voice  [1]  1
RECV   126   4   8:03:30   41   1   Voice  [1]  5
HANG   126   4   8:03:33   41   1   3   3   0  0  5
RECV   890   2   8:03:37   16   1   Voice  [1]  3
CALL   423   2   8:03:38   48   3   Video  [1  2  3  4]  2
```

Figure 2. Simulation log file of acess to the 3G services.

mated from the variance of a statistical process. Self-similarity is implied if $0.5 < H < 1$. We used one graphical method to test the self-similarity of the traffic: variance-time plot [1, 21].

Event	*Description*
MOVE	The MU must physically move within the city area.
RECV	The MU receives a call.
CALL	The MU originates a call.
HANG	The call received or originated by an MU terminates.
HOFF	The system must process handoff for a specific MU from one cell to another.

Table 1. Events table

For the variance-time plot, the process is self-similar if the estimated asymptotic slope $\hat{\beta}$ is between -1 and 0. The Hurst parameter can then be estimated as $\hat{H} = 1 - (\hat{\beta}/2)$. We estimated the H value for one cell sample. The asymptotic slope estimated is aproximately -0.25, resulting in an estimate $\hat{H} \approx 0.88$ of the Hurst parameter. This method suggests that the traffic sequence is self-similar.

The self-similar process has been constructed by superimposing several processes *on/off* [2], where times between arrivals has a heavy tailed distribution It has influenced the blocking rate. So the process of Poisson used to model the arrival of voice service requests started by users, was not the same to the arrival of web documents in a server. Since the transmissions of WWW and video documents are not completely started by user. For instance, a web page often contains several images and when user demands one of these pages the browser automaticaly generates a lot of additional requests to read these images. Therefore the blocking rates of WWW and video services were bigger than voice service due to the used model, which allows to simulate another additional request needed to provide these type of services. Power-tails distributions have been used to model network traffic behavior [12].

[2]The periods *on* correspond to the periods of transmission of web files and the periods *off* correspond to the periods where the server is not receiving data.

3. Data Traffic Modeling

Intuitively, we consider heavy-tailed distributions as models for possibly large values in a sample. Such models have been taken as basis for more sophisticated models in teletraffic data transmission [11, 28]. In certain applications, in particular in queueing theory, more structure for the distribution tail is needed. The Pareto distribution is characterized by a linearly increasing mean excess function. In addition, it has finite mean, infinite variance, and it has been used to model traffic having fractal characteristics [26].

The data traffic from the wireless network is modeled by Pareto distribution, where the traffic is generated by use of distribution inverse function. Like WAP (Wireless Application Protocol) data service has quickly developed [19], we have obtained from a wireless carrier of this service the average data traffic in the network. In this case, the average data traffic has been used in the simulation is 1.52kbps.

Heavy-tailed service times, has been researched in [3, 11]. Specifically, in [3] has been proved that when the service time is lighter than the tail of a Weibull distribution with parameter $\beta = 0.5$, the number of arriving customers comes into the picture as well. Then the combination of the number of customers and the likely large service time the queue-length large.

The resource occupation time for data service is modeled by another heavy tailed distribution, called Weibull distribution. In the case of our simulation, we used the method of sucessive projections [6, 9] to estimate the shape parameters. Thus the Weibull distribution inverse function has been used to generate the occupation time with average of 2.52 minute ($\approx$ 180 seconds).

The following subsection describes how the shape parameters were calculated for both Pareto and Weibull distributions.

3.1. Calculating Shape Parmeter of Pareto Distribution

There are in the literature a lot of methods that allow to estimate the α parameter value. Specifically, we used the Method of Moments, because this method does not need of an initial sample set. The sample average is defined as follows:

$$M(x) = \frac{\alpha}{\alpha - 1} \tag{1}$$

Therefore, we can calculate α.

$$\begin{array}{c} \alpha = \frac{M(x)}{M(x)-1} \quad where \\ M(x) = average \;\; data \;\; traffic. \end{array} \tag{2}$$

3.2. Calculating Shape Parmeter of Weibull Distribution

The method of sucessive projection has been used to determine parameters α and β of the Weibull distribution. This method can be considered as a generalization, described in [2] [24][6] [9]. The α and β values are obtained by the plans intersection in $\Re^3$, such that these values are greater than zero. The equations 3 and 4 represent the mean and the variance of Weibull distribution, respectively .

$$M = \alpha^{-\frac{1}{\beta}}\Gamma(1 + \frac{1}{\beta}) \tag{3}$$

$$\sigma^2 = \alpha^{-\frac{2}{\beta}}[\Gamma(1 + \frac{2}{\beta}) - \Gamma^2(1 + \frac{1}{\beta})] \tag{4}$$

This allows us to create a system as showed in Equation 5. Where M $\approx \overline{x}$ is the mean and the $\delta^2 \approx S^2$ is the variance.

$$\begin{cases} \alpha^{-\frac{1}{\beta}}\Gamma(1 + \frac{1}{\beta}) - \overline{x} = 0 \\ \alpha^{-\frac{2}{\beta}}[\Gamma(1 + \frac{2}{\beta}) - \Gamma^2(1 + \frac{1}{\beta})] - S^2 = 0 \end{cases} \tag{5}$$

The Equations 6 and 7 can be determined applying logarithm properties.

$$\beta = \frac{\log(\alpha)}{\log(\Gamma(1 + \frac{1}{\beta})) - \log(\overline{x})} \tag{6}$$

$$\alpha = 2^{-\frac{\beta}{2}[\log(S^2) - \log[\Gamma(1+\frac{2}{\beta}) - \Gamma^2(1+\frac{1}{\beta})]]} \tag{7}$$

In this case, we know the mean $\overline{x}$, that is, the average occupation time for data service. By expanding 6, we have 8):

$$\beta\log(\Gamma(1 + \frac{1}{\beta})) - \beta\log(\overline{x}) - \log(\alpha) = 0 \tag{8}$$

The Equation 8 can be divided in two function, where $g(\alpha, \beta)$ is convex and $h(\alpha, \beta)$ is concave. They can be computed by 9 and 10.

$$g(\alpha, \beta) = \beta\log(\Gamma(1 + \frac{1}{\beta})) + 0\alpha \tag{9}$$

$$h(\alpha, \beta) = \log(\alpha) + \beta\log(\overline{x}) \tag{10}$$

Therefore, we can write $f(\alpha, \beta)$ as shown in Equation 11.

$$f(\alpha, \beta) = g(\alpha, \beta) - h(\alpha, \beta) \tag{11}$$

The following hypothesis are necessary to determine $\overline{\alpha}$ e $\overline{\beta}$.

- $g(\alpha, \beta)$ convex
- $h(\alpha, \beta)$ concave
- $\exists\, \overline{\alpha}, \overline{\beta} : g(\overline{\alpha}, \overline{\beta}) = h(\overline{\alpha}, \overline{\beta})$

Thus a linear approximation of $g(\alpha, \beta)$ in $(\overline{\alpha}, \overline{\beta})$ can be made. We refer $x = \begin{bmatrix} \alpha \\ \beta \end{bmatrix}$. Then, we have a linear approximation $g(x)$ in x_k. Applying sucessive projection and making the intersection of two hyperplans we can determine $\overline{\alpha}$ e $\overline{\beta}$. Finally, the data service average occupation time can be generated.

4. Simulation Results

The simulation tool model both the traffic and mobility behaviour of users offering ability to consider different service types and different MU categories. Morever, it allows to estimate the blocking propability and the radio resource utilization. In particular:

- Voice and dada service are available anywhere.
- New calls and handoffs are differently treated.
- We consider 162 channel per cell.

- The Simulation time is 24h.
- The Timeout to handoff queue is 2 seconds.
- The increase of the signal power occurs to 50 meters of cell's boundary.
- The Mean call from the originating and receiving rate for categories 1, 2 and 3 is 0.9 calls/hour/MU.
- The Mean call originating and receiving rate for category 4 is 1.7 calls/hours/MU
- See Table 2 for the distribution of MUs among categories. The mobility parameter in the third column gives the time percentage that MU moves into the simulator period.
- The Mean duration for voice service is 120 seconds, for data service is 180 seconds, and for video service is 3600 seconds.
- The MU speed varies between 30 and 50 km/h

We use 162 channels per cell, a parameter used by the American D-AMPS (Digital Advanced Mobile Phone System) or TDMA IS-54[3], which was standardized by FCC (Federal Communications Commission). The bands of 25MHz are divided into channels of 30 KHz, that give us 416 duplex channels, with 21 for control. We apply a reuse factor of 7, for the 395 remainder, then we have 56 channels per cell. There are 3 time slots per carrier, that gives a service capacity of 168 channels or user per cell. Depending on the interference between channels, for example, this number can be decreased (54 x 3 = 162). In the case of GSM (Global System for Mobile Communications) we could consider until 192 channels per cell (3 sectors, 8 carriers per sector, 8 slots per carrier).

Category	*% of UMs*	*Mobility (%)*	*Description*
1	18.2	90	24h delivery boy
2	35.3	50	Common worker
3	26.3	30	Housekeeper
4	20.2	60	Taxis

Table 2. Categories and the MUs distribution

[3]Time Division Multiple Access was first specified as a standard in EIA/TIA (Electronic Industries Association) Interim Standard 54 (IS-54).

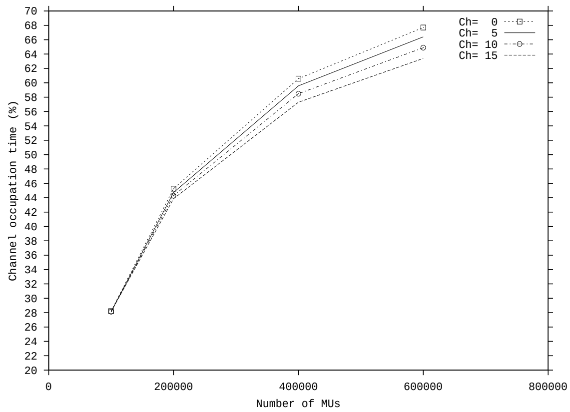


Figure 3. Channel occupation time in 3G telecommunication networks per number of MUs per cell (30/50km/h)

Figure 3 shows the influence of the number of MU in the effective channel occupation time with different variations of reserved channels to the handoff procedure. We see that when the number of MUs is increased, this will mean that more calls being held by each cell, leading to a better channel occupancy. Relatively, we can also note that a variation on number of reserved channels to handoff does not interfere in the channel occupation time.

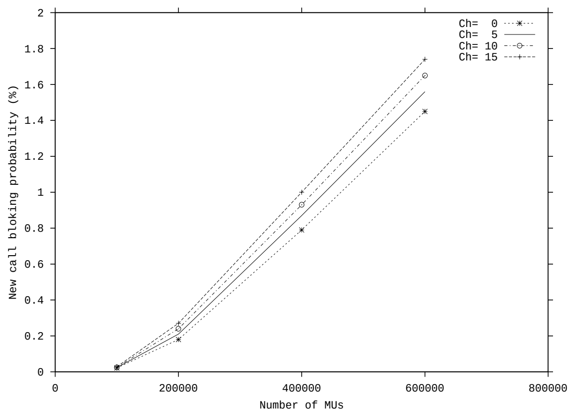


Figure 4. New call blocking probability in 3G telecommunication networks per number of MUs per cell(30/50 Km/h)

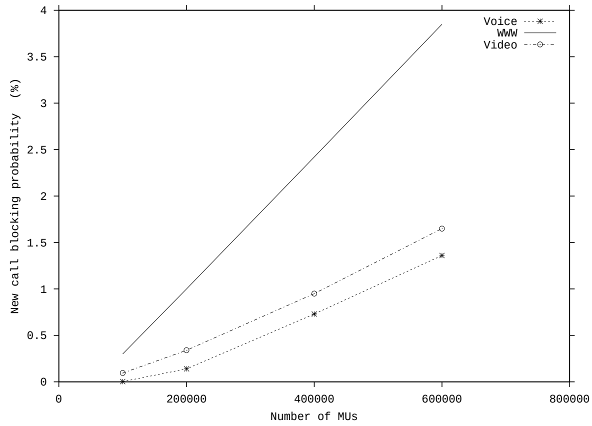
One of the main parameters used to measure QoS (Quality of service) is the blocking probability, i.e., the number of calls rejected because of lack in channel capacity. In practice, this value should not exceed 2% for new calls. In Figure 4 we observe that when the number of channels to handoff is increased, the new call blocking probability also raises. If we compare the new call blocking probability between 3G and current telecomunication networks, we could note a high blocking probability in 3G network. This happens because the same channels of current networks are used in 3G networks to move beyond of voice service, the video and data services. This implies in a larger consumption of resources.

Specifically, there is a reduction in the number of channels available to answer new calls in the system in such way to attend the requests of handoff. If we consider that the number of MU has a tendency to remain either constant or increase, the new call blocking will increase. On the other hand the MUs can perform more handoff, but also the QoS of the network is damaged.

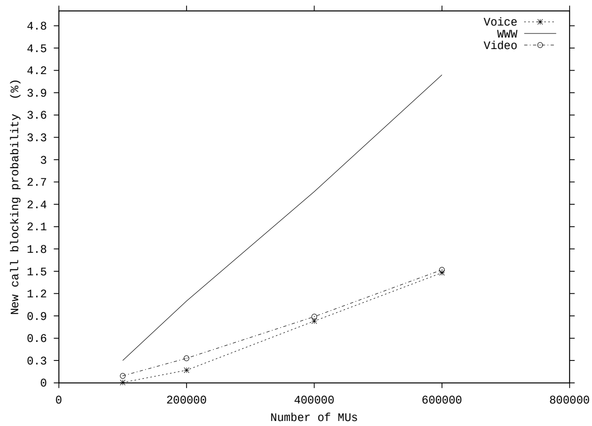
Figure 5 shows a new call blocking probability per service (voice, video, WWW), changing the number of reserved channels to handoff. We can note that the WWW and video services blocking rates are greater than voice service blocking rate when the number of reserved channels to handoff increases. This result may be explained by the fact that video connection requires a larger amount of resources to maintain the minimum QoS and the connection percentage is small. On the other hand, for the WWW service, the amount of the resource necessary is smaller than the video resources, but the connection percentage is bigger.

Besides that, the 162 available channels to meet the demand of new calls are decreased in the same amount of with the reserved channels to handoff. In addition, the low blocking probability of voice service may be explained by the fact that this service uses only one channel for each connection.

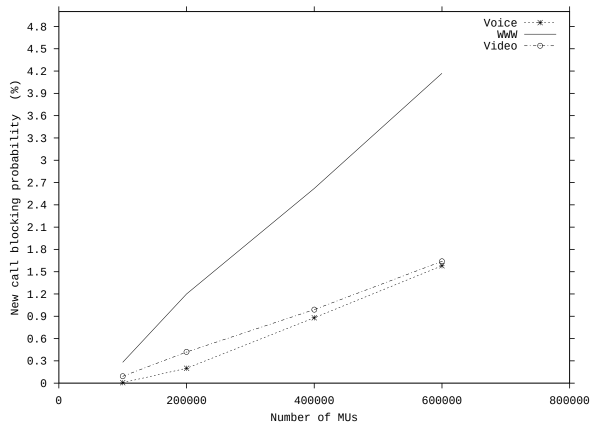
The simulator mobility model tries to control a blocking probability per cell around 1%. Considering different number of reserved channels to handoff call, Figure 6 indicates that as the number of MUs increases and the number of reserved channels to handoff decreases, the handoff blocking probability also increases. We can also note that the handoff blocking probability in 3G network tends to 0 when the number of reserved channels to handoff procedure are greater or equal 5. In this case, the superimposition of curves



(a) Ch. Handoff = 0



(b) Ch. Handoff = 5



(c) Ch. Handoff = 10

Figure 5. New call blocking probability in 3G telecommunication networks per type of service per cell(30/50 Km/h)

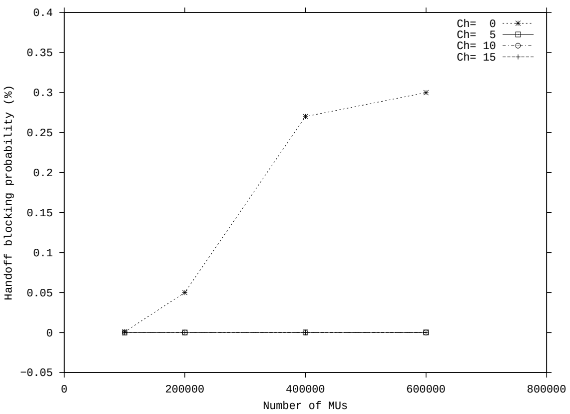


Figure 6. Handoff blocking probability in 3G telecommunication networks per number of MUs per cell (30/50 Km/h)

occurs as depicted in Figure 6.

In Figure 7, we analyze the variation of MUs speed fixing the number of channels to handoff equal 5. We can note how the MU mobility degree, might influence in the quality of service of the network. We observe that as the MU's speed and the number of MUs increases towards high values, the handoff blocking probability raises.

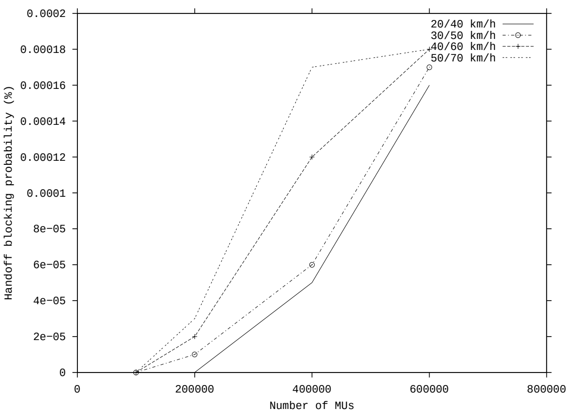


Figure 7. Handoff blocking probability in 3G telecommunication networks per number of MUs per cell changing MU's speed

Figure 8 shows the handoff blocking probability in 3G network per service with MU speed between 30 and 50 Km/h, changing the reserved channels to handoff. When the number of reserved channels to handoff is increased, the blocking probability reduces. In this case, the number of MUs must remain unchanged.

We also see that both voice and WWW service blocking probability tends to 0 for handoff channels greater or equal 10. While the video service blocking probability tends to $2.0 * 10^{-5}$, so it require larger amount of resources, in agreement with established criteria in the simulation.

We also note that rising the number of handoff channels, the carried traffic tends to decrease. This result can be explained by the fact that the number of channels to serve new call is decreased, while we increase the number of reserved channels to handoff.

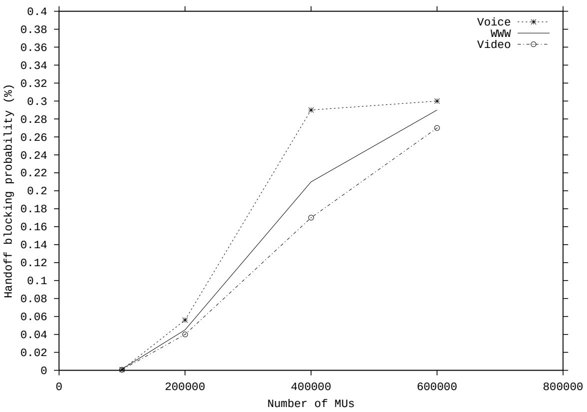
If we vary the MUs speed and fix the number of available handoff channels in 5, then we observe that, independent of MU speed, the carried traffic (in Erlangs) keep unchanged.

Specifically, when we increase the number of MU at system the carried traffic varies clearly. On the other hand, a increasing in the number of available channels to handoff procedure, causes a reduction in the number of available channels to new call, but also there is a reduction of the performed handoff number. In this case the traffic volume remains stable, but also there is no guarantee of quality to users demanding access to services.

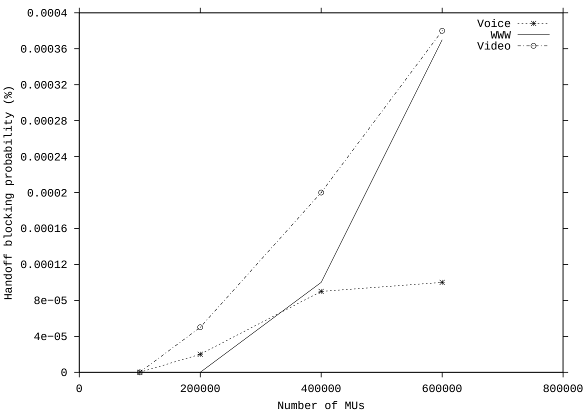
Figure 9 shows the carried traffic (in Erlangs) per cell. In this case, we vary the number of reserved channels to handoff procedure. We can note that rising the number of handoff channels, the carried traffic tends to decrease. This result can be explained by the fact that the number of channels to serve new calls are reduced, while we increase the number of reserved channels to handoff.

If we vary the MUs speed as is showed in Figure 5 and fix the number of available handoff channels in 5, then we observe that, independent of MU speed, the carried traffic (in Erlangs) keep unchanged as we can note by the superimposition of the curves.

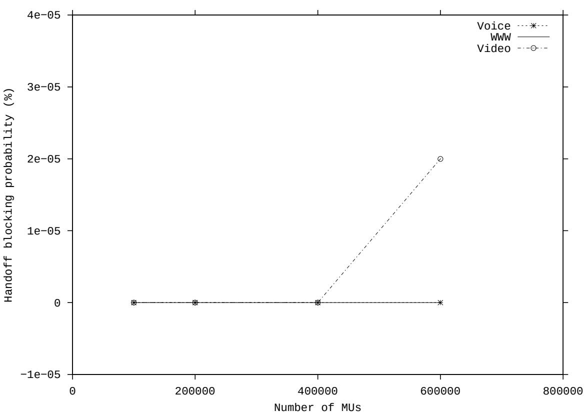
Specifically, when we increase the number of MU's at system the carried traffic varies clearly. On the other hand, a increase in the number of available channels to handoff procedure, causes a reduction in the number of available channels to new calls, but also there is a reduction of the performed handoff number. In this



(a) Ch. Handoff = 0



(b) Ch. Handoff = 5



(c) Ch. Handoff = 10

Figure 8. Handoff blocking probability to 3G mobile telecommunication network per service per cell (30/50 Km/h)

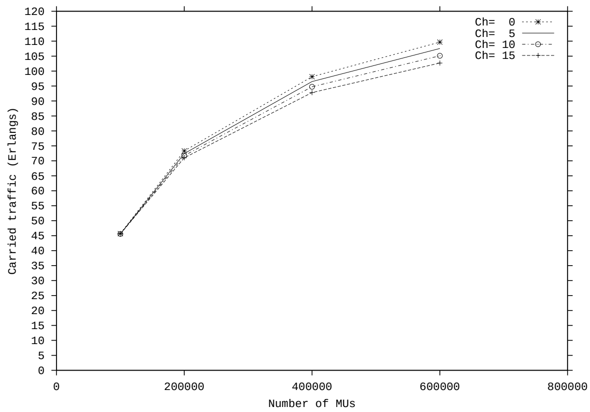


Figure 9. Carried traffic (in Erlangs) per cell to mobile telecommunication networks (30/50 Km/h)

case the traffic volume remains stable, but also there is no guarantee of quality to users who are demanding access to the services.

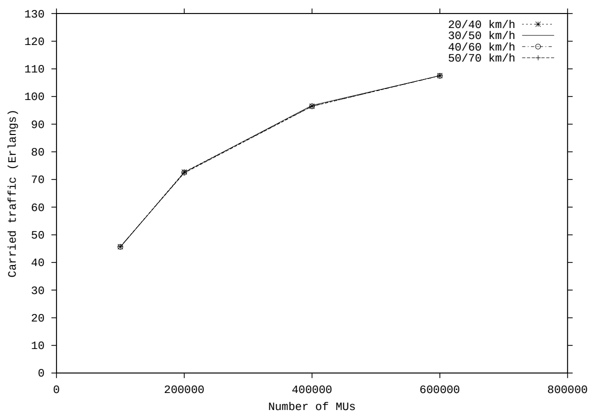
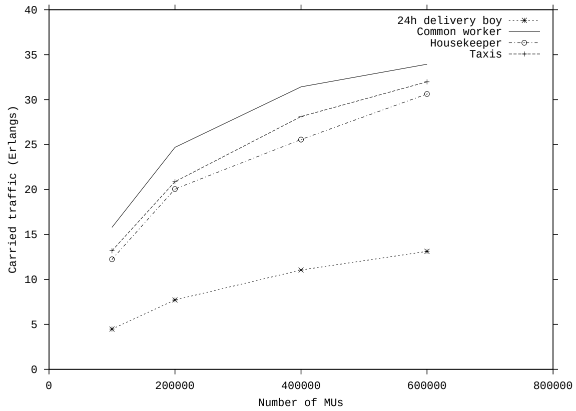
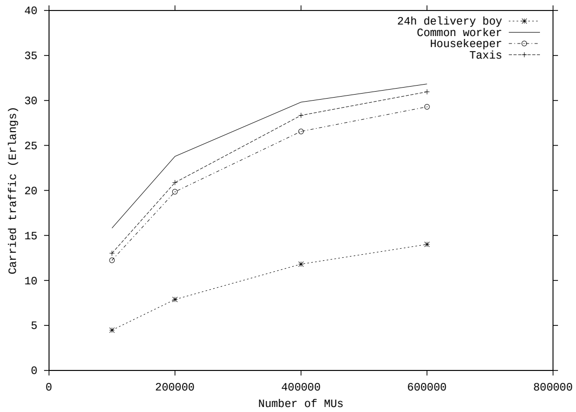


Figure 10. Carried traffic (in Erlangs) per cell to mobile telecommunication networks for different MUs speeds

Figure 11 shows the carried traffic (in Erlangs) to 3G networks per category of MU with *inner/outer* speed 30/50 Km/h with variation of the reserved channels to handoff. We can note that the carried traffic per category is little influenced by changes in the available channels to handoff.



(a) Ch. Handoff = 0



(b) Ch. Handoff = 5

Figure 11. Carried traffic (in Erlangs) per category per cell to mobile telecommunication networks

We can still verify that the category 2 (common worker) tends to have a larger traffic, that is delineated by the large number of connection performed to the 3G services for this type of user. This implicates in a rising on channel occupation time, generating a rise in the traffic volume of network.

We observe that carried traffic in the network does not depend on available channels to handoff. We still note that the tendency is that the voice service traffic is bigger than the video and WWW services traffic. This happens because a large number of requests is generated by voice services. These requests can use any of the 162 channels for a generated new call, they can decrease when we increase the number of reserved channels to handoff. In this case, the new call blocking probability increases, reducing the traffic volume in the network. This traffic volume depend on channel occupation time, what imply in a reduction of the carried traffic.

5. Conclusions

In this paper we have presented a performance analysis of third generation mobile telecommunication networks, using a simulator. We have considered some parameters, such as new call and handoff blocking probability, carried traffic (in Erlangs), and channel occupation time that make possible evaluate the QoS of mobile networks. Traffic analysis for future mobile systems should take into account a variety of services (voice, data, video) and environments (e.g.: private, outdoors, indoors) as well as the user mobility behavior. The simulator presented in this paper incorporates all the above mentioned features, besides it considers the self-similar network traffic (in this case we have used the heavy tailed distribution to simulate self-similarity of data traffic). In the case of the voice service: the call duration has been exponentially distributed and the arrival process of new calls have been Poissonian.

These results clearly show that the mobility directly influences in the network quality of service and that the different available types of services depend on other issues as carried traffic, bandwidth, etc. These features are essential part of mobile communication system design. Each type of traffic has different characteristics. Then, the capacity planning becomes a hard task with a variety of data applications, such as Internet access, email, file transfer, and with a variety of data rates and mix of traffic. Hence, in 3G network planning is crucial to use capacity planning techniques which give accurate results, because it directly affects the number of cells required to serve a given area. The simulation is one of the aspects that make possible the wireless provider to prepare for 3G wireless networks.

Future research must focus on methods to reduce the blocking probability and to maximize the utilization of the bandwidth according to the traffic and type of service. Priority techniques must be included in the simulator to consider QoS constraints and channels dynamic allocation tecniques.

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ATTACHMENT 4

NPSTC

The Collective Voice of Public Safety

Celebrating 10 YEARS 1997-2007

Ten Years of Progress | 1997-2007

NPSTC 700MHz Questionnaire Results

Final Analysis

NPSTC Broadband Interoperability Working Group

Emil Olbrich, Andrew Thiessen, Joe Ross

NPSTC is a federation of organizations whose mission is to improve public safety communications and interoperability through collaborative leadership.

Questionnaire Purpose

- The Broadband Interoperability Working Group (BBWG) within the NPSTC Interoperability Committee is tasked to investigate, report on, and propose solutions that deliver network and application broadband interoperability to the NPSTC governing board.
- The BBWG is in the process of analyzing wireless broadband technologies for use by public safety agencies in the 700MHz spectrum.
  - At the June 2006 meeting, the NPSTC governing board voted to investigate proposing a 700 MHz broadband standard.
  - The general process involves collecting requirements from public safety, evaluating marketplace capabilities versus the requirements and making a recommendation to the board on 700 MHz broadband networking standards.
- In order to determine which broadband standard or standards should be supported the BBWG created and commissioned a web-based 700 MHz Broadband Questionnaire to identify user needs and requirements.

Questionnaire Response

Open Date — Jan 22, 2007

- Emailed a 25-question Web questionnaire to 440 NPSTC public safety representatives for completion
- Target goal set for 250 responses — representing 250,000 users
- By the Orlando NPSTC meeting (Feb 5-7) we had a total of 46 responses to the questionnaire, or a ~10% return rate
- Asked NPSTC representatives to please respond to the questionnaire and inform other public safety users that may have not gotten the email to respond.

Close Date — Feb 28, 2007

- Received 629 initial responses
  - Over 140% return rate (from the 440+ emails sent out)
  - Representation from over 311,000 users in the public safety community
  - 433 respondents completed the entire questionnaire and provided contact information
  - 16 respondents did not provide contact information
  - No way to definitively prove that non-public safety agencies responded
  - Responses not weighted. Large and small municipals each got the same "vote"
- Exceeded target goals substantially
- Met March 31, 2007 delivery commitment for initial report

Results Highlights

Interest in 700MHz spectrum and technology is increasing

- Representation of over 300,000 users is a very good sample size, but limited response from law enforcement and large cities may have affected results.
- Respondents overwhelming reported a pent up desire for interoperable data
  - 96% want broadband
  - 92% think broadband interoperability is somewhat important to critical
  - Only 27% of have access today
  - 48% of all users expected to have access within five years
- Most respondents (56%) are likely to build/operate their own 700 MHz broadband network, and 22% anticipate deployment within four years.
- In a later question, some 40% of respondents said they want to own their own network, 40% had no preference, and only 20% had a preference to lease service from a third party. Almost all were willing to build shared networks, but most didn't know if their state or region could accomplish that.
- The greatest reason reported for not using broadband is the cost of commercial service, followed by the lack of wide-area broadband spectrum, availability of commercial services, and cost of wide-area public safety solutions.
- The most important data applications reported were AVL, GIS, field reporting, and email; while the least important were video, high-resolution image transmission, and building blueprints. However, the limited response from law enforcement and large cities may impact this response as they could be heavy users of these services.

Results Highlights (cont.)

Interest in 700MHz spectrum and technology is increasing

- Respondents reported that cell phones are the wireless device they use the most by far currently, however, future use was evenly distributed between rugged and non- rugged PDAs and Notebooks, cell phones, AVL, and MDTs.

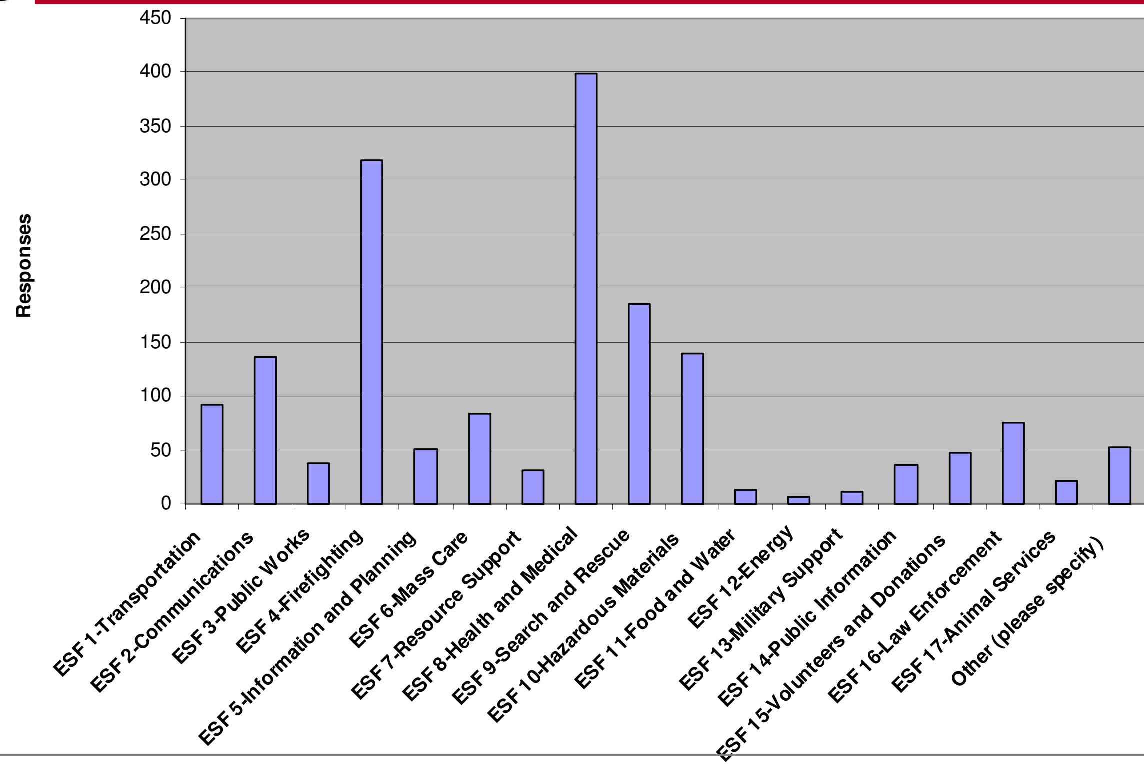
- Most respondents wanted direct mode to be an optional requirement in devices, and most either didn’t know or didn’t require direct mode. However, a substantial number of respondents wanted mandatory direct mode and required direct mode.

- The most important applications for direct mode (for data) are text messaging and file transfer. Direct mode video was of interested to less than half of those who had an interest in messaging and transfers.

- More than a third of respondents were not willing to pay more for direct mode. Of the remaining respondents willing to pay, the vast majority were only willing to pay 10 or 25 percent more.

- Lastly, a significant amount of “don’t know” or “no opinion” responses throughout the survey means that outreach and clarification of the issues must be addressed quickly. Many respondents skipped questions, leaving us to wonder how they would have responded with a clearer or simpler question and response.

ESF Categorized Responses



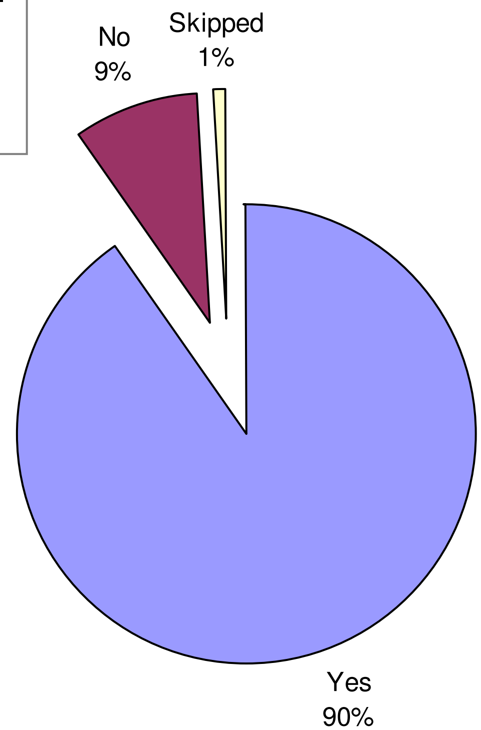
- Question 1 asked: What agency or agencies of public safety are you representing in this questionnaire? (Check all that apply)
  - We modified the Emergency Support Function (ESF) nomenclature model to categorize responses for the questionnaire — DHS sets ESF categories as part of the National Response Plan

- Health & Medical (EMS), Firefighting, and Search & Rescue represent the majority of respondents

- Law enforcement response was well below most categories — May effect results where law enforcement requires broadband services

Decision Making

- Questions asked:
  - 2. Do you have decision making responsibilities (financial or technical) for your agency?
  - 3. What is your position/title?
  - 4. What is your agency name? (i.e. Orlando PD)



- Overwhelming majority of responders have direct decision making responsibility (90%)
- Results show that the questionnaire targeted the correct audience

Users and Demand

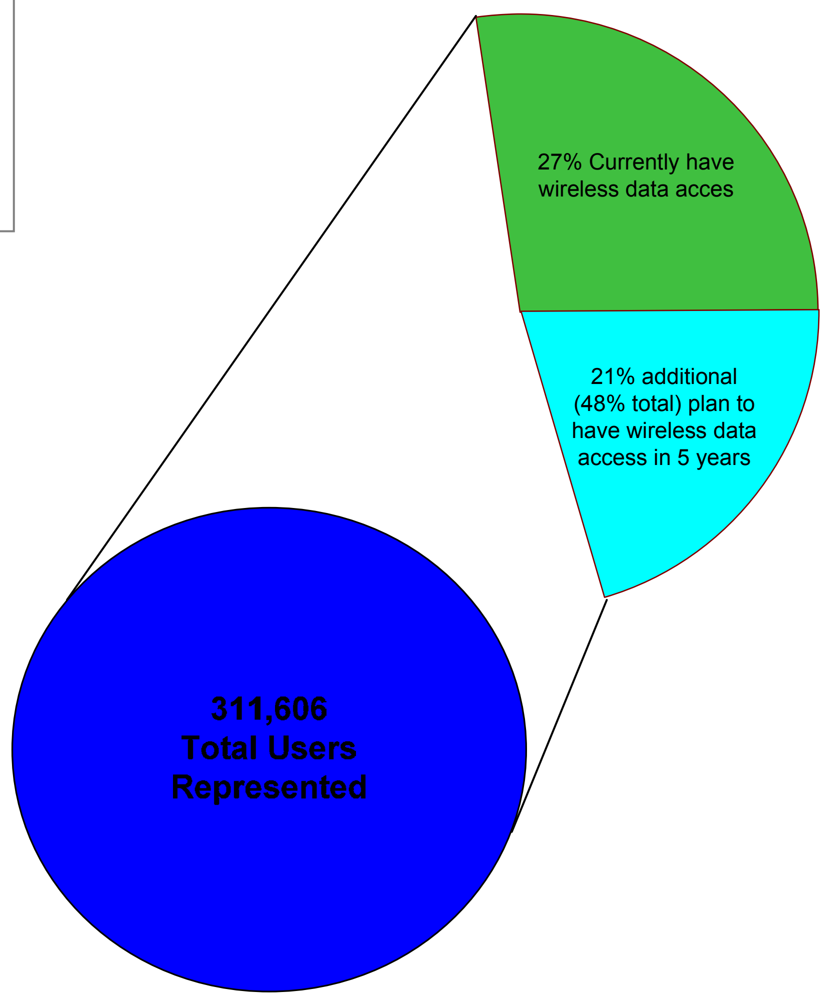
- Questions asked:
  - 5. How many people are in your agency?
  - 6. How many people in your agency currently have access to wireless data?
  - 7. In five years, how many people in your agency do you plan to have access to wireless data?

- Respondents represent a total of **311,606** public safety users (1/8 of est. 2.5M total)

- 27% (82,922) of these users currently have access to wireless data

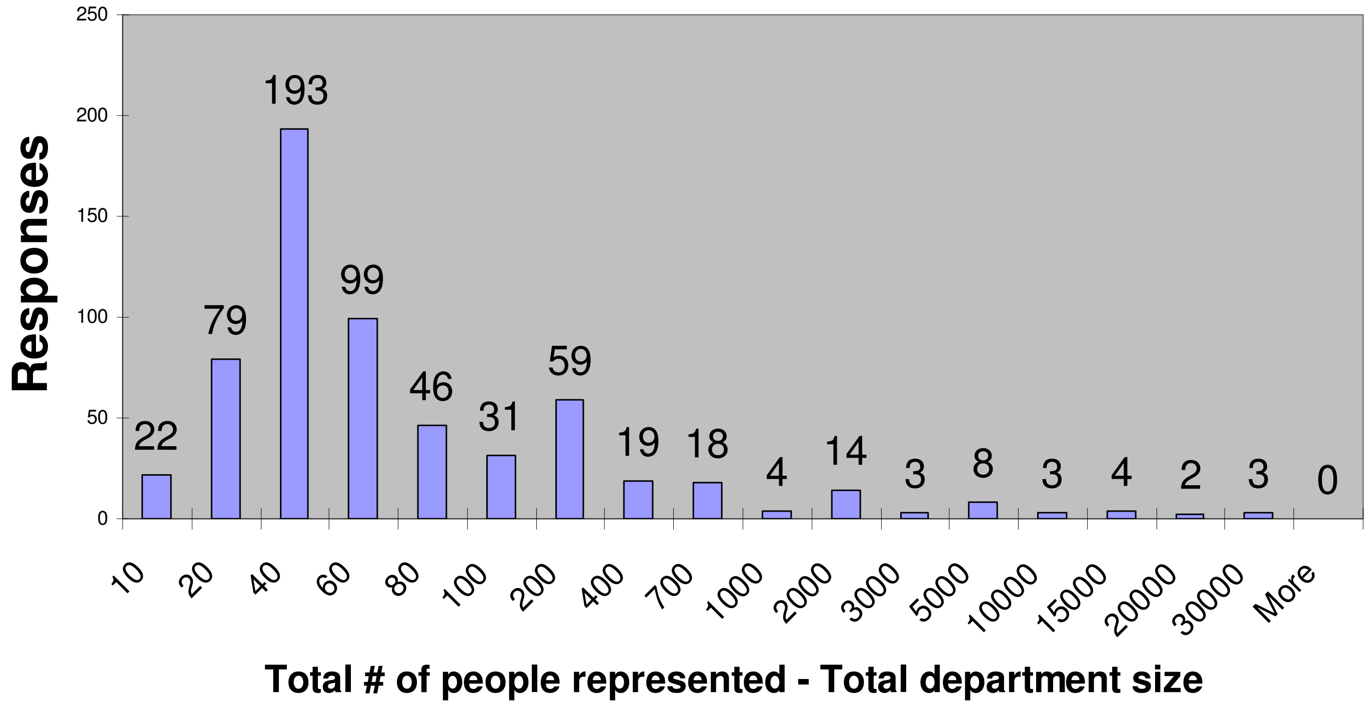
- 48% (148,189) of the users are planned to have wireless data access within five years

- Analysis
  - We have an good cross-section of all public safety from small to large and across all disciplines
  - Approximately ¼ of public safety users have access to wireless data
  - Within 5 years, this will **double** to nearly ½ of all public safety users — Represents an over 12% growth per year over 5 years



Agency Size Distribution

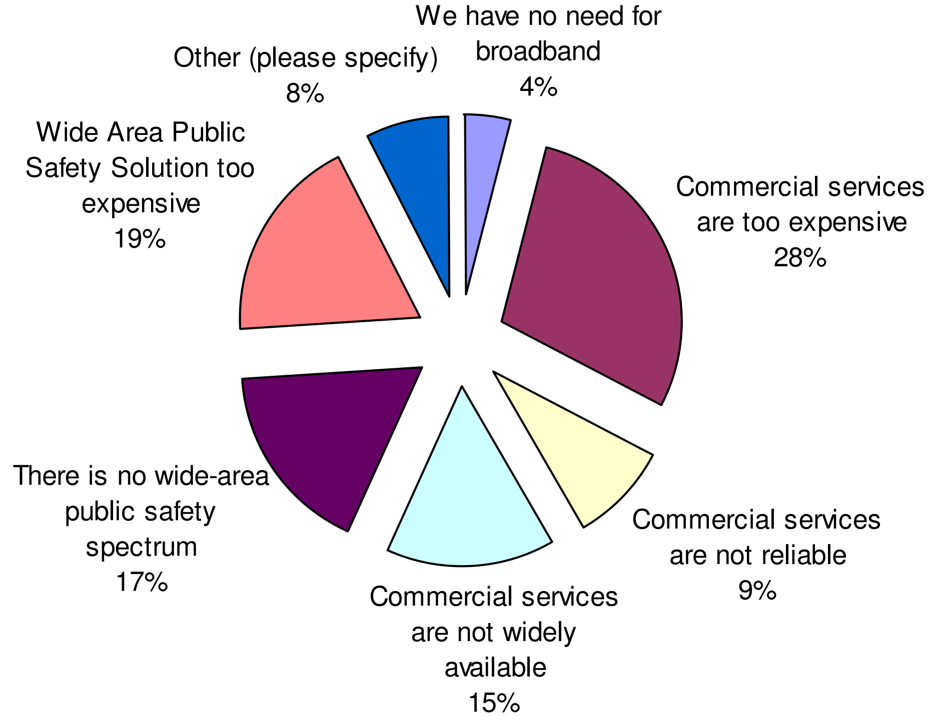
- Large distribution of the size of the agencies represented by the respondents from 1 to 30,000 users per department
- Agencies with approximately 40~50 users represented the largest percentage of respondents
- Several large public safety agencies represented
  - However, a few major metropolitan areas did not respond or gave very limited responses
  - Responses not weighted. Large and small municipals each got the same "vote"
- The data are dominated by small to medium sized agencies



Broadband Roadblocks

- Question asked:
  - 8. What is preventing your agency from adopting broadband wireless solutions to a greater extent? (check all that apply)

- Cost accounts for 47% of the reason why broadband adoption hasn't happened
  - May be misconceptions on cost of broadband systems & services
- "Other" responses showed:
  - Lack of on knowledge of 700MHz broadband
  - Funding
  - Use of existing commercial services or LMR data
- We can extrapolate that 96% of agencies need wireless broadband data access



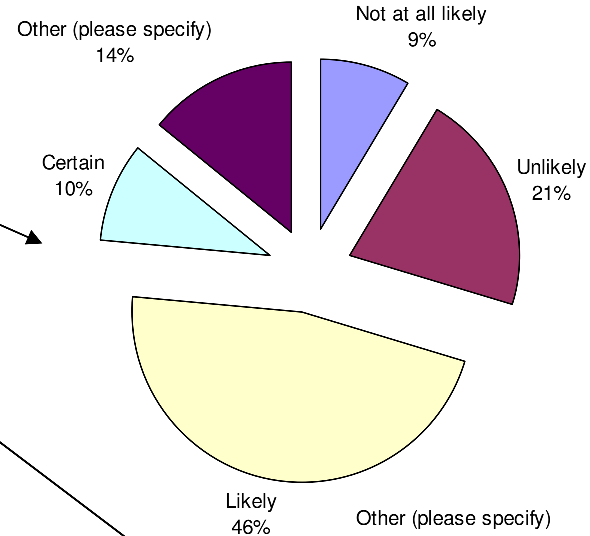
Broadband Deployments

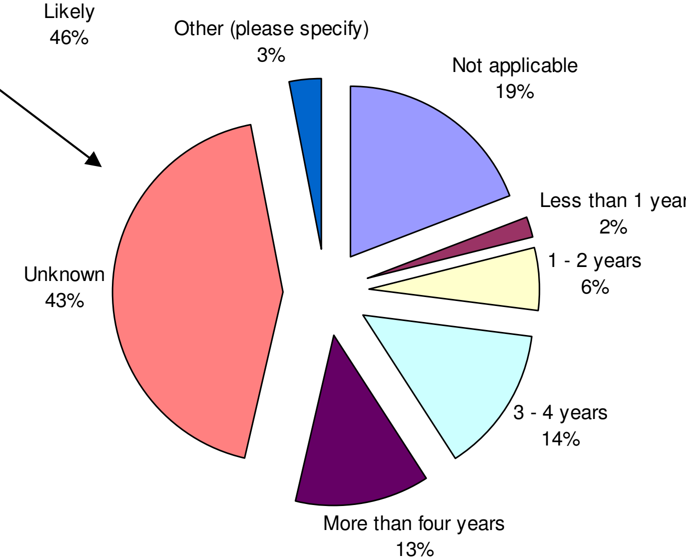
- Question asked:
  - 9. If broadband spectrum is available for public safety in the 700 MHz band, how likely is your agency to build and operate a system?
  - 10. If your agency intends to deploy a 700 MHz broadband network, when do you anticipate such a deployment?

- 56% of respondents are likely or certain to build/operate a 700MHz broadband system

- 43% of respondents don't know when they're going to deploy due to some major issues: (From respondent comments)
  - Don't know how they'll pay for it
  - Don't know when spectrum will be available
  - Don't know what technology to use

- 22% will start deploying systems within 4 years

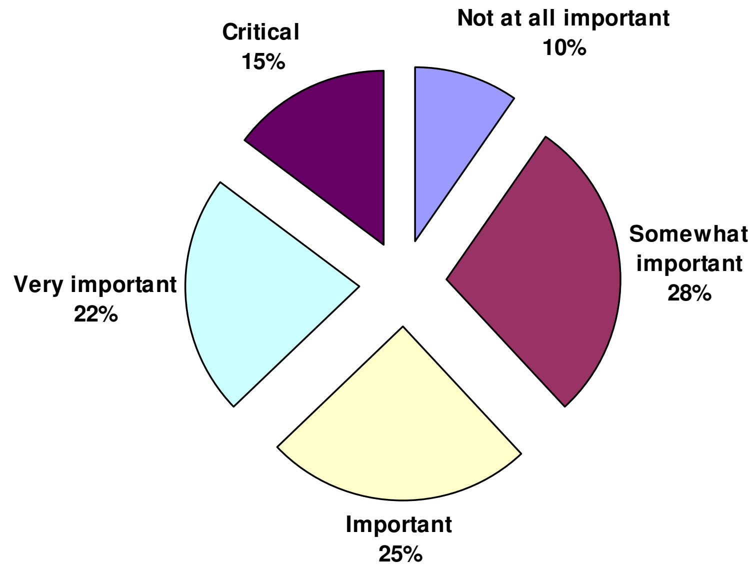




Broadband Interoperability

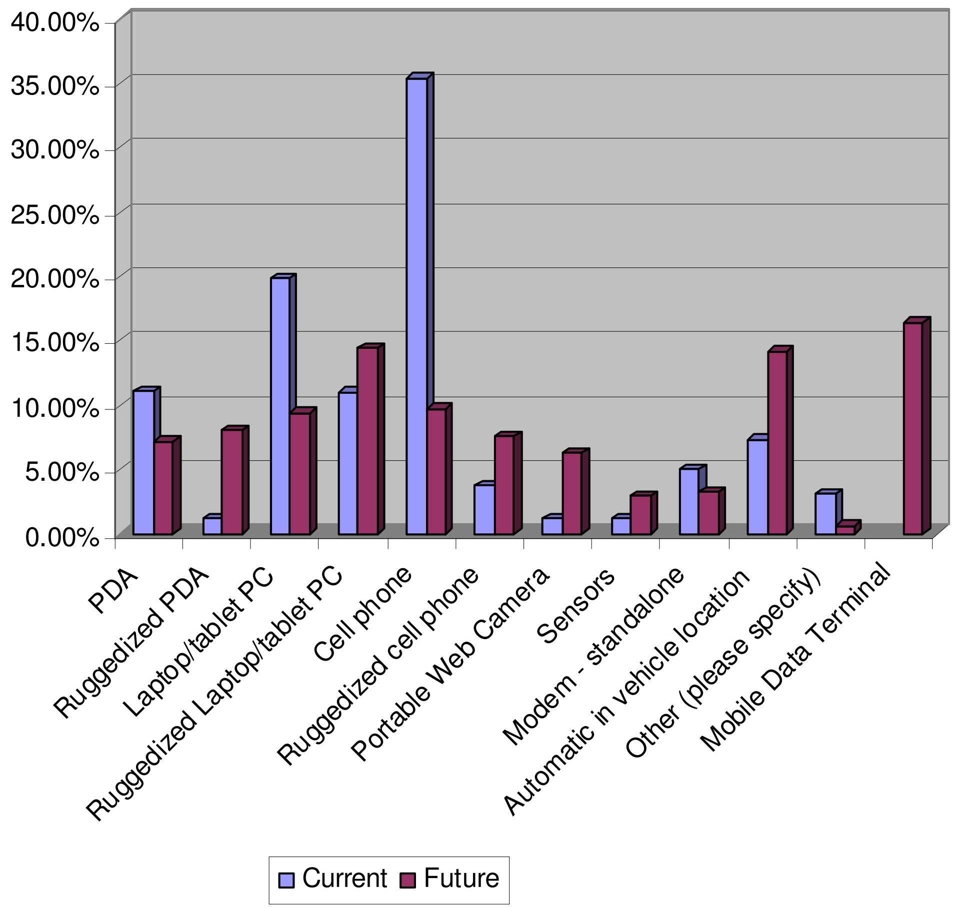
- Question asked:
  - 11. How important to you is wireless broadband data interoperability with other agencies or regions?

- 90% say it's at least somewhat important!
- If public safety wants a nationwide interoperable network, requirements and standards must be established very quickly (much less than 4 years)
- These requirements must be detailed enough to allow:
  - Definition of public safety specific requirements
  - Manufacturers to build systems that support these requirements
  - Show roadmap or growth plan for technology upgrades



Broadband Devices

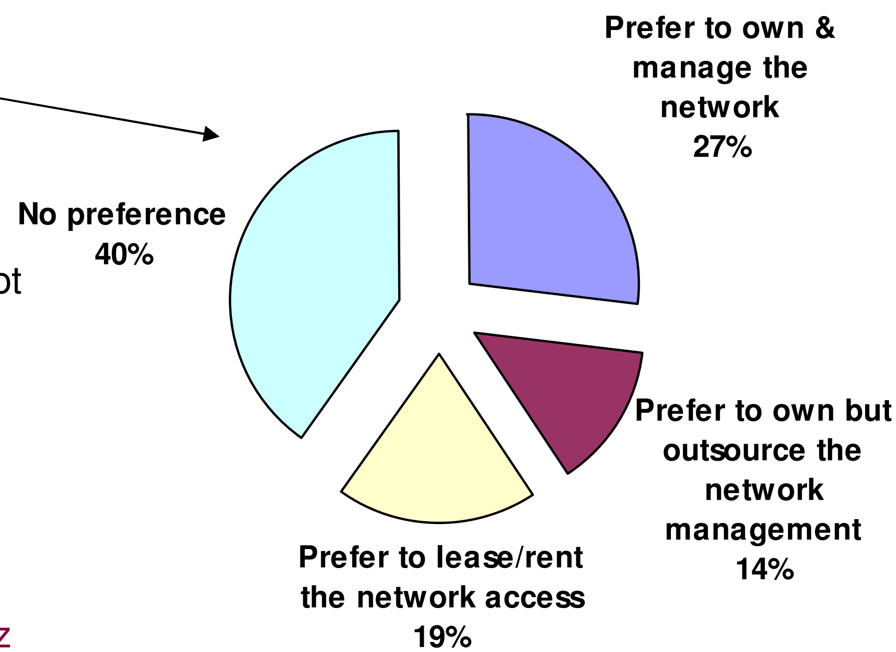
- Question asked:
  - 12. What kind of wireless devices do you use now in your agency? (check all that apply)
  - 13. What type of wireless devices would you like to have or use in your agency? (check all that apply)
    - PDA
    - Rugged PDA
    - Laptop/tablet PC
    - Rugged Laptop/tablet PC
    - Cell phone
    - Rugged cell phone
    - Portable Web Camera
    - Sensors
    - Modem - standalone
    - Automatic in vehicle location
    - Mobile Data Terminal (Note: this was accidentally omitted from question 12)
    - Other (please specify)



- Distribution changes significantly with what agencies "want" as oppose to "have" In the future agencies see:
  - Suggests larger distribution of device form factors for the future
  - These form factors are available today commercially but not necessarily for public safety solutions

Ownership and Operation

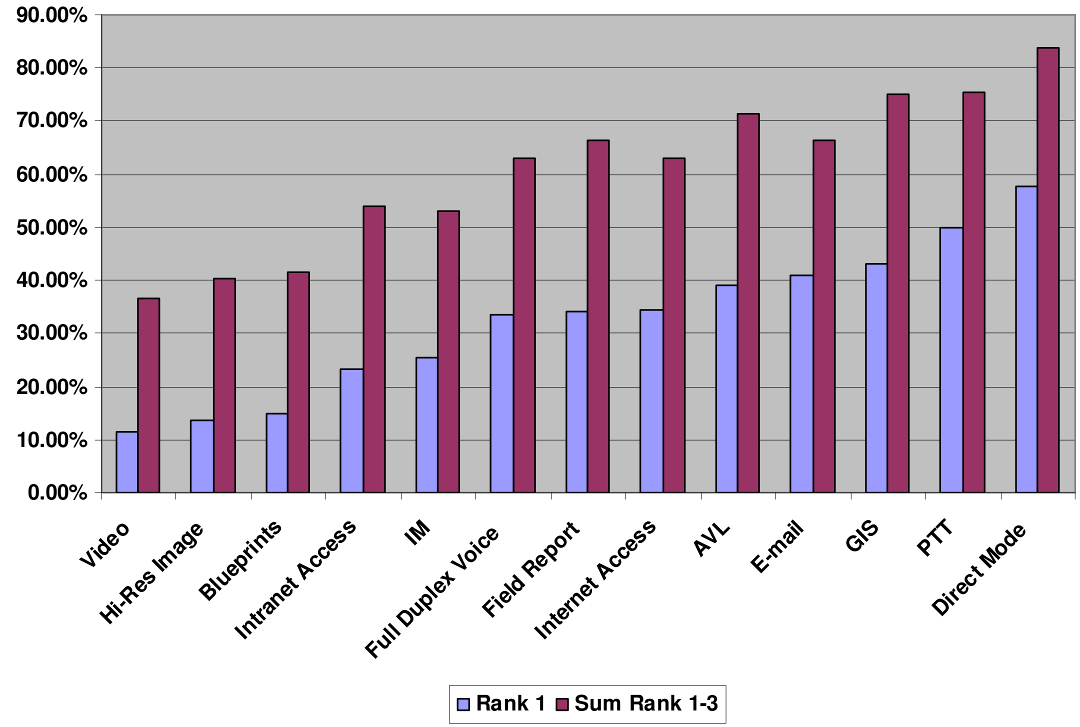
- Question asked:
  - 14. Does your agency prefer to own & operate their broadband network or would you consider outsourcing that to a commercial company?
  - 15. Would you consider sharing broadband infrastructure resources (to reduce costs) with other agencies and/or across districts if your quality of service, privacy and security could be maintained?
  - 16. Would state, local, and tribal public safety agencies in your area participate in building a regional 700 MHz broadband data network?



- 41% of respondents want to own the network; 40% did not have a preference
  - Of those that have a preference on network ownership/management two-thirds want to own the network
- 96% would consider sharing broadband infrastructure resources; 4% would not
- 68.2% say they don't know if their area public safety agencies would participate in building a regional 700 MHz broadband data network; 28.8% say their area agencies not participate; 3% say their area agencies would not participate
- Resource consolidation is key to public safety for 700MHz
- Need to be able to help facilitate the building of regional agreements and trust between multiple agencies and jurisdictions

Application Importance

- Application importance ranked 1 thru 8
  - 1 the most important
  - 8 the least important
- Top 5 applications as ranked by respondents as "Critical"
  - 57% Direct unit-to-unit communication
  - 50% PTT voice
  - 42% GIS
  - 41% Email
  - 39% AVL
- Summation of apps ranked 1 thru 3 shows that location based services extremely important
- Low ranking of video may also be due to lack of information on application usage
- Highest bandwidth applications were ranked the least important (video, imaging, blueprints)
  - May be due to fact that these applications are not available to the respondents, making it difficult to rank its use



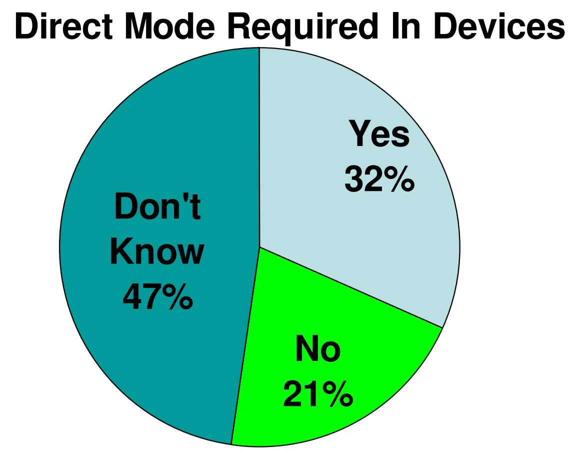
Direct Mode Need

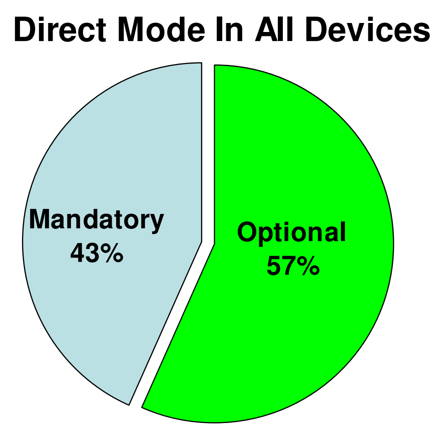
- Questions asked:
  - 18. Do you require the ability for data communication over the 700Mhz broadband system without infrastructure? (unit-to-unit)
  - 19. Should direct unit-to-unit data communication (in the absence of infrastructure) be a requirement for all wireless broadband user devices or optional?

- Definition: Unit-to-unit, peer-to-peer, direct mode all refer to allowing one device to communicate to another device directly without the use of infrastructure.

- Plurality do not know, if direct mode should be required

- Majority (57%) of respondents say that direct mode be optional in devices





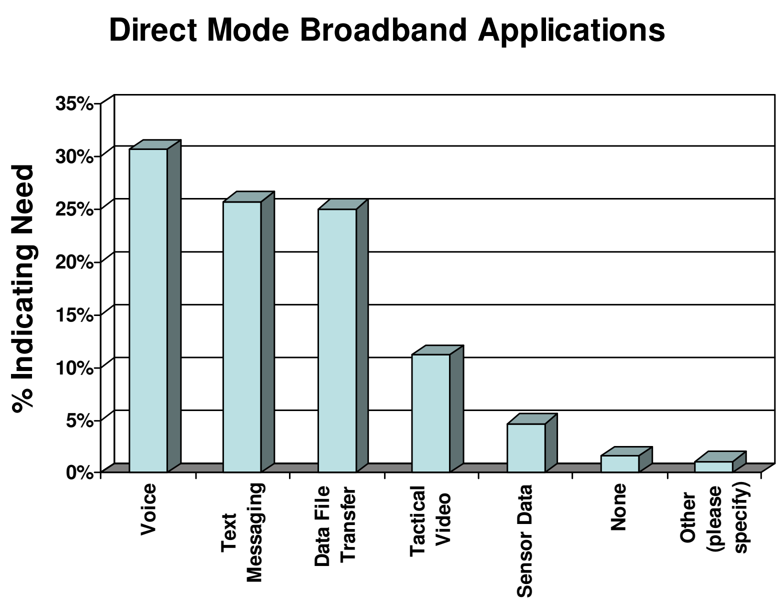
Direct Mode Apps & Cost

- Questions asked:
  - 20. What wireless broadband unit-to-unit data applications will you need to use (no infrastructure available)? (Check all that apply)

- Top 3 applications for direct mode
  - Voice 31%
  - Text Msg 26%
  - Data Xfer 25%

- Data file transfer and tactical video are the only applications that have a significant requirement for broadband.

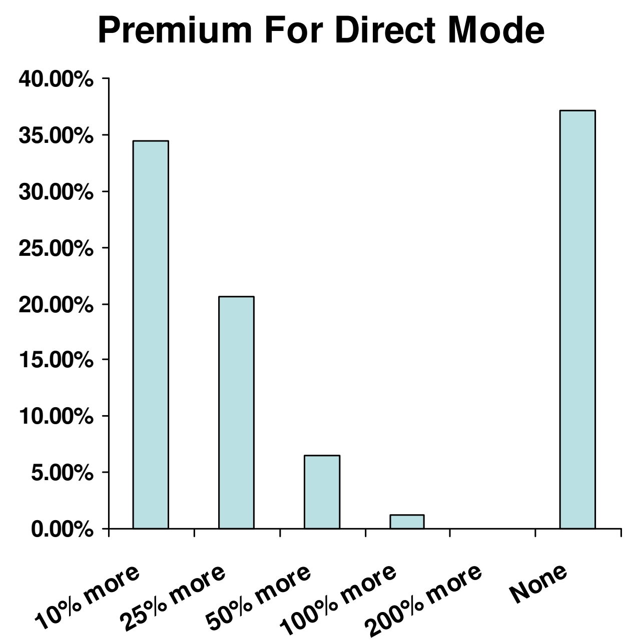
- Video was needed 1/3rd as much as voice



Direct Mode Apps & Cost (cont.)

- Question asked:
  - –21. What additional cost would you be willing to bear to be able to have unit-to-unit broadband data communication in your user device - when compared to a non-unit-to-unit device?

- ~63% of respondents willing to pay more for direct mode device
  - –Will allow for multiple cost tiers of devices
  - –Shows overall understanding that direct mode feature will cost more but manufacturers need to keep costs to a minimum

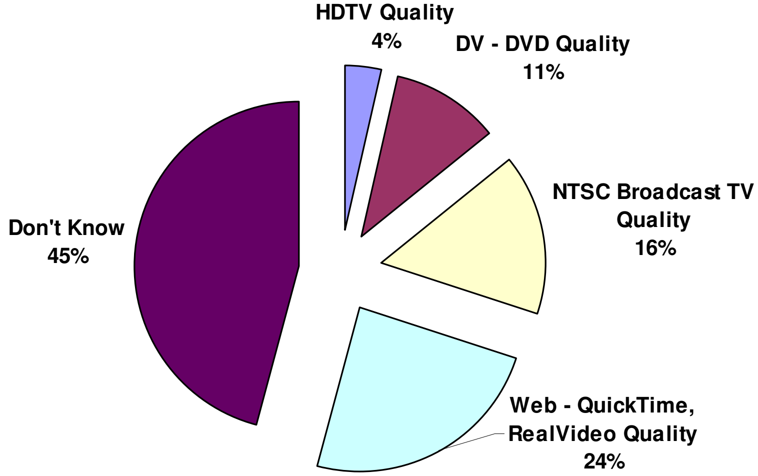


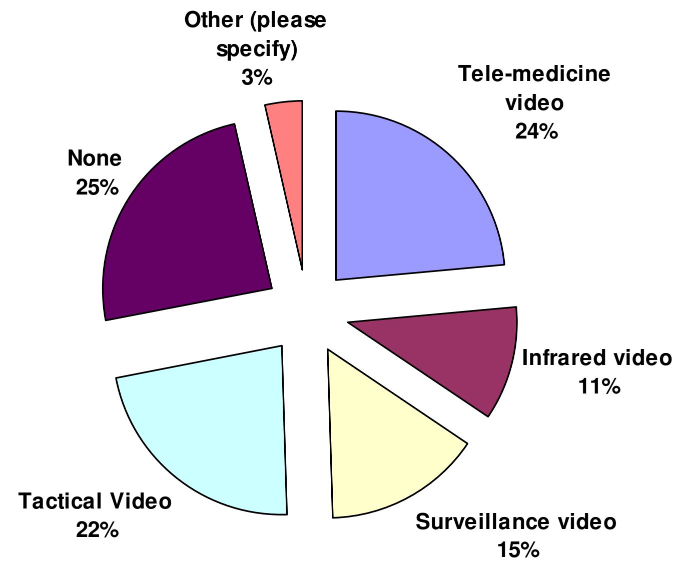
Video Quality & Need

- Questions asked:
  - 22. What wireless video quality would be the minimum acceptable for your typical video needs within your agency?
  - 23. Will you deploy any of the following video solutions on your 700 MHz Broadband network? (Check all that apply)

- 45% of respondents do not know what video quality they require
  - Plurality (24%) require "Web-based" quality

- Even distribution on video solutions
  - No video solution 25%
  - Tele-medicine 24%
  - Tactical 22%





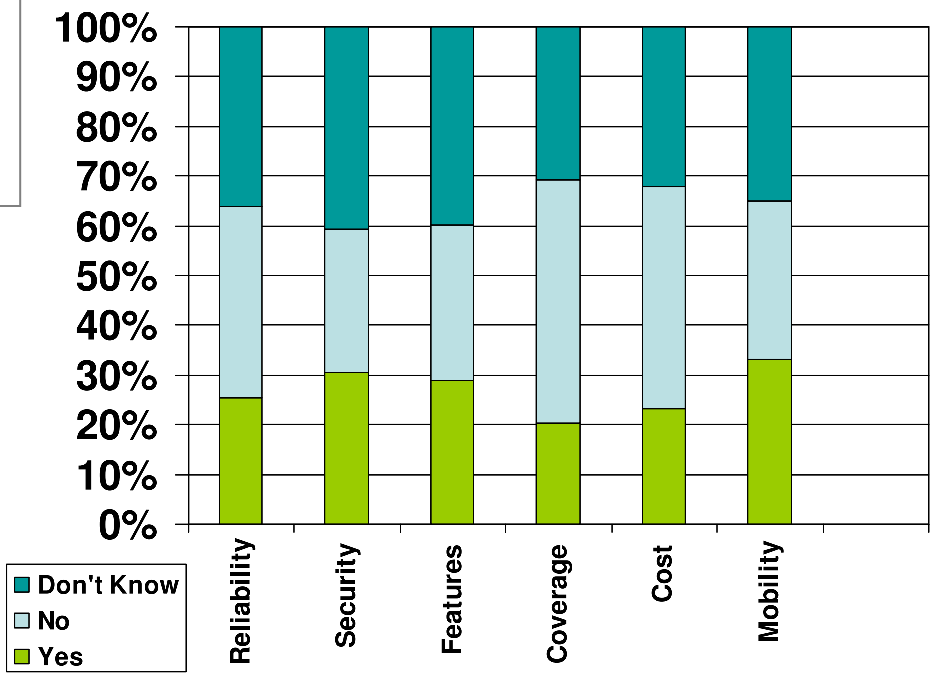
Commercial Services

- Question asked:
  - 24. Do current commercial wireless broadband solutions meet your agencies needs for:
    - Reliability
    - Security
    - Features
    - Coverage
    - Cost
    - Mobility

- Need a whitepaper to address the needs concerns listed above by respondents who “Don’t Know”

- Have this paper available to respondents via NPSTC

- Need something to overcome perceptions of broadband



Conclusions (1)

- The cost of broadband solutions including both the cost of systems deployment and services is a significant concern.
  - We need to focus equally on driving the down the cost of broadband systems and broadband service from a public safety built, PSBT, or existing commercial service provider.
- There is significant population of entities who want their own system — rule making efforts must deliver the choice to "lease" and "buy" service.
  - Standards will be critical to deliver interoperability between public safety and commercial networks.
  - Increased availability is important for commercial services.
- Due to the quantity of respondents wanting to deploy within four years and the importance of interoperability; FCC rulemaking to allow broadband must be concluded immediately, and we need to select a standard to ensure interoperability before too much time and money is spent planning non-interoperable solutions.
- The solution must deliver all forms of devices, including cell phones, PDAs, embedded modems, AVL modems, and remote sensors.

Conclusions (2)

- Direct mode: Data shows direct mode is necessary for broadband but is not mandatory in all devices
  - Peer-to-peer doesn't seem to be a deal-breaker for most
  - This is good given the lack of a broadband peer-to-peer solution on the horizon, suggests that although broadband does not allow for direct mode now (except Wi-Fi) you can deploy and add functionality later
  - The importance to many and the anticipated importance as data becomes more mission critical, will necessitate direct mode.
  - We will have very little headroom to provide direct mode (if a PC Card costs less than $300, a peer-to-peer device would have to cost less than $375).
  - The applications respondents seek from direct mode, do not necessarily require broadband — P25 data may suffice
  - If broadband direct mode is necessary, standards efforts must begin immediately to have a cost effective solution in five years. And, we must develop a standard that will not take a substantial portion of the spectrum to accommodate it (>25%)
  - This will allow deployments to happen now without the functionality and allow vendors to develop the technology to support direct mode
  - Not all devices need it embedded – reduces cost of devices and allows quicker time to market
  - Shows the need to define requirements for direct mode

Conclusions (3)

- No system specification document exists for manufacturers or public safety to reference and build broadband systems
  - This means that the concept of nationwide interoperability is just a concept and cannot be achieved
  - Without these specifications – we can expect large capital expenditures building disparate wireless networks across the nation
- Interoperability is key to managing the limited resources for public safety (spectrum & money)
  - Allows seamless roaming
  - Economies of scale leveraging commercial devices
- We need to publish a series of articles in *Spectrum* to illuminate these issues for public safety. The Broadband Working Group team is happy to spearhead this effort.

Thank You

ATTACHMENT 5

Scenarios and requirements

Data communications in emergency situations through Cognitive Radio

Colophon

Date :	14-July-2006
Version :	0.1
Change :	Updates due to Cross-layer and CCC.
Project reference:	AAF/D2.31
Freeband reference :	Freeband/AAF/D2.31
Company reference :	HGB2300-14702
URL :	N.A.
Access permissions :	Project
Status :	Draft
Editor :	Arjan te Marvelde
Company :	Thales Division Land and Joint Systems NL
Author(s) :	Arjan te Marvelde (TCNL), Frank Brouwer (WMC)
Reviewers:	Fokke Hoeksema (UT), Maurits de Graaf (TCNL)

Synopsis:

Scenarios and requirements for the project Adaptive Ad-hoc Freeband communications.

Abstract

This project: “Adaptive Ad-Hoc Freeband communications” researches key technical and legal aspects of communications in emergency situations through the use of cognitive radio. The project is part of the Freeband Communication programme, which aims at the generation of public knowledge in advanced telecommunication (technology and applications). This document contains user scenarios (serving as background for the requirements) and requirements for an emergency network and the networking nodes. These requirements will be used by the workpackages that define the architecture of a radio system, and design the networking and link layers of the project to guide their research.

Preface

The AAF project is part of the Freeband Communication programme, which aims at the generation of public knowledge in advanced telecommunication (technology and applications). Freeband is based on the vision of 4G networks and services. It specifically aims at establishing, maintaining and reinforcing the Dutch knowledge position at the international forefront of scientific and technological developments, addressing the most urgent needs for research and novel applications in the present unfolding of new technology. Freeband comprises more than 25 organisations, including all-important technology providers and many representative end-user organisations. The Dutch Ministry of Economic Affairs is co-funding this programme as part of the BSIK plan

The vision for Freeband for 2010 is to consider communication and information transfer from the perspective of the user, not the provider. The communication infrastructure will become transparent and abundant in all its layers. Freeband addresses the knowledge chain in communication in the direction of the new ubiquitous communication paradigm. Based on this vision key research questions take place in three main themes:

- **Society, Users and Applications:** what are the new possibilities in different sectors for ubiquitous communication and ambient intelligence, what do they presuppose as knowledge and how can they be realised?

- **Networking, Service Provisioning and Generic User Interaction:** the telecommunication infrastructure viewed from the user's perspective.

- **Enabling Technologies:** no new services emerge without adequate technology; conversely, it is the technology that drives the new paradigms!

Crisis situations require fast regain of control. Data communications can aid tremendously. Emergency systems (C2000) hardly support data communications. Cellular systems (GPRS) are not reliable enough in emergency situations. Data communications requires significant radio spectrum, which today is divided into small pieces. Regulatory bodies (FCC) recognise that new services require a new approach. Cognitive Radio is a paradigm shift in spectrum utilisation. This project: “Adaptive Ad-Hoc Freeband communications” (AAF) researches its key technical and legal aspects and realises a working solution.

This is deliverable D2.31 of the AAF project. This document provides user scenarios and requirements for Cognitive Radio – based ad-hoc networks for emergency situations. This is an update of deliverable D2.21. Further updates of this deliverable will be released later in the project.

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1 Introduction

The rapid advancements in portable computing platforms and wireless communication technology have led to a broad interest in the design of instantly deployable wireless networks. These so-called ‘ad-hoc networks’ are particularly suitable in situations where a fixed communication infrastructure, wireline or wireless, does not exist or malfunctions e.g. due to a disaster.

Important potential application areas of ad-hoc networking are emergency services, military (tactical communications), industry (distributed monitoring and control systems), research (distributed scientific experiments, sensor networks), road traffic (‘intelligent car’), etc.. Moreover, complementing the existing infrastructure based access networks (e.g., WLAN, UMTS) by providing extended coverage, wireless ad-hoc networks can be viewed as the next step towards the ultimate objective of ‘ubiquitous’ communications: enabling communications and access to information at any place, at any time and in any situation.

For example, wireless ad-hoc networks will enable emergency services to continuously overview and act upon the actual status of the situation by retrieving and exchanging detailed up-to-date situational awareness of the rescue workers. Deployment of high-bandwidth, robust, self-organising ad-hoc networks will enable quicker response to typical what/where/when questions, than the more vulnerable low-bandwidth communication networks currently in use.

This deliverable reflects the progress made by the project in the elicitation of technical requirements for a cognitive radio system for emergency communications. It provides an outline of the system architecture and high-level technology requirements.

The project started from the work carried out by a number of related projects that define the operational requirements for emergency networks. While these projects provide very detailed operational scenarios, it turned out, that the requirements they provide are on a level that is too high to serve as technical requirements for this project. In a number of meetings, these requirements were further refined. This has lead to this document. The “Radio System“ and the ”Networking and Link layer” - workpackages will use it as starting point for their research activities. This document will be updated and re-issued as required. The document is under configuration control and its issue number should be quoted whenever it is used as a reference.

This document is structured as follows:

Chapter 2 presents an overview of the sources that have been used for this work. There are a number of useful sources from international projects where, in close collaboration with users of emergency systems, requirements have been defined.

Chapter 3 presents the different user scenarios that should fall within the reach of a cognitive radio system that is targeted for ad-hoc emergency networks. While a few scenarios are presented in detail, also a higher level classification of the scenarios is offered.

Chapter 4 presents the services required in an emergency network.

Chapter 5 presents the requirements for a cognitive radio system for ad-hoc emergency networks.

Chapter 6 presents the conclusions of this work with regard to issues that should be addressed by other workpackages.

2 Sources

In order to define requirements, the project started from the work carried out by related projects where operational requirements for emergency networks were studied. There are compelling motivations for reusing the scenarios and requirements from other projects. First, and foremost, communications in emergency situations has recently gained much attention in the literature, especially since their needs for reliable communications and information provisioning is so evident. We believe that a sufficiently detailed starting point can be obtained from studying a selection of projects. As it turned out, the requirements from related projects are on a level that is too high to serve as technical requirements for this project directly. In the course of the project the requirements were therefore further refined.

In this chapter we briefly introduce the main sources for this document (besides the input from the project members). Note that this chapter is not meant to discuss all related projects, only the actual sources.

2.1 Public Safety Wireless Advisory Committee

Based on the experiences resulting from the co-ordination between the different services involved in a large incident the Public Safety Wireless Advisory Committee (PSWAC) was established. Due to the severity of the incident, several police agencies, fire rescue units, ambulances and helicopters were involved in the rescue, extrication and management of the disaster. It turned out that the radio systems used by different agencies could not communicate. In addition, radio frequencies available for public safety users were heavily congested. In their "Final Report of the PSWAC to the Federal Communications Commission" [3], they evaluated the wireless communication needs of federal, state and local Public Safety Agencies through 2010. The PSWAC final report defined and documented critical public safety wireless communication needs in 1996 and projected anticipated needs through the year 2010. The report focused on the requirements for communications resources and the radio frequency spectrum to support those requirements. Their main conclusions were that: (1) an additional 70 MHz of spectrum needs to be required in the period 1996-2010. (2) Interoperability needs to be improved and (3) more flexible licensing policies are desirable. Of specific interest to for this document is the report of the Operational Requirements Subcommittee, which presents the operational requirements for emergency services.

2.2 SAFECOM

In a sense, the work of the PSWAC was broadened and continued by the SAFECOM program. SAFECOM is an initiative of the department of homeland security. It is an umbrella program within the USA federal government to help public safety agencies improve their response through more effective and efficient interoperable wireless communications. Their "Statement of Requirements for Public Safety, Wireless Communications and Interoperability" [2], is a natural follow-on to the PSWAC final report, but differs in three ways. First, it is not keyed to the issue of spectrum allocation, but focused on public safety requirements from a broader perspective. Second (being 8 years later than the PSWAC) it takes more recent technology advancements into account. Third, it pays more explicit attention to the informational aspects of communications. The focus is more on data and video communications than in its predecessor.

2.3 Project MESA

Project MESA (Mobile Broadband for Emergency and Safety Applications) is a world-wide partnership project launched by ETSI (European Telecommunications Standards Institute) and TIA (Telecommunications Industry Association) at the end of 2000. Its purpose is to produce globally applicable technical specifications for digital mobile broadband technology, aimed at the sectors of public safety and disaster response. The first task that MESA carried out was to gather the functional requirements from representative players such a paramedics, firefighters rescue teams, police forces. This has lead to the “MESA statement of requirements” [1]. These requirements are an important source of information in understanding the difficult and dangerous working environments, which the public safety user community is facing. The IP Fire-fighter project has developed a prototype system using off the shelf equipment and techniques, for use of with modern fire-fighters, taking into account the MESA requirements [12].

2.4 WIDENS

The purpose of WIDENS (Wireless Deployable Network System) is to design, prototype and validate a rapidly deployable and scalable communication system for future public safety, emergency and disaster applications. The project focuses on designing a single hot spot which can be easily deployed, is optimised for high bitrate throughput and interoperable with existing core networks and private mobile radio systems. The system concept is based on ad-hoc network technologies, and the technological approach focuses on adaptations of existing technologies for the purposes of meeting the public safety requirements. Their “User requirements and First System Architecture Design” [5] presents a number of interesting starting points.

2.5 SPEARS

The SPEARS project (Scalable Personal Area Services) is aimed at the ad-hoc facilitation of the communication between and co-ordination of, emergency relief personnel, with a specific focus on a fire brigade, in disaster areas and under extreme conditions. The main goal of SPEARS has been to demonstrate just in time provisioning of data and scalable communication services running on a network, with high survivability, e.g. robust communication in disaster areas where the conventional communication infrastructure including cellular networks are out of commission. More specifically, the developed concept services are Status Telemetry Service, Video Messaging Service, Simple Voice/Data Messaging Service and whiteboard Service. The SPEARS deliverable on “Disaster management – scenario and use cases” has provided useful input with regard to the scenario.

2.6 EUROPCOM

The overall goal of the EUROPCOM (Emergency Ultrawideband RadioO for Positioning and COMmunications) project is to improve the safety and effectiveness of emergency service personnel operating inside buildings. More specifically aims are to improve situational awareness in emergencies, by measuring and reporting the location and status of emergency service personnel. To provide reliable communications in environments where conventional systems are infective or no longer operational. To locate survivors of an emergency in smoke-filled rooms or buried under rubble, and to map the inside of some-filled buildings, to assist navigation within the building. To achieve this the project aims to advance to a position where commercial development of such equipment, based upon Ultra Wide Band radio technology is possible. EUROPCOMs system requirements are documented in [6].

3 User scenarios

In order to obtain a common understanding of the background for the requirements, this chapter presents user scenarios. The sources referenced in the previous section provide many specific and detailed scenarios for emergency communications for the different disciplines (police, fire brigades, emergency medical services, etc). While such minute-by-minute descriptions provide a useful basis for understanding and developing a complete emergency system, they are too detailed for the purpose of this project, therefore we first discuss a scenario-classification in Section 3.1. Section 3.2 presents a generic scenario and Section 3.3 discusses a few exemplary scenarios in a greater level of detail. Section 3.4 then presents a number of observations that arose from studying various scenarios and that highlight the differences between emergency communication networks and other types of communication networks.

3.1 Characteristics of scenarios

The projects SAFECOM and MESA have provided valuable input in classifying and discussing the characteristics of user scenarios. They identify the following scenario characteristics: Operational Environment, Coverage area, Type of situation, Number of users and density, Mobility and the Use of sensors. Their scenario classification is presented in Table 3-1.

The assumption is that the devices that are specified and prototyped in this project will be able to work into different modes (e.g. ranging from “day-by-day” to “Humanitarian assistance” as in Table 3-1). In particular it will not be the case that a crew (being used to equipment in the day-by-day – mode, will have to work with completely new equipment in a disaster situation). It may however, very well be that the same equipment when working in emergency/disaster – mode has more functionality and other characteristics (e.g. more frequency bands) when compared to the day-by-day mode of operation.

3.1.1 Type of situation

The following types of situations can be distinguished:

- *Day by day operations. Typically, this is a single user (or a low number of users) communicating either directly with the remote control room or with the backbone private or public network. This is mainly covered with existing communication means (e.g. TETRA, UMTS, GSM) and the existing infrastructure, which is well-dimensioned for this purpose. When the density of the traffic or the number of communication partners in the incident area increases (as in the other types of operations), new equipment is needed. This is within the scope of the AAF project. Alternatives as satellite links or communication at low frequencies could be considered for communication with the remote control room.*

- *Emergency. In an emergency situation one has to deal with teams operating in a single hot spot area in an area of, say, 1 km^2. Connection to sensor installations in these areas may be required, but still the size of the emergency is small: operations are carried out mainly at the national level with a strong focus on a single discipline, and interconnection with non-emergency systems (e.g. military systems) is not required. An example is a house fire.*

- *Large-scale disaster. A large-scale disaster includes high traffic density at large areas with multiple hot-spots. As in an emergency, there are multiple groups of emergency workers and of emergency services of several disciplines. Co-operation with non-emergency services and with international emergency services is required. An example of this type of operations is the SE Fireworks disaster in Enschede.*

- *Humanitarian Assistance. Peacekeeping operations and humanitarian assistance have as characteristics: a large geographical area, high mobility of users, including aeronautical needs, and several distributed and moving hot-spots. The public infrastructure may have been destroyed. An example of this type of operations is the tsunami of December 2004.*

3.1.2 Operational environment

- *Indoor: Areas of hundreds of meters characterised by harsh signal propagation environments (multipath, Non-Line of Sight).*

- *Urban: Areas from hundreds of meters (districts) to up to 10 kilometres with signal propagation degraded by many existing obstacles.*

- *Rural: Areas more than 10 kilometres wide with signal propagation characteristics that are less critical than in the previous environments (fewer obstructions).*

3.1.3 Coverage area

The coverage area denotes the area of the incident situation (being a day-by-day situation, emergency, disaster or a humanitarian assistance operation).

- *Single hot spot: a bounded and easily identifiable specific coverage area*

- *Wide area: an extended coverage area covered by multiple hot-spots*

TABLE 3-1. CHARACTERISTICS OF SCENARIOS

	Day-by-day	Emergency	Disaster	Humanitarian Assistance
Operational environment	Indoor/urban/rural	Indoor/urban/rural	Indoor/urban/rural	Indoor/urban/rural
Coverage area	Single spot	Single spot	Wide Area	Wide Area
Number/density of users	Couple of units, ~2 –10 users	Several units, ~10-20 users	Dozens of units, ~100 users	Dozens of organisations, Hundreds of users
User groups	One or more, working mostly separately	Several Public Safety User groups co-operating	Several Public Safety User groups and civilian experts co-operating	Several Public Safety User groups, civilian experts and volunteers co-operating
User mobility	Fixed, pedestrian, vehicular	Pedestrian, vehicular	Pedestrian, Vehicular, Aeronautical	Pedestrian, Vehicular, Aeronautical
Use of sensors	Vital signals	Vital signals, environmental data, device telemetry	Vital signals, environmental data, device telemetry	Vital signals, environmental data, device telemetry

3.1.4 Number of users

- *Approximate amount and density of user terminals in the scenario.*

3.1.5 User groups

- *Several user groups cooperate during an emergency. When the complexity increases, also the size and the number of different cooperating user groups increases.*

3.1.6 User mobility

Mobility indicates the speed with which a communicating user is moving. The following mobility types are distinguished:

- *Fixed: 0 m/s*
- *Pedestrian: 0- 5m/s*
- *Vehicular: 1- 150 km/h*
- *Aeronautical: 200 Km/h and higher*

3.1.7 Use of sensors

Sensors (sources of information) and actuators (sinks of information) can be used in different ways. One possibility is that sensors are used to monitor the vital physical signals of the emergency workers involved. Another possibility is that existing sensors (e.g., in buildings or in industrial areas) to guide the emergency workers and to warn them for hazardous materials such as gas. Actuators could consist of equipment that is controlled from the emergency network.

3.2 Example Disaster scenario

Figure 3-1 presents an overall view of a disaster-type of scenario that fits in the scope of the project. In the figure, fire brigade units, as well as medical personnel and police forces, must fight a large fire in an effective way. During such an operation, the co-ordination between these emergency services requires flexible communication networks that optimally adjust to the geographical spread of the rescue personnel and their command-and-control structures, and to the widely varying requirements on transmission capacities and response times.

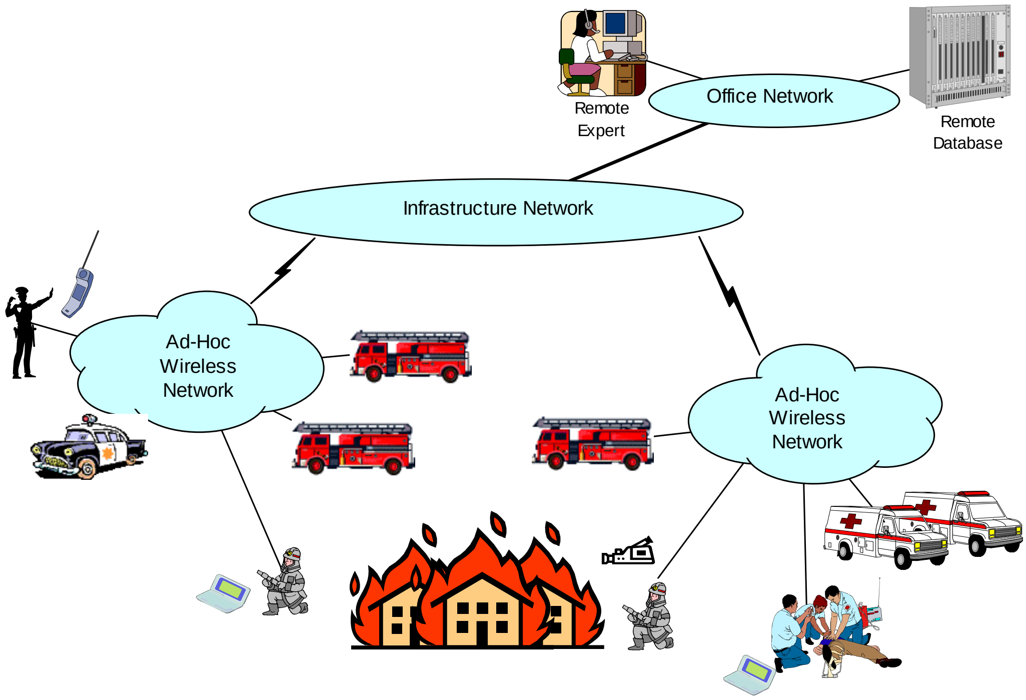

Figure 3-1. A disaster scenario

Various communication devices and wireless technologies are involved in this scenario:

- The first-aid personnel arriving at the fire will have a personal area network involving PDA's, camera's, sensors, actuators and instruments that communicate via short-range technologies, such as Bluetooth, UWB. Communication with ambulances may be realised via 802.11.

- The ambulances communicate with each other and are also communicating with other emergency services via the infrastructure network

- The firemen have access to the construction details and layout of the specific building via a remote database (accessible via the infrastructure network). In addition, they have on-line support from experts judging video images from robots and additional information about the actual status of the building (temperatures, tensions in the walls, etc.) obtained by communication with sensors placed throughout the building.

This scenario can be considered as typical for many disaster situations. All types of operational environments (urban, rural and indoor) play a role in this scenario. The urban environment is relevant for communication between vehicles at close distance near the fire. Rural communication takes place between the different hot-spots and indoor communications happens when fireman enter the building. The scenario will be dynamic in the sense that new teams will be arriving and fast expansion of the network will be required. All team members will be using sensors for the monitoring of their physical parameters and some additional capacity could be required so support video monitoring of injured people. All team members have access to geographical data (electronic maps) and could use access to the specialised databases relevant or their user group (e.g. for fingerprint matching). All teams and their members exchange voice communication between each other and command and control centre. Command centres could the in the area or at a remote location. All users and command centre could exchange short messages. A large number of real life situations such as fire, train or airplane crashes, large scale traffic accidents, industrial accidents or explosions would fit in this. The traffic is expected to be uplink dominant, meaning that substantial part of the traffic will be related to the two way communications between users and command and control centre.

3.3 Scenario descriptions

To give some more feeling of the dynamics of the different situations we present a concise version of the Terrorist Car Bomb scenario from SAFECOM (Appendix C.5). and two scenarios from SPEARS.

3.3.1 Terrorist car bomb (extended summary)

An explosion rocks the downtown area of the centre of the city, just as rush hour is beginning. The explosions destroys several cars in the immediate vicinity, blows out the glass doors of a bank building and starts fires. Numerous calls are received by the Public Safety Answering Point (1-1-2). Location information accompanying the calls allows to quickly identify the area affected. Police fire and Emergency Medical Services are dispatched to the scene. Within minutes, the first law enforcement personnel arrive on the scene. The assistant Chief of Police assumes the Incident Command for the initial response. The IC observes the scene and identifies the possibility that the explosion was caused by a car bomb. The IC immediately requests dispatch of an Explosive Ordnance Disposal (EOD) team. The police arriving on the scene establish an outer and inner perimeter and clear the area of non-first-responder individuals and witnesses. A roster of officers on the scene is quickly compiled by querying their communication equipment for GPS coordinates. The police helicopter with its stabilized platform video camera is also requested. Shortly thereafter, the first ambulances and fire trucks arrive at the outer perimeter. The first medical officer assumes the role of medical scene commander. The police clears a corridor to allow the arriving EOD team to conduct a Chemical, Biological, Radiological and Explosive sweep of the area. While this is underway, video from a camera mounted on one of the police cars that is responding to the explosion is transmitted to the dispatch centre and to the fire battalion chief who is being driven to the scene. When the Fire Battalion Chief arrives, a Unified Command structure is established. The medical scene commander requests the EMS dispatch to initiate a mass casualty alert to all hospitals in the area. The medical scene commander selects triage/treatment, transport and logistics areas and identifies them on a map display. This location information is transmitted to the computing devices in other emergency medical vehicles. As responders are dispatched and/or arrive on the scene, their communication devices provide identifying information and geographic location. Authentication of personnel from outside agencies is processed through a national database.

EOD completes the sweep, and concludes that the device was a conventional explosive. The EOD personnel do not observe anything that would indicated a secondary device. The EOD unit commander communicates the status to the safety officer, who informs the IC that responders may enter the inner perimeter. The IC broadcasts that responders may enter the inner perimeter. Fire units begin attacking the fires. The battalion chief reviews the building plans and develops the approach for moving people out of the building. The fire-fighters deploy a series of short range high bandwidth devices in an ad-hoc network to transmit fire-fighter vital signs and video from helmet mounted cameras back tot the fire command.

EMS triage officers begin tagging bodies with transmitter tags. These tags have unique identifiers that include the color coding, and an embedded GPS receiver. A timestamped location of these victims is periodically transmitted. The patient tag information is coupled to names, address etc. The transportation officer assigns patient transports based on hospital capacities and patient criteria. Police begins interviewing witnesses that have been moved in a witness area. Investigation begins. The investigators download stored video from the bank's surveillance camera's. The conclusion is reached that the explosion was caused by a car bomb. Surveillance video identifies the last three characters of the licence plate. A wild-card query of that license plate with model information on the car is then run against local and state registration and stolen vehicle databases. A matching vehicle is reported stolen. The Emergency Operation Centre (EOC) becomes active, providing coordination of resources and an interface to public and private organisations. The Public Works Street Maintenance Division is contacted to change traffic signals to steer traffic away from the area of the explosion and the key routes to the hospitals. Ambulances begin transporting patients to hospitals. The Transportation Officer notifies hospitals as ambulances depart for the hospitals; ambulance and patient status is updated. State troopers are assigned to secure other areas in the city. The police helicopter video system is linked to the Command Post and the EOC and a general sweep of the area is initiated, allowing Command staff to get an overall view of the incident scene. Additional laws enforcement support arrives and take over perimeter control, and police begin to evacuate other buildings in the area. As its size becomes too large, the perimeter control user group is divided into east perimeter control and west perimeter control user group. Police and firefighters assist people evacuating buildings. Investigations conclude with high probability that bomb was planted by terrorist group and identify suspects. A photograph of a vehicle and a suspect individual is broadcast to all law enforcement agencies in the region, and to handheld computing devices being carried by officers and agents working around the incident scene.

Ambulances complete transport of victims to hospitals. A police officer patrolling the airport identifies the broadcasted vehicle and notifies airport security. A user group is set up between the police department and airport security. The airport management is notified and the airport closed down. Police and FBI agents arriving on the scene are added to the user group. After a 20-minute search, the suspect is located and immediately taken into custody. An electronic case file is prepared and warrants are requested from the judge. Building evacuations are completed. Police officers from outside agencies are released. Evidence technicians begin collecting evidence at the site. Fire in the 1st National Bank building is extinguished, fire trucks return to station. Law enforcement command is moved to vacant storefront office and investigators begin to locate all bomb-related debris. The inner perimeter is expanded to include all of this debris.

3.3.2 Indoor firemen scenario: hazardous materials

A team of two firemen is searching for victims in a burning building. On their way through the building they find some barrels containing an unknown chemical fluid. All barrels have a 4-digit code on them. Since they are not sure whether they represent danger or not, they decide to take a picture and send it to their commanding officer and to ask for his advice. The commanding officer receives the picture(s) and can make a decision on how to deal with the barrels. He can consult an expert, e.g. by forwarding them to his Hazardous Materials officer. In this way his 'plan of attack' can be modified to take into account new circumstances.

3.3.3 On the road: fireman scenario

Imagine the situation where the fire brigade has much of the static data, e.g. roads, infrastructure, risk areas and attack plans, available in electronic form through some GIS system. This information is made available to the individual fire truck on its way to or present at the incident through its communication device, allowing the driver of the truck to get to the site of the incident at the shortest possible time or following the shortest possible route. At the site of the incident, both the entrance to the burning building and the locations of the water access points are clearly marked on the map, allowing him to park the fire truck at the optimal location and thus enabling a rapid deployment of the actual fire fighting action. As the first scouts enter the building in search for possible victims, their communication terminal can be used to display the floor plan. The scouts can use this to both trace their route through the building (very useful when they need to get out fast the same way) and to mark the rooms they have checked for victims.

3.3.4 Hotel fire (EUROPCOM)

The following scenario was taken from the Europcom project [6].

Incident description

- *Building type – 5 floors, each 100 x 75 metres*
- *Time – 02:30 hours*
- *Situation on arrival – Fire in kitchens on ground floor which ahs spread through the ducting to break out at roof level an possible also on the floors between ground floor and roof level. Due to the time of the incident, most residents are in their hotel rooms asleep.*

Response and evolution of events

- *Initial attendance – 3 pumping appliances and an aerial appliance.*
- *Attendance after requesting assistance – 15 pumping appliances and 2 aerial appliances.*
- *Plan of action – All floors, rooms and common areas to e searched and rescues made if necessary, fire to be located, contained and extinghuished.*
- *Priorities – Contain the fire situatioj and start searching the areas nearest to the fire as this is likely to be the area of greatest danger to the periosn in the buriling. Reequest further resrouces to deal with the incident.*

Initial stages of Incident

- *Immediately, breading apparatus (BA) crews would be committed to the incident to research the building room by room and all other areas starting in areas of greatest danger. BA crews would also be committed with a means to fight the fire in the kitchen area and the roof. The initial attendance would only allow three crews of 2 fire-fighters each. As more resources arrive, more crews can be committed.*
- *As the rooms and areas are searched and declared empty they would be recorded to save the same areas being searched twice. Later, there would be need to commit crews to all floors to ascertain if the fire had broken aout in any other areas.*
- *Relief crews for the initial crews committed would also have to be deployed.*

Intermediate stages of Incident

- *By now there should be a maximum BA crews committed and if necessary there would be crews on all of the five floors and in the roof space. The crews are likely to be located throughout the building due to the work being progressed and the change over fresh crews with those who need to withdraw due to being low on air after typically 20 minutes.*

Later Stages of Incident

- *For this scenario it is now deemed that the fires have been contained and that the hotel has accounted for all the persons in the building at the time of the fire. As such the fire fighting will be contained to cutting away and damping down and limited crews would be located in the building, probably on all floors to ensure the fire has been extinguished.*

Comments regarding the above scenario

- *The actions only refer to inside of the buildings and not the work being progressed outside such as water supplies, fire fighting (possible ladders to the roof area) command structure, press and support facilities for the crews within the building.*
- *Depending on the access points for the hotel it is likely that more than one point of entry will be used by the fire service and the incident ground would have been split in sectors to ensure all sides of the building are covered.*

3.4 Observations from the scenarios

The following observations were made while studying the different scenarios in literature.

- *Networks are created on ad-hoc basis. They are built up and dismantled over time. There will be one or more ad-hoc networks. Some or all of them will be connected to a fixed network infrastructure.*

- *Voice is pre-dominant. Data communication can be seen as an important supplementary service, especially in the higher levels of the hierarchy. While in action, first responders will have little time to look on displays. Therefore priority must be given to voice.*

- *Real time GIS (Geographical Information System) information is very helpful in creating a common operational picture and has applications ranging from the localisation and monitoring of victims to identification of blocked paths in a building. This also involves editing and transmission of a received image in order to denote changes in the situation.*

- *Video / Still picture: In contrast to voice, or the relatively small amount of bandwidth needed for GIS information, video and still picture seem to be applications that consume the most bandwidth. Especially for video that is to be used for medical purposes the quality should be high.*

- *Information recording must be possible. For later evaluation purposes, it must be possible to record the information that is exchanged during the emergency.*

- *Information authentication must be possible. It must be possible to ensure that the person giving information is a trusted source.*

- *Group communication (multipoint-to-multipoint) is essential. Group communication applies to simultaneous communication of voice, video and data messages to all members of a user group. The creation of user groups that may consist of people in various disciplines is an essential element in emergency communications. A specific group is group consisting of everyone in certain area (say 100m away from some coordinate). This 'geo-casting' could be used when for example hazardous materials are detected.*

- *Robust communication. Communication should be robust in various aspects: connections must not be broken due the movement of nodes that are part of the network, communication must be possible in difficult propagation conditions (multipath, non-line of sight), it must not be possible for an external user to jam communications.*

- *Device & physiological measurements are part of the data. They consist, like GPS of regular updates on heartbeat, blood pressure, amount of oxygen in the tank.*

- *Access to existing databases must be possible. Examples of this are medical records of patients, Licence plates of vehicles and fingerprint databases.*

- *Availability of communication medium - The communication medium should be continuously available and should provide sufficient service quality (limited delay and no loss of critical information) and coverage, i.e. the applied terminals must be reachable. The communication protocol should be energy-efficient and/or the terminal batteries should hold sufficient energy. The communication link must operate properly in high-noise environments.*

- *Information availability - The required information is typically retrieved from diverse sources yet should be appropriately integrated to be used effectively.*

- *Timeliness and up-to-date-ness of information - All relevant information must arrive on time (in real-time where applicable) at the destination. When a connection to the infrastructure network exists, database information must be kept up to date (consistent) with database information available in the backbone.*

- *Appropriate information filtering - Different degrees of information should be available at different command levels. In particular, the rescue workers should obtain only the absolutely most relevant information and should not be bothered with inappropriate details.*

- *Accuracy of information - The required information must be provided as accurately as possible, particularly for critical information. It is noted that the required degree of accuracy may dictate the most appropriate form of communication, e.g. via speech, video, picture or data.*

- *Security - Terminal and communication infrastructure should be affordable and secure.*

- *Connection properties – Connection setup times should be sort (< 1s). The duration of conversation between group members varies between 1 and 5 minutes.*

4 Services

As a background for the requirements, we present a concise description of the services that are needed in the emergency situation from the perspective of this project.

In [1] various existing and new services for a public safety communication system are defined. These are divided into three groups:

(1) General services with available standards. These include ie.g. real time-video, mail, picture, telephony, mutlimedia conferencing, location of vehicies and security services.

(2) Dedicated services include e.g. diverse database accesses, control of robots and senors on dedicated equipment.

(3) General services without available standards include e.g. location of equipment and people, body sensors, sensors of general interest (environmental factors), video camera remote control, identification of nodes in the network and resource-management services.

4.1 Service descriptions

The following services need to be supported by the network:

Conversational voice. Voice calls are used between emergency workers, to receive instructions from the dispatcher, to co-ordinate with the incident commander and co-ordinate efforts with local and neighbouring departments.

Short text/status messages/sensor information. Short text and status messages containing geographic information are relevant to know the whereabouts of every emergency worker and equipment. This information may be used on management level but also by co-workers to create a common operational picture. Health status messages can be used to monitor the health and condition of each emergency worker and to have the ability to remove an emergency worker from a life threatening situation. The data includes biometrics such as heart rate, temperature, respiratory rate, blood pressure and equipment status (e.g. remaining supply of oxygen tank). Short text messages includes information on contents, uses, ownership of buildings, medical records of patients.

Database access. Will be used by the emergency workers to get access to central databases in the infrastructure network, e.g. to identify a driver based on its license plate number, to match fingerprints and to get access to medical records.

Remote control. The network should also support the remote control of robots and other devices (like video cameras, or actuators) in the network. Robots may be used (under the control of an emergency worker or the commanding officer) to move into dangerous areas.

Real-time video. Real time video images (ground based and aerial) give a picture of the actual situation at the scene of an emergency. This is useful for immediate tactical emergency responses, to coordinate rescue efforts and to help distant medical personnel evaluate patient condition and treatment. These video pictures can also include non-visual imaging to warn of spreading fire, chemical hazards, etc. This includes infrared video (that can be used to identify hot-spots in a building).

Streaming video. Streaming video images give a picture of the past situation in an emergency. 'Streaming' video means that: either the video is completely recorded and with some delay transmitted, or the recording of the video is started and video is transmitted until the recording stops. Streaming video is useful to get a general impression of the area that need not to be real-time.

Multimedia conferencing. Used as an add-on to audio conferencing within a user group.

Report service. Used to electronically compile and submit reports of a disaster.

E-mail and web-browsing. Useful for information exchange in higher levels of the hierarchy.

Still pictures: Pictures of the scene are useful for tactical emergency decisions; pictures of victims can be used to help doctors at distant sites recommend best medical response to injuries. Still pictures contain maps and drawing of buildings, roads, utilities, hazardous locations as well as current pictures of the fire scene.

4.2 Service categories

These services can be categorised in the following categories. This section is based on an extract of the Quality of Service concept and architecture document of the 3rd generation Partnership Project [9]:

- *conversational class;*
- *streaming class;*
- *interactive class; and*
- *background class.*

The main distinguishing factor between these QoS classes is how delay sensitive the traffic is: Conversational class is meant for traffic which is very delay sensitive while Background class is the most delay insensitive traffic class.

Conversational and Streaming classes are mainly intended to be used to carry real-time traffic flows. The main divider between them is how delay sensitive the traffic is. Conversational real-time services, like video telephony, are the most delay sensitive applications and those data streams should be carried in Conversational class.

Interactive class and Background are mainly meant to be used by traditional Internet applications like WWW, Email, Telnet, FTP and News. Due to looser delay requirements, compare to conversational and streaming classes, both provide better error rate by means of channel coding and retransmission. The main difference between Interactive and Background class is that Interactive class is mainly used by interactive applications, e.g. interactive Email or interactive Web browsing, while Background class is meant for background traffic, e.g. background download of Emails or background file downloading. Responsiveness of the interactive applications is ensured by separating interactive and background applications. Traffic in the Interactive class has higher priority in scheduling than Background class traffic, so background applications use transmission resources only when interactive applications do not need them. This is very important in wireless environment where the bandwidth is low compared to fixed networks.

4.2.1 Conversational class

The most well known use of this scheme is telephony speech. Another example is video conferencing. Real time conversation is always performed between peers (or groups) of live (human) end-users. This is the only scheme where the required characteristics are strictly given by human perception.

Real time conversation scheme is characterised by that the transfer time shall be low because of the conversational nature of the scheme and at the same time that the time relation (variation) between information entities of the stream shall be preserved in the same way as for real time streams. The maximum transfer delay is given by the human perception of video and audio conversation. Therefore the limit for acceptable transfer delay is very strict, as failure to provide low enough transfer delay will result in unacceptable lack of quality. The transfer delay requirement is therefore both significantly lower and more stringent than the round trip delay of the interactive traffic case.

Real time conversation - fundamental characteristics for QoS:

- *preserve time relation (variation) between information entities of the stream;*

- *conversational pattern (stringent and low delay).*

4.2.2 Streaming class

When the user is looking at (listening to) real time video (audio) the scheme of real time streams applies. The real time data flow is always aiming at a live (human) destination. It is a one way transport.

This scheme raises a number of new requirements in both telecommunication and data communication systems. It is characterised by that the time relations (variation) between information entities (i.e. samples, packets) within a flow shall be preserved, although it does not have any requirements on low transfer delay.

The delay variation of the end-to-end flow shall be limited, to preserve the time relation (variation) between information entities of the stream. But as the stream normally is time aligned at the receiving end (in the user equipment), the highest acceptable delay variation over the transmission media is given by the capability of the time alignment function of the application. Acceptable delay variation is thus much greater than the delay variation given by the limits of human perception.

Real time streams - fundamental characteristics for QoS:

- *preserve time relation (variation) between information entities of the stream.*

4.2.3 Interactive class

When the end-user, that is either a machine or a human, is on-line requesting data from remote equipment (e.g. a server), this scheme applies. Examples of human interaction with the remote equipment are: web browsing, data base retrieval, server access. Examples of machines interaction with remote equipment are: polling for measurement records and automatic data base enquiries (tele-machines).

Interactive traffic is the other classical data communication scheme that on an overall level is characterised by the request response pattern of the end-user. At the message destination there is an entity expecting the message (response) within a certain time. Round trip delay time is therefore one of the key attributes. Another characteristic is that the content of the packets shall be transparently transferred (with low bit error rate).

Interactive traffic - fundamental characteristics for QoS:

- *request response pattern;*
- *preserve payload content.*

4.2.4 Background class

When the end-user, that typically is a computer, sends and receives data-files in the background, this scheme applies. Examples are background delivery of E-mails, SMS, download of databases and reception of measurement records.

Background traffic is one of the classical data communication schemes that on an overall level is characterised by that the destination is not expecting the data within a certain time. The scheme is thus more or less delivery time insensitive. Another characteristic is that the content of the packets shall be transparently transferred (with low bit error rate).

Background traffic - fundamental characteristics for QoS:

- *the destination is not expecting the data within a certain time;*
- *preserve payload content.*

TABLE 1: UMTS QOS CLASSES

Traffic class	**Conversational class**	**Streaming class**	**Interactive class**	**Background**
Fundamental characteristics	Preserve time relation (variation)between information entities of the stream Conversational pattern (stringent and low delay)	Preserve time relation (variation) between information entities of the stream	Request response pattern Preserve payload content	Destination is not expecting the data within a certain time Preserve payload content
Example of the application	Voice	Streaming video	Web browsing	Background download of emails

TABLE 4-1. COMMUNICATION SERVICES IN AN EMERGENCY NETWORK

	Symmetry constraints	Data Rate	End-to-end one-way delay	Type of Service
Conversational voice	Two-way (dialled) Multipoint-to-multipoint	4-25 Kbps	<150 ms preferred; < 400 ms limit	Real-time
Short text messages, status messages (health status, position updates,	Two-way Multipoint-to-multipoint	9600 bps	< 4s	Interactive
Database inquiry, file exchange	Primarily one-way Point-to-Point	Uses maximum rate available/allowed	< 10 s	Streaming
Telemetry[1], robotics and video camera remote control	Two-way Point-to-point	< 28.8 Kbps	< 250ms	Real-time
Real-time video	One-way Point-to-multipoint	100 kbit/s – 2Mbit/s[2]	< 500 ms	Real-time
Streaming Video	Point-to-multipoint	5 Kbit/s – 1 Mbit/s	< 10 s	Streaming
Multimedia conferencing	Two-way (dialled) Multipoint-to-multipoint	20 Kbit/s – 1Mbit/s	<150 ms preferred; < 400 ms limit; Lip synch < 100 ms	Real-time
Report service	Primarily one-way Point-to-point		< 4s	Streaming, interactive

1 **Telemetry examples are breathing apparatus, pulse monitors. Telemetry from environmental monitors include smoke, toxic gasses, temperature.**

2 With MPEG4 a datarate of 1 Mb/s will deliver a good quality.

E-mail	Two-way Point-to-multipoint		< 4s	Interactive
Web browsing	Primarily one-way Point-to-point		< 4s / page	Interactive
Still pictures	Two-way Point-to-multipoint	400 kbit/s (size: 250 Kbyte, delay 5s)	<5s	Interactive

Table 4-1 gives an overview of the different services that an emergency network should be able to provide offer together with requirements on throughput and delay as experienced by the user. Note that error requirements (for example requirements on the residual block error rate) are not explicitly mentioned in this table, as it is assumed that parameters of existing systems (e.g. Hiperlan2) are sufficient to cover the error requirements.

5 Requirements

This chapter presents the requirements for an emergency network and the networking nodes. For an introduction and definition of the terms used in this section (like access devices, networking devices, personal nodes, vehicle nodes Incident Area Network, gateway, Jurisdiction Area Network, communication user group we refer to the architecture document of this project [11]. To be more specific, in this chapter we focus on requirements for the Incident Area Network (IAN), that are below the application layer in the IP protocol stack. In order to be useful much more details are provided than in [1] and [2].

Examples of requirements that are not considered here are:

- *User interface requirements (these will be realisable to users' requirements, and will not be feasibility issue. Fore example how the display looks, how trustworthiness of a (2D or 3D)- position is indicated and status and alarm conditions are not taken into account here.*

- *Type of alarms user panic, temperature, pulse rate, battery status, tracks (history), other equipment status, eternal temperature, all user generated voice/data traffic*

- *Equipment specific requirements (for example ergonomic, environmental or built-in test requirements);*

- *Application requirements (like details on information recording, detailed functioning of applications such as input or modification of maps, addition of nodes and markers to maps or to users, measurement of distances on maps.*

Some of these requirements are considered in related projects such as EUROPCOM [6] and have been considered in SPEARS [4] and the IP Firefighter project.

Section 5.1 presents requirements on the System. Here "the System" is defined to be the IAN considered as a single entity whose networking facilities are thought to be realised by the AAF project. Section 5.2 presents the requirements of a single node, as proposed by the AAF project in the IAN.

5.1 System requirements

5.1.1 Overall mission definition

Req 1: The System shall be suitable for deployment at major emergencies, using vehicle-mounted antenna masts and small mobile units carried or worn by users, supporting the services of Table 4-1 between any pair of end-users connected to the System. See [6].

5.1.2 Coexistence with existing communication systems

Req 2: The System shall coexist with the communications systems of emergency services organisations and other public systems. These are expected to be PMR VHF, UHF, UMTS, TETRA. The end user shall have the communication services provided by other radios transparently extended by the System. (Based on [6]).

5.1.3 No single point of failure

Req 3: The System architecture will be such that within a network there are no network elements whose failure will impact large parts of the network (in particular, there will no single points of failure).

Discussion: While single points of failure in a network cannot always be avoided (e.g. due to distances, momentary network topology, etc.), a clear requirement is that there should be no ‘intrinsic’ single point of failure in the design of the system. For example, the communication system should not rely on single servers. This means that forms of distribution have to be found for authentication, DHCP, DNS (as there cannot be a single server for these services). An example mechanism that could be used instead of DHCP is the IPv6 auto-addressing facility. It also impacts mobility, since the standard mobile IP solution with a home agent forwarding packets to the moving destination contains the home agent as single point of failure. Another impact is that there should be a decentralised Spectral Resource Manager to which spectral measurements are sent and which calculates and distributes a map of usable spectrum to the relevant nodes.

5.1.4 Availability

Req 4: Average availability of the System to the user over time and over the coverage space shall be close to 100%.

Discussion: Note the difficulty of defining an availability requirement, as blank spots may be present in any network, due to the environment in which the network operates. Loss of overall availability due to equipment failures or power cuts shall be less than 1 hour per year (assuming continuous use).

5.1.5 Configuration of user groups

Req 5: The System shall support the configuration of user groups. These can either be pre-defined (e.g. by a system administrator before the operations) but these can also be defined on an ad-hoc basis by authorised users.

5.1.6 User group membership

Req 6: User group membership can include users from different agencies, jurisdictions, services and networks. This includes networks external to the Incident Area network (e.g. the PSTN network).

5.1.7 Size of user groups

Req 7: The System shall support user groups consisting of at least 100 users.

5.1.8 Efficient multicast

Req 8: When a user group consist of more than two users, the system shall provide a form of efficient multicast, in the sense that data shall not be duplicated unnecessarily.

5.1.9 Quality of Service

Req 9: The quality of service realised by the System shall be so the network can support all services mentioned in Table 4-1, with the indicated delay requirements, even when the load on the network exceeds 50%.

Discussion. In view of the fact that the emergency network consists of trusted and well-behaving users and nodes (see Section 5.1.15 Security) it could be sufficient to introduce priorities (instead of having a connection admission control scheme). Up to 8 priority levels seem to be standard in [10]. Even when priorities are the basis there are different schemes for dealing with priorities (e.g. strict priority [higher priority always gets the resource] or weighted mechanisms [higher priority has larger probability of getting the resource]). To support this the network layer must support QoS routing.

5.1.10Priorities of traffic

Req 10: When a solution with priorities is chosen, routing traffic gets the highest priority (1). This is followed by Delay sensitive traffic (priorities 2,3), then controlled load traffic (priorities 4,5,6,7). Last in line is the best effort traffic (8).

5.1.11 Configuration of priorities

Req 11: The System must support configuration of data-priorities based on user and on application.

Discussion. Priorities for users may be needed in order to give commanders/specialists the possibility to user their applications and get their information through in critical situations.

5.1.12 Pre-emption

Req 12: Pre-emption based on user pre-emption priority shall be supported

Discussion. While data priorities will ensure that packets with higher priorities will experience less delay and less loss than packets with lower priorities. With pre-emption, a call with high pre-emption priority can override calls through gateways or to end users meaning that the calls of lower priority are completely disconnected.

5.1.13 Automatic detection of failures

Req 13: The network shall automatically detect disruptions of communication paths (due to link failures, node failures or moving nodes). If the network topology is such that alternative communication paths exist to maintain existing user groups, reconfiguration of paths shall take place in 'real time' (with a target value of 50 ms).

Discussion. Note that standard IP routing protocols also provide for automatic reconfiguration. Their reconfiguration time is however in the range of 10 seconds, which will disrupt TCP connections for example. While this could be acceptable for planned mobility, such reconfiguration times are not well-suited for an emergency network where the users that are in communication are not even aware of the fact that their communication uses a third node which is moving away. This requirement imposes a challenge on the routing algorithms, especially for multicast routing, where a balance needs to be found between the amount of control traffic and the performance of a solution. To meet this requirement tight interaction between the networking layer and the MAC and physical layer is needed. A potential solution could also be multipath routing where automatically multiple disjoint paths between source and destination are set up.

5.1.14 Rapidly varying link qualities

Req 14: Communication shall be maintained in the presence of rapidly varying link qualities.

Discussion. Routing algorithms and also higher layer transport protocols must be able to deal with links that are rapidly varying in quality (on – off behaviour). This means that there should be some built-in hysteresis in the mechanisms.

5.1.15 Security - general

Req 15: The system shall provide the following security services to both users and nodes: (1) access control (operators shall have the means to supply or deny the service to individual users or user equipment); (2) authentication (assurance that the other users of the user group are the ones that they claim to be); (3) data confidentiality (protection form unauthorised disclosure); (4) data integrity (assurance that the data received is equal as the data that was sent without modification, insertion, deletion or replay); (5) non-repudiation (denial of participation in the communication); and (6) audit ability (possibility to store security related data for later analysis).

Discussion. Not all of these services need to be supported in the ad-hoc network. Some security services like (1) access control or (2) authentication may be done in the home location of the emergency workers before they will go to the emergency. Europcom proposes the following: “The system shall be able to authorise new users at a rate of at least 1/ second” [6].

5.1.16 Security – end to end

Req 16: An Emergency Services organisation connecting to the System shall be able use their own security within the System (e.g. end-to-end encryption). (See [6]).

Dsicussion: This may complicate access control mechanisms.

5.1.17 Secure routing

Req 17: The system shall provide secure unicast and multicast routing. In particular the following shall be supported: (1) Certain discovery (if there is a route between two nodes the routing algorithms shall discover it); (2) intrusion detection (identify misbehaving nodes and make them unable to interfere with routing); (3) location privacy (protect information about location of nodes in the network); (4) Self-stabilisation (automatic recovery from intrusion problems);

5.1.18 Interference to other systems

Req 18: The System shall meet all legal and regulatory requirements for its emissions. In particular, radiation from each transmitter shall not exceed the current US FCC and CEPT regulations.

Discussion: CEPT unintentional radiation levels are 500 uV/m/MHZ at 3 m above 960 MHZ and 200 uV/m/MHz at 3m below 960 MHz, this being equivalent to 75 uW in 1 GHz above 960 MHz or 12 uW below 960 MHz into an isotropic antenna. European regulations are still being discussed; hence the US regulations are used. (See [6].) It may be the case that the Systems supports different modes of operation corresponding to the emergencies. In modes corresponding to a small emergency no interference will be caused to any communications, whereas in modes corresponding to a big emergency some interference to others is allowable. Power levels used in existing systems (e.g. TETRA) are typically 1 Watt ERP for handled radios and 5 watts ERP for transportable based stations.

5.1.19 Hostile environment

Req 19: The System must be resistant to jamming. (This includes jamming of supporting systems such as GPS for localization, UMTS or TETRA for connection to the infrastructure network).

Discussion: Important implication of this requirement is that of a **robust Common Control Channel (CCC)**. Since the nodes in the System have no certainty on availability of the channel used for communication (traffic channel), a reference channel must be available thorugh which nodes will exchange information. This control channel must be insensitive to jamming. Different spread spectrum techniques exist that can be used to obtain this functionality. Examples are UWB (Ultra WideBand), Frequency Hopping Spread Spectrum (FHSS) and Direct Sequence Spread Spectrum (DSSS). In the FHSS scheme the signal is broadcast over a seemingly random series of radio frequencies, hopping from frequency to frequency at split second intervals, according to a table associating random numbers with frequencies. In the DSSS scheme each bit in the original signal is represented by multiple bits (chips) in the transmitted signal, known as the spreading code. The spreading code effectively distributes the signal across a wider frequency band, proportional to the number of bits used as a code. Another implication is that the system should **not rely on a connection with the infrastructure network**: it may be the case that the connection to this network (realised through e.g. UMTS) is jammed. Finally, due to its relatively low availability and vulnerability to jamming, the system should **not be dependent on GPS,** for its localisation.

5.1.20 Density

Req 20: The system shall operate with 100 nodes in an area of 1 km^2.

Discussion: This requirement needs further refinement.

5.1.21 Scaling

Req 21: The total number of vehicle nodes in an Incident Area Network shall scale to at least 250. The total number of personal nodes shall scale to at least 2500.

Discussion. This requirement is based on 5 Incident Area Networks where each network consists of 50 vehicles, where each vehicle was carrying 10 persons. The number of 5 comes from a DARPA presentation [DARPA].

5.2 Node requirements

This section presents requirements for personal and vehicle nodes.

5.2.1 Localization

Req 22: Nodes must be provided with localization capabilities.

Discussion: This means that the nodes shall interoperate with dedicated positioning systems such as GALILEO and GPS by taking measurements from them. But as these systems may be jammed or otherwise unavailable (See Section 5.1.19), nodes must also able to analyse received signal(s) from other nodes to derive their location when no location data is available within the transmission content (lost or errored). It remains to be analysed which possibilities are provided by an OFDM system for ranging and the determining the location. A starting point could be the way this problem is handled in CDMA or UMTS. It is known that the LORAN (and the older DECCA systems) have this possibility. It is known that UWB techniques could provide a solution tot this problem (maybe in combination with UWB fro the robust control channel). Typical frequency of position measurements are: 1 per second with a delay of less than 1 second. No more than 5 seconds when no measurements are available.

5.2.2 Supported datarates vs distance (general)

Req 23: The following transmission rates shall be supported between neighbouring vehicle nodes and/or personal nodes. These rates shall be supported for all types of terrains and under all weather conditions (including fog, rain) and under all propagation conditions (including non-line of sight). Examples are rural (air/waterborne), urban (city street, highway), and indoor (building with multiple stores, parking garage).

Table 5-1. Bandwidth vs distance, initial requirements.

Type of Terrain	Personal node– Personal node Personal node – Vehicle - node	Vehicle node – Vehicle node
Rural	500 m 2 Mb/s	2 Km 5 Mb/s
Urban	250 m (5 houses) 2 Mb/s	1 Km 5 Mb/s
Indoor	100 m (5- floors) 2 Mb/s	500 m 5 Mb/s

Discussion: We used the classification defined in Chapter 3. The 'indoor distance' from a person or vehicle to a vehicle must be interpreted as from a person/vehicle indoor (e.g. parking garage) to a vehicle that is outdoors. Note however, that these bandwidth requirements are based on a preliminary analysis, discussed in detail in Appendix A, that is based on the same starting points as a well-known assessment of uplink bandwidth needed for the MESA train-crash scenario [7]. Note here that Europcom [6] states that facilities by the System shall be available over much larger areas, up to 3 km diameter, using integration with other communications services.

5.2.3 Supported datarate vs distance (close distance)

Req 24: When in close range (<100 m) the bandwidths supported between neighbouring nodes shall exceed the values mentioned in Table 5-1.

Discussion: When in close range the user will expect to have available higher bandwidths in order to support other applications (for example the exchange of video or photo).

5.2.4 Presence of other nodes

Req 25: A node shall operate in the presence of other nodes at 1m or further away, with no noticeable disruption.

Discussion: this requirement on the density that should be supported.

5.2.5 Vehicle node speed

Req 26: The full system performance shall be maintained with any speed likely to be achieved by a vehicle. A vehicle node, which is moving with a speed up to 150 km/h, shall support communications to other vehicle nodes or personal nodes. If the speed exceeds this value communications shall still be possible, albeit with lower quality.

5.2.6 Personal node speed

Req 27: The full system performance shall be maintained with any speed likely to be achieved by a person. Personal nodes that are moving with a speed up to 5 m/s shall support communications to other personal nodes. If the speed exceeds this value communications shall still be possible, albeit with lower quality.

Discussion: Note that this requirement may impact the use of OFDM, as Doppler shifting must be taken into account when the speeds are high. Communications with higher speeds (e.g. from a vehicle to a helicopter) would require speeds that are higher (say, up to 300 km/h). This is formulated as an optional requirement.

5.2.7 High speed

Req 28: (optional). A node, which is moving with a speed up to 300 km/h, shall support communications to other nodes or nodes. If the speed exceeds this value communications shall still be possible, albeit with lower quality.

5.2.8 Mobility

Req 29: The system shall support both mobility of users and mobility of networks. Communication interruptions as a result from mobility shall be minimal (say, less than 50 ms)

Discussion. In order to realise this, a node, when on the move will probably use existing communication paths as long as possible (even when the quality of service degrades) while performing preparatory activities (like authentication, neighbour determination, determination of frequencies) to set up an optimal communication path. This is called a ‘soft’ handover.

5.2.9 Propagation environment

Req 30: Nodes shall be able to automatically adapt modulation, error correction and transmission power to difficult RF environments and propagation conditions (high noise figure) in order to maintain communication for critical services.

Discussion. The modulation scheme must be so that it can cope with higher loss or higher path loss at the expense of realising a lower bandwidth (while keeping the distance fixed) and/or realising shorter distances (while keeping the bandwidth fixed). This also relates to 'multistandard' radios where in a different standard is used when the distance between nodes is large.

5.2.10 Scanning information

Req 31: A node must have the possibility to make scanning information (including timestamps) available to other systems.

Discussion. This requirement addresses a general requirement in [2] with respect to the geo-location of source of attacks and jamming. For AAF, these requirements are handled as external to the system. There may be special vehicles/radio systems ("probing vehicles") that are able to scan the radio spectrum for jammers, but presumably not every vehicle will have this possibility.
Additionally, most (if not all) AAF nodes are assumed to have a more generic scanning facility. The information from all or a relevant subset of AAF nodes is aggregated by a spectrum manager, which in turn assigns radio frequencies to be used. The exchange of spectrum information uses the Common Control Channel (CCC). See also [11] and [13].

5.2.11 Power efficiency

Req 32: A node must be able to operate thorough power losses up to a defined period of time. In particular a vehicle node shall be able to operate without turning on the engine for at least 4 hours. Personal nodes shall be able to operate without recharging batteries for a period of 48 hours.

Discussion. This requirement must be considered together with expected activity levels. For vehicle nodes an activity level of 100% is reasonable, as vehicles nodes are likely to form the backbone of the network. For personal nodes estimations indicate that an activity level of 35% is reasonable. Europcom requirement is 6 hours of continuous active operation without recharging. It even seems that the distribution of activity is relevant (a battery usage of 1 consecutive hour out of 3 has a different impact than 3 consecutive hours out of 9). Existing TETRA radios have operating lifetimes typically ranging from 8 to 30 hours depending on battery and operating conditions.

Note that the power efficiency requirement may impact the routing algorithm. The network layer should provide mechanisms to lower the load on nodes that have fewer resources, even if those nodes are on the shortest (or on the 'best Quality of Service'-path) from source to destination. This requirement also indicates that it is important that information from the lower layers is accessible and can be controlled from the higher layers.

5.2.12 Interfaces

Req 33: Nodes shall provide interfaces to different types of sensors, antennas and other equipment (like recorders, databases, displays, headsets and other access devices). In particular an interface shall be provided to GPS sensors.

Discussion. Typically, vehicle nodes will transmit/receive via multiple wireless interfaces for reliable communication.

5.2.13 Multi-hop

Req 34: All nodes shall support the multi-hop capability.

Discussion. For multi-hop networking it is well known that communication protocols suffer from scalability issues when the size of the network increases. As a typical example, current IEEE 802.11 MAC protocol and it derivatives cannot achieve a reasonable throughput as the number of hops increases to 4 or higher [8]. In the architecture of the network as described in [11] a number of 2 hops seems to be realistic (from personal node – vehicle node – vehicle node – personal node).
However, the Hyacinth project has shown that the loss of aggregate throughput (goodput) can be compensated when using different frequencies for the separate hops (see [14]). Since the objective of AAF is to use free radio spectrum, the results from this project may be re-used for its benefits, although not to its full extent in case the AAF nodes will have only single radio.

5.2.14 Throughput in relation to number of hops

Req 35: The throughput between nodes that are 1 or 2 hops away shall be at least 50 % from the throughput between neighbouring nodes in Table 5-1.

5.2.15 Easy and fast deployment

Req 36: The nodes must support the ability to automatically configure themselves and configure a network. This includes but is not limited to: automatic detection of other (personal, vehicle) nodes, automatic establishment of a network between the nodes, automatic discovery of gateways to other networks (IAN, JAN), automatic direction of antenna's in case directional antenna's are used and the re-establishment of user groups. In particular this implies that (among many other things) for example the operational frequencies and IP-address should be automatically obtained.

Discussion: for a rapid deployment of the nodes by non-technical expert users, the nodes should be capable to configure themselves.

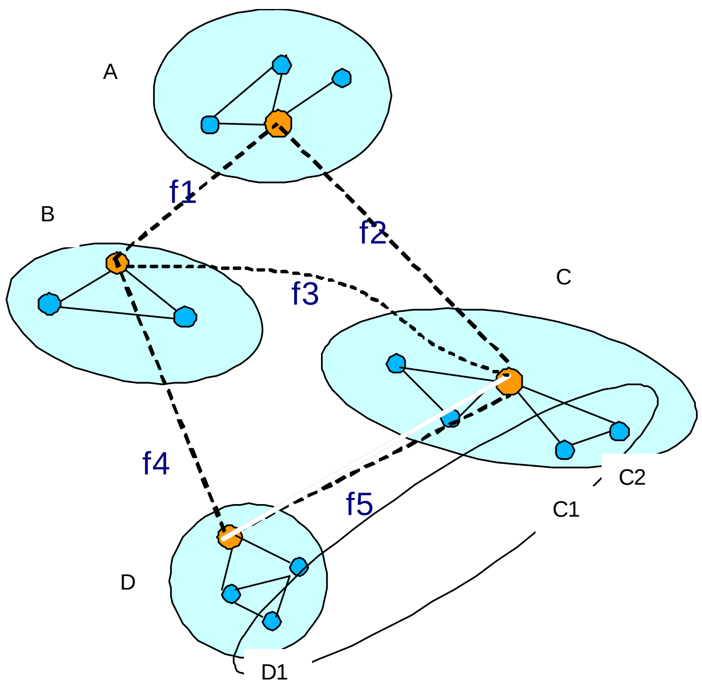

Figure 5-1. Steps that need to be taken in order to automatically configure a network

Figure 5-1 illustrates some of the steps that are needed in order to automatically configure the network. In the figure the lower cluster of personal and vehicle nodes (with label "D") arrives at a certain location. It is assumed that due to the distance the personal nodes in cluster "D" are not able to see nodes of other clusters. When they come within reach, the vehicle node "D" automatically detects the other nodes via a signalling channel. After this phase, the vehicle node finds a node to authenticate with, and establishes a communication channel to this node (assume this is node C). The authentication and authorisation phase is performed and the node D is granted access to the network. It then gets its network configuration parameters, and establishes data links to its neighbours (this includes the determination of the frequencies used for this communication). Note here that the neighbours need not necessarily be the same as the node that performed the authentication. In order to limit the power not all possible neighbours need to be chosen (maybe with full power both node A, B and C could be neighbours of D, but as the network is reliable enough, power can be reduced to have only B and C as neighbours). Then authentication and authorisation is performed for user groups (node D1 is in a user group with nodes C1 and C2). After this phase the initialisation phase is terminated and communication is possible between D1, C1 and C2.

5.2.16 Frequency Range

Req 37: Nodes shall operate in a frequency range in the 400 MHz-6 GHz frequency range.

Discussion: The frequency range was intensely discussed. The discussion involves the following issues: (1) legal aspects; (2) propagation characteristics; (3) throughput requirements. (1) With respect to legal aspects it was concluded that due to legal constraints, it is not realistic to assume that a cognitive radio system developed by the project would be able to co-exist with any licensed frequency band. In particular not the present C2000 system which uses frequencies in the 380-385 MHz and 390-395 MHz frequency range. From a legal perspective, cognitive radio systems are only possible at unlicensed frequencies. (2) Propagation characteristics would prefer a low frequencies (below 1 GHz) for maximum indoor penetration, covered distance using a limited transmit power and high mobility. (3) The throughput that can be realised by a node depends on the free frequency-bandwidth that is available. (The higher the free bandwidth the higher the throughput). As it can be expected that in the higher frequency ranges more free bandwidth is available, vehicle nodes with higher throughput requirements may operate in the higher bandwidths. The maximum frequency possible for Non line-of sight communications is 6 GHz.

This issue has led to a two track approach for the project. Track I is focussing on research on layers above the MAC, making use of available or (during the project) becoming available physical layer solutions based on 802.11 (to start with) and 802.16 standards (later in the project). The background is to use spectrum which is available right now in the unlicensed bands (2.4 GHz, 5.7 GHz). These solutions can be extended with cognitive radio features, like e.g. adaptive channel selection, and optimised for public safety requirements. Higher layer can already utilise this flexibility for ad hoc system initialisation and configuration and for robust routing and QoS provisioning. Research results of track I will be validated and demonstrated in WP5 in the project. The intention of track I is to make a Cognitive System. Track II will focus more on innovative physical and medium access layer solutions which however require new spectral legislation and require new standardisation. In these solutions spectrum can be used in a very adaptive way which will result in much higher capacity and robustness than the solutions in track I. Spin-of of track II will be first towards legislation, standardisation and advanced development and later, after the project, towards product development.

5.2.17 Environmental requirements

Req 38: The communication network equipment must be resistant to extreme temperatures, shock and vibration, salt and dust, radiation, rain, snow and ice, low pressure, lightening etc. Communication equipment for vehicle nodes must easily fit in a vehicle, communication equipment for personal nodes must be wearable by persons.

6 Conclusion

Technical requirements for a cognitive radio system that can be used in an emergency network have been derived based on emergency scenarios, a preliminary architecture and input from several public sources. Important services such a system should offer include voice, video, short messages and various kinds of database access and data transfer services between different user groups.

On a high level, some aspects that distinguish a cognitive radio-based emergency communication system from other types of communication networks are:

- *The fact that the spectrum is not fixed, but free spectrum needs to be determined by the nodes. After detection it needs to be communicated to other nodes. To use the free spectrum opportunities, nodes need to quickly adapt modulation and coding, requiring specific hardware.*

- *The requirement to support real-time services, such as multimedia conferencing, requires a solution where the network layer takes into account Quality of Service criteria from the underlying radio and MAC layer, in order to find the best path from source to destination. Also status information of the network nodes (e.g. remaining power) should be taken into account in finding a path.*

- *The robustness requirement, which both means that communications must be restored rapidly in case of failures and that communication under difficult propagation conditions, must be possible. Robustness also implies that there should be no single point of failure in the architecture (in particular there cannot be a single point in the network where all frequency measurement data are collected).The design of a robust signalling channel, needed for (e.g.) communication of free spectrum is a particular challenge.*

- *Self configuration requirements, which means that a network must be quickly operational, with little or no user intervention.*

- *Mobility requirements, stating that both users and network must be mobile, without interruption of communications. Mobility at high speeds will impact the use of OFDM solutions, due to the Doppler shift that cannot be neglected.*

- *Security requirements, which assert that it should not be possible to jam or listen in to communications. This also means that the communication system cannot be dependent on a dedicated positioning system, but must have localization capabilities.*

- *Most communications take place in user groups (multipoint-to-multipoint) requiring the use of efficient multicast services, when combined with the robustness requirement, this implies that new solutions have to be found.*

A further analysis of the bandwidth requirements is needed to make these tighter.

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Appendices

This appendix contains a first analysis of the bandwidth requirement between vehicle and personal nodes. This analysis is based upon the Train Crash scenario described in [7]. Note that MESA just provides one scenario and many more scenarios are possible, we use it in order to get some basis for our assumptions and to have consistency between the different projects.

First, we briefly revisit the MESA scenario, which uses the ITU M.1390 methodology for spectrum calculations, then we explain the additional assumptions needed to derive a bandwidth requirement between neighbouring nodes.

Table 6-1 summarises the essential parameters used in the Train Crash scenario.

TABLE 6-1 TRAIN CRASH- ESSENTIAL PARAMETERS

Variable	Value	Remark
Cell size	1 Km^2	This is the size of the area under consideration
Number of active Video Streaming units in Cell	50	all simultaneously active
Number of Still picture sequencing units in Cell	50	all simultaneously active
Video Streaming bandwidth	1000 Kbps	Assumed is MPEG4 compression, which will give a net bandwidth of 700 kbit/s, the additional 300 kbps is ‘overhead’ – it is unclear from the MESA documentation what is included in the overhead)
Still picture bandwidth	400 Kbps[3]	Assumed is a picture size of 250 Kbyte, pictures are to be transferred within 5 s
Scaling factor	1.5	the scaling factor accounts for RF channel overhead such as crypto coding and error recovery

Although the M.1390 methodology requires more parameters, the above parameters are already sufficient to calculate the uplink throughput requirement in Mbit/s. In terms of the architecture of Chapter 4 this is the bandwidth needed between the JAN Gateway and the JAN (Jurisdictional Area Network).

Video Traffic: 50 x 1 x 1.5 = 75 Mbit/s

Still Picture Traffic: 50 x 0.4 x 1.5 = 30 Mbit/s

This leads to an uplink throughput requirement of 105 Mbit/s. Currently available digital technology is able to realise 1.5 bit/s per Hz. This leads to the MESA requirement of 70 MHz of uplink bandwidth. So far nothing new.

Let us now proceed with the analysis of the bandwidth required between neighbouring nodes (and not just only the uplink bandwidth). The following parameters are taken with some minor adaptations adapted from MESA:

[3] Worst case requirement, 40 Kb/s would be more realistic.

TABLE 6-2. ADDITIONAL ASSUMPTIONS NEEDED FOR BANDWIDTH CALCULATIONS.

Variable	Value	Remark
Total number of vehicle nodes	65	consisting of 40 ambulances, 20 police cars, 5 firefighter trucks
Total number of personal nodes	255	consisting of 120 Medical staff, 20 Hazardous materials staff, 25 firefighters, 50 rescue squad members, 35 law enforcement officers, 5 robots for wreckage inspection

Figure 6-1 illustrates the calculation of bandwidth requirement between neigbouring personal nodes and from a personal node to a vehicle node. The personal nodes are coloured blue and the vehicle node is colored orange. In the figure it has been assumed that nodes A and B are in the same 'still picture' communication user groups while there is another member of the same 'still picture' communication user group associated to another vehicle. All communication to other personal nodes associated to other vehicles is assumed to take place via the vehicle node. As last assumption, there is a node D generating video traffic, which will be viewed by someone in the backbone (JAN).

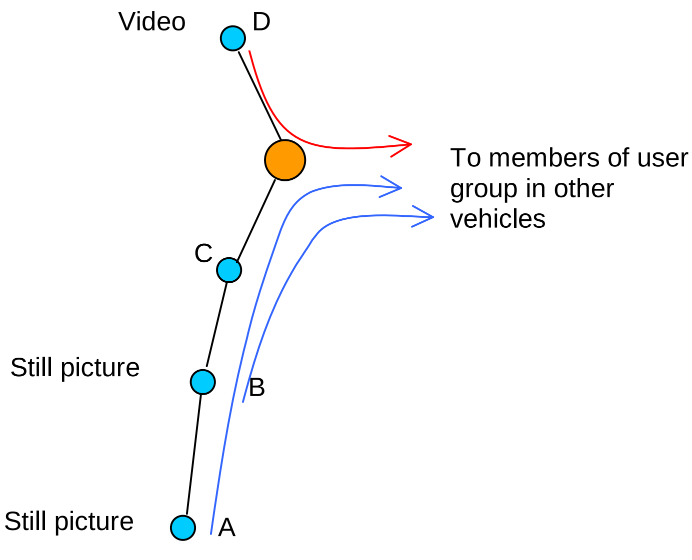

Figure 6-1. Illustration for calculation of bandwidth between personal nodes

This leads to the following calculation: between personal nodes a bandwidth supporting two still picture streams should be supported. With the previous assumptions this amounts to 2 x 1.5 x 0.4 (still picture) = 1.2 Mbit/s. Between a vehicle node and a personal node a bandwidth supporting one video stream should be supported. This amounts to 1.5 x 1 (video) = 1.5 Mbit/s. In Table 5-1 this value has been rounded upwards to 2 Mbit/s in order to account for additional traffic that was not in the calculation.

However, note that there is some inconsistency in the distances: if 255 people are in an area of 1 Km^2 it seems unlikely that the distance between two people is 500m. Note that even if one assumes that relaying between personal nodes is unlikely in practice and that there is no video communication, with the above service parameters, still picture exchange between two neighbouring personal nodes still requires 600 Kbit/s (in one direction). So one could consider relaxing the distances in Table 5-1.. The throughput requirements in this table seem to be 'reasonable'.

Figure 6-2 illustrates the calculation of bandwidth requirement between personal nodes and from a personal node to a vehicle node. This calculation is based on video traffic only: all video traffic is assumed to go to the backbone. The still picture traffic is assumed to remain internal and will not cross the gateway to the JAN. The bandwidth requirement is highly dependent on the number of hops that could exist between the gateway to the backbone and a vehicle node. In this figure this number of hops is assumed to be 3. In this case the link between vehicle D and the GW should be able to carry 4 video streams, leading to a bandwidth of 4 x 1 x 1.5 = 6 Mb/s. As in the previous case there is an inconsistency in the distance that should be supported. With 65 vehicles in an area of 1 km^2, a distance of 2 km between neighbouring vehicles is not possible, and we could consider relaxing the distance.

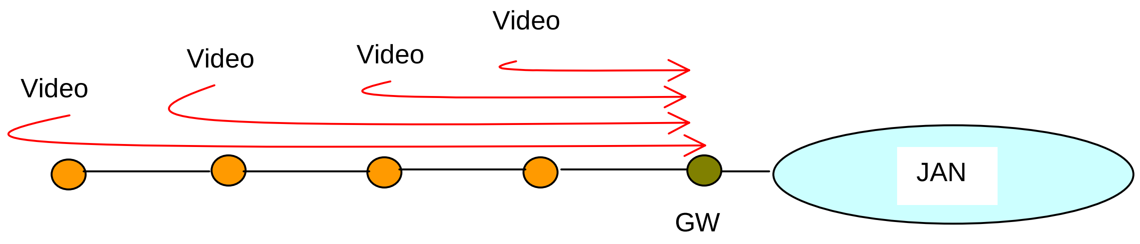

Figure 6-2. Bandwidth assessment between vehicle nodes

ATTACHMENT 6

RECOMMENDATION ITU-R M.1390

METHODOLOGY FOR THE CALCULATION OF IMT-2000 TERRESTRIAL SPECTRUM REQUIREMENTS

(1999)

Introduction

IMT-2000 are third generation mobile systems which are scheduled to start service around the year 2000 subject to market considerations. They will provide access, by means of one or more radio links, to a wide range of telecommunication services supported by the fixed telecommunication networks (e.g. public-switched telephone network (PSTN)/integrated services digital network (ISDN)), and to other services which are specific to mobile users.

A range of mobile terminal types is encompassed, linking to terrestrial and/or satellite-based networks, and the terminals may be designed for mobile or fixed use.

Key features of IMT-2000 are:

– high degree of commonality of design worldwide;

– compatibility of services within IMT-2000 and with the fixed networks;

– high quality;

– use of a small pocket-terminal with worldwide roaming capability;

– capability for multimedia applications and a wide range of services.

IMT-2000 are defined by a set of interdependent ITU Recommendations of which this one is a member.

Spectrum requirements for the terrestrial component of IMT-2000 were estimated in Report ITU-R M.1153 prior to WARC-92. Speech services were considered to be the major source of traffic at the time. As technological advancements provide additional capabilities in telecommunications users will demand more from wireless services. Future wireless services must support, not only speech but also a rich range of new services that will serve a wide range of applications. Services such as multimedia, Internet access, imaging and video conferencing will be needed in third generation wireless systems. In response to these new applications, IMT-2000 will support high rate data services. The provision of new services described in Recommendation ITU-R M.816 (Framework for services supported by IMT-2000) has an impact on the spectrum requirements for IMT-2000 systems.

There is a need to develop a new methodology for determination of spectrum requirements that can accommodate not only the new services of IMT-2000 but also the new radio transmission technologies being developed.

Scope

This Recommendation contains a methodology for the calculation of terrestrial spectrum requirement estimates for IMT-2000. This methodology could also be used for other public land mobile radio systems. It provides a systematic approach that incorporates geographic influences, market and traffic impacts, technical and system aspects and consolidation of spectrum requirement results. The methodology is applicable to both circuit switched and packet switch-based radio transmission technologies and can accommodate services that are characterized by asymmetrical traffic flows[1)].

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1) An example of the application of the methodology is provided in Appendix 1.

The ITU Radiocommunication Assembly,

considering

a) that the Radio Regulations (RR) identify the bands 1 885-2 025 MHz and 2 110-2 200 MHz as intended for use on a worldwide basis by administrations wishing to implement IMT-2000, as indicated in RR S5.388, and Resolution 212 (Rev.WRC-97);

b) that the initial implementations of IMT-2000 are expected to commence around the year 2000 subject to market considerations;

c) that the bands identified in *considering* a) are used differently in various countries;

d) that the traffic and service mix carried by IMT-2000 systems may vary from country to country, and also within countries. In some parts of the world additional spectrum may be required, whilst in other parts of the world frequency bands identified by *considering* a) could be adequate to meet IMT-2000 services present and future demands;

e) the need to support the operation of IMT-2000 terminals in different regulatory environments;

f) that the various radio access technologies that may be appropriate for IMT-2000 may have different channel bandwidth requirements, and hence varying impact on the basic frequency usage possibilities;

g) that traffic handled by mobile systems as well as the number and diversity of services will continue to grow;

h) that future systems may include the use of a range of cell types from indoor cells to satellite cells, which must be able to co-exist in a given location;

j) that IMT-2000 will offer higher data rate services than earlier systems in order to meet increasing customer demands, and this could create a demand for additional spectrum beyond that earlier estimated;

k) that efficiency of spectrum use requires consideration of the balances between IMT-2000 system costs and bandwidth needed;

l) that the methodology in Annex 1 is considered flexible enough to accommodate either a global view or the unique requirements of regional markets relative to terrestrial spectrum needs,

recommends

1 that the methodology for the calculation of terrestrial IMT-2000 spectrum requirement estimates as specified in Annex 1 should be used by administrations as the basis for performing calculations involving estimates of future IMT-2000 terrestrial spectrum needs;

2 that the methodology in Annex 1 could also be considered for the calculation of terrestrial spectrum estimates for other public land mobile radio systems, and its use is highly encouraged.

ANNEX 1

IMT-2000 terrestrial spectrum requirement methodology

1 Terrestrial methodology overview

A methodology for development of a terrestrial spectrum requirement is presented below. This methodology enables the calculation of spectrum estimates to support mobile communication services of today and the future. The equation for this estimate is provided in equation 1.

This methodology is consistent with the global IMT-2000 vision and is also consistent with the services as presented in Recommendation ITU-R M.816: "Framework for services supported by IMT-2000". The methodology is flexible enough to accommodate either a global view of spectrum needed or the unique requirements of regional markets.

The basic theme of this methodology is to determine the individual spectrum requirements for all representative combinations of specific environments and services (F_{es}) in a given geographical area, and to combine the set of individual spectrum requirements F_{es} together into a total terrestrial component spectrum requirement estimate, $F_{Terrestrial}$ by employing appropriate weighting factors (α_{es}) to the summation. The factor (α_{es}) takes into account the impact of concurrent services in a given geographical area. An additional adjustment factor (β) is available to apply to the composite summation to accommodate impacts such as multiple operators, spectrum sharing, and the like.

The estimation of a spectrum requirement for many years into the future is not an exact calculation. In particular, the methodology provided in this document is not intended to include the second or third order effects, but rather the calculations capture the significant first order influences which are the primary factors for terrestrial spectrum needed.

The spectrum required ($F_{Terrestrial}$) in MHz is:

$$F_{Terrestrial} = \beta \, \Sigma \alpha_{es} \, F_{es} = \beta \, \Sigma \alpha_{es} \, T_{es}/S_{es} \qquad (1)$$

where "e" and "s" are subscripts denoting dependency on environments and services respectively.

Therefore, $F_{Terrestrial}$ is the total required spectrum as a weighted summation of co-existing individual F_{es} in the same geographical area for all environments "e" and services "s" considered relevant, adjusted for influences such as spectrum sharing, multiple operators,

where:

$F_{Terrestrial}$	= Terrestrial Component Spectrum Requirement	Units: MHz
T_{es}	= Traffic/Cell_{es}	Units: Mbit/s/cell
S_{es}	= System capability	Units: Mbit/s/MHz/cell
α_{es}	= Weighting factor	Units: dimensionless
β	= Adjustment factor	Units: dimensionless

Equation 1 addresses both circuit and packet-switched services and includes consideration for traffic asymmetry in the uplink and downlink directions. Each of the factors of equation 1 will be defined further in the following subsections.

The calculations, parameters, and definition of inputs within the methodology are divided into four categories and serve to group similar aspects of the methodology into sub-units:

A geographic considerations,

B market and traffic considerations,

C technical and system consideration,

D spectrum results considerations.

An example is included in Appendix 1 that shows how the methodology is applied. This example is based on a representative subset of environments and services. The example is calculated with parameter values estimated from market research on public land mobile communications services, including IMT-2000, and with technical parameter values estimated from IMT-2000 radio transmission technologies, for the year 2010.

The results shown in this example should not be considered as providing an answer to the question of future spectrum requirements for public land mobile communications services, including IMT-2000, as all environments and services that must be considered for completeness have not been included in the example. Nonetheless, the example includes all environments and services required to sufficiently exercise all aspects of the methodology.

2 Methodology flowchart

The following material presents the methodology in "flowchart" format with a sequential listing of the steps divided among the four sub-categories. Subsequent sections of this document provide detailed information and description of the terms, parameters, calculations performed[2].

A Geographic considerations

A1 Select "e"

"e" - environment type: selects density and mobility.

These environments are defined by a combination of a density attribute and a mobility attribute considered jointly, and are shown in the following matrix:

Mobility	In-building	Pedestrian	Vehicular
Density			
Dense Urban (CBD)			
Urban			
Suburban			
Rural			

For example, "dense urban, in-building" could be a value of "e".

A2 Select direction of calculation

Uplink (from the mobile station to the base station) or downlink (from the base station to the mobile station).

A3 Establish representative cell area and geometry — Units: metres

Diameter if circular omnidirectional cell geometry; radius of vertex if sectored hexagonal cell geometry.

A4 Calculate Cell_Area A_e — Units: km^2

$Cell\_Area_e$.

B Market and traffic considerations

B1 Select "s"

s – service type: selects service type and hence $Net\_User\_Bit\_Rate_s$ (kbit/s)

---

2) The mathematical convention of describing a complex function as a function name and a list of input parameters is used in several places in this document. It is demonstrated as follows:

Function {parameter1, parameter2, …, parameterN}.

B2 Establish Population_Density$_e$ — Units: potential users/km^2

B3 Establish penetration_rate$_{es}$ — Units: %

B4 Calculate users/cell$_{es}$ — Units: users

Users/Cell$_{e\ s}$ = Population_Density$_e$∗Penetration_Rate$_{es}$∗Cell_Area$_e$.

B5 Establish traffic parameters

Busy_Hour_Call_Attempts$_{es}$ — **Units: calls in busy hour**

Effective_Call_Duration$_{es}$ — **Units: seconds**

Activity_Factor$_{es}$ — **Units: dimensionless**

B6 Calculate Traffic/User$_{es}$ — Units: call-seconds

Traffic/User$_{es}$ = Busy_Hour_Call_Attempts$_{es}$∗Call_Duration$_{es}$∗ Activity_Factor$_{es}$.

(NOTE – May be expressed as Erlangs, where an Erlang = call-seconds/3 600.)

B7 Calculate Offered_Traffic/Cell$_{es}$ — Units: call-seconds/cell

Offered_Traffic/Cell$_{es}$ = Traffic/User$_{es}$∗Users/Cell$_{es}$.

(NOTE – May be expressed as Erlangs, where an Erlang = call-seconds/3 600.)

B8 Establish Quality_of_Service_Function$_{es}$ Parameters — Units: varied

Group_Size$_{es}$;

Blocking Criteria$_s$ {Formula and Grade of Service for circuit switched; Formula and Delay for packet switched}.

C Technical and system considerations

C1 Calculate number of Service_Channels/Cell$_{es}$ required to carry Offered_Traffic/Cell$_{es}$ — Units: none

Service_Channels/Cell$_{es}$ =

(Quality_of_Service_Function$_s$
{Offered_Traffic/Cell$_{es}$*Group_Size$_{es;}$
Blocking Criteria$_s$})/Group_Size$_{es}$

C2 Determine Service_Channel_Bit_Rate$_{es}$ needed to carry Net_User_Bit_Rate$_{s}$ **Units: kbit/s**

C3 Calculate Traffic$_{es}$ **Units: Mbit/s/cell**

$\mathbf{T_{es}}$ = Service_Channels/Cell$_{es}$*Service_Channel_Bit_Rate$_{es}$.

(Note conversion to Mbit/s from kbit/s.)

C4 Determine Net_System_Capability$_{es}$ Parameters **Units: varied**

System Spectral Efficiency; Coding Factor; Overhead Factor; Deployment Model; and other factors.

C5 Calculate Net_System_Capability$_{es}$ **Units: Mbit/s/MHz/cell**

S_{es} = Function of {Spectral Efficiency; Coding Factor; Overhead Factor; Deployment Model, and other factors}.

D Spectrum results considerations

D1 Calculate individual F_{es} Component

(Answer will be for direction of calculation chosen either uplink or downlink.)

$F_{es} = T_{es}/S_{es}$ (either uplink or downlink) **Units: MHz**

D2 Repeat process for calculation of other direction (either downlink or uplink as appropriate)

Repeat steps A2 through D1.

D3 Calculate F_{es} for the Service "s" Combining uplink and downlink components

$F_{es} = (F_{es}$ uplink + F_{es} downlink) **Units: MHz**

D4 Repeat process (steps A1 through D3) for All Desired "e", "s"

D5 Determine weighting factor applicable to each individual F_{es}: α_{es} **Units: None**

D6 Determine Adjustment Factor(s): β **Units: None**

D7 Calculate Final Total $F_{Terrestrial}$ Spectrum Value **Units: MHz**

$F_{Terrestrial} = \beta \, \Sigma \alpha_{es} \, F_{es}$.

3 Deta = $\beta\ \Sigma\alpha_{es}\ F_{es}$.iled description of the methodology

A Geographic considerations

A1 Environment

The initial point for consideration of terrestrial spectrum requirements is to determine the characteristics of the cells which the system will use. The system will operate in a variety of scenarios, encompassing various combinations of density and mobility. A table of possible environments is given below, although no indication has been given of which specific environments should be considered. It is thought that the matrix below is flexible enough to cover most situations encountered in deployment of a public land mobile radio system.

The variable subscript “e” represents the environment for which the calculation is performed, and the environment is defined by a combination of a density attribute and a mobility attribute considered jointly, and are show in the following matrix:

Mobility	In-building	Pedestrian	Vehicular
Density			
Dense Urban (CBD)			
Urban			
Suburban			
Rural			

For example, “dense urban, in-building” could be a value of “e”.

Clearly some of these environments may be (geographically) overlapping, whilst others may be separate. For the calculation of the total spectrum required for IMT-2000, it will be necessary to determine the maximum spectrum which might realistically be needed in any one area. It is anticipated that not all combinations (values of “e”) will be needed and in most cases only a few combinations will need to be considered. For example, “dense-urban, vehicular” as a value of “e” may not be required in practice in some calculations. Therefore the first stage of the methodology is to determine the environments which could co-exist, and which would give rise to the greatest total spectrum demand.

In practice this will be a combination of overlapping dense urban and urban environments. The method to determine the total spectrum required is then applied to each of the members of this set of overlapping environments.

A2 Select direction of calculation

Uplink (from the mobile station to the base station) or downlink (from the base station to the mobile station).

The traffic and spectrum figures in steps A2 through D1 are calculated separately for uplink and downlink directions because of the traffic asymmetry in some services. The spectrum required for any F_{es} is the sum of the requirement for both directions.

A3 Establish representative Cell_Area and geometry

For each of the “e” environments identified in A1, the cell area and geometry has to be established. Typical examples could be a circle or hexagon, either of which could be considered as a whole or could be sectored. It is possible that, for operational reasons, different environments will use cells with differing geometry, and certainly there may be a range of cell sizes.

A4 Calculate $Cell\_Area_e$ Units: km^2

Having identified the cell geometry and dimensions for each environment, it is necessary to calculate the area of the cell.

For example:

For a circular cell, $Cell\_Area_e = \pi R^2 = \pi D^2/4$

where: R = radius of the circle

D = diameter of the circle

For a hexagonal cell, $Cell\_Area_e = (3/2) * (\sqrt{3}) * R^2$

where: R = radius (to vertex) of the hexagon.

For a cell which is a sector of a circle/hexagon, the area that should be used ($Cell\_Area_e$) is the area of the sector, and it may be sufficient to divide the area of the full circle/hexagon to obtain the sector area.

Other cell geometries and corresponding formula for calculating area may be used.

B Market and traffic considerations

B1 Select "s"

"s" – service type: selects service type and hence $Net\_User\_Bit\_Rate_s$ (kbit/s).

For a given public land mobile radio service there is a set of services that are offered. Selecting a service type "s" chooses a particular service from that set for the purpose of calculation.

As an example, in IMT-2000, a reasonable set of services (the range of "s") might be:

– Speech (circuit switched)
– Simple message (packet switched)
– Switched data (circuit switched)
– Medium multimedia (packet switched)
– High multimedia (packet switched)
– High interactive multimedia (packet switched)

B2 Establish $Population\_Density_e$ Units: potential users/km^2

For each environment considered, it is also necessary to determine a density of population. This will be a basic figure for the number of persons per unit area within the environment under consideration.

Similar geographic locations can have differing population densities as a function of the mobility component. For example, urban-pedestrian may have a population density of 100 000 users/km^2, yet the same area would not be physically able to have an urban-vehicular density of more than 3 000 users/km^2.

B3 Establish $Penetration\_Rate_{es}$ Units: %

This parameter is the ratio of the number of people subscribing to the service "s" over the total population, in environment "e".

It should be noted that the use of each service is not exclusive. Each $Penetration\_Rate_e$ refers to the penetration of that service as a proportion of the total potential user base. Since users can use more than one service it is possible for the *total* penetration in an environment (across all services) to exceed one (100%) if a high proportion of users are using more than one service.

B4 CalculateUsers/Cell$_{es}$

This parameter is dependent upon the population density and the cell area for each environment "e", and on the penetration rate for the service "s" and the environment "e".

It represents the number of people actually subscribing to the service "s" in a cell of environment "e".

$Users/Cell_{es}$ = $Population\_Density_{es} * Penetration\_Rate_{es} * Cell\_Area_e$.

B5 Establish traffic parameters

For each service, in each environment, the following parameters must be established:

Busy_Hour_Call_Attempts$_{es}$ **Units: number of calls in busy hour**

Defined as the average number of calls attempted for the average user during the busy hour. It should be noted that these calls may originate either from the user or from the network. No distinction is made here between these two sources, the result in terms of resource needed being the same. This parameter is self explanatory for circuit-switched services, and for packet-switched services a call is understood as a session.

Call_Duration$_{es}$ **Units: seconds**

This parameter is defined as the mean actual duration of the call or of the session during the busy hour.

Activity_Factor$_{es}$ **Units: dimensionless**

Defined as the percentage of time during which the resource is actually used during the call. For example, if voice is transmitted only if the user speaks, or if a packet transmission is bursty, the transmission is only active during a relatively small amount of time.

B6 Calculate Traffic/User$_{es}$ Units: call-seconds

This parameter is defined as the probability that the user is "offhook" and active in the busy hour for a circuit-switched call or a packet-switched session. It is clearly defined in Erlangs (call-seconds/ 3 600) for circuit-switched services and for packet-switched services has the equivalent unit of average relative activity in a period of reference of the busy hour.

$Traffic/User_{es} = Busy\_Hour\_Call\_Attempts_{es} * Call\_Duration_{es} * Activity\_Factor_{es}$.

B7 Calculate Offered_Traffic/Cell$_{es}$ Units: call-seconds

This is the total traffic issued in a given cell of environment "e" for service "s" during the busy hour.

$Offered\_Traffic/Cell_{es} = Traffic/User_{es} * Users/Cell_{es}$.

It is clearly defined in Erlangs (call-seconds/3 600) for circuit-switched services and for packet-switched services has the equivalent unit of average relative activity in a period of reference of the busy hour.

B8 Establish Quality_of_Service_Function$_{es}$ (QOS$_{es}$) Parameters Units: varied

Parameters required:

Group_Size$_{es}$

Blocking Criteria$_s$ (Formula and Blocking for circuit switched)

or

Blocking Criteria$_s$ (Formula and Delay for packet switched)

Discussion of Quality Of Service Aspects:

Bearer channel capabilities are characterized in terms of parameters having Quality of Service and Grade of Service significance. Establishing $Quality\_of\_Service\_Function_{es}$ parameter values (herein $Quality\_of\_Service\_Function_s$ is used generically to apply to both Quality of Service specifically and also to Grade of Service) directly impacts on the number of service channel resources that are required to transport the $User\_Net\_Bit\_Rate_s$ streams.

These parameters are necessary to determine the actual amount of resource which is needed to carry the traffic issued from the cell. For circuit-switched services, the necessary parameter is acceptable blocking, the maximum percentage of calls which cannot be treated by the network.

For packet-switched services, the quality of service is defined in terms of maximum packet delay and packet loss probability. The acceptable values of these parameters must be established for a given Service_Type "s".

The throughput of a packet-switched system is dependent on the choice of a suitable multiple access protocol (e.g. Aloha, PMRA, etc.). Given a particular protocol, the total throughput may be determined for a particular Service_Type "s" by application of a suitable traffic model and an appropriate packet $Quality\_of\_Service\_Function_{es}$.

Traffic models for packet switched are dependent on many parameters, some of which might be included in the $Net\_System\_Capability_{es}$ variable. Some example packet-switched traffic parameters are:

– statistical arrival times of various sessions;

– numbers of packet bursts per session;

– arrival times of packet bursts within a session;

– packet size statistics.

The values of the above are also Service_Type "s" dependent. When a session consists of multiple services an aggregate traffic model should be used.

The requisite function that is used for the calculation of $Quality\_of\_Service\_Function_{es}$ relative to the number of service channels is a matter of choice of the appropriate function to match the Service_Type "s" selected. For example, Erlang B with a blocking value of some percentage (say 2% blocking) has traditionally been used for speech (circuit switched) and may be an appropriate choice to apply in the determination of spectrum associated with the speech service type. Other functions as discussed previously, which describe $Quality\_of\_Service\_Function_{es}$ appropriate to packet switched would be used in calculations of packet-based service types.

In consideration that radio transmission technologies and system deployments may provide some measure of traffic "sharing" or "redirection" among adjacent cells (perhaps in hierarchical or other arrangements) it is appropriate to consider traffic and $Quality\_of\_Service\_Function_{es}$ within a grouping of cells.

The term $Group\_Size_{es}$ is used to describe the number of cells considered to be grouped for the purpose of application of traffic and $Quality\_Of\_Service\_Function_{es}$. The $Group\_Size_{es}$ does not imply any particular geometry, although an example could be a regular hexagonal cell grid which results in a $Group\_Size_{es}$ of seven, the value arising from the cell in question and the surrounding six first tier cells.

Essentially, the $Traffic/Cell_{es}$ is multiplied by the $Group\_Size_{es}$ and the $Blocking\_Criteria_s$ function applied over this grouping. Then to obtain the $Service\_Channels/Cell_{es}$ the $Group\_Size_{es}$ is divided out to restore the valuation to a per cell basis.

This calculation step has the impact of some reduction in the number of $Service\_Channels/Cell_{es}$ by considering some improvement in efficiency in the traffic spread in a geographic grouping. To the extent that grouping and/or traffic sharing across geographically grouped cells is included in the $System\_Capability_{es}$ parameter, then the $Group\_Size_{es}$ should be set to the value of one and the $Blocking\_Criteria_s$ function calculation performed on the traffic in a single cell.

Similarly, if the effects of a $Quality\_of\_Service\_Function_{es}$ are included in the $System\_Capability_{es}$ parameter, then the $Blocking_s$ function should be set to a value of one, which should in principle, also require that the $Group\_Size_{es}$ value be set to unity.

C Technical and system considerations

C1 Calculate number of $Service\_Channels/Cell_{es}$ required to carry $Offered\_Traffic/Cell_{es}$ **Units: none**

The calculation of the number of $Service\_Channels/Cell_{es}$ is a complex function that involves use of the parameters discussed previously:

$$Service\_Channels/Cell_{es} = (QOS_{es}\ \{Offered\_Traffic/Cell_{es} * Group\_Size_{es};\ Blocking\ Criteria_{s}\})/Group\_Size_{es}$$

$Service\_Channels/Cell_{es}$ is the actual number of “channels” that must be provisioned to carry the intended traffic. A service channel is a channel which supports a service needing to have transported the corresponding $Net\_User\_Bit\_Rate_{s}$ for the selected service “s”.

In general terms, a physical transmission facility offers a corresponding physical bit rate, which may be sub-divided into several sub-rate transmission pipes, each of which can support a number of service channels.

C2 Determine $Service\_Channel\_Bit\_Rate_{es}$ needed to carry $Net\_User\_Bit\_Rate_{s}$ **Units: kbit/second**

Due to modularity of the bit rate of the service channel, it is possible that the $Service\_Channel\_Bit\_Rate_{es}$ might be equal to or greater than the corresponding $Net\_User\_Bit\_Rate_{es}$. An example of this would be a $Service\_Channel\_Bit\ Rate_{es}$ of 16 kbit/s to carry a 14 kbit/s $Net\_User\_Bit\_Rate_{s}$, or an 80 kbit/s $Service\_Channel\_Bit\_Rate_{es}$ to carry a 64 kbit/s $Net\_User\_Bit\_Rate_{s}$.

$Service\_Channel\_Bit\_Rate_{es}$ can also include impacts related to coding factors and channel overhead. To the extent that the actual bit rate of the service channel, coding factors and channel overhead impacts are not included in the $Net\_System\_Capability_{es.}$ they should be included here. Ignoring any factors related to $Service\_Channel\_Bit\_Rate_{es}$ that cause it to be greater than the $Net\_User\_Bit\_Rate_{s}$, the $Service\_Channel\_Bit\_Rate_{es}$ is merely equal to the $Net\_User\_Bit\_Rate_{s}$.

C3 Calculate $Traffic_{es}$ **Units: Mbit/s/cell**

(Note conversion to Mbit/s from kbit/s.)

$T_{es} = Service\_Channels/Cell_{es} * Service\_Channel\_Bit\_Rate_{es}$.

At this stage the traffic has been totalled for all the factors represented by the environment, service type, selected direction of transmission, cell geometry, quality of service aspects, traffic efficiencies across a group of cells, and service channel bit rate requirements.

C4 $Net\_System\_Capability_{es}$ (S_{es}) **Units: Mbit/s/MHz/cell**

(An equivalent expression for bits/s/Hz/cell.)

Determine Net_System_Capability Parameters **Units: varied**

S_{es} is a measure of the system capacity of a specific technology. It is related to the spectral efficiency of mobile communication systems but contains many other factors. S_{es} has the unit dimension of Mbit/s/MHz/cell. which is a direct equivalent to bits/s/Hz/cell. $Net\_System\_\ Capability_{es}$ is not the same as spectral efficiency of the radio transmission technology. It is comprised of a number of effects that are combined in a complex manner appropriate to the radio transmission technology and the service type “s” and environment “e”. Often the values required to determine the $Net\_System\_Capability_{es}$ are obtained from the results of complex system simulations.

The major components of the Net_System_Capability$_{es}$ may include the following:

1) Radio transmission technology design or engineering impacts including but not limited to:
   - physical spectral efficiency of access technology used;
   - requirements of a specific Eb/N0;
   - requirements of a specific C/I;
   - requirements for a specific frequency reuse plan;
   - coding factors used by the radio transmission technology;
   - overhead factors used by the radio transmission technology;
   - environment – indoor, outdoor, stationary, pedestrian, vehicular.
2) Deployment models and/or deployment technique including microcells, macrocells, hierarchical cells, or overlay cells, etc.

It therefore follows that there is a tradeoff between Net_System_Capability$_{es}$ and the quality or grade of service.

C5 Calculate Net_System_Capability$_{es}$

S_{es} = Function of {Spectral Efficiency, Coding Factor, Overhead Factor, Deployment Model, and other factors}.

This calculation proceeds using the values and parameters discussed previously as a function of appropriate combining functions.

D Spectrum results considerations

D1 Calculate individual F_{es} Component for a given direction

- uplink (from the mobile station to the base station); or
- downlink (from the base station to the mobile station).

The amount of spectrum required for a given service and environment, in a given direction, is determined by dividing the Traffic$_{es}$ (as determined in § C3) by the Net_System_Capability$_{es}$ (as determined in § C4).

$F_{es} = T_{es}/S_{es}$ (either uplink or downlink) **Units: MHz**

D2 Repeat process for calculation of other direction (either downlink or uplink as appropriate)

Repeat steps A2 through D1 for the other direction (if not previously calculated).

D3 Calculate F_{es} for the Service “s”, combining uplink and downlink components

The total amount of spectrum required for a given service and environment is determined by directly adding the spectrum required for the uplink and downlink components.

$F_{es} = (F_{es}$ uplink $+ F_{es}$ downlink) **Units: MHz**

D4 Repeat process (steps A1 through D3) for all desired “e”, “s”

Repeat steps A1 through D3 for each combination of “e” and “s” that is being considered.

D5 Determine weighting factor (α_{es}) applicable to each individual F_{es} Units: None

The weighting factor (α_{es}) provides appropriate weighting in the spectrum requirements calculations and includes the following:

– weighting to adjust for geographical offsets in overlapping environments;

– weighting to correct for non-simultaneous busy hour traffic requirements.

The value for α_{es} may range from zero up to unity, and the default value is 1.

D6 Determine adjustment factor (β) Units: None

The adjustment factor (β) provides for impacts such as:

– multiple operators (reduced trunking/spectral efficiency);

– sharing with other IMT-2000 services/systems;

– sharing with non-IMT-2000 services/systems;

– guard bands;

– technology modularity. For example, if a technology uses 10 MHz frequency division duplex (FDD) channels, then the requirements will necessarily be an integer factor of 20 MHz;

– other adjustments to be justified.

This adjustment factor is an approximation across impacts of environments "e", services "s" and other influences. The default value for β is 1, and other values should be technically justified.

D7 Calculate the final total $F_{Terrestrial}$ Spectrum Value Units: MHz

For each environment and service, each F_{es} is multiplied by α_{es}, and then the individual products are added together. The result of the summation is multiplied by the adjustment factor (β) to derive the total terrestrial spectrum required $F_{Terrestrial}$.

$$F_{Terrestrial} = \beta \, \Sigma \alpha_{es} \, F_{es} \quad \text{MHz}$$

APPENDIX 1

Example calculations

This example provides guidance on the application of the methodology detailed in §§ 2 and 3 of Annex 1.

The example is calculated with parameter values estimated from market research on public land mobile communications services, including IMT-2000, and with technical parameter values estimated from IMT-2000 radio transmission technologies, for the year 2010 view. The results shown in this example should not be considered as providing an answer to the question of future spectrum requirements for public land mobile communications services, including IMT-2000, as all environments and services that must be considered for completeness may have not been included in the example.

Examination of environments and services reveals that there are potentially twelve values of the subscript "e" and six values for the subscript "s" that are representative major contributors to a spectrum requirement. Hence, a complete calculation of the terrestrial spectrum requirement estimate for public land mobile communications services, including IMT-2000, would require the use of 72 terms in the summation of individual F_{es} terms.

This example is based on a representative subset of environments and services as presented in the matrix below and these are sufficient to exercise all aspects of the methodology.

Representative environments "e" and services "s" (values for F_{es})

Environments "e"	High density-in building (CBD)	Urban pedestrian	Urban vehicular
Services "s"			
Speech (S)	F_{es}	F_{es}	F_{es}
Simple Message (SM)	F_{es}	F_{es}	F_{es}
Switched Data (SD)	F_{es}	F_{es}	F_{es}
Medium Multimedia (MMM)	F_{es}	F_{es}	F_{es}
High Multimedia (HMM)	F_{es}	F_{es}	F_{es}
High Interactive Multimedia (HIMM)	F_{es}	F_{es}	F_{es}

The figures presented in the tables below are often rounded figures, but the calculation is performed with more digits to provide more accurate example results.

A Example for the year 2010

A1 Environment

A subset of all environments is considered for the purpose of this example: only high density-in building also generally known as Central Business District (CBD); urban pedestrian, and urban vehicular. This subset of three environments is extracted from all possibilities because they correspond to superimposed layers in city centres.

It should be noted that no user should occupy two operational environments at a time.

A2 Direction of calculation

– uplink (from the mobile station to the base station); or

– downlink (from the base station to the mobile station).

The following calculations are detailed for each of the direction.

A3 Establish representative cell_area and geometry

The environments are defined to have the following geometry:

TABLE 1

Environment description

Environment "e"	High density-in building (CBD)	Urban pedestrian	Urban vehicular
$Geometry_e$	Circular	Hexagonal with three sectors	Hexagonal with three sectors
Cell $dimension_e$	Diameter = 100 m	Radius = 600 m	Radius = 600 m

A4 Calculate Cell_Area

Based on the cell description, the cell areas are calculated as follows:

TABLE 2

$Cell\_Area_e$

Environment "e"	High density-in building (CBD)	Urban pedestrian	Urban vehicular
$cell\_area_e$ (km^2)	7.85×10^{-3}	3.12×10^{-1}	3.12×10^{-1}

B1 Select service "s"

The services are as follows:

TABLE 3

Description of Service_Type "s" and corresponding $Net\_User\_Bit\_Rate_s$

$Net\_User\_Bit\_Rate_e$	Downlink (DL) net bit rate (kbit/s)	Uplink (UL) net bit rate (kbit/s)
Service Type "s"		
Speech (S)	16	16
Simple Message (SM)	14	14
Switched Data (SD)	64	64
Medium Multimedia (MMM)	384	64
High Multimedia (HMM)	2 000	128
High Interactive Multimedia (HIMM)	128	128

B2 Establish Population_Density

For the three environments considered, population densities can be chosen as follows:

TABLE 4

$Population\_Density_e$

Environment "e"	High density-in building (CBD)	Urban pedestrian	Urban vehicular
$Population\_Density_e$	250 000	100 000	3 000

B3 Establish Penetration_Rate$_{es}$

The following table describes the penetration rates used in this example calculation:

TABLE 5

Penetration_Rate$_{es}$ in Percent

Environments "e" / Services "s"	High density-in building (CBD)	Urban pedestrian	Urban vehicular
Speech (S)	73%	73%	73%
Simple Message (SM)	40%	40%	40%
Switched Data (SD)	13%	13%	13%
Medium Multimedia (MMM)	15%	15%	15%
High Multimedia (HMM)	15%	15%	15%
High Interactive Multimedia (HIMM)	25%	25%	25%

B4 Calculate Users/Cell$_{es}$

The table below gives the Users/Cell$_{es}$ calculated with the above assumptions:

TABLE 6

Users/Cell$_{es}$

Environments "e"	High density-in building (CBD) number of users	Urban pedestrian number of users	Urban vehicular number of users
Services "s"			
Speech (S)	1 433	22 756	683
Simple Message (SM)	785	12 469	374
Switched Data (SD)	255	4 052	122
Medium Multimedia (MMM)	295	4 676	140
High Multimedia (HMM)	295	4 676	140
High Interactive Multimedia (HIMM)	491	7 793	234

B5 Establish traffic parameters

The following traffic parameters are considered representative of the average user in each of the environment for each of the services:

TABLE 7

$Busy\_Hour\_Call\_Attempt_{es}$ expressed as calls in busy hour

Environments "e"	High density-in building (CBD) calls in busy hour		Urban pedestrian calls in busy hour		Urban vehicular calls in busy hour	
Services "s"						
Speech (S)	0.9		0.8		0.4	
Simple Message (SM)	0.06		0.03		0.02	
Switched Data (SD)	0.2		0.2		0.02	
Medium Multimedia (MMM)	0.5		0.4		0.008	
High Multimedia (HMM)	0.15		0.06		0.008	
High Interactive Multimedia (HIMM)	0.1		0.05		0.008	

TABLE 8

$Call\_Duration_{es}$ in seconds

Environments "e"	High density-in building (CBD) seconds		Urban pedestrian seconds		Urban vehicular seconds	
Services "s"						
Speech (S)	120		120		120	
Simple Message (SM)	30		30		30	
Switched Data (SD)	156		156		156	
Medium Multimedia (MMM)	13.9		13.9		13.9	
High Multimedia (HMM)	53.3		53.3		53.3	
High Interactive Multimedia (HIMM)	180		180		180	

TABLE 9

Activity_Factor$_{es}$

Environments "e"	High density-in building (CBD) dimensionless		Urban pedestrian dimensionless		Urban vehicular dimensionless	
Services "s"	Uplink	Downlink	Uplink	Downlink	Uplink	Downlink
Speech (S)	0.5	0.5	0.5	0.5	0.5	0.5
Simple Message (SM)	1	1	1	1	1	1
Switched Data (SD)	1	1	1	1	1	1
Medium Multimedia (MMM)	1	1	1	1	1	1
High Multimedia (HMM)	1	1	1	1	1	1
High Interactive Multimedia (HIMM)	0.8	0.8	0.8	0.8	0.8	0.8

B6 Calculate Traffic/User$_{es}$

TABLE 10

Traffic/User$_{es}$ in call-seconds

Environments "e"	High density-in building (CBD) call-seconds		Urban pedestrian call-seconds		Urban vehicular call-seconds	
Services "s"	Uplink	Downlink	Uplink	Downlink	Uplink	Downlink
Speech (S)	54	54	48	48	24	24
Simple Message (SM)	1.8	1.8	0.9	0.9	0.6	0.6
Switched Data (SD)	31.2	31.2	31.2	31.2	3.12	3.12
Medium Multimedia (MMM)	6.95	6.95	5.56	5.56	0.111	0.111
High Multimedia (HMM)	8	8	3.2	3.2	0.427	0.427
High Interactive Multimedia (HIMM)	14.4	14.4	7.2	7.2	1.15	1.15

B7 Calculate Offered_Traffic/$Cell_{es}$

TABLE 11A

Offered_Traffic/$Cell_{es}$ in call-seconds

Environments "e"	High density-in building (CBD) call-seconds		Urban pedestrian call-seconds		Urban vehicular call-seconds	
Services "s"	Uplink	Downlink	Uplink	Downlink	Uplink	Downlink
Speech (S)	7.74×10^4	7.74×10^4	1.09×10^6	1.09×10^6	1.64×10^4	1.64×10^4
Simple Message (SM)	1.41×10^3	1.41×10^3	1.12×10^4	1.12×10^4	2.24×10^2	2.24×10^2
Switched Data (SD)	7.96×10^3	7.96×10^3	1.26×10^5	1.26×10^5	3.79×10^2	3.79×10^2
Medium Multimedia (MMM)	2.05×10^3	2.05×10^3	2.60×10^4	2.60×10^4	1.56×10^1	1.56×10^1
High Multimedia (HMM)	2.36×10^3	2.36×10^3	1.50×10^4	1.50×10^4	5.98×10^1	5.98×10^1
High Interactive Multimedia (HIMM)	7.07×10^3	7.07×10^3	5.61×10^4	5.61×10^4	2.69×10^2	2.69×10^2

The group size is selected to be equal to 7. The Offered Traffic/Cell shown below is the traffic across all 7 cells expressed in Erlangs.

TABLE 11b

Offered_Traffic/$Cell_{es}$ ∗Group_$Size_{es}$in Erlangs

Environments "e"	High density-in building (CBD) call-seconds		Urban pedestrian call-seconds		Urban vehicular call-seconds	
Services "s"	Uplink	Downlink	Uplink	Downlink	Uplink	Downlink
Speech (S)	150.5	150.5	2123.88	2123.88	31.86	31.86
Simple Message (SM)	2.75	2.75	21.82	21.82	0.44	0.44
Switched Data (SD)	15.49	15.49	245.85	245.85	0.74	0.74
Medium Multimedia (MMM)	3.98	3.98	50.51	50.51	0.03	0.03
High Multimedia (HMM)	4.58	4.58	29.09	29.09	0.12	0.12
High Interactive Multimedia (HIMM)	13.74	13.74	109.1	109.1	0.52	0.52

B8 Establish Quality_of_Service_Function$_{es}$ (QOS$_{es}$) parameters

The quality of service function for circuit switched is selected to be Erlang B with a blocking of 2%. For packet-switched services the Quality of service function is a rounding up to the next integer number.

C1 Calculate number of Service_Channels/Cell$_{es}$ required to carry Offered_Traffic/Cell$_{es}$

The number of traffic channels required in the group is presented below:

TABLE 12a

Service_Channels per Group

Environments "e"	High density-in building (CBD)		Urban pedestrian		Urban vehicular	
Services "s"	Uplink	Downlink	Uplink	Downlink	Uplink	Downlink
Speech (S)	164	164	2 137	2 137	41	41
Simple Message (SM)	3	3	22	22	1	1
Switched Data (SD)	23	23	259	259	4	4
Medium Multimedia (MMM)	4	4	51	51	1	1
High Multimedia (HMM)	5	5	30	30	1	1
High Interactive Multimedia (HIMM)	21	21	122	122	3	3

The number of traffic channels required in the cell is service channels in the group divided by the group size of 7 and then rounded up. It is presented below:

TABLE 12b

Service_Channels/Cell$_{es}$

Environments "e"	High density-in building (CBD)		Urban pedestrian		Urban vehicular	
Services "s"	Uplink	Downlink	Uplink	Downlink	Uplink	Downlink
Speech (S)	23.43	23.43	305.3	305.3	5.86	5.86
Simple Message (SM)	0.43	0.43	3.14	3.14	0.14	0.14
Switched Data (SD)	3.29	3.29	37.0	37.0	0.57	0.57
Medium Multimedia (MMM)	0.57	0.57	7.29	7.29	0.14	0.14
High Multimedia (HMM)	0.71	0.71	4.29	4.29	0.14	0.14
High Interactive Multimedia (HIMM)	3.0	3.0	17.43	17.43	0.43	0.43

C2 Determine Service_Channel_Bit_Rate$_{es}$ needed to carry Net_User_Bit_Rate$_{s}$

In this example, it is assumed that the Service_Channel_Bit_Rate$_{es}$ is equal to the Net_User_Bit Rate$_{s}$.

TABLE 13

Service_Channel_Bit_Rate$_{es}$

Environments "e"	High density-in building (CBD) (kbit/s)		Urban pedestrian (kbit/s)		Urban vehicular (kbit/s)	
Services "s"	Uplink	Downlink	Uplink	Downlink	Uplink	Downlink
Speech (S)	16	16	16	16	16	16
Simple Message (SM)	14	14	14	14	14	14
Switched Data (SD)	64	64	64	64	64	64
Medium Multimedia (MMM)	64	384	64	384	64	384
High Multimedia (HMM)	128	2 000	128	2 000	128	2 000
High Interactive Multimedia (HIMM)	128	128	128	128	128	128

C3 Calculate Traffic$_{es}$

Based on the number of channels needed and on the service channel bit rate, the traffic in each cell can be derived.

TABLE 14

Traffic$_{es}$

Environments "e"	High density-in building (CBD) (Mbit/s/cell)		Urban pedestrian (Mbit/s/cell)		Urban vehicular (Mbit/s/cell)	
Services "s"	Uplink	Downlink	Uplink	Downlink	Uplink	Downlink
Speech (S)	0.37	0.37	4.88	4.88	0.09	0.09
Simple Message (SM)	0.01	0.01	0.04	0.04	0.002	0.002
Switched Data (SD)	0.21	0.21	2.37	2.37	0.04	0.04
Medium Multimedia (MMM)	0.04	0.22	0.47	2.80	0.01	0.05
High Multimedia (HMM)	0.09	1.43	0.55	8.57	0.02	0.29
High Interactive Multimedia (HIMM)	0.38	0.38	2.23	2.23	0.05	0.05

C4 Net_System_Capabiliy_ Parameters$_{es}$ (S$_{es}$)

A number of parameters must considered in determining key elements that influence the value of Net_System_Capability$_{es}$.

C5 Calculate Net_System_Capability$_{es}$

For the purpose of this example, an improvement factor that is the expected improvement of system capabilities in the year 2010 relative to current systems is applied to current generation capabilities to obtain Net_System_Capability$_{es}$.

In this example, the following net system capabilities have been used:

TABLE 15

Net_System_Capability$_{es}$ (S_{es})

Environments "e"	High density-in building (CBD) (kbit/s/MHz/cell)		Urban pedestrian (kbit/s/MHz/cell)		Urban vehicular (kbit/s/MHz/cell)	
Services "s"	Uplink	Downlink	Uplink	Downlink	Uplink	Downlink
Speech (S)	67	67	67	67	67	67
Simple Message (SM)	73	73	73	73	73	73
Switched Data (SD)	73	73	73	73	73	73
Medium Multimedia (MMM)	73	73	73	73	73	73
High Multimedia (HMM)	73	73	73	73	73	73
High Interactive Multimedia (HIMM)	73	73	73	73	73	73

D1 Calculate individual F_{es} component for a given direction (either uplink or downlink)

D2 Repeat process for calculation of other direction (either downlink or uplink as appropriate)

Using the traffic calculated above and the example net system capability, the F_{es} components for each direction, each environment and each direction can be derived as follows:

TABLE 16

Individual spectrum requirements (F_{es})

Environments "e"	High density-in building (CBD) (MHz)		Urban pedestrian (MHz)		Urban vehicular (MHz)	
Services "s"	Uplink	Downlink	Uplink	Downlink	Uplink	Downlink
Speech (S)	5.6	5.6	72.9	72.9	1.4	1.4
Simple Message (SM)	0.08	0.08	0.6	0.6	0.03	0.03
Switched Data (SD)	2.9	2.9	32.4	32.4	0.5	0.5
Medium Multimedia (MMM)	0.5	3.0	6.4	38.3	0.1	0.8
High Multimedia (HMM)	1.3	19.6	7.5	117.4	0.3	3.9
High Interactive Multimedia (HIMM)	5.3	5.3	30.6	30.6	0.8	0.8

D3 Calculate F_{es} for the service “s”, combining uplink and downlink components

The summation gives the following results:

TABLE 17

F_{es} combining the uplink and downlink components

Environments “e”	High density-in building (CBD) (MHz)	Urban pedestrian (MHz)	Urban vehicular (MHz)
Services “s”			
Speech (S)	11.2	145.8	2.8
Simple Message (SM)	0.2	1.2	0.05
Switched Data (SD)	5.8	64.9	1.0
Medium Multimedia (MMM)	3.5	44.7	0.9
High Multimedia (HMM)	20.8	124.9	4.2
High Interactive Multimedia (HIMM)	10.5	61.1	1.5

D4 Repeat process (steps A1 through D3) for all desired F_{es}

The results have been presented in tables that show the values for all services “s” and all environments “e”.

D5 Determine weighting factor (α_{es}) applicable to each individual F_{es}

If all services are assumed to have coincident busy hours, and the three environments are collocated in the same geographical area, the weighting factors are assumed to be one:

$$\alpha_{es} = 1 \text{ for all “e” and “s”}$$

D6 Determine adjustment factor (β)

To take account of the trunking inefficiency and the guard bands, an adjustment factor of 5% can be taken.

$$\beta = 1.05$$

D7 Calculate the final total $F_{Terrestrial}$ spectrum value

For this example, the summation of the components with the adjustment factor gives:

$$F_{Terrestrial} = 530.3 \text{ MHz}$$

In this example, the result shown for $F_{Terrestrial}$ is the spectrum requirement estimate for public land mobile radio service, including IMT-2000, in the year 2010 because of assumptions made in the traffic and market forecasts, (namely, that the forecasts included first and second generation public land mobile radio services, and future expected IMT-2000 services).

In must be restated that, the results shown in this example should not be considered as providing an answer to the question of future spectrum requirements for public land mobile communications services, including IMT-2000, as all figures given in this example are still under study and all environments and services that must be considered for completeness may have not been included in the example.