Mannesman's D2 GSM buildout in Germany. I participated in all levels of the design from original radio propagation analysis, to system rollout and optimization. I remained in Germany through the first year of commercial GSM wireless network operation leading the engineering team in GSM capacity analysis and related system planning.

4. In 1993, I joined QUALCOMM in San Diego to create that company's commercial wireless system design group. At that time, CDMA technology (handsets and base stations) had been shown to work, but no one had ever designed large scale CDMA networks employing the techniques used for AMPS, TDMA and GSM networks. My group was tasked with designing commercial CDMA networks for QUALCOMM's clients and potential clients. We had to start from scratch, designing the software and tools that we had at that time to design networks. I supervised the design of literally hundreds of wireless networks, for markets in the United States, South America, Europe, Africa, and Asia.

5. In 1998, I left QUALCOMM to join Leap as CTO, just as that company was being formed. As the Chief Technical Officer of Leap I have participated in many levels of wireless technology evaluation from a strategic level, and have spent significant resources analyzing wireless spectrum requirements using various technologies. I have also both promoted and analyzed wireless data applications for use in Leap's systems. This ranges from analysis of commercial CDMA systems, to 3G systems and includes evaluation of all potential wireless networks, including those at different spectral bands. Now, in addition to leading Leap's strategic technical direction, I'm responsible for the wireless data engineering group that was acquired late last year.

6. I sit on the Board of the CDMA Development Group (CDG). I have delivered speeches and presentations on behalf of Leap numerous times since our founding. I testified on behalf of the Personal Communications Industry Association (PCIA) during Chairman Tauzin's hearings regarding the spectrum cap in the summer of 2000.

7. Additionally, I have written and presented numerous technical articles for trade and other publications.

II. Summary of Conclusions

8. I am submitting this declaration in order to address what I perceive to be widely-held misconceptions about issues that are of fundamental importance to the Commission's decision on whether to retain or abandon the spectrum cap. I address three basic points, in turn:

9. **First**, I address the commonly-held misconception that 45 MHz is not enough spectrum to provide adequate wireless services today. 45 MHz is a huge amount of spectrum, and efficient carriers should need only a fraction of that amount in virtually all markets in the U.S.. Yet many carriers believe it is their birthright to use inefficient and often outdated technology.

10. **Second**, I address the commonly-held misconception that wireless data applications will require carriers to use significantly more spectrum. Most data applications, as it turns out, use surprisingly little bandwidth. And even the ultra-high-bandwidth applications that are predicted eventually to arrive on the wireless marketplace can be accommodated within existing spectrum holdings.

11. **Third**, I address the commonly-held misconception that the United States should follow the example of foreign countries in adopting a higher spectrum

aggregation limit. In fact, the denser populations and market characteristics in those foreign countries render higher spectrum allocations more appropriate there than here.

12. In sum, I conclude that there is no reason for the Commission to raise or abolish the spectrum cap at this time. If anything, and in light of recent and upcoming radical advances in wireless technology, the commission should consider lowering the cap of this precious public resource.

III. Mobile Wireless Spectrum is a Scarce Resource

13. There is approximately 2000 MHz of radio spectrum that is ideally suitable for mobile wireless communications. Frequencies much lower than 500 MHz propagate too easily – the signal carries too far – so that spectrum cannot be easily reused in multiple discrete cells, as is necessary to operate a successful mobile wireless system. Likewise, much above 2500 MHz the signal fades too easily: the general range from a tower (all other parameters being equal) is inversely proportional to the *square* of the frequency. Thus, in theory it takes approximately *four times* the number of cells sites to cover the same geographic area at 1900 MHz as it does at 800 MHz. And it would take twice as many again to cover the same area at 2690 MHz. Therefore, the total available ideal mobile wireless spectrum on the planet can be considered to be roughly in the range between 500 MHz and 2500 MHz. Go lower and the cells become too large and capacity too small. Go higher and the cells become too small and the service will suffer from coverage/service problems.

14. As it turns out, the same general range of frequencies that is optimal for mobile wireless services is optimal (but in many cases not as essential)for other services as well. Therefore, a number of other types of users must function within

that 2,000 MHz band. These include microwave transmission, fixed wireless services, dispatch and public safety, maritime communication systems, etc.

15. Historically, aside from limited dispatch services, there was a dearth of commercial demand for mobile services. Because of this, and because the spectrum could easily accommodate certain fixed use applications, it was allocated to such things as operational fixed services. However, in the long run, the applicability of the spectrum to mobile uses will become increasingly obvious and more of the fixed services will be relocated to spectrum that is less ideal for mobile applications.

16. There is currently a total of 188 MHz of spectrum allocated for CMRS use in the United States. This includes 50 MHz in the 800 MHz cellular bands, 120 MHz in the 1900 MHz PCS bands, and an additional 18 MHz in the SMR bands. The FCC has proposed to allocate, or is in the process of allocating, an additional 36 MHz in the 700 MHz band. This finite amount of spectrum must accommodate the voice and data applications of every wireless carrier, so it bears examining how those carriers are using their respective slices of spectrum, and whether they need more, or could get by with less.

IV. 45 MHz is a Tremendous Amount of Spectrum, Providing it is Used Efficiently

17. I have seen many carriers claim that they are facing capacity constraints on their ability to expand and add new customers, and that they therefore need more spectrum than they can acquire under the current 45 MHz spectrum cap. The fact is that 45 MHz is a huge amount of spectrum. 45 MHz should more than fill any carrier's spectrum needs – *providing they use it efficiently*. If a carrier finds itself capacity

constrained with 45 MHz, that can only be because it is using inefficient and/or outdated technology.

A. Network capacity, not the amount of available spectrum, is what matters

18. Obviously, spectrum is a scarce resource, so it becomes very important to determine how much spectrum is necessary to deliver the product that wireless carriers sell to their customers – airtime minutes. As it turns out, the amount of spectrum required by a carrier to deliver the same amount of wireless service can vary widely depending on the technology and architecture of its network.

19. The capacity of a wireless network is determined by how many customers can use the network while maintaining good telephone system performance across the breadth of the geographic market. In the design of any large area / heavy use system there is always a tradeoff between cost and performance. Commercial mobile networks are designed to balance the cost of providing service with the end user performance. Much like power systems, freeways or water/sewer systems, there are always localized areas of congestion and peak hours of use. Mobile systems are designed to offer good service everywhere in the market area during the peak use times for the majority of customers.

20. Wireless engineers typically measure the capacity of a telephone network in units called Erlangs (named after a Danish mathematician who was the first to study the problem of telephone traffic congestion). One Erlang is equal to sixty minutes of actual use of a single channel: an hour-long phone call from a single customer, or thirty simultaneous two minute phone calls from thirty users, both represent one Erlang.

21. This metric has been used for many years to evaluate system capacity traded with system quality (the probability to make a call) on both fixed and mobile networks. Generally, fixed telephone systems operate with an exceptionally high level of quality: 0.1% "blocking" probability or better, while during their busiest hours mobile systems operate with closer to 1-2% blocking probability.

B. Network capacity varies widely according to the technology used

22. In this section, I'll compare the capacity of the major wireless technologies in use today. The analysis reveals that the amount service a carrier can provide depends more on the efficiency of a carrier's technology than it does the amount of spectrum it uses. In fact, the least efficient systems in use today would require more than the entire 180 MHz of CMRS spectrum that is now available, just to deliver the system capacity that is delivered on 10 MHz of spectrum using the most efficient technology in use today.

23. First, I should explain a bit about the different technical standards that are now used in the United States. AMPS is the original analog system used by all cellular carriers. TDMA is the North American IS54/IS136 system used by some U.S. carriers, most prominently AT&T and its affiliates (Tritel, TeleCorp, and Triton). GSM is a European-designed second generation digital technology whose most prominent user in the United States is VoiceStream (and some Cingular markets), and is the dominant standard in Europe. In the comparisons in this section included different versions of CDMA technology: The first of these is CDMA 95A, which was rolled out in 1996 through 1998. The next is CDMA 95A/EVRC, which is the most advanced technology currently available. I've also included in some of my comparisons a so-called "third

generation" or "3G" technology that will be deployed in the U.S. in late 2001: CDMA 1X, also sometimes called CDMA2000 1X, or IMT 2000 MC 1X.[1]

24. The following chart represents the capabilities of the technology that will be deployed commercially in North America through the end of this year. The second column, Erlangs per 10 MHz is a measure of the pure capacity of the system, and in the third column I've calculated the number of subscribers the system could support, if the average subscriber uses 50 milliErlangs per month:

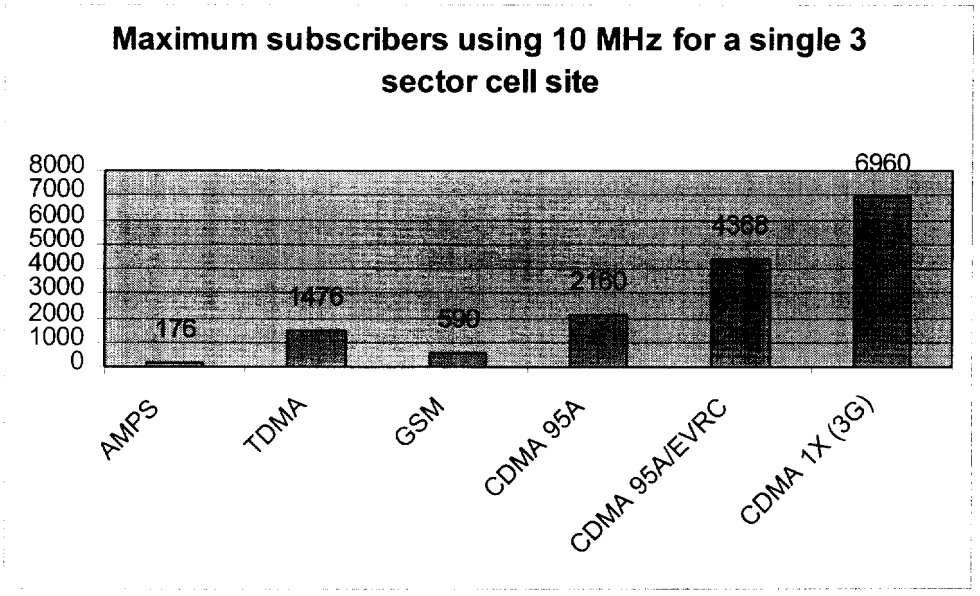
Technology	Channel Bandwidth(MHz)	Erlangs per 10 MHz	Subs (50 mE/sub)
AMPS	0.030	2.94	176
TDMA	0.030	24.60	1476
GSM	0.200	9.83	590
CDMA 95A	1.250	36.00	2160
CDMA 95A/EVRC	1.250	72.80	4368
CDMA 1X (3G)	1.250	116.00	6960

25. I should note that in this chart I'm simplifying somewhat, by using ideal assumptions. In the real world, factors such as non-ideal sector use and the need to use guard bands cause actual system capacity to fall below the numbers in this chart. These "real world" factors tend to reduce capacity commensurately across all technologies, so my idealized numbers are valid for purposes of comparison. Nonetheless, it bears mentioning that CDMA performance is the least denigrated by these

[1] I have not included in these comparisons the "3G" migrations for GSM and TDMA, because these are not planned for commercial operation in the U.S. in the near future: they will not be available in 2001 or even (to the author's knowledge) 2002. However, it bears noting that GSM will be followed by WCDMA technology in Europe and TDMA technology probably will be followed by EDGE technology in the Americas.

factors: CDMA compensates for non-ideal sector loading by using dynamic allocation of radio resources across sectors.[2]

26. The next graph, simply puts in graphical form the third column of the above chart: it compares the number of "average" subscribers (at 50 milliErlangs each) that could be carried on a system using 10 MHz of spectrum, with each of these technologies.

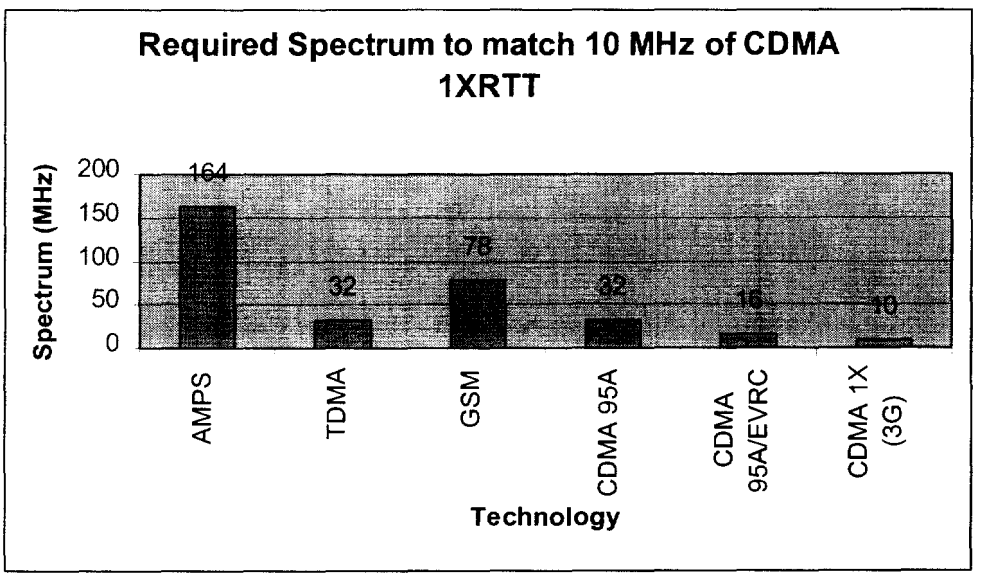


Once the overall *capacity* of a system is determined (in Erlangs), further calculations can be made to determine the number of *subscribers* that the system can support. The key determinant of ultimate subscriber capacity is, of course, Erlangs per subscriber during the busy hour. That is, how much the average subscriber uses the system. Other determinants include call blocking (grade of service, the inability to make a call due to lack of resources) and trunking efficiency. In the preceding tables, I've made some

[2] To the extent that techniques have been proposed and even deployed to increase the capacity of TDMA and GSM networks, such as hierarchical cells (micro cells), these techniques also could be employed in CDMA systems when needed.

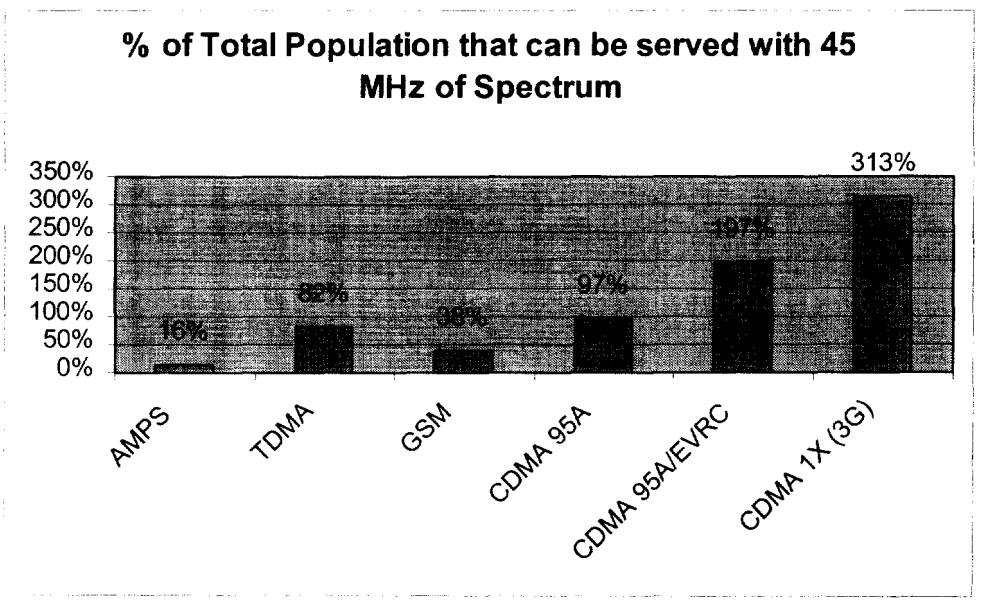
standard assumptions, and I've used a high-use call model (1,000 minutes of use per customer per month) similar to the model that is used in Leap's Cricket service plan in order to estimate the ultimate system capacity. This analysis is an ideal case: it uses no guard bands, and 100% efficiency is assumed for each technology.[3]

27. Clearly, some technologies deliver far higher system capacity than others. Put another way (and extending the simple analysis above), we might say that the same capacity that could be served using 10 MHz of spectrum on a CDMA2000 1XRTT system (available this fall), would require 16 MHz with a CDMA 95A/EVRC system, 32 MHz on a CDMA 95 system or TDMA system, 78 MHz of spectrum on a GSM system 164 MHz of spectrum on an AMPS system. The following graph graphically represents this comparison.



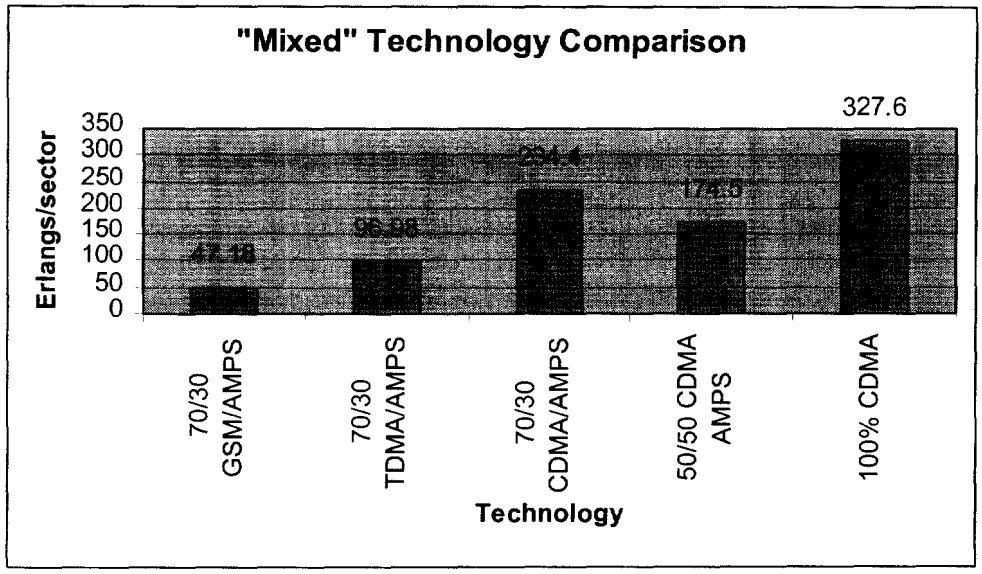
[3] Like CDMA 1X, European/Japanese WCDMA will also improve data speed and voice spectral capacity, but this technology is not included here because the exact future performance of these systems is not known at this time by the author.

28. This comparison is oversimplified, because networks cannot be designed around odd lots of spectrum. Rather, channel blocks of a certain minimum size (depending on the technology) must be used. The following chart compares the amount of spectrum required by the various technologies to serve a fixed loads. The following chart shows the percentage of population that can be covered if 45 MHz of spectrum was available to a single wireless carrier. The assumption here was that each cell site provided coverage for 10,000 people – the metric that Leap has used in designing high capacity networks. In other words, we design our system to that eacy cell site has approximately 10,000 residents. Keep in mind that this is the relative to the total population – this is 45 out of the total of 188 MHz available for all the wireless carriers in a single market. The other factor to keep in mind is that despite the fact that there are four or more competitors in all markets, they must divide the 100% population.



29. This last chart shows today's common scenario – mixed technology systems. All original cellular companies have 25 MHz of spectrum in the 800

MHz Cellular band and potentially up to another 20 MHz in the PCS spectrum band. They are in the midst of migrating their subscribers to digital systems. Here, CDMA denotes ANSI 95A w/EVRC.



30. These charts demonstrate that a carrier's "need" for spectrum is entirely dependent upon the technology it uses. The same carrier that was capacity constrained with 45 MHz of spectrum using a AMPS system would have surplus capacity using just 15 MHz of spectrum using a CDMA system.

V. Data Applications Will Not Require Significant Additional Spectrum

31. The above analysis demonstrates that efficient carriers should need very little spectrum to carry very large loads of voice traffic. For example, a carrier using CDMA 95 A/EVRC could use 10 MHz of spectrum to carry 15,000 customers per cell site with an average of 200 minutes of use per customer per month. Some carriers, however, state that they require additional spectrum in order to support wireless data applications. This assertion is worth examining.

A. Text-Based Applications Require Little Bandwidth

32. Mobile wireless data applications deployed during the past 2-3 years around the world include short message services (SMS) and Wireless Application Protocol (WAP) text browsing. Some carriers allow full Internet access of all available content (such as the i-mode service from DoCoMo in Japan) and others maintain a "walled garden" of content. Most all have a mix of specialized content and allow access to wider browsing by allowing wireless URLs to be entered on the handset. These applications use a scant amount of spectrum compared to voice calls.

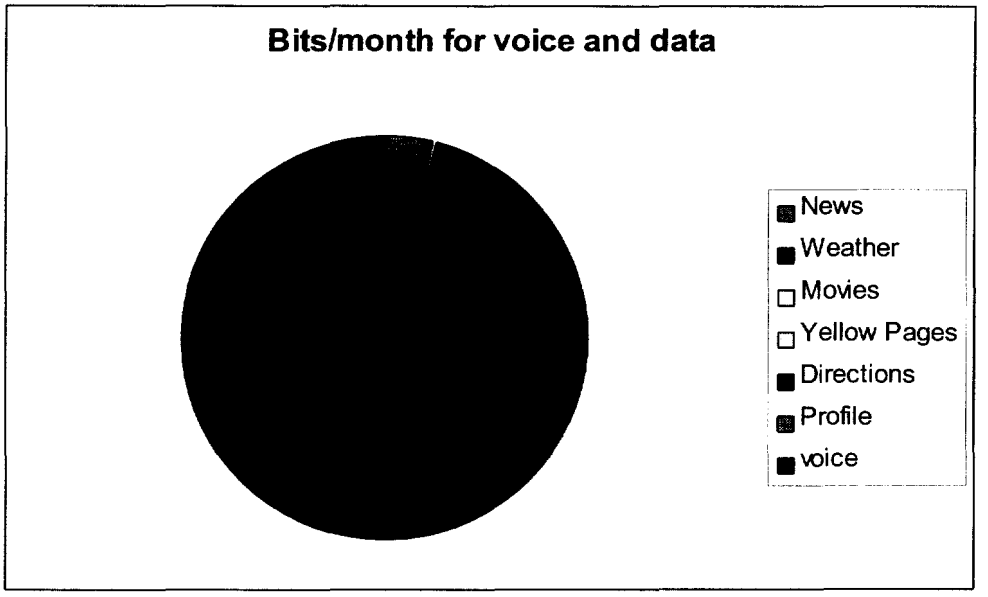
1. Short-Message Service

33. A typical SMS message is 100 ASCII characters long. Transmission of a 100 character message requires 800 bits of information data. A typical phone call is 100 seconds long. Standard second-generation digital vocoders use an average of about 4,000 bits per second (EVRC average rate). Therefore, a typical phone call requires the transmission of approximately 400,000 bits of data: the equivalent of about 400 text messages. Research shows that even the heaviest SMS users send approximately 5-10 messages per hour during periods of peak usage. Requiring 5,000 to 10,000 per hour among even the heaviest users, this is clearly a nominal spectrum requirement.

2. Wireless Application Protocol

34. Text browsing using WAP handsets, as currently deployed by AT&T, Sprint, Verizon, Nextel and others has similarly minimal capacity requirements. In the WAP structure there is a maximum download per deck of 1400 bytes. There are many decks viewed in a typical browsing session. A typical session uses a tiny amount of data. With the help of a senior software engineer who is intimately familiar with WAP usage patterns through development of them, I have created a model usage pattern to

predict the capacity requirements of an average "wireless web" user. Thus, I assume that the average user checks the weather daily, reads the news twice a day, and so on, and then determine the typical data requirements for each function. The result of this usage pattern demonstrates that *the **monthly** use would be about same quantity of bytes transferred as one of our Cricket users uses for voice **in a single day**!* The following charts show the monthly data requirements for the typical regular wireless web user.



Data application	Mbits/month with regular use
News	7.3
Weather	0.35
Movies	0.53
Yellow Pages	0.64
Directions	0.12
Profile	0.08

As a point of reference, a 4 Kbps (average rate) vocoder transmits 400 kilobits on an average phone call; for a heavy use mobile network like Leap's Cricket, this translates to 2400 Mbits/month.

3. Other (Future) Services

35. Of course, the above analysis is limited to applications that are currently available on the "wireless web." Industry observers appear to expect other advanced wireless features to develop. These are expected to include: location based services, mobile commerce, travel and restaurant guides and the like. These applications are alike in that they are essentially text-based, and as such (because text requires so little data) they will require relatively little bandwidth.

36. Additionally, many within the industry expect vertical applications, such as sales force automation, customer relation management and real estate property locators, to take hold. These would be customized applications allowing mobile workers to gain access to data outside the office: for example what leads a salesman should be following, what inventory is in the warehouse, and which new home just came on the market. Again, like SMS and WAP browsing, these text-based applications would be relatively thin-bandwidth applications.

37. From the standpoint of wireless network capacity and data transmission ability, these applications could be implemented today. The success of these applications will depend more on advances in such technologies as GPS systems, handset screen size and overall system security. And of course, the commercial success of these applications will require business and marketing developments: it remains to be seen what products the public will buy. What these applications really don't require is new spectrum.

B. High-Bandwidth Applications Are Not Available With Today's CMRS Technology

38. The above analysis demonstrates that text-based applications require very little bandwidth, and require far less than the capacity requirements of voice telephony. Some data applications, however, may use more. The only data applications that use significantly more capacity than standard voice are those that involve high-quality audio, image transfers or video. Yet these applications are really not available on wireless systems today.

39. A 2-minute video clip or a 3-minute MP3 quality song each will take about 3 Mbits of data. A typical graphic that one would download on a web page might take 50 to 100 Kbits of data.

40. These high-bandwidth applications can be accessed today using desktop systems. A typical desktop broadband feed permits about 100+ Kbps streaming for high quality video to a desktop and 20+ Kbps for good quality audio. It is possible for home internet users without broadband (cable modems or DSL) service to also access these application using 56 Kbps dial-up modems. In these cases the data speed is typically in the 20-40 Kbps range. Desktop users with modem speeds less than 56 Kbps really could not support streaming audio or video. But image transfers with these modem speeds remain feasible: a 28.8 Kbps modem would take 2-4 seconds to download a typical web graphic.

41. The wireless technologies available today really don't support high quality streaming audio and video. Today's wireless systems support between 9.6 Kbps-19.2 Kbps for 2G networks. At these rates, though, image transfers remain viable, though they could render web browsing slow: A simple graphic web page might take five or ten seconds or more to download at 19.2 Kbps, or twice that at 9.6 Kbps.

42. Because today's equipment does not *permit* high speed data transfers, it demands relatively little bandwidth, and relatively little spectrum. Data is delivered in fairly short bursts – someone browsing the web will typically download a webpage for a few seconds and then spend a few minutes reading it – and those bursts require relatively little bandwidth: a little more than two simultaneous phone calls in the case of a 9.6 Kbps data transfer.

1. DoCoMo i-Mode

43. By far, the world's most popular wireless data service is NTT DoCoMo's i-mode service in Japan. As of this writing, this service provides approximately 20 million users with an "always on" packet-based wireless data service. The DoCoMo i-mode service has prospered with a limited amount of spectrum in one of the worlds most densely populated areas.[4]

44. i-mode users receive a maximum data rate of 9.6 Kbps. To put this in perspective, the International Telecommunications Union ("ITU"), an international standards-setting and coordinating body, mandated that 3G networks achieve 300 Kbps in mobile environments and 2 Mbps in fixed modes of use. Today's 2G CDMA/GSM/TDMA networks all meet or exceed the i-mode speed, and most carriers have sufficient bandwidth to offer i-mode like services.

C. Next Generation Technologies Will Offer Dramatic Capacity Improvements

1. Like "2G", "3G" Capacity Will Depend On Technology

[4] DoCoMo has 56 MHz of 2G spectrum and 30 MHz of 3G spectrum for a total of 86 MHz. DoCoMo's 3G spectrum currently lies unused, and the majority of its 2G spectrum (approximately 40 MHz) is used for voice.

45. As there are in second-generation wireless, there will be varying technologies in the third generation. Those standards include the International Telecommunications Union's designation of International Mobile Telecommunications 2000 (IMT-2000) systems to replace and unify wireless mobile systems is also known as 3G. These include European Wideband CDMA (WCDMA) that will replace GSM as well as 1XRTT and 1XEV of the CDMA2000 standard that will replace cdmaOne ANSI 95 systems.

46. WCDMA systems will require a significant amount of spectrum per channel (5 MHz), and will therefore require significantly more spectrum to carry the same load than will CDMA 1XRTT. While there is a provision in the evolution of CDMA2000 that will also use wider channels to get higher speeds as well, the flexibility of using a narrower channels, combined with the latest capabilities of this technology that rival the higher bandwidth capabilities, has refocused attention on efficient bandwidth use.

47. Moreover, Asian and European carriers have chosen to devote new swaths of spectrum exclusively for third generation services (that have yet to be rolled out) while US carriers are planning on upgrading their current networks, when possible, to 3G in their existing spectrum. US Carriers who plan to import the European based technology, WCDMA, will have a more difficult time as it requires 10 MHz (5 MHz each way) for just a single channel of 3G, compared with 2.5 MHz (1.25 MHz each way) required by U.S. CDMA. Ironically, importing European WCDMA for use in the US is one reason that some carriers would push to remove the spectrum cap. The truth of the

matter is that the spectrum cap is supporting US technology. In fact the cap is holding back inefficient European technology from becoming the word standard.

2. *All* Next-Generation Technologies Will Offer Increased Capacity

48. All next-generation technologies, WCDMA and CDMA2000 alike, provide greater spectral capacity for both voice and data; no matter what 3G technology is chosen, it will at a minimum provide double the voice capacity of today's networks, and provide high speed capabilities as well.

49. The next generation of digital data transmission will greatly improve these data rates. Rates will exceed 2 Mbps for US CDMA systems (1XEV) and European WCDMA systems.

50. A quick calculation using the 3G technologies expected in the US and Asia by 2002 and in Europe by 2003 yields the capacity of these systems. Assuming a typical mobile wireless application (twice for about 2 minutes each by each customer during the busiest hour). A 2-minute video clip or a 3-minute MP3 quality song each will take about 3 Mbits of data. A single sector using a single frequency of 1XEV will supply an average of 1 Mbps of data. Therefore a single 3-sector site will supply 12 Mbps in each 5 MHz of spectrum. This is sufficient to supply 400 simultaneous users of streaming content at 30 Kbps, or more realistically 7,200 users of regular moderate (2 events/busy hour) use. Going back to our assumption of 10,000 users/cell site, this is over 70% of the population in the coverage area all using high bandwidth applications.

51. As stated earlier, the US CDMA carriers' migration to 3G in the form of CDMA2000 (CDMA-1XRTT and 1XEV) will mean close to twice today's voice spectral capacity and data speeds of over 2 Mbps in transportable environments. WCDMA, which will eventually supplant GSM for all applications, (but will initially be

deployed primarily for its high speed capabilities) will be able to deliver 384 Kbps for mobile applications and 2 Mbps for fixed applications.

52. Vocoder technology is also improving. With CDMA for example, the new Selectable Mode vocoder (SMV) will improve capacity more than 50%. Spatial antenna diversity in the form of "Smart Antennas" or through other means will also provide greater than 100% voice capacity improvements. These improvements are additive to the above technology improvements.

D. It's not clear why existing voice carriers (rather than start-ups) should provide wireless data

53. The above makes plain that both voice and data applications can be accommodated in 45 MHz of spectrum. Still, there can be no doubt that voice and data service requires more bandwidth – and potentially more spectrum – than does voice service alone.

1. Voice Networks Are Not Optimized For Data

54. What is not at all clear is that existing wireless voice carriers should also be the ones who provide wireless data services. Voice-based networks have been designed virtually from end-to-end to optimize that single application that is currently circuit-switched. Data networks, however, are packet-based. It's just not necessary to have much of the expensive circuit switching equipment in order to run a data network.

55. Moreover the type of traffic carried on data networks is substantially different from that carried on voice networks The demands that voice and data place on a network are very different, and optimizing a network for one will often come at the expense of the other. In some sense, mixing data and voice on the same

network is a bit like mixing motorcycles and 18-wheelers on the same freeway. It can be done, but it is not clear that existing voice carriers are best suited for data carriage as well.

2. There are Other Innovative Possibilities for Wireless Data

56. In his book, *The Innovator's Dilemma* (1997, Harvard Business School Press), Clayton Christensen describes how new, innovative technology can be effectively used to supplant mature technologies. Examples ranging from disk drives to automobiles are used to illustrate the phenomenon of stable industries failing to meet market needs by maintaining evolution paths based on the needs of their largest customers. Such businesses miss opportunities to capture newer, smaller markets that eventually grow large.

57. Leap's Cricket service has been described by several industry analysts as such a "disruptive business". By using the latest technology in moderately-sized markets and a consumer focused business, we have captured new customers that never thought they could afford to use wireless technology.

58. Likewise, newer, packet-switched technology is becoming available for wireless networks that eliminates the need for larger voice-focused circuit-switched systems. Such systems could be combined with advanced radio technology to provide high-speed mobile data networks from new carriers – *provided they get the opportunity to purchase spectrum to do so.*

59. Indeed, even now new wireless LAN systems (IEEE 802.11) operating in the ISM band are providing 11 Mbps data for campus and quasi-stationary environments for a fraction of the price of wide-area voice and data networks. While 802.11 systems are not designed for wide-area mobile networks, the example serves to

illustrate that innovation in wireless and packet networks continues, and provided there is spectrum for new entrants, healthy competition will permit entrepreneurial businesses to push all carriers forward with newer services at lower prices.

VI. The U.S. Should Not Follow the Foreign Example of Heaping More Spectrum on the Incumbents

A. U.S. Carriers Have A Lot Of Spectrum, But Less Than Foreign Carriers

60. US carriers have a range of spectrum depending on the market. In general, most of the large nationwide carriers have between 25 MHz and 45 MHz in most of their networks. During the recent FCC PCS re-auction (auction #35) many of the larger carriers filled out their holdings in large markets up to the current spectrum cap of 45 MHz. The large cellular-based carriers (Verizon , AT&T Wireless and Cingular) typically own the 25 MHz cellular license in a market and additional 1900 MHz PCS spectrum to fill out the cap of 45 MHz. Sprint PCS owns a 30 MHz block mostly nationwide (including affiliates), but as CDMA exclusive carrier is in less need of more spectrum than the others.

61. European and Asian carriers have more spectrum than US carriers. In Germany for example, the two original GSM carriers have 25 MHz each of 900 MHz spectrum and an additional 10 MHz of 1800 MHz spectrum. On top of that they were recently granted an additional 25 MHz of 1900 MHz spectrum, for a total of 60 MHz of spectrum holdings. In the UK, Vodafone has a total of 82 MHz while One2One and Orange each hold a total of 85 MHz (25 MHz of 3G spectrum and 60 MHz of GSM/DCS spectrum). In Japan DoCoMo has 56 MHz of 2G spectrum and 30 MHz of 3G spectrum for a total of 86 MHz. Their competitors have similar allocations on the average. The following table is a summary of all the mobile wireless carriers in each region.

Country	Spectrum
US	218 MHz *
UK	365 MHz
Germany	306 MHz
Japan	234 MHz

- includes 30 MHz in the future 700 MHz auction

62. So on the average a typical US wireless carrier has about half the spectrum of their European or Asian counterpart. With little knowledge of wireless system design or planning it would appear at first glance that US carriers are significantly disadvantaged in providing high quality voice and data services as they have on average half the spectrum of similar carriers in Europe and Asia. However, recall that in Europe and parts of Asia GSM is the voice technology used –a technology with significantly less capacity than US CDMA systems. Other factors are significant in such a comparison.

VII. European and Japanese Market and Population Characteristics Require More Spectrum than those in the United States

1. Inferior Landline Services In Europe And Asia Makes Wireless More Immediately Attractive

63. The US enjoys the most reliable fixed line telephone network in the world. Adding new lines, or obtaining new service is done rapidly and at low cost. This is not the case in many, even advanced, nations. Furthermore, outside of the U.S. wireline telephone use is metered (so that like most wireless services, customers pay by the minute), and more expensive. So for a person living in Europe or Asia, the difference between home telephone service and mobile service from a quality/cost standpoint is smaller.

64. The author, while living in Europe a decade ago (while working on GSM systems), had the experience of many and was forced to wait a month to obtain new

telephone service. In other areas of the world the wait is years or more for a phone line, which tends to operate at lower average service quality. Such conditions promote the use of wireless service as an option to fixed line service.

B. A. European and Japanese population densities require more spectrum.

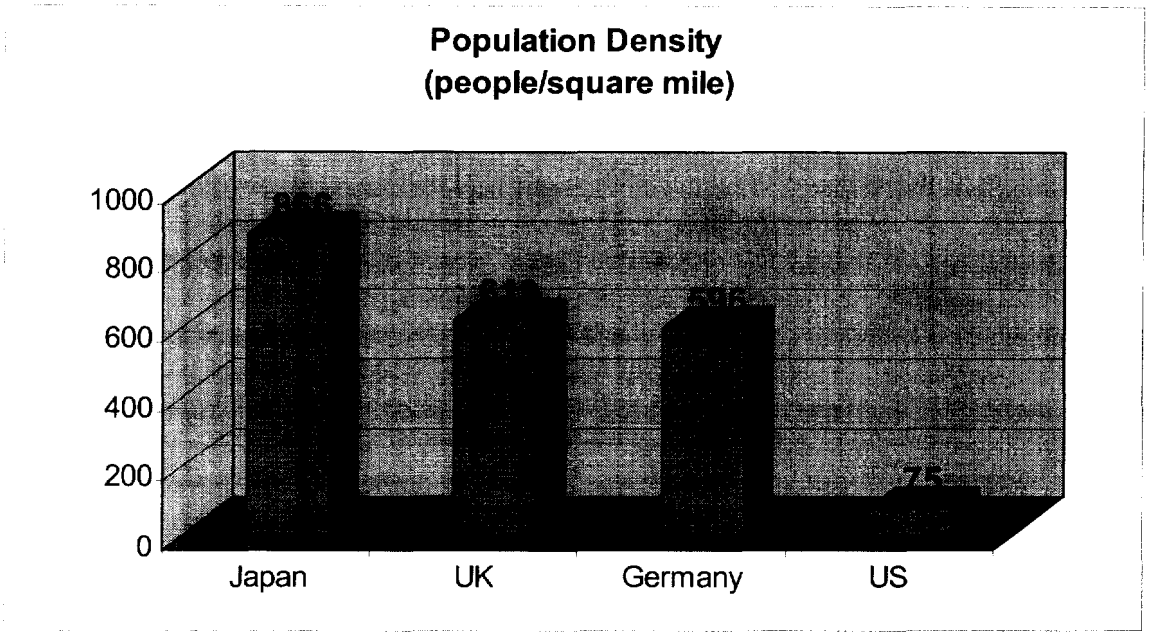
65. As described above, wireless systems are designed around capacity: how much load (minutes of use, or as engineers like to state load, Erlangs) will be generated in a given area. This of course is a function of how many people will place phone calls in a given area at a given time.

66. The key to successful radio network design is capacity planning and interference management. In FDMA (AMPS) and TDMA/GSM systems this takes the form of frequency reuse planning. Essentially, the same frequency is used in different parts of a market, but it is done sufficiently far apart that no interference occurs. This was the fundamental concept developed by Bell Laboratories 40 years ago in the 1960s during the development of cellular radio technology. When the load of a single cell exceeds the capacity, the cell is "split" – it is divided into two or more smaller cells each having the capacity of the original larger cell.

67. In order to accomplish this model of cell splitting and interference management, One has to be able to put the entire load that they'll be getting in the area served by one cell on frequencies that are not being used in adjacent cells. When the load is packed into a dense geographic area, one needs to use many small cells, rather than a few larger cells. The problem is that at some point, cells just can't get any smaller: the signal wants to propagate a certain distance and you can't keep it from doing so. Moreover, densely populated areas tend to have high-rise buildings, which exacerbate the

problem in a number of ways. In high-density areas, then, relatively more spectrum is needed than in low-density areas.

68. Fortunately, areas of high population density are very rare in the United States. The following chart shows the population density of the US compared with Japan, the UK and Germany.



source: Yankee Group

69. Thus, the significantly higher population densities in Europe and Japan require wireless operators there to use relatively more spectrum than they would in the United States. This is not to say that they need as much spectrum as they have, or that they are using their spectrum in the most efficient way possible. This only means that, all other things being equal, wireless coverage of areas (such as Europe and Japan) with greater population density takes more spectrum than coverage of areas (such as the United States) with lower population density.

VIII. Conclusion

70. The US has stood above many nations in business growth due to deliberate steps taken to promote competition. That U.S. engineers developed CDMA radio technology for commercial wireless networks is a perfect example of what comes from intense competition. Leap's Cricket service, a disruptive service for other carriers to try to implement, is also a result of competition, and has brought wireless service to Americans who thought they could never afford it, and at the lowest prices available anywhere in the world. With no spectrum cap in place, we and other entrepreneurial companies like ours would face virtually insurmountable obstacles to our ability to enter the market and provide this service.

71. In my opinion, there is no need for an increase in the amount of spectrum that wireless carriers are permitted to hold; certainly not this year or anytime in the near future. Spectrum is a finite public resource that is indispensable for both existing *and new* wireless companies. There is simply no compelling reason to modify or lift the spectrum cap at this time. Doing so would restrict both present and future competition

72. The fact is that if they choose to, carriers can get by on very little spectrum. Leap now offers our Cricket service that permits users to make unlimited local calls for a single low monthly rate – just like fixed line service; an all-you-can-eat plan. Our *average* customer uses more than a thousand minutes a month. And we have attracted a large number of customers. Yet Leap offers the Cricket service in markets in which we hold as little as 10 MHz of spectrum. We would not know what to do with 45 MHz of spectrum.

73. Some carriers are currently using inefficient technology – analog, TDMA and/or GSM – that wastes the spectrum assets of those carriers. Just by improving their technology, those carriers could increase by many times the effective capacity of their systems. But instead of obtaining more use out of what they have, those carriers would apparently prefer to acquire and put to inefficient use more and more of this scarce resource.

74. Nor can the large carriers claim that they need more spectrum in order to fulfill the demand they speculate will develop for some amorphous concept that they call "3G." It's hard to rebut a notion as vague as the big carriers' "3G" claims. But everything I know about the subject indicates that they're vastly overstating what they will need. On the one hand, wireless data simply does not and will not require vast amounts of bandwidth. Text applications require much *less* capacity than does voice telephony, and mobile Internet browsing capability has already been achieved using only slightly more the bandwidth (9.6 Kbps) than is consumed by two simultaneous phone calls (4.0 Kbps each). Moreover, the next generation of wireless equipment will (just as did every previous generation) offer far more capacity. Thus, any increase in capacity that is required by 3G wireless applications will be offset in large part by the increased efficiency of the same 3G systems. While future streaming video and audio applications will no doubt require more speed and bandwidth than today, it appears that it too will comfortably fit inside 45 MHz or less of spectrum.

75. The cap is so high today at 45 MHz that it is like having an NBA salary cap of a hundred million dollars; so high that each team could afford to hire the "dream team." Yet – to extend the analogy – some teams have chosen to spend their

$100 million by hiring the equivalent of collegiate bench-warmers. And now they're asking the league to raise the salary cap.

76. Any number of analogies come to mind. It's like asking for more public property so that you can continue to build low-rise offices, instead of building skyscrapers on what you already have. It's like asking for more landing slots so that you can run 14-seat propeller aircraft, instead of 747s. It's like ripping up the streets to lay more fiber, instead of increasing the capacity of the signals on both ends. Asking for more spectrum while you continue to use outdated, inefficient equipment is like, well, asking to have your cake and eat it too.

I certify that the forgoing is true and correct, to the best of my knowledge, information, and belief.

Executed in San Diego, California, on April 13, 2001

Mark C. Kelley