Traffic Sensitivity of Telephone Switching Equipment

Technology White Paper

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This Technology White Paper was prepared at the request of the National Telecommunications Cooperative Association (NTCA) in response to the Commission's request for comment in CC Docket No. 01-92.[1] It identifies the traffic sensitive portions of the telephone network and describes them from a technical perspective.

Vantage Point Solutions, Inc. (VPS) is a telecommunications engineering and consulting company providing a full range of services including Professional Engineering, Outside Plant Engineering Services, strategic planning, technology evaluations, network architecture design, regulatory expertise, and feasibility studies. VPS is focused on the unique business challenges faced by Independent Local Exchange Carriers (ILECs). VPS is at the forefront of the implementation of the new Next Generation switching platforms and developing the strategies for rural ILEC entities to migrate their networks from the legacy Time Division Multiplexed (TDM) digital switching networks to the new packet switching based Next Generation switching platforms.

The authors of this Technology White Paper have over forty (40) years experience in the telecommunications industry, including over ten (10) years switching systems engineering experience for a legacy switching vendor. [2]

[1] Developing a Unified Intercarrier Compensation Regime, *Further Notice of Proposed Rulemaking*, CC Docket No. 01-92 (FCC 05-33) ("FNPRM").
[2] Larry D. Thompson, PE – CEO, Vantage Point Solutions, John M. De Witte, PE, Vice President of Engineering, Vantage Point Solutions. See Attached Resumes.

In CC Docket 01-92 (FCC 05-33) Further Notice of Proposed Rulemaking (FNPRM) titled, "Developing a Unified Intercarrier Compensation Regime", the FCC requests comments regarding the traffic sensitivity of telephone switching equipment. The Commission states the following, ". . . we must be more specific about the meaning of the term 'traffic-sensitive.' If costs for a portion of the network vary with the number of customers on the network, would those costs be considered 'traffic-sensitive'? Or must costs vary with usage of a particular customer to be 'traffic-sensitive'?"[3]

This Technology White Paper establishes the fact that switching networks are indeed traffic sensitive and explains the factors that influence the traffic on a switching network. The traffic sensitive engineering elements of classical switching network and next generation switching networks are described, as are the relative costs associated with the traffic sensitive portions of the switching network.

I. CALL PATTERNS AND TRENDS

A variety of factors influence the traffic patterns of a switching network, including the following:

- Changes in subscriber use of the network
- The addition of carriers
- Changes in calling scope
- Subscriber calling scope and service cost.

Below is a technical explanation of how some of these factors impact cost.

[3] *Developing a Unified Intercarrier Compensation Regime*, CC Docket 01-92 (FCC 05-33) Further Notice of Proposed Rulemaking (FNPRM), Paragraph 66.

A. Subscriber Application Impacts on Switching Networks

When subscriber or carrier traffic patterns change, the traffic sensitive elements in the switching network must be re-engineered to accommodate those changes. One recent application that significantly changed traffic patterns was dialup Internet. If switching networks were *not* traffic sensitive, then one would expect that subscribers or carriers would be able to change their calling habits (such as increasing their holding time or increase their number or telephone calls) without impacting the switching network. Dialup Internet Access gained rapid acceptance in the mid 1990s. The long holding times associated with a dialup Internet session stressed the traffic sensitive elements of the switching network. The longer holding times forced telecommunications service providers to re-engineer their networks to accommodate this growth in traffic. This often necessitated significant upgrades of switching systems.

Several studies have been performed that describe the effects of dialup Internet traffic on switching networks. Telcordia Technologies published a study in June 1996 entitled *Impacts of Internet traffic on LEC Networks and Switching Systems*. In this report, the authors validate the classic traffic engineering methodology by recognizing that the traffic volumes offered by the onslaught of dialup Internet traffic "…are challenging the engineering, forecasting, planning, and operational procedures established by the Bell System over the past 80 years".[4] In addition, this study reiterates the fundamental level switching model assumptions by validating the engineering model for voice calls with the design assumptions that "(i) the average call holding time is around 3 minutes, (ii) the statistical call holding time distribution is well approximated by

[4] Amir Atai, Ph.D. and James Gordon, Ph.D., *Impacts of Internet traffic on LEC Networks and Switching Systems*, p2

an exponential distribution, and (iii) for call arrivals are Poisson."[5] The report further concludes that Internet traffic can generate average holding times as high as 20 minutes.[6] The conclusion of the report is that the impact of this radical change in traffic patterns by a new product or service (such as the Internet) can cripple existing switching systems unless additional switching resources are engineered.

Rural Local Exchange Carriers (RLECs) have engineered their telephone networks to accommodate the existing wireline traffic and accommodate their planned wireline traffic growth. As additional traffic is incrementally added to the network, telephone companies will be required to review their traffic data and add the appropriate traffic sensitive resources to their system.

As an example of the effect of holding time impacts on the switching networks, the Rural Utilities Service has bulletins that detail their traffic engineering guidelines[7], which recommend average holding times of 240 seconds (4 minutes) for toll calls and 150 seconds (3 minutes) for EAS calls. Based on our engineering experience with rural telecommunications service providers, we have added other average holding times to the 1996 RUS guidelines. Based on our switching equipment engineering experience, the average holding times for dialup Internet is 540 seconds (9 minutes), the average Basic Rate Interface (BRI) Integrated Services Digital Network (ISDN) Bearer Channel is 360 seconds (6 minutes), and the average Centrex Line is 300 seconds (5 minutes). These specific holding times are used in conjunction with the RUS recommendations for standard residential and business subscribers. Obviously, if the longer holding times for

[5] ibid, p2
[6] ibid, p3
[7] RUS BULLETIN 1753E-001 (Form 522), titled, "RUS General Specification for Digital, Stored Program Controlled Central Office Equipment, January 16, 1996.

these additional calls types were not considered, the traffic engineered capacity of a switching system would be insufficient.

It is clear that switching systems are impacted by the traffic load. If the switching network were not traffic sensitive, it is logical that changes in call frequency or call duration would have no impact on the switching network. As we have seen with examples such as dialup Internet, this has not been the case. We will discuss the economic impacts to the RLEC due to the switch network upgrades required.

B. Calling Plan Impacts on the Switching Networks

One possible argument against traffic sensitivity is that the addition of carrier interfaces directly into a switch does not increase the overall traffic, but merely redistributes the traffic among the available carriers. It has been our experience that the addition of a carrier often increases the traffic volume because of increased calling scope, increased subscriber convenience, or increased value to the subscriber. In order to quantify the increases in subscriber minutes with increased calling scopes, we analyzed two landline exchanges with very different calling scopes to see if the user patterns are different. This will help provide a foundation that the RLEC will likely experience additional network traffic load as they interconnect with carriers with larger calling scopes (such as wireless carriers). As shown previously with dialup Internet, traffic volume in the switching network can increase as new services are added. This often necessitates additional investments to the traffic sensitive elements of the switching network. By adding additional carriers to the network, the traffic load often increases, especially when these carriers have a larger calling scope than the incumbent carrier.

As the calling scope for a telecommunications service increases, the subscriber often uses the telecommunications service more, which stimulates additional traffic load on the switched network. To prove this point, two similarly sized and situated exchanges were selected for a traffic study. These exchanges are described below.

- Exchange A: The subscribers in this exchange have local calling within their exchange only. All other calls are toll calls. The local calling area covers 730 square miles and allows local calling to 699 subscribers.
- Exchange B: The subscribers of this exchange have local calling to 27 exchanges. The local calling area is 726 square miles and other calls are toll. The local calling area covers 16,050 square miles and allows local calling to 19,585 subscribers.

It was found that the average call duration for originating calls for subscribers in Exchange A was 1.84 minutes, based on almost 5M minutes of traffic. With the greater calling scope in Exchange B, the average call time was 2.01 minutes, based on 3.3M minutes of traffic. This represents an increase in 8.5% in call hold times over the traffic patterns in Exchange A.

As additional carriers with significantly different calling scopes and services, such as wireless carriers, interconnect with the landline networks, additional minutes are stimulated in the switched network. This stimulation of minutes in the network can result in additional investment as we saw with the deployment of dialup Internet.

II. CLASSICAL TDM SWITCHING SYSTEM TRAFFIC SENSITIVE ELEMENTS

As we will see, many elements of the switching network are traffic sensitive. However, since the wide scale deployment of digital switches, the impact of increased minutes of use (MOU) on the switching networks is not as pronounced as with previous generations of switching equipment. In the FNPRM, the Commission wrote:

> "We invite comment on the proposition that digital switching costs no longer vary with minutes of use due to increased processor capacity. Is this proposition correct for both end office switches and tandem switches? What about competitive LEC switches that have characteristics of both tandems and end offices? . . . Parties taking the position that switching costs do vary with minutes of use should identify the specific portions of the switch for which costs increase when minutes of use increase."[8]

Telephone switch engineering technical documents often make reference to traffic sensitive design and engineering. With telephone switching systems, multiple portions of the switching fabric are engineered to a particular Grade of Service (GOS). The traffic sensitive components are provisioned based on a particular GOS expressed in either Erlangs or Centum Call Seconds (CCS). These mathematical formulas are based on statistical probability of blocking. There are two (2) basic traffic measurements in telephony switching equipment: 1) Peg Count (defined as the number of times a particular circuit is utilized) and 2) Holding Time (defined as the amount of time that the circuit is held active by the subscriber. Peg Count (PC) multiplied by Holding Time (HT) provides traffic usage in Call Seconds. A *Call Second* is a unit for measuring communications traffic. It is defined as one call with one second of connect time. [9] Centum Call Seconds (CCS) is defined as one hundred call seconds. Since there are

[8] *Developing a Unified Intercarrier Compensation Regime*, CC Docket 01-92 (FCC 05-33) Further Notice of Proposed Rulemaking (FNPRM), Paragraph 68.
[9] Frank Hargrave, *Hargrave's Communication Dictionary*, pg 75

3,600 seconds in an hour, 1 call hour is equal to 36 CCS, or 1 Erlang. Traffic intensity (occupancy) is measured in Erlangs, with values ranging from zero (no occupancy) to 1 (100% occupancy). This measure is typically used to represent the average number of simultaneous connections observed in a measurement period (generally the Busy Hour.[10])

To determine a particular GOS, there are several mathematical probability equations which, although not developed specifically for telephone traffic calculations, are applicable to telecommunications traffic engineering. These mathematical equations have been used to develop traffic capacity tables. One of the mathematical equations utilized in telecommunications traffic engineering is the Poisson Distribution[11] equation. This equation describes the possibility that a random event will occur in some interval of time under the conditions that the probability of the event is very small and the interval is very large. Poisson Distributions are used in communications when traffic flows and waiting times are significant. It assumes blocked calls are held. The quantity of circuit facilities that are required for a particular GOS is based on the projected CCS capacity expected for the evaluated time interval (High Day Busy Hour – HDBH, Average Busy Season Busy Hour – ABSBH, etc.) using the Poisson Distribution tables.

To derive the size of some of the traffic sensitive switching elements in a Central Office switching system, the RLECs generally adhere to the traffic engineering rules published by the United States Department of Agriculture (UDSA) Rural Utilities Service (RUS)[12].

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[10] The Busy Hour is the hour of the day during which a telephone system carries the most traffic.
[11] Hargrave at 194. Named for the French mathematician Simeon D. Poisson (1781-1840) a Poisson distribution is a mathematical curve used in statistics to approximate the distribution and probability of occurrence for events.
[12] RUS BULLETIN 1753E-001 (Form 522), titled, "RUS General Specification for Digital, Stored Program Controlled Central Office Equipment, January 16, 1996. Section 16.1.1 page I-31 The purpose of RUS BULLETIN 1753E-001 is to provide a "user friendly" reformat of the text codified in 7 CFR 1755.522

Traffic engineering guidelines for a Digital Central Office switching system are described in Part 1, Section 16 of this document[13]. In Part 1, Section 16 of the Bulletin, RUS states that traffic be engineered based on the Erlang Lost-Calls-Cleared Formula. The assumptions utilized with this formula are:

1) Offered Traffic arrives at random times;

2) Holding times of connected calls are distributed exponentially, and calls with longer holding times occur less frequently than do short holding time calls;

3) Offered traffic not immediately served is discarded; and

4) Discarded traffic is not queued and does not reattempt a connection (call is lost)[14].

The document states that Poisson Distribution probabilities shall be used for determining the quantity of intraoffice paths, registers, and senders where full availability conditions apply.

Traffic engineering in a Central Office switching system is based the probability of blocked calls in a given timeframe. Telecommunications traffic is not constant when measured day-to-day or hour-to-hour. It would be cost prohibitive to engineer a traffic sensitive switching system to guarantee a non-blocking path at all times. Traffic in Time Division Multiplexed (TDM) Central Office Switching system is measured in Centum Call Seconds (CCS).

As defined earlier, the traffic levels in a Central Office switching system are based on Peg Count (PC) and Holding Time (HT). To estimate the quantity of facilities required in a switching system, Holding Times for various call types (residential,

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published at 60 FR 64311, dated December 15, 1995. The regulation at 7 CFR 1755 section 1755.522 is the authorized source for this RUS BULLETIN. This document is readily available to the public by access the RUS website at www.usda.gov/rus.

[13] Ibid.

[14] Frank Hargrave, *Hargrave's Communication Dictionary*, pg 194. Erlang B Formula).

business, Centrex, Internet, toll, etc.) are measured for the ABSBH timeframe and applied to the appropriate switching resources (lines, trunks, network, CPU, etc.). The total traffic is converted to CCS and the number of resources (line processors, trunk processors, network processor, and CPU processors) is engineered using the Poisson Distribution Tables.

Switching equipment manufacturers, both wireless and wireline, utilize voice traffic levels to properly engineer line and trunk quantities. These documents are normally proprietary to the vendor, but they often make reference to traffic sensitive switching components.

The non-traffic sensitive portions of a wireline switching network are the physical subscriber line termination interface (Line Card) and much of the physical subscriber local loop (typically copper cable) that connects the physical line termination to the subscriber. This is consistent with the findings in the FCC's *First Report and Order*.[15] The physical trunk termination interface (often referred to as a Trunk Card) is traffic sensitive since the quantity of the physical trunk interfaces required is driven by the traffic in the system. Let me discuss each of these elements in detail.

A diagram of a typical central office digital switch can be seen in Figure 1. The physical subscriber line termination is often referred to as a "line card" in the switching jargon. This physical line termination has a one-to-one relationship with the quantity of lines in the serving area. Simply put, for every subscriber line in the serving area, the RLEC must provide one line card termination. No traffic engineering is required for the line card.

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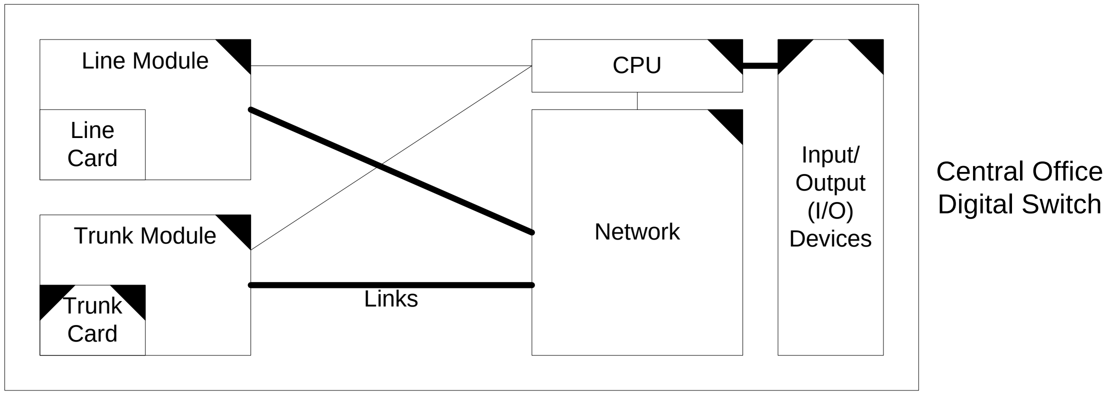
[15] Implementation of the Local Competition Provisions of the Telecommunications Act of 1996, CC Docket No. 96-98, First Report and Order, FCC 96-325, 11 FCC 15499 (1996) ("First Report and Order").



Not Traffic Sensitive

Line Interfaces	Physical Line Interface. Not Traffic Sensitive. Investment driven by number of customers.

Traffic Sensitive Elements - Pre-Engineered by Switch Vendor

Line/Trunk Modules	Controls Physical Terminations. Traffic Sensitive portions include the Peripheral Processor (limitation of Busy Hour Call Attempts) and Traffic Engineered Links to Network
Network	Controls Peripheral Terminations. Traffic Sensitive from the standpoint of Non-Blocking Cross-Connecting operation.
CPU	Controls Switch and Call Processing. Traffic Sensitive from the limitation of Processor Real Time (Feature Activations) and Busy Hour Call Attempts.

Traffic Sensitive Elements - Engineered by LEC

I/O Devices	Interfaces to other devices. Upgrades are required as more peripherals are added. Switch may have to be replaced if upgrades exceed capacity of pre-engineered elements above.
Trunk Cards	Interfaces to other Carriers. Upgrades are required as more carriers connect to the switch. Switch may have to be replaced if upgrades exceed capacity of pre-engineered elements above.

Figure 1. Traffic Sensitive Elements of a Digital Switch

After the line card, nearly every other piece of equipment in the switch is traffic sensitive. The driving design factor for traffic provisioning is Grade of Service (GOS). The GOS in a wireline switching system is generally expressed as a function of availability, or blocking. In most telephone switching systems, the vendor has "pre-engineered" portions of their switching network architecture to a particular GOS. In general, these elements of the switching network have been sized for the maximum capacity of the switching system and require only circuit pack additions (based on physical interfaces) to accommodate the traffic load. The vendors have adopted this practice for several reasons. The first reason is simple economics. It is much less expensive for vendors to market, stock, and maintain a single CPU processor size, network configuration, and Input/Output configuration than multiple configurations. A secondary reason is to simplify the overall engineering (and cost) of the switching system by allowing the addition of physical interface cards into a pre-engineered chassis. This allows the vendor to offer a competitive installation at varying switch sizes. The quantity of interfaces required is a function of traffic engineering for the entire switching system.

As discussed earlier, traffic engineering in a telecommunications Central Office switching system is based on the probability of blocked calls in a given timeframe. A common industry practice is to traffic engineer the switching systems to have a Grade of Service of P.01 (one call blocked in one hundred) based on the Average Busy Season Busy Hour (ABSBH) measured traffic levels.

To estimate the quantity of facilities required in a switching system, Holding Times for various call types (residential, business, Centrex, Internet, toll, etc.) are measured for the ABSBH timeframe and applied to the appropriate switching resources (lines, trunks, network, CPU, etc.). The total traffic is converted to CCS and the number of resources (line processors, trunk processors, network processor, and CPU processors) is engineered using the Poisson Distribution Tables.

Utilizing the RUS BULLETIN 1753E-001[16] specific trunking scenarios were examined that demonstrate that digital switching costs do vary with minutes of use. The RUS BULLETIN 1753E-001 assumes a trunk as a single DS0 and the chart ranges from

[16] RUS BULLETIN 1753E-001 (Form 522), titled, “RUS General Specification for Digital, Stored Program Controlled Central Office Equipment, January 16, 1996.

1 to 200 trunks. The probability of 1 in 200 (or 0.5%) calls are dropped was used for all calculations unless otherwise stated.

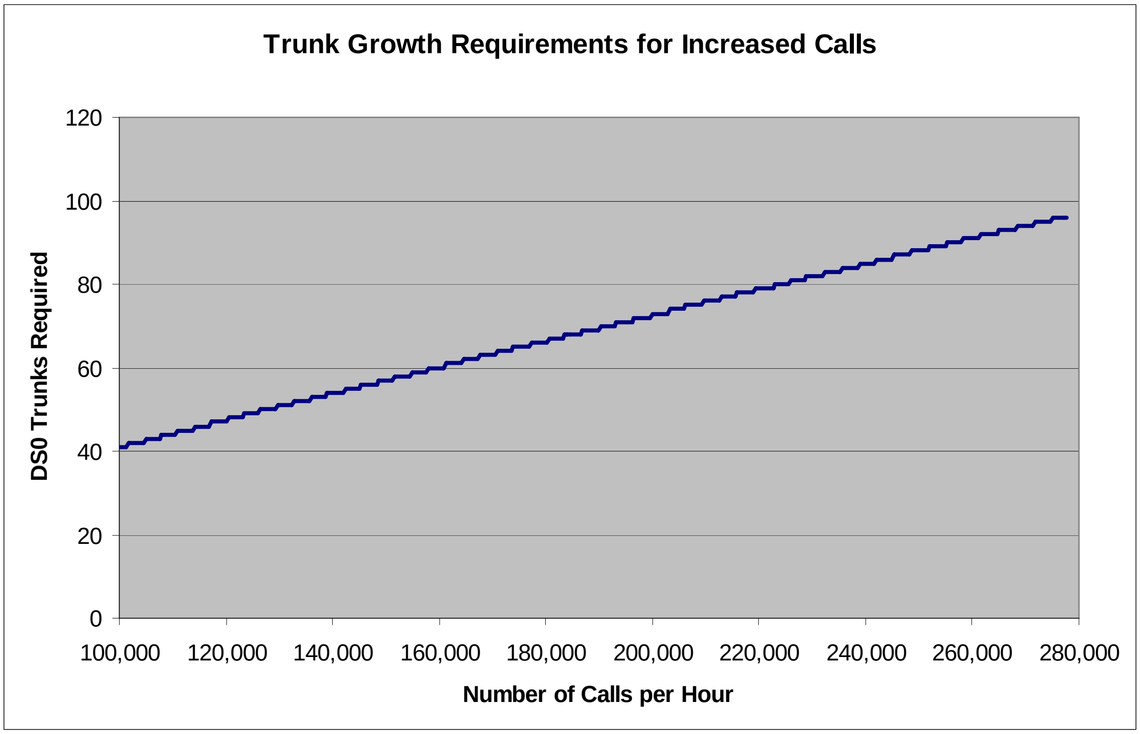


Figure 2: DS0 Trunks Required vs. Number of Calls

Figure 2 demonstrates the trunking requirements when the number of calls is increased in a given hour. Each call was held constant at 420 seconds or 7 minutes. From this it is clear that changing of traffic patterns (increased number of calls) will have an impact on the port requirements of a telephone switch. Figure 2 shows an increasing step function in the quantity of DS0 trunks required as the call traffic increases. Based on Traffic Engineering concepts utilizing the Poisson Distribution, the number of required trunks increases for an increasing number of calls (assuming the holding time for each call is fixed). It is evident that with a constant length call the number of trunks needed to support the call load is going to continue to increase with increased call volume.

Figure 3 shows the trunking requirements as the call duration is varied. For this graph the number calls during the busy hour is held constant at 1,000 calls with an increasing Holding Time.

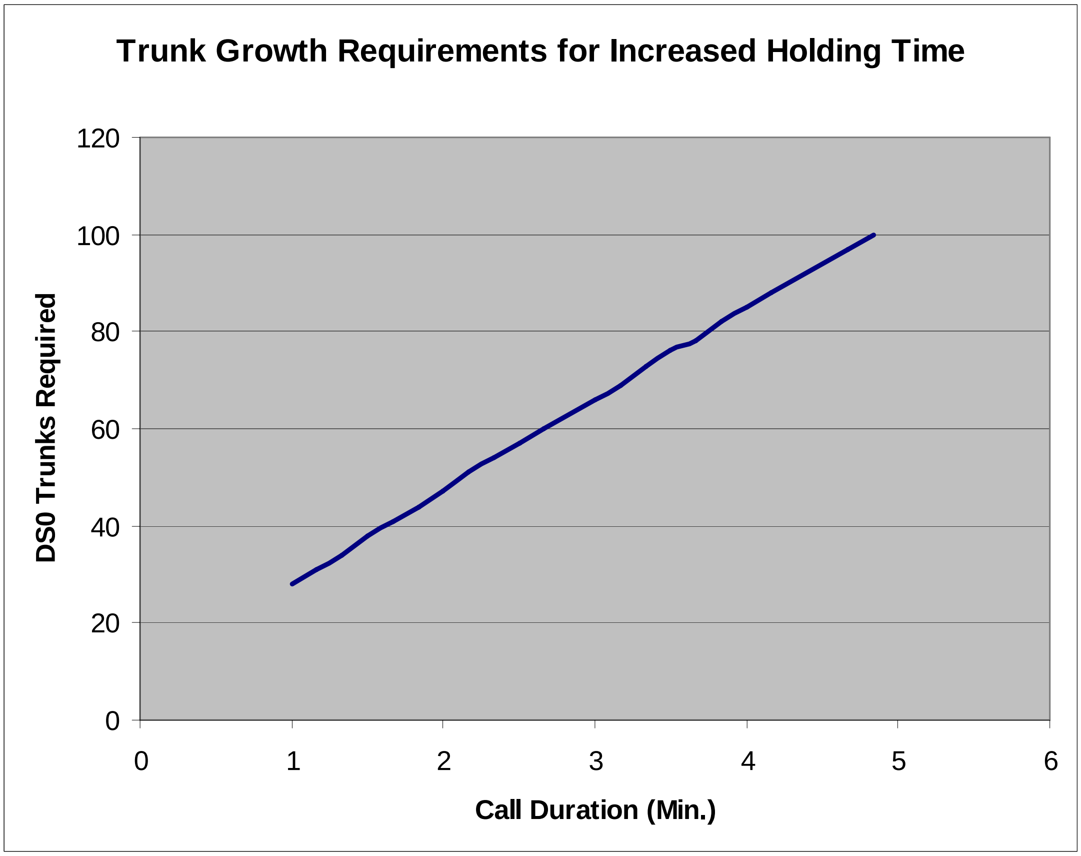


Figure 3: Trunks Required vs. Call Duration

Figure 3 shows that even with a constant number of calls, call duration has an extremely effecting factor on the number of trunks required. This was also shown earlier in our discussion of the impact of the Internet on the switching network when call durations increased dramatically.

Figure 4 shows the amount of traffic time available when the probability of a dropped call is increased. The amount of traffic time available was recorded as CCS. For this graph the number of trunks was held constant.

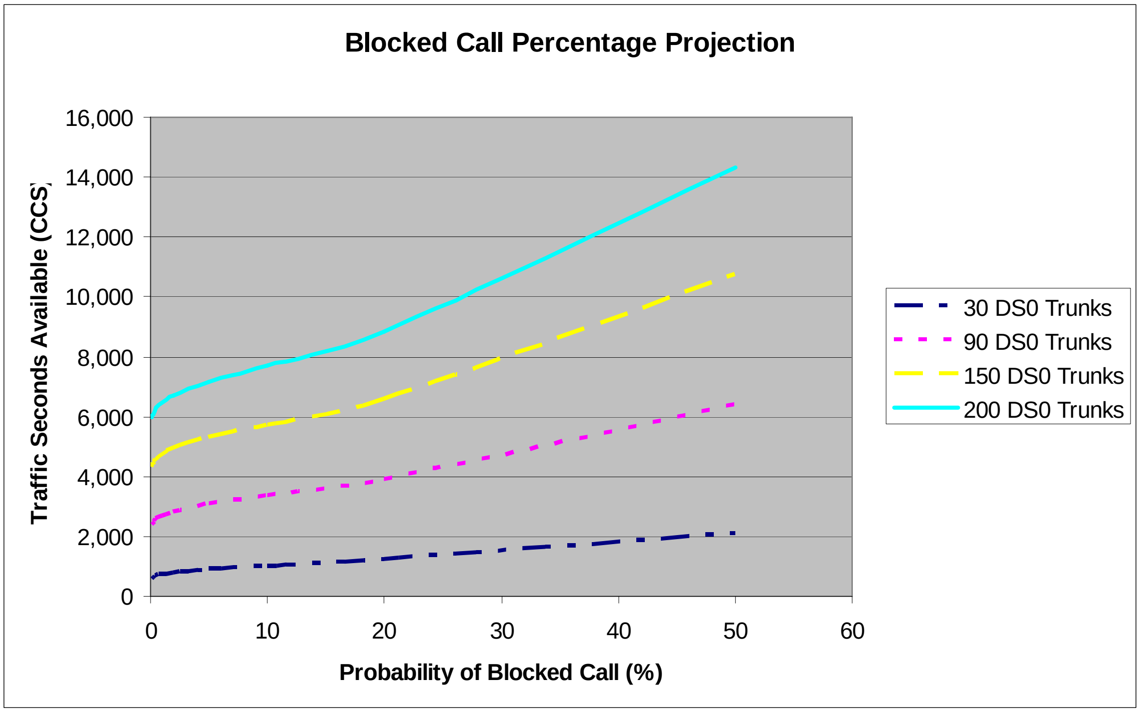


Figure 4: Traffic Available vs. Probability of a Blocked Call

Figure 4 shows that more traffic seconds are available if the percentage of blocked calls are increased. The network becomes less reliable as the CCS value increases. This seems intuitive; however the limiting factor is the number of trunks within the system. This demonstrates to keep the integrity and reliability of the system constant the number of trunks must be increased.

Therefore it has been shown that call volume and call duration highly affect the number of trunks required to support the switching network. This has a significant effect on the electronics of a switching system in all aspects. If a telecommunications service provider must increase the number trunks within a system, the overall capacity of the switching network will need to be increased as well. This results in an increase in the number of interface cards in the system, provided that the slot capacity has not been met on the shelf. If the network port capacity is reached an entire new switch will be required. In addition, the longer callers are on the network the larger the chance that these trunking limitations will be achieved. These graphs all support the idea that digital switching costs are directly related to the minutes of use on the network. This cost is not directly related to one specific component in the switch. It is, however, a driver for additional costs when the numbers of trunks need to be increased to support the demand. This is especially apparent when a RLEC is approaching switch capacity limitations. To increase the number of trunks (to ensure connection reliability) additional trunk interface cards need to be purchased. This is a stair-stepping function that has an associated upgrade cost.

All elements of a switching network, except the line card are traffic sensitive. However, with the advances in processing technology, the switching manufacturers have pre-engineered some of the switching components to accommodate a wide range of traffic levels. This is not an uncommon business practice since business economic analyses have repeatedly shown that it is less expensive for switching vendor to design, manufacture, stock, and support fewer items. One of the most prominent pre-traffic engineered components is the switching processor. Most switching manufacturers offer very little choice in the selection of processor capacities within a given switch product. It is a business decision for the switching vendors to select a processor design that will cover the target traffic levels of their market. In fact, over the life of a particular switching product line, the industry changes and growth in traffic has necessitated processor upgrades to accommodate the added switching requirements.

However, if a RLEC were to outgrow the capability of the processor or maximum interface quantity of a specific switch product line, they may be forced into the next larger switch in the vendor's product line or replacement with another vendor's platform. This results in a significant upgrade cost. This scenario is modeled in Figure 5.

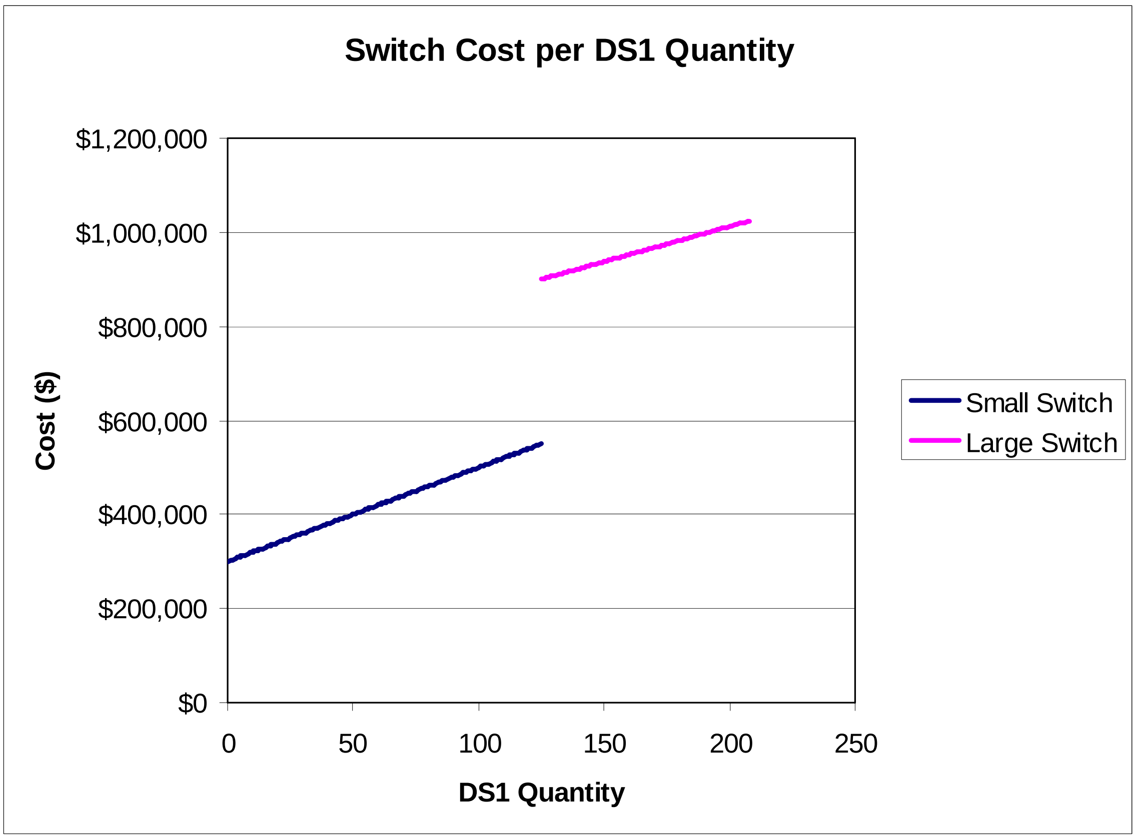


Figure 5: Switching Cost per Equipped DS1 Ports

From Figure 5, one can observe that there is traffic sensitivity as trunks are increased (due to increased call volume) within each product group (Small Switch or

Large Switch). There is a significant increase in cost if the traffic exceeds what can be provided by the small switch and the RLEC is forced into the large switch.

III. NEXT GENERATION SWITCHING SYSTEM TRAFFIC SENSITIVE ELEMENTS

Most experts believe that voice traffic will be carried on IP networks in the future. If this is the case, it would be important to consider the impact on IP switching systems as traffic increases. Again, the FNPRM requested:

> "We invite comment on the proposition that digital switching costs no longer vary with minutes of use due to increased processor capacity. . . . To what extent do any capacity constraints become obsolete as carriers migrate to Internet-protocol switching? Parties taking the position that switching costs do vary with minutes of use should identify the specific portions of the switch for which costs increase when minutes of use increase."[17]

When voice is carried on an IP network, it is often referred to as Voice over IP (VoIP). The core element of an IP network is the router. This is the device that switches the VoIP traffic and is functionally similar to the digital switch discussed in the previous section.

When traffic, such as voice, is processed by a router, the router becomes more expensive as the traffic demand becomes greater. This is due to the traffic sensitive elements of the router. Figure 6 shows a basic block diagram of an IP router with the traffic sensitive and traffic insensitive elements identified.

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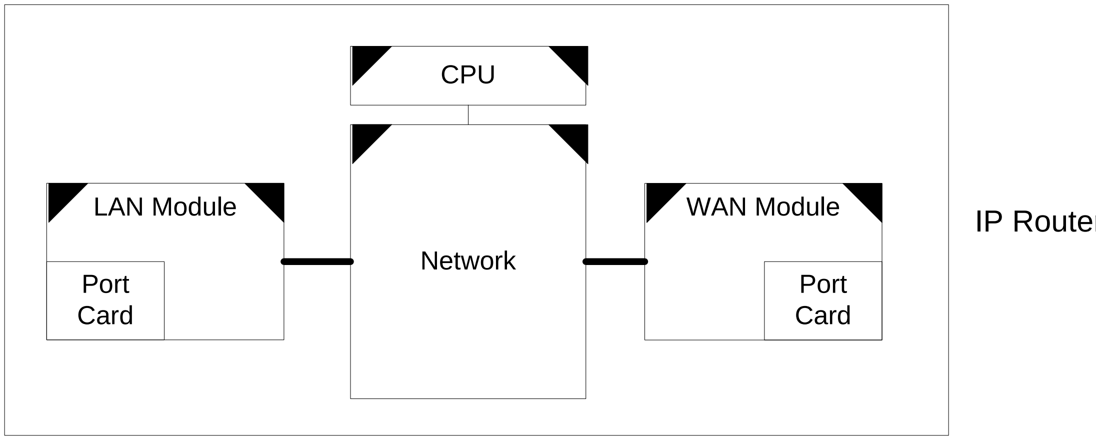
[17] *Developing a Unified Intercarrier Compensation Regime*, CC Docket 01-92 (FCC 05-33) Further Notice of Proposed Rulemaking (FNPRM), Paragraph 68.



Not Traffic Sensitive

Port Card	Physical Line Interface. Not Traffic Sensitive. Investment driven by number of customers.

Traffic Sensitive Elements - Engineered by LEC

LAN/WAN Module	Controls Physical Terminations. Traffic Sensitive portions include the Peripheral Processor (limitation of Busy Hour Call Attempts) and Traffic Engineered Links to Network
Network	Controls Peripheral Terminations. Traffic Sensitive from the standpoint of Non-Blocking Cross-Connecting operation.
CPU	Controls Switch and Call Processing. Traffic Sensitive from the limitation of Processor Real Time (Feature Activations) and Busy Hour Call Attempts.

Figure 6: Traffic Sensitive Elements of an IP Router

The processing power of a router is often measured in terms of packets per second (pps). With the increases in processor power, most routers can now process Millions of Packets per Second (Mpps). VoIP can be demanding on a router. As the volume of VoIP increases, so must the processing capabilities of the router, which increase the cost. This is shown for some typical routers in Figure 7.

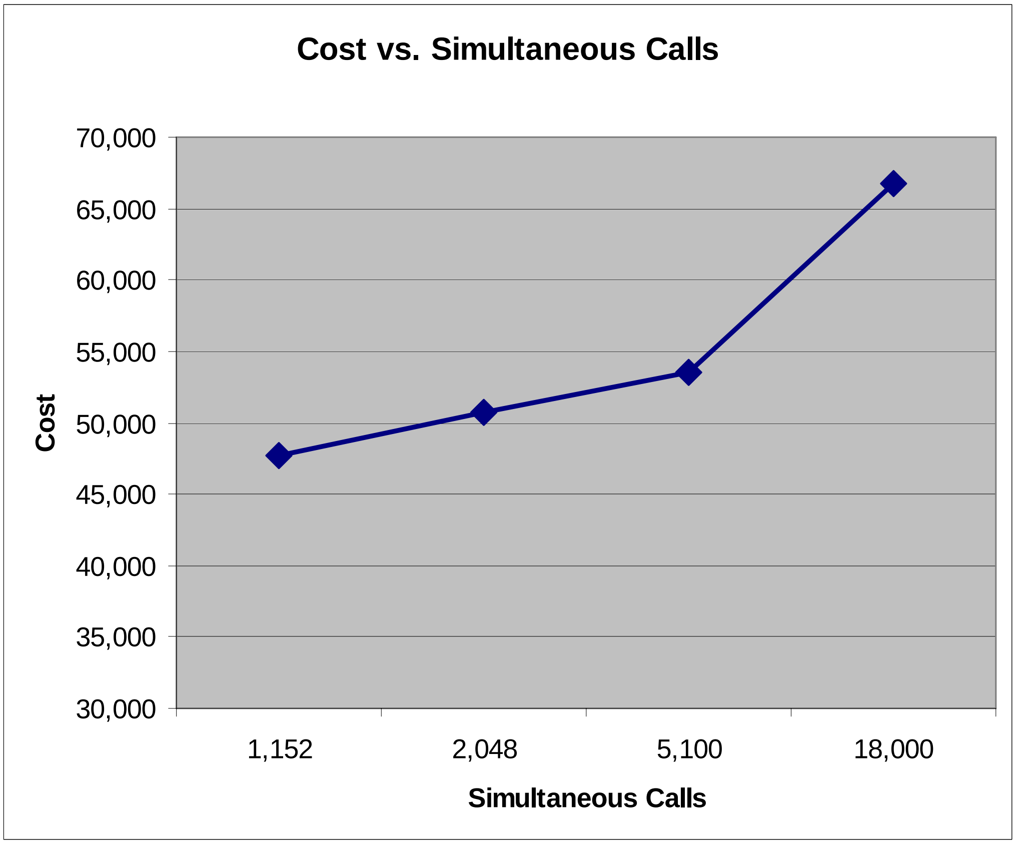


Figure 7: Cost vs. Simultaneous VoIP Calls

As the number of required simultaneous calls increases, the required processing power increases as well as the network interfaces. This increases the cost of the router. From this, our experience is that the costs of the core components in the next generation networks will also have traffic sensitive elements.

IV. TRAFFIC SENSITIVITY IN OTHER NETWORK ELEMENTS

The FNPRM, the FCC asked if there are traffic sensitive elements in the local loop:

> "Should the Commission revisit its decision in the Local Competition First Report and Order that loop costs are not traffic-sensitive?"[18]

Modern local loop architectures do contain some traffic sensitive elements. The physical subscriber local loop is defined as the physical facility that connects the subscriber premise to the switching network. This local loop can consists of fiber cables, copper cables, or electronic equipment (depending upon the design of the network distribution architecture).

It is common to have field electronics that contain a line card that connects to the subscriber using copper cable and connected to the central office using fiber cable. The filed electronics are often referred to as Digital Loop Carriers (DLCs).

As before, the portion of the network from the subscriber up to and including the line card is designed the same whether the subscriber uses the facility for one minute a day or 1,440 minutes (24 hours) a day. This portion of the local loop is not traffic sensitive.

However, the FITL electronics as well as the facilities from the electronics to the central office is traffic engineered based on the services offered and the call patterns and volumes. This architecture is often referred to as Fiber-in-the-Loop (FITL) and is shown in Figure 8.

[18] *Developing a Unified Intercarrier Compensation Regime*, CC Docket 01-92 (FCC 05-33) Further Notice of Proposed Rulemaking (FNPRM), Paragraph 67.

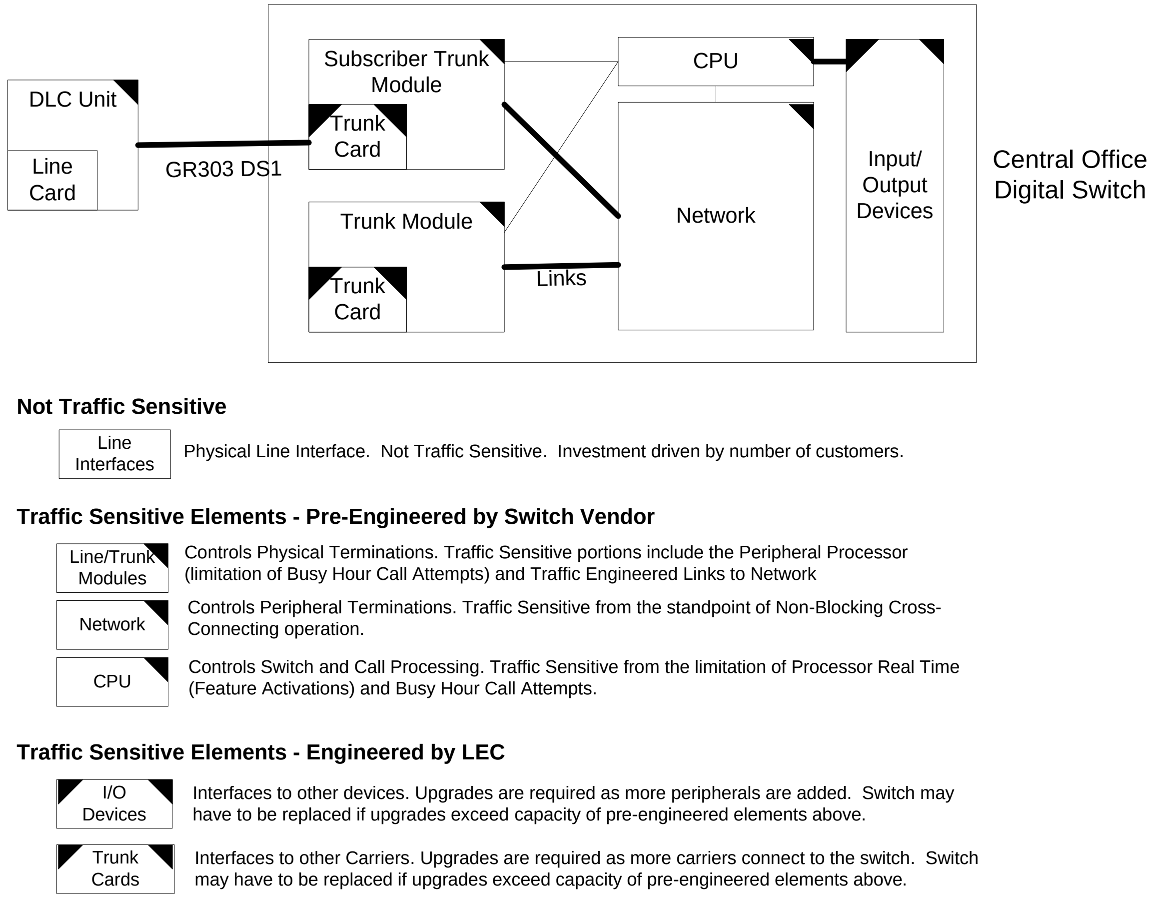


Figure 8: Traffic Sensitive Elements of the Local Loop

The FITL electronics is often connected to the switching system via GR303-based DS1 connections. These connections are traffic engineered based on the desired concentration ratio and Grade of Service (GOS) offered to the subscribers connected to the unit. Many RLECs traffic engineer the GR303 DS1 facilities using a concentration ratio of ranging from 2:1 to 4:1 depending upon the traffic mix at that FITL electronics (business, residential, etc.). Typically, FITL electronics serving business subscribers require a lower concentration level (2:1) while residential traffic patterns often yield a higher (4:1) concentration ratio. This difference in concentration ratios are due to the longer holding times for a business subscriber. These ratios could change based on the changing mix of traffic as time progresses.

V. SUMMARY AND CONCLUSION

Telecommunications Traffic, by its very nature, is not constant. The volume of telecommunications traffic is influenced by subscriber call patterns and call volumes relating to time-of-day, day-of-week, holidays, news events, and many other factors. Telecommunications service providers (including the RLECs) have used historical traffic analysis (to determine the HDBH and ABSBH timeframes) and Poisson Distribution engineering to size the traffic carrying capacity of their telecommunications switching network. The past introduction of new technology (such as dialup Internet) clearly had a profound effect on the traffic characteristics and the related engineering for a telecommunications network. Most providers were forced to add capacity to their networks to support the increase in traffic generated by their existing subscribers. Future introduction of new technology may have a similar effect if it changes the historical traffic patterns of a particular telecommunications service provider.

We have demonstrated that all components of a legacy switching network are traffic sensitive (with the exception of the physical line card). Some switching elements appear to be unaffected by changes in traffic due to the "pre-engineered capacity" designed into the system by the telecommunications switching equipment vendor. The telecommunications switching vendors have attempted to minimize the amount of traffic engineering that a telecommunications service provider must perform by sizing several of their switching equipment components (such as central processors and network matrix equipment) for the "worst case" scenario. This simplifies the traffic engineering process for the telecommunications service provider by leaving only the line aggregation and trunk modules for detailed “per site” traffic engineering functions. In addition, the major legacy switching equipment vendors recognize that their switching products are traffic sensitive and include traffic analysis and provisioning as part of their core training curriculum for their switching equipment.[19]

We have demonstrated that all components of a next generation switching network are traffic sensitive (with the exception of the port card). As the number of required simultaneous VoIP calls increase, the required processing power from the router network increases as well as the quantity (and bandwidth) of network interfaces. These upgrades and additions increase the cost of the router. If the growth of the packet traffic is significant, the router may require replacement with a larger, more expensive unit.

Clearly, the telecommunications switching networks of today (consisting primarily of legacy TDM switching equipment) and the telecommunications switching networks of the future (consisting of routed Next Generation switching platforms) are traffic sensitive. As a cost savings measure, vendors have strived to minimize the traffic engineering that must be performed by the telecommunication service provider with their products, but basic traffic engineering is still a requirement for proper operation. Arguments that indicate that current and future switching platforms will be immune to the effects of traffic, and be based strictly on quantity of end users are without merit.

[19] Website www.nortelnetworks.com – Training Curriculum, DMS-100/200 Engineering

About the Authors

Larry D. Thompson, PE - CEO

Larry has been an active participant in the telecommunications industry since 1985. He received a Bachelors of Arts in Physics (1983) from William Jewell College, a Bachelors of Science in Electrical Engineering (1985) from the University of Kansas, and a Masters of Science in Electrical and Computer Engineering (1986) from the University of Kansas. He is uniquely qualified to lead Vantage Point Solutions in the ever-evolving telecommunications industry. Larry has a proven track record in both the technical and leadership challenges of the business. Prior to Vantage Point Solutions, Larry was General Manager for the Telecom Consulting and Engineering (TCE) Business Unit of Martin Group.

From a technical standpoint, Larry has expertise in the design and implementation of voice, data, and video networks. Larry was lead engineer on the some of the largest Digital Subscriber Line (DSL) video deployments in ILEC service areas. In addition, Larry has architected and optimized many large voice, data, and video networks with a focus on throughput and security.

Larry is a registered Professional Engineer (PE) in the states of Colorado, Georgia, Idaho, Iowa, Indiana, Michigan, Minnesota, Missouri, Nebraska, New York, Ohio, South Dakota, Utah, Wisconsin, and Wyoming. He is a member of several engineering, math, and physics societies, including Eta Kappa Nu, Tau Beta Pi, Sigma Pi Sigma, and Kappa Mu Epsilon.

John M. De Witte, PE - Vice President of Engineering

John has been an active participant in the telecommunications industry since 1983. He received a Bachelor of Science degree in Computer Engineering (BSCprE) from Iowa State University (1982) and a Masters of Business Administration (MBA) from Kennesaw State College (1992). John is actively involved with the research, network architecture design, and economical implementation of emerging technologies into ILEC networks. John's solutions add new revenue to existing applications and create network architectures designed to accommodate future revenue opportunities.

John is a key resource for all aspects of telecommunication implementations, including feasibility studies based upon site specific cost estimates. He has mentored the engineering staff with the development of Plans and Specifications used in broadband state-of-the-art technology for video, voice, and data applications. John is very active in the applications of IP and ATM based convergent networks including Voice Gateways, Voice over IP (VoIP), and softswitching technology. Prior to Vantage Point Solutions, John was Assistant Director of Engineering for the TCE Business Unit at Martin Group.

John is a registered Professional Engineer (PE) in the states of Iowa, Kansas, Michigan, Minnesota, Missouri, Montana, North Dakota, Oregon, South Dakota, and Wisconsin. He is a member of the Institute of Electrical and Electronic Engineers (IEEE) and many other industry organizations.