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The Economics of New Ethernet/IP Access Networks

Network Strategy Partners, LLC
Management Consultants to the Networking Industry

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Occam Networks Inc. develops and markets a suite of Broadband Loop Carriers, innovative Ethernet and IP-based loop carrier platforms that enable telecommunications service providers to profitably deliver a variety of traditional as well as packetized voice, broadband and Internet Protocol (IP) services from a single, converged, all-packet access network. Occam is headquartered in Santa Barbara, Calif. Additional information can be found at www.occamnetworks.com.

Table of Contents

EXECUTIVE SUMMARY

New Ethernet/IP architecture-broadband loop carrier using new distributed intelligence and employing Ethernet and IP-enables carriers to overcome the existing barriers to healthy profit margins and deliver new bandwidth-intensive services. Other access network architectures including Next-Gen DLC and New SONET/ATM while capable of supporting most of these services do so less flexibly and with higher Total Cost of Ownership (TCO).

New Ethernet/IP's Total Cost of Ownership advantage over Next-Gen DLC and New SONET/ATM is 62% and 29% respectively when used to support a three-phase build-out of a typical access network reflecting a broad range of access network densities and remote terminal configurations. These cost savings are derived from lower capital costs (-32% versus Next-Gen DLC and –25% versus New SONET/ATM) and lower network operations expense (-49% versus Next-Gen DLC and –32% versus New SONET/ATM)—the two largest components of total cost of ownership.

The capital cost advantage is derived from the simple modular design that results in both lower common (fixed) and per port (incremental) costs. With both lower common and per port capital costs the advantage is sustained across all remote terminal sizes-48 to 1,152 subscribers per remote terminal. The capital cost advantage, furthermore, is sustained across service mixes ranging from one with 100% POTS and 10% data to one with 100% POTS, 50% data and 40% advanced video subscriber penetration rates.

More efficient use of feeder bandwidth also contributes to the capital cost advantage of New Ethernet/IP. It utilizes 74% less feeder bandwidth per subscriber than Next-Gen DLC for video services and 61% and 67% less than Next-Gen DLC and New SONET/ATM respectively for voice services. This is due to its use of Ethernet/IP that is simpler and consequently more efficient than the SONET/ATM/TDM combination employed by the alternative architectures. More efficient use of feeder bandwidth reduces capital expense by reducing both the size and number of transport ports in the access network.

Lower Service Provisioning and Configuration, Field Support and NOC Support expenses are the primary sources of the New Ethernet/IP Network Operations expense cost advantage. New Ethernet/IP eliminates per subscriber/per service/ per ISP virtual circuit provisioning. This eliminates most service provisioning and configuration work and, therefore, its expense. New Ethernet/IP's simple modular design requires fewer network elements and system components than the other architectures. Field and NOC personnel have less equipment to operate and maintain and, consequently, these expenses are reduced as well.

This paper provides a highly detailed side-by-side analysis of the three architectures as applied to a typical access network. The network is built out in three phases-Maximize Operational Efficiency from POTS and Data, Initial Triple Play and Mature Triple Play-that illustrate the versatile and broad-based economic advantages of New Ethernet/IP. The total cost of ownership, capital and operating expense savings cited above are based on a three-year build out of the three phases.

INTRODUCTION

Access networks play the most critical infrastructure and operational role as carriers focus on wringing out excessive and unsustainable operating expense and seek to grow revenue. Carriers realize that access networks-strategically close to customers, yet the most expensive portion of carrier infrastructure-are ripe not only for modernization, but that making the right access architecture investment is critical to their ongoing business success.

Over the next ten years, nearly every carrier's revenue streams will depend on:

- Continued support of POTS and associated special services but with much better operating margins
- Broadband penetration growing from 0-5% to 10-15% and onto mass-market penetration rates of greater than 30%-50%, but with much better operating margins
- A portfolio of video services, especially core services like broadcast TV and video-on-demand, while keeping operational expense in check despite the tremendous spike in bandwidth needed
- An expanding uptake of business services, especially Ethernet-based connections (over copper as well as fiber), but with the ability to support them at remote terminals rather than forcing expensive direct central office connections
- An increasing demand for new voice and unified services enabled by VoIP next generation softswitch
- The increasing need to transport all services on the same local loop

In addition, carriers are marching forward on the transition to converged packet infrastructure-at the core, at the edge, in services-and an effective access network must be aligned with this packet evolution in order for carriers to extract the kind of value expected from these packet infrastructure investments.

Carriers understand how critical it is to make investments in the right access network architecture because of the access network's critical role and its long installed lifespan. The access network architecture must simplify operations, provide a margin-aligned sustainable cost structure, and offer the scale and flexibility to cope with the next ten years of unpredictable service mix and escalating yet lumpy uptake rates of big-bandwidth services. A properly designed access network puts the carrier in control of its cost structure and service portfolio.

Specifically, a New Ethernet/IP access network enables carriers to overcome the substantial barriers to healthy margins and deliver new bandwidth-intensive services that carriers need for a sustainable business model. Access networks based on legacy technologies saddle carriers with high fixed cost, high incremental cost, high operating expense, and an inability to support even modest uptake rates of emerging services. A New Ethernet/IP access network not only overcomes these barriers, but also positions carriers with the kind of service mix and scale-range to economically cope with uncertain localized uptake rates.

ECONOMIC ADVANTAGES OF NEW ETHERNET/IP ACCESS NETWORKS

Carriers' business goals-namely, continuing to reap revenue but improve margins on POTS services and increase DSL take rates from 5-8% up to mass-market 30-50% levels-have important ramifications for access networks. Just to support Internet connections over the next ten years, access networks will have to:

- Handle much larger number of DSL ports
- Handle much more feeder bandwidth per subscriber, since broadband connections result in average time online per subscriber on the order of hours rather than minutes
- Handle much more feeder bandwidth per subscriber, due to richer content (e.g., listening to radio, downloading movies) being pushed by content industry heavy weights like Disney, SONY, and broadband-targeted packages from the likes of AOL
- Expand the reach of DSL and high-broadband services over DSL-moving small remote terminals (already the dominant portion of access nets) even further towards the customers in order to shorten loops and expand the footprint of houses served

Access networks will have to handle bandwidth of an order of magnitude higher when video services are added to the mix. Video bandwidth requirements will exceed those of broadcast TV and even VOD as video providers add a proliferation of subscription channels like the "The Birders' Channel" to fend off direct satellite TV.

Carriers can no longer afford access networks that are not optimized to handle this uncertain mix of voice, data, and video services across a wide range of small to large remote terminal sites with entrée costs that are prohibitive and operating costs that are unsustainable.

The remaining sections of this paper describe the economic advantages of New Ethernet/IP access networks versus New SONET/ATM and NGDLC architectures. We define these three access network architectures as follows:

- New Ethernet/IP – Broadband loop carrier using a distributed architecture, Ethernet Layer 2 transport and IP Layer 3 switching
- New SONET/ATM – New designs based on traditional SONET and ATM technology
- NGDLC – Traditional legacy DLC with upgraded broadband capabilities employing a mix of TDM, ATM and SONET technology

Figure 1 depicts the New Ethernet/IP architecture while Figure 2 depicts both the New SONET/ATM and NGDLC architectures.

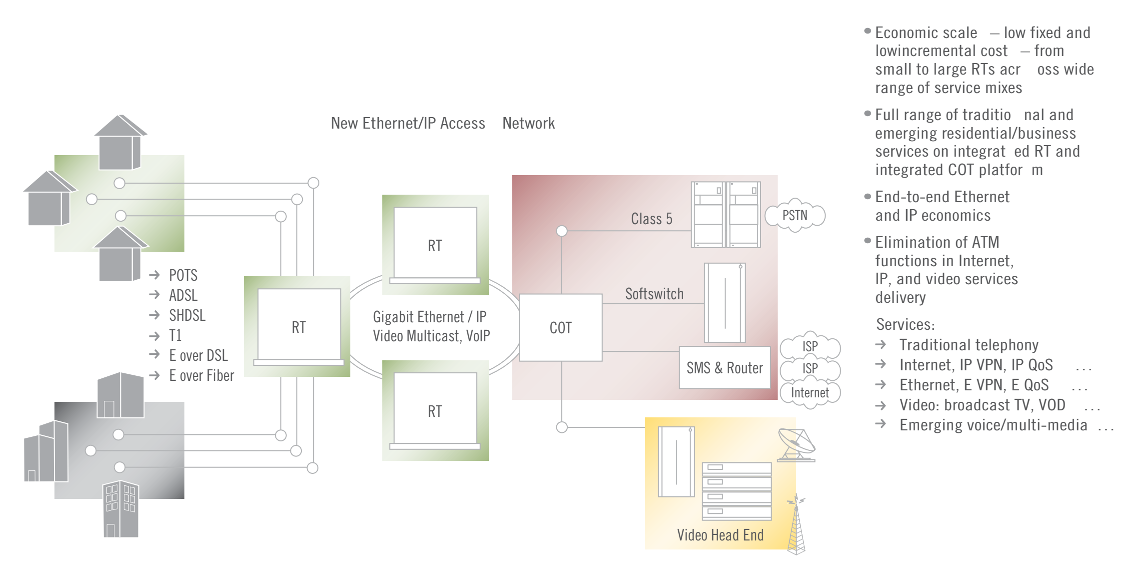

Figure 1

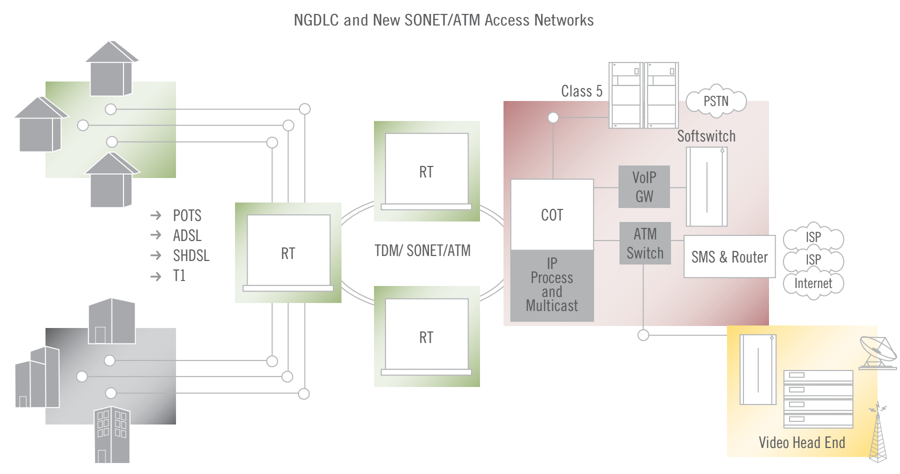

Figure 2

BUSINESS CASE: NEW ETHERNET/IP ACCESS NETWORKS

The economic advantages of the New Ethernet/IP access network architecture are demonstrated by examining the network shown in Figure 3. 8,448 Subscribers are served by Remote Terminals (RT) located on four access networks. Though shown as ring networks, any protected path topology could be used without significant impact on the overall cost analysis. The networks exhibit a wide subscriber density range-the small North ring serves 576 subscribers from four RTs while the West ring serves 4,272 subscribers from ten RTs. The RT sizes, also, are diverse ranging from 48 to 1,152 subscribers. The wide range in node and network sizes is intended to reveal the cost of the three architectures over all of the typical sizes found in ILEC systems. Node sizes are in even 48 port increments so none of the architectures are put at a disadvantage by using partial capacity.

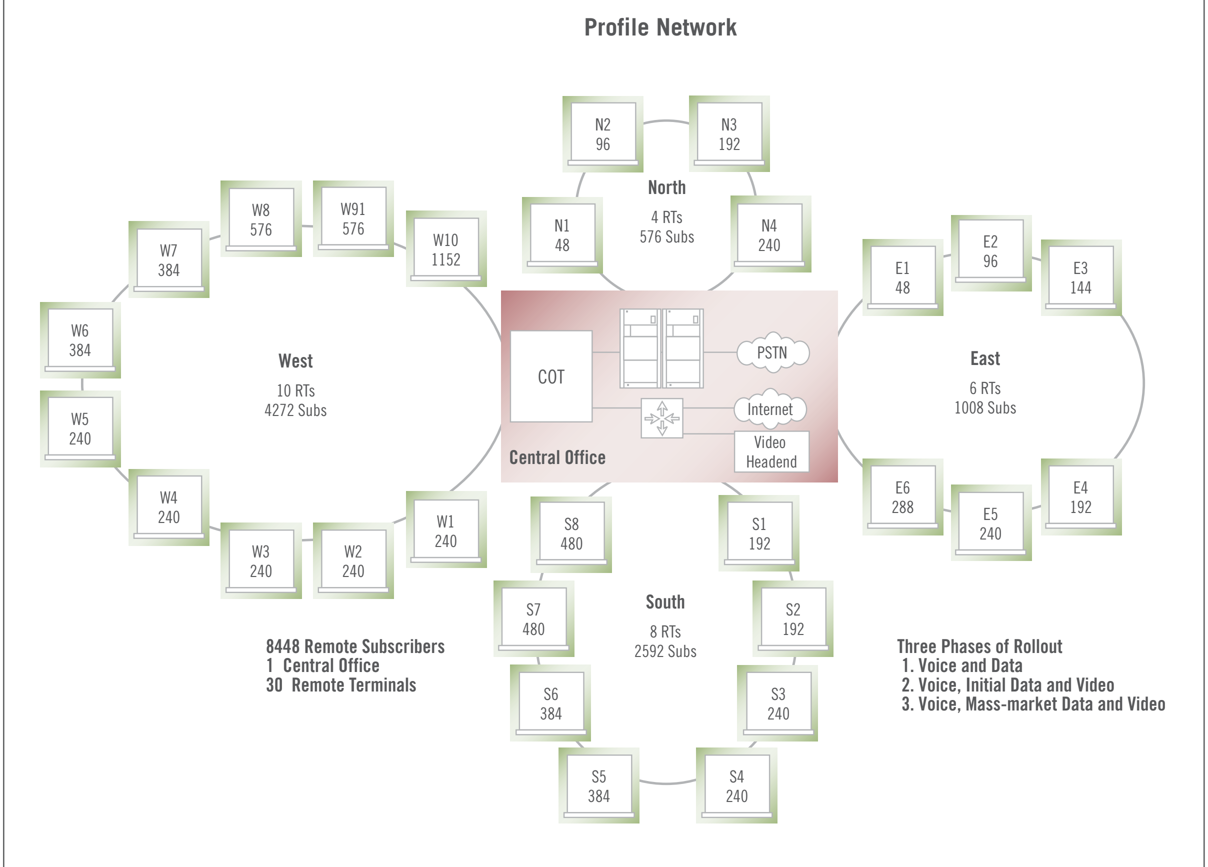

Figure 3

Table 2 (page 11) provides further statistics on the configuration of each RT.

The scalability and flexibility of the New Ethernet/IP architecture is demonstrated by modeling a three phase network build-out. All three phases assume 100% POTS penetration.

- Phase I Business Model: Maximize Operational Efficiency From POTS and Data
  Phase I models maximizing operational efficiency from traditional POTS and Data services. The service mix consists of POTS and 10% Data uptake. Phase I is intended to represent typical current operations.

- Phase II Business Model: Initial Triple Play
  In Phase II data penetration increases to 25% and video service is introduced with an uptake rate of 15% of subscribers. Phase II video service is broadcast TV and Pay Per View (PPV)[1]. Phase II is intended to represent operation that may be expected one year after launch of video services

- Phase III Business Model: Mature Triple Play
  In Phase III data uptake increases to 50% and video services increase to 40% uptake rate[1]. Phase III video service increases the number of broadcast and PPV channels and adds Video-on Demand. Phase III is intended to represent the long term demands on the access network as broadband data and digital video become mass-market services.

Table 1 (page 10) shows the usage and traffic engineering parameters used in the economic analysis.

[1]The CapX calculations, to follow, assume that all video subscribers also subscribe to Data service.

Table 1
Usage and Traffic Engineering Parameters

Service	Phase I Voice & Data	Phase II Initial Triple Play	Phase III Mature Triple Play
Voice			
Take Rate	100%	100%	100%
NGDLC per subscriber bandwidth[A]	64 Kbps	64 Kbps	64 Kbps
New SONET/ATM per subscriber bandwidth[B]	75 Kbps	75 Kbps	75 Kbps
New Ethernet/IP per subscriber bandwidth[C]	100 Kbps, with 4:1 efficiency	100 Kbps with 4:1 efficiency	100 Kbps with 4:1 efficiency
Data			
Take Rate	10%	25%	50%
Over-subscription	50:1	50:1	25:1
Average subscriber usage	1 Mbps	1 Mbps	1 Mbps
Video			
Take Rate	0%	15%	40%
Households with at least 1 TV in peak-time	N/A	60%	60%
Households with 2nd TV on different channel at peak-time	N/A	20%	20%
Bandwidth per video stream[D]	N/A	3.8 Mbps	3.8 Mbps
Number of broadcast and PPV channels offered	N/A	100	250
Number of concurrent channels possible on the DSL link to the household	N/A	2	2
All[E]			
Bandwidth protection	100%	100%	100%

Notes:

A – fixed bandwidth TDM (bandwidth is consumed whether a call is active or not)

B – fixed bandwidth ATM VC (CES) with overhead (bandwidth is consumed whether a call is active or not)

C – dynamic bandwidth utilization assuming conservative 25% off-hook and 100 Kbps per active call. QoS capabilities manage bandwidth so full bandwidth needed for all concurrent voice calls is always available.

D – MPEG2 encoding, includes overhead

E - To provide a balanced analysis the network is planned with 100% redundant bandwidth so that even the lowest priority traffic has protection bandwidth. In practice, Ethernet/IP offers the opportunity for more efficient bandwidth traffic plans.

Table 2 shows the number of subscribers for voice, data and video for each RT and the CO as derived by applying the usage assumptions from Table 1 (page 10) to the network diagram and node sizes of Figure 3 (page 11).

Table 2
Lines in Service

Site	Phase I			Phase II			Phase III		
	Voice	Data	Video	Voice	Data	Video	Voice	Data	Video
North Access Network									
N1	48	5	0	48	12	7	48	24	19
N2	96	10	0	96	24	14	96	48	38
N3	192	19	0	192	48	29	192	96	77
N4	240	24	0	240	60	36	240	120	96
Total	**576**	**58**	**0**	**576**	**144**	**86**	**576**	**288**	**230**
East Access Network									
E1	48	5	0	48	12	7	48	24	19
E2	96	10	0	96	24	14	96	48	38
E3	144	14	0	144	36	22	144	72	58
E4	192	19	0	192	48	29	192	96	77
E5	240	24	0	240	60	36	240	120	96
E6	288	29	0	288	72	43	288	144	115
Total	**1,008**	**101**	**0**	**1,008**	**252**	**151**	**1,008**	**504**	**403**
South Access Network									
S1	192	19	0	192	48	29	192	96	77
S2	192	19	0	192	48	29	192	96	77
S3	240	24	0	240	60	36	240	120	96
S4	240	24	0	240	60	36	240	120	96
S5	384	38	0	384	96	58	384	192	154
S6	384	38	0	384	96	58	384	192	154
S7	480	48	0	480	120	72	480	240	192
S8	480	48	0	480	120	72	480	240	192
Total	**2,592**	**259**	**0**	**2,592**	**648**	**389**	**2,592**	**1,296**	**1,037**
West Access Network									
W1	240	24	0	240	60	36	240	120	96
W2	240	24	0	240	60	36	240	120	96
W3	240	24	0	240	60	36	240	120	96
W4	240	24	0	240	60	36	240	120	96
W5	240	24	0	240	60	36	240	120	96
W6	384	38	0	384	96	58	384	192	154
W7	384	38	0	384	96	58	384	192	154
W8	576	58	0	576	144	86	576	288	230
W9	576	58	0	576	144	86	576	288	230
W10	1,152	115	0	1,152	288	173	1,152	576	461
Total	**4,272**	**427**	**0**	**4,272**	**1,068**	**641**	**4,272**	**2,136**	**1,709**
Total Profile Network									
Grand Total	**8,448**	**845**	-	**8,448**	**2,112**	**1,267**	**8,448**	**4,224**	**3,379**

TOTAL COST OF OWNERSHIP

Total Cost of Ownership (TCO), consisting of capital, network operations and environmental expenses, for each of the three architectures was calculated for the example network with usage and traffic requirements as specified in the preceding tables. Figure 4 shows the result for a network in which all three project phases are completed.

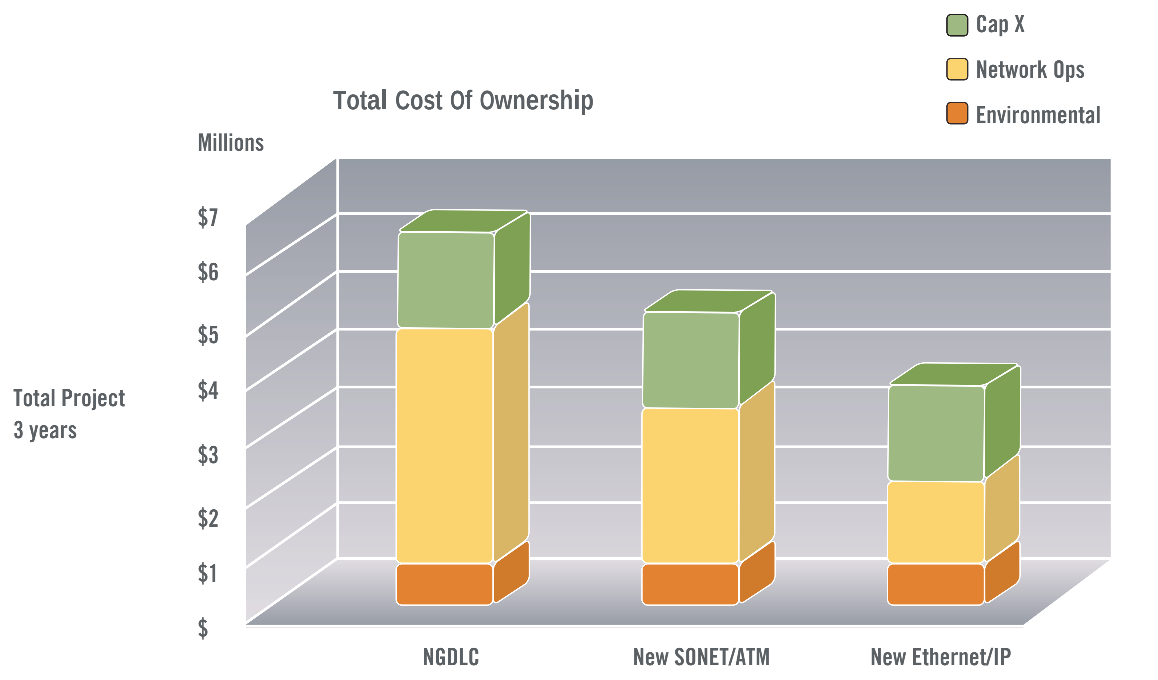

Figure 4

The New Ethernet/IP architecture has superior total cost of ownership compared to the other two architectures. In this example the New Ethernet/IP architecture enjoys a 29% total cost of ownership advantage over the New SONET/ATM design and 69% advantage over the NGDLC design. This superiority is attributable to lower capital and network operations expenses. These economic advantages and their underlying causes are examined below beginning with capital expense.

CAPITAL EXPENSE

Figure 5 summarizes the capital expense analysis. The columns graphed in Figure 5 show the investment added in each phase while the lines indicate the percentage of subscribers using voice, data and video services.

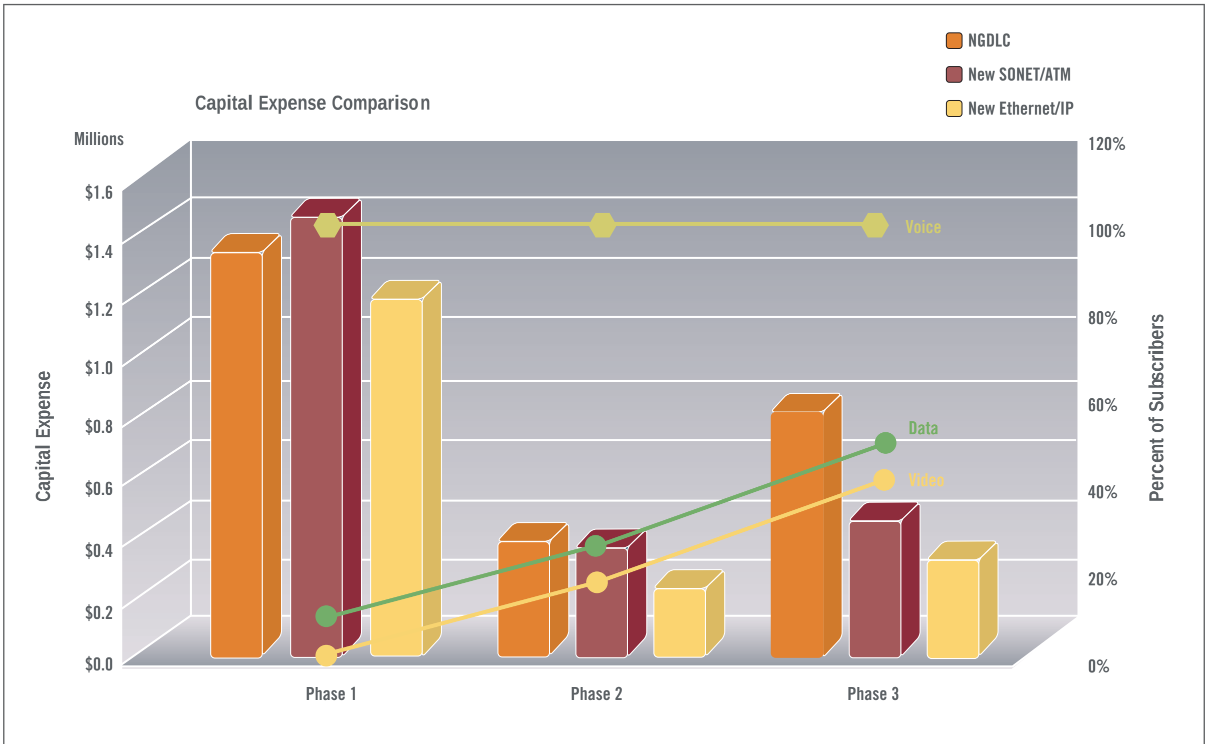

Figure 5

Capital expense includes the cost of the electronics used in the access network including central office terminals (COT) and remote terminals (RT). It excludes installation, engineering, and installation materials expense as well as the capital expenses associated with cabinets, cables, optical fiber and CPE.

The New Ethernet/IP architecture enjoys a consistent CapX advantage over both NGDLC and New SONET/ATM in all three project phases. It provides lower CapX in Phase I where only POTS and modest levels of Data are delivered and increases its advantage with the increased data and video penetration and usage modeled in Phases II and III. NGDLC becomes a particularly expensive architecture for Phase III with its high video penetration and usage.

Figure 6 provides another view of total capital expense showing the cumulative effect of New Ethernet/IP's more efficient use of capital at each project phase.

Figure 6

Total project capital expense, also, is lower for the New Ethernet/IP architecture for all four access networks ranging from the 576 subscriber North Access Network to the 4,272 subscriber West access network (See Figure 7.)

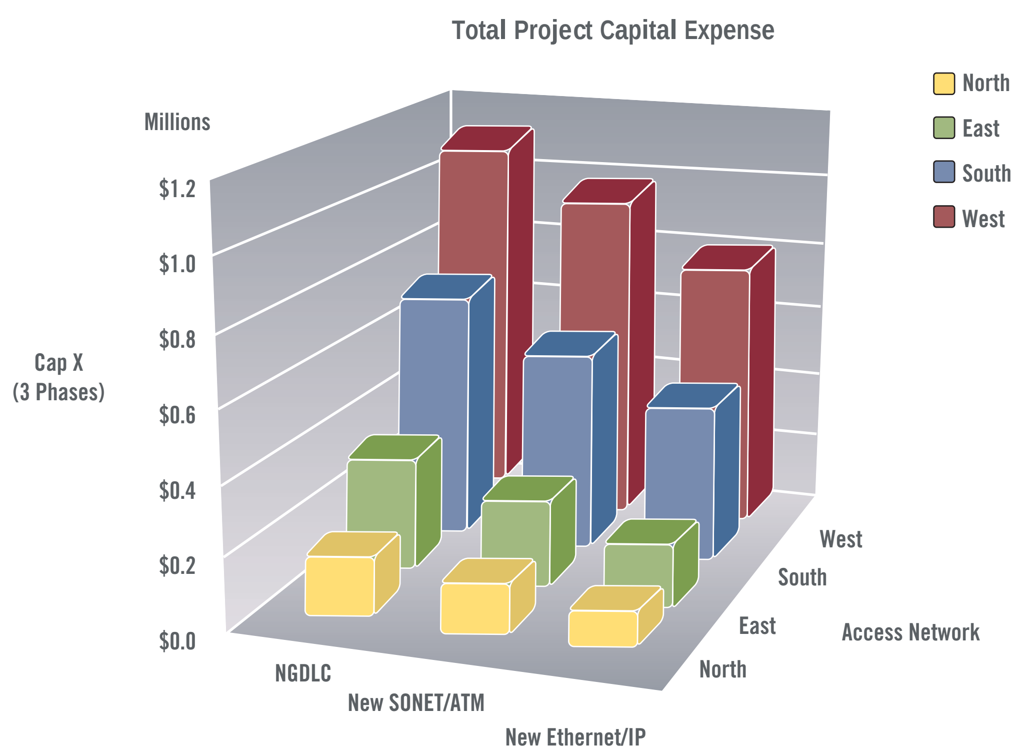

Figure 7

Figure 8 drills down into the cost structure of the three architectures by segmenting capital expense between common cost necessary regardless of system capacity and port cost that varies directly with the number of service lines supported.

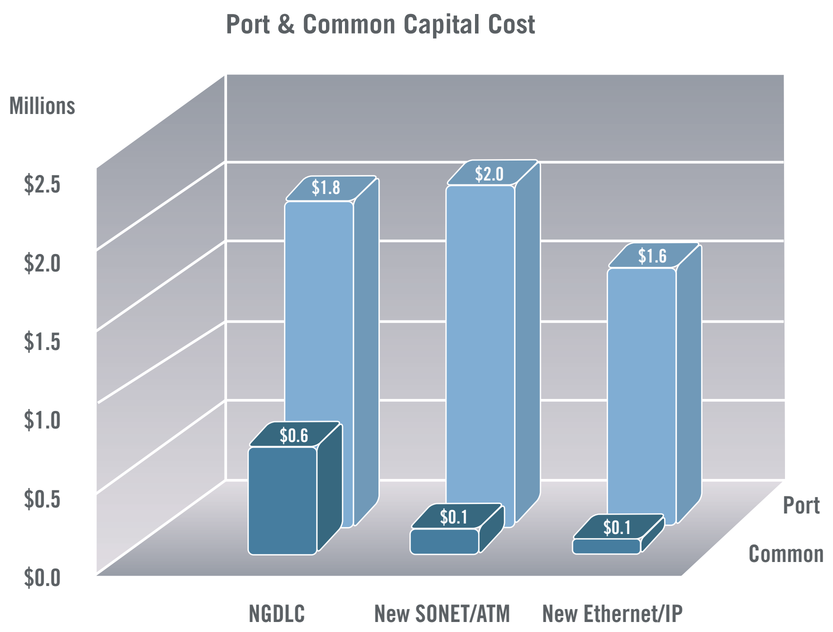

Figure 8

The New Ethernet/IP architecture has very small common cost and its port (incremental) cost is significantly less than the other two architectures. This cost advantage is due to the simplicity of the all Ethernet/IP design. The NGDLC design has especially high common cost because a separate CWDM system is need to accommodate the video traffic added in Phases II and III. These capital expense advantages mean that carriers no longer have to pay a high upfront penalty for expensive common system components, and once installed, continue to derive per-port cost savings. This becomes especially critical as carriers seek to add RTs to shorten DSL loops in order to support more bandwidth. Shortening DSL loops results in smaller serving areas with associated greater uncertainty in service mixes and uptake rates. The New Ethernet/IP cost structure, consequently, reduces the investment risk of service upgrade initiatives.

Figure 9 shows the total capital cost per site for each technology versus site size (number of subscribers).

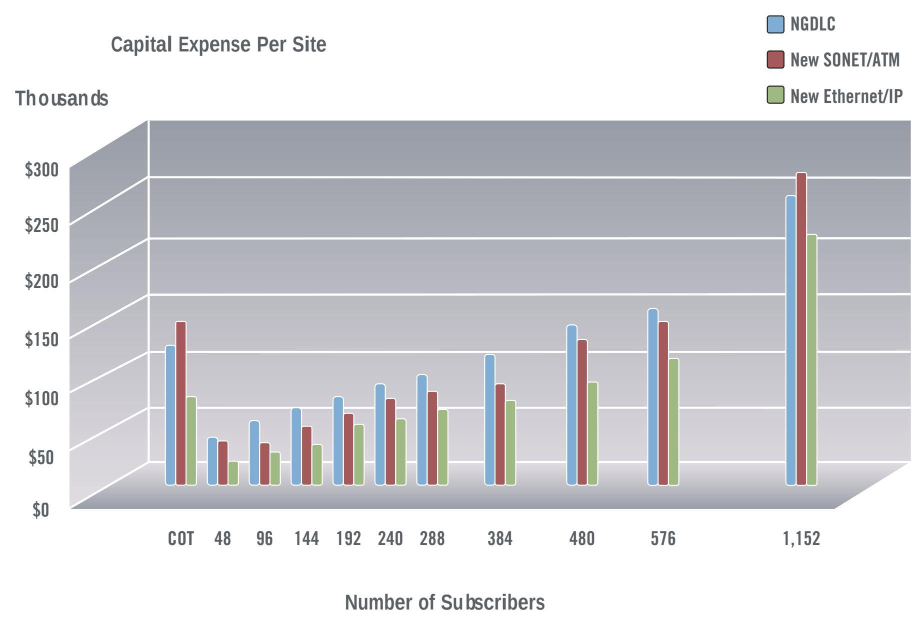

Figure 9

New Ethernet/IP access networks are more economical across all sizes of RTs from the smallest (48 subscribers) through the largest (1,152 subscribers). Its Central Office Terminal (COT) also is lowest cost. This enables carriers to adopt a single architecture and use a single product family across the entire access network, rather than using different platforms for different size RTs.

Figure 10 illustrates another source of economic advantage for the New Ethernet/IP architecture-fewer internal ports. We define internal ports to be those connecting the RTs to the Central Office Terminal (COT). They are internal to the access network architecture-necessary only to make the architecture work and serve no role in either delivering end-customer services or connecting the access network to upstream network services.

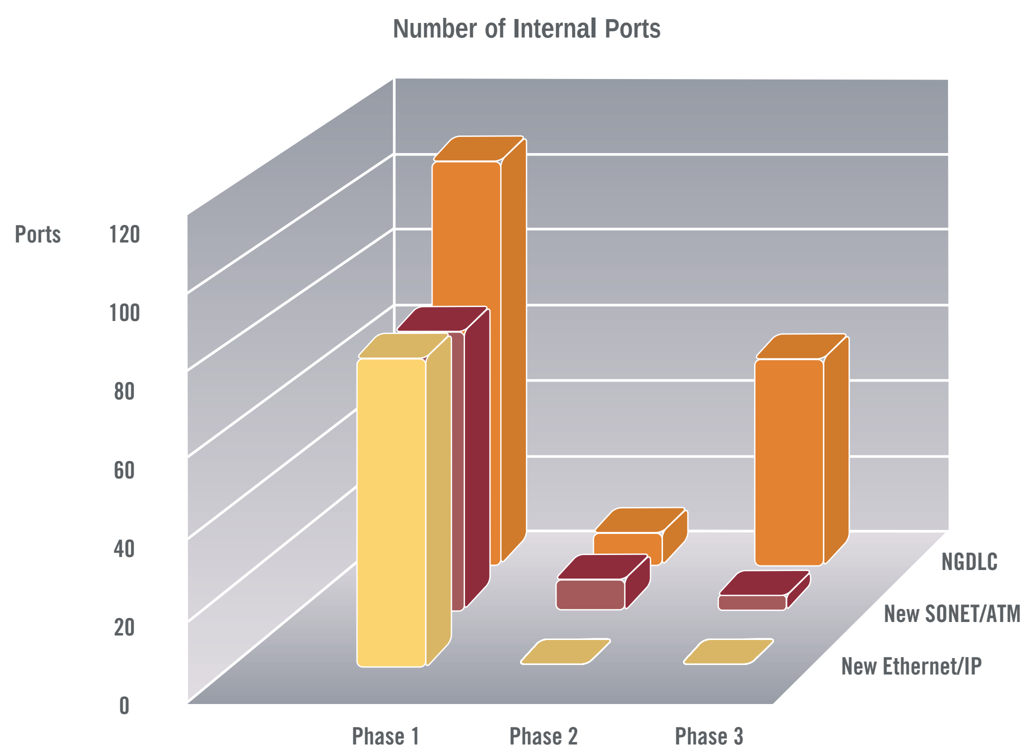

Figure 10

The NGDLC uses the largest number of internal ports in Phase 1. This is due to its use of lower speed OC-12 SONET versus the other architectures' use of OC-48 SONET or multiple Gigabit Ethernet for internal connectivity. In Phase 3 NGDLC requires additional CWDM ports to support advanced video services. These additional ports add directly to capital expense and indirectly to both capital and operating expense. NGDLC also has the additional complexity of adding IGMP Multicast equipment to support the video service introduced in Phase 2. The excessive number of internal ports adds to design and operational complexity with resulting capital and operational cost penalties.

FEEDER BANDWIDTH

Figure 11 shows feeder bandwidth consumption for the three architectures.

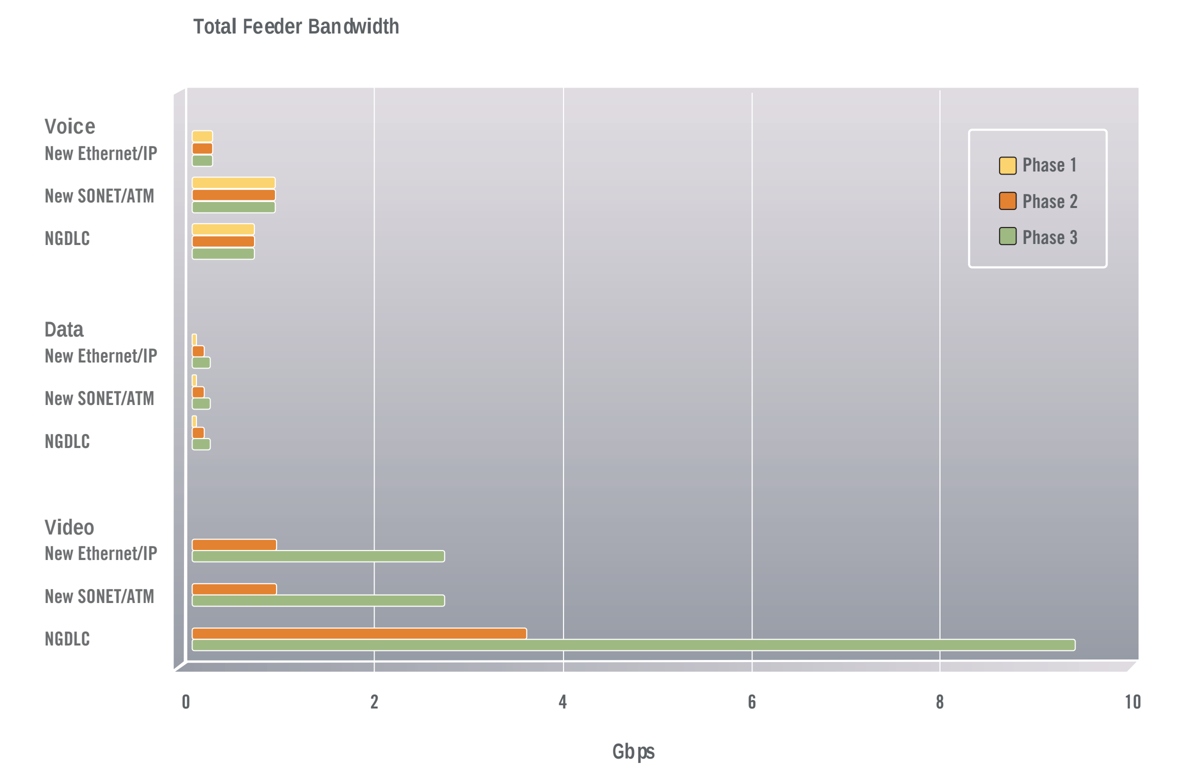

Figure 11

Efficient bandwidth utilization on the feeder network is another source of economic advantage for the New Ethernet/IP architecture. It handles voice traffic more efficiently than both New SONET/ATM and NGDLC and is dramatically more efficient than NGDLC in handling video traffic. Figure 11, also, shows the dramatic effect that video service has on total feeder bandwidth. The dramatic swing in bandwidth requirements caused by the addition of video underscores the importance of the New Ethernet/IP architecture's capability to reduce the risk of future service uncertainty (see discussion associated with Figure 8).

Voice

The New Ethernet/IP architecture has a significant feeder bandwidth advantage over the other architectures. This is attributable to the incorporation of VoIP processing within the RT permitting use of dynamic bandwidth allocation. Dynamic bandwidth allocation yields important bandwidth efficiencies since feeder capacity is only used when a caller is speaking. Since callers usually take turns speaking this provides at least a 50% bandwidth efficiency improvement-speaker pauses add additional dynamic bandwidth allocation efficiencies. (A conservative 4:1 efficiency gain is used in the profile network.) In contrast, the NGDLC design utilizes nailed up DS0 duplex channels (64 Kbps) while the New SONET/ATM design also uses nailed up bandwidth and incurs the ATM cell tax penalty.

Data

Data bandwidth is planned as 1 Mbps per subscriber with 50:1 oversubscription in Phases I & II, reduced to 25:1 oversubscription in Phase 3. The three technical approaches consume network bandwidth for data service with about the same efficiency. In practice, New Ethernet/IP consumes less overhead bandwidth than SONET/ATM, however this advantage is generally ignored in typical network planning and so is not considered here. (That is the 1 Mbps planned per customer absorbs the overhead regardless of amount actually consumed by the technical approach.)

Video

Video services are planned using 3.8 Mbps per video stream. Each active channel consumes that much bandwidth from the nearest multicast site. In the NGDLC network, multicast is from the Central Office where the additional multicast capable devices have been installed. The New SONET/ATM network multicasts at every site, but incurs additional costs for IP processing capability. The New Ethernet/IP network has multicast from every site, with no additional costs.

NETWORK OPERATIONS EXPENSE

Figure 12 compares Network Operations expense, the most important component of total cost of ownership, for the three architectures.

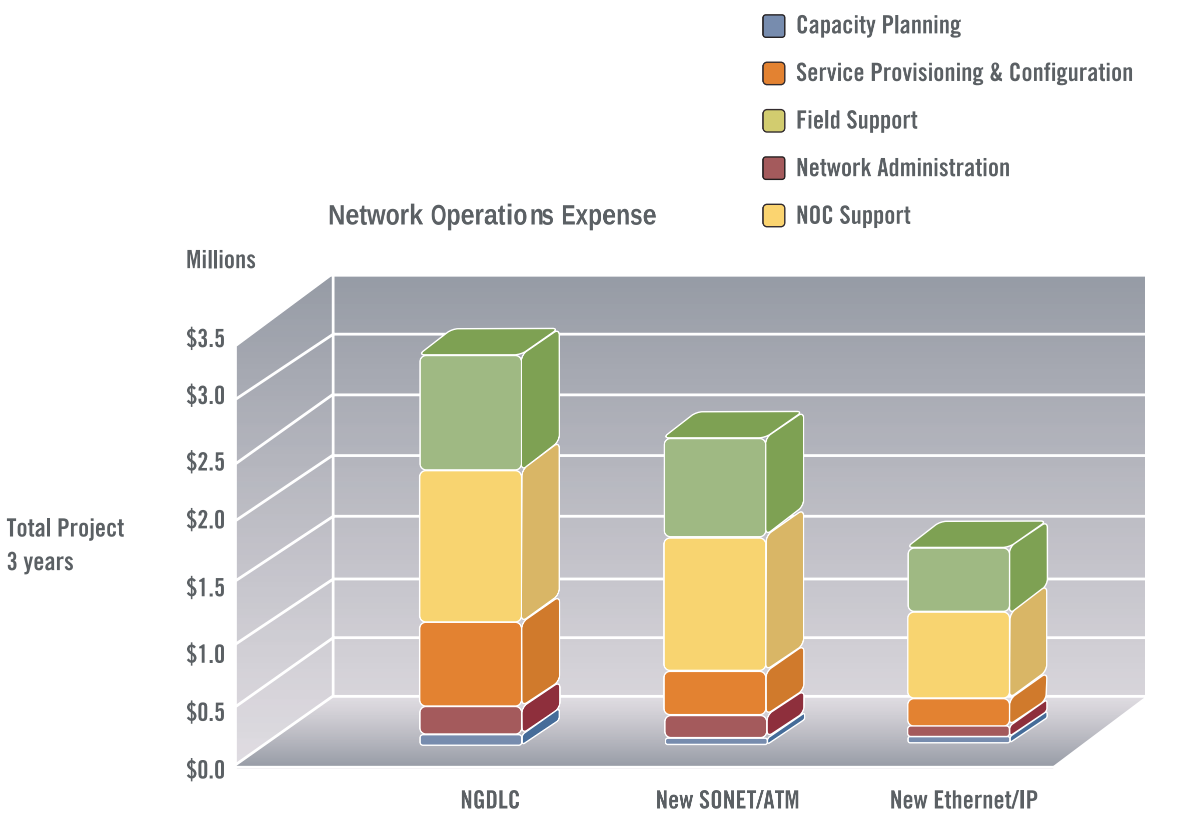

Figure 12

The New Ethernet/IP architecture enjoys a substantial network operations expense advantage over the other two architectures. Service provisioning expense is the largest contributing factor to the cost advantage while NOC and Field Support also add to New Ethernet/IP's network operations expense advantage.

The New Ethernet/IP architecture's significant service provisioning and configuration expense advantage is due to its elimination of per subscriber/per service/per ISP virtual circuit provisioning. The New Ethernet/IP design requires only one-time specification of service policies. This eliminates most of the service provisioning and configuration work. Figures 13 and 14 illustrate this work reduction schematically.

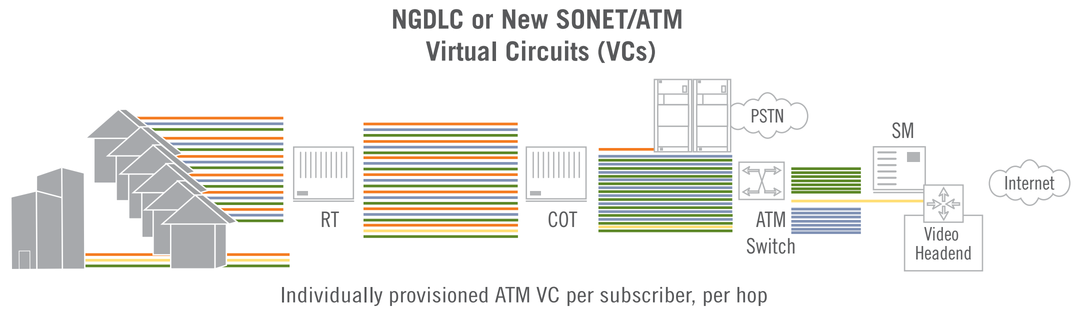

Figure 13

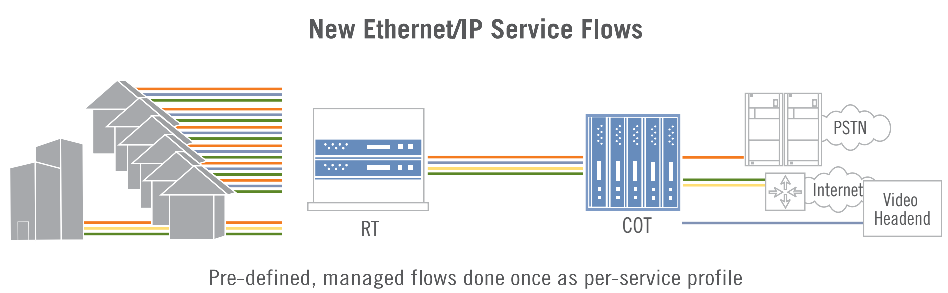

Figure 14

Field and NOC support are lower for the New Ethernet/IP architecture because it employs fewer network elements and system components than the other architectures. We define network elements as complete systems such as digital loop carrier and course wave division multiplexing systems while system components consist primarily of interface cards or system modules. Figures 15 and 16 show the number of the network elements and systems components.

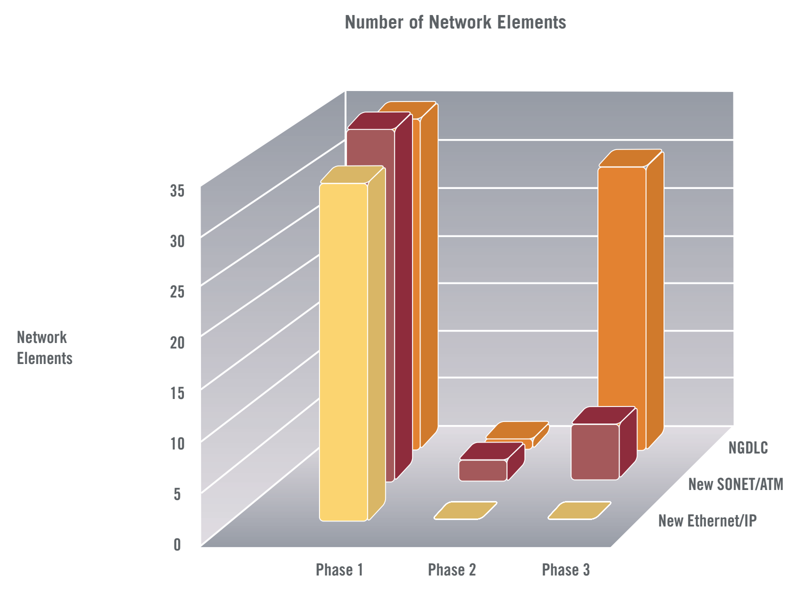

Figure 15

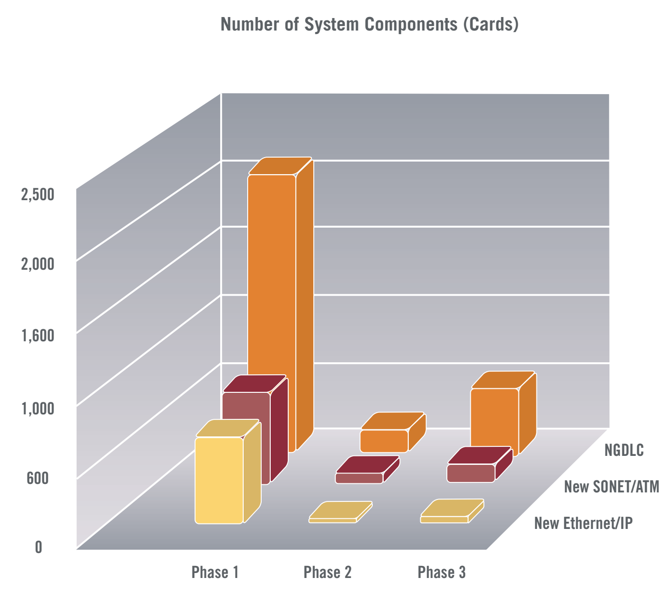

Figure 16

ENVIRONMENTAL EXPENSE

Environmental expense is the least important component of total cost of ownership amounting to no more than 18% of total cost. It is comprised of the annual cost of supplying power and battery and re-generation services to the remote terminals of which power is about three-fourths of total environmental expense. The cost of power is determined by the average power consumption of each remote terminal module while battery and re-generation expense is a function of peak (or rated) power usage since sufficient backup capacity must be provided to meet all foreseen needs. As depicted back in Figure 4, the technical approaches are about equal in this category.

ADDITIONAL ECONOMIC CONSIDERATIONS

A New Ethernet/IP architecture provides additional economic advantages including:

- New Ethernet/IP can replace additional components especially at smaller sites where low to moderate density does not warrant standalone devices. Stand alone optical multiplexers and Ethernet switches can often be avoided as well as ATM switches at the central office.

- New Ethernet/IP supports a very cost effective approach to softswitch transition. Performing VoIP gateway functions in the RT eliminates multiple TDM/VoIP conversions. This reduces capital expense by eliminating the need for extra GR-303 cards and standalone VoIP gateway platforms when the carrier begins the transition to Next Gen softswitch platforms.

- New Ethernet/IP supports more flexible network topologies (more nodes on a ring, multiple ring from the same node, longer distances, etc.)providing more network design opportunities to reduce cost and improve performance.

- New Ethernet/IP supports optical and copper access technologies on the same platform simplifying operations.

- New Ethernet/IP cost-effectively enables new service offerings, including:

    - Services based on Ethernet over DSL or Ethernet over Fiber – This is especially important for broadening the geographic availability of Ethernet-based services by Ethernet-enabling existing copper plant.

    - Granular data rates from 1 Mbps to 1Gbps in 100kbps increments – This provides opportunities to increase revenue by offering more pricing options versus TDM's and SONET's larger data rate increments.

    - Ability to provision DSL-based, Ethernet-based, and other services remotely in software – This eliminates costly truck rolls for moves/adds/changes like service activation or bandwidth upgrades and supports value-added customer controlled service management options.

    - Variable protection schemes – This opens the possibility for a broad range of services with different levels of protection at different price points. This is especially important for tapping into the broader market as demand for Business Continuity and Disaster Recovery services move downstream from price-insensitive Fortune 50 data centers. Variable protection schemes are valuable for improving profit margins because they permit tuning each customer's level of protection to his willingness to pay while the incremental cost of delivering the added protection is quite low.

CONCLUSION

The New Ethernet/IP architecture is built upon the philosophy of Occam's Razor, "What can be done with less, is done in vain with more." This economic analysis demonstrates the merit of the philosophy. The simple modular design built upon Ethernet and IP yields lower Total Cost of Ownership than the Next-Gen DLC and New SONET/ATM architectures because it handles voice, data and video in one unified manner which results in fewer network elements, system components, and internal ports. This simple unified solution, also, dramatically simplifies provisioning and configuration management from a per service, per subscriber, per ISP process to one-time specification of service policies. Consequently, by doing the job with less the following economic benefits are realized:

- Lower capital costs across all remote terminal sizes and service mixes due to lower common and per port capital cost
- More efficient use of feeder bandwidth
- Lower service provisioning and configuration expense
- Lower field and NOC support expense
- Lower incremental cost to accommodate increased penetration and usage of data services
- Lower incremental cost to accommodate increased penetration and usage of video
- Lowest cost support for POTS without compromising future service opportunities
- Less capital deployment risk

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