

A Business Case Comparison of Carrier Ethernet Designs for Triple Play Networks



Network Strategy Partners, LLC

MANAGEMENT CONSULTANTS TO THE NETWORKING INDUSTRY

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Executive Summary

Many Service Providers around the world have concluded that in order to maintain growth and margins in their businesses they must become a full provider of multimedia services—Triple Play Networks. It has now become table stakes to offer IPTV, Video-on-Demand, Voice-over-IP, and High Speed Internet over a broadband network. While there is consensus among most Service Providers that the future aggregation and core networks will be Ethernet and IP/MPLS, they have differing opinions as to the architecture and design of these networks.

This paper compares the Total Cost of Ownership for two Carrier Ethernet designs for the Aggregation Network.

- Cisco IP NGN Carrier Ethernet Design
- Hierarchical-Virtual Private LAN Service (H-VPLS)

IP NGN Carrier Ethernet Design is a Cisco® end-to-end network system design approach for the Cisco IP NGN (Next Generation Network) architecture, which provides the ability to treat each service with optimal transport mechanisms, thereby providing efficiency, reliability, superior quality of experience, and adaptability to future services. IP NGN Carrier Ethernet Design is a service-aware network layer architecture that supports essential service attributes at both Layer 2 and Layer 3 (including layer 3 in the aggregation network), making it an optimal design to converge residential and commercial business services. It also advocates the integration of application layer intelligence into the fabric of the network and the distribution of that higher layer intelligence close to the user. This includes functions such as session border controller, video error repair, video quality monitoring, and deep packet inspection.

The H-VPLS design uses standard Layer 2-only Ethernet data forwarding and control plane mechanisms to emulate Ethernet bridging (known as VPLS instances) in the aggregation network, per subscriber QoS and per subscriber VLANs for all services. This model also uses a centralized BRAS (Broadband Remote Access System) for PPP services and a separate policy based solution for IP sessions. H-VPLS limits the scope of deploying PIM to the IP/MPLS backbone and uses IGMP snooping in conjunction with VPLS to emulate multicast in order to deliver broadcast video traffic. H-VPLS's underlying tunneling technology is MPLS with its associated QoS capabilities and rapid service recovery times.

The Total Cost of Ownership comparison of the IP NGN Carrier Ethernet Design versus the H-VPLS Design is made by calculating revenues, CAPEX, OPEX, cash flow, Net Present Value, and IRR for both approaches over a five year period for a hypothetical

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network. The hypothetical network characterizes expected Triple Play service requirements and the network topology of a large metro area.

The key findings are:

- 1) There is a strong business case for the IP NGN Carrier Ethernet Design with a payback in the second year of operation and positive cash flow thereafter.
- 2) The Total Cost of Ownership (CAPEX and OPEX) of the H-VPLS Design is significantly higher than the IP NGN Carrier Ethernet Design.
- 3) The IP NGN Carrier Ethernet Design also allows reduction of network traffic and CAPEX by implementing Integrated Video Connection Admission Control (CAC).

Introduction

Many Service Providers around the world have concluded that in order to maintain growth and margins in their businesses they must augment their business services and residential voice and data services to become a full provider of multimedia services—Triple Play Networks. It has now become table stakes to offer IPTV, Video-on-Demand, Voice-over-IP, and High Speed Internet over a broadband network. While there is consensus among most Service Providers that the future aggregation and core networks will be Ethernet and IP/MPLS, they have differing opinions as to the architecture and design of these networks. Some important design issues include:

- Should bridging, H-VPLS, or Layer 3 be used for aggregation? Should all services be treated the same?
- Should per subscriber QoS or per-service QoS be used? Should all services be treated the same?
- Where should the subscriber management function be located in the network?

This paper analyzes the business case for two Carrier Ethernet Aggregation Network designs that resolve these issues differently¹:

- IP NGN Carrier Ethernet
- H-VPLS

¹ A Centralized Design is a third approach to Carrier Ethernet Aggregation Network design. The Centralized Design uses Layer 2 bridging in the aggregation network and uses the BRAS as the gateway for all IP traffic including voice and video. See *A Business Case Comparison of the IP NGN Carrier Ethernet Design to the Centralized BRAS Design for Triple Play Broadband Access Networks*, Network Strategy Partners, LLC; October 2006 -- <http://www.cisco.com/>

The business case is analyzed by computing the Total Cost of Ownership (TCO) incurred by each design to support a hypothetical Triple Play network over five years.

The analysis begins by identifying the challenges associated with the delivery of transport and application services. Then, an overview of each design and its underlying rationale is presented. Next, the hypothetical network representative of a large service provider Carrier Ethernet Aggregation Network is defined by specifying the network characteristics of the Carrier Ethernet solution, service assumptions and a traffic forecast.

Network configurations to meet the service and traffic requirements of the hypothetical network are specified and used to calculate Total Cost of Ownership (CAPEX and OPEX) and a revenue allocation for each design. Financial metrics including cash flow, payback, Net Present Value (NPV), and Internal Rate of Return (IRR) are used to compare IP NGN Carrier Ethernet Design with H-VPLS and to quantify business case advantages.

An Appendix examines the financial impact of the IP NGN Carrier Ethernet Design with Integrated Video Connection Admission Control (CAC).

Transport and Application Service Delivery Challenges

At the highest level broadband services can be grouped into two categories:

- Transport services
- Application services

Transport services are bandwidth services defined by quality of service (QoS), committed information rate (CIR), peak information rate (PIR), and other network traffic parameters. An example of a transport service is a business VPN with service level agreements defined for CIR, PIR, jitter, delay, and loss guarantees. These services typically do not provide any application layer guarantees. A second example of a transport service is residential high speed Internet (HSI). A service provider might, for example, offer a lower cost HSI service with no QoS guarantee (best effort) and a more expensive HSI service with bandwidth guarantees of 5 Mbps down and 1 Mbps up.

While transport services are all about delivering bandwidth and QoS guarantees, application services are focused on delivering a quality of experience (QoE) to a customer. A residential customer viewing a TV show or video-on-demand, for example, has no interest in the underlying QoS parameters of the transport network. His interest is in the quality of the video experience. For video the industry norm is to quantify this “annoyance factor” as less than one artifact or visual impairment per two hour movie. Voice customers, similarly, are interested in good sound quality and reliability but don’t care about the VoIP compression data rates or VLAN CIR.

QoE can be mapped to network QoS requirements—in the case of video it is 10^{-6} packet loss. However, this QoS is the same for all users and aggregate DHCP QoS can be used in conjunction with per service VLANs.

IP NGN Carrier Ethernet Design Overview

The IP NGN Carrier Ethernet Design is a Cisco an end-to-end network layer system design approach for the Cisco IP NGN (Next-Generation Network) architecture, which provides the ability to treat each service with optimal transport mechanisms, thereby providing efficiency, reliability, superior quality of experience, and adaptability to future services. Cisco IP NGN Carrier Ethernet is a service-aware network layer design that supports essential service attributes at both Layer 2 and Layer 3 (including Layer 3 in the aggregation network), making it an optimal design to converge residential and commercial business services. It also advocates the integration of application layer intelligence into the fabric of the network and the distribution of that higher layer intelligence close to the user. This includes functions such as session border controller, video error repair, video quality monitoring and deep packet inspection.

The IP NGN vision instantiated by the IP NGN Carrier Ethernet Design is any service to any screen on any device. This includes computers, TVs, home entertainment systems, cellphones, and handheld devices. Service providers are focusing initially on a core set of services—voice, Internet, IPTV, and video-on-demand (VoD). Over time these services will grow to include more advanced and customized services including advanced video, video conferencing, gaming, personalized subscriber services, security services, fixed mobile convergence services and new forms of internet-based digital media distribution. The IP NGN Carrier Ethernet Design provides a flexible network infrastructure to allow for the rapid introduction of Triple Play and advanced services without a forklift upgrade of the network infrastructure.

IP NGN Carrier Ethernet explicitly recognizes that fundamental differences between transport and application services drive the need for a flexible access and aggregation network that can provision the right services to the right customers with the appropriate QoS *or* QoE guarantees. The IP NGN Carrier Ethernet design provides this necessary flexibility and reliability by using a flexible Layer 2 and Layer 3 aggregation network.

IP NGN Carrier Ethernet, for example, provides the same QoS for all users of application services such as broadcast video, VoD, and VoIP and employs aggregate DHCP QoS in conjunction with per service VLANs. (See QoS versus QoE discussion of last section.) This is done to simplify service delivery as operationally complex per subscriber QoS and per subscriber VLANs are not needed to deliver the QoE required by these applications².

² In fact, the reality is that video cannot be shaped or policed in the face of congestion because the video experience will not be tolerable. So what is really needed is application intelligence that makes a decision and effectively prevents congestion—either this VOD stream can be delivered with 10^{-6} packet loss or it cannot, and if it cannot then the session must not be started. This not only prevents a bad user experience, but it prevents the potential degradation of the video service for all other users. The Appendix examines

H-VPLS Design Overview

The H-VPLS³ design approach uses Ethernet bridging (i.e. VPLS instances) in the aggregation network, per subscriber QoS and per subscriber VLAN for all services. This model also uses a centralized BRAS (Broadband Remote Access System) for PPP services and a separate policy based solution for IP sessions.

The H-VPLS design limits the scope of deploying PIM to the IP/MPLS backbone and uses IGMP snooping to emulate multicast over VPLS to deliver broadcast video traffic. The H-VPLS's underlying tunneling technology is MPLS with its associated QoS capabilities and rapid service recovery times.

The H-VPLS design's use of per subscriber QoS and per subscriber VLAN for all services is effectively a one-size fits all services model that essentially builds point-to-point tunnels over Ethernet. One can think of this model as a circuit based approach vs. the IP NGN Carrier Ethernet IP/MPLS based approach. The total cost of ownership (TCO) implications of this are examined in the Business Case Results section at the end of this paper.

Network Design Assumptions

The network architecture depicted in Figure 1 is used to calculate TCO for each network design. Three types of central offices are considered:

- Video Headend
- Video Hub Central Office
- Video Serving Central Office

The aggregation network is assumed to be an Ethernet ring connecting a set of Video Serving COs to a Video Hub CO. In each Video Serving CO an Ethernet switch/router interconnects a set of access devices to the Carrier Ethernet aggregation ring. The access devices can be DSLAMs (for DSL access), OLTs (for PON access), or E-FTTH Access Devices (for active Ethernet access). The Video Hub CO is the hub of the Ethernet aggregation ring. Two Ethernet switch/routers and two BRAS routers are used for redundancy. All routers and switches in the Video Hub CO provide interconnectivity between the aggregation ring and the core IP/MPLS network. VoD servers also are located at the Video Hub CO. A Video Headend, additionally, is located on the IP/MPLS

the financial impact of IP NGN Carrier Ethernet Video on Demand (VoD) Capacity Admission Control (CAC).

³ H-VPLS is Hierarchical-Virtual Private LAN Service. By building two- or three-tiered hierarchical networks, H-VPLS improves the scalability of multipoint VPLS. VPLS is a new class of VPN technology operating on a provider-managed IP/MPLS-based WAN. See Internet Draft—draft-ietf-l2vpn-vpls-ldp-04.txt—produced by the IETF PPVPN Working Group.

core network and provides both IPTV and VoD content to each of the aggregation networks and Video Serving COs.

Network traffic engineering rules are used to assign capacities to all links in the network. The network is engineered such that there is adequate capacity to reroute traffic in the case of any single link or router failure. This applies to the ring as well as the redundant switch/routers and BRAS routers in the Video Hub CO.

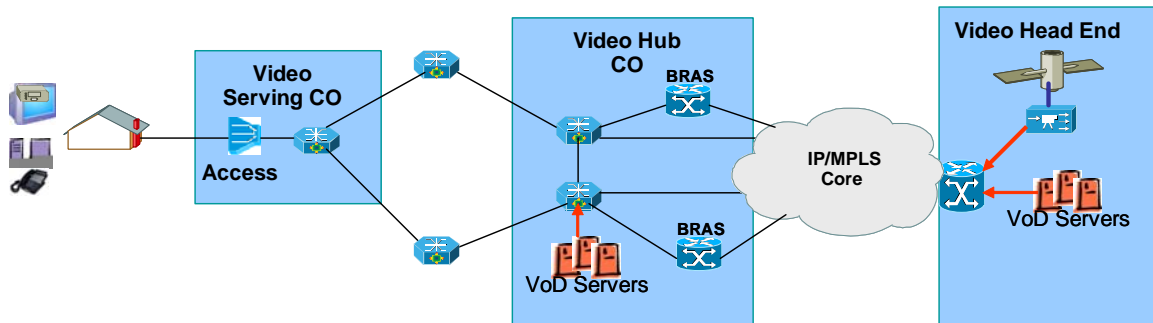


Figure 1
Network Architecture Overview

The analysis that follows uses a hypothetical network consisting of one Video Headend, 10 Video Hub COs, and 100 Video Serving COs (with 10 Video Serving COs per Video Hub CO). It assumes that, on average, there are 10,000 households passed per Video Serving CO and that the average number of households per access device is 300.

The IP NGN Carrier Ethernet Design uses a network configured with the Cisco 7609 Router⁴ at the Video Serving CO and Video Hub COs and the Cisco 10000 Series Router (BRAS) in the Video Hub CO. The IP NGN Carrier Ethernet Design uses L2/L3 forwarding on the aggregation ring, passes all Internet traffic through the BRAS, and passes all video traffic directly from the core IP/MPLS network to the aggregation network and Video Serving COs.

The H-VPLS Design uses an H-VPLS switch in the Video Serving CO that connects to the aggregation ring. In the Video Hub CO a Layer 3 Router (from the same vendor supplying the switch) provides interconnectivity between the H-VPLS network and the core IP/MPLS network. In the H-VPLS Design all Internet traffic is passed through the BRAS and video is passed directly from the core IP/MPLS network to the aggregation network and Video Serving COs.

⁴ In the Video Serving CO the Cisco 7609 Router configuration uses a 24 Port GbE Card for access device interconnection and a 4 port 10 GbE card for connection to the aggregation ring. In the Video Hub CO the Cisco 7609 Router uses a 24 port GbE card to connect to a Cisco 10000 Series Router and a 4 port GbE card to connect to the aggregation ring.

Service Assumptions and Traffic Forecast

The following residential Triple Play services are used as a basis for the traffic forecast and network design:

- IPTV (SDTV and HDTV)⁵
- Video on Demand (SD VoD and HD VoD)
- Voice over IP (VoIP)
- High Speed Internet (HSI)

Service pricing assumptions drive the revenue calculation. The service pricing assumptions for IPTV, VoIP, and HSI services are specified in Table 1. VoD service is a pay-per-view model and assumes that there are four different types of VoD, each with a different price. VoD Type I is free. VoD Type I offerings include reruns of TV programs and sporting events. VoD Type II-IV are pay-per-view with pricing based on the type of content offered. VoD pricing assumptions are specified in Table 2.

Service	Monthly Price
IPTV	\$65
VoIP	\$30
HSI	\$25

Table 1
Monthly Service Pricing for IPTV, VoIP, and HSI

VoD Service	Price per VoD
VoD Type I	Free
VoD Type II	\$2.99
VoD Type III	\$3.99
VoD Type IV	\$10.00

Table 2
VoD Service Pricing per VoD for Different Types of VoDs

⁵ SD is Standard Definition and HD is High Definition.

Service penetration rates⁶ are a primary driver of network traffic. The assumed rates are presented in Table 3. These rates specify the percentage of households passed that subscribe to Triple Play services (IPTV, VoD, VoIP, and HSI).

Service	Year 1	Year 2	Year 3	Year 4	Year 5
IPTV	8%	17%	24%	26%	27%
VoD	8%	17%	24%	26%	27%
VoIP	13%	22%	28%	33%	37%
HSI	13%	22%	28%	33%	37%

Table 3
Triple Play Service Penetration Rate Assumptions

Another important factor in forecasting traffic is the distribution of High Definition (HD) and Standard Definition (SD) video content. The projected distribution of HD and SD content for IPTV and VoD is specified in Table 4 and the distribution of IPTV channels over the five year period⁷ is presented in Table 5.

Distribution	Year 1	Year 2	Year 3	Year 4	Year 5
IPTV SD %	98%	90%	80%	70%	57%
IPTV HD %	2%	10%	20%	30%	43%
VoD SD %	98%	95%	90%	85%	80%
VoD HD %	2%	5%	10%	15%	20%

Table 4
Distribution of SD and HD Video Content for IPTV and VoD over a Five Year Period

# Channels	Year 1	Year 2	Year 3	Year 4	Year 5
Total Channels	150	200	250	300	300
SD Channels	147	180	200	210	171
HD Channels	3	20	50	90	129

Table 5
Number of SD and HD Channels Broadcast over a Five Year Period

⁶ These penetration rates are based on market projections by Network Strategy Partners, LLC.

⁷ This is data from a major ILEC/PTT

Service	Average Data Rate
SDTV & VoD	2 Mbps
HDTV & VoD	9 Mbps
VoIP	32 Kbps
High Speed Internet	250 Kbps

Table 6
Average Service Data Rates

Table 6 specifies the assumptions for average data rates. Video and voice services are stream oriented services and, therefore the average data rates are fairly close to the instantaneous data rate of the stream. High Speed Internet service is a highly bursty service. When large downloads are occurring data is being transported at line rates, however, for a large percentage of the time there is little or no data being transported. This leads to an average rate of 250 Kbps.

In addition to penetration rates, HD/SD content distribution, and average data rates, network traffic also is driven by concurrent usage. More specifically, for VoIP, HSI, and VoD services, traffic is only generated when subscribers are using the service. This is not true for IPTV because it is a multicast service and all channels are continually multicast around the aggregation ring regardless of usage.

The model assumes that 25% of VoIP and HSI subscriber are using the service concurrently during prime time (4 hours in the evening). VoD service concurrency assumptions are based on the number of VoDs viewed each month and the length of an average VoD session. It is assumed that, on average, a subscriber watches 28 VoDs per month, 50% of those VoDs are viewed during prime time, and the average length of a VoD is 1.5 hours. Therefore, 14 VoDs are watched at prime time in one month and the average number of VoDs watched at prime time by a subscriber is 0.466. Given that a VoD is 1.5 hours this implies an average of 0.7 hours of VoD usage per subscriber during prime time. Because prime time is 4 hours long this implies a VoD concurrency rate of 18% during prime time.

The assumptions specified above are used to forecast network traffic and capacity requirements over the five year period studied in this paper. Figure 3 presents the forecast of network capacity needed in the Video Serving CO. This is the capacity required between the Access Switch/Router and the Access Devices (DSLAM, OLT, CMTS, or E-FTTH). Figure 3 presents the capacity forecast for the aggregation ring. This is the total ring capacity in Gbps required over the five year period of study.

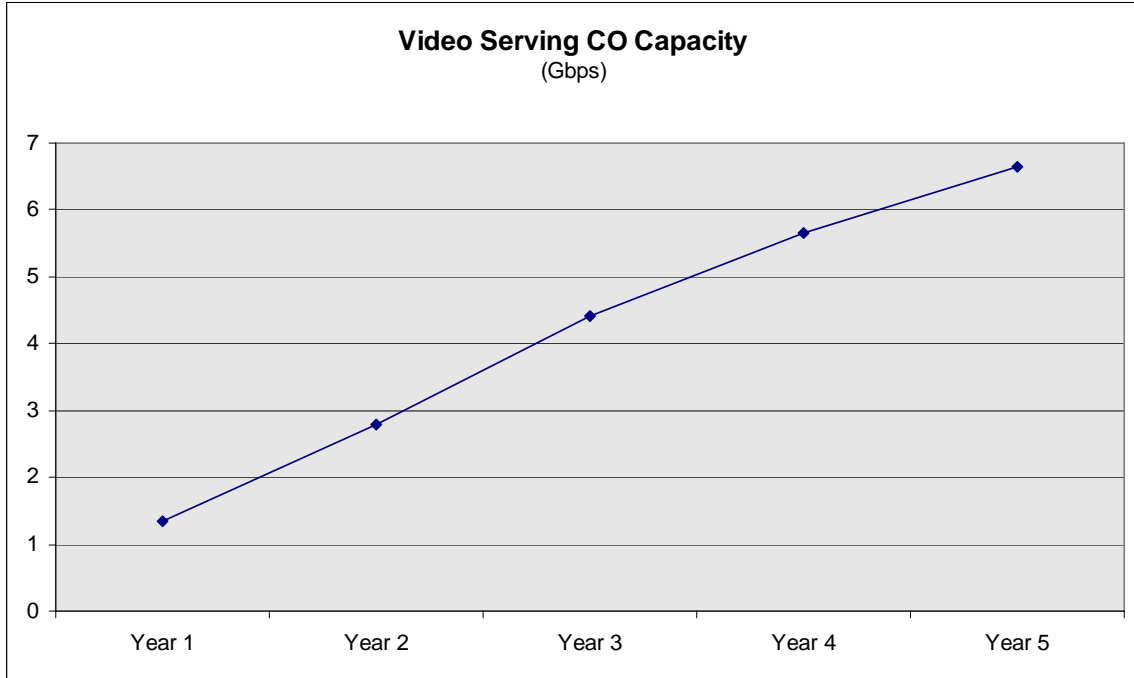


Figure 2
Network Capacity Required in the Video Serving CO to Provide Service to all Subscribers in the CO in Gbps

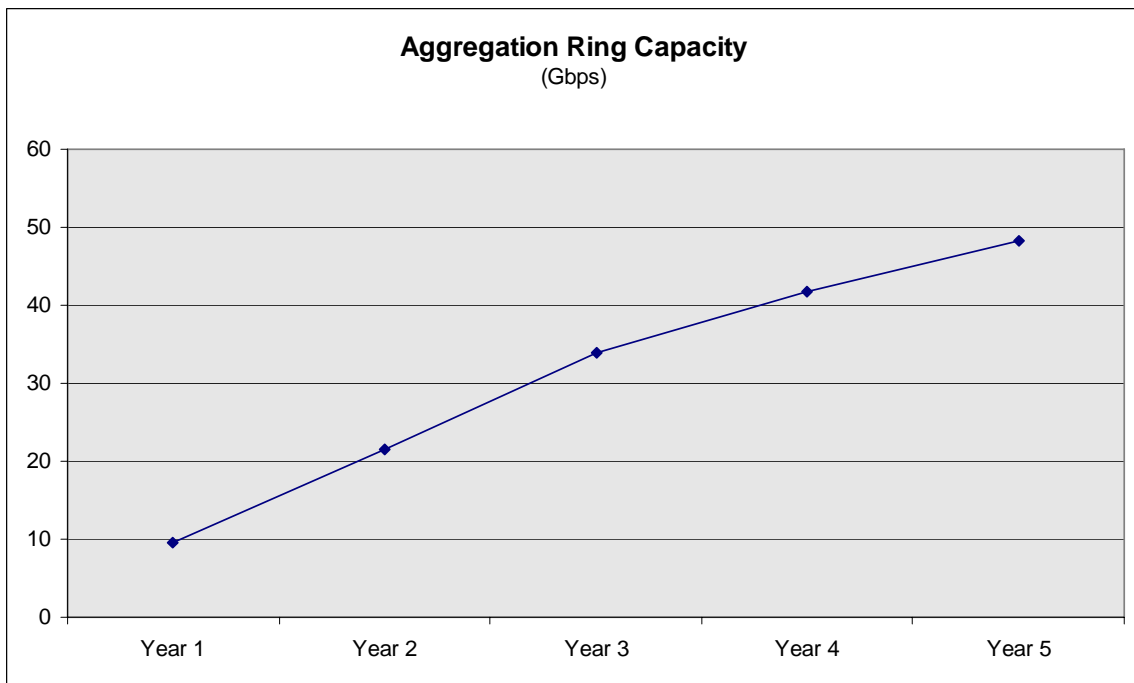


Figure 3
Network Capacity Required in the Aggregation Ring in Gbps

Network Configurations and CAPEX

The service assumptions and traffic forecast described in the previous section are used to calculate the equipment configurations and CAPEX in the network. In the Video Serving CO the total traffic from all services (IPTV, VoD, VoIP, and HSI) is calculated for each access device (DSLAM, CMTS, OLT, or E-FTTH). The service penetration rates are used to find the number of subscribers of each service on each Access Device. Given the number of subscribers for each service on an access device, the average data rates for the service, and the concurrency of use, the average traffic per Access Device is calculated. This number is used to determine how many GbE interfaces are required between the Access Device and the Switch/Router in the Video Serving CO.

The access traffic is then aggregated on the ring. The ring capacity is selected such that there is adequate capacity on the ring to forward all traffic in the case of a single point of failure. Similarly, the capacity of the Switch/Routers, the BRAS routers, and the Core Network connections in the Video Hub CO are selected so that all traffic is forwarded if there is any single point of failure. 10 GbE interfaces are used on the ring links and the core network links and 1 GbE interfaces are used on the BRAS links. The traffic algorithm determines the number of 10 GbE and 1 GbE interfaces needed to support demand in the failure scenario.

Network capacity assignment and configurations also are affected by Video on Demand (VoD) and IPTV AD Insertion. If video connection admission control is used then it is possible to reject VoD sessions if traffic exceeds network capacity. The Appendix examines the financial implications of Integrated Video CAC in detail.

After all network traffic and capacity calculations are finalized, the network equipment is configured and CAPEX is calculated based on equipment configurations and average street prices of equipment.

Business Case Results

The assumptions for network architecture and Triple Play service characteristics are used to forecast network traffic. The traffic forecast, in turn, is used to configure the IP NGN Carrier Ethernet and H-VPLS aggregation networks which are then used to calculate capital expense (CAPEX). Network engineering and financial analysis are carried out over a five year period. Operational expenses (OPEX) are calculated using a financial model developed by Network Strategy Partners.

Revenues are projected from service penetration and pricing assumptions. Only a percentage of the revenue, however, is used to calculate key financial metrics (Cash Flow, NPV, and IRR). This percentage of the revenue is called Allocated Revenue. This is done in recognition that only aggregation network capital and operating expenses are being modeled while many other aspects of network infrastructure costs, sales, marketing, and G&A are outside the scope of the analysis. Allocated Revenue is estimated to be 15% of business revenue and is associated with the total cost of

ownership of the aggregation network. It is used to estimate the cash flow and Net Present Value of the aggregation network investment.

The five year cumulative financials for the two designs are compared in Table 7. At the top of the table is a high level summary of Allocated Revenue, CAPEX, OPEX, NPV, and IRR. Below that are the detailed results. These results clearly demonstrate that the IP NGN Carrier Ethernet Design is more cost effective than the H-VPLS Design. IP NGN Carrier Ethernet Design both CAPEX and OPEX advantages.

The capital cost advantage is primarily due to the fact that the L2/L3 1 GbE and 10 GbE ports on the Cisco 7609 Router are significantly less expensive than similar H-VPLS ports. As traffic increases due to increased VoD and higher levels of HD content, greater numbers of access 1 GbE ports and ring 10 GbE ports are required. This cost differential becomes even more important as services and traffic grow in the later years of this analysis.

Operational benefits are related both to this lower CAPEX⁸ as well as lower environmental expenses and more efficient network operations processes. The OPEX model uses a bottom up approach to calculating operational expenses. The OPEX components are listed and defined in Table 8. Each of these line items uses a set of formulas to calculate expenses based on labor costs, the network size, CAPEX, equipment configurations, power consumption, and network operational procedures.

Figure 4 summarizes CAPEX over the five year period of study for each design. The IP NGN Carrier Ethernet capital investment in Year 1 provides adequate capacity for Year 1 and Year 2 because of the superior GbE and 10 GbE port density of the Cisco 7609 Router. Only modest capital investments in IP NGN Carrier Ethernet are needed to keep up with network growth in Years 3-5. The H-VPLS Design, in contrast, requires on-going capital investments to satisfy growth in demand. This is primarily due to lower H-VPLS port densities.

Figure 5 summarizes OPEX over the five year period. It also shows consistently lower OPEX for IP NGN Carrier Ethernet Design as compared to the H-VPLS Design. Some components of OPEX are ongoing expenses (for example, capacity management, network upgrades and patches, and network care) and other operational expenses are a function of new equipment deployments (EF&I, training, environmental expenses, etc.). This is why total OPEX can vary (and even decrease) from year to year.

In summary, the IP NGN Carrier Ethernet Design has lower CAPEX and OPEX than the H-VPLS Design. The IP NGN Carrier Ethernet Design, consequently, has higher Net Present Value and IRR.

⁸ Some of the OPEX components are impacted by CAPEX (Maintenance, EF&I, etc.)

Financial Summary

	IP NGN Carrier	
	Ethernet	H-VPLS
5 Year Total Allocated Revenue	\$ 331,389,972	\$ 331,389,972
5 Year Cumulative Capital Cost	\$ 34,455,590	\$ 82,675,775
5 Year Cumulative Network Operations Expenses	\$ 36,336,427	\$ 57,817,453
Internal Rate of Return (IRR)	261%	111%
5 Year Cumulative Cash Flow From Operations	\$ 260,597,955	\$ 190,896,744
5 Year Net Present Value (NPV)	\$ 223,239,745	\$ 159,005,182

Details

Allocated Revenue	IP NGN Carrier	
	Ethernet	H-VPLS
SDTV	\$ 82,004,400	\$ 82,004,400
HDTV	\$ 30,501,900	\$ 30,501,900
VoIP	\$ 71,820,000	\$ 71,820,000
High Speed Internet	\$ 59,850,000	\$ 59,850,000
SD VoD	\$ 76,346,164	\$ 76,346,164
HD VoD	\$ 10,867,508	\$ 10,867,508
Total Cumulative Revenue	\$ 331,389,972	\$ 331,389,972

Capital Costs	IP NGN Carrier	
	Ethernet	H-VPLS
Video Serving CO Switch/Routers	\$ 27,293,500	\$ 60,536,125
Video Hub CO Switch/Routers	\$ 4,409,340	\$ 19,386,900
Video Hub CO BRAS	\$ 2,752,750	\$ 2,752,750
Total Cumulative CAPEX	\$ 34,455,590	\$ 82,675,775

Operating Expenses	IP NGN Carrier	
	Ethernet	H-VPLS
Engineering, Facilities, and Installation (EF&I)	\$ 3,445,559	\$ 8,267,578
Capacity Management	\$ 1,136,562	\$ 1,633,273
Network Upgrades & Patches	\$ 641,138	\$ 921,333
Network Care	\$ 4,096,620	\$ 5,879,683
Testing and Certification Operations	\$ 499,588	\$ 499,588
Testing and Certification Capital	\$ 689,112	\$ 1,653,516
Training	\$ 721,480	\$ 721,480
Service Contracts	\$ 5,168,339	\$ 12,401,366
Sparing Costs	\$ 689,112	\$ 1,653,516
Floor Space Cost	\$ 505,814	\$ 750,000
Power Cost	\$ 1,524,240	\$ 2,260,080
Cooling Cost	\$ 4,786,114	\$ 7,096,651
Network Management Equipment & Software	\$ 1,676,806	\$ 3,323,447
Network Transport Costs	\$ 10,755,944	\$ 10,755,944
Cumulative Annual Expenses	\$ 36,336,427	\$ 57,817,453

Cumulative Cash Flow	\$ 260,597,955	\$ 190,896,744
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Net Present Value (NPV)	\$ 223,239,745	\$ 159,005,182
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IRR	261%	111%
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Table 7
Five-Year Cumulative Financials

Operations Expense	Definition
Engineering, Facilities, and Installation (EF&I)	This is the cost of engineering, facilities, and installation of network equipment.
Capacity Management	Capacity management is the engineering function of planning and provisioning additional network capacity.
Network Upgrades & Patches	This includes both hardware and software upgrades to the network.
Network Care	This includes network provisioning, surveillance, monitoring, data collection, maintenance, and fault isolation.
Testing and Certification Operations	Testing and certification is needed for all new hardware and software releases that go into the production network.
Testing and Certification Capital	This is capital equipment required for the test lab.
Training	Training expenses are required initially and also on an on-going basis.
Network Management Equipment and Software	This is all the hardware and software required to manage the network.
Network Transport Costs	These are the costs associated with the transport network.
Service Contracts	These are vendor service contracts required for on-going support of network equipment.
Sparing Costs	These costs are associated with line card spares.
Floor Space Cost	These costs are associated with the floor space cost/square meter in the CO.
Power Cost	This is the cost to power equipment.
Cooling Cost	This is the cost of the HVAC system and its associated energy use to cool equipment.

Table 8
Definition of Operations Expenses

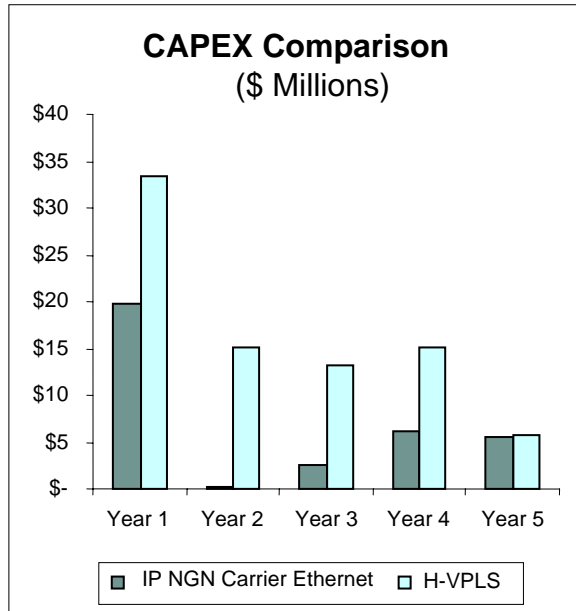


Figure 4
CAPEX Comparison over Five Years
IP NGN Carrier Ethernet Design versus H-VPLS

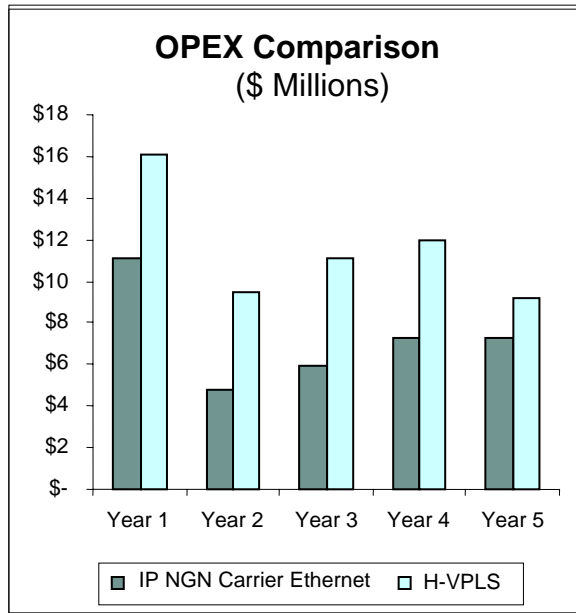


Figure 5
OPEX Comparison over Five Years
IP NGN Carrier Ethernet Design versus H-VPLS

Conclusion

The Cisco IP NGN Carrier Ethernet Design is both a flexible and cost effective approach to building Ethernet aggregation networks. IP NGN Carrier Ethernet uses combined Layer 2 and Layer 3 forwarding to allow service providers to build next generation networks for all services. A Total Cost of Ownership analysis compares the Cisco IP NGN Carrier Ethernet Design to an H-VPLS Design for a hypothetical aggregation network used to deliver Triple Play services for a large service provider.

The comparison shows:

- 1) There is a strong business case for the IP NGN Carrier Ethernet Design. The hypothetical network studied in this paper shows a strong IRR and NPV for the IP NGN Carrier Ethernet capital investment.
- 2) The cumulative five-year Total Cost of Ownership (CAPEX and OPEX) of the H-VPLS Design is significantly higher than that of the IP NGN Carrier Ethernet Design.
- 3) The IP NGN Carrier Ethernet Design also allows reduction of network traffic and CAPEX by implementing integrated video connection admission control. (These results are provided in the following appendix).

Appendix

Financial Impact of Integrated Video Connection Admission Control

One of the key benefits of the Cisco IP NGN Carrier Ethernet Design is the capability to implement Video Connection Admission Control (CAC). VoD is a major driver of network traffic. VoD is unicast, therefore, separate streams from VoD servers must be transported across the aggregation network to support each VoD session. The network is engineered such that all traffic will be passed over redundant links in the case of any single link or router failure. The worst case condition for VoD traffic is when a link or router fails and all traffic must be transmitted on the redundant link (or around the ring in the opposite direction). This traffic load is presented in Figure 6. As penetration rates of VoD increase over the five year period it is clear that VoD traffic dominates the network. In fact, the main driver of VoD traffic is a projected increase in HD VoD traffic over the five year period as illustrated in Figure 7.

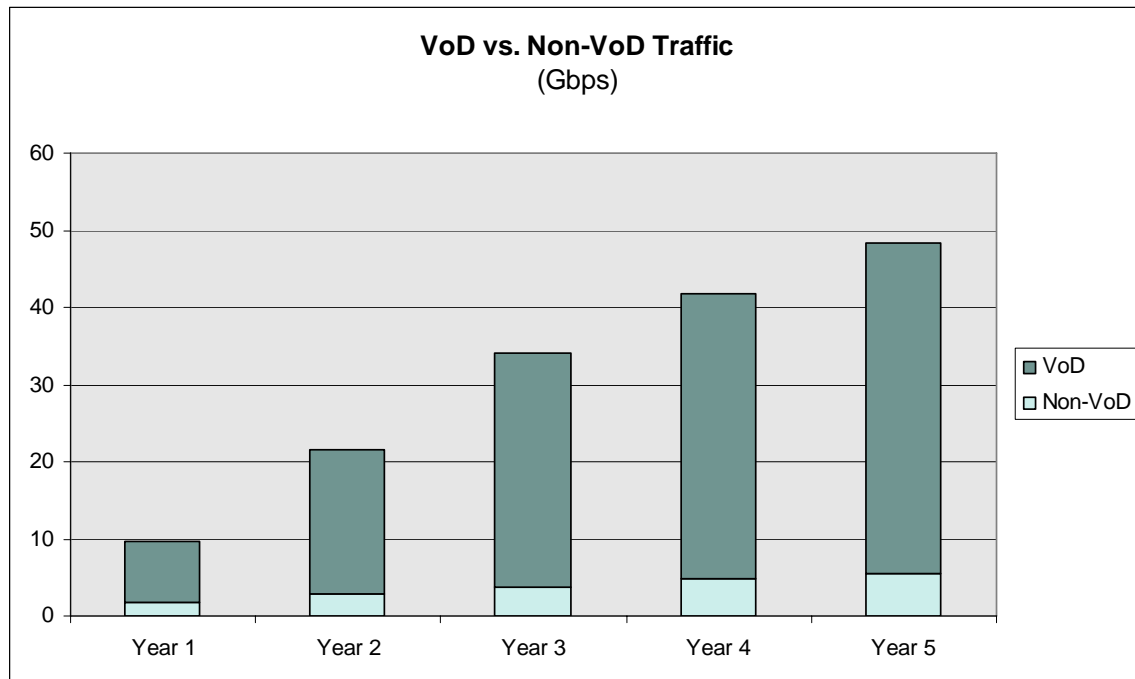


Figure 6
Total Aggregation Network Traffic broken down into VoD and Non-VoD Services

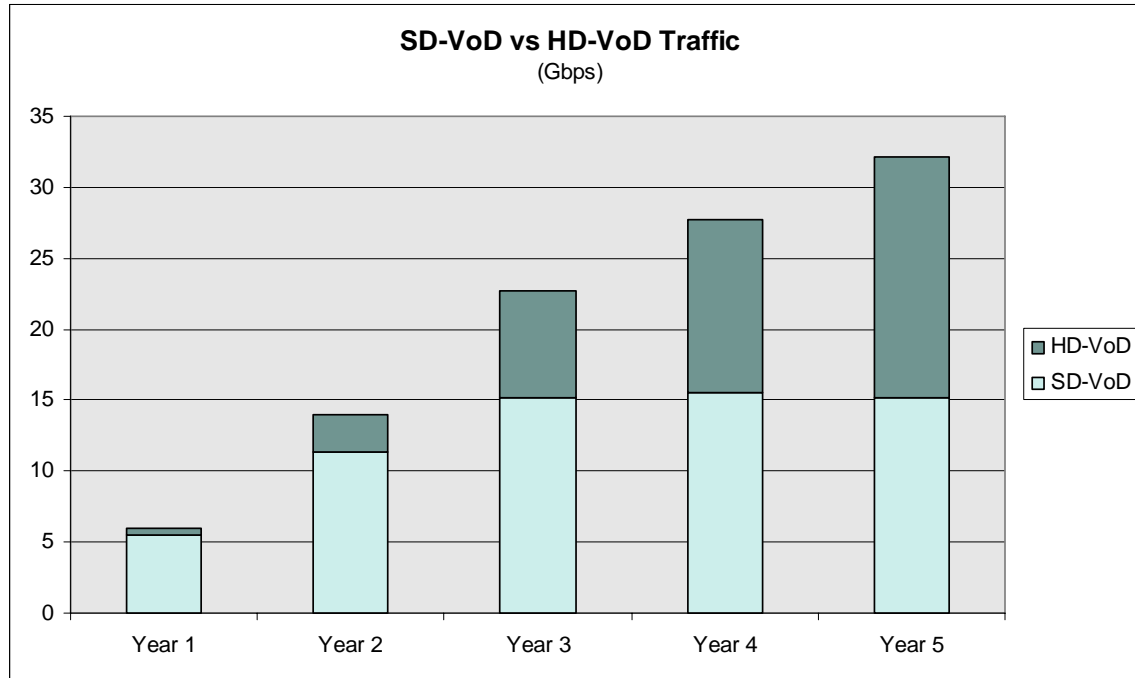


Figure 7
VoD Traffic broken up into SD and HD Components

Video is very different from statistical packet services (such as email and web services) in that it is intolerant of packet loss. If there is any significant level of packet loss greater than 10^{-6} , video streams will freeze and the video quality levels become unacceptable. In contrast statistical packet services can tolerate reduced capacity and packet loss for short periods of time because TCP windows at the source will shrink, thus reducing network traffic. In a failure scenario, therefore, TCP packet services will gracefully degrade. Because VoD services are intolerant of packet losses or significant packet delays, a reduction of network bandwidth during a peak period of demand will result in all VoD sessions losing packets. Video quality across all users degrades to an unacceptable level. This is clearly a catastrophic failure. There are two approaches to designing a network such that this situation never occurs:

1. Ensure that there is adequate network capacity in a failure state
2. Use Video CAC to reject specified video sessions in a network overload condition

If video CAC is not implemented the entire ring must be designed to handle the traffic load during a network failure. This generally requires a doubling of network capacity even though the extra capacity will only be needed if a network failure occurs during prime time (the busy period). A network failure during prime time is a rare event. This extra capacity, therefore, is rarely required.

Integrated Video Connection Admission Control

The optimal way to solve this type of network congestion is to use application intelligence to deny a new subscriber's VOD request when the network is operating at full capacity—to prevent congestion in the first place. This affects one subscriber only by delaying his request until sufficient bandwidth becomes available—all current viewers are unaffected. This is accomplished by performing integrated video connection admission control (CAC).

Integrated admission control interoperates with complex network topologies that have redundant load-sharing paths in the network's transport layer. These CAC mechanisms also must work with access links and business policies that enforce other types of constraints on a subscriber's service. CAC, consequently, works in coordination with network routers, policy and VOD servers, to collectively improve the visual quality of experience.

Figure 8 shows the capacity required in the aggregation network for the IP NGN Carrier Ethernet design with video CAC and that required by the H-VPLS Design *without* video CAC. It is clear that a significant amount of additional capacity is required in the network if Video CAC is not implemented. This results in a more expensive network design. Table 9 presents a summary of the five year cumulative financials for the IP NGN Carrier Ethernet Design with Video CAC and the H-VPLS Design without Video CAC. The five year cumulative CAPEX for the IP NGN Carrier Ethernet Design is reduced over the five year period from \$34,455,590⁹ to \$28,633,990. Cumulative CAPEX for the H-VPLS Design remains at \$82,675,775.

⁹ See Table 7 for the cost of the IP NGN Carrier Ethernet Design if VoD CAC is not enabled.

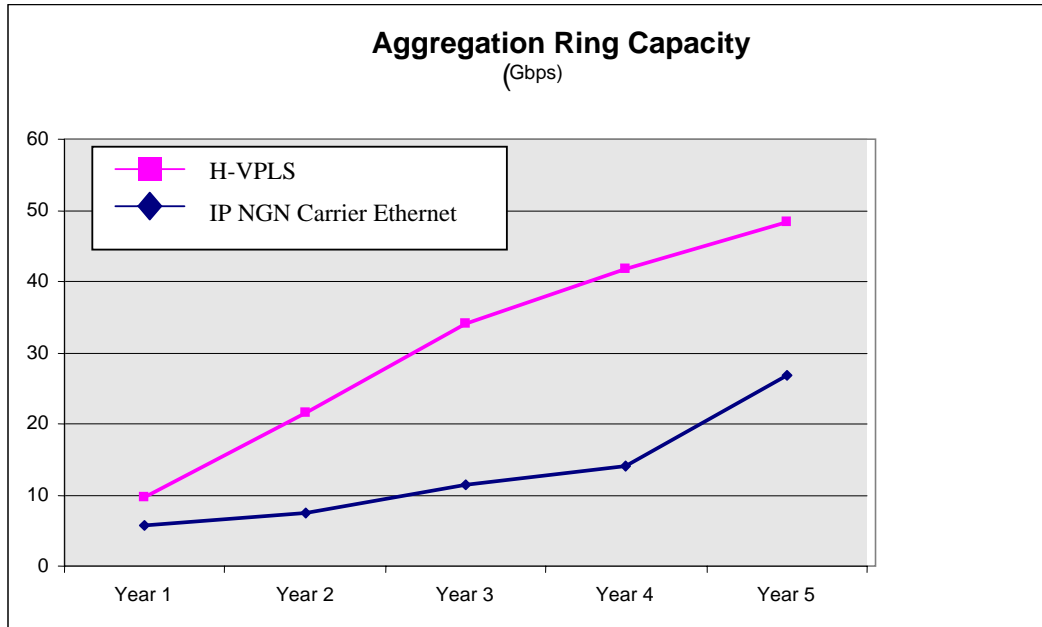


Figure 8
Comparison of Aggregation Capacity
IP NGN Carrier Ethernet Design with Integrated Video CAC
versus H-VPLS Design without Video CAC

Financial Summary

	IP NGN Carrier Ethernet	H-VPLS
5 Year Total Allocated Revenue	\$ 331,389,972	\$ 331,389,972
5 Year Cumulative Capital Cost	\$ 28,633,990	\$ 82,675,775
5 Year Cumulative Network Operations Expenses	\$ 28,049,447	\$ 57,817,453
Internal Rate of Return (IRR)	263%	111%
5 Year Cumulative Cash Flow From Operations	\$ 274,706,535	\$ 190,896,744
5 Year Net Present Value (NPV)	\$ 235,162,748	\$ 159,005,182

Table 9
Financial Comparison
IP NGN Carrier Ethernet Design with Integrated Video CAC
versus the H-VPLS Design without Video CAC