Evolving To The IP Solution –
IP Access To Embedded Circuit Switched Systems

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ABSTRACT

Many MSOs (multi-system operators) are providing telephony service and Internet access as well as entertainment video. These are usually provided in today's market as three separate networks – a video network, based on a hybrid fiber-coax infrastructure, a data network, built on the HFC infrastructure using CableLabs' DOCSIS specifications, and telephony network, also built on the HFC infrastructure. Some MSOs are considering combining the data and telephony networks, to reduce the cost of network implementation and maintenance.

Two approaches are considered: (1) Providing an IP telephony network on top of the DOCSIS network, using the CableLabs' PacketCable specifications, and (2) Providing IP telephony access to existing telephony equipment in the headend. The latter approach allows existing circuit switches deployed by an MSO or other service provider to provide telephony service to cable users on an IP based cable access plant. This scenario allows a migration from circuit based telephony to packet based telephony. Normalized costs are evaluated. From an end-user perspective and from an access network perspective – the two approaches are transparent. However from a service provider and network architecture perspective, the two approaches are vastly different.

INTRODUCTION

Today's cable service providers are exploring adding revenues to their income by adding new services beyond traditional entertainment video. Internet access and residential telephony service are two good examples – built on the existing video distribution network, these subscriber services offer new revenue streams that leverage the existing service provider investment.

Internet access is the service that allows subscribers to use their personal computers (PCs) to access an Internet Service Provider, or ISP. *Roadrunner* and *@home* are two ISPs that partner with MSOs to provide Internet service. The MSO works with the subscribers to provide cable modems in the home, and provides a CMTS in the hub or headend that routes the data packets to the ISP. Subscribers usually pay a monthly fee for the high-speed access a cable modem network provides to the Internet, in addition to the fee for cable television services. MSOs leverage the installed HFC network to minimize the cost of deploying this additional revenue-generating service.

Residential telephone service is another revenue stream being offered by MSOs. In this model, the MSO works with the subscriber to provide a box on the side of the house – a network interface unit (NIU). The NIU has telephone jacks (RJ11) on one side, and a coax connection on the other side, for the cable drop. Each telephone jack is connected to the one twisted pair in the house telephone wiring, providing a new phone line for the house. The NIUs on the side of the house vary from vendor to vendor, providing one or multiple new phone lines for each house. Subscribers typically pay a monthly fee for each phone line activated.

Depending on the technology selected by the NIU vendor, different headend equipment and different network bandwidth is required to provide telephone service. Two technologies are currently being explored for phone service: circuit-switched technology and IP-based technology. This paper compares circuit-switched and IP-based technology for telephony, and proposes a hybrid solution providing IP access to circuit-switched headend telephony equipment. Normalized cost is used to compare the different technical solutions.

DEPLOYING CIRCUIT-SWITCHED TELEPHONY SERVICE

Figure 1 shows an architecture that provides telephony to the cable network subscribers. In this architecture, the cable operator chose to deploy an overlay telephony network at the service level (i.e., it uses the same coax cable to the home but the operator has separated voice and data bandwidth over the cable). Note that the only integration of voice and high-speed data in this architecture is the sharing of the HFC physical facilities.

An example of how the bandwidth on the cable spectrum might be allocated to

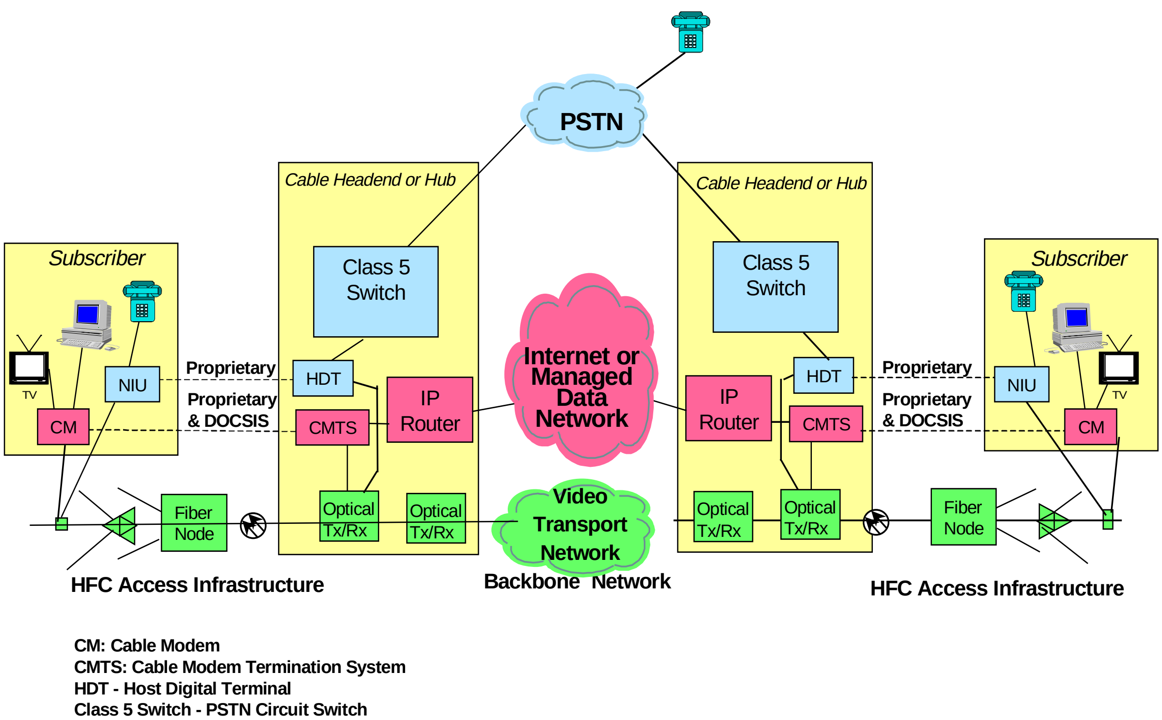


Figure 1: Overlay Networks

Figure 2: Spectrum Allocation for Overlay Networks

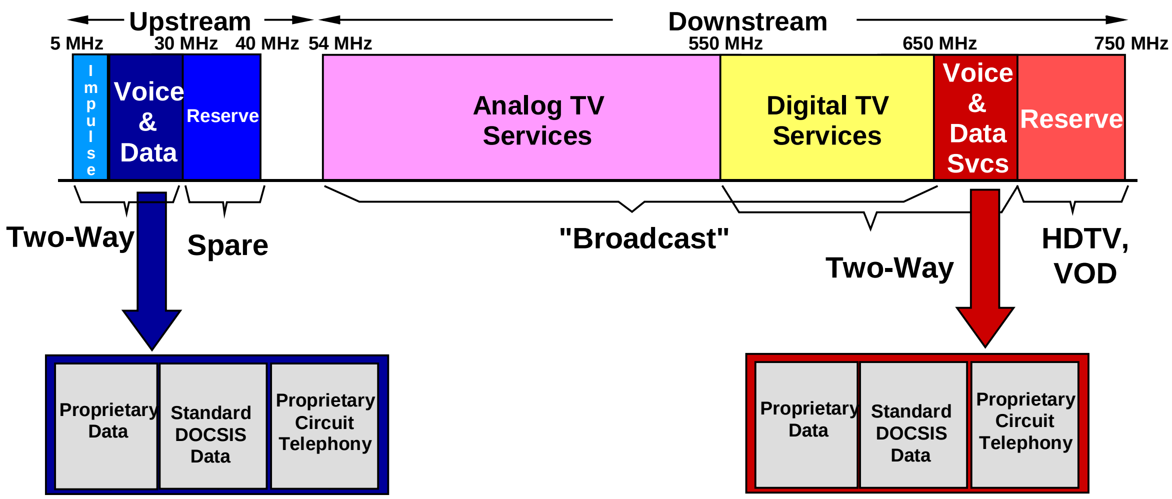


Figure 2

support these overlay networks is shown in Figure 2.

The bulk of the spectrum is reserved for television services, and the new revenue streams are allocated 5-40 MHz and 650-700 MHz. This bandwidth is divided among the standard and proprietary data protocols, and the separate circuit telephony protocol. When telephone service and Internet access are both deployed over a common IP network, then the underlying physical network, the IP network, and the common spectrum can all be shared.

This type of architecture has a few advantages:

- Provides immediate implementation of telephony service by using two-way cable networks and circuit-based backbone transmission and switching equipment.
- Quality of service is very similar to the old twisted pair.
- Telephony services are transparent to user.
- Performance and reliability is very high and is only limited by reliability of the cable plant.
- Fairly secure. In the last few years, this implementation has been supplemented with efficient security mechanism for privacy and other security attacks.

Among the disadvantages we can mention the following:

- It is an overlay network incompatible with packet switching technology.
- Evolution to packet-based telecommunication is very limited or null (forklift-upgrades are needed).
- Costly solution. Uses technology that is currently in decline (or at least not aggressively increasing)
- Current mature circuit-based over cable technology cannot take advantage of the IP backbone network without expensive multiplexer and conversion systems.

DEPLOYING IP ACCESS TO EXISTING CIRCUIT-SWITCHED TELEPHONE EQUIPMENT

A technology emerging in telephony service is IP Telephony – the ability to deploy telephone service over IP networks. IP Telephony offers efficiency in the use of cable spectrum, and in the use of cable network infrastructure, particularly in networks that include IP access to Internet Service Providers. Many, but not all, of the features used in residential telephony service are available in IP Telephony implementations. For service providers who have Class 5 circuit switches available, it's possible to upgrade the access to those switches from an overlay circuit switch network to an integrated IP telephony access network, as an interim step to providing full IP telephony.

This Hybrid Solution is characterized by efficiently providing high quality telephony and the full set of features (the same ones that the subscribers currently enjoy via the old copper twisted-pair technology), via IP access to circuit equipment.

Figure 3 shows one possible implementation of the Hybrid Solution.

This solution is appealing because it does not disrupt the video entertainment nor the packet data services infrastructure. This Hybrid solution takes advantage of the deployed IP access and backbone networks to carry the voice traffic (in packetized form) to the packet-circuit gateway (NCSG) at the edge of the network.

From an engineering point-of-view this Hybrid Solution has the following characteristics:

1) provides significant capital cost savings,
2) minimizes the development of new operations systems while improving the performance and cost effectiveness of MSO's cable network flow-through provisioning, and
3) leverages the continued use of (potential existing switches) Class 5 (telephony switches) operations support systems infrastructure.

The Hybrid solution represents a

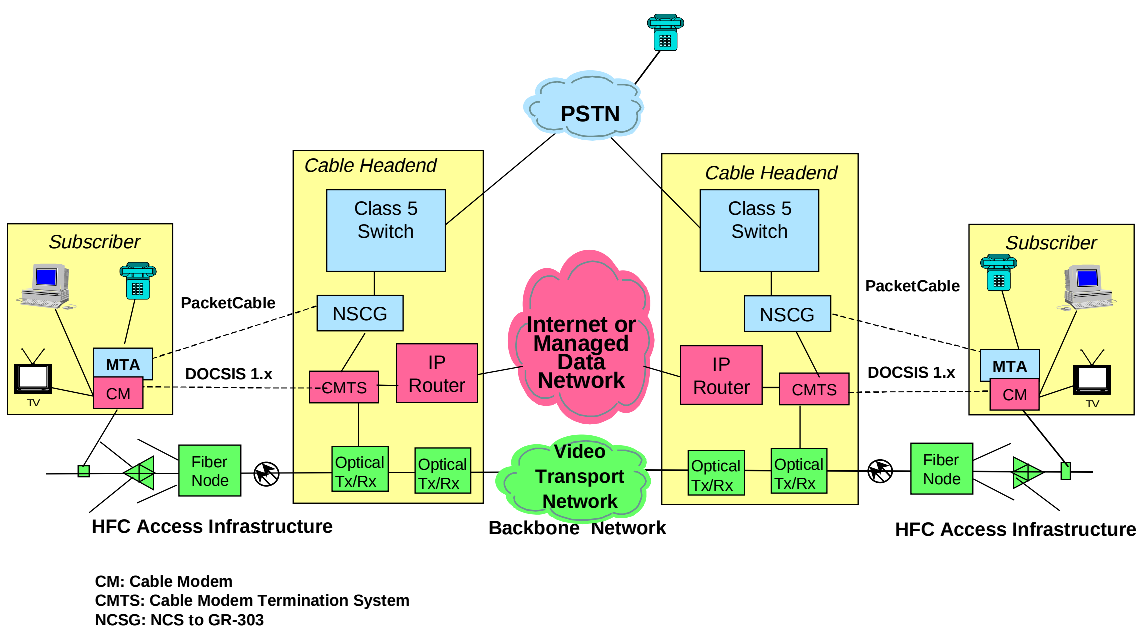


Figure 3: Hybrid Telephony Solution

major step towards the realization of most MSO's strategy for an any-distance, any-service, converged consumer franchise and the continuous reinvention of the MSO's broadband business. As the PacketCable standards mature and new technologies emerge, the cable network will become ready to go from a hybrid (IP and circuit) to the full end-to-end IP telephony solution. As the cable network evolves to a full packet-based network, the Class 5 switch evolves functionally to a full packet-based switch. This transition provides key technologies and capabilities necessary to evolve today's circuit switched networks into the cost efficient voice/packet network of tomorrow, while protecting the cable operator's investment in their embedded base of network elements and revenue generating services.

The NCSG (gateway) is supported by OAM&P systems that leverage current OSS systems capabilities and interfaces. In this solution, all network provisioning is done at the Class 5 switch through existing interfaces, and billing information flows are done over the current paths.

As the gateway between the cable network and the Class 5 switch, the NCSG translates between MGCP/NCS signaling and RTP bearer path on the cable network side to a GR-303 compliant interface that terminates on the Class 5 switch. Call processing and any associated functions in the cable network's core network, are performed in the circuit switched environment using the MSO's embedded base of Class 5 switches. The NCSG interfaces with the BTI (MTA/CM) at the subscriber premises via the CMTS over the cable plant (i.e., the Hybrid-Fiber Coax network).

The major components in the solution are:

- NCS Gateway (NCSG)
- Cable Modem Termination System (CMTS)
- Broadband Telephony Interface (BTI) consisting of Multimedia Terminal Adapter (MTA) and Cable Modem (CM)
- Data Server software platform (DNS/DHCP/TOD/TFTP Servers)
- IP Configuration Manager software platform
- IP Fault Manager software platform
- Element Management Systems (NCSG/CMTS/BTI EMSs)

A brief description of each component follows:

NCS Gateway (NCSG) is deployed at the edge of the circuit-switched network. On its feeder side, it provides DS1 interfaces (or STS1(E) or DS3 interfaces) upstream to an Class 5 switch, a local digital switch. On the distribution side, the NCSG provides access to IP networks utilizing Voice over IP (VoIP) packet technology. From the perspective of the serving digital switch, the NCSG is one or more GR-303-compliant remote digital terminals; from the perspective of the Broadband Telephony Interface (BTI), the NCSG appears as a PacketCable Media Gateway and Call Management Server.

Cable Modem Termination System (CMTS) – terminates the HFC Network at the cable system's head-end. The CMTS includes an IP router that essentially transfers IP packets between the cable distribution network (HFC, BTIs) and the NCSG while performing the appropriate physical and data-link layer conversions (i.e., RF cable to 100BaseT). The CMTS interfaces to the IP network and to the HFC.

Additionally, the CMTS provides the following capabilities:

- Data service support, auto discovery and auto provisioning, IP multicast, IP filtering (according to port number and source/destination addresses).

- Bandwidth allocation controls, RF channel operations, channel assignments, registration and management authentication, encryption key management, and quality of service (QOS) processing, and event message generation.
- SNMP Agent for CMTS management.

Multiple CMTSs may be provided depending on the capacity needs of the service provider.

Broadband Telephony Interface (BTI) – consists of a Multimedia Terminal Adapter (MTA) and a Cable Modem (CM) combined as a single unit:

Multimedia Terminal Adapter (MTA) - is a hardware device that interfaces standard analog phones to an IP network providing analog voice, analog fax, and telephony modem communication over an IP communications network. On the user side, the MTA provides multiple telephone line ports. Each telephone line port interfaces to standard analog touch-tone devices. The MTA originates or terminates voice/FAX telephone calls at its telephone line interface ports. The MTA communicates with the NCSG to provide subscribers with the telephony features set that reside in the Class 5 switch.

For telephony call management, the MTAs communicate with the NSCG by transmitting various control messages using the Network-based Call Signaling (NCS) protocol, which is carried over UDP/IP through the CM and CMTS and terminating on the NCSG. These messages also include the control messages to setup calls, transmit control information such as DTMF digits, and release calls. The MTA is initialized and registered with the NCSG, using NCS Protocol. The voice/fax data for calls to/from a MTA is transmitted over the HFC plant to the destination MTA via Real Time Protocol (RTP) over UDP/IP. The NCSG converts the voice packet to a DS0 stream for the Class 5 switch.

Cable Modem (CM) – acts as a transparent bridge to interface the MTA or terminal equipment attached to a local Ethernet LAN to the HFC Network. The CM transmits IP packets generated by the MTA or attached terminal equipment to the CMTS and forwards IP packets received from the CMTS to the MTA or attached terminals as appropriate. In particular, a CM interfaces the MTA and a PC to the HFC Network according to the DOCSIS CMTS-RFI Specification[i] .

The CM also provides the following functions:

- IP packet filtering : IP filters may be applied to restrict the types of services accessible to a CPE including e-mail server and web server. The IP filters may be defined either through a configuration file or through SNMP.
- SNMP Agent: the CM provides full management access supporting the MIB II and the DOCSIS MIBs (RF, Cable Device, BPI).
- Provides monitoring information to the CMTS.

Data Server software platform (DNS/DHCP/TOD/TFTP Servers) – is a suite of software solutions for the integrated IP services management that are required to support IP Telephony over cable networks. The DHCP and DNS Servers are fully integrated systems to synchronize updates in real time and run autonomously. This provides maximum flexibility in configuring and deploying services across the network. In addition, the data server platform solution facilitates building redundancy and fail safe uninterruptability into the network infrastructure. Data Servers support

10/100BaseT Ethernet interfaces. A brief description of each Server follows.

The DHCP Server is used to make dynamic IP address assignments to the BTIs.

to perform operations such as retrieving configuration information out of a user profile database and sending them to a CMTS or other network device. TFTP could also be used to update firmware in BTIs.

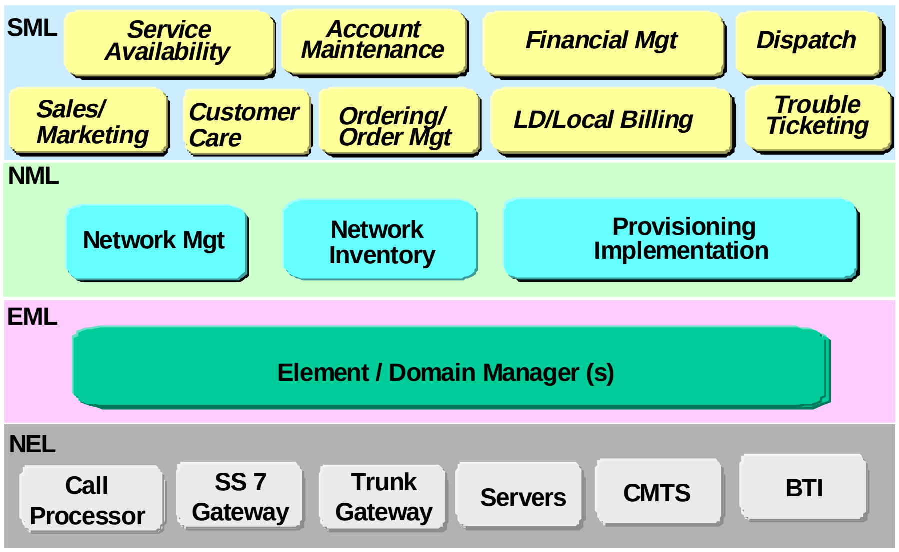


Figure 4: Telecommunications Management Network Model

The DHCP Server supports the definition of vendor classes, configuration of address pools, and the specification of lease parameters for IP Address pools.

The DNS Server provides the NCSG the data necessary to maintain a full cache of Fully Qualified Domain Names (FQDNs) to BTI IP addresses. It supports policies to check and handle if the client's requested hostname are a duplicate within a domain or across the HFC enterprise. It also supports secondary server updates.

The TOD Server is used to support the synchronization of IP devices supporting the IP telephony service.

The TFTP Server is used to support software downloads to IP devices supporting the IP telephony service. TFTP may be used

Configuration Manager software platform (IPCM) - is the customer provisioning system in an overall operations architecture based on the Telecommunications Management Network ("TMN") model. TMN is a layered model that divides the functionality needed to manage network elements and the services provided by Business Management, Service Management, Network Management, and Element Management. Figure 4 is an illustration of that model. The IPCM is part of the network management layer and is the heart of the solution's flow-through customer provisioning process. The IPCM accepts customer service provisioning requests from the Network Inventory.

Once network and Class 5 switch provisioning is complete, the IPCM provides customer service NCSG provisioning, and full BTI provisioning when the BTI is powered up at the customer site. The solution supports both data and voice provisioning and utilizes the PacketCable MTA Provisioning Flow. The IPCM supports northbound standard CORBA/IDL interfaces and interfaces to the BTI EMS and NCSG. The northbound CORBA interface supports create, modify and disconnect changes to the NCSG.

The OSS architecture for the NCSG solution, presented here, is focussed on two areas: customer service provisioning and fault management.

IP Fault Manager (IPFM) - receives network element alarms from the NCSG, CMTS, BTI and the Data Servers. The IPFM performs standard fault maintenance capabilities (filtering, thresholding, throttling, correlation, etc.).

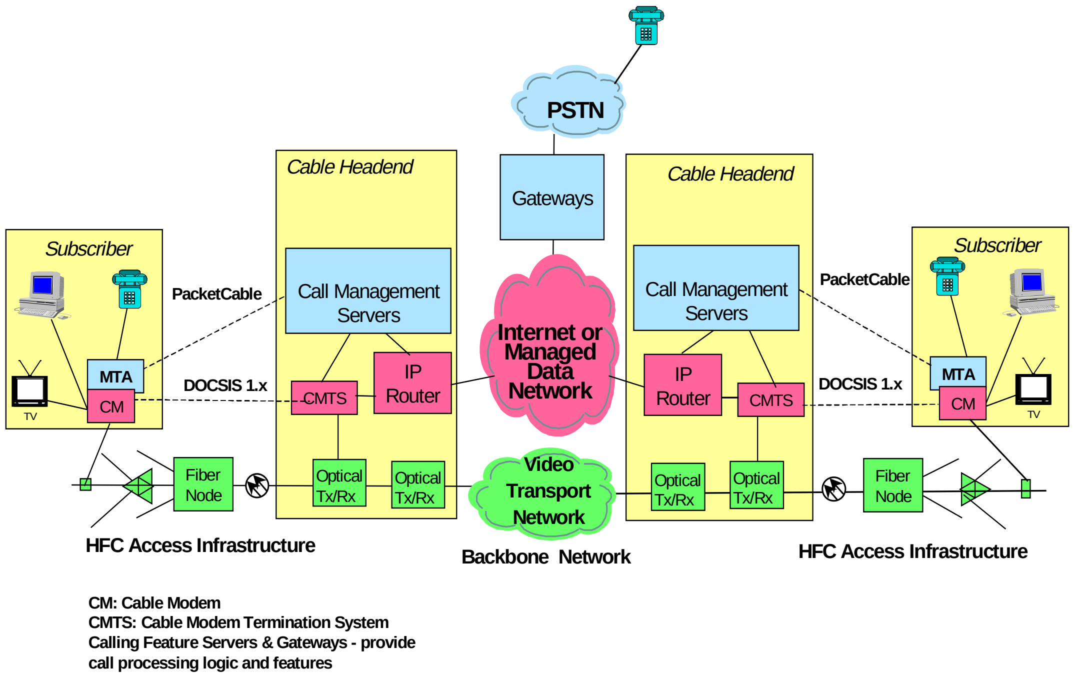
Element Management Systems (NCSG/CMTS/BTI EMSs) - BTI-EMS, CMTS EMS and the NCSG Element Manager provide element management layer support for the IP access network.

The proposed Hybrid solution assumes that an appropriate infrastructure made of data routers, optical systems, data servers, etc., are already in place in the MSO's network.

DEPLOYING IP ACCESS TO IP TELEPHONY EQUIPMENT

Figure 5 shows the architecture for the end-to-end IP telephony over cable. This architecture has no circuit-based equipment and the transition to full packet-based telephony (IP telephony) has taken effect. Notice that this transition includes an evolution of the NCSG system to a call management server and gateways' implementation. The functionality of the different boxes, included in the description of the NCSG solution, applies here as well. Call management servers and gateways shown in the diagram above are PacketCable compliant; basically, they translate the functionality of the Class 5 switch into the end-to-end IP network environment. The overall effect of providing IP access to the telephony system on the Internet access network is to raise the level of the network shared among the services to the IP level. This allows the maximum re-use of deployed equipment and applications.

Figure 5: IP Telephony



As an additional point of comparison, the telephony and high-speed data integration even at HFC level is more effective in the NCSG/Full-IP solution. Figure 6 shows the bandwidth shared by the HSD and telephony services (in addition to the video entertainment services).

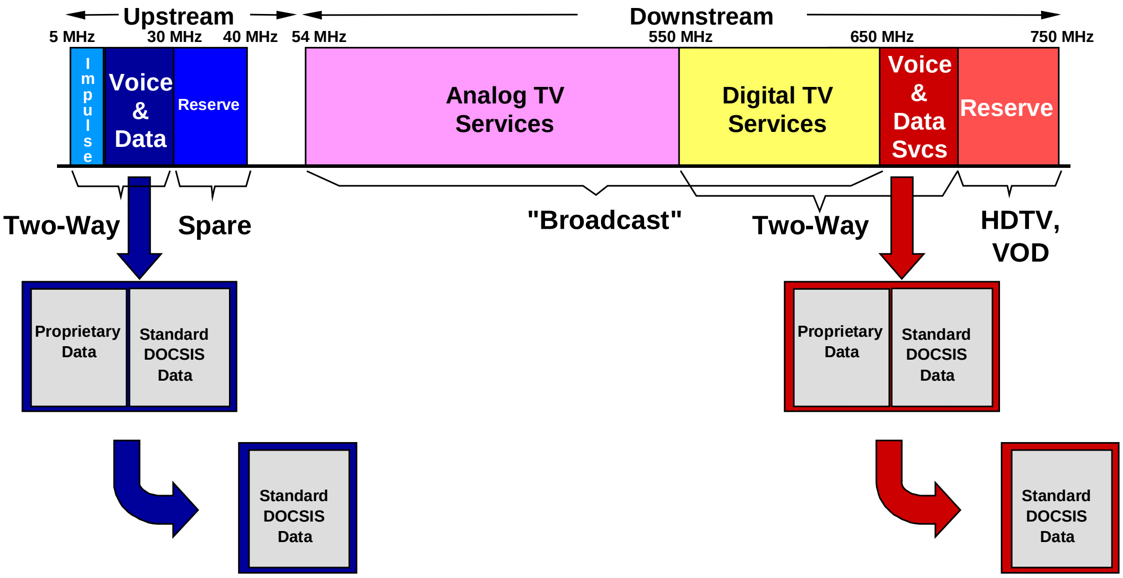


Figure 6: Spectrum Allocation in Full IP Solution

COST COMPARISON

Figure 7 shows a comparison between the circuit-based telephony overlay network architecture, the Hybrid solution using NCSG gateway and the full end-to-end converged IP telephony network solution, using normalized price-per-subscriber.

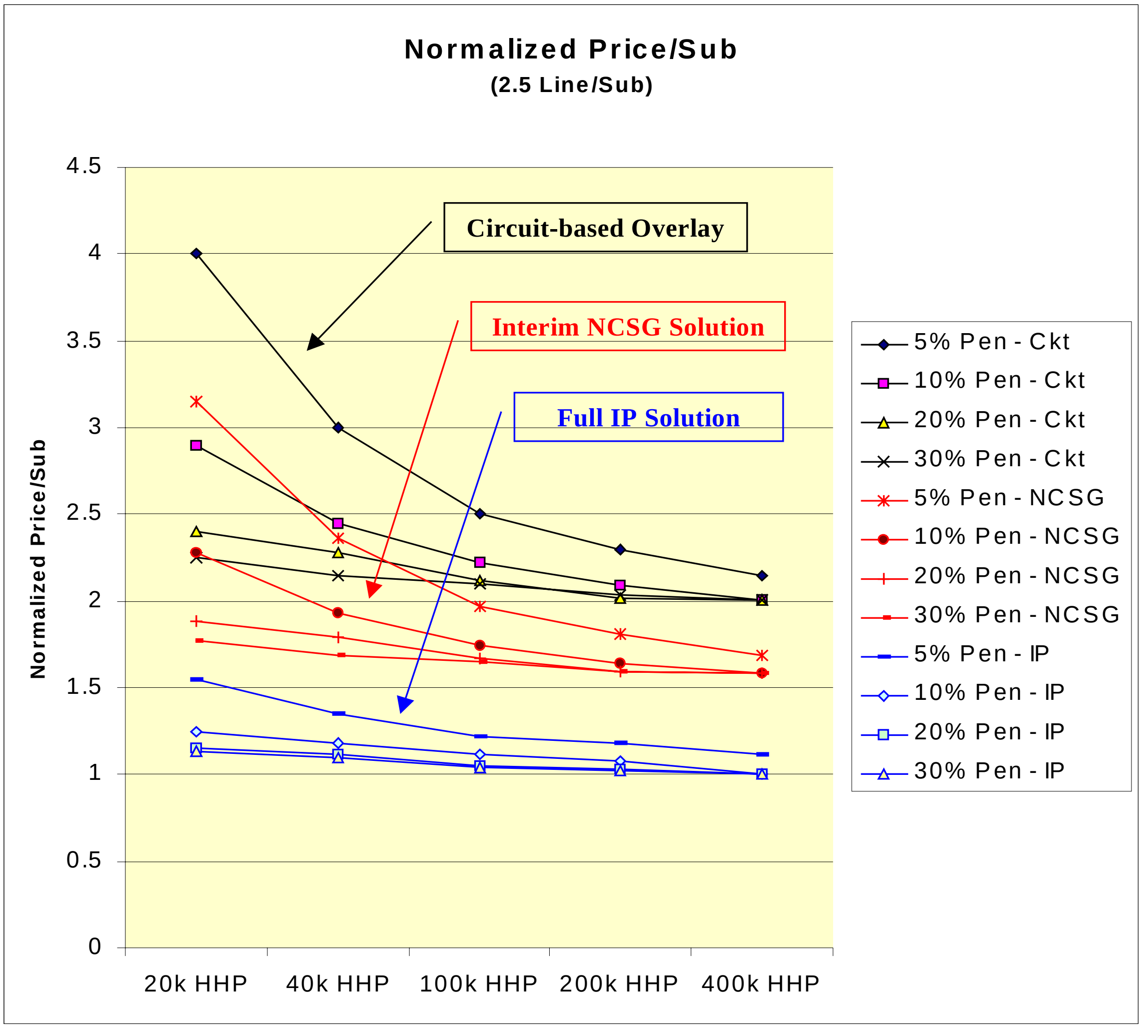


Figure 7: Normalized Price / Sub

Notice that even for large deployments (optimal scenarios for the overlay solution) the circuit-based telephony overlay network is twice as expensive as the full IP solution. The reason behind this is the duplication, in the case of circuit-based network overlay, of equipment throughout the network. The Hybrid solution appears to be significantly less expensive than the circuit-based overlay solution.

Up to now the comparison has been done on equipment alone. If we consider that the circuit-based overlay network solution has two full networks to operate, maintain, provision, etc., the cost of the network increases significantly. In this architecture there are two independent and complete networks, this means that it requires two sets of specialized personnel, training, procedures, etc. The operation cost is significantly higher in the circuit-based solution than the other two architectures under discussion.

CONCLUSION

The IP technology for telephone service provides enhanced use of Internet access networks, so an MSO expecting to provide both Internet access and telephone service should consider the use of IP telephony equipment for telephone service. If the MSO has invested in headend telephone equipment as well as Internet access network, an Hybrid solution like the one described here can provide an excellent method for leveraging existing investments as well as evolving the network to a converged multi-service network in the future.

ABOUT THE AUTHORS

J.C. Proano and Jane Gambill work in Lucent Technologies Cable Communications Architecture, providing network solutions to drive the growth of the cable industry, and the Bell Labs development of Cable Solutions.

For the last 10 years, Jay has been a member of Bell Laboratories in AT&T and Lucent Technologies. He has a broad experience in domestic and international telecommunications systems development. During his work at Bell Labs he has held positions in systems engineering and architecture development for: SONET transmission systems, ring technologies, HFC networks, CATV analog video systems, SDH broadband digital switching systems, and Cable networks. Jay is currently responsible for IP telephony architecture. Jay holds Ph.D., MS, and Diploma Engineering degrees, in Electrical Engineering and Applied Mathematics.

Jane has been with Bell Labs since 1982, designing and developing IP telephony equipment since 1992. Before that, she designed and developed business circuit telephony equipment and real time operating systems. She received an MS in computer science from the University of North Carolina, Chapel Hill, in 1982, and a BA, with majors in mathematics and computer science, from the University of Tennessee, Knoxville in 1980.

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[i] CableLabs Data-Over-Cable Service Interface Specifications, *Radio Frequency Interface Specification*, Version 1.1.