A Passive Optical/Coax Hybrid Network Architecture for Delivery of CATV, Telephony and Data Services

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Abstract

A number of architectures have been proposed to provide VSB/AM modulated video, digital compressed QAM video and telephony services over a hybrid optical/coax network. The majority of these architectures employ an RF carrier for each individual POTS circuit, which is dynamically allocated to serve only active POTS lines. The disadvantages of this approach include the inherent blocking factor that must be accounted for and the difficulty in migrating from single POTS to a rich menu of enhanced telephony and data services.

The Passive Optical Network Architecture (PON) has the advantage of being able to allocate bandwidth dynamically to any customer on demand. Additionally, as overall network capacity demands grow, the capacity of the network can be expanded incrementally to match increased demand.

A Passive Optical/Coax Hybrid Network (POCN) can be designed which provides video as well as enhanced telephony and data services, while providing all of the economies associated with an optical/coax cable architecture. The optimum economic serving areas for telephone and video based services are remarkably similar.

This paper describes a POCN network, and the economics for providing both CATV and POTS based service.

INTRODUCTION

MSOs today are faced with their most difficult strategic problem in terms of evolution of their network. The challenge is both technical and financial because of the need to plan network evolution to accommodate the non-traditional CATV services in the loop. There are obvious difficulties in implementing a future-proof network without financial implications. The difficulties are, of course, enhanced by MSOs lack of experience in the new services and by recently imposed regulatory constraints.

Rapid fiber deployment in the CATV network using FTF or FSA architecture[1] is providing the necessary infra-structure (bandwidth and network topology) for provision of a rich menu of services by MSOs. These include such new revenue opportunities as Video-on-Demand (using compressed digital video), POTS and data services in the loop. The capability of wireless implementation in a POCN environment offers a major new growth market for network services such as PCS.

PASSIVE OPTICAL NETWORKS (PONs)

The intent of telephone companies (TELCOs) to deploy fiber in the loop for provision of narrow-band telephone and broadband services is well known. For the last decade, TELCOs have struggled with the question: What is the optimal architecture for introducing fiber in the loop (FITL)? Two FITL network architectures have emerged as contenders: double-star FTTH (Fiber to the Home) or FTTC (Fiber to the Curbside) and passive optical networks (PONs).

In double-star ("Active Star") implementation, a high speed fiber feeder connects up to 1,000 subscribers to the CO via a remote terminal multiplexer or concentrator. The fiber drop from the remote node now connects a curbside location (FTTC for serving 4 - 16 subscribers) or directly subscriber premises (FTTH). Some RBOCs have expressed the commitment to a limited deployment of this architecture using new generation Digital Loop Carrier (NGDLC) for implementation of narrow-band services.

Although passive optical networks were initially introduced to improve the economics of bringing fiber closer to the subscriber, several other benefits have since then emerged in some implementations. PONs use passive optical splitters (instead of active remote electronics at the node in an NGDLC implementation) to distribute the CO signals to subscribers.

In it's most common implementation, telephony over a PON uses a TDM technique in the downstream direction to deliver up to 672 DS0 (64 kb/s) channels to subscribers. Figure 1 shows the block diagram of a PON system being currently deployed in the United States.

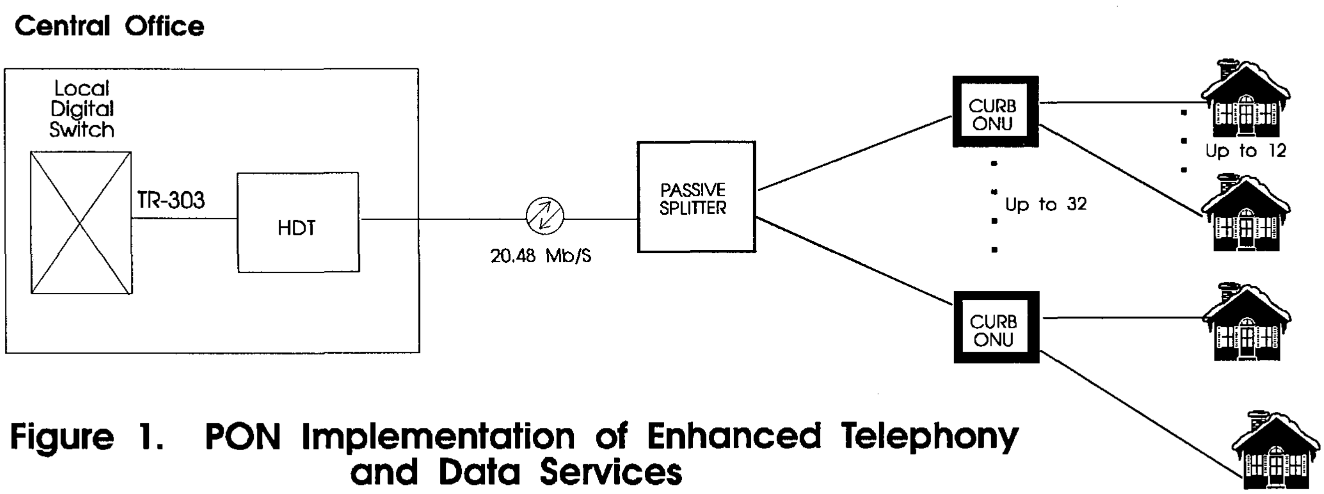

Figure 1. PON Implementation of Enhanced Telephony and Data Services

The Host Digital Terminal (HDT) is the interface between the public switched telephone network (PSTN) and the distribution network. The distribution of bandwidth to subscribers in the upstream direction is accomplished by a TDMA technique[(2)]. Each TDMA system has the capacity of up to 224 DS-0 channels; three TDMA systems may be accommodated by each Host Digital Terminal. The TDMA system operates on the fiber at 20.48 Mb/s.

The optical fibers pass through the passive optical splitters for distribution to the Optical Network Units (ONUs). The number of fibers, and the number and type of splitters, can vary from one system configuration to the next; the optical link budgets are engineered to accommodate a maximum splitting ratio up to 1:128 for narrowband applications.

The deployment of electronics to serve subscribers for telephony and data services occurs at each curb-side location. Each TDMA channel can address up to 128 physical termination devices, hence the 224 DS-0 channels may be shared as needed among the users served by those terminations.

Services available from an ONU are a function of the channel units installed. Channel units for POTS, ISDN, data and other special services are generally available.

PASSIVE OPTICAL/COAX HYBRID NETWORK

The impetus for deployment of Passive Optical/Coax Hybrid Network (POCN) to deliver enhanced telephony and broadband services (entertainment video, VOD) has recently gathered momentum from both major players in the subscriber loop: telcos and MSOs. The recent FCC decision allowing telcos to enter video dial tone business has accelerated their plans for FITL deployment. Thus, the primary driver for telcos for FITL deployment today is new revenue opportunities from the delivery of video dial tone-based services. This is in sharp contrast to original thinking at RBOCs where the primary driver for FITL deployment has been copper parity for POTS. The current FITL strategy at RBOCs appears to be a cost effective deployment of fiber within few hundred feet of subscriber premises using the FSA concept. The drop to subscriber premises is coax which will initially deliver video services. This is a significant difference from NGDLC and FTTC implementations with broadband overlay where two separate drops (wire and coax) are required to deliver telephony and video services. By addition of necessary HDT and CPE, a smooth migration path for provision of enhanced telephony and data services is envisaged.

From the CATV industry side, MSOs are well positioned to implement a POCN for delivery of not only CATV but enhanced telephony and data services. The implementation of FTF architecture in CATV networks has allowed MSOs to begin placing large amounts of fiber close to subscribers. A fiber node serving area in FTF does not exceed a few miles radius (2,000 subscribers). The more aggressive implementations limit fiber serving areas to around 2,000 feet radius (500 subscribers or less). The following table illustrates the sizes of fiber serving areas in various fiber deployment scenarios. Figure 2 depicts block diagram of a POCN for integrated service delivery of CATV and enhanced telephony.

Fiber Serving Area Size (# of Passings)	550 MHz CATV	1 GHz CATV	Enhanced Telephony	Enhanced Telephony, CATV, VOD, PCS
FTF/FSA	1000-2000	200-500		
PON			128, maximum per PON; 4-32 per ONU	
PON with Broadband Overlay				128 (Enhanced Telephony) 16-32 (Video)
FSN				500
POCN				50-100

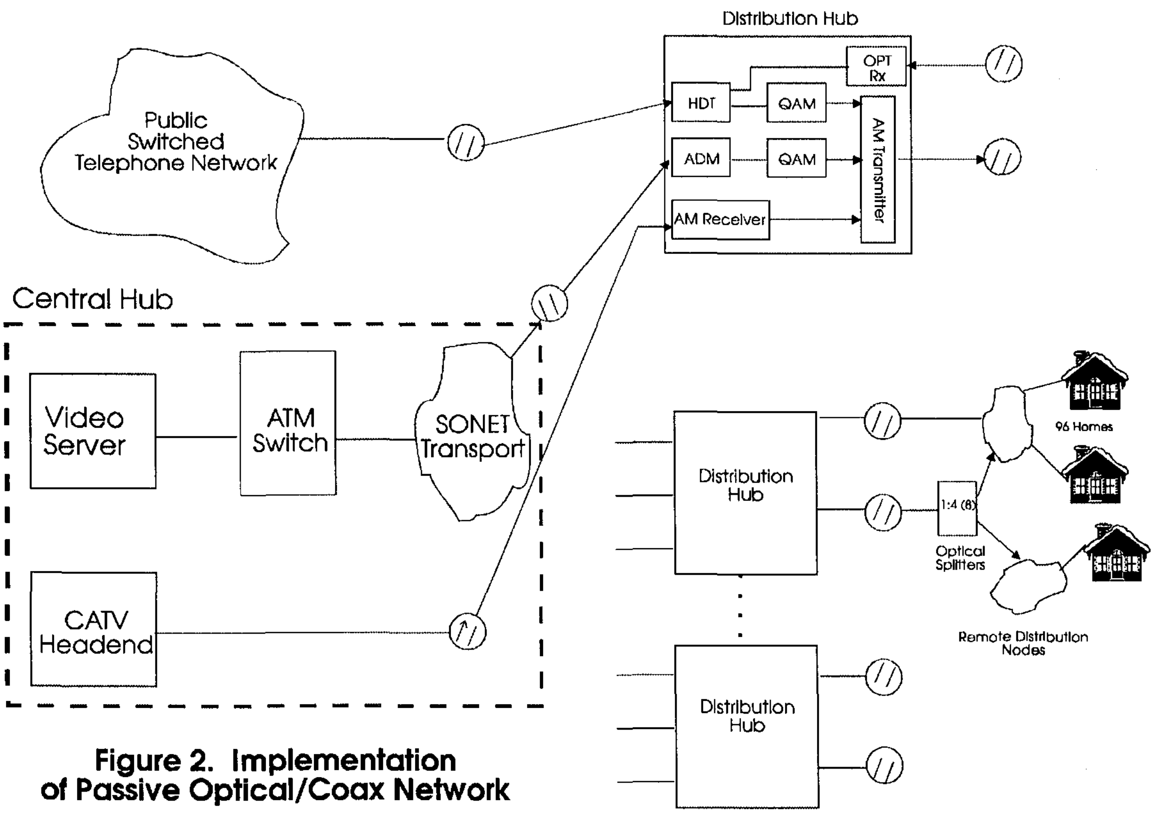

Figure 2. Implementation of Passive Optical/Coax Network

Various frequency plans have been proposed for broadband hybrid fiber/coax networks[4,5]. The Full Service Network proposal[5] from Time Warner recommends the following frequency assignment scheme:

Reverse Path

5-30 MHz — Coaxial plant status monitoring and IPPV carriers.

850-1000 MHz — Digital Services: POTS and data

Forward Path

50-450 MHz	Traditional VSB-AM Cable
450-750 MHz	Digital Services: Video-on-demand, POTS and data

The POCN proposal in this paper is similar in spirit to the FSN and uses the following frequency plan:

Reverse Path

5-25 MHz	Digital Services: Enhanced telephony and data
25-31 MHz	Coaxial plant status monitoring and IPPV carriers

Forward Path

50-450 MHz	Traditional VSB-AM cable
450-600 MHz	Digital Services: Video-on-demand, POTS and data
600-1000MHz	Not required because of narrow-casting and smaller node size

THE CENTRAL HUB

The Central Hub is a regional headend[6], which has the necessary capital intensive equipment including:

1. Conventional CATV (VSB-AM) headend equipment.

2. Video Server

3. ATM Switching

4. SONET multiplexing and transmission equipment.

DISTRIBUTION HUB

A Distribution Hub location serves 10,000-40,000 subscribers via a star network of remote fiber nodes. It receives 50-450 MHz conventional CATV signals in VSB-AM format from the Central Hub.

VOD signals in compressed digital format (MPEG II) and PON downstream channels (20-48 Mb/s) are transported to each hub location using a SONET OC-48 ring. The digital signals in SONET format are converted to 16-level QAM channels in 450-600 MHz band. All the downstream signals are now combined before intensity modulating a linear DFB transmitter. The serving area of a Distribution Hub is divided into fiber distribution nodes, each serving approximately 100 potential subscribers each. The selection of node size is based on considerations involving return signals for enhanced telephony and data services. A 4-way or 8-way optical splitter is used in the

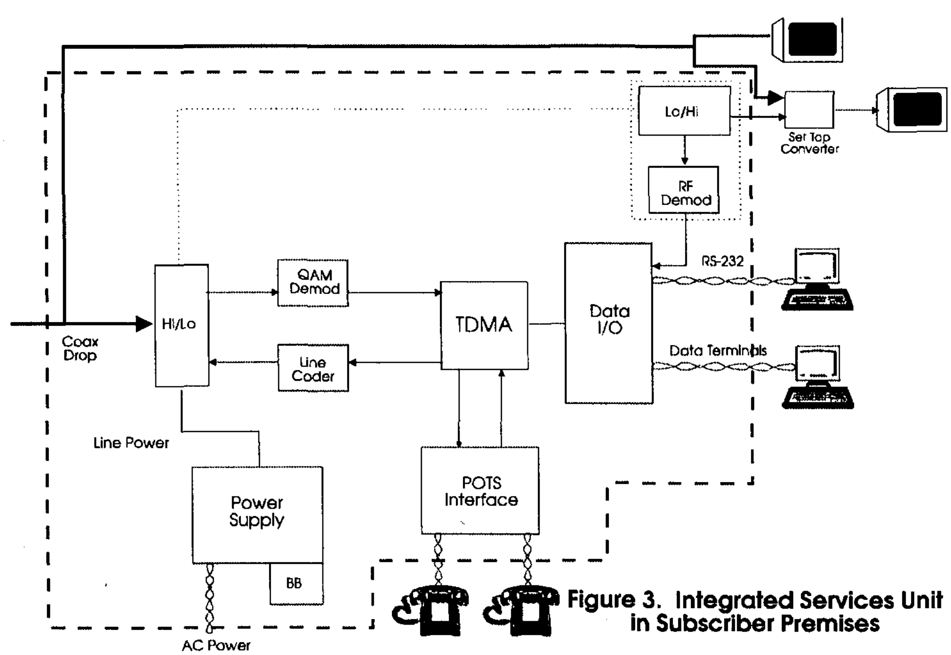

Figure 3. Integrated Services Unit in Subscriber Premises

POCN forward path instead of 1:16 or 1:32 way splitter commonly used in PON telephony networks.

CPE AND RETURN PATH

The equipment in customer premises to provide CATV, VOD and enhanced telephony is shown in Figure 3. The coax drop from the fiber node terminates on an Integrated Services Unit (ISU) in subscriber premises.

The 20.48 Mb/s downstream TDM signal from the HDT is demodulated before delivery to the TDMA module. In the upstream direction, the subscribers ISU's are synchronized to the HDT, so that returning time slots interleave automatically as they move through the fiber/coax distribution network. A ranging protocol from the HDT and a programmable delay element in the ISU's permits synchronization to be achieved between the HDT and subscribers within a serving node(s). Consequently, 20.48 Mb/s TDMA bursts from each ISU are synchronously received in appropriate time slots for multiplexing.

The POTS interface provides all A/D conversion and BORSHT (Battery, Overvoltage, Ringing, Supervision, Hybrid and Test) functions for connection to standard telephone sets. Data terminal devices connect to ISU by RJ-45 connectors. Date I/O module provides network adapter functions for asynchronous data devices (RS-232, etc.) The digital multiplexing and network access functions are implemented by the TDMA circuitry in the ISU. The TDMA output is line coded to shape the output digital spectrum compatible with reverse path characteristics in a sub-split coaxial distribution system.

It is assumed that traditional CATV services, including scrambled premium programming, is received via a cable-ready TV set or a one-way set top converter as appropriate. The reception of encrypted, compressed digital VOD channels will be via a 2-way set top converter with enhanced capabilities such as QAM demodulation, decompression, deencryption and D/A conversion.

For VOD services, there is a need to adopt signalling standard for set top converter units to communicate with ISU.

ECONOMICS

Any system evaluation must include an examination of system requirements for very low initial penetration, incremental expansion, and maximum system capacity.

As previously discussed POCN network minimum configuration provides 224 DS-0 slots (POTS lines) for 128 subscribers. These subscribers may be served from one distribution hub feeding hundreds of fiber nodes. Therefore, at extremely low penetration, the POCN network can be economically implemented albeit requiring more complex provisioning and traffic engineering practices. As penetration grows, the system can be incrementally expanded in 128 subscriber increments. When implemented in advanced fiber/coax cable TV architectures, there is an excellent match between homes served per node and the size of POCN nodes.

Importantly, many MSO's have not decided whether to be in the telephony providers including call routing. Any system chosen for implementation of telephony over a fiber/coax transmission path should not preclude the CATV operator's future choices of telephony service offerings. Unlike alternative architectures, the POCN network is non-blocking. It does not limit the offering of telephone services to single POTS lines. Rather it supports dynamic bandwidth allocation up to a DS1 per subscriber. This allows the CATV operator great flexibility when considering the costs of implementing advanced data and video conferencing to the home. In summary, the POCN architecture is not limited to POTS or conventional CATV, but is rather a means of delivering variable bandwidth for enhanced telephony and a rich menu of broadband services.

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