A New Economic Coax Approach to MDU and Hotel Internet Access

Jack Terry
coaXmedia, Inc.

Abstract

This paper presents a new, but DOCSIS-compliant, economic system approach for multi-dwelling unit (MDU), hotel, and university campus or hospital high-speed Internet access that operates effectively in existing in-building TV coax. The system offers plug and play end-user attachment without PC reconfiguration or installation of an Ethernet NIC card as multi-megabit Internet access is achieved through the use of the PC's existing parallel or USB port. Within-MDU ingress interference is isolated from the main hybrid fiber-coax network and the system offers improved bandwidth management and efficiency, particularly in the upstream or return direction. The coaXmedia user interface consumes less than one tenth of the power of that of a Cable Modem thus making it easy to provide for lifeline services.

BACKGROUND

The demand for high-speed Internet access is driving the telecommunications industry like few forces have in the past. While the Cable and Telephone industry position their networks for the future, ever-changing technology has previously made it both costly and risky to invest in new delivery systems.

Most current approaches for delivery of Internet services in MDUs utilize telephone wiring in "data above voice" configurations. Such approaches usually require selective identification and disconnection of each telephone pair and the insertion of a modem function at the central end of the telephone loop. Such intrusive installation is both costly and time consuming. A second modem is required at the user end of the telephone pair to connect to the user's PC or in-home network. Since MDU telephone wiring generally has worse inter-pair crosstalk performance than that of outside wiring and suffers considerable electrical ingress interference it is usual to insert the data on the telephone loop within the building to ensure adequate performance.

The high frequency loss of longer telephone loops between the central office and the MDU considerably limits their potential two-way transmission speed.

The use of low-cost wireless data transmission works well where the distances are short and spectrum is abundant. For densely populated MDUs this is not usually the case.

THE PRESENT CABLE ENVIRONMENT

Cable Modem Internet service has now penetrated well over one million residences and has become extremely popular due to its exceptional speed. However the introduction of Cable Modem service in MDUs is problematic due to the complex and irregular topology of the TV coax wiring and the sharing of limited available upstream bandwidth. In addition, points of ingress interference in MDU coax distribution and home wiring are very difficult to locate and particularly difficult to isolate. Such ingress interference can cause failure of two-way services to all users in an MDU and potentially other users upstream of the MDU on the Hybrid Fiber-Coax (HFC) network.

Both Cable Modem and Telephone loop data modems are usually interfaced to the PC using an Ethernet 10baseT connection. This requires that a Network Interface Card (NIC) be installed in each PC and the PC network software configured. Since the average PC users are not usually technically skilled, this installation and/or configuration is frequently performed by the Cable or Telephone network provider. In this way the network provider becomes potentially liable for problems in the PC, often when the trouble is not related to the network provider's work. While this issue can be alleviated in some cases by use of USB ports, a large proportion of PCs are not so equipped. In hotel/motel situations, users do not generally require networking between themselves and are rarely adept or willing to reconfigure their PCs each time they rent a room or return to their home or office.

MDU and hotel coax distribution systems, which can be served by Cable, Satellite or Broadcast network operators, are usually configured as passive "tree and branch" systems using splitters and/or relatively long coax runs with taps or couplers arranged to serve the apartments or rooms. Such passive distribution arrangements frequently serve from 30 to 100 rooms or apartments and are arranged such that the TV signal levels fed to each apartment or hotel room are typically within a 10 dB range. These coax distribution systems typically have losses in the range of 15 dB to 25 dB and are usually fed from a centralized one-way broadband TV channel amplifier to ensure adequate signal levels for the users. Larger high-rise MDUs and hotels usually have a number of centralized amplifiers each feeding a passive coax distribution sub-system serving separate areas or floors of the building.

THE OPPORTUNITY

The spectrum of the MDU TV services usually lies below 750 MHz, whereas the coax cable can handle frequencies beyond 1 GHz. The passive splitters or couplers, although usually only rated for use in the TV bands, usually perform adequately in terms of loss and/or port isolation when carrying more robust digital signals of up to 1 GHz. Furthermore, the loss per unit length of the in-building coax wiring, rather than being a problem, helps attenuate echoes at these higher frequencies and thus permits much simpler equalization in digital receivers.

Clearly there is an opportunity to utilize the higher frequency spectrum of in-building coax for high-speed Internet access services using robust digital modulation techniques. Ingress interference is much less at frequencies above those of TV channels and, being contained by the one-way characteristic of the central TV channel amplifiers -- at least at the TV downstream channel frequencies and higher, any ingress interference is prevented from exiting the MDU and interfering with the HFC Cable network.

The available above-TV-channel spectrum in in-building coax can be arbitrarily divided up to offer high-speed data in both directions. Due to the relatively high field-strength radiation of portable cellular handsets it is prudent to operate at frequencies of 900 MHz and above. Using presently installed splitters and couplers it is also better to keep to frequencies of 1 GHz and below. This available 100 MHz of available spectrum is plenty to serve the statistical two-way Internet access needs of 50 to 100 users or client modems. If higher capacity is needed, additional downstream spectra can be allocated in bands between 1 GHz and about 1.6 GHz, provided that higher frequency specified splitters are substituted. Such higher uni-directional capacity can provide for additional digital video-on-demand (VOD) services, in either Internet Protocol (IP) format or in native MPEG2 format. In all cases the spectrum between 900 MHz and 930 MHz can be utilized for upstream transmission. The use of this single upstream spectrum provides adequate traffic capacity and simplifies control.

AN ALTERNATIVE APPROACH

An alternative system approach, named coaXmedia, has been devised which takes advantage of the topology and performance of in-building coax distribution to provide high-speed Internet services.

This system architecture is DOCSIS-compliant at a network level, consistent with existing Cable Modem operation and service practices and yet offers plug and play end-user attachment without PC reconfiguration or installation of an Ethernet NIC card. At the same time the approach isolates within-MDU ingress interference from the main hybrid fiber-coax network and provides bandwidth management and efficiency, particularly in the upstream or return direction.

The per-MDU common equipment installation is extremely simple and there is no need for a truck-roll or appointment to provide service to each customer. Indeed, the customer interface can be drop-shipped to the consumer and is easier to hook-up than a VCR. Multi-megabit Internet access is achieved through the use of the PC's existing parallel or USB port using a simple "enabler" which can be optionally loaded from the MDU central hub modem, via the PC's existing serial connector -- no floppy disks or CDs.

The primary purpose of this "enabler" is to place a "connection" icon on the user's desktop for ease of access to the service. There is never the need to perform another enabler load when moving the PC between coaXmedia client modems, such as when moving between hotel rooms or returning home, as the "enabler" does not need to contain any addressing or configuration information.

The coaXmedia client modem is extremely simple since it does not require a tuner or even a microprocessor for its operation. Other simplifications result in a complexity of around a quarter of that of a conventional Cable modem. The client modem is thus very low in cost and this cost will continue to track at significantly less than half of the cost of technology-evolving conventional cable modems. Additionally, the coaXmedia user interface consumes less than one tenth of the power of that of a Cable Modem. Installation costs are minimal and marketing of the service by the Cable MSO is simplified as service may be offered on a same-day trial basis.

The coaXmedia client modem can be packaged on a single printed circuit board housed in a plastic case of approximately the size of a small cellular phone. This case may be included as a pod inserted in a piece of coax cord connected to a coax wall receptacle. This pod will also have a thin data cord with a multi-faceted connector that may be inserted into the parallel, serial or USB connector on a PC or laptop. Future connectors may include an infrared transceiver for communication with similarly equipped PCs or PDAs. Power is provided using a low-cost, single AC voltage, UL/CSA approved, transformer cube.

THE COAXMEDIA ARCHITECTURE

A diagram illustrating the overall coaXmedia architecture is shown in Figure 1.

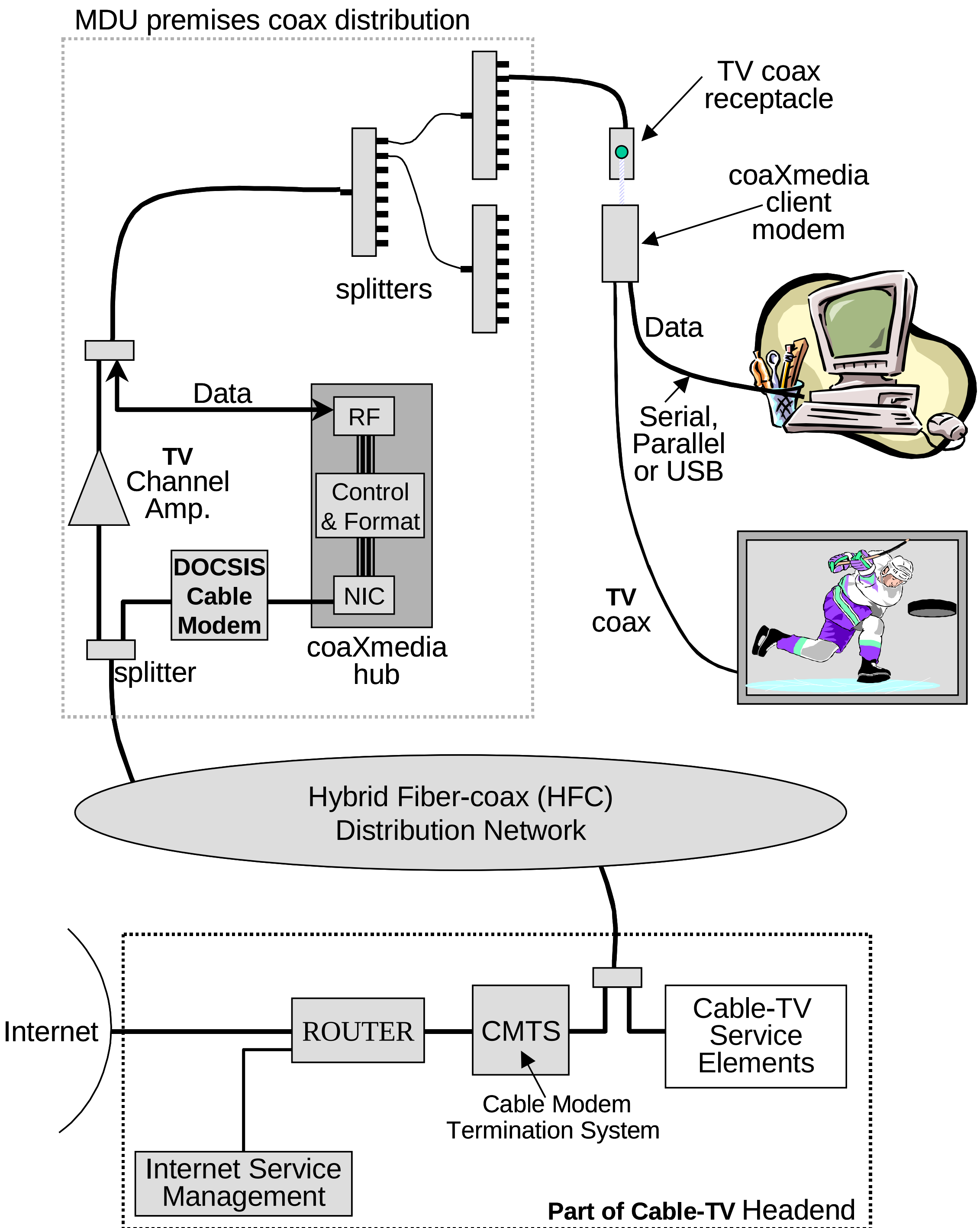

Figure 1. The coaXmedia Architecture

In this arrangement a single DOCSIS-compliant off-shelf Cable Modem is used to serve the statistical data needs of multiple users connected via a passive in-building coax distribution system.

At the user or client ends of the system a very simple modem interface is used to interface to the user's PC via its existing serial, parallel or USB port. In this way no NIC card or network configuration is required in the users

PC. Point-to-Point Protocol (PPP) is carried on RF channels on the in-building coax distribution to a central RF modem.

A protocol converter is provided between this central RF modem and the shared DOCSIS-compliant Cable Modem. This converter translates the data format between the Point-to-Point Protocol used by the PC and the 10baseT used by the DOCSIS Cable modem. Thus any IP protocol, such as TCP/IP, UDP/IP, etc., is carried transparently to and from the Internet. Special prioritization is available for low-latency requirement traffic, such as IP voice or multimedia, in both directions of transmission.

The protocol converter also acts as a proxy server in order to connect the many coaXmedia client modems and their PCs to one or a few DOCSIS-compliant Cable modems. This involves providing IP addresses to the PCs in response to PPP connection requests. The protocol converter translates single or multiple socket addresses that uniquely identify multiple sessions or windows running within each PC, in order to present unique socket addresses to servers that exist on the IP network.

The field-trial version of the protocol converter is supported by a PC motherboard and is packaged, together with the coaXmedia central modem RF board, in a PC rack-mount, pizza box sized case, for wall mounting. This PC motherboard, upon booting, makes a DHCP request via its Cable modem to a server in the headend and receives a leased IP address – just like a user-PC provided with regular Cable modem service. If the protocol converter has multiple Cable modem connections to the headend then this action is repeated for each Cable modem.

The many client-PC's are be made to appear, from a headend service management perspective, as though they are connected via individual Cable modems. Thus a function is provided in the headend that collects associated user-PC MAC and assigned IP address information from the coaXmedia protocol converter and presents this as an interface to service management functions that also manage single-user Cable Modem services.

RF TRANSMISSION

The in-building RF system presently uses 15 Msymbol/sec BPSK or QPSK modulation in a single downstream "channel" with a center frequency of approximately 970 MHz. Higher symbol rates are planned which could offer at least 30 Mb/s net downstream data capacity.

The downstream signal is transmitted continuously and formatted in a standard MPEG2/DVB structure. The MPEG2 frames comprise a framing (47 hex) / super-framing (inverted 47 hex) byte, 187 information bytes and 16 forward error correcting (FEC) bytes – a total of 204 bytes. Certain reserved MPEG2 "Packet IDentification" (PID) codes are used to indicate that the following information bytes are data of a particular type rather than digital video or idle frames.

Conventional synchronized scrambling is employed for spectral reasons and the 16-byte FEC field is always used or reserved for error correction. These structures facilitate the use of the same industry-standard off-shelf set-top technologies in both data and digital TV applications. Frame interleaving, while available, is not used in in-building passive coax distribution as this would delay latency-sensitive traffic and is not necessary for error protection purposes.

Upstream transmission in the in-building coax uses a BPSK modulated 915 MHz RF signal carrying a 15 Mb/s digital stream. Upstream transmission is only permitted from one coaXmedia client modem at a time as specified by downstream "polling" contained in the downstream data control envelope. Thus there is no collision of upstream signals. The upstream signal comprises a preamble signal that is ramped up in level followed by a sync byte. A scrambled client modem source address, a length field and then data follow this preamble. The length of the data field is dependant on how much is requested by the central modem or the remaining amount of upstream data buffered in the client modem. As in the downstream direction, special provision is made for the needs of low-latency traffic.

COAX PATH LOSS COMPENSATION

Path losses between each client modem and the central modem will have a wide variation due to the coax distribution topology and loading variations. The system is designed to accept losses of 40 dB or more.

Loss variations in the downstream direction are compensated by an automatic gain control (AGC) function contained in each coaXmedia client modem receiver.

The upstream AGC method involves adjusting each of the client modem transmitters such that their signals, upon arrival at the upstream receiver in the central modem, are approximately equal.

Each time a data burst is sent to a client modem an extra bit is included which indicates if the previous transmitted burst from that modem was above or below the ideal level required at the central modem receiver. This bit is used by the client modem to slightly adjust, either upward or downward, the level of its next transmitted burst. Thus all signals received by the central modem from every client modem become aligned in level and cycle upward and downward by a small amount. This is an ideal situation since the upstream BPSK receiver has a much wider acceptable input signal range than the small level variations received. Control systems of this type are fast to react to changes in transmission path attenuation and are intrinsically stable.

PRIVACY

A minimal cost moderate level of data privacy is provided using individual spectral scrambling sequences and/or sequence start points for each client modem in each direction. The method of establishing such scrambling sequences is itself secure. Higher levels of encryption security, like those used in DOCSIS-compliant Cable modems, will be made available, where required, at a slightly additional cost.

TECHNOLOGIES

The systems about to go into public trial use available low-cost, commercial RF and digital technologies. The coaXmedia client modem receiver may use tuner/demodulator chipsets commonly used in satellite set-top boxes.

Near-term plans include moving most functions into a pair of custom chips; one a small RF analog chip, the other a semi-custom chip containing the digital functions. This technology evolution will result in a coaXmedia modem the size of a small cellular phone that may become part of a coax cord assembly and consume very little power.

The coaXmedia hub or proxy server is presently constructed using a normally rack-mounted diskless, low cost, PC motherboard equipped with an RF/protocol board and one or more 10baseT NIC interfaces. This may be mounted, together with one or more off-shelf cable modems, on a wall adjacent to the existing building TV distribution amplifier.

INSTALLATION

As illustrated in Figure 1, the central installation requires only the addition of two coax splitters to which are attached a conventional cable modem and the coaXmedia hub. The coaXmedia client modems are simply introduced, *by the end-user*, between the TV wall receptacle and TV set (if any). An associated transformer cube is then plugged into a convenient power receptacle and the data cord plugged into the user's PC. No network-stack configuration of the PC is required, thus offering a real plug-and-play high-speed Internet access service.

SUMMARY

The coaXmedia system presents a new, economic approach for MDU or hotel high-speed Internet access that works well over existing in-building coax.

This coaXmedia system is DOCSIS-compliant as seen from the headend networking elements, consistent with existing Cable Modem operation and service practices and yet offers plug and play end-user attachment without PC reconfiguration or installation of an Ethernet NIC card. The per-MDU common equipment installation is extremely simple and there is no need for a truck-roll or appointment to provide service to each customer. Indeed, coaXmedia modems can be mailed and are easier to hook-up than a VCR.

The approach isolates internal MDU ingress interference from the main HFC network and provides improved bandwidth management and efficiency, particularly in the upstream or return direction.

Multi-megabit Internet access is achieved via the PC's existing parallel or USB port using a simple "enabler" that places a connection icon on its desktop and activates the PC's existing PPP direct connection facility. The "enabler" can be loaded from the coaXmedia central hub via the PC's existing serial connector -- no floppy disks or CDs.

The coaXmedia system approach is, and will track at, significantly less than half of the cost of a conventional Cable modem approach. Additionally, the coaXmedia user interface consumes less than one tenth of the power of that of a Cable Modem.

Marketing of the service by the Cable MSO is simplified as whole-MDU installation may be offered on a same-day trial basis.

BIOGRAPHY

Jack Terry was with Nortel and its subsidiary, BNR from 1974 until 1999. He was responsible for technical development of Nortel's DMS-100 series of telephony switches that resulted in the universal deployment of digital switching in USA and Canada during the early 1980s. Jack joined BNR following 15 years engineering experience with Marconi Communications Systems R&D in U.K. where he was engaged in the fields of high-power TV transmitters, Video equipment and Digital Telephony PCM Transmission and Switching systems.

As a Nortel technology VP during the 1990's, Mr. Terry provided industry leadership in the field of digital architecture and services in Cable-TV networks that helped seed today's direction of Internet access (DOCSIS) Cable Modems. In April of 1999 Jack and a small team founded coaXmedia, Inc. that today is operating as a small R&D company specializing in exploitation of TV coax wiring for high-speed Internet access.

During his career Jack has filed numerous patents. He is a Fellow of the IEEE and in 1995 received the IEEE Engineering Leadership award for his pioneering contributions to digital switching and line circuit technology. Jack is also a Fellow of the International Engineering Consortium, a Senior Member of The Society of Cable Telecommunications Engineers and a member of Sigma Xi. Mr. Terry's previous leadership activities within IEEE included Chair, IEEE Communications Society / Society of Cable Telecommunications Engineers joint Technical Committee on Cable Telecommunication Systems and Applications from 1995 to 1998.