CATV BROADBAND TECHNOLOGIES

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Abstract: *Cable television systems can be successfully used as broadband multimedia networks. Cable TV providers can offer additional services over CATV network, such as Internet access, video on demand and other applications. The article describes different techniques and technologies applied in modern two-way interactive CATV systems that enable variety of new service*

Key words: *CATV Network, Cable Modem, Internet Access, Wireless CATV*

1. INTRODUCTION

Traditional CATV networks are growing into two-way, multimedia networks. In recent years cable providers are trying to offer multiple services over a single network. Internet access, high speed data transfer, video on demand and games are some of the applications driving this trend. The problem of delivering new services over CATV networks is characterised by certain infrastructure investments, and there are different possibilities of upgrading existing CATV networks.

2. UPGRADING OF A CATV NETWORK

The main function of traditional CATV networks -distribution of TV and radio programs - has rapidly changed in a last few years. Because CATV was originally founded as a broadcasting network, it has a tree-like formation, starting from a headend and branching into each household. Currently, cable television is being focused as a new and unique type of information infrastructure. Modern cable infrastructure should be designed to deliver a variety of new communication services and to support both current and future applications. CATV networks are originally designed to broadcast time division multiplexed analog television and radio signals in the frequency band from 47–862 MHz. But for Internet access and other new interactive services, traffic must flow in both directions. The frequency range between 5 and 30 MHz is allocated for the upstream transmission of analog and digital signals. For more efficient introduction of new interactive services in CATV networks, the return channel for the upstream transmission can have extended bandwidth from 5 to 55 MHz or even 5 to 65 MHz. In these cases the downstream frequency band starts at 73 MHz or 86 MHz respectively.

In the recent years CATV network topologies have been changed, and beside the usual tree and branch structure the star and ring topology was introduced. Nowadays, the broadband cable networks use the Hybrid Fiber Coaxial (HFC) technology. By using Hybrid Fiber Coax network a wider bandwidth can be utilized. The optical nodes of the CATV systems come

closer to the subscriber's outlet. The ring topology gives higher reliability and is usually used in the optical network. From the optical node and in the house network, the star topology is preferred.

The first task of a cable TV operator that wishes to offer interactive services is to upgrade its cable plant to handle bidirectional information flow. The operators have to add return amplifiers and band-splitting filters (diplexers) in the CATV network, to separate the upstream and downstream signals, and amplify each direction separately in the right frequency range. They also have to install intelligent controller in the headend - Cable Modem Termination System (CMTS) that manages the system operation, and special units at the end subscribers to separate the upstream and downstream traffic. The major elements of a bidirectional CATV system with Internet connection is shown on Fig. 1.

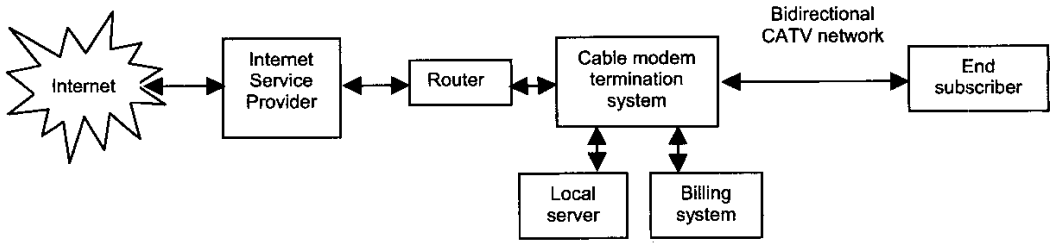

Fig. 1. Communication paths for the internet access in a CATV system

The CMTS takes the upstream traffic coming in from customers and routes it to an Internet Service Provider (ISP) for connection to the Internet. At the head end the cable providers will also have servers for accounting and logging, and Dynamic Host Configuration Protocol (DHCP) for assigning and administering the IP addresses of all cable system's users.

Downstream transmission from the headend is a typical broadcast. The same signal is sent to all users in the network. The upstream transmission is, in contrast, inherently personalcast. Each subscriber is placing a different signal into the network. These different signals must share the same part of transmission spectrum and different access methods are needed to arbitrate which signal is actually carried. Access methods can be Time Division Multiple Access (TDMA), Frequency Division Multiple Access (FDMA), Carrier Sense Multiple Access (CSMA), etc. Which method is appropriate depends on the expected application.

Upstream transmission presents a technical challenge, because multiple noise sources invariably accompany the multiple signal sources. In the reverse direction it is more difficult to keep appropriate carrier/noise (C/N) ratio than in the forward direction, because of the phenomena called noise funnelling. The effect of noise funnelling (noise accumulation) originates in return path of the CATV network because the network operates as a system with several inputs and one output. The sum of input noise and the noise arise from each return path appears at the network output. Reducing the number of noise sources funnelling into a single upstream channel can solve the noise ingress problem. Careful plant engineering is often required for the upstream signal to arrive to the headend in recognisable form.

3. CABLE MODEMS

Digital data signals are distributed on radio frequency (RF) carrier signals through the cable network. Cable modems convert digital information into a modulated RF signal and also RF signals from a cable network back to digital information. These conversions are performed

by cable modem at subscriber premises, and by headend equipment handling multiple subscribers.

By providing Internet access over the CATV network it is necessary to determine what kind of network technology to use to connect the customer to the Internet. A single TV channel with the bandwidth of 7 MHz (VHF band) or 8 MHz (UHF band) can support multiple data streams or multiple subscribers using shared Local Area Network protocols (LAN). This technology allows transmission of digital data over one or more TV channels of a CATV network. The broadband LAN is built on two TV channels, one transmitting data from the headend to subscribers (downstream), and the other transmitting data from the subscribers to the headend (upstream). At the headend, a frequency translator connects the two channels into a channel pair. One or more channel pairs can be allocated to a LAN service. Using a standard analogue TV channel bandwidth for data transfer allows the use of the same equipment as is used for analogue cable TV transmission in the headend and in the cable plant.

Different modulation techniques can be used to optimise data speed, which is transmitted usually within a TV channel with 6 MHz bandwidth in USA or 8 MHz in Europe. The most of the cable modem manufacturers use Quadrature Amplitude Modulation (QAM) in forward direction with feasible speeds for 64 QAM up to 41 Mbit/s, or 256 QAM with the information rate of 55 Mbit/s, and Quaternary Phase Shift Keying (QPSK) in reverse direction with speeds up to 10 Mbit/s. The QAM has excellent spectral effectiveness and is relatively robust. The higher speed is appropriate for new or upgraded cable networks, while the lower speed is more tolerant to cable plant imperfections with interfering and reflected signals. The QPSK modulation in the reverse direction is a good compromise between the spectral effectiveness and the reliability of data transmission through a noisy medium. The various solutions impose different equipment costs, achieve different coding efficiencies, and have different sensitivities to noise and distortion in the cable network.

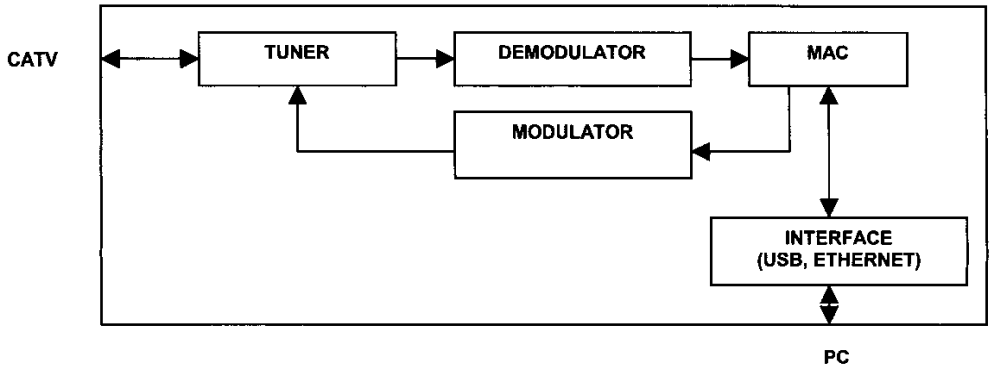

Fig. 2. Block diagram of cable modem

A cable modem consists of a standard television tuner, a 64 QAM demodulator and an Ethernet connection to the customer's computer, as seen on Fig. 2. The return path from the computer carries acknowledgments messages or upstream file transfers such as e-mail. The upstream signal is modulated with Quaternary Phase Shift Keying (QPSK) for return over the cable system to the headend. This signal is feed though a driver with variable output level, so the signal level can be adjusted to compensate for the unknown cable loss to the headend. An internal processor with memory controls the tuner and the return path as well as more complex functions such as downstream packet filtering. The Media Access Control (MAC)

sits between the upstream and downstream section of the cable modem, and is the interface between the hardware and software of the various network protocols. The data that pass through the MAC goes into the computer interface of the Cable Modem (Ethernet, USB, PCI bus or whatever).

The cable network is shared by all subscribers connected to it. This makes the cable plant, considered as a communication system, basically different from a telephone network that dedicates a twisted pair line between the central office and each subscriber. Sharing access among multiple users gives rise to privacy and security problems. One user connected to a cable network can potentially receive transmissions intended for another, or make transmissions pretending to be another user. Therefore security aspects will play an important role. Privacy of users has to be guaranteed and the possibility of illegal access has to be avoided. Careful traffic control should be performed on a CATV system to maximise data speeds even if new subscribers are added to the system. Cable data networks can be custom tailored and subdivided within each part of the network to meet customer demands, to provide faster service for each individual subscriber.

Since cable subscribers share the transmission media, there is a worry that if the number of subscribers per node goes up, at some point the performance of the entire system may go down. If there would be just one cable modem in operation, the user would theoretically have a download data capacity of 41,4 Mbit/s in a 64 QAM system, or 55,2 Mbit/s in a 256 QAM system (for European 8 MHz channel bandwidth). The Ethernet connection from the cable modem to the PC could be a bottleneck with speeds up to 10 Mbps, but downloads at these speeds would still be OK. A much more likely bottleneck could be the CATV systems connection to the Internet itself. If the link between the cable operator and the Internet service provider has insufficient capacity, it will be overloaded and will not accommodate the traffic requested by subscribers. Cable operators can use Local servers to cache popular Web sites of high interest closer to the user, which can reduce dependence on the access to Internet.

There is also the possibility to use more bandwidth (more TV channels) for a cable modem service. But the addition of more channels for a cable modem service reduces the number of available TV channels or other digital services in a CATV system such as digital television, video on demand, telephony etc. Adding more channels can increase the downstream capacity, but if the upstream capacity is the limiting factor in a particular CATV system, the traffic jam problem will be even bigger.

In the areas where there is no CATV infrastructure installed, there is a wireless solution to bring the broadband service to the subscribers.

4. WIRELESS CABLE TV SYSTEMS

Wireless cable TV could be the television broadcasting technology of choice in many of the fast developing regions. Wireless cable TV systems can be put into operation easy and quick and can therefore be a highly profitable subscription television solution. In a wireless system, there is no need for costly laying and maintenance of cables. This significantly reduces the initial capital investment and the time required to put a system into operation. The installation of a wireless cable TV system can take only a few months. The return on investment is usually quick, as income can be expected immediately after the installation of the transmitter and the first subscriber connection. Therefore, for the investor, it is profitable because it can be implemented and maintained at a lower cost and quicker than a conventional CATV system.

Wireless cable TV is capable of offering subscribers more than 30 broadcast quality TV programs which are much more reliable than in a conventional CATV system as they are broadcast over the air rather than through the wires. Two-way wireless operation is also possible. There are different solutions for the return channel path. A service provider can use telephone line, integrated services digital network (ISDN), or wireless return as necessary to meet customer needs.

In a wireless solution a duplex operation is required to enable the two-way simultaneous exchange of data information between the service provider and a customer. This is especially delicate when both parties share a single, common link of wireless transmission. Several solutions to this problem are possible. The two most available solutions for point-to-multipoint communications are to separate the communications in frequency or in time. The design criteria most critical to select the proper duplexing scheme is the type of traffic that will be carried and the environment in which the system will operate.

Wireless duplexing can be implemented by dedicating two separate and distinct frequency bands, one for upstream transmissions and one for downstream transmission, with a guard band that may cut into usable spectrum. The guard band provides the necessary upstream/downstream isolation to make a system operate properly. This technique is referred to as frequency division duplexing (FDD). In FDD systems spectrum is wasted because as the amount of traffic varies in each direction, it rarely matches FDD's fixed up/down allocations. Traffic can be bottlenecked in one direction while capacity goes unused in the other direction.

With Time Division Duplexing (TDD), transmit and receive operate on the same frequency, but at different times on a fixed interval. And because of the relative high speed of switching between the two functions, simultaneous, two-way communications are preserved. No guard band is needed. By implementing a sophisticated media access control protocol, adapting TDD can be achieved to increase its advantages for broadband wireless access by varying the upstream and downstream bandwidth based upon traffic. With Adaptive TDD, channel allocations shift instantly to accommodate high data traffic in either direction on a burst-by-burst basis. The result is much more efficient use of spectrum.

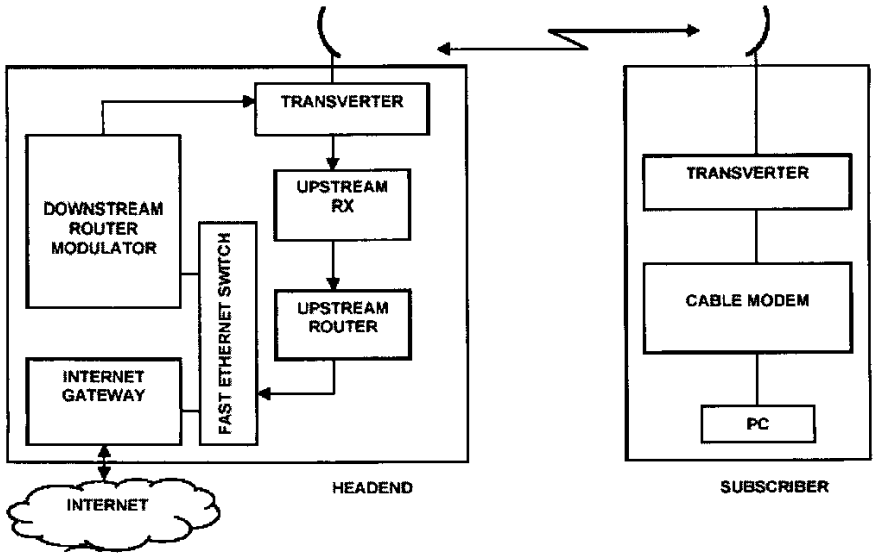

Fig. 3. Wireless Return Using the QPSK Signal from a Cable Modem

Possible solution of using wireless bidirectional acess to Internet is shown on Fig. 3. Wireless broadband modems offer similar performance to cable modems operating over wired CATV systems. Transverters and upconverters can take the standard upstream QPSK output signal of a cable modem (5 to 30 MHz or even 65 MHz) and translate it to the frequency band used for the transmission. A transverter is simply a combined downconverter and upconverter. Transmitting back to the downstream transmitter site allows integrated transmit and receive antennas at the customer site. These cost less than separate antennas and, as they are pointing in the same direction, the transmit antenna is automatically aligned when the receive antenna is installed and aligned.

5. CONCLUSION

Cable television network can be successfully integrated with computer data network to offer new services to the subscribers. High-speed cable modems are the basis of packet-based services for data, voice, and video services in the future, using upgraded CATV network infrastructure. Digital and analog signals will work in the same advanced telecommunications networks to deliver telephony, data, video and all other high speed data services to residential, educational, business, public, and government customers.

In the areas where there is no CATV infrastructure installed, there is a wireless solution to bring the broadband service to the subscribers. Wireless systems are desirable because they can be designed quickly, they are much cheaper to install and operate than wired technologies and they can be put into operation much easier and quicker. These systems can bring TV signals and other broadband services to rural population out of the reach of cable and ordinary broadcast services. It is also possible to install bidirectional wireless system for interactive two way services. It is feasible to use cable modems in wireless systems, since wireless broadband modems offer similar performance to cable modems operating over wired CATV systems.

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