AN INTRODUCTION TO CABLE MODEM SYSTEMS

Part II

The first part in this series of articles, outlined the basic system components & detailed the CMTS configuration. This second part explains the actual detailed working & transmission in a Cable Modem system. To properly understand the operation of a Cable Modem system, let us follow the processes that take place in the operation of the system. Other articles in the magazine, several months ago, have explained that there are also non DOCSIS systems that are used for Internet delivery. The non DOCSIS systems boast certain features, such as being able to operate with higher noise thresholds. For this they use different modulation schemes, and larger bandwidths for transmission of the same amount of traffic. In this article, we will restrict ourselves only to DOCSIS systems.

INITIALIZATION MODULATION DETECTION

When a Data Over Cable Service Interface Specification (DOCSIS) cable modem is powered up, it goes though several handshaking procedures. This handshaking first of all setup the cable modem in such a way that it does not disturb other cable modems already on the system. For this, on power up, the cable modem scans the CATV system forward path for the QAM (Quadrature Amplitude Modulation) carrier & detects the level of QAM. The system could be utilising QAM 16, 64 or QAM 256 modulation. As detailed in Part 1 of this article, 64 QAM supports 27 Mbps and 256-QAM supports 38 Mbps nominal data throughputs. Higher orders of QAM are desirable, since they offer higher data throughput, over the same bandwidth, or conversely consume lower bandwidth. The data rates shown in Table 1 and Table 2 are supported by DOCSIS. However, higher QAM modulation places very stringent demands on the C/N levels that a CATV network can consistently maintain. This is the weak point for most networks, particularly, the large, all copper (No Fibre) CATV networks deployed in India. Once the system QAM is identified, the Cable Modem synchronises itself with this QAM carrier stream. This is sometimes called QAM lock. Once QAM lock is established, the Cable modem needs to initialise itself for transmission in the Reverse Path.

REVERSE PATH FREQUENCY

The first step is to establish the Reverse path frequency at which the Cable Modem should transmit to the CMTS at the Head End. This information is included in the Upstream Channel Descriptor (UCD) data packet in the Forward path. The UCD provides broadcast instructions to cable modems about where to set their Reverse path transmit frequency.

TRANSMIT LEVELS

The Cable modem needs to send its signal through the Reverse Path, to the CMTS. The level of the signal transmitted is critical. Too high a signal level will cause the Cable modem to distort. It will also unnecessarily burden the return path amplifiers, which if overdriven, can cause distortion of the data, of all Cable Modems. The modem begins to transmit on the assigned Reverse path frequency at its lowest transmit power level, gradually increasing the power until the cable modem termination system (CMTS) "hears" the new modem. At this point, the CMTS and modem begin two-way communication. The transmit level is now fine tuned for the optimum level. As explained in our article " Balancing The Reverse Path " a Cable modem is specified to transmit in the Reverse Path, at a level of 92 dBU to 112 dBU. An improperly balance reverse path could force the cable modem to transmit at levels upto 120 dBU to be "Heard" by the CMTS. Clearly, such high levels, which are beyond the Cable Modem's rating, will cause distortion of the transmitted Data packets.

Table 1 Forward Path Specified by DOCSIS				
Modulation format	Channel bandwidth	Symbol rate (Msym/sec)	Raw data rate	Nominal data rate
64-QAM	6 MHz	5.056941	30.34 Mbps	~27 Mbps
256-QAM	6 MHz	5.360537	42.88 Mbps	~38 Mbps

TIMING OFFSET

Next, Timing Offsets are established. The timing offset is the delay or silent period needed between the transmissions of 2 cable modems, to ensure that the data packets of any 2 cable modems do not collide on the system.

THE IP ADDRESS

Each cable modem in a system is assigned a unique IP address. This permits it to be specifically identified, by the CMTS. As a result, data can be specifically directed by the CMTS to the particular Cable Modem. Actually, data packets for all Cable modems co-exist on the system. However, each cable modem extracts only those data packets that bear its IP address. To establish its Internet protocol (IP) address, the cable modem sends the CMTS a Dynamic Host Configuration Protocol (DHCP) request to obtain an IP address and other parameters necessary to establish IP connectivity. After the IP address is established, the modem requests the current date and time from the Time-of-Day (ToD) server. Accurate timing is necessary for time-stamping logged events.

After DHCP and TOD, the CMTS downloads to the modem operational parameters using trivial file transfer protocol (TFTP). When the operational parameters have been transferred to the modem, it completes its identification process. If the cable operator is using DOCSIS baseline privacy (BP, a type of data encryption for cable modem traffic) on the network, the cable modem must be provisioned for this and BP initialized. Assuming all of the cable modem initialization steps are successful, the modem is now considered operational. The entire initialisation process is done automatically by the cable modem, within a few seconds of it being powered up. Ofcourse, if the reverse path is not balanced properly, or the system noise is too high, the initialisation will fail.

Table 2 Reverse Path Specified by DOCSIS					
Symbol rate(ksym/sec)	Channel bandwidth	QPSK nominal data rate	QPSK nominal data Rate	16-QAM raw data rate	16-QAM nominal data
160	0.20 MHz	0.32 Mbps	~ 0.3 Mbps	0.64 Mbps	~ 0.6 Mbps
320	0.40 MHz	0.64 Mbps	~ 0.6 Mbps	1.28 Mbps	~ 1.2 Mbps
640	0.80 MHz	1.28 Mbps	~ 1.2 Mbps	2.56 Mbps	~ 2.3 Mbps
1280	1.60 MHz	2.56 Mbps	~ 2.3 Mbps	5.12 Mbps	~ 4.6 Mbps

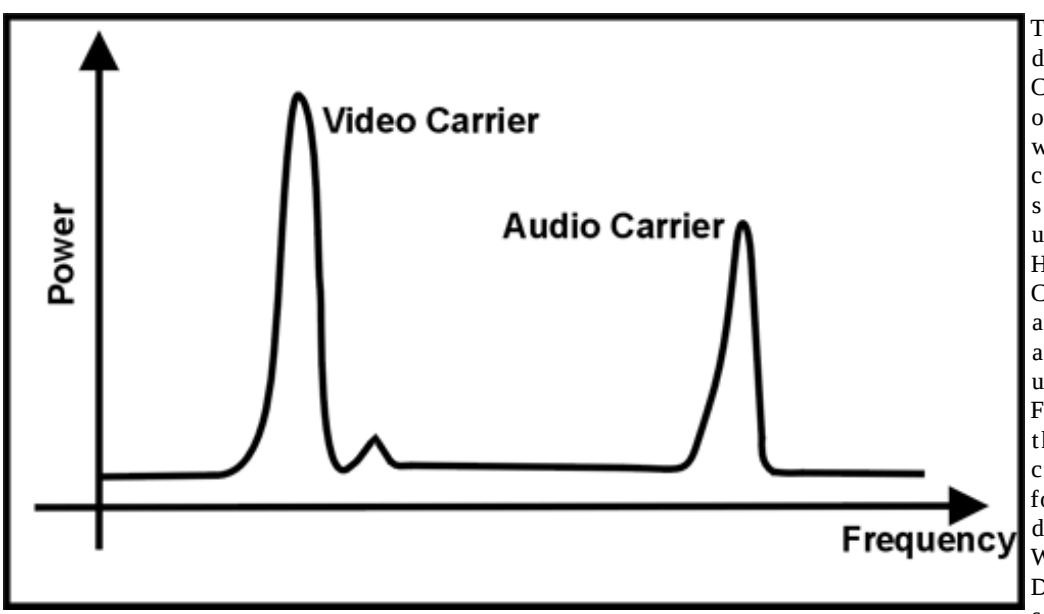
SYSTEM REQUIREMENTS FOR DOCSIS

Most new CATV networks that deploy cable modems, are often frustrated by the fact that freshly installed Cable Modems fail to initialise ! This has led to a large population of "Silent" cable modems. Noise is a major concern for Indian CATV systems, because the entire network is one large, Coaxial cable labyrinth. For a full copper system catering to say 10,000 TV sets, the noise from each TV set, poor connectors, poor workmanship & ofcourse poor shielding, will all add upto an unacceptable level of noise.

Fiber Node, localise the noise summation to within each node only. Each node could cater to 2000 TV homes. To be able to consistently deploy cable modems, the CATV system must meet the minimum specification laid down by the DOCSIS specification.

Table 3 : Minimum Forward Path Characteristics	
Parameter	Value
RF channel spacing (design bandwith)	6 MHz
Transit delay from headend to most distant customer	<=0.800 msec (typically much less)
Carrier-to-noise ratio in a 6 MHz band (analog video level)	Not less than 35 dB (see Note below)
Carrier-to-interference ratio for total power (discrete and broadband ingress signals)	Not less than 35 dB within the design bandwith
Composite triple beat distortion for analog modulated carriers	Not greater than -50 dBc within the design bandwith
Composite second order distrotion for analog modulated carriers	Not greater than -50 dBc within the design bandwith
Cross-modulation level	Not greater than -40 dBc within the design bandwith
Amplitude ripple	0.5 dB within the design bandwidth
Group delay ripple in the spectrum occupied by the CMTS	75 NS within the design bandwith
Carrier hum modulation	Not greater than -26 dBc (5%)
Burst noise	Not longer than 25 usec at a 10 Hz average rate
Signal level slope, 50-70 MHz	16 dB
Seasonal signal level variation	8 dB
Maximum analog video carrier level at the CM input, inclusive of above signal level variation	77U
Lowest analog video carrier level at the CM input, inclusive of above signal level variation	55U
Notes : 1) Transmission is from the headend combiner to the modem input at the customer location. 2) For measurements above the normal downstream operating frequency band (except hum), impairments are referred to the highest-frequency NTSC carrier level. 3) For hum measurements above the normal downstream operating frequency band, a continuous-wave carrier is sent at the test frequency at the same level as the highest-frequency NTSC carrier. 4) This presumes that the digital carrier is operated at analog peak carrier level. When the digital carrier is operated below the analog peak carrier level, this C/N may be less. 5) Measurement methods defined in NCTA Recommended Practices for Measurements on Cable Television Systems, 2nd edition, or Digital Transmission.	

Most of these specifications will be met if the system meets the BIS specifications. However, in practice, few systems, not only in India, but also internationally, meet these specifications at subscriber's premises.



The deployment of Cable Modems, often dovetails with a complete system upgrade to Hybrid Fiber Coaxial architecture, ie a system that uses both, Fiber optics (on the trunk) and coaxial cables for the final distribution. While the DOCSIS specifications for the CATV network are very comprehensive, Tables 3 & 4 summarise certain important specs. The full specifications are available as The DOCSIS Radio Frequency Interface Specification. (www.cablemodem.com/RFI-I06-001215.pdf). Readers note that this is a 450 page specification !

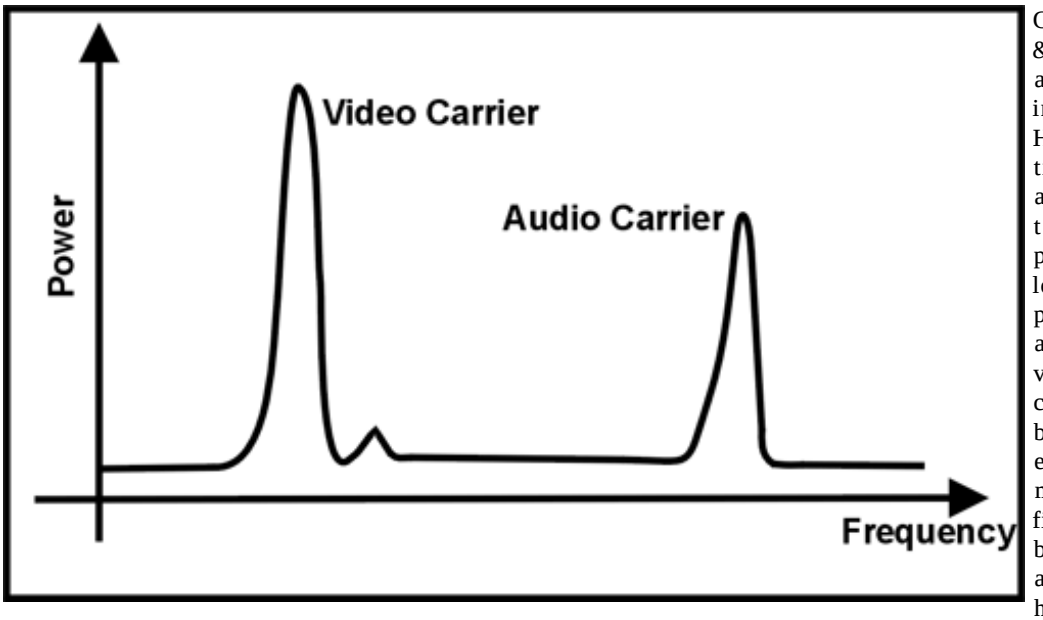
SETTING CARRIER LEVELS

The Cable Modem transmits its data as digital signal bursts, over the allocated bandwidth. Fig 4 indicates the Vision & Sound carriers in a typical analog TV signal. The video carrier is more than 12 dB higher than the audio carrier & over 20 dB more than the colour burst or any other signal component. Hence, for all practical considerations of amplifier loading, the level of the video carrier can be used for setting up levels. Fig 5 shows a typical Digital signal, occupying the same bandwidth, as an analog signal.

The digital signal maintains a consistently high level of signal power. It is therefore recommended

that the Digital carrier's average power level be maintained at 6 dB lower, preferably 10 dB lower than the Analog Carrier levels.

PRICING & SUPPORT DOCSIS



Cable modems & CMTSs are all interoperable. Hence, first time buyers are very often tempted to purchase the lowest cost products, from a multitude of vendors. This could prove to be an expensive mistake. The first time buyer will need a lot of "hand-holding" during the initial deployment & system setup. Hence it is imperative that buyers verify whether the vendor has the manpower & capabilities to offer this initial hand holding. We have heard of entire plants that have remained "silent" due to lack of support by the vendor.

It would be recommended that technical support be evaluated and the prime criteria when selecting the vendor, for initial supplies. Only after the system is commissioned & consistent stable operation is achieved, that the CATV company should consider, alternate DOCSIS products, with price as a driving criteria.

OTHER IMPORTANT ISSUES

Installing, connecting and configuring cable modem equipment--the CMTS, router, Ethernet switch, access server and other components--are perhaps the easiest parts of deploying high-speed data. Operating the service is where the real challenges occur. Once a cable network deploys cable modem services, its business quickly changes from an entertainment delivery service to a full-fledged telecommunications service. The management's mindset needs to change accordingly.

TABLE : 4 DOCSIS 1.0 Minimum Reverse Path Characteristics	
Parameters	**Values**
Frequency Range	5 MHz to 42 MHz edge to edge
Transit delay from the most distant CM to the nearest CM or CMTS	<=0.800 msec (typical much less)
Carrier-to-noise ratio	Not less than 25dB
Carrier-to-ingress power (the sum of discrete and broadband ingress signals) ratio	Not less than 25 dB (see Note 2 below)
Carrier-to-interference (the sum of noise, distortion, common-path distortion, and cross-modulation) ratio	Not less than 25 dB
Carrier hum modulation	Not greater than -23 dBc (7%)
Burst noise	Not longer than 10 sec at a 1 KHz average rate for most cases (see Notes 3,4 and 5 below)
Amplifier ripple	5-42 MHz : 0.5 dB/MHz
Group delay ripple	5-42 MHz : 200 MHz
Micro reflections-single echo	-10 dBc@ <= 0.5 usec -20 dBc @ <= 1.0 usec - 30 dBc @ > 1.0 usec
Seasonal signal level variation	Not greater than 8 dB min to max

Notes for Table 4 : 1)Transmission is from the CM output at teh customer location to the headend. 2) Ingress avoidance or tolerance techniques MAY be used to ensure operation in the presence of time-varying discrete ingress signals that could be as high as 0 dBc [CableLabs1] 3) Amplitude and frequency characteristics sufficiently strong to partially or wholly mask the data carrier. 4) CableLabs report containing distribution of return-path burst noise measurements and measurement method is forthcoming. 5) Impluse noise levels more prevalent at lower frequencies (< 15 MHz)

COMPUTER EXPERTISE

It is imperative that appropriate computer expertise be employed immediately, even before the system is setup. While computer expertise is mandatory, the cable modems interface with the customer's PCs, through a Ethernet or Network Card or " LAN card ". This card is to be fitted inside the computer, and the computer configured for the network. Most computer owners will be extremely reluctant to have their computer opened & configured by a "Cablewallah" ! Also the expertise required for interfacing the network card & cable modem, is quite different from that required for RF CATV work The high-speed data installers and technicians must understand Ethernet, data networks, personal computers (PCs) and software.. Hence the CATV company will have to recruit two different groups of technicians for painless cable modem deployment.

BANDWIDTH MANAGEMENT

Despite the reduction in the cost of internet bandwidth, it still is one of the highest priced, worldwide. The quality of bandwidth too is very poor. A 2 MBps line from VSNL costs Rs 1 Lakh per month, and the 2 Mbps is actually shared between 4 users ! Further, broadband users, are typically unwilling to pay significantly more than Rs 1000 per month. To make the business viable under these market conditions, several Cable modem ISPs limit their cable modem throughput to 64 Kbps for domestic users and 128 Kbps for commercial users.

Table 5 : Cable Modem Input Characteristics	
Parameter	Value
Centre frequency	91 MHz to 857 MHz +/- 30 kHz
Level range (one channel)	45 dBU to + 15 dBU
Modulation type	64-QAM and 256-QAM
Symbol rate (nominal)	5.056941 Msym/sec (64-QAM) and 5.360537 Msym/sec (256-QAM)
Bandwidth	6 MHz (18% square root raised cosine shaping for 64-QAM and 12% square root raised cosine shaping for 256-QAM)
Total input power (40 MHz to 900 MHz)	<90 dBU
Input (load) impedance	75 ohms
Input return loss	>6 dB (88-860 MHz)
Connector	F connector

The domestic user is typically charged Rs 800 per month and the commercial user, twice this amount. If such a revenue structure is to be implemented it is best that the cable modem

throughput is regulated from day one itself. Initially providing users a high band width and after they are accustomed to this high speed service, they will complain loudly when their throughput is reduced. CUSTOMER SUPPORT Telecommunications are often perceived to be "Mission Critical" services. The customer demands a fully functional service, every time that he plans to use it. The unavailability of e-mail or access to the internet may have serious financial repercussions on the customer. The cable modem service provider therefore needs to set up and maintain a customer service cell that logs complaints 24 hours a day, seven days a week. Customers often need an assurance that their service would be resumed within a committed period of time such as 6 hours of receiving the complaint or overnight whichever is earlier.

Table 6 : Cable Modem Output Characteristics

Parameter	Value
Frequency	5 MHz to 42 MHz edge to edge
Level range (one channel)	68 dBU to 155 dBU (16-QAM) 68 dBU to 118 dBU (QPSK)
Modulation type	QPSK and 16-QAM
Symbol rate (nominal)	160, 320, 640, 1,280 and 2,560 ksym/sec
Bandwidth	200, 400, 800, 1,600 and 3,200 kHz
Output impedance	75 ohms
Output return loss	>6 dB (5-42 MHz)
Connector	F connector

CONLUSION

It is hoped this series of articles have provided the reader a basic understanding of how a cable modem works, the CMTS configuration as well as provide some practical pointers for commercial deployment of the system. Cable Networks need to re-align their mindset, from being an entertainment company to a Telecommunications service provider, if they are to successfully tap this business potential.