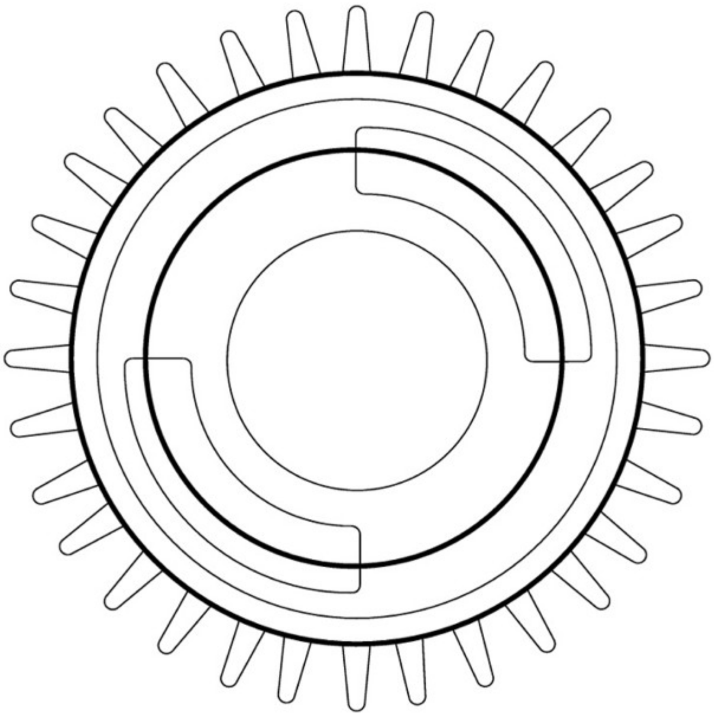
DOCSIS 3.0

Cable's position in the broadband market.



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Introduction

Streaming media, gaming and a rich variety of on-demand services are pushing broadband bandwidths ever upward. With this increase in usage comes additional revenues, opening up new distribution channels for content owners.

Competition for broadband subscribers has never been fiercer, as incumbent fixed-line telephony operators increasingly deploy higher-speed services aimed at stealing not only residential data subscribers, but also residential video subscribers, away from cable operators.

Certain DSL technologies (VDSL[1]) are now able to provide beyond 50 Mbps of bandwidth, and fibre-to-the home initiatives offer even greater bandwidth potential for both video and data services.

The demand for wireless broadband is also increasing rapidly. The perceived competition between the three main access technologies means that the market still exhibits some instability but with the number of locations available for public WiFi[2] access estimated to grow worldwide from 2,000 in 2001 to 42,000 in 2006[3], wireless broadband is becoming an increasingly powerful player in the broadband marketplace.

Cable operators need the capability to provide higher-bandwidth services so they can:

- Protect the installed base of high- speed data customers
- Deliver competitive, high-capacity commercial services to business customers
- Use video over IP to deliver subscriber-specific interactive video services to counter the large channel line ups provided by satellite operators.

As a counter to the perceived threat, CableLabs, in the United states, through its member cable operators, has established the DOCSIS[4] 3.0 Channel Bonding Initiative. The goal of this initiative is to develop a standardised approach to bond multiple physical channels into a single, virtual, high-bandwidth channel.

This paper discusses the current broadband competitive landscape and technologies and how DOCSIS 3.0 may fit into an ever increasing range of broadband offerings.

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1 VDSL – Very High speed DSL

2 WiFi - short for 'Wireless Fidelity' is a trademark for sets of product compatibility standards for wireless local area networks (WLANs).

3 *Source:* In-Stat/MDR reports, June, 2002.

4 DOCSIS – Data Over Cable Service Interface Specification.

Broadband Technology

DSL

The DSL (Digital Subscriber Line) "family tree" comprises two main branches; symmetric and asymmetric. Symmetric DSL services provide identical data rates upstream and downstream; asymmetric DSL provides relatively lower rates upstream but higher rates downstream.

Four significant variations of DSL exist:

- ADSL, RADSL
- HDSL, SDSL, and SHDSL
- VDSL (VADSL, BDSL)
- IDSL

ADSL and RADSL

Asymmetric Digital Subscriber Line supports up to 8 Mbps downstream and 1 Mbps upstream and was designed to provide higher downstream data rates at the expense of upstream rates. Many typical uses of the Web, such as file downloads and general web browsing, benefit from greater downstream bandwidth but require relatively little in the opposite direction.

Rate-Adaptive DSL (RADSL), is an implementation of ADSL that automatically configures the modem at start-up to adjust its rate according to the quality of the phone line. RADSL supports a much lower maximum date rate (1,088 kbps) than regular ADSL.

HDSL, SDSL and SHDSL

A symmetric solution,High Bit/Data Rate DSL offers the same bandwidth both upstream and downstream. HDSL requires two phone lines to deliver the basic data rate (1,544 kbps), and it can deliver a maximum rate of 2,048 kbps using three lines.

Symmetric DSL improves on the older HDSL technology by implementing the same basic data rate (1,544 kbps) while requiring only a single phone line.

Another variation, Symmetric High Bit Rate DSL attempts to improve on both HDSL and SDSL by only requiring a single line and by integrating low-level services of interest to small businesses.

VDSL

Very High Bit Rate DSL needs shorter cable lengths than most other forms of DSL (maximum 4,500 feet as compared to 18,000 feet for regular ADSL), but it also achieves the highest data rate (roughly 51,840 kbps). VDSL is also known as BDSL. It was originally named VADSL ('A' for asymmetric) but later was extended to support both symmetric and asymmetric varieties of DSL.

The bandwidth levels supported by VDSL are needed to support certain high-end applications such as High-Definition Television (HDTV) that requires, for example, up to 20,000 kbps (See Appendix 1 for a detailed overview of VDSL).

IDSL

ISDN DSL implements, as the name suggests, a hybrid DSL/ISDN solution. As such, IDSL offers only limited data rates (128 kbps, although multiple circuits may be bonded).

DSL Type	Description	Data Rate	Distance Limit	Application
ADSL	Asymmetric Digital Subscriber Line	1.544 to 6.1 Mbps downstream; 16 to 640 Kbps upstream	1.544 Mbps at 18,000 feet; 2.048 Mbps at 16,000 feet; 6.312 Mpbs at 12,000 feet; 8.448 Mbps at 9,000 feet	Used for Internet and Web access, motion video, video on demand, remote LAN access
RADSL	Rate-Adaptive DSL	Adapted to the line, 640 Kbps to 2.2 Mbps downstream; 272 Kbps to 1.088 Mbps upstream	Not provided	Similar to ADSL
HDSL	High bit-rate Digital Subscriber Line	1.544 Mbps duplex on two twisted-pair lines; 2.048 Mbps duplex on three twisted-pair lines	12,000 feet on 24 gauge wire	WAN, LAN, server access
SDSL	Symmetric DSL	1.544 Mbps duplex (U.S. and Canada); 2.048 Mbps (Europe) on a single duplex line downstream and upstream	12,000 feet on 24 gauge wire	Same as for HDSL but requiring only one line of twisted-pair
VDSL	Very high Digital Subscriber Line	12.9 to 52.8 Mbps downstream; 1.5 to 2.3 Mbps upstream; 1.6 Mbps to 2.3 Mbps downstream	4,500 feet at 12.96 Mbps; 3,000 feet at 25.82 Mbps; 1,000 feet at 51.84 Mbps	On-demand services, HD video and broadcast
IDSL	ISDN Digital Subscriber Line	128 Kbps	18,000 feet on 24 gauge wire	Similar to the ISDN BRI service but data only (no voice on the same line)

Table 1 DSL Summary

Wireless

One thing is for certain, demand for wireless broadband is going to increase rapidly. However, perceived competition between the three main access technologies means that the market still exhibits some instability.

Wireless network technologies are primarily seen as a competitive 'threat' to the newly emerging mobile 3G services. In the main, for mobile applications this could be argued to be the case, but for broadband access in rural areas, this technology is seen as one of the most cost effective solutions and as such a possible competitor to some cable networks.

WiFi (802.11), WiMAX (802.16) and 802.20 are three main technologies for providing broadband network connections.

WiFi

WiFi is well established, has a reasonably large installed base and is in use globally in offices and homes. Companies such as Starbucks and McDonalds have have adopted this standard for their own public network platforms.

WiFi has a number of variants (See Appendix 2). The 802.11b standard offers speeds with a maximum rate of 11Mbps in the 2.4 GHz spectrum band, 802.11a offers speeds with a maximum rate of 54Mbps in the 5 GHz band; and 802.11g is a standard for data rates of up to a theoretical maximum of 22Mbps at 2.4 GHz.

WiMAX

WiMAX[5] is backed extensively by Intel and Nokia, and is rapidly emerging as a favourite, though cards employing the technology and WiMAX-enabled laptops are not expected to reach the market until 2007.

WiMAX, based on the 802.16 standard, has huge bandwidth, typically more than 30 times that of 3G data services, and it allows subscribers to receive broadband network access simply by attaching a receiver to their home. This method is being trialled by British Telecom in rural areas as an alternative to laying cables. The standard is also suitable for people on the move as WiMAX can be used in vehicles up to a speed of 150 Km/h.

802.20

The 802.20 wireless networking standard will let you travel at 250 Km/h and still keep a network connection, and so is ideal for deployment on high speed trains.

There are some overlaps between the two technologies, but they are not meant to compete. WiMAX is intended for fixed locations like houses, or a mobile user with a PDA or laptop. 802.20 is intended for high-speed mobility, and can be overlaid on top of an existing WiMAX network.

Wireless Type	*Name*	*Data Rate*	*Band*	*Application*
802.11a	WiFi	54 Mbits/s	5.0 GHz	Wireless hotspots and home/office working
802.11b	WiFi	11 Mbits/s	2.4 GHz	Wireless hotspots and home/office working
802.11g	WiFi	22 Mbits/s	2.4 GHz	Wireless hotspots and home/office working
802.16a	WiMAX	70 Mbits/sec	2.5 to 5.0 GHz	Metropolitan wireless networking
802.16e	WiMAXm (mobile)	70 Mbits/sec	2.5 to 5.0 GHz	Low mobility wireless working
802.20		Not defined yet	Dependent upon licensing	Mobile wireless working up to 250 Km/h

Table 2 Wireless Summary

5 WiMAX - Worldwide Interoperability for Microwave Access.

DOCSIS

The Data Over Cable Service Interface Specification (DOCSIS), developed by CableLabs and approved by the ITU[6], defines interface requirements for cable modems involved in high-speed data distribution (both MPEG and IP data) over cable television networks. Other devices that recognize and support the DOCSIS standard include High Definition TVs (HDTV) and Web enabled set-top boxes for regular televisions.

There are two key components in the DOCSIS architecture: a Cable Modem (CM) which is located at the customer premise, and Cable Modem Termination System (CMTS), which is located at the head-end of service providers and used to aggregate traffic from multiple Cable Modems and then communicate with the backbone network. DOCSIS specifies modulation schemes and the protocol for exchanging bidirectional signals between these two components over cable.

There are three versions of DOCSIS implemented and deployed presently:

- **DOCSIS 1.0** - High Speed Internet Access.

  Key features: Downstream traffic transfer rates between 27 and 36 Mbps over a radio frequency (RF) path in the 50 MHz to 750+ MHz range, and upstream traffic transfer rates between 320 Kbps and 10 Mbps (Average 5 Mbps) over a RF path between 5 and 42 MHz. But, because data over cable travels on a shared loop, individuals will see transfer rates drop as more users gain access.

- **DOCSIS 1.1** - Data, Voice, Gaming and Streaming.

  Key features: DOSCIS 1.1 is interoperable with DOCSIS 1.0. It enhanced QoS for multiple services such as voice and streaming; Improved security over DOCSIS 1.0; and more robust upstream data transmission (average 10 Mbps).

- **DOCSIS 2.0** - Symmetric services.

  Key features: Operates at 64 QAM[7] and has new 6.4 MHz wide channel. It has increased bandwidth for IP traffic by using enhanced modulation and improved error correction. The result for upstream transmission is 30 Mbps, which is 3 times better than DOCSIS 1.1 and 6 times than DOSCIS 1.0. DOSCIS 2.0 is interoperable and backward compatible with DOCSIS 1.x.

The latest DOCSIS specification **eDOCSIS**[8] has been published to the industry. eDOCSIS stands for embedded DOCSIS, which would provide a subordinate function at the core chip level to the host device. And, rather than utilising a home networking protocol, an eDOCSIS device would feed directly into a cable network's DOCSIS channel. eDOCSIS is intended to solve end device (and traffic) management, configuration and security issues to significantly reduce cost in the service operation and to improve speed and quality of end customer services.

6 ITU – International Telecommunications Union

7 QAM – Quadrature Amplitude Modulation

8 *Cable Labs reference:* CM-SP-eDOCSIS-I06-050812

EuroDOCSIS

To fully integrate with European DVB-C based platforms, an addition to the DOCSIS standard was developed in mid 1998, introducing the options of an 8MHz bandwidth downstream channel (within a 100 to 860 MHz spectrum) and ITU-T J.83 A Forward Error Correction. On the upstream, the recommended upstream bandwidth has been increased from 5 to 42 MHz to 5 to 65 MHz . These additions to the standard have since been formally named as 'EuroDOCSIS'.

For those operators in Europe using a standard 8MHz channel spacing, EuroDOCSIS has a number of advantages:

- Simplification of spectrum planning, i.e. 8MHz DOCSIS channels can be more flexibly interleaved with 8MHz (DVB) digital video channels.
- Increased forward path data capacity in an 8MHz vs a 6MHz stream (38 or 52 Mbps with QAM 64 and QAM 256 respectively).
- Increased upstream bandwidth (up to 65MHz).
- Addresses concerns over disparity between DVB and DOCSIS physical layer standards.

1.0

To deliver data services over a cable network, one television channel (in the 50 - 750 MHz range) is typically allocated for downstream traffic to homes and another channel (in the 5 - 42 MHz band) is used to carry upstream signals.

A head-end cable modem termination system *(CMTS)* communicates through these channels with cable modems located in subscriber homes to create a virtual local area network (LAN) connection. Most cable modems are external devices that connect to a personal computer (PC) through a standard Ethernet card or Universal Serial Bus (USB) connection.

The cable modem access network operates at Layer 1 (physical) and Layer 2 (media access control/logical link control) of the Open System Interconnect (OSI) Reference Model. Thus, Layer 3 (network) protocols, such as IP traffic, can be seamlessly delivered over the cable modem platform to end users.

DOCSIS uses MPEG packets[9] to deliver downstream data. The maximum symbol rates are 5.056941 Msps for 64 QAM[10] and 5.360537 Msps for 256 QAM. After removing error correction overheads this results in a single downstream 6 MHz television channel supporting up to 27 Mbps of downstream payload data from the cable head-end at 64 QAM and up to 39 Mbps using 256 QAM.

9 MPEG Packets – 188 byte packets with a Forward Error Correction overhead of 16 bytes giving an overall packet length of 204 bytes.

10 EuroDocsis symbol rates are 6.952 Msps for both 64 and 256 QAM resulting in 38 and 52 Mbps respectively.

Upstream channels may deliver 500 Kbps to 10 Mbps from homes using 16 QAM or QPSK modulation techniques, depending on the amount of spectrum allocated for service. Using 64 QAM, upstream speeds can be raised to 30 Mbps. This upstream and downstream bandwidth is shared by the active data subscribers connected to a given cable network segment, typically 500 to 2,000 homes on a modern Hybrid Fibre-Coaxial (HFC) network.

1.1

The major difference between DOCSIS 1.0 and DOCSIS 1.1 is that DOCSIS 1.0 uses Service ID (SID) to identify cable modems and the devices behind them, while DOCSIS 1.1 uses Service Flows. It also has improved MAC framing features and improved provisioning and authorisation with advanced BPI[11]+ features.

Service Flows are the fundamental unit in DOCSIS 1.1 for Quality of Service (QoS) provisioning. DOCSIS 1.1 allows multiple service flows per cable modem. This means that different types of traffic like data, voice, and video can be separately identified on the same cable modem. This allows the system to apply different QoS levels in order to provide specialised treatment on a per service basis.

2.0

With peer-to-peer applications and teleworking becoming increasingly popular, the need for higher upstream capacity and symmetrical data flows in cable networks led to the development of DOCSIS/EuroDOCSIS 2.0.

DOCSIS 2.0 builds upon DOCSIS 1.1, and provides all of the features and functionality that DOCSIS 1.1 provides. In addition, it provides the following enhancements:

- Significantly enhanced upstream capacity
- 6.4 MHz maximum upstream channel width
- 30 Mbps maximum upstream channel capacity
- Synchronous-CDMA operation
- Increased robustness to upstream noise and channel impairment
- Enhanced Reed-Solomon error correction
- Trellis Coded Modulation
- Channel utilization statistics

3.0

Cable TV networks are architecturally distinct from their telephony rivals in as much as telephone networks are to a great extent point-to-point networks. With the move away from traditional circuit switched to packet switched systems, the telephony operators will be able to provide targeted, non-contended bandwidth[12] to the subscriber.

11 BPI – Baseline Privacy Interface

12 Bandwidth is not contended on the 'last mile', however from the DSLAM or ONU the bandwidth will be shared.

Cable networks are to a greater extent point-to-multipoint networks. Depending upon where the 'edge' devices such as CMTS and QAM modulators are placed determines the number of subscribers that will contend for bandwidth.

In order to address these issues, DOCSIS 3.0 is being developed as a means by which cable operators can offer increased bandwidth and push the network 'edge' ever closer to the subscriber.

In short DOCSIS 3.0 will offer;

- Higher bandwidth through channel bonding. Multiple 6 MHz (or 8 MHz) channels are bonded, treating them logically as one
- Minimum 160 Mbps downstream, 120 Mbps upstream. (DOCSIS)
- IPv6 supported for advanced networking capabilities
- Distributed CMTS architecture.

Channel Bonding Overview

Using 256 QAM, approximately 40 Mbps of downstream payload bandwidth is available in a single 6 MHz RF channel[13]. Using existing DOCSIS 2.0 specifications, multiple RF channels can be used to increase the total bandwidth available.

However, with the current standards, a single cable modem can access only a single channel, and thus it cannot receive more than 40 Mbps.

In order to compete with VDSL, cable operators are looking for a mechanism to offer peak rates of much greater than this 40 Mbps to individual customers. Channel bonding will enable this by creating a single 'logical channel' composed of multiple 6 or 8 MHz channels.

Channel bonding will place additional requirements on the existing DOCSIS architecture;

Firstly, the Cable Modem Termination System (CMTS), receiving a stream of packets from a high-speed network interface, needs to be able to transmit these packets in parallel over multiple 40 Mbps RF channels to a cable modem.

Secondly, the cable modem within the subscriber's home will then need to be able to receive data from multiple RF channels in parallel. It will need the ability to re-order the data packets to reflect the order in which they were received by the CMTS (i.e. before they were transmitted over the multiple RF channels in parallel).

Standards to define the CMTS to cable modem interface are needed to enable the parallel transmission and reordering to recreate the original stream.

For upstream traffic the functions of the Cable Modem and CMTS are reversed.

13 Using 256 QAM 52 Mbps within an 8 MHz EuroDOCSIS channel

Channel bonding is one of the issues being addressed by DOCSIS 3.0. The standards are being developed so as to support both upstream and downstream channel bonding so that cable operators can logically bond together RF channels and then multiplex packet transmissions over those channels.

Channel bonding is initially focused on supporting high-speed data services but can also be used to deliver Video Over IP. The specification allows operators to bond at least four channels, but vendor specific implementations could support the bonding of even more channels.

Although channel bonding could eventually deliver up to a Gigabit per second, in early implementations operators are likely to achieve up to about 160 Mbps downstream by bonding together four 40 Mbps channels, it is likely that market forces will determine the eventual number of bonded channels used as the norm.

How It Will Work

Essentially, each DOCSIS packet is provided with an identification header before it is sent down one of the designated RF channels between the CMTS and the modem. The process will allow the receiver to review the sequence numbers and recombine the packets in the right order to logically bond channels between the network edge and subscribers.

The implementation of channel bonding will take advantage of the evolution of a new distributed CMTS architecture proposed in DOCSIS 3.0. Each cable modem will still appear as a single entity to the CMTS but the DOCSIS MAC protocol will be modified so that it can synchronize the multiple streams.

Channel bonding will be configured at the CMTS. During the modem registration process in DOCSIS 2.0, the cable modem indicates its capabilities and the services for which it is subscribed. In DOCSIS 3.0, this negotiation will be extended to include support for channel bonding so that the cable modem can request that the CMTS bond a number of channels to create the required high-capacity upstream and downstream traffic flows. When completed, the standard will allow operators to logically bond together upstream or downstream RF channels and multiplex packet transmission over those RF channels.

Spreading Data Over Multiple Channels

A key feature of DOCSIS is the concept of service flows (introduced in DOCSIS 1.1) and packet classifiers. A packet classifier is a set of rules that are used to segregate a specific set of packets, such as those between the two endpoints of a Voice over IP (VoIP) phone call or other application, into a service flow.

The service flow is the DOCSIS entity to which a specific Quality of Service (QoS) is applied. A new term, Single Link Service Flows (SLSF) will be used to refer to the existing DOCSIS service flows. SLSFs are necessarily restricted to a single RF channel. DOCSIS 3.0 extends this concept of service flows to support channel bonding by introducing the concept of the Multi-Link Service Flow (MLSF). As the name suggests, an MLSF is a service flow that can be transmitted over multiple RF channels (links) in a bonding group.

A bonding group is therefore defined as a set of upstream or downstream channels bonded together to provide high capacity transmission of data packets. An MLSF has a data rate which is approximately equal to the sum of the individual RF channel rates.

The DOCSIS channel bonding mechanism is based on classifying packets into a high throughput Multi-Link Service Flow (MLSF), which bonds together multiple RF channels.

Each MLSF is mapped to multiple SLSFs, one per RF channel in the bonding group. Non-bonded traffic can continue to operate over SLSFs as in current operation. But traffic loads must be balanced between MLSFs and SLSFs in the same way that they are currently balanced between service flows with DOCSIS 2.0.

Downstream channel bonding is performed for subscriber traffic only. These packets are classified into a high-throughput MLSF that provides the appropriate QoS and will distribute the traffic across the SLSFs for the RF channels that comprise the bonding group.

Channel bonding adds a sequence number in a bonding extended header of the packets prior to distributing them for simultaneous forwarding on multiple downstream channels. This header is used to reorder the packets upon reception.

The CMTS will transmit DOCSIS MAC management messages as non-bonded packets on a single downstream channel. It will transmit all downstream packets (bonded and non-bonded) with the same DOCSIS Program Identifier (PID) used currently. This enables multiplexing of DOCSIS and non-DOCSIS traffic (e.g. video) on a single RF channel at the MPEG layer, just as is done with existing DOCSIS implementations.

The CMTS forwarding function delivers packets to a MAC-layer interface for forwarding downstream. The DOCSIS forwarder classifies the packets either directly into an individual SLSF or into an MLSF.

A given bonding group may have several MLSFs, and both MLSFs and SLSFs share the same service flow ID numbering space within the MAC Domain. All cable modems including DOCSIS 3.0 cable modems intended primarily for bonded operations define a non-bonded downstream SLSF that serves as the primary downstream service flow for that cable modem.

The DOCSIS forwarder implements a multi-link distributor function for each downstream bonding group. The multi-link distributor is responsible for scheduling packets from multiple MLSFs onto the channel group. Once a particular MLSF packet is scheduled for forwarding on the channel group, the multi-link distributor sends the packet to one of the SLSFs for the bonding group.

For each downstream channel, the packet scheduler schedules the packets for all of the SLSFs assigned to that channel. This includes the non-bonded SLSFs as well as the bonded SLSFs that contain bonded packets. The interaction between an MLSF distributor and the set of packet schedulers will be specific to each vendor’s CMTS implementation.

Cable Modem Downstream Channel Bonding Operation

The cable modem will implement a multi-link 'collector function' which stores bonded packets that are received out-of-order. It will deliver downstream packets of any given bonding group in the order of the sequence number of the packets within that bonding group. In one example, the sequence of four packets (A, B, C and D) is delivered to a single MLSF, and then distributed to two SLSFs for forwarding downstream.

The cable modem collects the packets, A, B, C and D, and forwards them in packet sequence order as signalled in the header of the bonded packet. The cable modem will need to rapidly detect a lost bonded packet on a bonded downstream channel when it receives a subsequent, higher-sequence bonded packet on that channel, and the cable modem will assume that a bonded sequence numbered packet is lost, if it is not received within a specified number of milliseconds of a subsequent sequence number.

Packets must be forwarded from the cable modem in the correct order. If a packet is lost on a particular channel, this will cause packets with higher sequence numbers to be held in cable modem memory until the cable modem can determine that the packet is lost rather than misordered. Thus it is an important requirement of downstream channel bonding operation that the maximum interval for out of- order packets to be emitted is limited. This puts an upper limit on the amount of reassembly memory required in the cable modem and also limits the forwarding delay of packets received on the other channels.

Configured Downstream Channel Bonding Groups

CMTS platforms will support vendor-specific configurations of configured downstream channel bonding groups with the following attributes:

- Bonding group identifier
- Bonding channel set, i.e. a list of downstream channel IDs

The bonding group ID and downstream channel ID will be unique within a given MAC Domain. The simplest mechanism for configuring downstream channel bonding is to assign an MLSF directly to a configured bonding group. In order to facilitate cable modem configuration files that may be used independently of the particular DOCSIS MAC

Domain in which a cable modem registers,operators will be able to configure bonding groups with similar purposes to the same bonding group ID within each MAC Domain.

The cable modem and the CMTS will support at least four channels per downstream bonding group. A cable modem will need to support at least one downstream bonding group, i.e. 1 MLSF. (See Figure 3).

In this example, the CMTS implements a single configured bonding group. All MLSFs configured in the cable modem configuration file of the DOCSIS 3.0 cable modems in the MAC Domains are assigned to the multi-link distributor for that bonding group. The multilink distributor schedules packets from the MLSFs assigned to its bonding group.

When a packet is scheduled, it is distributed to a single “bonded" SLSF for that bonding group on a particular channel.

Downstream QoS

The CMTS or Modular-CMTS (M-CMTS) needs to maintain the DOCSIS QoS for an MLSF when considering the aggregate service provided to the MLSF by the set of bonded channels. The CMTS needs the ability to restrict any MLSFs that cannot meet its QoS requirements, and it needs to maintain the QoS requirements of every SLSF to which the MLSF is distributed.

The scheduling of downstream bonded packets from an MLSF to its set of SLSFs is CMTS vendor dependent, but the final protocol when defined within DOCSIS 3.0 will set certain requirements, such as that the CMTS or M-CMTS will need to emit packets on the same channel in strictly non-decreasing sequence number order, and the CMTS will only be able to emit packets out-of-order by only a defined number of milliseconds.

Upstream Channel Bonding

The detailed specifications for upstream channel bonding are less well-developed than for downstream, but they will follow the same general principles. A bonded upstream channel will consist of a bonding of service flows across multiple upstream channels, with each flow uniquely identified by its service flow identifier and the associated upstream channel. The cable modem will need to range on all upstream channels that compose the bonded upstream channel and negotiate the upstream channel set with the CMTS.

Taking Advantage of Channel Bonding Packet-based channel bonding will enable flows to remain almost the same as they are with DOCSIS 2.0, with packets entering a similar architecture as they do today. It enables the coexistence of DOCSIS 1.x, 2.0, and 3.0 cable modems across common network infrastructure, and it will not impose a new infrastructure design on cable operators.

Modular CMTS

Summary

DOCSIS Version	*1.0*	*1.1*	*2.0*	*3.0*
Services				
Broadband Internet	✔	✔	✔	✔
Tired Services		✔	✔	✔
VoIP		✔	✔	✔
Video Conferencing			✔	✔
Commercial Services			✔	✔
Entertainment Video				✔
Consumer Devices				
Cable Modem	✔	✔	✔	✔
VoIP Phone		✔	✔	✔
Residential Gateway		✔	✔	✔
Mobile Devices				✔
IP Set Top Box				✔
DOCSIS Downstream Bandwidth				
Mbps per channel	40	40	40	160
Gbps per node	5	5	5	5
DOCSIS Upstream Bandwidth				
Mbps per channel	10	10	30	120
Gbps per node	80	80	170	170
EuroDOCSIS Downstream Bandwidth				
Mbps per channel	40	40	40	160
Gbps per node	5	5	5	5
EuroDOCSIS Upstream Bandwidth				
Mbps per channel	10	10	30	120
Gbps per node	80	80	170	170

Broadband Market Trends

The number of locations available for public WiFi access is estimated to grow worldwide from 2,000 in 2001 to 42,000 in 2006 with service revenues experiencing a corresponding growth, reaching $642.6 million in 2006, up from $11.3 million in 2001[14].

The Impact of DOCSIS 3.0

Multi-channel cable modems can be created by extending existing DOCSIS chipsets available from multiple vendors. In the most likely scenario, modem silicon vendors will produce combined downstream and upstream channel bonding chip set solutions. Channel bonding products are expected to come to market in a relatively short timeframe, since some existing DOCSIS chipsets can be extended to support the emerging specification.

Operators will therefore be able to protect investments in existing infrastructure equipment. Channel bonding will be implemented on evolving chassis-based CMTS platforms, as well as on M-CMTS platforms, which can also be referred to as a “decoupled CMTS” because it separates the logical functions of a CMTS platform. There is naturally a trade-off, since reliability and manageability can be better delivered using a chassis-based system. But the promise of increased flexibility and pay-as-you-go scalability constitute a major advantage of the M-CMTS architecture.

These channel bonding solutions will consist of the CMTS or M-CMTS, cable modems and other customer premises equipment. This approach leverages current silicon efficiently and will allow operators to rapidly capitalize on the opportunity to deliver higher bandwidth data services via channel bonding.

Silicon vendors as well as vendors of CMTS platforms and cable modems are working closely with CableLabs and operators to accelerate the availability of equipment to support channel bonding.

As cable operators strive to protect their installed base and deliver higher-speed data services, channel bonding is quickly becoming a critical technology. CableLabs is defining specifications for channel bonding within the DOCSIS 3.0 standard under development.

14 *Source:* In-Stat/MDR reports, June, 2002

Appendix 1 – DSL Standards

ADSL

ADSL was first standardized in 1995 by the American National Standards Institute as T1.413, and then by the ITU in 1999 as G.992.1 (G.dmt).

- **G.dmt (G.992.1) Full-rate ADSL**. This specification calls for operation rates of up to 10 Mbps downstream and up to 768 kbps upstream when operating over telephone lines at distances of up to 18,000 feet.
- **G.lite (G.992.2)** This specification delivers data transmission greater than 4 Mbps downstream and up to 512 kbps upstream. G.lite enables simultaneous voice traffic and data traffic without requiring installation of a voice-data splitter and without requiring microfilters on every phone or answering machine.
- **G.dmt.bis (G.992.3) & G.lite.bis (G.992.4) ADSL2** Completed and approved by the International Telecommunications Union (ITU) in 2002, this supersedes existing ADSL standards. The standards are G.dmt.bis and G.lite.bis designated as G.992.3 and G.992.4 for full-rate ADSL and splitterless ADSL, respectively.
- **ADSL2+ (G.992.5)** Reached consent at the ITU in January 2003, joining the ADSL2 standards family as G.992.5. ADSL2+ doubles the downstream bandwidth, increasing the downstream data rate to as much as 25 Mbps. ADSL2 enables an optional mode that allows for transmission of data in the voice bandwidth, adding 256 kbps of upstream data rate. ADSL2 also supports bonding of multiple phone lines using inverse multiplexing for ATM and Ethernet.
- **Reach-Extended ADSL2 (RE-ADSL2)** The ADSL2 Annex L standard, was ratified by the ITU in October 2003. Annex L proposes new power spectral density (PSD) masks that can result in a significant increase in ADSL's reach.

HDSL

This variety of DSL was created in the late 1980s to deliver symmetric service at speeds up to 2.3 Mbps in both directions. Available at 1.5 or 2.3 Mbps, this symmetric fixed rate application does not provide standard telephone service over the same line and is already standardized through ETSI and ITU (International Telecommunications Union). Seen as an economical replacement for T1 or E1, it uses one, two or three twisted copper pairs.

- **G.hdsl (G.991.1)**. The HDSL system uses echo cancellation technique for the separation of the directions of transmission, so that one twisted pair can carry both directions. Two different options for the line code are possible, Pulse Amplitude Modulation 2B1Q and the Carrierless Amplitude/Phase Modulation CAP. CAP is applicable for 2048 kbit/s only, while for 2B1Q two different frames for 1544 kbit/s and 2048 kbit/s are defined. The 2B1Q for 2048 kbit/s caters for both duplex transmission on a single pair and parallel transmission on two or three-pairs. This allows for the distribution of the signal to several pairs and for reduction of the symbol rate and an increase of the line length. CAP is defined for one- or two-pairs only and the 1544 kbit/s 2B1Q for two-pairs only.

SDSL

Symmetric DSL (SDSL) is a vendor-proprietary version of symmetric DSL that may include bit-rates to and from the customer ranging of 128 kbps to 2.32 Mbps. SDSL is an umbrella term for a number of supplier-specific implementations over a single copper pair providing variable rates of symmetric service. SDSL uses 2B1Q HDSL run on a single pair with an Ethernet interface to the customer.

The industry is expected to quickly move towards the higher performing and standardised G.shdsl technology developed by the ITU with support from ANSI committee T1E1.4 (USA) and ETSI (European Telecommunications Standards Institute).

SHDSL

- **G.shdsl (G.991.2)** is industry standard symmetric DSL, approved by the ITU-T February 2001. SHDSL achieves 20% better loop-reach than older versions of symmetric DSL, it causes much less crosstalk into other transmission systems in the same cable, and multi-vendor interoperability is facilitated by the standardisation of this technology. SHDSL systems may operate at many bit-rates, from 192 kbps to 2.3 Mbps, thereby maximizing the bit-rate for each customer. G.shdsl specifies operation via one pair of wires, or for operation on longer loops, two pairs of wire may be used.

VDSL

The purpose of this paper is to give the reader an overview of the high speed broadband competitive landscape. As such VDSL represents the biggest challenge to the Cable Operator in terms of like-for-like bandwidth capacity. VDSL will therefore be covered in some detail here.

It is becoming increasingly clear that telephone companies around the world are making decisions to include existing twisted-pair loops in their next generation broadband access networks. Hybrid Fibre Coax (HFC), a shared access medium well suited to analogue and digital broadcast, comes up somewhat short when asked to carry symmetric services such as voice telephony, interactive video, and high speed data communications at the same time. Fibre all the way to the home (FTTH) is still prohibitively expensive in a marketplace soon to be driven by competition rather than costs.

An attractive alternative, soon to be commercially practical, is a combination of fibre cables feeding neighbourhood Optical Network Units (ONUs) and last leg premises connections by existing or new copper. This topology, which can be called Fibre to the Neighbourhood (FTTN), encompasses Fibre to the Curb (FTTC) with short drops and Fibre to the Basement (FTTB), serving tall buildings with vertical drops.

One of the enabling technologies for FTTN is Very high rate Digital Subscriber Line, or VDSL. In simple terms, VDSL transmits high speed data over short reaches of twisted-pair copper telephone lines, with a range of speeds depending upon actual line length. The maximum downstream rate under consideration is between 51 and 55 Mbps over lines up to 1000 ft (300 metres) in length.

Downstream speeds as low as 13 Mbps over lengths beyond 4000 ft (1500 meters) are also being considered. Upstream rates in early models will be asymmetric, just like ADSL, at speeds from 1.6 to 2.3 Mbps. Both data channels will be separated in frequency from bands used for POTS[15] and ISDN[16], enabling service providers to overlay VDSL on existing services. At present the two high speed channels will also be separated in frequency. As needs arise for higher speed upstream channels or symmetric rates, VDSL systems may need to use echo cancellation.

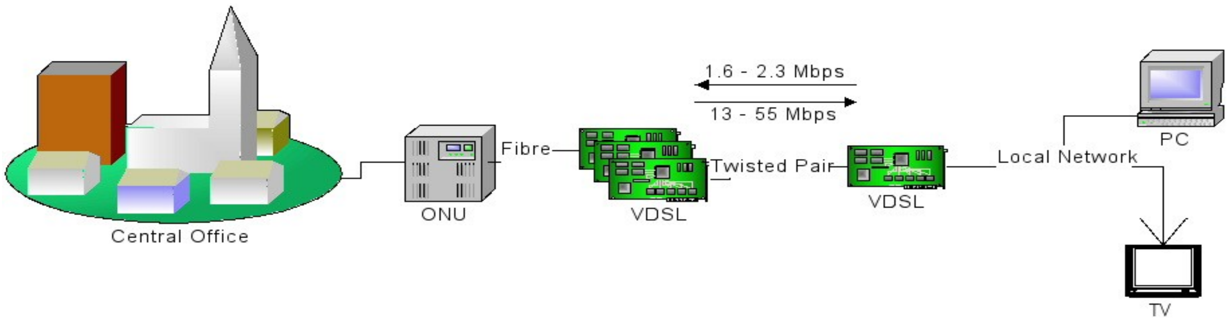

Figure A.1 VDSL Overview

VDSL Projected Capabilities

While VDSL has not achieved the degree of definition of ADSL, it has advanced far enough to discuss realisable goals, beginning with data rate and range. Downstream rates derive from sub-multiples of the SONET[17] and SDH[18] speed of 155.52 Mbps, namely 51.84 Mbps, 25.92 Mbps and 12.96 Mbps. Each rate has a corresponding target range.

Data rate	***Range***	
	Feet	***Metres***
12.96 - 13.8 Mbps	4500	1500
25.92 - 27.6 Mbps	3000	1000
51.84 - 55.2 Mbps	1000	300

Table A.1.1 VDSL Downstream ranges

Upstream rates under discussion fall into three general ranges:

- 1.6 - 2.3 Mbps
- 19.2 Mbps
- Equal to Downstream

15 POTS – Ordinary analogue telephony service.

16 ISDN – Integrated Services Digital Network

17 SONET – Synchronous Optical Networking

18 SDH – Synchronous Digital Heirarchy

Early versions of VDSL will almost certainly incorporate the slower asymmetric rate. Higher upstream and symmetric configurations may only be possible for very short lines.

Like DOCSIS, VDSL must transmit compressed video, a real time signal unsuited to error retransmission schemes used in data communications. To achieve error rates compatible with compressed video, VDSL will have to incorporate Forward Error Correction (FEC) with sufficient interleaving to correct all errors created by impulsive noise events of some specified duration. Interleaving introduces delay, in the order of 40 times the maximum length correctable impulse.

Data in the downstream direction will be broadcast to every CPE[19] in a premises or be transmitted to a logically separated hub that distributes data to addressed CPE based on cell or TDM[20] multiplexing within the data stream itself. Upstream multiplexing is more difficult. Systems using a passive network termination (NT) must insert data onto a shared medium, either by a form of TDMA[21] or a form of FDM[22]. TDMA may use a species of token control called Cell Grants passed in the downstream direction from the ONU modem, or contention, or both (contention for unrecognised devices, cell grants for recognised devices).

Migration considerations will ensure that VDSL units that can operate at various speeds with automatic recognition of a newly connected device to a line or a change in speed. Passive network interfaces need to have hot insertion, where a new VDSL premises unit can be put on the line without interfering with the operation of other modems.

VDSL Issues

VDSL is still in the trial stage; some preliminary products exist, but not enough is known yet about telephone line characteristics, RFI emissions and susceptibility, upstream multiplexing protocols, and information requirements to frame a set of definitive, standardisable properties.

One large unknown is the maximum distance that VDSL can reliably realize for a given data rate. This is unknown because real line characteristics at the frequencies required for VDSL are speculative and items such as short bridged taps or unterminated extension lines in homes, which have no affect on telephony, ISDN or ADSL, may have very detrimental affects on VDSL in certain configurations.

Furthermore, VDSL invades the frequency ranges of amateur radio, and every above-ground telephone wire is an antenna that both radiates and attracts energy in amateur radio bands. Balancing low signal levels to prevent emissions that interfere with amateur radio with higher signals needed to combat interference by amateur radio could be the dominant factor in determining line reach.

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19 CPE – Customer Premise Equipment (Set Top Box etc.)

20 TDM – Time Division Multiplexing

21 TDMA – Time Division Multiple Access

22 FDM – Frequency Division Multiplexing

Summary

VDSL achieves data rates nearly ten times greater than ADSL, but ADSL is the more complex transmission technology, in large part because ADSL must contend with much larger dynamic ranges than VDSL. However, the two are essentially the same. ADSL employs advanced transmission techniques and forward error correction to realize data rates from 1.5 to 9 Mbps over twisted-pair ranging to 18,000 feet; VDSL employs the same advanced transmission techniques and forward error correction to realize data rates from 13 to 55 Mbps over twisted pair ranging to 4500 feet. Indeed, the two can be considered a continuum, a set of transmission tools that delivers about as much data as theoretically possible over varying distances of existing telephone wiring.

VDSL is clearly a technology suitable for a full service network (assuming "full service" does not imply more than two HDTV channels over the highest rate VDSL). It is equally clear that telephone companies cannot deploy ONUs overnight, even if all the technology were available. ADSL may be not a "full service network" technology, but it has the singular advantage of offering service over lines that exist today, and ADSL products are closer in time than VDSL. Many new services being contemplated today can be delivered at speeds at or below T1/E1 rates -- video conferencing, Internet access, video on demand, remote LAN access. For such services, ADSL/VDSL provides an ideal combination for network evolution. On the longest lines, ADSL delivers a single channel. As line length shrinks, either from natural proximity to a central office or deployment of fibre based access nodes, ADSL and VDSL simply offer more channels, and capacity for services that require rates above T1/E1.

As a final note, the ITU and ANSI committee T1E1.4 have begun work on a VDSL2 standard, based on ADSL2 and T1.424. The goal is to facilitate multi-mode ADSL2/VDSL2 implementations. VDSL2 is intended to deliver data rates up to 100 Mbps over short loops in order to enable services such as HDTV. Whereas VDSL uses both DMT and QAM as alternate modulation schemes, VDSL2 will only specify DMT. Although the ITU has just begun work on the VDSL2 standard, the committee has already agreed that VDSL2 will include several features contained in ADSL2, such as loop diagnostics modes, low power modes, and a common management interface with ADSL2. Additional VDSL2 features include Trellis coding, optional fast start-up, digital duplexing, and windowing. The VDSL2 standard is expected to be ratified in early 2005.

Appendix 2 – Wireless Standards

Local Area (LAN) Standards

IEEE 802.11 (WiFi)

The 802.11 standard now has a number of variants building upon and enhancing the original standard and extending its applicability to other regions of the world.

The original 802.11 working group developed three physical layers (PHY) for Wireless Local Area Networks (WLAN) applications, using Infra-red (IR), 2.4 GHz Frequency Hopping Spread Spectrum (FHSS), and 2.4 GHz Direct Sequence Spread Spectrum (DSSS), in-conjunction with the one common media access layer (MAC) Task Group work. The original Standard is published as IEEE Standard 802.11-1997.

- **802.11a**: Developed a PHY standard to operate in the US allocated UNII band. (5.725-5.875GHz). Supports rates up to 54 Mbit/s.
- **802.11b**: Developed a standard for a higher rate PHY in the 2.4GHz band. Supports basic rates of 1b, 2, 5.5 and 11 Mbit/s.
- **802.11e**: Enhance the 802.11 Medium Access Control (MAC) to improve and manage Quality of Service, provide classes of service, and enhanced security and authentication mechanisms.
- **802.11g**: To develop a higher speed(s) PHY extension to the 802.11b standard. Data rates of at least 20 Mbit/s are expected.
- **802.11h**: Enhancing the 802.11 Medium Access Control (MAC) standard and 802.11a High Speed Physical Layer (PHY) in the 5GHz Band supplement to the standard; to add indoor and outdoor channel selection for 5GHz license exempt bands in Europe

<table>
<tr><td colspan="3">IEEE 802.2
Logical Link Control (LLC)</td></tr>
<tr><td colspan="3">IEE 802.11
Media Access Control (MAC)</td></tr>
<tr><td>Frequency Hopping
Spread Spectrum
PHY</td><td>Direct Sequence
Spread Spectrum
PHY</td><td>Infra-red PHY</td></tr>
</table>

MAC	OSI Layer 2 (Data Link)
PHY	OSI Layer 1 (Physical)

Figure A.2.1 802.11 OSI Mapping

ETSI HiperLAN Type 1

HIPERLAN Type 1 was developed for the 2.4GHz licence exempt band.

- **ETSI ETS 300 652:** HIgh PErformance Radio Local Area Network (HIPERLAN) Type 1

ETSI HiperLAN Type 2

HIPERLAN Type 2 is developed for the 5GHz licence exempt bands.

- **ETSI TS 101 475 V1.3.1** Broadband Radio Access Networks (BRAN); HIPERLAN Type 2; Physical (PHY) layer
- **ETSI TS 101 761-x** Broadband Radio Access Networks (BRAN); HIPERLAN Type 2; Data Link Control (DLC) Layer; Part x (5 parts published).

Metropolitan Area (MAN) Standards

IEEE 802.16 (WiMAX)

The IEEE has developed a Broadband Fixed Wireless Access (BFWA) standard within their 802.16 working group. The scope includes P-MP systems operating in the frequency range 10-66GHz and includes both the Physical and MAC layers. This is now a published IEEE Standard for Local and metropolitan area networks. An amendment has been published dealing with lower frequency systems (including license-exempt frequencies).

- **IEEE 802.16-2001:** Air Interface for Fixed Broadband Wireless Access Systems
- **IEEE 802.16a-2003**: Amendment to IEEE Standard for Local and Metropolitan Area Networks - Part 16: Air Interface for Fixed Broadband Wireless Access Systems - Medium Access Control Modifications and Additional Physical Layer Specifications for 2-11 GHz.
- **IEEE 802.16e:**This specification extends WiMAX to mobile clients by allowing true mobile wireless connectivity at broadband speeds throughout a cell that is potentially 30 miles in radius. This metropolitan-area-network (MAN) technology will enable wireless business solutions to operate in a connected mode in a city-sized area. The 802.16e technology will also support local and regional roaming in and out of service-provider territories, extending the flexibility of the solution. Service will likely be provided as an enhancement to existing offerings from Wireless Internet Service Providers (WISPs). As an extension to 802.16a, the 802.16e architecture is optimized for (and backward-compatible with) fixed base stations, rather than being built from the ground up for mobile clients.

IEEE 802.20

ETSI HiperMAN

The ETSI BRAN HIPERMAN project considers systems that will operate below 11GHz. Originally targeting the licensed frequency bands, work is under way to address licence exempt operation in the 5.8GHz band.

- **ETSI TS 102 177 V1.1.1** Broadband Radio Access Networks (BRAN); HIPERMAN; Physical (PHY) layer.
- **ETSI TS 102 178 V1.1.1** Broadband Radio Access Networks (BRAN); HIPERMAN; Data Link Control (DLC) layer

ETSI HIPERACCESS

The HIPERACCESS Point to Multi-Point (P-MP) system is envisaged for licensed activity in frequency ranges above about 11GHz and focuses on candidate frequency bands for Fixed Wireless Access systems such as 26/28GHz, 32GHz and the 40GHz Multimedia Wireless Systems band. During early 2002 the first standards for HIPERACCESS systems were approved and published.

- **ETSI TS 101 999 V1.1.1** Broadband Radio Access Networks (BRAN); HIPERACCESS**;** PHY protocol specification
- **ETSI TS 102 000 V1.3.1** Broadband Radio Access Networks (BRAN); HIPERACCESS**;** DLC protocol specification

Harmonised Standards

These are useful compliance standards associated with conformity with Article 3.2 of the Radio and Telecommunications Terminal Equipment (RTTE) Directive in Europe. In essence Article 3.2 states that radio systems shall not cause harmful interference to other networks and use terrestrial and space service spectrum resources effectively. Self-declarations to this effect are required to support CE marking in Europe. Other articles address safety and EMC issues.

- **ETSI EN 301 893 V1.2.3** Broadband Radio Access Networks (BRAN); 5 GHz high performance RLAN; Harmonized EN covering essential requirements of article 3.2 of the R&TTE Directive.
- **ETSI EN 301 753 V1.2.1** Fixed Radio Systems;Multipoint equipment and antennas; Generic harmonized standard for multipoint digital fixed radio systems and antennas covering the essential requirements under article 3.2 of the Directive 1999/5/EC.

Appendix 3 – DOCSIS Standards

The published DOCSIS standards are listed in the following tables. (Source: *CableLabs http://www.cablemodem.com/specifications/*)

DOCSIS 1.0

Reference	Date	Title
SP-BPI	11/06/01	Baseline Privacy Interface Specification
SP-CMTRI	8/04/97	Cable Modem Telephony Return Interface Specification
SP-CMCI	3/01/02	Cable Modem to Customer Premises Equipment Interface Specification
SP-CMTS-NSI	7/2/96	Cable Modem Termination System Network Side Interface Specification
SP-OSSI	11/06/01	Operations Support System Interface Specification
SP-OSSI-RF	11/06/01	Operations Support System Interface Radio Frequency MIB
SP-OSSI-TR	2/09/98	Operations Support System Interface Specification Telephony Return MIB
SP-OSSI-BPI	11/06/01	Operations Support System Interface Baseline Privacy MIB
SP-RFI	11/06/01	Radio Frequency Interface Specification
TP-ATP	3/31/01	Acceptance Test Plan
SP-PICS	10/14/98	Conformance Checklist / PICS Proforma

Table A.3.1 DOCSIS 1.0 Interface Specifications Summary

DOCSIS 1.1

Reference	Date	Title
SP-BPI+	08/12/05	Baseline Privacy Plus Interface Specification
SP-BPI	11/06/01	Baseline Privacy Interface Specification
SP-CMCI	07/30/03	Cable Modem to Customer Premises Equipment Interface Specification
SP-OSSIv1.1	09/07/05	Operations Support System Interface Specification
SP-RFIv1.1	09/07/05	Radio Frequency Interface Specification
SP-CMTS-NSI	07/02/96	Cable Modem Termination System Network Side Interface Specification
BPI ATP	01/12/05	DOCSIS 1.1 and 2.0 BPI Acceptance Test Plan
CMCI ATP	01/12/05	DOCSIS 1.1 and 2.0 CMCI Acceptance Test Plan
OSSI ATP	09/09/05	DOCSIS 1.1 and 2.0 OSSI Acceptance Test Plan
RFI ATP	09/09/05	DOCSIS 1.1 and 2.0 RFI Acceptance Test Plan
SP-PICS	09/07/05	Conformance Checklist / PICS Proforma

Table A.3.2 DOCSIS 1.1 Interface Specifications Summary

DOCSIS 2.0

Reference	Date	Title
SP-RFIv2.0	08/12/05	Radio Frequency Interface Specification
SP-OSSIv2.0	08/12/05	Operations System Support Interface Specification
SP-BPI+	08/12/05	Baseline Privacy Plus Interface Specification
SP-BPI	11/06/01	Baseline Privacy Interface Specification
SP-CMCI	04/08/05	Cable Modem to Customer Premises Equipment Interface Specification
SP-CMTS-NSI	07/2/96	Cable Modem Termination System Network Side Interface Specification
BPI ATP	01/12/05	DOCSIS 1.1 and 2.0 BPI Acceptance Test Plan
CMCI ATP	01/12/05	DOCSIS 1.1 and 2.0 CMCI Acceptance Test Plan
OSSI ATP	09/09/05	DOCSIS 1.1 and 2.0 OSSI Acceptance Test Plan
RFI ATP	09/09/05	DOCSIS 1.1 and 2.0 RFI Acceptance Test Plan
SP-PICS	09/07/05	Conformance Checklist / PICS Proforma

Table A.3.3 DOCSIS 2.0 Interface Specifications Summary

Appendix 4 – DAVIC & DVB-RCC

Overview

The Digital Audio/Video Council and DVB communications protocols were developed in the late 1990s and were intended to complement the DVB video broadcast standard.

Market forces have determined that DOCSIS and its European counterpart EuroDocsis have become the dominant communications protocols in use on cable TV networks today. However, for the sake of completeness a brief comparison of the three technologies is included here.

DAVIC

DAVIC is a non-profit organisation formed in 1994 with the purpose of promoting the success of digital audio-visual applications and services.

Its DAVIC 1.0 (December 95), DAVIC 1.1 (September 96) and DAVIC 1.2 (December 96) RF cable modem standards were designed to support audio-visual applications and data services, while DAVIC 1.3, 1.4 and 1.5 aim to support enhanced digital broadcasting, interactive digital broadcasting and communications services (i.e. telephony).

DAVIC 1.2 was offered as a candidate standard to the MCNS[23] consortium, but was not selected, in part because of its much less flexible and robust upstream support.

DVB

DVB (Digital Video Broadcasting) is an organisation committed to the development of a family of standards for Digital Television. It has been highly successful in the development of its DVB-S, DVB-C, DVB-T and now DVB-H digital broadcast standards.

Like DAVIC, the DVB project represents a broad coalition of organisations including broadcasters, digital satellite, terrestrial, and cable-operators, together with hardware and software suppliers. It aims to work by consensus, but with interactive services and data network standards this has proven to be increasingly difficult given the interests of broadcasters and some suppliers may be quite different from those of independent cable network operators.

DVB's work has included development of specific standards for the delivery of audio, video, and data services over cable and LMDS[24] networks; DVB-C (cable only) and DVB-RCCL (Return Channels for Cable and LMDS).

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23 MCNS – Multimedia Cable Network System

24 LMDS - Local Multipoint Distribution System - the broadband wireless technology used to deliver voice, data, Internet, and video services using microwave technology.

The DVB-C standard is almost identical to the DAVIC 'Passband Unidirectional PHY on Coax' standard with minor modifications. DVB-C is available as ETSI standard ETS 300 429, title: Digital Video Broadcasting(DVB); Framing structure, channel coding and modulation for cable systems. It has been ratified by the ITU as ITU-T J83 Annex A. In addition, ETS 300 802 defines network independent layers for both cable and LMDS networks.

The DVB-RCC (Return Channel for Cable) standard is almost identical to DAVIC 1.2 'Passband bidirectional PHY on coax' with minor modifications. DVB-RCC is available as ETSI standard ETS 300 800, title: 'Digital Video Broadcasting (DVB); Interaction channel for Cable TV distribution systems (CATV)'. It was ratified by the ITU as ITU-T J112 Annex A in March 98. (DOCSIS was ratified as Annex B at the same time).