Cable Technologies
DOCSIS, PacketCable, CableHome

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Overview

» Market Data
» Cable system architecture
» DOCSIS
» PacketCable
» CableHome
» CableLabs
North America Total Broadband CPE Unit Shipments

Source: Infonetics, September, 2005
# VoIP Market Share

VoIP Subscribers, in 000’s

<table>
<thead>
<tr>
<th>Service Provider</th>
<th>Q4 2004</th>
<th>Q1 2005</th>
<th>Q-Q Growth</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vonage</td>
<td>388</td>
<td>535</td>
<td>38%</td>
</tr>
<tr>
<td>Cox</td>
<td>380</td>
<td>413</td>
<td>9%</td>
</tr>
<tr>
<td>Time Warner</td>
<td>219</td>
<td>372</td>
<td>59%</td>
</tr>
<tr>
<td>Cablevision</td>
<td>273</td>
<td>364</td>
<td>33%</td>
</tr>
<tr>
<td>Insight</td>
<td>64</td>
<td>70.4</td>
<td>10%</td>
</tr>
<tr>
<td>Charter</td>
<td>45</td>
<td>49.5</td>
<td>10%</td>
</tr>
<tr>
<td>Covad</td>
<td>20.5</td>
<td>23.4</td>
<td>14%</td>
</tr>
</tbody>
</table>

Source: Point Topic, July, 2005
Cable Terminology

» Cable Modem.
  • Subscriber device, connects customer’s PC or LAN to the cable TV plant (HFC)

» Cable Modem Termination System (CMTS).
  • Head-end equipment that concentrates communication to/from all subscribers’ cable modems

» DOCSIS Provisioning Server
  • Provides network configuration (IP address, etc), date and time and cable modem configuration
  • Provides also downloadable code image (software) for cable modems, for software upgrade
  • Support the following network services:
    » DHCP (Dynamic Host Configuration Protocol)
    » TOD (Time and Date Service)
    » TFTP (Trivial File Transfer Protocol)

» Embedded Multimedia Terminal Adapter (EMTA)
  • Cable Modem with voice ports for VoIP service
    » Allows connection of a plain analog telephone
Cable Architecture

New Services Opportunities

- HVAC control
- Fire sense & control
- Security
- Air quality monitoring
- Child monitoring
- Energy management, etc.

Operator Core Backbone

- Remote file sharing
- Shared calendar
- Unified messaging
- Managed services

Core Network

Provisioning Servers

- DOCSIS
- CableHome
- PacketCable

MPEG Services

IP Services

CableHome

CableHome

CMTS

CMTS

CMTS

CM

CM

CM

CM

CM

CM

EMTA

EMTA

EMTA

EMTA

Operator administered

Aggregation Network

Access Network

Backend

Headend

CPE

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What is DOCSIS?

» Data Over Cable Systems Interface Specification (DOCSIS)
  • Industry effort, led by CableLabs® to create an open standard for data (internet) over cable TV
  • Specified in 1997, first products certified in March 1999
  • DOCSIS allows MSO’s to achieve higher levels of penetration via retail, auto-provisioning, external cable modems, and self-installs.

» DOCSIS only deals with the communication between the CM and the CMTS.

» DOCSIS utilizes 1 downstream channel from the channel lineup and 1 or more channels from the return path to achieve bi-directional connection.

» Maximum raw data throughput
  • 43 Mbps downstream
  • 10 Mbps upstream
Cable Services Protocol Stack

Legacy System

- VOD
- INTERACTIVE SERVICES
- ANALOG
- MPEG

CBR TELEPHONY

Internet World

- Applications
- PacketCable™
- DOCSIS™

HFC

DOCSIS™

CableHome™

PacketCable™

Home Network

Analog Telephones

Cable Head End

Home
DOCSIS 1.1 Overview

» Backward compatible with DOCSIS 1.0
» Enhanced Quality of Service (QoS) Allows cable operators to deploy new services such as:
  • Tiered data services with guaranteed bandwidth
  • Voice over IP
  • IP Multicasting

» Improved security (Baseline Privacy +) based on SNMPv3
  • Reduces possibility of theft of service
  • Provides secure software downloading

» Concatenation and Fragmentation
  • Allow more efficient use of available bandwidth
  • Guarantee real-time traffic for voice over IP.

» Specification released in 1999
DOCSIS 2.0 Overview

» Backward compatible with DOCSIS 1.0, 1.1
» Advanced Upstream PHY enables symmetrical services
  • Higher order modulation formats and increased symbol rates
    » 8QAM, 32QAM, 64QAM
    » 5.12 Msps
    » Maximum raw upstream data rate: 30.72 Mbps
  • Synchronous-Code Division Multiple Access (CDMA)
    » Multiple modems can transmit simultaneously on the same RF channel, separated by different orthogonal codes.
    » Robust upstream for noise environments
» Improved noise immunity
  • FEC correction for 16 bytes per Reed-Solomon block (vs. 10 for DOCSIS 1.1)
  • Adaptive equalizer structure with 24 taps (vs. 8 for DOCSIS 1.1)
  • Improved ingress cancellation
» Specification released in 2001, but most plants are still running 1.1
Future DOCSIS Initiatives

» **DOCSIS 3.0**
  - 100 Mbps downstream, 50 Mbps upstream
  - Video services (broadcast and video on demand)
  - Additional bonded downstream and upstream channels (4 or more)
    » Existing CMs work on 1 channel, D3.0 works on multiple channels
  - Specs: 2006, products: early 2007???

» **Commercial Services over DOCSIS (CSoD)**
  - VPN service
  - T1 replacement

» **eDOCSIS**
  - Allows integration of DOCSIS modems into non-traditional devices, such as TVs, Set Top Boxes, etc.

» **Modular CMTS (M-CMTS)**
  - Allows easier integration of data service and other services, such as video
HFC Plant Requirements

» Cable Plant must be “clean” and upgraded to 2-way capable
» 100 mile maximum distance

» Downstream
  • A DOCSIS channel takes the place of a single analog television channel
  • 88 – 860 MHz (108 – 862 MHz Europe)
  • Channel spacing: 6 MHz (8 MHz Europe)
  • Modulation: 64QAM, 256 QAM

» Upstream
  • Upstream channels use spectrum previously reserved for STB communication
  • 5 – 42 MHz (5 – 65 MHz Europe)
  • Noisy portion of spectrum requires flexible channels
    » Amateur radios, home intercoms, impulse ingress due to switching transients, household appliances, etc.
  • Multiple upstream channels can be associated with each downstream channel
  • Modulation: QPSK, 8QAM, 16QAM, 32QAM, 64QAM, 128QAM (CDMA only)
# DOCSIS Data Rates

## Downstream Data Rates

<table>
<thead>
<tr>
<th>Modulation</th>
<th>Symbol Rate</th>
<th>Raw Throughput</th>
</tr>
</thead>
<tbody>
<tr>
<td>64 QAM (6 bits/symbol)</td>
<td>5.056941 Msps</td>
<td>30.34 Mbps</td>
</tr>
<tr>
<td>256 QAM (8 bits/symbol)</td>
<td>5.360537 Msps</td>
<td>42.88 Mbps</td>
</tr>
</tbody>
</table>

## Upstream Data Rates

<table>
<thead>
<tr>
<th>Modulation</th>
<th>160 kbps</th>
<th>320 kbps</th>
<th>640 kbps</th>
<th>1.28 Msps</th>
<th>2.56 Msps</th>
<th>5.12 Msps</th>
</tr>
</thead>
<tbody>
<tr>
<td>QPSK 2 bits/symbol</td>
<td>320 kbps</td>
<td>640 kbps</td>
<td>1.28 Mbps</td>
<td>2.56 Mbps</td>
<td>5.12 Mbps</td>
<td>10.24 Mbps</td>
</tr>
<tr>
<td>8QAM 3 bits/symbol</td>
<td>480 kbps</td>
<td>960 kbps</td>
<td>1.92 Mbps</td>
<td>3.84 Mbps</td>
<td>7.68 Mbps</td>
<td>15.36 Mbps</td>
</tr>
<tr>
<td>16QAM 4 bits/symbol</td>
<td>640 kbps</td>
<td>1.28 Mbps</td>
<td>2.56 Mbps</td>
<td>5.12 Mbps</td>
<td>10.24 Mbps</td>
<td>20.48 Mbps</td>
</tr>
<tr>
<td>32QAM 5 bits/symbol</td>
<td>800 kbps</td>
<td>1.6 Mbps</td>
<td>3.2 Mbps</td>
<td>6.4 Mbps</td>
<td>12.8 Mbps</td>
<td>25.6 Mbps</td>
</tr>
<tr>
<td>64QAM 6 bits/symbol</td>
<td>960 kbps</td>
<td>1.92 Mbps</td>
<td>3.84 Mbps</td>
<td>7.68 Mbps</td>
<td>15.36 Mbps</td>
<td>30.72 Mbps</td>
</tr>
</tbody>
</table>
CM Registration Steps

» Downstream channel searching and synchronization
» Obtain upstream parameters
  • CM chooses a temporary upstream channel
» Ranging: 0 – 215 minislots (6.25 us each)
  • CMs must adjust transmit timing to account for propagation delay of up to 100 miles of cable
  • Transmissions from all CMs must be synchronized at CMTS.
» Establish IP connectivity
  • DHCP used to assign IP address
  • Additional parameters communicated through DHCP extensions
    » IP address of TFTP Server, TOD server
    » Time zone
    » Name of configuration file
CM Registration Steps (cont.)

» Establish time of day using TOD server

» Transfer operational parameters
  • Configuration file downloaded using TFTP
  • CMTS assigns new upstream channel, in which case repeat ranging

» Firmware upgrade (optional)
  • Automatic upgrade if current firmware version is different than version indicated in configuration file
  • Dual images protects against power outages during upgrade

» Registration: CM authorized to use the network based on MAC address

» Baseline Privacy initialization, if CM is provisioned to run Baseline Privacy
Downstream MPEG Framing

» 188-byte MPEG-2 packets (4-byte header, 184 bytes payload)
» ITU Recommendation defines:
  • Framing structure (MPEG-2)
  • Channel coding (RS FEC, Interleaving, Randomization and Trellis)
  • Channel modulation (64/256 QAM)
» DOCSIS frames can be mixed in with frames for other services (digital video, for example)
» DOCSIS frames can span multiple MPEG packets

<table>
<thead>
<tr>
<th>MPEG Header DOC</th>
<th>Pointer_field</th>
<th>Stuff-bytes</th>
<th>Start of MAC Frame #1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Doc</td>
<td>(=0)</td>
<td>(0 or more)</td>
<td>(up to 183 bytes)</td>
</tr>
<tr>
<td>MPEG Header</td>
<td></td>
<td></td>
<td>Digital Video Payload</td>
</tr>
<tr>
<td>Video</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MPEG Header</td>
<td></td>
<td></td>
<td>Continuation of MAC Frame #1</td>
</tr>
<tr>
<td>Doc</td>
<td></td>
<td></td>
<td>(184 bytes)</td>
</tr>
<tr>
<td>MPEG Header</td>
<td></td>
<td></td>
<td>Digital Video Payload</td>
</tr>
<tr>
<td>Video</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MPEG Header</td>
<td>Pointer_field</td>
<td>Tail of MAC Frame #1</td>
<td>Stuff_bytes</td>
</tr>
<tr>
<td>Doc</td>
<td>(=M)</td>
<td>(M bytes)</td>
<td>(0 or more)</td>
</tr>
<tr>
<td>MPEG Header</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Video</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Upstream Bandwidth Allocation

- Upstream bandwidth is allocated by the CMTS
- Dynamic mix of contention- and reservation-based transmit opportunities
- The upstream channel is modeled as a stream of “mini-slots”
- The upstream transmission time-line is divided into Information Elements (IEs)
  - Each interval is an integral number of mini-slots.
  - Each interval is labeled with a usage code
    - What type of traffic can be transmitted during that interval
    - What physical-layer modulation is allowed
- Types of Information Elements
  - Request: Contention interval where CMs may request bandwidth
  - Request/Data: Contention interval where CMs may request bandwidth or transmit short data packets
  - Long and Short Data Grant: Provides opportunity for a CM to transmit upstream packets without contention
  - Data Acknowledge: Acknowledges that a data PDU was received, if requested by CM
- Scheduling algorithm is not specified by DOCSIS
  - Many different scheduling algorithms may be implemented by different CMTS vendors
The CMTS controls the upstream channel through the Allocation MAP

- Defines transmission opportunities on the upstream channel
- Includes a variable number of information elements (IEs). Each information element defines the allowed usage for a range of mini-slots.

The set of all maps describes every mini-slot in the upstream channel
MAC-layer security services for DOCSIS CMTS - CM communications

Security goals

- Provides data privacy equal to or better than that provided by analog modems or DSL
- Provide MSOs with service protection; i.e., prevent unauthorized users from gaining access to the network

Two component protocols:

- Encapsulation protocol for encrypting packet data across the network
  - 3-DES Cipher Block Chaining (CBC) encryption
  - MAC headers are not encrypted
  - The payloads and headers of MAC management messages are sent in the clear to facilitate normal operation of the MAC sublayer.
- Key management protocol providing the secure distribution of keying data from CMTS to CMs
  - CMs must have factory-installed RSA private/public key pairs
PacketCable

» Provides packet-based voice, video and other high-speed multimedia services over hybrid fiber coax (HFC) cable systems

» Allows connection of a plain analog telephone using an Embedded Multimedia Terminal Adapter (EMTA)

» Goals
  • Enable voice quality capabilities comparable to or better than PSTN
  • Provide a network architecture that is scalable and capable of supporting millions of subscribers
  • Support primary and secondary line residential voice communications capabilities
    » Battery backup capability
    » Electronic surveillance possible

» Leverages QOS capabilities of DOCSIS 1.1/2.0

» Based on NCS variation of MGCP

» PacketCable 1.0 specification released in 2000

» PacketCable 2.0 will be based on SIP
  • Specification date, TBD
CableHome

» Standardizes residential gateway (home router) functionality
  • NAT, Firewall, DHCP
  • No subscriber configuration needed (“works out of the box”)
  • Common consumer applications are not broken by NAT

» Allows cable company to control home networks and offer managed services
  • Parental controls, firewalls, email virus scanning
  • All centrally configured and controlled
  • Remote diagnostic tools for MSO customer care
  • Ability to drive new services for consumers (data, voice, video)

» QOS integration with DOCSIS 1.1

» UPnP Discovery allows remote visibility and control of devices in the home
# CableHome Technical Value

<table>
<thead>
<tr>
<th>Functionality</th>
<th>Existing Product Features</th>
<th>CableHome Features</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Network Management</td>
<td>Console, Telnet,</td>
<td>SNMPv3</td>
<td>» Remote configuration and management</td>
</tr>
<tr>
<td></td>
<td>Web-based, UPnP</td>
<td></td>
<td>» Proactive event reporting</td>
</tr>
<tr>
<td>Device Provisioning</td>
<td>Unmanaged DHCP</td>
<td>SNMPv3, Managed DHCP</td>
<td>» Zero config for residential gateway</td>
</tr>
<tr>
<td>Address Translation</td>
<td>Unmanaged NAPT</td>
<td>SNMPv3, Managed NAPT &amp; NAT</td>
<td>» MSO manageability and visibility</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>» Support for popular apps</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>» Eliminate unnecessary traffic on HFC</td>
</tr>
<tr>
<td>Secure Software Download</td>
<td>None or Firmware</td>
<td>Secure Software Download (DOCSIS 2.0</td>
<td>» Remote device functionality upgrade</td>
</tr>
<tr>
<td></td>
<td></td>
<td>and 1.1)</td>
<td>» Upgrade to firewall policies</td>
</tr>
<tr>
<td>Security/Firewall</td>
<td>None or weak/No Firewall</td>
<td>Medium Security/Policy file Download</td>
<td>» Secure Management &amp; Firewall</td>
</tr>
<tr>
<td>QoS</td>
<td>None</td>
<td>Supports PacketCable Telephony and UPnP QoS</td>
<td>» Enables a higher quality user experience for multimedia</td>
</tr>
</tbody>
</table>
» **CableLabs** serves the cable television industry by:

- Researching and identifying new broadband technologies
- Authoring specifications
- Certifying products
- Disseminating information.

» **Certification**

- Cable companies will NOT purchase cable modems or other cable products without certification
- Certification Waves, typically 9 weeks
- Cost of $60k to $110k, depending upon product
- Very difficult to pass. Any failures during testing result in no certification. You must resubmit in next cert wave and pay again ($$$).

» **EuroDOCSIS and EuroPacketCable** certified by tComLabs in Belgium