Cable Modems 101

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The purpose of this document is to introduce the non-technical reader to cable modems on cable television systems through these topics:

- What is the current architecture of choice for cable television systems?
- How are cable modems applied to a cable television system?
- How have cable modem capabilities evolved?

1. Introduction to Cable Television Architectures

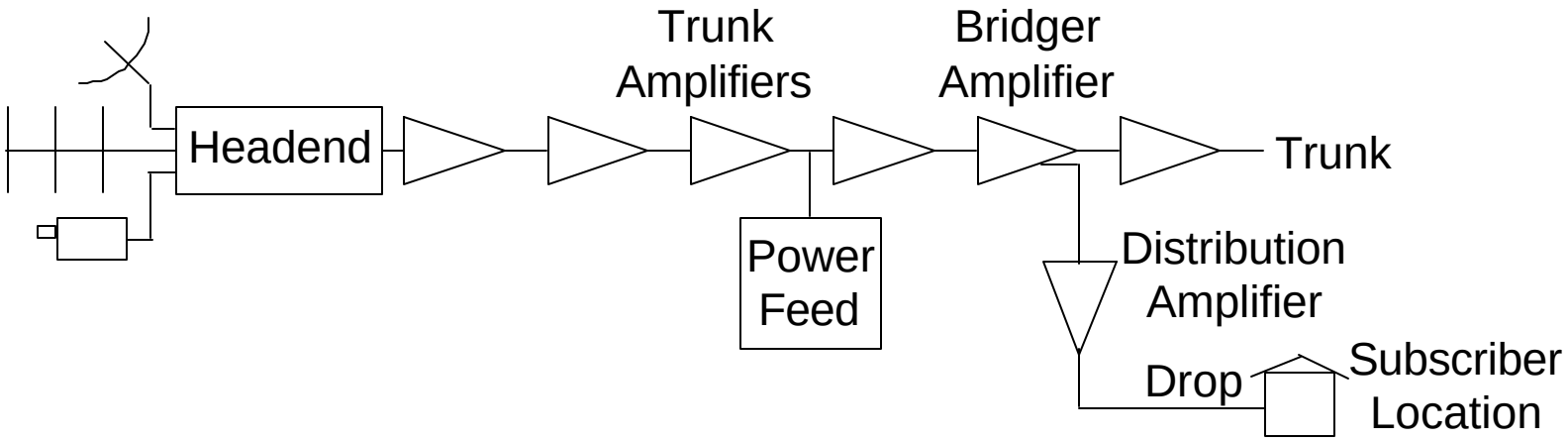
In this segment, we introduce the reader to the HFC concept

- The architecture of choice is called Hybrid-Fibre/Coax (HFC), because it comprises fibre in the centre of the network combined with coaxial cable for the last distance to the subscriber
- This architecture is preferred because coaxial cable is currently the most economic way of developing and delivering broadband power to large volumes of subscribers
- In this section, we address
  - The legacy platform of headend, coaxial lines and amplifiers
  - How television and other signals share the coax
  - Fibre to the serving area
  - Two-way via hybrid-fibre coax
  - Evolution to Fibre-to-the-Premises (FTTP) and passive optical networks

The base business of the cable industry continues to be the delivery of television programs to homes. New services are being added

- The genesis of the cable television ("CATV") industry was picking up distant television signals off-air at hilltop sites and delivering those signals over wires to homes in unserved or under-served areas
  - The hilltop sites became known as "headends"
  - Tree-and-branch structure of (originally twin-lead, but later) coaxial cable
  - Amplifiers placed at intervals to make up for cable losses
  - The cable industry proud of its local, garage-workshop origins
- Nowadays, CATV systems pass most homes in many countries, with very large penetrations in some cases
  - Most programming is picked up at headends from digital satellites
    - Also some off-air pickup, direct feeds, local origination
  - Mainly television, but music programs are also offered
  - Mix of analogue and digital means of program delivery
  - Conditional access in set-top boxes allows tiering of services and video-on-demand
  - Significant and growing local telephony penetration in some countries

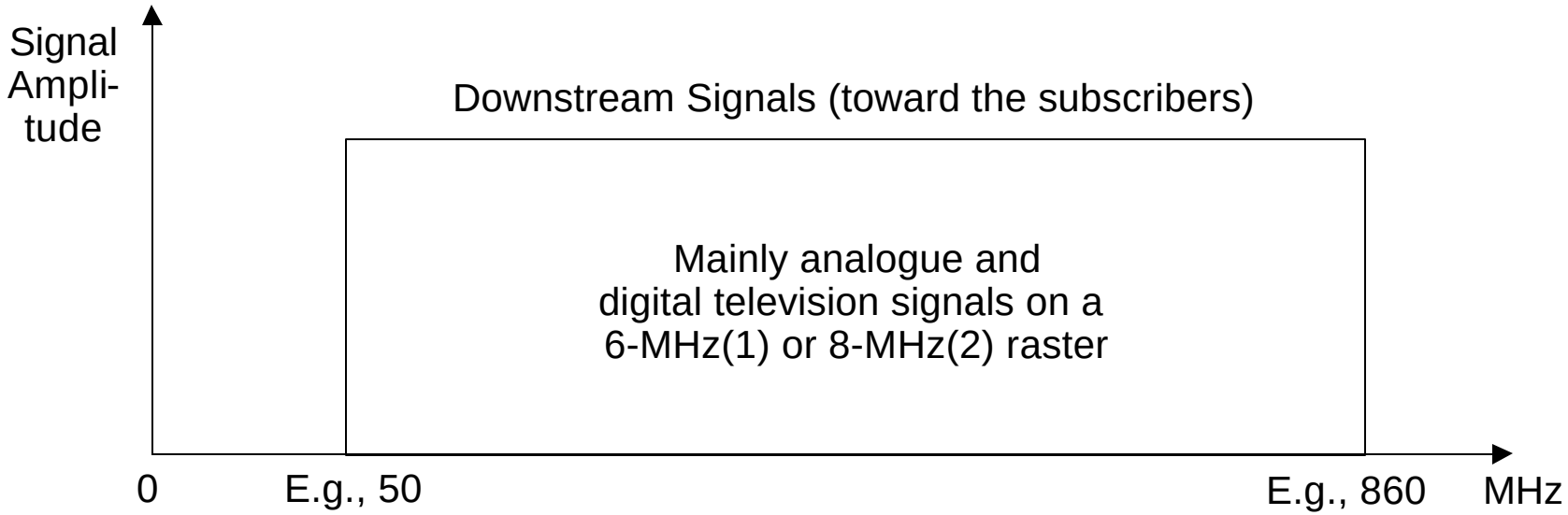
Cable systems were originally designed to deliver television signals to homes over an extensive coaxial tree-and-branch structure[1]



- The cable provides a private limited copy of the radio spectrum
- Television and other signals are sent from the headend all at the same time, each on their own frequency assignments
- Delivered to homes via coaxial trunks, amplifiers, feeders and drops as shown
- Television receivers and set-top boxes tune to the program wanted
- Electric power for the amplifiers is injected into the cable from the electric power grid at intervals, sometimes with standby batteries

Note 1: Called tree-and-bush in the U.K.

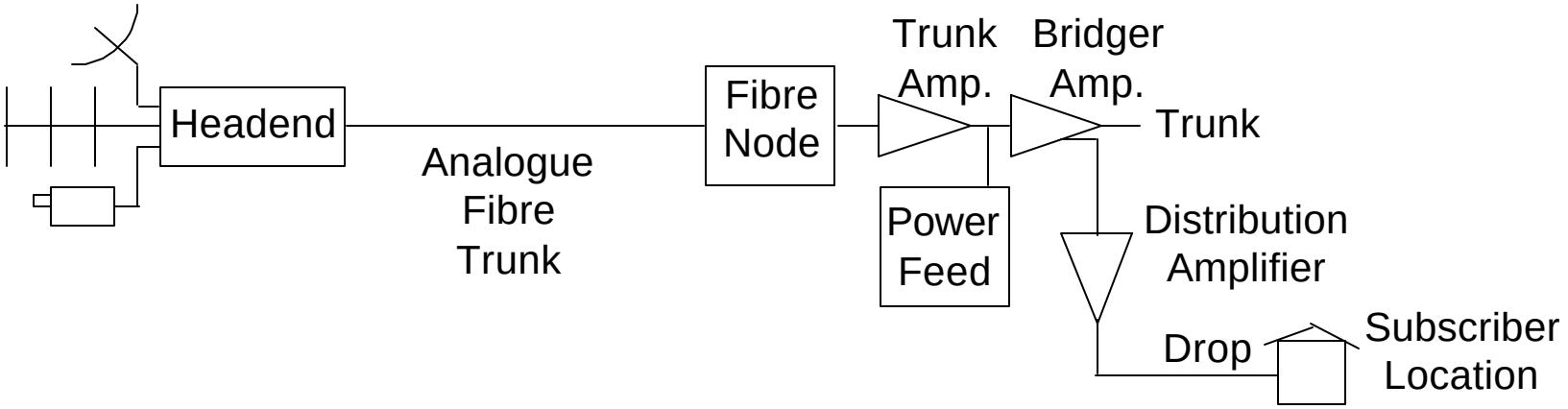
Television signals are sent down the coax in a way similar to how they are sent over the air



- The downstream signals mainly comprise television channels for distribution to everyone and are therefore allocated the largest portion of the cable spectrum
- As it is a linear system, analogue and digital signals of various services can be assigned to different parts of the spectrum, allowing flexibility in adding new technology and services -- a strategic advantage for cable

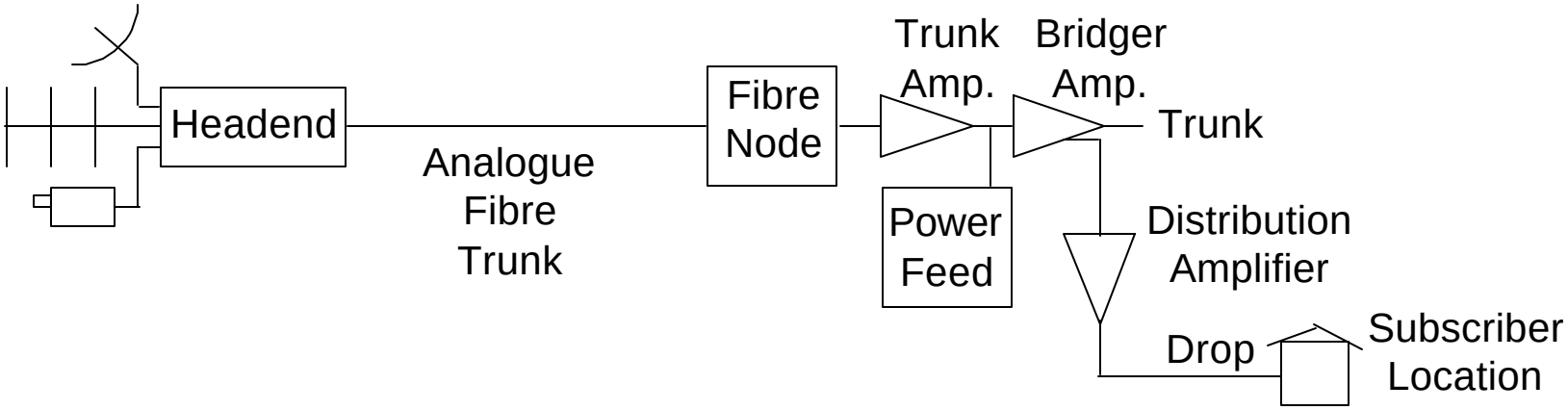
Note 1 -- 6 MHz, based on U.S. standards, is used in most countries of the western hemisphere.
Note 2 -- 8 MHz, based on European standards, is used elsewhere.

Fibre is now widely adopted in cable systems



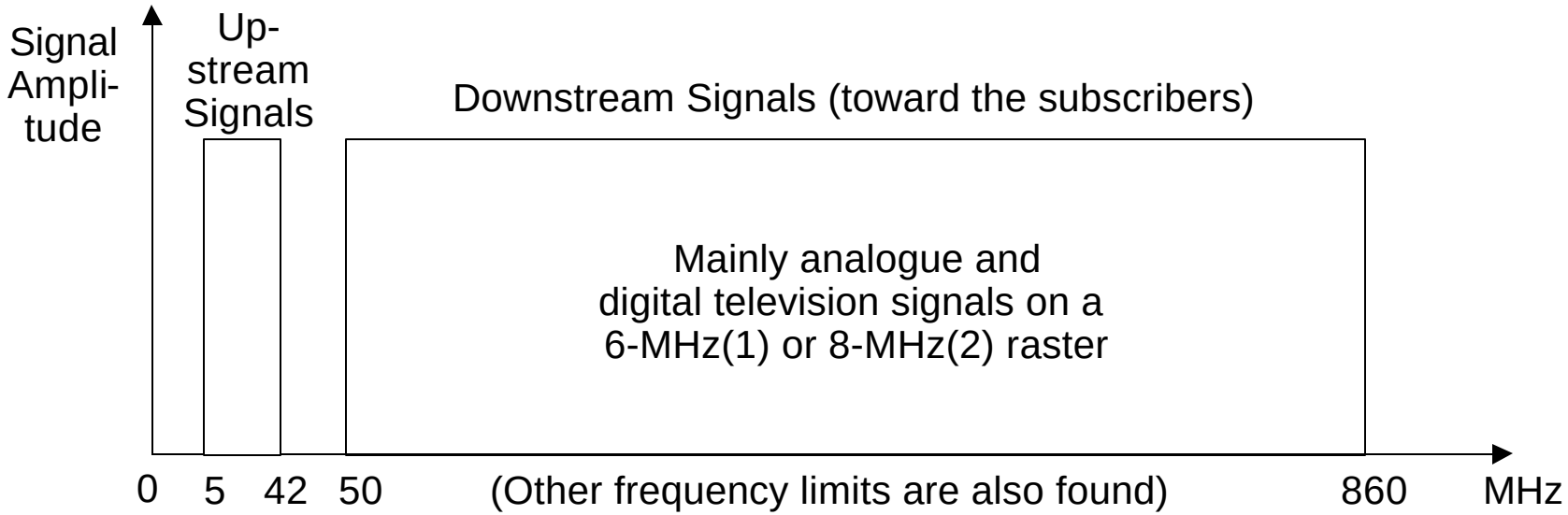
- Today, analogue fibre leapfrogs from the headend to fibre nodes that each serve 200 - 2,000 homes passed, resulting in big improvements in quality, bandwidth, reliability and economics compared with all-coax
- At the headend, the combined RF signal that would otherwise go on the coax is used to amplitude modulate a linear laser
  - Often a single laser is used to feed multiple fibre nodes, through optical splitting and amplication, to save cost
- Photodiodes recover the original RF signal at the fibre nodes
- The recovered RF signal is launched down the remaining coaxial plant toward the subscribers

If two-way, it is called Hybrid-Fibre/Coax (HFC). HFC is a prerequisite for cable modem service



- Reverse (upstream) amplifiers are added to the trunk, bridger and distribution amplifiers
  - Downstream uses the high pass and upstream uses the low pass filter spectrum on the single coaxial cable
- Lasers are applied at each fibre node to send the upstream RF signals to the headend
  - Upstream may use separate fibres from downstream, or different wavelengths on downstream fibres
- HFC is the architecture of choice for new builds and rebuilds

The two-way capability is achieved by assigning different parts of the cable spectrum to the downstream and upstream directions



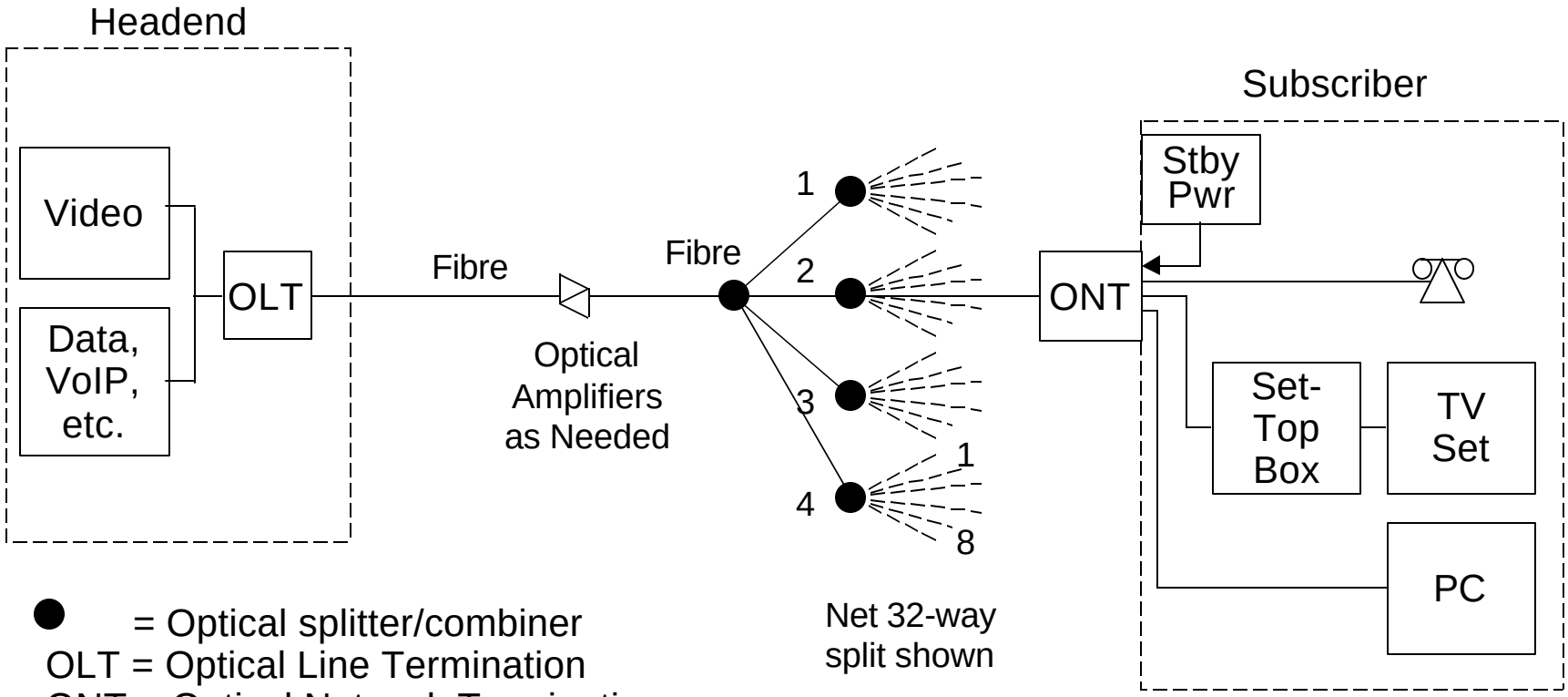
- On the coax, the two directions are separated by filtering
- On the fibre, the upstream direction may be on a separate fibre or on a different wavelength on the downstream fibre
- The upstream channelization is optimized for demand rather than necessarily re-using the same 6- or 8-MHz downstream raster

Cable systems will migrate to Fibre-to-the-Premises when the cost of optical devices falls sufficiently low

- Today, fibre nodes are placed at neighbourhood points where the cost of opto-electric conversion is balanced by the quantity of subscribers passed
  - Fibre nodes are penetrating deeper into the neighbourhoods as their costs fall
- A passive coaxial bus will be achieved where the fibre nodes get close enough to the homes to eliminate the remaining amplifiers
  - Big saving in costs
  - Bandwidth of many Gigabits/sec to/from every home
  - Already achievable in dense areas
  - Big strategic advantage over competing broadband platforms
- At some time in the future, the fibre node economic points will move into the homes, achieving FTTP
  - Further large operating cost savings
  - A Passive Optical Network (PON) architecture may apply, as shown on the next slide
  - Already provided for in the FTTP standards

Future CATV and telco FTTP architectures are closely aligned in standards, as in this example

- Downstream RF analogue/digital signal broadcast to all ONTs on 1550 nm
- Digital downstream can ride in the RF broadcast signal, or use 1490 nm
- Upstream on 1310 nm (allows cheaper lasers at homes)



2. Introduction to Cable Modems

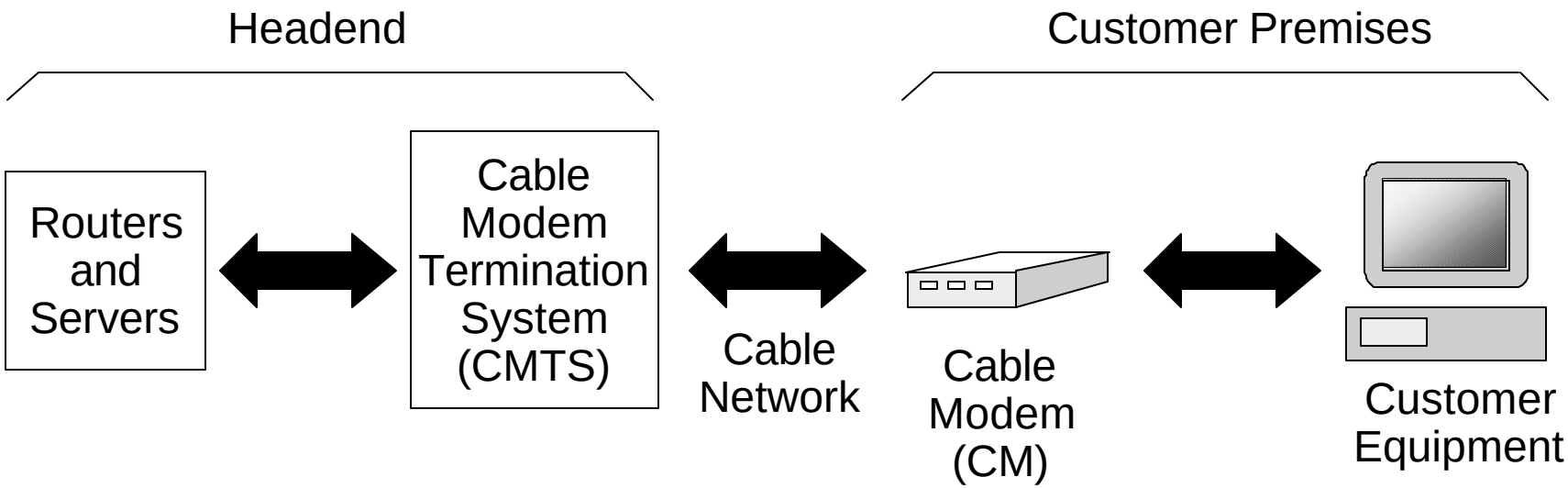
In this segment, we introduce cable modems on HFC

- History and role of cable modems
- Elements of a cable modem system
- How cable modems share the cable resource
- What's needed to upgrade a cable system to support cable modems

Cable modems led the way in high-speed IP and multi-service access and still retain a lead over competing platforms in some markets

- The first economical wide-scale means of high-speed access
- Were able to beat other approaches to the consumer high-speed Internet market, by riding on the pre-existing broadband distribution networks that are the cable television systems in many countries
- Cable modem introduction was critically aided by early and pragmatic industry standardization that was goal-driven by purchasers
- The competing platform of asymmetric digital subscriber line (ADSL) over telephone copper pairs had a late start but is becoming widely-deployed because there are more telephone lines in the world than homes passed by cable
- In order to match DOCSIS-3.0 cable modem capacity, telcos will be forced to bring fibre into, or very near to, the home
- Cable modems will remain a strong player in markets with well-developed cable infrastructure

A cable modem system transfers data traffic over the cable system at local-area-network-like speeds



- DOCSIS-1.0 provides 27 to 38 Mb/s downstream and up to 3.2 Mb/s upstream; newer version provide more
- Shared medium; engineer to provide offered throughput in busy hour
- Eliminates the access bandwidth bottleneck represented by telco loops
- Always connected
- Very strong consumer interest from the beginning

Cable modems use digital radio-frequency carriers that are assigned their own slots among the TV channels in the cable system spectrum

- Downstream
  - Cable modems use the same modulation pattern as digital television
  - Downstream digital TV or cable modem carriers support gross bit rates of up to 30 Mb/s (6 MHz channels) or 51 Mb/s (8 MHz channels)
  - Information in the digital signals tells the cable modems, set-top boxes and TV sets which downstream channels they should join
- Upstream
  - Cable modems are assigned upstream carrier frequencies and time slots by the CMTS at the headend based on the cable modems' bids for upstream capacity

Adding cable modems to a one-way fibre/coax system requires several changes

- Coax refurbishing, if not already done for digital video
- Two-way activation
- Servers and routers at the head end; everything that an ISP would need
- Subscriber cable modems and software
- Operations support systems, including security
- Methods and training for high-speed data
- Keeping the cable plant tight against ingress (interfering impulsive noise and radio signals) and common-path distortion (faults that cause the downstream signals to interfere with the upstream ones)

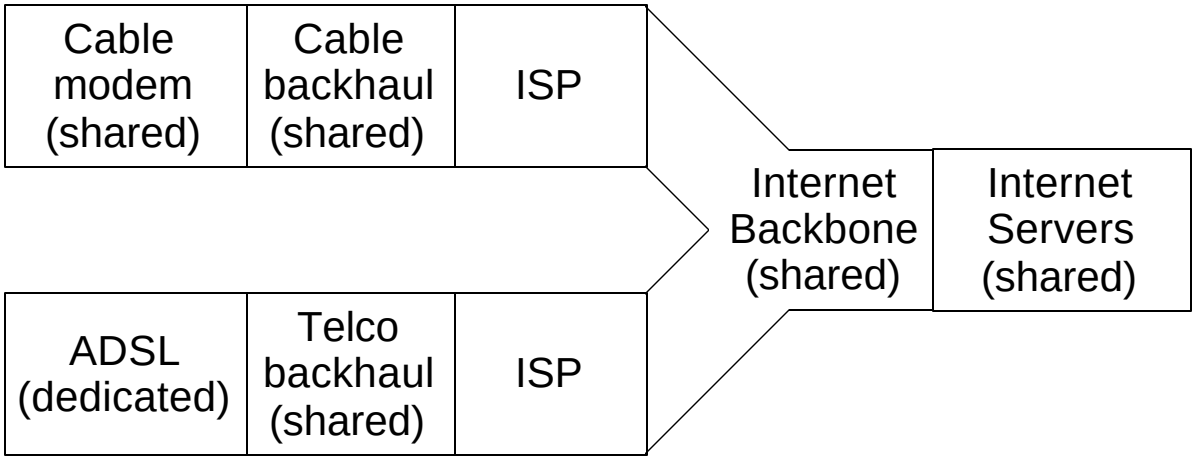
- The widespread successful deployments have shown that, after a period of learning, it is practical to provide a reliable service on an on-going basis

Cable modems lead to different technical constraints on the downstream and upstream paths

Parameter	Downstream	Upstream
Key transmission hazards	Micro-reflections Direct pickup of broadcast signals Impulse noise interference	Interfering radio signal ingress Impulse noise interference
Spectrum available	Relatively large	Limited on coax, addressed by fibre node splitting as traffic grows
Multiple access schemes	Time-division multiplex on one or more r.f. carriers	Time-division multiple access on one or more r.f. carriers
Modulation schemes (DOCSIS-1.0)	64 or 256 QAM in a 6- or 8-MHz TV channel, like digital cable TV	QPSK or 16 QAM in up to 3.2 MHz
Frequency agility strategy	Frequency assignment by the cable operator	Interference avoidance within operator-set policy

A properly-engineered cable modem system will not cause your neighbours to hate you

- Telco marketing campaigns have been seen suggesting that your neighbours will hate you for using shared bandwidth when they want it
  - Arguing that ADSL lines have dedicated bandwidth and constant speed
- But this is, at best, a myth
  - The whole Internet is a shared medium that slows down when busy
  - Properly engineered cable modem systems will support the promised access throughputs in the busy hour
  - Telcos have not always remembered to properly engineer their shared backhaul sections (routers and switches)



Traffic engineering is important in cable modem design and operation

- The shared resource must be designed and managed to maintain the offered quality of service
- While the peak downstream bit rate is 30 Mb/s (6 MHz channels) or 51 Mb/s (8 MHz channels), after accounting for overheads only 28 or 47 Mb/s are available for traffic
- Typically individual users are throttled back to allow economic placement of fibre nodes while meeting the offered quality of service
  - Leading operators now throttling at 8 Mb/s; originally it was much lower
- In response to increasing traffic, operators have the following options:
  - Assign more television channels to cable modem service
  - Split the fibre nodes. There are 2 to 3 subtended coax legs, so give them each their own downstream and upstream bandwidth on the fibre
  - Deploy more fibre nodes closer to the subscribers
  - Deploy DOCSIS-3.0 (described later), which allows bonding of multiple RF channels

3. Cable Modem Evolution

DOCSIS-standard cable modems now dominate over proprietary ones

- DOCSIS: Data Over Cable Service Interface Specification
  - Now managed by CableLabs
  - Focused on cable systems that follow U.S. standards
  - Versions as below

DOCSIS-	Targeted Applications	Main Characteristics
1.0	High-speed Internet access	Modem price decreased from 300 USD in 1998 to below 30 USD in 2004; 3.2 Mb/s upstream
1.1	Voice, gaming, streaming	Quality of service and other features added; 10 Mb/s up-stream; essential for PacketCable (VoIP, etc.)
2.0	Capacity for symmetric services	Upstream increased to 30 Mb/s
3.0	Next generation network	Bond up to 4 channels to deliver 160 Mb/s downstream and 120 Mb/s upstream

- EuroDOCSIS maintains variants applicable to European and other cable systems
  - EuroDOCSIS downstream capacities typically 8/6 of the CableLabs versions due to the increased RF channel width

Source: CableLabs

Thank you for reading this document. We hope you found it useful.

- For further information, or to make comments, please contact us at

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