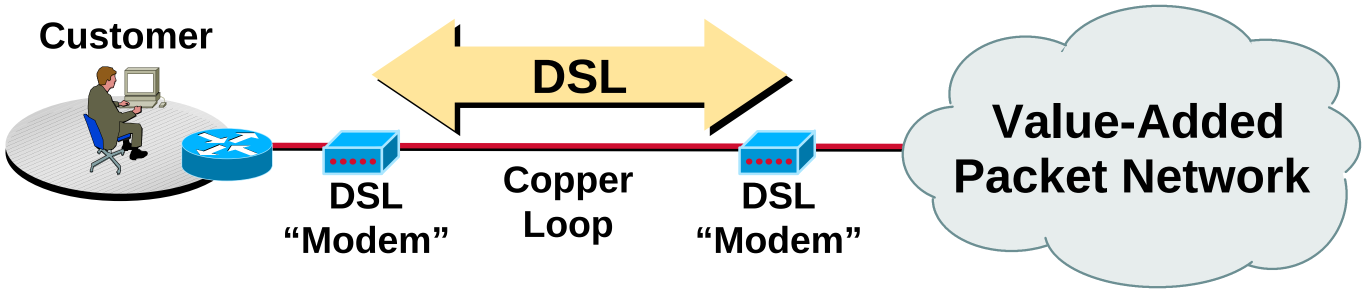
CISC452-00W Telecommunications Systems

Lesson 2
Residential Broadband

Slides courtesy Cisco Systems

Defining DSL: Digital Subscriber Loop



Like dial, cable, wireless, and T1, DSL is a **Transmission Technology,** NOT a full end-to-end solution

Users don't "buy" DSL, they "buy" services, such as high-speed Internet, leased line, VPN, and Video on Demand

DSL Modem Technology

DSL Service	Max. Data Rate Down/Uplink (bps)	Line Coding Technology	Analog Voice Support	Max. Reach (km-feet)
VDSL– Very High Bit Rate DSL	25M/1.6M or 8M/8M	???	Yes	.9–3,000
ADSL–Asymmetric DSL	8M/1M	CAP & DMT	Yes	5.5–18,000
IDSL–ISDN DSL	144K/144K	2B1Q	No	5.5–18,000
SDSL–Symmetric DSL	768K/768K	2B1Q / CAP	No	6.9–22,000
HDSL2– High Bit Rate DSL	1.5M–2.0M/ 1.5M–2.0M	Optis	No	4.6–15,000

Residential

SOHO

Business

Trade-off is Reach vs. Bandwidth

Reach numbers imply “Clean Copper”

Different layer 1 transmission technologies, need a common upper protocol layer to tie them together

RADSL (Rate Adaptive ADSL)

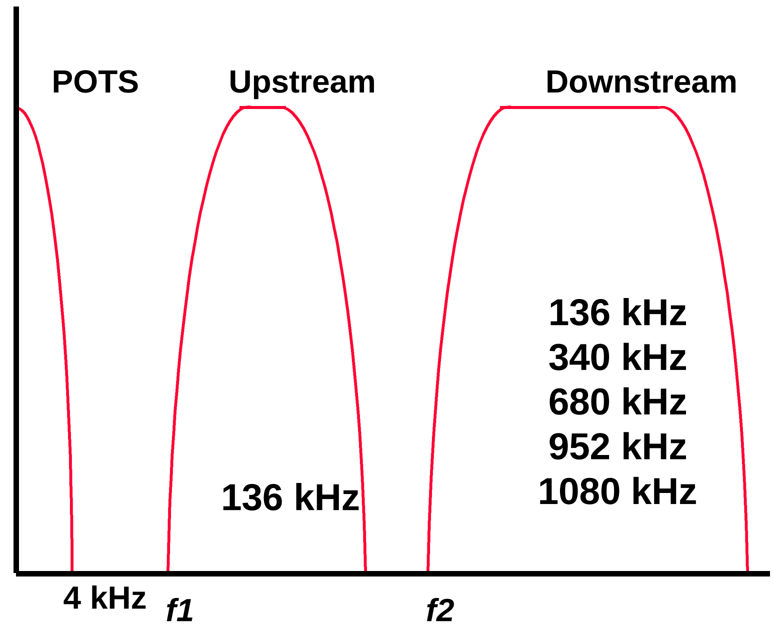
- **Mass deployment technology**
  - **Good Reach**
  - **Preserves Baseband POTS**
  - **Rate adjusts to local loop conditions**
  - **Good Spectral Compatibility**
- **Competing line code variations - CAP, DMT, G.Lite**

Carrierless Amplitude and Phase

One Supplier (GlobeSpan)

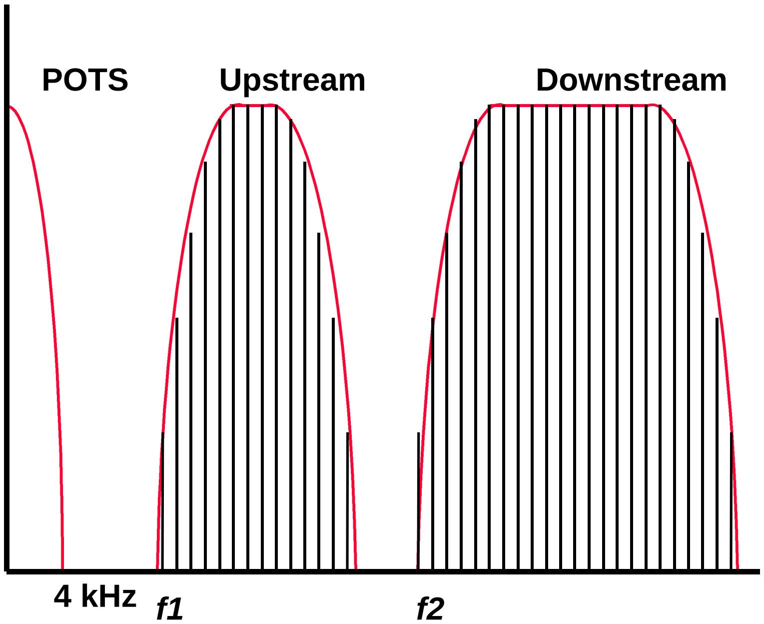
Utilizes CAP encoding within upstream and downstream multiplexed carriers

Rate adapts by modifying #bits/cycle (Constellation size) + Carrier baud rate



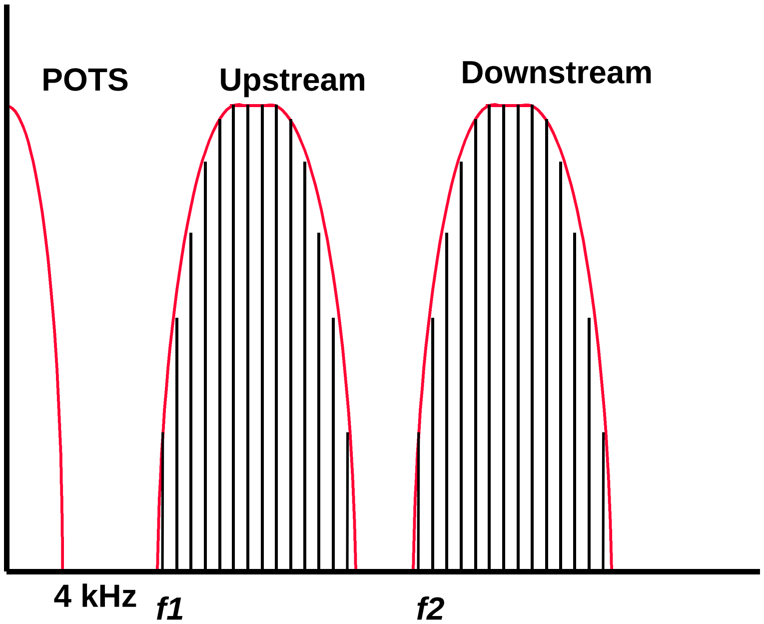
Discrete Multi-Tone

- ANSI T1.413 Standard for ADSL
- Multiple Suppliers
- Utilizes QAM line code within many multiplexed bands or "tones"
- Rate adapts by changing or zeroing-out bits/tone

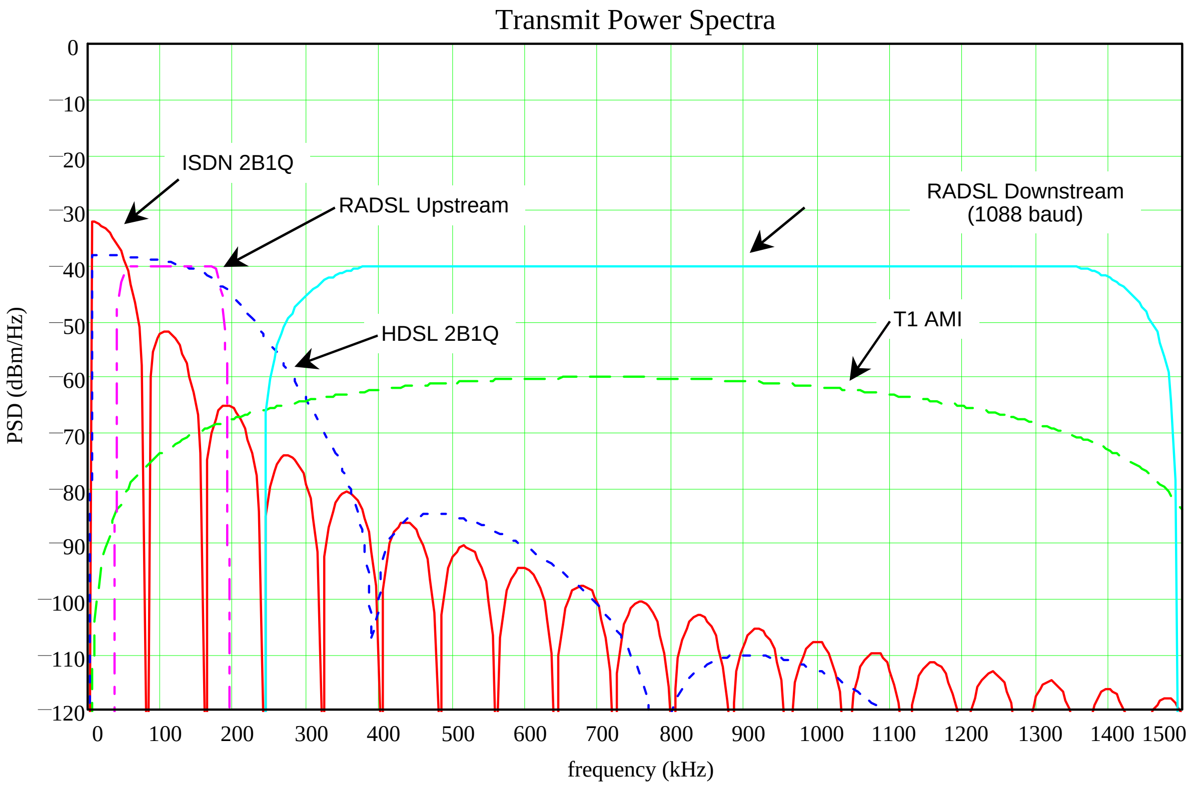


G.Lite

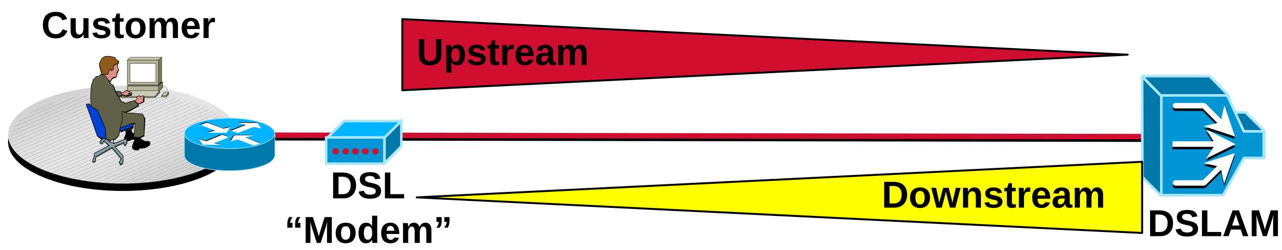
- **Sub-rate (<1.5Mbps), splitterless, consumer-oriented standard**
- **Promoted by UAWG (Intel, Microsoft, Compaq)**
- **Based on DMT standard (lower 128 tones)**
- **Should interoperate with "full-rate" DMT (g.hs used to signal at startup)**
- **Targeted for 1H 1999**



Frequency Spectrum Utilization



Crosstalk

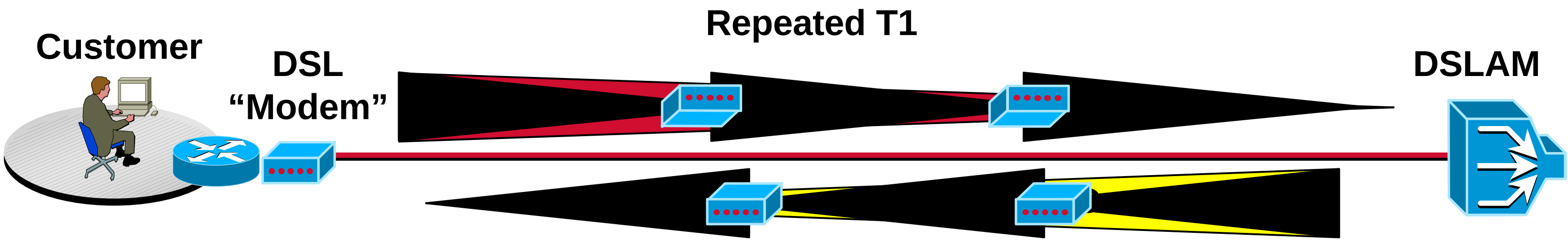


Downstream power is highest at the DSLAM and lowest at the CPE.

Upstream power is lowest at the DSLAM and highest at the CPE.

If these signals are in different frequency spectrums then they will not crosstalk, otherwise there will be interference from one signal to the other.

Crosstalk - ADSL and T1



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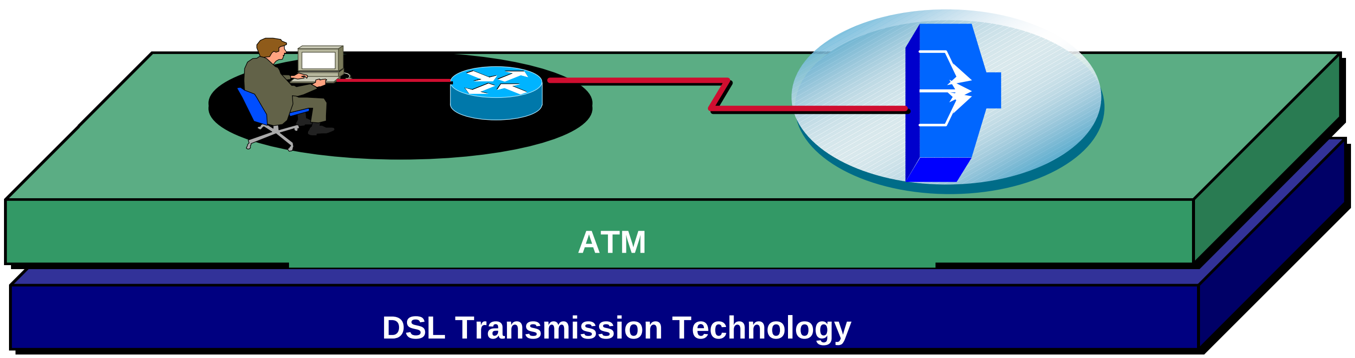
ATM over xDSL

Multiple connection multiplexing

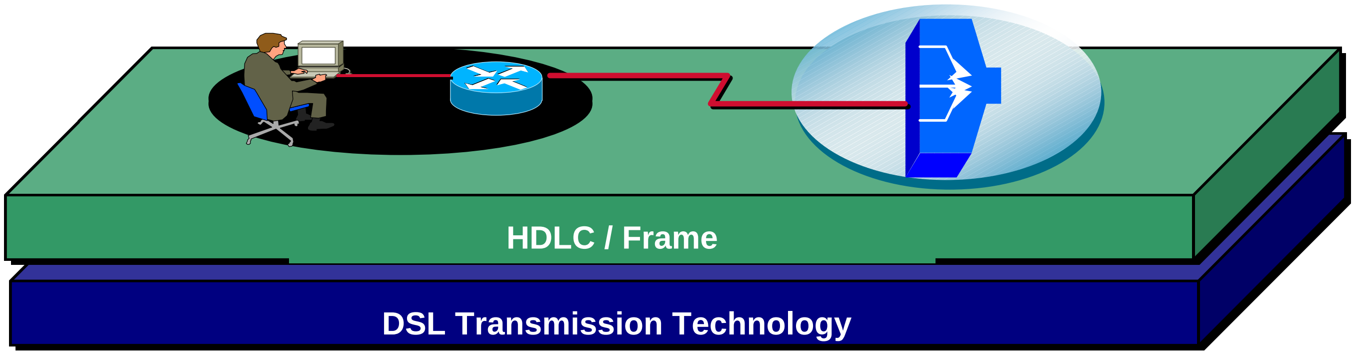
Built in QoS / CoS for newer services



IDSL

Legacy CPE requires that the access link use HDLC or Frame links.

ITU-C on DSLAM will interwork from Frame to ATM



ADSL Terminology

ATU-C: ADSL Transmission Unit, Central

- The ADSL point of termination in the central office
- An ADSL modem

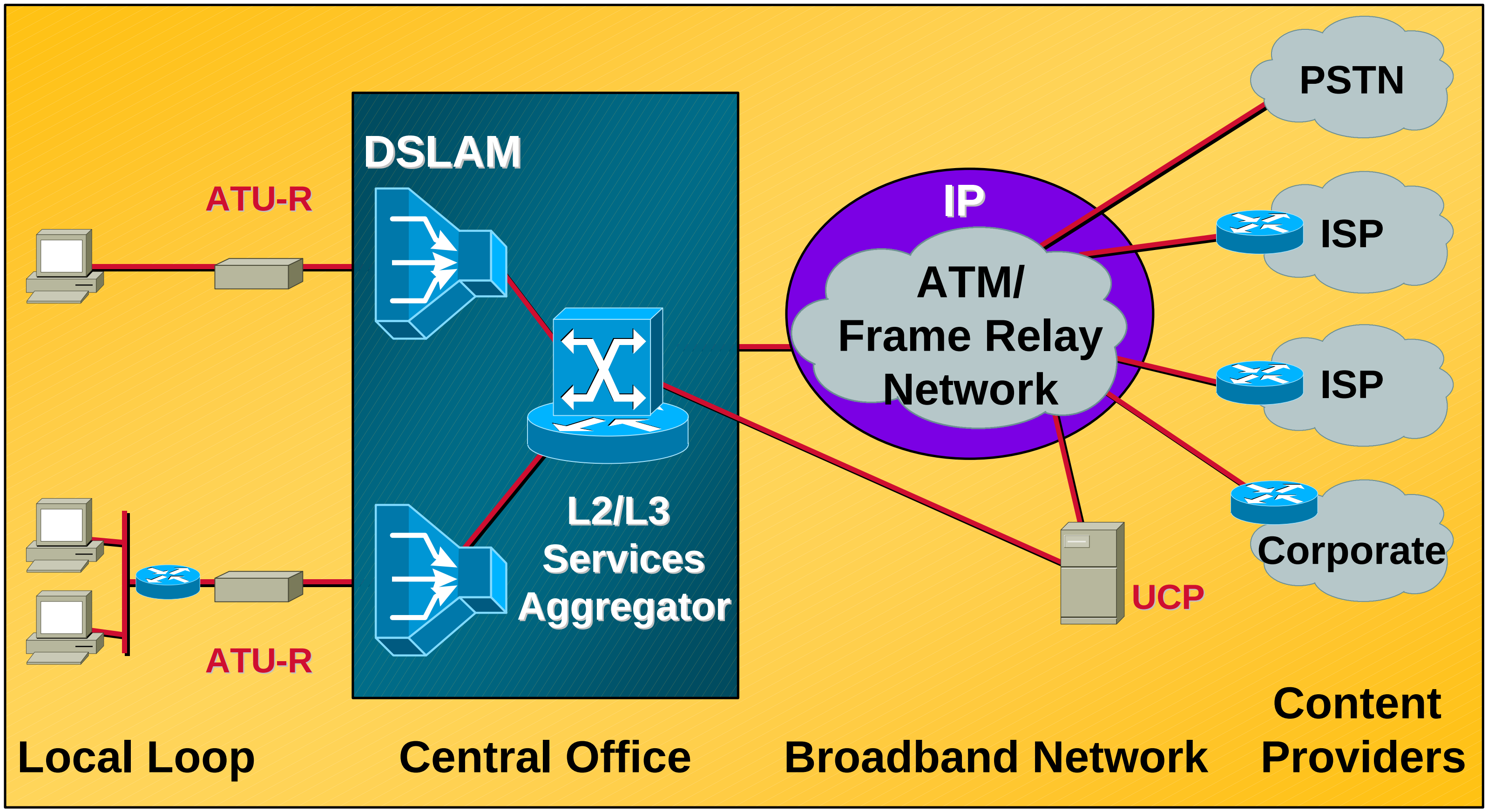
ATU-R: ADSL Transmission Unit, Remote

- The remote user's ADSL modem
- The CPE

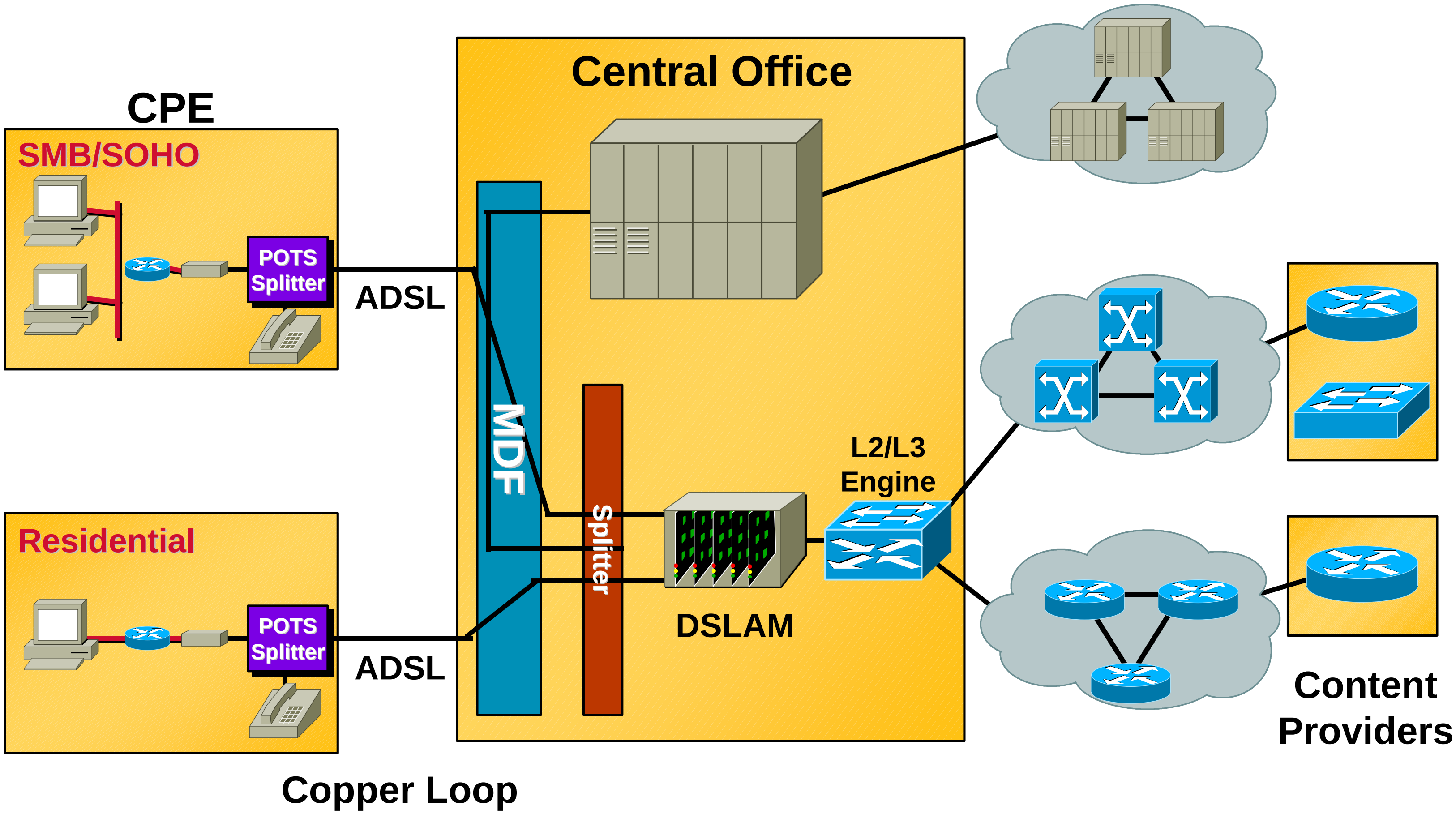
DSLAM: DSL Access Multiplexer

- Central office device that concentrates many ADSL connections into one
- DSLAM contains ATU-Cs

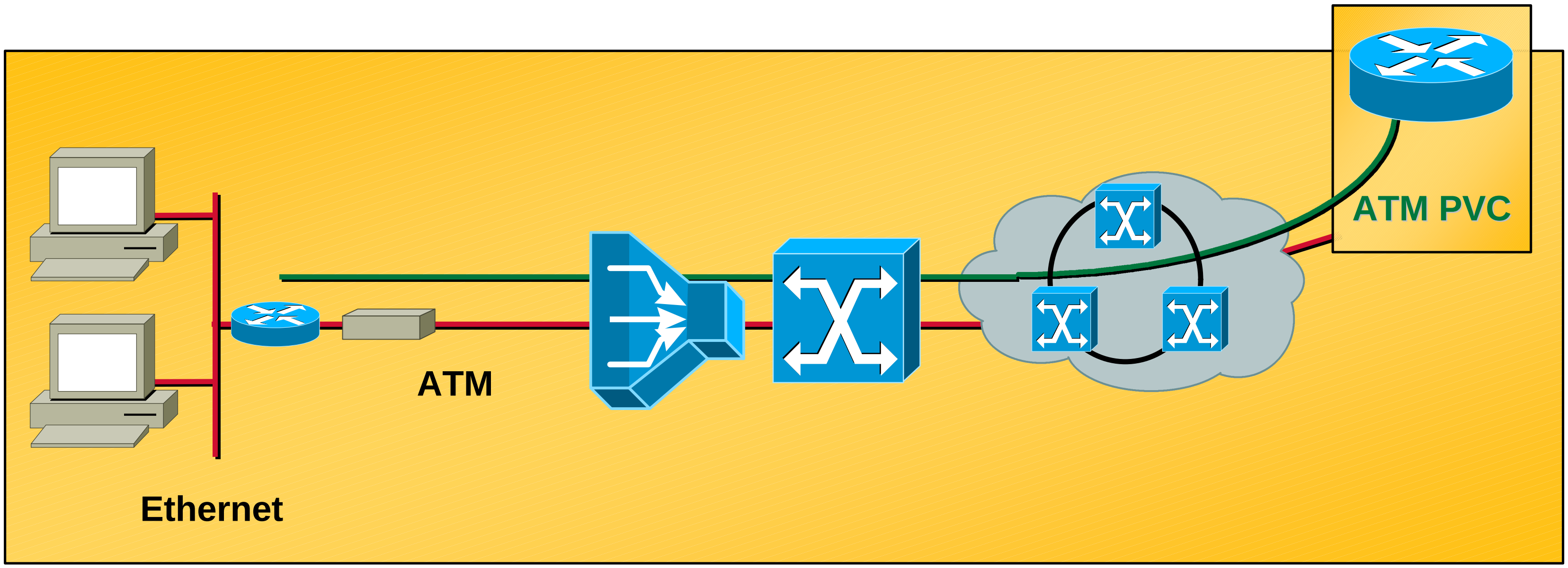
End-to-End ADSL Architecture



ADSL—Data Bypass



“Classic” VPN ATM-to-ATM Solution



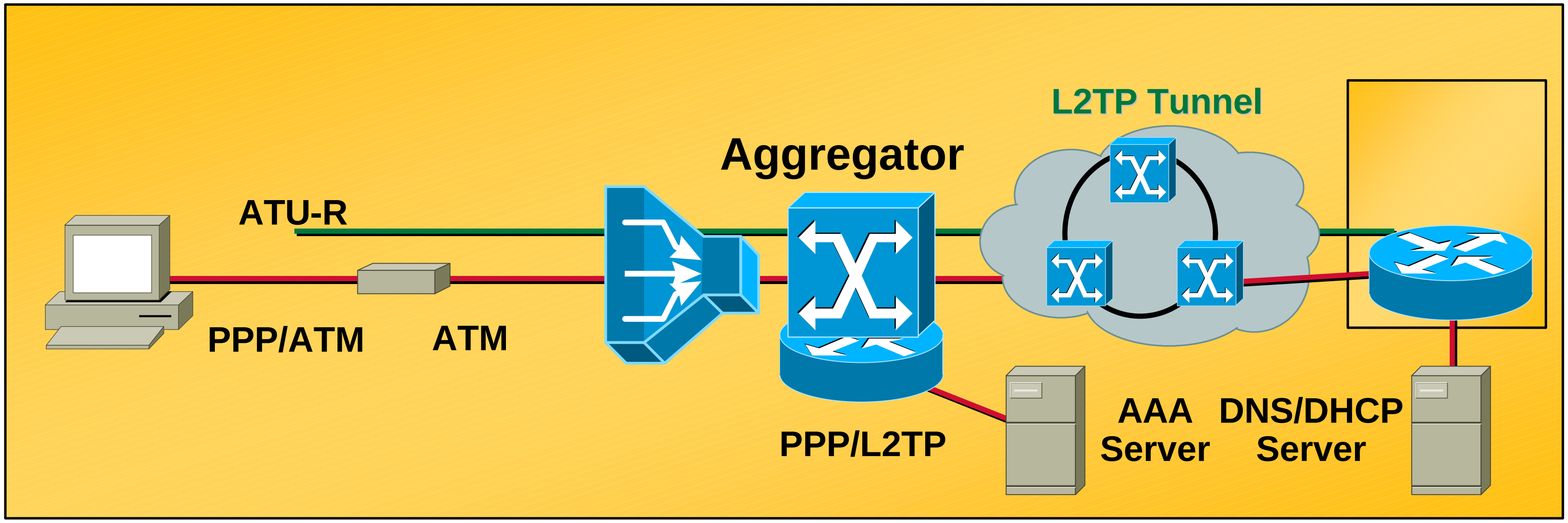
Protocol Transparency

VC between CPE router and ISP central router

Multiple QoS classes and guaranteed levels of QoS

IP services mapped over ATM

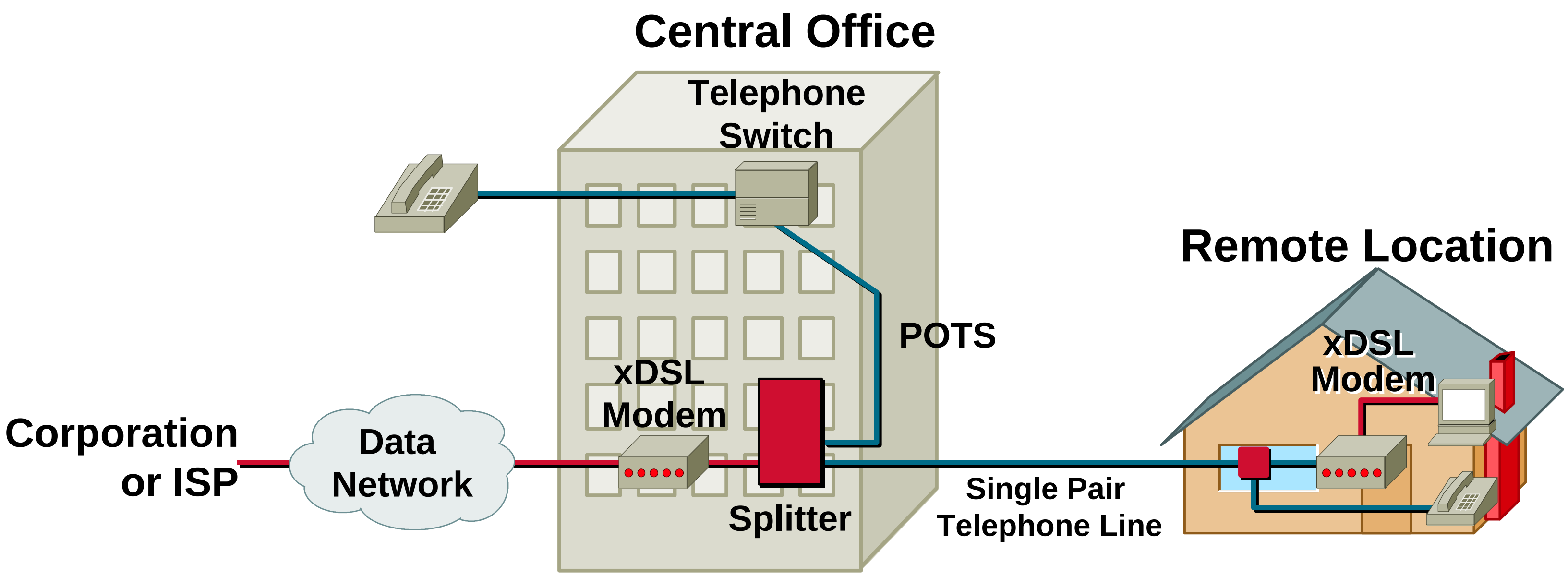
PPP over ATM over ADSL with L2TP Tunnel



Essential operational functions can be delivered using well established features in PPP/L2TP, such as:

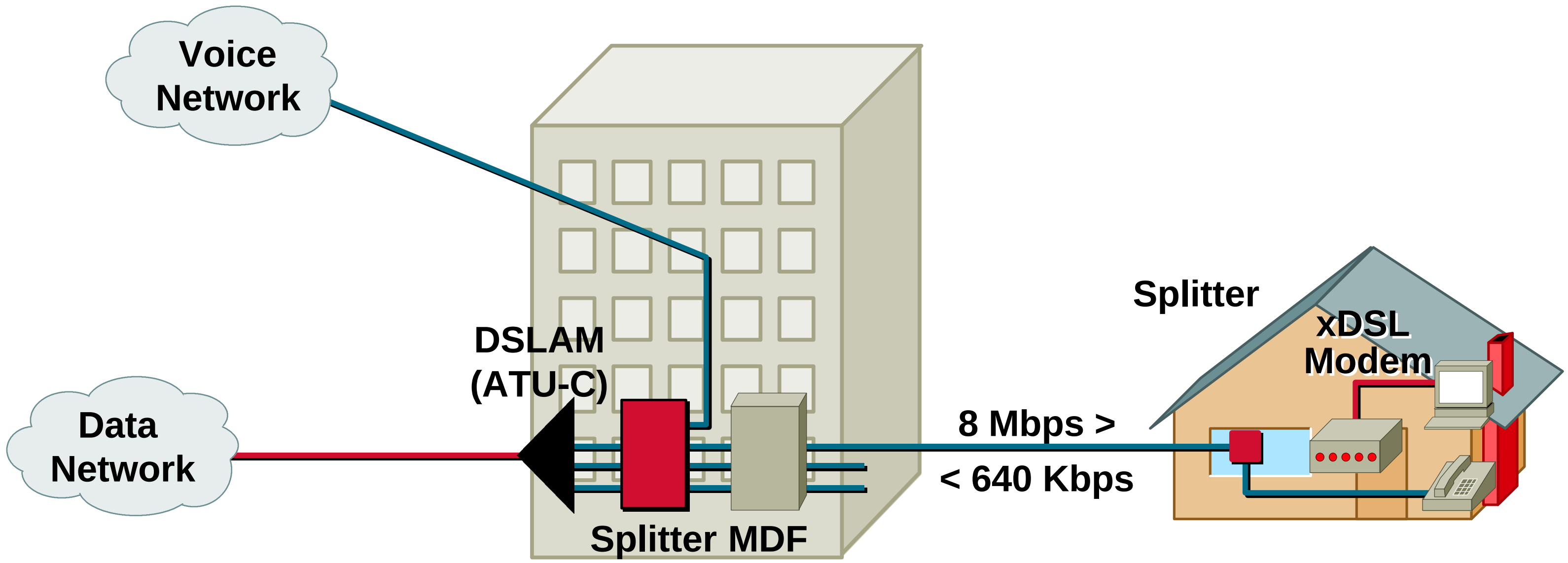
- Authentication (PAP, CHAP, etc.)
- Address Administration done at the service provider gateway
- Layer 3 autoconfig (DHCP, DNS, etc.)
- Dynamic Selection of Multiple Destinations (via multiple PPP Sessions)
- Encryption

Generic xDSL Implementation



An Access Solution: Connects Remote User to Central Office as a Dedicated Circuit

ADSL



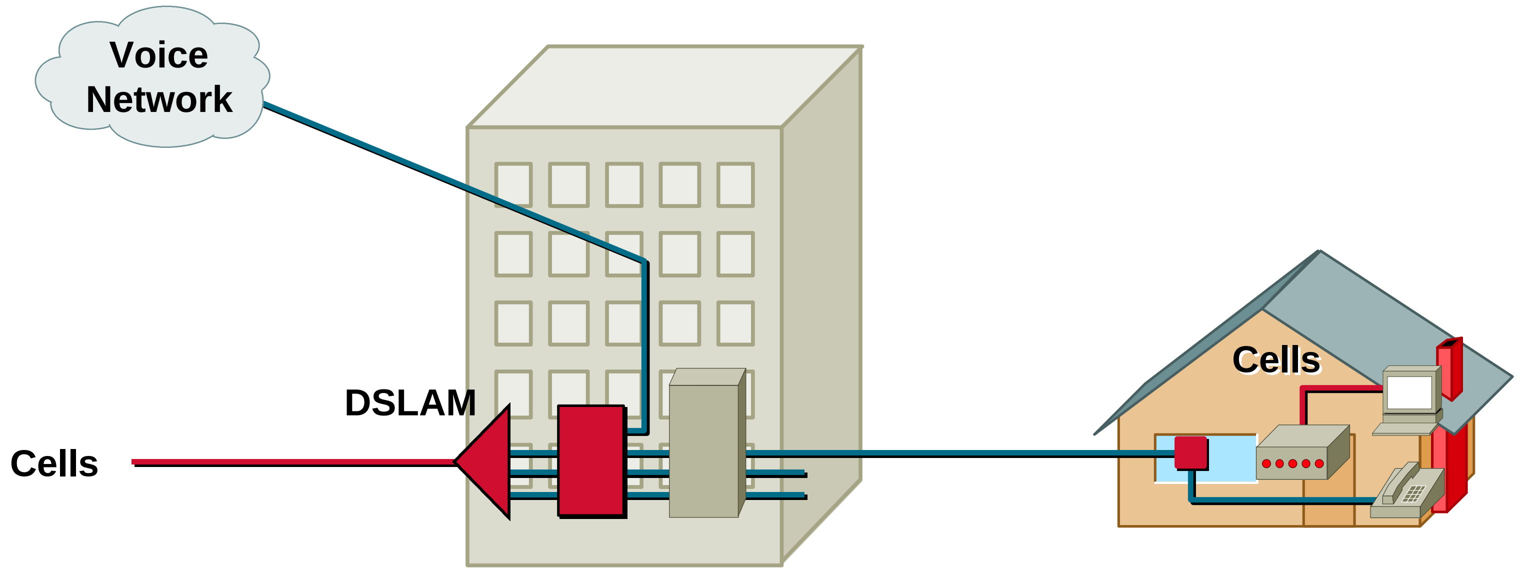
Advantages

- Date rate
- Uses in-place copper loops
- POTS on same line
- Reduces load on C.O. switch
- Emerging as the standard

Disadvantages

- Expensive modems, today
- Speed/distance trade-off

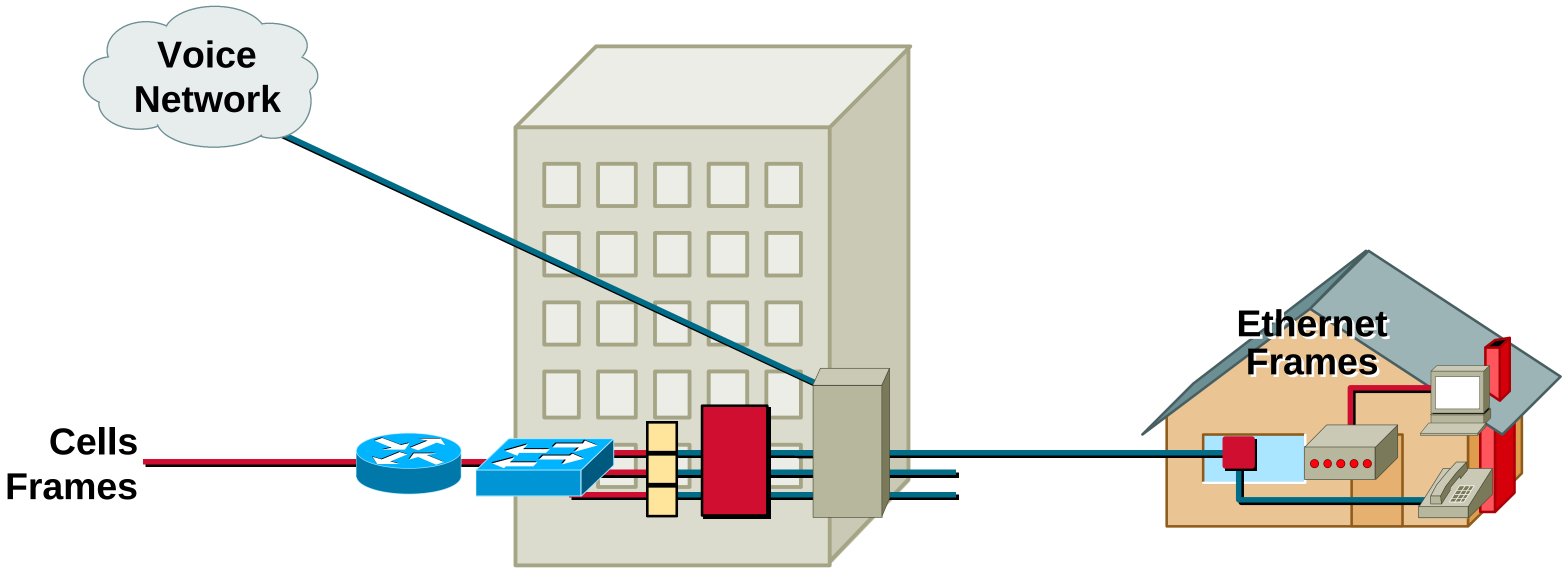
Connectivity, ADSL



The ADSL Reference Model

- DMT modems and a dumb DSLAM
- Ethernet or ATM25 to the desktop
- Cells to the CPE
- Cells to the backhaul network
- 1577 IP over ATM

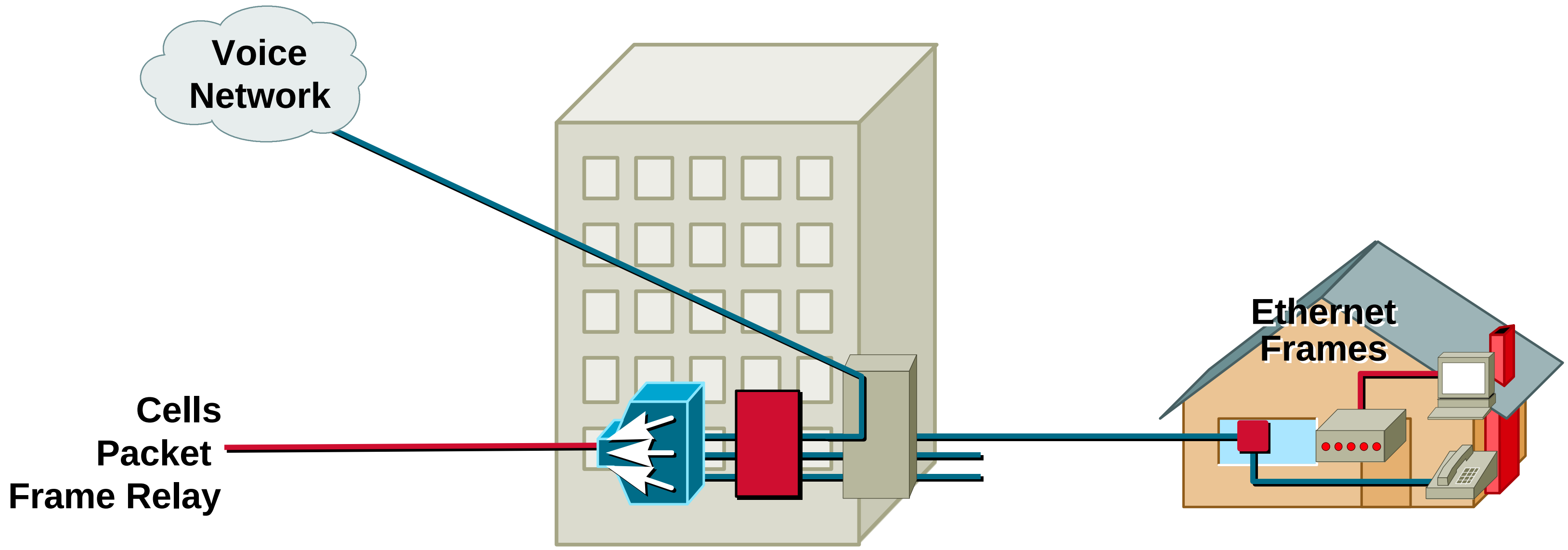
Connectivity, ADSL



Today's Reality

- Standalone ATU-Cs (modems)
- Switches and/or routers for aggregation
- Bridged Ethernet to the desktop
- 1483 encapsulation
- One PVC per user to the backhaul network

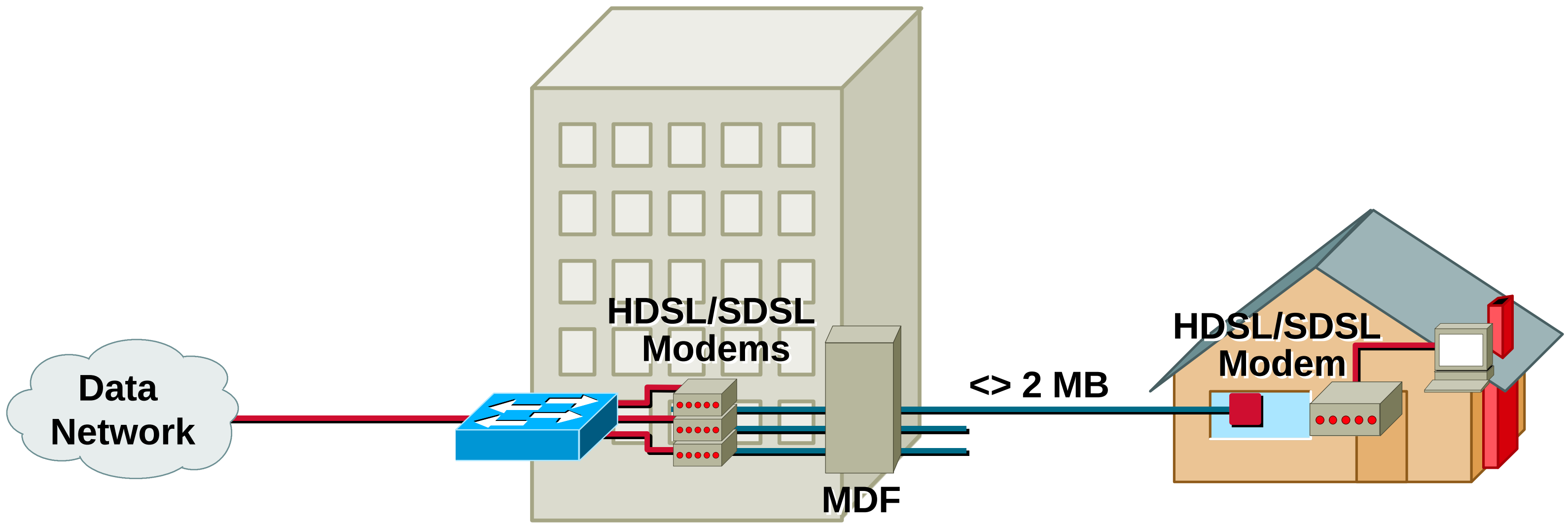
Connectivity, ADSL



What It will Evolve to

- Ethernet frames or cells to the desktop
- 1483, PPP over ATM, or 1577 connectivity
- Cell, Frame Relay, or packet backhaul
- Traffic shaping, per user
- Layer 3 service in the C.O.

HDSL/SDSL



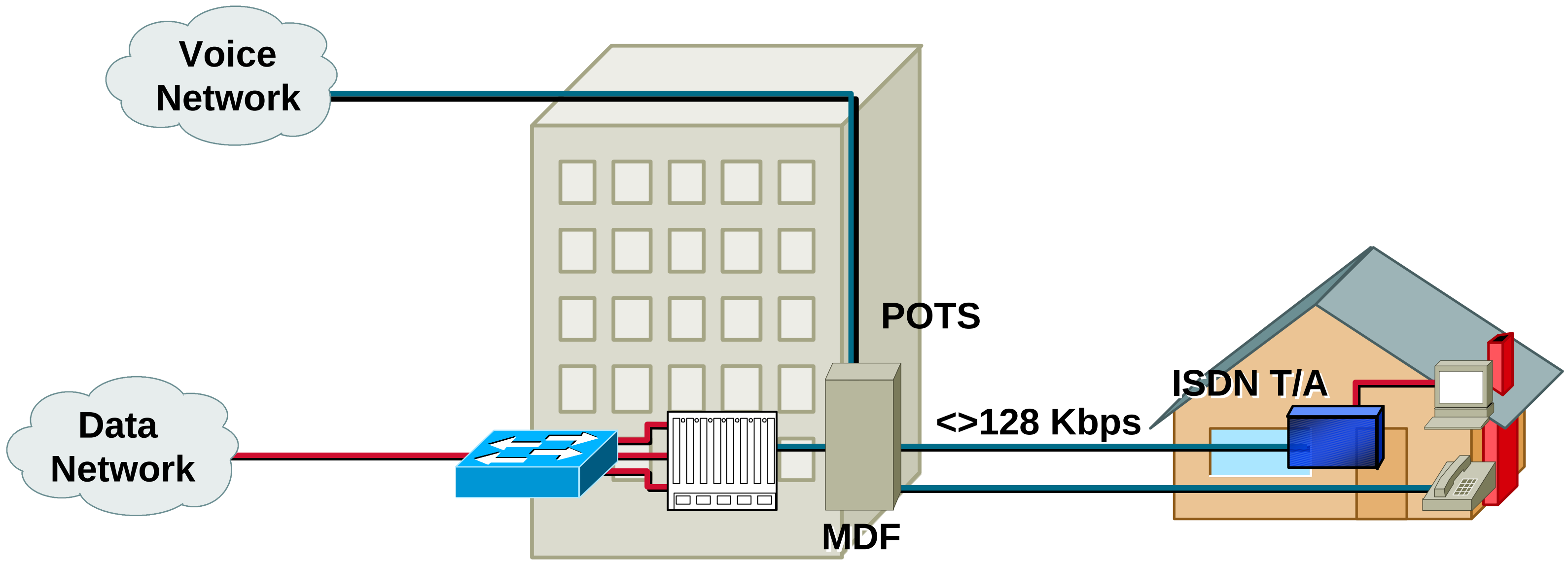
Advantages

- Proven technology
- Uses in-place copper loops
- Reduces load on C.O. switch

Disadvantages

- Two MB maximum data rate
- POTS requires second line
- Few vendor choices

IDSL



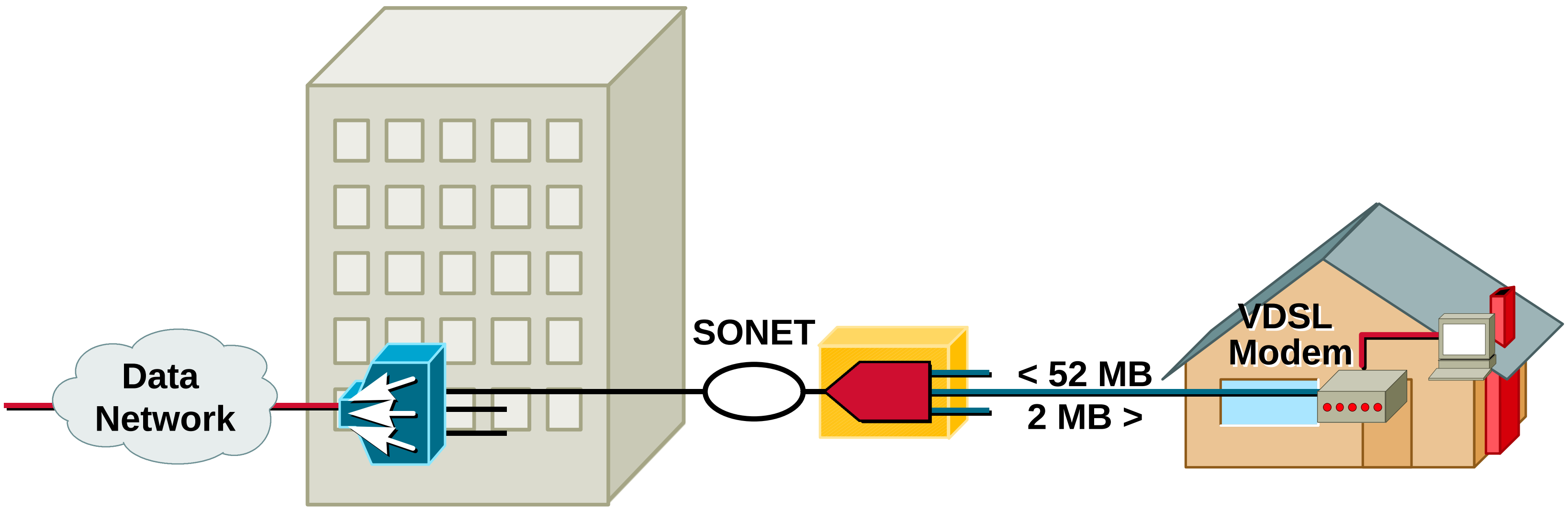
Advantages

- Reduces load on C.O. switch
- Uses standard ISDN equipment
- Inexpensive to deploy

Disadvantages

- Limited data rate
- Second line for POTS

VDSL



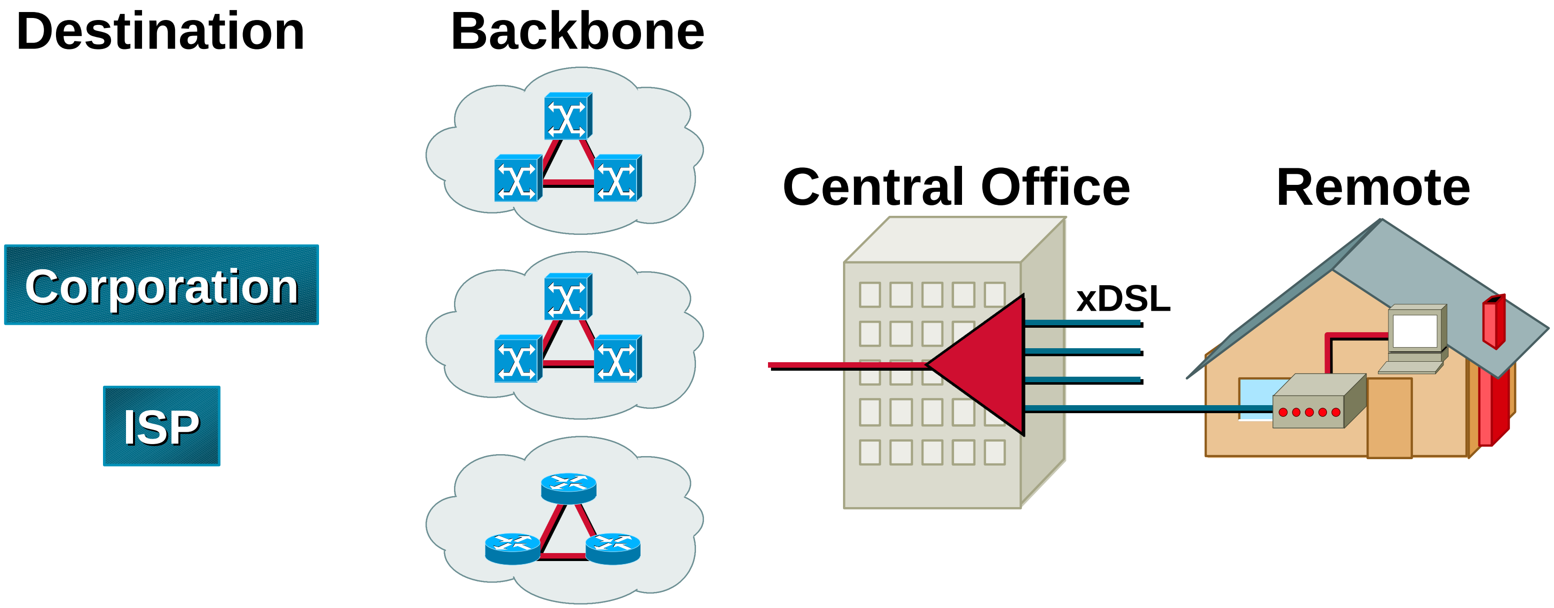
Advantages

- Enormous data rate
- Uses in-place copper loops
- Avoids C.O. switch

Disadvantages

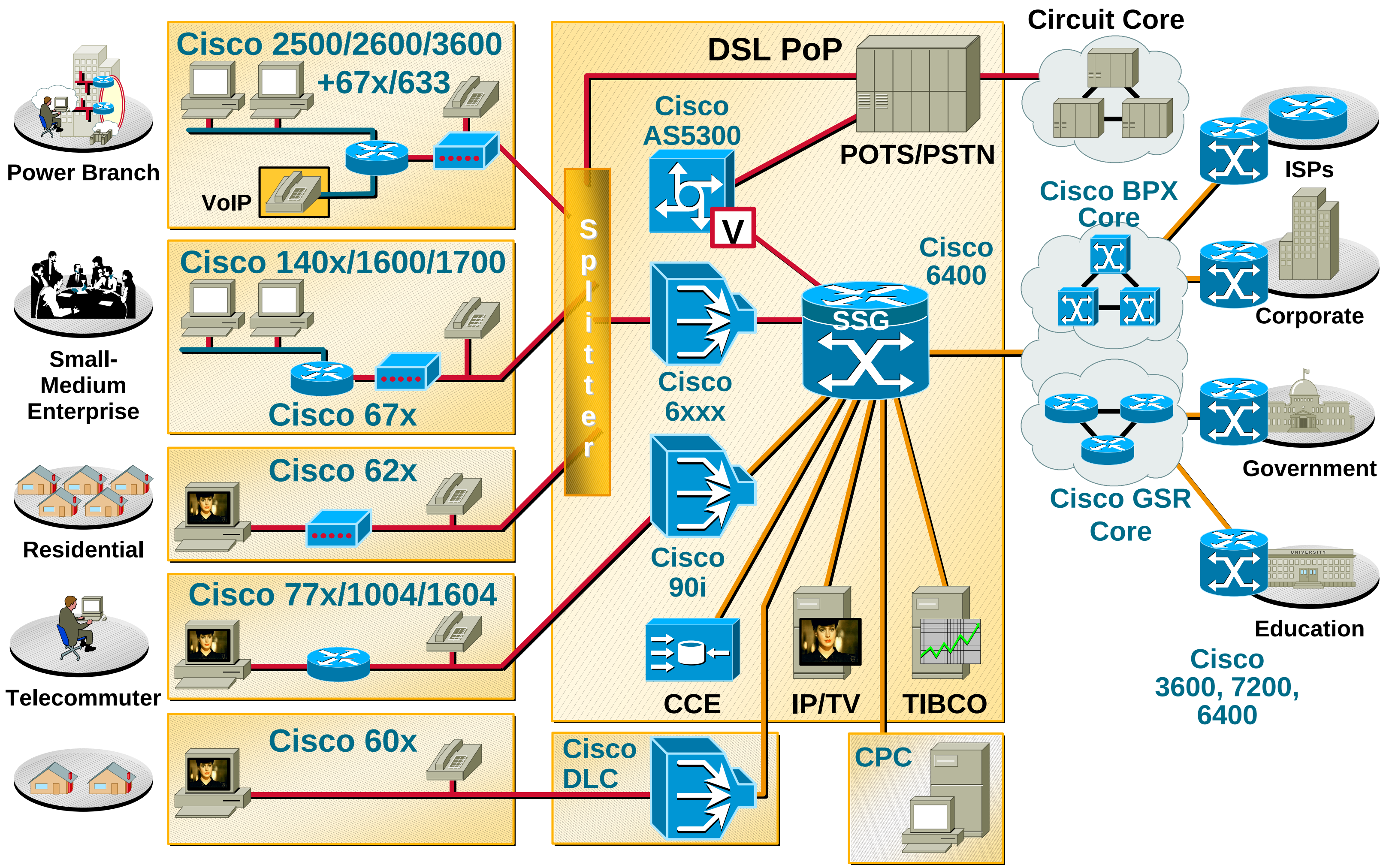
- No standards
- Limited ongoing development
- Unavailable
- Short distance limit

Connection Variables



- **Network service definition has significant effect on data connection**
  - How many destinations? 1 or N?
  - Simple connectivity or value-added service?
  - Cells to the user or frames?
  - Flat-rate billing or usage based?

Building End-to-End Networks and Services



The Future for xDSL

How many systems will be upgraded to DSL for POTS service?

How many Loops qualify?

How popular will competing technologies become?

How will ISP's price higher Internet services?

Is there a market for access networks that can provide multiple services?

Cable Network

Pre World War II

The concept of television is born!

Competing and divergent views on implementation methods promoted by several sources

Cable Network

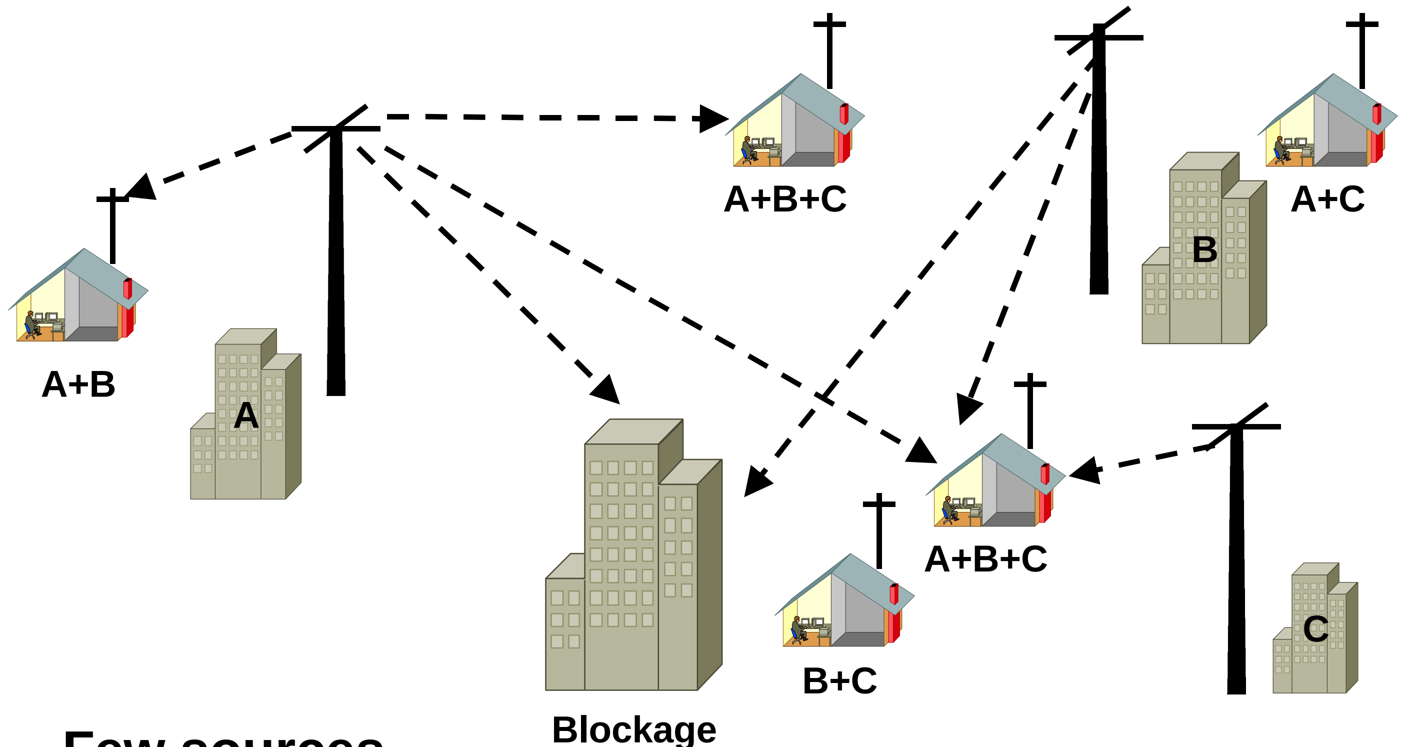
Post World War II

Television becomes a reality!

Television transmitters established:

- Limited content
- Few broadcast sources
- Limited urban coverage, or near rural transmitters

Cable Network



Few sources

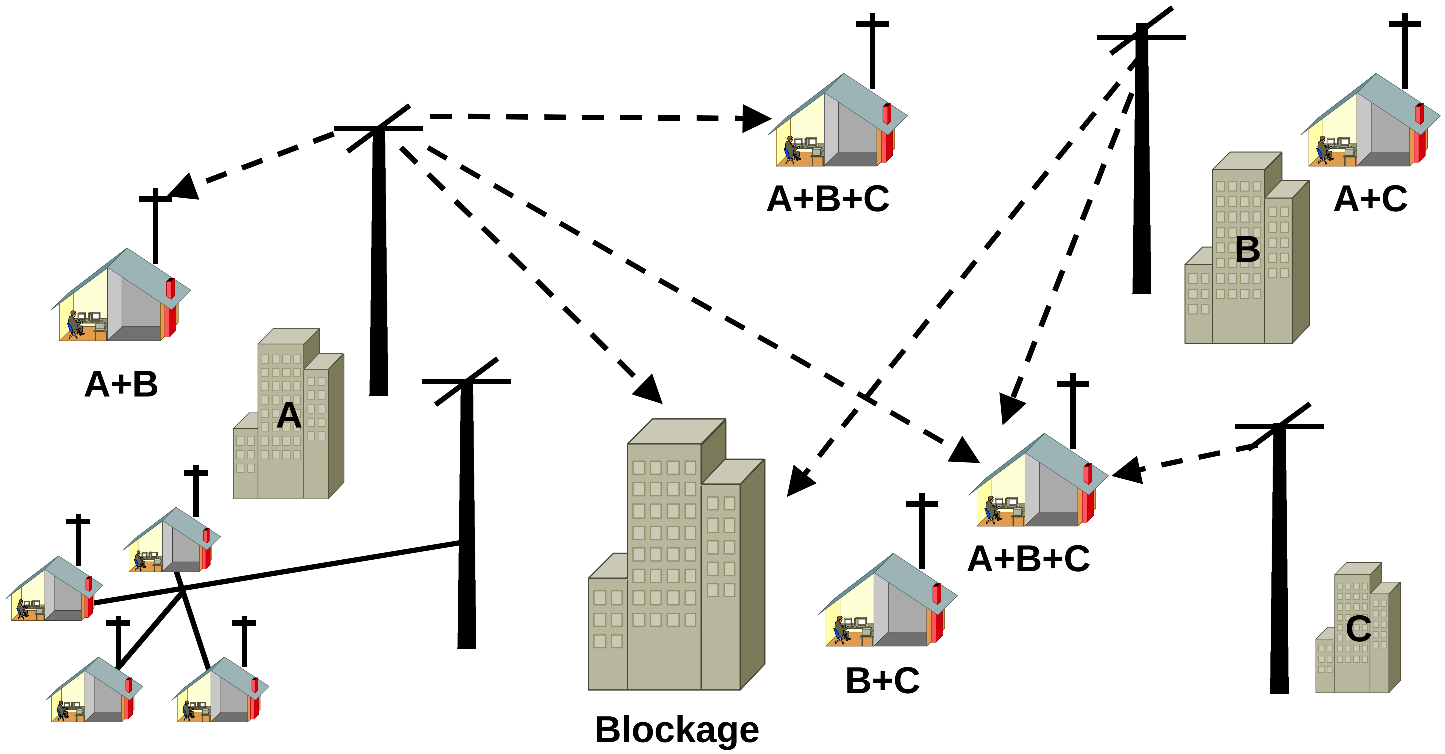
Limited content

Limited reach

Signal blockage

= **Excellent to Poor Picture Quality Reception**

Cable Network



The Community Antenna circa 1948

Few sources

Limited content

= **Excellent to Poor Picture Quality Reception**

Cable Network

Introduction of the Community Antenna!

Makes video available to many

Improves signal quality

Extended coverage through amplification

Amplification has range limitations because of excessive noise

Cable Network

CATV as we know it is born:

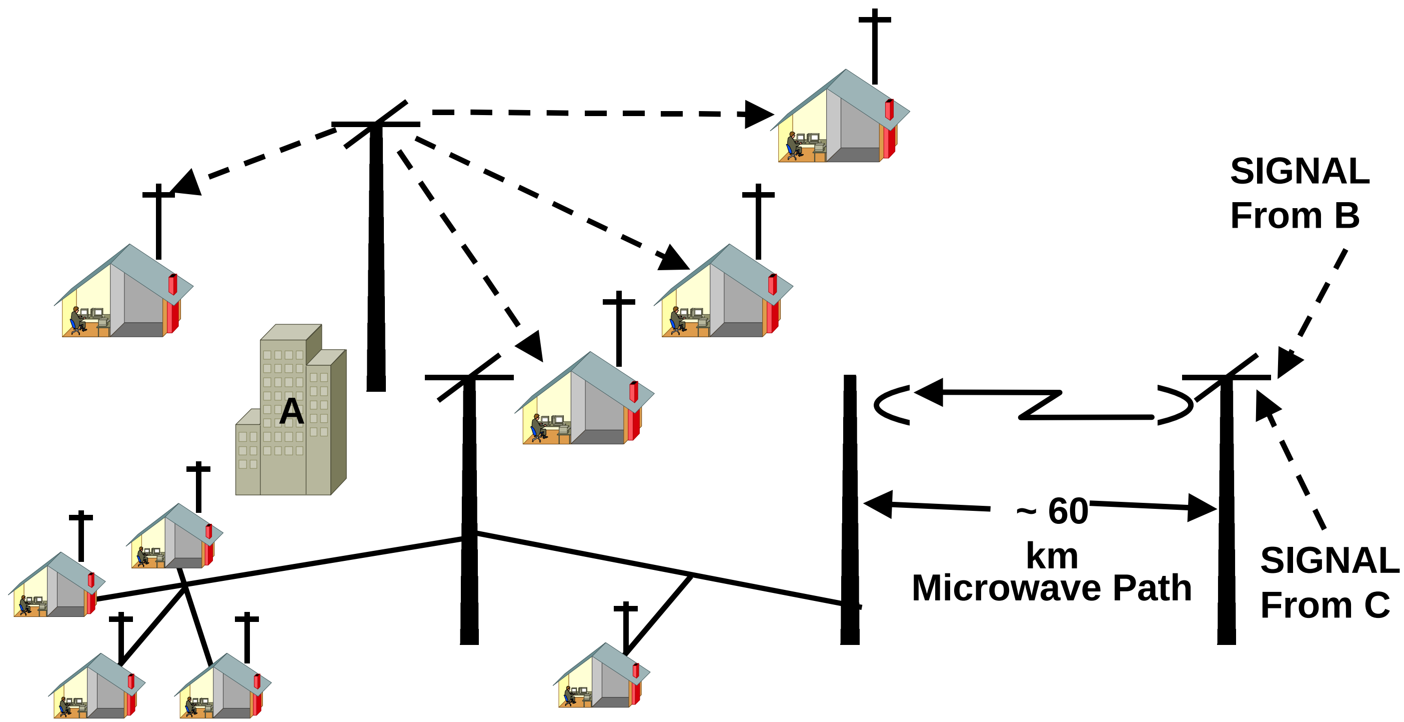
- One way broadcast signal distribution
- Signal amplification over coaxial cable
- Amplifiers powered through coaxial cable plant
- Range limitation because of noise build up

But!

- Limited content:
  - Current affairs and panel discussions
  - Little entertainment
- Reduced broadcast hours
- Few broadcast/content sources
- Frequent outages

Cable networking advances

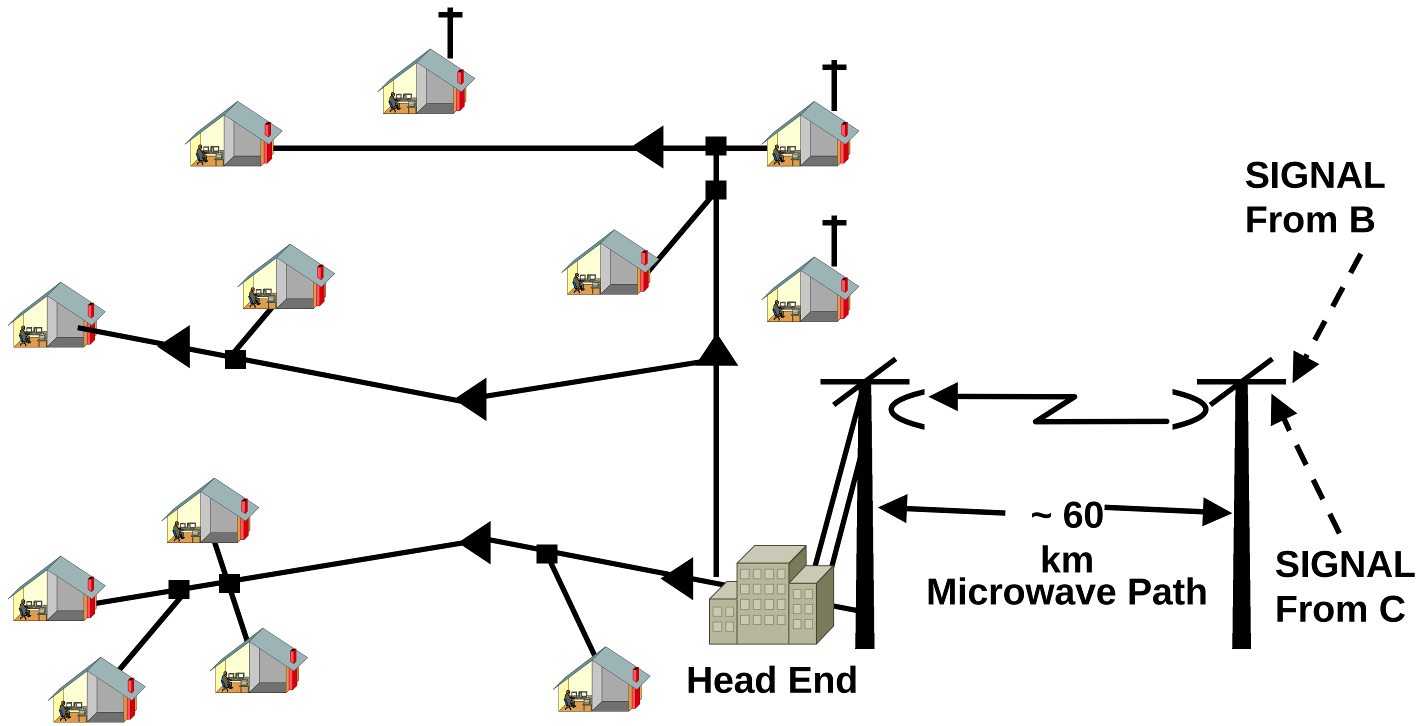
Cable Network



Microwave + The Community Antenna

Microwave Broadens the Distribution Range of Quality Video Reception to a Larger Subscriber Population

Cable Network



(Basic Networking into the 1990's)

Amplifiers Extend Distribution

Signals Distributed to Subscriber Via Tap ■ and Drop Cable

Cable Network

Cable Networking Standards Evolve:

- Based on available vendor product and cost:
  - Diameter and quality of Coaxial Cable
  - Bandwidth specification on amplifiers
  - Power distribution products
  - Set Top devices
- Standards primarily defined channel capacity:
  - Initially 16 channels, followed by:
    - 32 channel systems
    - 64 channel systems
- Limited quality control, faults often identified by customer call

Cable Network

Limited Content and Signal Sources Available:

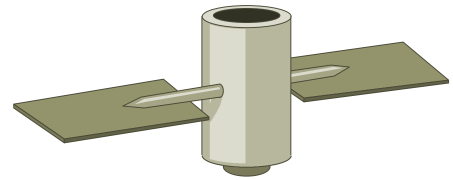
Content sourced from:

- Local “OFF AIR” pickup
- Remote “OFF AIR” pickup with microwave back haul
- Film and tape
- Emerging local content as mandated by FRANCHISE terms:
  - Local affairs, educational etc.…

Consequently:

- 16 or 32 channel systems are considered adequate
- Systems were “LOCAL”, limited to regional FRANCHISE
- “Owned and Operated” by local entrepreneur

Cable Network



Satellite transmission emerges:

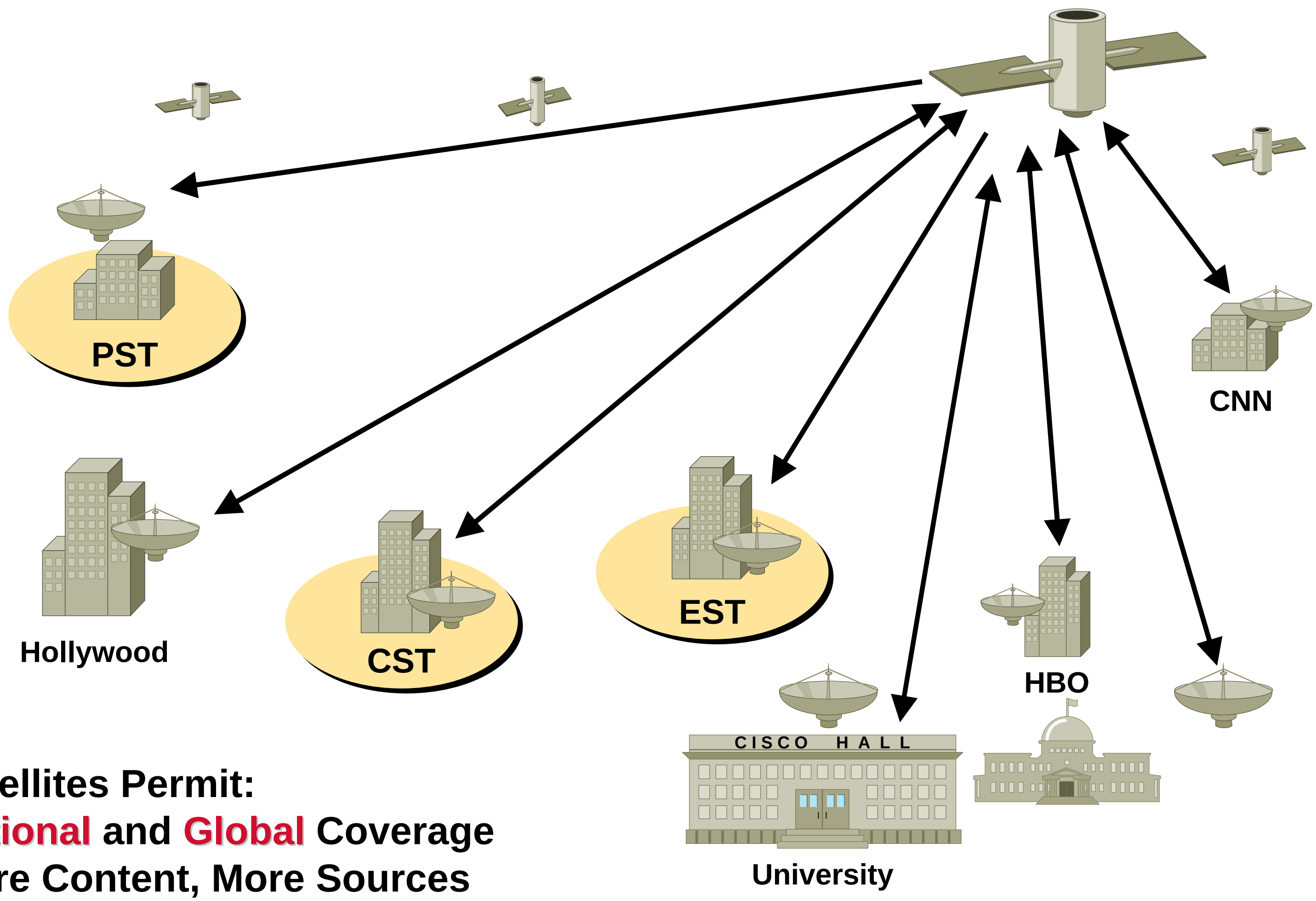
- New content becomes available
- National coverage by a single source is now possible
- A national market develops for content producers
- A “CORNUCOPIA” of content offered to the market

Resulting in:

- New customer demand for content (HBO, CNN, ESPN, International)
- New marketing concepts e.g.., “Pay Per View” , “Premium channels”
- Market DEMAND compels CATV operators to:
  - Increase system capacity
  - Improve service quality
  - Invest heavily in their networks, or “Cash In” and sell out to stronger players…

The MSO Emerges

Cable Network



Satellites Permit:
National and Global Coverage
More Content, More Sources

Cable Network

Growth Caused By Increased Traffic, Content and Market Demand

Results in:

- Industry consolidation
  - Expansion of MSO holdings

TCI	14 M basic subscribers
TIME WARNER CABLE	7 M basic subscribers
MEDIA ONE	5 M basic subscribers

- System clustering (property exchanges)

Cable Network

Upgrading the Cable Network:

To meet customer
service expectations

To increase capacity

Defend against loss of market share

To support new services
and revenue growth

Cable Network

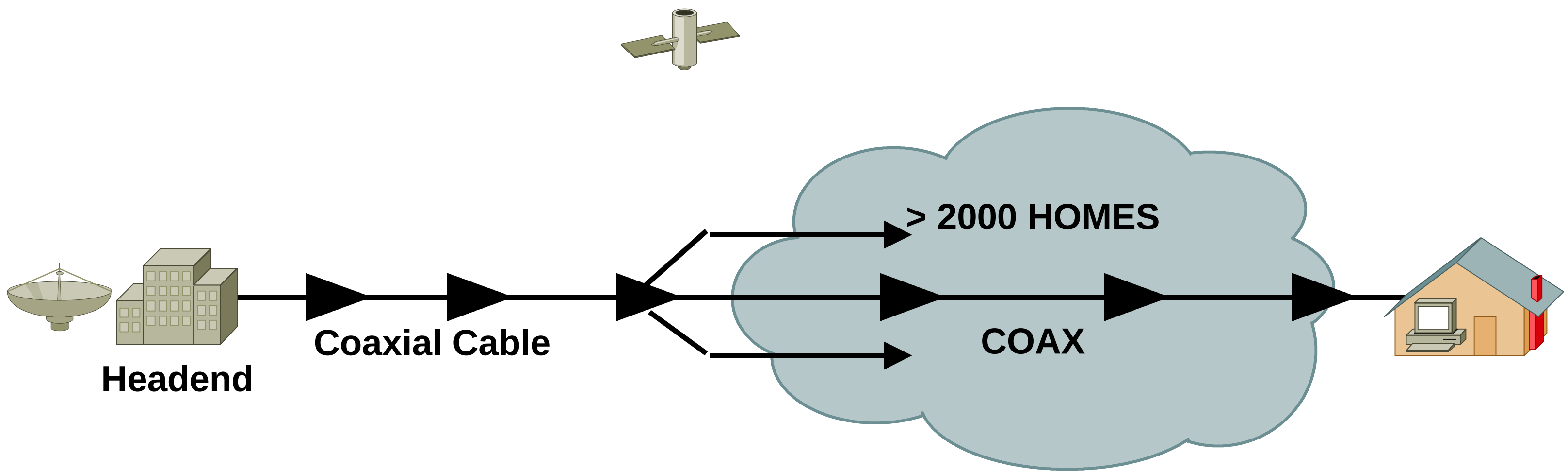
Upgrading the Cable Network:

Introduce Fiber Optics technology to the network

- Improve signal quality
- Reduce maintenance effort and cost
- Remove bandwidth constraints
- Reduce operating cost
- Reduce the number of failure elements

HFC (Hybrid Fiber Coax) Is the Result !

Cable Network

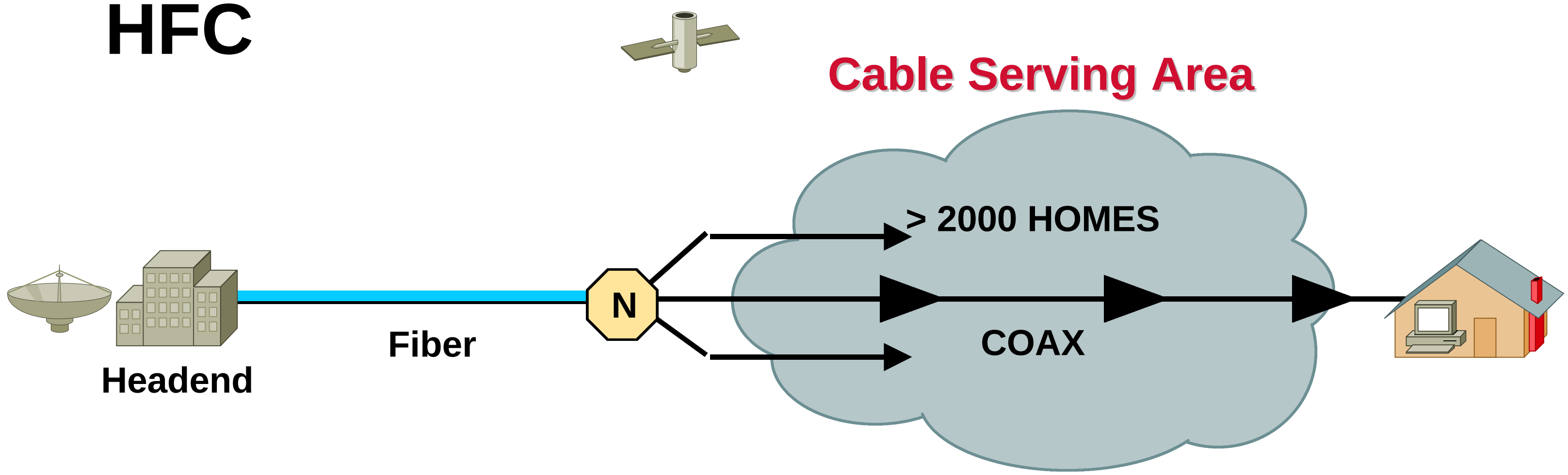


Bypass and eliminate coaxial cable and amplifiers from a portion of the downstream path and replace the link with fiber

Make ready for two way operation!

Cable Network

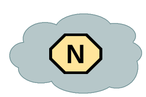
HFC



Typically Fewer than **Five** Amplifiers in Cascade

The video signal is transmitted over fiber to the node, where it is converted to an electrical signal and forwarded to the subscriber over existing coaxial cable

Provision is made to support return traffic for future services

NODE 

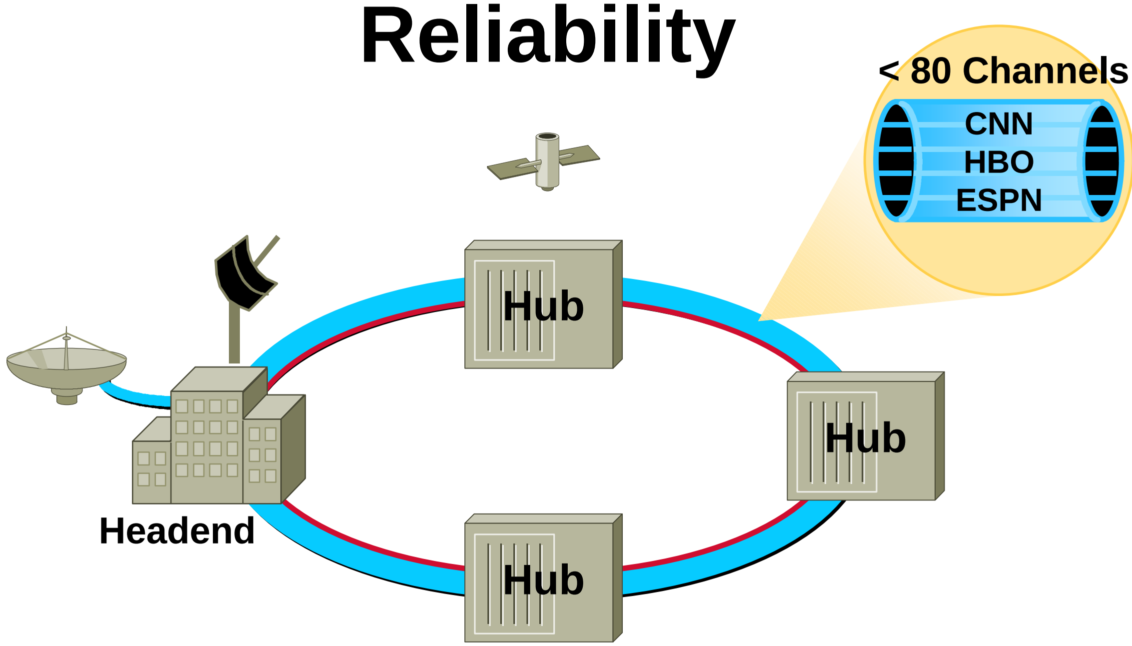
Cable Network

Cable Plants Are Upgraded for:

- Improved reliability
- Smaller serving area
- Increased bandwidth
- Increased availability
- Improved “end-to-end” signal quality
- Advanced network management
- Two way operation
- Platform for advanced services

Cable Network

Reliability



RING architecture

Analog fiber RING for broadcast video

Headend/hub to improve reliability

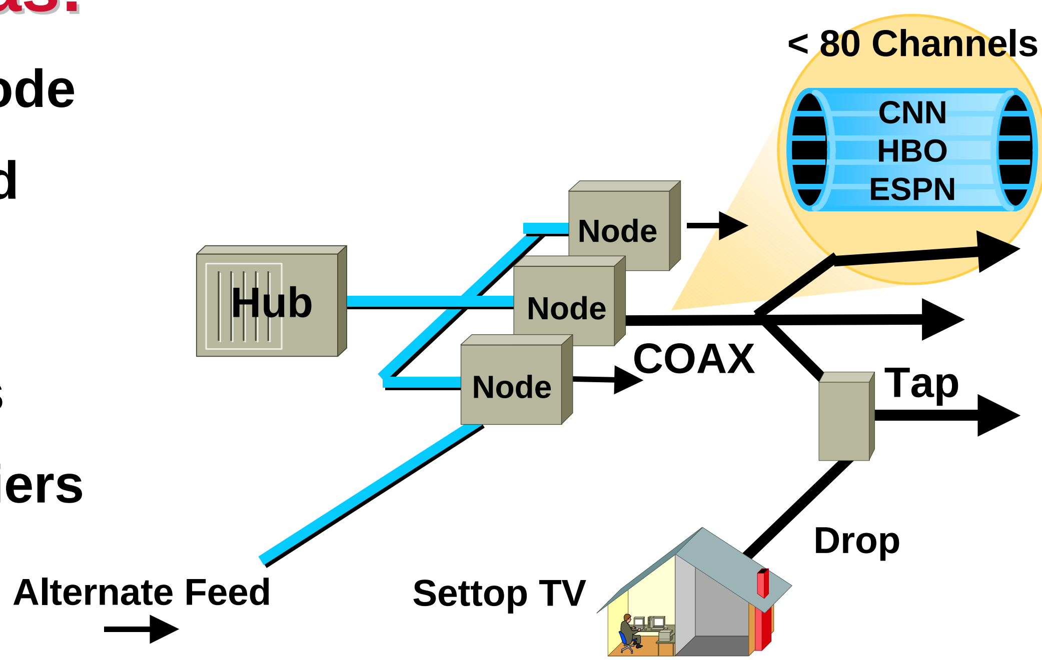
SONET/SDH RING overlay for reliability of advanced services

Cable Network

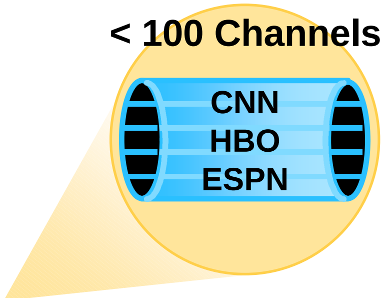
Reliability, Increased Access Bandwidth

Smaller, robust serving areas:

- HFC to the node
- Alternate feed to the node
- Target nodes of 500 homes
- Fewer amplifiers



Cable Network



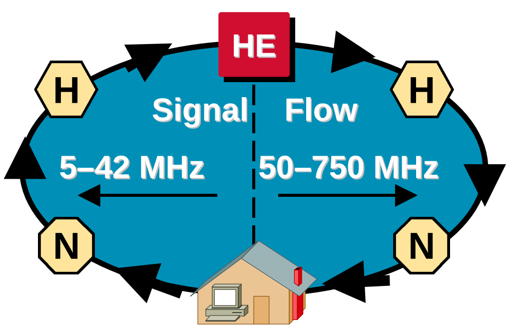
Increased bandwidth:

Downstream “rebuilds” to 750 MHz

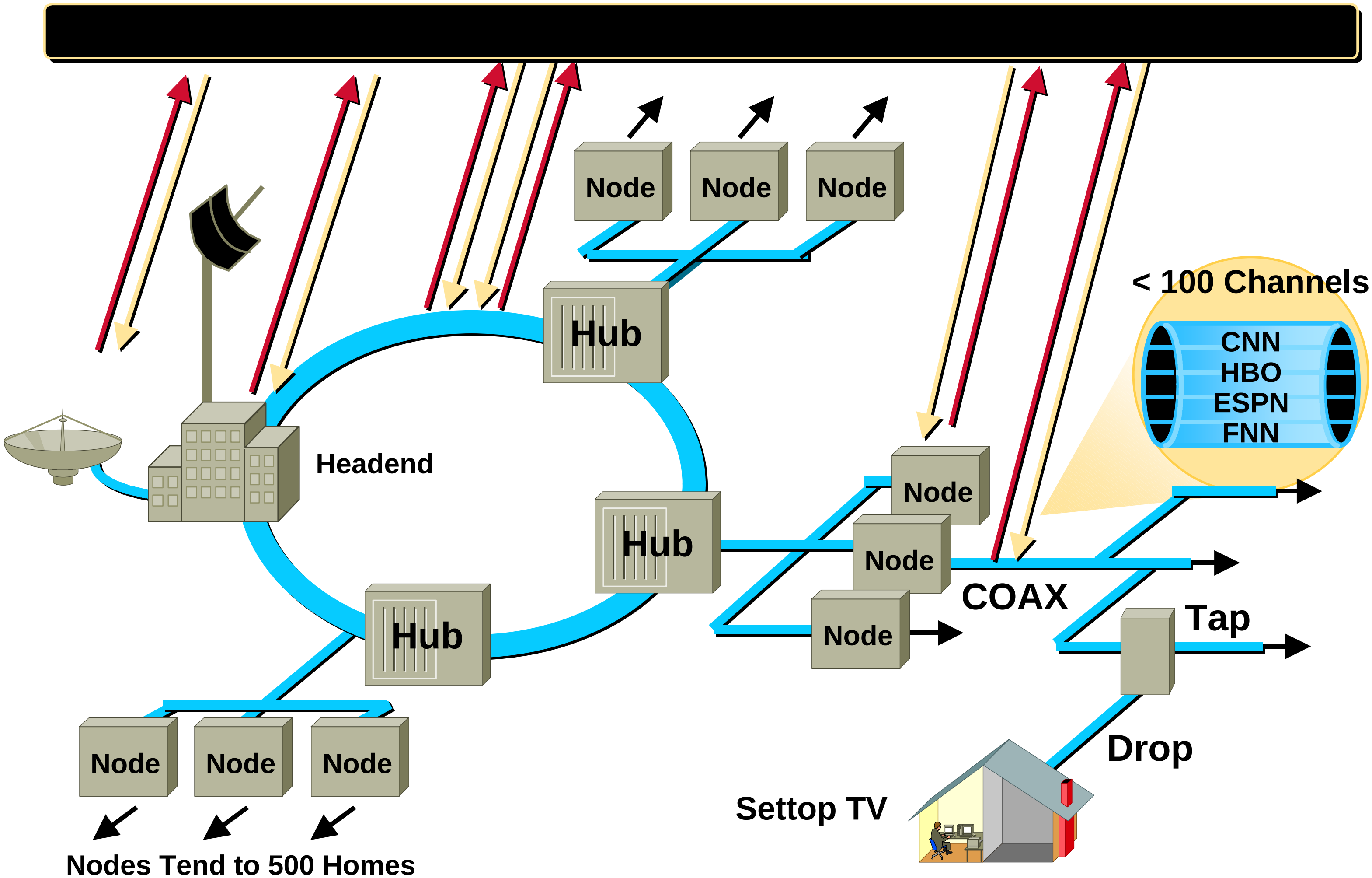
Wide band amplifiers etc…

Two way operation:

Upstream (5–42 MHz) “Provisioned” and “Operational”



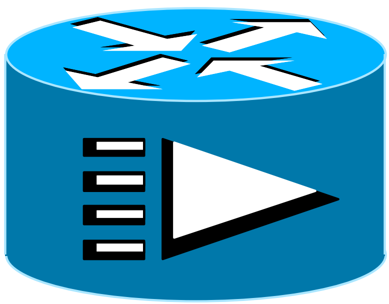
Cable Network



Cable Network

An Advanced Services Platform
Based on
"DOCSIS"
(Data Over Cable Services
Interface Specifications)
enables
High Speed Data over Cable

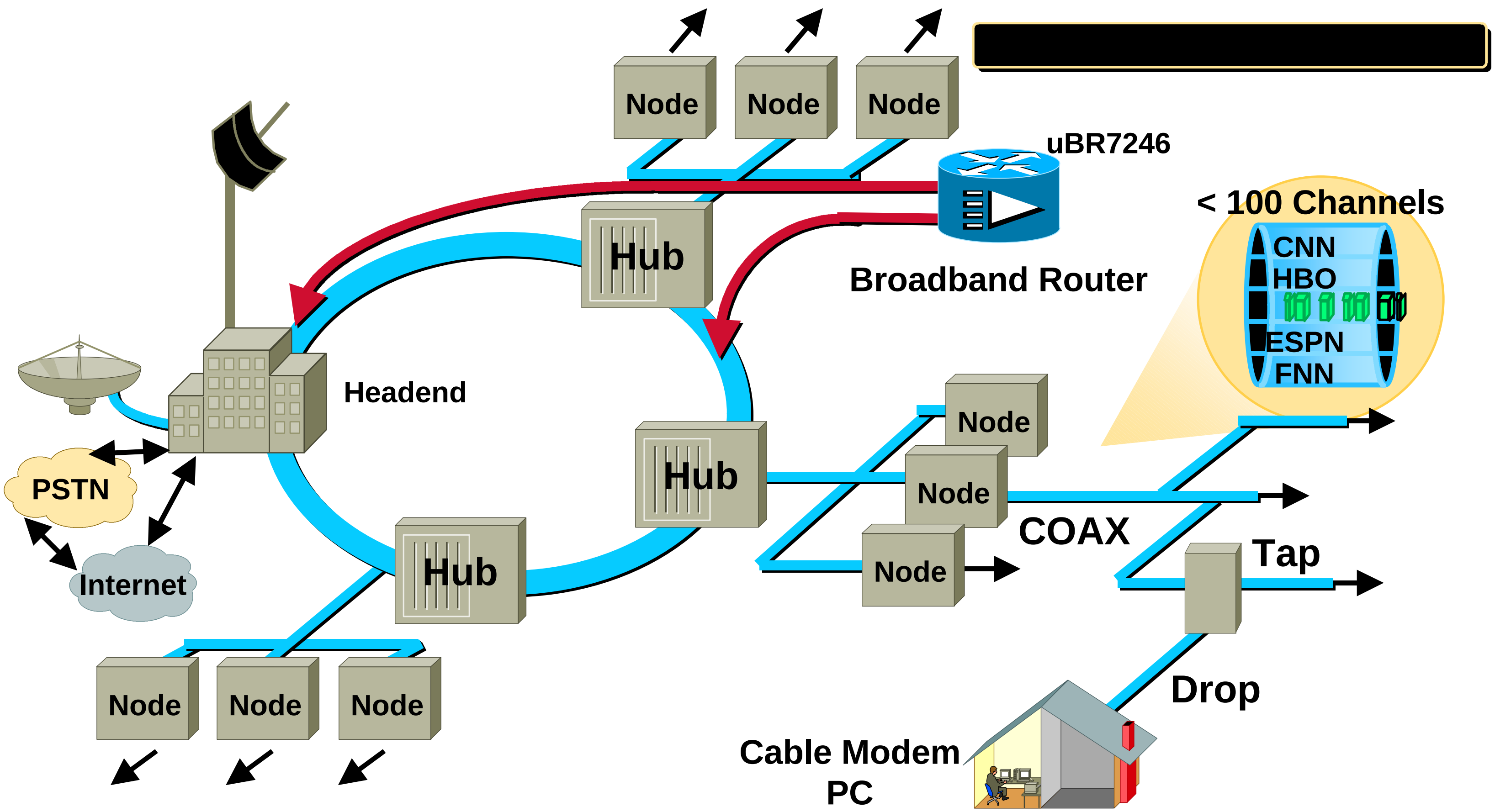
Cable Network



Cisco Universal Broadband Router
uBR 7246

Cable Network

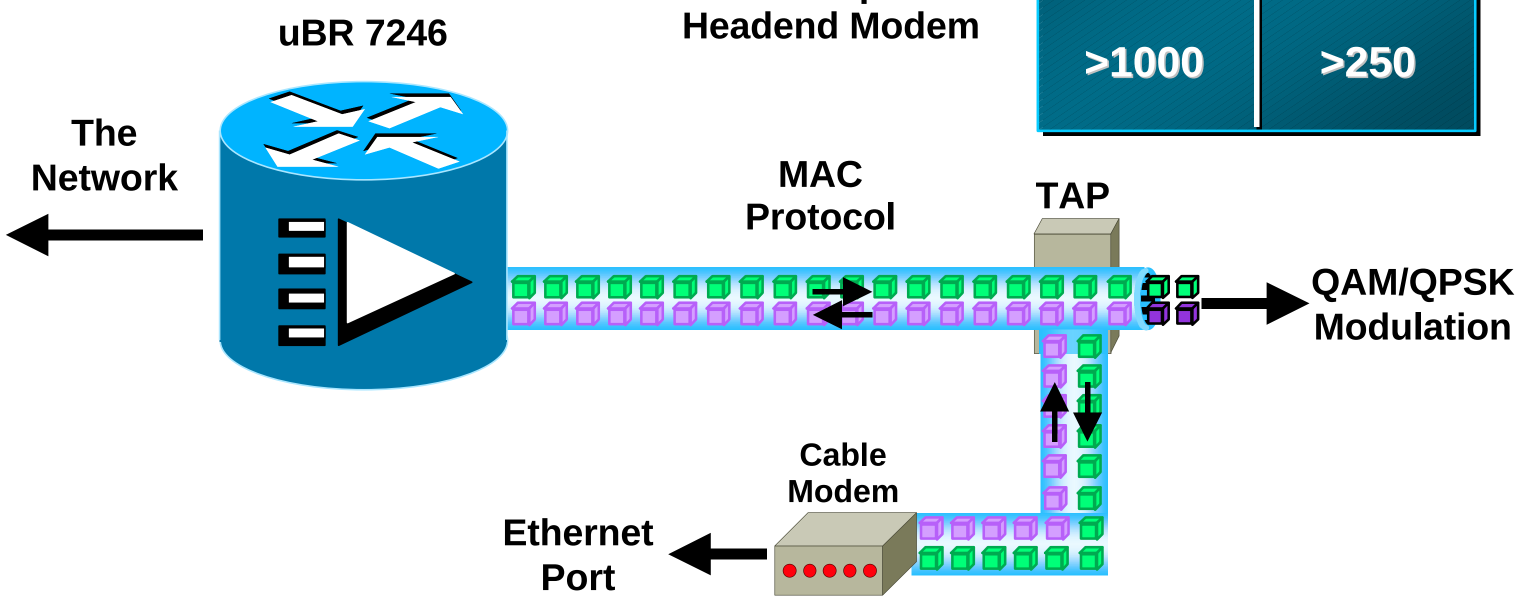
Advanced Services



Cable Network

DOCSIS Standard DATA Platform

	Usage Rate Per User	
Usage Rate Per User	128kbs	512kbs
Number of Users per Headend Modem	>1000	>250



Cable Network

DOCSIS Standard DATA Platform Offers:

- High bandwidth
- QoS (Quality of Service)
- MPEG packet format
- Network management
- Multicast
- Privacy
- Security
- Future capabilities:
  - VoIP (Voice)
  - IP Video

Cable Network

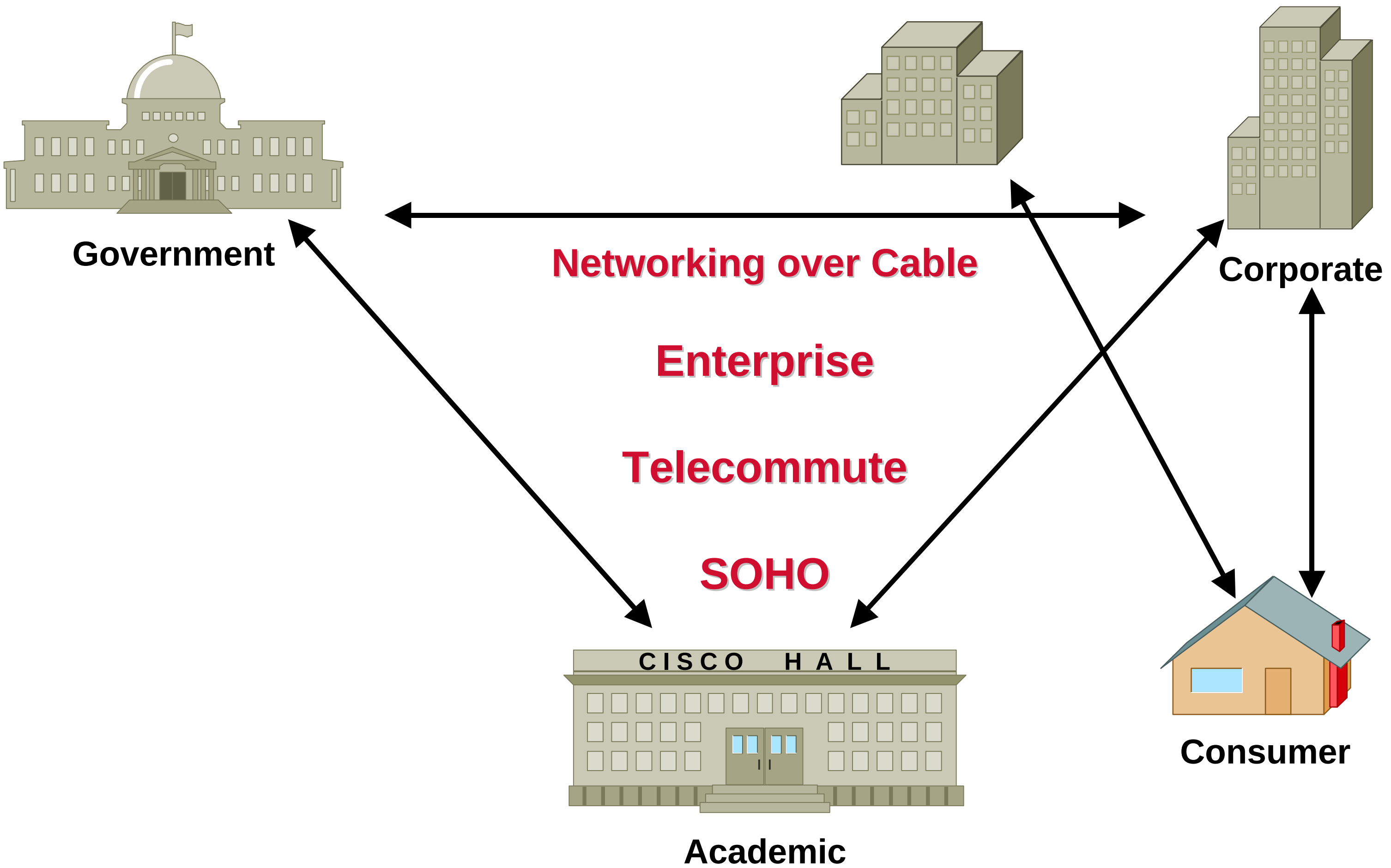
DOCSIS Standard Data Platform Offers:

Possible service applications:

- Internet access
- Enterprise
- Telecommute
- Virtual private network
- Voice
- SOHO

Cable Network

Offers New Service Possibilities



Upgraded Cable Plant

Cable plants are upgraded for:

- More reliable topology
- Increased bandwidth/smaller serving areas
- Increased availability
- More reliable signal
- Advanced network management
- Two way operation
- Advanced services

Cable Data Standards

MCNS

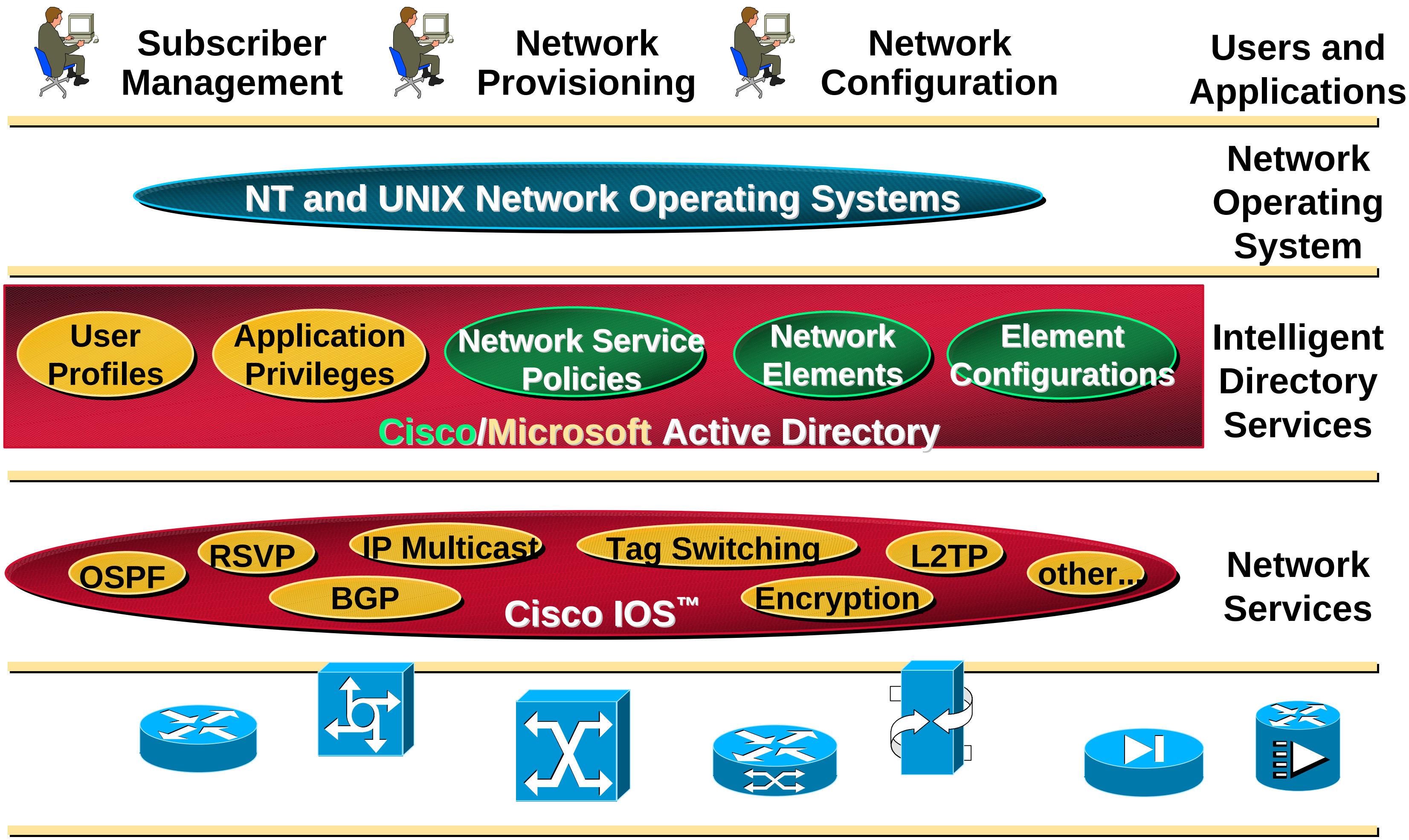
A. Industry-developed spec

B. Inexpensive implementation

C. Already successful in the marketplace

IEEE 802.14: wait and see…

Network Services Solutions



Services

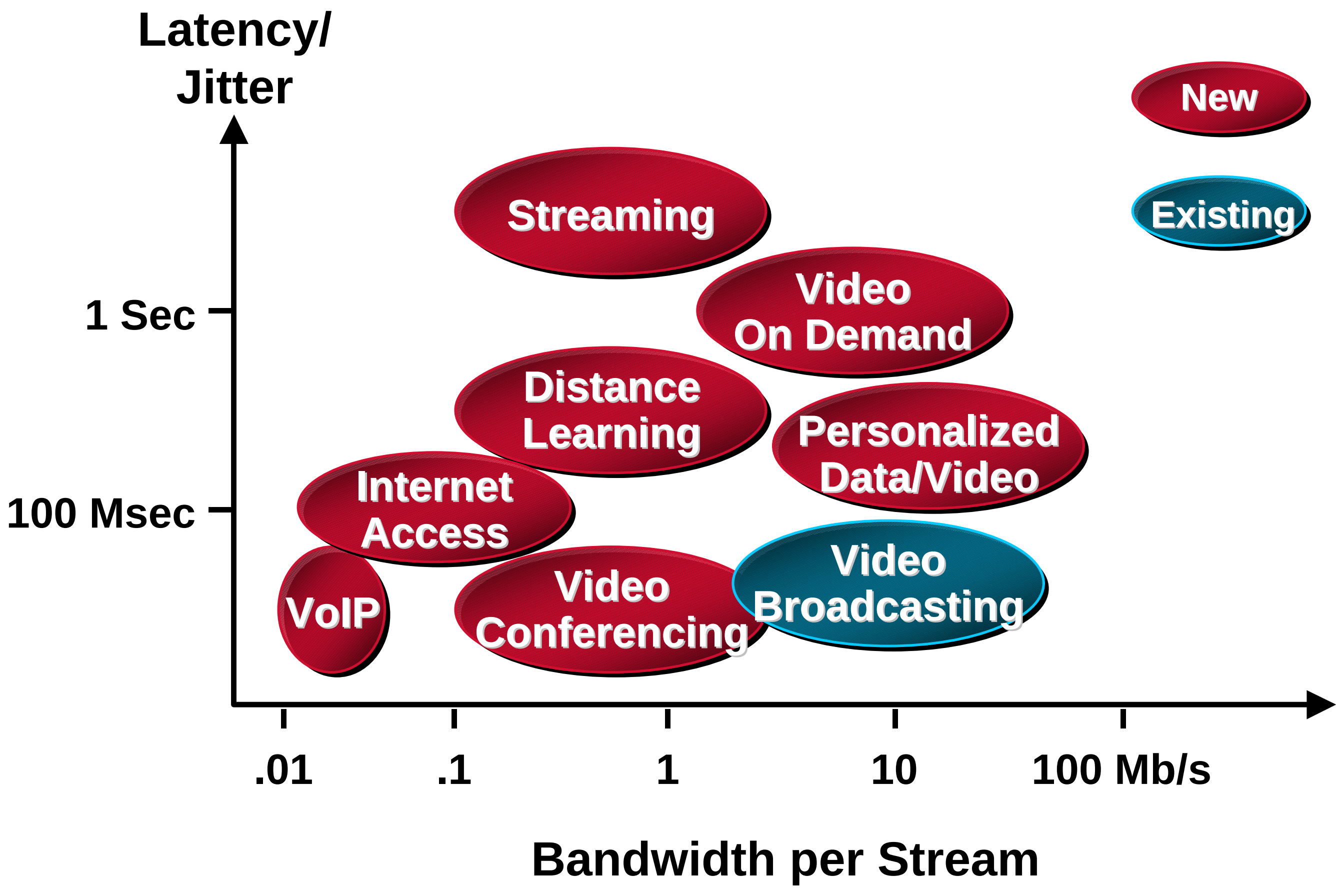
Existing Services

- Analog broadcast video
- Digital broadcast video

New Services

- Internet access: Web, e-mail
- IP-based services
  - Voice
    - H.323
  - Webcast video
    - Lower-bandwidth video over IP
    - Video on demand
  - Video conferencing and collaborative applications
  - Radio/music
  - Push services
  - Personalized video and data

Application Opportunities



Video As Data: Bandwidth

Assume 100 video channels

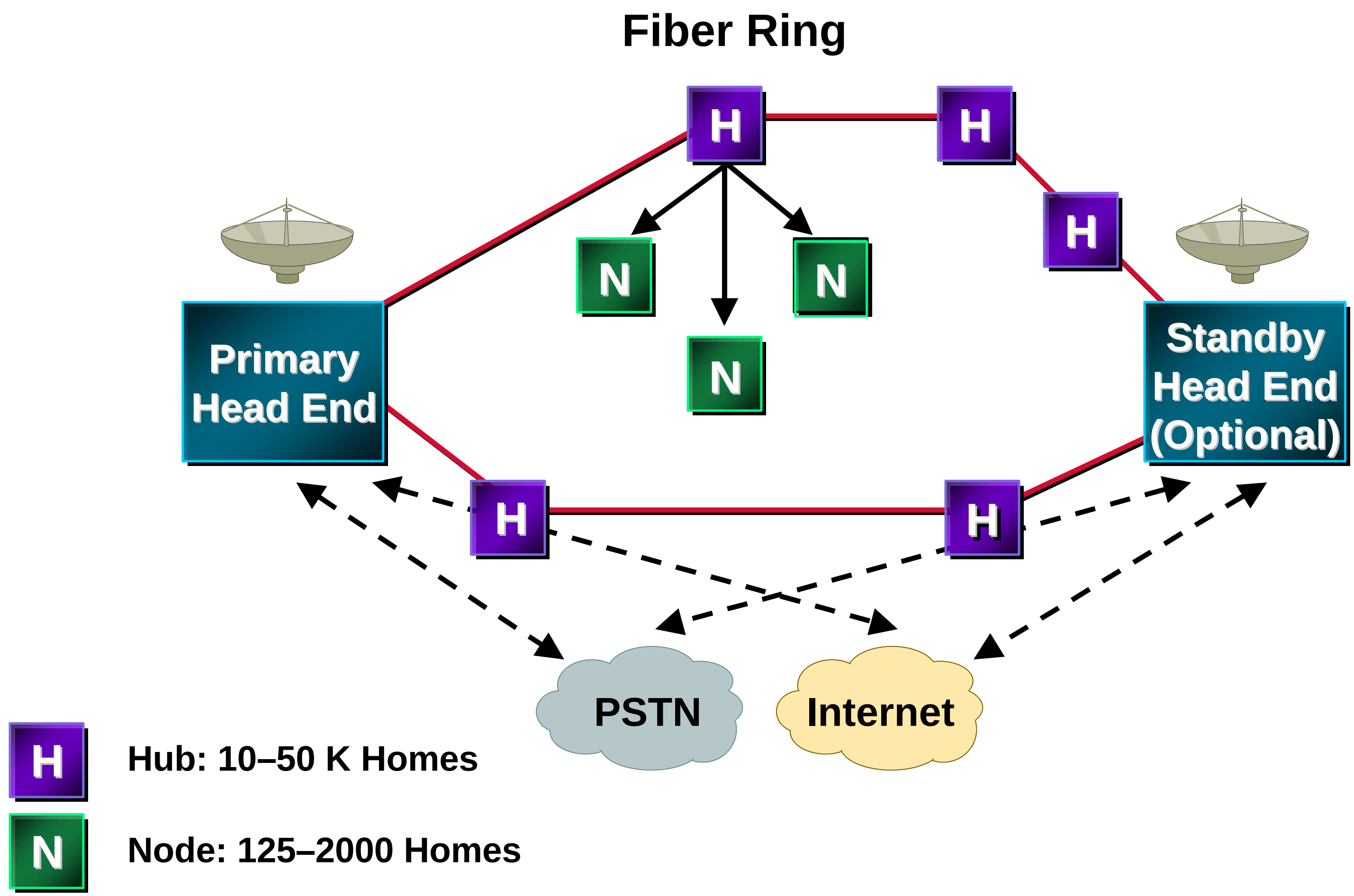
Assume 5 Mbps each

Total bandwidth only 500 Mbps

Less than one OC-12!

High end routers and switches have a dozen or more OC-12 ports

Backbone Structure



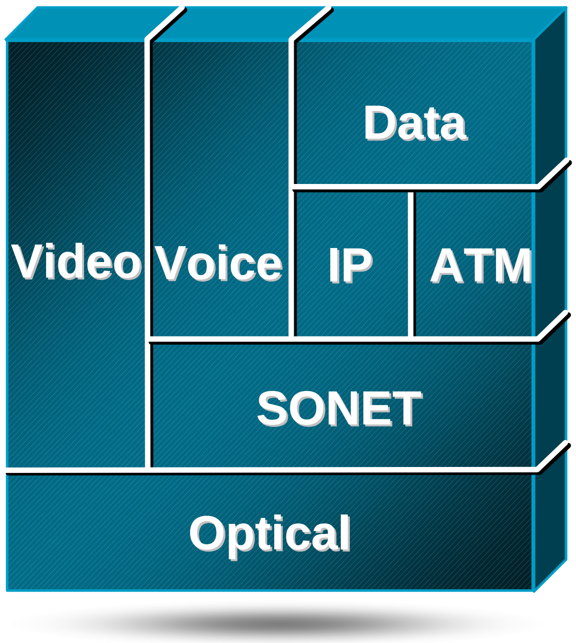
Separate Infrastructures

Benefits

- Uses existing equipment

Problems

- Duplicate networks
- Costly
- Unwieldy, complex
- Video is not networked, only point-to-point links



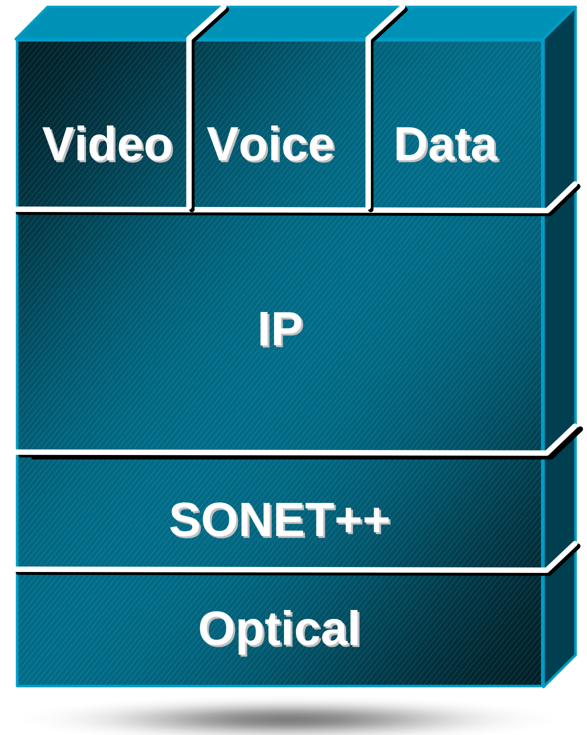
IP Transport Infrastructure

Benefits

- Unified network infrastructure
- IP brings scale and security
- IP is ubiquitous
- QoS w/ RSVP, L3 services
- Lower cost of ownership
- Leverage the Internet growth
  - Applications/content/services
  - Cost/performance curve
  - Interoperability

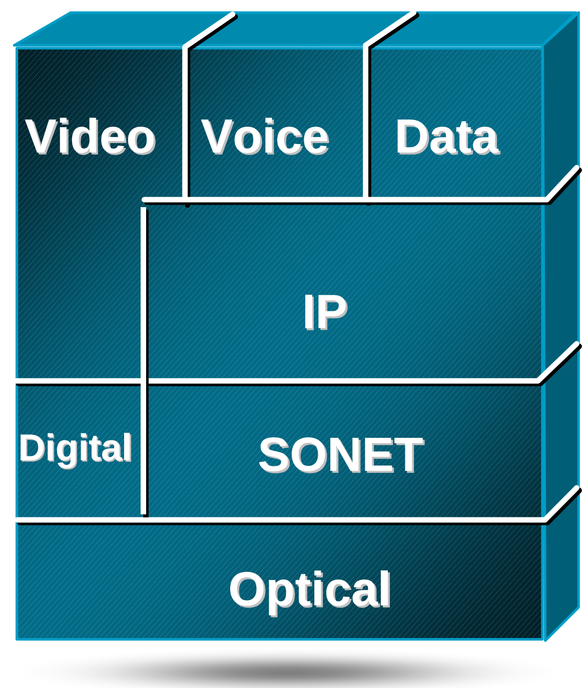
Problems

- Backbone-class devices only emerging now
- SONET integration
- New IP-based telephony



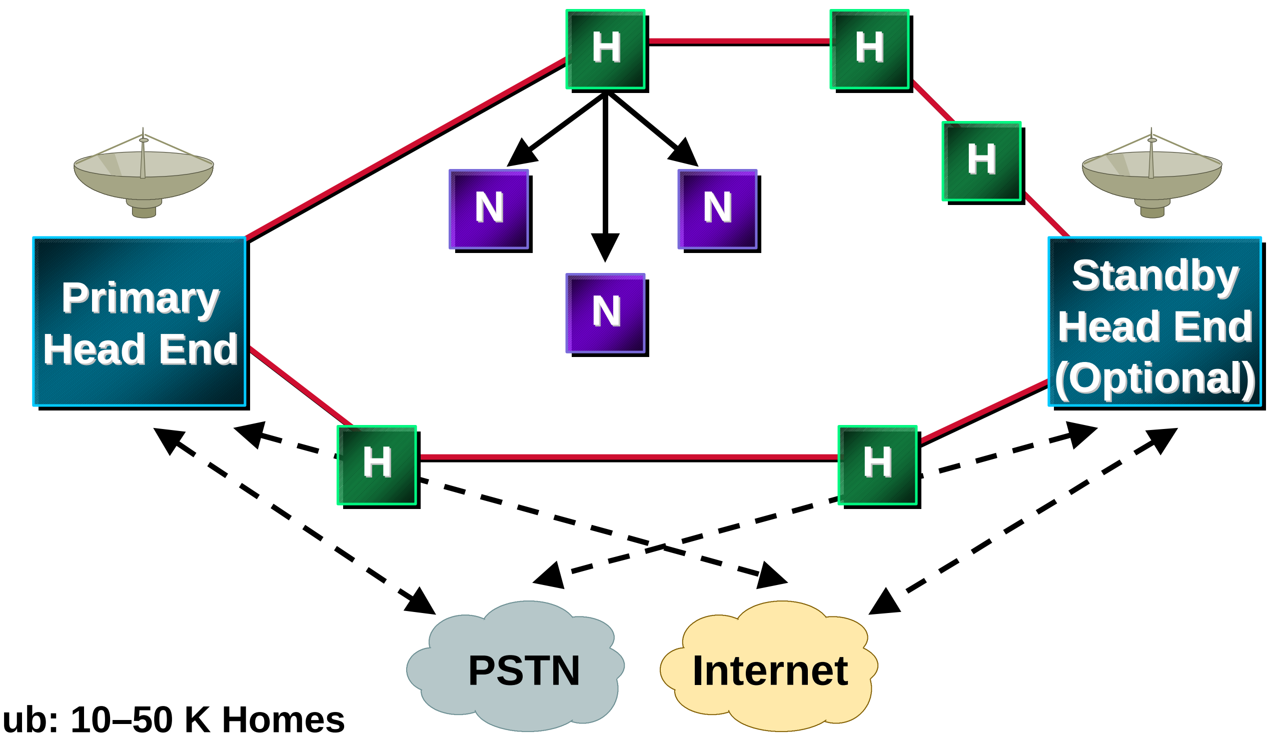
Final Backbone Architecture

- **Retains current digital video transmission**
  - **Simple broadcast**
  - **It works and it's cheap**
- **Uses IP transport for:**
  - **Switched video**
  - **Two-way video**
  - **Complex routes: studios, post production, ad houses, local sources**



Final Backbone Structure

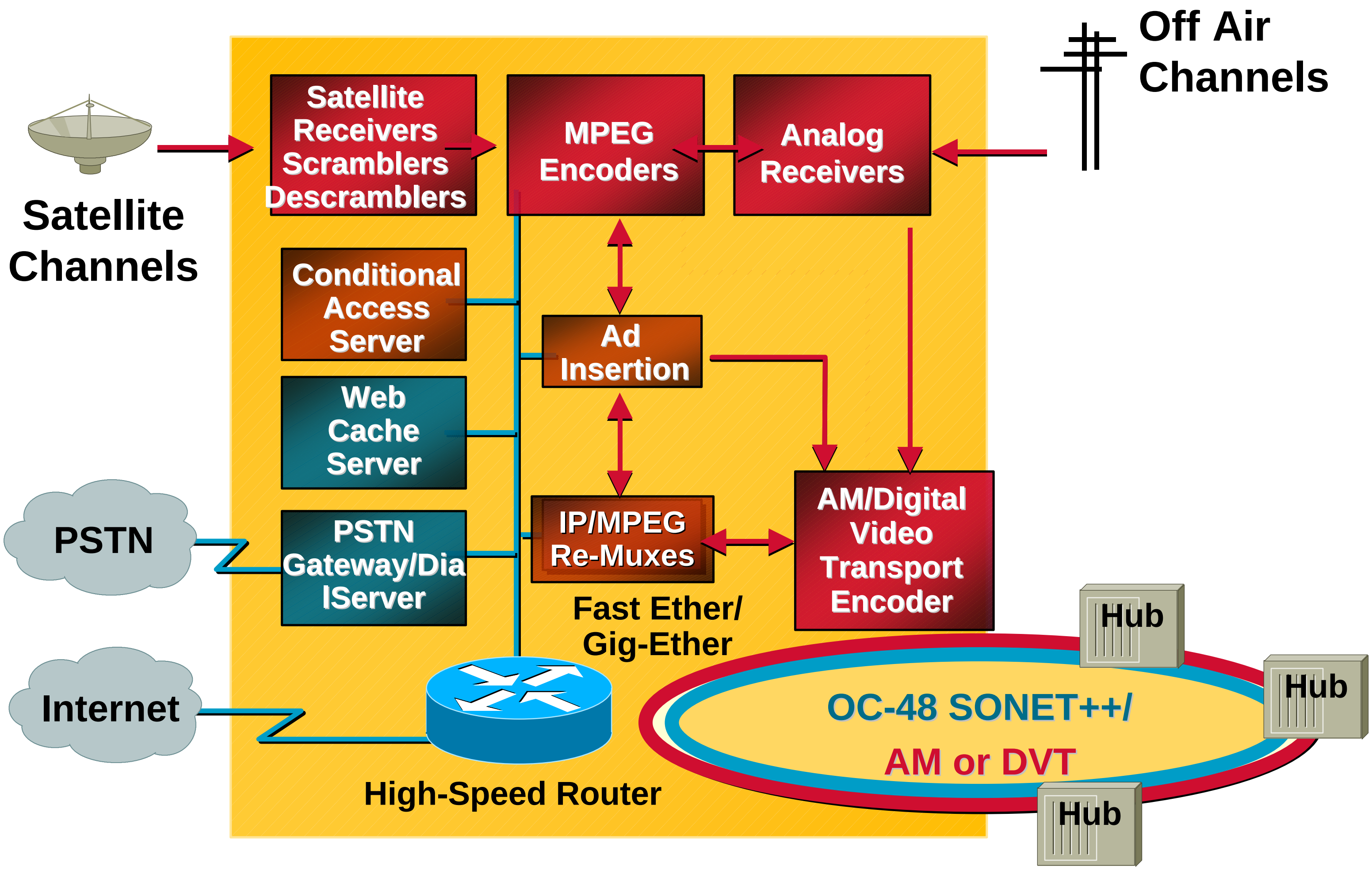
Digital Video Transport + SONET++ Ring



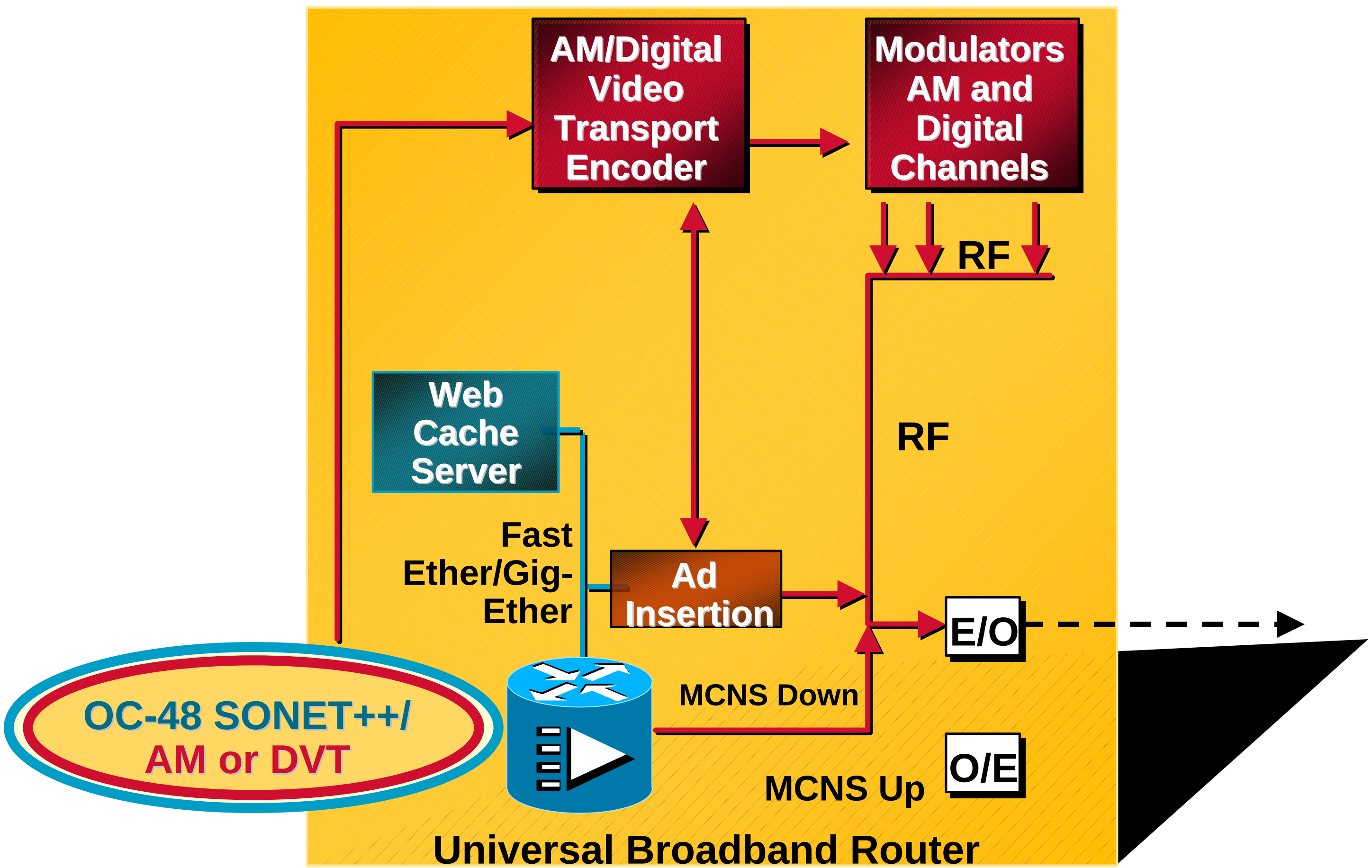
H Hub: 10–50 K Homes

N Node: 125–2000 Homes

Head End Diagram

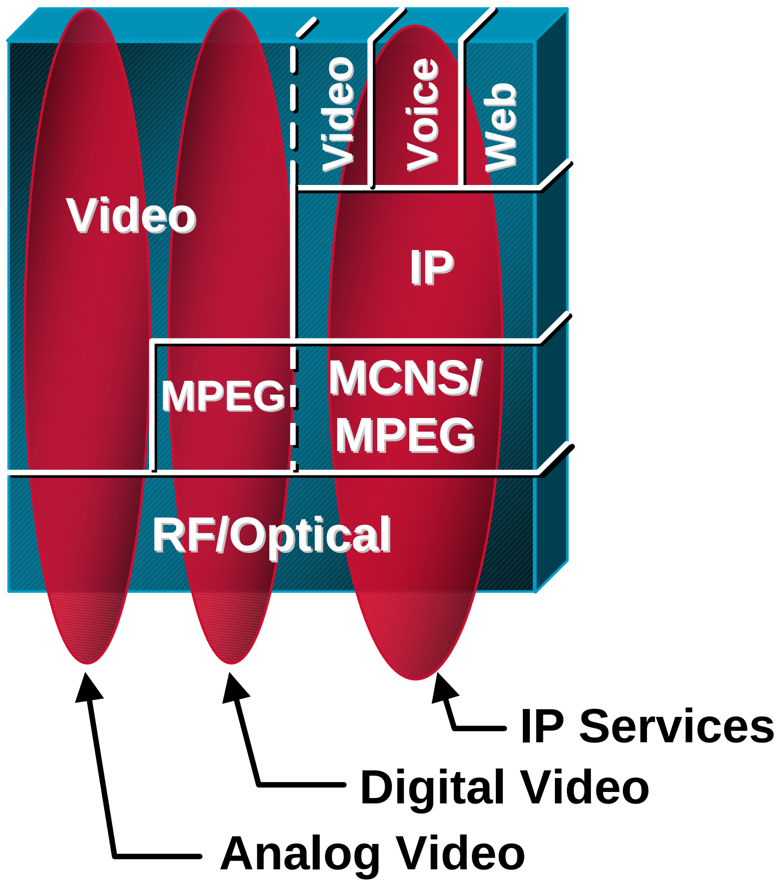


Hub Diagram

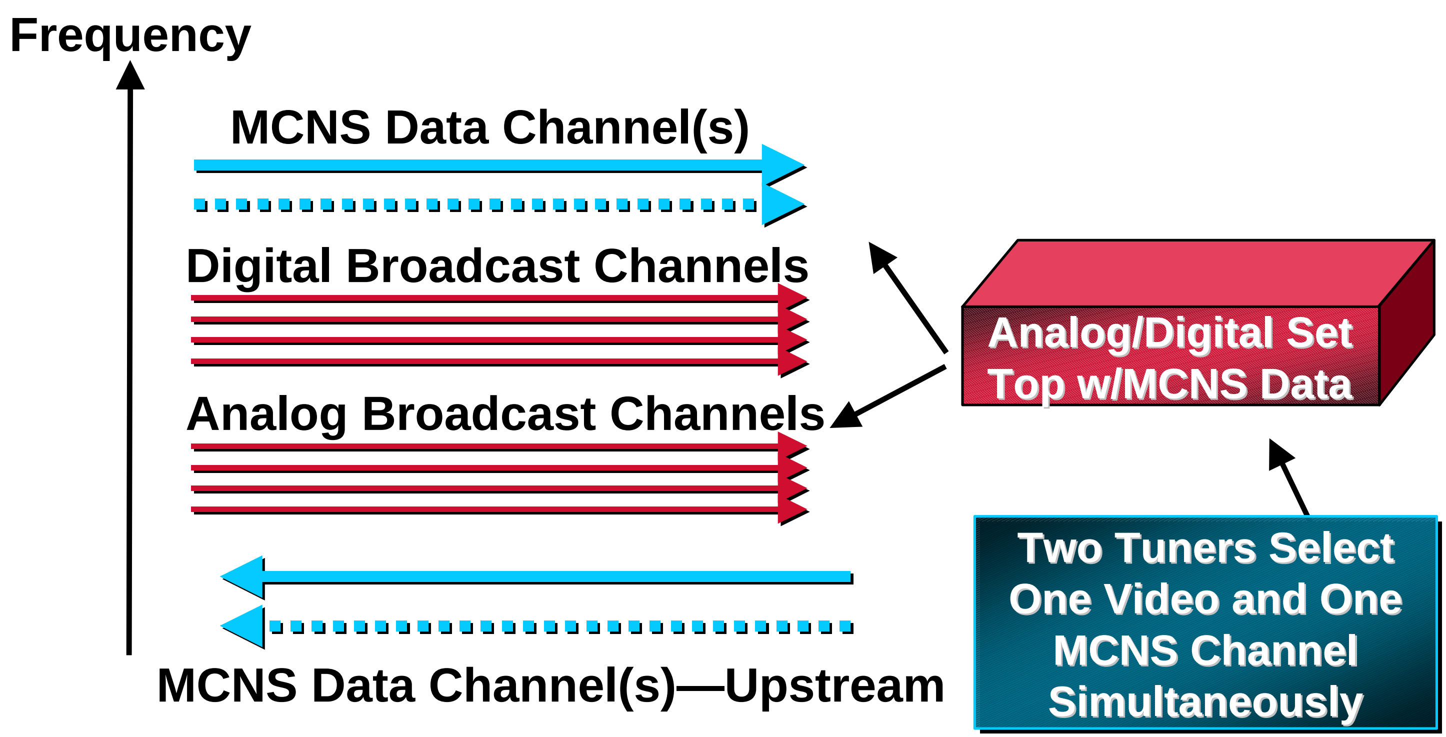

AM/Digital Video Transport Encoder
Modulators AM and Digital Channels
RF
RF
Web Cache Server
Fast Ether/Gig-Ether
Ad Insertion
E/O
O/E
MCNS Down
MCNS Up
OC-48 SONET++/ AM or DVT
Universal Broadband Router

Access Network: HFC

- **Analog video on RF**
- **Digital video**
  - MPEG/64QAM
- **Voice, Web, webcast video**
  - IP/MCNS/64QAM



RF Spectrum Map



Typical Bandwidth per Data User

Assumptions:

50% of homes passed are subscribers

10% of subscribers are active

One downstream at 64-QAM per 4 fiber nodes

One upstream at 2560 Mbps per fiber node

HP Per Node	HP Per Downstream	Peak Data Rate (D/U)	Average Data Rate (D/U)
500	2000	27 Mbps/ 4 Mbps	270 Kbps/ 102 Kbps
1000	4000	27 Mbps/ 4 Mbps	135 Kbps/ 51 Kbps

Typical Cost at Head End/Hub Is $5/Home Passed
More Bandwidth is Available with More HE Gear

Residence Network Diagram