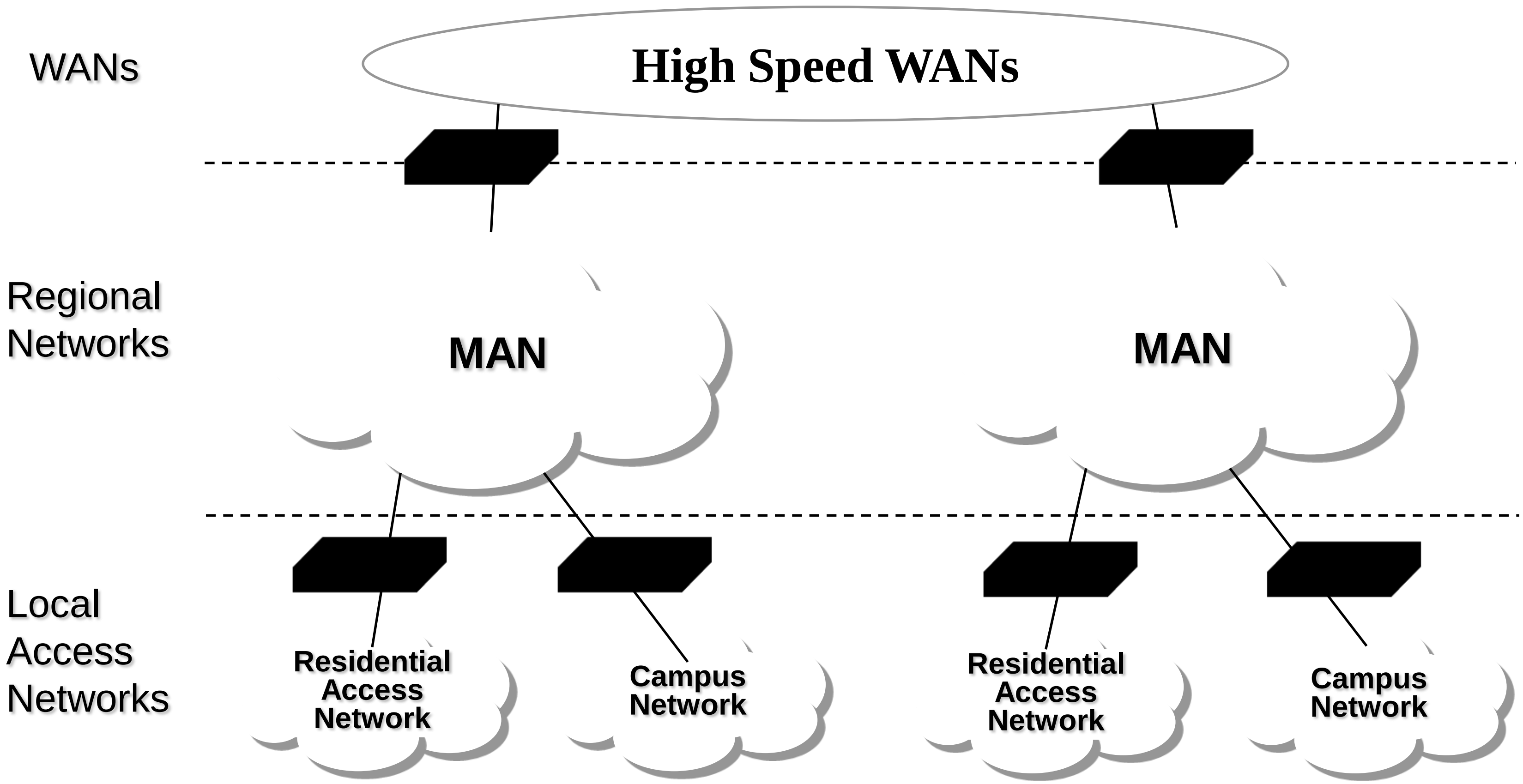
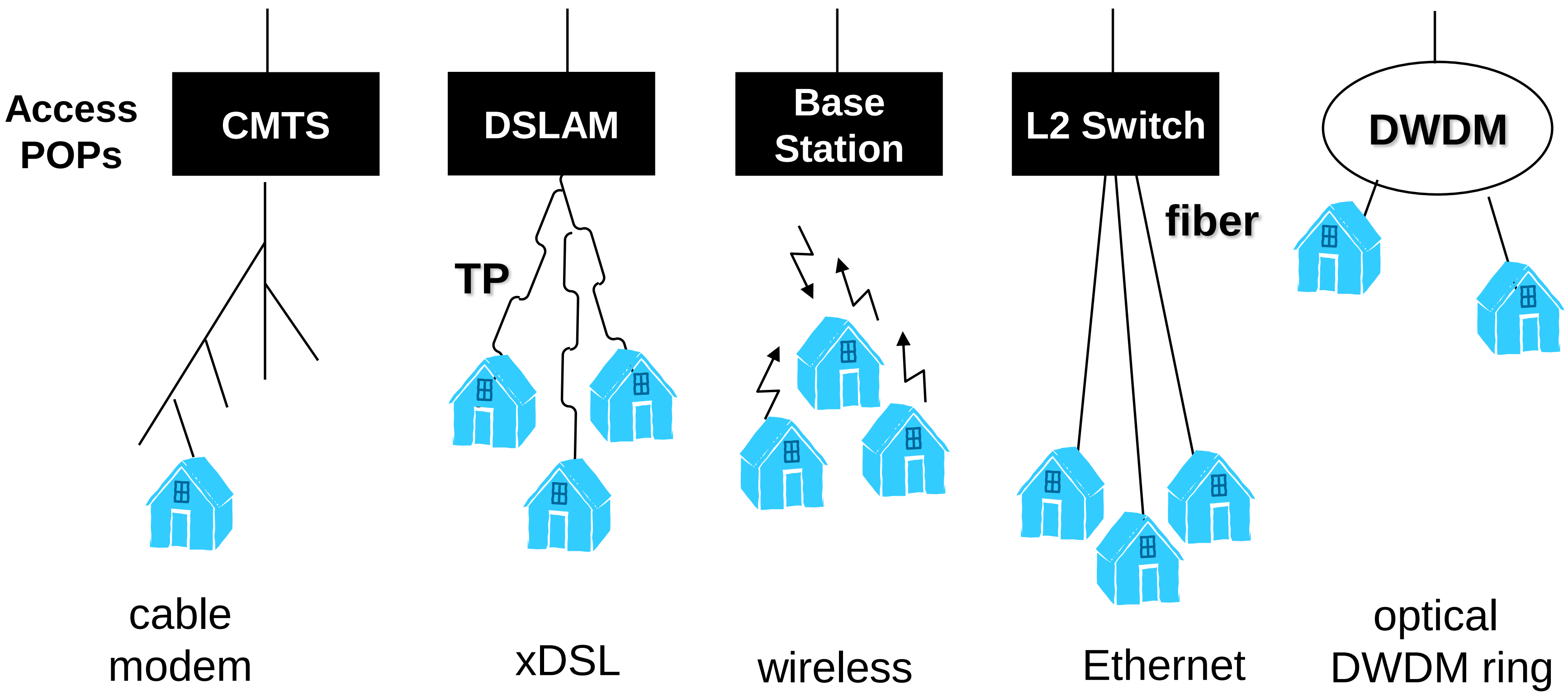
Infrastructure Transmission Media

Network Infrastructure



Access Networks



Transmission Media

- Access Network technologies
  - Local Area Networks
  - xDSL
  - Cable and HFC
  - Optical Networks
  - Wireless
  - DVB (Satellite/Terrestrial)

Advances in Local Area Networks

High Speed Ethernet and Switching

Expedited Traffic Capabilities

Selective Forwarding

Virtual LANs

High Speed LANs

High Speed LANs

- IEEE 802.3 Ethernet
  - 10 Mbps
  - 100 Mbps
  - 1,000 Mbps
  - 10,000 Mbps under work
- Fast packet switches
- Full-duplex links

Advances in LAN Technologies

- Expedited Traffic Capabilities
- Filtering Services that Support the Dynamic Use of Group MAC Addresses (Selective multicasting)
- Virtual LANs

Traffic Types in a Typical LAN Environment (1)

- **Network control**
  - characterized by a 'must get there' requirement to maintain and support the network infrastructure
- **Voice**
  - characterized by less than 10 millisecond delay, and hence maximum jitter (one way transmission through the LAN infrastructure of a single campus)
- **Video**
  - characterized by less than 100 millisecond delay
- **Controlled Load**
  - important business applications subject to some form of 'admission control', be that pre-planning of the network requirement at one extreme to bandwidth reservation per flow at the time the flow is started at the other extreme
- **Excellent Effort -or CEO best effort**
  - best effort type services that an information services organization would deliver to its most important customers

Traffic Types in a Typical LAN Environment (2)

- **Best Effort**
  - LAN traffic as we know today
- **Background**
  - bulk transfers and other activities which are permitted on the network but which should not impact the use of the network by other applications

Traffic Type to User-priority Mapping

User_priority	Acronym	Traffic Type
1	BK	Background
2	-	Spare
0 (default)	BE	Best Effort
3	EE	Excellent Effort
4	CL	Controlled Load
5	VI	Video
6	VO	Voice
7	NC	Network Control

Recommended Traffic Type to Traffic Class Mapping

<table>
<tr><th>Number of Queues</th><th colspan="8">Defining Traffic Type</th></tr>
<tr><td>1</td><td colspan="8">BE</td></tr>
<tr><td>2</td><td colspan="4">BE</td><td colspan="4">VO</td></tr>
<tr><td>3</td><td colspan="4">BE</td><td colspan="2">CL</td><td colspan="2">VO</td></tr>
<tr><td>4</td><td colspan="2">BK</td><td colspan="2">BE</td><td colspan="2">CL</td><td colspan="2">VO</td></tr>
<tr><td>5</td><td colspan="2">BK</td><td colspan="2">BE</td><td>CL</td><td>VI</td><td colspan="2">VO</td></tr>
<tr><td>6</td><td colspan="2">BK</td><td>BE</td><td>EE</td><td>CL</td><td>VI</td><td colspan="2">VO</td></tr>
<tr><td>7</td><td colspan="2">BK</td><td>BE</td><td>EE</td><td>CL</td><td>VI</td><td>VO</td><td>NC</td></tr>
<tr><td>8</td><td>BK</td><td>-</td><td>BE</td><td>EE</td><td>CL</td><td>VI</td><td>VO</td><td>NC</td></tr>
</table>

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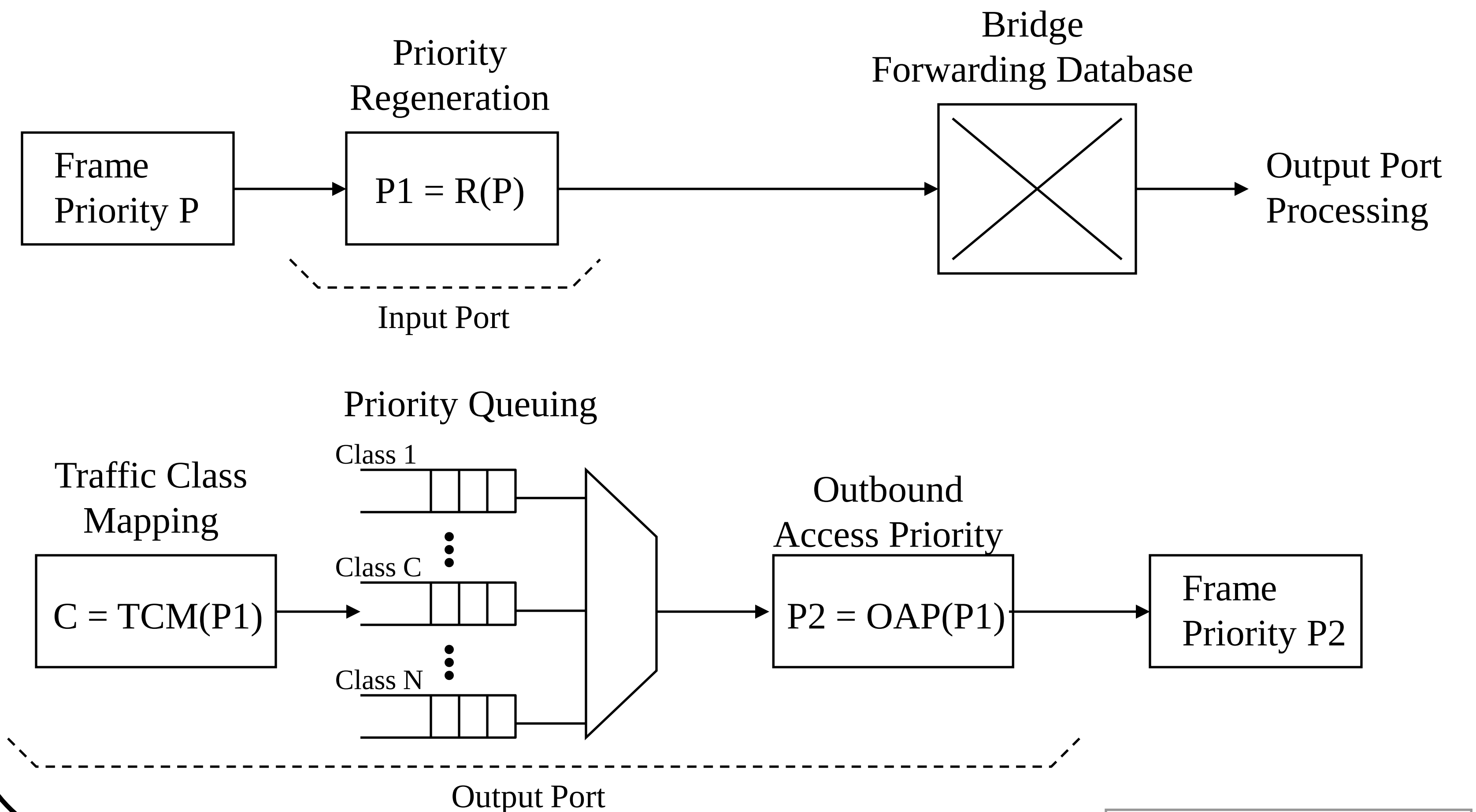
Summary of the Process



Conclusion

- Expedited traffic capabilities
  - Allow the transmission of time-critical data to be expedited (to achieve low latency) even when it is in competition for network bandwidth with other non-time-critical data
  - Not intended to provide guaranteed quality of service

Filtering Services for the Dynamic Use of Multicast Addresses

Why Selective Multicasting?

- Broadcasting of multicast traffic overloads slower links, and limits the total volume of multicast traffic

- Solution:

  Allow users to explicitly indicate their interest in receiving traffic on given multicast addresses

Basic Filtering Services

- A bridge must support the basic filtering services
- Basic filtering services allow the specification of the following Filtering Database entries
  - For individual MAC addresses:
    - Static entries which indicate for each outgoing port if frames destined for the specified individual MAC address should be filtered or forwarded
    - Dynamic entries which are created and updated by the learning process
  - For a specific group MAC address:
    - Static entries which indicate for each outgoing port if frames destined for the specified individual MAC address should be filtered or forwarded
    - If no static entry is present for a specific group MAC address, frames destined to the group MAC address are broadcast on all outgoing ports

Extended Filtering Services

- Extended filtering services add the following capabilities to the basic filtering services
  - For individual MAC addresses:
    - Static entries may contain a value which indicates the dynamic filtering information should be used for a specific port rather than always forward or always filter
  - For a specific group MAC address:
    - Static entries may contain a value which indicates the dynamic filtering information should be used for a specific port rather than always forward or always filter
    - Group Registration Entries - dynamic filtering entries which are created and maintained through the use of the GMRP protocol
  - Entries corresponding to All Group Addresses which do not have a specific group MAC address entry
  - Entries corresponding to All Unregistered Group Addresses which do not have a specific group MAC address entry

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GMRP

GARP Multicast Registration Protocol

GMRP
GARP Multicast Registration Protocol

- A mechanism that allows bridges and end stations:
  - to dynamically register (and subsequently de-register) group membership information with the MAC bridges attached to the same LAN segment
  - to disseminate that information across all bridges in the bridged LAN that support Extended Filtering Services
- Operation of GMRP relies on the services provided by the *Generic Attribute Registration Protocol* (GARP)

Result of Group Membership Information Registration and Propagation

- Frames sent to a particular group can be received on all LAN segments to which registered GMRP participants are attached
- Bridges filter frames on ports which have not had group registration entries created by GMRP
  - frames are not transmitted on LAN segments which neither have registered GMRP participants, nor are in the path through the *active topology* between the sources of the frames and the registered members

Open Host Group Concept

- Any GMRP participants that wish to receive frames transmitted to a particular group or groups register their intention to do so by requesting membership to the group(s) concerned
- Any MAC service user that wishes to send frames to a particular group can do so *from any point of attachment* in the bridged LAN
- MAC service users that are sources of MAC frames for the group do not have to register as members of the group themselves unless they also wish to receive frames sent to the group by other sources

IEEE 802.1Q

Virtual Bridged Local Area Networks

Motivation

- Increased bandwidth on LAN segments
- Larger LAN switches (number of ports)
  - larger subnetworks
    - geographical scope
    - number of users
- Same bridged LAN capable of serving several *logical groups* of users
  - groups defined according to a number of attributes
    - corporate divisions
    - higher layer protocols
    - collection of servers they share
    - etc...

Definition

- A virtual LAN (VLAN) is a collection of LAN segments and the stations/devices connected to them within a bridged LAN that has exactly the same properties of an independent LAN.
- In a bridged LAN comprising several VLANs, traffic belonging to a VLAN is restricted from reaching users in other VLANs

Advantages

- Flexibility in user locations and logical groups of stations
- Facilitating easy administration of:
  - moves
  - adds
  - changes in group membership
- Restricting traffic on portion of network where stations belonging to a VLAN are present implying an increase in performance and in the level of security
- Providing priorities for Ethernet
- Goal:
  - compatibility with existing bridges and end-stations

Residential Broadband Services

xDSL

Cable Modem

Applications

- VoD and NVoD (video on demand and near VoD)
- Distance learning
- Teleconferencing
- Electronic commerce, home shopping
- Telemedicine
- Telecommuting

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Residential Access Architectures

- Twisted copper pair from central office to home
- Cable Access networks
- Hybrid Fiber-Coax
- Fiber to the home (FTTH) and fiber to the curb (FTTC)
- Wireless
- DVB: Satellite and Terrestrial

xDSL

Digital Subscriber Loop (xDSL) Technologies

TECHNOLOGIES	BANDWIDTH	RANGE	MEDIA	SYMMETRY
DSL	160 Kbps duplex	18,000 ft	1 twisted pair	symmetric
HDSL	1.544 Mbps duplex	12,000 ft	2 twisted pairs	symmetric
SDSL	1.544 Mbps duplex	10,000 ft	1 twisted pair	symmetric
ADSL	1.544 Mbps downstream 640 Kbps upstream	18,000 ft	1 twisted pair	asymmetric
RADSL	Varies with ADSL range	18,000 ft	1 twisted pair	asymmetric
VDSL	52 Mbps downstream 4 Mbps upstream	1,000 ft	1 twisted pair	asymmetric

HDSL: High Speed DSL

- 1.5 to 2 Mbps both ways up to 12,000 ft from central office
  - Transmit T1/E1 traffic over 2 twisted-pair copper wires
- Range can be extended by using repeaters along the line to the customer

SDSL: Single Line DSL

- Both ways bandwidth: 1.544 Mbps
- No interference with POTS
- Range up to 10,000 ft

ADSL: Asymmetric DSL

- Upstream bandwidth: 16 Kbps to 640 Kbps
- Downstream bandwidth: 1.5 Mbps to 9 Mbps
- No interference with POTS (uses 0-4 KHz range)
- Phone still works while surfing or when ADSL modem fails
- Range up to 18,000 ft

RADSL: Rate Adaptive DSL

- Subset of ADSL
- Automatically adjusts line speed based on a series of initial tests that determine the maximum speed possible on a particular line
- The line condition is affected by the distance between the CO and the subscriber, the gauge of the wire etc…

VDSL: Very High Speed DSL

- Operates on a single copper twisted pair
- Delivers asymmetric data rate at much higher speed than ADSL
- However, range is limited to 1,000 to 4,500 ft
  - Suitable for deployment in dense environments
- Targets ATM network architectures

Cable Modems

Cable Modems

- First used to serve the interactive television market
- Internet and WWW revived interest
- Two proposals
  - IEEE 802.14 (dead)
  - MCNS DOCSIS
    - Data Over Cable Service Interface Specification

Cable Network Infrastructure

- Downstream link
  - 6MHz channels above 50MHz
- Upstream link
  - below 50MHz
  - only some can use upstream link
- Problems
  - Reliability
  - Cable signal quality (esp. for upstream)

Hybrid Fiber Coax HFC

- Fiber optic cable
  - Solves both the power and the signal quality issues
  - Expensive
    - does not use existing infrastructure
- HFC
  - Leverages 50% of the cabling in the network
  - Since shared medium, can install more headends as demand increases

Optical Networks

Enabling Technologies

- DWDM
- Optical fiber
- Amplifiers
- Add/Drop Multiplexers
- Optical Cross-connects
- Wavelength Converters

DWDM

- Dense Wavelength Division Multiplexing (DWDM): “WDM” and “DWDM” can be used interchangeably, but DWDM implies closely-spaced wavelengths, e.g., 0.8 nm apart (~100 GHz).
- Interesting because:
  - Can exploit more of fiber’s bandwidth.
  - Each λ has flexibility to carry traffic of different bit rates and protocols
  - Can increase capacity of existing fiber by changing end nodes.

Optical Fiber

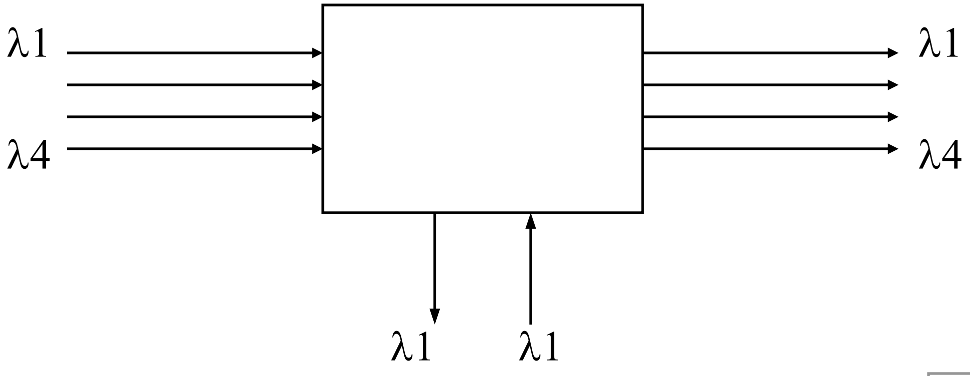
- Recent advances have improved reach, bit rate, and signal quality.
- Example: Lucent TrueWave fiber carried 1 Tbps in 1998.
- Approx 0.2 dB/km attenuation;
  Non-amplified signals have a range of about 200 km, thus need for amplifiers to extend reach.

Optical Amplifiers

- Regenerators/repeaters
  - Needed before the development of amplifiers
  - One regenerator per wavelength
  - Need to detect signal information (opaque)
- Erbium-Doped Fiber Amplifier (EDFA)
  - Introduced in 1989
  - Allows unrepeatered transmission to 10000 km.
  - Amplifies simultaneously all the wavelengths in a given band which are multiplexed on a single fiber, e.g. 100 wavelengths
  - May be spaced up to 120 km apart; typically, 20–100 km.

Add/Drop Multiplexers

- A node which can pull out wavelengths (drop) and also insert wavelengths (add)
- Typically not reconfigurable
- Often used in metro area rings



Optical Cross-connects

- A switch which directs an input signal to a particular output port based on input port and wavelength.
- All-optical / transparent
  - Benefit of format and protocol transparency
  - Various approaches being tried: MEMS (Xros, OMM Inc, Lucent), thermo-capillary [ink jet] (Agilent), liquid crystal (Chorum),...
  - Today: 1000x1000 products being developed.
- Optoelectronic / opaque
  - Optical inputs and outputs, but electronic switching matrix
  - Detectors and transmitters needed for O-E-O conversion
  - Management and monitoring advantages
  - Much more commonly found in today’s products

Wavelength Converters

- Wavelength converter: maps the signal from one given input wavelength to a desired output wavelength.
- May be used:
  - as a component of a wavelength-interchanging switch
  - to reduce complexity of photonic switch fabric
- Without wavelength conversion, it is necessary to have wavelength continuity end to end.

Recent Optical Transmission Achievements

Total BW	λ's × Gbps/λ	Distance	Date	Developer
40 Gbps =	1×40	65 km	1998	Alcatel
160 Gbps =	32×5	9300 km	1998	
2.64 Tbps =	132×20	120 km	1996	NEC
1.4 Tbps =	70×20	600 km	1997	NTT
1 Tbps =	100×10	400 km	1997	Lucent
320 Gbps =	64×5	7200 km	1997	Lucent

Wireless Transmission Infrastructures

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Wireless Benefits

- Practical aspect
  - Quicker to install, availability
  - Lower cost infrastructure
  - No right of way issue
  - Flexibility
  - Control and Ownership
- Mobility (when applicable)

Wireless Contexts

- Broadband wireless access (>1.5Mb/s)
  - Local Multipoint Distribution System (LMDS)
  - Multichannel Multipoint Distribution System (MMDS)
  - IEEE 802.11
- Large campuses and businesses
  - IEEE 802.11
- Small offices and home offices (SOHO)
  - HomeRF
  - Bluetooth

MMDS

- Wireless technology used for TV signal transmission for more than 30 years
- Could be deployed using many small cells (<5mile radius)
  - 33 analog channels (6MHz each) converted to 99, 10Mb/s digital data streams
  - 1Gb/s aggregate capacity
- … Or few large cells (>20mile radius)
  - Capacity reduced to around 200Mb/s

LMDS

- Broadband wireless technology used to deliver voice, data, Internet and video services in the 25GHz and higher spectrum
- Coverage limited to cell (*local*)
  - Range up to 5 miles
- Point-to-multipoint or broadcast (*multipoint*)
- Data rate of 1-10Mb/s

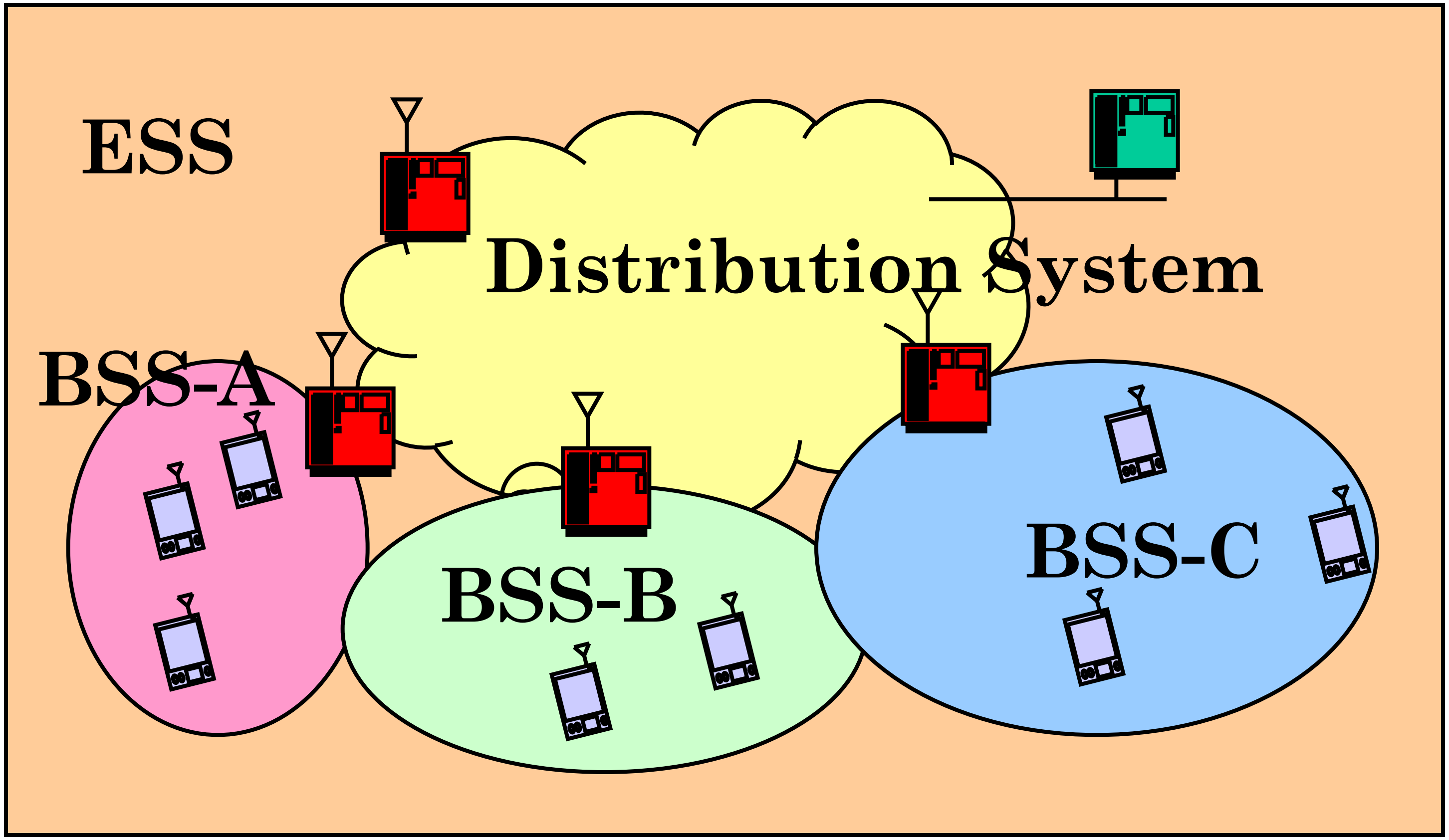
IEEE 802.11

- Requirements
  - Mobility
    - Power management
    - “Seamless” connections
  - Security
    - Support for encryption
  - Single MAC, supports multiple PHYs
  - Needs to be robust against interference

IEEE 802.11 Architecture

- Basic Service Set (BSS)
  - "Ad Hoc" network
  - Direct communication between hosts
  - Limited coverage area
- Extended Service Set (ESS)
  - Adds infrastructure, by differentiating between
    - Access points
    - Stations
  - Distribution System interconnects multiple BSS cells via access points to form network
    - Extends wireless coverage area

BSS and ESS



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Medium Access: DCF

- Distributed Coordination Function
  - Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA)
  - Uses Clear Channel Assessment (CCA)
  - MAC level acknowledgments
  - RTS/CTS exchanges (Request to Send/ Clear to Send) for robustness against hidden node problem

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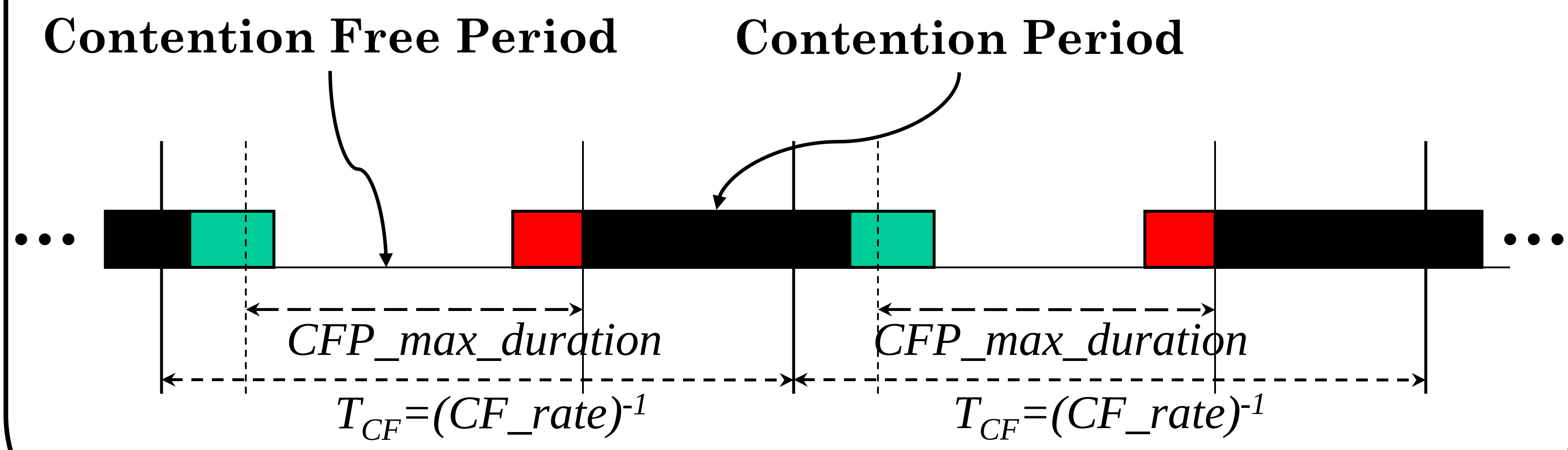
Medium Access: PCF

- Point Coordination Function
  - AP polls stations in Contention Free (CF) period
  - CSMA/CA in Contention period



Possible Physical Layers

- Frequency Hopping Spread Spectrum (2.4GHz)
  - Hopping over 79 channels
  - 1-2Mb/s
- Direct Sequence Spread Spectrum (2.4GHz)
  - 11 chip Barker sequence
  - 1-2Mb/s
- Baseband IR
  - 1-2Mb/s
  - Diffuse infrared

Possible Physical Layers

- IEEE 802.11a
  – High Speed in the 5GHz Band (5GHz)
  – Uses Orthogonal Frequency Division Multiplexing (OFDM) to increase resilience to multi-path fading
  – Rate increased up to 54Mb/s
- IEEE 802.11b
  – High Speed in the 2.4GHz Band
  – Uses Complementary Code Keying (CCK)
  – Rate increased up to 11Mb/s

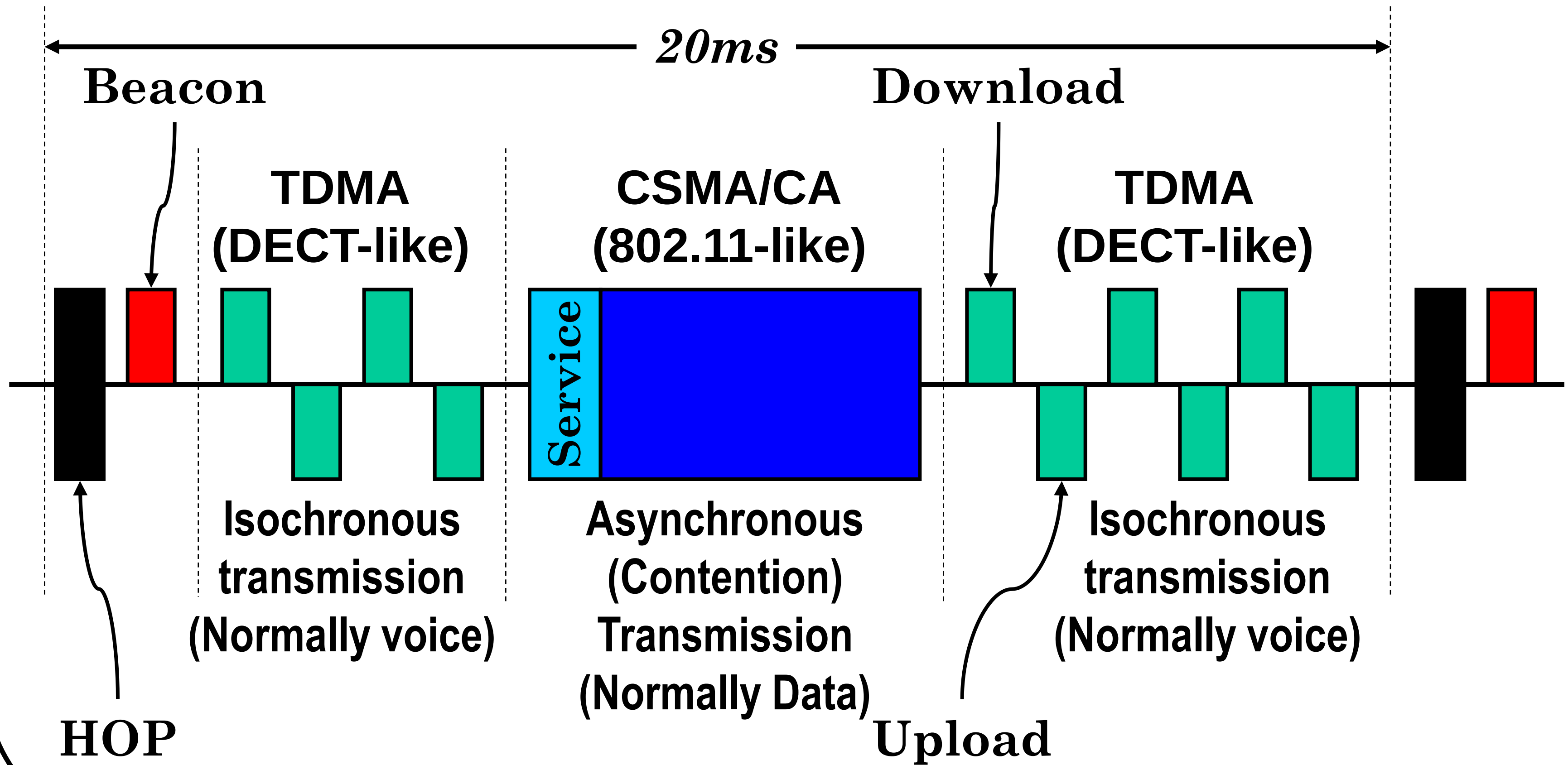
Home Networking

- Number of information appliances in a home projected to increase
- Hence, need for users to share their broadband connectivity throughout their home
- Why wireless:
  - Mobility
  - No ugly visible wires
- Proposals:
  - HomeRF
  - Bluetooth

HomeRF

- Connectivity to mobile devices
  - Cordless telephones
  - Data pads
- Connectivity to other PC's or resources
- Low cost
  - Unlicensed 2.4GHz band
  - DECT (Digital Enhanced Voice Communications) for voice
    - 32kb/s ADPCM
  - Simplified IEEE 802.11 support for TCP/IP
    - Same hop sequences
    - Comparable backoff, packet structure, ad-hoc capabilities

HomeRF Frame



HomeRF Features

- Hybrid TDMA/CSMA frame
- Beacon from Connection Point (CP) sets frame structure
- Frequency hopping, 50hops/sec
  - To protect from interference
- 1 or 2Mb/s nominal rate
  - Actual rate much less
- Range: up to 50m (usually much less)

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Bluetooth

- Same spirit as HomeRF, but designed to be cheaper
- Also derived from IEEE 802.11
- Range reduced to 10m
- Data rate reduced to 721Kb/s
- Particularity: Very fast frequency hopping
  - 1600 hops per second

Problems with HomeRF and Bluetooth

- Limited number of users supported
  - Do not work properly for more than 4-5 users
- Interoperability problems between Bluetooth and IEEE 802.11

Broadcast Network Infrastructures

Outline

- What role can broadcast technology play in today's Internet?
- Technical discussion of the technology (how does it work?)

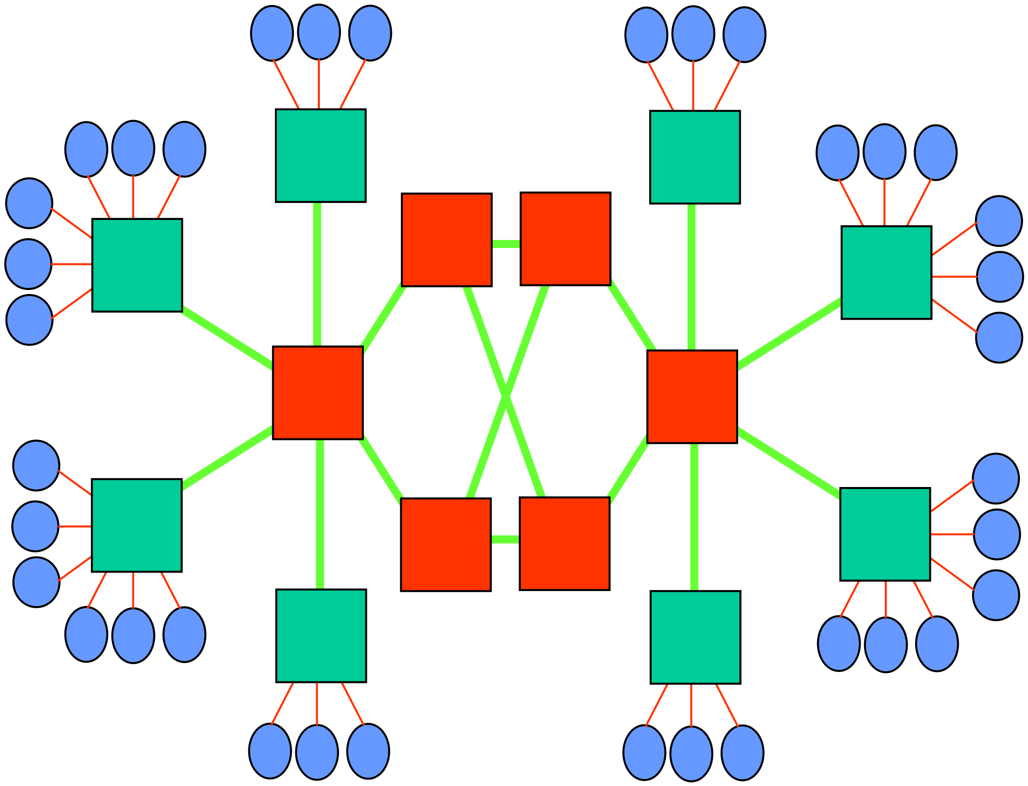
State of the Internet

- Internet traffic is exploding
- Internet traffic load per on-line user is increasing exponentially
- New applications need real-time and high quality content delivery
- Virtual communities are getting larger, more dynamic and more dispersed
- Internet enabled appliances are on the increase

The Result

- Congestion on the Internet
- Unpredictable performance
- Non-uniform, poor quality experience to all users
- No mechanism for guaranteed quality of service

The Problem: Internet Infrastructure



Point-to-Point

Multi-hop

Best-effort

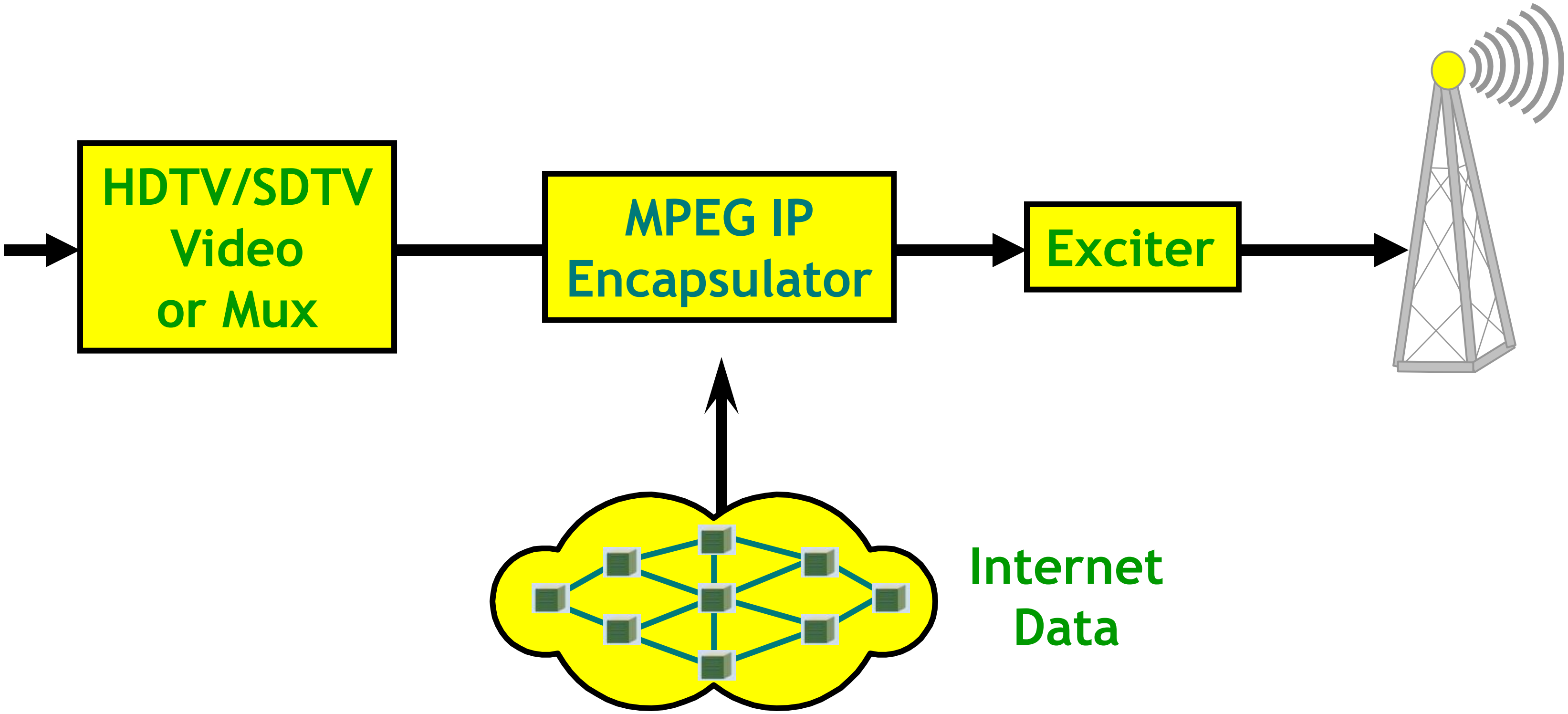
Current Solutions & Their Effect

- Broadband access technologies (Cable, DSL)
  - Decongest the “last mile”
  - Move congestion to the “on ramps” and “off ramps”
- Gigabit and terabit speed routers
  - Decongest the “on ramps” and “off ramps”
  - Move congestion to the “core”
- Optical networking technologies (DWDM)
  - Decongest the core
  - Move congestion to the “data centers”
- Web caching technologies
  - Decongest the “data centers”
  - Limits use of dynamic, real-time content
- Content replication
  - Adds significant load and complexity to infrastructure

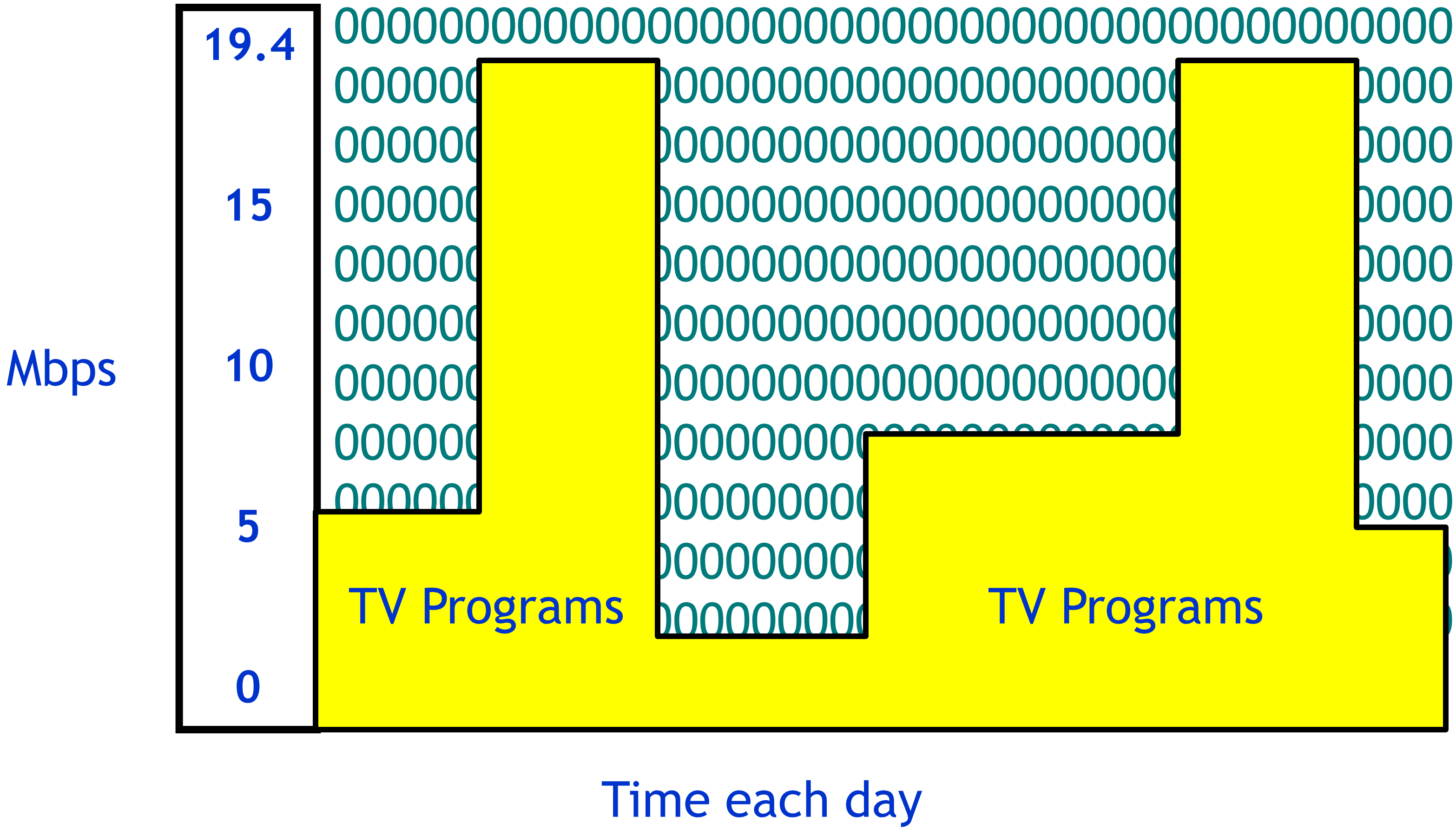
Digital TV Systems

- Current Digital TV Systems are based on MPEG technology
  – Satellite Direct-To-Home systems (typically 30 Mb/s per transponder)
  – Terrestrial HDTV (19.4 Mb/s)
  – Digital Cable (typically 38 Mb/s per channel)
- The transmission channel is a “bit pipe” running at a fixed bit rate, with one or more video programs.
- Data is transmitted in MPEG-2 Transport format.

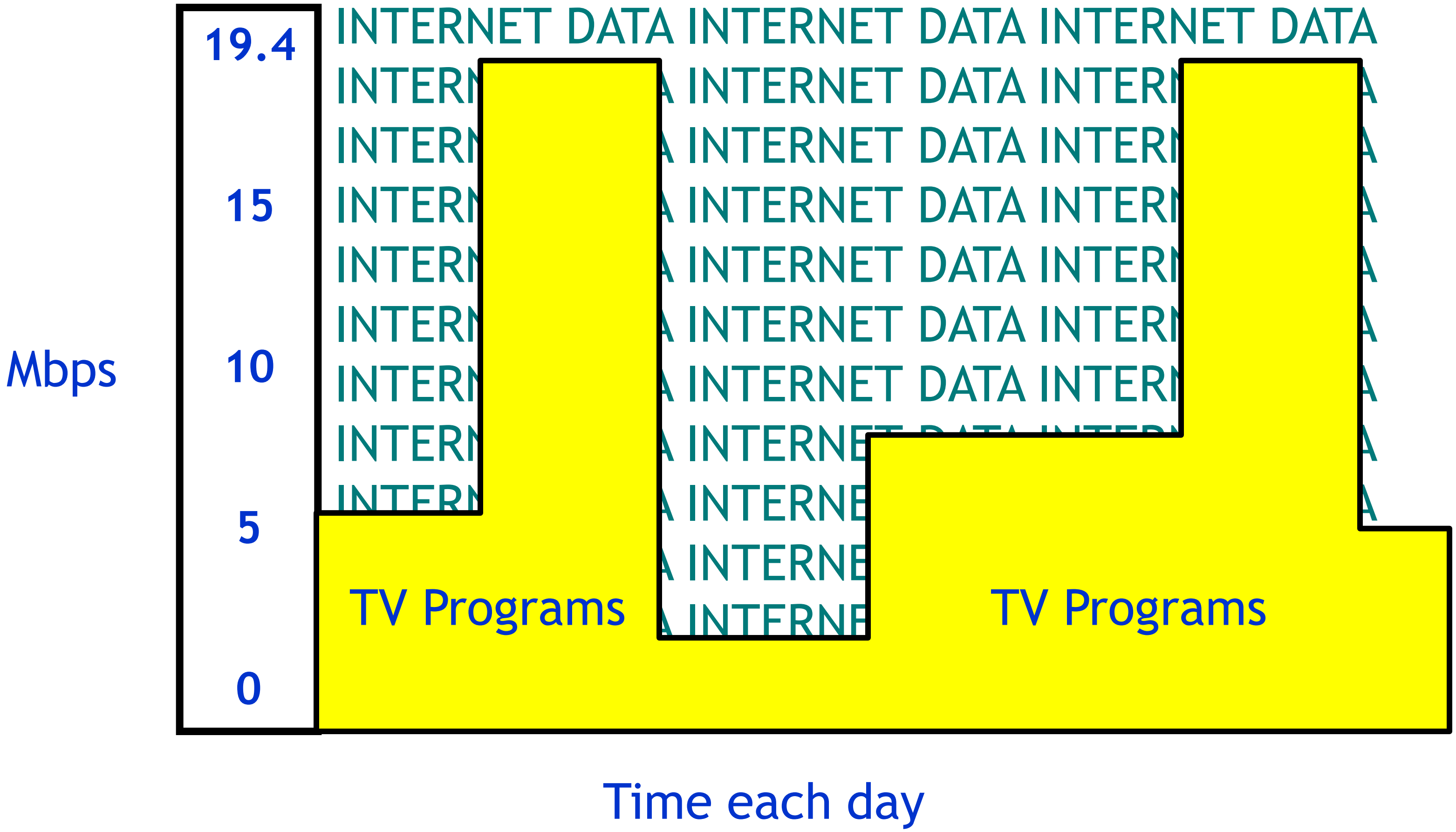
Data-Enabling the Digital Spectrum



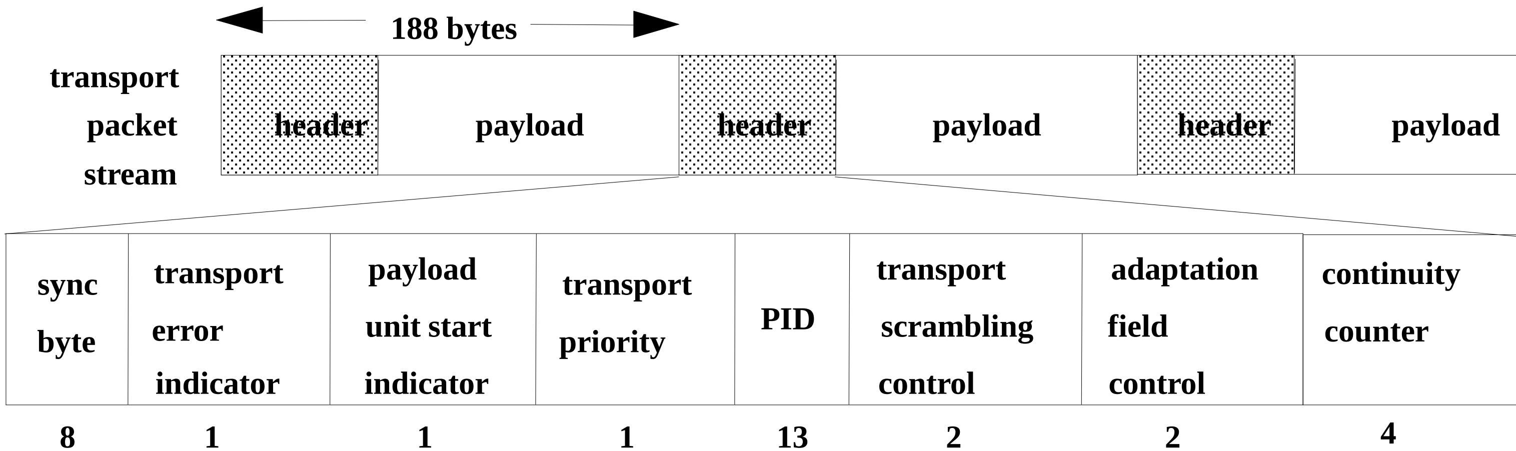
Wasted Bandwidth



Reclaim that Bandwidth



A Primer on MPEG-2 Technology



- MPEG data is transmitted in fixed-size packets.
- MPEG packets are 188 bytes long, with a 4-byte header
- Main fields in the header:
  - Sync Byte: always 0x47, allows for packet delimitation
  - PID: differentiates between multiple streams

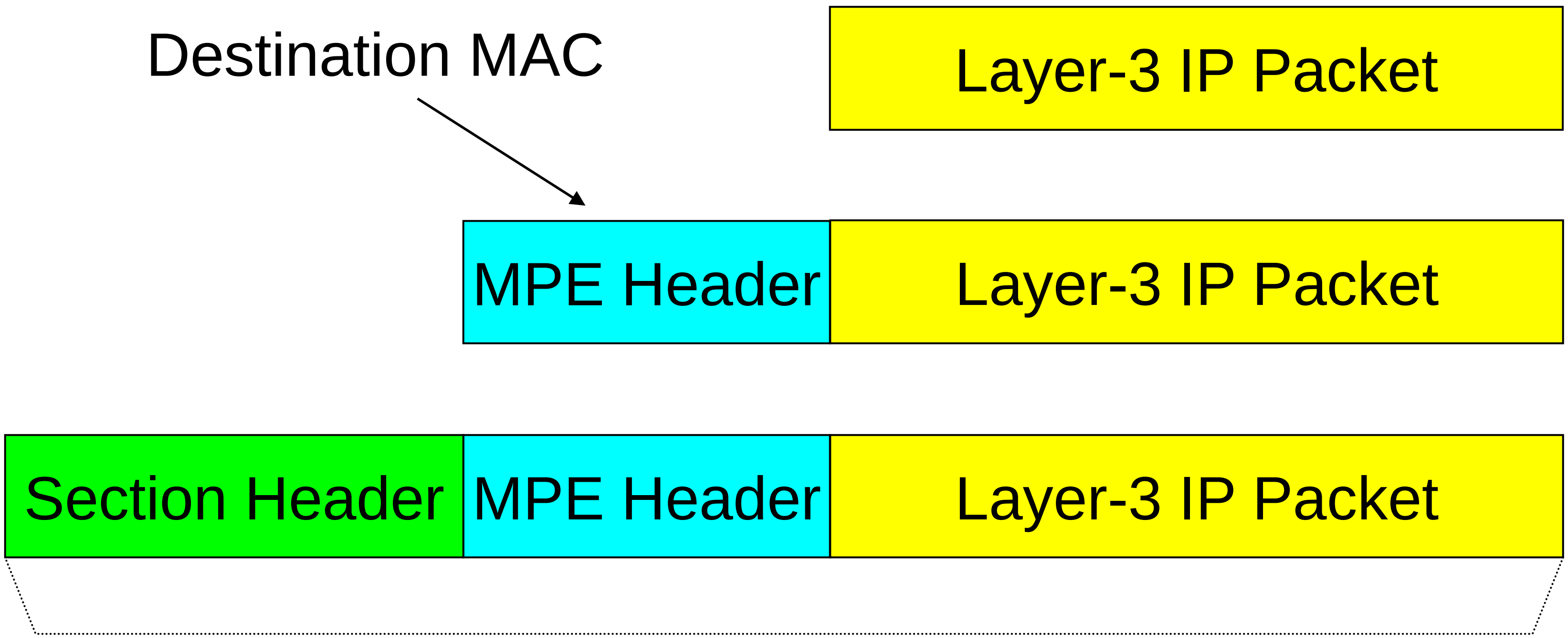
MPEG Stream Components

- A typical MPEG stream is composed of:
  - Compressed MPEG Video
  - Compressed MPEG Audio
  - Administrative Information (tables, conditional access, etc.)
  - Data
  - "Unused" packets (NULL packets)
- Each stream is carried on a separate PID
- IP Packets can be carried into MPEG packets as data

Transporting IP over MPEG

- DVB Standard defined in EN 301 192; ATSC is very similar.
- Basic Idea:
  - Start with the layer-3 IP packet
  - Add a standard MPE header that contains a ***destination MAC address***.
  - Add the MPEG private section header
  - Packetize into 188-byte MPEG Transport packets
  - IP packet boundaries do not necessarily need to align with MPEG transport payload boundaries

Illustration



This PDU becomes the payload of MPEG Packets

Encapsulation Details

Table id	Section syntax indicator	Private Indicator	Res	Private section length	Mac Address 6	Mac Address 5	Res	Payload scrambling control
(8)	(1)	(1)	(2)	(12)	(8)	(8)	(2)	(2)

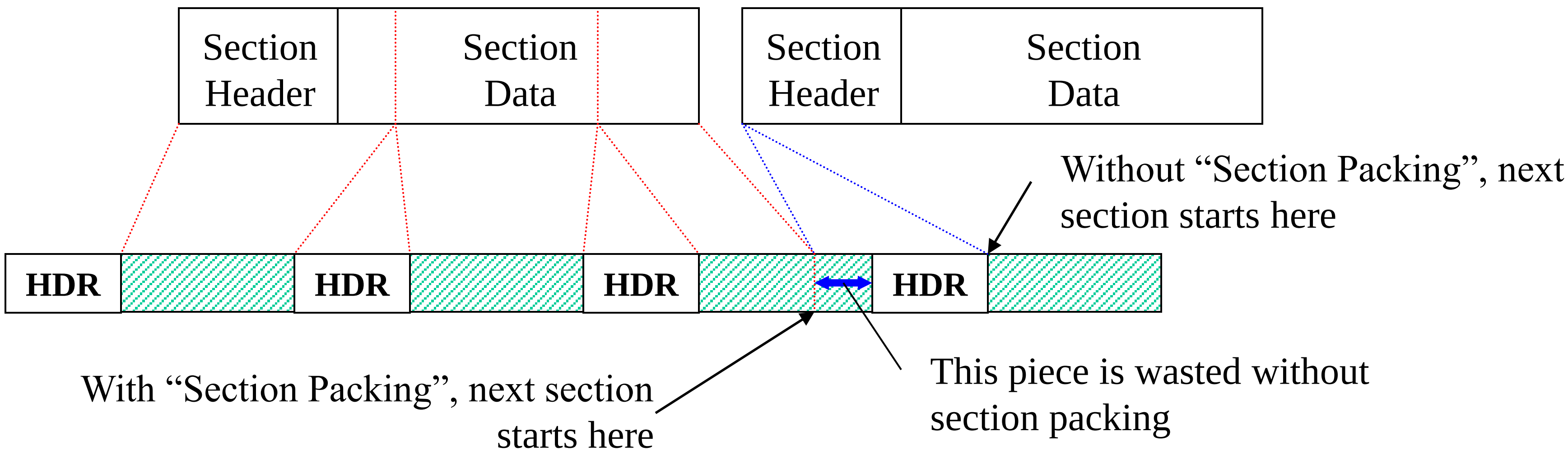
Address scrambling control	LLC SNAP flag	Current next indicator	Section number	Last section number	Mac Address 4	Mac Address 3	Mac Address 2	Mac Address 1
(2)	(1)	(1)	(8)	(8)	(8)	(8)	(8)	(8)

LLC/SNAP header	IP Datagram data bytes	Stuffing bytes	CRC-32 Checksum	Padding
8	46<=n<=1500	(0)	(32)	0<=n<=183

Optional; Value is:
`AA-AA-03`
`00-00-00`
`08-00`

Key
(n) =bits
n = bytes

Packetization Process



- Sections go in the payload of transport packets
- Sections can be larger or smaller than transport packets
- "Section Packing" improves the efficiency

Receiver Operation

- The MAC address in the header identifies the intended receiver.
- Same rules as an Ethernet MAC address
- A receiver will only accept:
  - Packets directed at its MAC address
  - Multicast packets from groups it subscribed
  - Broadcast packets
- Accepted packets are typically delivered to the IP stack in the receiver.

End-to-End Operation