Lecture 9

DHCP and Networking Summary

ELEC 3506/9506
Communication Networks

Dr Wibowo Hardjawana
School of Electrical and Information Engineering

IP addresses: how to get one?

That's actually two questions:

1. Q: How does a *host* get IP address within its network (host part of address)?
2. Q: How does a *network* get IP address for itself (network part of address)

How does *host* get IP address?

- hard-coded by sysadmin in config file (e.g., /etc/rc.config in UNIX)
- DHCP: Dynamic Host Configuration Protocol: dynamically get address from as server
  - "plug-and-play"

DHCP: Dynamic Host Configuration Protocol

goal: host *dynamically* obtains IP address from network server when it "joins" network

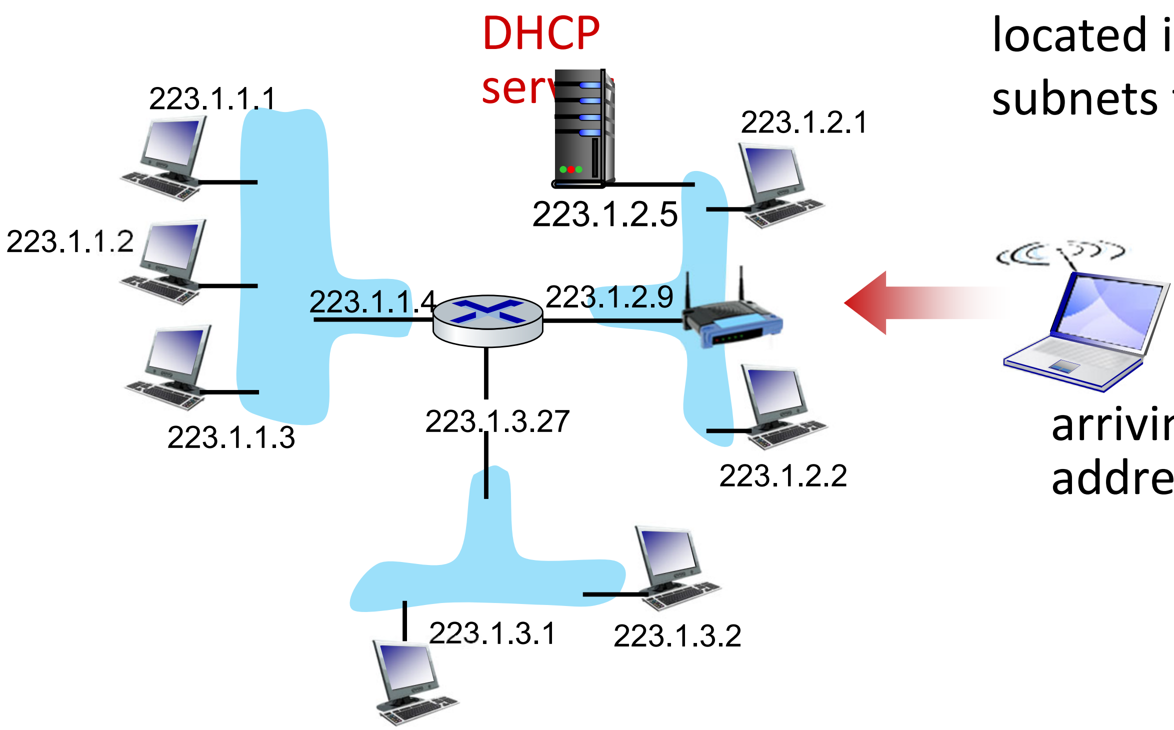
- can renew its lease on address in use
- allows reuse of addresses (only hold address while connected/on)
- support for mobile users who join/leave network

DHCP overview:

- host broadcasts DHCP discover msg [optional]
- DHCP server responds with DHCP offer msg [optional]
- host requests IP address: DHCP request msg
- DHCP server sends address: DHCP ack msg

ARP ≠ DHCP

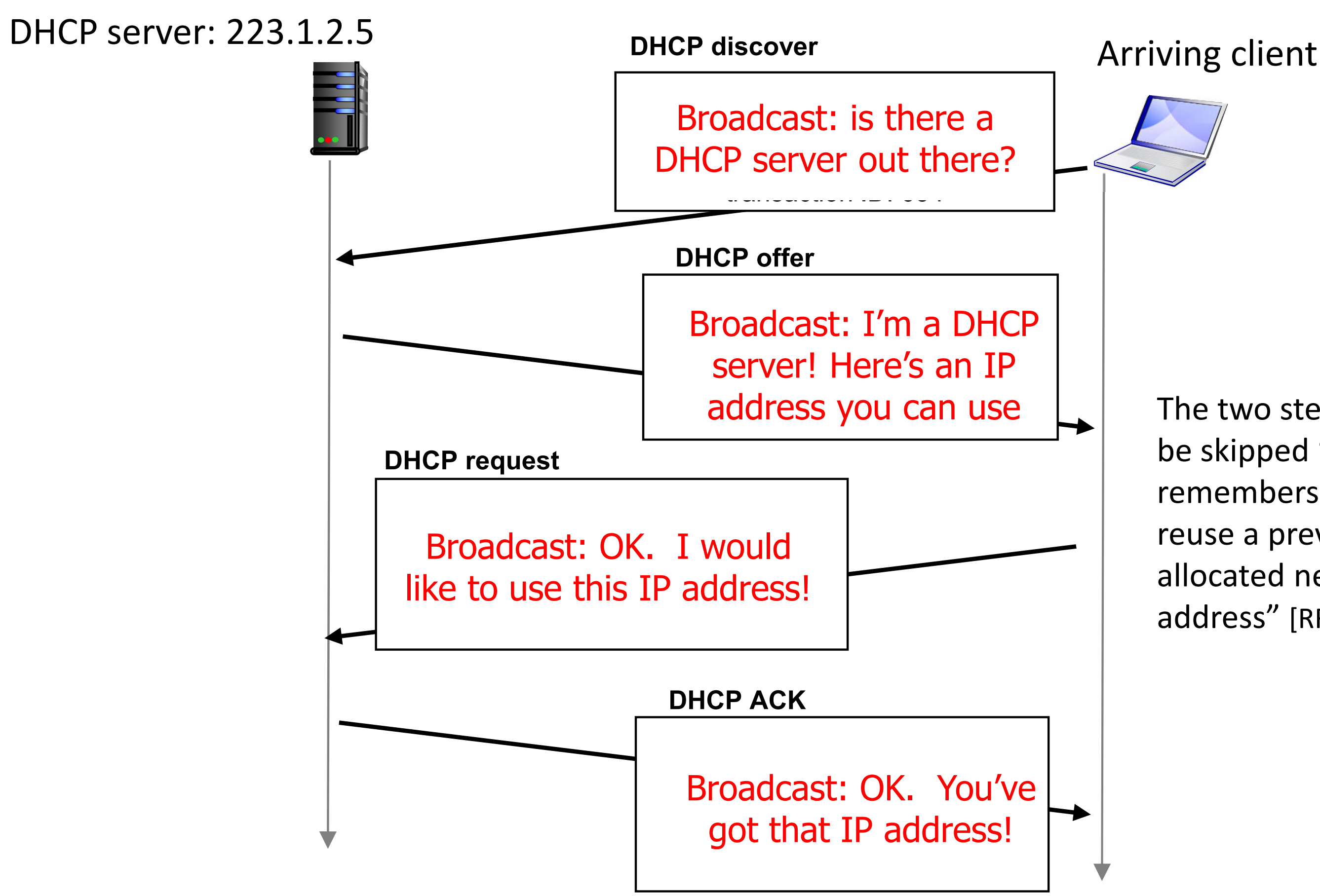
DHCP client-server scenario



Typically, DHCP server will be co-located in router, serving all subnets to which router is attached

arriving DHCP client needs address in this network

DHCP client-server scenario



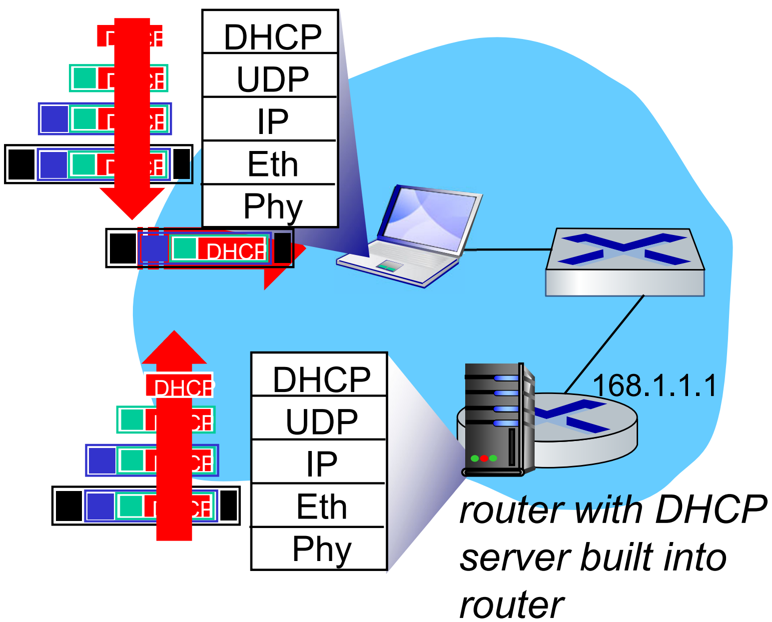
The two steps above can be skipped "if a client remembers and wishes to reuse a previously allocated network address" [RFC 2131]

DHCP: more than IP addresses

DHCP can return more than just an allocated IP address on the subnet:

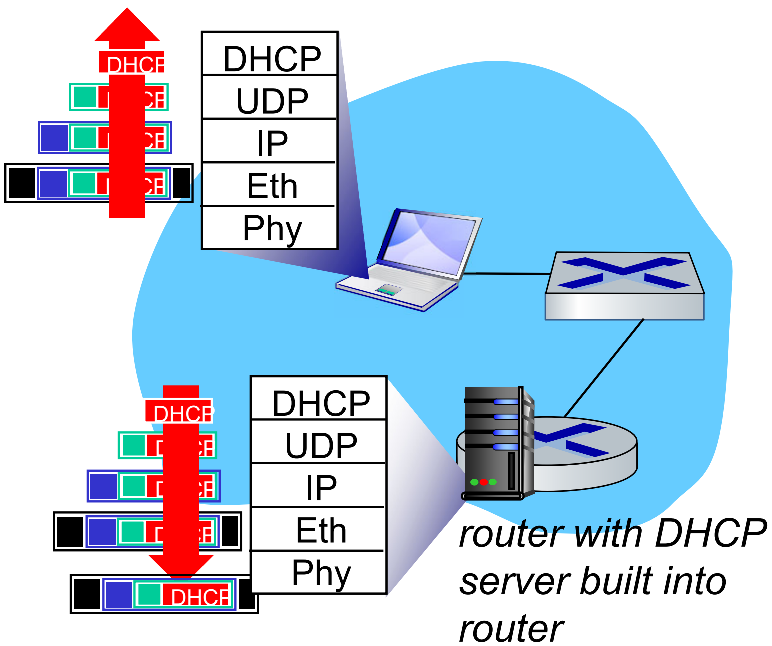
- address of first-hop router for the client (Gateway Router for client)
- name and IP address of DNS server
- network mask (indicating network versus host portion of address)

DHCP: example



- Connecting laptop will use DHCP to get IP address, address of first-hop router, address of DNS server.
- DHCP REQUEST message encapsulated in UDP, encapsulated in IP, encapsulated in Ethernet
- Ethernet frame broadcast (dest: FFFFFFFFFFFF) on LAN, received at router running DHCP server
- Ethernet demux'ed to IP demux'ed, UDP demux'ed to DHCP

DHCP: example

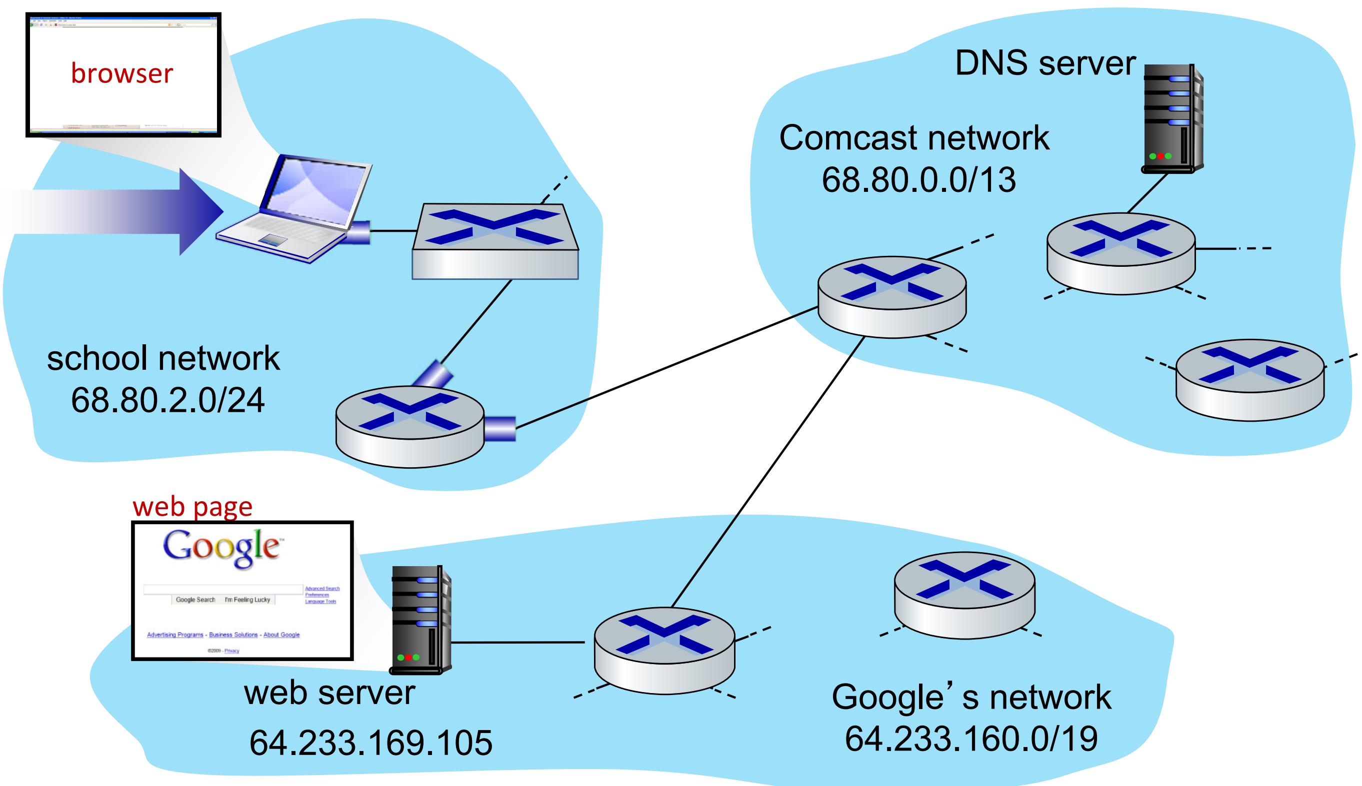


- DHCP server formulates DHCP ACK containing client's IP address, IP address of first-hop router for client, name & IP address of DNS server
- encapsulated DHCP server reply forwarded to client, demuxing up to DHCP at client
- client now knows its IP address, name and IP address of DNS server, IP address of its first-hop router

Synthesis: a day in the life of a web request

- our journey down the protocol stack is now complete!
  - application, transport, network, link
- putting-it-all-together: synthesis!
  - *goal:* identify, review, understand protocols (at all layers) involved in seemingly simple scenario: requesting www page
  - *scenario:* student attaches laptop to campus network, requests/receives www.google.com

A day in the life: scenario

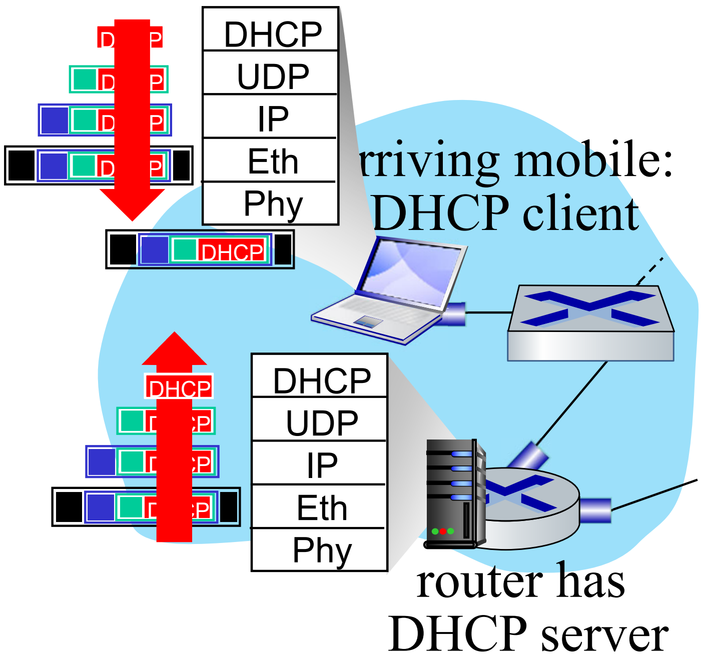


scenario:

- arriving mobile client attaches to network ...
- requests web page: www.google.com

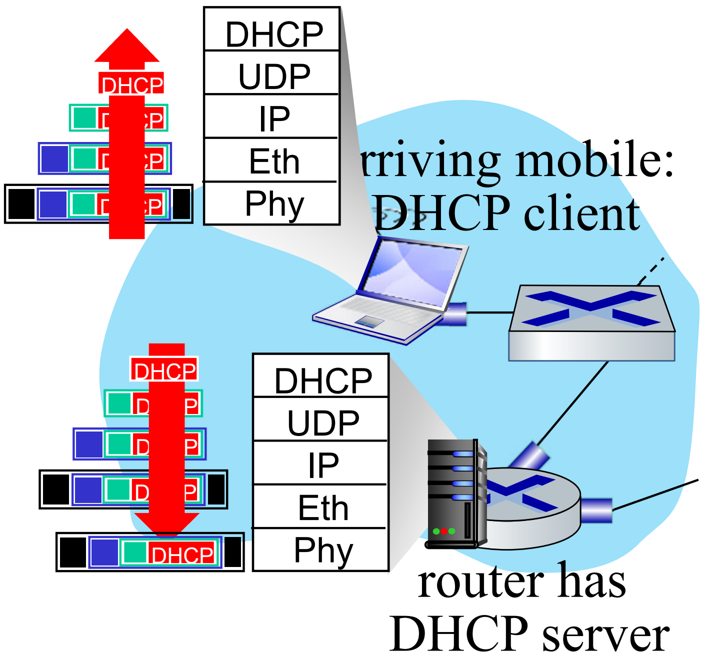
Sounds simple!

A day in the life: connecting to the Internet



- connecting laptop needs to get its own IP address, addr of first-hop router, addr of DNS server: use DHCP
  - DHCP request encapsulated in UDP, encapsulated in IP, encapsulated in 802.3 Ethernet
  - Ethernet frame broadcast (dest: FFFFFFFFFFFF) on LAN, received at router running DHCP server
  - Ethernet demuxed to IP demuxed, UDP demuxed to DHCP

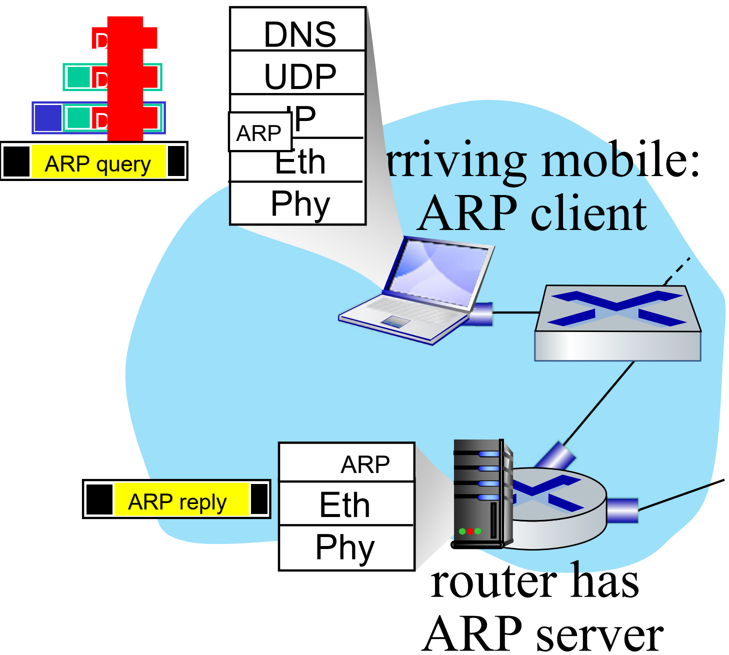
A day in the life: connecting to the Internet



- DHCP server formulates DHCP ACK containing client's IP address, IP address of first-hop router for client, name & IP address of DNS server
  - encapsulation at DHCP server, frame forwarded (switch learning) through LAN, demultiplexing at client
- DHCP client receives DHCP ACK reply

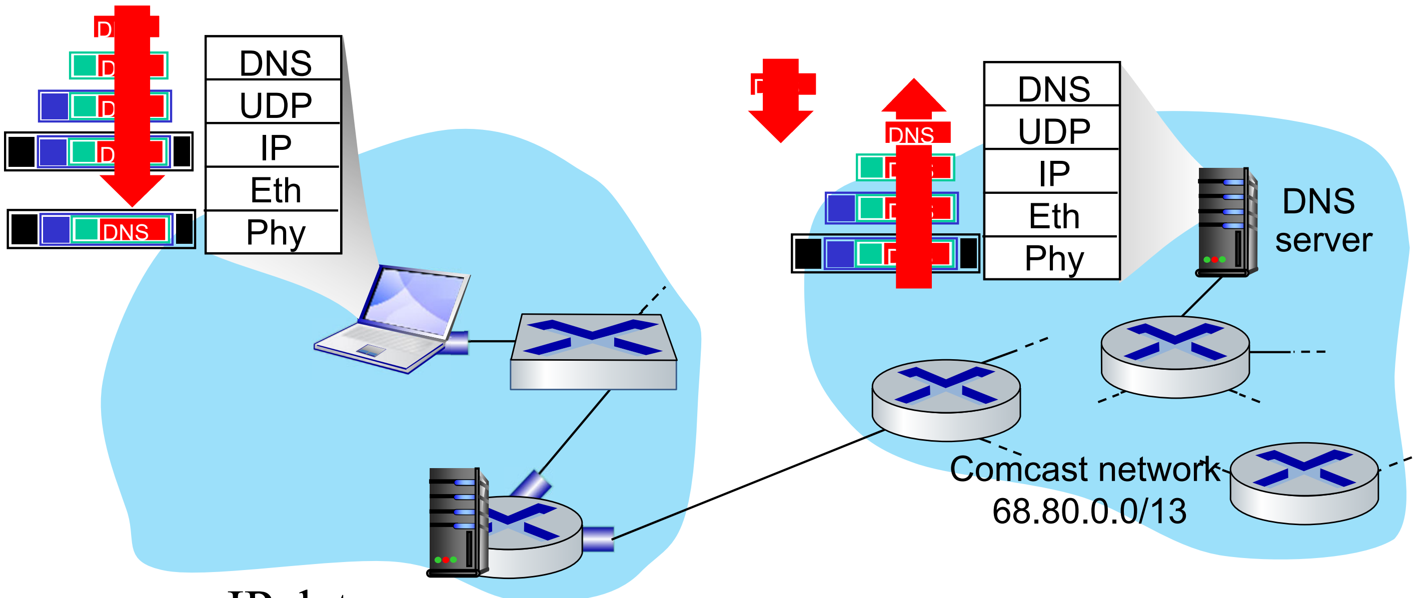
Client now has IP address, knows name & addr of DNS server, IP address of its first-hop router

A day in the life... ARP (before DNS, before HTTP)



- before sending HTTP request, need IP address of www.google.com: DNS
  - DNS query created, encapsulated in UDP, encapsulated in IP, encapsulated in Eth. To send frame to router, need MAC address of router interface: ARP
- ARP query broadcast, received by router, which replies with ARP reply giving MAC address of router interface
  - client now knows MAC address of first hop router, so can now send frame containing DNS query

A day in the life... using DNS

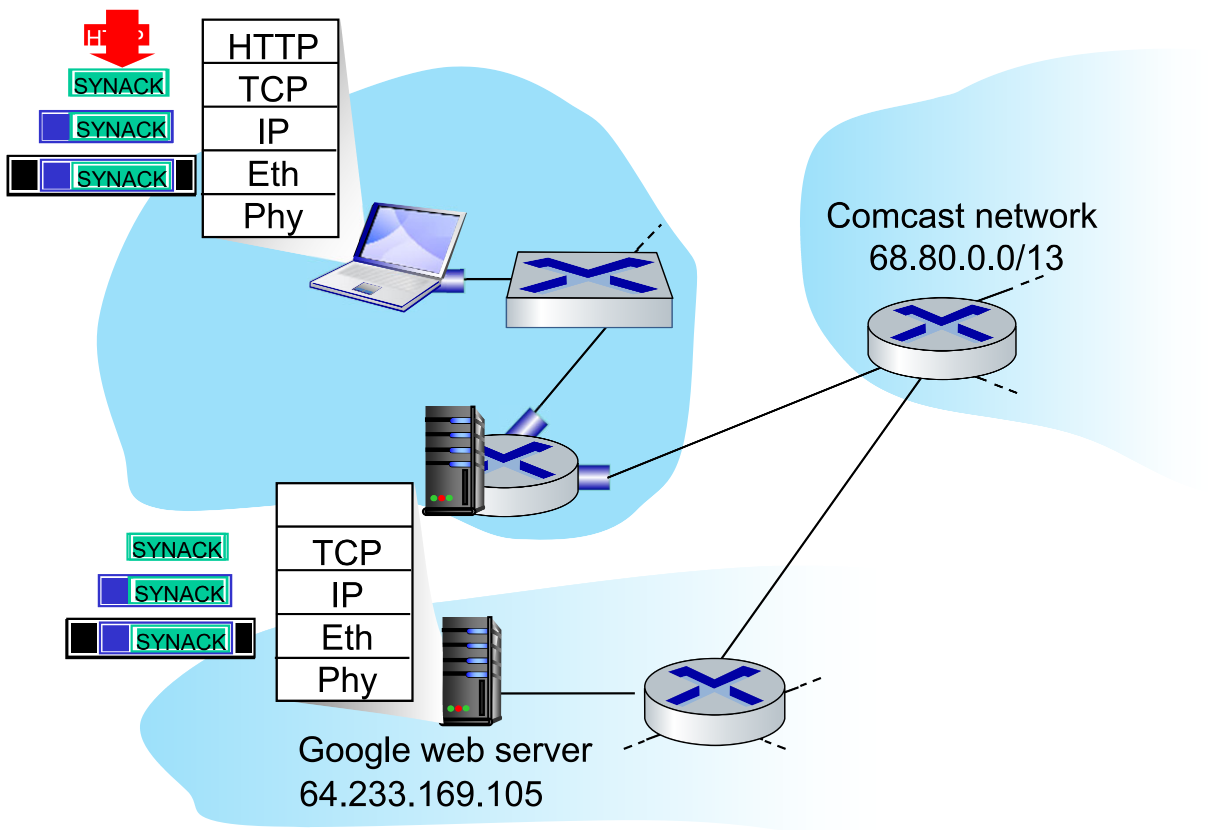


- IP datagram containing DNS query forwarded via LAN switch from client to 1st hop router

- IP datagram forwarded from campus network into Comcast network, routed (tables created by RIP, OSPF and/or BGP routing protocols) to DNS server

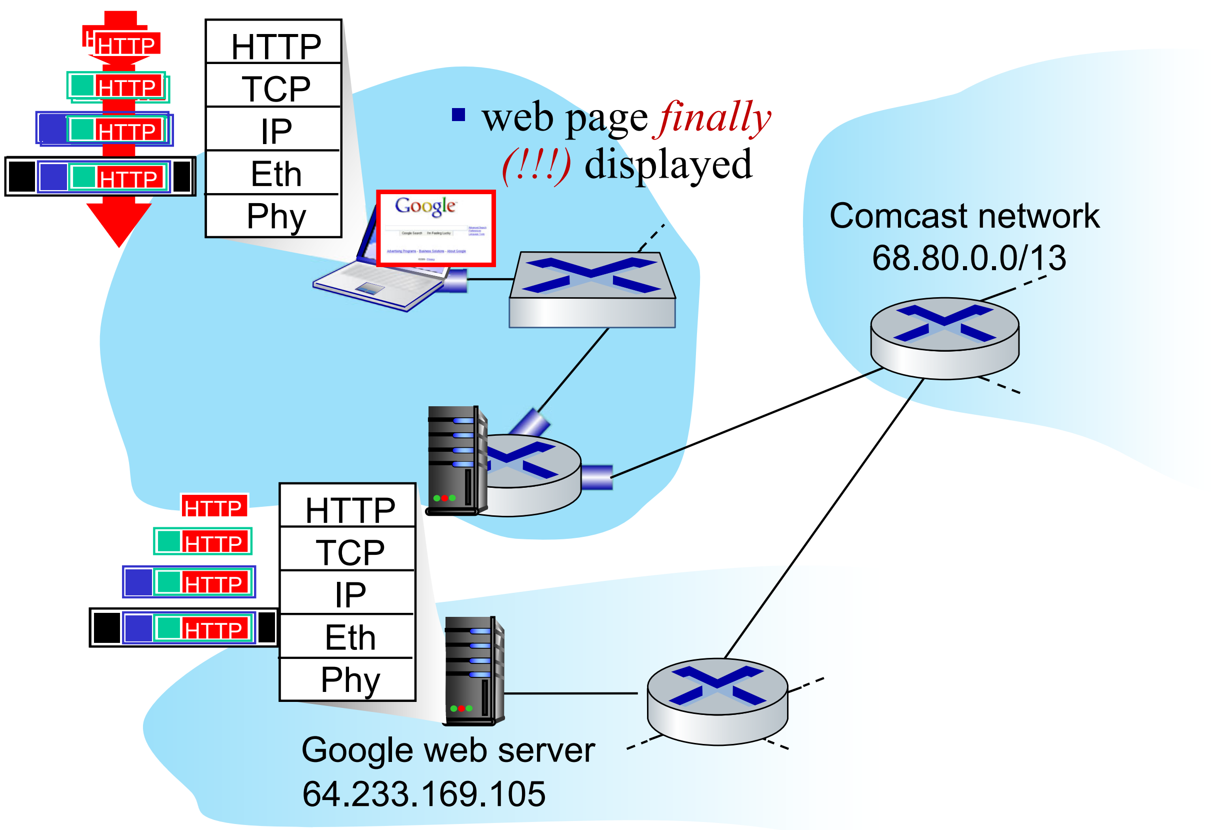
- demuxed to DNS
- DNS replies to client with IP address of www.google.com

A day in the life…TCP connection carrying HTTP



- to send HTTP request, client first opens TCP socket to web server
- TCP SYN segment (step 1 in TCP 3-way handshake) inter-domain routed to web server
- web server responds with TCP SYNACK (step 2 in TCP 3-way handshake)
- TCP connection established!

A day in the life... HTTP request/reply



- HTTP request sent into TCP socket
- IP datagram containing HTTP request routed to www.google.com
- web server responds with HTTP reply (containing web page)
- IP datagram containing HTTP reply routed back to client

Recommended Reading

- J. F. Kurose and K. W. Ross, Computer Networking: A Top-Down Approach, 8th ed., 2022, Chapters 4 and 6

Lecture 9

WAN Technologies

ELEC 3506/9506
Communications Networks

Dr Wibowo Hardjawana
School of Electrical and Information Engineering

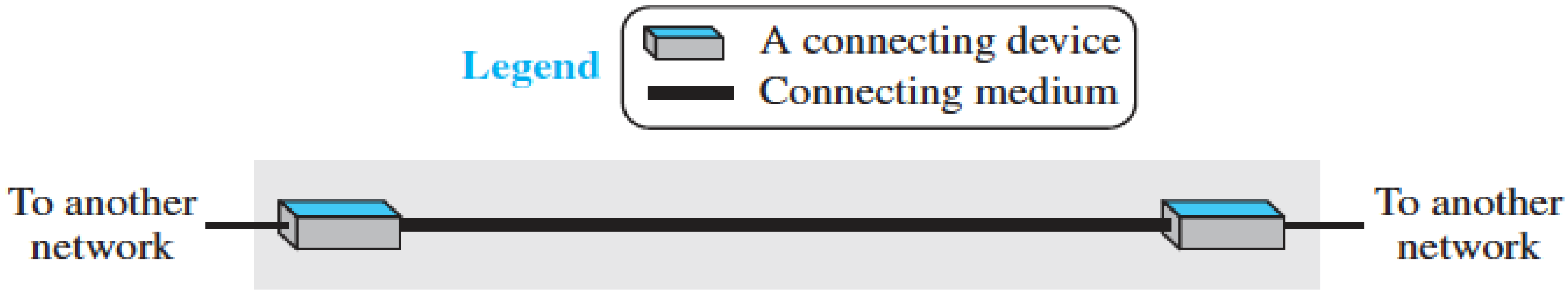
Topics of the Day

- WAN (Wide Area Network) Overview
- ~~Dial-up Service~~ *Legacy*
- xDSL (Digital Subscriber Line)
- ~~SDH/SONET (Synchronous Optical Network)~~ *Legacy*
- ~~ATM (Asynchronous Transfer Mode)~~ *Legacy*
- FTTx (Fibre-to-the-X)
- Cable Networks
- MPLS

LAN vs WAN

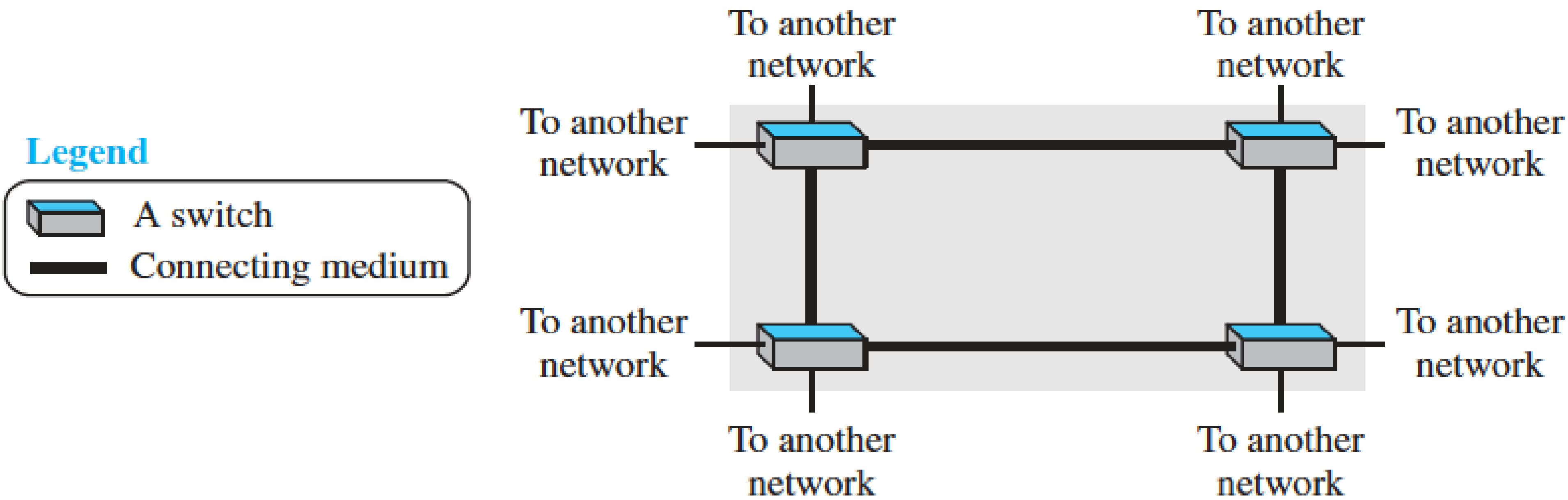
- Goal is to carry Ethernet/IP traffic from/to end users.
- Local area network (LAN)
  - Interconnects hosts (computer, laptop, cellular phone, workstation….)
  - Usually privately owned
  - Typically spans a single office, building, or campus
- Wide area network (WAN)
  - Interconnects connecting devices (switches, routers, modem)
  - Normally run by communication companies and leased by an organization that uses it
  - Spans across large geographic areas: a town, a state, a country, or even the world
  - LANS are usually connected to WANs
  - Two types: Point-to-Point and Switched

Point-to-Point WAN



- Point-to-point WAN: a network that connects two communication devices through a transmission media (cable or air)

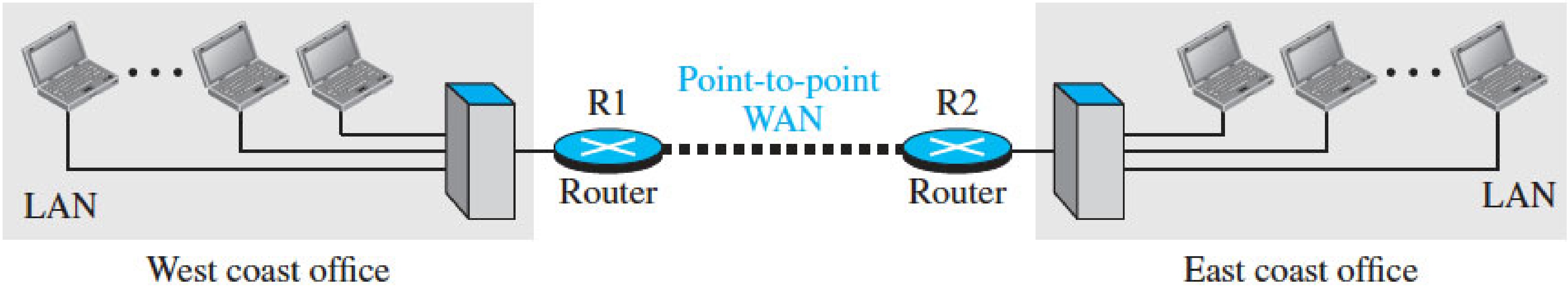
Switched WAN



- Switched WAN: a network with more than two ends
- Used in the backbone of global communication

Internetwork

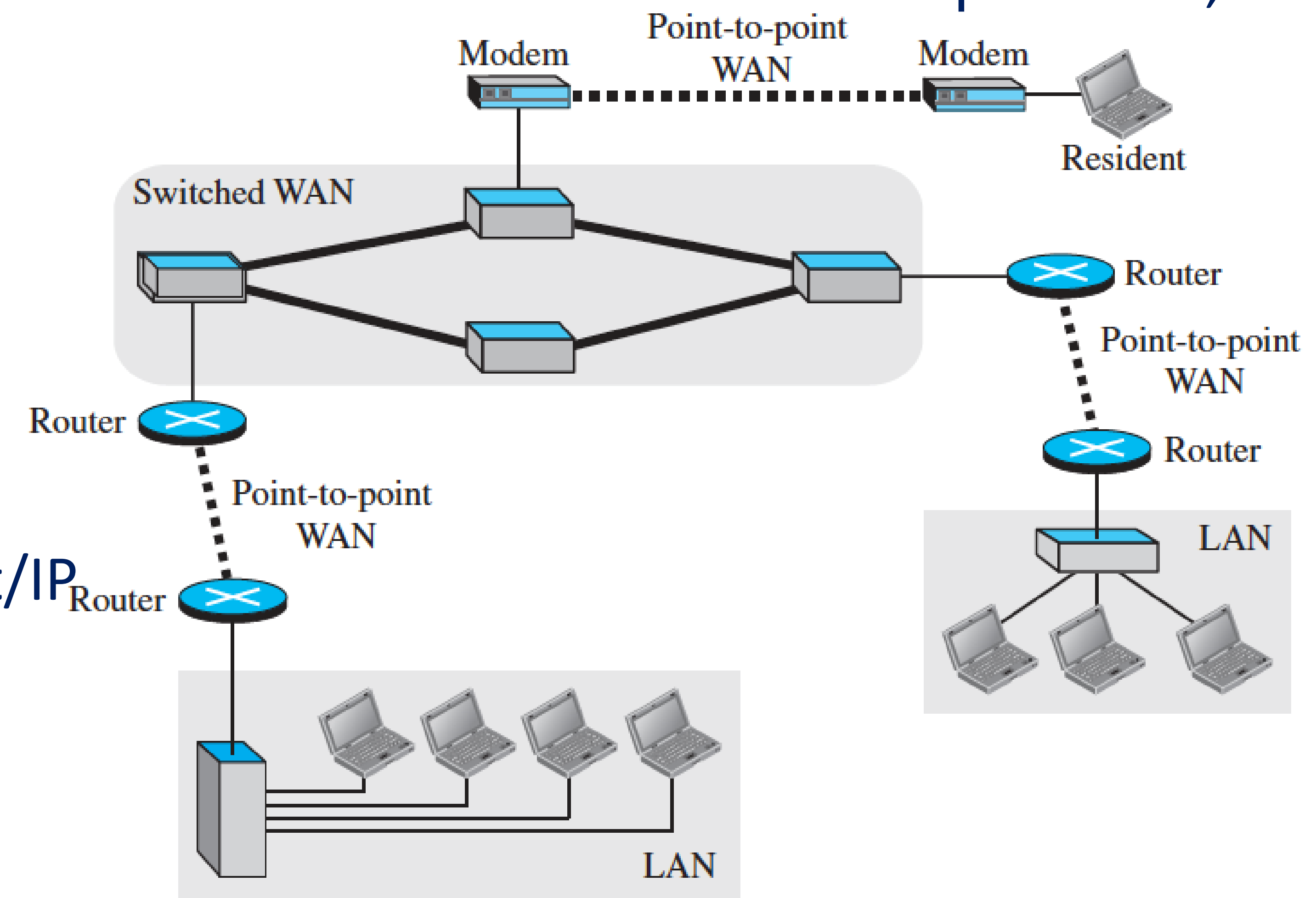
- LANs and WANs are connected to one another (internetwork)



Internetwork

Ethernet/IP on top of xDSL, HFC

Direct Ethernet/IP



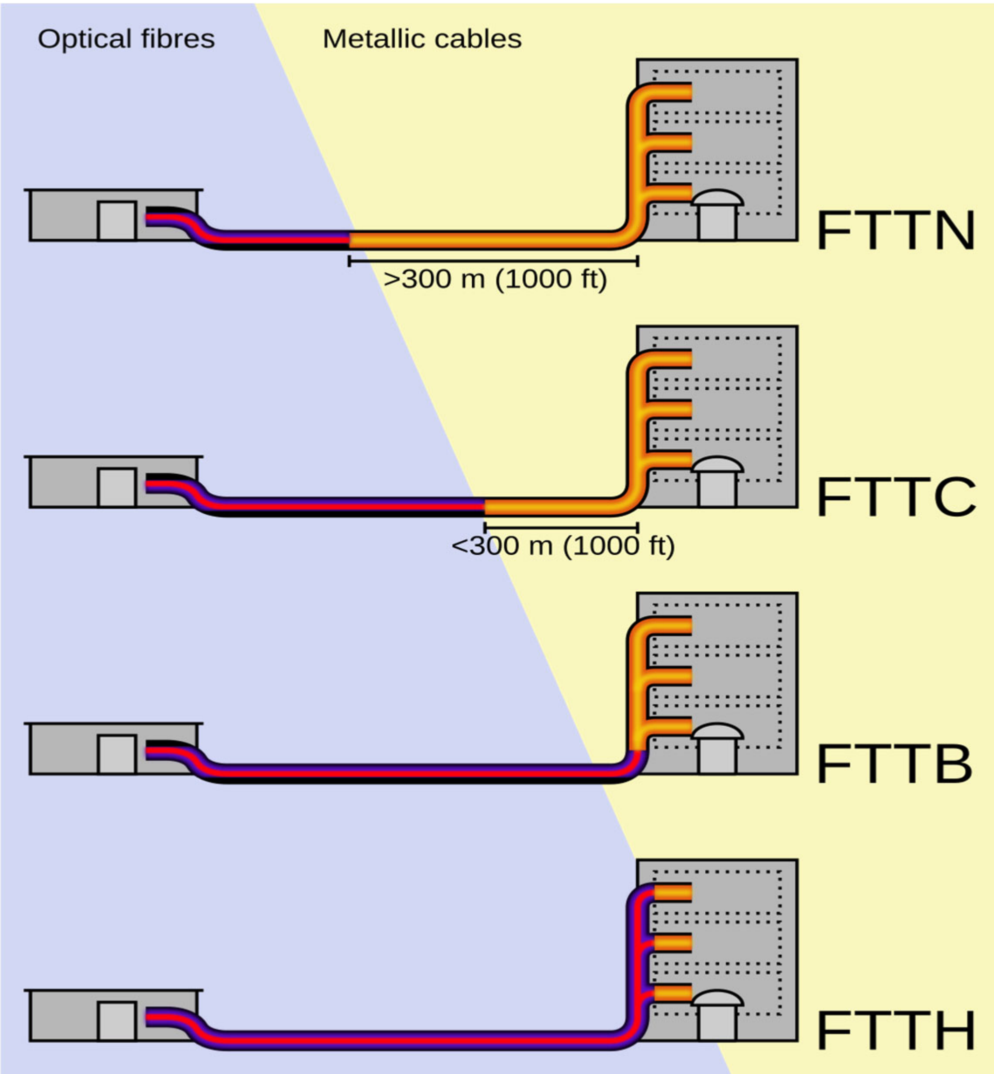
Regardless, direct or not, delivered by using FTTx architectures

Accessing the Internet

- To access the Internet (Ethernet IP traffic), a user needs to be physically connected to an Internet Service Provider (ISP)

- The physical connection is normally done through a point-to-point WAN (last-mile or access networks). Possible ways include:
  - Using hybrid optical fibre
  - Using copper networks
  - Using cable networks
  - Using wireless networks

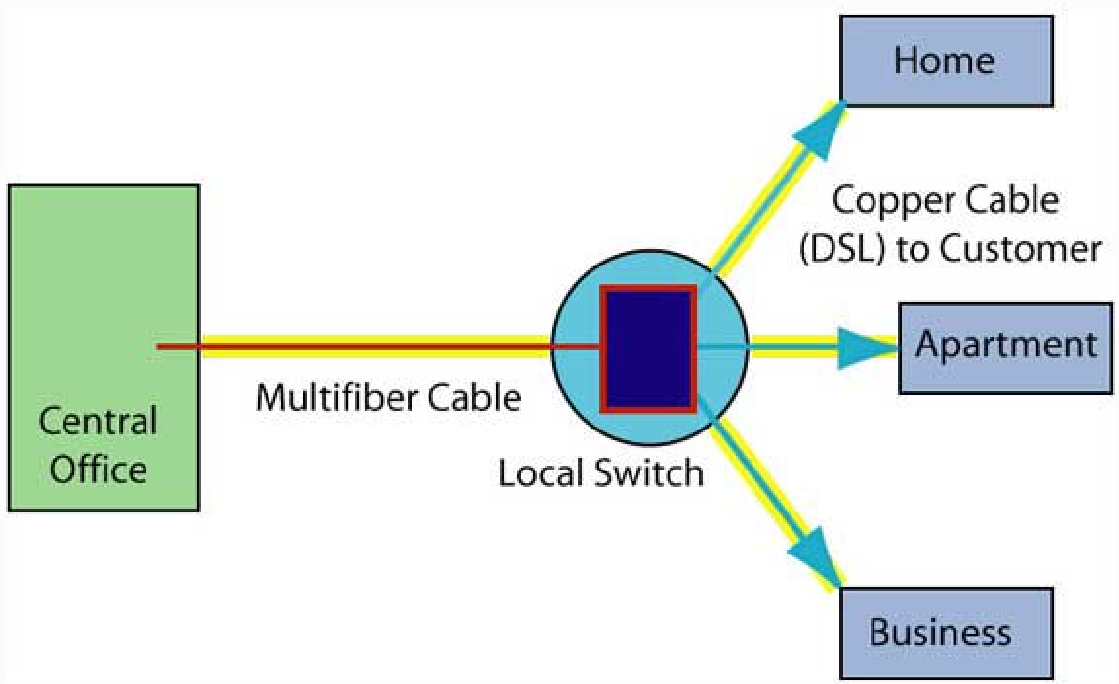
FTTx Technologies



- Mix of technology of copper, coaxial and fibre cables to deliver internet
- FTT**X** (**N**ode, **C**urb, **B**uilding, **H**ome) architectures vary with regard to the distance between the optical fibre and the end user
- Central Office carries internet traffic to multiple end users within the building
- Metallic cables=twisted copper wires Cat 5 or coaxial cables
- Fibre terminates at **X,** and the optical signal is converted to an electrical signal
- Example: NBN, Vodafone Vision etc

https://en.wikipedia.org/wiki/Fiber_to_the_x

FTTx Technologies – Digital Subscriber Line Access Multiplexer (DSLAM)



- Active fibre network and Mainly for FTTN or FTTB, where DSLAM facilitates the use of xDSL at the premises
- “Powered” DSLAM provides electrical and optical conversion and communicates with modems in the apartments (WiFi, Ethernet)
- Ethernet over fibre

https://www.thefoa.org/tech/ref/appln/FTTHarch.html

Digital Subscriber Line (DSL)

- A family of technologies for supporting high-speed digital communication over the existing copper wires telephone lines (xDSL):
  - ADSL : Asymmetric Digital Subscriber Line
  - SDSL : Symmetric Digital Subscriber Line
  - HDSL: High-bit-rate Digital Subscriber Line
  - VDSL : Very-high-bit-rate Digital Subscriber Line

- Allows simultaneous voice and data communications over copper wire lines

xDSL

- Asymmetric: downstream (ISP to user) has more bandwidth than upstream (user to ISP)
- Reflects the data requirements of home users
- Use the existing telephone lines (local loop)
- ADSL achieves much higher data rate than traditional dial up service. How?
  - Twisted-pair cable can actually handle bandwidths up to 1.1 MHz
  - But the filter at the end office of telephone company limits the bandwidth to 4 kHz (sufficient for voice)
  - By upgrading the filter, the entire 1.1 MHz is available for data and voice communications

- Multiple xDSL technologies

xDSL Bandwidth Portion

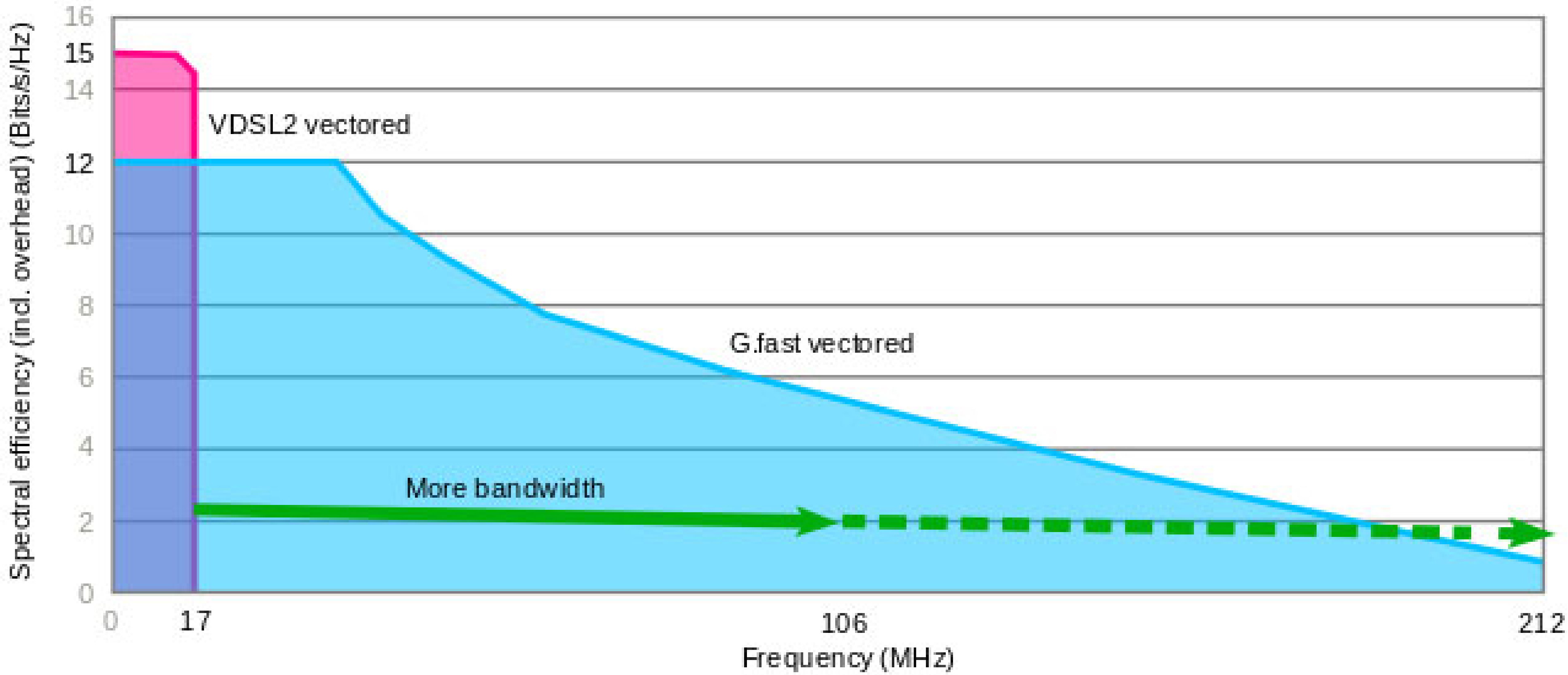


Image Source: https://arstechnica.com/information-technology/2016/10/xg-fast-dsl-does-10gbps-over-telephone-lines/

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ITU-T/ETSI Standards

(European Telecommunications Standards Organization)

Technology	Standard	Yr. approved	Data rate	Applications
HDSL	G.991.1	1998	2048 kbit/s	1.5–2 Mbit/s symmetrical service
SHDSL	G.991.2	2001	768 kbit/s	HDSL on a single pair
ADSL	G.992.1	1999	6 Mbit/s / 640 kbit/s	Internet access, multimedia database access, and video distribution
ADSL2	G.992.3	2002	8 Mbit/s / 800 kbit/s	
ADSL2+	G.992.5	2003	16 Mbit/s / 800 kbit/s	
VDSL	G.993.1	2004	52 Mbit/s / 2.3 Mbit/s	Internet access, HDTV service
VDSL2	G.993.2	2006	100 Mbit/s	Internet access, HDTV service over longer loops with more users than VDSL
VDSL2 vectoring	G.993.5	2010	200 Mbit/s	
G.fast	G.9701	2014	1000 Mbit/s	Internet access, 4K TV service

HDTV: high-definition television
SHDSL: single-pair high-speed DSL

Yoshihiro Kondo, “G.fast Ultrafast Access Technology Standardization in ITU-T”, *NTT Technical Review*

xDSL Limiting Factors

- Limiting Factors
  - Line distance: signal strength degrades with distance
  - Wire gauge: increasing wire size, less signal attenuation
  - Bridging tap: undesired interference to DSL due to echoed signal

xDSL: Data Rate vs. Distance

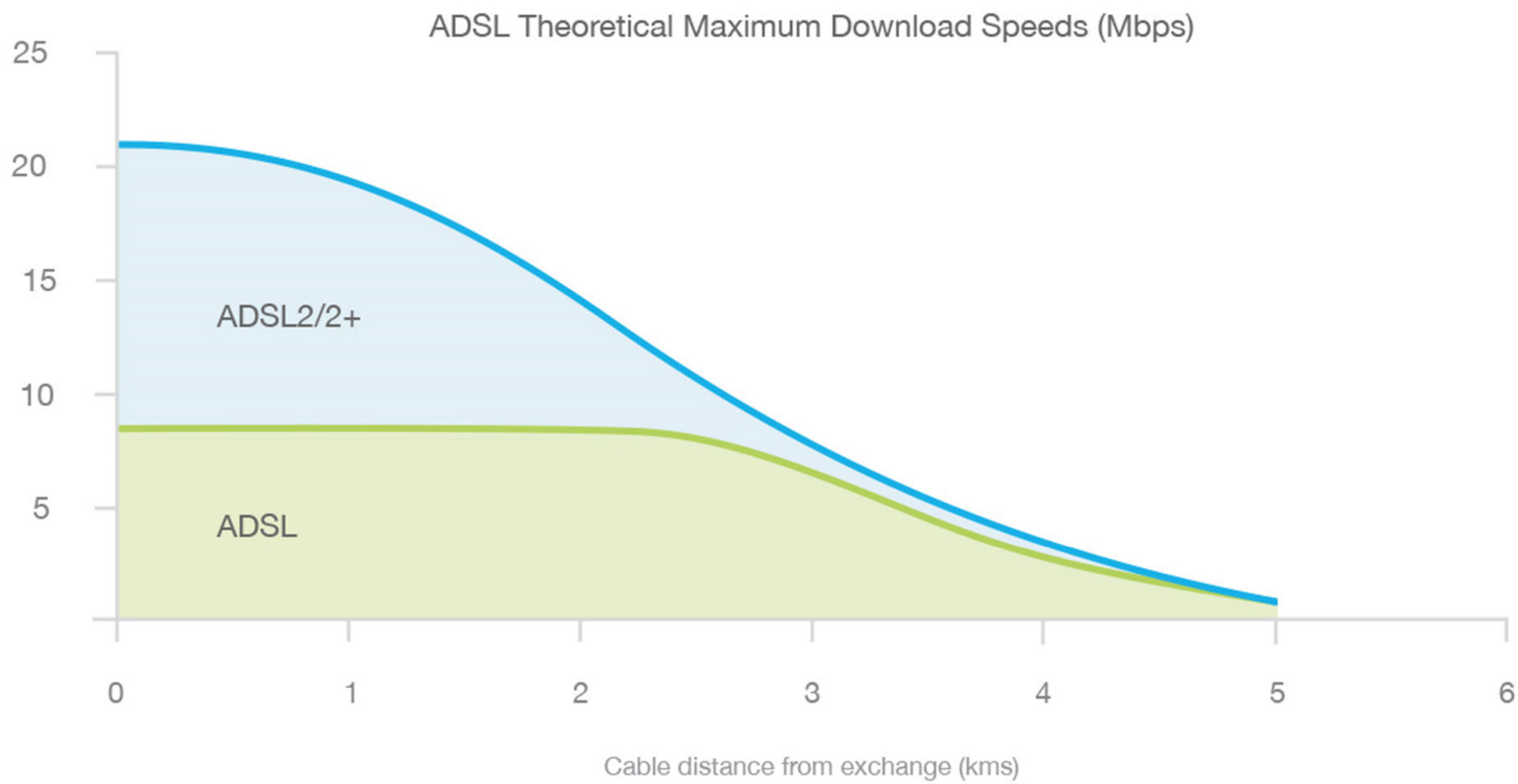


Image Source: *http://support.belong.com.au/adsl/join/what-is-the-difference-between-adsl2-and-adsl*

CABLE NETWORK

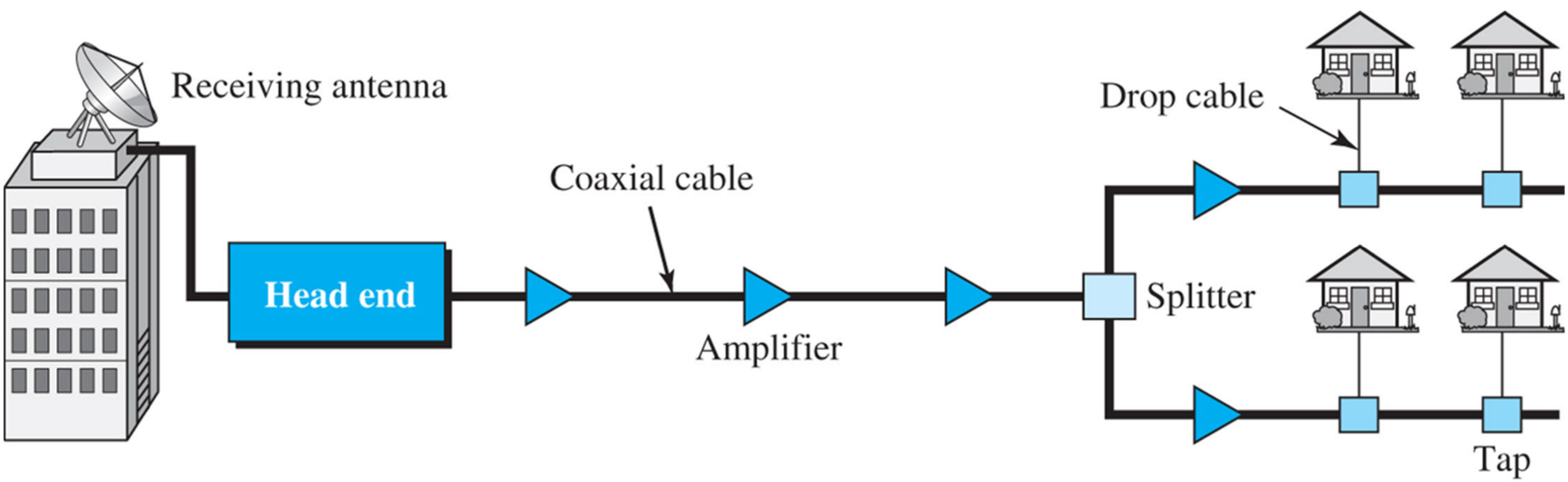
- Cable networks were originally created to provide access to TV programs for those subscribers who had no reception because of natural obstructions such as mountains.

- Later cable networks became popular with people who just wanted a better signal.

- In addition, cable networks enabled access to remote broadcasting stations via microwave connections.

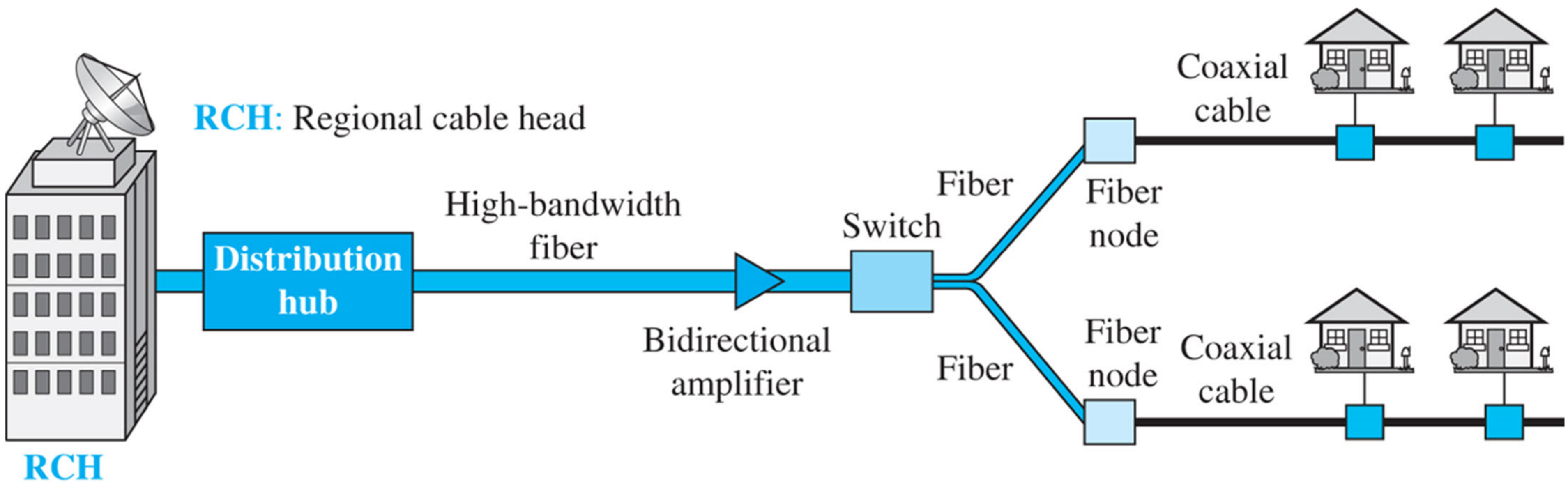
Traditional Cable Network

- Cable TV started distributing broadcast video signals to locations with poor or no reception in the late 1940s. I
- Community antenna TV (CATV) that received the signals from the TV stations and distributed them via coaxial cables.
- Head end performs the signal processing function, and amplifiers are used to strengthen the signal at the user-end



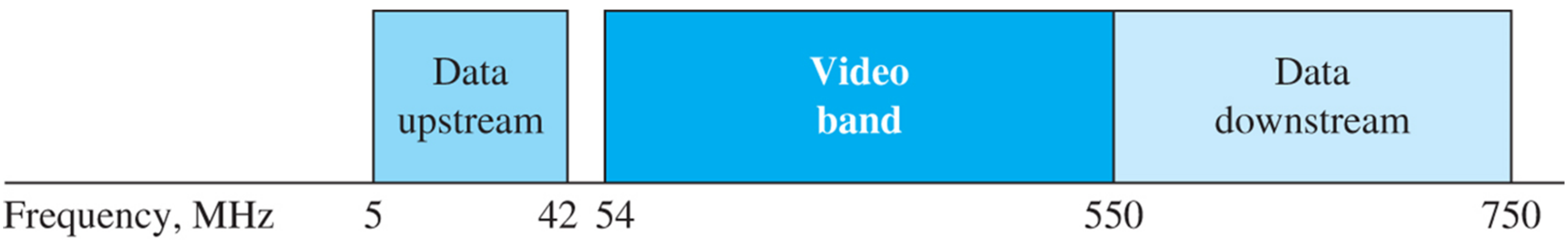
Hybrid Fiber-Coaxial Network (HFC)

- Second generation of cable networks, fiber-optic + coaxial cable
- The transmission medium from the cable TV office to a box, called the fiber node, is an optical fiber cable
- Fiber node through the neighborhood and into the house is still coaxial cable.



Cable TV for Data Transfer

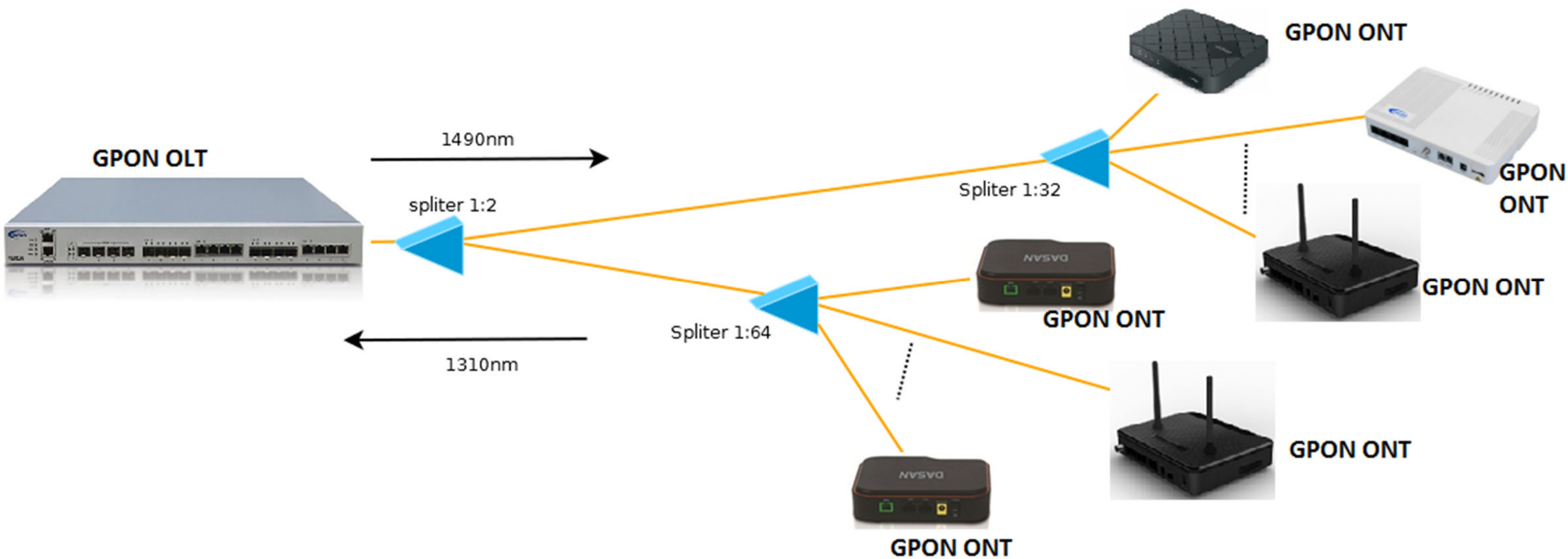
- DSL uses the existing unshielded twisted-pair cable, which is very susceptible to interference.
- Coaxial cables, used in a cable network , alleviate this problem



Sharing

- Both upstream and downstream bands are shared by the subscribers.
- The upstream data bandwidth is 37 MHz, and only six 6-MHz channels are available in the upstream direction.
- Subscriber shares these channels in time to send data in the upstream direction.
- When the users are a few, much higher data rate than xDSL (for the same distance and bandwidth); time-sharing reduces rates as the number of users increases
- FTTB and FTTN alternatives of DSLAM

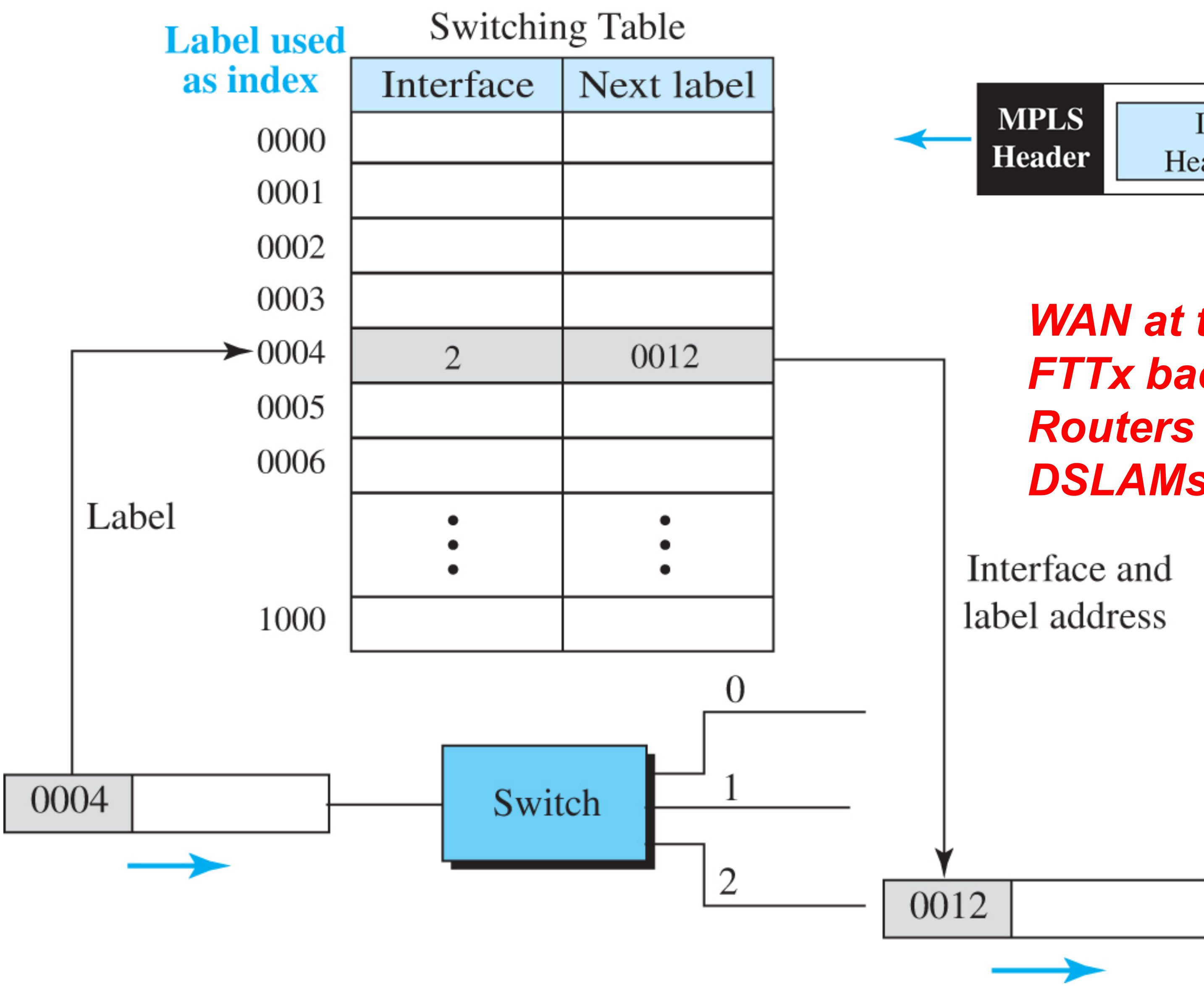
PTTx Technologies - Gigabit-capable Passive Optical Network (GPON)

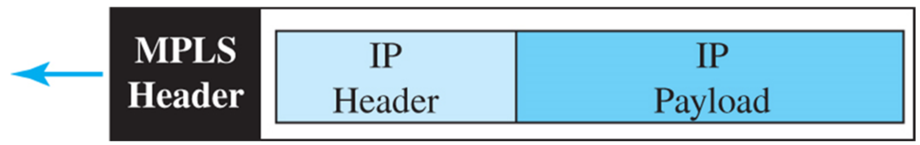


- Optical fibre all the way with unpowered splitters and shorter coax or copper cables
- OLT (optical line termination – central office) and ONTs (optical network terminals – end user side) carry Ethernet traffic by using TDMA at a Gbps rate
- OLT and ONT provide electrical and fibre signal conversion to copper wire Ethernet

https://en.wikipedia.org/wiki/GPON

Multi-Protocol Label Switching (MPLS)





WAN at the Network Layer for FTTx backbone networks (IP Routers connected to OLTs or DSLAMs or Cable Heads)

Recommended Reading

- Behrouz A. Forouzan, Data Communications and Networking with TCP/IP Protocol Suite, 6th ed., 2022, Chapters 5 and 7