Networking Technologies and Applications

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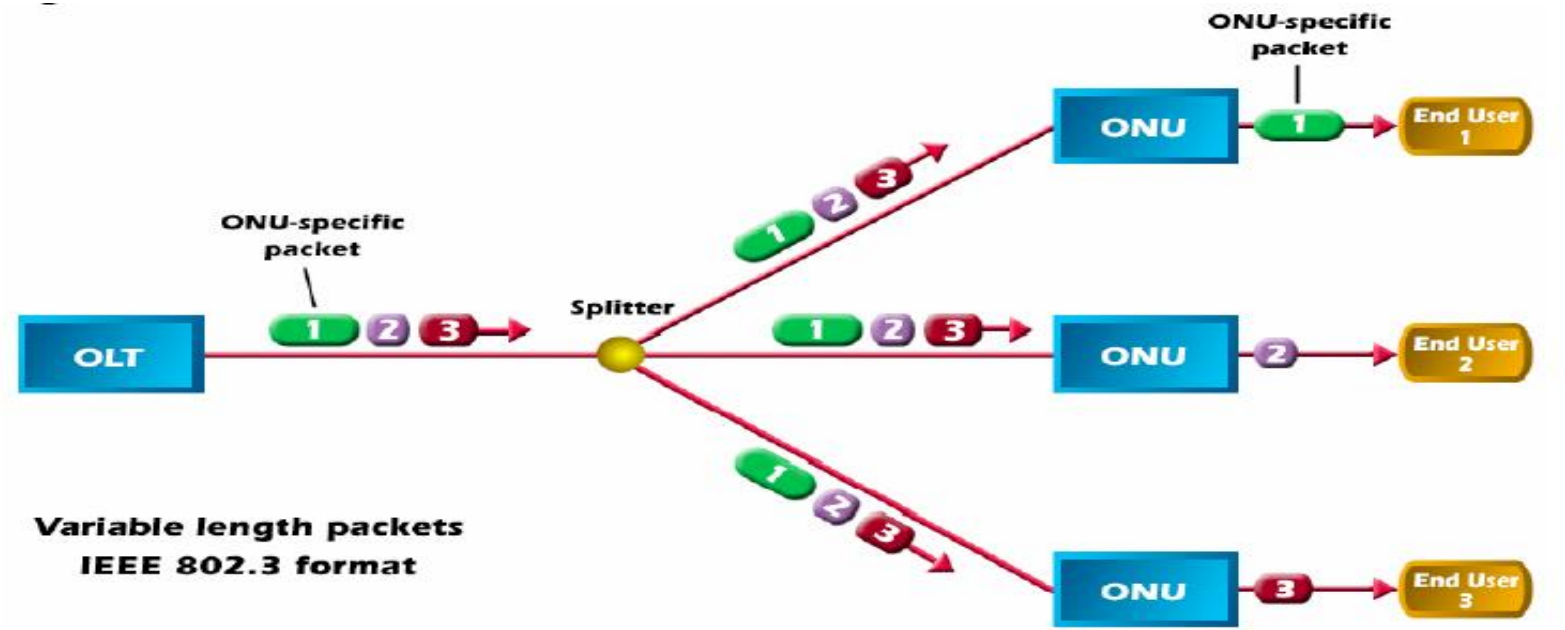
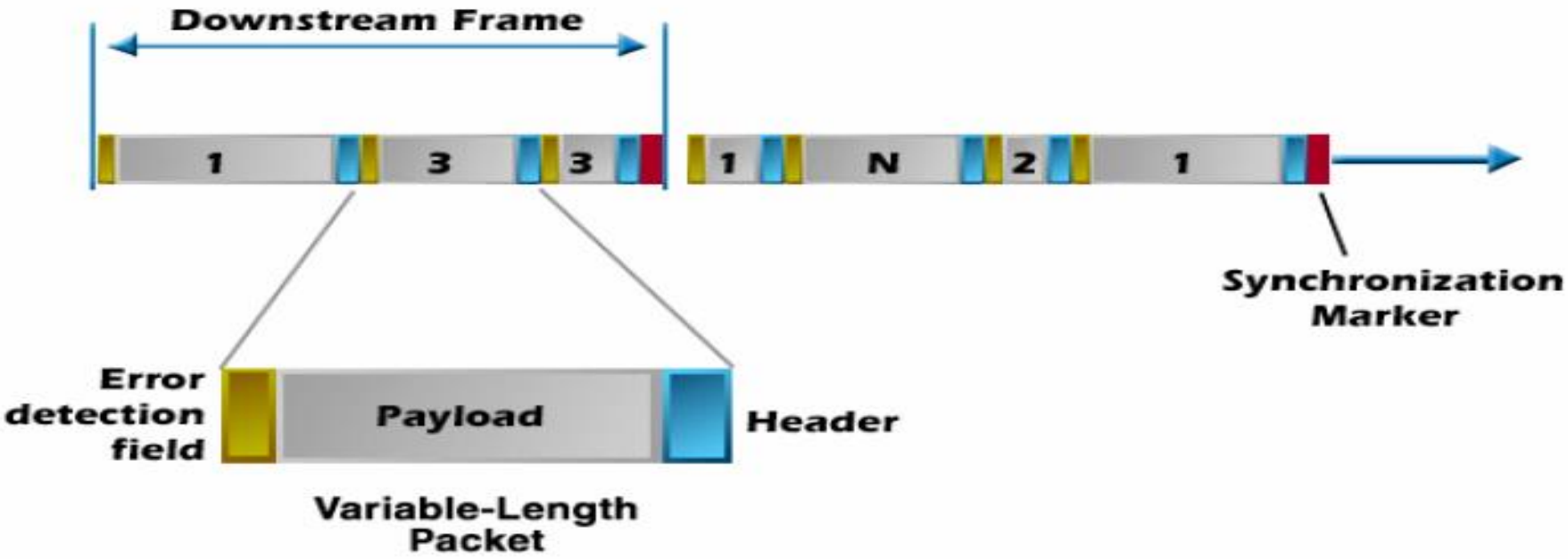
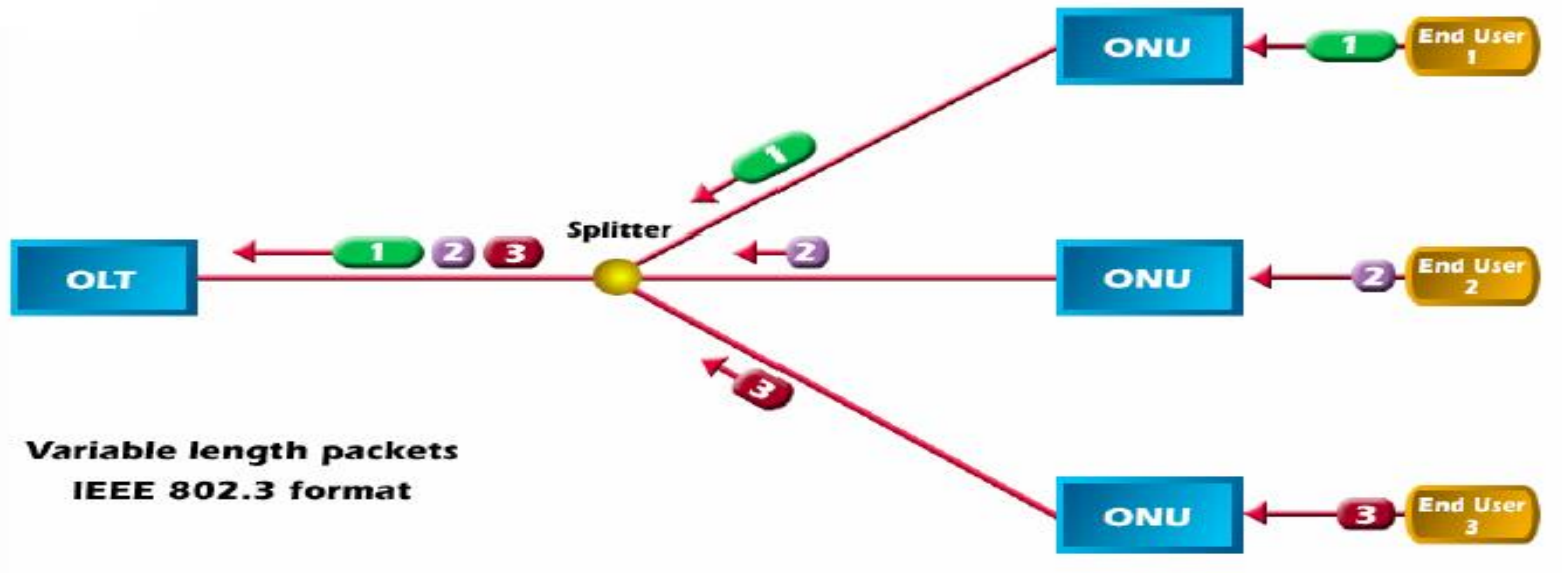
EPON downstream traffic



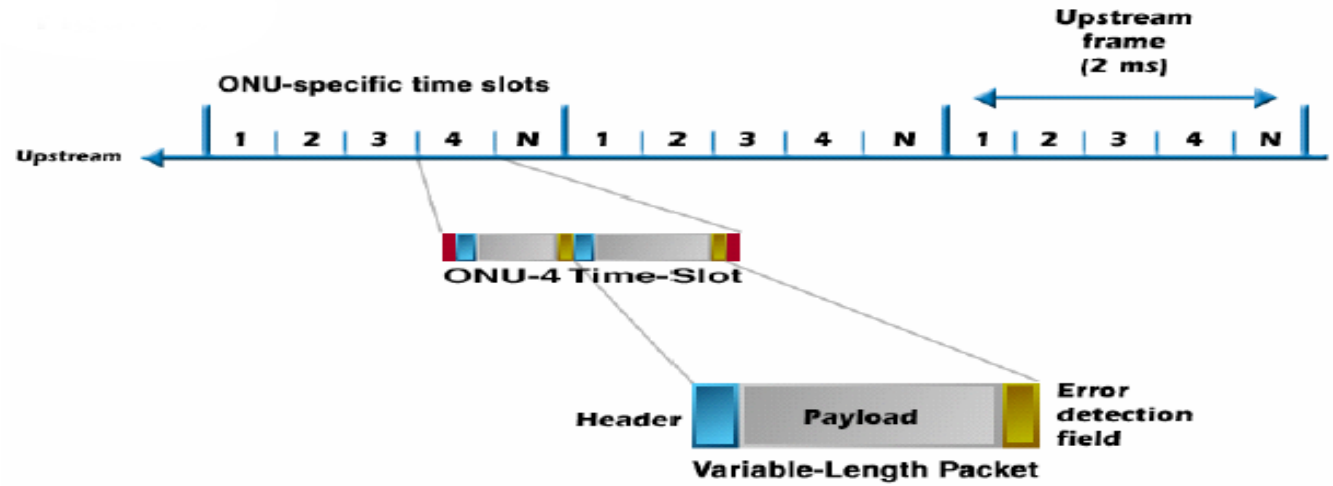
EPON downstream packets



EPON upstream traffic



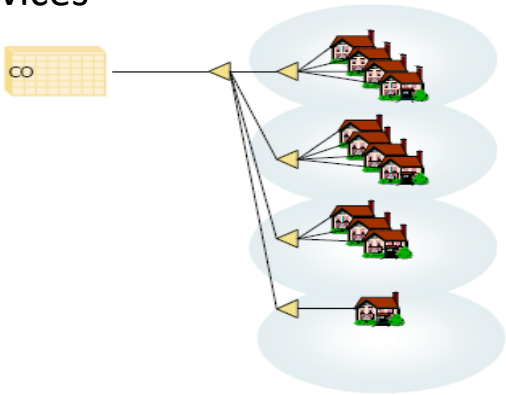
EPON upstream packets



- The upstream traffic divided to frames
- Each ONU has its own time slot, that it fills with his own variable length packets

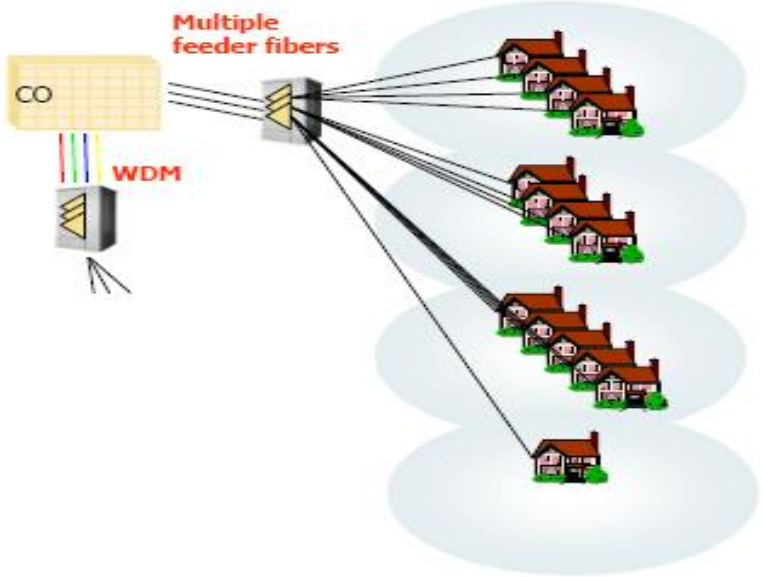
Traditional PON

- Main idea:
  - Its is not worth having a separate fiber for each user from the OLT
  - Bring on fiber close to the subscribers, and share it with passive devices
- Drawbacks
  - Splitters are dummy devices, cannot be controlled remotely
    - If a problem occurs, splitters has to be checked one by one
  - Not flexible
    - A 5th subscriber cannot be added to a 4-line splitter
    - The networks should be designed with over-provisioning in mind, not violating the 32 rule
- Solution: plan the network with 16 or 24-line splitters
  - Place for extensions
  - The remaining 16 subscribers will pay more



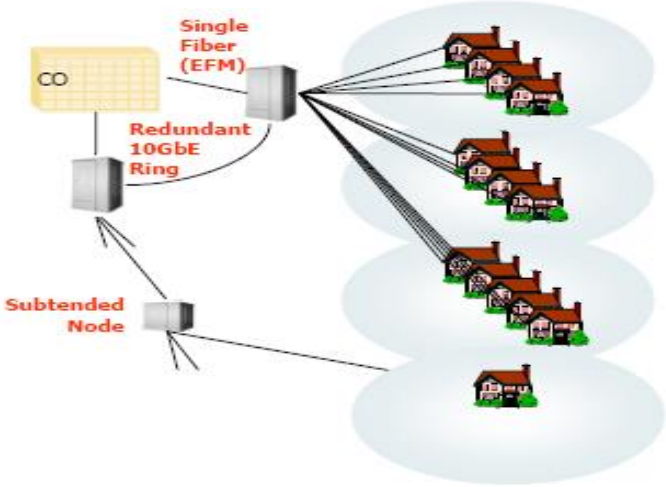
Passive Star PON

- Splitters in the same box
  - Easier to discover the faulty splitter
- Still a tree topology
  - If the connection between the splitter and the Central Office is cut, no backup



Active Star

- Drawback: need for powered active nodes
- Using intelligent devices at the edge of the network has many advantages
  - The active node can act as an IGMP proxy for multicast traffic
    - Detailed in a later course
  - Fault-tolerant solution
    - Active nodes joined in a ring
    - Ethernet Protection Switching Rings (EPSR)
    - 50 ms switching time in case of an error
      - Minor image quality degradation for a video stream
      - A phone conversation is not interrupted
  - Easy to manage, easy to repair



BPON

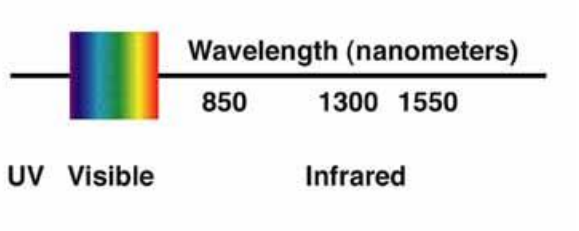
- Broadband PON
  - ATM-based
  - Better than traditional APON
    - Higher transmission speed
    - DBA – Dynamic Bandwidth Allocation
    - Security enhancements
  - Current APON/BPON systems in 3 operation modes
    - 155 Mbps downstream, 155 Mbps upstream
    - 622 Mbps downstream, 155 Mbps upstream
    - 622 Mbps downstream, 622 Mbps upstream

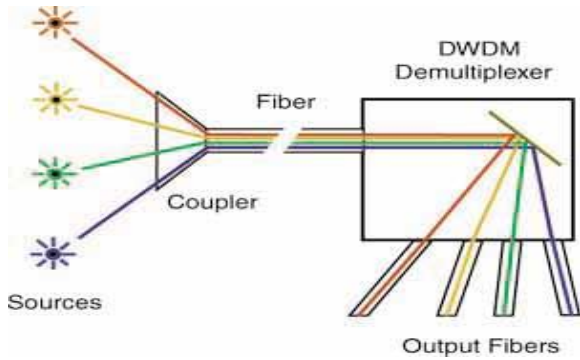
GPON

- Gigabit PON
  - ITU-T G.984 standard
  - Several downstream/upstream versions
    - Most popular - 2.48 Gbps dowsntream, 1.244 Gbps upstream

WDM-PON

- WDM – Wavelength Division Multiplexing
  - Several wavelengths (colors, frequencies) on the same fiber
  - Up to 160 colors
    - On a 10 Gbit/s fiber, speed of 1.6 Tbit/s
- WDM-PON
  - Combines the advantages of TDM-PON and AON
  - Virtual P2P connection for each ONU
  - Lower delay than in TDM-PON

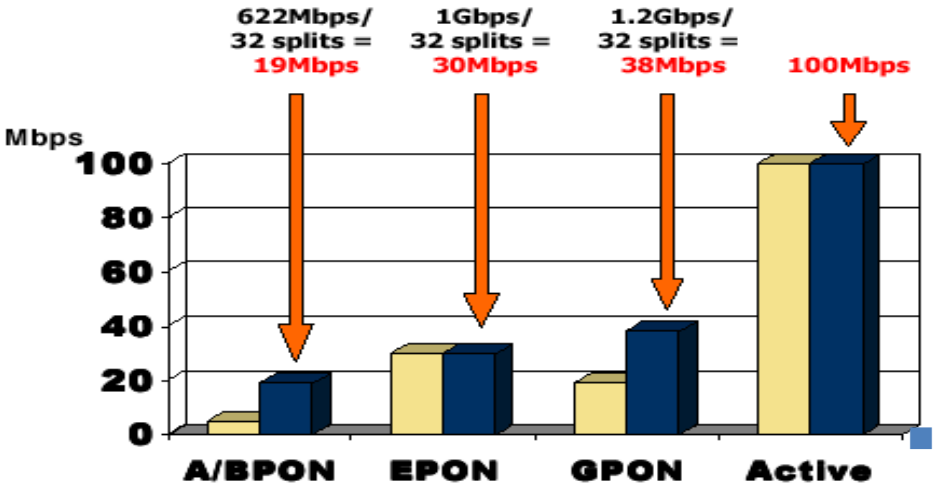




WDM-PON versions

- No standardized solution
  - We can have deicated uplink and downlink wavelength for each ONU
  - We can allocate adaptively wavelengths to ONUs, based on their actual needs – adaptive lasers
  - We can have many ONUs over the same wavelength, and use TDM
  - Composite PON (CPON) – WDM technology for downstream, TDMA for upstream

Comparison of transfer speeds

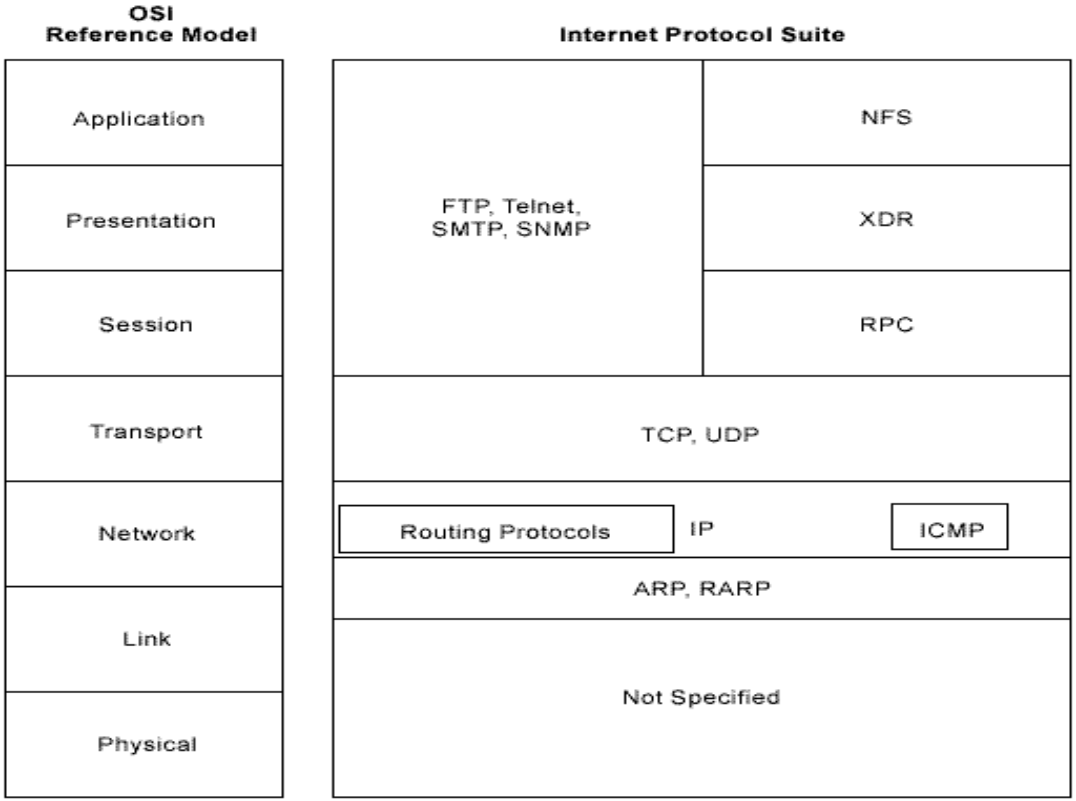


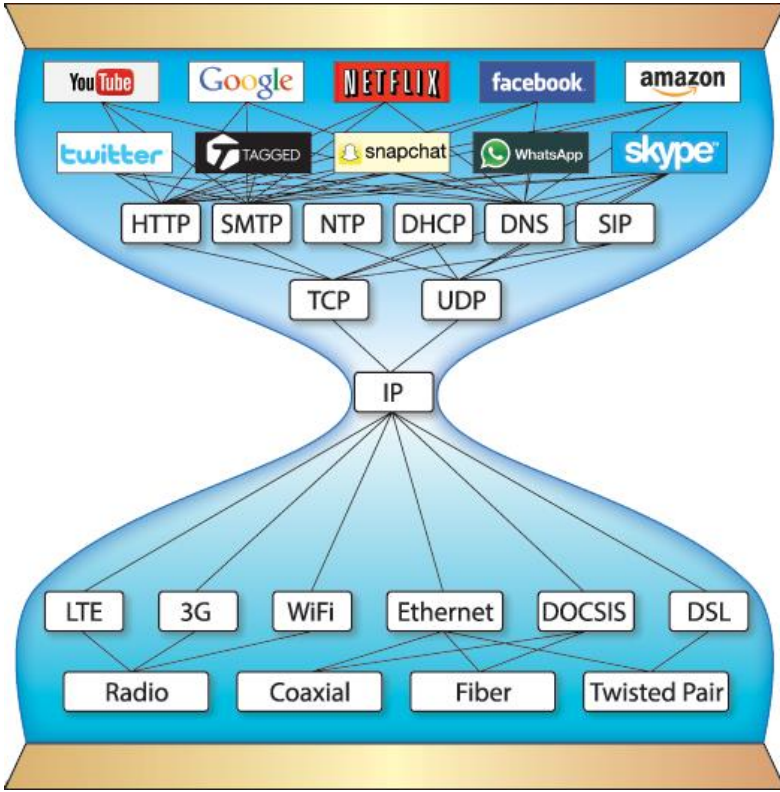
- With PON, slower speeds
  - Shared segment between the OLT and the first splitter
  - Situation is better if splitters are not fully loaded
    - Shared between 16 or 24 subscribers, not 32

If Active Nodes, each subscriber has his own fiber

- Individual users usually 100 Mbps in the two directions
- Business subscribers – up to 1 Gbps

Layering and hourglass model





IP (Internet Protocol)

- Allows any to nodes to communicate over the Internet
- The goal is to deliver a packet to the destination – no guarantees (**best effort**)
  - No guarantees for the delivery
  - No guarantees for the ordering
- The packet crosses several routers, gateways
  - Routing protocols needed
  - Packets sent towards the same destination can follow different paths
    - Packet switching vs. Circuit switching

IPv4 header

Octet	0								1								2								3							
Bit	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
0	Version				IHL				DSCP						ECN		Total Length															
32	Identification																Flags			Fragment Offset											
64	Time To Live								Protocol								Header Checksum															
96	Source IP Address																															
128	Destination IP Address																															
160	Options (if IHL > 5)																															
192																																
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- **Version** – 4 (IPv4)
- **IHL** - Internet Header Length (32 bit words)
- **DSCP** – Differentiated Services Code Point
  - Support for QoS – **Best Effort (BE), Expedited Forwarding (EF), Assured Forwarding (AF)**

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- **ECN** – Explicit Congestion Notification
  - Packets are not dropped in case of congestion, just marked
  - The destination tells to the source to lower its sending rate
- **Total Length –** in bytes
  - Maximum packet 65.535 byte

IP fragmentation

- The packet crosses several networks during its transmission
  - Lower MTU (Maximum Transmission Unit) -> fragmentation
  - The IP header contains the fragment number
  - Reassembly of the fragments is also done by IP
- Fragmentation can be avoided
  - “Path MTU discovery”- minimum MTU on the path
  - The source sends small packets than the Path MTU

The IPv4 header

Octet	0								1								2								3							
Bit	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
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- **Identification** – identifier of a fragmented IP packet
- **Fragment Offset** – the offset of the fragment, compared to the beginning of the large packet (0 for the first fragment)
- **Flags –** 3 bits to control fragmentation
  - First bit set to 0 (reserved for future use)
  - **DF – Don't Fragment bit** – if larger than the path MTU, just drop it (e.g., for Path MTU Discovery)
  - **MF – More Fragments bit** – more fragments will come (1 if the last fragment, otherwise 0)

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- **Time To Live** – limits the spreading of the packet
  - Each router decreases it with 1, before forwarding. If it reaches 0, the packet is dropped
- **Protocol** – Which protocol generated the payload
  - ICMP (1), IGMP (2), TCP (6), EGP (8), IGP (9), UDP (17), IPv6 (41), RSVP (46), OSPF (89)

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Octet	0								1								2								3							
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- **Header Checksum** – controls only if the header is correct
  - If an error in the payload, that should be handled by the encapsulated protocol
  - As the TTL is decreased, each router should recalculate the checksum, and refresh this field accordingly
- **Options** – rarely used (as opposed to IPv6)