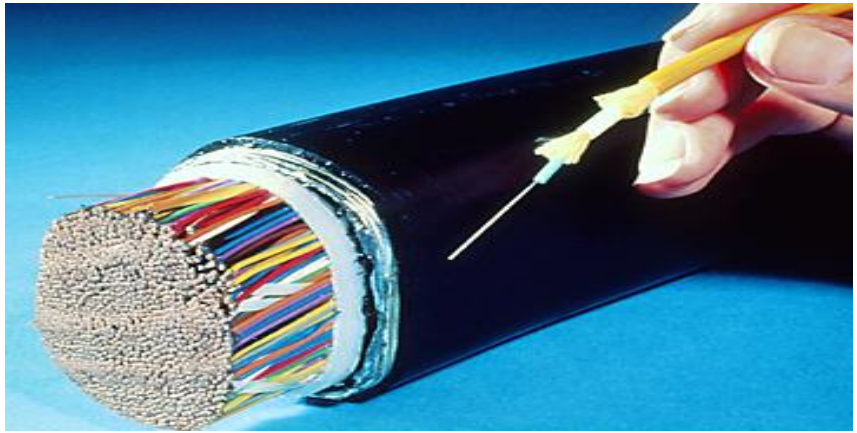
Networking Technologies and Applications

Rolland Vida
BME TMIT

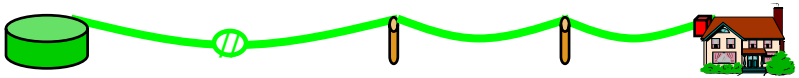
September 30, 2016

Fiber vs. Copper

- On an optical fiber more than 2.5 million parallel phone calls
- Compared to a similar capacity bundle of twisted pair connections, 1% in weight and size



Fiber vs. Copper

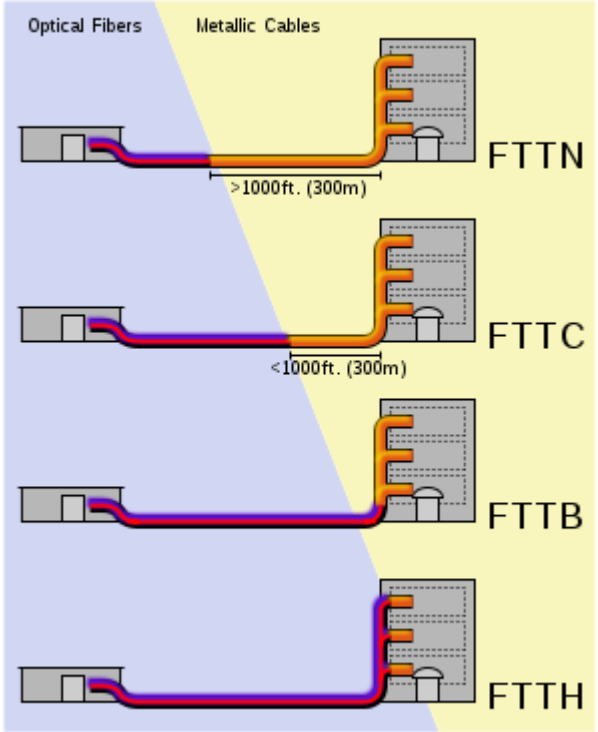


- Optical fiber
  - Transports light pulses
  - Not influenced by electromagnetic interferences
  - Repeaters after ~30 kms
  - Low dilatation
  - Fragile, quite rigid material
  - Chemically stable

- Copper twisted pair
  - Transports electric waves
  - Sensible to electromagnetic interferences
  - Repeaters after 5 km
  - Dilatation in case of high temperatures
  - Can be bended
  - Sensible to galvanic reactions
  - Can be reused
    - The copper could be sold

FTTx

- FTTx – Fiber To The x
  - FTTB – Fiber To The Building
  - FTTC – Fiber To The Curb
  - FTTD – Fiber To The Desk
  - FTTE – Fiber To The Enclosure
  - FTTH – Fiber To The Home
  - FTTN – Fiber To The Neighborhood
  - FTTO – Fiber To The Office
  - FTTP – Fiber To The Premises
  - FTTU – Fiber To The User

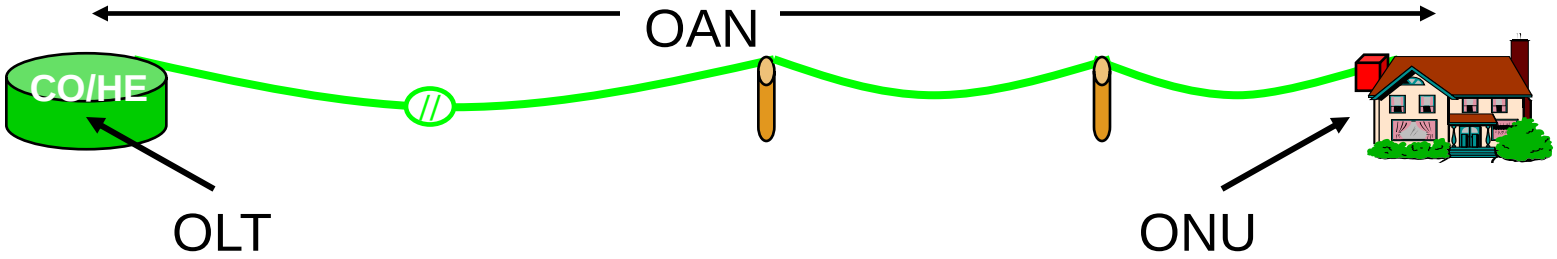


FTTC

- Fiber To The Curb
- Fiber from the local switching center near to the homes
  - The connection terminated by an ONU at the subscriber
    - Optical Network Unit
  - Many twisted pairs or coaxial cables added in the „last mile”
    - Very short loops, can be extended with a DSL segment
      - e.g., VDSL – very popular in South-East Asia
    - Suitable for MPEG-2 streams and videoconferencing

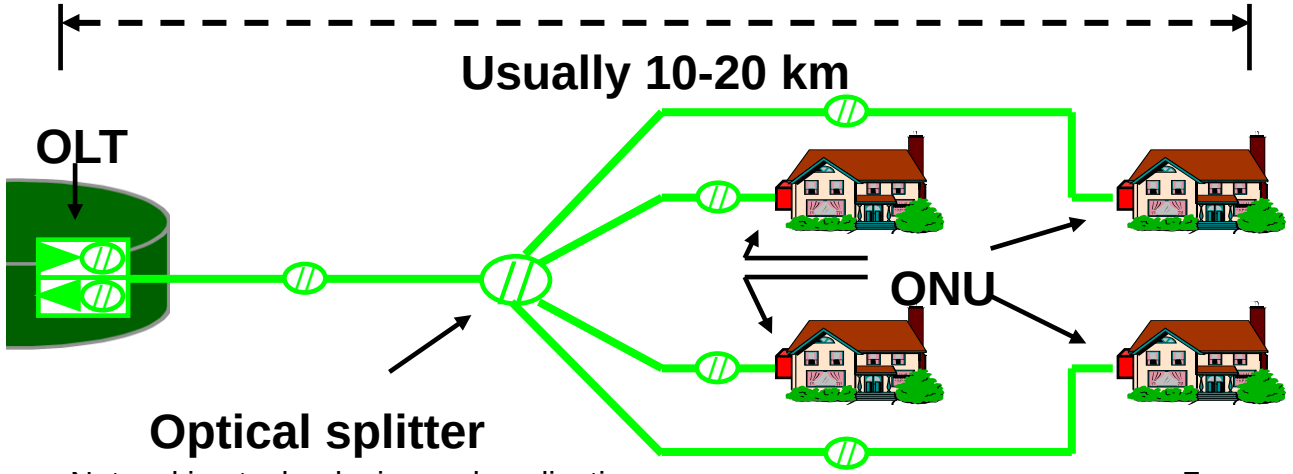
FTTH

- Fiber To The Home
- System components
  - OAN: Optical Access Network
  - ONU/ONT: Optical Network Unit/Terminal
    - At the subscriber
  - OLT: Optical Line Termination
    - At the service provider



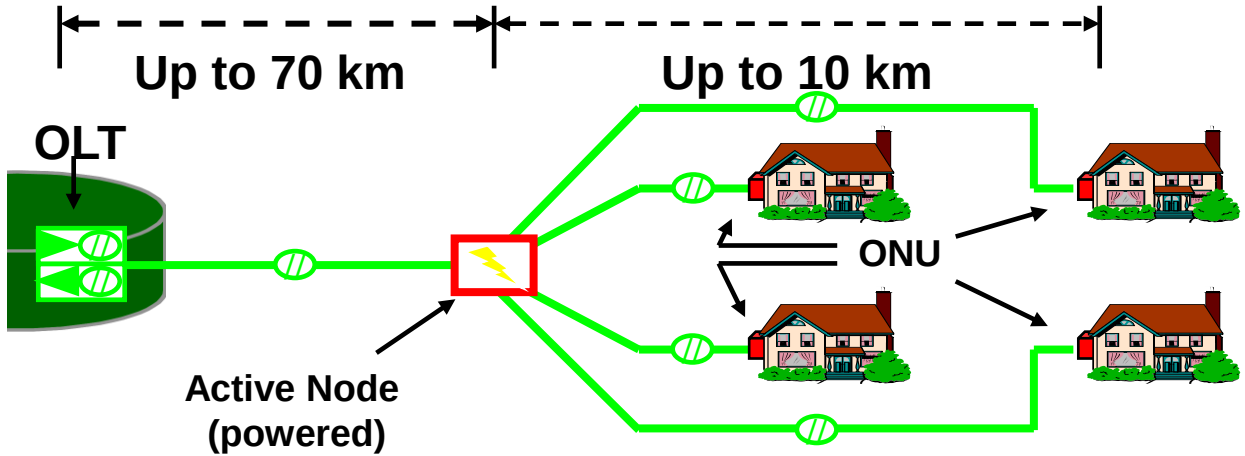
FTTH architectures

- PON – Passive Optical Networks
  - Many subscribers (max. 32) share an optical fiber
  - Optical splitters to separate or aggregate the signals to/from different subscribers
  - No need for power supply for the splitters
  - Shared network – Point to Multipoint (P2MP)



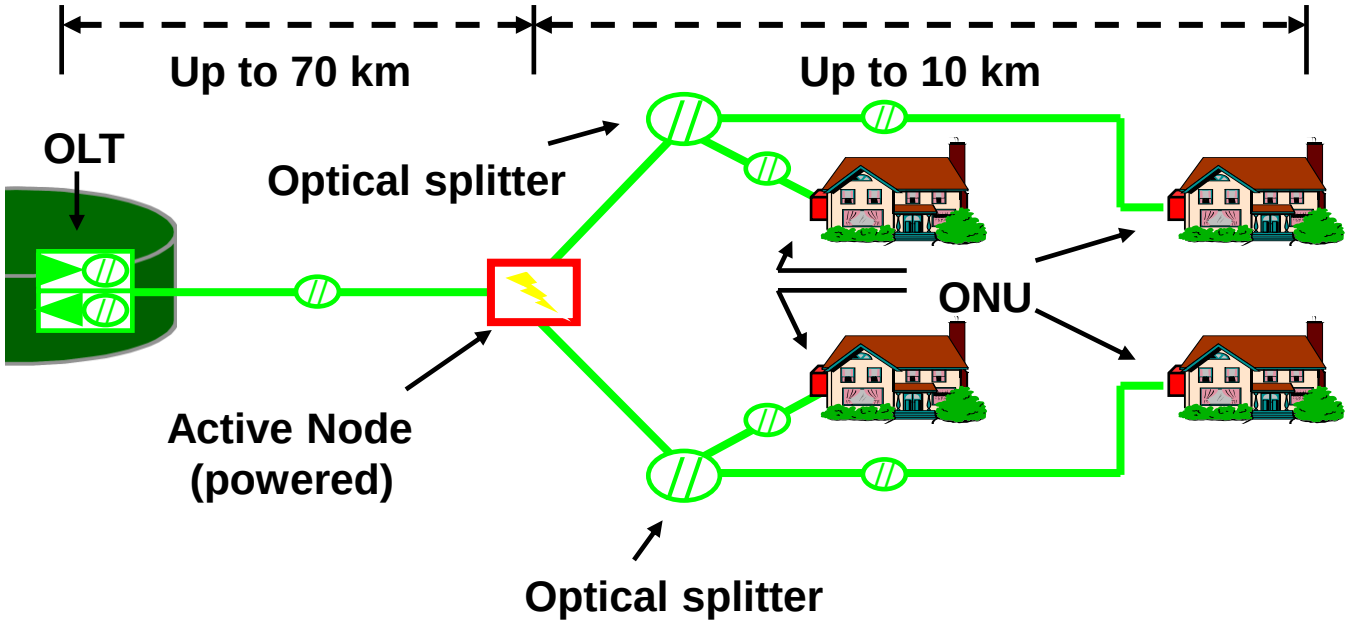
FTTH architectures

- Active Node
  - Each subscriber has his own optical fiber
    - Point to Point (P2P)
  - Active, powered nodes to separate the traffic
    - Ethernet switch
  - Layer2/Layer3 switching/routing



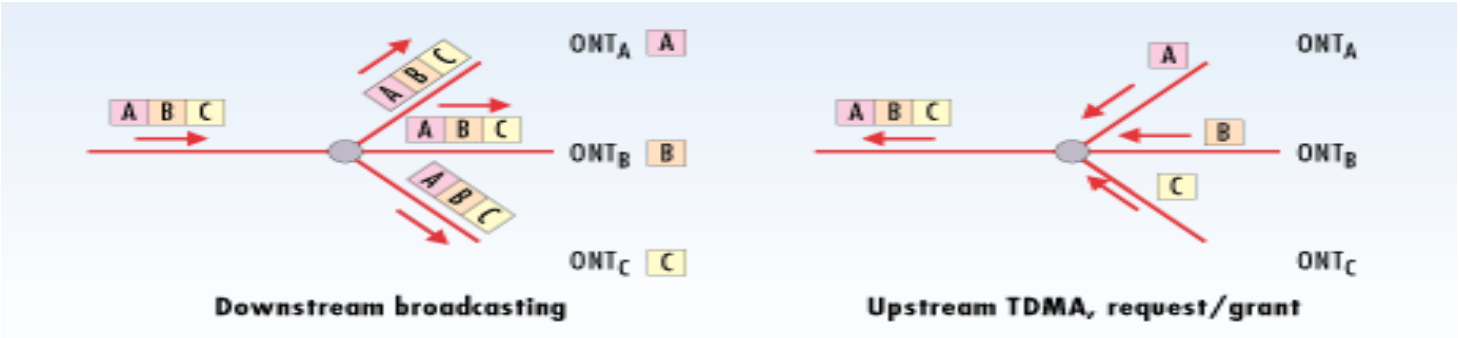
FTTH architectures

- Hybrid PON
  - A combination of the two architectures



PON - upstream and downstream traffic

- The upstream and downstream traffic handled differently
  - Broadcast downstream
    - The splitter forwards all the data to all the connected segments
    - The ONU handles only the packets that it is the destination of (based on the header)
  - Upstream traffic with TDMA
    - The OLT assigns time slots to the ONUs
    - Synchronized sending of packets
    - The ONU can ask for further slots, if needed



Ethernet or ATM?

- Two concurrent technologies
  - APON – ATM-based PON
    - The first PON implementation
  - EPON – Ethernet-based PON

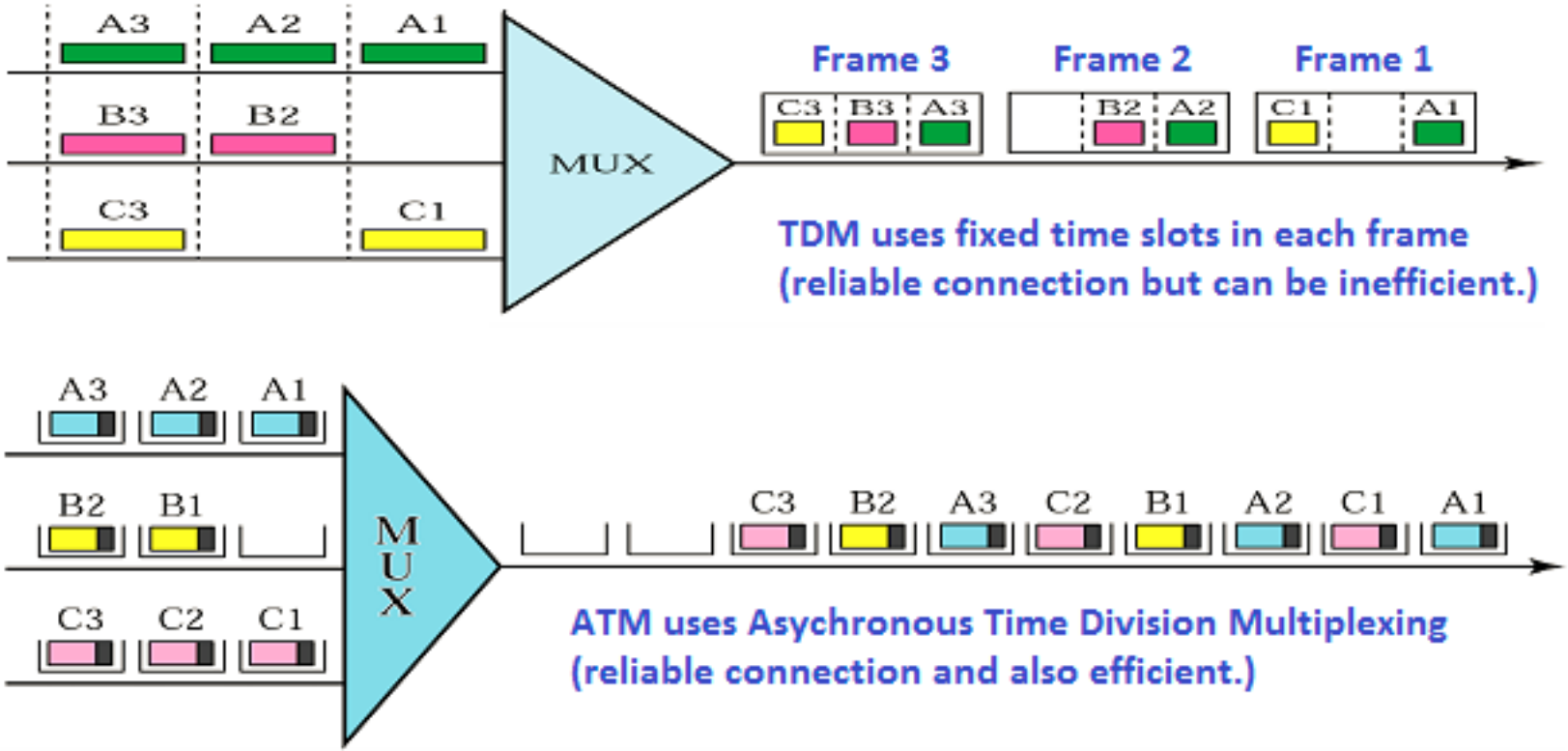
ATM (Asynchronous Transfer Mode)

- Proposed for parallel handling of different traffic types (audio, video, data)
  - 1500 byte Ethernet frames are too large
    - 1.500 byte = 12.000 bit
    - On 10 Mbps Etherneten 0.1 µs bit time → 1.2 ms / frame
  - If more sources (stations or applications) are waiting in a queue, too long waiting times
- Audio and video applications have strict **delay** and **jitter** requirements

ATM (Asynchronous Transfer Mode)

- ATM solution
  - Fixed size **ATM cells**: 5 byte header + 48 byte data = **53 byte**
  - **Segmentation and Reassembly (SAR)**
    - Variable length frames are fragmented at the sender, and reassembled at the receiver, based on the header
  - **Asynchronous Time Division Multiplexing**

ATM (Asynchronous Transfer Mode)



Why ATM is not (really) used?

- Very popular at the beginning of the 90's
  - More and more multimedia traffic, with QoS requirements
- **Drawbacks**
  - Too much overhead with the headers
    - Ethernet – 14 byte / 1500 byte (~ 1%)
    - ATM – 5 byte / 53 byte (~ 10%)
  - Fragmentation and reassembly (SAR) too complicated
    - High speed ATM cards too expensive, compared to similar speed Ethernet cards
  - On 10 Gbps Ethernet, instead of 1.2 ms, only 1.2 µs is the sending time of a 1500 byte frame
    - With such speeds, no need to worry about QoS

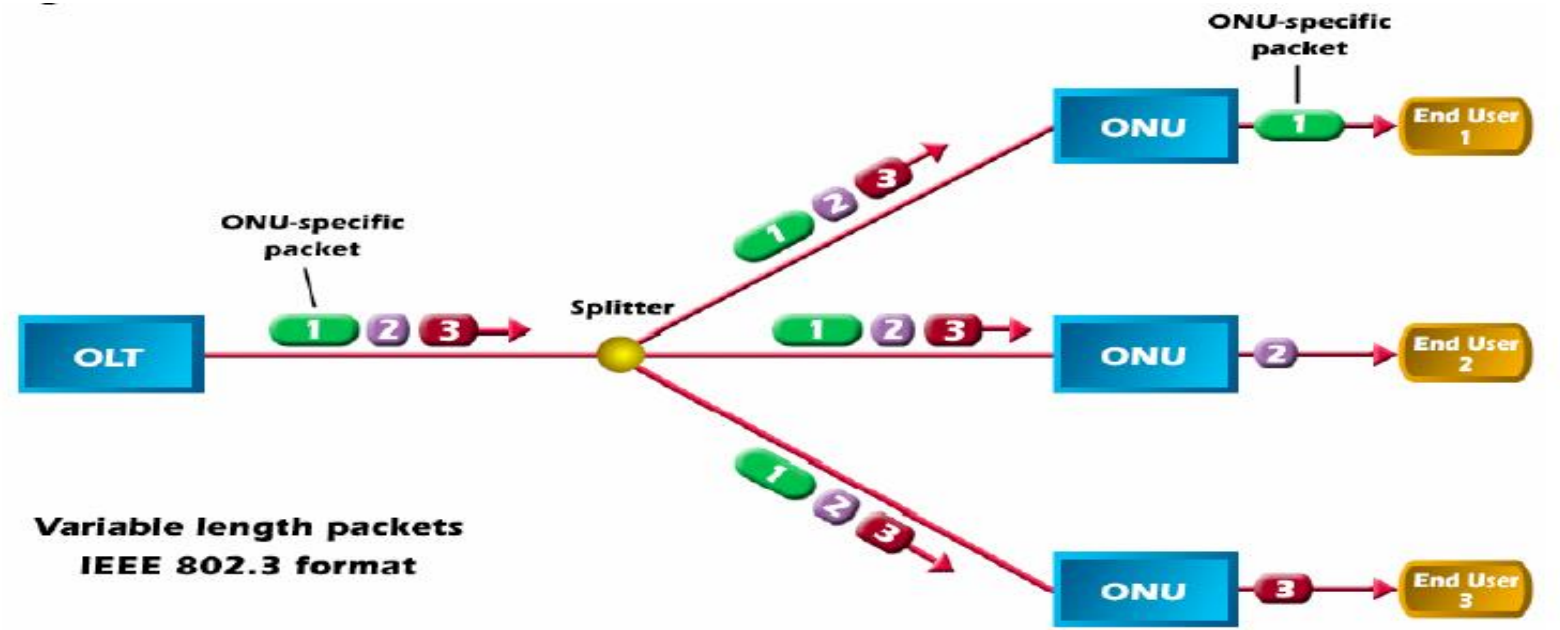
APON

- Segmentation and Reassembly (SAR)
  - Fix sized packets
    - 53 byte long ATM cells
  - Data passes through an ATM Adaptation Layer-en (AAL), where it is split in 48 byte long packets
    - Plus 5 byte long headers
  - Packets are reassembled at the destination
- Because of the SAR, ATM is very suitable for video and voice transfer
  - Delay-sensitive traffic can be well transmitted in small, fixed size cells
  - Time consuming procedure
  - 5-byte headers are too long (10% overhead)
- Fixed sized cells well suited for the PON TDMA upstream traffic
  - Easy to handle time slots, no collisions

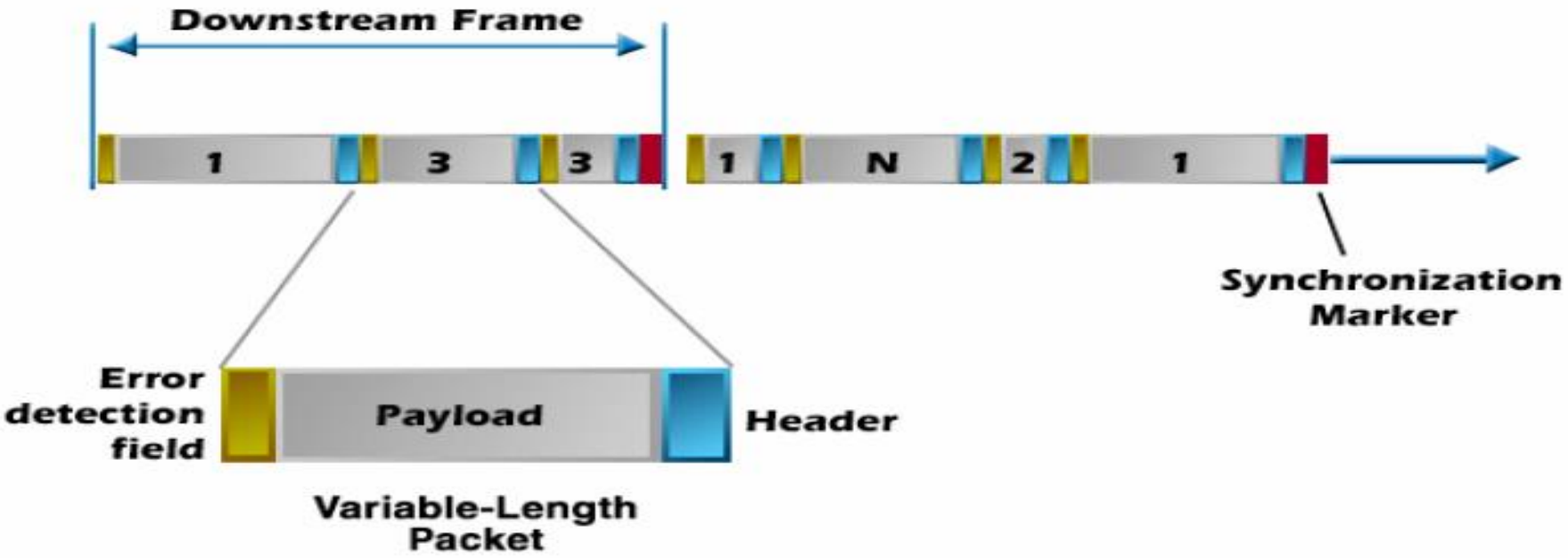
EPON

- Data sent in IEEE 802.3 (Ethernet) frames
  - Variable size frames, between 64 and 1518 bytes
- How to handle TDMA-based upstream communication?
  - We might use maximum length slots
    - Any frame can fit in
    - Not efficient, too much bandwidth wasted
  - We might have fixed length slots, filled with several frames
    - More efficient, but not ideal
    - Hard to fill a fixed length slot with variable size frames
  - Ethernet frames could be divided in fixed length chunks
    - Easier to upload
    - The price is a SAR function that has to be added to the EPON protocol stack

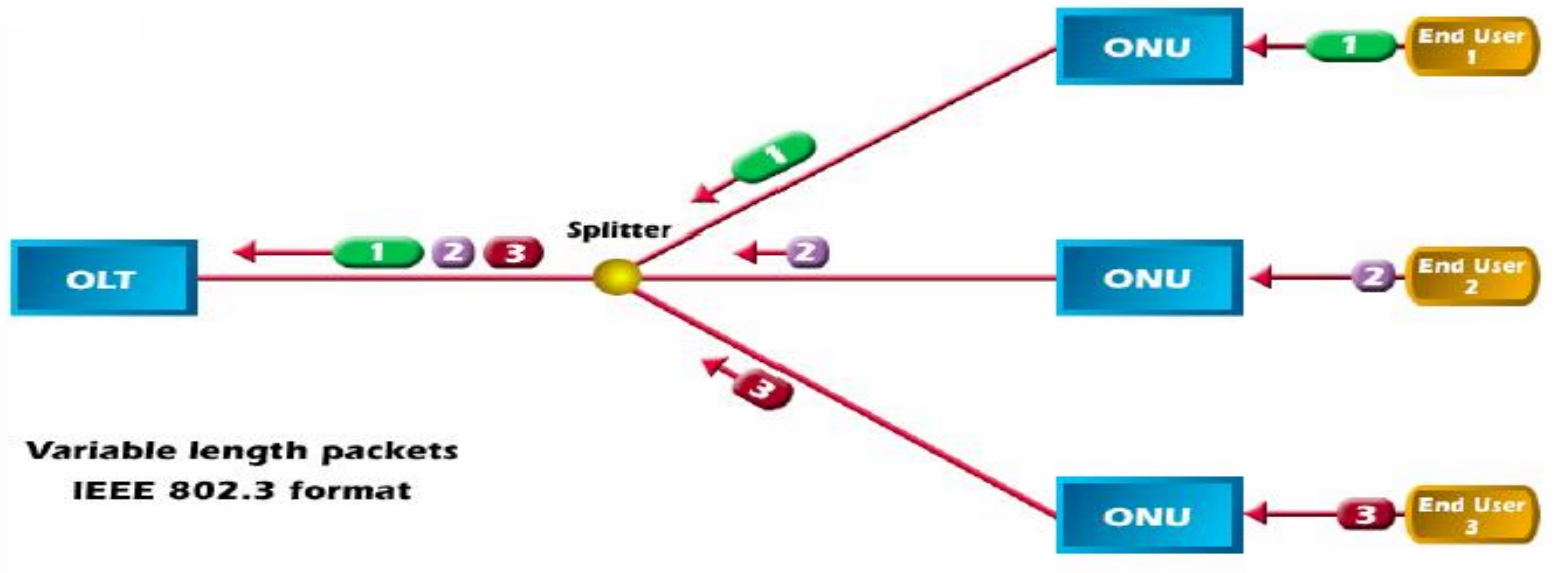
EPON downstream traffic



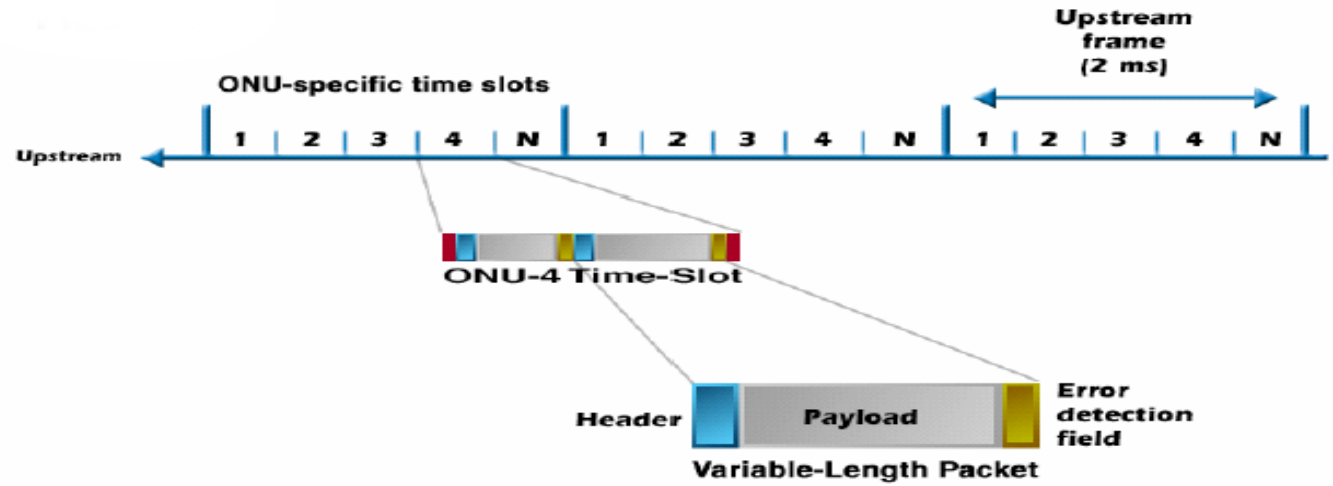
EPON downstream packets



EPON upstream traffic



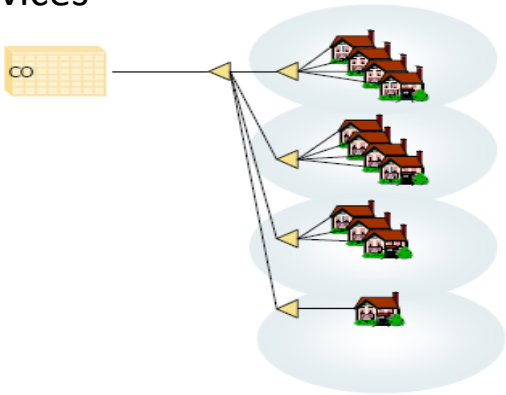
EPON upstream packets



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

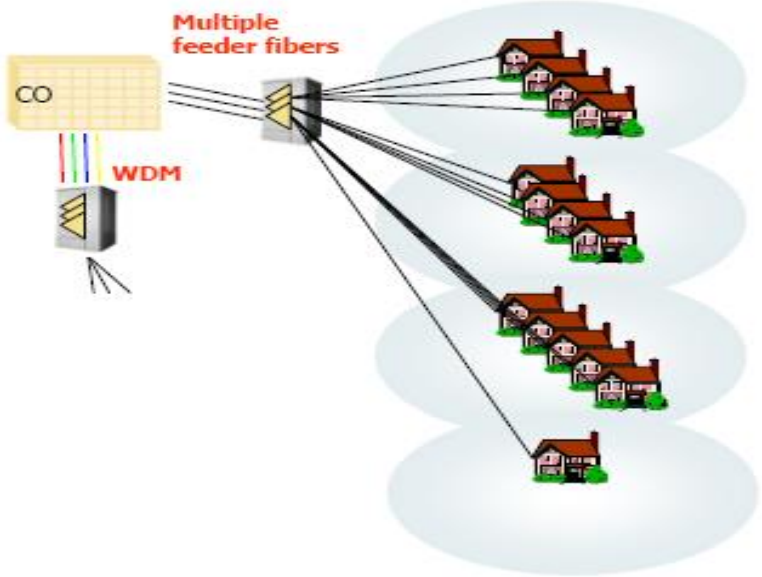
Traditional PON

- 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



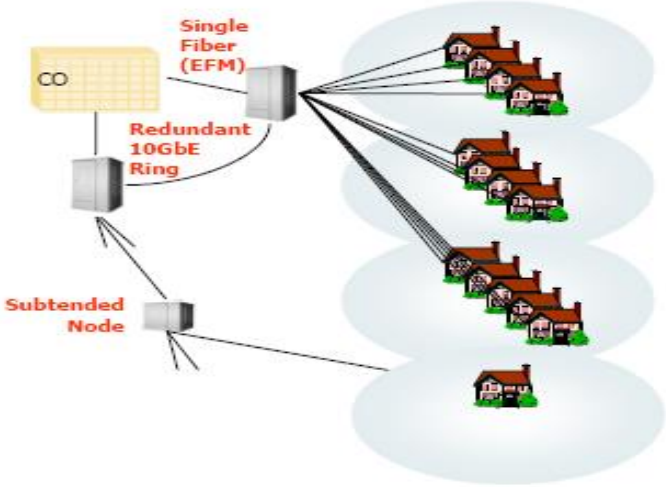
Passive Star PON

- 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



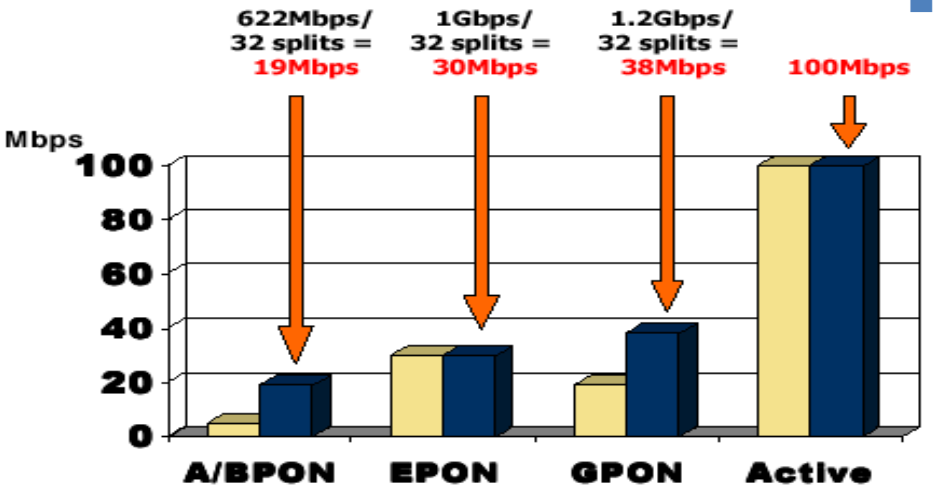
BPON

- 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

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