An Efficient MAC Layer Protocol for EPON

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EFM, November 2001

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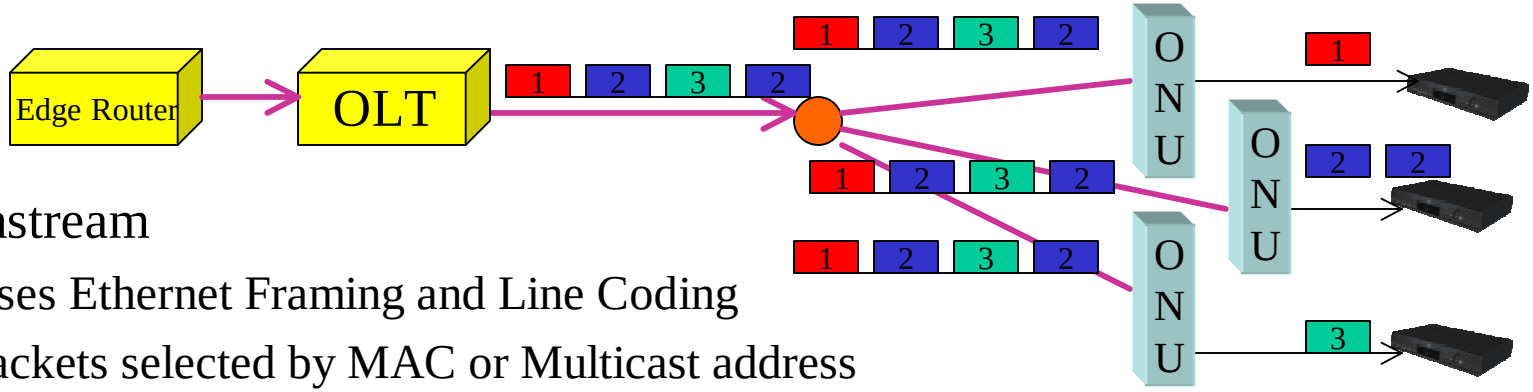
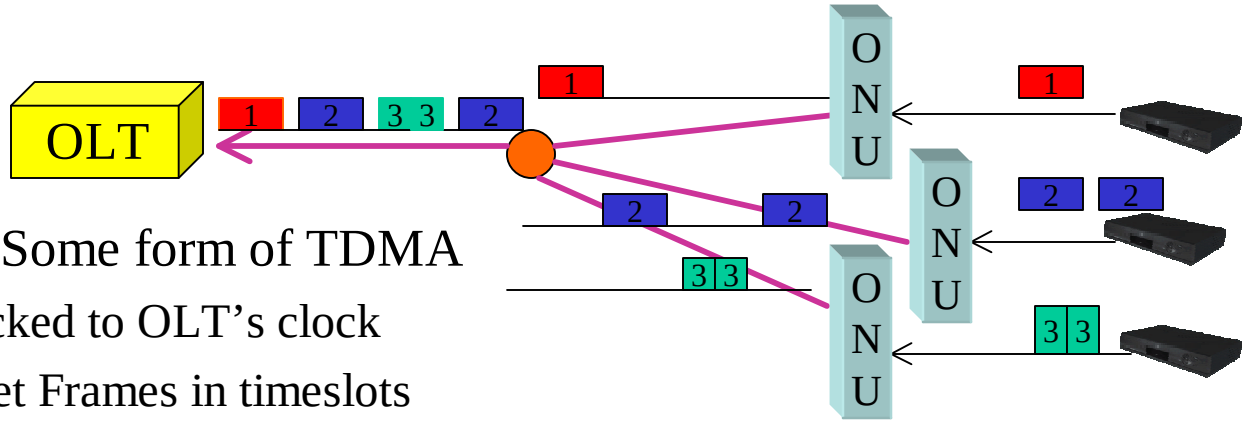
Abstract:

A MAC Layer protocol for Point-to-Multipoint EPON systems is proposed. The scheme requires only two control messages yet provides for ONU discovery, continuous ranging, and dynamic time slot allocation. Cold start-up, addition of new active ONU's and inactivation of ONU's is supported. The slot allocation technique is a variable TDMA scheme based on allocating a variable number of contiguous time-slots to ONU's based on their slot requests.

Generic EPON Architecture



- Downstream
  - Uses Ethernet Framing and Line Coding
  - Packets selected by MAC or Multicast address
  - QOS / Multicast support provided by Edge Router



- Upstream Proposals: Some form of TDMA
  - ONU clocks are locked to OLT's clock
  - ONU sends Ethernet Frames in timeslots
  - **Must avoid timeslot collisions**
  - BW allocation easily mapped to timeslots

A Proposal

- OLT/ONU implemented using Gbit optics and electronics.
  - ONU locks clock to OLT's downstream data traffic.
- Designed for optical splits of up to 1:64.
  - Current limited of 1:32 due to optical power budgets.
  - Statically allocating BW results in 15 Mbs for 64 split, 30 Mbs for 32 split.
- Partition upstream BW into 100 Frames, 10 msecs each.
- Each frame is further subdivided into 512 Time-Slots.
  - Each slot is 19.5 usecs in length or approximately 2400 bytes.
  - Traffic is packed into slots with no fragmentation of packets.
- During a Frame, each active ONU requests the number of slots it needs for the **next** frame.
  - How the ONU determines number of slots to request is handled by upper layer.
  - Each active ONU is "guaranteed" a single slot every frame.
  - This slot is used for: next frame slot requests, ranging, OAM&P, and the leftover for ethernet traffic.
  - Minimum BW per ONU is approximately 1 Mbs.

A Proposal:
Slot Allocation / 802.3 Compliance

- OLT "Grants" requests for slots for the next frame at end of every frame.
  - ONU's are granted contiguous slots during a frame.
    - This reduces Guard-band time necessary to turn on/off ONU transmitters.
    - Guard band time is currently set to 8 usecs.
      - This guard-band time is a major limiting factor to link utilization (would love to make is smaller).
      - For fully configured system of 64 active ONU's, guard band overhead is 5%.
- By overseeing slot requests, the OLT can control/police slot allocation based on limits set by **Higher Layer Policies**.
  - OLT can implement sophisticated policies with *simple* "slot allocation" mechanism.
- 802.3 compliance:
  - Useful for aggregation of Gbit EPON links to 10 Gbit links for MDU's.
    - Reduces number of fiber links from Head-end to neighborhoods/basements.

A Proposal:
Control Messages

- Downlink
  - At End of Each frame OLT Broadcasts **Start Next Frame (SNF)** msg containing:
    - Current Time at OLT
    - Offset to first slot
    - Discovery Allowed Flag
    - ONU (N) / One set of entries per active ONU /
      - RTT
      - Start Slot Number
      - Number of allocated slots
  - After first discovery, ranging updates occur continuously (once every frame)
- Uplink
  - Each ONU has at least one upstream Timeslot the first slot containing:
    - OLT Time Value found in SNF (ranging information)
    - Adjustment to OLT time value (used when discovery collisions occur)
    - Number of Slots Request & Heartbeat
    - OAM&P traffic
    - Rest of initial slot and subsequent allocated slots are used for Ethernet traffic

A Proposal:
Discovery and Ranging

- Discovery
  - At end of current frame, OLT broadcasts SNF with "Discovery Allowed" set.
    - Receiving non-active ONU immediately transmits "1st slot" information.
    - OLT receives ONU's 1st "slot" and updates its active ONU list.
    - End of next frame, OLT transmits SNF with newly activated ONU included along with default allocation.
  - Collisions of 1st "slot" from non-active ONU's are lost
    - waiting ONU detects SNF without allocation, so chooses small random number, wait that number of slots and transmit 1st "slot" with wait time in "Adjustment to OLT time value" field
    - Adjustment value allows multiple ONU's to be discovered in single frame.
  - ONU's that do not obtain an allocation during a Frame, required to go through discovery again
- Ranging
  - OLT utilizes values obtained from ONU 1st "slot" fields and computes RTT value
    - During next SNF, OLT fills the RTT fields with values obtained for each ONU.
  - Each ONU receives RTT values and adjusts its local clock time accordingly.

Summary of Proposal

- Protocol with only two control messages yet provides for:
  - ONU discovery, continuous ranging, and dynamic time slot allocation.
- Explicit control mechanisms for upstream traffic based on variable allocation of time slots.
  - Handle bursty traffic, CBR traffic, and VBR traffic.
  - Efficiently utilizes link bandwidth with with minimal Guard Band overhead.
- Mechanism allows “easy” implementation of high-level services:
  - Dynamic Bandwidth Allocation
  - Flexible SLA’s
  - BW policing/enforcing aberrant ONU’s by limiting number of slots granted during a given frame.
  - Asymmetric BW provisioning for different customers on single EPON link.
    - On a per Mbit/sec basis
- 802.3 compliance allows for aggregation to Higher speed links.

Thank-you

Backup Slide
Why Dynamic Bandwidth Allocation is Important

- Upstream bandwidth is shared, making it a **Precious Resource** that needs to be used efficiently.
- DBA allows more subscribers to be serviced with a single EPON
  - reducing costs of deployment
- Service Providers need/want mechanisms to support flexible Service Level Agreements:
  - Asymmetric bandwidths to different customers on single EPON
  - Guaranteed BW to some customers, Best-Effort to others, etc..
- Burstiness of "data" streams from multiple subscribers can be handled seamlessly/efficiently.
- Enforcement/policing can be implemented to avoid subscribers from swamping shared links.