Passive Optical Network (PON)

Upstream provisioning using the Dynamic Bandwidth Allocation (DBA) algorithm
In this student lecture we will cover:

- PON and need for upstream bandwidth allocation
- DBA algorithm for US bandwidth allocation
- MPCP to implement DBA control

**DBA Model**

<table>
<thead>
<tr>
<th>Bandwidth Type</th>
<th>Priority</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control Bandwidth (OAM, MPCP)</td>
<td>Highest Priority</td>
</tr>
<tr>
<td>Assured Bandwidth (data transfer, email)</td>
<td>Highest Priority</td>
</tr>
<tr>
<td>Best Effort Bandwidth (Unreliable, UDP)</td>
<td>Low Priority</td>
</tr>
<tr>
<td>Fixed Bandwidth (time critical and fixed)</td>
<td>High Priority</td>
</tr>
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</table>

\[ B_{\text{total}} \]

\[ B_{\text{target}} \]
PONs are a point to multi-point architecture

- DS traffic originates from single point (OLT)
- US traffic originates from multi-point (ONU)
- Finite downstream and upstream bandwidth
- Originally static multiplexing controlled US
- DBA algorithm double the traffic efficiency
PON Components:
Optical Line Terminals (OLT), Optical Network Units (ONUs), passive splitters, and Optical Network Terminals (ONTs).

Time Division Multiplexed (TDM):
PONs use optical **power** splitters.

Wave Division Multiplexed (WDM):
PONs use optical **wavelength** splitters.
PONs uses small (about the size of a pack of chewing gum), relatively inexpensive optical splitters, placed near the ONT.

PON is usually refers to TDM technology, where BPON designates WDM technology.
Current TDM APON implementations generally are asymmetric, running at speeds of 622 Mbps downstream and 155 Mbps upstream.

The upstream becomes a “bottle neck”.

EPON is typically a symmetrical 1 Gbps
Issues in EPON systems using TDMA

- Allocation of one fixed timeslot for every ONU is inefficient
- Statistical multiplexing leads to variable polling cycle time
  - Jitter, Delay, and SLA
- Solution: Dynamic Bandwidth Allocation using multi-point control protocol
Choi-Huh DBA algorithm model

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$B_{\text{total}}$ $B_{\text{target}}$
Control Bandwidth

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<td>Fixed Bandwidth (time critical and fixed)</td>
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<td>Control signaling: OAM, Multi-Point Control Protocol</td>
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Control signaling: OAM, Multi-Point Control Protocol \(\approx 2.4\%\)
High Priority: \( GH_i = BH_i \)

Control Bandwidth (OAM, Queue Length)

Highest Priority

Fixed Bandwidth

High Priority

First look at \( \sum GH_i \),

\[ \sum GH_i = 1.2 \text{ Mb} \]

\( = 60\% \text{ of bandwidth} \)
Then look at $\Sigma GM_i$,
Assume $\Sigma GM_i = 0.4$ Mb
= 20% of bandwidth

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<tr>
<td>Assured Bandwidth</td>
<td>Medium Priority</td>
</tr>
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Low Priority: \( B_{best} = B_{target} - \sum (GH_i + GM_i) \)

then \( GL_i = (RL_i/\sum RL_i) \times (B_{best}) \)

\( GL_i = QL_i / T_{update} \)
Control Bandwidth
High Priority: $GH_i = BH_i$

Med Priority: If $\sum RM_i \leq B_{target} - \sum GH_i$
then $GM_i = RM_i \times (QM_i / T_{update})$
else if $\sum RM_i > B_{target} - \sum GH_i$,
then $GM_i = (RM_i / \sum RM_i) \times (B_{target} - \sum GH_i)$

Low Priority: $B_{best\ effort} = B_{target} - \sum (GH_i + GM_i)$
then $GL_i = (RL_i / \sum RL_i) \times (B_{best\ effort})$
$GL_i = QL_i / T_{update}$
Multi-Point Control Protocol (MPCP)

Specifies point-to-multi-point communication between PON OLT and ONTs.

MPCP is a MAC layer protocol. Supported by bridging elements.

Functions:

• Provide ONT/ONU timing synchronization
• Implements Auto Discovery
• Bandwidth/Timeslot assignments to ONTs
Active message exchange:
OLT Gate: DS S/D, Time stamps, ONT discovery, continuous ranging, and dynamic time slot.
Grant Levels: High, Med, and Low

ONU Report: US Queue level, length, and amount

Auto-Discovery:
OLT Gate: Multi-cast, I am granting to ONU MAC address.
ONU Register_Request: I want time slots and here is who I am. Echo OLT.
OLT Register: New ONU MAC address, Echo ONU
OLT Gate: New ONU MAC address, Grant
ONU Register_ACK: I got the message, Channel established
Results of PONs using DBA with MCPL

• Implement QoS
  • Less delay for time critical applications
  • Less jitter
• One-tenth average transfer delay
• Double bandwidth utilization
• Added revenue due to “over subscription”
Conclusions

• Static Multiplexing is inefficient when many PON ONTs are not used

• DBA enables the QoS allocation to enable statistical multiplexing with jitter.

• DBA algorithm uses MPCP to query and grant transmission allocation to ONU.s. MCPC is a standard MAC protocol.
Resources


5. Wang, W., Soto, W., Ly, A., Ivancovsky, D., Anderson, T.,
Rundquist, R., “DBA (Dynamic Bandwidth Allocation) Overview”,
EFM Interim meeting, 10/10/2001, URL (http://grouper.ieee.org/
groups/802/3/efm/public/sep01/wang_1_0901.pdf.)

6. Bemmel, Vincent, “MPCP and TDM Services”, IEEE 802.3ah EFM,
St. Louis, MO, Mar. 12, 2002, URL (http://grouper.ieee.org/groups/
802/3/efm/public/mar02/bemmel_1_0302.pdf.)

7. InStat MDR, “Installation Cost Key to Passive Optical Network
(http://www.instat.com/newmk.asp?ID=217.)

CMP Media LLC, May 17, 2002, URL (www.commweb.com/
techcenters/main/experts/3783/COM20020219S0005.)

passive_optical_network.asp.)
Questions

1. What is the reason that the Dynamic Bandwidth Allocation algorithm being proposed for TDM PON upstream, instead of the TDM PON downstream?

2. How is QoS implemented in Dynamic Bandwidth Allocation algorithm?

3. How much bandwidth is available for “Best effort” for the following 32 ONT APON upstream (155 Mbps) application?

Each report = 64 bytes every 2ms plus 1 us guard band per report,
High Priority/report for all PONs = 120 kb,
Med Priority/report for all PONs = 100 kb.