

EPON: Challenges in Building a Next Generation Access Network

Glen Kramer
Teknovus, Inc.

Outline

1. Ethernet Passive Optical Networks –
A frontier of access architectures
2. Internet as a business place
Model suggested by the concept of
Community Networks
3. Open research problems

I. Ethernet Passive Optical Networks

1. PON – a natural step in access evolution
2. PON topologies
3. TDM vs. WDM PON
4. What is Ethernet PON (EPON)?
5. Transmission in EPON

PON – a natural step in access evolution

Point-to-point links

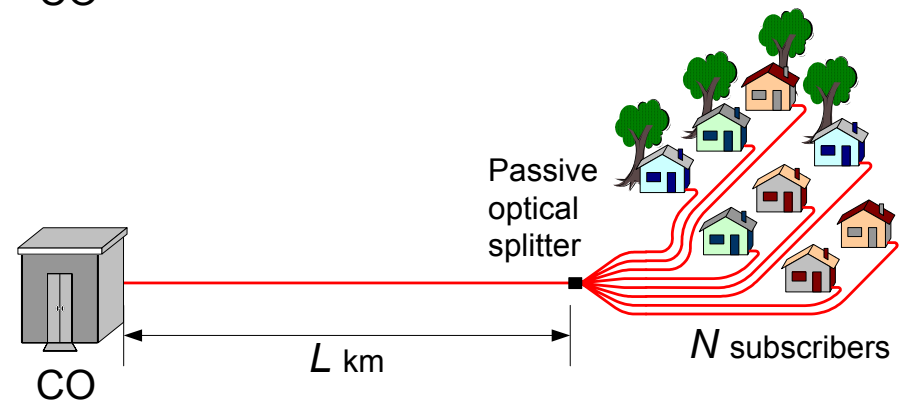
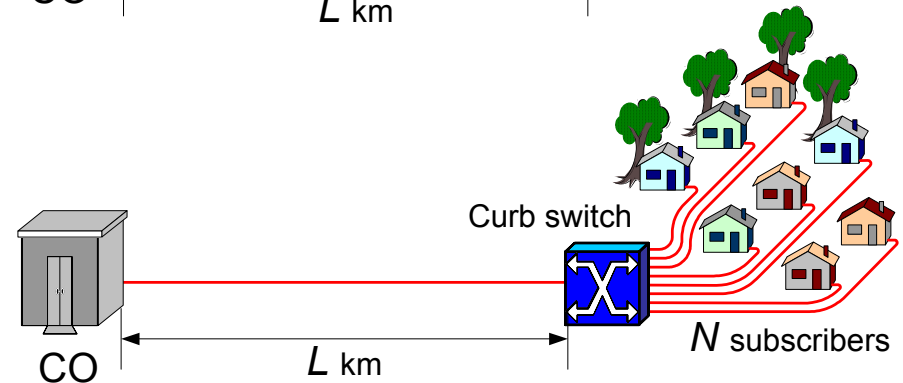
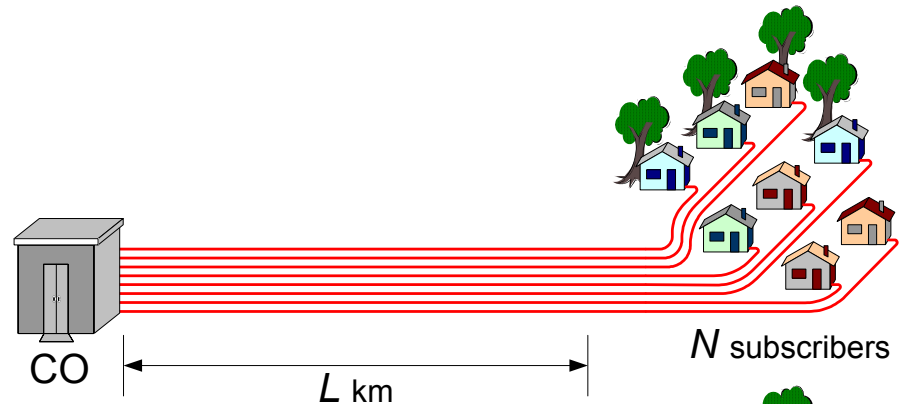
- N fiber lines
- $2N$ transceivers

Concentration switch in the neighborhood

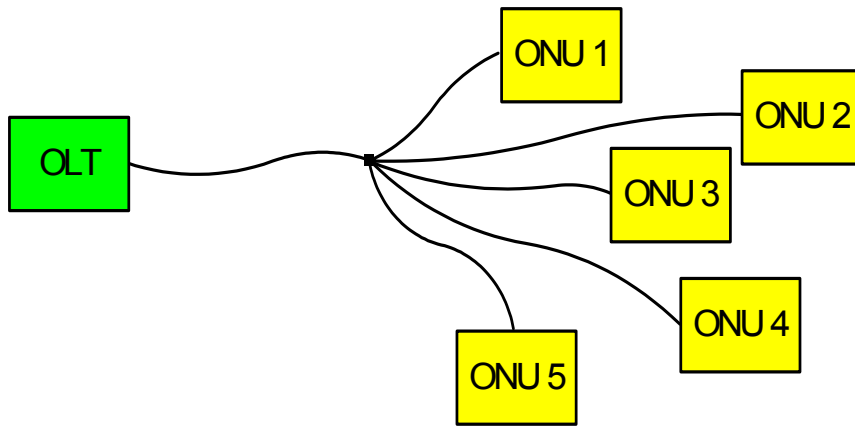
- + 1 fiber line
- Power in the field
- $2N+2$ transceivers

PON – a distributed switch

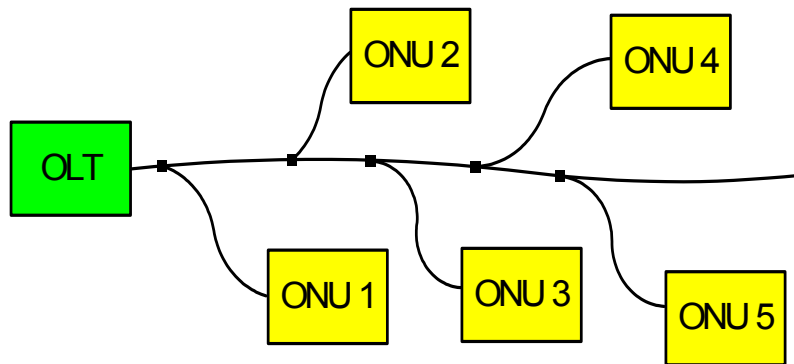
- + 1 fiber line
- + $N+1$ transceivers
- + Path transparency



PON topologies

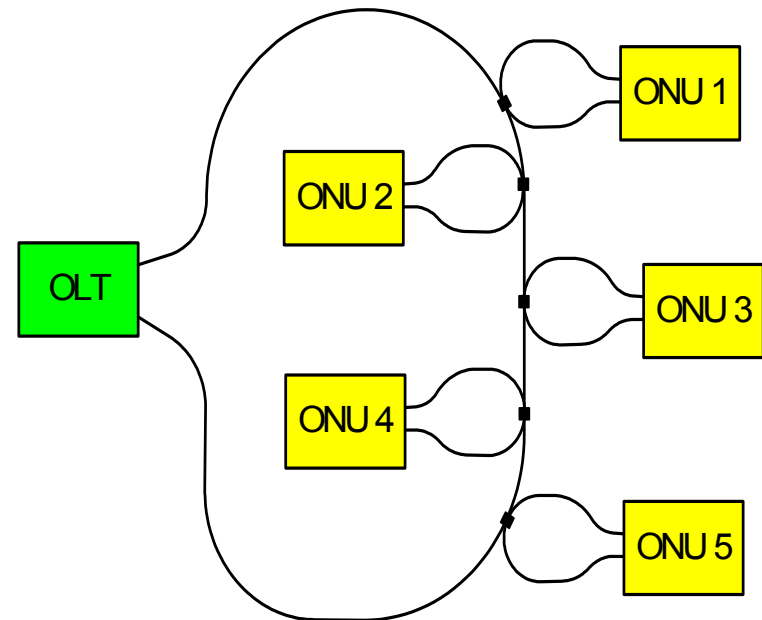


(a) Tree topology



(b) Bus topology

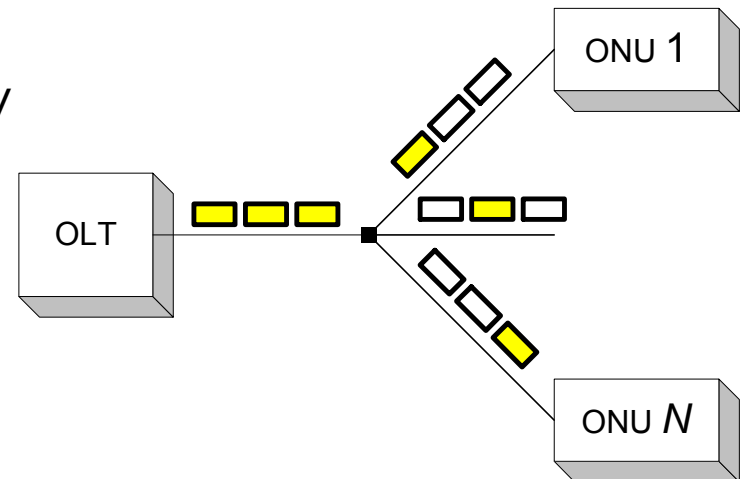
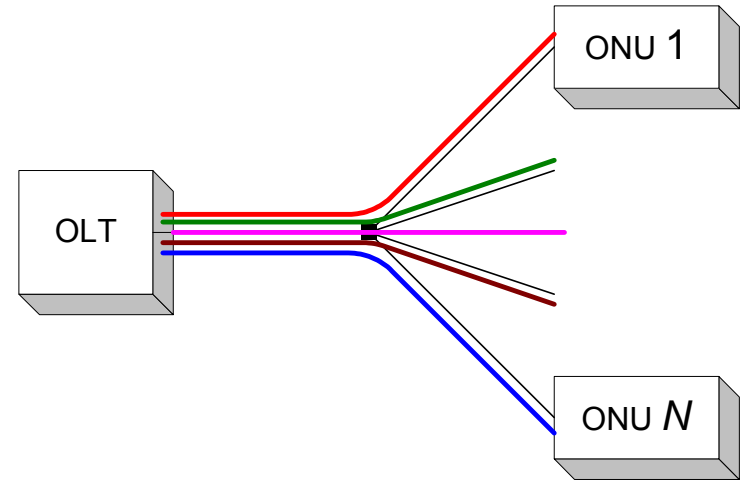
OLT – Optical Line Terminal
ONU – Optical Network Unit



(c) Ring topology

WDM vs. TDM PON

- Non-traditional connectivity
 - **Downstream:** broadcast
 - **Upstream:** Point-to-point, but collisions possible
- Upstream channels must be separated. How?
 - **WDM**
 - Each ONU must have different λ (inventory problem)
 - OLT must have a receiver array
 - Expensive
 - **TDM**
 - Receiver and electronics run at higher speed
 - Time synchronization



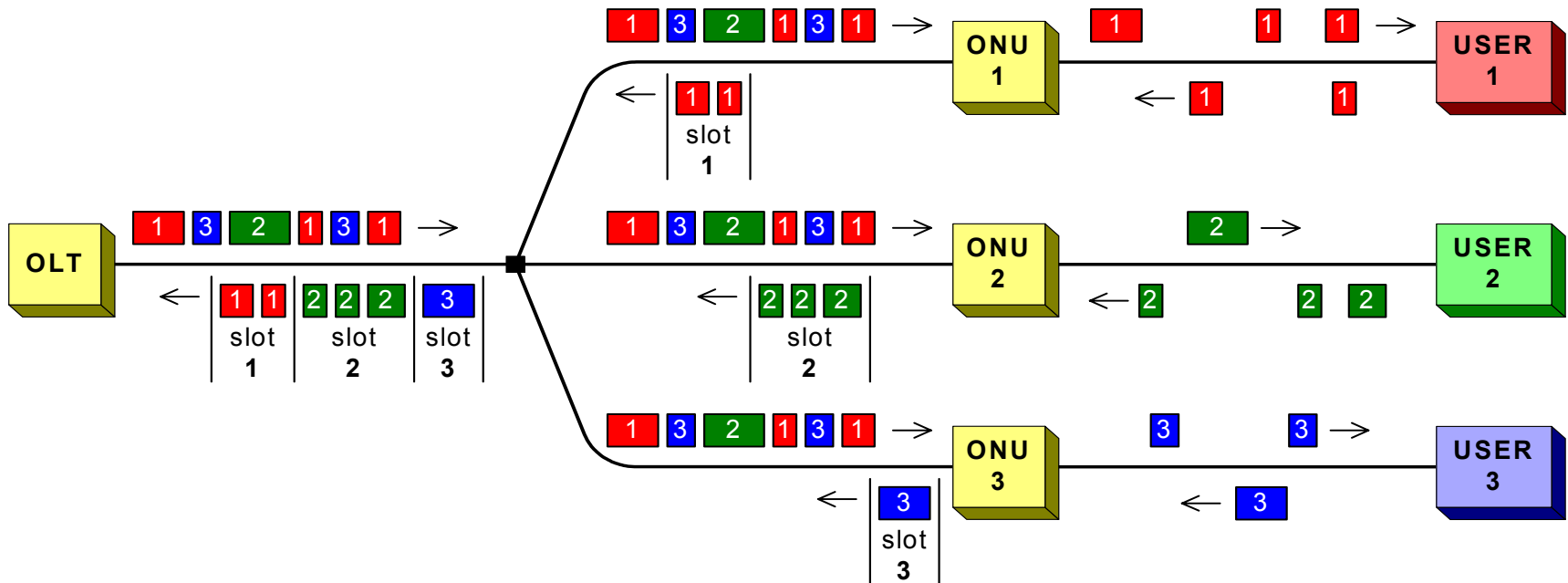
What is Ethernet PON (EPON)?

- EPON preserves 802.3 frame format
- EPON uses existing 802.3 MAC (!)
- EPON uses existing 8B/10B encoding
- EPON uses standard 802.3 line rate (1 Gbps)

Focus: simplicity and integrity of Ethernet

Work is done by IEEE802.3ah task force

Transmission in EPON



▪ Downstream [→]

- Broadcast channel
- 802.3 Frames extracted by ONUs

Upstream [←]

- Upstream time slicing
- No packet fragmentation
- No collisions

EPON Features

- EPON is inexpensive, flexible, efficient
- 802.3ah draft standard does not mandate a scheduling algorithm
- To understand EPON scheduling requirements, we need to understand business model

II. Internet as a business place

1. Current business model
2. Why it doesn't work
3. Does the right model already exist?

Current Business Model

Content Provider

- Sells content or services to individual subscribers.
- Has to maintain accounting/billing services



Internet Service Provider (Long-Haul Carrier)

- Connects multiple points-of-presence
- Subsidizes Internet traffic from the long-distance voice revenue



Access Network Operator

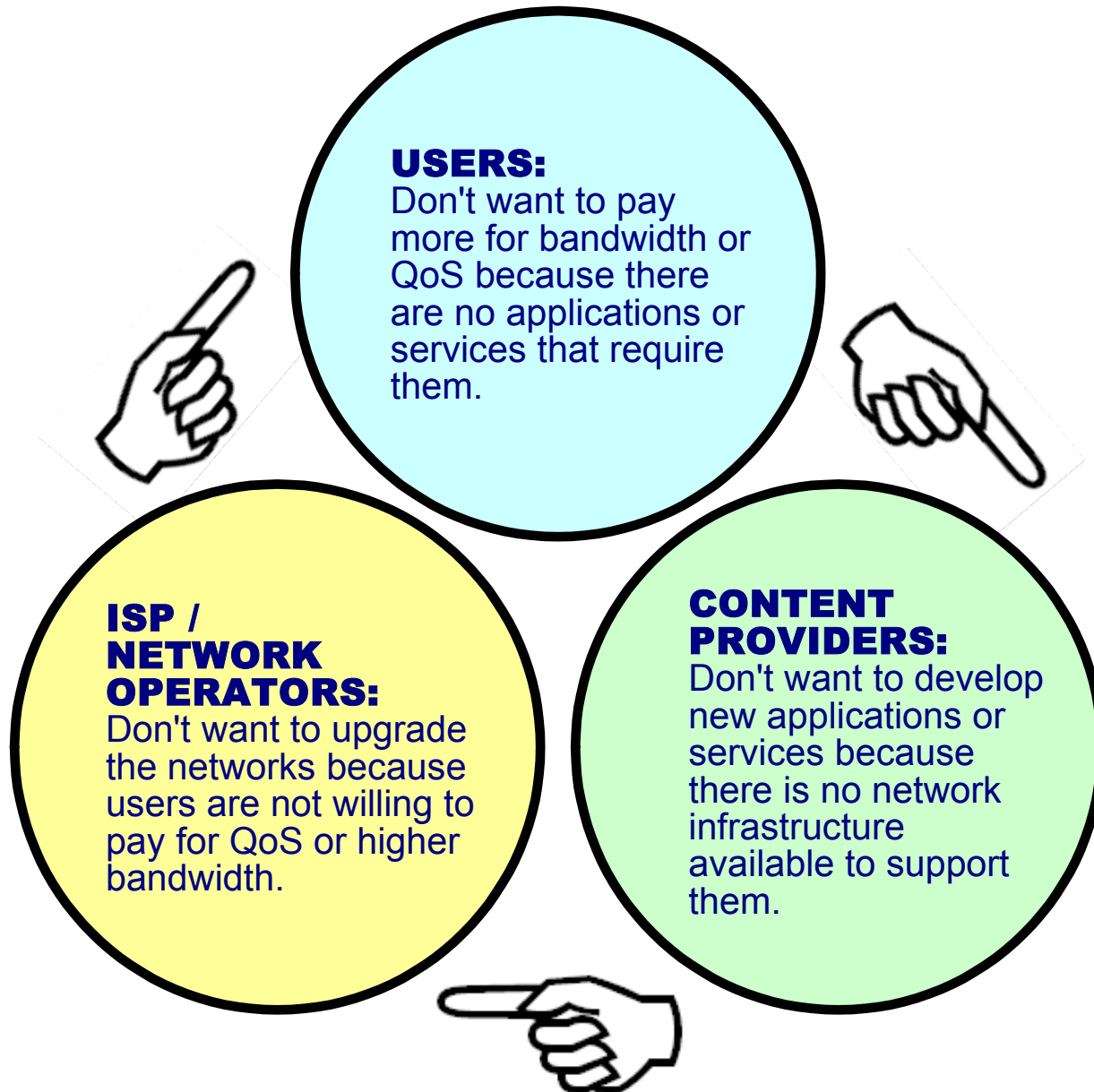
- Often vertically integrated with ISP
- Charges flat fee for subscriber access
- Is not interested in allowing multiple ISPs or new services because revenue would not change (flat fee)



Subscriber

- Pays for access
- Pays for content and services to multiple content providers (separate bill for different services: E*Trade, IEEE Explore, Wall Street Journal, etc.)

Why it doesn't work



Does the right model already exist?

Internet content distribution

Content Provider

- Sells content or services to multiple ISPs at wholesale prices



Internet Service Provider

- Re-sells content / services to individual subscribers
- Competes with other ISP in quality, selection, and prices



Access Network Operator

- Transparent to subscribers
- Gets paid by ISP for enabling subscriber access to ISP's point-of-presence
- **Allows subscriber access to multiple ISPs**



Subscriber

- Interacts only with ISP (one account/bill)
- Can chose among multiple ISPs
- Does not care for guaranteed bandwidth, QoS, but wants seamless service when needed

Food distribution

Producer / Grower

- Sells produce to multiple super-market chains at wholesale prices



Supermarket Chain

- Re-sells produce to individual consumers
- Competes with other chains in quality, selection, and prices



Infrastructure Provider (Municipality)

- Transparent to consumers
- Gets paid by chain for enabling consumer access to store (roads, parking)
- Allows consumer access to multiple supermarket chains



Consumer

- Interacts only with supermarket store (one bill for multiple items)
- Can chose among multiple stores
- Does not care for reserved parking, but wants it to be available when needed

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Another example

“Think of it like roads and airports... We use a common carriage transport infrastructure to access the equivalent of a carrier neutral colo where we can select interurban airfares based on competitive pricing mechanisms...”

(Quote found on **www.lightreading.com**)

Advantages of new model

- The new model
 - assumes separation of ISP and local loop (access network operator)
 - naturally promotes ISP competition in services and content
 - creates incentives for access network operator to enable open access

III. Open Research Problems

- 1 When time comes, how can EPON be upgraded?
- 2 Open access
- 3 Global fairness vs. scalability

EPON – an evolutionary step

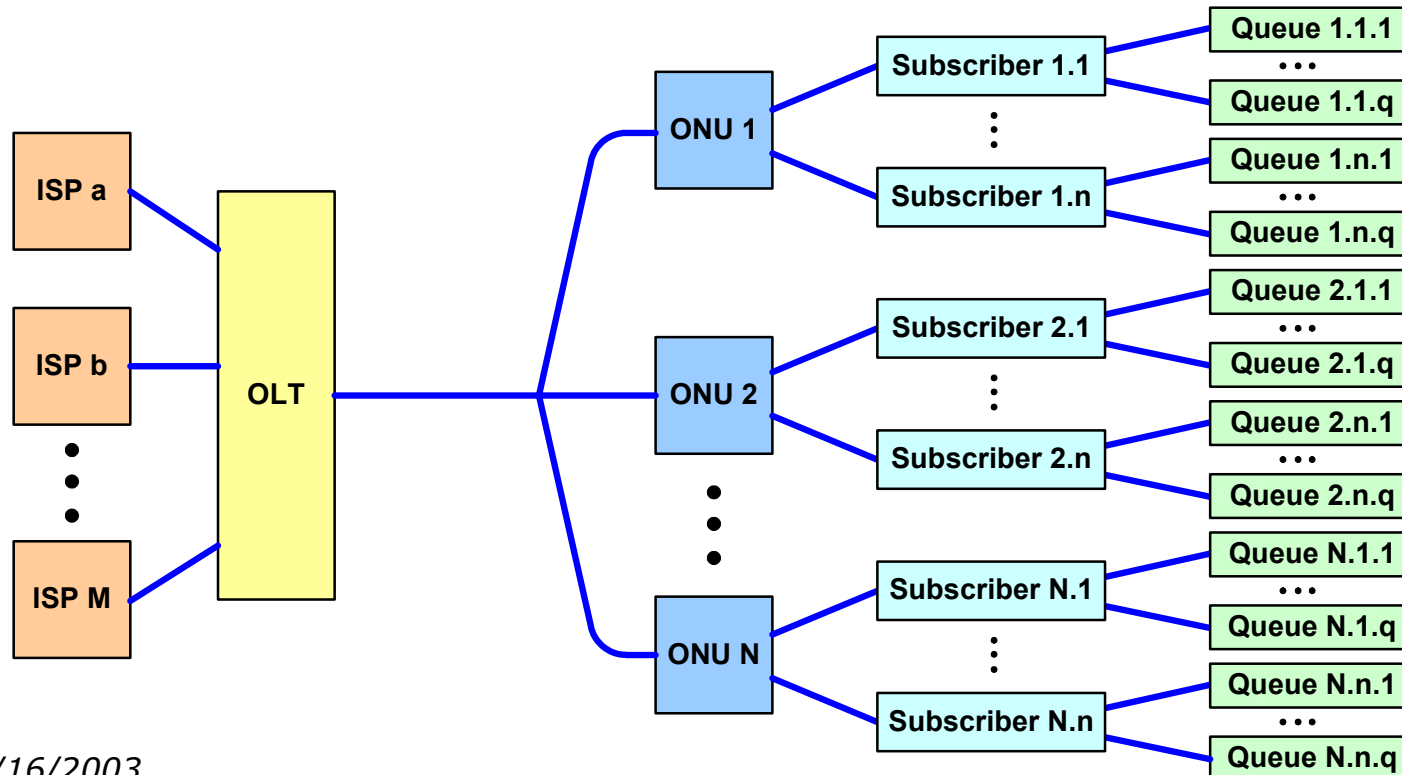
- EPON is a giant step forward compared to technologies deployed today (DSL, CM)
- But, unavoidably, traffic demand will catch up (give us the bandwidth – we will find how to use it)
- EPONs should provide seamless and robust upgrade path. What will it be?

Upgrade Scenarios

- **Wavelength upgrade**
 - Move premium ONUs to separate wavelengths
 - Less ONUs per λ => more bandwidth per ONU
 - Inventory problem (ONUs are different) or tunable lasers
- **Rate upgrade**
 - Increase rate of EPON (1 Gbps -> 10 Gbps)
 - OLT should support new rate (for premium ONUs) and old rate (for non-premium ONUs)
 - Dispersion penalties affect maximum distance
- **Spatial upgrade**
 - Split 32-user EPON into two 16-user EPONs
 - Deploy multiple trunks or put splitter in the CO
 - Eventually becomes point-to-point topology

What is Open Access?

- EPON connects multiple ISPs to multiple subscribers
- Each subscriber can choose one or many service providers for various services or various sessions
- EPON can facilitate open access
 - **Emulation sublayer isolates users and/or ISPs**
 - **A logical link is established between an ISP and a queue**



Open Access Problem

Some issues where never explored

- ISPs pay to network operator. Who has SLA with network operator: subscribers or ISPs?
 - If SLA is with ISP, how to guarantee minimum service to subscribers?
 - How network operator can specify and maintain SLA with ISPs if subscribers constantly migrate from one ISP to another?
 - If SLA is with subscribers, how ISP should pay to network operator (usage-based billing, flat fee)?
- Should network operator maintain dual SLAs: primary with subscribers, secondary with ISPs?
 - What scheduling algorithm could support this?

Fairness Requirements

- SLA includes guaranteed bandwidth B^{MIN} and excess bandwidth B^{EX}
- B^{EX} must be divided between busy queues **fairly**, for example, according to weights w assigned to each queue

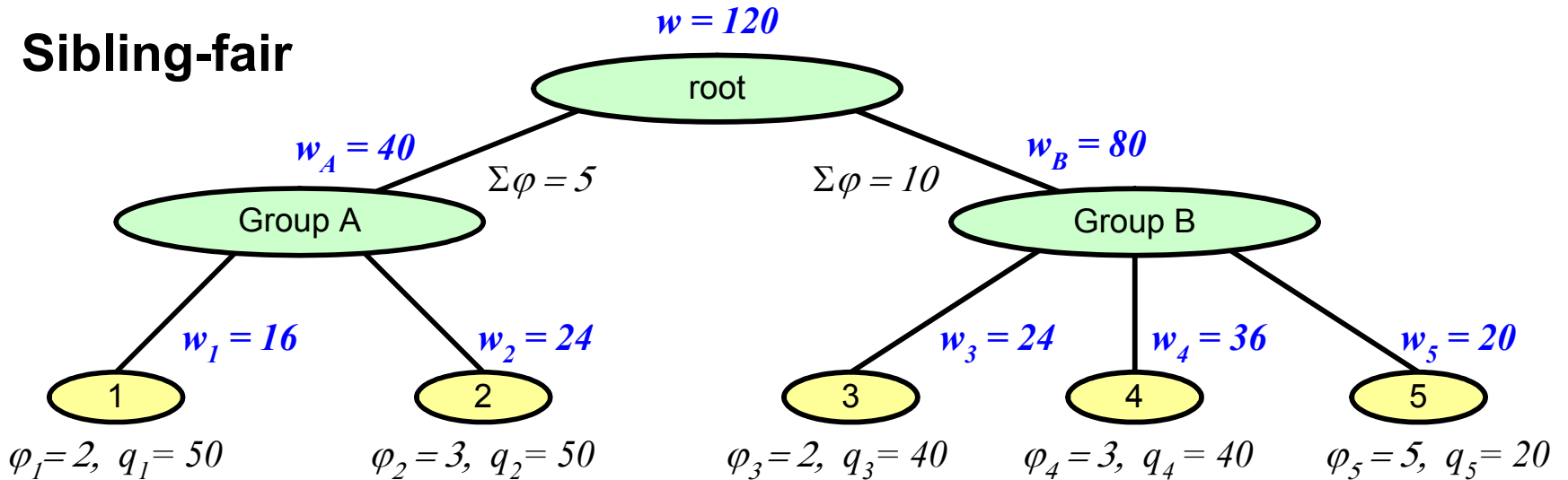
$$\frac{B_i^{EX}}{w_i} = \frac{B_j^{EX}}{w_j}$$

Fairness Problems

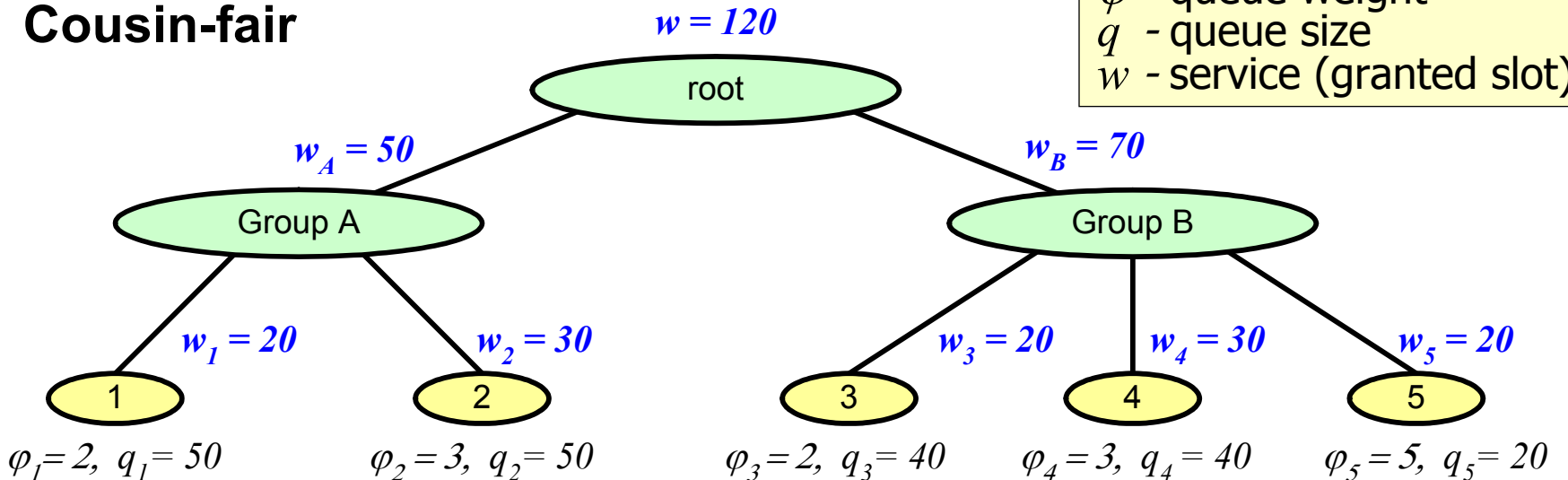
- Many **single-level** (non-hierarchical) fair queuing protocols exist today (WFQ, WF²Q, STFQ, VCFQ, etc), but they are **not scalable** (in EPON they need a separate message to each subscriber/queue).
- **Hierarchical** scheduling protocols provide fairness only among **siblings**, but not among **cousins**. In EPON, this means that queues with equal backlog and weights may get different (**unfair**) service if they are in different ONUs.
- Should fairness be enforced across cousins served by **different ISPs**?
 - What if ISPs have different SLAs with access network operator?

Cousin-fairness vs. Sibling-fairness

Sibling-fair



Cousin-fair



φ - queue weight
 q - queue size
 w - service (granted slot)

To get more information about EPON ...

visit:

- **IEEE 802.3ah (EFM) task force web site**

<http://grouper.ieee.org/groups/802/3/efm/>

- Presentation materials
- Mailing lists / reflector archives
- Draft standard (need to be 802.3ah member)

- **IEEE EPON Forum**

<http://www.ieeecommunities.org/epon>

- Journal articles
- White papers
- EPON-related patents
- Online discussions

