

PON Technology Evolution Strategies for Increased Bandwidth and Reach



Ronald Heron
Fixed Access Division CTO Group
July 2nd, 2008

Deployment Status and Outlook

North America - **GPON**

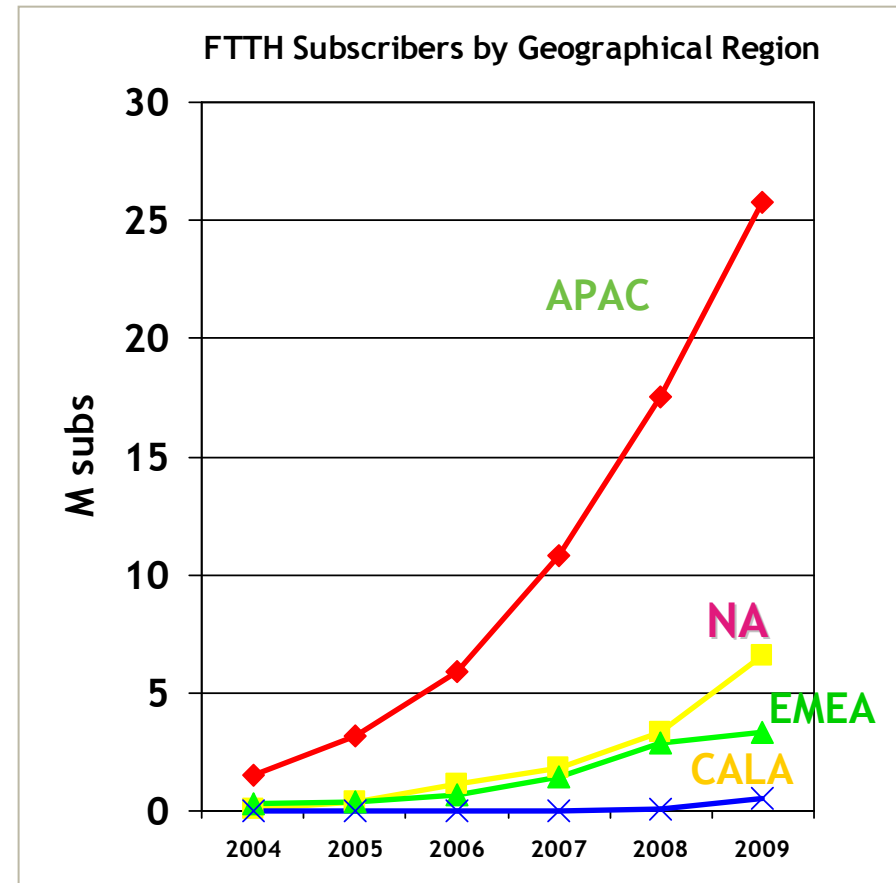
- Municipalities and small operators
 - a mix of *Active Ethernet* and *GPON*
- Verizon
 - leading with *FTTH GPON*
- AT&T, Bell Canada, other ILECs
 - FTTN for overbuild, *FTTH GPON* for *GFld*

Europe - **GPON, AE, P-P**

- Municipalities and competitors
 - a mix of *FTTH PON*, *Active Ethernet* and *Point to Point fiber*
- Large ILECs (FT, Telefonica, BT)
 - FTTN and some *FTTH GPON* deployment

Asia - **EPON & GPON**

- Japan - leading with *FTTH EPON*
- Korea - FTTBuilding and *FTTH EPON & GPON*
- Singapore - preparing for FTTH to every home



Source: Infonetics Research, Inc, Sept. 2006

So, what's next?!

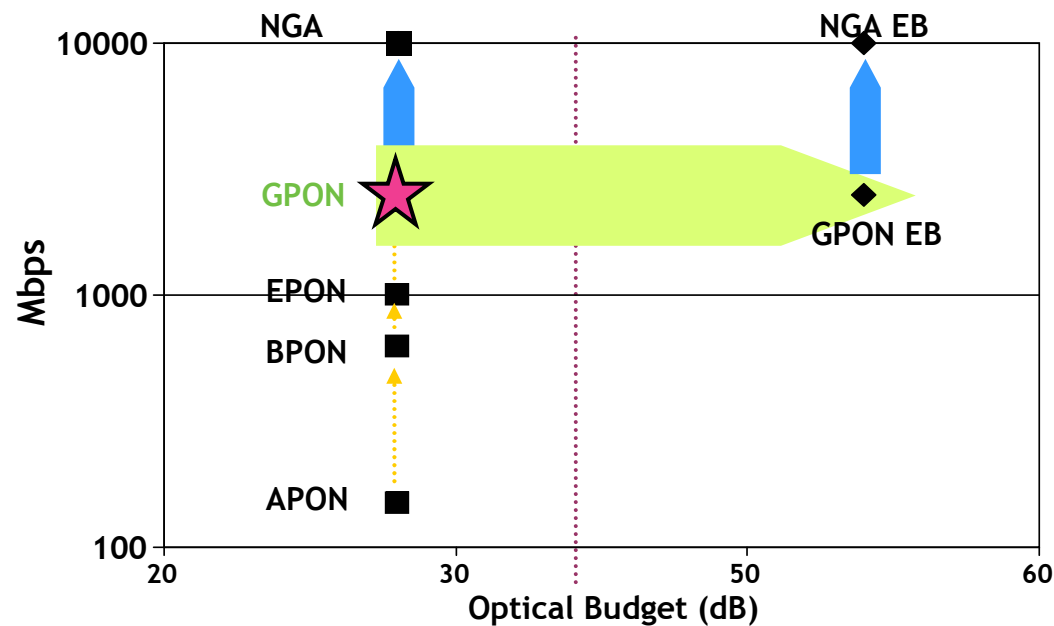
The Challenges Ahead for PON

1. Increased Bandwidth (NGA)

- Driven by continued appetite for more BW

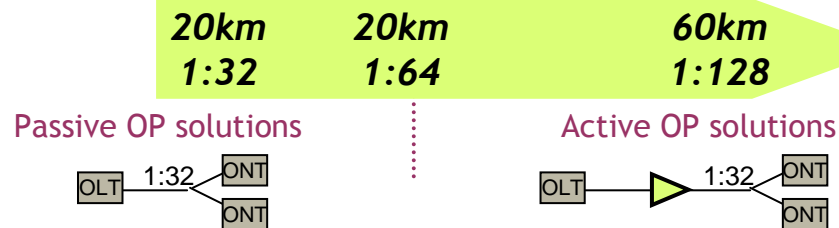
3. Increased Bandwidth and Reach

- Logically, must address both



2. Increased reach & splits

- Increased subscribers per OLT
- Margin for additional filters & connectors
- 100% coverage
- Elimination of COs



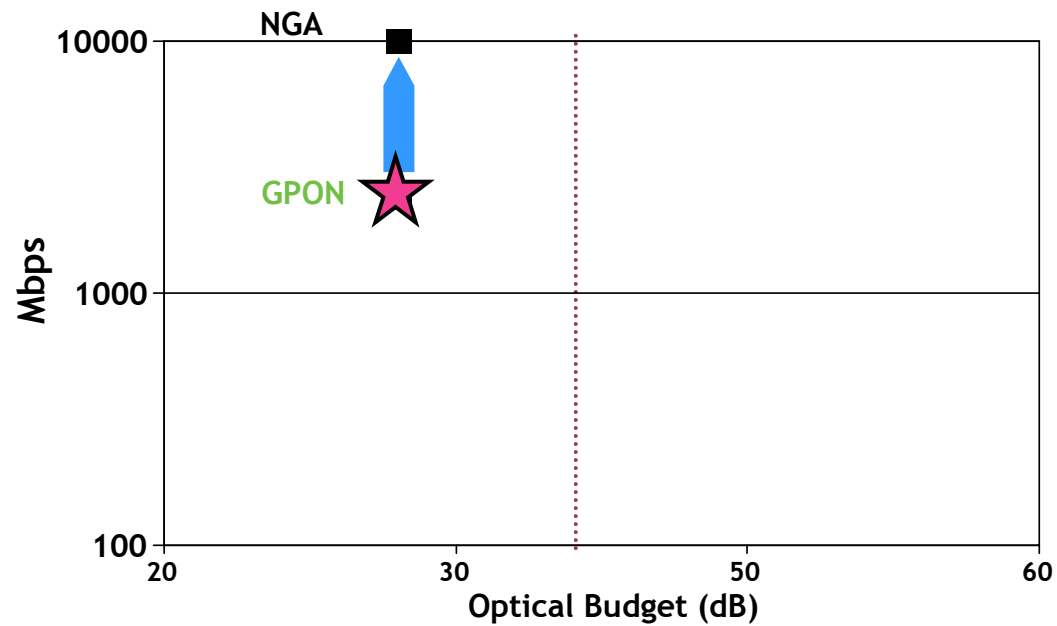
4. Operational excellence

- Optical monitoring
- In-band OTDR

Agenda

1. Increased Bandwidth (NGA)

- Driven by continued appetite for more BW

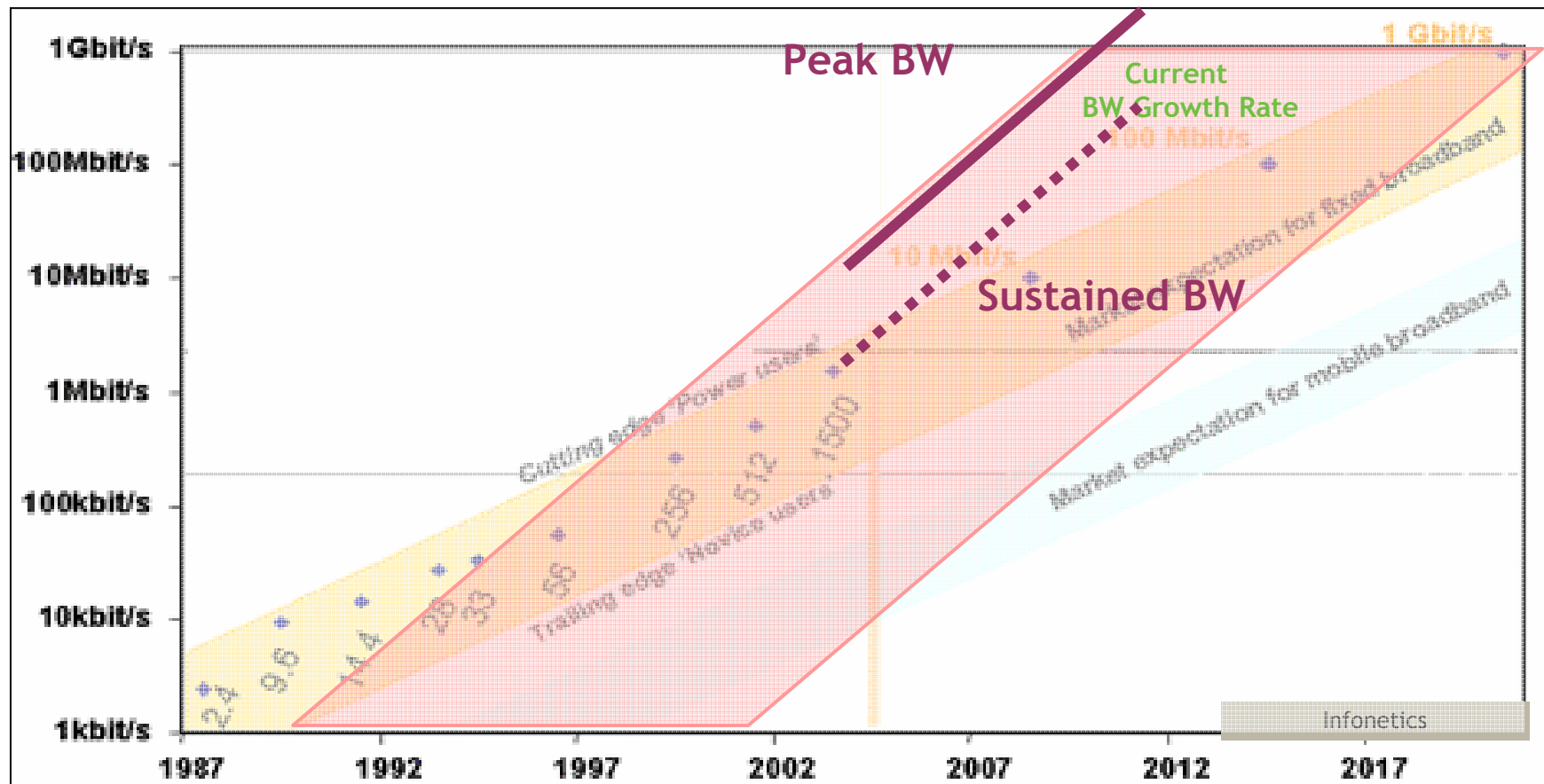


3. Increased Bandwidth and Reach

2. Increased reach & splits

4. Operational excellence

Long Term Bandwidth Trends



Global BW growth trend is continuing
It may have even accelerating (temporarily?) to close to **10x per 3-4 years.**

Increased Bandwidth:

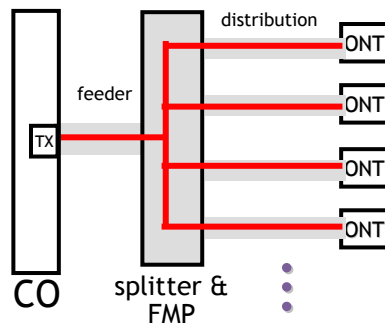
...What are the NG PON Requirements and Options?

Requirements (stated by FSAN)

- Increase **Bandwidth by 4x** (from current PON)
- Respect **similar Optical Distribution Network** (dB)
- Respect existing wavelength allocations
- Keep changes of MAC layer to minimum
- Enable **coexistence with current PON**
- Reuse equipment practice/EMS, etc.
- Minimize cost
- Support Extended Reach PON

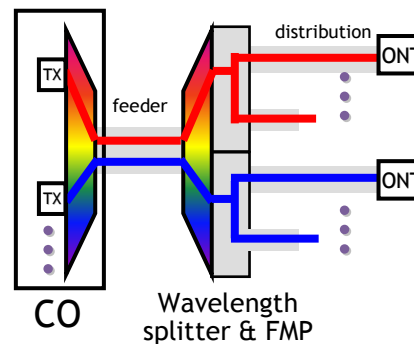
Possible architectures to consider:

A. Pure TDM PON



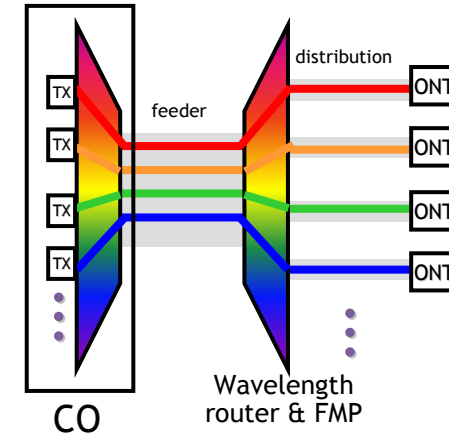
A bump from 2.5Gb/s
to 10Gb/s (still TDM)

B. Hybrid TDM/WDM PON



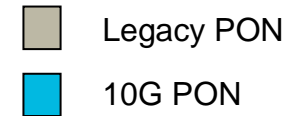
Use MWDM to overlay
multiple TDM PONs

C. Pure WDM PON



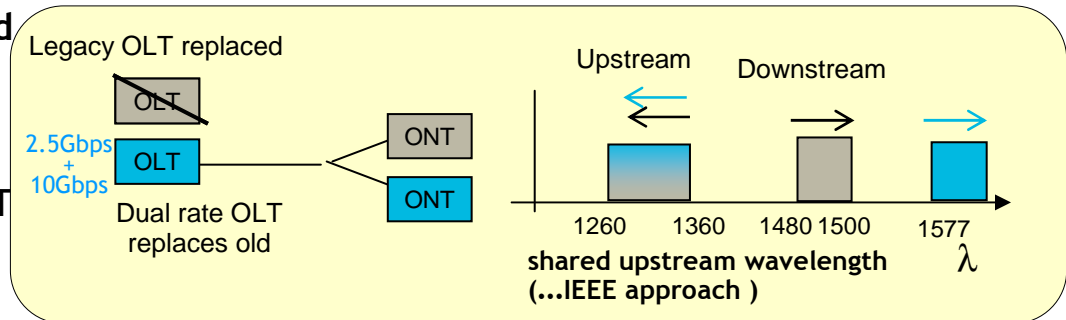
Use WDM to dedicate
wavelengths to
individual users

A. Pure TDM Approach




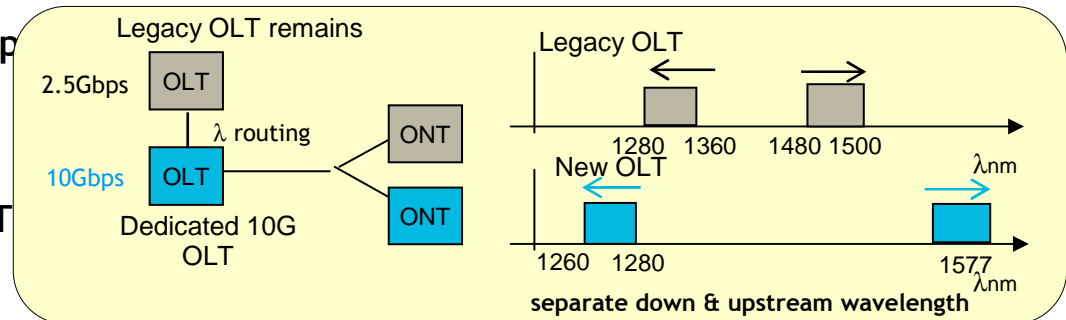
(A1) 10G PON - 1 Lambda Overlay with shared upstream

- Replace OLT with new dual rate OLT
 - 10GPON is burdened by the legacy
- Requires wavelength blocking filter at ONT
- IEEE approach
 - 10:1 asymmetry may be inadequate, 10:10 symmetry is expensive



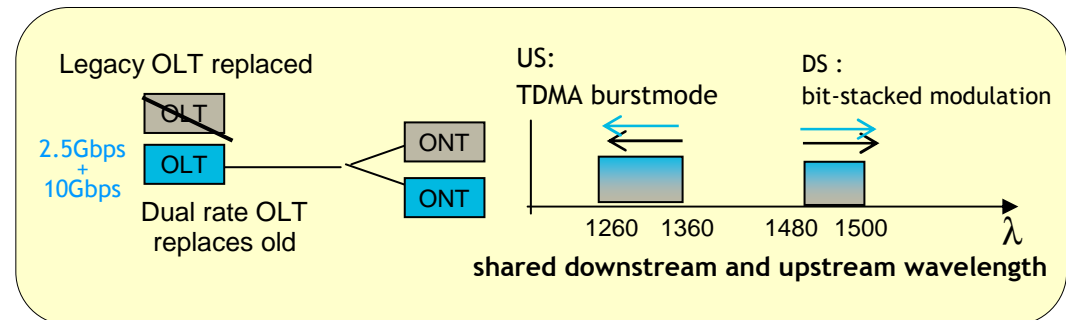
(A2) 10G PON 2 Lambda Overlay (down and up)

-  **Preferred**
- New OLT does 10GPON on different wavelengths (down and up)
 - 10GPON is streamlined
 - Requires wavelength blocking filter at ONT
 - FSAN approach
 - 2.5 or 10G up, still considering wavelength choice

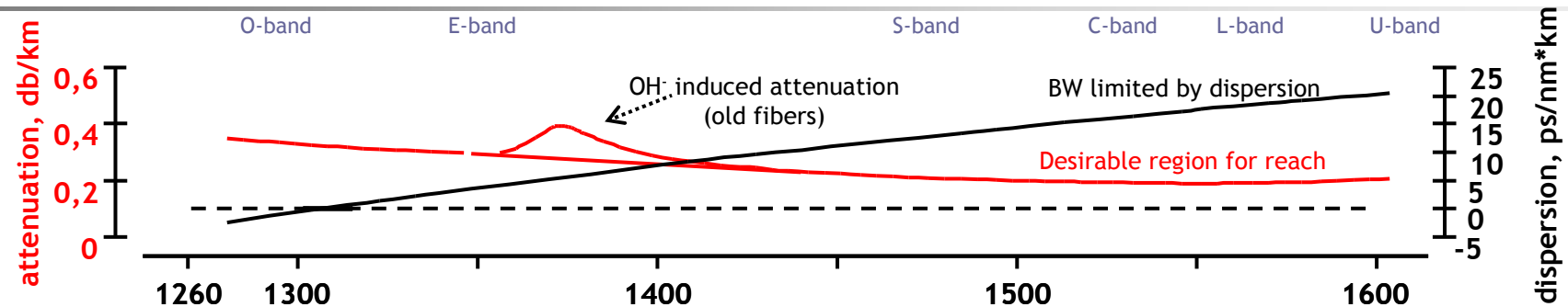


(A3) 10G PON - Bit Stacked

- 10GPON and GPON share downstream wavelength using intensity modulation. Upstream does dual rate on the same λ
 - 10GPON is burdened by the legacy
 - no need for WBFs
 - 3dB penalty due to modulation



Tradeoffs in Choosing 10GPON Wavelength Plan



XGPON Upstream options & Issues:



Option D remains an attractive universal option

Option D: 1260-1280: Option C: 1340-1360:

- | | |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <ul style="list-style-type: none"> ■ spectrum available ■ Un-cooled operation ■ Dispersion good (DML) ■ Good for 2.5 & 10G ■ Synergy with IEEE | <ul style="list-style-type: none"> ■ spectrum available ■ Un-cooled operation ■ Dispersion good (DML) ■ Good for 2.5 & 10G |
| <p>But...</p> <ul style="list-style-type: none"> ■ Poorer attenuation ■ Slight cost premium for 2.5G (vs C or L) | <p>But...</p> <ul style="list-style-type: none"> ■ Poorer attenuation ■ Slight cost premium for 2.5G (vs C or L) |

Option B is desirable but feasibility with video must be demonstrated

Option B: 1540-1560:

- Good attenuation
- But...**
- Poor dispersion (EML+)
 - 2.5G ok but not 10G
 - Conflict with RF video
 - Possibly move down into WBF filter region but feasibility tbd. (requires narrow filter)
 - Cooling, power, etc.

Option A: 1595-1615:

- Good attenuation
- But...**
- Poor dispersion (EML+)
 - 2.5G ok but not 10G
 - High macro-bending losses
 - Potential conflict with overlay OTDR
 - Cooling, power, etc.

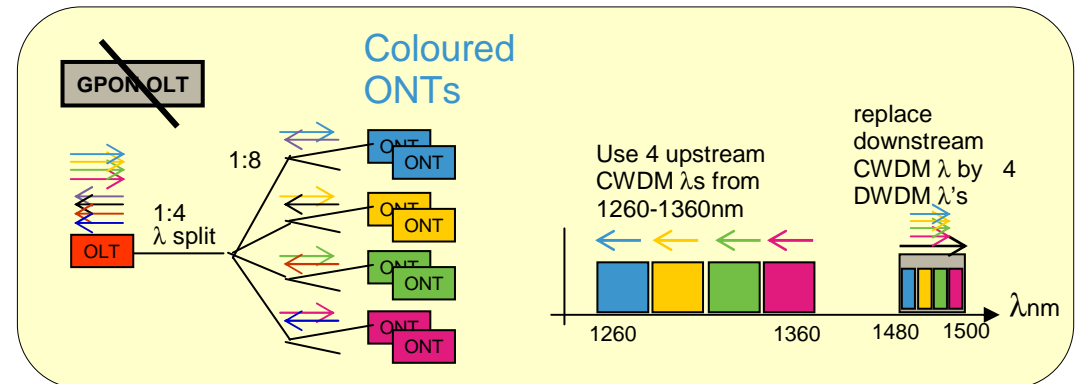
Must avoid risk of fracturing market



B. Hybrid TDM/WDM PON

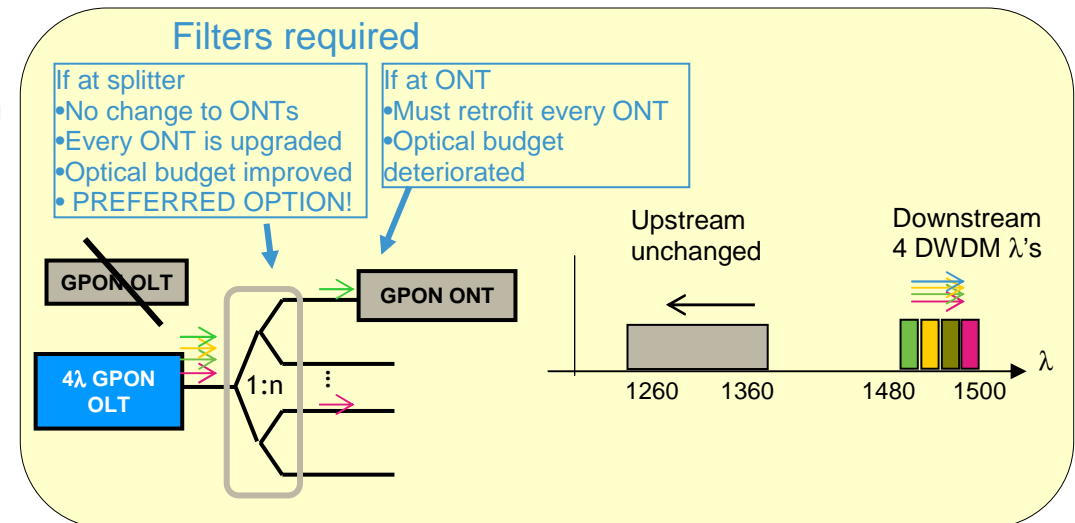
(B1) Stack 4x GPONs down and 4 up using different wavelengths

- 4x 2.5Gbps down, 4x1.2Gbps up
- Same ODN, change splitters
- Improved optical budget
- Requires coloured ONTs or wavelength locking
 - OPERATIONALLY NOT ACCEPTABLE



(B2) Stack 4x 2.5 GPONs down on a single fiber with a shared upstream wavelength

- Attractive**
- 4x 2.5Gbps down, 1.2Gbps up
 - Need filters -> best at splitter
 - No change to ONTs
 - change splitters
 - dual-use splitter at day 1 would allow for easy upgrade
 - Improved optical budget
 - Issue: is 8:1 asymmetry acceptable?



Cost Effective Upgrade Strategy
 Approach merits consideration by ITU as appendix to G984

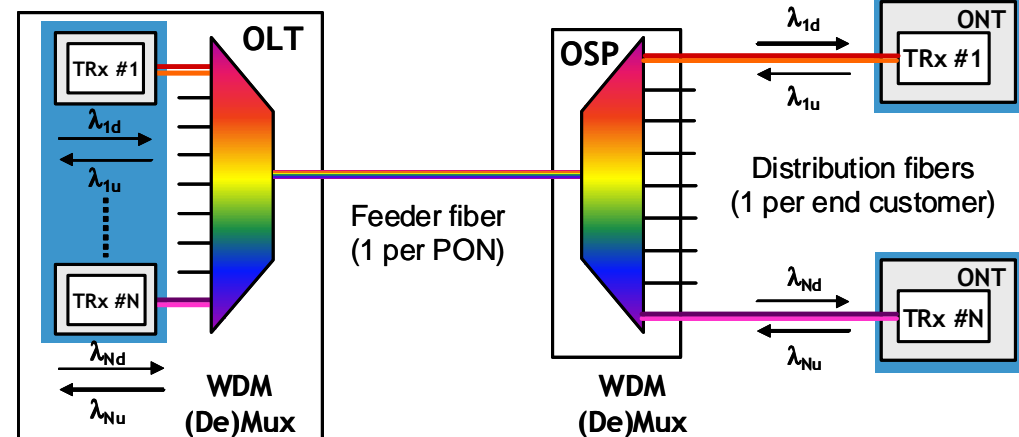
C. Pure WDM PON

Benefits

- “upgradeable to higher speed / new services etc. on a per-user basis” (**not really**)
- low power optics (no split: reduced loss)
- simple electronics (no burst mode)
- passive ODN

Issues

- wavelength selected lasers
 - *fixed wavelength DFB lasers*
 - *tuneable optical emitters*
 - *remotely seeded optical transmitters*
 - *wavelength programmable lasers* (i.e. “set-and-forget”)
- WDM optics still expensive
- Requires DWDM splitters in the field
- Expected benefits of provisionable bandwidth (“like Point to point”) not achieved
 - Requires complex DWDM automated routing system in CO

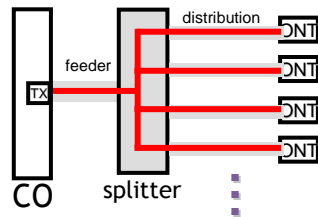


Several approaches are under study but still too expensive for mass market

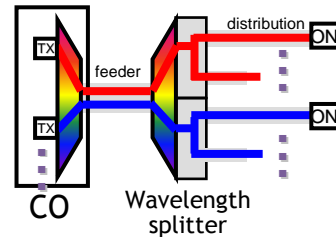
Increased Bandwidth:

Cost Comparisons of Different Technology Options

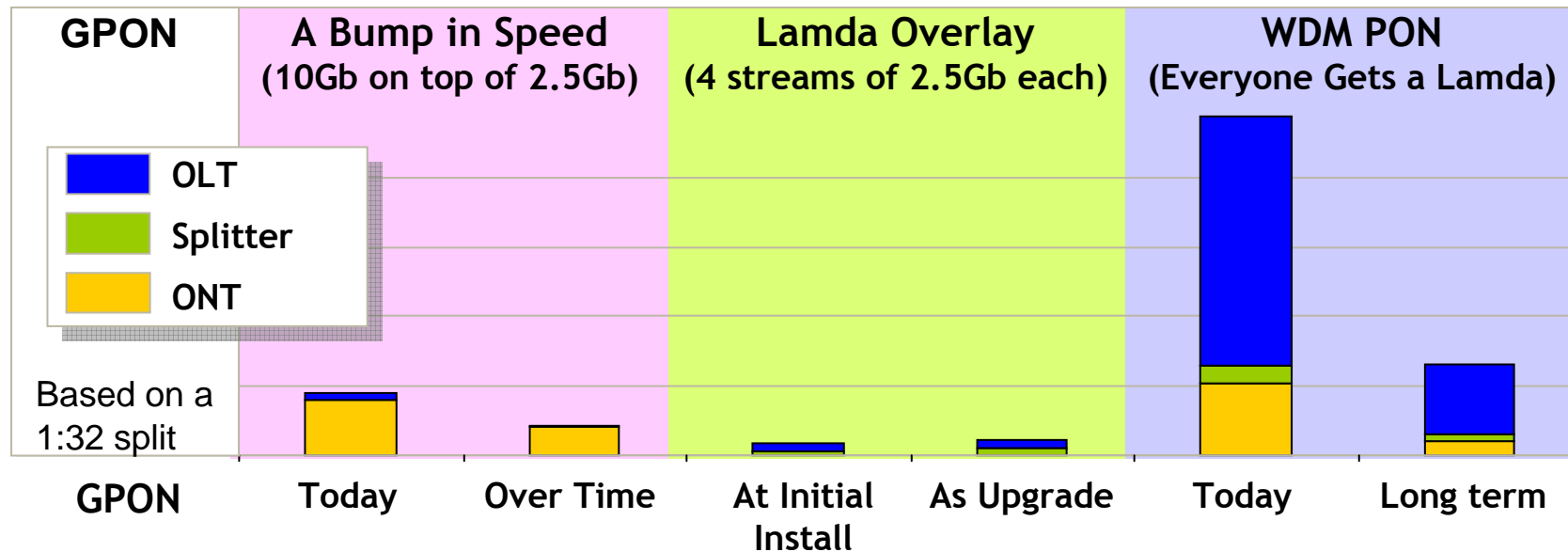
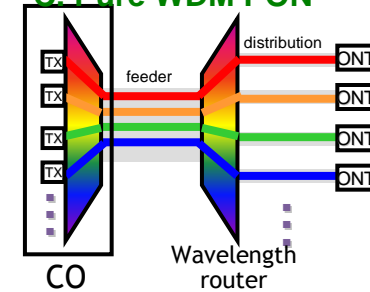
A. Pure TDM PON



B. Hybrid TDM/WDM PON



C. Pure WDM PON



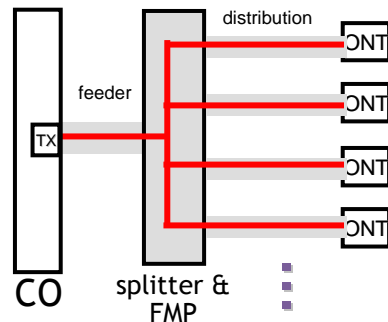
Hybrid TDM/WDM is an economical evolution for installed PONs
10Gb PON will become viable as component costs come down

Pure WDM PON is cost prohibitive for the foreseeable future

1. Increased Bandwidth

...Summary and Technical Challenges Going Forward

A. Pure TDM PON



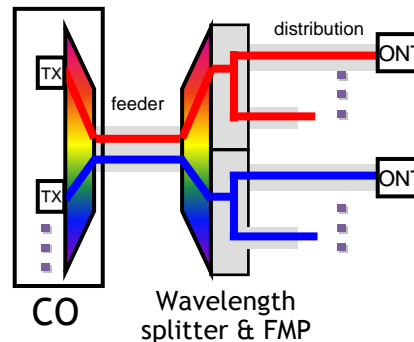
Preferred solution is 10G PON with 2 λ Overlay

- 1540-1560nm is attractive upstream band but conflicts with RF video
- 1260-1280nm may be most universal upstream band, esp. for 10G upstream

Technical Challenges:

- 10G transceivers (down and up)
- Narrow wavelength filters

B. Hybrid TDM/WDM PON



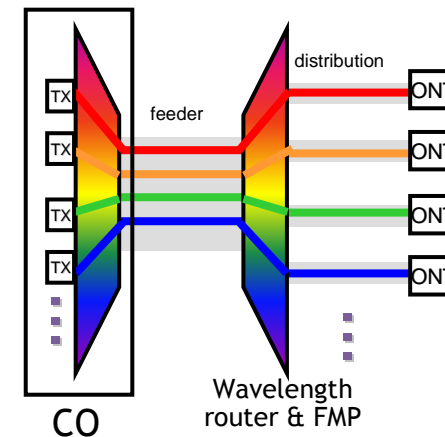
4 λ hybrid GPON is a very cost effective upgrade from GPON to 10G

- No truck roll to ONT
- Issue is 8:1 asymmetry

Technical Challenges

- Minimal new technology
- should have ITU addendum to G.984.1

C. Pure WDM PON



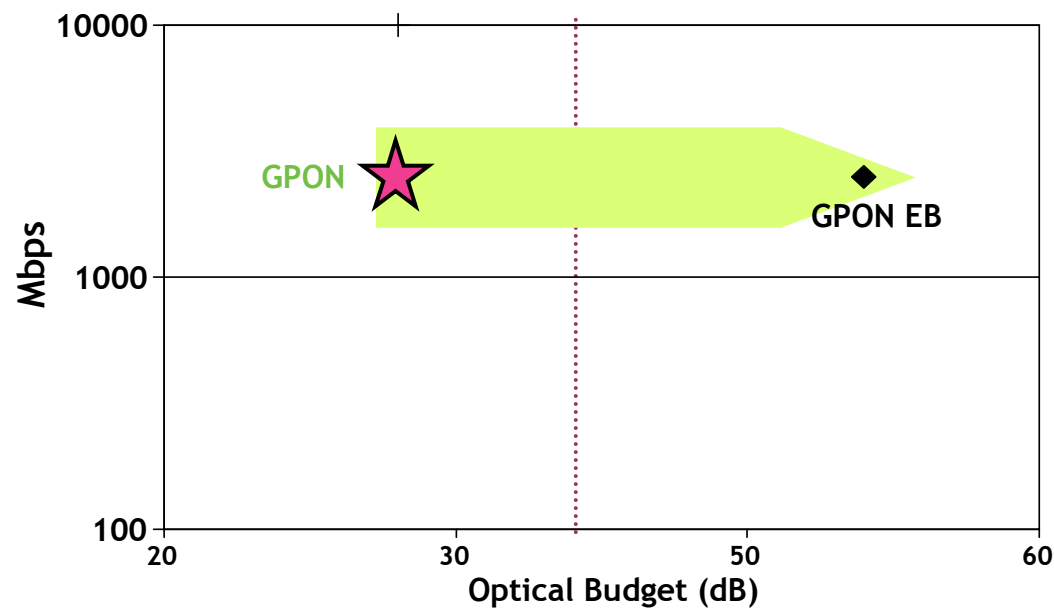
Pure DWDM PON is not economically viable for foreseeable future

Technical Challenges

- Tunable / setable lasers
- Wavelength filters

Agenda

1. Increased Bandwidth (NGA)



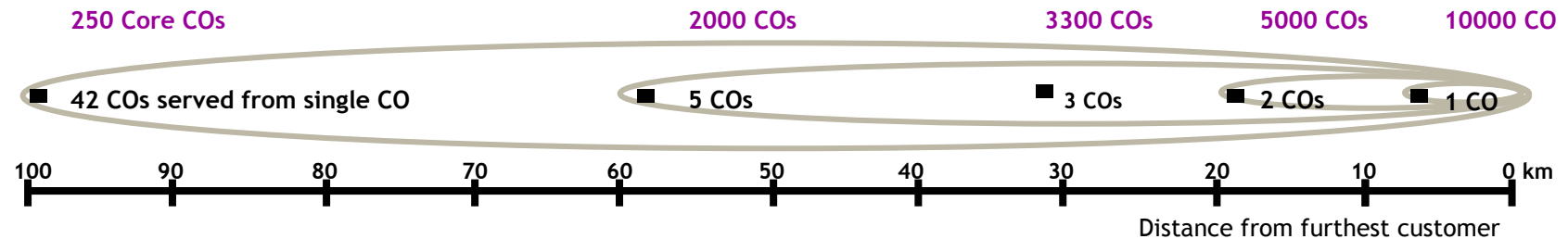
3. Increased Bandwidth and Reach

2. Increased reach & splits

- Increased subscribers per OLT
- Margin for additional filters & connectors
- 100% coverage
- Elimination of COs

4. Operational excellence

Reach Extension - Motivation



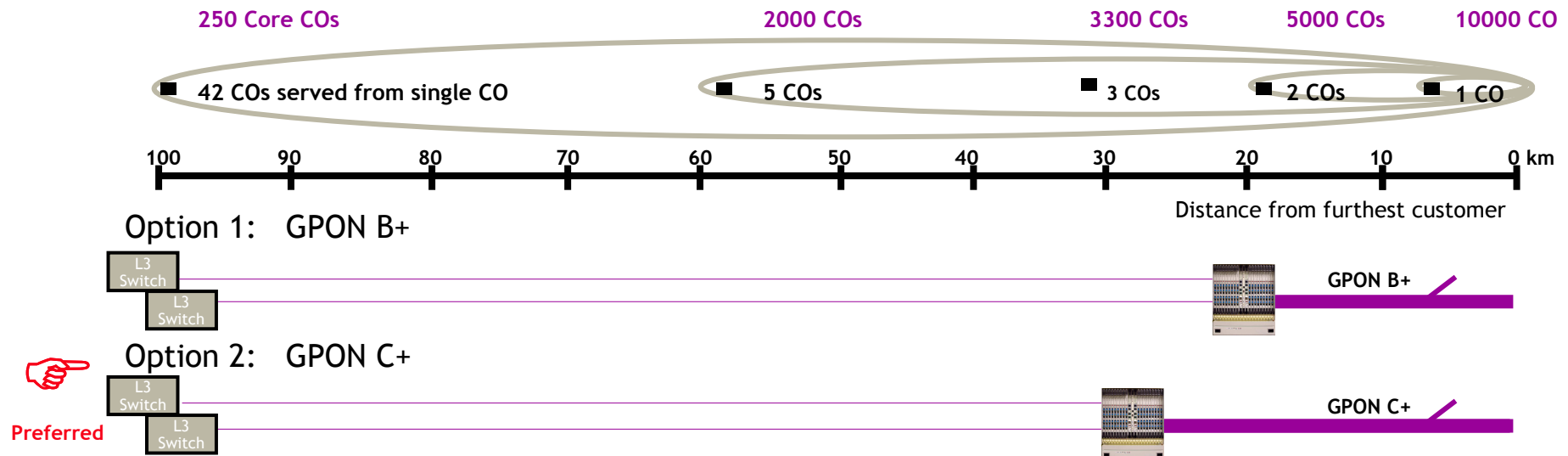
The motivation for extending reach is to reduce the number of Central Offices

- Decommission existing COs - a long term process of removing legacy equipment
- Avoid costly CO acquisition for new deployment

Questions

- How much centralization makes sense?
- What is the best solution?

Reach Extension Options

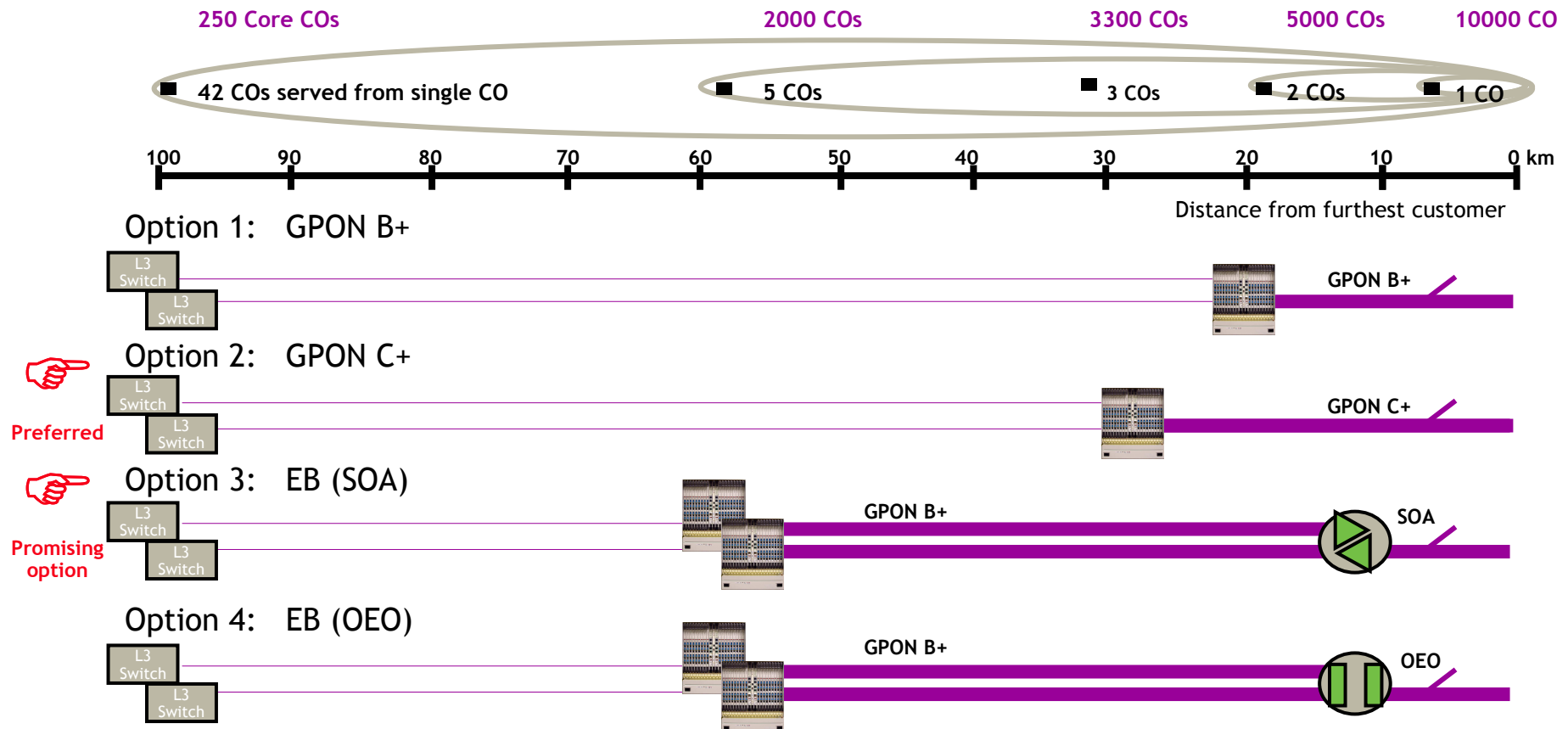


Preferred approach is an all-passive solution

- Class B+ allow 20km reach
- Class C+ could allow 30km reach

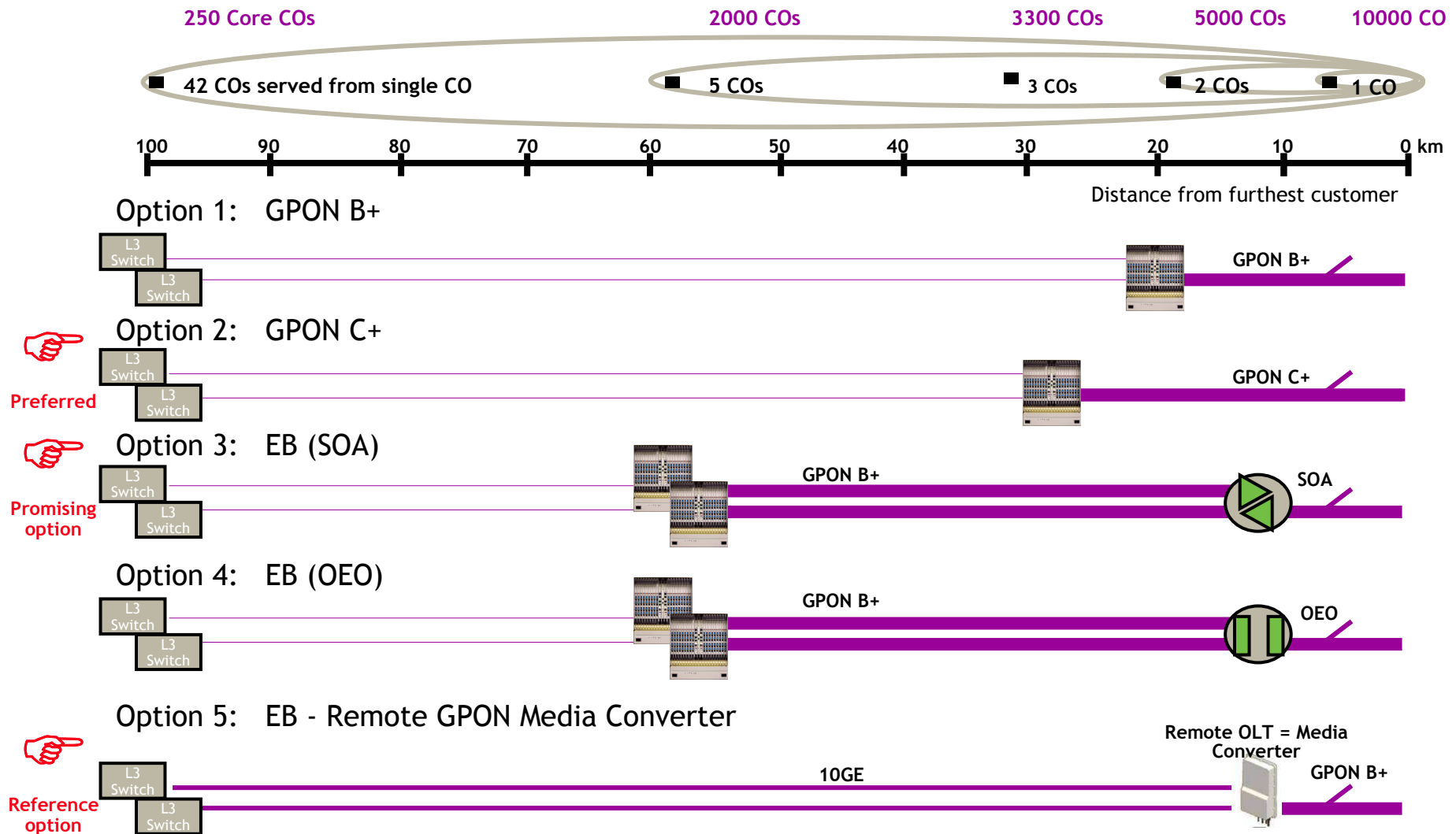
**This is already a significant improvement over copper plant
Could reduce number of COs by 50-66%.**

Reach Extension Options



Efforts are under way to validate these approaches.
Economic justification is still in question. Reduce 80% of COs but actives!

Reach Extension Options

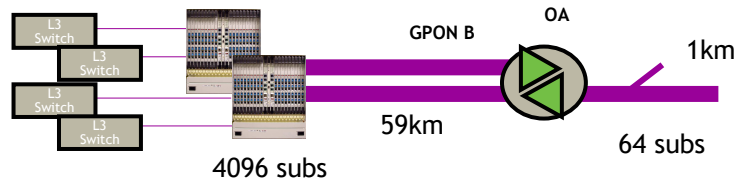


An attractive option (i.e. reference option using existing technology) is to deploy a small remote OLT (brick) in the outside plant. Simple "Media converter", standard dual-homing, fiber efficiency

Reach Extension Options

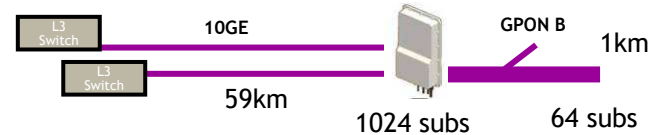
...Comparing Power and Cost

Option 3: Optical Amplifier



Option 5: Remote GPON Media Converter

Remote OLT = Media Converter



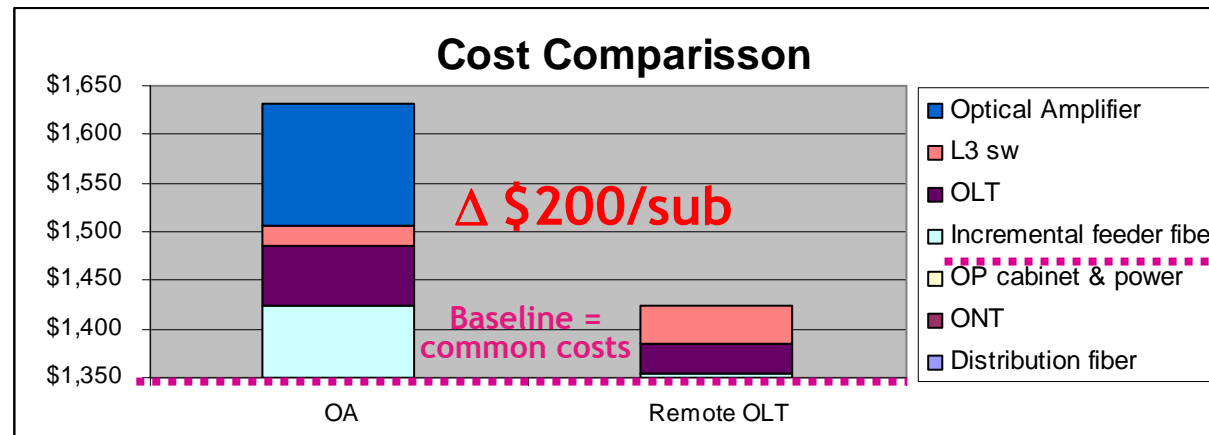
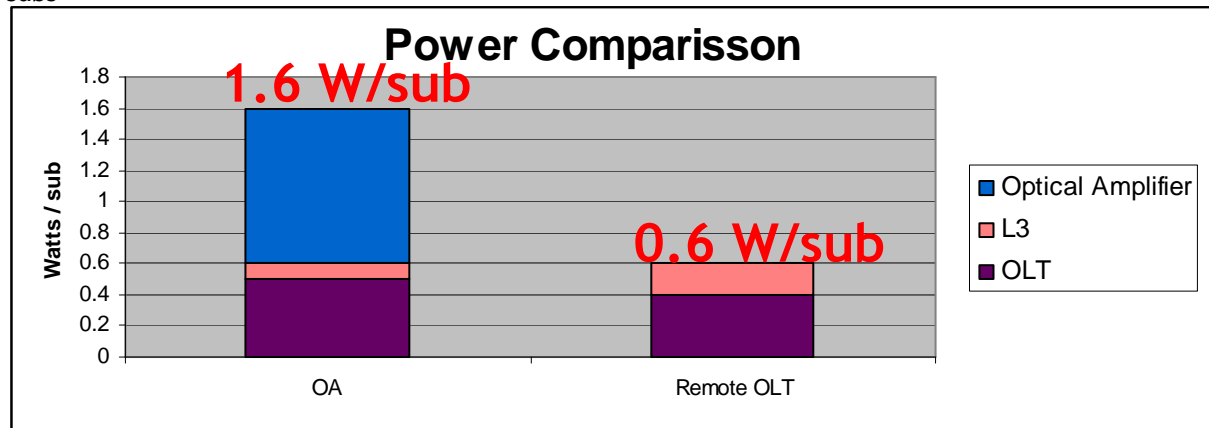
Notes:

- Optical Amplifier has very high power consumption
- There are 2x the number of OLTs

- Long Feeder Fiber (59km) for only 64 users
- 2x OLT cost
- Optical Amplifiers are still expensive

Notes:

- L3 switch is slightly higher but is a small component

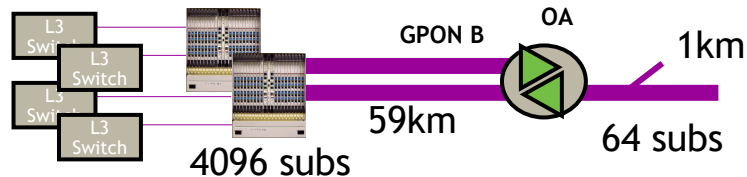


- Long Feeder Fiber (59km) shared by many users (1024)
- L3 switch is more but very small component

Reach Extension Options

...Comparison Assumptions

Option 3: Optical Amplifier



Power

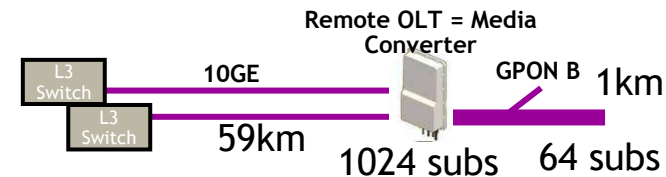
- $OA = 2 \text{ OAs} \times 30W/OA / 64 \text{ subs} = \mathbf{1W/sub}$
- $OLT = 2 \text{ OLTs} \times 15W/PON / 64 \text{ subs} = \mathbf{0.5W/sub}$
- $L3 \text{ switch} = 4 \cdot 10GE \text{ ports} \times 100W/10GE / 4096 \text{ subs} = \mathbf{0.1W/sub}$
- **Total = 1.6 W/sub**

Cost

- Feeder Fiber = $59km \times 2 \text{ fibers} / \mathbf{64 \text{ subs}}$
- OLT = $\mathbf{2 \text{ ports}} / 64 \text{ subs}$
- Eth switch = $\mathbf{4 \text{ -10G Ports}} / \mathbf{4096 \text{ subs}}$
- Optical Amplifiers = $\mathbf{2 \text{ OAs}} / \mathbf{64 \text{ subs}}$
- Common costs
 - Distribution & drop = $1km \times 1 \text{ fiber/sub} = \1000
 - ONT, civil works, power, outdoor cabinet = same

BACKUP

Option 5: Remote GPON Media Converter



Power

- $OLT = 1 \text{ OLTs} \times 20W/PON / 64 \text{ subs} = \mathbf{0.3W/sub}$
- $L3 \text{ switch} = 2 \cdot 10GE \text{ ports} \times 100W/10GE / 1024 = \mathbf{0.2W/sub}$
- **Total = 0.5 W/sub**

Cost

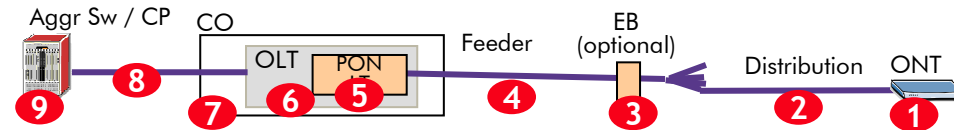
- Feeder Fiber = $59km \times 2 \text{ fibers} / \mathbf{1024 \text{ subs}}$
- OLT = $\mathbf{1 \text{ port}} / 64 \text{ subs}$
- Eth switch = $\mathbf{2 \text{ -10G Ports}} / \mathbf{1024 \text{ subs}}$
- Common costs
 - Distribution & drop = $1km \times 1 \text{ fiber/sub} = \1000
 - ONT, civil works, power, outdoor cabinet = same

Dual Homing for Extender Boxes

...Different Solutions for Different Needs

Reference: Unprotected PON

- So far has been considered acceptable for typical mass market service.

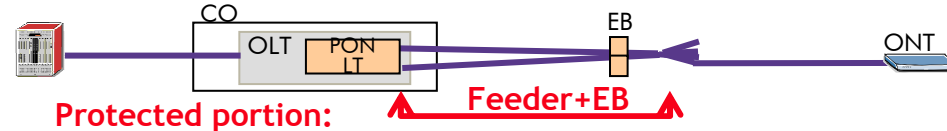


Where things can go wrong...

(1) Dual Feeder (single LT)

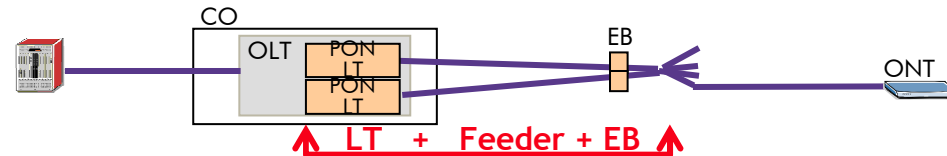
- Could be suitable for developing countries with frequent cable cuts
- A solution for long reach EB application. Assumes there is fiber route diversity from CO

simple first solution



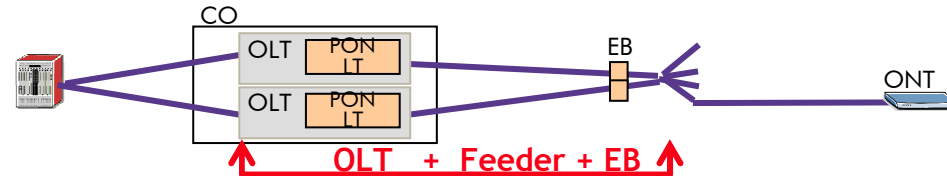
(2) Dual LT + Feeder (single OLT)

- Same as 1) but allows a little more flexibility



(3) Dual OLT + Feeder (single CO)

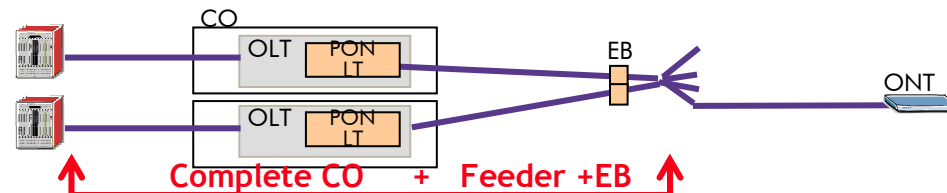
- Adds complete equipment redundancy
- Solving 3) allows for 4)



(4) Dual CO + Feeder

- Adds CO redundancy for protection against power plant failures, CO destruction, or aggregation switch / content provider failure
- In case of extreme CO consolidation, this would be a long term requirement

Target solution



Dual Homing for Extender Boxes

...Addressing the Challenges

- **Challenge 1: Detecting failure**

- Propose to detect LOS of all ONTs at OLT
- Correlate with dying gasp from ONT to avoid false failures (e.g. all ONTs powered down)

- **Challenge 2: Configuring backup OLT**

- a) Provisioning & configuration info
 - Propose to pre-configure OLT using EMS (later, use inter-OLT communication)
 - Need Strict use of EMS to avoid provisioning conflicts
- b) Ranging
 - Re-ranging on the fly can be very quick
 - In the future, could use a delta calculation between OLTs to accelerate
- c) Service status (MAC address, IP status, etc)
 - Propose to reconfigure on the fly
 - In the future, could use Inter-OLT communication to accelerate

- **Challenge 3: Deciding and executing switchover**

- Initially EMS driven, later, autonomous using inter-OLT communication?

- **Challenge 4: Restoration**

- Propose to stay in backup mode until manually re-armed

Standardization will be required to allow for <second response

2. Increased Reach and Split

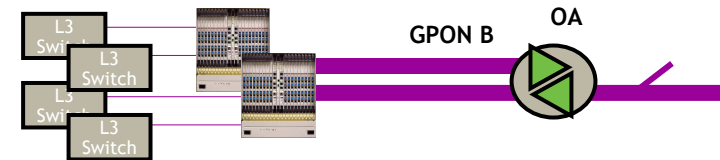
...Summary and Technical Challenges Going Forward

Preferred Options

- (2) GPON C+
 - All-passive approach with 20-30km reach provides significant CO consolidation (vs copper)
 - preferred approach
 - **Technical Challenges - mostly addressed**



- (3) Optical Amplifier
 - Shows promise for extending to 60km but still has high power and cost
 - **Technical Challenges**
 - Power & cost!
 - May require multi- λ amplification to prove-in
 - Dual Homing standardization

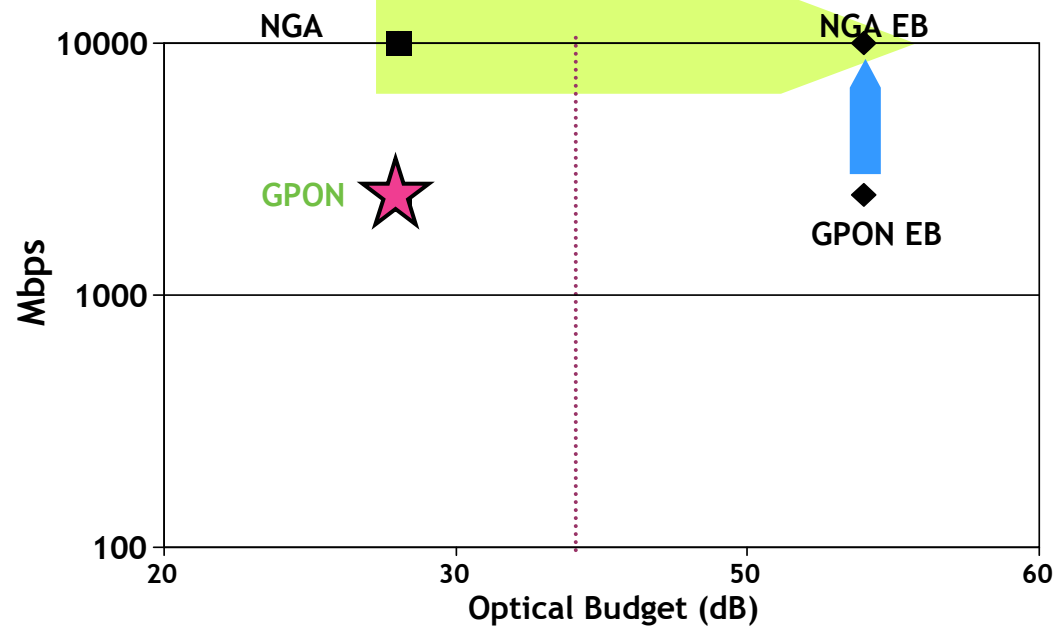


- (5) Remote GPON OLT
 - Is a very economical reference solution
 - **Technical Challenges - packaging**



Agenda

1. Increased Bandwidth (NGA)



3. Increased Bandwidth and Reach

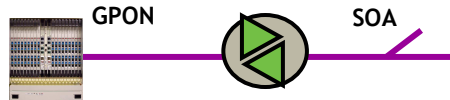
- Logically, must address both together

2. Increased reach & splits

4. Operational excellence

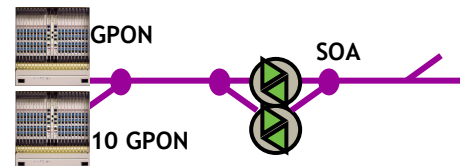
Combining Reach and Bandwidth

Starting point: GPON + SOA



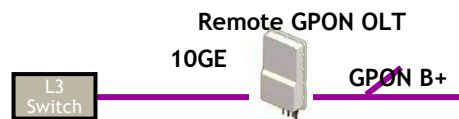
Complexity of dual homing not shown

Add 10GPON with λ overlay and new remote SOA amplifier



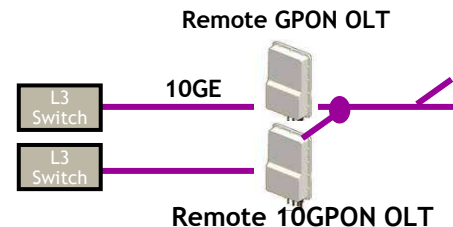
- Need new wavelength filters at SOA location
- Complexity of dual-homing compounded

Starting point: Remote GPON



Dual Homing addressed using standard dual 10GE links.

Add remote 10GPON with λ overlay

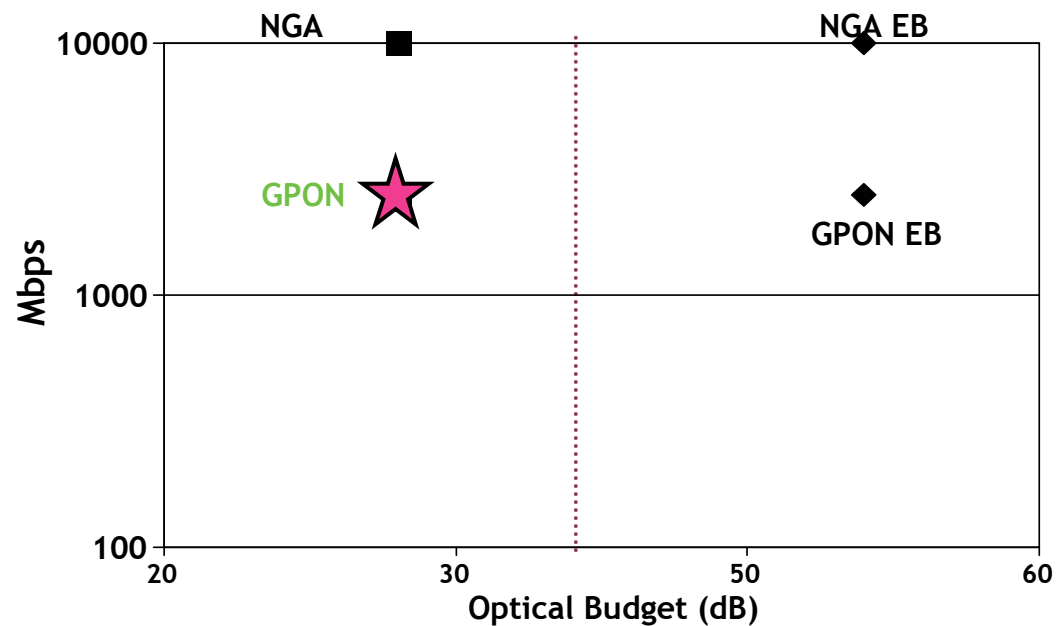


- 10GPON combined with GPON in same way as for CO deployment

Solutions exist for both.
Remote OLT is a simple replication of CO solution in the OP.

Agenda

1. Increased Bandwidth (NGA)



3. Increased Bandwidth and Reach

2. Increased reach & splits

4. Operational excellence

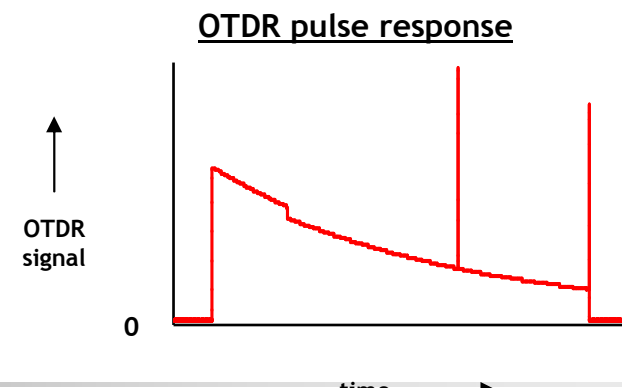
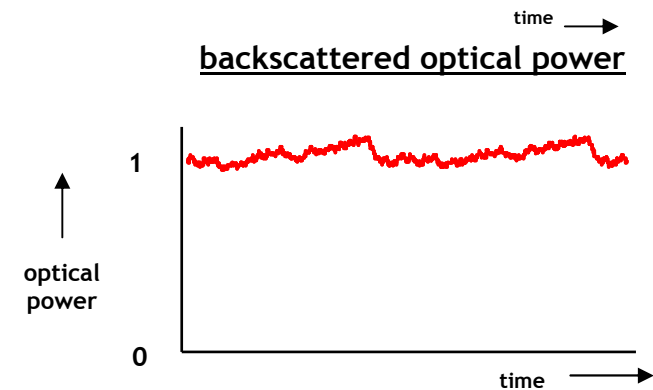
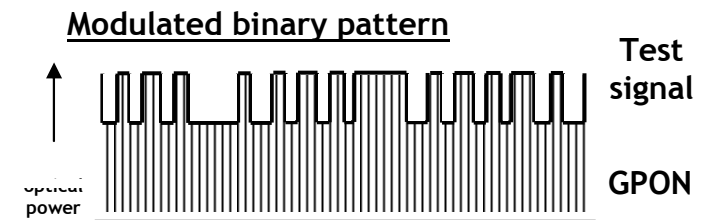
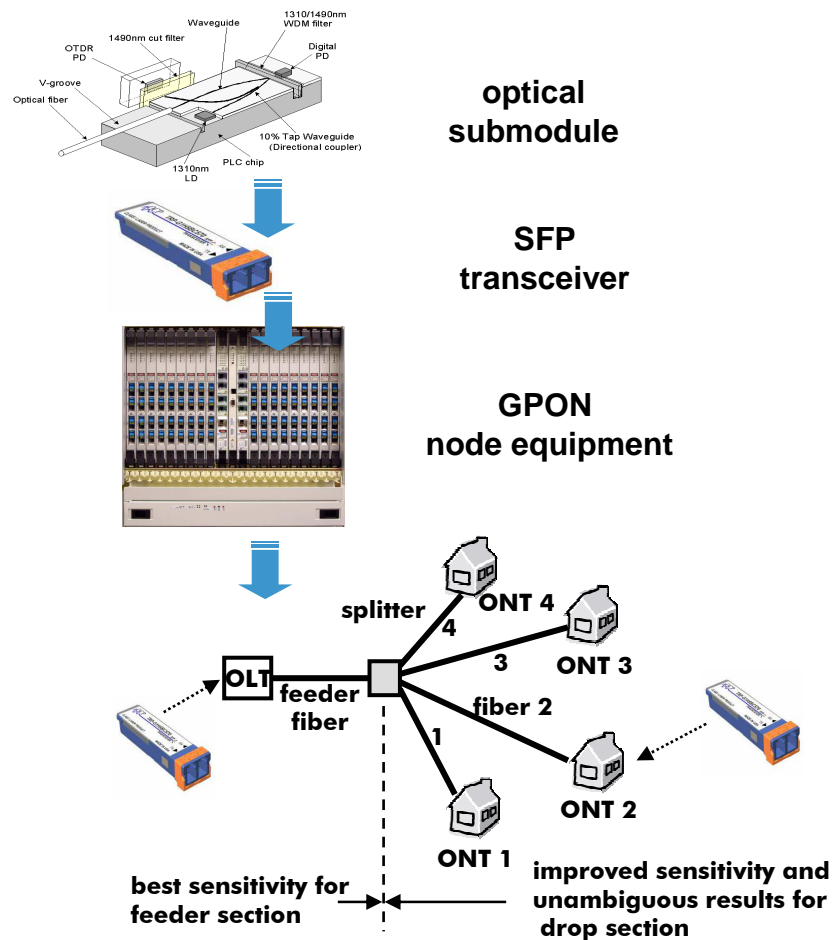
- Optical monitoring
- In-band OTDR

Operational Excellence:

...OTDR monitoring in PONs

Embedded in-band OTDR provides:

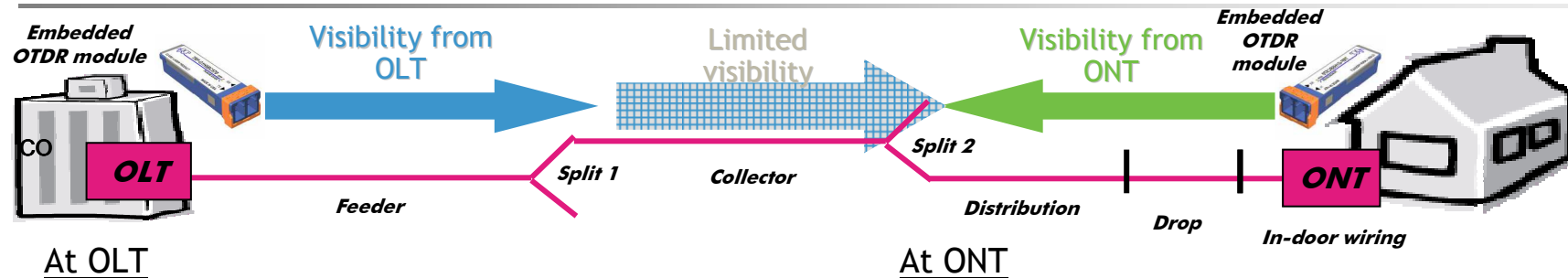
- continuous non-intrusive monitoring and fault localization
- measurements from both ONT and OLT side



Embedded OTDR provides continuous non-intrusive monitoring

Value Proposition

...Knowledge Provided by OTDR



- ONT responding or not (LOS)
- Transceiver Temperature
- Transceiver Voltage
- Laser Bias Current
- Transmit power
- Receive power (per ONT)

Existing info available

*Fiber Monitoring as per
G.984.2 Amendment 2 (draft)
...lots of good additional
information*

- Transceiver Temperature
- Transceiver Voltage
- Laser Bias Current
- Transmit power
- Receive power (difficult)

OTDR from OLT



Knowledge gained:

- Exact location of problem in feeder
- Lack of signal strength / resolution to see beyond 1:8 without affecting service.
 - Can go into intrusive testing mode

Incremental info from OTDR

OTDR from ONT



Knowledge gained:

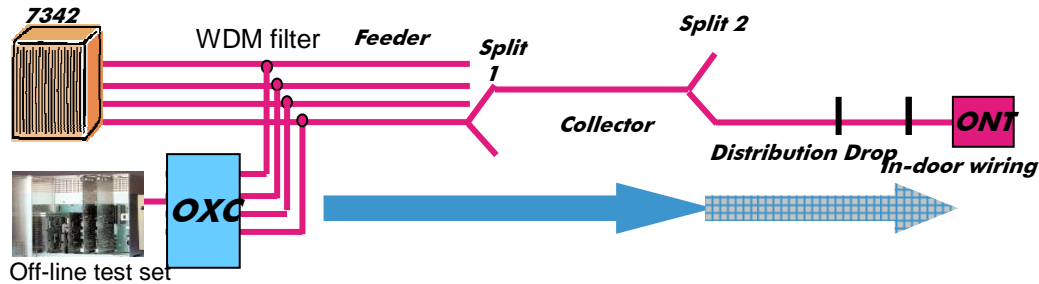
- Exact location of problem in distribution
- HOWEVER,
 - If fiber breakage then no information available to management system

Value Add: Operator will know exactly where problem is and can accelerate repair.

Value Proposition

...Embedded vs Off-line OTDR

Approach 1: Off-line Test with WDM combination



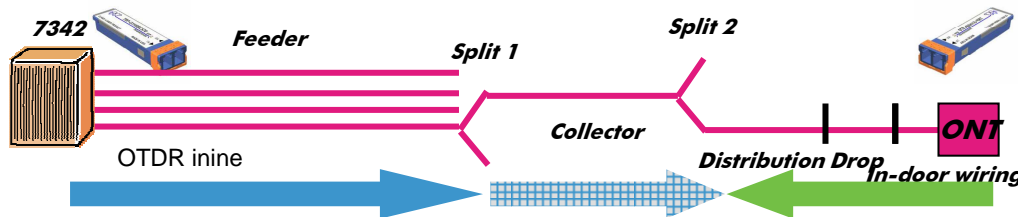
Pros

- No single point of failure
- Strong OTDR signal allows visibility to ONT

Cons

- WDM loss (0.5-1 dB)
- Cost of OXC and large OTDR
- Not well adapted to a future NGPON with WDM
- Non-continuous

Approach 2: Embedded OTDR approach



Pros

- No external equipment
- Continuous (but slow) monitoring
- Cost effective
- Is friendly to future NGPON that uses WDM
- Single-ended gives significant info

Cons

- Full single-ended test requires intrusive test
- Dual ended:
 - No info from ONT if fiber cut

Embedded approach appears to be clean, attractive approach.
Economic analysis still required.

In Conclusion

1. Increased Bandwidth

- Preferred solution is **10G PON with 2 λ Overlay**
 - 1540-1560nm is attractive upstream band but conflicts with RF video
 - 1260-1280nm may be most universal upstream band, esp. for 10G upstream
- **4 λ hybrid GPON** is a very cost effective upgrade from GPON to 10G
 - No truck roll to ONT
 - Issue is 8:1 asymmetry
- **Pure DWDM PON** is not economically viable for foreseeable future

2. Extended Reach

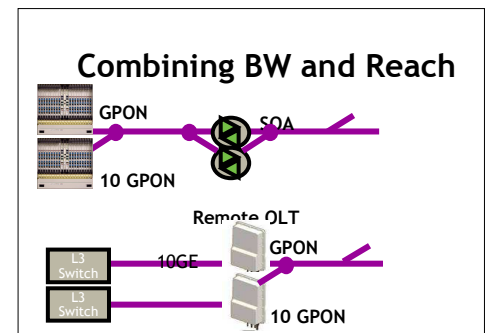
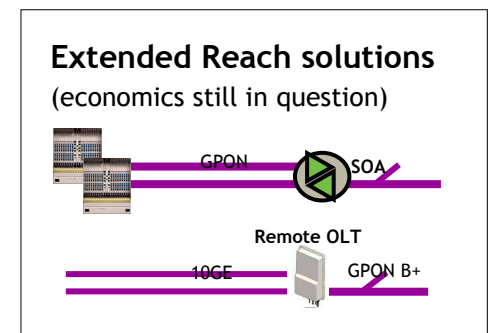
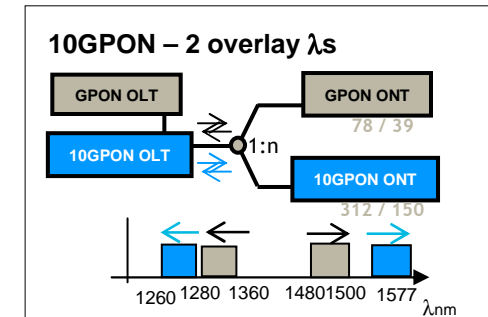
- **All-passive GPON C+** provides significant CO consolidation (preferred)
- **Optical Amplifier** shows promise for 60km but still has hi power and cost
- **Remote GPON OLT** is a very economical reference solution so far

3. Increased Bandwidth & Extended Reach

- **10G PON with 2 λ Overlay** can be combined with either an **SOA** approach or a **remote OLT** to provide both BW and reach

4. Operational Excellence

- **Embedded OTDR** is a technology that will cost-effectively provide continuous non-intrusive monitoring of the PON network



Thank you

ronald.heron@alcatel-lucent.com

