FTTH Look Ahead - Technologies & Architectures

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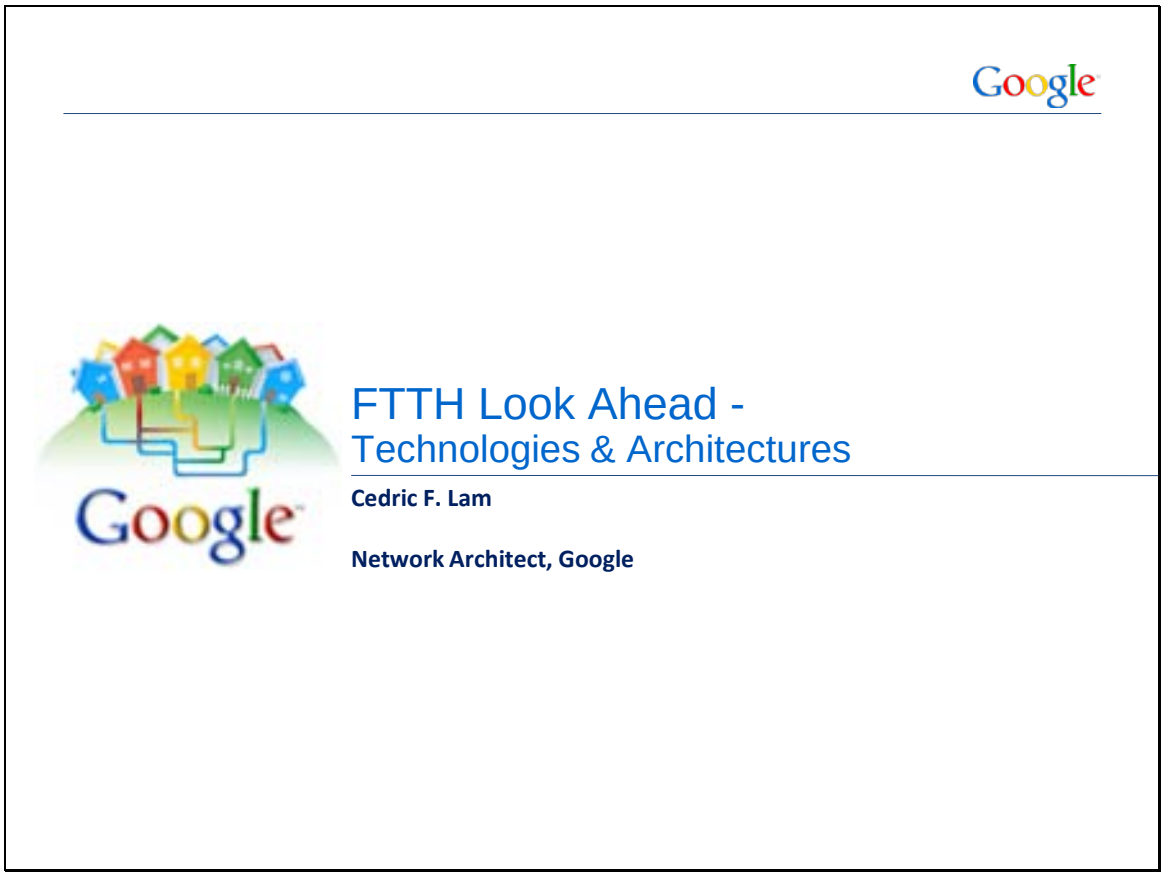
Abstract *We review the trade-offs, challenges and potentials of various FTTH architecture options.*



Google's Mission

To organise the world's information
and make it universally accessible and useful

Outline

- **Introduction**
  - Content-driven Internet Transformation
  - Google Fiber Project
- **FTTH Architectures & Challenges**
  - Technology options
  - Network design considerations and challenges
  - Next generation FTTH evolution
- **Applications**
- **Conclusion – call to action**

Introduction

Internet Becoming More Content-Centric

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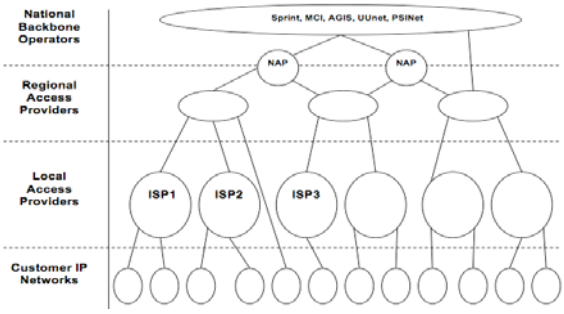
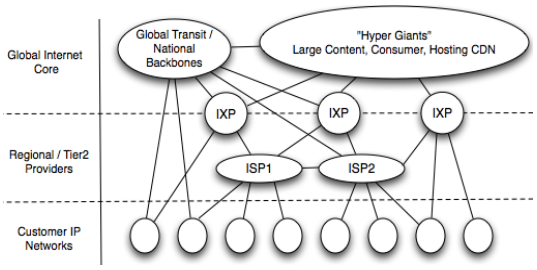
Textbook Internet 1995-2007



Internet Today



- **Tier-1 Global Core**
- **Commoditization of IP hosting/CDN**

Ref: C. Labovitz et al: ATLAS Internet Observatory 2009 Annual Report.
http://www.nanog.org/meetings/nanog47/presentations/Monday/Labovitz_ObserveReport_N47_Mon.pdf

The "ATLAS Top 10"

Google

Rank	Provider	Percentage
1	Level(3)	5.77
2	Global Crossing	4.55
3	ATT	3.35
4	Sprint	3.2
5	NTT	2.6
6	Cogent	2.77
7	Verizon	2.24
8	TeliaSonera	1.82
9	Savvis	1.35
10	AboveNet	1.23

(a) Top Ten 2007

Rank	Provider	Percentage
1	Level(3)	9.41
2	Global Crossing	5.7
3	Google	5.2
4		
5		
6	Comcast	3.12
7		
8		
9		
10		

Intentionally omitted

(b) Top Ten 2009

- **Transition from focus on connectivity to focus on content**
- **New technologies are reshaping definition of network**
  - Web applications, cloud computing, CDN

Ref: C. Labovitz et al: ATLAS Internet Observatory 2009 Annual Report.
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TVs Are Growing Bigger, Higher Definition and More Intelligent

Google

Analog

Digital - SD

HDTV

IPTV

4K

3D TV

Web, Gaming and Entertainment are Merging

More & More Computing Applications are Moving into the Cloud

Google bing amazon.com

Google Search I'm Feeling Lucky

Gmail by Google YouTube facebook twitter Y!

Google Docs orkut beta Picasa Blogger

Everything is accomplished in the network!

Broadband Infrastructure is Key to Economic Growth

- **Broadband enables people to work from everywhere**
  - Reduces traffic jam & greenhouse emission
  - Increases productivity because of closer collaboration
  - Google Instant: search while you type
- **Creates more opportunities through enhanced information flows**
- **2009 US Federal Government American Recovery and Reinvestment Act**
  - $7.2B Broadband Stimulu
  - http://broadbandusa.sc.egov.usda.gov/
- **Access infrastructure build out is extremely capital intensive**
  - Future-proof broadband access infrastructure ensures continual growth
  - Fiber is the ONLY future-proof broadband access medium

What is Google Fiber Project?

- **A real-life FTTH experiment**
  - Covering 50k to 500k households in select cities.
  - Provide 1Gb/s access speed to individual households through FTTH
- **Announced Community RFI in Feb 2010**
  - More than 1000 municipalities and more than 100k individuals responded to the online RFI

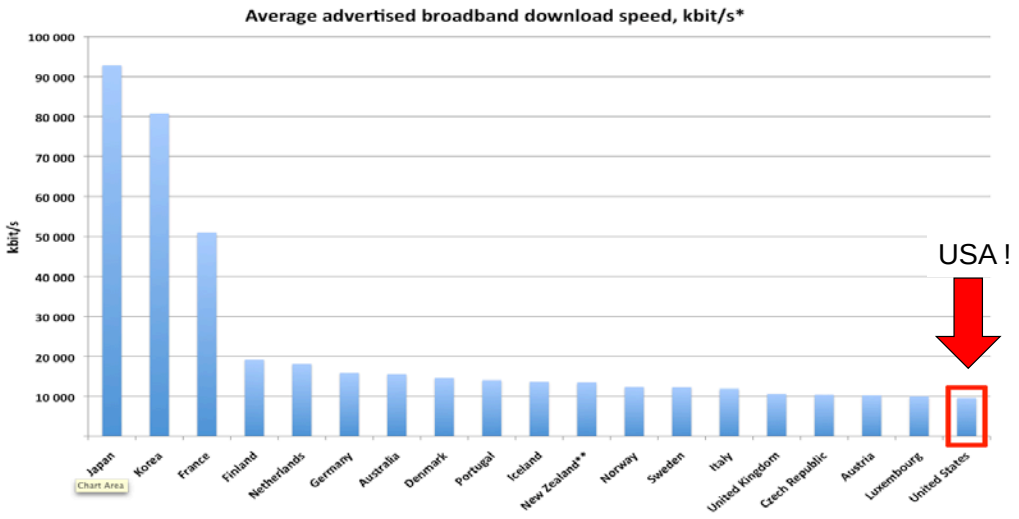
Map of cities responded to Google Fiber RFI

Each large dot represents locations where more than 1,000 residents submitted a nomination.

http://www.google.com/appserve/fiberrfi/

Why are we doing this?

- **The US is falling behind in broadband access deployment in OECD nations.**
- **To understand next generation broadband access network applications and technologies.**



What are we doing?

- **Experimenting different technologies for broadband access network deployments.**
  - From trenching and construction to different optoelectronics technologies and network architectures.
- **To encourage and stimulate innovations in broadband access network technologies and applications**

FTTH Architectures and Challenges

Passive FTTH Network Architecture Options

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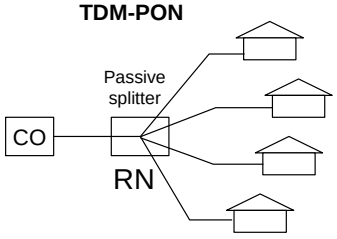
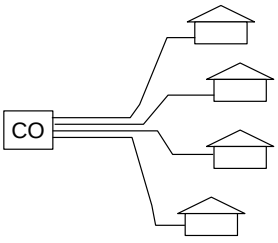
TDM-PON



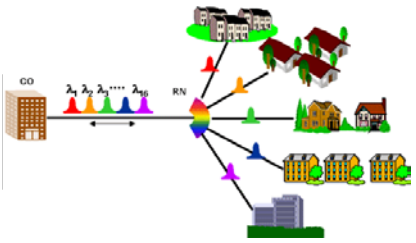
Passive power-splitting from CO to end users (PON)

- Fiber consolidation, saving in CO space and termination.
- Shared bandwidth among users, difficult to scale bandwidth and reach
- Difficult to upgrade users (shared transceiver)



Home-run from CO to end users

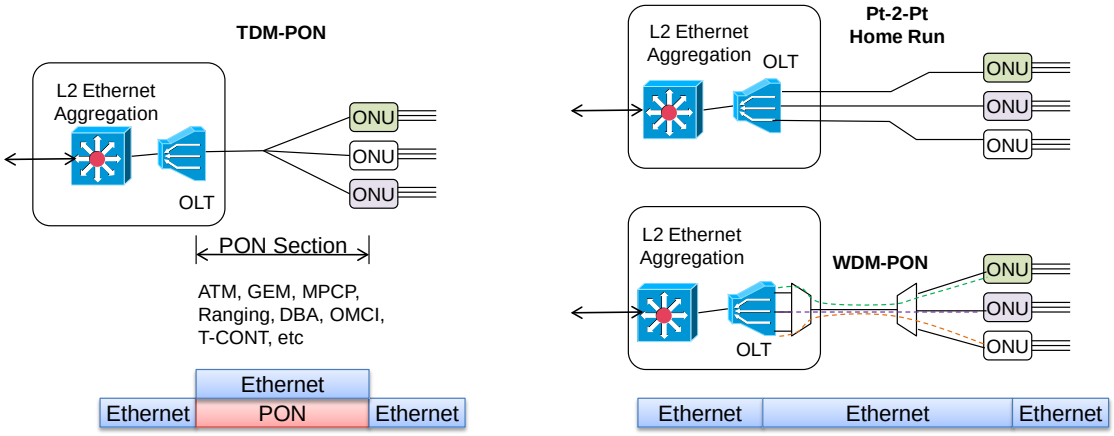
- Ultimate future-proof, privacy, and bandwidth to end users.
- Easy to scale distance
- Lots of fibers and TRX at CO to terminate users, space & power density issue.
- Fiber cut difficult to repair (poor MTTR)



WDM-PON

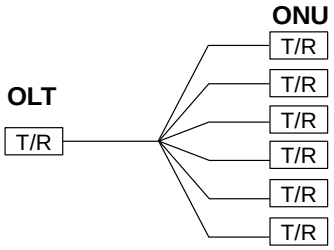
- Fiber consolidation, saving in CO termination.
- Future-proof with virtual fiber from CO to end users.
- Immature technology and poor equipment density. Lots of potential for development

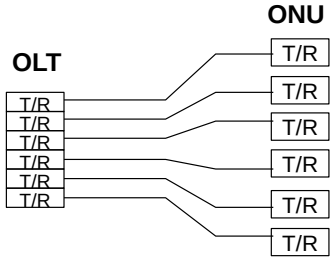
Protocol Perspective



- **Pt-2-Pt and WDM-PON provides simple end-to-end Ethernet transparency.**
  - No need to learn and handle complicated PON-Ethernet mapping and PON management functions.
  - Easy to understand and provision

TDM PON vs. Pt-2-Pt Home Run





- N+1 optical transceivers
- To achieve symmetric Gigabit transmission performance between ONUs and OLTs, both OLT and ONU need to run at **substantially** higher speed than 1Gb/s.

- 2N optical transceivers
- For pt-2-pt home run, **all transceivers are 1Gb/s**

Performance vs. Cost

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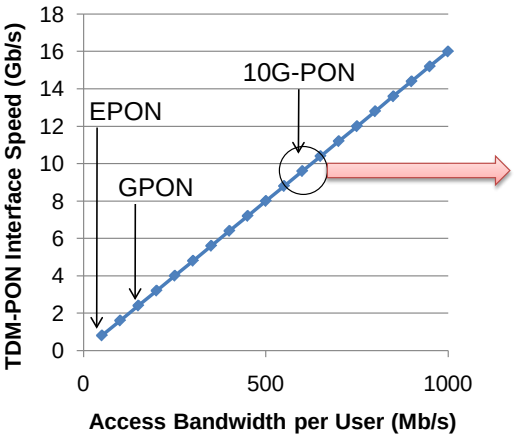
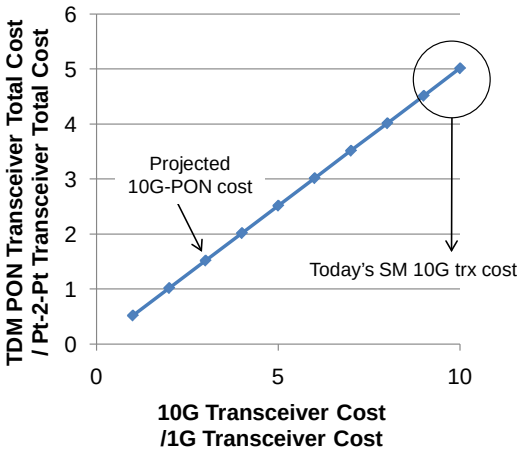
TDM PON interface speed vs. avg. per user access bandwidth



Total optical transceiver cost for symmetric10G-PON & pt-2-pt homerun



- FTTH active equipment cost is dominated by optical transceiver costs.
- Assume 1:32 splitting ratio for TMD-PON and 50% usage
- Streaming applications require large constant bandwidth with long holding time. Limited statistical multiplexing is achievable.

Scaling Issues of TDM-PON

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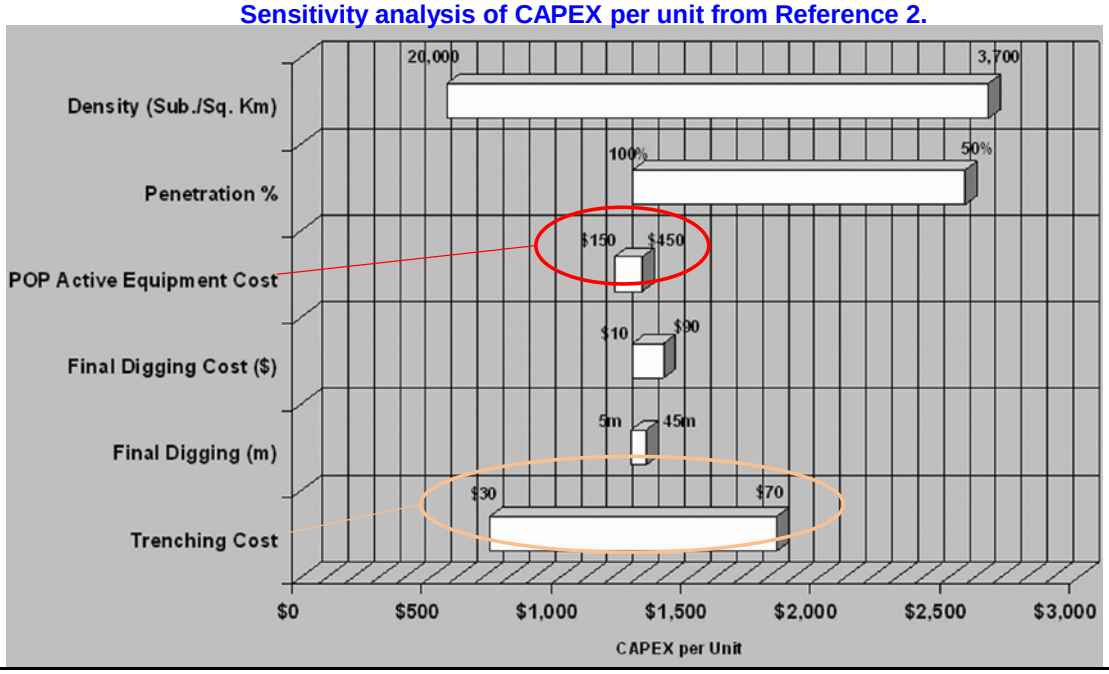
- **Rx sensitivity decreases with PON BW**
  - APD and power control are already used in 10G PONs.
  - High-speed FEC is unavoidable ⇒ Latency
  - High-speed RF electronics increases complexity, power and costs.
  - Can trade off with splitting ratio, then becoming more and more like pt-2-pt home run
- **Dispersion is no longer negligible at higher line rate**
  - EDC, DFB/EMLs are needed at ONUs
- **Other remedies**
  - Use optical amplifier to improve sensitivity (this techniques has deferred R&D of coherent receivers in long-haul optical networks for almost 2 decades)
  - Is it worth the complexity to go to coherent transceiver techniques including optical OFDM in optical access networks?

Trenching Dominates CAPEX in FTTH Deployment

- **Trenching consists of 70-80% of the total cost for infrastructure build**

Sensitivity analysis of CAPEX per unit from Reference 2.



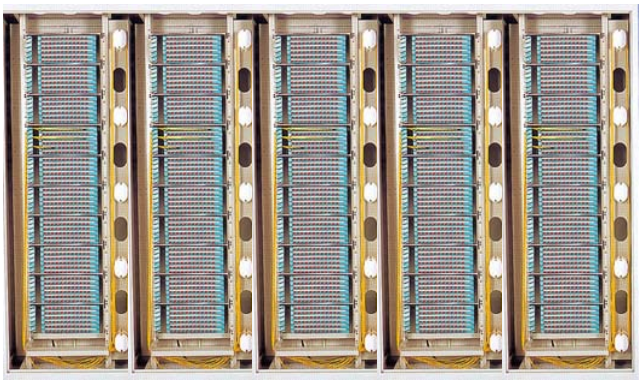
Green Field vs. Brown Field – life is not so simple

- **Green Field**
  - After trenching, cost difference of putting in 1 fiber vs. 100 fibers is small, might as well use pt-2-pt architecture to future proof the new infrastructure which already costs billions to construct.
  - It is better to invest on new trench techniques to reduce the major cost component in deployments.
- **Brown Field**
  - Maximize current conduit usage and minimize new trenching
  - Current TDM-PONs help to reduce conduit space requirements and minimize upfront CAPEX
  - Investigate new techniques to maximize current infrastructure capability.

Operational Challenges for Pt-2-Pt Home Run

Google

- **Typical CO serves 10k – 30k users**
  - Terminating 10k-30k fibers is a challenge
  - Largest fiber cable available in NA has only 864 cores.
  - State-of-the-art fiber patch panel can terminate ~6300 fibers with LC connectors on a standard 7-foot telecom Rack
  - 30k users require 35 cables & 5 racks
  - Lots of real estates



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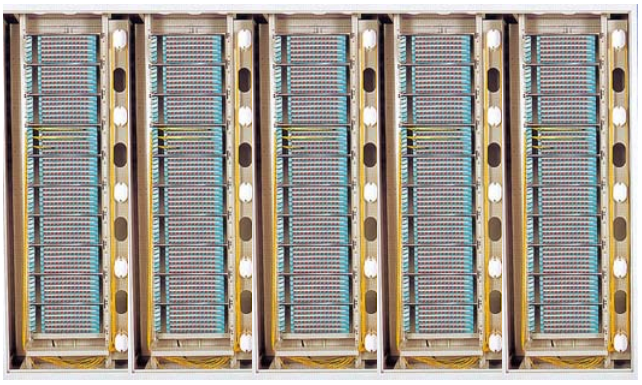
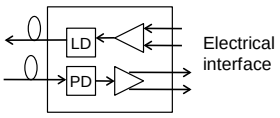


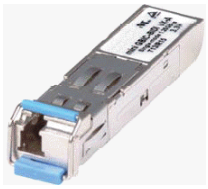
High Density Optical Transceiver Modules

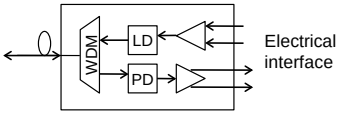
SFP
• 1Gbps
• 2 fibers tx/rx



SFP

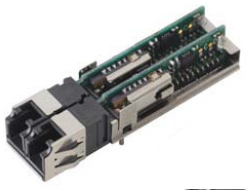
SFP - BiDi
• 1Gbps
• 1 fiber tx/rx

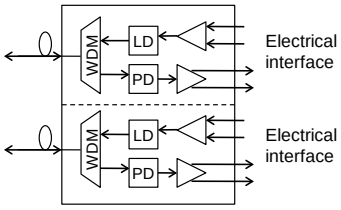




SFP-BiDi

CSFP - BiDi
• 2 Gbps
• 1 fiber tx/rx



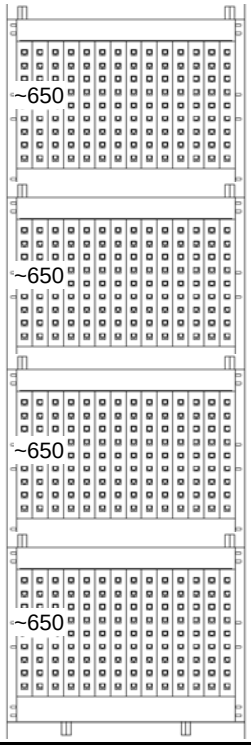


CSFP-BiDi

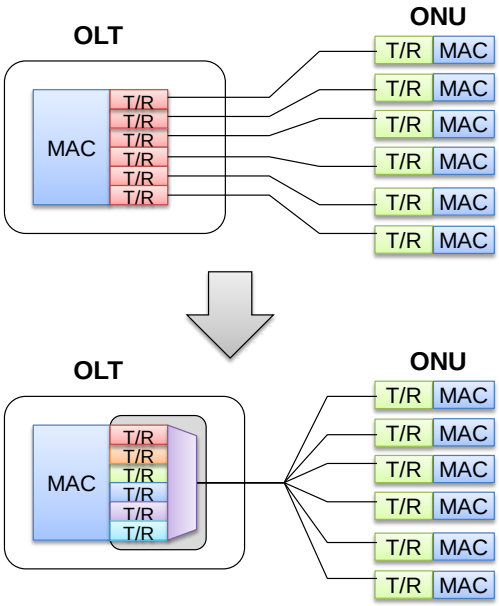
~1 Watt per GbE transceiver (10km, single mode)

Space & Power Density of Home-Run OLT

- **State-of-the art commercial equipment supports ~650 single GE connections per 10 RU**
- **~2600 connections per 7-ft rack from simple space requirement perspective**
- **Practical limit of air condition can dissipate 2000-3000 watt/sq-m**
- **NEBS (GR-63-Core) recommends heat dissipation of 1810 watt/sq-m.**
- **Power per GbE port ~2.5W (including electronics)**
  - Limits to about 1200 terminations per rack

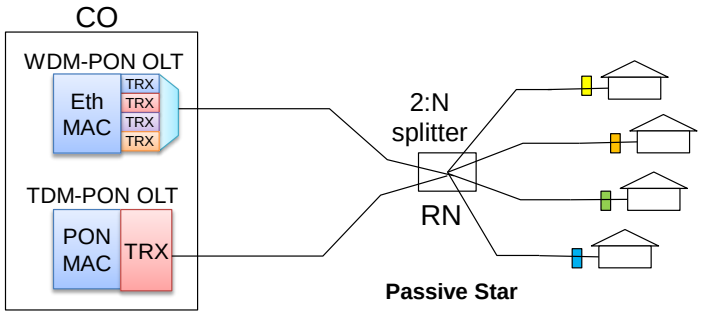


Technology Migration to WDM-PON



- **WDM-PON shares the benefits of fiber consolidation of TDM-PON and bandwidth scalability of pt-2-pt home-run architecture**
- **Reuse most of the electronic designs in pt-2-pt OLT**
- **Only replace the PHY layer with integrated WDM transceiver arrays at the CO**

TDM-PON to WDM-PON Migration



- **Broadcast & Select Architecture**
- **TDM-PON filters pre-installed at TDM-PON receivers to block unwanted wavelengths**
- **WDM-PON receivers use tunable filters to select desirable wavelengths**
- **Minimum additional ODN infrastructure cost disturbance to existing TDM-PON users. WDM filter loss may be overcome with low-cost optical amplifiers**

Enabling Technologies for WDM-PON

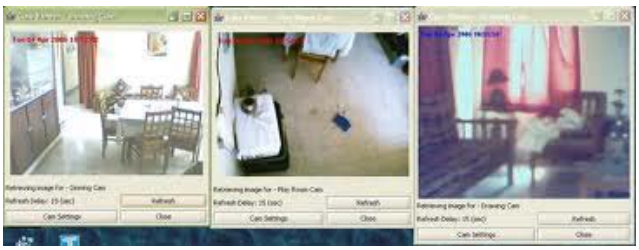
- **Photonic integrated circuits**
  - Multi-wavelength laser arrays + PLC WDM MUX-DMUX
  - Provide space and power density advantage
- **Colorless ONU**
  - Low cost tunable laser diodes (sub $100 price)
  - Low cost tunable filters (for broadcast-n-select architecture)
  - Low cost integrated amplification technologies
- **Athermal active and passive optical components**
  - Temperature control consumes vast amount of power

Potential Applications with 1 Gb/s

Smart Home

Remotely control & access every piece
of home equipment from anywhere in the world at any time.

24x7 Home Surveillance from Anywhere



Make use of upstream bandwidth!

Telepresence – Work from Home

Conclusion

Conclusions – Call to Action

- **1Gb/s symmetric access bandwidth to customers is not unimaginable.**
- **TDM-PON will soon run out of juices for scaling beyond 1Gb/s**
- **Pt-2-Pt home-run fibers offer the ultimate scalability, security and access bandwidth, but is very capital intensive.**
- **WDM-PON has the benefits of both TDM-PON and pt-2-pt home-run systems.**
  - Low-cost, low-power and large-scale integrated WDM technologies are important to realize next generation WDM-PONs.
  - Low-cost, high-volume tunable lasers and receivers will facilitate smooth transition from TDM-PON to WDM-PONs.

References

1. C.F. Lam, Passive Optical Networks – Principles and Practice, Academic Press, 2007
2. S. Azodolmolky & I. Tomkos, "A Techno-economic study for active Ethernet FTTH deployments," Journal of Telecommunications Management, Vol. 1, 3, pp291-310, 2008
3. C-Y Lee, G. Keiser & S-L Lee, "A Comprehensive Methodology for Comparing Different FTTP Solutions," paper NThD3, OFC/NFOEC 2008