Opportunities and Challenges When Designing the Next Generation FTTH Architectures

Michel Vernimmen
SR. Field Application Engineer
CommScope CFHP MEA

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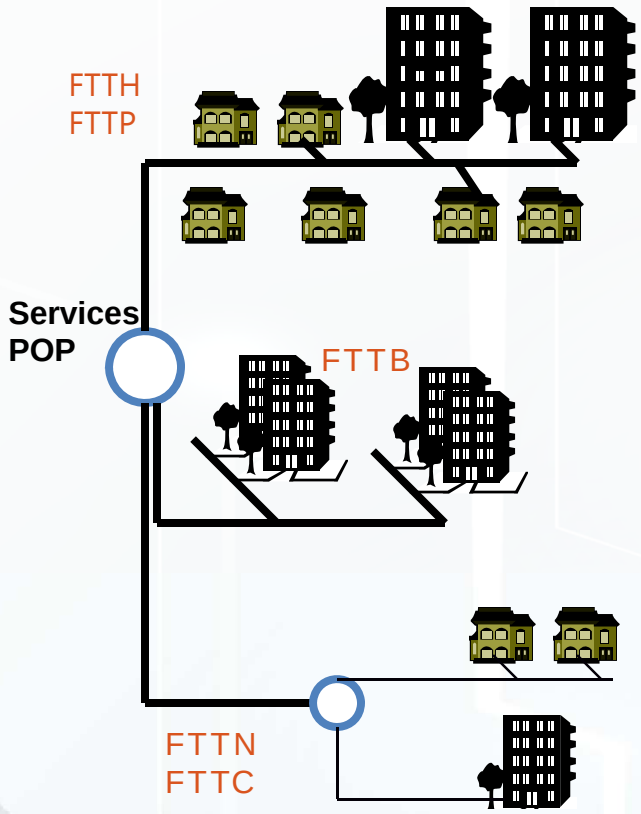
FTTH Definitions

What is FTTx ?



Fiber all the way to the premise or home

- Single family units (SFU and multi-dwelling units (MDU)
- Homes passed & homes connected
- Standard wiring within the living unit beyond the NT

Most deployment statistics do not differentiate !!!

Fiber up to the building

- Common practice in Asia for brownfield
- Reducing cost & avoiding permits and disturbances
- Copper wiring within the building beyond the O/E equipment

Shorter legacy wiring allowing higher bandwidth !!!

Fiber up to a network node or cabinet

- Common practice for most incumbents
- Reducing cost (2/3) & avoiding permits and disturbances
- Legacy wiring behond the node

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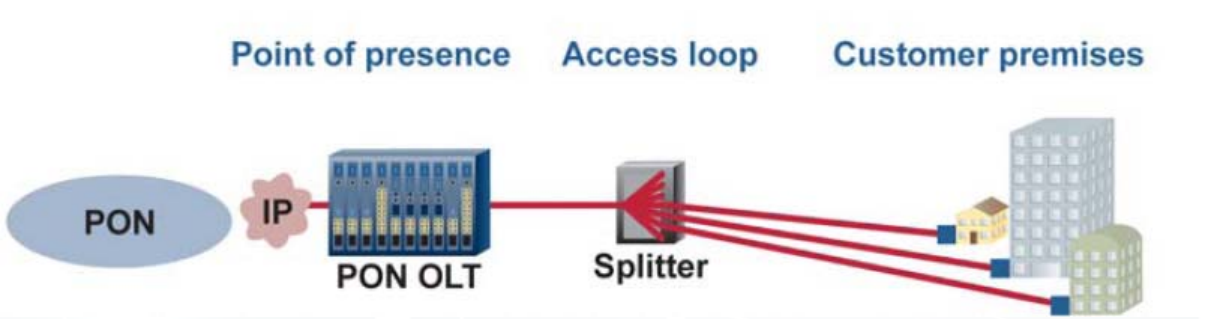
FTTH Definitions



- HP: homes passed is amount of customers that could take service
- HC: homes connected is amount of customers that do take service (pay)
- TR % = HC/HP
- Utilization rate (on OLT ports and splitter ports) = amount of active customers per OLT port
    - Strong point of optimization during most deployments

Why FTTx? Why Now?

Telco's are suffering with aging copper cable plants and are losing broadband customers to CATV and landline customers to cell phones and VoIP

New services are becoming available to enhance revenue - and customers demands

Regulations: Utilities CLEC's ISP's

New technology (xPON) and cheaper components makes FTTx cheaper

Why should we deploy FTTH ?

The reason is simple.

- Copper, coax, Wi-Fi and WiMAX can not carry the capacity
- Customers are demanding more and more bandwidth to meet their needs
- The increasing bandwidth-hungry services 3D TV, IPTV, HDTV, video on demand, interactive online games, home offices are pushing facilities to their limits and, in some cases, beyond
- Fiber is the future of communications technology
- Eliminates the potential bottleneck represented by copper or coax in the last mile
- This has made FTTH the leading choice of service providers

Why should we deploy FTTH ?

- **This shouldn’t come as a surprise**
  - Demand for Internet bandwidth alone is doubling every year
  - Telco's have implemented "high-speed" protocols like xDSL, but these have been stopgap measures at best
  - FTTH permanently eliminates the slowdown
  - It doesn't take too many users streaming music, playing games, or downloading video to overwhelm the copper network

Why should we deploy FTTH ?

If you think cable is a "high-speed" medium, consider this

A small movie download is about five gigabytes of data. Some can be larger than 100 gigabytes. Over cable, a five GB download would take about hours

FTTH reduces that download time significantly

		DOWNLOAD SPEEDS							
		Broadband					Fiber		
TIME/TYPE	SIZE	1M	5M	10M	20M	40M	100M	250M	1G
4-min Song	4MB	30s	5s	3s	1.5s	0.75s	0.3s	0.12s	0.03s
5-min Video	30MB	3m	40s	26s	13s	6.5s	2.5s	1s	0.2s
9-hr Audiobook	110MB	10m	2m	1.5m	46s	23s	9.2s	3.68s	0.9s
45-min TV Show	200MB	20m	5m	3m	1.5m	0.75m	16s	6.4s	1.7s
45-min HDTV Show	600MB	1h	15m	8.5m	4m	2m	50s	20s	5s
2-hr Movie	≤ 1.5GB	2h	24m	21.5m	10.5m	5.25m	1.5m	0.6m	8s
2-hr HD Movie	≤ 4.5GB	6h	72m	60m	32m	16m	4.5m	1.8m	25s
Misc. Archive	10 GB	No Way	Nope	Too Long	Slow	Little Better	Better	Much Better	1m 20s

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Why should we deploy FTTH ?

What does it enable for me ?

- Customers want to see, hear, and read whatever they want **whenever** they want it, virtually **without limit**

- Today, that **expectation is becoming universal**. We want to watch movies when the mood strikes us. We want to make videos and upload them to the world and place phone calls over the Internet. We want to play games with hundreds or thousands of other players interacting in real time

- We want to be able to work at home with the same capabilities we have in the office, including face-to-face contact. We want to be able to bank, shop, even see the doctor, all without leaving the house. And when we're away from home, we want to be able to manage and monitor the security systems and appliances we've left behind

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Why should we deploy FTTH ?

FTTH is the only technology that will meet the needs of the future

- Technology that will deliver bandwidth hungry applications
- Products/services that have yet to be conceived
- What will the future bring ?
- Make sure your network can deliver !!!

We are moving toward a converged world.

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More subscribers and devices to connect, as fiber expands into the access to supply more bandwidth.

WIRELINE BROADBAND

500
service providers
plan to launch FTTH services in North America by 2020 [1]

30M
new subscribers
to be connected by broadband in Asia-Pacific 2016-17 [2]

WIRELESS BROADBAND

150M
5G subscribers
by 2021 [3]

2.5M
LTE small cells
to be deployed from 2016 to 2020 [4]

The demand for fiber connectivity is **unprecedented**

MORE BANDWIDTH

8X
mobile data traffic growth
from 2015 to 2020 [5]

330M
4K UHD TVs
sold by 2019 [6]

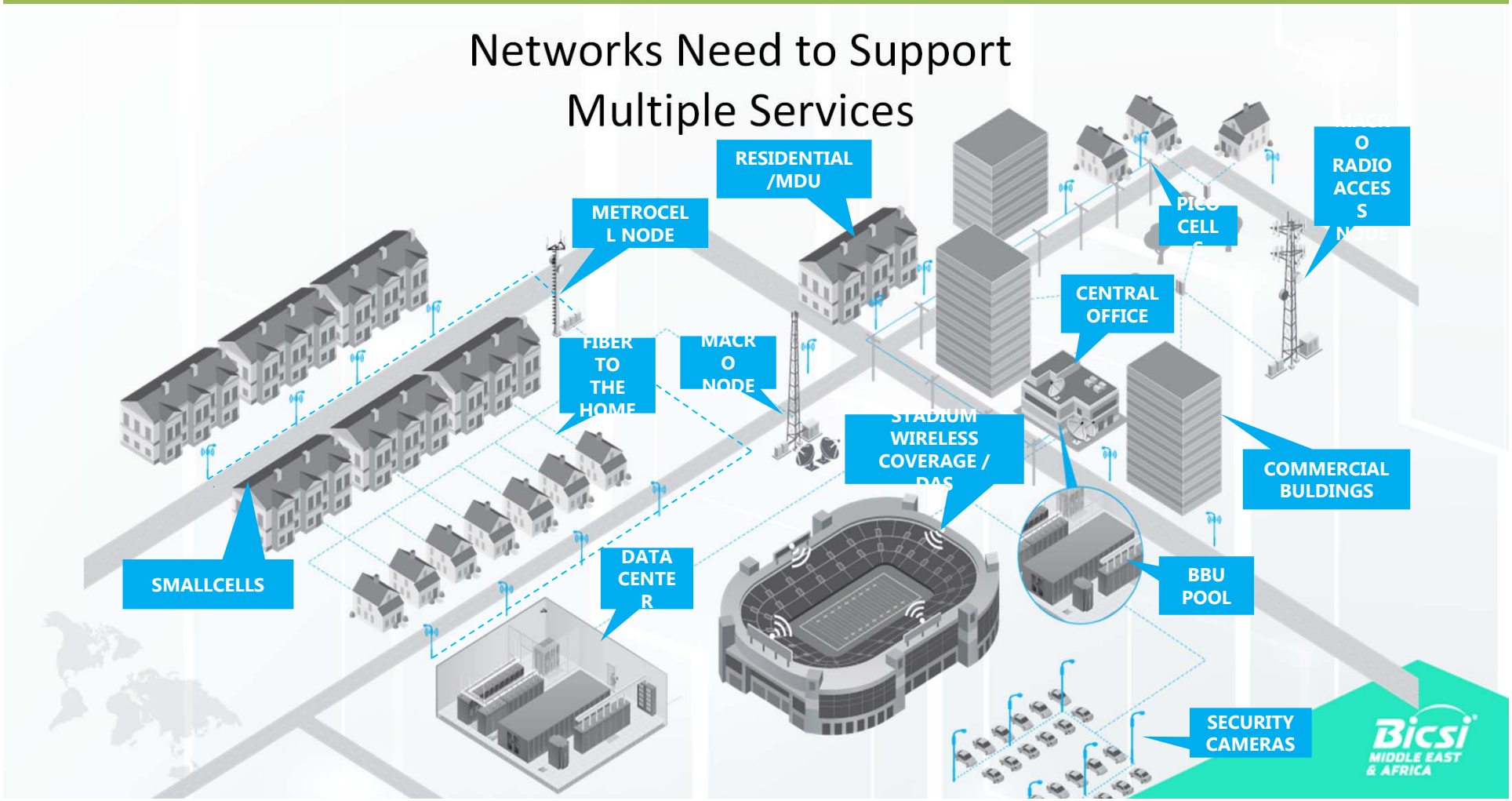
INTERNET OF THINGS

3.1B
M2M connections
by 2020 [5]

601M
Connected wearables
by 2020 [5]

1. FTTH Council Americas 2. FTTH Council APAC/Ovum 3. Ericsson Mobility Report 2/16 4. ABI Research 5. Cisco VNI Mobile, 2016 6. Parks Associates: Connected CE 10/15

Networks Need to Support Multiple Services



Evolution to Converged Networks

Monetizing spare capacity in the fiber network with additional services helps build a stronger business case for expansion.

Most FTTX networks today are using just two or three wavelengths – one for GPON downstream, one for GPON upstream, and one for RF video.

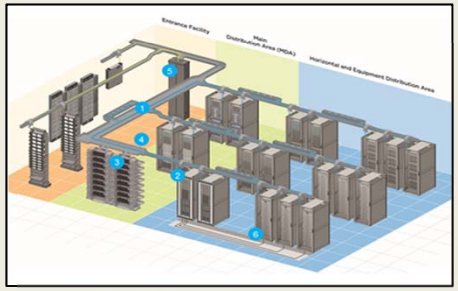
The vast spectrum of C/DWDM wavelengths remain unused, and hence offers a path for growth and evolution.

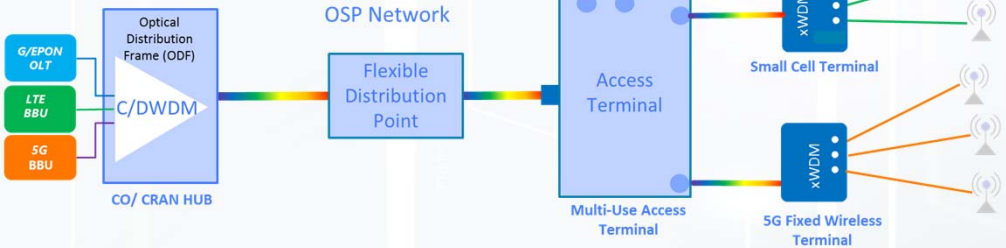
FTTX networks have an extensive footprint that is perfect for fast-growing mobile applications such as DAS/small cell/Wi-Fi backhaul and C-RAN fronthaul. These new services can be marketed as 'virtual dark fiber' or wavelength services, and would be far less costly yet faster to deploy than laying P2P dark fiber.

Network convergence will impact the passive layer

The legacy networks and players define the migration path & architecture

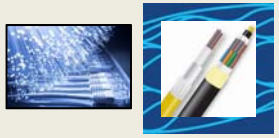
- Increase WDM devices
- Increase fiber density
- C-RAN BBU pools
- Datacenter structure
- NFV, SDN & MEC





Edge type	Volume	#Fibers
* Residential homes	70K	1
* 5G Fixed Wireless	2K	5
Macro cell sites	100's	24
Small cell sites	1000's	6
PtP Business sites	300	2
IOT nodes	* PON? based - complementary	1

- Increase cable density
- Multi-Use FDH



- Edge densification
- Edge Powering

- Multi – use Terminals
- Increase passive devices

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Smart connectivity between people and intelligent devices enabling a new Lifestyle and sustainable Economy growth

Artificial intelligence
Mechatronics
Nano technology
3D printing
°
°
°
Plasmonics
Renewable energy & storage

1991: Web version 1

2004: Web version 2

Web version 3

Transportation
Security & surveillance
Healthcare
Retail & industrial asset management
Education
°
°
°
Leisure
Financial & insurance services
Agriculture

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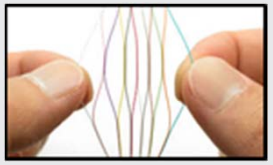
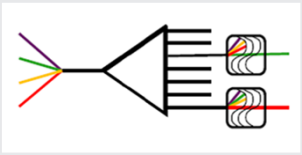
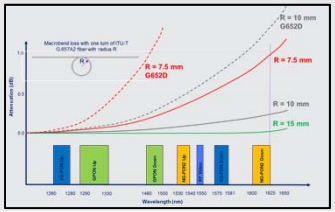
Physical layer varies but includes common characteristics, required to explore the full potential and have sustainability

FAST	DENSITY	SECURE	FUTURE READY	FLEXIBLE
FTTP = 20x more labour as core	Influence on civils; up to Δ of **50%** of cost	**1%** failure/yr = **10%** of Capex in Opex/yr	All Wavelengths up to **1650nm**	Avg **10+** nodes interventions/edge
LARGE DATA RULE   **CONNECTION 20 or 5 MIN**	 **NEW TECHNIQUES FOOTPRINT ↘ 30%**  	 **AUDITS: up to 10% FAILURES**	 **NG-PON** 	 **PASSIVES LIFETIME 25 YRS+**
Pre-terminated	Compact design	Ease of use	Performant	Modular

The journey towards higher revenues and lower costs

2018
1st ROLL-OUTS

Convergence of Network Infrastructure e

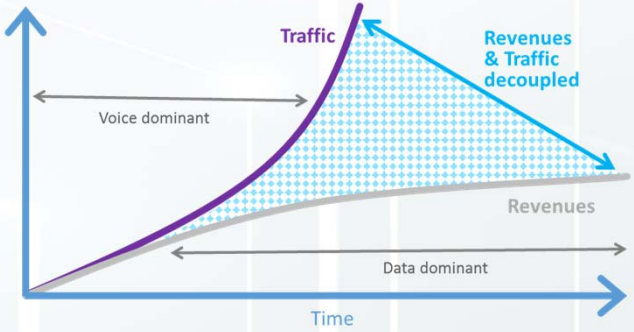
2022 ?

Convergence of Platforms e

2025 ?

Full Convergence
Hardware , Software and Physical Networks e

1. Labour to Material transfer lowering installed cost CO/ODN
2. One instead of multiple ODN reducing civils cost & OPEX
3. NFV and SDN optimizing use and lowering cost of hardware
4. New value add services and dark fibre/wavelengths revenue



Convergence results in:

Push down cost

Lift up revenue

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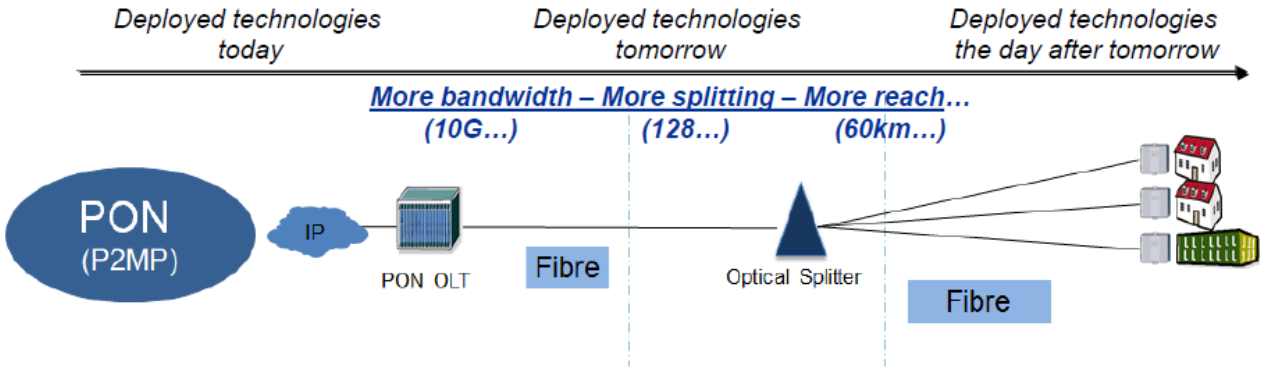
PON Evolution

PON Evolution to NG-PON2



Class B optics

1:64 Split ratio
20km reach

Class C Optics

1:128 Split ratio
60km reach

NG-PON1 technologies
XG-PON1 : 10Gb/s DS – 2.5Gb/s US
XG-PON2 : 10Gb/s DS - 10Gb/s US

The evolutionary approach of NG-PON1
Reuse Optical Distribution Network
Coexistence of G.PON/NG-PON customers

NG-PON2 technologies

"the revolutionary approach"

Some operators are using XGPON1 to provide services to businesses while sharing fiber

XGS-PON is also an intermediate stop being considered

Some big operators are intentionally skipping XGPON1 and XGS-PON and go directly to NGPON2

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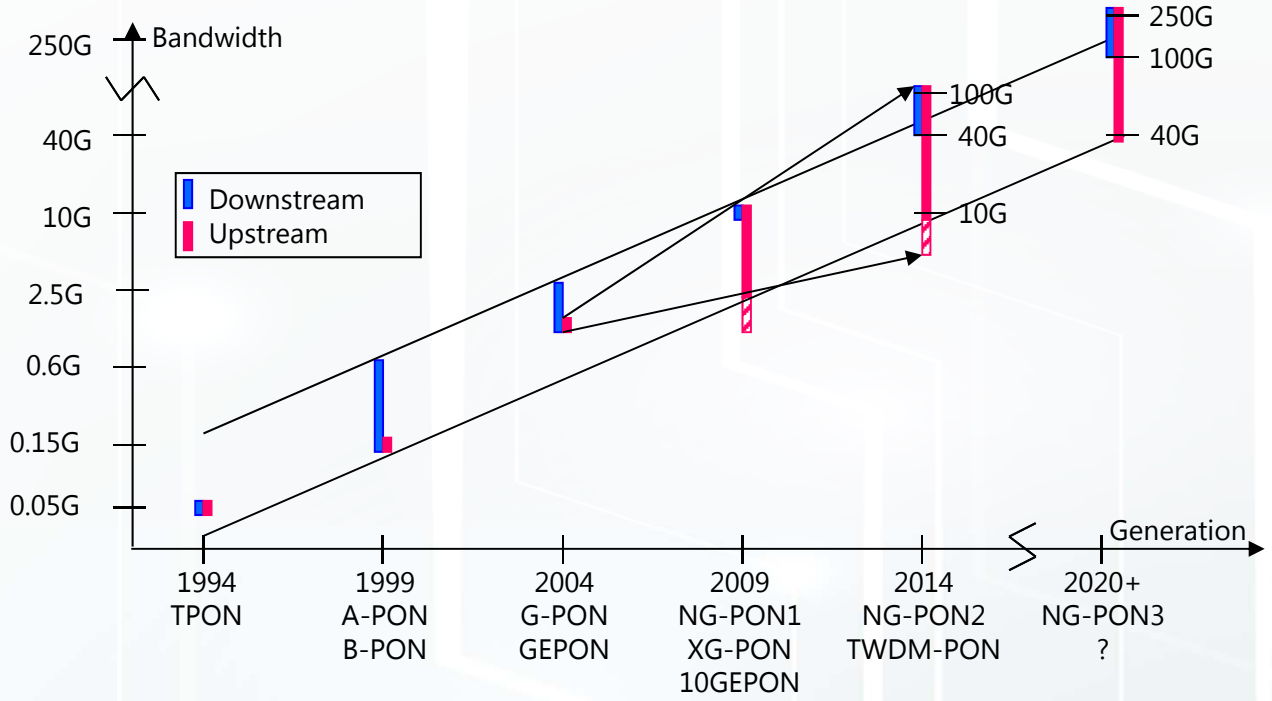
PON Evolution

- G-PON (Gigabit-capable PON)
- NG-PON1 = XG-PON (10Gbit-capablePON)
- NG-PON2 = TWDM-PON (40Gbit-capable PON)

Capacity Development for PON



G-PON

- G-PON: Gigabit-capable passive optical networks
- System defined in the Recommendation ITU-T G.984 series
  - Recommendation ITU-T G.984.1: System requirements
  - Recommendation ITU-T G.984.2: PMD specifications
  - Recommendation ITU-T G.984.3: TC specifications
  - Recommendation ITU-T G.984.4: OMCI - Subsumed by Recommendation ITU-T G.988
    - Now used for all ITU PONs and P2P systems
  - Recommendation ITU-T G.984.5: WDM matters for the future
  - Recommendation ITU-T G.984.6: Reach extension
  - Recommendation ITU-T G.984.7: Long reach
  - Plus supplements…
- Standards considered stable and mature
- Minor optional enhancements continue even now

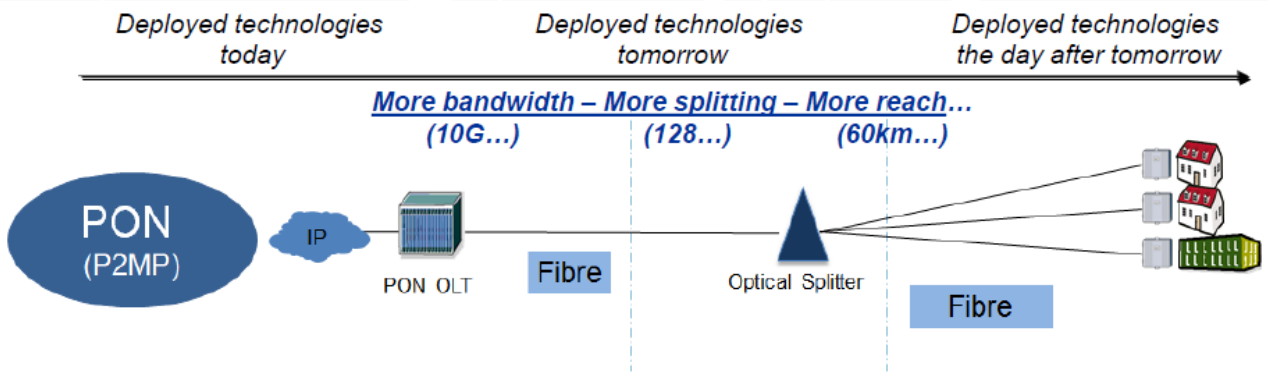
XG-PON

- XG-PON: 10-Gigabit-capable passive optical networks
- System defined in the Recommendation ITU-T G.987 series
  - Recommendation ITU-T G.987: Definitions, abbreviations and acronyms
  - Recommendation ITU-T G.987.1: General requirements
  - Recommendation ITU-T G.987.2: Physical media dependent (PMD) layer specification
  - Recommendation ITU-T G.987.3: Transmission convergence (TC) layer specification
  - Recommendation ITU-T G.987.4: Reach extension

NG-PON2

- NG-PON2: 40-Gigabit-capable passive optical networks
- System defined in the Recommendation ITU-T G.989 series
  - Recommendation ITU-T G.989 : Definitions and conventions
  - Recommendation ITU-T G.989.1: General requirements
  - Recommendation ITU-T G.989.2: Physical media dependent (PMD) layer specification
  - Recommendation ITU-T G.989.3: Transmission convergence (TC) layer specification (draft in progress)
    - Based on G.987.3, with wavelength control and 10G upstream added
  - Recommendation ITU-T G.9802 (ex. G.multi) = Wavelength control layer (consented in December 2014)
    - Meant as a general framework for TWDM-systems, of which G.989 is one
  - Recommendation ITU-T G.984.5 = Wavelength coexistence
  - Recommendation ITU-T G.988 = ONU management and control interface
    - Standard in force, can be easily reused for TWDM

PON Evolution to NG-PON2



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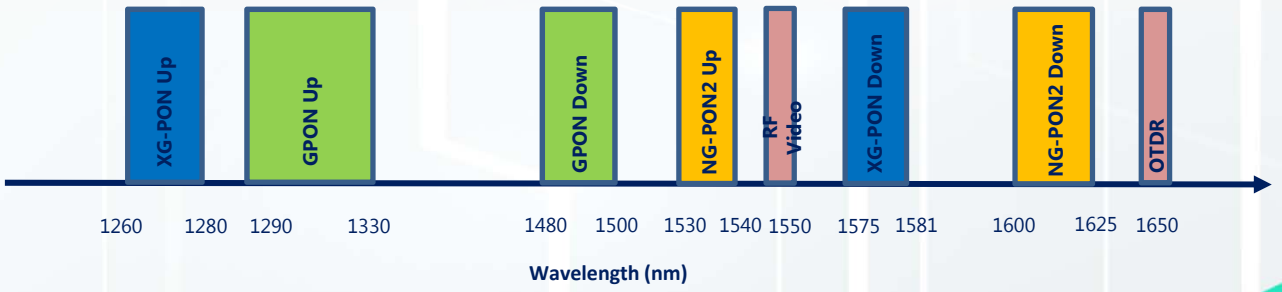
NG-PON2 technologies

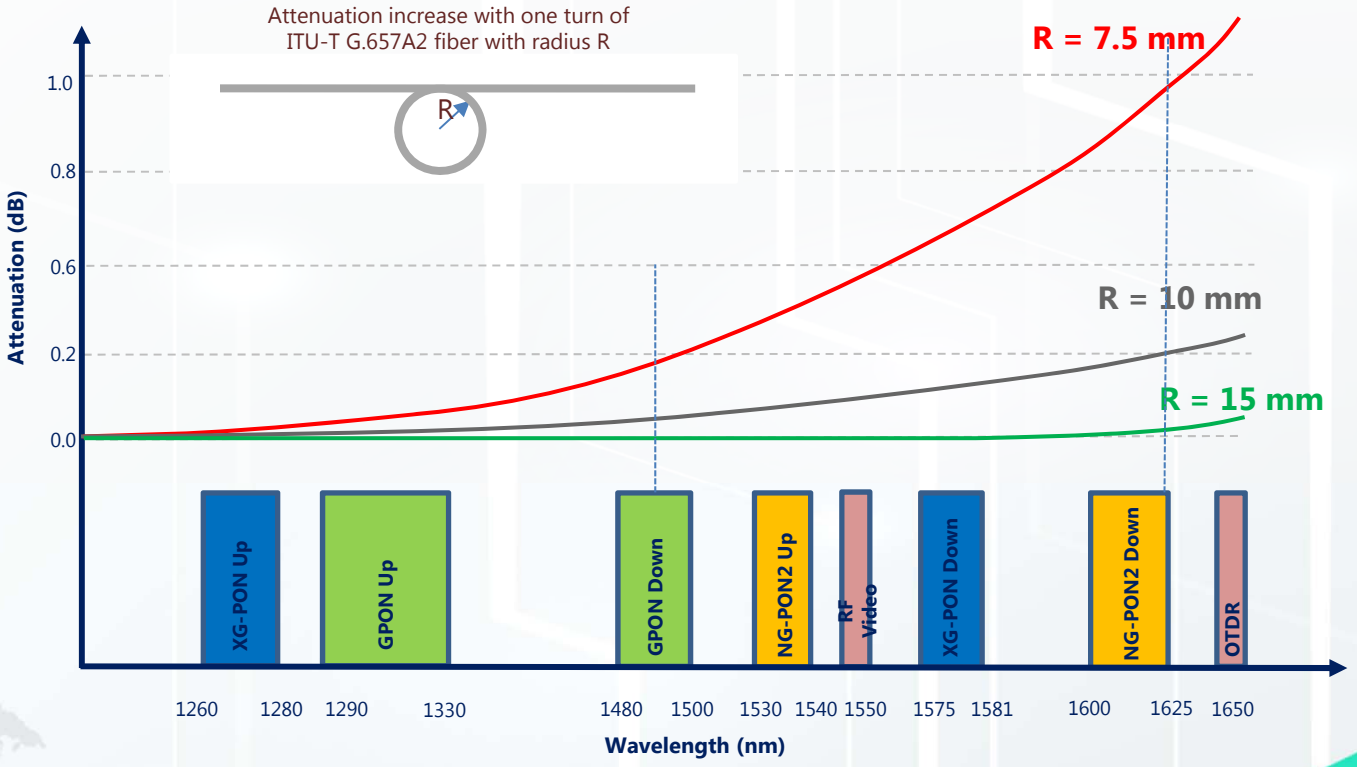
"the revolutionary approach"

Wavelength bands in PON

- GPON 2.5 Gb/s down, 1.2 Gb/s up, shared
- RF Video overlay
- XG-PON1 10 Gb/s down, 2.5 Gb/s up, shared
- XG-PON2 10 Gb/s up and down, shared
- NG-PON2 10 Gb/s per wavelength (4 wavelengths downstream, 8 wavelengths upstream)
- Network monitoring



Macro-bending loss in fibers



Mission Critical: Cable Management – Physical Protection

PON Technology evolution in Service Providers – Operators

- The **first big FTTH deployments in the USA** in 2005-2007 were made upon **BPON** technology, offering from 10 to 100 Mbps per user typically
- Then the **big roll-outs around 2010-2012 mainly in Asia and Europe** were made using **GPON** technology, that have provided speeds typically around 100-300 Mbps and a maximum of 1Gbps
- And now, in **2018**, we are at the edge where big operators are considering deploying this next year with new technologies that can provide even higher speeds

The Evolution of the Wireline Network

Priorities

- Speed of Deployment
- Network Capacity
- Multi-Service

Needs

- Simplicity
- Efficiency
- Flexibility
- Easy Installation

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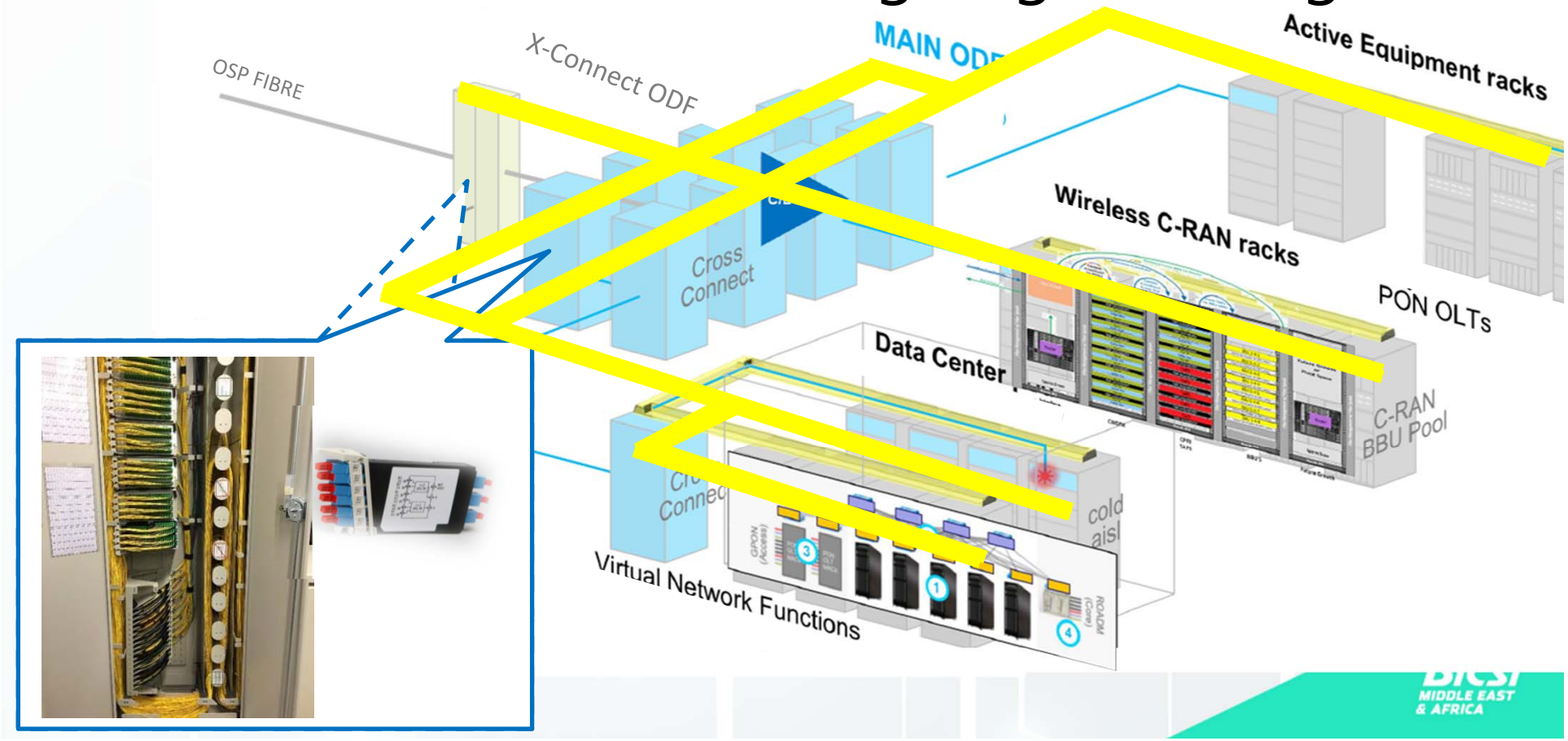
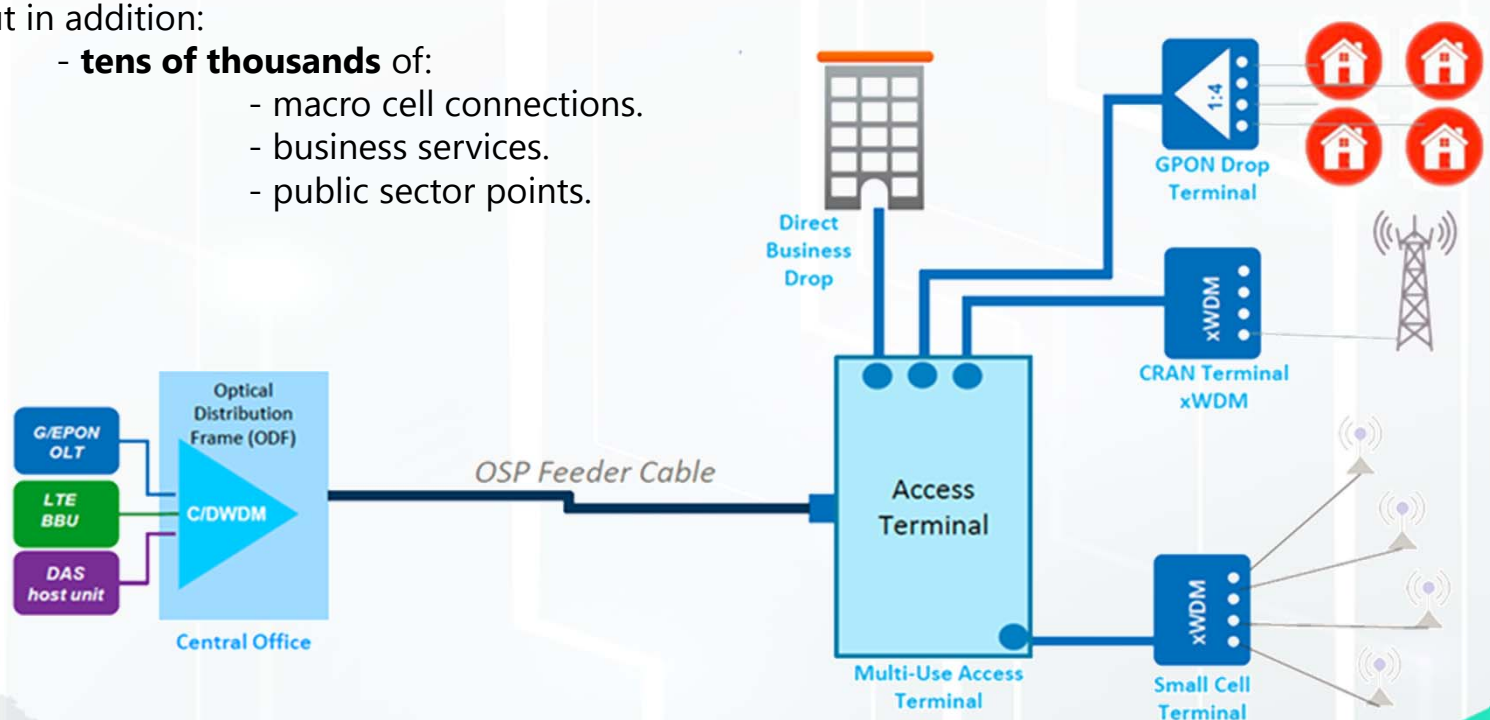
How is the Central Office going to change ?



How is the distribution network going to change ?

Operator just this month wanted to cover 4 M hp in 19 cities, but in addition:

- **tens of thousands** of:
  - macro cell connections.
  - business services.
  - public sector points.



Which technology trend adoptation to expect

- **XG-PON1 technology** started to be installed by some operators over the past year, as a first evolution to cover business customers, but the asymmetrical service that it offers (10Gbps down, 2,5Gbps up) seems that will limit soon its deployment. Operators like Orange have used this solution for business customers

- **XGS-PON** that is starting to be available now, is more attractive for operators than XG-PON1 because it offers a symmetrical service (10Gbps down and 10Gbps up). Also it has the big advantage that it is based in the future NGPON2, where all operators see themselves in a few years. So XGS-PON can very easily be the intermediate stage to NGPON2. Operators like Elisa in Finland have recently made testing of the solution

- **NGPON2** is a multi-wavelength already approved standard. It can support up to 8 streams/wavelengths of 10Gbps down and upstream. The use of tunable optics in this technology allows many possibilities to control bandwidth, and assign more or less speeds. But also allows maintenance and upgrades to customers in a much simpler and non-disruptive way

- Although at least three of the biggest FTTH service providers have decided to go for NGPON2, the capital costs today for NGPON2 actives are still high and this very probably is going to make XGS-PON systems are gradually being installed over the next year, solving in part the time to market objectives of the service provider

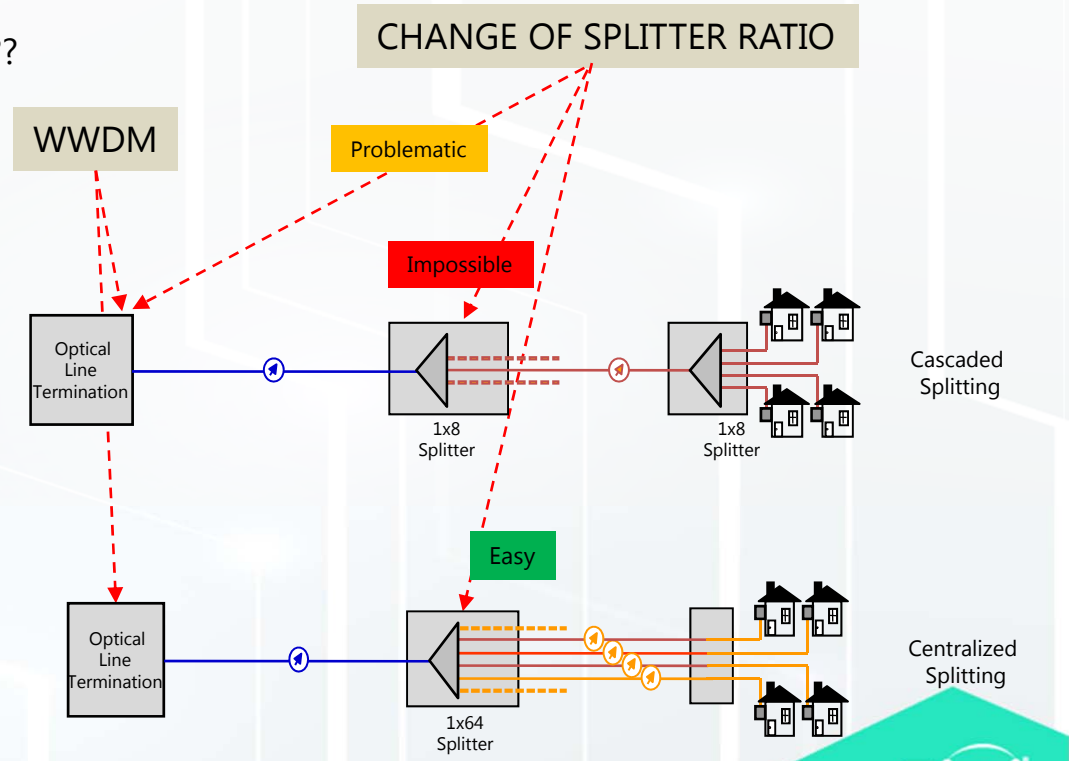
- Verizon has recently trialed the interoperatobility between different vendors of NGPON2 OLTs and ONTs

How easy is it to change or adopt new technologies?

201 — 10G integration, How ???

201 — EMEA big roll-outs based on GPON 1:64

200 — American big roll-outs based on BPON 1:32



Architecture

Objectives for Network Designs

- Future-proof Your Network
  - Meet actual and future Bandwidth demand
  - Adaptable to future equipment upgrades
  - Scalable without re/over building
- Needs to be Efficient at low and high take rates
  - Cost-effective growth strategy
  - Fully leverages electronics investment
- Must Minimize network installation complexity
  - Value-added products
  - Reduced-labor products
- Should Minimize up-front CAPEX investment
  - Defer as much CAPEX to subscriber turn-up as possible
- Should Minimize OPEX

PON Diagram

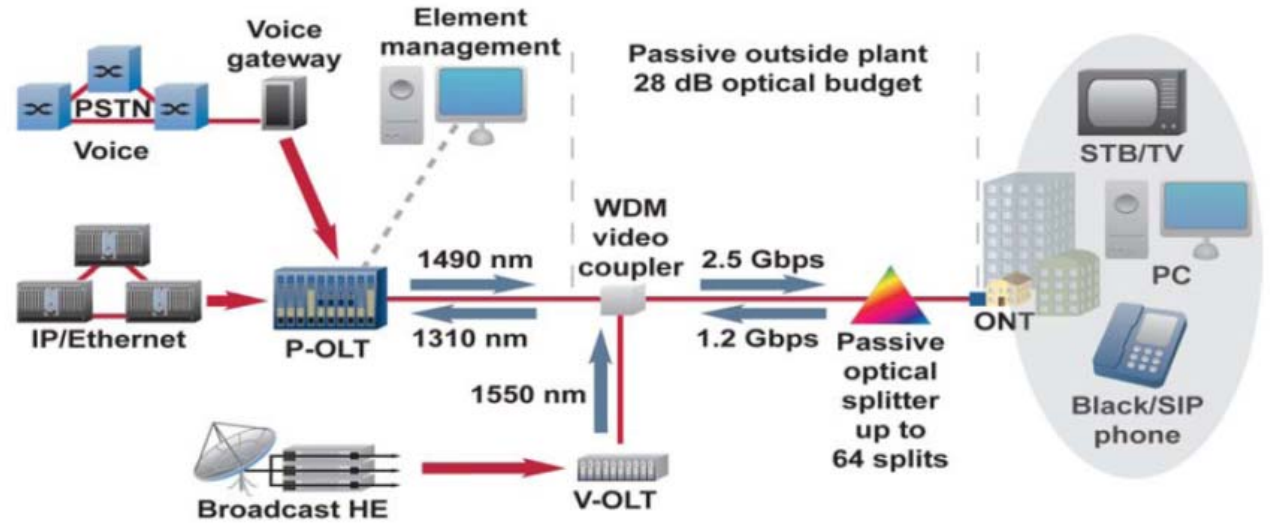


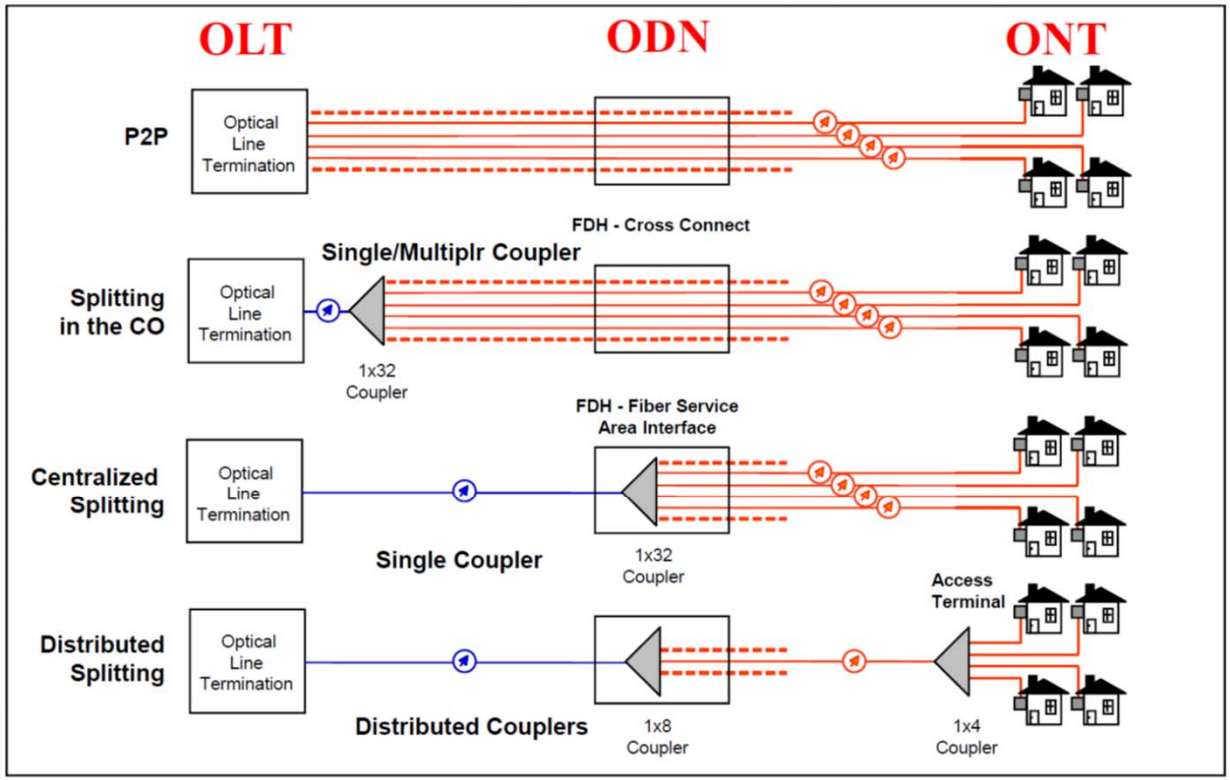
Figure 10: Schematic diagram of a GPON network.

Data Center / Central Office

OSP

Inside-Building

FTTx Architectures

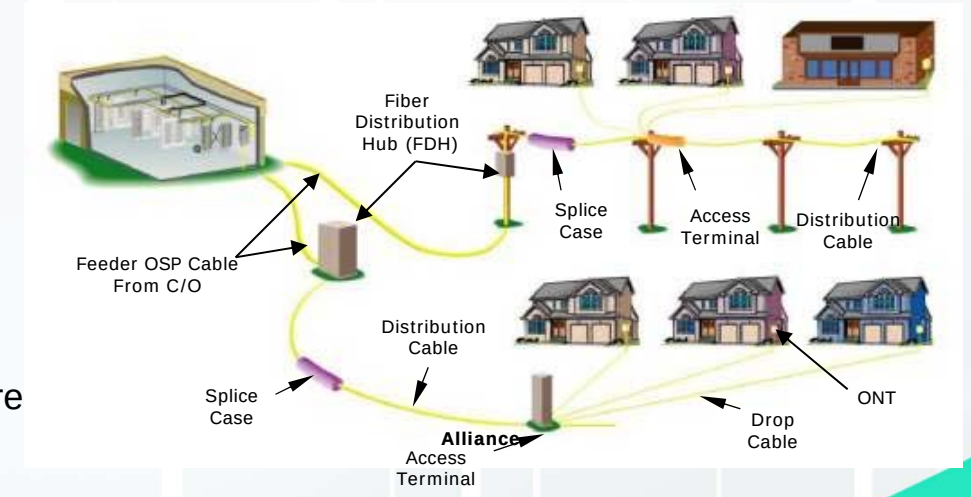


Splitter Deployment Strategy

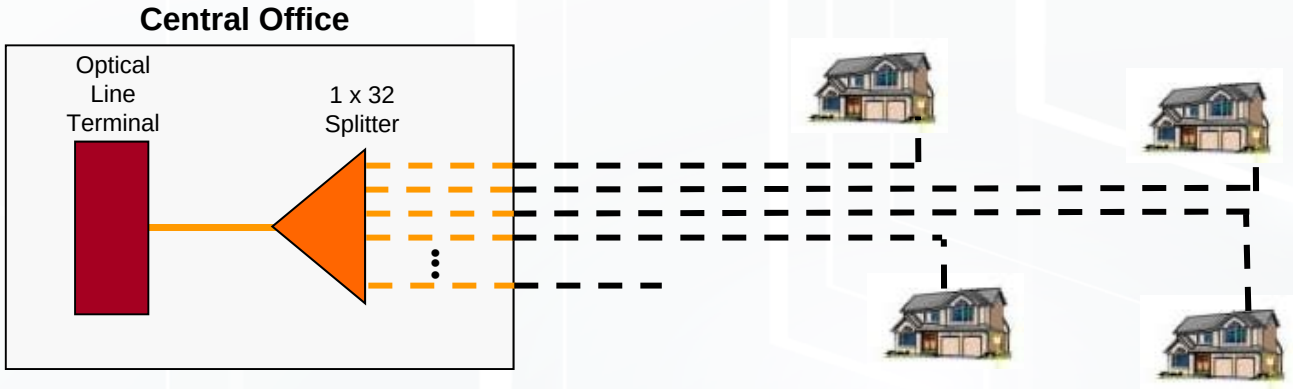
Implications for FTTH Deployment

- Optical Splitters are Used in a FTTH Deployment to Provide the Most Effective Use of the OLT Electronics
- Typically 1 x 32 Optical Splitters are Used, 1 x 16 Splitters May be Used in Applications Where Loss Budget Will Not Allow 1 x 32's to be Used; 1x64 Can Be Used as Well

- Where to Locate the Splitters is a Critical Decision
  - In C/O
  - Cascaded in OSP
  - Centralized in OSP
- OLT Utilization and Operational Expenses are Key

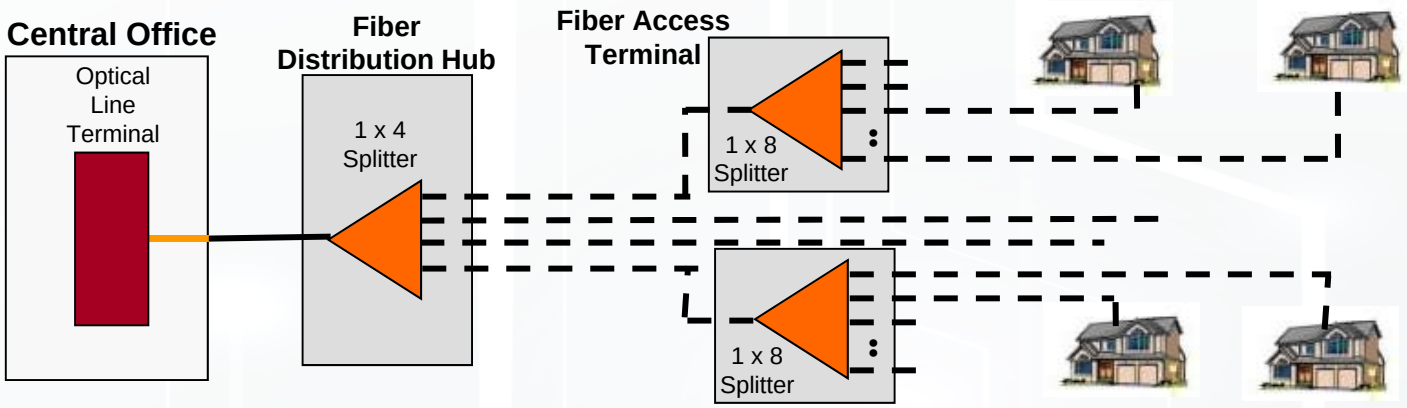


Implications for FTTH Deployment in the CO



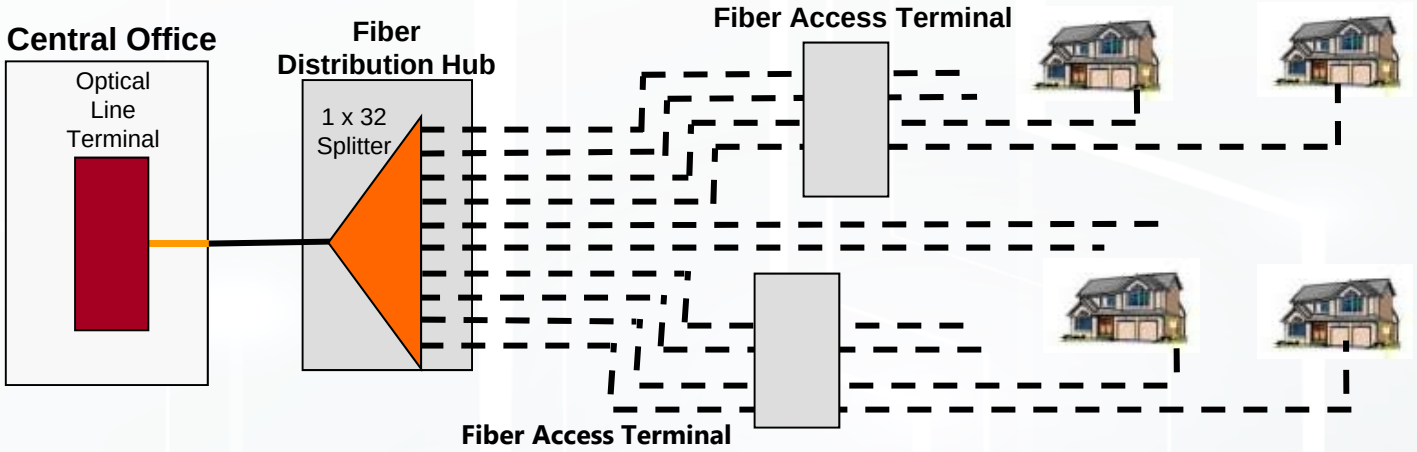
- Concept : Optical Splitter is Located in Central Office and All Fibers are Run From C/O to Subscriber
- Theory : Maximum Network Flexibility and Bandwidth Capability is Achieved When Splitter is in C/O and Each Subscriber Has a Fiber Running All the Way Back to the C/O
- Reality : Works Well When Subscribers are Close to C/O, Creates a Large Amount of Fiber in the OSP Network

Implications for FTTH Deployment Cascaded



- Concept : Splitters are Located in FDH and FAT OSP Locations
- Theory : Cascading Splitters in OSP Will Minimize the Amount of Fiber That Needs to be Deployed to Provide Service
- Reality : Cascaded Splitters Reduce Distribution Cable Material Costs But Creates Inefficient Use of OLT Equipment and Increases Trouble Shooting Difficulty

Implications for FTTH Deployment Centralized



- Concept : All Splitters are Located in FDH OSP Locations
- Theory : Centralizing the Splitter Locations for a Neighborhood Will Maximize OLT Utilization and Provide a Single Point of Access for Troubleshooting
- Reality : Provides Best OLT Utilization Flexibility in Limited Take Rate Builds and Provides Easy Craft Access for Troubleshooting

Centralized versus decentralized splitters

Centralized split

+ Optimized OLT and splitter port utilization
+ Best optical budget
+ Easier record keeping
+ Fewer access points and related truck rolls (easier deployment)
+ Simple network testing / maintenance,…

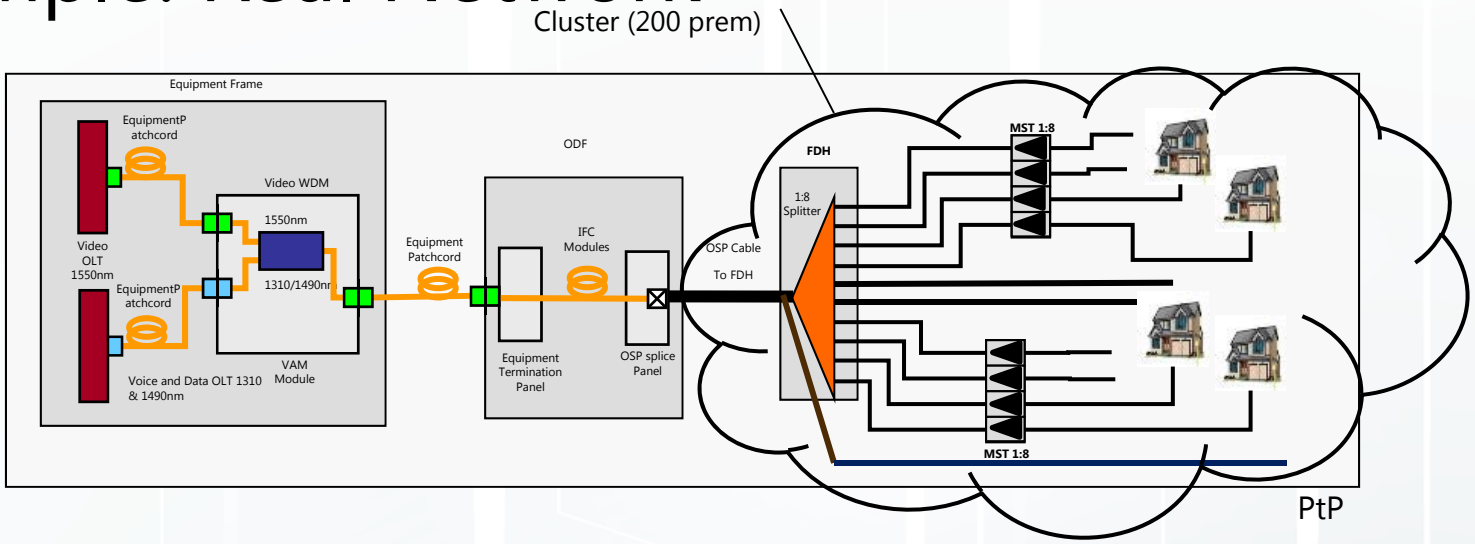
- Larger concentration point and related cost

Decentralized

+ Reach optimization (rural)
+ Cost optimization at high take rates
+ Less fiber needed
+ Smaller access points (cities)
+ Optimized more for MDU deployments in EMEA

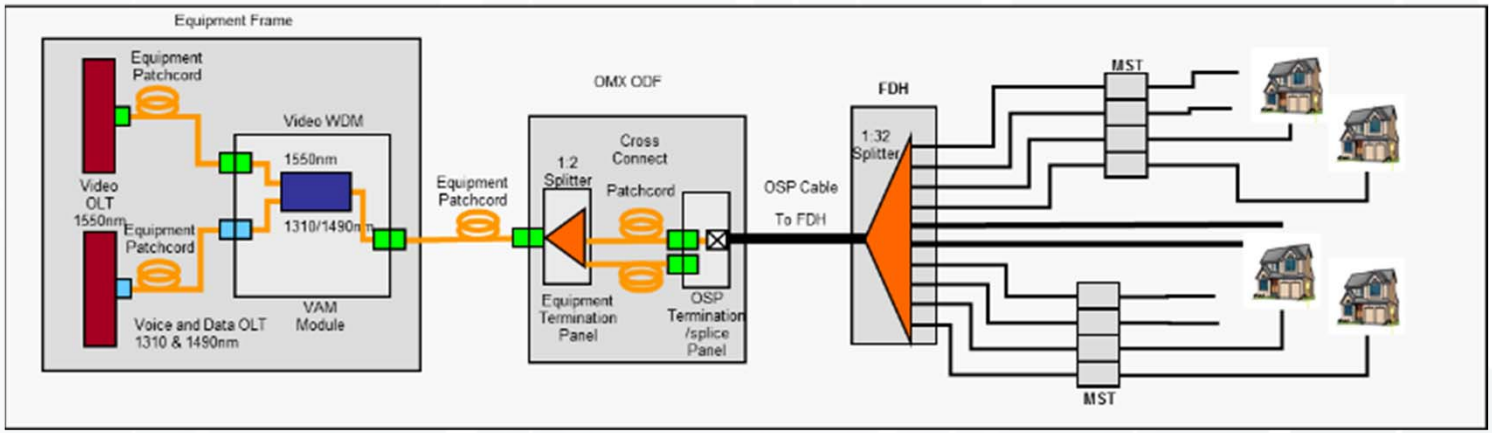
- More complex record keeping

Example: Real Network



- PON Architecture for residential customers and PtP for business customers
- Take rate 10-15% (PON)
- Splitters deeply moved towards the customer resulting in:
  - Minimizing splicing and fiber size requirements
  - Decreasing utilization rate of active OLT ports in CO and bad utilization of power and cooling and real estate

Example: Alternative Architectures



- Splitters moved backwards towards the CO resulting in:
  - Increasing the required amount of fibers (cables) and splices
  - Strongly increasing the utilization rate of active OLT ports in CO
    - From 12.5% to 78% = 600% improvement

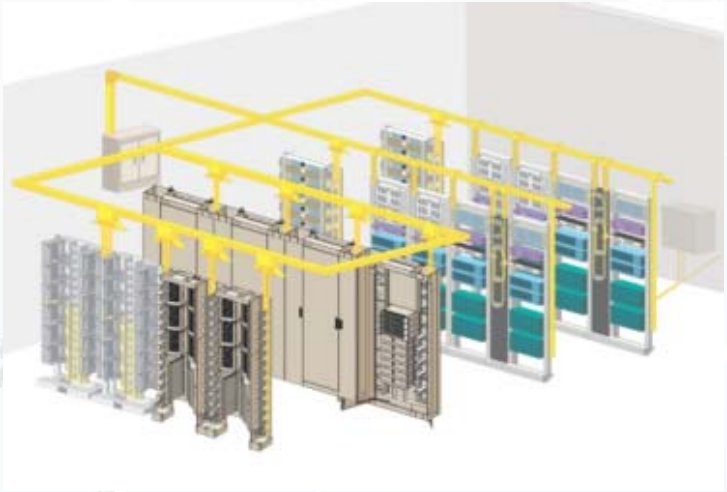
Infrastructure Network Elements

Main FTTH infrastructure elements are:

- **Access Node or POP:** (point of presence)Building communications room or separate building
- **Feeder cable:** Large size optical cables and supporting infrastructure e.g. ducting or poles
- **Primary fiber concentration point:** (FCP) Easy access underground or pole-mounted cable closure or external fiber cabinet (passive, no active equipment) with large fiber distribution capacity
- **Distribution cabling:** Medium size optical cables and supporting infrastructure, e.g. ducting or poles
- **Secondary fiber concentration point:** (FCP) Small easy access underground or pole cable joint closure or external passive cabinet with medium/low fiber capacity and large drop cable capacity
- **Drop cabling:** Low fiber-count cables or blown fiber units/ ducting or tubing to connect subscriber premises
- **Internal cabling Fiber in the Home:** Includes fiber entry devices, internal fiber cabling and final termination unit

Access Node or POP

- Starting point for the optical fiber path to the subscriber
- House all active transmission equipment from the telecom provider.
- Manages all fiber terminations and facilitate the interconnection between optical fibers and active equipment.
- The physical size of the access node is determined by the size and capacity of the FTTH area in terms of subscribers and future upgrades.

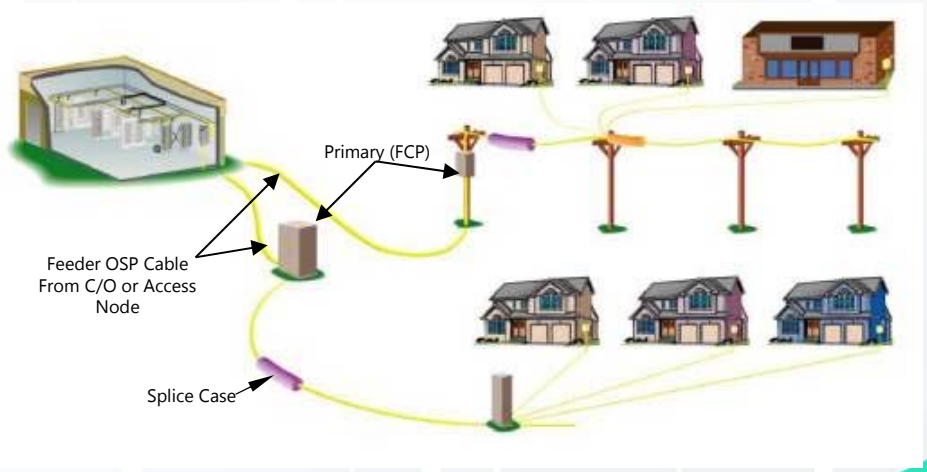


Feeder cable

- The feeder cables run from the Access Node to the primary fiber concentration point (FCP) and may cover a distance up to several kilometers
- The number of fibers in the cable will depend on the build type.

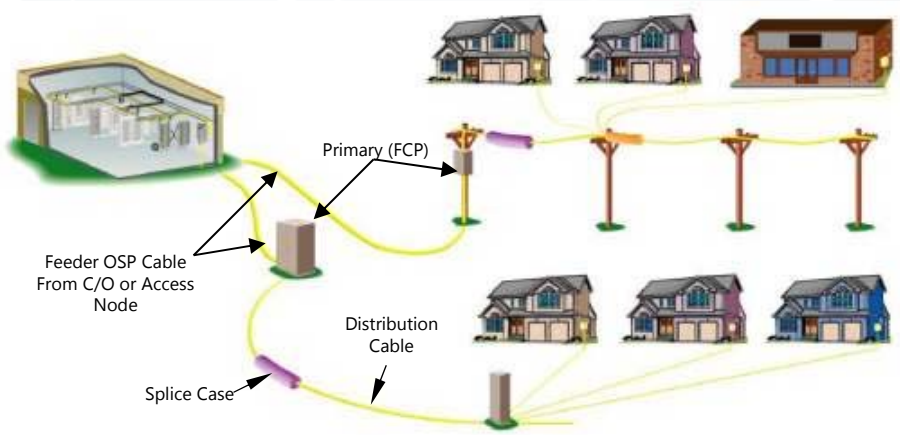
Primary fiber concentration point

- The feeder cables run from the Access Node to the primary fiber concentration point (FCP) and may cover a distance up to several kilometers
- At this stage the feeder cable fibers are separated and spliced into smaller groups for further routing via the outgoing distribution cables
- The FCP unit may take the form of an underground or pole-mounted cable joint closure designed to handle a relatively high number of fires and connecting splices. Alternatively, a street cabinet structure may be used



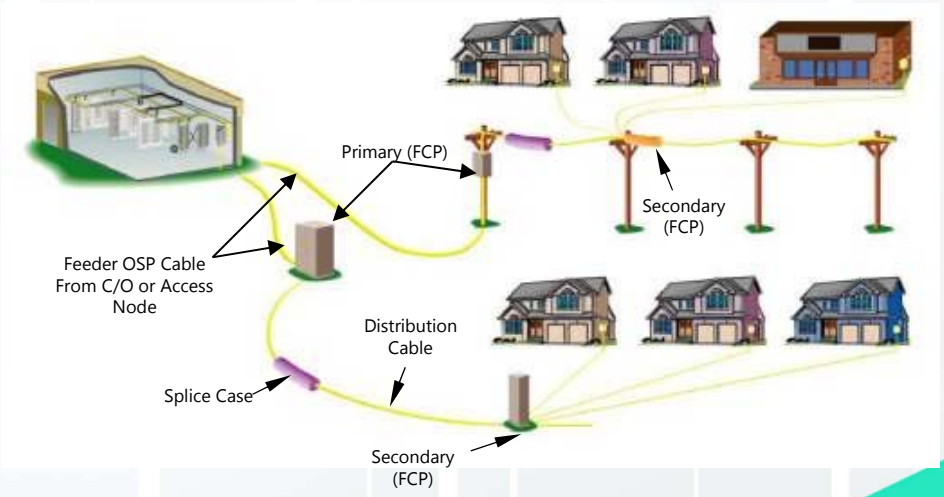
Distribution cabling

- Distribution cabling that connects the FCP to the subscriber does not usually exceed distances of 1km
- Cables will have medium-sized fiber counts targeted to serve a specific number of buildings or a defined area



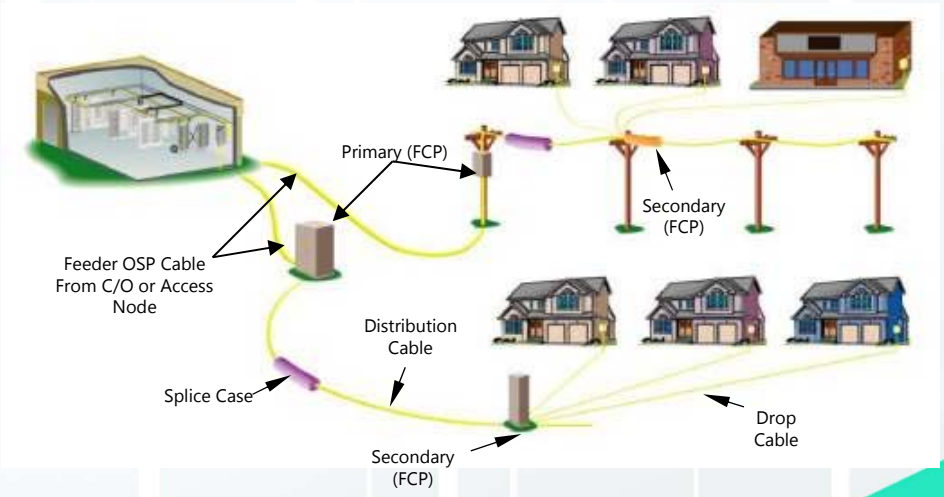
Secondary fiber concentration point

- At the secondary FCP, distribution cables are spliced to the individual fibers or fiber pairs (circuits) of the drop cables
- Enabling the drop cabling to be split out as close as possible to the majority of subscribers
- The secondary FCP is typically an underground or pole-mounted cable joint closure designed to handle a relatively small number of fibers and splices. Alternatively, a small street pedestal structure may be used



Drop cabling

- Drop cabling forms the final external link to the subscriber and runs from the last FCP to the subscriber building for a distance not exceeding 500m which is reduced considerably in high-density areas.
- Drop cables used for subscriber connections, usually contain a number of fibers but may include additional fibers for backup or for other reasons.



Internal cabling Fiber in the Home

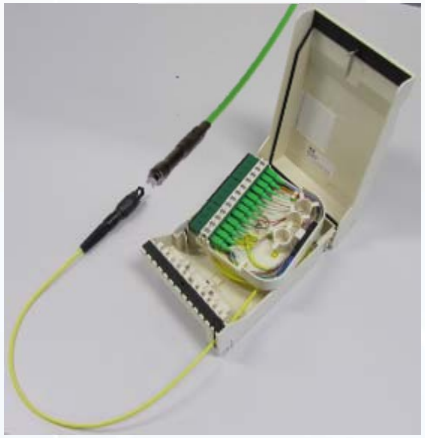
- The in-house installation extends from a building entrance facility placed typically in the basement of an MDU building to an optical telecommunications outlet (socket) in the subscriber's premises

New Technologies

Consider Plug & Play vs Splice

Plug and Play Solutions

- Reduce # of skilled laborers required
- Reduce amount of time to install and turn up service
- Minimal capital investment in tooling required
- Increased network loss



Splice Solutions

- Requires higher level of skilled labor
- Longer Installation times
- More tenant disruption
- Higher Capex on splice machines

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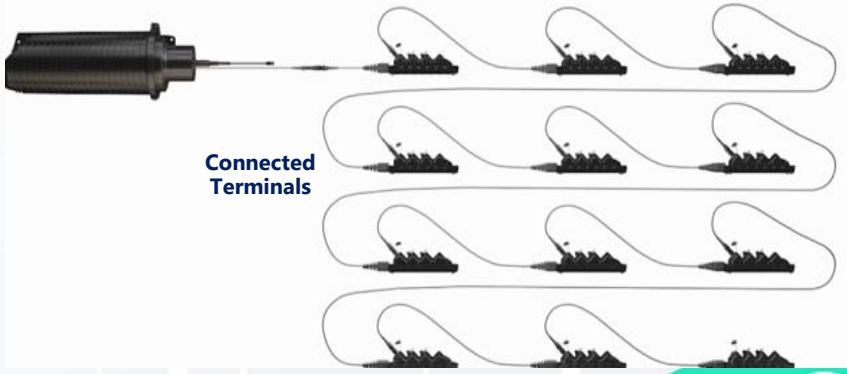
OSP Access Network Design Considerations

- Access solutions need to be flexible to accommodate Direct Connect, FTTH Drops and DWDM's for Wireless
- Modular plug & play solutions allow flexible deployment options within a common architecture
- Consider hardened fiber connectors to enable faster and more cost effective service turn-up



What To Do?

Evaluate Network Architectures that Speed Deployment and Add Flexibility

1. Evaluate Different Splitting Architectures to Reduce Costs / Free Up Fiber
2. Hardened Connectivity to Speed Deployment and add points of flexibility
3. Points Of Flexibility to allow for New / Reconfiguration of services
4. Evaluate Emerging Technology (Power, Path Redundancy, Maintenance Challenges)

1 Evaluate Different Splitting Architectures to Reduce Costs / Free Up Fiber

Why?

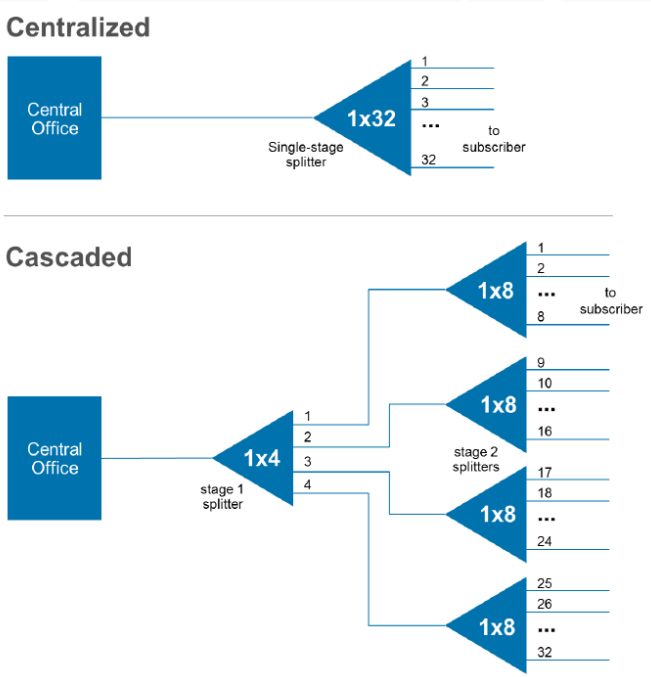
- Reduces fiber required for FTTH / Free up fiber for other applications
- Allows for building a network to an expected “Take Rate”

Challenges to Consider:

- Increased OLT costs
- Challenges with IT provisioning systems

Methods:

- Cascaded split at FDH and Terminals
- Distributed splits at Terminals
- Tap Splits
- Connectorise Splitters and Fiber to Maintain Flexibility for Upgrades



2 Hardened Connectivity to Speed Deployment and Add Points of Flexibility

Why?

- Hardened Connectors replace splices reducing total installed cost
- Points of flexibility for reconfiguration of networks

Challenges:

- SKU / over-length Management
- Cleanliness / Craft interaction

Types:

- Single Fiber
- Multi-Fiber

3 Points Of Flexibility to Allow for New / Reconfiguration of Services

Why?

- Gives quick access for turn-up of **new applications**
- Allows for reconfiguration
- Reduces future splicing costs

Challenges:

- Documentation and Management

How:

- Keep Points of Flexibility (like traditional FDH's) with more functionality
- Can be hidden as access is not as common

4 Evaluate Emerging Technology (Power, Path Redundancy, Maintenance Challenges)

The Industry needs to keep innovating to continue to solve the next generation of problems presented by the trends.

Power

- Small Cells
- Wi-Fi
- Fixed Wireless Drops
- Cameras
- IOT

Protection

- 5G reliability
- Cell Backhaul
- High Cap/ Lifeline Services
- Move from Luxury to Necessity

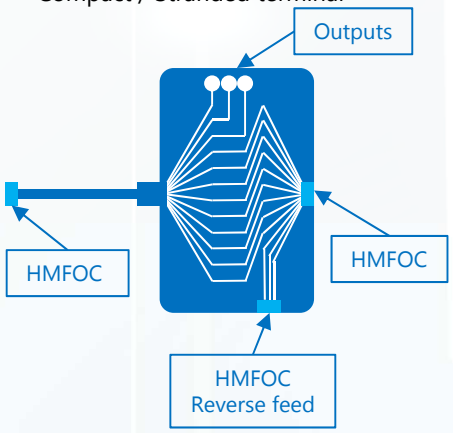
Fiber Ease of Use

- Fiber going more places
- Inexperienced Technicians
- Home Owners

Flexible Fiber Indexing Solution will allow multi-purpose network & delayed capex

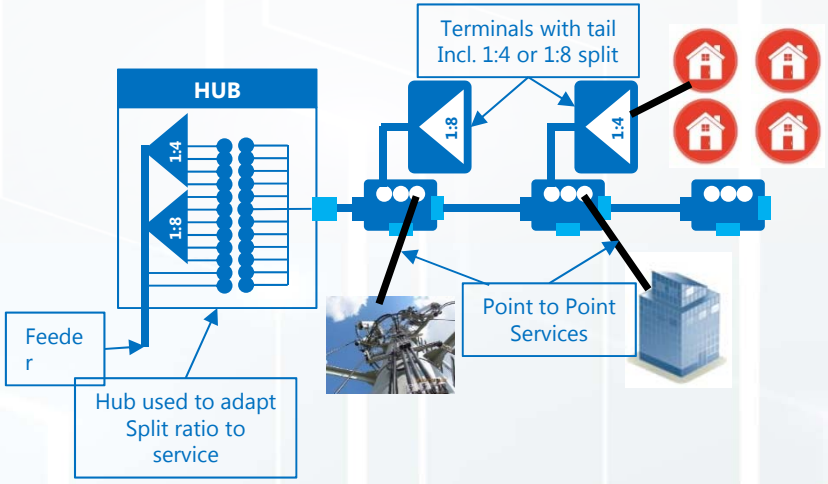
New Flexible Indexing Terminal

- More than one fiber branched off at terminal
- Reverse feed in Multi-Fiber Connector (HMFOC)
- Higher Fiber Counts – 24 FO HMFOC and cable
- Regular terminals originally might evolve into more Compact / Stranded terminal



Network Topology & Benefits

- Additional services supported by the network (mix of P2P and GPON) → more revenue from the Network
- External terminals added only upon service activation & take rate increase → Delayed Capex



In Summary

Convergence

Utilization of the network to address multiple market segments, adding additional revenue streams and de-risking the business case

The future is here

Demand for bandwidth and IOT will drive Metrocell densification deployments

Flexible

Network operators need to be able to support multiple network applications on a single network

Network friendly

Network architecture and product selections need to focus on providing the Density, Accessibility and Flexibility needed for the future

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Thank You

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