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at the MassTech Collaborative

Understanding FTTH Architecture

TOPOLOGY AND COMPONENTS

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Understanding General Terms

Q: What is meant by a Central Office or a Hut?
A: The location where all major electronics for the system are housed for a given town.

Q: What is topology?
A: In a FTTH system, the word "topology" in is most often used with the physical fiber plant or Outside Plant (OSP).

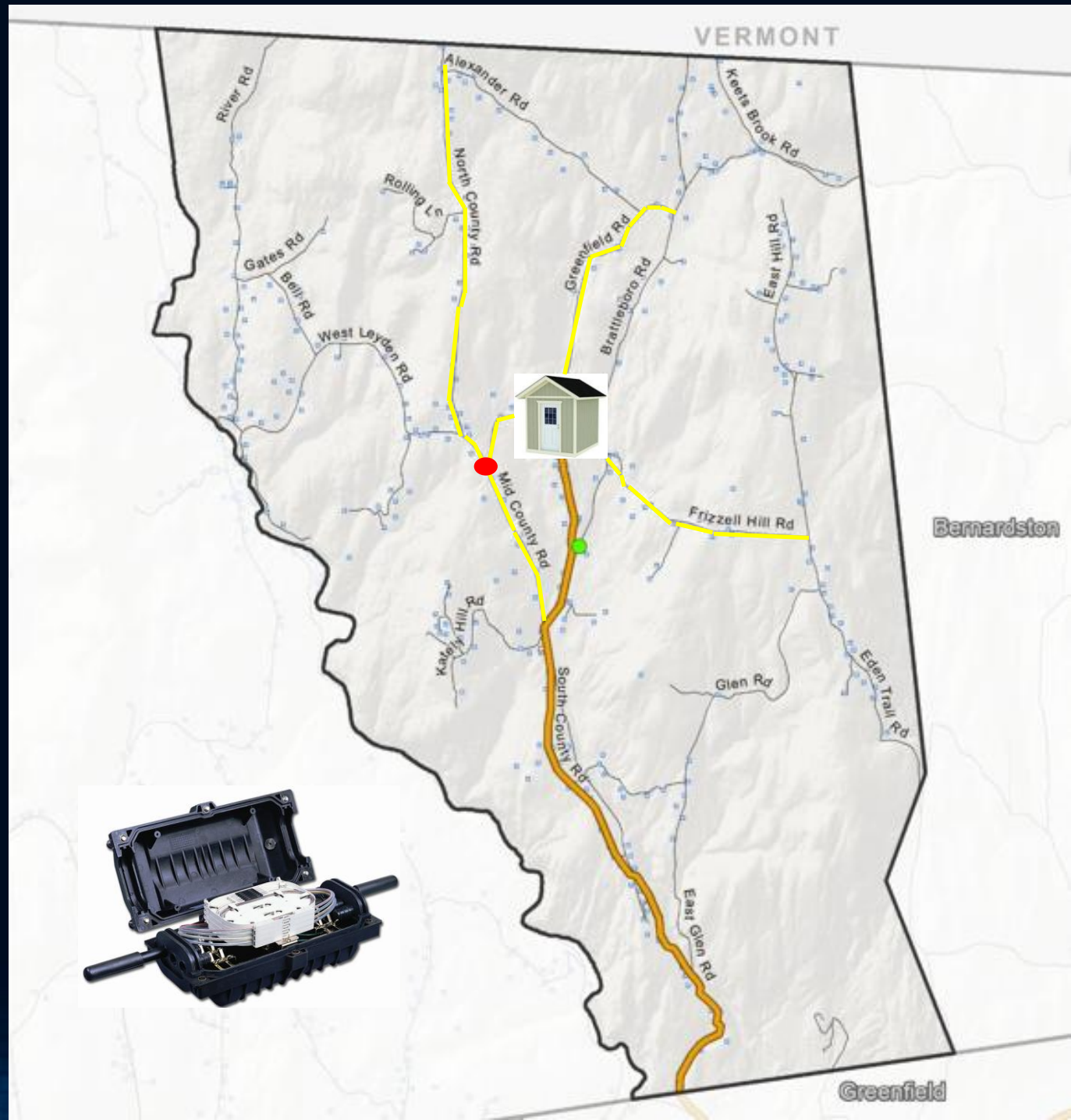
Q: What is splice closure or case?
A: A fiber management product that protects and houses optical splices.

Q: What is a PON?
A: A Passive Optical Network that distributes an optical signal from the CO to the customer.

Q: What is Active Ethernet?
A: A technique that uses Ethernet (a data communications protocol) as the main transmission method over fiber optics with data rates up to 1 Gb/s.

Q: What is meant by G-PON?
A: Gigabit PON is a system that handles data rates up to 2.5 Gb/s.

Q: What is meant by an OLT, ONT, and splitter?
A: OLT - Optical Line Terminal, located in the CO or hut, is the interface to the customer and provides the subscribed services.
ONT – Optical Line Terminal, located at the customer/subscribers location, converts the optical media being sent by the OLT.
Splitter - A passive device that splits the light source in separate paths.



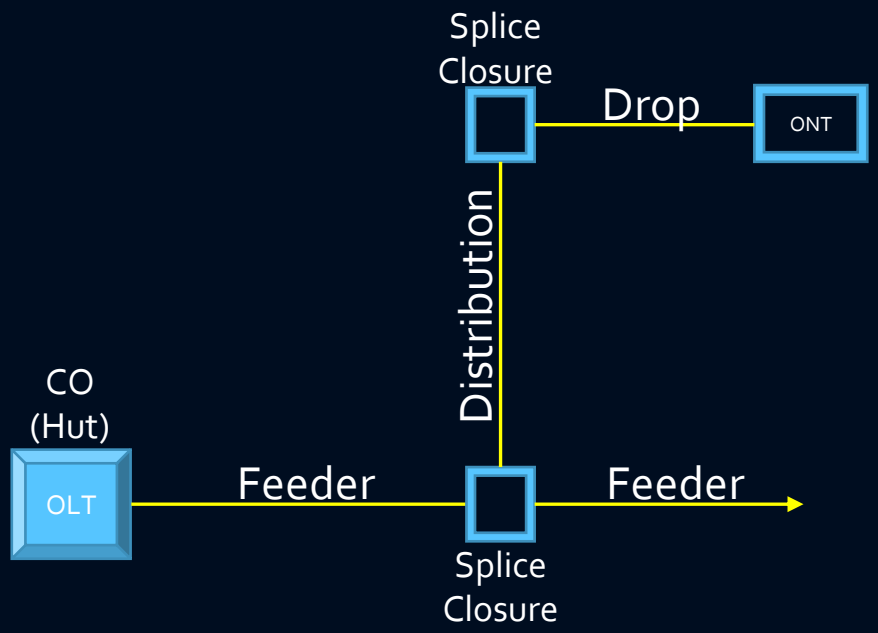
Fiber Cables for FTTx

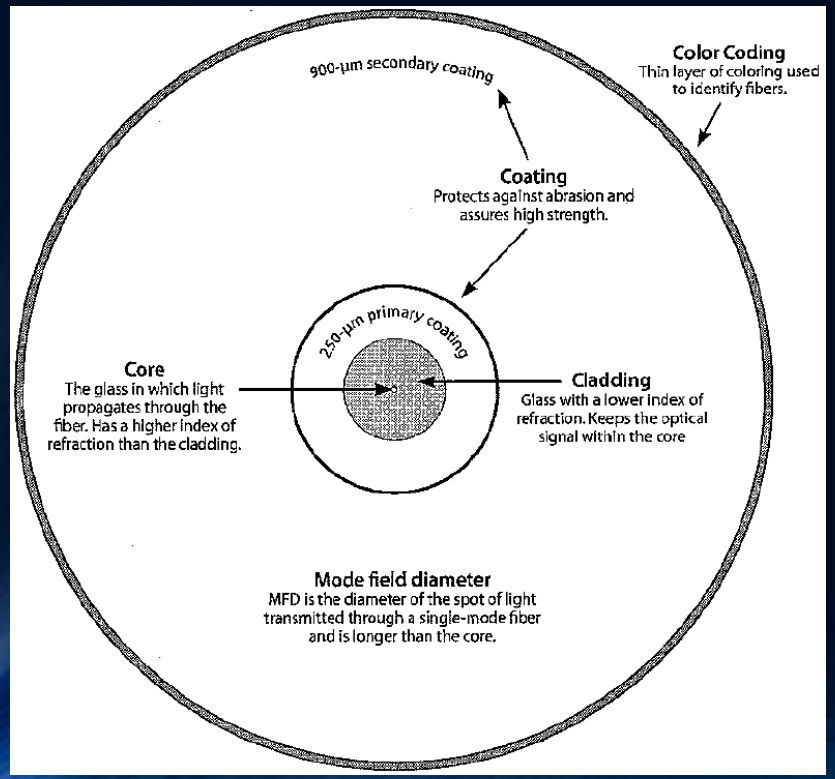
- Single-mode fiber (SMF) is used in a FTTx application
- Optical fiber is the transmission component of the ODN

Feeder Cables – These cables are the main cable(s) being routed through a populated area. Assemblies are normally fiber-rich, including fiber counts from 72 to 1,728 strands.

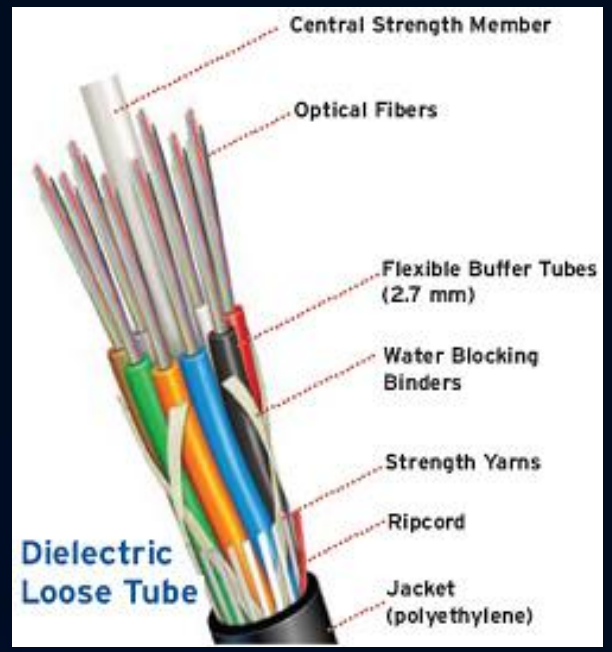
Distribution Cables – Intermediate link between the feeder cable and the drop cable.

Drop Cables – Traditional used outdoors and can be designed for aerial, direct buried, or ducted installations. Fiber counts can vary from 1-12 strands.





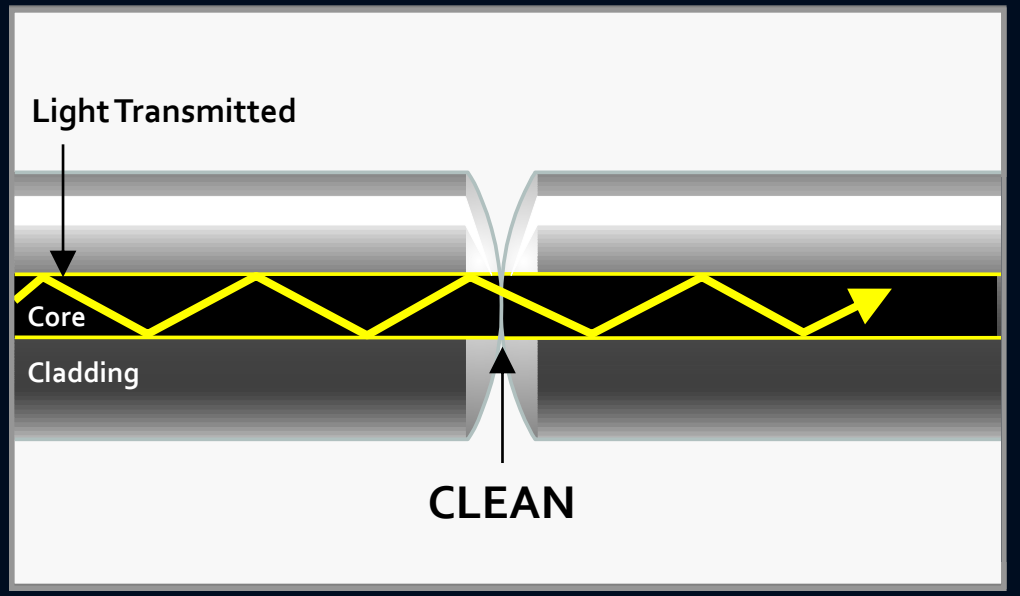
Courtesy of Light Brigade



Fiber Connections

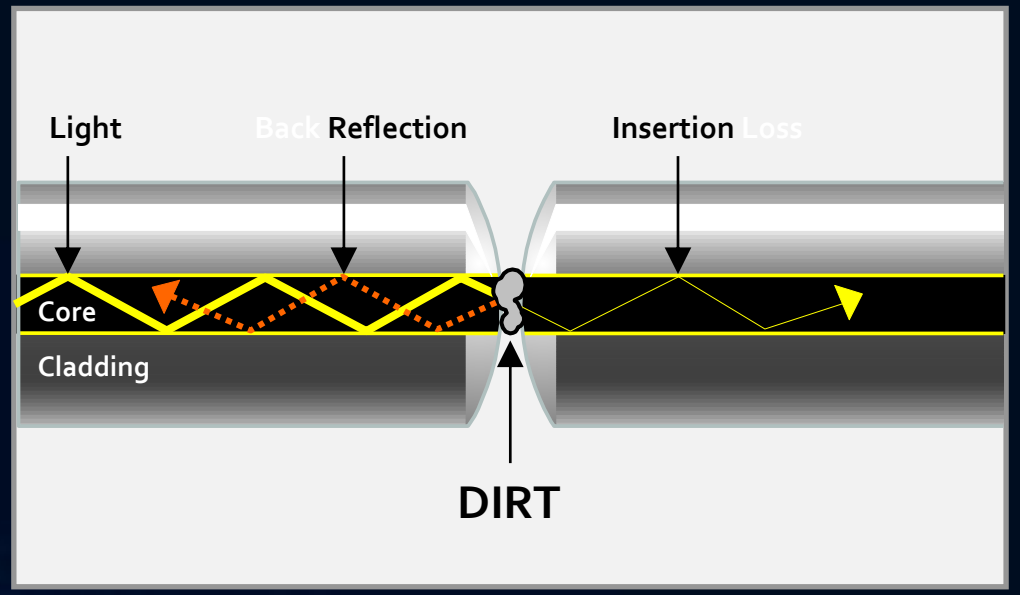
The 3 basic principles that are critical to achieving an efficient fiber optic connection are:

- Perfect Core Alignment
- Physical Contact
- Pristine Connector Interface



CONTAMINATION is the #1 source of troubleshooting in optical networks.

- A single particle mated into the core of a fiber can cause significant back reflection, insertion loss and even equipment damage.
- Visual inspection of fiber optic connectors is the only way to determine if they are truly clean before mating them.



Fiber Optic Network Architectures

- The selection of FTTH networks revolves around two primary paths – Passive Optical Network (PON) and Active Optical Network (AON), a.k.a. Active Ethernet

- Passive Optical Network – Networks are classified as "passive" if they have no powered electrical devices between the laser source (OLT) and the end point (ONT). A splitter is used to divide the fiber for up to 128 subscribers, but the most common is 32 splits

One Fiber Feeds Many (P2MP)

- Active Ethernet (AE) – "Active" means these networks have electrical device endpoints with direct connections, or "Point-to-Point" connections, to the subscriber

One Fiber Feeds One (P2P)

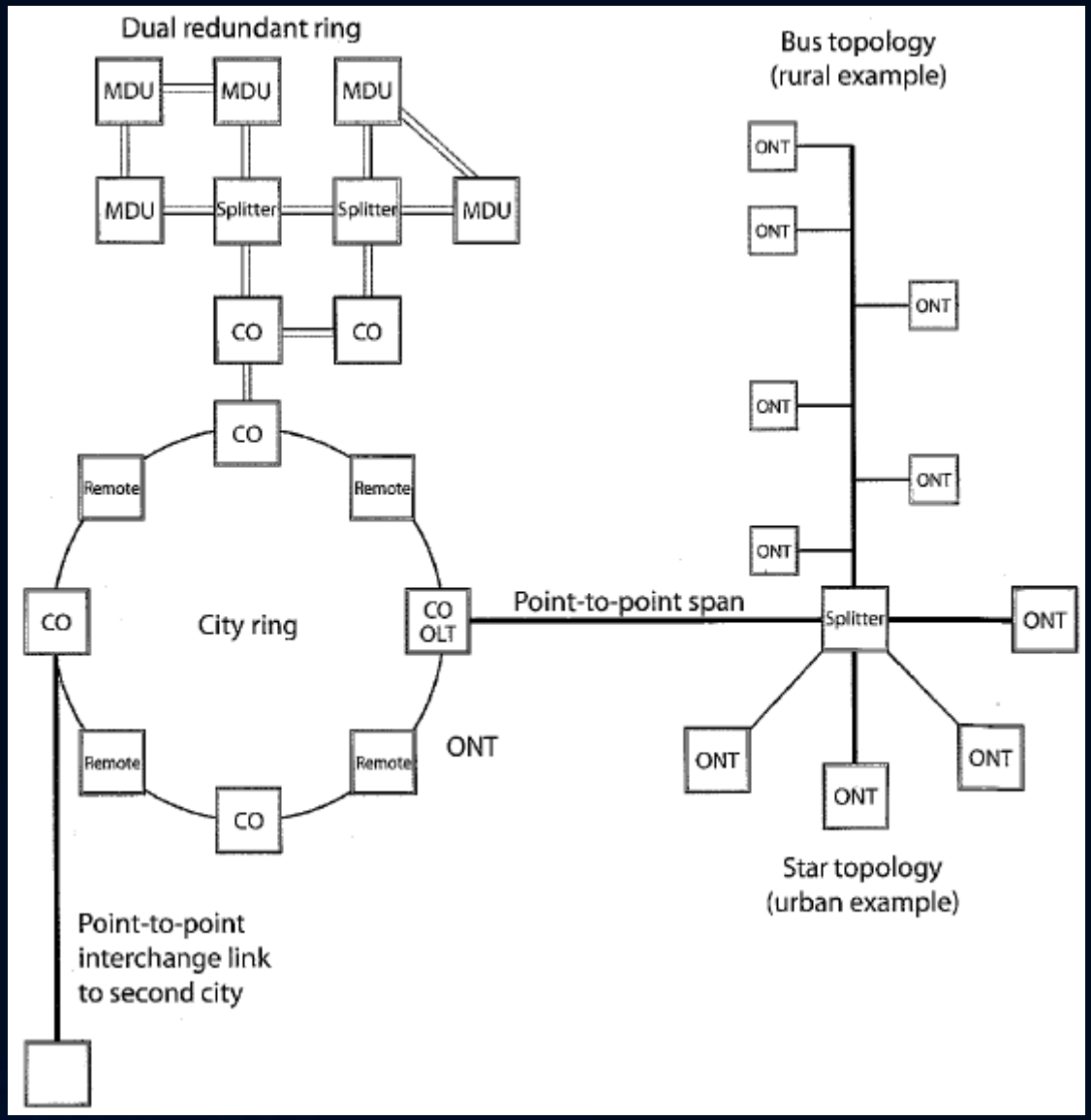
Network Topology

Physical topologies fall into several easily identifiable configurations:

- Point-to-point (P2P)
- Bus (branch)
- Star
  - Point-to-multipoint (P2MP)
  - Extended star
  - Distributed star
- Ring
  - Dual-redundant ring
- Mesh

Depending on the design, terms line "star", "bus", "branch", or "ring" may be used to describe a PON.

The star topology is a natural for FTTP as it spreads out from a central splitter.



Courtesy of Light Brigade, Inc.

Point-to-Point Topology (P2P)

- P2P topologies consist of a fiber run from the Central Office (CO), a.k.a. Point-of-Presence (PoP) or Hut location, to the end customer without any optical splitters in the network
- Different from FTTH PON systems in that a dedicated bandwidth link is provided to an individual subscriber instead of being part of a shared PON
- Active Ethernet (AE) uses a P2P topology

Lightweight enclosure (Hut)
Courtesy of Emerson
Network Power

P2P Fiber

Advantage: Easy to test and troubleshoot
Disadvantage: OSP cost higher compared to PON

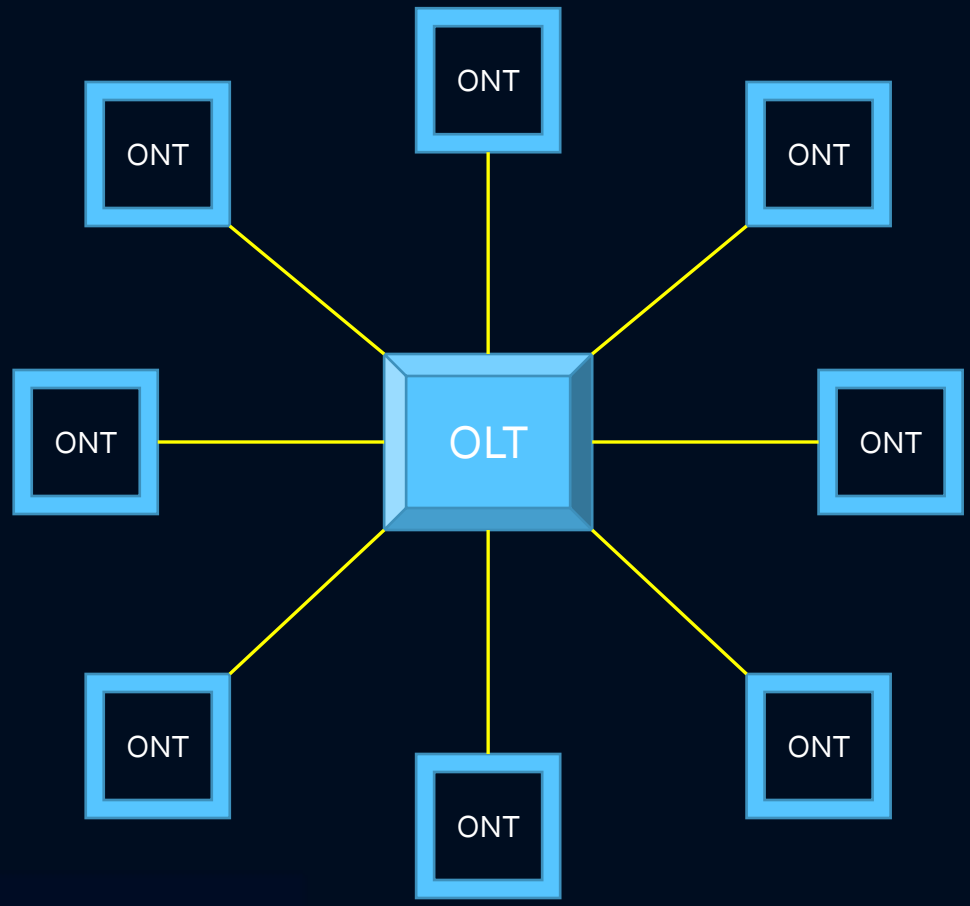
Subscriber's Optical
Network Terminal (ONT)

Star Topology (P2MP)

- The star topology used in PON systems has a central transmission/reception point
- Network traffic must pass through this central hub
- Central hub can provide signal reconditioning and amplification
- Easiest topology to implement and maintain as nodes can be added or removed

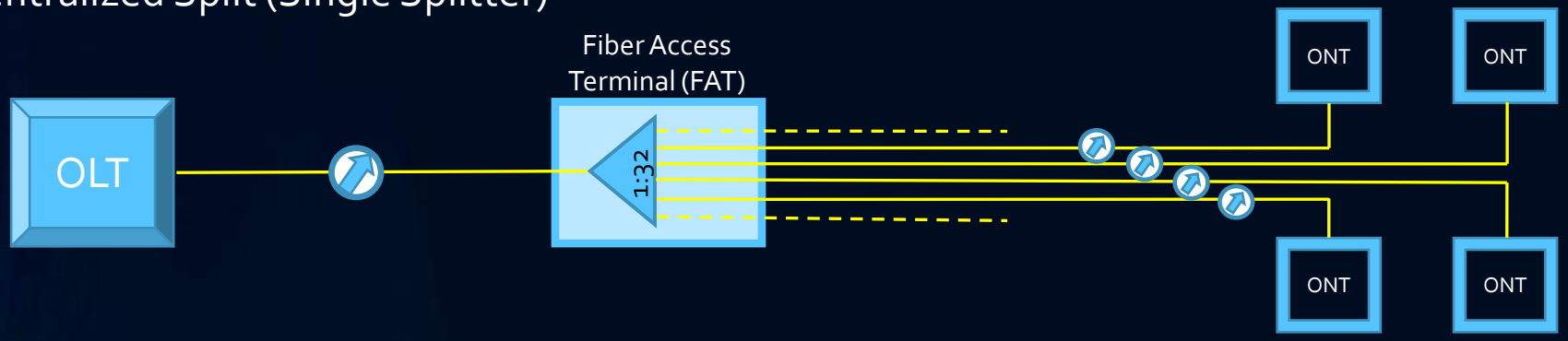
Advantages:
- Minimizes troubleshooting
- No powered components in mid-span

Disadvantages:
- Power/Bandwidth divided between customers
- Distance limited
- Limited to no redundancy



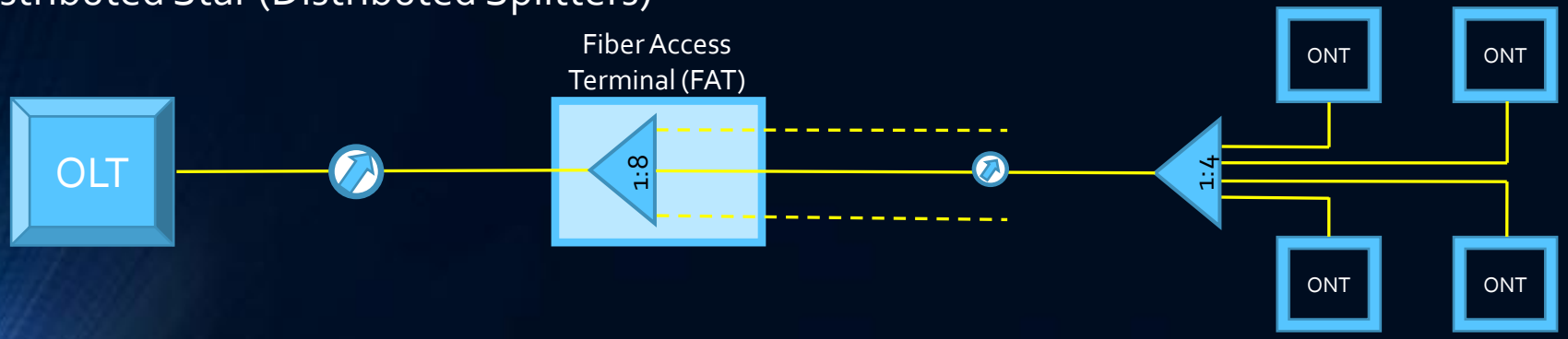
PON Star Configurations

Centralized Split (Single Splitter)



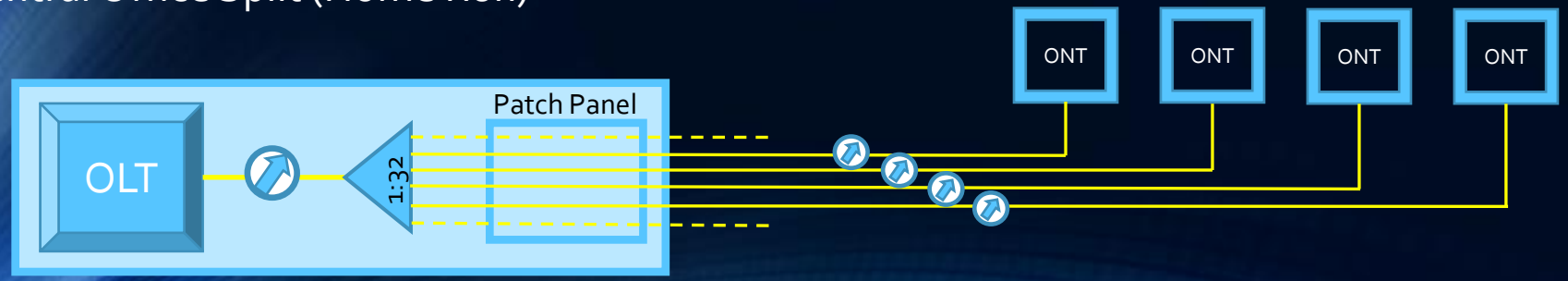
- Splitter is placed in a single location in the OSP and each drop cable is routed directly to the subscriber.
- Allows for maximum OLT utilization and future migration.
- Lower operational expenditure as all changes occur in one location

Distributed Star (Distributed Splitters)



- Uses multiple splitters that are concatenated together along the length of one or more legs.
- Minimizes amount of distribution, but requires careful planning and migration for growth.

Central Office Split (Home Run)

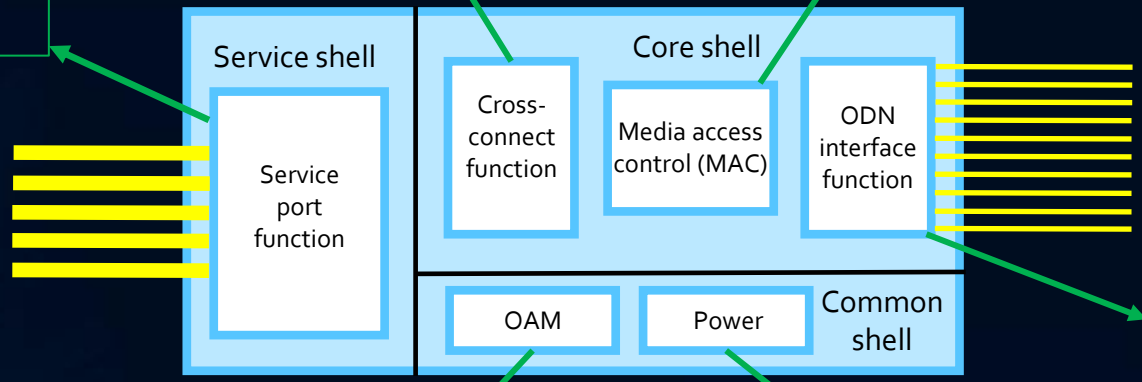


- Splitters are located at the CO (hut).
- Requires fiber rich system throughout
- Most costly to deploy
- Lowest operational expenditures due to reduced need for truck rolls
- Interchangeable for GPON and AE

Network Components

Primary piece of equipment in a PON system is the **Optical Line Terminal (OLT)**

- Primarily located in CO, headend, node, or remote
- Serves as an interface to the subscriber and Public Switched Telephone Network (PSTN)
- One of the two powered units in the PON configuration
- Responsible for the electro-optical conversion process
- Consists of three separate parts: Service shell, Core shell and Common shell



Provides connection verification between the OLT and ONU/T

Provides addressing and channel access control to allow several terminals to communicate within a multiple access network

Responsible for insertion of ATM cells or Ethernet packets into upstream payload and extracting the cells and packets from the downstream payloads

Converts electronic signals and inserts Ethernet packets into the payload

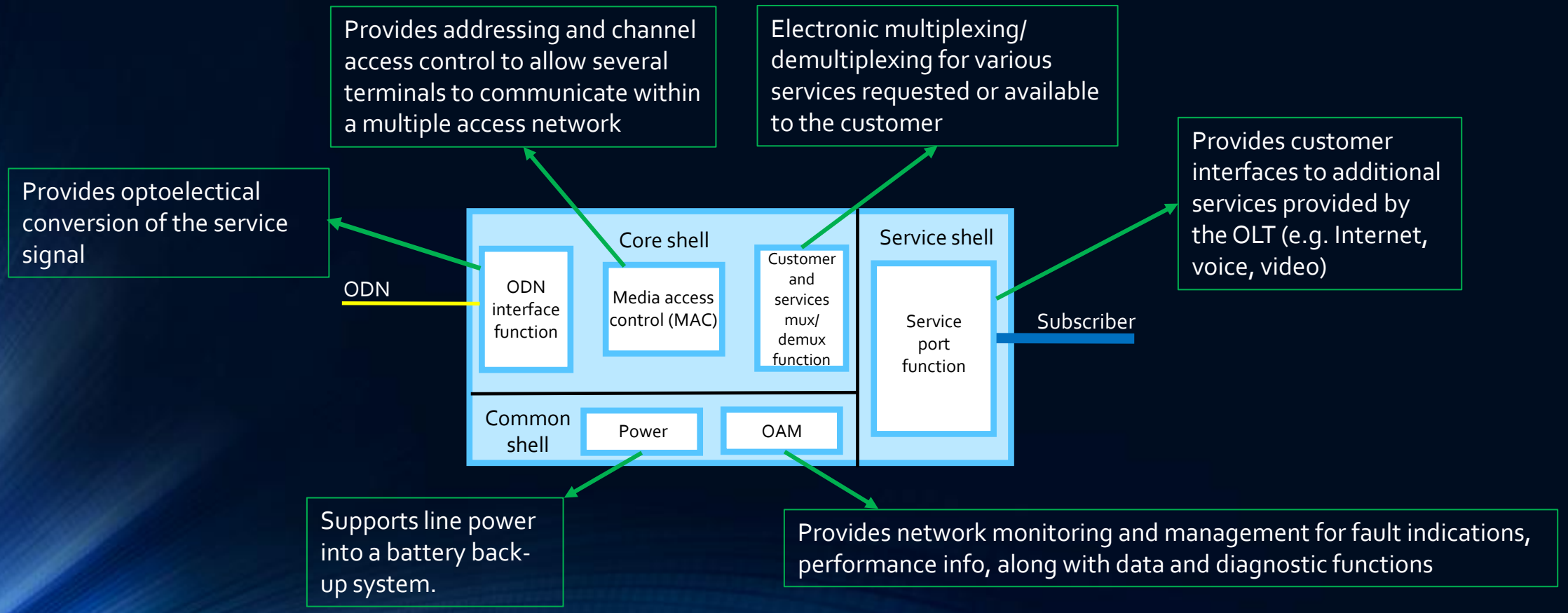
Provides network monitoring and management for fault indications, performance info, along with data and diagnostic functions

Supports a -48VDC, A & B input feeds

Network Components (con't)

Optical Network Terminal (ONT), Optical Network Unit (ONU), and Network Terminal (NT) are used synonymously to describe the end-user interface unit.

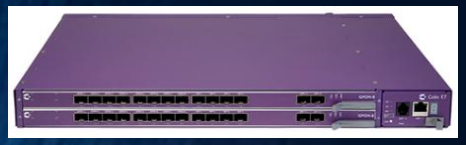
- ONT and NT is mounted at the customer's premise, while ONU is usually mounted in a curbside cabinet
- Converts optical media from the OLT into an electronic format that interfaces with subscribers network
- Similar to the OLT, the ONT consists of three separate parts: Service shell, Core shell and Common shell
- Outdoor and indoor ONT are available at the subscriber location



Network Components (con't)

Calix E7-20 OLT

Nokia 7360 OLT



Calix E7-2 OLT

Zhone MKX OLT's

Adtran TA5000 Series OLT

Calix Outdoor ONT

Adtran Outdoor ONT

Outdoor 24W, 12VDC ONT UPS

Calix Indoor ONT

Adtran Indoor ONT

Indoor 24W, 12VDC ONT UPS

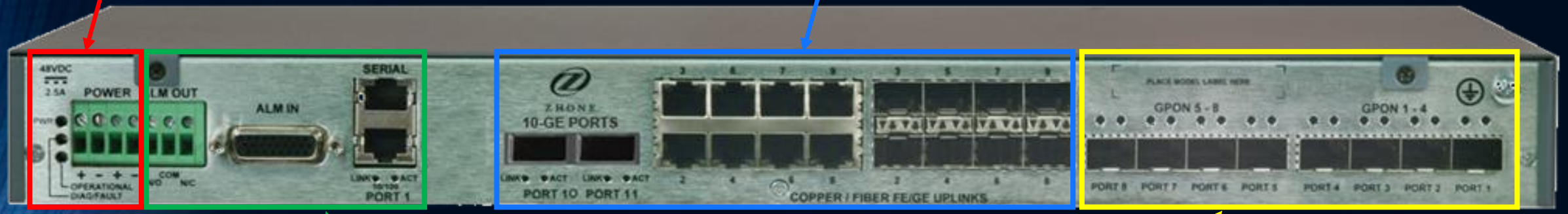
Optical Line Terminal (OLT) Chassis

Zhone 198 MKX 1U G-PON OLT
Dimensions: 1.72” H x 17.4” W x 11.3” D

- -48VDC, A & B input feeds
- Fused at 2.5A

- (2) XFP-based 10Gb/s Ethernet
- (8) RJ45 100/1000Mb/s Ethernet
- (8) SFP-based 100/1000Mb/s Ethernet

SFP/XFP



Courtesy of Zhone

- Serial craft management interface
- 10/100Base-T management interface
- Port status LEDs
- Alarm Outputs/Inputs

- (8) SFP-based GPON
- 256 Subs @ 1:32 split

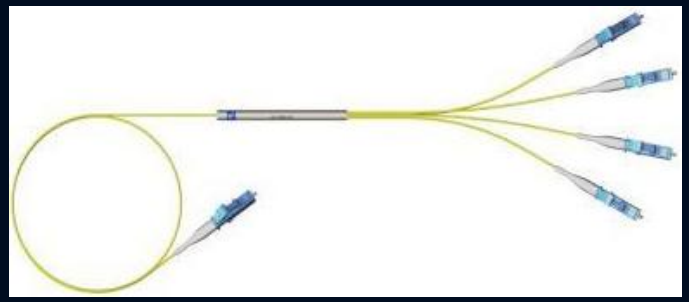
G-PON SFP

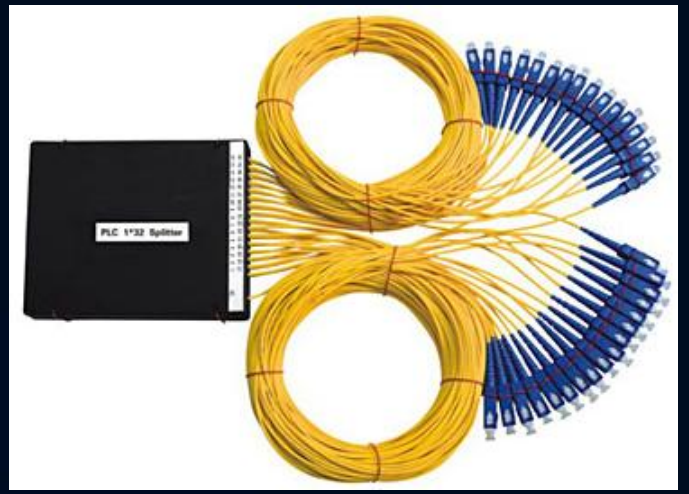
Network Components (con't)

Optical Splitters (a.k.a optical couplers)

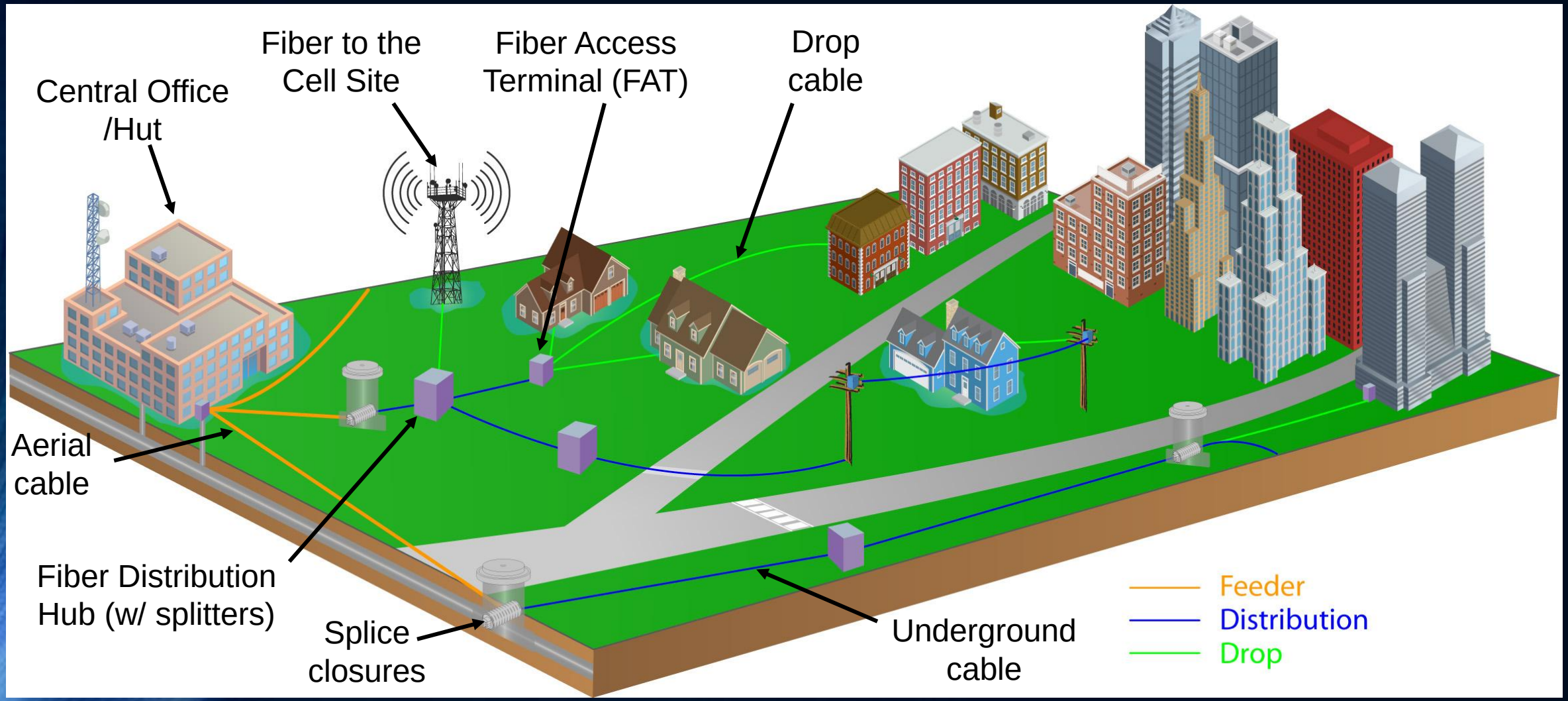
- Are passive devices that do not require electrical-to-optical or optical-to-electrical conversion during its operation
- Are critical to the Passive Optical Network
  - Splits an incoming light source into two separate paths
  - Repeating this split multiples the number of devices that can be connected to a single port
  - Reduces fiber count in the OSP (excluding a Central Office splitting scenario)
- Ports are all equal
  - The light is replicated
  - Has no affect on bandwidth
- Are wavelength independent couplers (WIC) and only add attenuation regardless of the wavelength or direction of the light.
- Types of splitters
  - Fused Biconical Taper (FBT) – low split count
  - Planar Lightwave Circuits (PLC) – high split count
- Splitters come in a number of configurations
  - 1x2, 1x4, 1x8, 1x16, 1x32, 1x64
  - 2x2, 2x4, 2x8, 2x16, 2x32, 2x64

Patch Panel





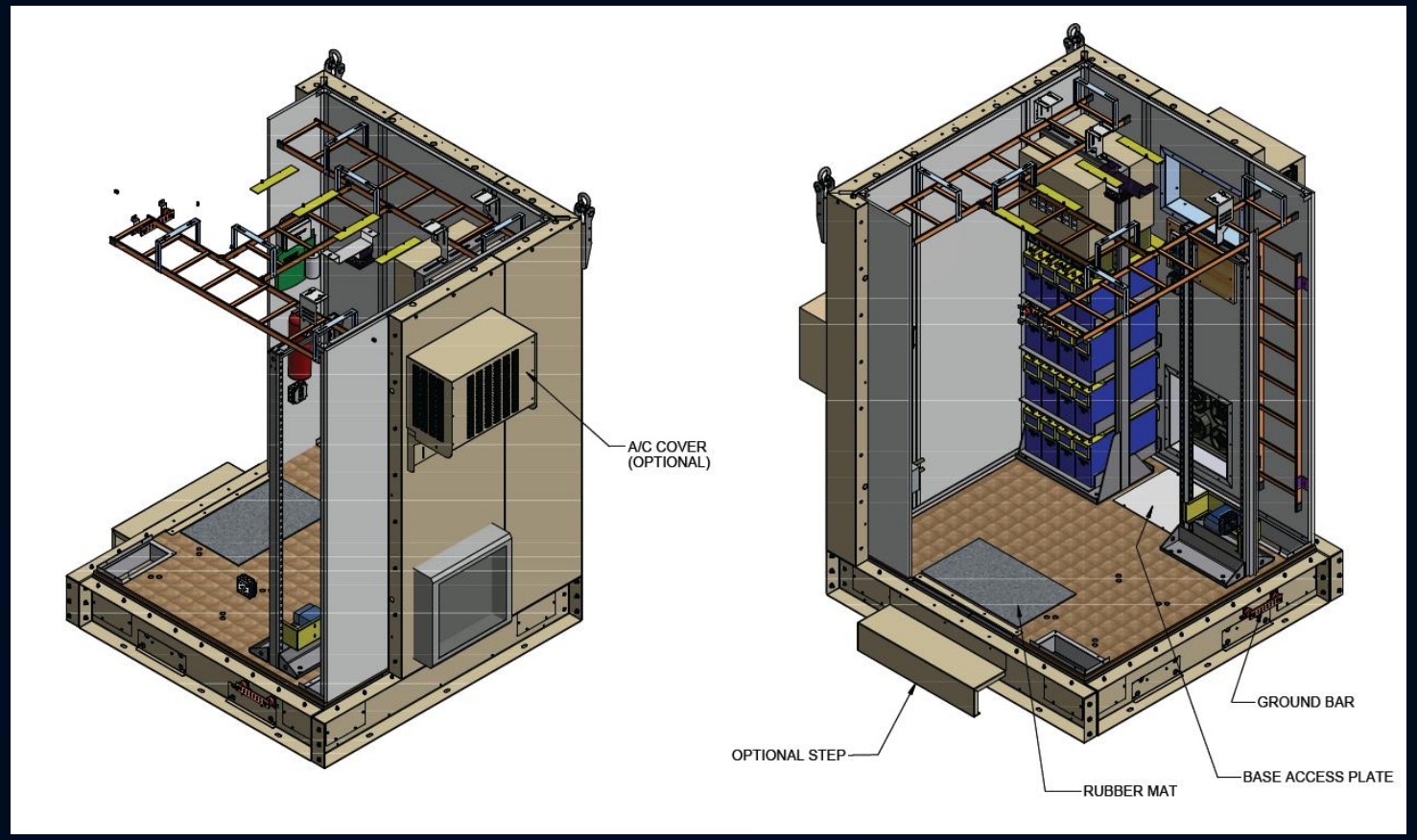
The FTTx Network – Macro View



Courtesy of Zhone

6 x 6 Modular Enclosure (CO or Hut)

- High efficiency "free air" system
- R12 insulation, 120MPH wind rated, 200PSF live load rated roof
- NetSure 721 DC Power system
- 2 x 19" equipment racks included
- 200A Power Transfer Switch with 24pos load center, surge arrestor & camlok style generator connector
- Wall and floor cable entrance
- DC Lighting w/ motion controlled outside light
- Door contact for intrusion
- Smoke detector



Courtesy of Emerson Network Power

Enclosures and Cable Management Products

Fiber Distribution Hub (FDH)

Aerial Splice Closure

Fiber Transition Terminal (FTT)

Fiber Access Terminal (FAT) or Pedestal

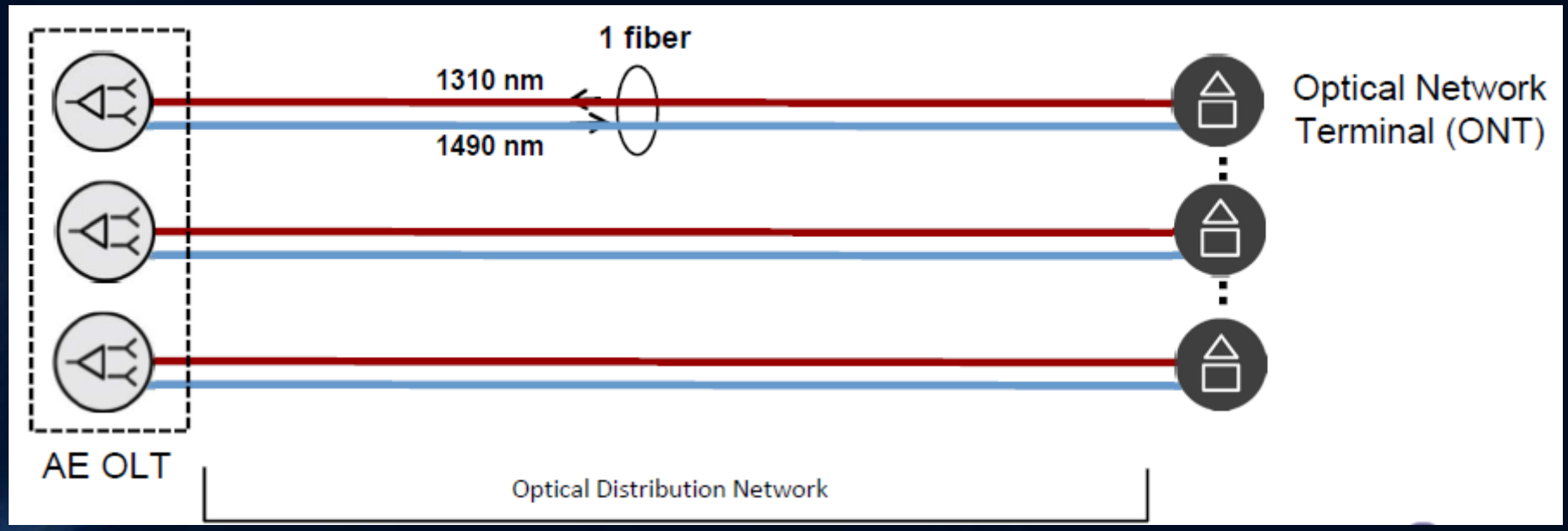
Calix ODC-200 showing service and management compartments

Vault or Handhole

ONT housing w/o ONT installed

Active Ethernet (IEEE 802.3) Architecture

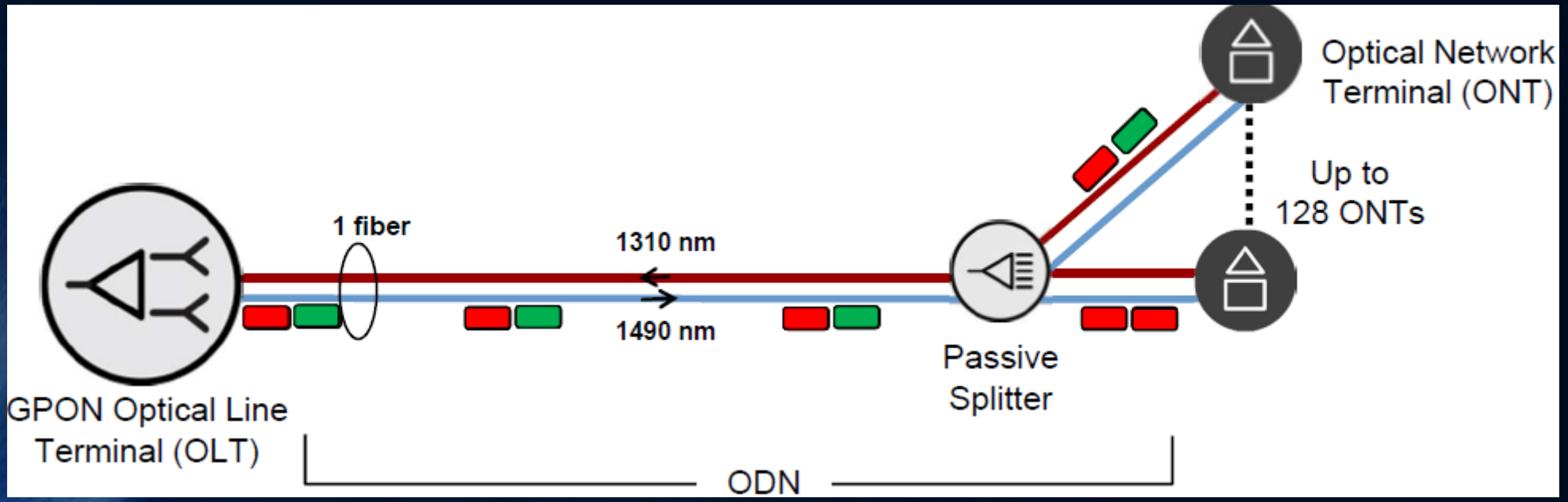
- Dedicated data rates of 10/100/1000 Mb/s upstream/downstream (symmetrical)
- Requires a point-to-point fiber topology; a fiber rich OSP deployment
- 10 to 60 km distance limitation
- A 10 Gb/s connection to a subscriber is possible provided there was an appropriate port on the Ethernet router.



Courtesy of Calix

G-PON (ITU G-984) Architecture

- Data rates up to 2.488 Gb/s downstream and 1.244 Gb/s upstream.
- This standard allows for a maximum of a 128 way split (128 subscribers on a G-PON port).
- The common split deployed is a 32 way split
- 20 to 35 km distance limitation (B+, C+, C++ optics) from OLT to ONT
- With 32 subscribers on a G-PON port (shared medium) each subscriber could receive sustainable bandwidth of approximately 80/40 Mb/s upstream/downstream.
- Supports encrypted transmission in the downstream direction, such as the Advanced Encryption Standard or AES

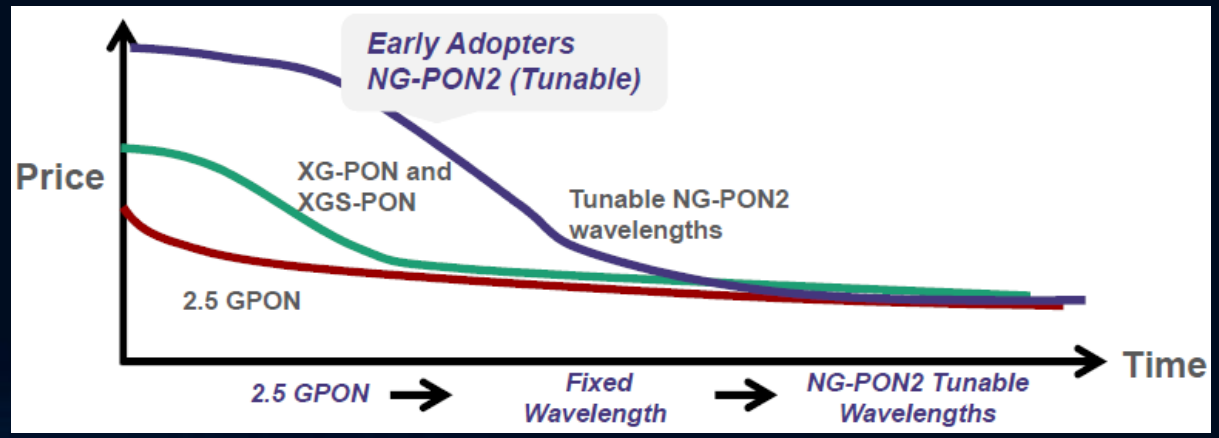


Courtesy of Calix

Next Generation PON Standards

Standard	Bandwidth Option	Primary Focus
XG-PON1 (ITU G.987)	10G Down 2.5G Up	10/10 MDU and Business
NG-PON2 (ITU G.989)	4 to 8 x 10G TDM Down 4 to 8 x 2.5G or 10G TDM Up 8 P2P Up and Down @ 100GHz	Residential/Business/MDU
XGS-PON (G.9807.1)	10G Down 10G Up	Business/MDU

- Next Gen standards can coexist with previous standards utilizing different wavelengths up/down (e.g. 1577nm Down/1270nm Up)
- Dates and pricing based on how fast market and applications develop



Courtesy of Calix

G-PON and Active Ethernet

Both Great Access Technologies

G-PON is more flexible, lower cost to deploy

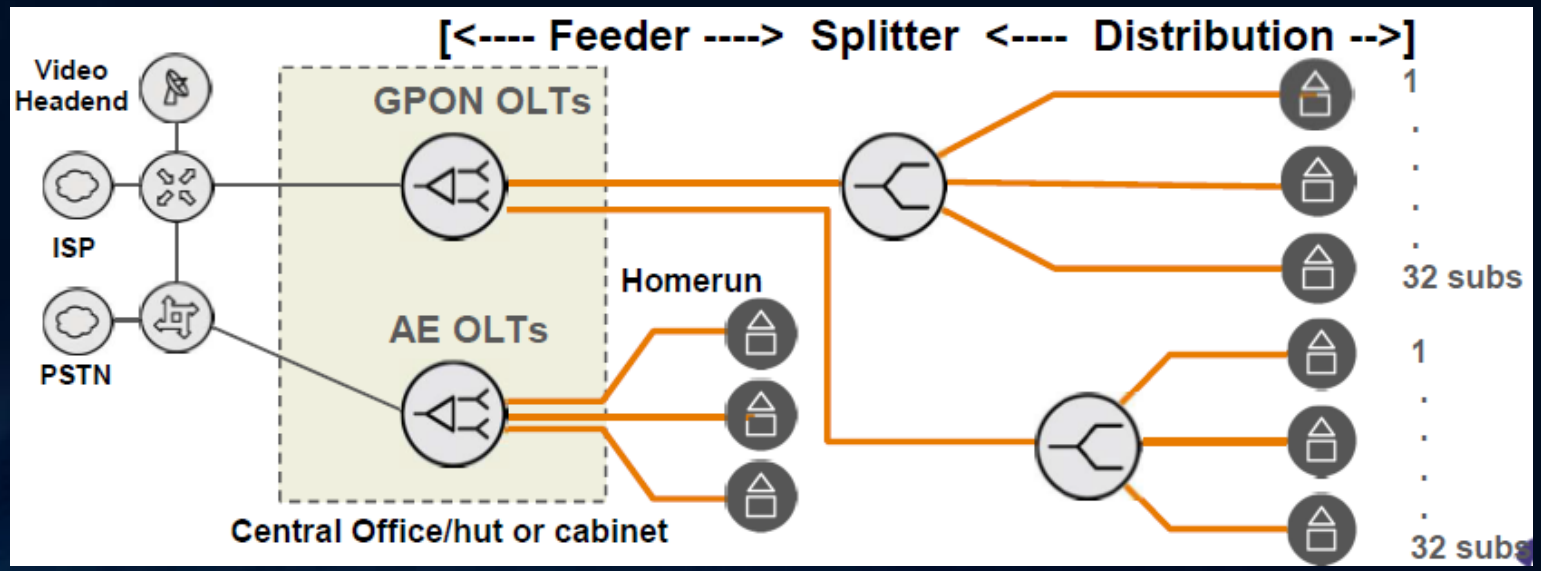
- 2.5 Gb/s of shared bandwidth
- Can be home-run with splitter in CO/Hut or splitter in the field (P2MP)
- Can be deployed in areas with limited fiber cable
- Optical reach is out to 35 km
- Great port/subscriber density – 256 subscribers/8-port G-PON card
- Consumes less CO space and 1/3 as much power

AE has higher, dedicated bandwidth

- Delivers up to 1 Gb/s to every home and business served
- P2P fiber topology required
- Symmetrical bandwidth better suited for high bit-rate services (100 Mb/s+) to medium and large businesses
- Optical reach out to 60 km
- Consumes more CO space and power than G-PON

Outside Plant (OSP) is Key

- G-PON fiber requirement is skinny in the "feeder" portion – 1 fiber/PON
- Preferred approach for both GPON and AE is a home-run topology
- Home-run fiber topology allows
  - Full-fill on PON OLT
  - Easy migration to AE when and if needed
- The cost of FTTH OSP is in the construction, not the fiber strands
- With field splitters "beef up" feeder count for as-needed AE subscribers



Courtesy of Calix

Applications

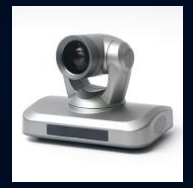
Desktop Computer

Analog Phone

VoIP Phone

WiFi Access Point

Surveillance Camera

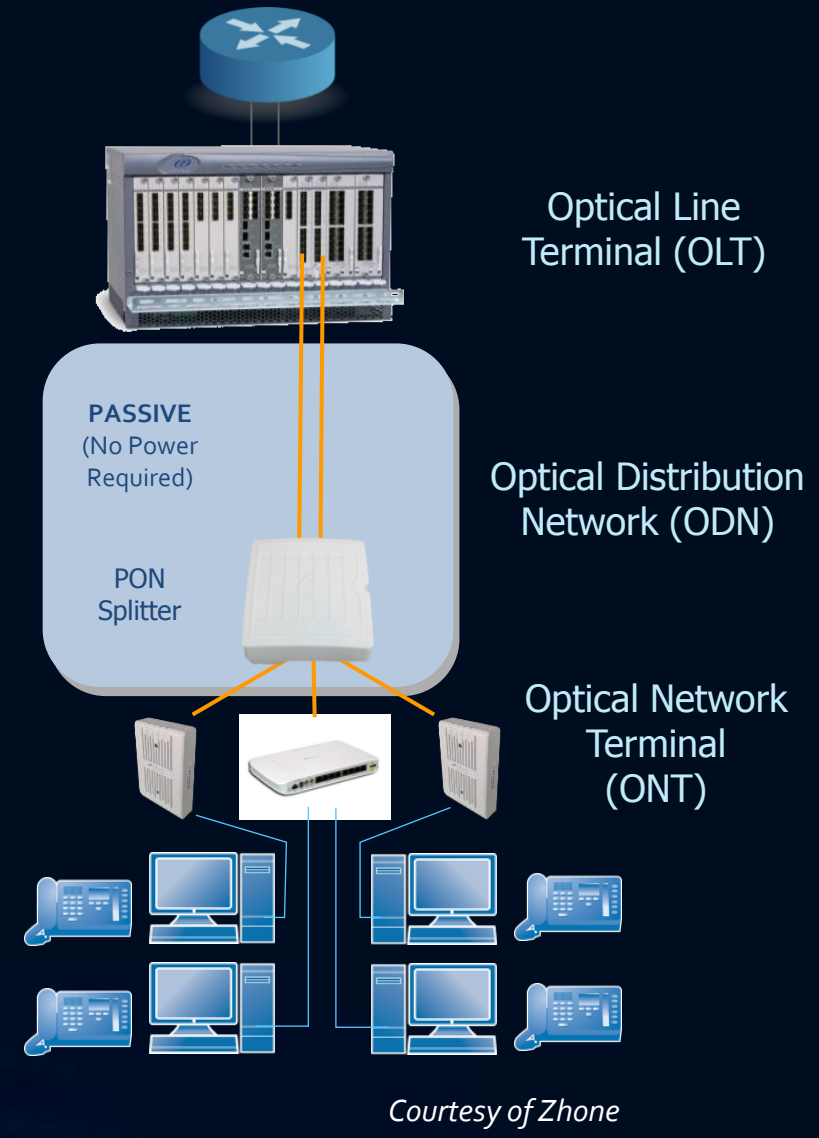


Video Conferencing

Analog / Digital Video

Sensors / Monitoring

Passive Optic Network (PON)



Courtesy of Zhone

Radio Access Options for Fixed Wireless

Point to Multipoint vs. Point to Point

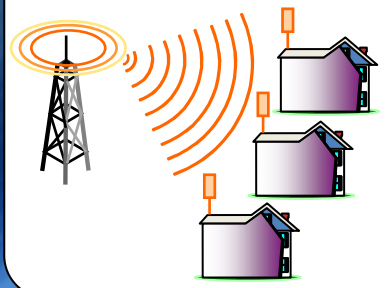
Description:

- The most common Fixed Wireless setup is a "Point to Multipoint" network where customer equipment receives a signal propagated over a wide area from a tower
- However, dedicated Point-to-Point links can be used as an alternative and can provide higher throughput

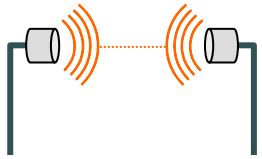
Equipment:

- Point to Point requires more advanced equipment at the customer site than Point-to-Multipoint
- Installations are more complex, requiring exact alignment

Point to Multipoint



Point to Point



Base Station Antennas

Line of Sight vs. Non-Line of Sight

Description:

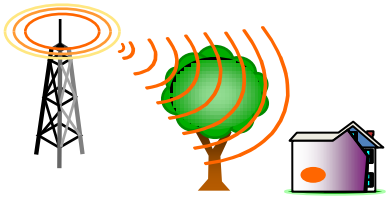
- Fixed Wireless signals may be obstructed by topography, trees, and buildings
- Solutions which require clear sight of the base station are termed Line of Sight (LOS)
- Solutions which can tolerate some obstruction are termed Non Line of Sight (NLOS)
- NLOS is best at lower frequencies (e.g. 900MHz)
- Fixed Wireless providers can use a mix of NLOS and LOS antennas to cover an entire town

Equipment:

- LOS deployments generally require external CPE

Line of Sight

Non-Line of Sight



Last Mile Fixed Wireless

Due to the nature of the terrain and canopy density in western Massachusetts, it is rather difficult for wireless systems to penetrate certain areas.

- Common Fixed Wireless Bands
  - 2.4Ghz – LOS or "soft obstacles", allows for modest foliage penetration
  - 5Ghz – LOS, easily blocked by hills and foliage.
  - TVWS – Frequencies made available for unlicensed use at locations where the spectrum is not being used by licensed services, such as television broadcasting. NLOS, superior foliage penetration, low throughput.
- Channel Width - a.k.a. bandwidth, represents an entire range of frequencies used by the carrier radio to transfer data. The larger the channel width, the greater the potential for throughput.

Base Station/AP	Band	Throughput	Channel Width	No. Subs.
Mimosa A5-360	5Ghz	1Gbps	20/40/80 Mhz	53
Cambrium ePMP	5Ghz	220Mbps	40Mhz	53
Ubiquiti Rocket M5	5Ghz	150+Mbps	40Mhz	53
Ubiquiti Rocket R5-AC	5Ghz	500+Mbps	80Mhz	53
Cambrium PMP450	2.4Ghz	125Mbps	40Mhz	60
Ubiquiti Rocket M2	2.4Ghz	150+Mbps ad	40mhz	60
Carlson RuralConnect 3G	TVWS	12Mbps	6Mhz	60
6Harmonics GWS	TVWS	26Mbps	8Mhz	60