Finley Engineering Company, Inc.
FTTP OSP Design Considerations
Memphis, Tennessee
May 5, 2008

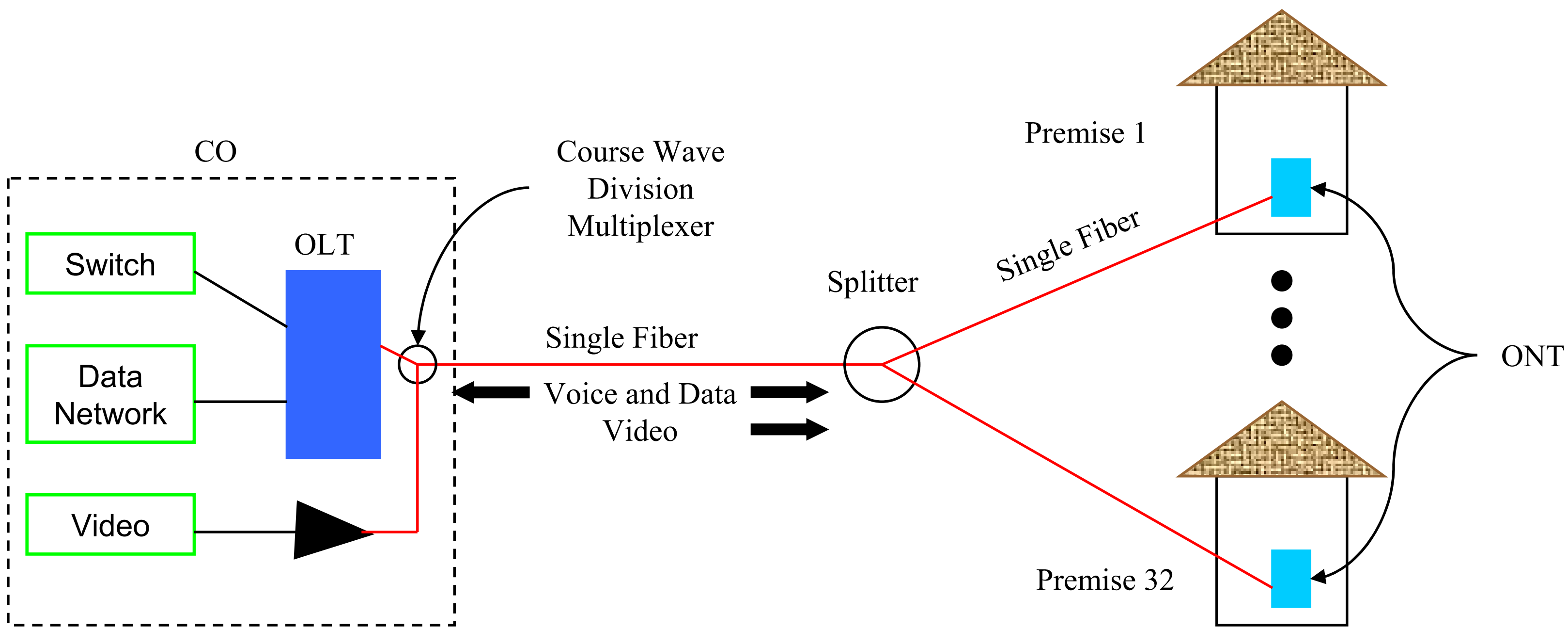
Presented by:
Dean Mischke, P.E.

Design Considerations

- Fiber Design
  - Terms
  - Standards
  - Network Architecture
- Fiber Sizing and Assignment Issues
- Ribbon Cable in FTTP Designs
- Loose Tube Cable in FTTP Designs
- PON Splitter Cabinet Sizing

Terms

- PON: Passive Optical Network is defined as any optical network where the active components are limited to the Central Office and Customer Premise.
- Splitter: Optical device that divides (downstream) and combines (upstream) a single optical source to multiple destinations. In FTTP networks, this device is passive in that it does not require power.
- OLT: Optical Line Terminal – Active optical to electrical unit at the CO.
- ONT: Optical Network Terminal – Active optical to electrical unit at the premise.



Standards Bodies

- International Telecommunications Union (ITU) http://www.itu.int: A global standards body based in Geneva, Switzerland with significant influence in the European Union and Asia. This body is becoming the defacto standard claiming 191 member states, including the U.S.
- IEEE http://ieee.org: Previously known as the Institute of Electrical and Electronic Engineers. Originally started out as an association of Professional Engineers; however, they have branched into a global standards body that many companies and countries adhere to.
- Full Service Access Networks (FSAN) http://www.fsanweb.org: FSAN is comprised of over 15 Operator Companies including Qwest, BT, Bell Canada, NT, etc. and 36 Member Companies including Adtran, Calix, Tellabs, etc. FSAN began with a group of Operator Companies looking for a FTTP PON solution before ITU and IEEE were able to publish their standards. Many of the FSAN Standards were adopted by the final ITU standards.

PON Types

- APON: Asynchronous Transfer Mode PON uses an ATM-based 53-byte cell to transfer data.
  - Initial offering 155.52 Mbps Downstream, 155.52 Mbps Upstream
- BPON: Broadband PON based on the APON architecture.
  - Initial offering 155 Mbps Downstream, 155 Mbps Upstream
    - Ratified in 1998 by ITU 983.1
  - 622.08 Mbps Downstream, 155.52 Mbps Upstream
    - Ratified in 2000 by ITU 983.2
  - 1.2 Gbps Downstream (Added Jan. 2003)
    - Ratified in 2003 by ITU 984.1 through 3
  - Strong encryption implemented to improve security and prevent "eavesdropping"

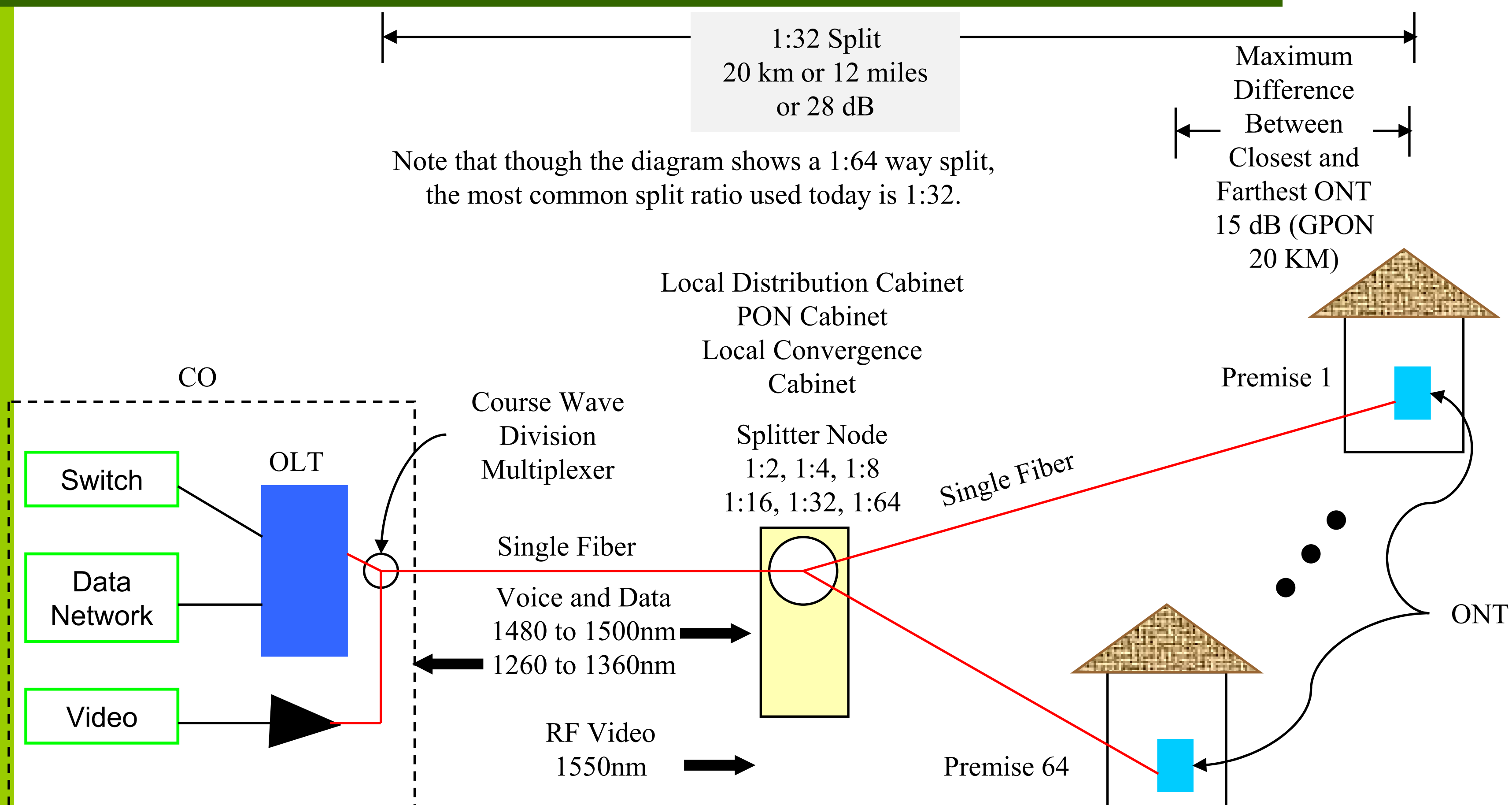
PON Types

- EPON: IEEE's 802.3ah standard for Ethernet PON uses IP-based protocol to transfer data.
  - 100 Mbps Symmetrical
- GPON: Gigabit Passive Optical Network is a PON architecture that uses IP-based protocols to transfer data. ITU's 984.1, .2, and .3 standard for GPON ratified in 2004 and Amendment 1 ratified in 2006.
  - 1.244 Gbps and 2.488 Downstream
  - 155.52, 622.05 Mbps, 1.244 Gbps and 2.488 Upstream
  - Compatible with BPON architecture
  - System will support network redundancy
  - Vendor OLT and ONT interoperability is a key goal

FSAN Standards

- The following standards apply for APON and GPON
  - Fiber loop length limited to 20 km between OLT and ONT.
  - System will support from 2 to 64 splits within the 20 km in any increments or combinations (1:2, 1:4, 1:8, 1:16, 1:32, 1:64). Most designs are based on a 32-way split.
  - Total optical budget is 30 dB. **NOTE: ITU G.984.2 Amendment 1 limits this to 28 dB.**
  - Maximum difference in optical budget between the first ONT and the last ONT is 20 dB, although many manufacturers can now support a higher optical budget difference.
  - Video is an analog overlay to the digital voice and data.
  - Voice and Data downstream transmission is 1480 to 1500nm.
  - Voice and Data upstream is 1260 to 1360nm.
  - Analog Video overlay on a single fiber system for downstream is 1550nm.

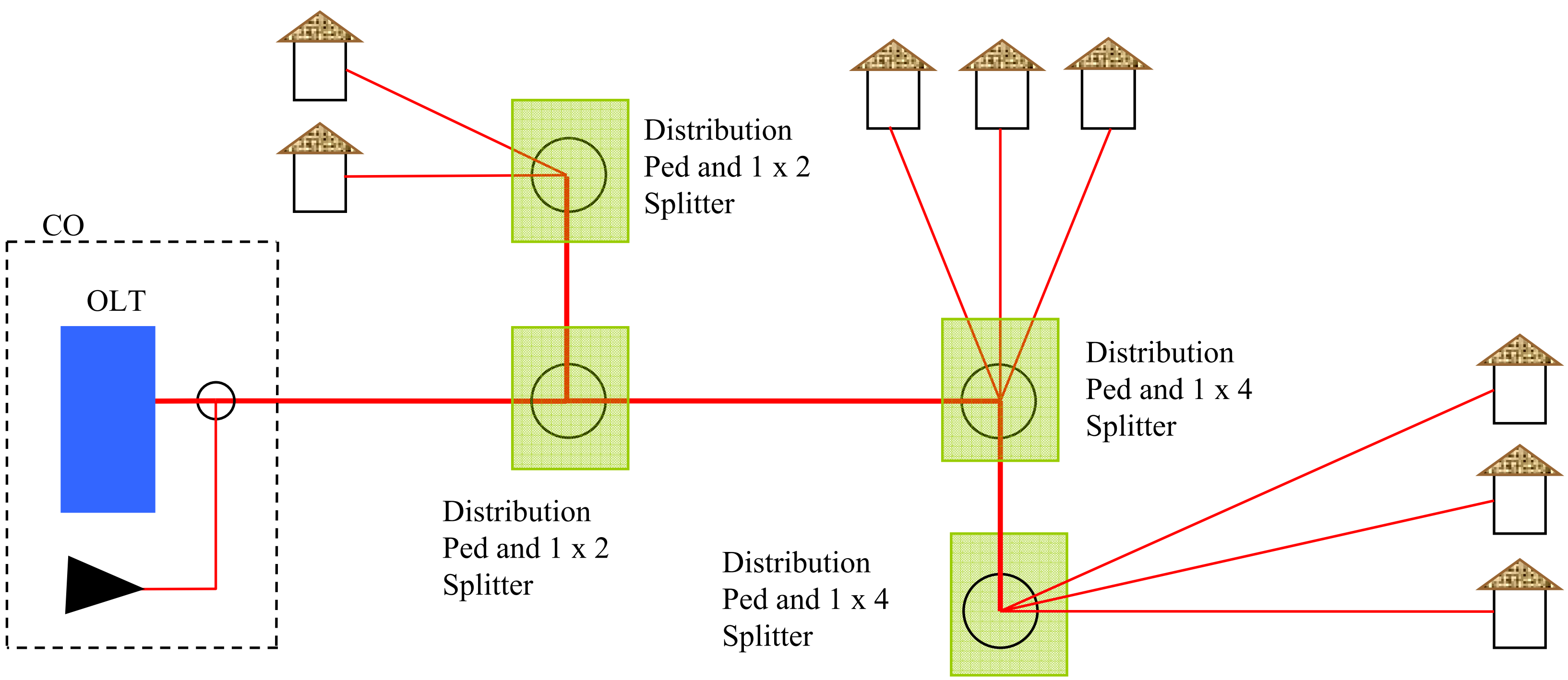
FSAN Standards



ITU Standards G.984.2

- ITU G.984.2 Amendment 1 Industry Best Practice for 2.488 Gbps Downstream and 1.244 Gbps Upstream
  - Document Download Site http://www.itu.int/publications/default.aspx
  - Design Link Budgets are now set as midway between the Class B (26 dB) and Class C (31 dB) budgets in the original G.984.2 Standard:
    - 1490nm Optical Budget is 28 dB
    - 1310nm Optical Budget is 28 dB
    - Includes all optical components between ONT and OLT
    - 1550nm budget is dependent on the RF Optical Transceivers
  - OLT must support Forward Error Correction in the downstream
- Amendment 2 is Pending

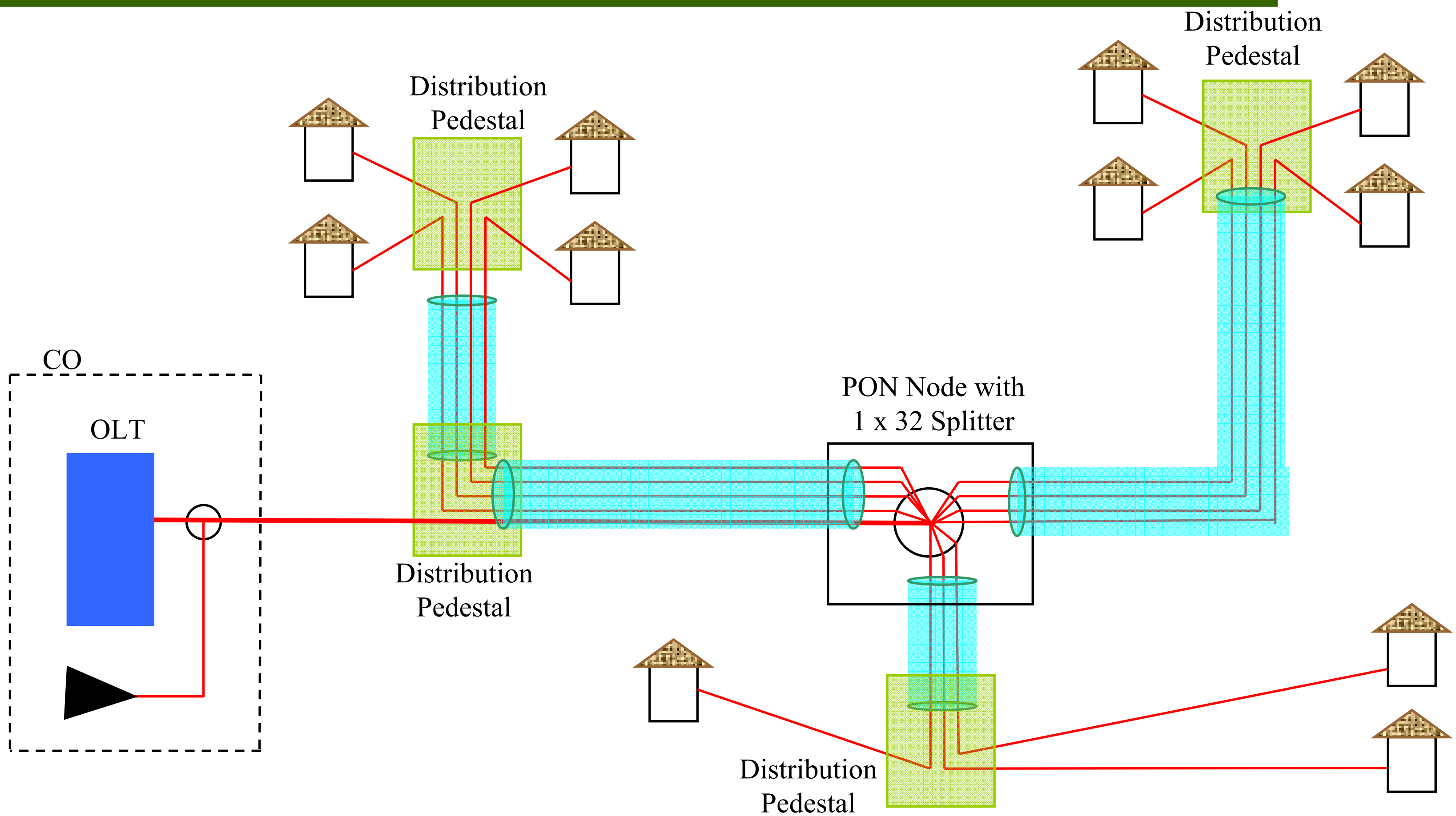
Distributed Splitter Network



Distributed Splitter Network

- Advantages
  - Lower cost in applications with high fiber utilization
  - Slightly lower fiber count in distribution network
  - Distributed splitter network can be advantageous for low density rural applications
- Disadvantages
  - Slightly higher feeder fiber count
  - Higher percentage of unused or stranded splitter/PON ports
  - Difficult to isolate sections for troubleshooting
  - Difficult to provide for future growth in an area without stranding ports on the Central Office Optical Line Terminal and splitter
  - Record keeping of fiber assignments, etc. can be complicated to maintain
  - Not adaptable to an Active system

Remote Centralized Splitter Network

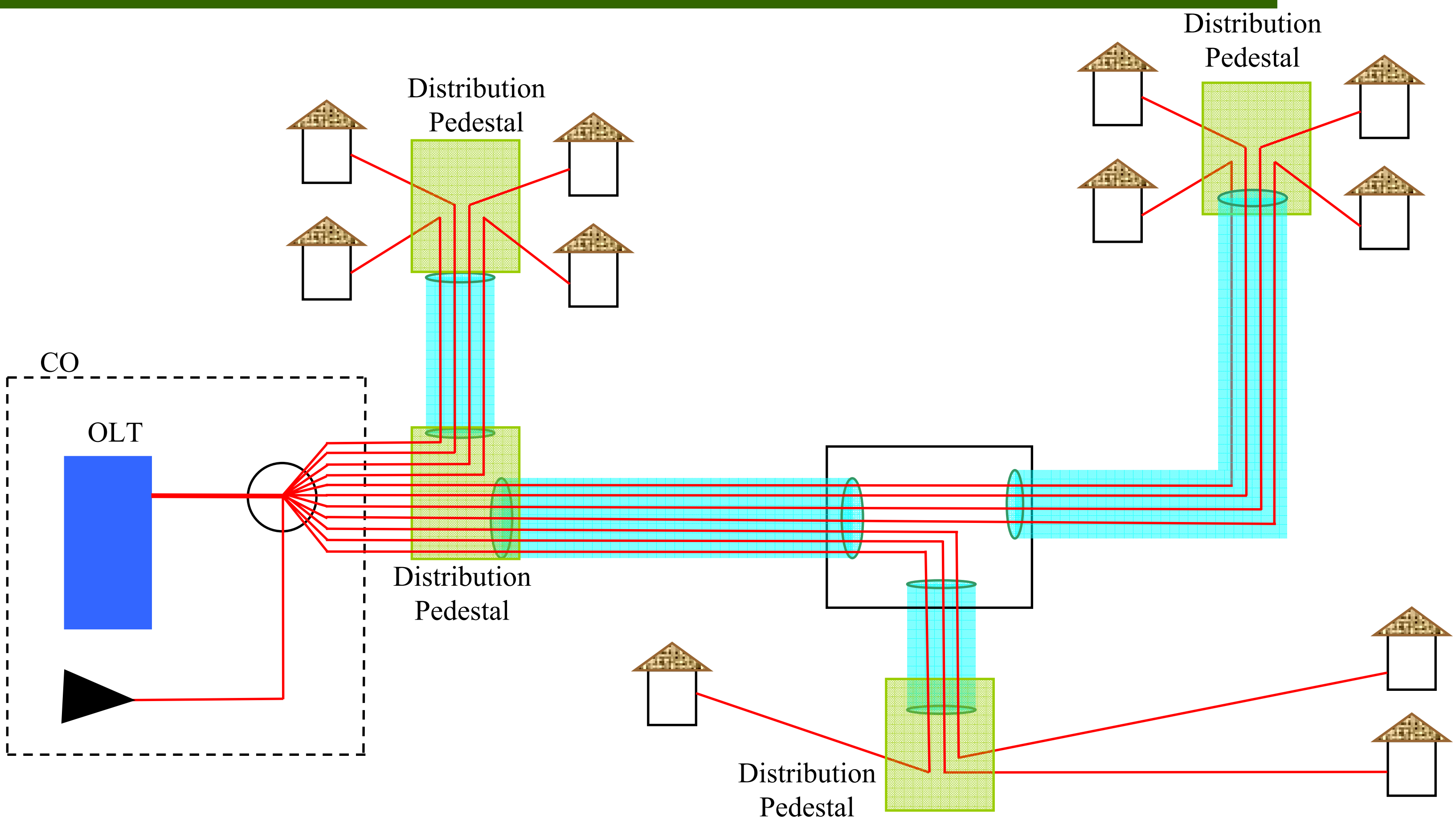


FINLEY ENGINEERING
INNOVATION TO THE NEXT POWER

Remote Centralized Splitter Network

- Generally the architecture of choice for rural and urban applications
- Advantages
  - Lower Cost in applications with low port utilization
  - Splitters are deployed only as they are needed
  - Each splitter/PON can serve a larger area
  - Slightly lower fiber count in the feeder network
  - Single start point for troubleshooting
  - Easy to adapt to growth
- Disadvantages
  - Slightly higher distribution fiber count
  - Records become slightly more difficult
  - Higher splicing costs
  - Requires power at Splitter site if the Telephone Company converts to an active system

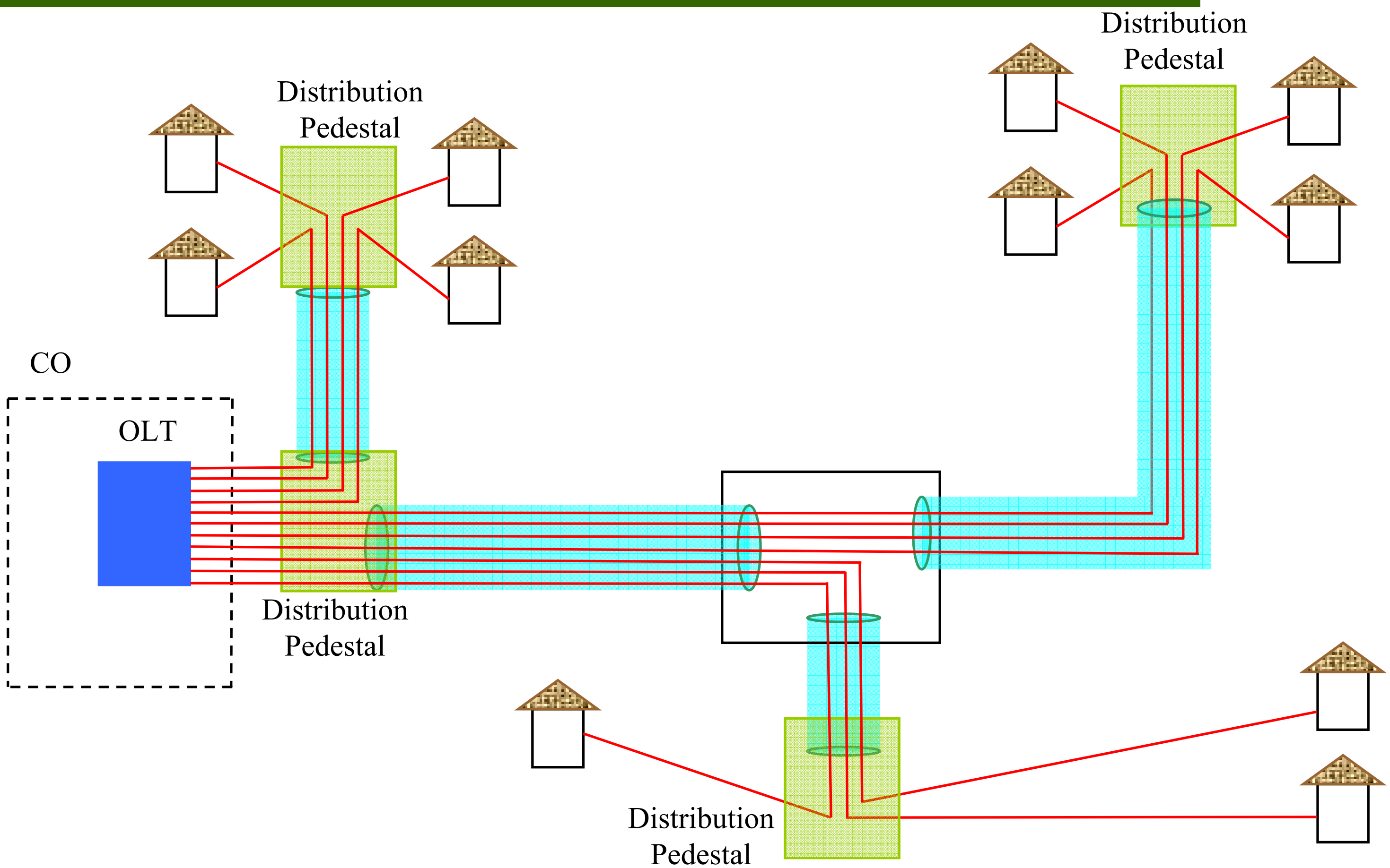
Home Run GPON Network



Home Run GPON Network

- Becoming the architecture of choice for urban applications
  - Advantages
    - Very high OLT port utilization
    - Splitters are deployed only as they are needed
    - Each splitter/PON can serve the entire serving area
    - No Splitter cabinets in the exchange
    - Single start point for troubleshooting
    - Ease of record keeping, much like copper cross connect assignments
    - Migrates to the Active Network without the need for powering in the field
  - Disadvantages
    - Approximately 10% more expensive due to higher distribution fiber count and associated splicing

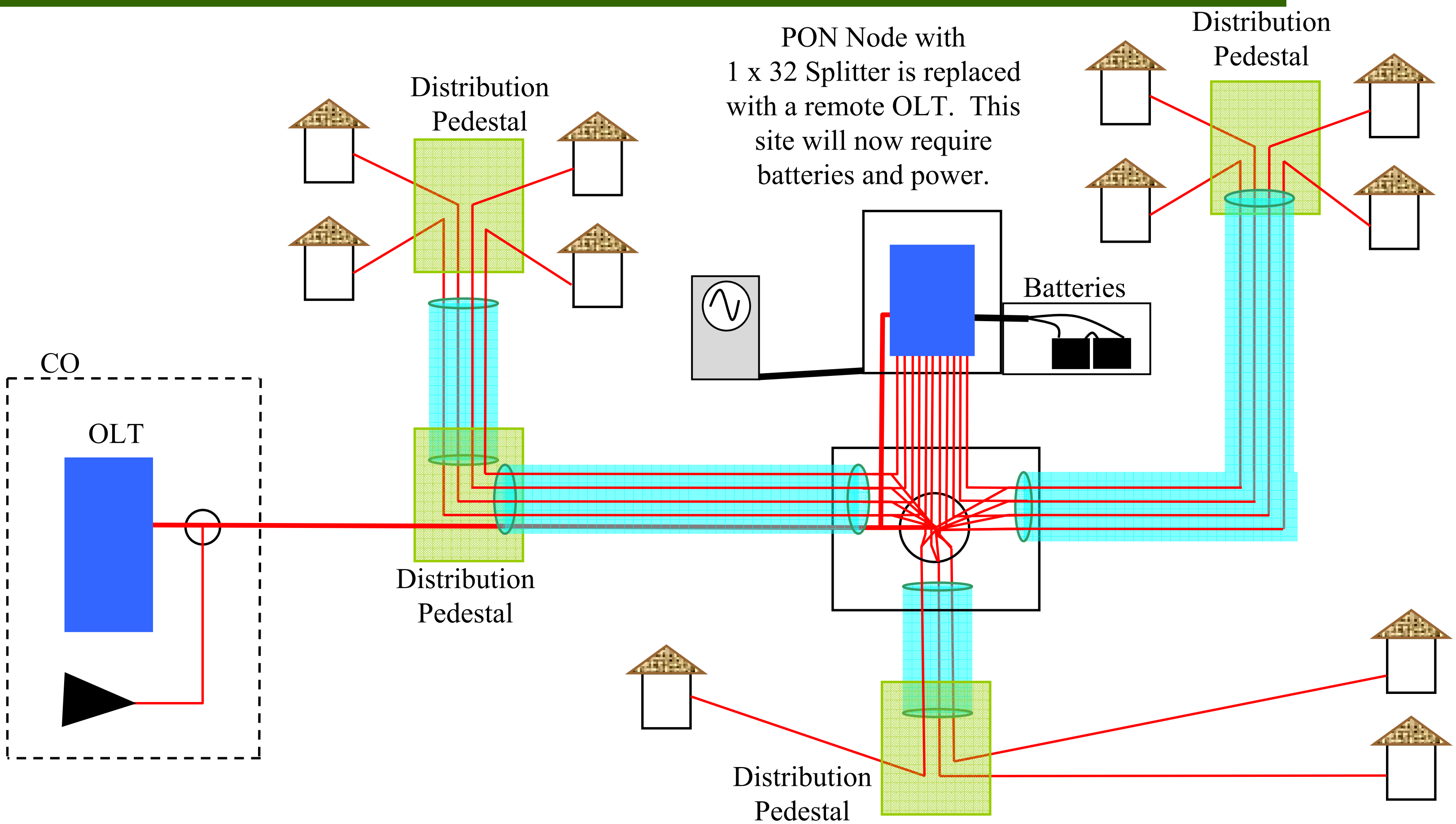
Home Run Active Network



Home Run Active Network

- Purists claim that this design is the ultimate goal of FTTP
  - Advantages
    - Dedicated OLT port for each customer
    - Eliminates the cost of Splitters
    - Single start point for troubleshooting, a fault on one customer does not affect the other customer
    - Very secure since each customer has their own dedicated fiber and optical interface
    - Ease of record keeping
  - Disadvantages
    - Cost of OLT ports can drive the cost up an additional 10 to 20% for electronics

Evolution of the Remote Centralized Splitter Network To Active



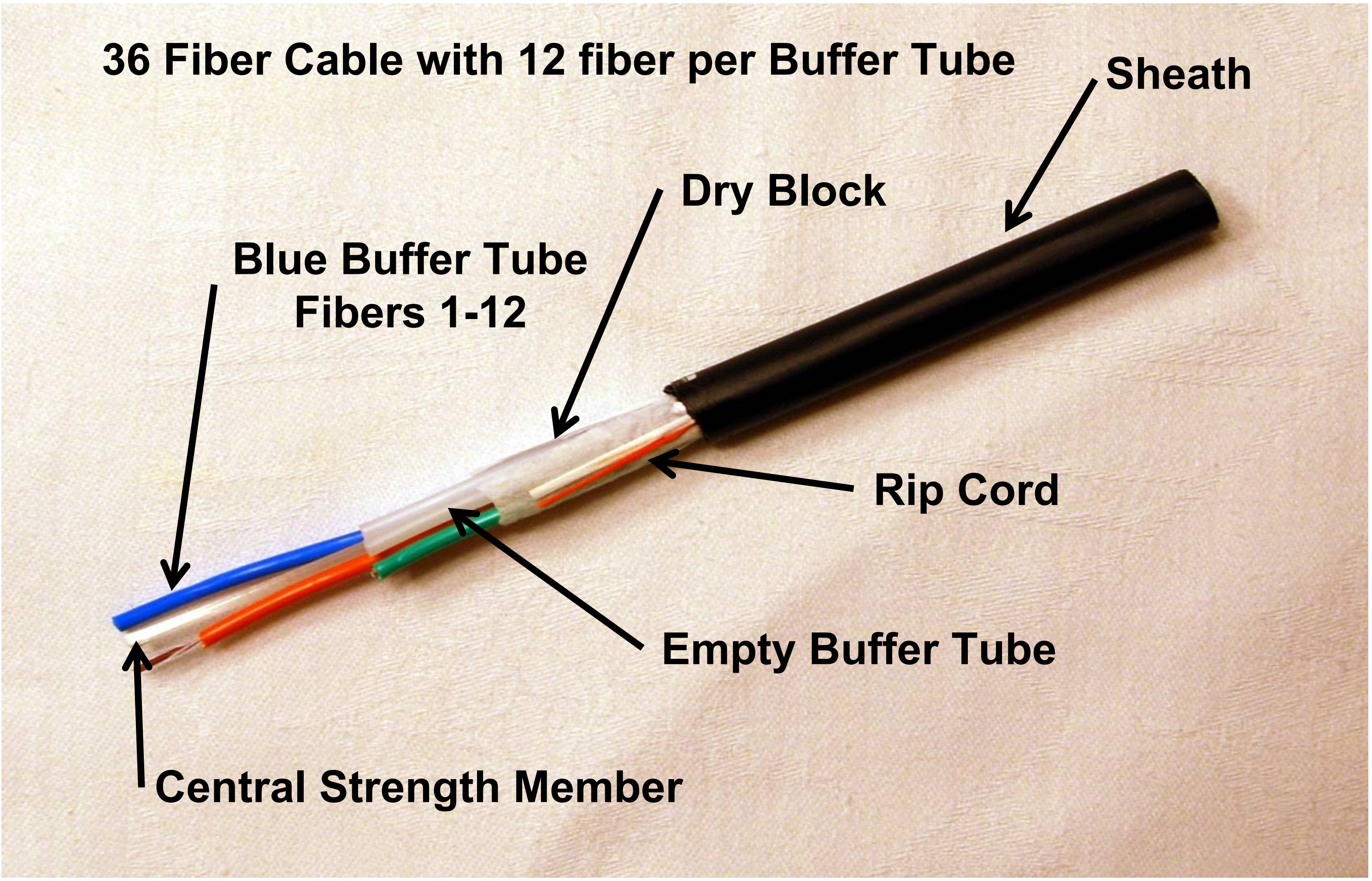
Overall Design Considerations

- Prepare a written "Design Criteria" for each project
- Electronics products will come and go
  - Do not design to the electronics
- The fiber design will need to last at least 20 to 40 years
  - Do not take any shortcuts on the design. They will come back to haunt you.
  - The design should allow for the possibility of an Active FTTP system in the future.
  - If you need to extend the reach of an FTTP design, the first area to look at is eliminating the ability to do RF Video.
- An urban cable mile may be 17 to 20% longer than a route mile if you are using slack storage under the splice pedestals
- A rural cable mile may be 10% longer than a route mile

Overall Design Considerations

- Design Considerations
  - Standard Fiber sizes 864, 576, 432, 288, 144, 96, 72, 48, 36, and 24 fiber. Limit 12 fiber to drops only. Very rural – whatever it takes to make it work.
  - Delay changes to a smaller size cable to junction points as splicing costs quickly erode any savings the smaller size provides.
  - Limited taper points also help future proof the design.
  - 144 Fiber appears to be the practical limit for the size of cable that will fit in most distribution pedestals. Some may splice up to 72 fiber.
  - Limit the number of pedestals where you enter the same buffer tube to three pedestals or less if practical.
  - Only cut the fibers needed at any given pedestal.
  - Express all spare fiber to the end of the line where practical.

Loose Tube Cable in FTTP

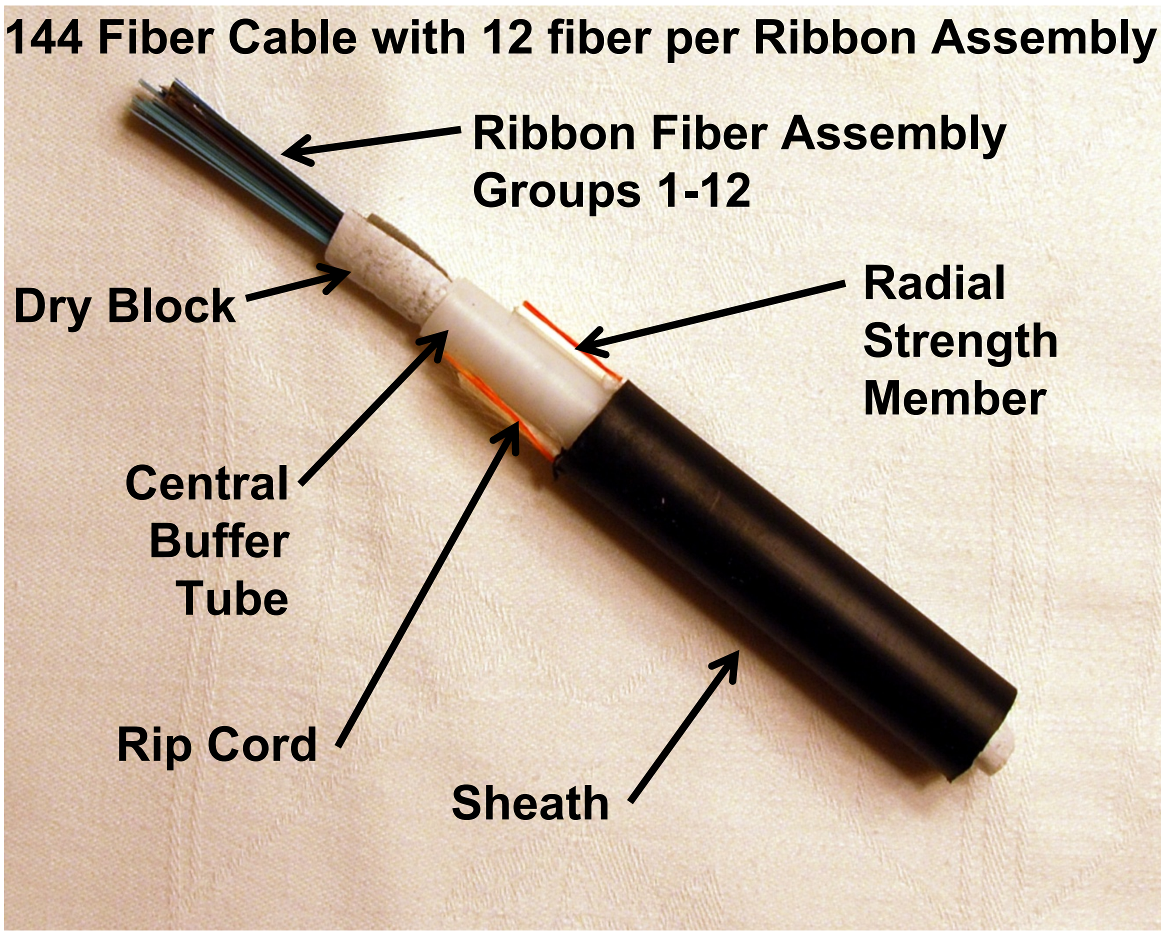


Loose Tube Cable in FTTP

- Advantages:
  - Proven Technology
  - Many companies already have splicing tools
  - Lower cost for fibers below 144 Fiber
  - Ease of access to individual fibers
  - Fibers not accessed can remain in the buffer tube providing a measure of protection – important in splice pedestals
- Disadvantages
  - Available in sizes only up to 432 Fiber
  - Cable becomes very large for sizes over 288 fiber
  - Restoration can take longer for large count cables
  - Buffer tube storage can be an issue in large count cables
  - Need to pay attention to buffer tube storage in cold weather

FINLEY ENGINEERING
INNOVATION TO THE NEXT POWER

Ribbon Cable in FTTP



Ribbon Cable in FTTP

- Advantages:
  - Proven Technology
  - Lower cost for cables 144 fiber and larger
  - Ease of access to individual fibers
  - Faster restoration of large count cable once the preparation work is complete
  - Large count cables will fit in a smaller duct than the same sized Loose Tube
  - Higher fiber count in a splice tray
- Disadvantages
  - More difficult to store pass-through fiber in a ped or splice case
  - Fiber more exposed when pass-through fibers are stored in a splice ped
  - Ribbon is less tolerant to physical damage than loose tube
  - Some Manufacturers have concerns regarding using a Figure-Eight Machine during installation

Overall PON Cabinet Criteria

- Many Names:
  - Local Distribution Cabinet
  - Fiber Termination Cabinet
  - Local Convergence Cabinet
  - Fiber Cross-Connect Cabinet
  - Fiber Distribution Cabinet
  - Other???

Overall PON Cabinet Criteria

- Telcordia Compliance: (GR-326, GR-449, GR-487, GR-1209, GR-1221)
- USDA Listed
- Ease of access to the back of the patch panel for repairs or cleaning
- Splitter modules are consistent from one cabinet size to the next
- Contains adequate space for spare splitter port parking
- Contains provisions to allow for express fibers to a customer
- Growth
  - It is easy to add more patch panels and splitters in the future
  - Is it possible to convert the cabinet to support an active node

FINLEY ENGINEERING
INNOVATION TO THE NEXT POWER

Overall PON Cabinet Criteria

- Splicing within the cabinet
  - Saves space and eliminates the cost of a separate splice cabinet or splice case
  - Does not eliminate cable slack storage
  - Easy access for alterations and additions
  - May be less expensive than external splicing
- External Splicing
  - Splice can be stored below ground away from traffic
  - Depending on manufacturer, the cabinet may be less expensive
  - May simplify replacing a damaged splice cabinet
  - More difficult to access fibers for troubleshooting or additions
- Jumper Management and Bend Radius
  - Look to make sure the cabinet is well laid out with sufficient routing guidelines
  - Does the cabinet maintain proper bend radius

PON Splitter Cabinet Sizing

- Sizes available: 32 Fiber (1 Splitter) to 864 Fiber (Home Run and Centralized Local Distribution Cabinet)
- Sizing will be dependent on rural or urban applications
- Specific cabinet sizing is a trade off between size of the distribution area and number of cabinets
  - Rural areas: Serving areas tend to get too large well before the ideal cabinet size is reached
  - Urban areas: Due to the density, the number of fibers can exceed the available cabinet sizes before the serving areas become unmanageable

FINLEY ENGINEERING
INNOVATION TO THE NEXT POWER

PON Splitter Cabinet Sizing

- The best balance is to size the serving area between 384 fiber and 576 fibers
  - Smaller sizes mean more sites with a greater number of partially filled splitter ports
  - Need to leave room to allow the site to grow if there is significant growth in the serving area
  - Order a larger cabinet than what you need - the difference in cost of the shell is typically relatively small
    - Only populate the number of patch panels that you need for the immediate future
  - Size the feeder fiber to support a 1 x 16 split in the future

FINLEY ENGINEERING

INNOVATION TO THE NEXT POWER

Thank You

References

- www.fsanweb.org
- www.itu.org
- www.ponforum.org
- www.ieee.org