AFCS Application

FTTP PON Fiber to the Premises and Passive Optical Networks

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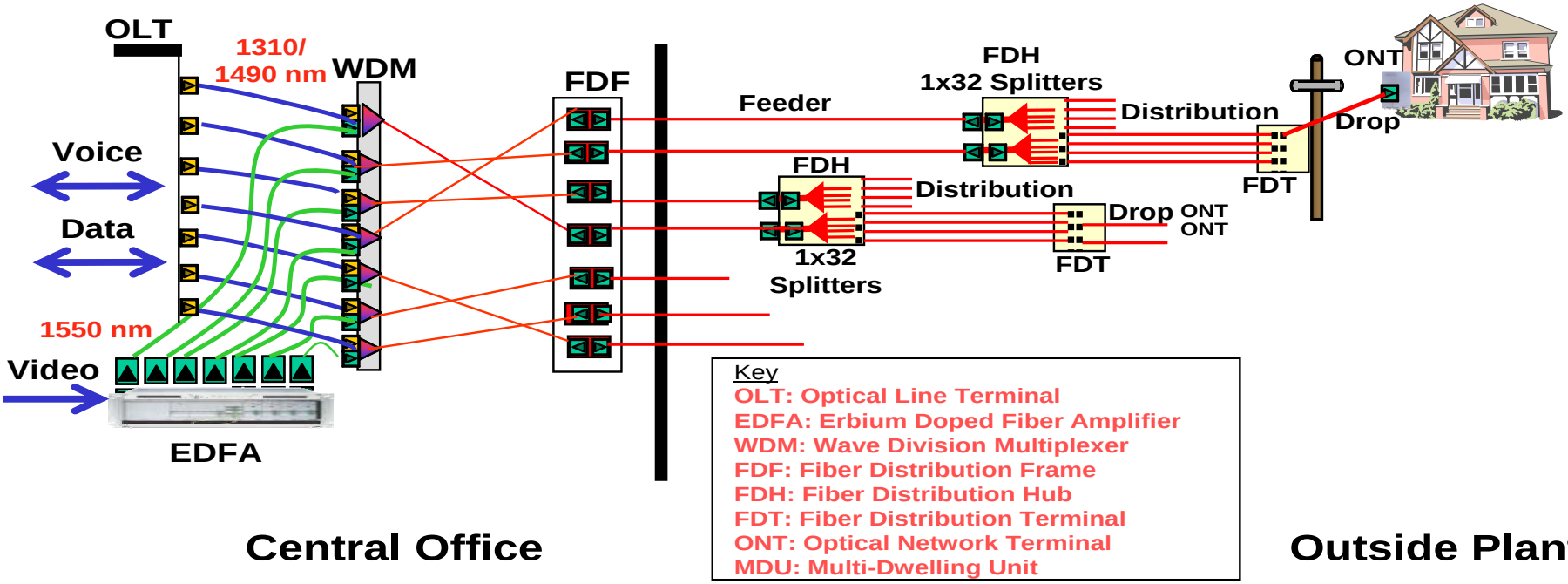
Basic Description

- Background on FTTP PONs
  - FTTP is the prominent technology in the access networks of many carriers.
  - The dominant FTTP design is a PON architecture with passive optical splitters. Splitters allow sharing of facilities by multiple customers.
  - Splitters can be deployed in a single stage (centralized design) or multiple stages (distributed design). Optical splitters can be included either within an Exchange (Central Office) or in a Fiber Distribution Hub (FDH).

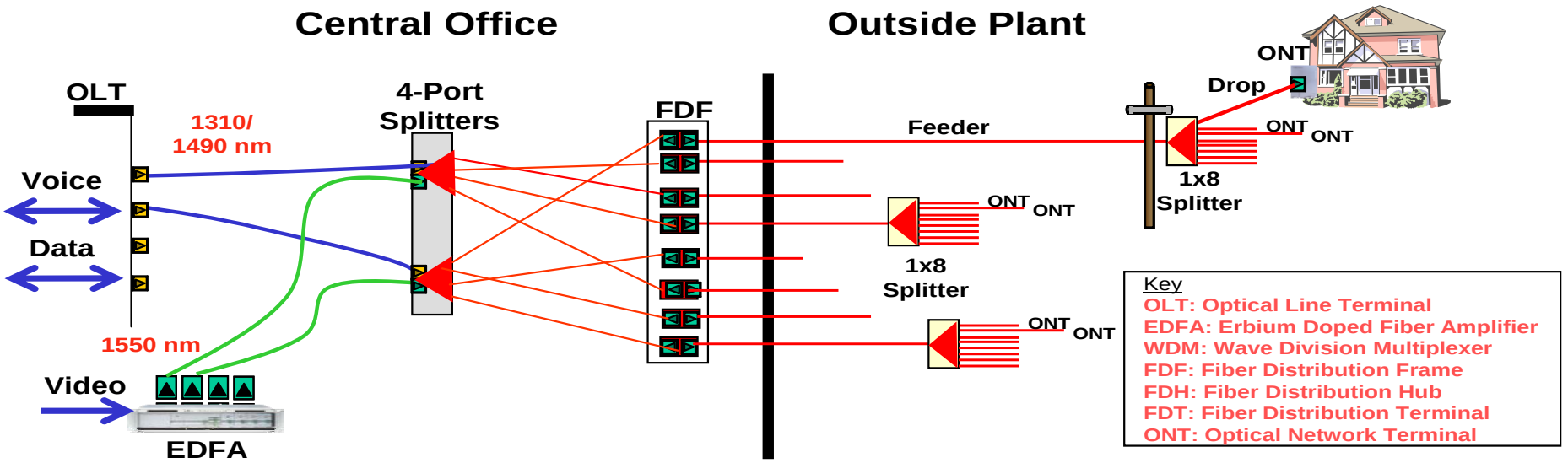
Basic Description

- Optical Switches in FTTP PONs
  - Optical switches enhance the benefits of FTTP by automating a number of work functions in the operation of an FTTP network.
  - Optical switches can automate fiber cross connections and rearrangements and enable fiber protection and restoration.
  - When interfaced to fiber test equipment, optical switches can provide remote fiber testing, monitoring and trouble shooting.
  - These applications reduce costs and improve service quality and are possible with both central and distributed PONs.

Current FTTP Architecture: Centralized Splitting



Current FTTP Architecture: Distributed Splitting



Present Mode of Operation – Network Creation

- Fibers are Placed, Tested and Connected
  - Optical losses and reflections are measured to insure they meet engineering specifications prior to acceptance of contract completion and payment.
  - After testing, cross connections at the Fiber Distribution Frame (FDF) are made between the fibers from the CO to the outside plant feeder fiber.
- Testing of Distribution Fiber
  - For one way testing, the technician travels to the FDH with an OTDR. A distribution fiber is connected, the test is conducted and the reading recorded. The process is repeated for each fiber until all have been tested.
  - For two way testing, one technician travels to the FDH with an Optical Power Meter and a second technician travels to the far end termination with an Optical Source. The technicians coordinate connections to a selected fiber, conduct the test and record the reading. The process is repeated for each fiber in the FDH until all have been tested and results recorded.

Present Mode of Operation – Network Creation

- Testing of Feeder Fiber
  - Feeder fiber testing is similar but conducted from the Central Office. For two way testing, a second technician will test toward the CO from each FDH.
  - Splitter testing: If a new splitter is required to be added, bidirectional loss tests are typically performed requiring two technicians.

Present Mode of Operation – Service Activation

- Establishing Service
  - The technician travels to an FDH to cross connect a splitter port and the distribution fiber to serve the new customer. The technician then goes to the serving terminal near the customer's home to place a fiber drop.
  - Occasionally, there may be errors in the assignment or cross connection. The technician must contact a Facilities Assignor to resolve the error and establish the proper connection. This can result in considerable lost time.

Present Mode of Operation – Service Activation

- Cancelling Service
  - Most service disconnects are a result of customers moving from their home. Since the new occupant may order service, connections are left in place so service turn up can occur without a dispatch to the FDH. Even if a customer moves to a competitor, the cost of winning them back plus disconnecting and reconnecting them justifies leaving the physical connection in place.
  - A splitter port occupied by a disconnected customer reduces utilization on all connected facilities and equipment from the FDH to the Central Office.

Present Mode of Operation – Maintenance

- Normal Trouble-Shooting
  - When there are physical troubles in the outside plant facilities or the CO or home electronics, multiple technicians are typically dispatched simultaneously to isolate and fix the trouble.
  - Trouble isolation can be time consuming especially if it is beyond the splitter.
- Off-hours Trouble-Shooting
  - If the trouble occurs outside of normal work hours, the restoration process will be prolonged. Technicians must travel to work, gather equipment and begin the trouble isolation and service restoration process.
  - Customers are typically out of service during this entire process.

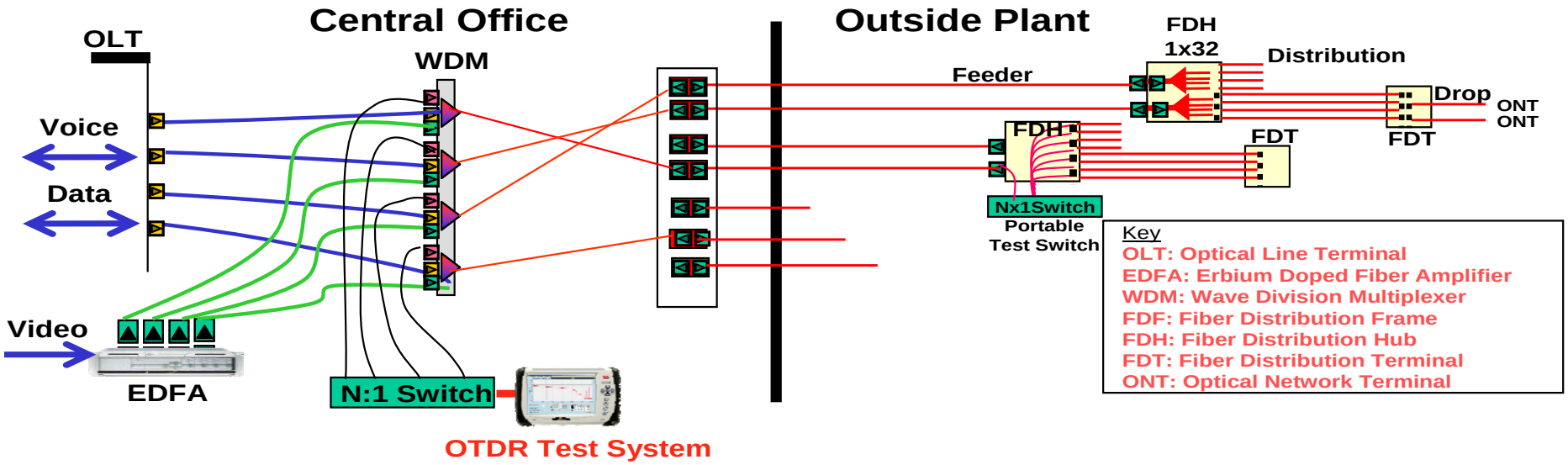
How AFCS Can Help – Network Creation

- Fiber Conformance Testing at the FDH
  - Optical switches, interfaced to OTDRs, can support conformance testing to insure the plant meets design specifications. There are four options:
    - A switch in the FDH provides automated test access to both feeder and distribution fibers. An outside FDH switch requires power and hardened electronics.
    - A small temporary switch in the FDH allows remote testing with an OTDR.
    - Locate splitters (or entire FDH) in the CO or in an environmentally controlled vault or hut. The savings from eliminating an outside FDH can offset the cost of a few thousand feet of distribution fiber and the associated costs.
    - A switch in the CO with specialized OTDRs or/and software can “look through” a splitter. This allows fully centralized testing and monitoring of the PON.

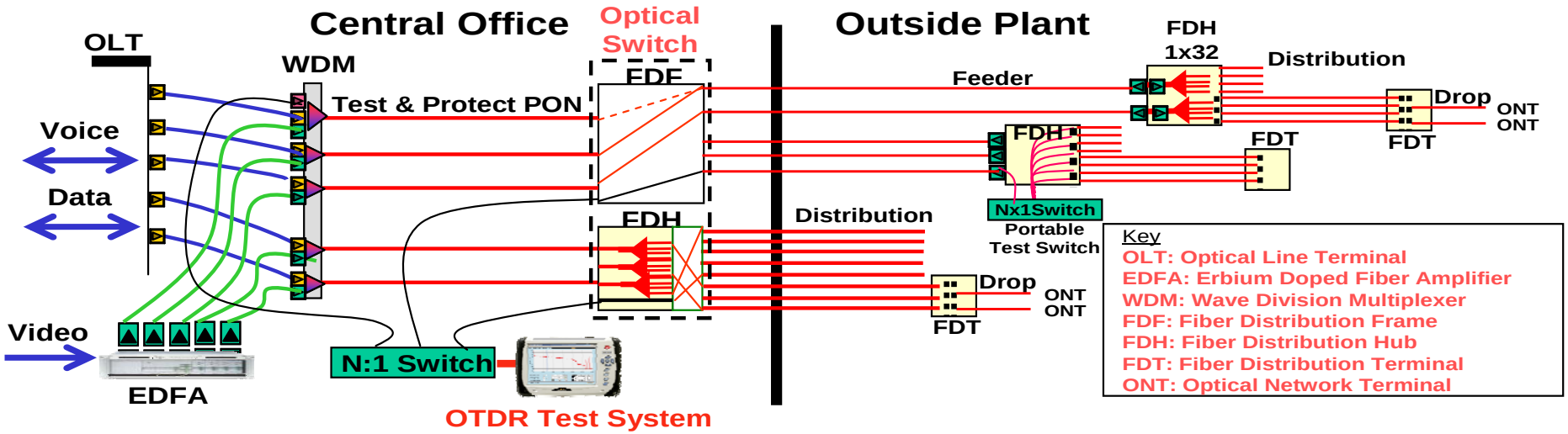
How AFCS Can Help – Network Creation

- FDF Cross-Connections
  - An optical switch can also automate the FDF cross connections.
  - This will allow just in time provisioning of FTTP capacity out to the FDH as service demand requires. The FDF switch can also facilitate access to the centralized OTDR for remote test access.

Optical Switches Used for Testing



Optical Switches Used for Cross Connects & Testing



How AFCS Can Help – Service Activation

- **FDH Cross-Connections:** An FDH optical switch automates cross connections between the splitter and distribution fiber. Automation eliminates potential human errors such as connections between incorrect connector ports, improperly cleaned connectors or creation of micro-bends when running fiber jumpers and the labor to make the connection.
- **Increased Equipment Utilization:** An FDH optical switch readily allows disconnected customers to be removed from the splitter with no incurred labor cost. This recovers stranded facilities for reuse.
- **Load Balancing PON Splitters:** An FDH optical switch also enables load balancing. As bandwidth usage increases over time, some 1x32 splitters will have too many heavy bandwidth users while others have too many low bandwidth users. An optical switch will help balance low usage and high usage customers on a splitter and avoid potential bandwidth unavailability during peak usage hours and manual customer rearrangements.

How AFCS Can Help – Service Activation

- Testing Prior to Dispatch
  - An optical switch with a remote OTDR can test a fiber to insure the assignment is correct prior to dispatching technicians for the service order installation.
  - This avoids lost time by the installation technician trying to resolve errors during the install. It also insures that the technician can remain on schedule and arrive at subsequent customer appointments on time.

How AFCS Can Help – Maintenance

- Fault Isolation
  - Optical switches, interfaced to OTDRs, can aid in fault isolation. Automated Optical Switches can provide the means to remotely test and troubleshoot problems. Isolating trouble locations saves repair technician labor and speeds service restoration by dispatching the correct technician to the fault location.
  - Automated remote testing can also be used to conduct periodic performance monitoring of the fiber to detect faults such as loose or contaminated connectors or micro-bends before they become service affecting.

How AFCS Can Help – Maintenance

- Line Card Protection
  - An FDF optical switch can also provide 1:N OLT line card protection. A standby line card can be connected to the switch. If a line card fails, the feeder connected to the failed line card would be rearranged to the standby line card. The switch would minimize service interruption. Without a switch, line card protection is not practical.
  - A failure in an unmanned CO or outside of normal working hours would result in an extended service interruption until a technician can be dispatched to the CO.
  - For select customers demanding high availability of service, a second distribution fiber can be run to a home or small business and end to end protection can be offered at Ethernet cost rather than traditional SONET costs.

Benefits of the FTTP PON Application

- Technical Benefits
  - An optical switch deployed as a fiber optic cross connection system removes the last manual bottleneck in a carrier network, the FDF. The fiber optic cross connection system adds an intelligent and flexible element.
  - Inventory databases are automatically updated and include all patchcords.
  - Inadvertent errors & contamination introduced when “hands are in the plant” are eliminated.
  - Service quality and overall reliability is improved.

Benefits of the FTTP PON Application

- Quantitative Financial Benefits
  - Quantitative financial savings for the various Network Creation, Service Activation and Maintenance applications are described.
  - Following the textual descriptions of the savings are detailed savings calculations for each of these applications. Included are the assumptions upon which the savings calculations are based.

Benefits – Network Creation Applications

- Fiber Conformance Testing at the FDH
  - Fiber testing in an FDH can take two minutes or more per fiber. A technician cleans each connector; attaches the OTDR; initiates the test; waits for the test to complete; reviews the test results; removes the OTDR; re-cleans and caps the fiber connector.
  - Depending on the FDH location, the technician may also be cramped for space. This slows down the process and results in errors. Many FDHs are located on poles, 4 to 5 meters off the ground. This can extend the test time even further.
  - Factoring in travel, set-up and miscellaneous lost productive time, a technician can spend 2+ days testing the distribution fibers from a typical FDH serving about 225 homes. The labor costs double if two technicians conduct the tests.
  - An automated FDH optical switch and remote OTDR can eliminate manual test labor. Portable FDH optical switch saves @ 50% of technician time at the FDH.

Benefits – Network Creation Applications

- FDF Cross Connections
  - A typical 15,000 household CO would have about 67 FDHs. As many as 7,500 or 50% of the households passed could be connected to the FTTP network in just five years. An average of 5 splitters would be in each FDH. Five splitters in each of the 67 FDHs would translate into 335 FDF cross connects between the WDM and feeder fibers.
  - An average cross connection would require 30 minutes to an hour of labor. An automated FDF optical switch would eliminate these labor costs.

Benefit Calculations for Network Creation

Network Creation Savings Calulations

$80	Hourly Labor Rate

Application: Fiber Conformance Testing at FDH

Assumptions:

300	Fibers per FDH
225	Households (HHs) per FDH Serving Area
2.5	Testing Time (Minutes) per Fiber
90	Setup & Travel Time (Minutes) per Day
50%	Reduced Savings if Portable FDH Switch

Savings per FDH by FDH Switch Type				
	Integrated Switch		Portable Switch	
	1 Tech	2 Techs	1 Tech	2 Techs
Hours	15.5	31.0	7.75	15.5
Total $	$1,240	$2,480	$620	$1,240
$/HH Passed	$5.5	$11.0	$2.8	$5.5

Application: FDF Cross Connections

Assumptions:

15,000	Central Office Serving Area (HHs)
225	FDH Serving Area (HHs)
67	FDHs per Central Office
50%	HHs Connected to FTTP after 5 Years
10%	Prepositioned Capacity for Growth
32	Connected HHs per Splitter
5	Active 1x32 PON Splitters per FDH
335	FDF Cross Connections per CO
30	Labor (Minutes) per Cross Connection

Savings:

$13,400	Total Savings After 5 Years per CO
$1.8	Savings per HH Connected

Benefits – Service Activation Applications

- FDH Cross Connections
  - A high volume of manual cross connections are performed in an FDH. In a 15,000 household CO, as many as 7,500 or 50% of the households passed could be connected to the FTTP network in just five years. Each cross connection requires travel and setup. Total labor time ranging from 30 minutes to an hour per cross connect would be saved with an automated FDH optical switch.
  - Automating FDH cross connects will avoid the impact of potential human errors such as connections between incorrect connector ports, improperly cleaned connectors or creation of micro-bends when running fiber jumpers. These errors reduce quality of service to subscribers.

Benefits – Service Activation Applications

- Increased Equipment Utilization
  - A splitter port occupied by a disconnected customer reduces utilization on all connected facilities and equipment from the FDH to the CO. This includes the splitter, feeder, FDF, WDM, EDFA and OLT. The installed cost for these components can easily exceed $100 per customer. Over a 10 year period, nearly 40% of facilities could be stranded based on a 25% annual churn rate.
  - With an optical switch to automate the FDH cross connects, disconnected customers can be removed from the splitter with no incurred labor cost. This reduces the capital costs for these facilities by 40% and the overall maintenance expense with 40% less facilities deployed.

Benefits – Service Activation Applications

- Load Balancing PON Splitters
  - An optical switch facilitates balancing low usage and high usage customers on a splitter. This avoids potential bandwidth unavailability during peak usage hours and manual customer rearrangements. It is difficult to speculate on long term bandwidth demand. It is reasonable to expect that in 10 years, 10% of splitters would require some customer rearrangement.
  - Factoring in time for the engineer, facility assignor and field technician, an average of four hours of labor could be spent on each splitter. This labor can be saved with an optical switch.

Benefit Calculations for Service Activation

Service Activation Savings Calulations

$80	Hourly Labor Rate

Application: FDH Cross Connections

Assumptions:

30	Time (Minutes) per Cross Connection
$40	Savings per Cross Connection
1%	Frequency of Errors per Manual Cross Connects
90	Time Lost (Minutes) Due to Cross Connect Error
$1.2	Savings per Cross Connect for Errors Avoided

Savings:

$41	Total Savings per Household Connected

Application: Increased Equipment Utilization

Assumptions:

10	Time Period (Years) of Service Availability
25%	Annual Subscriber Churn Rate
40%	Disconnected HHs on Active Splitter Ports
$130	Cost of Stranded Equipment per Disconnected HH

Savings:

$87	Total Savings Per Active Subscriber After 10 Years

Application: Load Balancing PON Splitters

Assumptions:

10	Years in Service When Load Balancing Required
10%	PON Slitters Requiring Rearrangements
4	Time (Hours) per Rearranged Splitter
32	Connected HHs per Splitter

Savings:

$1	Savings Per HH Connected

Benefits – Maintenance Applications

- Fault Isolation
  - Outside plant fiber and connector troubles are estimated to occur at the rate of 2% to 4% per year per customer.
  - Remote testing capability will reduce labor for fault isolation of cut cables or disconnected connectors saving 1 to 2 hours of testing by two technicians.
  - In addition to the cost savings, services will be restored sooner resulting in higher customer satisfaction.

Benefits – Maintenance Applications

- Line Card Protection
  - A typical line card has four ports and supports up to 128 customers with a 1x32 optical split and 256 customers with a 1x64 optical split. MTBF (Mean Time Between Failure) for a line card is about a 4% annual failure rate.
  - An optical switch would minimize service interruption with a line card failure. This could reduce out of service durations by 2 to 4 hours in an unmanned Central Office or when troubles occur outside of normal working hours.
  - Improved service reliability and customer satisfaction will also result when a switch is used to provide 1:N OLT line card protection.

Benefit Calculations for Maintenance

Maintenance Savings Calulations

$80	Hourly Labor Rate

Application: Fault Isolation

Assumptions:

3%	Annual Outside Plant Failure Rate per Subscriber
1.5	Reduced Fault Isolation Time (Hours)
2	Technicians

Savings:

$7	Annual Savings per Subscriber

Application: Line Card Protection

Assumptions:

4%	Annual Line Card Failure Rate
60%	Failures During Premium Pay Hrs (Nights & Sunday)
$40	Incremental Premium Pay Rate per Hour
4	Time (Hours) to Repair Trouble
128	Connected Households per Line Card

Savings:

$0.03	Annual Savings Per HH Connected

Benefits of the FTTP PON Application

- Who Can Benefit from the Application
  - Wireline carriers deploying Fiber to the X (home, premise, curb, node, etc.)
  - MSOs deploying Fiber to the X (FTTX)
  - Community based network operators and municipalities
  - Construction and Development Enterprises
  - Multi-Dwelling Unit (MDU) managers

Benefits of the FTTP PON Application

Savings Summary		
Application	**Savings Metric**	**Savings**
Network Creation		
Fiber Conformance Testing at FDH		
Integrated Switch (1 or 2 Techs)	$ per HH Passed	$6 to $11
Portable Switch (1 or 2 Techs)	$ per HH Passed	$3 to $6
FDF Cross Connections	$ per HH Connected	$2
Service Activation		
FDH Cross Connections	$ per HH Connected	$41
Increased Equipment Utilization	$ per Subscriber [1]	$87
Load Balancing PON Splitters	$ per HH Connected [1]	$1
Maintenance		
Fault Location	$ per Subscriber per Yr	$7
Line Card Protection	$ per HH Connected per Yr	$0.03

[1] Savings After 10 Years

Customers' Feedback

- Positive Comments
- Challenges
- Different Ideas or Suggestions