ReadyLinks

White Paper

Triple-Play FTTH E-Ring - Gigabit Ethernet Ring Passive Optical Networks using ReadyLinks Optical Service Gateways

This paper describes how Fiber to the Home Service Providers can implement Ethernet Ring Passive Optical Networks utilizing ReadyLinks' RHINO™ Gigabit Ethernet FTTH Optical Service Gateways to serve both residential and business users. The pros and cons of Ethernet Ring PON FTTH vs. splitter-based GPON FTTH will be detailed. The advantages of using Gigabit Ethernet Switches and RHINO FTTH Gateways for open standard Ethernet Ring PON FTTH will be identified for various customer configurations.

Fiber to the Home (FTTH) continues to gain acceptance around the world as the most cost effective way to deliver high-bandwidth Triple Play Video, Data and Voice services to residential and small business customers. FTTH is the technology of choice when future needs for significant bandwidth usage per subscriber is taken into account. The FTTH technology and topology deployed by a Service Provider, System Integrator, Municipality, or Utility is dictated by a number of important factors:

- **Video drives the Triple Play Business Case** - The revenues derived from Video services is the key component of a triple play business case top line. However, the costs incurred from building a robust video network are expensive.
- **Huge Video revenues will be realized from digitized/stored content** - There will always be a need for real time content (Sports, News, etc.) However, the largest revenue potential will come from giving access to niche entertainment. Given the cost of digitizing and storing content has fallen dramatically, essentially everything can be stored and made available for distribution. The delivery of this content will be in either an on demand or purchased download format. The revenue potentials from this archived content can equal or even exceed the popular "Hits" content. This business model can be seen in the success of iTunes, eBay, Google, Netfix and others.
- **The move to all IP Services is inevitable** - The most flexible and cost effective way to deliver voice, data and video services is to use IP and Ethernet. To develop and protect your Triple Play Services subscriber base, It is critical to create a technology plan that takes you to an all IP Fiber to the Home network.
- **Your current network MUST evolve from current state** - Unless a network is starting from scratch and can be built all-IP, most existing networks have to evolve from their current topology. This evolution manifests itself in transitional technologies such as: GR-303 VoIP gateways, RF video overlays, spectrum and video compression techniques etc.
- **Bandwidth requirements will continue to dramatically increase** - It is tempting to attempt to leverage copper or wireless delivery technologies for IP Triple Play Services. However, over the last 10 years we have gone from 56Kbps to 100Mbps to the home which is a about a 2000X increase. If this increase rate were to hold we would be at 200 Gigabits per second in 2017!

FTTH Services and Bandwidth Requirements

Access speeds to homes and businesses have been rising steeply over the last decade. It wasn't long ago that many of us were thrilled to have 56Kbps dial-up internet access services! Now that all Video, Data and Voice services can be delivered using packet networks, the need for speed has passed 25Mbps, is approaching 100Mbps, with 1Gbps in the immediate future.

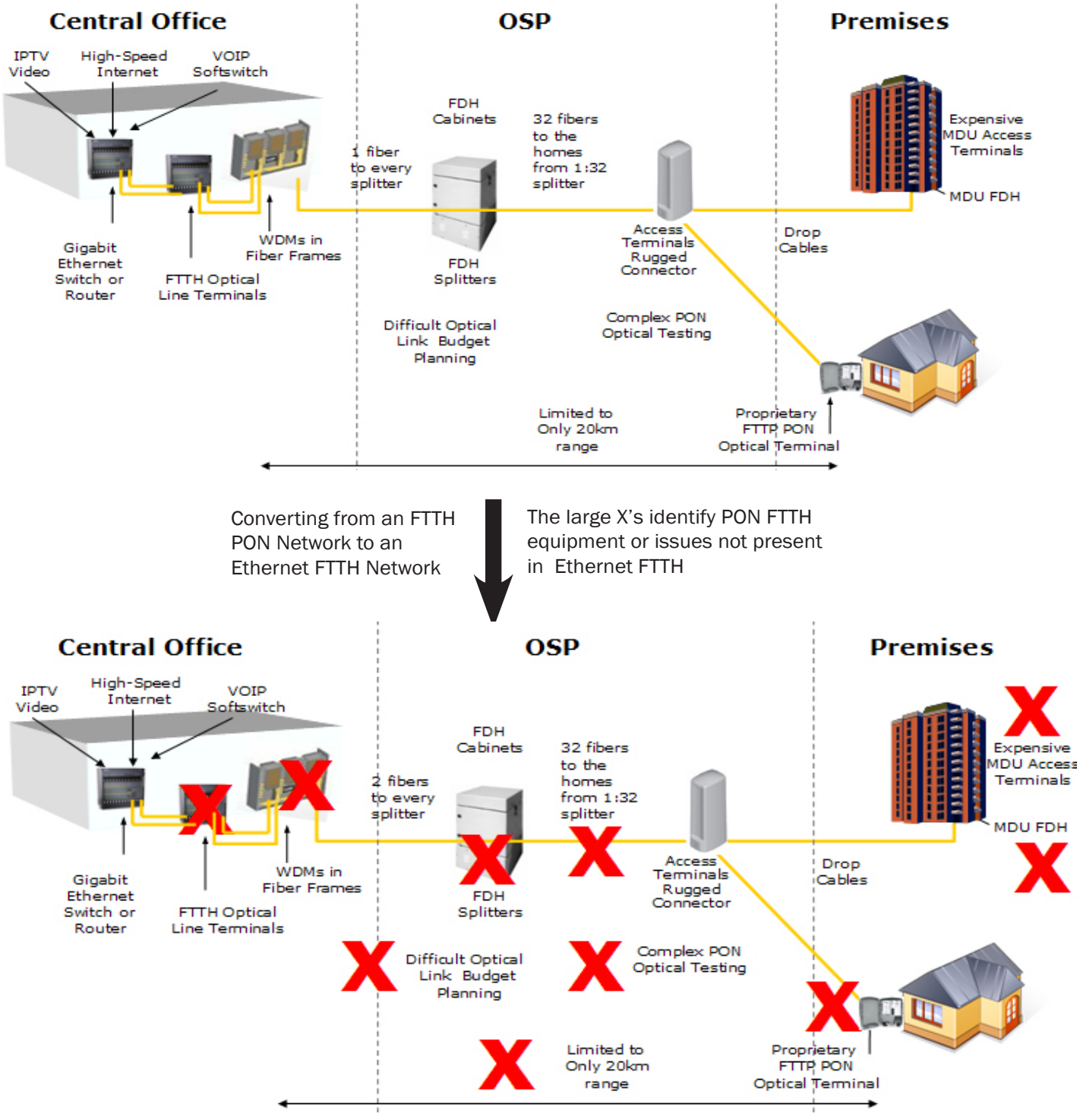
Bandwidth intensive content such as High Definition TV, interactive gaming and peer-to-peer video applications will consume a majority of the bandwidth. Who knows where the bandwidth limits needs to be? FTTH services are much like the PC industry. For every leap in processor speed and memory expansion, applications seem to absorb all available resources.

It is imperative that this "need for speed" is recognized and planned into any FTTH technology choice and network deployment configuration.

Simplifying Splitter-based PON FTTH to Direct Ethernet PON FTTH to Ethernet Ring PON FTTH

There are two primary FTTH architectures being deployed today and both are configured in a star topology. As for BPON/ GPON, optical splitters are placed in the either the central node or remote cabinets to distribute signals to each customer. These splitters are in various ratios from 1:4 to 1:32. The use of splitters reduces the number of fibers in the feeder portion of the network, but complicates the connectivity and adds to the deployment cost. In the case of a Direct Ethernet Point-to-Point FTTH architecture, a single fiber, single mode 100Mbps or 1Gbps Ethernet link is implemented between every endpoint and an Ethernet switch port in the central node. This is simpler, but can be very expensive depending on the switch and optics used.

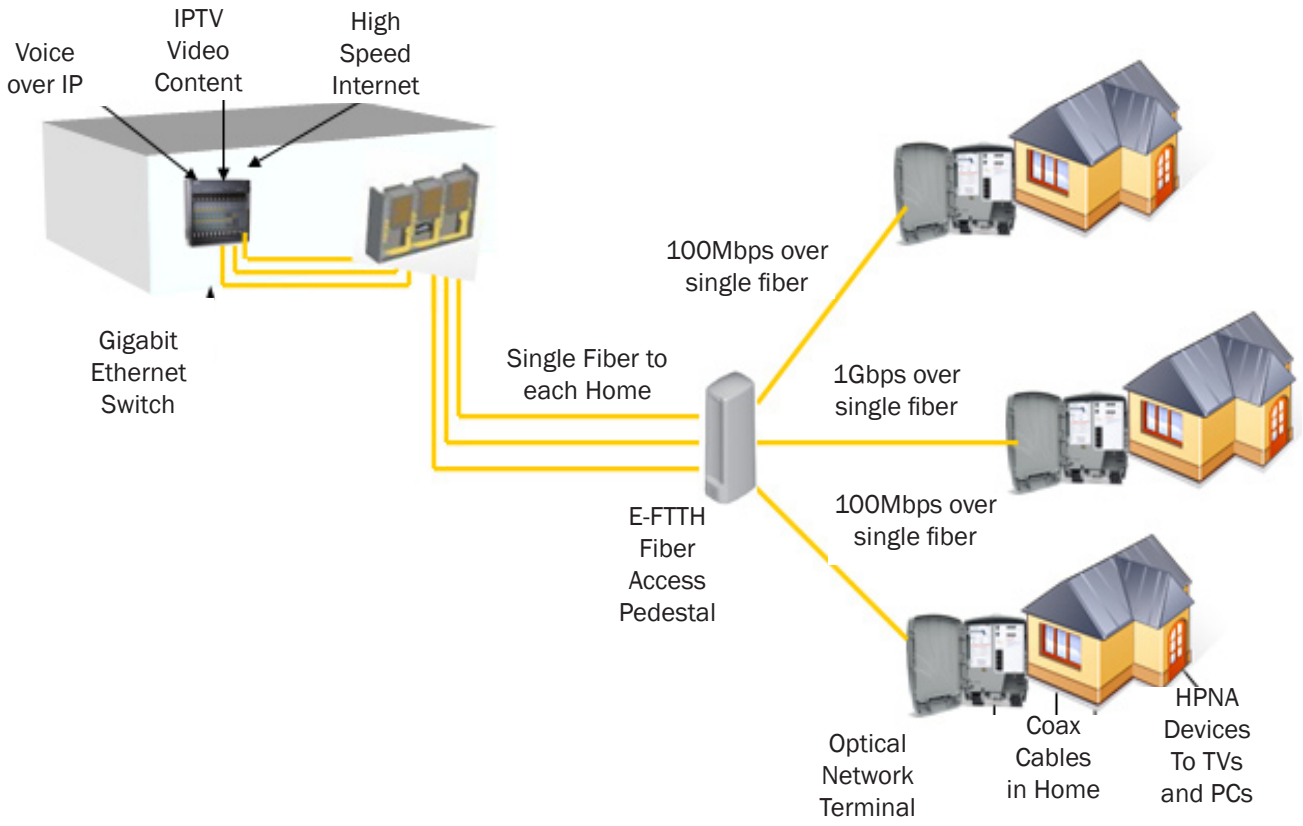
Step 1: Simplifying an FTTH Splitter PON to a Direct Ethernet FTTH Network



Ethernet FTTH Networks - Simple, Open, Flexible and Powerful

The resulting simplified Direct Ethernet FTTH network is shown in Step 2. This is a point to point Ethernet FTTH. Significant complexity and cost has been removed from the network. FTTH Optical Line Terminals, Optical Splitters, Large fiber cross-connect cabinets, and complex PON gateways are no longer needed. There are several FTTH deployment situations, such as very dense urban areas and planned communities, where Direct Ethernet FTTH is the most economical configuration.

Step 2: Using Point to Point Ethernet FTTH from C.O. to Each Home - 100Mbps or 1Gbps



However, there are some drawbacks to this architecture. Direct Ethernet FTTH as a point to point configuration requires a "home-run" fiber to every home. It also requires an optical port on the High Speed Ethernet Switch for every home served . However, given a single fiber to each home is used, the ever-decreasing cost of multi-fiber cables and the actual fill rates of FTTH GPON equipment, the incremental cost difference of the extra feeder fiber is not as significant as in the past.

A source of significant cost is that Point-to-Point Ethernet utilizes an Ethernet switch port in the Central Office for every residence served. Residences will not utilize 100Mbps or 1Gbps of bandwidth per home for a long time. So using an Ethernet Switch 100M/Gigabit port per home is wasteful. Furthermore, the optics required to reach each home from the Central node is expensive. The ideal FTTH solution would share a Gigabit Ethernet Switch port over many homes.

On the positive side, Ethernet FTTH ports are easier to add, move, change and traffic balance than GPON ports. With Ethernet FTTH there are more fibers entering the Central Site. Cost effective high density fiber frames have been introduced that manage the thousands of fibers entering this Central Site. Managing the fibers centrally is significantly less expensive than managing fibers in the Outside Plant.

Furthermore, FTTH fiber plant will have a useful life of 30 years. During this time there will be at least 4 or 5 major optical technology upgrades. The simplicity of having a fiber connected between the Central node and each residence is the most flexible and future-proof method of insuring that investment spent today can be leveraged tomorrow. Two fibers to every home is the most desirable long term.

Finding the Ideal FTTH Ethenet-based PON Topology

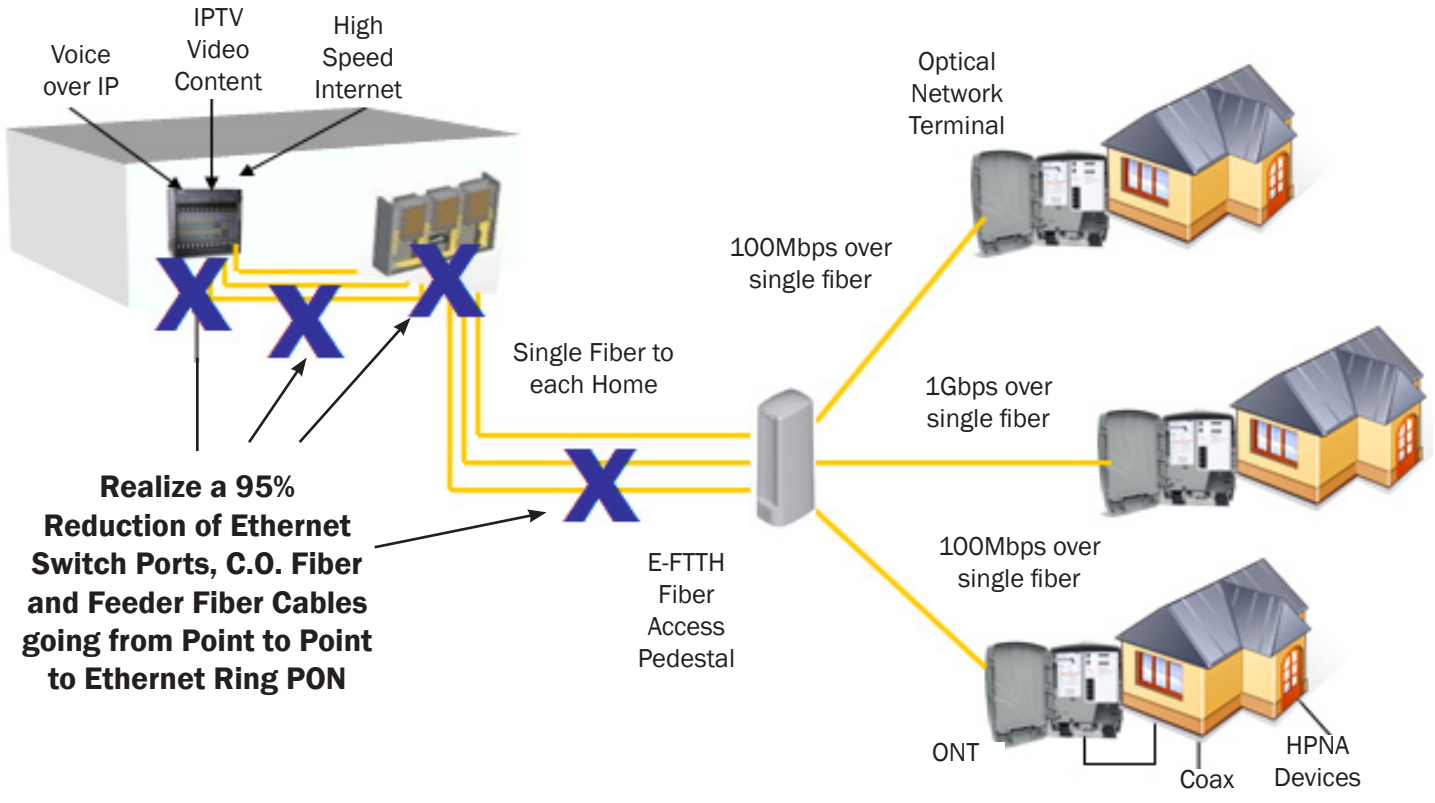
Taking into account the advantages of Direct Ethernet FTTH configuration over Splitter-based PON (GPON), but realizing the disadvantages of the "home-run" costs, the following criteria for the optimal FTTH configuration emerge:

- Utilize Gigabit Ethernet Networking for IP-based Triple Play Services
- Reduce the complexity of data traffic management using open Ethernet standards
- Minimize the amount of electronics in the Central Office
- Reduce the numbers of fibers and connections in the Central Office
- Minimize the number of fibers in the Fiber Optic Feeder cables
- Must be completely passive in the Outside Plant
- Eliminate Outside Plant cabinets, use only small pedestals, hand holds, and aerial cases.
- Use cost effective optical drop cables to the home with 2-4 fibers for flexibility.
- Provide for network redundancy in the event of fiber breakage
- Support optical distances between C.O. and residences from 1km to 80km
- Provide environmentally hardened home gateways
- Do not impose limits on the number of homes that can be attached to the PON

There is an FTTH PON configuration that realizes all these requirements - **Ethernet Ring FTTH** Passive Optical Networks.

Much like the exercise shown in Step 1 of taking out the equipment, fiber and complexity out of splitter-based FTTH GPON to create Direct Ethernet FTTH, the same exercise can be done on Direct Ethernet FTTH to create Ethernet FTTH RPON. As will be explained in a moment, E-Ring FTTH uses Ethernet Rings to connect the residences and small businesses to the Gigabit Ethernet Switch in the Central Office, Headend or Data Center. Because multiple residences can be connected together on a single fiber ring, there are many areas that can be reduced. Step 3 indicates the substantial reductions in Ethernet Switch Ports, Central Office fibers, fiber frame terminations, and Outside Plant fiber optic feeder cables.

Step 3: Creating a Ring PON by removing the Extra Ethernet Ports, Fiber Connections and Fibers

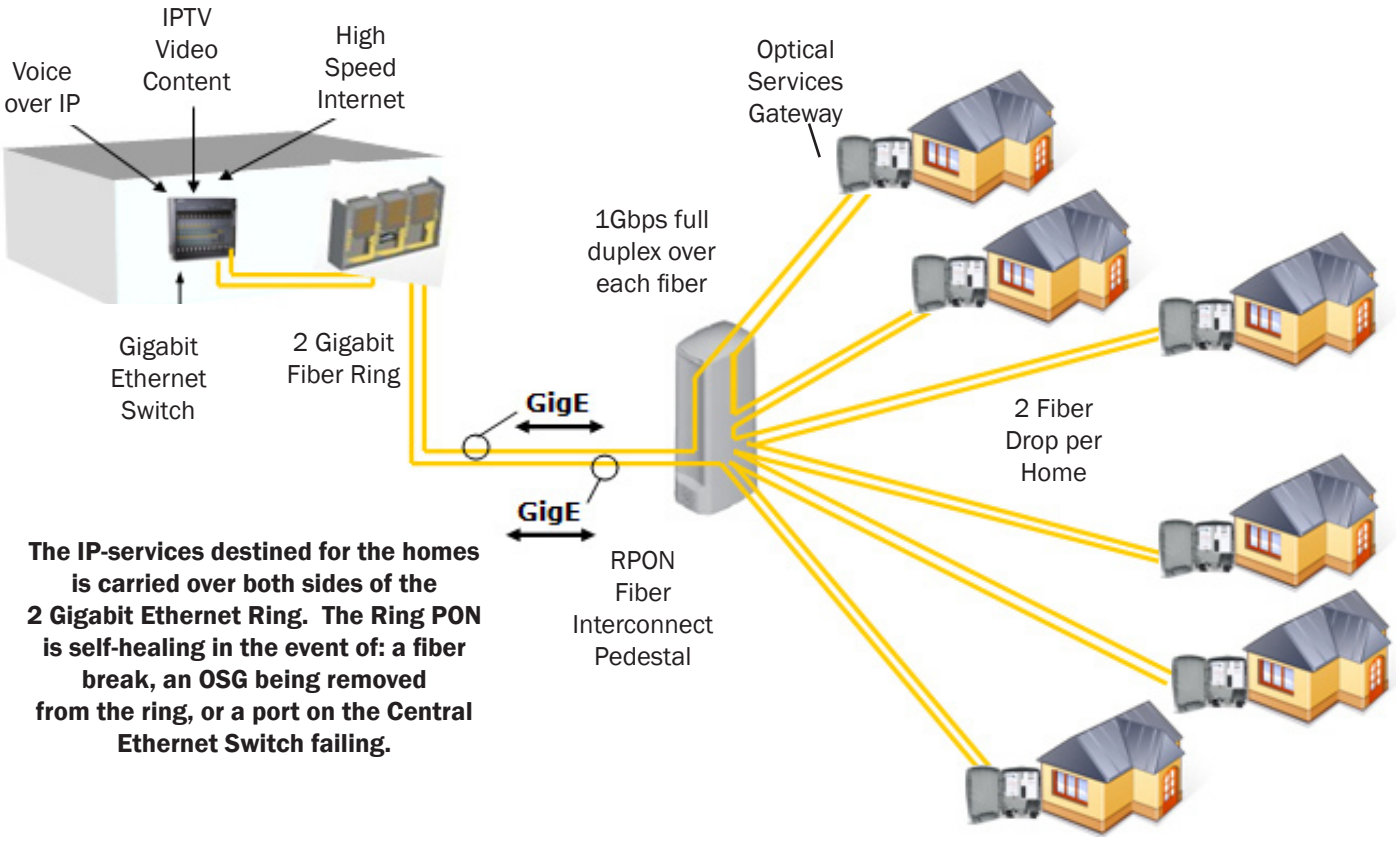


FTTH E-Ring - Using Gigabit Ethernet Rings for IP-based Triple Play Services Delivery

The idea behind FTTH Ethernet Ring PONs is simple: Transport IP Ethernet-based services over the most cost effective and flexible infrastructure possible. E-Rings utilize the transport ring construct that has been deployed in global networks for 40 years. Rings have now been brought to the edge of the network.

As can be seen in Step 4, E-Rings are simply constructed. Two Gigabit Ethernet ports on a high speed Ethernet Switch in the Central Node are connected in a ring to the Optical Services Gateways at the residence. The Ring is created by connecting the homes in a pedestal equipped for 4, 8 or 12 homes. The number of homes on a ring is not physically constrained by the fiber network. The only constraint is the amount of IP Services traffic on the 2Gbps ring. Several RPON pedestals can be connected on the ring to serve 40 homes or more depending on the services bandwidth to be delivered to each home.

Step 4: Implementing 2Gbps FTTH Ethernet Ring Passive Optical Network



The IP-services destined for the homes is carried over both sides of the 2 Gigabit Ethernet Ring. The Ring PON is self-healing in the event of: a fiber break, an OSG being removed from the ring, or a port on the Central Ethernet Switch failing.

Many people ask: if E-Ring is such a good idea, why are FTTH BPON and GPON networks are so prevalent today? The answer is the technology underpinning these PON architectures was state-of-the-art at the time they were designed and a great deal of effort has been expended to make them work. The BPON and GPON vendors who have brought these systems to market enjoy the fact that there is little or no interoperability between BPON/GPON electronic components.

The recent technology advances that now makes FTTH E-Rings a reality include:

- New High-speed Ethernet switching chips that can handle Ethernet rings and are environmentally hardened
- New cost effective Gigabit speed Optical Small Form-factor Pluggable (SFP) modules that are also hardened
- Industry de facto protocols and standards for creating Ethernet rings
- Linux software based Optical Services Gateways
- High-speed high-density Gigabit/Terabit Ethernet switching platforms with open Ethernet interfaces
- The roll-out and rapid acceptance of all IP-based voice, data and video services

Introducing the ReadyLinks RHINO Optical Services Gateway

The ReadyLinks RHINO OSG provides 1Gbps Ethernet FTTH terminations for IP-based triple-play services using a 2 Gigabit per second Ring-based Passive Optical Network infrastructure. The 2Gbps Ethernet transport ring ensures bandwidth will be available for demanding Video, Data and Voice services. The RHINO OSG has many industry leading features:

- Two VoIP phone ports used for existing analog phones. The RHINO supports SIP and MGCP with VoIP Softswitches.
- Four 10/100Mbps Ethernet Ports for devices in the home
- One HPNA 3 port to use existing coax home wiring for distribution of IP Ethernet services
- Hardened outdoor version and indoor version (INT) with mounting options
- Lower optical transceiver costs - RHINO supports the complete distance range of single mode and multi-mode SFP laser packs. Transmission distances from the Central POP to the OSG can be from 1 to 80 kilometers.

Figure 1: ReadyLinks Gigabit Ethernet FTTH Optical Services Gateway

Integrated HPNA 3 for Easy Home Networking with HPNA Set-top Boxes

The optional RHINO HPNA 3 Coax port is connected to existing home coax wiring to deliver IPTV, High-Speed Internet and VOIP to reduce residential installation costs. The RHINO HPNA 3 is compatible with HPNA modules in the home connected to Ethernet devices such as PCs, IP-based home security cameras, VOIP phones and Ethernet-based Set-top boxes. The status of the RHINO HPNA port and the HPNA devices in the home can be monitored remotely.

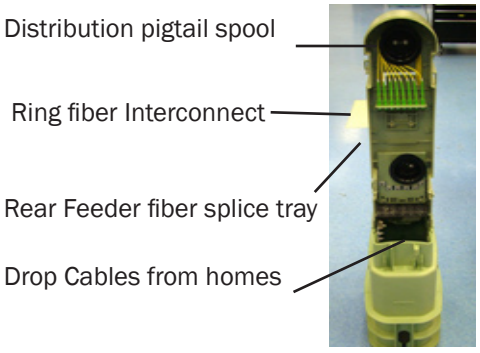
E- Ring Fiber Connections between the C.O. Ethernet Switch and the Optical Services Gateway

The most commonly used E-Ring optical connections are single fiber, single mode, dual wavelength. The C.O. Ethernet Switch is provisioned with two optical 1Gbps full duplex ports to terminate the ring. These two fibers are brought over to the main fiber distribution frame for connection to the outside plant cable. The outside plant feeder cable is routed to the E-Ring pedestal where the ring fiber is routed into the splice tray and spliced to a connectorized pigtail. If the ring terminates on a single pedestal the other fiber back to the C.O. is also spliced into the pedestal for the return path. If there are more pedestals on the ring, the first fiber is routed to the other pedestals.

Connecting the Ring E-Ring in the Pedestal

Once the C.O. distribution fiber is brought into the pedestal, the FTTH homes to be served are connected. A two fiber drop cable is laid to each home. These drop cables are brought into the bottom of the pedestal and are terminated with a two connector pigtail. In order to connect the ring, the homes are interconnected one to another. The complexity, cost and optical losses associated with fiber cross-connections required by GPON are avoided. The pigtails from each home are color coded to insure proper installation and there are panels for craft documentation of homes connected.

There is no other outside plant apparatus required by E-Ring!



Comparing Ethernet Direct/Ring FTTH to GPON FTTH

There are a number of issues to be reviewed in order to understand which FTTH topology should be used. The following table compares the pros and cons of Ethernet FTTH and GPON FTTH architectures:

Issue Area	Ethernet Direct/RIng FTTH	GPON FTTH
Resource planning in access	Simple: dedicated fiber, point to point optics	Complex: shared medium, subscribers mutually dependent
Engineering Rules	Simple: dedicated fiber, point to point optics	Complex: needs to work for every customer per PON tree
First Cost of Electronics	Only Gigabit Ethernet Switch in Central Office and Open Standards Ethernet OSG at home required with simple Fiber Drop Pedestal	Requires Gigabit Ethernet Switch plus GPON Optical Line Terminals plus PON Splitters in large OSP cabinets plus Fiber Drop Pedestal plus Proprietary PON ONT
Fiber Topology Options	OSG optical terminations can be mix/match depending on need. An OSG can be connected directly if desired.	GPON topology fixed with bandwidth, options in split ratios. No support for direct connections to the C.O.
Optical Loss Budget	ONT can be over 80km from Central Office.	All GPON terminations must be within 20km to meet optical power budget
User Data Security	Shared media between subscribers	Shared media between subscribers
Fiber Troubleshooting	Simple: failure uniquely located by Ring link that failed	Complex: location of failure behind splitter difficult to identify
Encryption Key Management	Not needed	Required
Bandwidth Efficiency	Optimal: no restriction, flexible per subscriber. Provider managed.	Restricted: control protocol overhead (guard times), encryption overhead
Bandwidth/technology upgrade path	Simple can be done on a per customer basis	Complex: replacement of all active equipment at once or wavelength overlay
Customer Turnover	Directly connect subscriber with Ethernet connection from new Provider	Configuration change (wholesale)
Connecting a new Subscriber	Open Ring and insert new customer. User configuration automatically download upon power on.	Configuration of OLT, adding drop cable to splitter if port available, or add new PON splitter with new drop
Restoral time after cable break	E-Ring fiber topology is similar to GPON, but does not have complexity of splitters and breaks are easier to find.	Shorter in the feeder part due to fewer fibers to splice, longer in the subscriber drop due to more difficult diagnostics

Key:	Easier and/or More Cost Effective	Similar in Task and/or Cost Effectiveness	More Difficult and/or More Expensive

Table Source Information: Cisco White Paper “Fiber to the Home Architectures” and ReadyLinks Customers

Building Ethernet FTTH Systems with High Capacity Ethernet Switches

The cost effective RPON FTTH architecture shown in Step 4 can be implemented by combining high-capacity Ethernet Switches and ReadyLInks RHINO Optical Service Gateways. Service Providers, Utilities and Municipalities that deploy Ethernet FTTH can expect to realize the benefits described in the table above.

FTTH E-Ring Triple Play Services using Ethernet Switches and ReadyLinks OSGs

The power of Ethernet FTTH architecture lies in the availability of IP-based voice, data and video services. The technology to deliver Voice over IP, IP-based TV, and High-speed Internet Data simultaneously directly over Ethernet-based networks is a recent breakthrough. These services are represented in a very simple manner in Step 4. Certainly there are detailed integrations that must be done at various layers in the network stack - physical layer, network layers, and application layer.

Voice over IP - In order to deliver IP-based voice services previously provided by time domain circuit-based voice networks, VoIP Softswitches are deployed that interact with the legacy voice networks. The ReadyLinks Optical Service Gateways contain the software and hardware that interfaces legacy analog telephones to the IP Softswitches. The OSGs convert the signals and analog voice from telephones into IP-based signals and encoded voice packets that the VoIP Softswitch. The IP data traverses the Ethernet Switch like all other IP data. ReadyLinks OSGs support both SIP and MGCP protocols with VoIP softswitches from vendors such as MetaSwitch and CopperCom. The VOIP data streams are managed on a Virtual LAN (VLAN) channel in the combined IP data stream.

High Speed Internet Data - IP-based Internet data has been delivered from Internet Service Providers over various types of modems (dial-up, ISDN, DSL, Cable) connected to PCs for over 20 years. With the advent of Ethernet-based RPON FTTH, Internet access can now be delivered at speeds exceeding 100 Megabits/second. This enables a range of new services unfathomable just a couple of years ago. What enables these great speeds is high-speed 10 Gigabit/second uplink connections on the central Ethernet Switch connected to ReadyLinks OSGs via 1Gbps fiber rings. These high speed rings are delivered into the home by the Optical Services Gateway via the Ethernet connectors or the optional HPNA 3 coax connector. The Internet data streams are managed on a separate VLAN channel in the combined IP data stream.

IPTV - Delivering TV channels over IP data streams is a recently introduced technology and is now being deployed around the world. In order to deliver IPTV, there are a number of video servers, software middleware, network components, intelligent devices and Video Monitors that must be integrated across the IP network. For the purposes of Ethernet RPON FTTH, the IPTV video streams are fed into the central Ethernet Switches and transported to the ReadyLinks OSG for delivery to IP-based Set-top boxes. There are some enabling protocols such as IGMP IP Multi-casting that must be used to provide an IPTV viewer experience that rivals other video distribution systems such as Cable TV and Satellite TV. IPTV data streams are managed on the Ethernet FTTH over a separate VLAN channel in the combined IP data stream.

E-Ring FTTH Motivations and Implementation

Now that we have examined the technology, architecture, deployment options and benefits of Ethernet Ring FTTH, we can go back and examine the issues outlined on the first page of this White Paper :

- **Video drives the Triple Play Business Case** - FTTH Gigabit E-Ring is an ideal way to deliver Video. Given the broadcast and unicast capabilities of an Ethernet-based network, the bandwidth utilization is very efficient. IGMP V2 is utilized to manage the content streams. VLANs (Virtual LANs) are implemented to further segment and manage video streams.
- **Huge Video revenues will be realized from digitized/stored content** - E-Rings provide the flexible IP and Ethernet environment required to effectively deliver digitized/stored content. Since E-Rings are all IP, the content flows are easy to manage with high Quality of Service. Any content, can be delivered anywhere, at any time.
- **The move to all IP Services is inevitable** - The most flexible and cost effective way to deliver voice, data and video services is to use IP and Ethernet. To develop and protect your Triple Play Services subscriber base, It is critical to create a technology plan that takes you to an all IP Fiber to the Home network using either Ethernet in Point to Point or Ring configurations.
- **Your current network MUST evolve from current state** - A technology transition play from the current network topology to IP and Ethernet. The key is to determine how to move to an all fiber network as quickly as financially feasible.
- **Bandwidth requirements will continue to dramatically increase** - We postulated earlier that in 2017 200 Gigabits per second might be required for advanced services delivery. This certainly is an incredible amount of bandwidth, but fiber optics can support these types of transmission speeds via Dense Wavelength Division Multiplexing. What ever the number of Gigabits per seconds to be delivered turns out to be eventually, Fiber to the Home will be the only delivery option.

Final Thoughts

This paper has highlighted and contrasted the differences between Ethernet Direct/Ring FTTH and GPON FTTH. It has been shown that Ethernet Rings are more flexible, cost effective, simpler to deploy, and will support future services and technologies better than GPON FTTH. Service Providers who have implemented GPON FTTH did so appropriately, as the new cost effective optical and data technologies embodied in E-Rings were not previously available at the time of their decision. The good news is that Ethernet Rings are easily implemented in conjunction with GPON FTTH in either coresident or cap-and-grow deployment configurations.

Implementing high density centralized Ethernet Switches with ReadyLinks RHINO Optical Services Gateways is the optimal way to deliver cost-effective Fiber to the Home deployments. Moreover, with both Ethernet and HPNA 3 interfaces built into the ReadyLinks OSG, service delivery to home based routers and IPTV Set-top boxes is quick and easy.

Service Providers, System Integrators, Municipalities, Utilities and Campuses that deploy Ethernet Ring FTTH networks will dramatically improve their chances for success in an increasingly competitive world.

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