FTTP Shootout – Active Ethernet vs PON

Introduction:
Triple play rollouts are one of the bright spots in the global telecom industry today. Carriers and municipalities that announce plans to rollout triple play (voice, video and data) services are faced with a number of choices for an access mechanism – DSL, Fiber or even wireless. This paper focuses on fiber as the access mechanism and compares the Active Ethernet and PON architectures. The paper shows how Active Ethernet is not only more cost-effective than PON but also results in a more profitable services platform that accommodates the inevitable changes in services over time.

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PON technology primer:
PON is a shared medium in which a fiber is 'passively' split into many end user connections. The term passive refers only to the optical splitter, which does not require external electrical power to function. Each end user has an ONU (Optical Network Unit) while the fiber terminates at a central office in an OLT (Optical Line Terminal), which require electrical power. Between the OLT and the ONU may be one or two stages of passive splitters which split the connection to multiple end points.

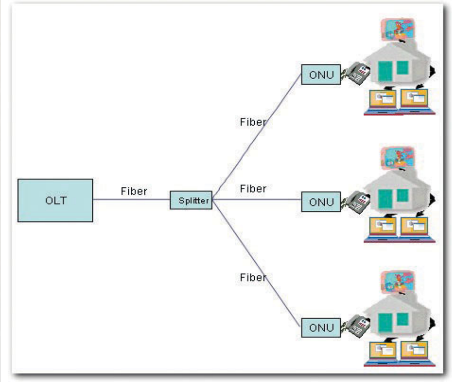

Figure 1: PON Architecture

Active Ethernet technology primer:
Active Ethernet is a dedicated medium in which each end user is allowed independent access. Each end user has a home gateway directly connected to the Ethernet router in the central office or street cabinet by a direct fiber. Between the central office and the end user, there can also be an aggregation Ethernet router.

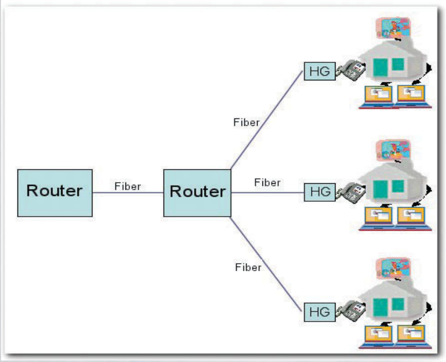

Figure 2: Active Ethernet Architecture

Fiber plant costs:
PON proponents argue that compared to Active Ethernet, the PON architecture requires lesser cost for the outside plant since it requires less fiber. Construction of the fiber access network is the most labor-intensive task in an FTTH project and thus the most expensive. This includes digging the trenches and laying down the fiber or if it is an aerial deployment, it involves clearing or replacing the existing utility poles and stringing the fiber on them.

A perusal of the architectures of PON and Active Ethernet show that the fibers laid out follow the same routes, thus requiring the same number of trenches dug or poles strung.

The difference is only in the number of fibers that are laid in the trenches or strung along the pole. This length of the optical fiber required was also calculated for each of the architectures using typical prices for single mode fiber. Since PON has a restriction of

PON and Active Ethernet take the same routes and labor effort (trenched or aerially strung) to build the fiber plant

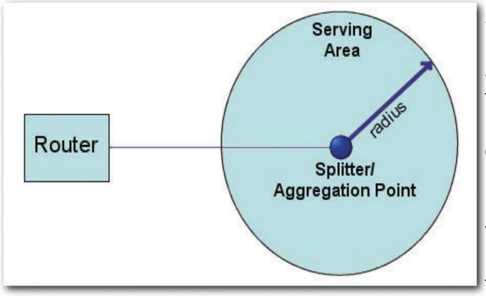

Figure 3: Serving area calculation

32 users per port and a distance limitation of 20 km, that was used as the baseline. The number of fiber miles required was calculated based on user density or the radius of the serving area as shown below.

In the areas of highest density, where the serving area was only a 1 km radius, the additional optical fiber required per user was 4.2 km. For this small difference, Active Ethernet delivers 300% of the bandwidth of PON. As the user density decreases, the extra fiber length required drops linearly.

Even in an area with high user density, the additional optical fiber for Active Ethernet over PON never exceeds 4.2 km per home.

Take rate predictions:
Active Ethernet requires an individual optical fiber connection per user. Riverstone's routers support modular optics so that each fiber can be driven by different optics which is selected based on the distance of the user from the router. Each user is independent of the other and any combination of distances maybe served.

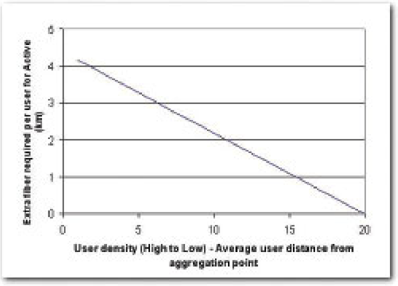

Figure 4: Additional optical fiber miles per home, for Active Ethernet

This user independence also serves another purpose. Today business parks with multiple tenants may require more than a 100Mbps of bandwidth, and using the same fiber a Gigabit Ethernet or 10Gigabit Ethernet connection maybe provided by provisioning the appropriate port on the Ethernet router. In the future, other locations which require Gigabit Ethernet speeds can undergo the same transformation easily.

PON on the other hand, makes each user dependent on the other users, since it is a shared medium. So the optical budget of the PON has to be divided among the users of the PON. Therefore the service provider has to have early and accurate knowledge of the take rate in its serving area on a granular basis and the distance of each of its users. While distance to each of the users it plans to serve can be determined, take rates on a granular basis are historically hard to predict. A mistake in the take rate and user density assumptions could result in severe penalties with a PON.

This is because PON is a shared medium and typically uses a two-stage splitter architecture where each OLT is connected to a 1:4 splitter, followed by 4 1:8 splitters to accommodate 32 users. This limits the reach of the fiber from each of the splitters. So even a small serving area has to be wired for a expected user rate and any variation results in increased costs or lost revenue. Under-predicting the take rate results in users who cannot be serviced without more investment; over-predicting the take rate results in investment that is unused. Neither of these options results in success for a carrier in a competitive environment.

PON strands users and investment, if the service provider does not correctly estimate take rates at a granular level. Active Ethernet is flexible and can support these variances.

Active Aggregation:
An Active Ethernet architecture typically uses an aggregation Ethernet router located in a street cabinet closer to the end user. PON uses a passive splitter at this aggregation point. The use of a passive splitter is listed as a capital cost advantage for PON since it does not require electrical power and has a small form factor. However, this difference in the number of active elements is limited to the aggregation routers in the field.

- PON requires power at every customer premise just like Active Ethernet does.
- PON requires power at the OLT just like Active Ethernet does.

With Active Ethernet, in large FTTH deployments, up to a 1000 users can be aggregated into one street cabinet. Thus even for a deployment with > 100000 homes, the number of additional locations where power is required with Active Ethernet is in the 100s. This high aggregation ratio can be achieved because Active Ethernet supports greater distances than PON.

Active Ethernet also offers other benefits in the longer term which decrease operating expense; increase revenue potential and quickly payback the additional investment in powered field locations.

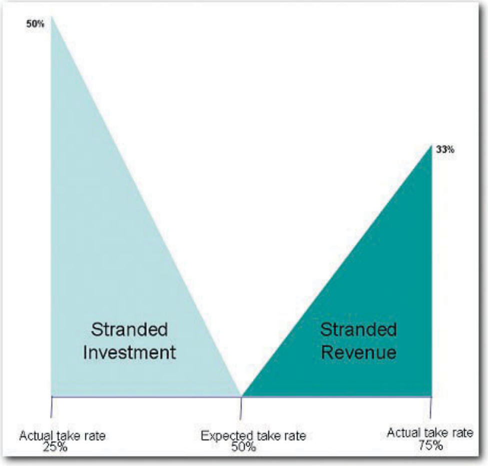

Figure 5: PON requires accurate take rate predictions

Service Troubleshooting:
An Ethernet router at the aggregation point allows a service provider to monitor the services being delivered continuously while a passive splitter does not. When a customer reports a problem, an active Ethernet router can send debugging information back to the Network Operations Center (NOC). Tools like SNMP, Ethernet OAM, MPLS OAM and EFM OAM can be linked into the Network Management System. This allows the NOC to isolate the problem to a section of the network and the device in the section. Personnel can be dispatched for a quick and focused repair mission.

A passive splitter cannot transmit any information back to the NOC and personnel will have to be dispatched to the field, potentially to multiple locations, to debug the problem. At the cost of a few hundred dollars a truck roll, extra visits required to the field easily add up and annual operating expenses can increase rapidly. This also increases the time it takes to address a customer trouble report and could result in lowered satisfaction rates.

Business Services:
Though an FTTH project may primarily target residential users, businesses that are in or near residential developments, like banks, grocers, supermarkets and megastores are also addressable customers. These businesses are usually run by large corporations and need premium services like Virtual Private Networks with committed bandwidth rates, QoS and high uptime. Security is also very important to these businesses. A shared medium such as PON will not meet the security needs of these enterprises.

Deploying an Active Ethernet router at the aggregation router also provides flexibility to address large business customers with the need for > 1Gbps service. Adding new modules to the router can be easily done to service these customers. This is not possible in a PON architecture.

Services:
An FTTH build is a long term investment. It is not just about delivering the voice,

video and data services of today:

- 200+ video channels
- 1 or 2 lines of telephony
- Internet access – 1 to 3 Mbps to the home, 256kbps from the home, reflecting the current nature of information downloading

There has always been service innovation in delivering the products that satisfy the needs of residential and business customers and this innovation should not be restricted by the pipes used to carry these services. This is where Active Ethernet outshines PON because the bandwidth of Active Ethernet far exceeds that of PON.

In the foreseeable future we can see service innovations such as:

- High definition broadcast video into the home
- High definition video on demand into the home
    - o The DVR may become obsolete as the triple play service provider themselves offer programming on demand or the network becomes the DVR
- Videoconferencing with High Definition
    - o Consumer electronics companies are working on devices that can bring high definition video conferencing to economical price levels
- Video blogs
    - o Blogging is an exploding phenomenon. Video blogs are a new type of blog that are increasing on the web and these require high bandwidth for both video uploads and downloads
- The home as the information server
    - o Digital cameras and digital camcorders are dropping fast in price.
    - o Software to process images and video is becoming cheaper and easier to use and most home PCs have the processing power required for these applications. Residential users are ready to share this content but the only restriction is bandwidth
- Remote education on demand

These services which are conceivable today not only show that high bandwidth is required but also the need for symmetry in bandwidth availability. No longer is content downloaded to the home, it can be uploaded from the home also.

PON cannot support even the applications that will arise in the near future like High Definition video. Active Ethernet can.

PON is inherently a low-bandwidth asymmetric architecture which can only support today's services and does not create a platform for the future. The highest capacity PON is GPON where users can get up to 39Mbps each into the home. As the picture below shows, HDTV today needs 19Mbps and two streams of HDTV to a home easily overwhelm the GPON connection. While compression technologies like Windows Media 9 and MPEG-4 can reduce this requirement by half or more, new applications will keep arising that take up more

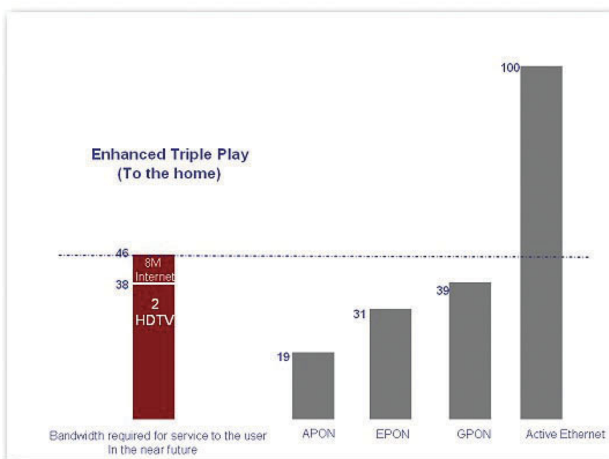

Figure 6: PON does not provide the bandwidth required by future applications to the home

bandwidth. The important factor to consider in an FTTH project, is that this is an investment that should continue to payback over a long time and not be limited by the technology deployed.

PON proponents argue that the video signal is provided through an out-of-bandwidth means using a separate wavelength. However, this is typically RF analog video and cannot support the advanced and profitable on-demand and feedback functions that can be supported by IP multicast video over the data link.

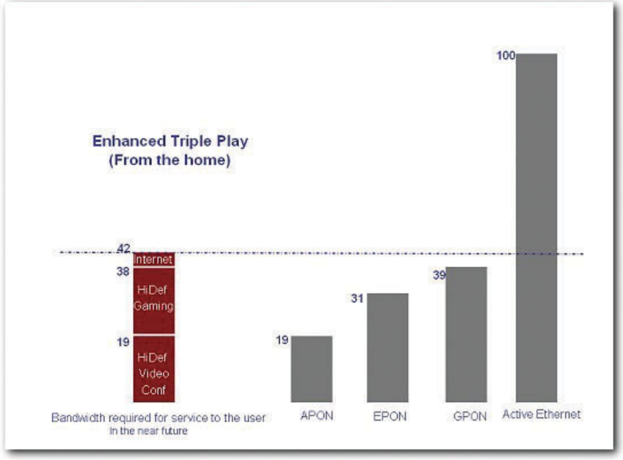

Figure 7: PON does not provide the bandwidth required by future applications to the home

The same applies to the services that are sourced from the home. High definition video conferencing and high definition gaming are services that providers can offer, to gain higher margins. However, these cannot be supported because of the asymmetric connections supported by most PON technologies. Even if symmetry is enabled at a higher cost, the bandwidth available is limited in PON.

Summary

This paper shows clearly that there are a significant number of advantages to implementing a large FTTH deployment based on Active Ethernet. Flexibility for future services and relative immunity to take rate predictions are among the strongest areas for Active Ethernet while they are the weakest areas of PON. Of course, the one advantage for PON is the number of fiber miles required, which is actually one of the smaller and least important parts of the overall cost structure.

A recent study of the cost of FTTH deployments (“Towards Technologically and Competitively Neutral FTTH Infrastructure” by Anupam Banerjee and Marvin Sirbu, Carnegie Mellon University) analyzed the most significant factors determining the final cost-per-home of an FTTH build. As illustrated, with all other factors defaulting to median values, changes in Trenching Cost can change the per Home cost of running fiber to vary from about $1700 per home to over $4000 per home. Similarly, changes in Take Rate can cause the Per Home Cost to range from $1400 to $3200. Thus this chart illustrates that the most significant factors impacting the per home cost of fiber are Trenching Cost, Take Rate and % of Buried Plant, with the influence of other factors being relatively minor. Both Active Ethernet and PON take the same fiber routes so there is no difference in the % of Buried Plant for either approach. More interesting is the component with the second highest influence – take rate. With the significant influence Take Rate exerts over the overal cost structure, errors in predicting Take Rate disproportionately impact the overall cost. In this paper, we also showed that PON is less forgiving of take rate variations from what was predicted, with cost optimization requiring an almost impossible degree of accuracy in predicting take rates on a granular, block by block level. The component that had the least impact on the cost of the project was the cost of fiber, meaning the one advantage of PON will play a relatively small, almost insignificant role in determining overall cost.

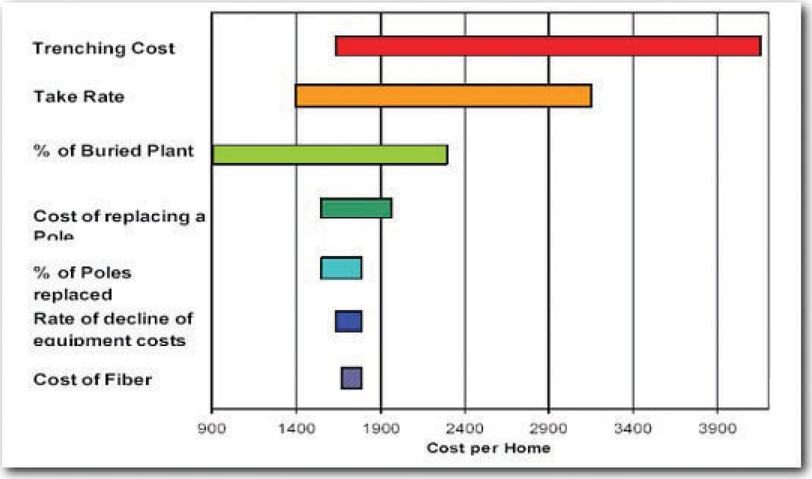

Figure 8: FTTH deployment, Impact of Various Factors on Overall Cost Per Home (sensitivity analysis). This chart depicts the potential influence of changes in individual factors such as Trenching Cost on the overall Cost per Home of FTTH when other variables remain constant.
(Source: "Towards Technologically and Competitively Neutral FTTH Infrastructure" by Anupam Banerjee and Marvin Sirbu, Carnegie Mellon University)

Active Ethernet presents the best solution for FTTH services:
- Active Ethernet is required to enable applications like HDTV, HD-VOD
- Active Ethernet delivers higher revenue & profit potential by enabling additional services in the future
- Active Ethernet enables the delivery of residential and business services flexibly
- Active Ethernet is based on IEEE-standards and has been deployed at numerous carriers worldwide

Riverstone Networks is a pioneer in carrier Ethernet. Riverstone delivers triple play FTTH networking solutions using Active Ethernet and VPLS/MPLS technology enabled by the RS and 15000 Ethernet router product lines. Riverstone has significant experience delivering triple play services, at projects like Utopia and carriers like Telefonica. Information about Riverstone Networks' Active Ethernet solution can be found at www.riverstonenet.com.

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