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INVENTION DISCLOSURE

1. **Invention Title.**

Expandable Extended-Reach EPON over HFC Network System

2. **Invention Summary.**
Methodology that extends reach of EPON over HFC network to greater than 50 Km using 20 Km optical components. Methodology provides guidelines to distribute signal to multiple physical-layer-converter units providing flexibility for upgrading network based on penetration, without impacting performance and reducing number of OLTs needed.

3. **Invention Description**.

   a. **Describe the invention in detail.**
   File (EPONbasedHFCNetworkSystem.docx)[see below]

   b. **Why was the invention developed? What problem(s) does the invention solve? How is it better?**
   - To extend the reach of system that could be used in next generation systems over HFC
   - To provide flexibility in migration as usage increases
   - To reduce deployment costs sharing the costs of one OLT with multiple PHY converters. This is an advantage over existing EPON/EPOC systems.
   - To preserve performance regarding reach and number of users.

   c. **Briefly outline the potential commercial value and customers of the invention.**
   Significant commercial value

4. **HOW is this invention different from existing products, processes, systems?**
This methodology is an enhancement to the EPOC proposal that was implemented by Broadcom and is being proposed in the IEEE.

Expandable Extended-Reach EPON over HFC Network System

Cable Operators have been exploring EPON based evolution scenarios over their Hybrid Fiber Coax networks where the EPON OLT can be reused as a network aggregating unit for this system and the subscriber end devices could be made to operate using an standard EPON media access control layer (MAC) and a physical layer that is suitable to carry the EPON MAC layer. This invention disclosure describes a system that using the same optical components in the network aggregation side of the system it can expand significantly in reach and flexibility regarding the evolution options for the cable operator while reducing deployment costs.

Traditional EPON systems have a reach of 20 kilometers for up to 32 end stations or OLTs. That reach is predominantly based on the optical loss budget rather than the distance traversed on the fiber. In EPON

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the optical loss budget for a 20 km 32 end stations systems is about 23 dB in the upstream and 21 dB in the downstream. The upstream direction uses typically 1310 nm lasers while in the downstream 1490 nm lasers are used. The loss for 20 km of fiber is 7 dB for 1310 nm and 5 dB for 1490 nm. In order to divide the optical signal to 32 subscribers the fiber would have had to undergone five successive two way splits (32=2^5). If each split accounts for a loss of 3.2 dB (3dB 1x2 split and 0.2 excess loss) the end-to-end loss due to the optical splitting in EPON accounts for 16 dB loss (5x3.2dB)

SM fiber attenuation for 1310 nm is less than 0.35 dB/km while the attenuation for 1490 nm transmission is less than 0.25 dB/km. So with these assumptions 20 km results in 7dB loss. Adding to the optical splitting loss you have a total of 23 dB that is reflected in the EPON standard. A system that with a reach of 50 km would require an additional 10.5 dB in optical power.

In the case of a modified EPON system where it is expected to transition to a coaxial medium for the last portion of the system, the fiber will most likely be running point to point to the “PHY Media Converter”. Only after conversion to RF to continue over the coaxial domain, the transmission paths are split. Since in this traditional configuration no optical splitting is taken place, there is an additional 16 dB of budget that can be leverage to different topology scenarios. One scenario could be that of a 50 km optical path (10.5 dB) followed by a 4-way optical split (6.4 dB) which roughly adds to the 16 dB power budget that was gain but using the lower power lower cost 20 km OLT compatible technology.

Another alternative could be using an optical link that includes an 8-way optical split (9.6 dB). The additional remaining loss budget (5.4 dB=16dB-9.6 dB) could be used to extend an additional 15 km of reach totaling 35 km from OLT to the PHY Media Converter using an OLT rated for 20 km reach. A system that starts with a point to point link which target a serving area of 500 homes, would require two or three node segmentations processes before resulting in a fiber-to-the-last-active FTTLA architecture. This proposed invention is flexible to handle such migration strategy by the addition of “PHY media converters” for each fiber segmentation.

The sequential EPON MAC is well suited to distribute and handle traffic from each new node segment that is created. The use of a 10G MAC allows for the cost effective sharing of this new architecture where the OLT costs can be distributed among 8 or even 16 or 32 coaxial serving areas that have been segmented through deeper fiber penetration. This architecture is more compatible with the cable industry that have Hub-to-node fiber distances of larger than 20 km while using the lower cost optical components. This architecture is also suitable to the node segmentation processes that cable operators follow based on need for higher performance. Figure 1, 2 and 3 show three architecture scenarios of fiber length and node segmentation on how this approach could be implemented.

Figure 1- EPON Based HFC Network with 50 km Fiber Reach using 1 PHY Media Converter

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Figure 2 - EPON Based HFC Network with 50 km Fiber Reach Expanded to 4 PHY Media Converters

Figure 3 - EPON Based HFC Network with 30 km Fiber Reach Expanded to 16 PHY Media Converters