Simplifying and Future-proofing RFoG Networks with a Two-way EDFA

Introduction

Passive optical networks and other fiber to the home (FTTH) solutions essentially eliminate the physical bandwidth bottleneck connecting voice, data and video subscribers to the core network. Two current market dynamics have motivated the Society of Cable Television Engineers (SCTE) to develop a set of standards called ***Radio Frequency over Glass*** or RFoG:

- the proliferation of FTTH networks and
- the continued deployment of widely deployed sub-carrier modulated RF networks by both CATV and telephone network operators.

In short, the RFoG standards specify the requirements to support two-way RF delivery over FTTH networks which benefits both telcos and cable operators. A two-way EDFA is a novel solution for an RFoG optical network node because it simplifies deployment and leverages the enormous capability and bandwidth capacity of fiber optic networks.

RF video overlay is the most popular PON video solution

Today, the most widely deployed FTTH video solution is sub-carrier modulated RF-based using a 1555 nm wavelength overlay. Erbium Doped Fiber Amplifiers (EDFAs) are deployed in these networks to amplify the downstream nominal 1555 nm wavelength to enable the broadcast video signal to be split, combined with other wavelengths and delivered over a 28 db optical budget to the optical-to-electrical conversion point or Optical Network Termination (ONT) at the home.

Set-top boxes (STBs) deployed in these FTTH networks enable interactive, customized viewing features such as video-on-demand. These STBs utilize a two-way, burst-mode communication scheme to support the unique viewer functionality. Cable modems supporting high-speed internet access function in a similar way. Until the creation of the SCTE's RFoG standards, there has been no standardized method of supporting both the downstream and upstream transmissions of the STB and the cable modem over a FTTH network.

All-optical approach to RFoG deployment in RF overlay applications

A key RFoG specification is the use of a separate wavelength for the upstream transmission. The SCTE has selected two wavelength options for the upstream transmission: 1310 nm and 1610 nm. The 1310 nm wavelength can be used in RFoG applications where compatibility with either the IEEE 802.3ah/av EPON (Ethernet Passive Optical Network) or the ITU G.984 GPON (Gigabit-capable Passive Optical Network) standard is not important. Both of these standards specify the use of 1310 nm for upstream transmission.

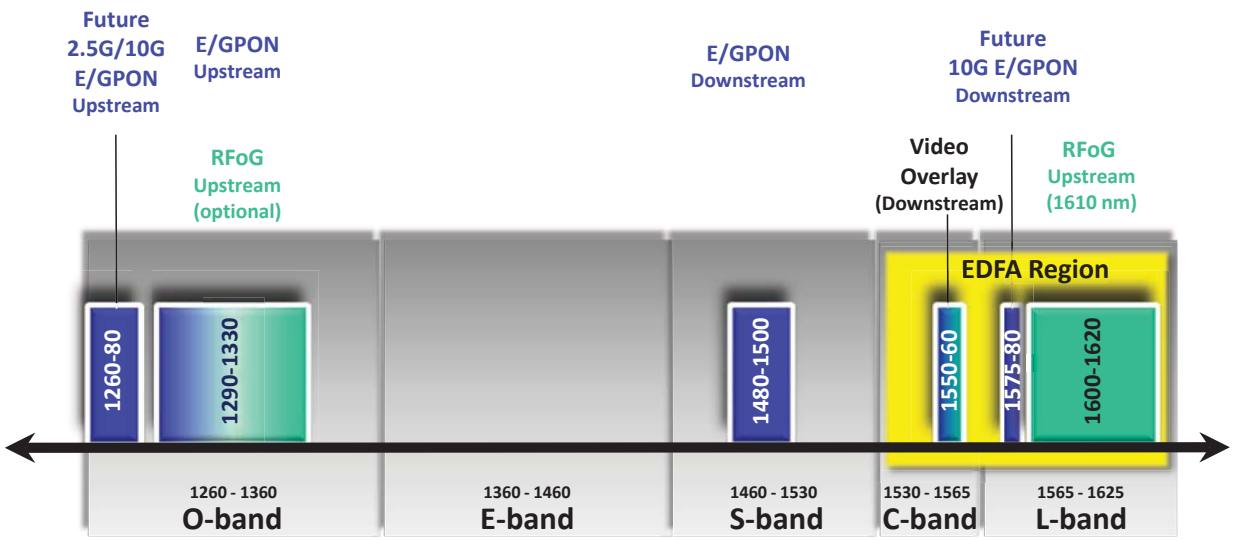

Figure 1 GPON, EPON, RFoG Optical Wavelength Plans

The 1610 nm wavelength has been chosen to ensure its compatibility with the wavelength plans in both current GPON and EPON deployments and their evolution. Both the ITU-T and the IEEE have selected the 1577 nm wavelength for the future downstream 10 Gbps PON upgrades, so 1610 nm is a safe spectral distance away. Prior to selection of the 1610 nm wavelength, all of the early RFoG deployments utilize the 1590 nm wavelength and will continue to do so for some time. Furthermore, there is no current plan to use 1590 nm for future PON evolution, so it is possible that 1590 nm will continue to be used in RFoG networks. Both widely deployed PON solutions, EPON and GPON, as well as RFoG use the 1555 nm wavelength for video overlay applications. See Figure 1 (above) for a depiction of the GPON, EPON and RFoG wavelength plans.

A novel approach to RFoG Optical Node deployment uses a two-way EDFA which enhances the utility and flexibility of the RFoG network for both today's applications and tomorrow's network upgrades. EDFA amplification of C-band and L-band signals is a mature technology and is used to amplify and maintain the optical signal integrity, both downstream and upstream, as well as enable the use of other optical wavelengths for network bandwidth expansion and segmentation.

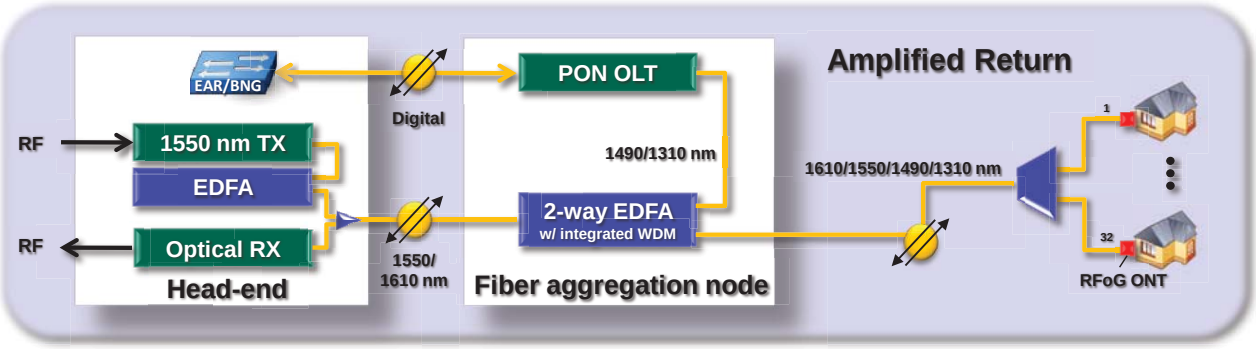

Figure 2 RFoG PON Overlay Network

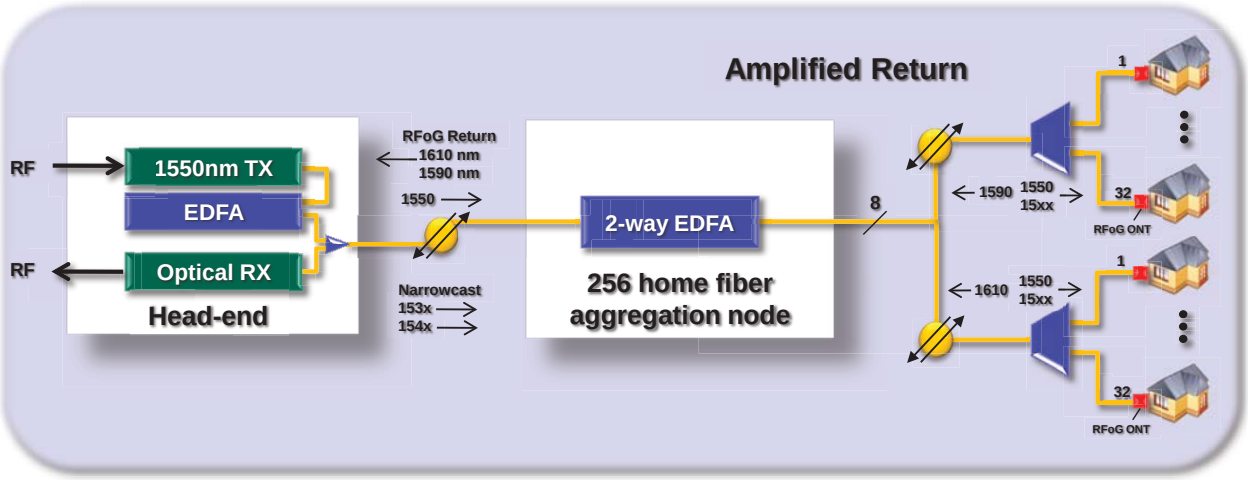

Figure 3 "Amplified PON" Segmentable RFoG Network
Downstream, Upstream Wavelength Segmentation

Figure 2 (opposite) depicts the deployment of a two-way EDFA in a PON overlay application. The EDFA simultaneously amplifies the downstream 1550 nm broadcast video signal in the C-band, as well as the upstream bandwidth from 1585-1620 nm in the L-band. The flat gain performance of the upstream EDFA enables support for multiple wavelengths simultaneously between 1585 and 1620, including 1590, 1610 and other ITU grid channels, each supporting up to 40 Gbps per channel. Thus, the future network capacity enabled by a fiber optic network is very large and preserved with the amplified return path approach.

The EDFA chassis can also include integrated Wave Division Multiplexers (WDM) which combine the upstream O-band (1310 nm) and downstream S-band (1490 nm) PON signals. This eliminates the need for external WDM solutions.

All-optical RFoG deployment supports narrowcasting and network segmentation

The two-way EDFA can be applied to pure RFoG networks in non-overlay applications as well. As discussed above, an all-optical amplification approach unleashes the enormous capability of a fiber optic network. EDFAs can be produced that support flat gain performance over a relatively wide optical window. This permits the deployment of multiple wavelengths of bandwidth-intensive information, both downstream and upstream, using the same EDFA.

Referring to Figure 3 (above), not only are two unique wavelengths supported in the upstream direction (1590 and 1610), but multiple downstream wavelengths can also be used. This enables targeted narrowcast content delivery to very small network segments. The figure depicts a 256/128 home node fed with two narrowcast signals on separate wavelengths. This would enable unique two-way content delivery to and from as few as 64 homes.

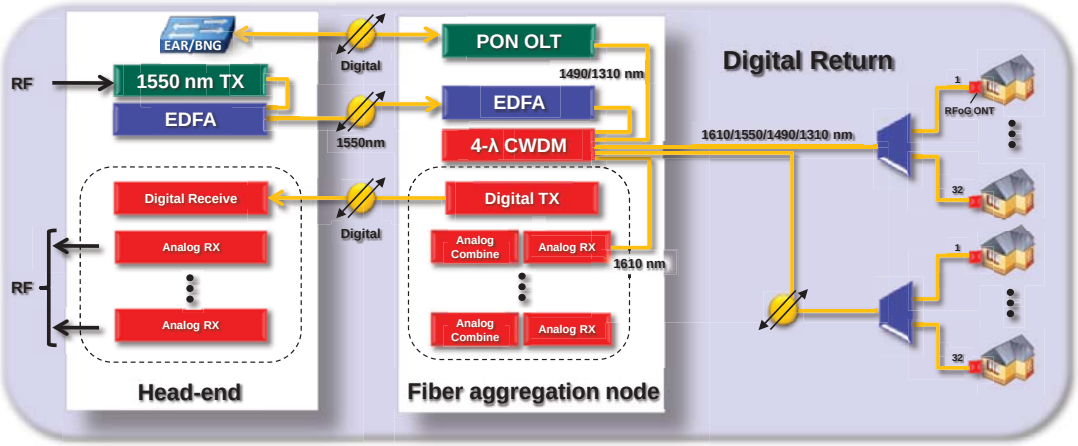

Figure 4 Digital Return RFoG Solution

Digital return solutions restrict network flexibility and capacity

Commonly deployed RFoG optical network nodes require extra equipment to support the upstream RFoG wavelength signal. In most of today's two-way networks, digital return solutions are deployed which must detect the burst-mode signals from each home on each PON, extract the RF information, combine it with other transmissions, digitize it and finally transmit the resulting digital stream to the set top box controller and Cable Modem Termination System (CMTS). The number of RF return signals combined and transmitted over a common return must be restricted to permit an acceptable Signal to Noise Ratio for signal recovery for the CMTS and STB controller.

The digital return solution depicted in Figure 4 (above) has several limitations compared to the amplified approach enabled by the two-way EDFA. The lack of support for multiple downstream and upstream wavelengths for today's narrowcasting and network segmentation requirements and tomorrow's potential DWDM PON upgrades is apparent.

Furthermore, the digital return solutions are designed and optimized around the specific modulation schemes and spectrum utilization of currently deployed RF networks, thereby prohibiting their use with alternative or future schemes.

Conclusion

A fiber optic network is the ultimate solution to enable maximum bandwidth delivery to subscribers. The RFoG set of standards being developed by the Society of Cable Television Engineers recognizes the power and value of fiber networks by enabling an all-fiber connection to each subscriber in a RF network.

The use of a two-way EDFA simplifies the deployment of RFoG networks and also "future-proofs" today's network by enabling significant incremental functionality and leveraging the enormous capability and bandwidth capacity of fiber optic networks.

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