WHITE PAPER

Leveraging RFoG to Deliver DOCSIS® and GPON Services Over Fiber

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As cable operators ready their networks to deliver Ultra-Broadband services to residential and commercial subscribers, they face important topology considerations — particularly when supporting new greenfield buildouts and brownfield plant modernizations. Emerging as a viable solution for cable operators, radio frequency over glass (RFoG) solutions allow cable operators to deploy fiber connectivity directly to the premises while leveraging existing DOCSIS® infrastructure. Providing a migration path to higher-bandwidth Gigabit passive optical networking (GPON) deployments in the future, RFoG is proving ready to aid operators initiating the journey to an all-fiber network

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Combining hybrid-fiber-coax (HFC) technology, along with the DOCISIS infrastructure and newer fiber to the premises (FTTP) technologies such as RFoG and ultimately GPON, will allow operators to cost-effectively deploy fiber directly to the premises. The primary benefit to any operator will be the ability to leverage existing CMTS and cable modem investments and back-office applications, all while maintaining service continuity with existing video, VoIP, and Ultra-Broadband Internet services. Motorola is in a unique position to provide FTTP solutions to cable operators, since we offer both proven expertise in HFC, DOCSIS, and FTTP access network solutions and a robust solution for implementing standards-based RFoG solutions that provide a path to GPON deployments in the future.

An Introduction to RFoG

RFoG allows cable operators to continue to use traditional back-office HFC equipment and applications with new FTTP deployments. With RFoG, cable services are delivered over fiber and will work exactly as if they were delivered over coax. Cable operators can continue to rely on the existing provisioning and billing systems, CMTS platforms, headend equipment, set-top boxes, conditional access technology, and cable modems. Newly installed fiber-optic micronodes — which are also referred to as optical network units (ONUs) — can be located at each subscriber's premises to convert the lightwaves into electrical signals. This is done in place of the same function traditionally performed back at the higher-level serving area nodes in the HFC network. The RF infrastructure stays in place, and the difference is that fiber termination is moved from a fiber node to the customer premises.

Unlike HFC networks, GPON FTTP deployments do not offer a traditional analog return path in support of two-way data communications. In the case of RFoG, the return path necessary for allowing DOCSIS customer premises equipment to communicate with headend infrastructure lies in the newly installed micronode and remains transparent to the overall network architecture scheme.

In the future, operators will be able leverage their new all-fiber access network and deploy FTTP technologies such as GPON when and where it makes sense. The question on timing of any access network evolution and investment is tied to factors beyond the technology alone, to such things as the cost of deployment, potential operational savings, and competitive environments, but GPON is capable of delivering significantly more services than RFoG when the operator is ready to take that next step.

For legacy brownfield cable infrastructure, RFoG can potentially offer a cost-effective upgrade path for expanding plant capacity while delaying investments in alternative infrastructures that will not correlate to the market demand (e.g., major new real estate developers calling for all-fiber infrastructure). For many new communication infrastructure buildouts, cable operators face increasing pressure from real estate developers to deploy fiber directly to the premises. This is due in large part to the perception that access to all-fiber networks have greater value and adds thousands of dollars of value to a home.

Upgrading a Rural Access Network to 1 GHz

RFoG is an alternative solution that can be considered when upgrading an HFC serving area to higher bandwidth. For example, consider an existing 550 MHz HFC plant serving a low-density rural area where there is a growing market need for new Ultra-Broadband services. The traditional approach to this situation would be to invest in a 1 GHz plant upgrade to increase the bandwidth. In this scenario, though, RFoG becomes a compelling economic argument.

Upgrading the HFC plant to 1 GHz would require all of the HFC equipment to be replaced, and a new optical node and several new RF amplifiers may have to be installed every mile. This is a significant capital expenditure, particularly in a rural environment where the homes are distant from each other and there are fewer homes to defray the cost of an HFC upgrade.

By deploying an RFoG solution instead, the cable operator obtains a 1 GHz network and lowers the operating expenditure by not having to power or maintain the HFC equipment. In addition, the cable operator can avoid the sunk cost of additional coax access infrastructure and future-proof its investment by preparing a cost-effective migration path to GPON. RFoG allows cable operators to leverage DOCSIS infrastructure today while deploying fiber all the way to the premises and creating more equity in their access infrastructure.

Why RFoG?

Cable operators continue to find ways to drive more capacity out of their existing HFC plant with bandwidth optimization solutions such as node splitting, analog channel reclamation, DOCSIS 3.0 channel bonding, switched digital video, MPEG-4 compression, and home gateway bandwidth management. But as pressure builds for FTTP deployment, especially in new residential areas, RFoG provides cable operators with a viable Cable PON fiber solution. RFoG can be an important solution for preventing encroachment by carriers and mitigating lost opportunities to FTTP deployments offered by incumbent telcos.

After making significant investments to upgrade their infrastructures, cable operators need an access network that leverages this investment and works within existing operational systems and back office procedures. It is important to evaluate HFC, DOCSIS, and GPON solutions that allow cable operators to deliver flexible and scalable broadband services while building out last-mile infrastructure to support future Ultra-Broadband services. However, operators should carefully evaluate RFoG solutions that are closely tied to emerging standards and can efficiently migrate to full PON-based services in the future.

As operators consider the evolution to all-fiber networks, it is important to understand that the deployment of RFoG does not inherently give the cable operator any additional bandwidth because it still utilizes the same frequency spectrum of an HFC network. However, it does allow cable operators to build future-proof access infrastructure that will potentially tap the 30 THz theoretical carrying capacity of a fiber optical connection to the home. By deploying fiber instead of coax for last-mile connections, cable operators can avoid the potentially sunk cost of deploying coax today and replacing it in a few years as subscribers demand higher-bandwidth, Ultra-Broadband services. They can also improve their ability to compete with carriers for new real estate developments by offering fiber access to triple-play services.

Perhaps the most attractive benefit of RFoG is the potential to reduce operational costs. The term "passive" simply describes the fact that optical transmission has no power requirements or active electronic parts once the signal is going through the network. Less active equipment on the network delivers lower per-subscriber maintenance costs over the lifecycle of the network.

In many cases, RFoG will deliver major operational advantages over HFC. For example, PON equipment needs less power and cooling than the nodes and outside plant used in a typical cable network. Also, fiber delivers a "cleaner" signal, because it's impervious to the kind of interference that can plague RF over coax. Standard PONs provide a reach of up to 20 kilometers using unpowered components, whereas HFC networks require RF amplifiers approximately every 1,000 feet to maintain signal quality.

When deploying FTTP solutions, it is crucial to leverage existing business support system (BSS) and operational support system (OSS) infrastructure so cable operators can preserve existing investments in provisioning, administration, billing, troubleshooting, and administrative applications. Rushing to add new BSS and OSS applications, workflows and processes to support fiber would be inefficient and would result in increased operational costs and decreased customer service levels. By implementing a non-proprietary, standards-based approach to RFoG, cable operators can deploy FTTP solutions that provide a competitive advantage today and support the cost-effective migration to GPON, without the need to replace the last-mile links to the customer premises.

RFoG Implementation

The simplest RFoG implementation is to perform the necessary conversions in the headend and send downstream traffic over optical signals to set-tops and DOCSIS cable modems located on the customer premises. Video controllers and data networking services are fed through a CMTS/edge router, and electro/optical conversion is then performed by an Optical Tx platform. Downstream data and video traffic is fed over a 1550 nm wavelength through a wave division multiplexing (WDM) platform and a splitter to a micronode located at the customer premises. Regeneration is needed in the HFC node for retransmitting the return signals to the hub. If necessary, an erbium-doped fiber amplifier (EDFA) can be used to boost the downstream optical signal to cover a greater distance.

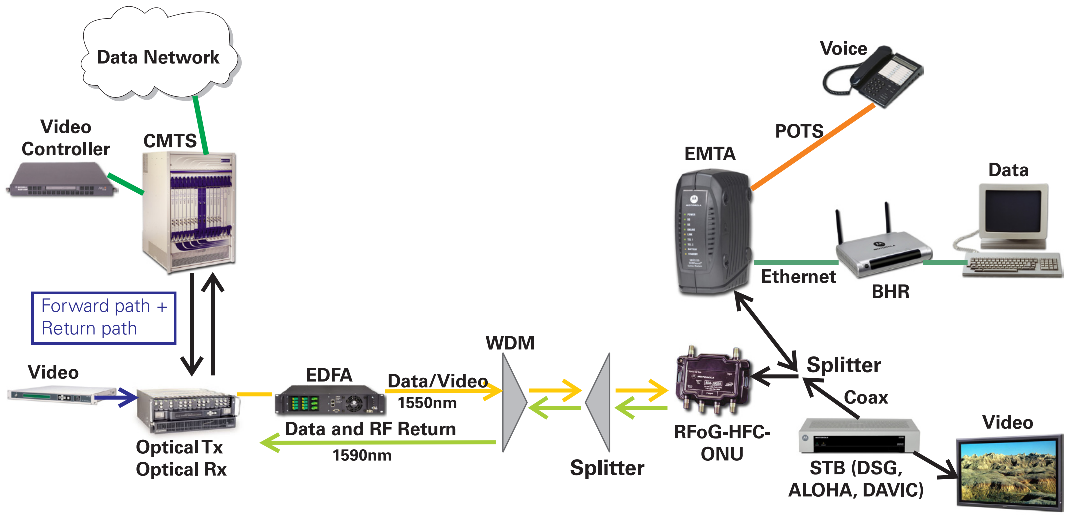

Figure 1: Cable operators can perform electro/optical conversion at the headend, and a Motorola micronode at the customer premises converts the optical signals for distribution of voice, video, and data traffic over internal networks.

A micronode attached to the customer premises terminates the fiber connection and converts the traffic for delivery over the in-home network. Video traffic can be fed over coax to a set-top box, and voice and data traffic can be delivered to an embedded multimedia terminal adapter (eMTA), which connects to analog telephone lines over the subscriber's internal phone wiring and to PCs via Ethernet or WiFi. The return path for voice, data, and video traffic is over a 1310 or 1590 nm wavelength to an Rx platform, which converts the optical signal and feeds it back into the CMTS.

As mentioned earlier, there are two options for the return wavelength on the RFoG network: 1310 nm or 1590 nm. A 1310 nm return wavelength is slightly lower in cost than a 1590 nm return wavelength, but 1310 conflicts with the PON return wavelength. 1590 nm does not interfere with the GPON wavelengths, so it can enable a smooth migration to PON at a later date. With 1590 nm, cable operators can operate a coexisting GPON solution in the future on the same fiber access network as the RFoG solution, and it also allows re-use of the RFoG micronodes for GPON.

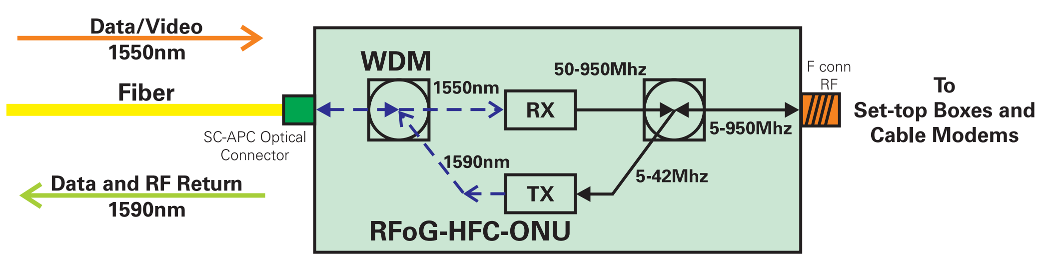

Figure 2: A Motorola micronode is deployed at the customer premises to terminate the fiber connection, and it converts the optical signals to run over internal coax networks.

There are also two options for the fiber architecture: tapped and dropped. Tapped is point-to-multipoint from the node so a single fiber goes down the street and a portion of the signal is tapped to each home. This emulates the HFC tapping architecture, but it does require continuous design effort to select the appropriate tap values for each serving area, and there could be operational challenges to insert/add new homes at a later date. The benefit of this architecture is that it does reduce the fiber bundle that goes down the street. For the dropped fiber architecture, it is point-to-point from the node/splitter, and a dedicated fiber is "dropped" to the home. This is the same fiber architecture being deployed for PON today, so the PON technologies and cost curves can be leveraged. This also lends itself well to future migration to PON.

GPON Implementation with RFoG Enhancements

Cable operators can also deploy a GPON architecture today utilizing an RFoG return path so they can continue to leverage existing customer premises equipment. This approach requires the use of four wavelengths. Downstream GPON traffic flows from the cable operator's data network to an Optical Line Terminal (OLT), which sends the GPON traffic to a WDM device using the 1310 and 1490 nm wavelengths. DOCSIS and video traffic from the CMTS is converted to optical traffic and (if needed for distance) sent through an EDFA amplifier to a WDM platform. The WDM device combines the flows and sends the traffic through a splitter to a micronode at the customer premises, which sends the video traffic over coax and the voice and data traffic over 1550, 1490 and 1310 wavelengths to an Optical Network Terminal (ONT), which converts the optical traffic and sends the data traffic over Ethernet and the analog voice traffic over the existing home phone wiring.

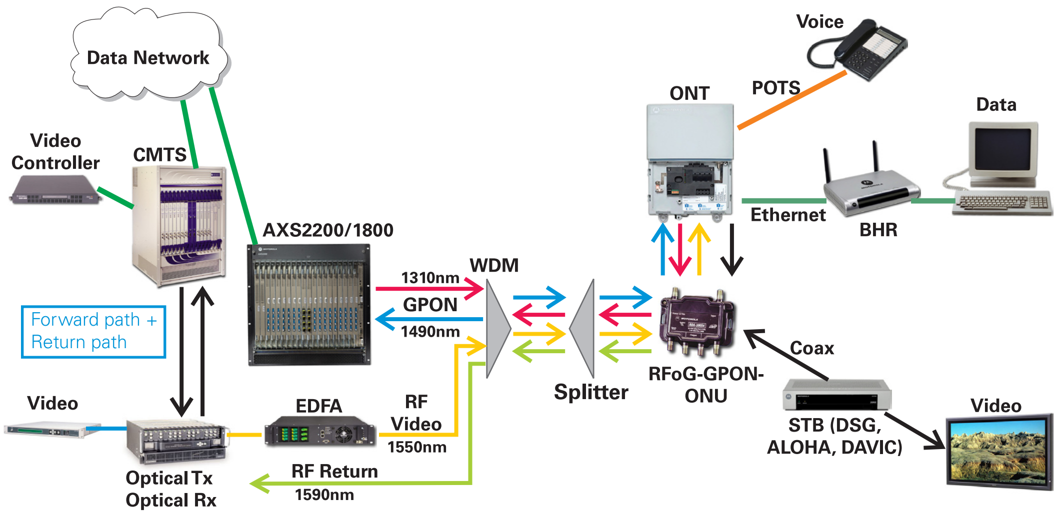

Figure 3: By implementing a GPON architecture with RFoG, cable operators can gradually migrate to GPON while preserving DOCSIS services.

All return path traffic is converted to optical by the micronode and sent over a 1590 nm wavelength to the headend, where an optical receiver converts it and sends it through a CMTS for access to voice, data, and video network resources. This solution allows cable operators to implement a "mixed system" supporting both GPON and DOCSIS services.

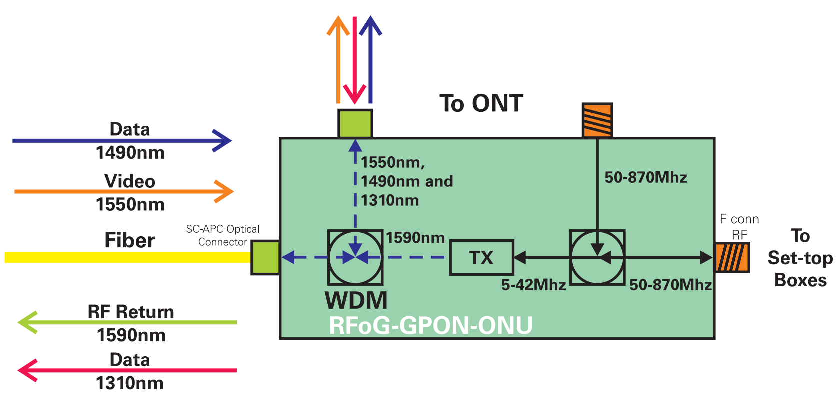

Figure 4: The Motorola micronode converts the video traffic to run over internal coax networks and sends the voice and data traffic to a Motorola ONT over 1550, 1490, and 1310 wavelengths for distribution over internal voice and Ethernet networks.

The following table summarizes the advantages and disadvantages of RFoG and GPON with RFoG enhancements.

	GPON with RFoG Enhancements	RFoG
Advantages	• Optics to the end user • GPON provides huge downstream and upstream bandwidth • Long-term service and revenue potential	• Optics to the end user • No change for HFC back-office • System ready for migration to GPON
Disadvantages	• Change to HFC back-office (for provisioning of voice and data services) • Higher CPE cost (ONT)	• No additional upstream or downstream bandwidth • Similar costs to GPON

Coexisting RFoG and GPON Solutions

With advanced design considerations, cable operators can concurrently operate RFoG and GPON solutions in the same serving area so a home receiving services through RFoG can be a neighbor of a home receiving services through GPON. A WDM platform is the demarcation point between RFoG and GPON, and cable operators can gradually migrate subscribers to a GPON solution based on market requirements. Figure 5 is a network diagram showing how RFoG and GPON solutions can coexist for the same serving area.

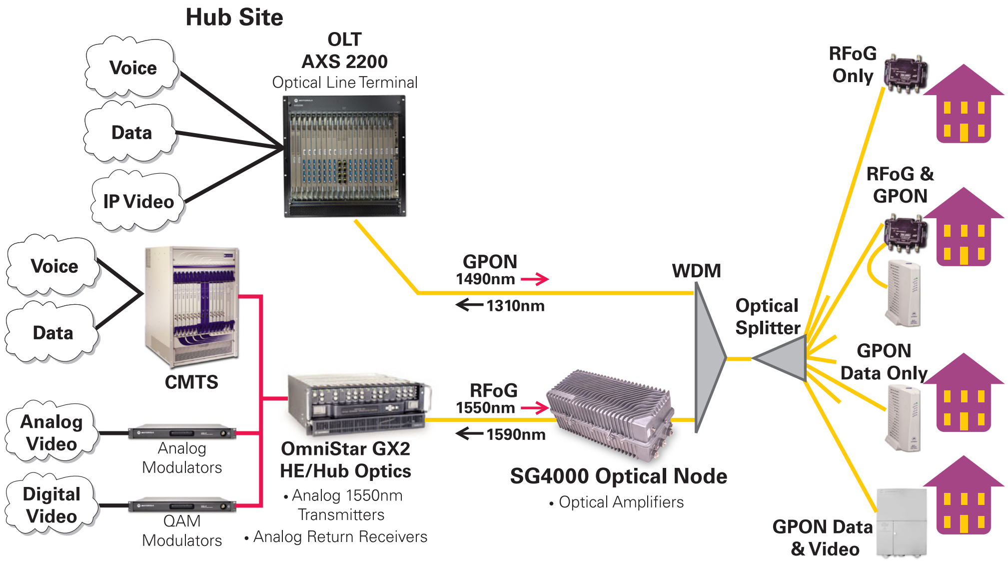

Figure 5: RFoG and GPON can coexist in the same serving area, allowing operators to cost-effectively migrate to PON while leveraging deployed access network infrastructure.

Initially, the cable operator would deploy an RFoG micronode with a PON optical expansion port. Figure 6 is a diagram of this micronode. The PON-specific wavelengths, 1490 nm and 1310 nm, are routed to the expansion port. If and when a cable operator needs to deliver more Ultra-Broadband services to a specific home, such as higher-speed symmetrical data service or IPTV, a GPON ONT can be connected to the expansion port. The RFoG micronode can still be utilized to deliver traditional video services and handle the legacy return signals as long as needed.

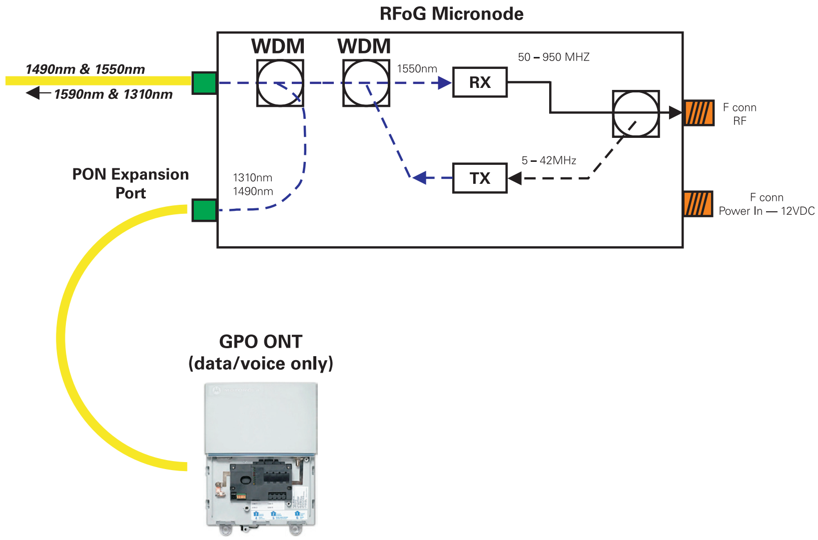

Figure 6: RFoG micronode with a PON expansion port. A GPON ONT is connected to the expansion port when Ultra-Broadband services are required.

Conclusion

Today's PON solutions do not support the ability to utilize existing DOCSIS infrastructure deployed in residential homes, headends, and hubs, and they are not integrated into existing OSS infrastructure for provisioning, billing, and customer support. Motorola offers expertise in HFC, DOCSIS, and FTTP access network solutions and offers a cost-effective migration path for deploying RFoG today while providing a path toward PON deployments in the future.

With Motorola's RFoG solutions, cable operators can utilize their existing DOCSIS set-tops and DOCSIS equipment and applications. Motorola offers expertise in both HFC and fiber access network infrastructure and offers the professional services expertise that can help cable operators gradually migrate to fiber infrastructure according to economic demands.

- **GX2 OmniStar HFC chassis**
  - 1550nm Transmitter module
  - 1550nm EDFA module
  - 1590nm Receiver module
- **QA200 EDFA**
- **SG4000 HFC Node**
  - Optical Amplifier module

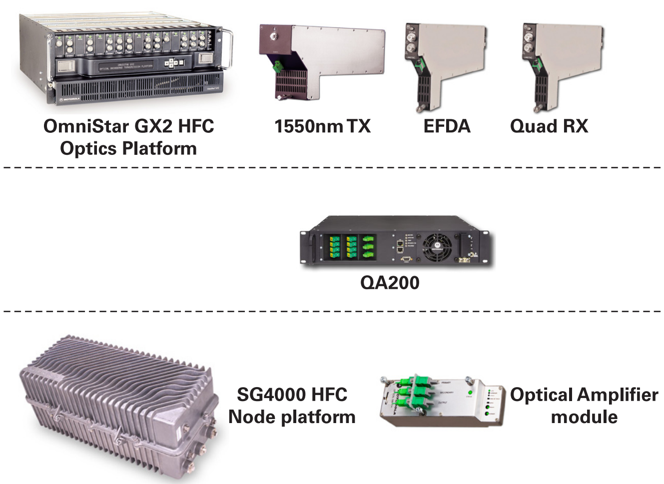

Figure 7: Motorola offers a full range of products for supporting flexible RFoG deployments.

RFoG is an emerging standard that is today in its infancy, so selecting standards-based RFoG solutions is essential for preserving investments in fiber deployments. As the only major vendor with proven expertise in deploying both HFC and fiber access network solutions, Motorola offers an unbiased perspective on deploying high-performance access networks that support Ultra-Broadband service delivery. For more information about Motorola RFoG solutions, contact your Motorola account representative or visit www.motorola.com.

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