



# Cable Optimized Optical Migration is the Key to Revitalizing Operators' Competitive Advantage

Agressive Use of RFoG in Combination with Other Solutions  
Maximizes Near-term ROI and Long-term Stability





## Contents

Introduction .....	3
RFoG and Fiber Deep – The Linchpins in Cable Network Evolution .....	3
The Motorola Advantage in Cable-Optimized Solutions .....	4
RFoG Performance .....	4
Architectural Flexibility .....	5
RFoG with Fiber Deep .....	5
GPON Strengths.....	5
Leveraging RFoG and GPON Compatibility .....	6
Forthcoming Advances in Motorola PON Solutions.....	6
Application Scenarios for Cable-Optimized FTTP.....	7
Commercial Services.....	7
Wireless Backhaul.....	7
Residential Services .....	8
Conclusion .....	8

## Introduction

The cable industry has reached a strategic flashpoint where niche-driven opportunities for aggressive deployment of fiber can be leveraged to accelerate the migration to all-optical networks that will be essential to addressing market challenges in the years ahead.

Operators can now leverage cable-optimized fiber-to-the-premises (FTTP) platforms such as RFoG (RF over Glass), together with low-cost fiber deep solutions, as optimal solutions for their immediate needs in commercial services, greenfield residential build outs, and many other incremental applications, thereby setting the stage for more pervasive use of FTTP at acceptable capital costs when market conditions require. By developing a strategic framework that encourages opportunistic use of fiber in the context of long-term migration goals, operators can avoid a potentially costly day of reckoning in the transition from HFC to all-fiber networks.

The need for a cost-effective optical migration path in cable is obvious. Slowly but surely, the cable industry's biggest competitors are driving fiber to the premises in single- or two-stage processes. By the end of 2008, Verizon had passed nine million living units with its all-fiber FiOS facilities, with plans to reach 18 million by year-end 2010. AT&T, deploying fiber-to-the-node as a first step, was at the 14 million passings mark at year-end 2008, on its way to 30 million by year-end 2010.

Eventually, the capacity advantages of telco gigabit passive optical network (GPON) infrastructure will be present on a broad enough scale in major markets to prompt all-fiber responses from cable operators. Consequently, it is essential that the cable industry be freed from the Hobson's choice of either having to continually convince investors that coaxial plant is sufficient to meet all competitive challenges for the foreseeable future or at some point having to acknowledge that an immense new capital spending program will be required if cable operators are to remain competitive.

There is no better case to be made for a new, strategically aggressive approach to the use of fiber than the range of cable-ready optical solutions now on offer from Motorola. Until now, the idea of migrating to all-fiber or nearly all-fiber networks posed untenable cost and strategic challenges for cable operators, who have steadfastly insisted on HFC-optimized approaches to meeting capacity needs. Fortunately, as commercial services and other specific market opportunities demanded a greater use of fiber, this adherence to HFC requirements led Motorola to produce a set of optical solutions that position FTTP as a natural, cost-effective progression in cable network evolution. These options, described in detail below, include:

- Fiber Deep
- RF over Glass
- GPON
- EPON TDM over Ethernet
- Hybrid Solutions Leveraging Wavelength Division Multiplexing and Other Advanced Technologies

As the pioneer in fiber distribution solutions for HFC architectures and a global market leader in FTTP, Motorola has built on its tradition as an optical innovator with a comprehensive portfolio of next-generation HFC-compatible solutions. Furthermore, it has ensured that core components of its legacy HFC product line are equipped to support the most flexible, least costly approaches to deploying these new fiber solutions as new needs emerge. And by adhering to standards in all aspects of its development efforts, Motorola has ensured that its next-generation fiber solutions can be readily deployed in other HFC vendor environments.

## RFoG and Fiber Deep – The Linchpins in Cable Network Evolution

RF over Glass (RFoG) technology is rapidly becoming the foundation platform for cable's evolution to FTTP. At the same time, low-cost extensions of fiber from existing nodes to strand-mounted nodes using existing amplifier housing, such as Motorola supports with its Mini Bridger technology, offer operators a way to substantially reduce the size of HFC service areas.

Fiber deep extensions, by lowering the number of households contending for dedicated bandwidth, allow operators to deliver ever more unicast services. And, by shortening the coaxial links to where there are only one or two amplifiers in line, fiber deep opens more RF spectrum in the downstream and upstream paths. Leveraging fiber deep today to introduce more unicast channels and to expand available spectrum for channel bonding in DOCSIS 3.0 deployments not only assures operators will remain competitively strong in the near term; it positions them for rapid, low-cost FTTP extensions of fiber in the years ahead.

RFoG allows operators to build a foundation for rapid migration to all fiber operations in the future.

For immediate FTTP requirements, RFoG is by far the most cost-effective option available to cable operators. Rather than using the baseband digital multiplexing common to GPON and other fiber access platforms in telecommunications, RFoG allows MSOs to extend amplitude-modulated optical signals from HFC nodes all the way to customer premises, with no regeneration required in the downstream.

RFoG delivers the same types of services that are transmitted over any HFC network, including TV and DOCSIS-based data and voice. In the downstream, however, the elimination of RF amplifiers extends the upper limits of the frequency to 1 GHz and above. Similarly, there are no RF amplifiers to amplify noise levels in the 5–42 MHz return path, which allows use of higher rates of quadrature amplitude modulation (QAM) than would otherwise be the case.

Moreover, techniques that limit the amount of premises-generated ingress noise entering the fiber path lower the noise quotient to the point where more of the available return spectrum becomes available, often including the 5–15 MHz segment, which is unused in most HFC networks. The combination of higher QAM and expanded spectrum usage over RFoG can be leveraged to increase upstream bandwidth by 30 percent or more in comparison to typical HFC capacity.

These great advantages can be put to use in a variety of ways. Because RFoG and legacy HFC service distribution operate concurrently from the same hub and headend, cable operators can begin implementing all-fiber network extensions incrementally at minimal costs as conditions dictate. The RFoG platform can be used as the primary conduit for all services delivered to all customers in a node serving area, or it can be operated as a separate network for a specific class of users, such as businesses or high-end residential customers.

By enabling the use of fiber to address immediate needs more aggressively than would otherwise be the case, RFoG allows operators to build a foundation for rapid migration to all-fiber operations in the future. Optimization for future migration is intrinsic to RFoG, which is designed to comport with the PON architectural specifications of IEEE PON networks. Through the use of multiple wavelengths, operators can add new PON platforms using the same fiber infrastructure they deploy for RFoG, greatly expanding their bandwidth and service options for the business and residential markets at low incremental costs.

One sign of cable operators' growing embrace of RFoG is the fact that the Society of Cable Telecommunications Engineers is developing standards to create a more interoperable environment for vendor RFoG solutions. The SCTE's Interface Practices Subcommittee (IPS) is selecting return path wavelengths for RFoG to ensure compatibility with other PON technologies. Other areas of work include setting parameters for outdoor connectors and for transceiver burst timing on the return path.

As with any other new technology, volume demand for standards-compliant RFoG solutions will serve to drive costs down. Already, RFoG is cost competitive with traditional HFC deployments in greenfield situations. Research shows deployments of RFoG over existing cable infrastructure range from \$350 to \$600 per connected premises, including the fiber. This is a fraction of the costs associated with any other FTTP solution.

It is also important to note that RFoG, like any FTTP platform, offers great operations cost savings over the life of the network. With no active electronics between the hubs and subscriber locations, RFoG eliminates leakage and the need for sweep testing, while radically reducing power requirements on the outside plant. The premises-mounted fiber termination modules used in RFoG, known as optical network units (ONUs), are powered from the subscriber site with optional battery backup and therefore do not impose any power penalties on the network.

The all-fiber network also delivers major long-term savings by virtue of the fact that it is not susceptible to the same degree of deterioration that metallic networks experience from climatic conditions and other corrosive factors. Cable operators that have been long-term users of all-optical networks report maintenance costs are a tenth or less of what they routinely experience with HFC networks.

## The Motorola Advantage in Cable-Optimized Solutions

### RFoG Performance

Motorola has designed a RFoG solution that uniquely maximizes the performance and flexibility of this technology for cable operators. For example, Motorola's system offers superior bandwidth conserving benefits with respect to the aforementioned RFoG return path technique.

In RFoG architectures, the ONU terminating the fiber link at each premises serves as a “micronode” that interfaces with coax in a manner that is analogous to the interface between distribution fiber and coax at HFC nodes, but with a key difference. While the downstream video and DOCSIS voice and data signals are converted from optical to electronic for distribution over coax in the home, just as they are converted at the HFC node in the shared access mode for distribution to all customers in the service area, the conversion process in the upstream handoff from the internal coax to the RFoG link is refined to accommodate noise reduction requirements in the optical return path.

Using sophisticated burst signal management techniques, Motorola’s micronode upstream transmitter senses when the customer’s cable modem is transmitting within the timing intervals assigned to each modem from the cable modem termination system (CMTS). By turning the transmitter on and off in sync with these bursts at microsecond intervals, the micronode prevents upstream transmission of ingress noise on the coax when the modem is not transmitting. This reduces the cumulative amount of noise moving over the upstream path.

Equally important, the Motorola micronode, operating at 1.5-microsecond on/off cycles, is fast enough to accommodate the burst intervals set for DOCSIS 3.0. At 1.6 microseconds, these burst intervals are significantly shorter than the intervals set for other DOCSIS modes. This is a crucial differentiation in the capabilities required for RFoG deployments to accommodate the introduction of DOCSIS 3.0 without upgrading the micronodes.

### **Architectural Flexibility**

Architectural flexibility is a hallmark of Motorola’s RFoG platform. This flexibility begins with how operators choose to deploy the last-mile fiber: either in PON architecture mode, where the signal is split onto multiple fibers running to each premises, or in traditional cable distribution mode, where the signal is passed from the node into feeder lines that are attached to drop fibers connecting to individual premises.

The number of premises that can be served in either approach without use of amplification varies, depending on the customer density and distances signals have to travel. In a typical HFC service area, the PON architecture can be used to reach 32 individual customers, as long as none of them are more than 20 link kilometers from the regional distribution hub.

By deploying an erbium-doped fiber amplifier (EDFA) in front of the splitter at the node, the operator can boost the RF optical signal without regeneration to greatly expand service reach in a variety of configurations. The node-mounted EDFA, along with WDM, transceivers, and other RFoG components, readily plugs into Motorola’s widely deployed SG 4000 HFC node and is compatible with other vendor nodes as well. Depending on distances, the EDFA-powered PON links can reach up to 250 end users.

Use of an EDFA at the node also allows the operator to position the splitter or splitters deeper in the distribution plant. By placing splitters in environmentally hardened strand-mounted housing beyond the nodes, the operator can serve clusters of buildings, such as multi-tenant and single office buildings and/or multi-dwelling and single residential units in situations where fiber connectivity is a superior option to coax.

### **RFoG with Fiber Deep**

The node-mounted EDFA can also be used to serve fiber-deep extensions of the HFC architecture in tandem with supporting the RFoG infrastructure. Motorola’s widely deployed Mini-Bridger technology allows operators to extend fiber deeper from existing node positions using existing amplifier modules. Line technicians simply replace the lid of the strand mounted Motorola amplifier with an optical node housing to create a new node serving area.

The EDFA delivers the wavelength carrying HFC services to the fiber deep nodes and, at the same time, powers the RFoG wavelength to expand the base of fiber-connected services. This dual-pronged RFoG/fiber-deep option represents an extremely cost-effective way to implement optimal combinations of reduced coaxial service areas and FTTP footprints within the existing node service areas to meet near-term revenue opportunities and competitive challenges. And it creates an architectural framework for ongoing expansion of the FTTP customer base over time.

### **GPON Strengths**

Another great advantage associated with relying on Motorola for cable-optimized optical solutions is the company’s global leadership in GPON technology. Widely used by Tier 1 carriers here and abroad, Motorola’s GPON platform is also becoming an important resource for cable operators as they expand commercial service offerings into the larger SMB, enterprise, and institutional markets.

## Cable Operators can operate RFoG and GPON, or other PON networks, over the same shared fiber infrastructure.

GPON is a standardized platform supporting passive distribution of a 2.4 gigabit-per-second payload in the downstream with return capacity of 1.2 Gbps split across as many as 64 FTTP access lines. Because GPON supports multiple formats common to telecommunications, such as Ethernet, T-1 and many others, it gives operators the versatility to support enterprise customers with services that are compatible with legacy CPE.

Motorola's GPON optical network terminals (ONTs), in wide use for residential as well as business services, are intelligent devices with embedded support for session initiation protocol (SIP)/H.248 clients, IP group multicast protocol (IGMP) multicasting, direct software upgrades, and other applications. The ONT portfolio includes units designed to connect single family, small business, and multi-dwelling living units to video, data, and voice services.

The Motorola GPON solution supports a variety of home networking technologies, including Multimedia over Coax Alliance (MoCA) and Home Phoneline Networking Alliance over Cable (HPNA-C), and set-top terminal platforms, including QAM, QAM/IP and IPTV. The GPON portfolio includes software system support for access over XML and other interfaces to business and operational support systems, as well as support for rapid provisioning, service management, and performance monitoring.

### **Leveraging RFoG and GPON Compatibility**

Because RFoG is designed to operate over the same line distances – 20 Km. – set by GPON and other PON standards, cable operators can operate RFoG and GPON or other PON networks over the same shared fiber infrastructure by employing different wavelengths for the downstream and upstream components of each. Separate light streams serving RFoG and GPON customers from the hubs to the nodes can be wavelength multiplexed together at the hubs or nodes and then split for distribution over the home run fibers, allowing the operator to connect customers to RFoG via ONUs or to GPON via ONTs.

In situations where operators are likely to mix the two platforms in this fashion, they will want to use the 1590 nm upstream option offered with RFoG, leaving the use of the 1310 wavelength for the GPON upstream, as dictated by the standard. Downstream, the RFoG would operate over the 1550 nm wavelength and GPON would transmit on the 1490 nm wavelength.

Motorola takes the combined platform capabilities a step farther by providing premises equipment that supports delivery of both the GPON and the RFoG signals to the same location. An expansion port on the RFoG ONU can be used to connect the GPON wavelengths over an internal fiber link to an indoor ONT, which Motorola developed in response to growing demand for GPON termination solutions that avoid the costly requirements of Network Equipment Building Systems (NEBS) compliance associated with outdoor gear.

This RFoG/GPON combination option provides operators with an opportunity to serve a multi-tenant office building, wherein some offices require the SMB services offered over DOCSIS while others require the service classes delivered by GPON. The ONT, with four Ethernet ports, allows the operator to provide GPON services over Ethernet LAN connections to up to four tenants. Of course, the compact internal ONT can also be used in instances where operators are offering GPON without RFoG, where the external fiber is connected transparently to the internal fiber link without use of an ONU.

### **Forthcoming Advances in Motorola PON Solutions**

As PON technology enters the cable mainstream, Motorola is positioned to be as responsive to cable's needs as it has been to the needs of the telecommunications industry as a whole. The company has been developing new iterations of the GPON interface to accommodate an ever broader array of sector needs, including those of the enterprise community, as well as cable.

One of the innovation tracks has to do with the amplification aspects of the technology, which will benefit cable as well as enterprise customers by greatly extending the reach of GPON distribution nodes into locations far removed from existing networks, including rural franchise areas served by cable operators. Continuing innovation around low-cost internal ONTs is another development area that could benefit cable operators, especially in future situations where GPON or some other non-RF version of the technology becomes widely used in the residential market.

Motorola also recognizes there is growing interest in Ethernet PON (EPON) within the cable industry, including the next-generation 10 Gigabit EPON technology now under development by vendors and the IEEE. In light of cable's widespread use of gigabit Ethernet as a distribution platform over metro backbones, as well as the industry's embrace of the Metro Ethernet Forum's definition of Carrier Ethernet as a standardized set of service solutions for the business market, 10G-EPON could well prove to be the natural path for cable's expansion into pervasive deployment of FTTP in the future. As part of the Society of Cable Telecommunications Engineers' work on RFoG standards, cable operators are already factoring in the return path wavelength choices associated with 10G-EPON to ensure there are no conflicts.

Motorola is participating closely in these developments and will be introducing products optimized for cable as operators define their requirements. In fact, one step already taken in this direction is Motorola's introduction of an Ethernet solution for TDM-based backhaul. Operators can be assured that, just as Motorola has maximized compatibility between its RFoG and GPON solutions, it will introduce EPON solutions that can easily co-exist in the RFoG FTTP environment.

## Application Scenarios for Cable-Optimized FTTP

### Commercial Services

The market opportunity where flexible use of new cable optical system options is most critical can be found in commercial services. Traditionally, operators have either had to rely on use of coax to serve businesses that happen to be in reach of the existing network or they've had to allocate fiber from existing service area bundles to serve larger businesses whose service requirements go beyond what can be delivered over DOCSIS channels on the coax.

This approach has several drawbacks, starting with the fact that, once available fibers are allocated from the bundles, the operator is unable to add new commercial customers who require fiber-based service without incurring great costs.

Smart, flexible application of Motorola's RFoG and its other cable-optimized fiber solutions in conjunction with the use of HFC plant to serve all classes of business needs allows operators to maximize returns on their considerable investments in commercial service operations. Now their commercial service units can compete toe-to-toe with incumbent telecommunications carriers across the entire service area, overcoming the inefficiencies that come with offering just certain types of services suited to certain types of businesses that happen to be in close proximity to cable plant.

Along with architectural flexibility, greater efficiency in the commercial services arena requires that operators no longer have to use separate back-office and provisioning systems for RF-based and PON-based services. Motorola, with IT teams working together from the DOCSIS and PON sides of its business, has made great strides in this direction by developing a mediation layer that allows the legacy back-office systems to treat the PON-delivered services as though they are part of the DOCSIS infrastructure.

Essentially this means that PON customer ONTs can now be provisioned through the same CMTS mechanisms that are used to provision DOCSIS services, including Layer 2 Virtual Private Networks and TDM Emulation. With these back-office efficiencies, operators can readily orchestrate implementation of RFoG and GPON options individually and in combination with each other from one business location to the next while fully utilizing HFC plant for both residential and small-office business customers.

RFoG is especially vital to the operator's ability to adequately serve all the businesses in the SMB sweet spot where high prices and poor service on the part of incumbent telecommunications companies has opened a big market opportunity for cable operators. And it affords operators the opportunity to offer TV channel packages especially suited to business needs.

In instances where guaranteed carrier-class services such as Fast Ethernet, multiple T-1s, VPNs, and VLANs are required, the RFoG FTTP infrastructure can be used to offer GPON or EPON services. At the same time, with Motorola's multi-wavelength RFoG/GPON option, the operator can use a single fiber to serve both the small and large businesses at a given location. And, where clusters of office buildings are located at a significant distance from the HFC network, the EDFA powering option can be used to extend the RFoG/GPON distribution network to these customers as well.

### Wireless Backhaul

The Motorola optical portfolio also provides operators with the means to provide cellular carriers the backhaul services they need to accommodate ever expanding capacity requirements. Traditionally, cellular carriers rely on T1 transport from incumbent carriers, but T1 doesn't offer enough capacity to handle the surging demand for IP multimedia and high-speed Internet access over mobile networks.

Cable operators can out-compete traditional carriers for this high-capacity business by offering much lower-cost transport over their Ethernet-based optical infrastructures, provided they meet the rigorous performance requirements that mobile carriers expect from carrier-class TDM networks.

Motorola's TDM circuit emulation over Ethernet allows cable operators to meet the low jitter and low delay standards of cellular backhaul in multi-wavelength as well as single wavelength environments, thereby

greatly reducing the costs of service to customers in comparison to what incumbent carriers charge. With backhaul accounting for about 40 percent of total cellular operating costs, cable operators have a major opportunity to capture this business in the context of leveraging their gigabit Ethernet backbone and PON distribution infrastructures.

### **Residential Services**

One of the early drivers behind use of RFoG in cable has been demand for fiber-based services from planned community developers. The platform provides a means by which operators can leverage their existing headend and hub resources to satisfy these requirements through EDFA-based extensions of fiber reach into the new sub-development.

Similarly, RFoG provides cable operators an opportunity to cost-effectively meet rising demand from the owners of apartment buildings for fiber-based services. Now that incumbent telephone companies are offering IPTV as part of their residential service packages, they are evangelizing fiber connectivity in the MDU marketplace. Cable operators can pre-empt these initiatives by leveraging RFoG before telco TV services become available.

RFoG also provides operators with a cost-effective, all-fiber option in instances where old HFC plant requires a major upgrade, including rural areas where the operator may want to consolidate once-isolated operating territories into the operational domain of a regional master headend. Replacing old coaxial plant in remote areas with a local RFoG distribution network that's connected by long-distance fiber to the regional headend can become an efficient, cost-effective way to build for the future in legacy or newly acquired rural franchise areas. This is especially important in areas where economic growth fueled by government initiatives is likely to open new opportunities for advanced telecommunications infrastructure providers.

### **Conclusion**

There are an abundance of market-driven opportunities for more extensive use of fiber in cable networks, and there is an ideal solution or combination of solutions for each type of opportunity. The key to maximizing the near- and long-term benefits associated with these options is a technically savvy, open-minded decision-making environment that encourages innovation while insisting that key personnel have a good working knowledge of the new networking options that are available to address immediate needs.

Such a strategic framework will lead inevitably to more aggressive use of fiber. As cable managers become well versed in the cable-optimized options made possible by Motorola, they will naturally choose fiber over other alternatives based on performance, operations cost efficiencies and initial cost analysis.

The ROI benefits from aggressive use of FTTP in the commercial services, wireless backhaul, new residential and residential rebuild segments, in combination with competitively superior service offerings made possible by low-cost fiber deep extension of HFC, will strengthen cable operators' financial positions in the short run. In the long run, cable operators will find themselves in the enviable position of being able to deploy FTTP ubiquitously at cost levels that are well below those of competing networks.



Motorola, Inc. [www.motorola.com](http://www.motorola.com)

MOTOROLA and the Stylized M Logo are registered in the US Patent & Trademark Office. All other product or service names are the property of their respective owners © Motorola, Inc. 2009. All rights reserved.

568711-001-a 01/09