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## Fiber to The MDU

*Editor’s Note: Considering the number of condominiums, apartments, etc in a given residential architecture, it was inevitable that this market needs to be studied for its direct fiber challenges and opportunities. In John George’s thorough piece following, look for the benefits and obstacles regarding the economics of FTT-MDU compared to FTTH. Corning’s C. Mark Turner follows the George piece with a thoughtful look at how multimode fiber may couple with single-mode in the access space. Considering that has been the history of optical fiber—a complementary relationship between the two—it makes perfect sense to try to better understand where it is going.*

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## Fiber to the MDU: Architecture Options and Considerations for Condominiums and Apartments

*John George, Director, FTTX Solutions, OFS*

While FTTH receives much attention, there are about 30M Multiple Dwelling Units (MDUs) currently in the U.S., and about 300K – 400K new MDUs are built annually. Customers in these residences may place a greater value on video, data, gaming, and voice services given their liberation from time-consuming yard work and home maintenance. But, as with FTTH, Fiber to the MDU (FTT-MDU) must compete with alternative technologies to meet stringent return on investment (ROI) requirements. This article will discuss and compare Fiber to the Multiple Dwelling Unit, Building, and Complex (FTT-MDx) in the context of access bandwidth demand that is growing at a rate of over 40% annually.

### Video: Designing for Profitable Revenue and Bandwidth Demands

Service providers are racing to become dominant providers of video-based services for good reason: Video sells, and can be very profitable. Video-based applications will increasingly dominate the high-margin space for broadband services. A future high definition 3-D video application may require over 1 Gbps for each stream to or from the

subscriber based on current technology projections. Today we see increasing needs for higher and symmetrical bandwidth to upload or e-mail video clips, photos, and for online video games. To support ever higher definition video, in conjunction with personalized video delivery to/from each subscriber, a successful FTT-MDx plan should include a network which can be cost effectively scaled to support 1 Gbps per subscriber and even 10 Gbps rates over the 25 year to 40 year lifetime of the outside cabling system, without labor intensive and expensive outside cabling upgrades. <sup>1</sup>

The outside FTT-MDU network elements – optical cable, cabinets, splitters, jumpers, and connectors, in aggregate typically account for only \$100-\$250 of the typical installed network cost of \$1200 (electronics included) per unit connected (aerial) and \$1700 per unit connected (buried), while the installation and placement of these components constitutes typically \$200 to \$700 per home connected <sup>2</sup>. Though 1 Gbps speeds are not immediately required, the FTT-MDU network infrastructure should be designed to support a cost-effective upgrade path for multiple generations of electronics to reach gigabit speeds without expensive replacement of outside plant elements

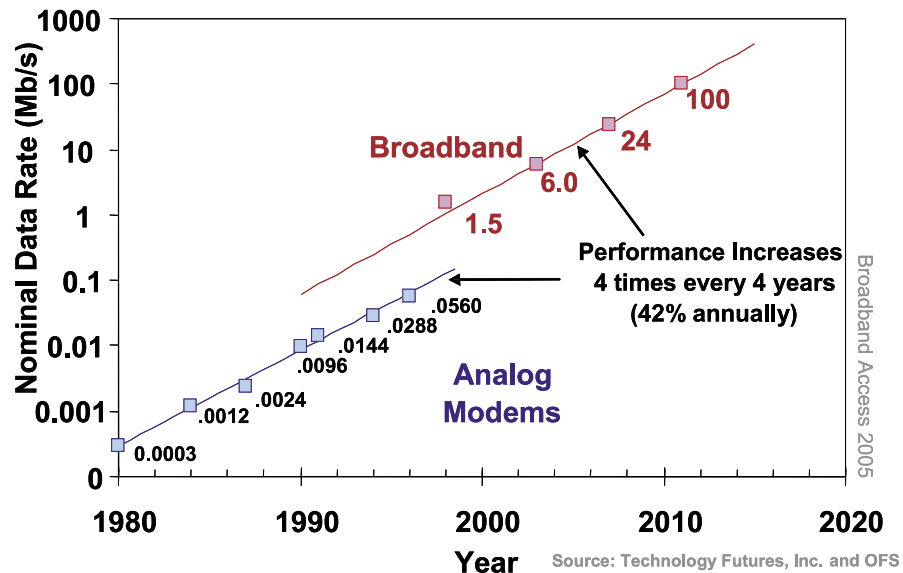


Figure 1 – Projected bandwidth demand per subscriber on track to reach >1 Gb/s by 2020.

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## **Fiber-to-the-MDx Options**

What is Fiber to the MDU? Like FTTH, it is fiber to each living unit, with one dedicated optical networking unit (ONU) serving each living unit. FTT-MDx options exist in which fiber is pushed close to the MDU, which more or less resemble Fiber to the Node (FTTN), Hybrid Fiber Coax, (HFC), and Fiber to the Curb (FTTC) networks. Or fiber can serve an MDU building, with copper feeding tens of living units from an optical networking cluster in the basement. All of these approaches can support video, voice, and Internet services today, but some may not support future video-intensive applications.

### **Fiber to the Multiple Dwelling Complex**

This architecture, which we could call FTT-MDC, would consist of one or a few fibers from the CO serving a node, and from that node many apartments or condominiums would be connected by twisted pair or coaxial copper cabling. Given the size of some apartment complexes, the copper cabling could reach several thousand feet to the unit in some cases. With this architecture one can support a high revenue array of services over the short-to-medium term. The relatively long lengths of copper using xDSL technologies would result in a maximum assured bandwidth per subscriber of 25 Mbps to 50 Mbps downstream, and a few megabits per second upstream. While HFC can supply up to 6 Gbps of total bandwidth to the node, this must be shared by all of the subscribers on the node, resulting in an assured-bandwidth limit of about 9 Mbps downstream and 1 Mbps upstream with 400 subscribers per node, and 8 times that level with 50 subscribers per node.

### **Fiber to the Multiple Dwelling Building**

In an FTT-MDB installation, the fiber is deployed to a node in or on the building, and this node serves all units within that building. In such a case, the length of twisted pair copper can be reduced to less than 330 feet, and the quality of the copper cable may be upgraded to Category 5e, which can ultimately support 1 Gbps data rates at such short lengths. As with FTT-MDC, there is an HFC version of this architecture in which the last few hundred feet can be COAX cable.

### **Fiber to the Multiple Dwelling Unit**

In this option, a dedicated fiber or pair of fibers reaches an ONU inside each dwelling unit. From the ONU, very short lengths of CAT5 cable, coaxial cable, and phone wire connect to the end equipment. FTT-MDU provides the greatest potential bandwidth to each living unit, with the lowest cost per bit capability. In addition, FTT-MDU should provide the lowest life-cycle cost based on its more reliable, passive optical path. The two main types of FTT-MDU architecture are the passive optical network (PON) and Ethernet Switched Optical Network (ESON).

The PON typically consists of a single fiber from the network that serves 8 to 32 subscribers through a simple passive optical element known as a splitter. While the bandwidth of one fiber is shared with several subscribers, this won't be a limitation within any of our lifetimes: A single optical fiber can easily and cost effectively support 10 billion

bits per second (Gbps) with one wavelength, and 160 Gbps with 16 low cost wavelengths using coarse wavelength division multiplexing (CWDM) on zero-water peak fiber. The ultimate capacity of a single zero water peak fiber is 50 trillion bits per seconds (Tbps) at its theoretical limit. A key advantage of the PON is the fact that it can use a fully passive optical distribution network from the network to the home, thus eliminating the life cycle and maintenance cost associated with powered OSP electronics.

Like the PON, the ESON also has a fiber or few fibers connecting from the network to a bandwidth-sharing element, in this case an Ethernet switch, and from the switch a dedicated fiber or pair of fibers connects to each living unit's ONU. The Ethernet switch converts the optical signal to electrical energy, switches the signal to the destination address or network element, and then converts the data back to an optical signal transmitted to the network or subscriber.

### Cost per Megabit Comparison

With today's access network optoelectronics, FTT-MDU provides 38% to 89% lower cost per Mbps for an installed Greenfield network compared to FTT-MDB or FTT-MDC. If one considers the future practical potential based on upgrading the optoelectronics, the FTT-MDU cost per Mbps is 88% to 99% lower than that of the other options. Clearly, FTT-MDU offers the best performance value and highest potential for generating video revenue for a small incremental added first cost, as shown in Table 1.

FTT-MDx Cost vs Performance Comparison (Greenfield or Brownfield, Estimated)	Fiber to the Multiple Dwelling						HFC to the	
	Unit		Building		Complex		Unit	
	Down	Up	Down	Up	Down	Up	Down	Up
Bandwidth (Mb/s) with 2006 Equipment	70	35	30	30	25	1	9	1
Practical Bandwidth Potential (Mb/s)	10,000	10,000	1,000	1,000	50	5	60	60
Relative Cost (2006)	1,200		1,100		1,000		1,000	
Relative cost for future upgrade to practical potential	600		400		200		300	
<b>Relative Cost per Mb/s 2006</b>	<b>11</b>		<b>18</b>		<b>38</b>		<b>100</b>	
<b>Relative Cost per Mb/s Practical Potential</b>	<b>0.1</b>		<b>0.8</b>		<b>22</b>		<b>11</b>	

**Table 1 – Cost per Mbps Comparison of FTT-MDx Options**

Notes

1. All cases show maximum worst case non-blocking bandwidth, which will be increasingly required for personalized and symmetrical video applications.
2. Costs are relative and include electronics, installation, and cabling system.
3. FTT-MDU is GPON with a 1:32 split ratio, with a single ITU-G.652D fiber to each unit.
4. FTT-MDB is fiber to a node inside, on, or near the building and Category 5e or better copper cable to a maximum reach of 330 feet to the subscriber.
5. FTT-MDC is fiber to a node in the MDU complex and twisted pair copper cable from the node for a maximum of 3000 feet to the subscriber using ADSL2+ in 2006 and VDSL2+ for future upgrade. Spectrum reallocation could enable 27.5 Mb/s symmetrical in the future upgrade.
6. HFC is fiber to a node and coaxial cable from the node to the subscriber in a typical tree-branch or bus-tap architecture. HFC assumes 850 MHz of available COAX spectrum and 400 subscribers per node in 2006, 950 MHz and 50 subscribers per node in the practical potential case, 30 or 38 Mb/s per 6 MHz channel, and all services over IP using DOCSIS. In practical potential case it is assumed that half of COAX bandwidth is allocated for upstream transmission.
7. Relative cost per Mb/s is relative cost for Greenfield 2006 divided by the sum of upstream and downstream bandwidth. For practical potential the denominator is the Relative cost for Greenfield 2006 plus the Relative cost for upgrade to practical potential.

Fiber bandwidth does not degrade significantly over 20 KM access distances, while the bandwidth of copper cabling drops exponentially with distance, after only a few tens of meters. In addition, optical fiber bandwidth is theoretically 50,000 times greater than the highest bandwidth copper cable. As a result, FTTH-MDU provides the lowest cost per bit for both Greenfield and Overbuild deployments. However, the business case payback may be quicker for FTT-MDC in buried overbuild situations if one can use the existing last few thousand feet of copper cabling plant. In this case the total installed cost per unit can be reduced by over 50% versus burying new fiber cable to each subscriber.

### **FTT-MDU Strategy for Managing Churn**

Within MDUs, subscriber turnover or “churn” and density greatly exceed that of single-family residences. Several MDU churn studies have concluded that the average MDU resident moves every 1.6 years. Others say the industry’s average annual turnover rate is a surprisingly high 80% and up, while others in the business tend to put it closer to 60% or 70%. By comparison, churn in single-family homes is primarily caused by subscribers switching providers and averages less than 20% per year.

One strategy to accommodate churn that might appear to be economical would be to have a technician be dispatched to install the ONU and service when a tenant moves in and be dispatched to disconnect the service and remove the ONU to be reassigned to other subscribers when the tenant moves out. At \$250 to \$500 per ONU, this might appear to be a cost-effective approach. However, the high cost of truck rolls can easily exceed any savings resulting from increased ONU utilization. High turnover or churn can quickly erode the bottom line. Second, the constant handling of the cabling and facilities will, over time, create maintenance problems. Increased maintenance problems result in more

truck rolls and dissatisfied customers and lost revenue. MDU complexes have had severe problems with the telecommunications facilities that have caused a need to replace the network prematurely. This further erodes the bottom line.

OFS' studies show that with churn rates less than 45% it is most economical to dedicate ONUs to a living unit. In fact, at 80% churn this dedicated ONU approach nets \$300 in annual savings per unit. Lastly, by dedicating facilities to a living unit, the problem of churn causing maintenance problems is eliminated. When properly built, FTTH will perform best when no "hands" are in the plant.

### **FTT-MDU Life Cycle Cost Advantages and Considerations**

While FTT-MDU offers the best bandwidth deal based on first cost and upgrade cost, there are also life-cycle cost savings in its favor: FTT-MDU networks have much lower operating expense than the other FTTH-MDx options. Since FTT-MDU has few or no active elements requiring electrical power, battery back-up, maintenance, and powering costs are drastically reduced. It has been estimated that the life-cycle cost savings alone of FTTH networks justifies a \$100 to \$250 higher first installed cost relative to traditional fiber to the x networks.

However, having a passive outside plant network alone does not assure life-cycle cost savings. The passive optical elements in the outside network must be reliable to prevent costly truck rolls for network repair, and keep subscribers happy. A subscriber losing the triple play from a single connector failure may leave for a competitor, resulting in >\$1200 per year in lost revenue. Outside plant elements should protect the optical fiber and connections through heat and humidity extremes, ice, wind, and installation stress. For example, housing optical connectors and splitters in sealed cabinets and enclosures has proven to be the most reliable method of managing these elements. In addition, fusion splicing to join optical fibers wherever possible in the outside network typically offers the lowest installed cost, with the highest reliability.

With fusion splicing, glass fiber ends are precisely and quickly melted together to permanently join the fibers, using lightweight handheld equipment. The need for connectors to ease access for trouble shooting fiber links has been negated by readily available test equipment that can isolate cable cut locations anywhere in the entire passive link by accessing fibers at the subscriber or network end. Much of the projected lower maintenance cost associated with fiber access networks is based on fusion splicing technology, which has been proven reliable for over 20 years in backbone, metro, and access networks.

### **Optical Fiber Cable and Connectivity Considerations**

Video applications with increasing definition, 3-D, and customized personalized content will provide the ROI justifying ultra-high-data rates per home. To keep pace, FTT-MDU networks designed with the future in mind can evolve over the 25 year to 40 year life of the optical cabling system without expensive replacement of outside cable and components. Development of 10 Gbps FTTx systems is underway, and such systems are very intolerant

of signal loss in the optical path. In addition, a low-loss system can extend the reach of the network, thus reducing the number and cost of central offices or head ends. Designing the optical path with low-loss fiber, low-loss splitters, low-loss fusion splices, and low-loss connectors within cabinets and the CO can reduce optical signal loss by 50% and double network reach. In addition, using Full Spectrum Zero Water Peak G.652D fiber (ZWP) can double the wavelength capacity and bandwidth potential of a PON network compared to conventional single-mode fiber. Finally, low labor cable designs and compact splitter cabinets can further reduce the cost to install the optical network.

## **Conclusion**

Fiber to the MDU provides the best bandwidth value for Greenfield or Brownfield deployments where infrastructure must be installed all the way to each unit. Where copper to the unit exists, each carrier can make a business-case-driven decision on how close to push fiber to the subscriber to support bandwidth needs. Careful attention to the relatively low cost optical path of any FTTx network can increase ROI. The use of a low-loss, full-spectrum optical path can enable greater bandwidth and revenue-generating potential, while proven outside plant technologies can help realize the reliable service and operating expense savings possible with fiber optic networks.

(1): "FTTH Design with the Future in Mind" - FTTH Prism, Fall 2005, Page 27.

(2): OFS OptiCost Modeling of Various FTTM Deployments Assuming High Volume Pricing.