Category 1: Fiber and Wireless: Competitors or Collaborators?

Editor's Comment: We first recognized the "special relationship" between fiber and wireless regarding access when looking through national telecom legislation that had muni fiber and muni wireless unceremoniously lumped together. The more we dug into the issue, the more complex it became. For example, the wireless community is now in transition from muni Wi-Fi to Wimax, with the industry divided on which is better for what application and how rapidly Wimax will come about. FTTH has its own internal issues of course (BPONvs. GPONvs.GEPON for example). We have tried to frame this debate using some of the most knowledgeable voices in both industries and to let the reader form his or her own conclusions. Despite the gooey talk later, there is a municipality by municipality battle raging in America, with some opting for fiber, some for wireless, and some for both. We thank all of our contributors on a job well done.

A Few Thoughts on the Muni Fiber Vs. Muni Wireless Debate

By Michael Render, partner, RVA LLC (Render, Vanderslice and Associates)

In terms of raw numbers, municipal wireless is "winning." According to Muniwireless.com, there were 91 municipal wireless systems actively serving public customers in the United States as of April 2006. This compares to just 33 municipal FTTH systems actively serving customers as of April 2006 based on RVA data. Near-term growth may also be stronger for muni wireless. There are said to be nearly 200 additional muni wireless systems in various stages of deployment.

In actuality, the term "winning" may be meaningless for this debate. In my opinion, wireless and FTTH are actually running two completely different races.

The motivation for FTTH installation is usually long term and broad in nature. Fiber installations seek to enhance both economic growth and human resource retention by providing cutting-edge broadband service to the community. They also are designed to bring "multiple-play" services to residences, including high-

CLEC Model

Although there have been many business plans written for deploying FTTH to overbuild various towns by CLECs, none has been funded. This is a result of the financial community being hurt during the telecom boom (and then bust) in 1998-2004.

No Single Model Will Get the Job Done

All of the FTTH models profiled offer sound financial and strategic reasons for deploying FTTH networks. For some traditional carriers FTTH represents a defensive tool aimed at fending off competition that threatens their core businesses. For other aggressive carriers FTTH is an offensive weapon allowing them to increase market share and create new sources of revenue.

Consumers, developers and government leaders are creating new models because they see the lifestyle and economic benefits that advanced FTTH networks can deliver to their communities and are tired of waiting on incumbent service providers to deliver the promise of FTTH.

All agree that eventually FTTH will be the network of choice. The real questions remaining are who has the model that will justify the tremendous investment and how fast can this FTTH model be deployed. But maybe the question needs to be rephrased since no single model works equally well in every community. The country is not a homogenous landscape that provides equally all the government and market incentives to fully fund an ubiquitous FTTH network. To get a true national FTTH network requires multiple robust models, each model being the most efficient path to FTTH given the local political and market forces.

Category 4: FTTH-Only Applications

Applications Compelling Fiber to the Home

By John George, Director, FTTx Solutions, OFS

FTTH today is cost competitive with competing copper-based technologies and has superior bandwidth potential leading to widespread deployment that began in 2002 in Japan and 2004 in the US and Europe. FTTH has reached about 4 millions homes in the United States and more than 10 million globally. By 2010 FTTH is projected to reach over 25 million homes in the United States alone. With cost parity and superior performance, FTTH is easy to justify for many service providers. Yet the question remains—is there an application that is uniquely supported by FTTH?

IEntertainment, telecommunications, and workplaces are becoming dominated by video. Video itself is not a killer application. Video enables several killer applications that could drive bandwidth beyond copper or coaxial cable in the near future. In the last century video was broadcast television in which the same few channels were sent to all subscribers. Today it is enabling revolutionary new applications that are fast becoming customized and personalized for every user, driving up bandwidth both to and from homes. Video will continue to penetrate communications and entertainment, facilitated by four enablers: (1) improving and lowering cost displays, (2) increasing bandwidth, (3) Moore's law, and (4) increasing data storage capacity. Here is a sample of the applications supported by personalized and customized video, enabled by FTTH:

- Online Video Stores—Thousands of titles, archives of everything, any time for instant viewing or download. Replacing Bricks and Mortar Video is a $16 billion[1] opportunity. There are dozens of these websites today, though the download takes about one hour with a fast DSL or cable modem. In today's High Definition (HD), an agonizing four hours might be required.
- Telemedicine—HD video and imaging from individual to physician. Only 10 percent of the $1.5 trillion Healthcare Industry represents a $150 billion opportunity!
- Gaming—3D versions in high definition can create new revenue-generating opportunities.
- Video Conferences and Learning —HD and 3D enable the in-person experience.
- Social Video—Our kids are already loving it—just consider the popularity of youtube.com with 100 million downloads and uploads/year, and other similar websites.
- Video Mail—Video clips of a child's birthday, a product presentation, detailed damage assessment for an insurance company, advertising, etc.
- Video Telephony—HD and 3D will finally make it real.
- "Video" commuting—using all of the above applications, saving $3/gallon on gas or thereabouts.
- Remote Video monitoring—for security, baby-sitting, enabling access for a repair person, etc.
- Community Video—local institutions or individuals could stream video of local sporting events, musical performances, religious services, or any other video of interest.
- Virtual Identities—people might create a fantasy character and manipulate their "video" character in a virtual fantasy world—greatly enhanced by HD and 3D symmetrical video.
- Etc, etc—it's impossible to imagine all of the possibilities

Transporting standard definition DVD-quality video, with the highest available compression, requires data rates of about 2 Mbps. Add high definition and the data rate is multiplied again, today by four and potentially by 100 times in the future. With advanced three-dimensional video (3D video) the data rate, compared to DVD quality video, may soar by a factor of 1200! Super Definition and Ultra Definition video has already been demonstrated and 3D video is being developed today. Below in table 1 we see the bandwidth required for video transport has already increased fivefold while compression is reaching its limits.

Table 1—Current 2D Video Formats and Bandwidth Requirements (Approximate)

Current 2D Video (popular examples)	Format	Image resolution		Resolution (Mega Pixels per frame)	Frames per second	Mb/s Uncompressed	Mb/s per Stream (compressed)	
		Horiz.	Vertical				MPEG-2	MPEG-4
Standard Definition (SDTV)	480p	720	480	0.35	30	249	4	2
High Definition (HDTV)	1080i	1920	1080	2.1	30	1,493	20	10

Notes: 1) Mbps uncompressed is Megapixels/frame x frames/sec x 24 bits/pixel.
2) 480p is progressively scanning 480 lines per inch for each frame, 30 times per second
3) 1080i is interlaced, scanning every other line (540 lines) per inch, 60 times per second, for an effective frame rate of 30 per second.

Lifelike Displays Enhance Video - Requiring more Bandwidth

The trend to larger screens, even higher definition, and 3D video will multiply bandwidth demands exponentially. Large screens not only provide a more lifelike experience, but also enable viewing multiple videos on the same screen simultaneously. This is of great value to sports fans, which are typically the most willing to pay for entertainment. The monitor makers see increasing screen size as a market demand; One manufacturer just announced a 103" Plasma TV that will be on sale later this year. Clearly, we are headed toward wall-sized video monitors futurists have predicted. But large screens require proportionately higher definition to maintain video sharpness.

Figure 1—103" HDTV Plasma Monitor

In response, the International Telecommunication Union (ITU) is currently developing a standard for transporting super- and ultra-high definition video for large-screen applications. This standard for "Large Screen Digital Imagery" can support both high- definition, large-screen displays, and ultra-high-definition smaller displays. Within the current draft of the new standard, and the most optimistic compression, bandwidths of up to 200 Mbps per video stream will be required as shown in Table 2 below, which is 20 times that of today's HDTV!

Table 2—Projected future 2D Video Formats and Bandwidth Requirements

Future 2D High Definition (Projected)	Format	Image resolution		Resolution (Mega Pixels per frame)	Frames per second	Mb/s Uncompressed	Mb/s per Stream (compressed, projected)	
		Horiz.	Vertical				H.262 or MPEG-2	H.264 or MPEG-4
Super HD	2160p	3840	2160	8.3	60	14,930	100	50
Ultra HD	4320p	7680	4320	33.2	60	59,720	400	200

(based on draft ITU-T J.601 "Transport of Large Screen Digital Imagery" standard)

What is next after super-HD and ultra-HD video? Three-dimensional video might create true lifelike moving images, and it is being developed today. While it's difficult to predict exactly what type of technology will be used to record and display 3D video, the many proposals under investigation share a common requirement: More bandwidth. Three-dimensional video requires multiple cameras, potentially 20 or more, each filming from a different angle. For example, even today such multi-camera infrastructure is used to film some NFL football games, with dozens of cameras offering as many views to the production crew and viewer, though not yet in 3D. In the next table is projected the bandwidth required to transport future 3D video over the FTTH network, and the numbers seem incredible. It is assumed that video compression will improve by a factor of four from today's MPEG-4 level, yet with such a 600 to 1 compression ratio the data rate per stream is projected to exceed 1 Gbps and even 10 Gbps, as shown in Table 3.

Table 3—Projected future 3D Video Bandwidth Requirements

3D	Image resolution			Resolution (Mega Voxels)	Frames/ sec	Bits per Voxel	Mb/s Uncompressed	Comp. Ratio	Mb/s comp.
	Horiz.	Vert.	Depth						
Std Definition 3D	1024	768	20	16	60	40	37,749	300	126
High Definition 3D	2160	1080	20	47	60	40	111,974	400	280
Super Definition 3D	3840	2160	20	166	60	40	398,131	500	796
Ultra Definition 3D	7440	4320	20	643	60	40	1,542,758	600	2,571

While tables 2 and 3 project very-high data rates for future video, this pales in comparison to what might be required to support such video integrated into entertainment, business, and personal applications. This will require huge increases in the bi-directional access bandwidth provided for each home and business, as shown in Table 4 in the color shaded cells.

Table 4—Projected access data rates per home required in 2010, 2020, and 2030.

2010 - Access Speed Reqd			Total
High Definition	Qty	Mb/s	Mb/s
Video Streams	3	10	30
Internet/E-mail	1	62	62
Gaming	1	20	20
Voice	3	0.3	1
			113
Std. Definition			
Video Streams	3	2	6
Internet/E-mail	1	12	12
Gaming	1	4	4
Voice	3	0.3	1
			23

Assumptions		
Data Rate	Std	HD
(Mb/s w/MPEG-4)	2	10
File transfer time (sec)		60

2020 - Access Speed Reqd			Total
Ultra HD 2D	Qty	Mb/s	Mb/s
Video Streams	3	200	600
Internet/E-mail	1	1,227	1,227
Gaming	1	400	400
Voice	3	0.3	1
-			**2,227**
Std 3D			
Video Streams	3	126	377
Internet/E-mail	1	768	768
Gaming	1	252	252
Voice	3	0.3	1
			1,398
Super HD 2D			
Video Streams	3	50	150
Internet/E-mail	1	307	307
Gaming	1	100	100
Voice	3	0.3	1
-			**558**

Assumptions			
Data Rate	Super 2D	Std 3D	Ultra 2D
(Mb/s w/max compr	50	126	200
File transfer (sec)		60	

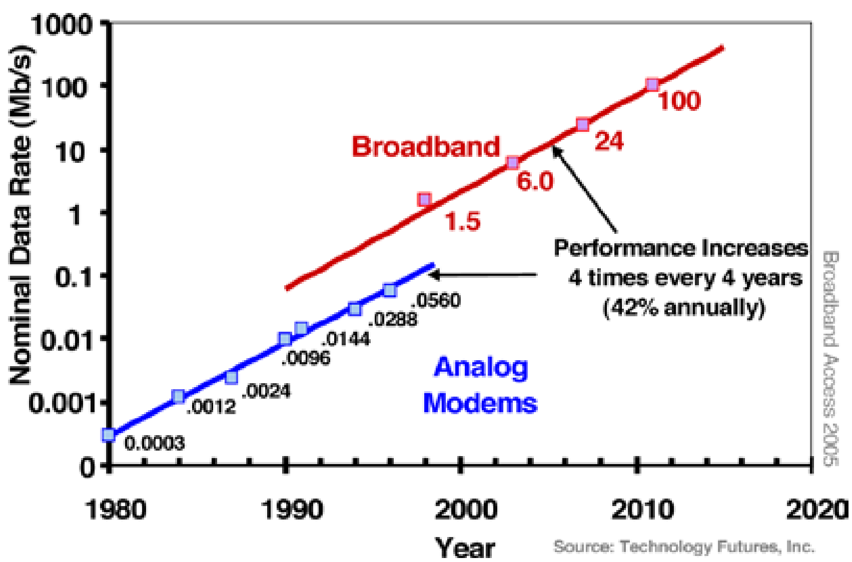
2030 - Access Speed Reqd			Total
Ultra HD 3D	Qty	Mb/s	Mb/s
Video Streams	3	2,571	7,714
Internet/E-mail	1	15,942	15,942
Gaming	1	5,143	5,143
Voice	3	0.3	1
-			**28,799**
Super 3D			
Video Streams	3	796	2,389
Internet/E-mail	1	4,910	4,910
Gaming	1	1,593	1,593
Voice	3	0.3	1
-			**8,892**
HD 3D			
Video Streams	3	280	840
Internet/E-mail	1	1,717	1,717
Gaming	1	560	560
Voice	3	0.3	1
-			**3,118**

Assumptions			
Data Rate	High 3D	Super 3D	Ultra 3D
(Mb/s w/max. comp	280	796	2,571
File transfer (sec)		60	

The increase in video bandwidth per stream is understandable given increasing definition and 3D video. The surprising increase is projected for Internet and e-mail access data rates. In 2020, a presentation or recording of a child's birthday party might include 10 minutes of standard 3D video, and even compressed by a factor of 300 the file size would be 10 GB! To send this file in 60 seconds with no oversubscription would require 768 Mbps. The same in 2030 with super 3D video would require 4.9 Gbps.

The trend in access data rates also supports the likelihood of a multi-Gigabit per home future, shown in Figure 2, which suggests symmetrical demand per home of about 2 Gbps in 2020 and 67 Gbps in 2030.

Figure 2—Projected Data Rate Required Per Home



Do these projections seem high? Even if bandwidth demand growth slows to 25 percent/yr after 2010, the required rates will be over 300 Mbps and 3,000 Mbps in 2020 and 2030, respectively.

Compression to the Rescue?

Won't video compression save us from exploding video bandwidth demands? The short answer is that without compression, today we would not have HDTV from cable or satellite providers, or even the current low-resolution Internet video clips. Compression has already greatly enabled bandwidth-limited networks but is quickly running out of steam. Transporting a single uncompressed HDTV signal requires 1.5 Gbps of bandwidth. The experts have compressed HDTV by about 75 times, down to only 20 Mbps per stream using MPEG-2. The emerging MPEG-4 standard might cut that in half to 10 Mbps, a compression ratio of 150! Compression works by eliminating redundant data in the stream, then reduced data stream is sent over the network to the receiver, where the "decoding" chip must reconstruct the full video stream. However, with high compression image quality suffers since there is only a finite percentage of redundant data in a video. Once the redundant data are compressed, excessive reliance on algorithms that predict motion and color changes increases the probability of errors. These can be manifested in pixilation, lower definition, and detectable color variations compared to the uncompressed original. Even so, the projections above assume an increase in compression ratio from 150 today to 600 in the future. In spite of increasing compression ratios, data rates are projected to grow at 40 percent—50 percent annually to keep pace with video application demands.

Bandwidth Requirements Becoming Symmetrical

Data rate requirements will soon be symmetrical to support the growing personalized video files and video telephony that subscribers will transmit to the network. Sending video content and video communications from the home will drive "upstream" bandwidth requirements to new heights. In Japan, NT&T has already observed this data rate symmetry in its FTTH network. Increasing symmetry in bandwidth demands is now exposing deficiencies in DSL and cable modem networks which allocate upstream bandwidths of only 10 percent to 20 percent that of downstream, to support web surfing applications and transmission of text e-mails.

How can we support these Exploding Bandwidth Demands?

Wall-sized video, higher definition, and 3D will likely drive bandwidth per home well into the Gbps range. Symmetrical bandwidth pipes will be a necessity. But will the network be capable of providing that kind of bandwidth for each home? Can access network speeds economically keep pace with exploding video bandwidth demands? The answer is a resounding yes, if the network is FTTH and designed to support 25 years of bandwidth growth, without expensive replacement of cabling infrastructure.

The Optical Distribution Network: Pay Attention to the ODN—it must Support Upgrades for Many Decades.

The optical distribution network consists of the optical fiber cable, connectors, splitters, jumpers, and WDM multiplexers and de-multiplexers. (A view of a typical ODN and its elements is shown in figure 7. It is the optical path that must support many generations of applications and upgrades 25 to 40 years into an uncertain future.

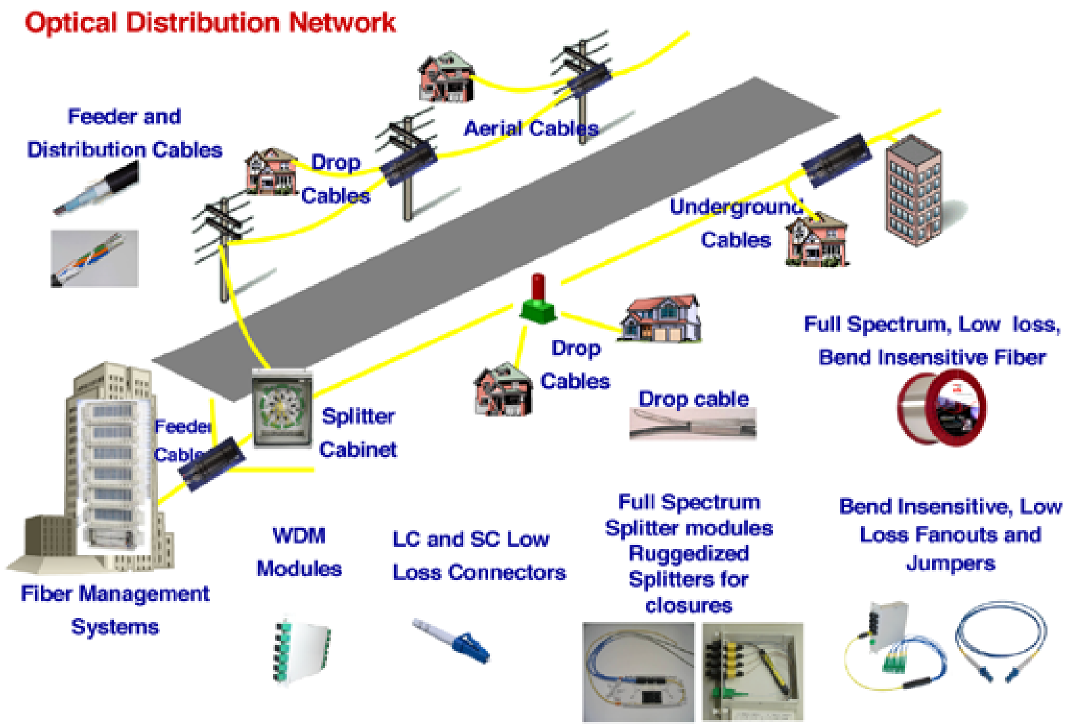


Figure 3

Some easy guidelines for building an ODN for cost effective current and future applications are shown below.

- Full Spectrum Optical Path
  - Elements
    - G.652D Full Spectrum or Bend Insensitive Full Spectrum Fiber (Note: No practical benefit from special high power fiber)
    - Full Spectrum Splitters loss rated for 1260 nm—1620 nm
  - Benefits
    - Lower life cycle cost
      - Insurance against re-cabling to support future upgrades.
      - Enables lower cost Full Spectrum CWDM options.
    - Greater revenue potential and flexibility.
      - Enables all WDM PON upgrade possibilities.
      - Enables CWDM PON overlay option

- Low Loss Optical Path
  - Elements
    - Low loss optical fiber cable over the Full Spectrum from 1260—1620 nm
    - Low loss connectors, splitters, and jumpers.
    - 50% reduction in signal loss vs. conventional components
  - Benefits
    - Lower cost - 1.5 to 3 times longer reach reduces electronics locations and allows maximum split ratios and port utilization.

        - ⊙ Greater reliability margin to maintain services with aging and stress on ODN elements.
        - ⊙ Lower optical power and lower cost support of legacy analog video.

- Easy to install and upgrade
    - o Elements
        - ⊙ Low labor to install cables (dry with no filling compound)
        - ⊙ Modular splitters upgradeable to lower split ratio and/or WDM
        - ⊙ Easy to provision cabinets and patch panels
        - ⊙ 1 feeder fiber for every 8 homes
    - o Benefits
        - ⊙ Lower first cost
        - ⊙ Less opportunity for error
        - ⊙ Low cost /less disruptive upgrade to future xPON or WDM PON
        - ⊙ Lower cost upgrade to 1:8 split ratio PON and/or CWDM-PON

- Reliable Optical Path
    - o Elements
        - ⊙ Fusion splicing where possible, vs. OSP connectors
        - ⊙ Bend Insensitive fiber
        - ⊙ Standards compliant products from reputable manufacturer.
    - o Benefits
        - ⊙ Lower life cycle cost by reducing costly truck rolls for repair and maintenance.
            - Splicing proven for 20 years in backbone networks, cost effective today for FTTH.
            - Bend insensitive fiber can prevent network failure from inadvertent tight bends that can occur anywhere.
        - ⊙ Increased revenues through improved service reliability and subscriber retention.
- Optimized Outside Plant Design
        - ⊙ Can save $50 - $100 per home passed, and enable cost effective upgrades.
        - ⊙ How? By using cost models to identify the optimum design for each customer's dynamics.
            - Optimize fiber counts, cable placement, splitter placement and packaging, cabinet size, etc

Conclusion

Video applications offering increasingly lifelike experiences will continue to drive 40 percent annual growth in household bandwidth (data rate) demands. The Optical Distribution Network (ODN) is the optical fiber pathway for PON systems, between the centralized electronics in the network, and the electronics at the subscriber's premises. Well-designed ODNs can support the fantastic video, data, and voice services enabled by fiber optics for many decades through many generations of electronics, without expensive replacement of outside optical cabling system. The ODN consists of relatively low-cost elements that are expensive to install and disruptive to replace. Service providers need to understand how to design and deploy ODNs today that provide reliable and cost effective support for the variety of current and future PON architectures that must be supported over the potential life of the ODN. The ODN should be capable of economically maximizing revenues for future video applications with reliable service to maximize subscriber retention. Specifying an ODN providing Full Spectrum, low loss, and reliable performance in easy to use packaging is a cost effective key to maximize the return on investment and value of FTTH networks.

References

1. “The New King of Big TV’s Is Queen-Size” - By DAMON DARLIN, NY Times, July 24, 2006
2. “It Doesn’t Just Look Real—it’s Real - The big shift in how we watch will be from flat screen to 3-D.”, Newsweek International, David H. Freedman, Sept 18, 2005
3. “3 Deep” by Alan Sullivan, IEEE Spectrum, July 2005
4. “Transport of Large Screen Digital Imagery”, ITU-T J.601, PREPUBLISHED RECOMMENDATION, November 2005
5. http://en.wikipedia.org/wiki/Video
6. “Wavelength-division-multiplexed passive optical network (WDM-PON) technologies for broadband access: a review”, Amitabha Banerjee, et al, November 2005 / Vol. 4, No. 11 / JOURNAL OF OPTICAL NETWORKING
7. “WDM PON for Next-Generation Optical Broadband Access Networks”, Chun-Kit Chan, et al, Lightwave Communications Laboratory, Center for Advanced Research in Photonics, The Chinese University of Hong Kong, Shatin, Hong Kong
8. “FTTH Design with the Future In-Mind” John George, FTTH Conference 2005