AC 2012-5216: THE FUTURE OF THE BASIC BUILDING BLOCK OF TELECOMMUNICATIONS NETWORK

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The Future of the Basic Building Block of Telecommunications Network

Abstract

The most basic building block of the Telecommunications industry is the cabling systems that make up the wired networks. Over the years we have seen tremendous change in the reliability and effectiveness of this core technical component of the network. This paper will provide a survey and discussion of the uses of the primary types of cabling that are currently in broad deployment in our networks. It will examine how different cabling types can be effectively used in WAN Telecommunications Networks. Exploring the effectiveness of provisioning of cable designed for single service applications transitioned to multi-service broadband networks, also review the current economic models relating to cable deployments. Finally predictions will be made on the future of WAN deployments.

I. Introduction

The fundamental component of telecommunications is the actual physical cable that connects the world's networks to each other and to end-users. This is true even for wireless technologies which are beholden to the different types of cable to provide the backbone for the access points. Starting with the telegraph which used a precursor to twisted pair cable, through video service anchored by coaxial cable and leading into optical fibers, there has been a continual technological advance in telecommunication cable technology.

The internet age introduced the greatest accelerant for change in the history of telecommunications. It forced solutions that were originally designed for single service applications such as voice calling to multi-service including voice, video and data. It's also changed the network policy the world over with legislation that is driving tremendous change moving forward. Some of this legislation based on modern thought is to abandon legacy technologies such as twisted pair and coaxial cable in place of pure fiber optic networks.

This paper will explore the history and reliability of different types of telecommunications cable. It will explore the benefits and capabilities of legacy cable such as twisted pair and coaxial as a medium for delivering next generation data solutions. It will also explore the challenges service providers face when moving to a fiber optic network. It is crucial to understand this information as there are billions of dollars at stake over the next decade. Additionally, the benefits of existing networks wrought by generations of labor may be eliminated if we move too hastily into the world of fiber optics. The findings will point to the fact that there is currently no easy answer to the question of which cable should we use. Costs, technological advances, existing infrastructure, political climate, and macro economics all play a role in determining what cables will best serve the needs of the network owners and users.

II. The Birth of Modern Wired Telecom-Systems

The birth of modern wired telecommunications systems can be traced to May 1st 1844. It was on this date that Alfred Vail and Samuel Morse used their partially completed electrical telegraph to send the news of Henry Clay's nomination from Annapolis Junction, Maryland to members of Congress at the Capitol in Washington DC. This was full hour and a half quicker than the message was able to get to the capitol by human carrier. It was this event that proved how much more effective even the most basic telecommunications system was at transferring information than any other method used throughout the whole of human history [1].

Even as rudimentary as the electrical telegraph was, making the feat possible meant that the inventors had to find solutions to the core issues that exist even with today's ultra high speed technical telecommunications systems. The cost was prohibitive, so monies had to be appropriated from the federal government. The amount required for the telegraph at the time was $30,000 or close to $773,000 in today's dollars [2].

There were major reliability issues with the actual physical makeup of the cable. The original insulator for the cable pair was made of cotton and shellac varnish. The shellac failed and there were numerous shorts that developed making the cable unreliable. To deal with these issues effectively required a complete redesign of the telegraph network from a buried application to an aerial solution. The most famous issue that was successfully resolved was the data encoding problems. Morse had to change his original inefficient encoding method based on individual words to one where binary code was used for individual letter values. This, of course, resulted in what we now know today as Morse code [3].

Even from the very beginning, the reliability and effectiveness wired telecommunications systems depended heavily on issues such as available resources, engineering prowess, network design and the physical materials used in cable manufacturing. Initially all network design was based on the concept of providing a single service very reliably, but over time networks were adapted to provide multiple services over the same cable because of the bandwidth technology.

III. An Approach to Reliability

Telecommunications networks are heterogeneous by their nature. They include elements such as repeaters, TAPS, Customer Premise NID's (Network Interface Devices), and cables. Fiber optic systems include lasers, optical splice systems, and various other elements not found in copper based networks. Because of the complex nature of network design it is difficult to quantify the reliability of the network cabling by itself. In many published studies failure is usually measured by total network uptime using metrics such as MTBF (Mean Time Between Failures), MTTR (Mean Time to Repair) and DPM (Defects per Million). In instances where cabling is cited as the specific point of failure, the details of the actual failure event is generally not disclosed.

Additionally manufacturers of UTP, Coax, and Fiber cable tend not to publish details of cable failure. Motivations such as competitive pressures and consumer opinions discourage voluntary releasing of data about manufacturing defects or cable failure. The high quality of manufacturing techniques and resulting low rates of cable failure resulted in a lack of need for legislation requiring the release of failure data. A more pragmatic approach for the purposes of contrasting cable reliability is to explore the actual causes of failure in cable.

IV. Economies of Fiber Optic vs. Copper Network

The question must be asked, if fiber optic cable is so much more effective and reliable at transmitting data, why have telecommunication network providers adopted its use in every single possible area? The answer has much more to do with economics of network operations than it does in the effectiveness of it. It is simply not cost effective to deploy a Fiber to the Home/Business (FTTH/B) end to end fiber optic network.

As an example, CATV companies currently prefer a Hybrid Fiber-Coax (HFC) network where fiber is used in the backbone usually supporting groups of 500 homes or less and Coax is used for the distance from the fiber termination point to the home. This provides enough bandwidth to allow the CATV companies to offer a plethora of services including traditional video entertainment, video on demand, high speed internet, and local and long distance telephony. It also significantly reduces the need for expensive fiber optic electronics at both the head-end and at the customer premise[4].

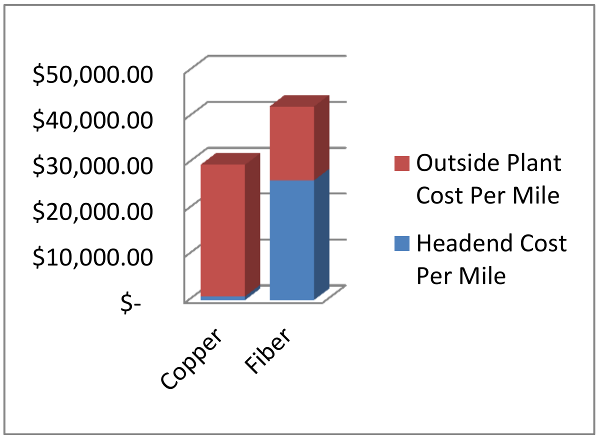

Figure 1 - Copper vs. Fiber Cost per Mile

In an all fiber Passive Optical Network (PON) the cost for the 'drop' from the WAN to the customer premise is $748.00 which includes material and labor. In a HFC deployment only a traditional Coax drop is required which costs an estimated $125.00. The savings are just as start when it comes to head-end equipment. In a network deployment cost analysis the costs are typically measured per Outside Plant mile. Costs are incurred for both the Outside Plant and Headend equipment. In a FTTH PON deployment the costs for head-end equipment is $16,118 per mile. The cost for outside plant deployment is $26,084 per mile. Comparatively in a HFC deployment the costs for outside plant deployment is $28,682 per mile but the Headend equipment is $820 per mile [5]. The stark nature of the difference of these numbers can be seen in figure 1 above.

Fortunately the market continues to remain dynamic as major corporations such as Google experiment with their own fiber to the home build outs [6]. It will take time to see how this new competitive pressure affects costs and industry build-outs.

V. FTTH/B: Current and Future Trends

Although there is still a compelling economic model for copper based solutions, there is currently an accelerating adoption rate for Fiber to the Home and business. Part of this adoption rate is spurred by a need for even greater bandwidth by business users. In a 2010 study conducted by Corning and Intel, the case is made for bandwidth needs in excess of 40Gb/s for a typical virtualization server by the year 2020 with 25% of the servers requiring 100Gb/s bandwidth [7]. It is these tremendous bandwidth requirements inside the data center that will be one of the drivers a need for even greater WAN bandwidth connecting the data centers to the outside world.

There is also a political component. The general consensus among government leaders across the world can be seen in the focus on legislation that will drive universal access to broadband. A secondary political initiative is to favor fiber optic communications over copper solutions. These initiatives are having an effect on network rollouts. Starting in 2001 there were nearly zero FTTH/B solutions deployed. Today the top industrialized nations have connected nearly 50 million homes and business with FTTH/B. The breakdown in subscriber numbers can be seen in figure 2 below.

In October 2011 Neelie Kroes, vice-president of the European Commission in charge of the Digital Agenda, unveiled proposals to accelerate investment in next-generation fiber networks. She proposed two models centered on changing wholesale access pricing on existing copper networks. The first would see a gradual reduction in wholesale prices for universal access to existing copper networks. The resulting fall in retail broadband prices would encourage incumbents to move to fiber networks.

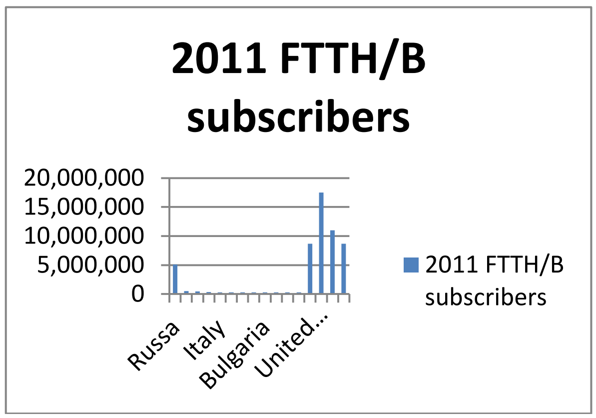

Figure 2 - Number of FTTH Subscribers, Source IDATE

The gradual implementation of the price cuts would give them time to weather the transition and allows consumers to adapt to higher bandwidth offers. The second model could see incumbents escape at least part of the price cuts if they agree to switch to fiber within a certain period and switch off their copper networks [8].

Even with the growth rate of FTTH The abdication of copper based solutions espoused by Neelie Kroes may be considered premature. Although copper solutions are clearly the more mature cable technology advances are still being made. In 2011/2012 BT in the United Kingdome will be introducing a technology to consumers that will allow 20Mbps connections over legacy twisted pair using a variant of digital subscriber line called ADSL2+[9]. Also in 2010 Alcatel-Lucent announced that its Bell Labs research arm demonstrated a technology they call phantom mode which will drive 300Mbps over twisted pair, and 100Mbps at over 1km distant from the

VI. Security issues with Cable and Wireless

As long as there have been communication networks, there have been security issues. No communication networks are immune to security threats and no perfect communication transport mechanism has ever been devised. When engineering communication networks, considerations such as the value of the data or how sensitive the nature of what is being transmitted must be taken into account. Highly valuable or sensitive data would demand much more extensive security considerations than data with less applicable significance. There are deep differences between wired and wireless networks as it relates to security.

The most insecure networks are wireless. This isn't to say that all wireless technology is insecure as there are some wireless technologies that can be highly secure. One such example of a secure wireless network is Infrared (IR) wireless networks where the IR signals have to be in the line of sight between the transmitter and the receiver. Unfortunately IR wireless technology offers very low bandwidth and is generally not that popular of a networking standard. Heavily deployed wireless technologies such as WiFi, LTE, and microwave are much more prone to security issues. One significant reason, is because unlike IR, the electromagnetic energy used by these more popular technologies radiate through obstacles. The signals can be picked up and decrypted by anyone with the right tools. Ultimately the only way to secure the highly adopted wireless networks is through the encryption of data.

Encryption is of course a critical element to security on wire line networks, but there is another major consideration which is the physical elements of the connecting cables and their termination points. At different points of all wire line networks there are termination points, usually terminations are clustered in an area such as a communications closet or a network building. Because there is generally access to a large amount of the network cables from these points, physical security measures are required to limit access. The security issues are different along the cable routes and with the different types of cables.

The weakest security exists with the metallic implementations of network cabling including Twisted Pair and Coaxial Cable. Twisted pair has the obvious problem that it can be tapped into at any point along which it is run. This presents a challenge to network administrators who must device security measures for both the data flowing on the networks as well as the physical implementation of the networks. Twisted pair cabling also emits electromagnetic energy that can be picked up with sensitive equipment even without physically tapping into the media; this is known as cross-talk and for many years was just considered a nuisance. Now it is considered a security threat. One procedure developed for the military is called Tempest Proofing. Tempest proofing means that specific steps were taken to properly shield electromagnetic signals so they wouldn't be picked up by undesirable entities. All of the variants of Coaxial cable have the same basic security weakness inherent in twisted pair cable. There are some differences as Coax is bulkier and harder to work with. Coax also has better inherent shielding minimizing cross talk. Even with these differences coaxial security issues are comparable to twisted pair [10].

Fiber Optic connections are considered very secure. In fiber optic data is transmitted as beams of light; therefore no electromagnetic waves are generated. Insulation surrounds the fiber optic strands making it impossible to detect the light pulses without tapping into the actual strands. The fiber strands are extremely thin and virtually impossible to tap into without breaking the strand. In most network deployments a broken strand would be detected and immediately shutdown the connection. Even if an attempt was made to compromise a fiber optic cable it would usually be discovered by time domain reflectometry. Fiber optic connections aren't perfect and there have been highly sophisticated taps used for corporate espionage, government espionage, network disruption or damage but the instances of these being successful are rare [11]

VII. Cables vs. Wireless (pros and cons)

January 9, 2007, was a watershed moment for the telecommunications industry. This was the day that the late Steve Jobs and Apple computer introduced the iPhone. Very quickly after its release it became apparent that the iPhone was going to be a disruptive technology in the wireless segment of the telecommunications industry. In the same way that wired internets "always on" and unmetered connection changed the way people were able to consume Internet content on their home computers, the iPhones required data plan changed the way people consumed information. Use patterns and service expectations formerly only reserved for wire line providers were not also understood to be available through mobile providers. The quick adoption of this new type of wireless device is heavily encouraged by service providers who are benefiting in growth of consumer ARPU numbers due to the required data plans [12].
There are strong benefits to wireless technologies in a telecommunications network. The first and most obvious is that wireless provides for a mobile experience where wired connections are static to the location they are placed. Another major benefit is the lower cost to deploy a wireless network. As an example Verizon's FTTH/B service cost ~ $1350 to hook up each location [13]. No matter if copper or fiber, the costs to deploy a wire line connection is very high. This makes the business model behind companies based on wire line technology much more stable as they tend not to have nearly as much competition as their wireless counterparts. The competitive environment is much richer with wireless where there can be many service providers offering service over the same geographical area. The highly competitive nature of the industry results in subscriber churn or just 'churn'. Churn is a term that describes subscribers who leave one carrier for another due to the ease of transition. There are many reasons subscribers may feel dissatisfied. The following chart shows the different categories of wireless user dissatisfaction [14]. Many of the points of customer dissatisfaction such as roaming, call quality, and handset simply don't have a wire line equivalent.

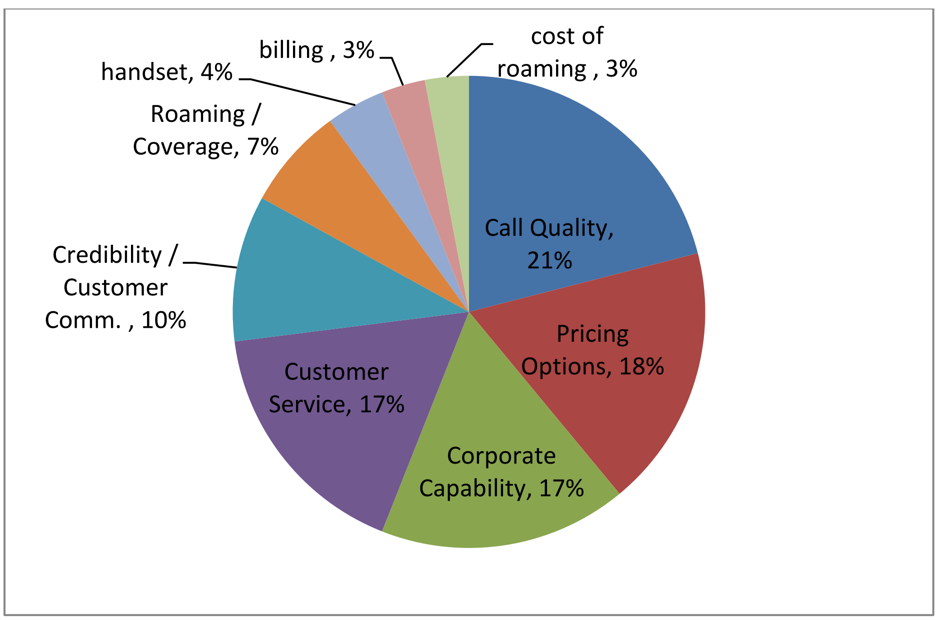

Figure 3 - Cost of wireless network

New technologies are being enacted by the wireless carriers that will help mitigate some of the negative issues associated with wireless vs. wired. The most popular of these new technologies is a new wireless standard called Long Term Evolution (LTE) which has seen nearly universal acceptance as the wireless network standard for the majority of the developed world. LTE provides potential downstream rates of 300 Mb/s and upload rates of up to 75.4 Mb/s, this makes LTE highly competitive with the best of what is available with popular twisted pair copper solutions such as ADSL.

LTE will enable innovative business models, potentially delivering unforeseen levels of revenue and profit growth to wireless providers. LTE offers technological solutions formerly only provided for by cable based telecommunication providers. These practices include end-to-end IP broadband architecture, quality of service (QoS) for multi-service delivery including video conferencing and IPTV and extensive network traffic monitoring. By providing unprecedented capabilities to monitor traffic and usage (with deep packet inspection, session management) and monetize broadband wireless connectivity, QoS and subscriber profile and location data, wireless operators can safely open their LTE networks to third-party devices and content, thereby boosting on-portal/off-portal usage and making their services more attractive to end-users. It will also enable them to generate revenue from different kinds of transactions (beyond voice calls and megabits) between subscribers and content providers, advertisers and other commercial entities. These factors have the potential to positively impact operator income statements by reducing churn and acquiring customers who were previously only served by wire cable solutions [15].

Even with all these benefits, there is still one major drawback of wireless, and that it's limited by the available bandwidth and topography. If there are too many users trying to use the same spectrum, the system simply will not work. If the users are located inside of a structure that blocks the wireless signal, then they will not have connectivity.

This is where copper and fiber based solutions have a very clear advantage. The highest available bandwidth of copper solutions is available to any customer who has a copper line run to their premises no matter how dense the user base is in a specific geography. When you take the bandwidth in a FTTH/B solution into consideration there is no comparison. Bandwidth is virtually limitless with fiber optics.

To compete with the benefits of a copper solution, a major near term objective for wireless providers will be the continued investment and build out in the actual network. Initially this will be done by lighting dark fibers that are currently in the ground from former network build outs. Ultimately the existing resources will be exhausted and here will be demand for more towers, higher speeds and stronger backbone connections. This will be a worldwide phenomenon [16].

VIII. Cables and Green Energy Technologies

Large elements of the energy infrastructure of the world are based on electrical networks that are as vast and complicated as anything that can be seen in the telecommunications sector. In a manner similar to the telecom companies which used new technologies to turn formerly single service networks to multi-use, energy delivery organizations have realized they can also leverage their electrical distribution networks to include communications functions. The term Smart Grid has been adopted to describe the comprehensive communication functions of electrical networks. According to IC Insights, spending on Smart Grid semi conductors, a core component of smart grid technologies is set to double between 2011 and 2015 [17].

A Smart Grid system has many benefits, including improved response to power demand, intelligent management of outages, better integration of renewable forms of energy and the storage of electricity [18]. Figure 4 shows the annual growth of sales of Smart Grid between years 2011-2015.

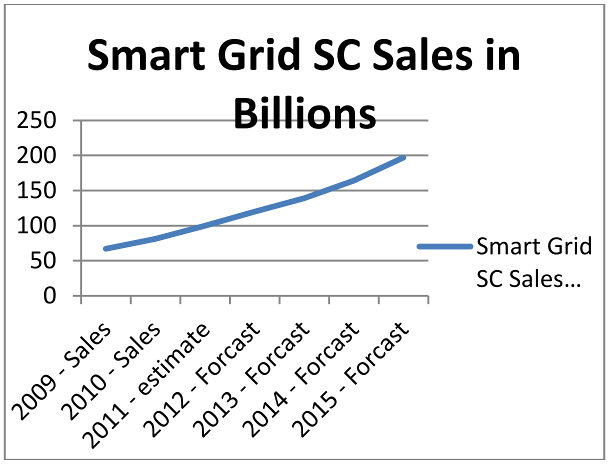

Figure 4- Annual Growth between 2011-2015

Like any new market changing technologies there have been major debates about moving to the new technology. These issues involved have long been part of the dialog of the telecommunications industry but are new for the electrical industry. These concerns include data management issues, and network security issues [17].

A core component of the Smart Grid is the meters that are connected to use points such as homes or business. Generally speaking the Smart Grid meters are connected using wireless or BPL technologies. This does not mean that the Smart Grid is completely separate from traditional communication cablings. Tantalus Systems Corp and EBP created a Smart Grid meter that connects via fiber optics which allows a utility to provide Intelligent Power Management, Broadband, Telephone and Video Services [18].

A- Broadband over Powerline (BPL)

Another area at the intersection of the telecommunications and energy arena is the attempts by electrical distribution companies to offer broadband services. These services are commonly referred to as Broadband over Powerline (BPL). Through the last decade there was much hope by both government and the private sector that the electrical distribution companies could leverage their networks for competitive broadband services, the technology never materialized in any meaningful way [19]. BPL lost market to other technologies like DSL and Cable due to issues such as radio frequency interference, high attenuation, noise interference and data security concerns.

B- High Temperature Superconductor (HTS) and the Smart Grid

In the way that fiber optic technology revolutionized the telecommunications industry with its potential for zero loss due to total internal reflection, the electrical industry is undergoing just as significant revolution with a new cable type based upon High Temperature Superconductor (HTS) technology. In a traditional copper or aluminum energy cable electrons move at random and lose energy in collisions as the collisions generate heat. In a HTS cable electrons move in pairs and don't collide, thus no conversion to heat energy. HTS cable is considered a virtually perfect conductor of electromagnetic energy with nearly zero resistance. These results in a real world increase in power capacity one hundred and fifty times that of copper [20].

HTS as a backbone offers many benefits that impact both the communication and power distribution functions that the HTS cable provides. One specific benefit of HTS cable is that it is manufactured in a much smaller footprint yet still compatible with existing equipment and cable laying techniques. This backwards compatibility makes the cable operationally transparent to the energy service provider.

HTS power cables that require less area and distribute more power can replace over-taxed and aging copper cables in dense urban and metropolitan areas freeing substantial amounts of underground "real estate" that could be used for power, gas, water, and sewer and telecommunications networks. Another benefit to having more underground plant area available is attack-resistance. HTS cables provide the low impedance and high capacity that allows for simple and easy power transfer between substations. This allows network engineers to design and build a tightly meshed urban grid, while also limiting potentially damaging fault current magnitudes caused by intentional acts [21].

C- Telecommunications and Energy Future:

An additional benefit of HTS cable is its inherent positive environmental impact. Significant savings in Energy and CO_2 are realized because of the more efficient transmission properties of the HTS cabling as it is shown in Fig. 5. Factors external to the telecommunications industry have historically pressured more efficient use of energy. This will contribute to faster adoption rates of Smart Grids as a replacement to traditional electric grids. Consumers will not escape this trend and will be incentivized through legislation and the use of innovative products to be more energy use aware. Even though the outlook is dim for broadband service

Significant Energy and CO_2 Savings

Cable System	AC Conventional	AC HTS	DC HTS
Capacity (MVA)	1500	1500	1500
Voltage (kVrms)	275	66	130
Current (kA/phase)	1	3.3	12
Loss (kW/km)	740	200	20
Loss cost reduction ($/km/year)	--	473,000	630,000
CO_2 reduction (ton-C/km/year)	--	568	757
CO_2 dealing – 30 years ($/km @ $100/ton-C)	--	1.7 M	2.3 M

1/4

Further reductions 1/10

Source: Hirose et al., Sumitomo Electric Industries (SEI) Technical Review 62 (2006) pp. 15-23.

Note: AC HTS cable estimates based on "future target values".
DC HTS cable estimates are immediately feasible.

Figure 5 - Significant Energy and CO_2 Savings

over power lines, it does not mean that at some point the Smart Grid couldn't be used to provide two-way data communications to all users connected to the network. Recent technological developments have overcome many of these roadblocks to BPL's adoption [21]. In February 2011 the Institute of Electrical and Electronics Engineers (IEEE) published the final BPL standard for medium access control and physical layer specifications. The combination of a standard and the latest technology may mean growth for BPL in the future.

Even if BPL never materializes, an end-user accessible low-speed data network seems especially likely as the Smart Grid is fundamentally an information layer integrated on top of the electric network. These slower speed network connections could be used to communicate information to the electric utility from many different use points. This two-way data exchange with the electric service provider means that consumers will drive more efficient energy use into their daily lives. There will also be creativity exhibited in the types of electrically aware devices that are created. In the telecommunications industry, as higher speed networks became widely available, applications not previously possible were invented such as online video and web based document creation. That same type of innovation will be exhibited when the Smart Grid becomes ubiquitous. There will eventually be a higher level of adoption of Smart Grid aware appliances and consumer electronics which will further automate efficient energy use.

IX. Distribution of Service by Cable Types

Trends over the last five years provide some interesting information. Data collected from the Federal Communication Commission by connection type is as shows in Table 1.

Table1. Reporting instructions for mobile wireless changed between the June 2008 and December 2010 data.

Connection Type	Late 2008	Mid 2009	Late 2009	Mid 2010
aDSL -	30198	30618	30972	30793
sDSL	241	217	225	191
Other TP	705	686	716	758
Cable Modem / Coax	40251	42722	43162	43924
FttP	2884	3543	3975	4436
Satellite	938	990	1116	1144
Fixed Wireless	485	487	525	546
Power Line	5	5	5	6
Mobile Wireless	26532	38395	55842	71177

It should be noted that this data is internet connection type and should be considered 'last mile' technology. The majority of long line WAN network deployments are single mode fiber optic cable. It is this last mile technology that is the bottleneck for end-user speeds. Of all the related technologies such as Satellite, Powerline, and Fixed Wireless, the only technology aside from coax and twisted pair is Fiber Optics [22]. Although there is a duality of DSL cable transmission technologies including synchronous and asynchronous digital subscriber lines; aDSL maintains the lion's share of the market. Having a synchronous connection tends to be more important in a business setting so it can be concluded that service providers use different technologies primarily to artificially segment their consumer and business offerings. Although only a cable related technology for backhaul, the growth trends of mobile wireless connectivity show significant growth in the market compared to any other technology. Much of this can be attributed to the adoption of consumer friendly smart phones in the time period this data was collected. As the smart phone market is in an early lifecycle growth phase more data will need to be collected as the adoption slows down. It is at that point that a truer picture of the actual growth rate of the individual cable based technologies compares to wireless technologies.

This is a current snapshot of available speeds to premise based on cable type. What is most telling about this data is that in real world deployments at three megabit service is the functional top of what is currently available via twisted pair based aDSL technology. A more interesting representation of the data can be seen in figure 6 that graphically present the data in a way that shows trends and market penetration by technology:

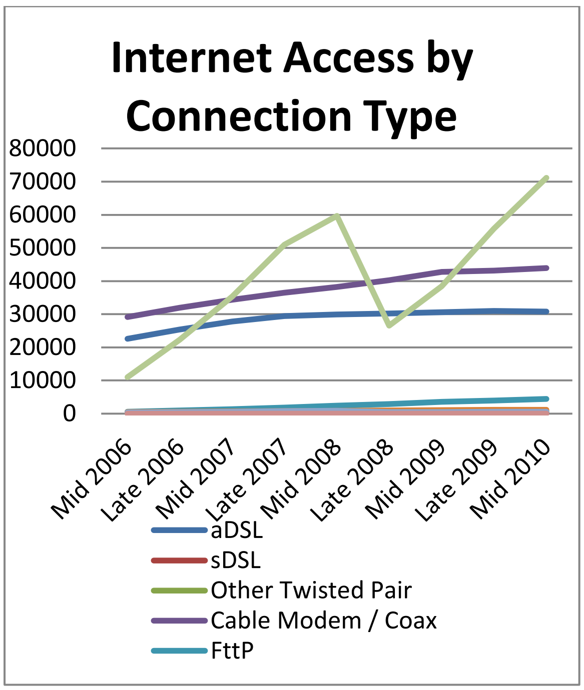

Figure 6 - Internet Access by connection type

This data very clearly shows that although there are twisted pair technologies such as hDSL and higher grades of aDSL, service providers have adopted a 'good enough' strategy in deployment.

This artificial limiting of available bandwidth hinders the mass adoption of technologies such as HD video that require higher available bandwidth than 3mbps. Additionally the lack of deployment of higher speed DSL based technologies may potentially hinder the adoption of emerging technologies such as telemedicine that work best with the highest available bandwidth.

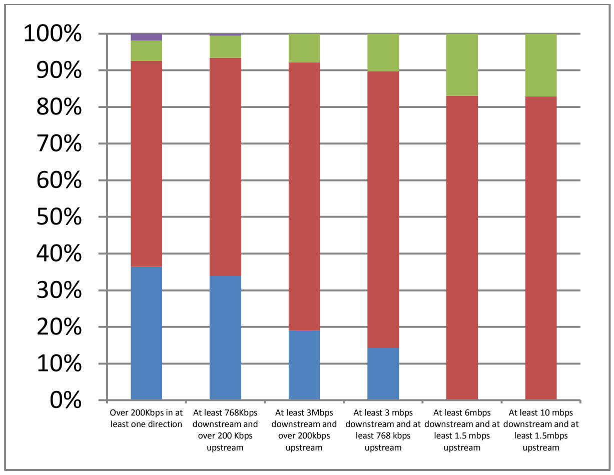

Figure 7 - Cable types in relation to speed offered

X. Conclusion

Current regulation and socio-political trends are accelerating the switch. Older technologies such as twisted pair and Coaxial Cable are slowly being phased out but continued improvements to the technology are extending its life. In addition to the policy related motivators, adoption of fiber optics as an end to end solution will accelerate even more as Headed costs are reduced and existing infrastructure is replaced over time.

There is one inescapable trend that has existed from the very beginning of the telecommunications industry, and that trend is a continually growing need to expand the uses of the networks. It is this need has driven increases in the reliability and effectiveness of telecommunications cable technology and will continue to do so for the foreseeable future.

XI. Future Work

Although all industrialized nations have national broadband plans that eschew copper technologies in favor of fiber optics, it’s still not clear that this is the best course of action. There is not enough information on exactly what speeds need to reach the inflection point for the maximum economic and social effects of wider, faster internet. Some examples of higher bandwidth applications include VoIP, Videoconferencing, HD Telemedicine, Distance Learning, IPTV, and Telecommuting. These applications and others tend to have a positive net economic and employment impact. For example, in a 2007 study by MIT researchers found that each percentage point increase in broadband equaled 0.2 to 0.3 employment increase overall. If the vast majority of the benefits such as data needs and employment impact for the next 10-20 years can be achieved with new uses of existing copper based plant, then the FTTH/B emphasis by governments around the world may negate over time.

Although we have cited recent discoveries by Bell Labs, more research needs to be done with regards to manufacturers to determine exactly where the price performance rates are going to be for these higher speed next-generation DSL Solutions. If pricing is close to the head end costs of fiber optic deployments then the cost/benefits may fall back to fiber optic solutions.

Additionally realistic research needs to be done to determine the reduction rate in the fiber optic head end cost per mile.

Finally more data needs to be collected on the copper/fiber ratios of the nations such as Japan and Korea with the greatest penetration of broadband. This information needs to be compared against less dense geographies such as the United States to determine if there actually are benefits to following the lead of these ostensibly better connected nations.

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