FUTURE DIRECTIONS IN CABLE BROADBAND BANDWIDTH CAPACITY

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Abstract

This paper takes a long term look at cable's broadband bandwidth needs over a 10+ year horizon. It discusses several drivers that forecast bandwidth needs down the road. We compare HFC potential against FTTP architectures and shows that there is plenty of capacity left in coax to compete with GPON or even co-exist with it. HFC also has the significant advantage in that it can incrementally expand bandwidth through this entire process without requiring a massive infrastructure overhaul like pure FTTP providers.

How far can the MSOs take coax looking way out on the 10+ year horizon? With the recent evaluations of the RF overlay systems, we take a closer look at the theoretical maximum capacity of coax. The paper discusses how HFC can offer 1+ Gbps services over coax and what is needed beyond our current DOCSIS systems.

Introduction

HFC has long enjoyed the position as the leader in providing broadband content to the home for both video & high speed data. Now it's being besieged by FTTP and satellite HD technologies and many have claimed its days are numbered. Our analysis shows that there is plenty of capacity left in coax to compete with GPON and even 10G PON technologies, given the appropriate investments. HFC also has the significant advantage in that it can incrementally expand bandwidth through this entire process without requiring a massive infrastructure overhaul like FTTP.

DRIVING BANDWIDTH NEEDS

This section discusses several drivers to forecast bandwidth needs down the road. Some of these may appear to conflict with each other, but each gives a unique perspective on bandwidth needs.

Moore's Law continues

Over the years, Moore's Law has driven data bandwidth growth and it looks to continue for the foreseeable future. Simply stated, Moore's Law is the doubling of transistors per device every 18-24 months. This increased technology capacity has resulted in a corresponding improved performance, density and power. Some studies have shown that high speed data broadband service offerings have closely tracked Moore's Law over the last 8-10 years. The implication that it will continue to track means that we'll need to offer 100 times today's bandwidth in another 10-15 years. With broadband providers offering data services around 10Mbps today, this means that the broadband providers should be prepared to make 1 Gbps services generally available in 10-15 years.

There are several aspects of data bandwidth growth that need to be examined. In Andrew Odlyzko's paper "Internet traffic growth: Sources and implications," he contends that the data traffic growth will continue to follow Moore's Law and is primarily driven by file transfers as opposed to streaming traffic like video. As bandwidth growth is modeled, it may be necessary to separate traffic that is streamed and requires constant bit rate service from the more general, best effort high speed data traffic that is following the Moore's Law growth.

But there are some questions with this argument. Will Moore's Law continue forever? Will technology improvements continue in the density and power areas but less so in the performance area? We may not know the answer for another decade, but must prepare in case it does continue to track.

Supply Side Economics

Is the right question to ask: "What is the demand for bandwidth?" Some insist it is not and instead we must look at the bandwidth supply rather than the demand. Internet demand is (nearly) infinite and users have been shown to try and consume everything given to them. So the operators should assume that any high speed data offering could probably be 100% utilized.

Instead of looking at demand, the right question should be "How much bandwidth should I supply?" And the answer to that is based primarily on competition. In the early days, cable modems were competing with dial-up services and only needed to offer 1Mbps service, even though the channel supported almost 40 Mbps. As DSL penetration increased, cable ratcheted up its data rates to maintain a sufficient performance edge. As FTTP penetrations like Verizon's FIOS increase, competitors will be able to flip the tables on cable and it will be up to cable to race and keep up with FTTP.

The difference between FTTP and HFC is most notable in the upstream direction. Since the HFC upstream capacity is significantly less than the downstream, competitors could cause an immediate disruption in cable operator's business by emphasizing services that use significantly more upstream capacity. We are just starting to see this in current marketing efforts.

Video dominates & HD becomes Mainstream

Among Video, Voice and Data services, by far the one with the largest bandwidth requirements is video. Not only does video require a high data rate of multiple Mbps, it streams for extremely long periods of time, maybe even several hours. We are also reaching the point where High Definition (HD) is becoming main stream. HD has a significant impact on bandwidth requirements, increasing the video bandwidth by a factor of 2-4X over Standard Definition (SD) video.

Many indications over the last year have shown that HD adoption is accelerating. As HD content rolls out, it will cause a significant impact on short term bandwidth needs. But what are the longer term impacts once the majority of video content is delivered as HD? To deliver one or two narrowcast (i.e. personalized) HD streams along with a couple of SD streams to each subscriber would require ~20Mbps per home using MPEG-4.

However, this may actually be understating the bandwidth needs. As HD penetration becomes truly pervasive, then we may need to support 3-4 HDTV's per home with a couple extra HD streams going to a DVR for recording. On top of this, some of these streams may also be high quality 1080p HD content requiring additional bandwidth. This longer term scenario would require closer to 40-50Mbps per home to support streaming HD video. The bottom line is that Service Providers will need to continue to offer more bandwidth capacity to the home as the percentage of HD content increases along with the percentage of HDTV penetration.

Burst speeds vs. Sustained rates

Throughout computer history, data networks have been useful because of the nature of statistical multiplexing. By offering a shared resource with high burst rates, users get the impression that they have high data rate services. In reality, data usage is very bursty and average data rates are significantly lower than the burst rate.

An example broadband system might be engineered today to provide 1% concurrency for a 10Mbps data service. This means that during peak busy hour each user will get an average of 100Kbps. As network speeds increase, the statistical gain also increases. This implies that the concurrency can be reduced as burst speed increases. So in this example, the operator could decide to offer a 100Mbps service with 0.25% concurrency. The result is that each user would get an average of 250Kbps during peak busy hour.

The significance of this is that the data service rate increased by 10-fold while the actual bandwidth provided by the operator only had to increase 2.5x. This factor will become especially important as broadband providers look to start offering Gbps services. Note, this analysis applies only to bursty data applications and does not apply to streaming voice or video. Care must be taken with concurrency if the bulk of internet traffic becomes streaming video.

Not All Subscribers are created equal

Another important aspect of understanding bandwidth needs is to look at the usage across the many different subscribers. Many operators have noted that a relatively few users consume a proportionately large amount of the bandwidth. One piece of data indicated that 5% of the users consume two thirds of the total bandwidth and that 25% of the users consume 95% of the bandwidth.

This has a major implication in how an operator rolls out its bandwidth capacity increases. If it can increase bandwidth incrementally to a small number of power users, then it can avoid costly upgrades that go across the board to all subscribers.

Peer-to-Peer (P2P)

As discussed previously, Internet demands appear to be virtually unlimited and one of the driving applications behind this is Peer-to-Peer (P2P) applications. From its start in music file sharing, P2P is branching out into many more main stream applications. As P2P video file sharing becomes prevalent, it will significantly increase the bandwidth demands on the system, especially in the upstream.

Home Generated content

Consumer devices and in particular mobile devices have made tremendous progress in recent years and look to continue in coming years. They have all become rich multimedia devices. Mobile devices some day will include 10 Megapixel digital cameras that can stream video clips. Digital camcorders are becoming HD capable and inexpensive. All of this combined with the ease of use being introduced by UPnP/DLNA will create a tremendous amount of user generated content that will be shared over the Internet.

In addition to these consumer devices, the introduction of low cost video cameras (a.k.a. webcams) will increase the number of applications like video surveillance or “nanny cams” that can be shared over the Internet. Video telephony will also increase the amount of traffic coming from the home, and as previously mentioned, these applications will have a much larger and earlier impact on the upstream bandwidth needs.

Wireless Backhaul

Mobile Devices are evolving from their roots as a telephony device to a full multimedia device supporting streaming video. This evolution is going to create a tremendous demand for 4G capable wireless networks like WiMax and LTE as well as technologies like Metro-Wi-Fi. As the number of mobile devices continues to rise along with improved video quality and screen sizes, the bandwidth needs will continue to escalate. Cell sizes will need to continually shrink to accommodate the wireless bandwidth density. Cable operators have a further incentive for creating wireless networks to maintain a competitive position with Telcos who already own spectrum and provide cellular services.

As 4G cell sizes are reduced to several hundred meters, the number of cell sites increases significantly and the site become more geographically dispersed. This creates a great opportunity for the Broadband Service Providers to supply the backhaul over their existing infrastructure. This may put tremendous additional bandwidth demands on their access networks.

3-D and Multi-view technologies

Since video is the main bandwidth hog today, it is important to understand future variations that will be hitting the market and potentially creating the next big impact to the industry. At consumer shows like CES, we are starting to see High Definition technology that supports both 3-D and multi-view technologies. The initial thrust for this technology will be the gaming world, studios starting to create 3-D movies as well as sports casting. Eventually, this technology may become main stream just like HD. The 3-D technology may cause a 50-100% increase in the bandwidth required to deliver the content. The multi-view causes an even larger increase, as it needs to deliver separate HD streams for each view provided to the user.

Future User Experiences

As we gazed into a very foggy crystal ball, we tried to imagine what applications of the future might drive a new paradigm in bandwidth requirements. There may be other technologies in addition to 3-D and multi-view just discussed that will impact the user experience. An ultra-HD technology may be developed that offers even higher video resolutions, with corresponding higher bandwidth demands.

As we think about enhancing the user video experience, the simple 2-way video call may be improved through the use of tools such as avatars and facial recognition. Beyond this, we may get into other enhancements to the user video experience with things like visualization and holography. At this point, there is no hard data on the bandwidth capacity impact, but we should continue to monitor and keep an eye for killer bandwidth applications. The only thing we do know is that bandwidth needs have always increased.

EXISTING HFC CAPACITY UPGRADES

Current techniques for expanding HFC bandwidth are well known and include: RF Upgrades (1GHz), node splitting and deep fiber expansion, Switched Digital Video (SDV), reclamation of analog channels, MPEG-4 encoding, DOCSIS 3.0 & M-CMTS.

Node Splits and Deep Fiber

In today’s HFC plants, there are many that still have 500, 750 or even >1000 Households Passed (HHP) per fiber node. These plants were designed and optimized for a broadcast system. As we evolve to a completely on-demand system, one of the most effective means of increasing bandwidth capacity is to reduce the node size by a factor of 2, 4, 8 or even more.

Typical Fiber Nodes have 2 to 4 coax outputs. This allows the operator to split a node 2-way to 4-way by replacing electronics inside the existing housing without pulling any additional fiber. The operator also has the option of splitting the upstream independent of the downstream. Splitting the downstream does require additional narrowcast wavelengths to be sent to the node.

To reduce node size further, the operator can push the fiber deeper into the HFC plant. This can often be done cost effectively using smaller satellite nodes. While many of today's HFC systems support a six amplifier cascade (N+6), newer deep fiber systems may eliminate (N+0) or have a single (N+1) amplifier. A deep fiber system may reduce node size to 125 HHP or even less.

A key issue with node splitting and pushing fiber deeper is available fiber count. The number of fibers in an HFC plant can vary dramatically from plant to plant. For those plants with low fiber count, Wave Division Multiplexing (WDM) becomes a critical technology in providing additional narrowcast wavelengths and hence additional bandwidth capacity. A good example of this technology is Motorola's Enhanced Coarse WDM (E-CWDM) system that was announced at the 2007 SCTE Cable-TEC show last June.

A key advantage for HFC systems is that they only need to split nodes that need the extra capacity. For example, if an entire community is configured with 750 HHP, but only one neighborhood has exhausted its on-demand bandwidth, the operator only needs to split that one node to expand bandwidth capacity to meet demand.

<u>SDV</u>

Switched Digital Video (SDV) is different than the other bandwidth approaches. Rather than increasing bandwidth capacity, SDV provides a mechanism to better utilize existing capacity. SDV allows the operator to convert a fixed number of broadcast channels into a potentially unlimited number of video channels within existing spectrum. This becomes even more important as the amount of HD content being offered increases.

In addition to increasing the number of offered channels, SDV is an important mechanism to allow the transition to new technologies, such as migrating to 1 GHz tuners, or from SD to HD as well as from MPEG-2 to MPEG-4. Over time, once the new technology becomes the dominant installed based, then any remaining broadcast technology can also be converted to the newer technology while the older technology will be completely switched using SDV.

<u>Analog Reclamation</u>

Analog TV channels consume 50-75% of the spectrum in today's typical HFC system. Analog TV channels are also extremely inefficient with the use of spectrum. A single 6-MHz TV channel can be replaced by a digital QAM channel delivering 10-15 SD programs. Digital QAM channels are also very versatile and can be dynamically assigned to VOD, SDV or high speed data.

So why aren't cable operators just dumping all of their analog channels and going all digital? Supporting analog TV channels has become a competitive advantage for cable operators over satellite providers. This will become even more critical after 2009 when the Over-the-Air analog channels are no longer broadcast. Many homes have a 2nd, 3rd and even 4th TV in the house. Satellite providers must add a new STB for every additional TV in the house. Once the Over-the-Air analog channels are removed, cable service will be the only way for consumers to get basic local services to these other TVs.

Over time, those operators that want to continue to offer an analog service can still reclaim a large portion of the analog channels to get a significant increase in bandwidth capacity while still offering consumers a reasonable analog service. For example, a HFC system with 125 6-MHz channels could reduce the number of analog channels from 75 to 25. This would double the bandwidth capacity available for digital QAMs, while still offering a basic analog service with all local and major network TV channels.

DOCSIS 3.0 and M-CMTS

DOCSIS 2.0 systems are currently in their prime, but will be running out of steam over the next several years as it tries to compete with FTTP. The DOCSIS 2.0 cable modem can support up to 38 Mbps downstream and 30 Mbps upstream before it hits a brick wall. DOCSIS 3.0 will be coming on line shortly and its channel bonding feature will allow significantly improved data rates to the subscriber. A DOCSIS 3.0 cable modem with 8 downstreams and 4 upstreams could enable a 300 Mbps downstream and 100 Mbps upstream service.

While DOCSIS 3.0 enables a bigger IP pipe to the subscriber, it does not impact the additional headend costs relative to video bandwidth associated with today's integrated-CMTS. A new Modular-CMTS (M-CMTS) architecture has been defined by DOCSIS to address this. It decouples the upstream from downstream and separates the RF technology from the CMTS core. This allows commodity driven Universal Edge QAM modulators to be shared between VOD, SDV and CMTS resources. This is the first major step in reducing the cost of delivering IP packets over DOCSIS and should reduce its cost relative to delivering video from 10-20X in the early days down to ~2X. Over time, the gap should continue to shrink as improvements are made to the all-digital CMTS core.

Upstream splitting and stacking

The current HFC bandwidth capacity is extremely asymmetric, with the downstream spectrum occupying 54 MHz to 1GHz while the upstream spectrum is limited to 5-42 MHz in North America. The upstream bandwidth capacity is further hampered by operating in a much noisier environment. To get the most out of an existing upstream requires the use of advanced technologies like SCDMA and improved ingress cancellers. SCDMA allows the operator to re-coup data bandwidth from the lower 5-15 MHz spectrum. All told, an operator can get a total of 140 Mbps of DOCSIS upstream bandwidth with appropriate improvements.

After improving the existing upstream, another common method of increasing upstream capacity is to split it into smaller node sizes. This can be done independent of splitting downstream node sizes and can also reduce the noise per upstream. Most fiber nodes support two to four coax legs. Each coax leg is potentially a separate upstream return spectrum.

HFC VS. GPON COMPARISON

But how does HFC today stack up against GPON in raw bandwidth capacity? It turns out quite well . . . in the downstream. Up until now, we've discussed many mechanisms that HFC may use to incrementally increase bandwidth. At this point, we will compare an HFC system using these available enhancements to a GPON system. The HFC system under consideration has 1GHz RF with deep fiber nodes [125 House Holds Passed (HHP), 100 subs]. We also assume about half of the analog channels have been reclaimed, so the system reserves ~40 analog channels and 8 digital simulcast QAM channels (i.e. 80-120 digital video broadcast streams). This means about 100 QAM channels are available for switched VOD/SDV/Data. This is approximately 1 QAM per sub or slightly less than 40Mbps downstream capacity per sub.

This is almost identical switched downstream capacity to a GPON system with 64 subscribers (i.e. 2.4 Gbps / 64 subs = 37.5 Mbps per sub). The implication here for the HFC system is a significant increase (almost 100-fold) in the number of QAM modulators to achieve this. Edge QAM devices will need to continue to make significant improvements in cost, density and power to achieve this. However, the undesirable alternative for MSOs is to pull fiber to all 100 homes. It should be noted that some FTTP vendors are deploying GPON with 32 subscribers per PON. The HFC can continue to match this by pushing the fiber even deeper (e.g. N+0 with 50-65 HHP).

The GPON system still has an edge in RF bandwidth, burst speed and upstream capacity. The GPON system has an optional 750MHz RF carrier while the previous HFC system had set aside about 350MHz for analog and digital simulcast channels. For certain applications like large file transfers, the burst speed of the network is critical and GPON still has a large edge in this category. For upstream bandwidth, GPON supports ~1Gbps while the DOCSIS 3.0 system only supports about 100Mbps which it will still fall short of GPON's upstream capacity.

UPCOMING HFC BANDWIDTH CAPACITY UPGRADES

Modulation improvements

As HFC systems continue to improve, they will eventually be able to support higher order modulations like 1024 QAM. Increasing the QAM constellation density increases the MPEG-2 transport bit rate almost 28% to almost 50 Mbps. However, this higher throughput comes at a cost: the required threshold signal-to-noise ratio (SNR) to achieve the same reliability (bit error rate) is at least 6 dB higher using conventional J83.B FEC coding. Using 1024 QAM with advanced FEC can yield up to 23% higher throughput with a moderate increase of ~3dB in threshold SNR.

RFoG & CablePON – FTTP for cable

MSOs may have certain targeted areas where it makes economic sense to install a complete fiber based solution. This may include support for an industrial park or FTTP in a new housing development. If the existing bandwidth requirements allow, the cable operator may initially support existing cable services over the FTTP, while having the fiber in place for future expansion. This approach is called RF over Glass (RFoG) and is currently being standardized by the SCTE.

There may be some applications where the current HFC bandwidth solutions are inadequate. Some of these include Gbps Commercial Services or 4G Cellular & other wireless backhaul. For these, Motorola's CablePON solutions allow operators to offer a GPON solution where needed but within their existing legacy cable equipment infrastructure. This solution is different than a traditional GPON deployment in that the MSO leverages the fiber portion of its HFC to transport the services. This is also different from traditional GPON in that the devices fit into the MSOs back office infrastructure. Another important aspect is that this solution fits within the cable operators existing router and M-CMTS infrastructure without requiring expensive B-RAS equipment.

RF Overlays

Other technologies like RF Overlay systems offer the prospect of increased RF bandwidth capacity. Some recent technologies offer a 2-3 GHz system adding additional downstream and upstream capacity. These systems are being evaluated from both a technology and business perspective. While it may not make business sense to apply this technology to an entire plant, it may prove useful to bring additional bandwidth to a particular site (i.e. a surgical strike) where it is not feasible to extend the fiber portion of the plant. RF Overlay technology will most likely be used in conjunction with other plant upgrade techniques.

DOCSIS 3.0 Mid-Split Systems

In addition to channel bonding, DOCSIS 3.0 also supports an option for a mid-split HFC system with additional upstream capacity. The upstream spectrum is increased from 5-42MHz to a 10-85MHz range. The added frequency range is also significantly less affected by impulse and ingress noise, so the net effect is that upstream bandwidth capacity may almost quadruple (e.g. from 27MHz usable at 16-QAM average to 70MHz usable at 64-QAM average). The mid-split upgrade needs to be done in conjunction with reclaiming the lower analog TV channels (channels 2-6) and a plant upgrade that replaces/eliminates the old diplex filters.

DIBA – CMTS By-Pass technology

As the world migrates to an all IP environment for the delivery of video, the additional cost of delivery over a DOCSIS network becomes more important, even with an M-CMTS approach. Motorola has pioneered a concept called DOCSIS IPTV Bypass Architecture (DIBA) that allows session oriented IP traffic to bypass the CMTS core and go directly from its server to the Edge QAM device. This greatly reduces the needed CMTS core capacity which in turn reduces the relative cost of delivering IP packets over DOCSIS by more than two thirds.

Over the long term, DIBA holds the promise on economically converting cable systems to an all IP infrastructure all the way to the home. Motorola has published several white papers on this topic, including a paper at the 2007 SCTE Emerging Technology conference. These papers provide a detailed description of DIBA.

Hybrid PON Coax (HPC) systems

As bandwidth needs for residential users continue to increase, it will eventually make sense to take the small percentage of users who consume a significant portion of the total available bandwidth on existing HFC systems and offer them Gbps services thru an FTTP solution. In this scenario, it would be highly desirable that an MSO have the capability to drop fiber to any existing individual subscriber.

One method of accomplishing this is with a concept called Hybrid PON Coax (HPC). The HPC system is basically a CablePON/GPON overlay on top of existing HFC plant. HPC allows the MSO to install pockets of FTTP within its existing HFC infrastructure. Having the ability to drop a fiber connection to a single home without upgrading its entire plant can give MSOs marketing leverage to combat its telco rivals.

Statistics have shown that a small percentage of users consume a large portion of the data bandwidth. The MSO can potentially move 5-10% of its subscribers to FTTP and free up two thirds of its high speed HFC data bandwidth. This means that with a relatively small fiber plant investment, the MSO can significantly extend the life of its HFC. The HPC also allows the MSO to combat the telco marketing in being able to offer FTTP to anyone, but with the huge advantage compared to them that it only needs to pull fiber to the select few that need the Gbps service.

Headend Impacts from Bandwidth Increases

Increasing HFC bandwidth capacity is more than just upgrading cable plants, it is providing equipment at the access edge to deliver this capacity. For HFC to compete with GPON, it will require a significant investment in additional Edge QAMs and CMTS core capabilities. Other video capabilities like transcoding and encryption will need to be scaled as well. As technology progresses these functions will get pushed from the core further out to the access edge.

In addition to the video components just described, there will need to be new advances in the high speed data transport beyond the current M-CMTS developments to economically scale data traffic for tens or hundreds of Gbps data rates. Current CMTS architectures provide high touch, per subscriber services similar to B-RAS equipment. In order to economically get a hundred fold increase in data bandwidth, we will need to start migrating to Class based services and other technologies that can leverage standard Ethernet switching equipment.

There will also be the need to converge future generations of DOCSIS CMTS and GPON OLT products. As just discussed cable operators may need to start deploying HPC systems. With M-CMTS decoupling the PHY layer in DOCSIS, a similar approach can be taken with GPON to create a common packet processing core for both technologies going forward. Both share similar capabilities in routing, traffic shaping and policing as well as seamless mobility support. This platform should also be extended to support other access technologies such as WiMax, LTE and metro-Wi-Fi.

NEXT GEN COAX – FUTURE OF HFC

RF Upgrades – 3GHz & beyond

With the recent evaluations of RF Overlay equipment, we have taken a closer look at the theoretical maximum capacity of coax. It turns out that the typical hardline coax being used today has a limit of ~5GHz before waveguide effects take over. There may be other effects that limit the total coax capacity, but we should continue investigation in this area to understand completely how far we can push cable.

For RF designs, the complexity is often related to the number of octaves (i.e. doubling of frequency) that the design must cover. Current 1GHz systems must cover more than 4 octaves since they start at 50MHz. Going from 1 to 4 GHz adds two more octaves. As investigation continues on multiple GHz systems, the lower couple octaves (e.g. 50-200MHz or -400MHz) should be considered dropped for new systems to help minimize cost and complexity.

As deep fiber architectures eliminate other active components, we will reach the day where the coax is the final limitation on bandwidth capacity to the home. If the cable hardline is ultimately replaced by fiber, the coax drop line has a much higher RF frequency limit due to its much smaller diameter. This could allow cable to the home to even exceed 5 GHz. Other areas of investigation could look at ways of increasing the theoretical limit of the cable as well as using different waveguide mode(s) along with the lower order mode to increase the cable's capacity.

Next Gen Coax System

How far can the MSOs take coax looking out on the 10+ year horizon before it hits the brick wall? From above, the RF hardline cable might be capable of supporting systems in the 3-5GHz range. However, no standard exists yet for devices above 1GHz. With the increased bandwidth needs, the old 6MHz channel size no longer makes sense in this range. This gives us the opportunity to define a new Next Gen Coax system above 1GHz.

To be competitive with FTTP, Next Gen Coax must support extremely wideband channels (e.g. >100MHz wide) with dense advanced modulations (e.g. 1024/4096 QAM or equivalent) that are capable of delivering greater than 1 Gbps symmetrical bandwidth to individual subscribers in a single or a small number of bonded channels. The new standard should also eliminate MPEG-2 transport and DOCSIS layers and define a simple all IP infrastructure that unifies all devices, including cable modems and STBs with end-to-end IP connections. An all IP infrastructure will also help with integrating the Next Gen Coax system with other FTTP and wireless access technologies.

These wideband channels would be of great value in existing HFC as well. The ability of offering symmetric Gbps services within the existing 1 GHz spectrum would significantly level the playing field with FTTP competitors. It may make sense to roll the wideband channel support out initially within existing frequency ranges and then allow for 1-5 GHz operation in future releases.

Next Gen Coax vs. 10G PON

Given the expected timeframe, a Next Gen Coax system would need to compete with a 10G PON system. How does this compare? Assuming the 1-5GHz range is split 2:1 in favor of downstream traffic with a 1024 QAM modulation or equivalent, the Next Gen Coax system could theoretically support a total of 20Gbps downstream and 10Gbps upstream bandwidth capacity. This is roughly equivalent to a pair of 10G PON systems. This means that MSOs could keep their node sizes roughly twice the size of the PON group (e.g. 125 HHP) and still provide the equivalent bandwidth per subscriber as a 10G PON.

If it turns out that there are other limitations in reaching a 5GHz system, the MSO can still provide a 3GHz system that would provide an additional 10Gbps downstream and 5Gbps upstream capacity. This along with smaller node sizes (e.g. 50 HHP) can still keep coax competitive with 10G PON systems.

Next Gen Coax development should start now so it can keep pace with 10G PON development. As MSOs upgrade to N+0 and N+1 cable architectures, we should consider enabling at least 3GHz RF, if not the full 5GHz as feasible. When you combine these changes with the Hybrid PON Coax architecture that allows select users to migrate to FTTP if needed, then the HFC system appears to have a very long life ahead of it. And most important, all bandwidth increases are incremental and invested as needed.

HOME NETWORKING IMPACTS

The Broadband pipe into the home is becoming a fire hose. The prospect of offering 100's Mbps or even >1Gbps to a home only makes sense if the home network can handle that in addition to all of its local LAN traffic. This will place a burden on existing multimedia home networks. To meet this need will require multiple wired and wireless home networks to be interconnected.

For home networking over cable, next generation MoCA will be needed to scale to several hundred megabits per second to match or exceed DOCSIS 3.0 speeds. This next generation MoCA will become critical for cable operators to deliver its DOCSIS 3.0 bandwidth throughout the home and compete with FTTP.

Another important piece of the future home networking scene will be 802.11n. This next generation Wi-Fi network supports more than 100 Mbps and provides a number of features that will improve robustness and range. We also expect to see smart antenna developments coupled with 802.11n to improve performance. Work on the following generation to 802.11n has started and may be a step towards approaching Gbps wireless rates in the home.

Looking even further out there is the possibility of 60 GHz technology evolving to provide higher bandwidth home networking. The major issue with 60GHz technology will be the ability to propagate through walls to provide whole home coverage. It is possible that 5 GHz technology may be the limit in terms of whole home wireless coverage.

Next Gen Coax as Home Network technology

As the Next Gen Coax technology is developed as a multi-gigabit access technology, it should also be extended within the home as the first multi-gigabit in-home network. No other home networking technology seems poised to address this challenge. While GPON currently provides 2.4 Gbps to the side of the house, actual burst data rates to consumer devices will be limited to the home networking technology, which today is on the order of 100 Mbps or less.

If cable operators can develop multi-gigabit technology delivered all the way to consumer devices throughout the home over coax, it can once again leapfrog its Telco rivals. Another advantage with this approach is the economies of scale from the consumer devices sharing the same technology as the access devices. We've seen the benefits of this in the Wi-Fi world.

CONCLUSION

We have seen that the bandwidth needs will continue to increase for the foreseeable future and that cable operators will need to extensively support Gbps services within 10-15 years. The cable operators will also get severe competitive pressure from FTTP providers like Verizon FIOS further accelerating the need to increase bandwidth.

With existing upgrades and continued technological developments in devices like Edge QAMs, the cable operator is in excellent position to compete with GPON with respect to downstream traffic. This bodes well for offering personalized HD video services. As new applications start to drive upstream capacity, this will expose the upstream as the cable operator's Achilles heel. Increasing upstream capacity is an area that needs continued research and development.

In the near term, there may be scenarios such as offering Gbps Commercial Services, wireless backhaul, or residential green field builds where the cable operator needs an FTTP solution. For these, Motorola's CablePON solutions allows MSOs to offer FTTP where needed while operating completely within a legacy cable equipment environment. As the bandwidth race continues, it may become necessary for MSOs to be able to offer Gbps service to select power users on existing HFC thru a Hybrid PON Coax (HPC) system. Moving the heavy users off the HFC network extends the HFC useful life and having the ability to drop a fiber connection to any home without upgrading its entire plant can give MSOs marketing leverage to combat its telco rivals.

Looking far out on the 10+ year horizon, there is a possibility of a new Next Gen Coax system. Capable of operating up to 3-5 GHz with very wideband channels, the cable operator can offer symmetric Gbps services to the user while matching the overall bandwidth of a 10G PON system while maintaining 50-125 HHP node architectures. This Next Gen Coax architecture may also be a catalyst to enable Gbps services throughout the home network as well.

With all told, the future does not look bleak for HFC, but it looks to have a long and healthy life. And the most important piece of this is that the HFC can grow incrementally as needed without the need for a forklift upgrade like its competitors.