



The video service industry is a perpetually changing environment that offers new and exciting products. Telecommunications companies are now entering the video distribution industry at an unprecedented rate and all eyes in the U.S. are on the rollout of video services by Verizon and SBC over their broadband networks. The introduction of video services by these two major telecommunications providers will undoubtedly change the shape of the video industry in the U.S. for the foreseeable future.

With major companies like Verizon and SBC entering the fray, many industry observers are interested to learn what each will bring to the table. Most knowledgeable observers agree that the average consumer is much more concerned about the breadth and quality of services available to the home, and much less concerned about how the services get there. However, the nature of the video technology and the broadband network infrastructure that enable video services are key to determining what services can be offered today and in the future.

Continual advances in technology and application services will create an increasing demand for bandwidth, and tax the network infrastructure of video service providers. The advent of high-definition television (HDTV) programming, associated new form-factor sets (such as LCD TVs), and the impending mandated digital TV transition are all expected to contribute to a boom in TV sales, and consequently increase the average number of TVs per household. This in itself does not concern the video service providers. However, the predicted large increase in the number of TVs on at any given time plus the increased demand for bandwidth-hungry HDTV content does raise concern. HDTV content represents a fraction of the total number of available channels today, but HDTV programming is growing and is universally expected to do so at an ever-increasing rate. Increased adoption of HDTV programming will rapidly push some broadband network infrastructures to their limits.

Video compression techniques are currently utilized to enable HDTV programming. With current compression techniques, HDTV requires 14 to 19 Mb/s. Future advanced compression techniques such as MPEG-4 Part 10 and VC-1 will reduce HDTV bandwidth

requirements on the order of 8 to 16 Mb/s. However, recent studies have shown that average viewers perceive differences in quality when even moderate increases in video compression are applied. Consequently, signals simply can't be compressed indefinitely without some sacrifices in quality.

Primary Network Architectures

Advanced digital signal compression technologies are a key enabler of television over Internet protocol (IPTV) that offers a different interactive and on-demand service feature set than traditional broadcast distribution. IPTV, with its packet-switched video transmission protocol, also reduces bandwidth requirements relative to traditional RF-based video services that simultaneously transmit all broadcast content. Bandwidth requirements of HDTV can still challenge an IPTV system, however. As a result, video compression and IPTV can not simply combine to enable less-capable broadband architectures to enter into triple-play services.

There are three primary network architectures compatible with broadband triple-play service provisioning: hybrid fiber coax (HFC), xDSL and fiber to the home (FTTH). While re-use of an existing infrastructure can delay costs and perhaps meet immediate bandwidth demands, limitations of legacy HFC and copper networks restrict their ultimate bandwidth capability, network reach, and operating cost structure.

The hybrid fiber coax (HFC) design deployed by cable TV multiple system operators (MSOs) is the original "made for TV" architecture, as it was designed to support a large number of broadcast channels using radio frequency (RF) transmission. While total effective bandwidth for an RF-based system can sound very large, at nearly 5 Gb/s, most of it is dedicated to supporting several hundred broadcast channels. The small percentage remaining is shared between on-demand services, Internet data and voice traffic. Since HFC network bandwidth is shared across a large number of subscribers, RF video is the most effective solution and IPTV, with interactive and on-demand features, is not a clear fit, but the cable TV industry continues to evaluate alternative options.

The various flavors of DSL cover a wide range of capabilities. Basic ADSL inarguably provides data rates too low to deliver a competitive video offering, even as compression techniques improve. Only recently have network operators begun to offer services greater than 1.5 Mb/s, with some areas seeing capabilities in the range of 3 Mb/s. A critical limitation of xDSL is that the total bandwidth must be shared among all services, with a balance being forced between data, voice and video services if a triple-play is attempted. ADSL2+ and VDSL2 offer much higher data rates over very short copper loop lengths and are now being considered as the paths for telcos to deliver video services over copper-based networks. Still, due to the significantly limited bandwidth capability of xDSL relative to FTTH or even HFC, switched video solutions like IPTV are the only option for providing video over DSL and at best only promise to deliver a few simultaneous channels to each user. Network operators hope that shortened copper loops and further advanced compression will address this issue.

FTTH designs address the shortcomings of both HFC and DSL alternatives, while being able to support either IPTV or RF video or even a combination of the two. FTTH's clearest

advantage is its dramatically increased bandwidth capability. Fiber allows higher fundamental data rate capacity than xDSL, and has none of the length-dependent limitations of copper. By exploiting wavelength division multiplexing (WDM), FTTH can also incorporate an “RF overlay,” thereby replicating the full capability of an HFC system for video services on a dedicated wavelength while reserving separate wavelengths for upstream and downstream data and voice services. So, unique in comparison to the legacy network broadband options of HFC and xDSL, FTTH can efficiently support either RF video or IPTV, with ample bandwidth to support current and future bandwidth-intensive applications.

Conventional Single-Mode Fiber and Stimulated Brillouin Scattering (SBS)

Video signals are commonly considered to have the most demanding requirements of the triple-play of services, whether transported in the RF or IP domain. While web pages can load slowly, email can be delayed, and phone call quality can be less than pristine, any degradation of TV signal quality creates immediate havoc for the operator.

Transport and distribution of IPTV follow the same line of thinking as other IP services, although issues such as latency and packet loss become much more demanding. These issues have been reasonably well addressed in a number of different forums.

HFC networks must be carefully designed and monitored to maintain acceptable signal quality, particularly due to the noise and distortion contributions from coaxial cable signal leakage and RF amplifiers. FTTH networks, on the other hand, completely eliminate all but the short in-home coax connections. So, while RF signal impairments are still a source of concern in HFC networks, maintaining video signals almost entirely in fiber over FTTH automatically improves end-of-line transmission quality. RF video transmission, while very well understood in the cable TV industry, has not received a great deal of significant treatment in the context of FTTH PON architectures. Particularly, the issues associated with optical RF video transport and distribution for FTTH networks are rarely addressed beyond a single overly simplified model. While RF video transport over fiber eliminates the noise and distortion seen in HFC networks due to signal leakage and RF amplifiers, a look at the most common network configurations for RF video transport in FTTH networks reveals potential optical limitations. Fortunately, recent developments in fiber technology address these limitations, as we will examine later.

PON implementations generally have several commonalities among them, with each complying with the requirements prescribed in the relevant ITU-T BPON and GPON standards recommendations, supporting video-service transmission between 1550 nm and 1560 nm. PON implementations require that RF video signals are amplified in the optical domain due to the relatively high received-power requirements at the optical network terminal (ONT) and due to the high passive losses seen in the PON optical distribution network (ODN) between the optical line terminal (OLT) and subscriber-premises-located ONT. These high power requirements and high losses result in launch power requirements in the range of 14 dBm to 20 dBm, particularly when video signals are transported over long distances in a broad area ODN. The actual required power levels are obviously dependent on distance,

choice of standard or specialized optics and electronics, design margins, and overall configuration of the PON ODN.

At such high power levels Stimulated Brillouin Scattering (SBS) is observed in conventional single-mode optical fiber. SBS comes into effect above a certain optical launch power and thereafter reduces the power of the transmission signal and imparts severe noise and distortion on it, degrading the signal quality. SBS, therefore, acts to limit the maximum amount of optical power that can be launched into a length of optical fiber by establishing a threshold above which RF video signals (both analog and digital) can be severely degraded. RF video signals, with their requirement for high optical launch powers, are particularly susceptible to SBS.

Higher SBS Threshold in Optical Fiber

The effect of SBS has been known for quite some time and has been an issue in video transport networks for nearly 10 years. Without some means of suppressing the effect, typical 1550 nm video transmitters would only be capable of supporting launch powers lower than those achievable with 1310 nm transmitters. This would significantly erode the economics of a 1550 nm system, as the number of optical amplifiers required would dramatically increase to accommodate short low-power spans. Through various electronic techniques, optical transmitter manufacturers have mitigated the effects of SBS to effectively raise the SBS threshold, but even these techniques have had their limitations, as they in turn introduce other limiting signal degradations to the system. In effect, the industry has learned to live within the limitations of SBS, assuming that the SBS characteristics of single-mode fiber are set in stone.

Recent improvements in the fundamental understanding of SBS behavior in optical fibers, however, have allowed the design of ITU-T G.652.D-compliant single-mode fibers with significantly increased SBS threshold levels while maintaining backward compatibility with legacy standard single-mode fiber. By incorporating fibers with enhanced SBS threshold, network operators are seeing more flexibility in network architecture, video transmission equipment choice and design budgets and margins.

Two capabilities can be realized by exploiting fibers with higher SBS thresholds. The most obvious is the ability to increase optical powers in the network by removing attenuation pads or introducing higher output Erbium Doped Fiber Amplifiers (EDFA). By doing this, a network can benefit from longer system reach and potentially allow for removal of some EDFAs in long backhaul links by increasing individual amplifier spans.

The less obvious advantage of a fiber infrastructure with increased SBS threshold is the ability to increase signal quality and reach without increasing the optical power relative to a standard fiber configuration. If the fiber itself has an increased SBS threshold relative to standard single-mode fibers, then the SBS mitigation applied to the transmitter can be reduced, resulting in a narrower linewidth and less susceptibility to nonlinearities and dispersion. In this scenario, a link can be operated at the same optical power commonly used

with standard fibers with standard off-the-shelf transmitters and EDFAs, but the signal quality can be dramatically improved and much longer distances can be accommodated.

The changing landscape of the video services industry, with increasing demand for HDTV and triple-play services, will clearly require more advanced service delivery network infrastructures. HFC, xDSL, and FTTH are broadband solutions that can all enable video services. However, FTTH is unique in its ability to enable very high bandwidth and both IPTV and RF video transmission. The introduction of high SBS threshold single-mode optical fiber further enhances the RF video transmission capabilities of single-mode fiber, making it the most versatile and future-proof video service infrastructure solution.