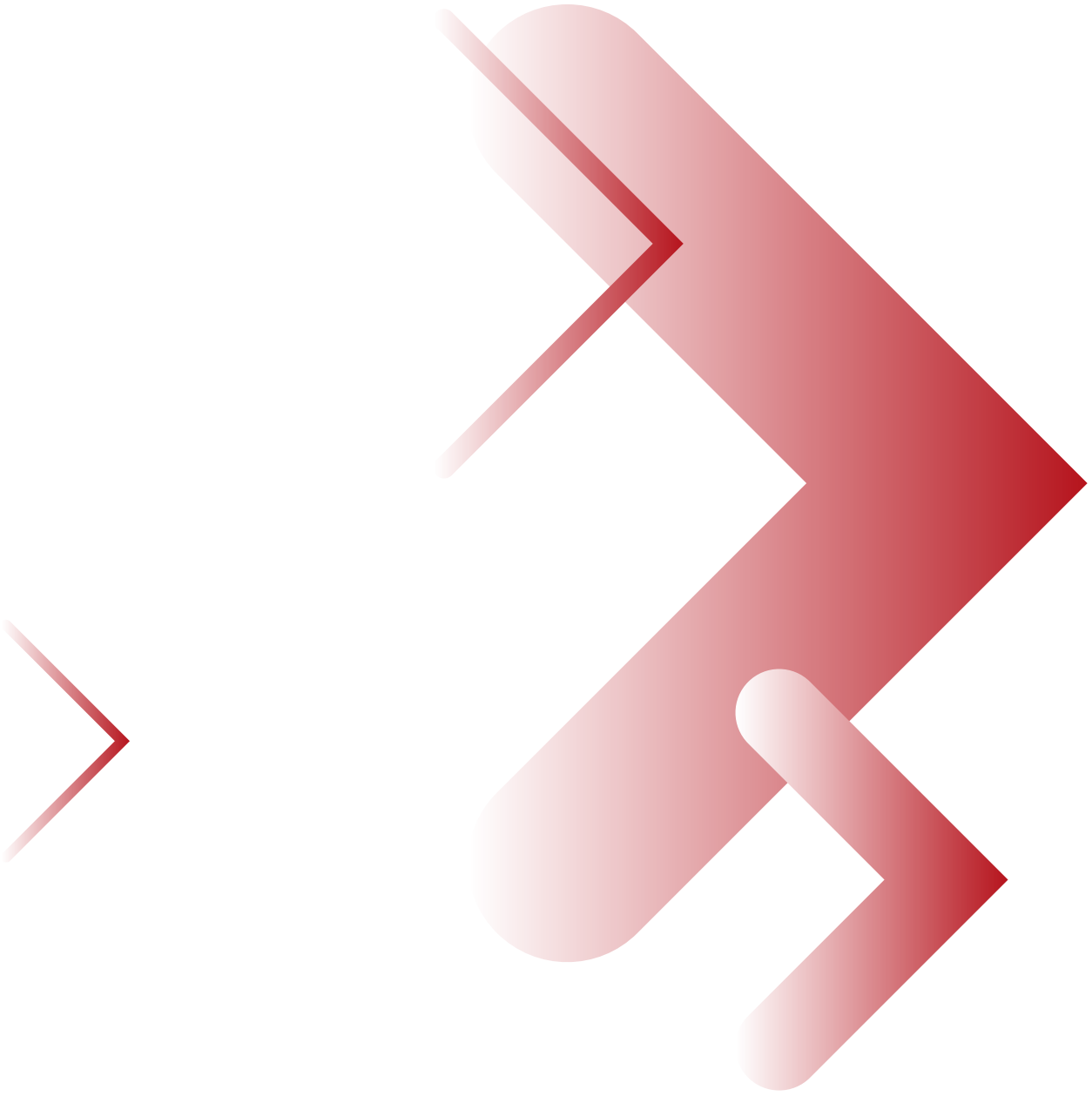
WHITE PAPER

Home Networking Technologies

Delivering Media in the Digital Home



For more than a decade, operators have put tremendous effort into expanding the carrying capacity of their network infrastructure. Spurred initially by demand for broadband Internet service, operators have more recently recognized that the enhanced bandwidth and increased reliability of their networks would lend themselves to delivery of an even greater array of value added, revenue generating consumer services. Most prominent among these are standard and high definition television, video on demand services and voice over IP (VoIP). Prior investment in the network infrastructure that leads from the operator to the home has yielded the capacity to bring such services to the consumer's front door.

Entertainment Services within Home Networks

The nature and design of the applications consumers' desire – not only for TV and VoIP, but gaming, music and data usage – are causing operators to consider the uncertainties that arise once their services cross the consumer doorstep.

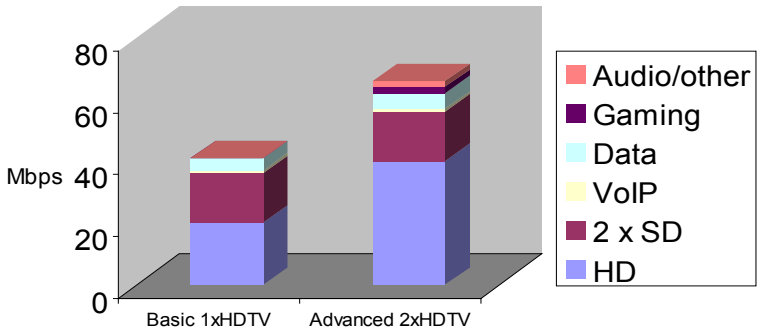
Self-contained data networks are increasingly common in new homes and they are readily deployable in others via off-the-shelf, consumer-friendly solutions. That availability has many consumers interested in new ways of using their media throughout their home such as listening to the music stored on their PC via their home audio system, viewing video and photos stored on their PC on any TV in their home, or watching video stored on their DVR system on a laptop in another room.

Consumers crave having their content freed from the shackles of place, enabling uninterrupted, consistent content-driven services regardless of location. Within the home, this scenario envisions an advanced level of flexibility in which a consumer could locate content while surfing the web, pause playback, then continue viewing the content via their set top box on their television, and then pause again and complete the experience in yet another location. In another scenario, the consumer's DVR located in a living room would be accessible to any other set top box or PC located throughout the home. Service providers are well situated to deliver and capitalize on these applications.

The Bandwidth Challenge

As operators look to offer these broad entertainment and other services to their subscribers, the network in the home becomes increasingly important. The quality and quantity of bandwidth within the home will be critical to delivering a compelling service that will attract and retain subscribers. IPTV and related video services demand high bandwidth and exceptional performance including low latency to a level that has not previously been a concern for home networks.

Perhaps the most significant realization for operators that hope to profit by enabling these applications has been that the bandwidth requirements for running these applications across the network inside the home can quite easily exceed those that bring the service to the house. In addition, the variety of existing in home wiring options has further confused planning for these services.



Total Bandwidth > Broadband Access Bandwidth

FIGURE 1: HOME NETWORK TRAFFIC MODEL

Basic	Advanced
MPEG-2 - no DVR	Multiple HD Streams
1 HD = 20 Mbps	2 HD = 40 Mbps
2 SD = 16 Mbps	2 SD = 16 Mbps
VoIP = 1 Mbps	VoIP = 1 Mbps
Data = 4 Mbps	Data = 5 Mbps
	Gaming = 2 Mbps
	Audio/other = 2 Mbps streaming
Total 41 Mbps	Total 65 Mbps

FIGURE 2: ESTIMATED BANDWIDTH USAGE PER HOUSEHOLD TYPE

A brief look at the bandwidth requirements of various media types will help to illustrate the challenge.

Estimated Bandwidth for Network-Based Entertainment Services

Standard definition MPEG-2 video stream	6-8 Mbps
High definition MPEG-2 video stream	12-20 Mbps
Standard definition MPEG-4 video stream	2 Mbps
High Definition MPEG-4 video stream	8 Mbps
Voice over IP	1 Mbps
Broadband data service	5 Mbps
Online multiplayer gaming	2 Mbps
Audio streaming	2 Mbps

* MPEG-4, if applicable, can reduce video bandwidth up to 50%

Keeping these figures in mind helps to enumerate the challenge – each signal or stream requires full access to its required bandwidth at all times in order to maintain acceptable service levels. Service operators are looking to have at least 75 Mbps of bandwidth within the home network today to enable successful delivery of service. At the same time, service providers need to be ever-vigilant in managing the time and cost of installation. It is also important to consider consumer perception as many are unwilling to have operators perform damaging wiring installations throughout their homes. As such, the most expedient or highest bandwidth option may not always prove to be the most effective solution.

Maximizing Subscriber Experience by Overcoming Jitter and Latency

There is a divide between how consumers expect television to behave and the method of delivery employed in modern networks. More than half a century of analog television accustomed viewers to an experience in which instant response was the norm. Later digital video broadcast systems still followed a synchronous approach, where video arrives in a continuous stream that is assembled by the decoder. The advent of packetized networks, specifically the Internet, has fundamentally changed the nature of the underlying delivery infrastructure.

Among the most significant factors to impact the consumer's experience are two issues that arise in many networked applications. Called latency and jitter, these two issues are technical in nature; nevertheless they present an important business consideration in preparing for and deploying networked entertainment services. As operators explore and retool to deploy services that rely on wired and wireless in-home networks, it is important to consider how each manages jitter and serves to minimize latency.

Jitter

The viewer experiences jitter as degraded video quality and consistency. It manifests itself in a variety of ways such as image freezes, a momentarily empty screen, and missing audio. Typically, the viewer will see the image freeze, and then skip quickly through a frame in order to not lose the following frame. Jitter is the most visible detractor from user quality of experience.

What is occurring is essentially a timing error. Timing is critical to the smooth, uninterrupted delivery of video over a network. These hiccups are inherent in virtually every IP network including the standard data delivery network. When dealing with data jitter is perceived as nothing more than a slight delay at the receiving end; jitter does not impact the successful delivery of the data.

Jitter is more obvious in video because video needs to be delivered in a precise, timely manner in order to be displayed properly. As with all data, video is sent over an IP network in small chunks called packets. When a packet of video arrives earlier or later than expected, it forces the end device such as a set top box or PC to work around the timing error. When packets arrive late, the decoding device does not have frames of video in its queue. The viewer then sees the video freeze and hears the audio stutter while the decoder waits for the next packet of video in the sequence.

When packets arrive early, the decoder has to store these packets in its buffer. The buffer quickly fills up with stored video information and then must empty itself in order to be ready for subsequent packets. Each packet lost is approximately seven frames of video – more than enough to be perceived by the viewer. Each of these resets causes the video to freeze and then restart. In addition, there will be audio disruptions during this event which may highlight the corresponding video problems.

The industry standard for Digital Video Broadcasting is a maximum of 40 milliseconds of peak-to-peak jitter (± 20 milliseconds) from source to end device (ETSI TS 102 034 Digital Video Broadcasting (DVB); Transport of DVB Services over IP-based Networks) To date, network operators have generally been successful in managing jitter for video as it arises between the operator's video headend and the subscriber's set top box. The challenge arises when a local network infrastructure in the consumer's home outside the purview of the operator becomes part the end to end video network. In designing a home entertainment network that will support video it is critical to consider the quality of service (QoS) capabilities of the network technologies used in the home for reducing the amount of jitter perceived by the decoder.

Latency

The user experiences latency as delays in the responsiveness of the entertainment system. Until recently, latency was not a significant concern for home entertainment applications that generally originated at an operator's headend and terminated at the subscribers set top box. Networks generate small amounts of latency, for example when a subscriber changes channels or requests an on demand title for playback, but typically these delays are not enough to detract from the user's experience.

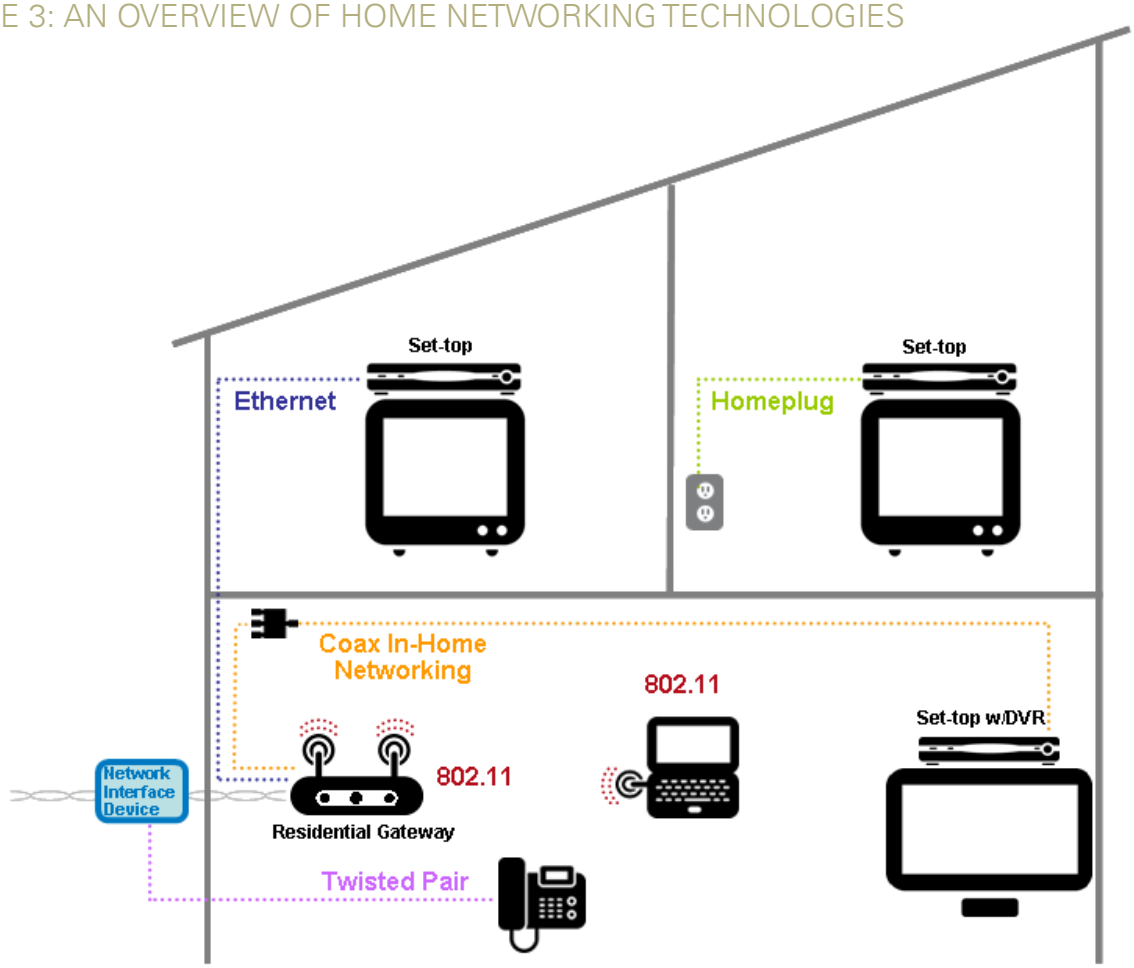
Many of today's new compelling applications are not so forgiving. When using a remote control, game controller, keyboard, microphone or other input device in which two way communications take place, users expect to see an instant response on the screen. For example, if video and audio arrive independently over the network, the two can very apparently be out of sync.

When considering home networking technologies it will be critical to consider latency. Jakob Nielson's *Designing Web Usability* [2] is a commonly cited reference for response time goals. In this reference, Nielson categorizes:

- 100 milliseconds as the maximum delay before the user no longer feels that the system is reacting instantaneously.
- 1 second as the maximum delay before the user's flow of thought is interrupted.
- 10 seconds is the maximum delay before you lose the user's focus on the current dialog.

A number of factors can contribute to latency in networks, including distance, signal interference and compression or conversion between devices. The main culprit in a home entertainment network will tend to be the router. As such it is important to consider networking solutions that introduce no more than a reasonable amount of latency.

FIGURE 3: AN OVERVIEW OF HOME NETWORKING TECHNOLOGIES



Ethernet

Ethernet is the most widely deployed wired technology for local area networks and is included by default in most modern PCs. Ubiquitous in the wiring of commercial environments, Ethernet cabling can also be found in a sizable percentage of new homes built in the past decade. Available for nearly thirty years, Ethernet equipment is economical and widely available, offering a very low cost interface for integration within set top boxes. Its widespread usage in the PC market means that many consumers are familiar with Ethernet, making self-installation a possibility for certain applications. Ethernet also offers generous bandwidth and is capable of exceeding 900 Mbps throughput coupled with excellent overall system reliability after installation is complete.

At the same time, Ethernet presents a variety of challenges for networked home entertainment. While self-installation is possible in homes that are pre-wired, the vast majority of homes will require new wiring. It can take two installers several hours to install CAT5 cabling. Once installers arrive at a house, they may spend hours crawling around the home, stapling Ethernet cables, running wires through attics, and drilling new holes–all the while incurring the ire of customers.

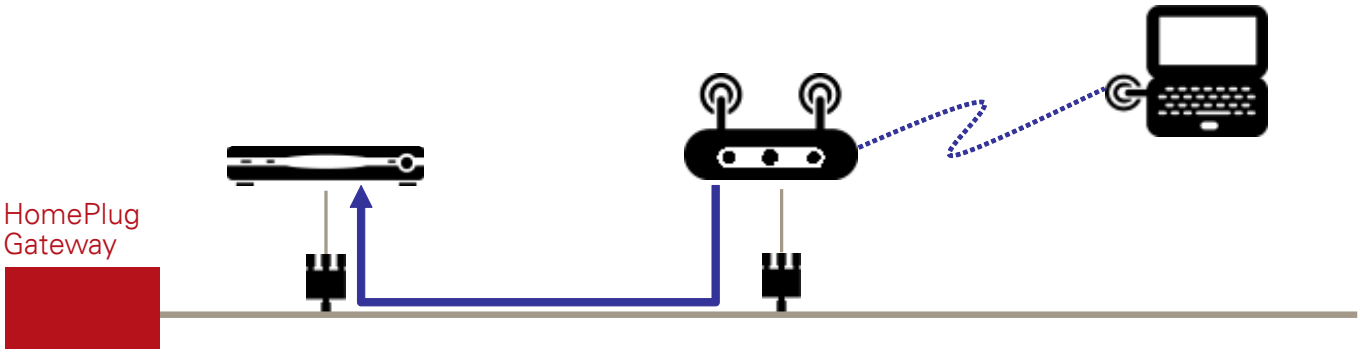
Ethernet presents an additional challenge for video applications because many installations do not provide an inherent Quality of Service mechanism. Many installations therefore require multiple, parallel runs of Ethernet cable. This provides the video services with an independent path, physically separate from any other triple play services, to maintain acceptable service levels.

HomePlug

HomePlug is a networking technology that skirts the rewiring challenge by taking advantage of the near universal presence of power outlets. HomePlug is designed to a home network by simply plugging devices into standard power outlets. This essentially eliminates the need for new wires and avoids the complexity engendered by wireless networks.

Evolving HomePlug specifications have been put forth, but the most relevant to home entertainment networks is HomePlug AV. HomePlug AV theoretically offers sustained throughput of 120 Mbps and in practice it readily delivers 50-70 Mbps, sufficient to support a wide range of today's most varied multimedia entertainment installations. While early generations of powerline-base networks struggled to overcome the inherent noise in electrical wiring, the latest generation of HomePlug AV features significant technical advances that enable it to effectively circumvent interference and fluctuations. Its advantages, particularly in its use of existing wires, make HomePlug AV an important consideration in homes with limited existing wire options. Designed with entertainment services in mind, HomePlug AV offers effective QoS and is capable of providing a good user experience in many challenging environments.

FIGURE 4: HOMEPLUG EXAMPLE



HomePNA

HomePNA is a wired solution that offers a cost-effective alternative to rewiring. It is applicable to a number of challenging environments. In older homes HomePNA enables an operator to effectively deliver broadband services throughout the home by taking advantage of any existing coaxial cables as well as twisted-pair telephone wires. This greatly reduces and in many cases eliminates the need for rewiring along with its costs in manpower, equipment and time.

In homes already wired with coax, HomePNA provides an interface for connecting the Ethernet signal from the operator's network interface directly to the coax wiring in the home. HomePNA also provides an interface between the network interface and existing phone lines throughout the home. This enables the operator to deploy cost-effective, Ethernet-equipped set top boxes without rewiring with CAT5 cable generally associated with Ethernet. Reducing the amount of new wiring also means that installation rarely requires more than one technician or a significant time investment. A wide variety of low-cost interface devices enable set tops boxes, PCs, telephone and other devices to directly connect and share the HomePNA network.

In practice, HomePNA delivers broadband-caliber data rates exceeding 100 Mbps - more than enough for services to expand well into the future. HomePNA features effective QoS that ensures that the multiple signal paths traveling between the operator's network interface and individual devices throughout the home are maintained. Advanced protocols within HomePNA manage the transmission of all data services – voice, video and broadband data—to guarantee service delivery and maintain the high quality experience expected by even the most demanding consumer.

802.11n

One way to avoid the challenges of rewiring or contending with varying wiring in the home is to eliminate wires altogether. 802.11n, the most current superset of the widely used wireless standard utilized by consumers in more than 100 million deployed PCs and mobile devices, may offer a compelling option for some operators. In its existing form, 802.11n offers approximately 125 Mbps of throughput under ideal, undisrupted circumstances. In practical application, it reliably delivers 60 Mbps over a distance of 60 feet, including passing through as many as three typical interior household walls. Eliminating the need for wires altogether, 802.11n equipped devices require only a power source to function.

While 802.11n has not yet become a ratified standard the WiFi Alliance has been certifying devices based on a stable draft of the standard. Wireless networks can also be impacted by environmental and equipment factors that are beyond the control of the operator. As the standard matures and improves, these issues are likely to be reduced or eliminated. In fact, 802.11n actually takes advantages of some of the interference and line of sight issues that hindered previous wireless solutions, turning them into essential QoS enhancements. As with any wireless network, operators need to consider enabling security protocols to protect their subscribers and the network. As these concerns are addressed, the advantages of 802.11n in terms of ease of installation and network flexibility are very compelling.

Multimedia Over Coax

MoCA is a networking specification designed for the home coaxial cable to facilitate high-speed networking. Already in commercial deployment, MoCA enables operators to use existing coax wiring to interconnect set top boxes, PCs, wireless devices such as network routers and other devices by directly connecting them to the coaxial jacks throughout the house.

MoCA delivers broadband-caliber data rates exceeding 130 Mbps. Currently MoCA specifies as many as sixteen end points, satisfying a large percentage of today's installations. More complex future deployments, in which consumers desire multi-room sharing of high definition video sources, may need to address bandwidth and QoS considerations as these systems scale in the future. Once installed, MoCA has proven to be exceptionally reliable with consistent QoS.

	Ethernet	HomePlug	HomePNA	802.11n	MoCA
Bandwidth in Mbps	900	50-70	100	125	130
Wiring	New	Existing	Existing	N/A	Existing
QoS Features	Some	Y	Y	Y	Y
Standards/ Specifications Finalized	Y	Y	Y	Y	Y
Products Available	Y	Y	Y	Y	Y

FIGURE 5: COMPARISON OF TECHNOLOGIES

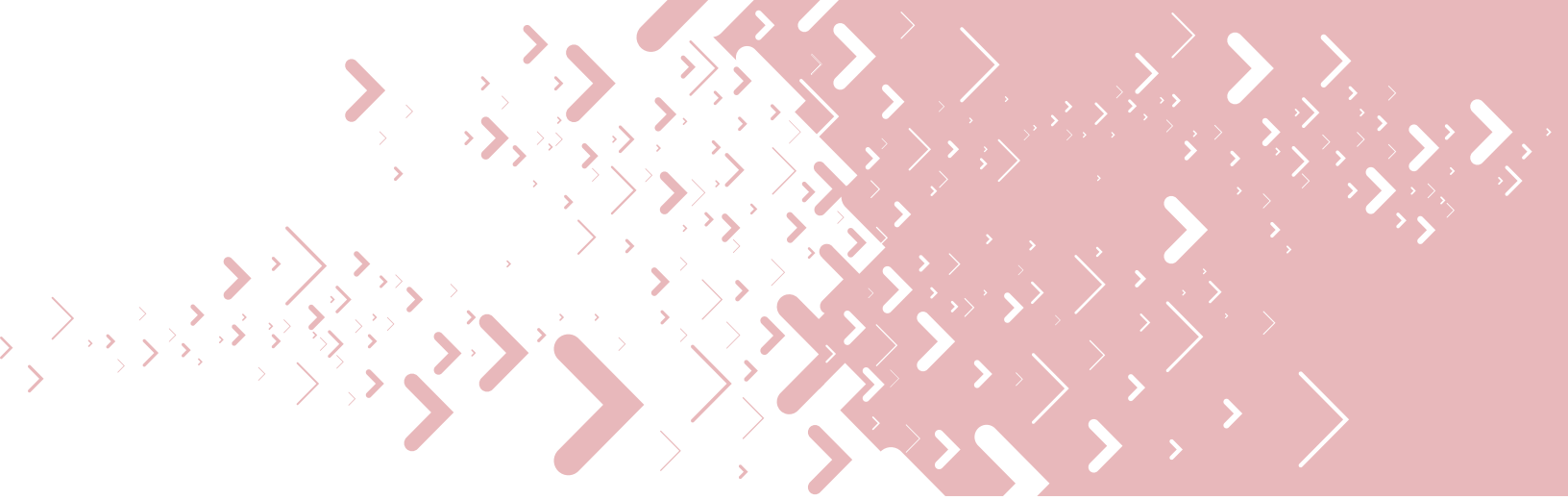
Future Directions

While providers today face a somewhat confusing array of technology considerations and tradeoffs, work is underway to lessen some of the differences. The International Telecommunications Union (ITU) has undertaken development of a new standard, called G.hn, which aims to standardize home networking chips. The goal is a standard deployable by 2010. It remains to be seen whether or not G.hn will be cost effective and meet the performance level of existing technologies.

Meanwhile, MOCA, HomePNA and HomePlug are all expeted to release next generation specifications that will increase bandwidth and reduce cost in the very near future.

Conclusions

Distribution of entertainment services within the home presents service providers with a tremendous opportunity to increase their value and appeal to consumers. The good news is that operators have a variety of networking technologies to choose from to make this possible. It is likely that no one technology will provide a "one size fits all" solution and it is therefore imperative for providers to fully understand all of the options available to them. Striking a balance between performance, future growth potential, ease of installation and other factors will be the key to fruitful deployments.



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