

Network Capacity in the Home

Executive Summary

Most new homes are wired with Category 5e cable to every room. Usually these cables are brought to a utility closet and marked for future use. The commoditization of Cat5e cable has reduced performance to raise serious questions about the actual bandwidth of generic CAT5e currently installed in residences. For many future applications the capacity of this system may be inadequate. Solutions are offered to “future-proof” these systems.

IP Systems in the Home

My home and most others built to date have network connections in every room. It is debatable whether or not the capacity of the cable and the number of connections typically installed is adequate for the near future “wired” home. Applications of networked technology using Internet Protocol (IP) continue to multiply at Moore’s Law type rates. In addition, current applications continue to demand more bandwidth also at a rate approaching Moore’s Law.

Gordon Moore, co-founder of Intel, postulated in 1965 that processor speed would double every 2 years.) The trend has continued for more than half a century and is not expected to stop for another decade at least and perhaps much longer. “Almost every measure of the capabilities of digital electronic devices is linked to Moore's law: processing speed, memory capacity, even the resolution of digital cameras,” according to Wikipedia. In fact an Intel colleague suggested that the rate of increase was actually closer to doubling every 18 months than every 24 months.

IP isn't the Internet

Internet Protocol (IP) is the language that computers use to communicate with each other over the internet. However it is not limited to the internet. Most networks (commercial, residential, wired and wireless) use IP as the basic standard for communications. As the demand for communications between computers has increased, IP has remained the standard for communications. Every device on these networks has an IP address of the format 000.000.000.000. Most use some sort of category cable or fiber to communicate between processors, hubs and switches. Hubs split the same signal to all connected devices, switches distribute only the signals that apply to the connected devices. Processors use the signals for a specific application.

You do not need to understand IP. However some of the characteristics of IP need to be discussed to understand some of the limits this places on AV systems. Not all category cable carries IP signals. Baluns are a good example of analog and digital signals carried on a these ubiquitous cables that do not follow IP.

Quality of Service (QoS) is part of the IP that is not implemented on the Internet. It gives priority to certain type of data including video, audio, security as opposed to file transfers, email and other data that is not as time sensitive. Most residential networks do not implement QoS during setup. Delaying audio, video or security files will cause interruptions in the playback of those files if the interruption is longer than the amount stored in the buffer. In applications such as VoIP or teleconferencing, a buffer that is too large makes conversation impossible because of the delays between statements and

responses. Typically delays greater than 0.1 seconds are objectionable. Because of the multiple paths data can take from source to destination timing issues are complex for high quality video teleconferencing over the public internet. Private network (not Virtual Private Network) teleconferencing can implement QoS for high quality teleconferencing while gaining additional data capacity.

IP Applications

Residential applications of IP are exploding.

- Multiple computers in the home require file transfer and network printing
- Access to the internet has progressed from:
 1. Dial-up (56 Kbs)
 2. DSL or Cable modem (1.5 Mbit/s)
 3. FTTH (fiber to the home @ 100 Mbit/s)
- File types are exponentially increasing in size:
 1. Audio MP3
 2. Standard definition video
 3. High Definition Video
- Streaming audio and video are bandwidth hogs
- Teleconferencing or video phone technology remains on the horizon
- Multiplayer gaming within the home
- Multiplayer gaming over the internet
- New networked devices require access to the network
 - o Current
 - Computers
 - Security Cameras (standard definition to high definition)
 - NannyCams
 - Media servers
 - DVRs
 - Appliances
 - Control systems
 - VoIP telephone
 - Electronic Butler
 - o Future
 - Autos (navigation system update, system monitoring, monitoring of young drivers)
 - HVAC management
 - Hot water control and management
 - Energy management
 - Additional appliances such as refrigerators, stoves and microwaves many be monitored and controlled remotely
 - Garage door control
 - Sprinkler control
 - Home theater media and control
 - Spa
 - Lighting control
 - Fitness
 - Tele-Health
 - “Help, I’ve fallen and I can’t get up”
 - Remote vital sign monitoring for Heart rate, BP, weight, sugar, and diet

- Remote administration of therapy
 - Video phone
 - AV control

The lines between current and future are blurry. Everything on the future list is possible and being done today. The real question is the rate of adoption and the when of implementation.

IP Infrastructure requirements

It is clear that the requirements for the future are only going to increase. The real question is will the installed infrastructure be adequate to support the requirements. IP will automatically down speed if there are connections issues. In addition, if there are errors and packets of data do not arrive intact, the data is retransmitted slowing down the average performance of the network.

Simply connecting to the network and transmitting files is not verification of the performance of the network. Kinked CAT cables decrease performance dramatically even though the cable is not visible damaged. Wires that are stretched while pulling during installation will not perform at their full rated capacity. Wire locations near to interference sources can cause packet repetition. Low quality cables are not capable of sustaining the performance after installation.

In addition multiple users that share the network resources limits the amount of data that can be transmitted. If little Susy is running a print job, little Bobby is playing a MP3 file from a server, the video server is downloading a movie from the internet, and Daddy is finishing a report via a VPN back to the office, will mother be happy if the playback of Gray's Anatomy has glitches because the network is overloaded? Given the size and bandwidth requirements for HD television, this is not a difficult scenario to imagine.

Wireless Networks

A wireless system is certainly not up to the task. Maximum capacities for current standards are:

802.11b

Release Date	Op. Frequency	Data Rate (Typ)	Data Rate (Max)	Range (Indoor)
October 1999	2.4 GHz	4.5 Mbit/s	11 Mbit/s	~35 m

802.11g

Release Date	Op. Frequency	Data Rate (Typ)	Data Rate (Max)	Range (Indoor)
June 2003	2.4 GHz	23 Mbit/s	54 Mbit/s	~35 m

802.11n

Release Date	Op. Frequency	Data Rate (Typ)	Data Rate (Max)	Range (Indoor)
June 2009 (est.)	5 GHz and/or 2.4 GHz	74 Mbit/s	300 Mbit/s (2 streams)	~70 m

802.11n is a proposed amendment which improves upon the previous 802.11 standards by adding multiple-input multiple-output (MIMO) and many other newer features. Though there are already many products on the market based on Draft 2.0 of this proposal, the TGn workgroup is not expected to finalize the amendment until December 2009. (Data from Wikipedia)

A single highly compressed HD data stream will require almost the entire max data rate of 802.11n. It would not function in a marginal signal area. In addition the security issues surrounding wireless are less than ideal. There is a potential of interference when multiple channels are operated in the same area.

Wired Networks

10/100 BASE-T electronics and Cat 5e cables are the defacto standards for home networks. In the situation described above with Susy, Johnny, Mom and Dad all using the network simultaneously the system would crash as certainly as with an 802.11n wireless hub.

It is clear that the only network that could possibly support the family described is a 1000 BASE-T network with a high quality CAT 6 cable properly installed. The cable standard provides performance of up to 250 MHz and is suitable for 10BASE-T / 100BASE-TX and 1000BASE-T (Gigabit Ethernet). It is expected to suit the 10GBASE-T (10Gigabit Ethernet) standard, although with limitations on length if unshielded Cat 6 cable is used. Category 6a is required for frequencies up to 500 MHz, twice that of CAT 6 and is the standard for 10GBASE-T networks up to 100m (330 ft.)

Note that CAT 6 connectors are required to maintain the integrity of the network. Since most CAT 6 cable is 23 AWG the wire will not fit into regular RJ-45 connectors. In addition CAT 6 connectors are designed to minimize the amount of twist that must be removed from the cable to make the connection. This minimizes the crosstalk between pairs.

Other advantages to CAT 6

Our research has indicated a significantly higher performance for Baluns and HDMI signal extenders when CAT 6 cables are used in place of CAT 5e Cables. We were able to extend a 1080p /60 HDMI signal three times as far with CAT 6 cable. In addition they are more resistant to kinking during installation and are stronger.

It is interesting to note that as High Definition Television, on line gaming and other applications become more common in the home, the network performance level previously associated with commercial applications becomes important in the home. Surfing the internet is no longer the most difficult challenge to the home network. In fact, many homes may require higher network performance than most businesses who are simply looking to retrieve alpha-numeric data from small files compared to the size of the files typically required for multi-media. In addition while there are time constraints for multi-media data, delays in delivery of alphanumeric and HTML data are not especially noticeable.

Fiber

Some leading edge advocates recommending installing fiber in homes. There are no drawbacks to this installation; however there are risks. Currently the cost of the electronics to convert electrons to photons is quite significant so the timing of fiber replacing copper in the home may be distant. In addition the type of fiber (Single Mode or Multi Mode) is debatable and they are not interchangeable. The number of fibers is also subject to debate. Four fibers or more may be required for sending all the various signals around the home yet current solutions typically limit the number to two.

Nevertheless the cost of the fiber is relatively low and certainly makes sense given the difficulty of installing anything in the future.

Fiber makes a great deal of sense in certain applications. It is essential for cable runs over 100m, the limit to which copper categories are certified. Since it is resistant to lightning surges and ground loops there are many advantages to using fiber between buildings or to outside installations. Capacity for the fiber is not an issue, although high bandwidth electronics may cost more. I recently was involved in designing a system for an estate that required ten High Definition Security cameras with runs up to 1 mile. Due to both bandwidth and distance only fiber could have been used for this project.

Conclusions

It is highly likely that current network infrastructure in the home is inadequate to meet tomorrow's demands. The intelligent designer will guide the customer towards CAT 6 cable at a minimum and with 1000 BASE-T networks as a premium step. 10GBASE-T networks with CAT 6a should be installed in the finest installations. Care should be taken to insure proper installation so that the cables are not damaged.

Multiple jacks throughout the home will be required, including garage, patio, kitchen and utility rooms. Assume that IP cameras will become part of the security system and that all electrical devices as well as electronic devices may someday be part of the network!

Demands on the network for consumer applications are greater than commercial because of the type of data being transmitted. Be a leader and build systems for the foreseeable future.

Bill Schripsema
Director of Product Management
Liberty Wire and Cable