Network Working Group
Request for Comments: 1686
Category: Informational

M. Vecchi
Time Warner Cable

August 1994

IPng Requirements: A Cable Television Industry Viewpoint

Status of this Memo

Abstract

This document was submitted to the IETF IPng area in response to RFC 1550. Publication of this document does not imply acceptance by the IPng area of any ideas expressed within. The statements in this paper are intended as input to the technical discussions within IETF, and do not represent any endorsement or commitment on the part of the cable television industry or any of its companies. Comments should be submitted to the big-internet@munnari.oz.au mailing list.

Table of Contents

1. Executive Summary

This paper provides comments on topics related to the IPng requirements and selection criteria from a cable television industry viewpoint. The perspective taken is to position IPng as a potential internetworking technology to support the global requirements of the future integrated broadband networks that the cable industry is designing and deploying. The paper includes a section describing the cable television industry and outlining the network architectures to support the delivery of entertainment programming and interactive multimedia digital services, as well as telecommunication and data communication services.

Cable networks touch on residences, in addition to campuses and business parks. Broadband applications will reach the average, computer-shy person. The applications will involve a heavy use of video and audio to provide communication, entertainment and information-access services. The deployment of these capabilities to the homes will represent tens of millions of users. Impact on the network and the IPng requirements that are discussed include issues of scalability, reliability and availability, support for real-time traffic, security and privacy, and operations and network management, among others.

2. Cable Television Industry Overview

Cable television networks and the Internet are discovering each other. It looks like a great match for a number of reasons, the available bandwidth being the primary driver. Nonetheless, it seems that the impact of the cable television industry in the deployment of broadband networks and services is still not fully appreciated. This section will provide a quick (and simplified) overview of cable television networks, and explain the trends that are driving future network architectures and services.

Cable television networks in the U.S. pass by approximately 90 million homes, and have about 56 million subscribers, of a total of about 94 million homes (U.S. TV CENSUS figures, 9/30/93). There are more than 11,000 headends, and the cable TV industry has installed more than 1,000,000 network-miles. Installation of optical fiber proceeds at a brisk pace, the fiber plant in the U.S. going from 13,000 miles in 1991 to 23,000 miles in 1992. Construction spending by the cable industry in 1992 was estimated to be about $2.4 billion, of which $1.4 billion was for rebuilds and upgrades. Cable industry revenue from subscriber services in 1992 was estimated to be more than $21 billion, corresponding to an average subscriber rate of about $30 per month (source: Paul Kagan Associates, Inc.). These figures are based on "conventional" cable television services, and are expected to grow as the cable industry moves into new interactive digital services and telecommunications.

The cable industry’s broadband integrated services network architecture is based on a hierarchical deployment of network elements interconnected by broadband fiber optics and coaxial cable links. In a very simplified manner, the following is a view of this architecture. Starting at the home, a coaxial cable tree-and-branch plant provides broadband two-way access to the network. The local access coaxial cable plant is aggregated at a fiber node, which marks the point in the network where fiber optics becomes the broadband transmission medium. Current deployment is for approximately 500 homes passed by the coaxial cable plant for every fiber node, with variations (from as low as 100 to as many as 3000) that depend on the density of homes and the degree of penetration of broadband services. The multiple links from the fiber nodes reach the headend, which is where existing cable systems have installed equipment for origination, reception and distribution of television programming. The headends are in buildings that can accommodate weather protection and powering facilities, and hence represent the first natural place into the network where complex switching, routing and processing equipment can be conveniently located. Traffic from multiple headends can be routed over fiber optics to regional hub nodes deeper into the network, where capital-intensive functions can be shared in an efficient way.

The cable networks are evolving quite rapidly to become effective two-way digital broadband networks. Cable networks will continue to be asymmetric, and they will continue to deliver analog video. But digital capabilities are being installed very aggressively and a significant upstream bandwidth is rapidly being activated. The deployment of optical fiber deeper into the network is making the shared coaxial plant more effective in carrying broadband traffic in both directions. For instance, with fiber nodes down to where only about 100 to 500 homes are passed by the coaxial drops (down from tens of thousands of homes passed in the past), an upstream bandwidth of several MHz represents a considerable capacity. The recent announcement by Continental Cablevision and PSI to provide Internet access services is but one example of the many uses that these two-way broadband capabilities can provide.

The cable networks are also rapidly evolving into regional networks. The deployment of fiber optic trunking facilities (many based on SONET) will provide gigabit links that interconnect regional hub nodes in regional networks spanning multiple cable systems. These gigabit networks carry digitized video programming, but will also carry voice (telephone) traffic, and, of course, data traffic. There are instances in various parts of the country where these regional networks have been in successful trials. And given that compressed digital video is the way to deliver future video programs (including interactive video, video on demand, and a whole menu of other applications like computer supported collaborative work, multiparty remote games, home shopping, customized advertisement, multimedia information services, etc.), one can be guaranteed that gigabit regional networks will be put in place at an accelerated pace.

The cable networks are evolving to provide broadband networking capabilities in support of a complete suite of communication services. The Orlando network being built by Time Warner is an example of a Full Service Network(TM) that provides video, audio and data services to the homes. For the trial, ATM is brought to the homes at DS3 rates, and it is expected to go up to OC-3 rates when switch interfaces will be available. This trial in Orlando represents a peek into the way of future cable networks. The Full Service Network uses a "set-top" box in every home to provide the network interface. This "set-top" box, in addition to some specialized modules for video processing, is really a powerful computer in disguise, with a computational power comparable to high-end desktop workstations. The conventional analog cable video channels will be available, but a significant part of the network’s RF bandwidth will be devoted to digital services. There are broadband ATM switches in the network (as well as 5E-type switches for telephony), and video servers that include all kinds of movies and information services. An important point to notice is that the architecture of future cable networks maps directly to the way networked computing has developed. General purpose hosts (i.e., the set-top boxes) are interconnected through a broadband network to other hosts and to servers.

The deployment of the future broadband information superhighway will require architectures for both the network infrastructure and the service support environment that truly integrate the numerous applications that will be offered to the users. Applications will cover a very wide range of scenarios. Entertainment video delivery will evolve from the current core services of the cable industry to enhanced offerings like interactive video, near-video-on-demand and complete video-on-demand functions. Communication services will evolve from the current telephony and low-speed data to include interactive multimedia applications, information access services, distance learning, remote medical diagnostics and evaluations, computer supported collaborative work, multiparty remote games, electronic shopping, etc. In addition to the complexity and diversity of the applications, the future broadband information infrastructure will combine a number of different networks that will have to work in a coherent manner. Not only will the users be connected to different regional networks, but the sources of information - in the many forms that they will take - will also belong to different enterprises and may be located in remote networks. It is important to realize from the start that the two most important attributes of the architecture for the future broadband information superhighway are integration and interoperability. The Internet community has important expertise and technology that could contribute to the definition and development of these future broadband networks.

3. Engineering Considerations

The following comments represent expected requirements of future cable networks, based on the vision of an integrated broadband network that will support a complete suite of interactive video, voice and data services.

3.1 Scaling

The current common wisdom is that IPng should be able to deal with 10 to the 12th nodes. Given that there are of the order of 10 to the 8th households in the US, we estimate a worldwide number of households of about 100 times as many, giving a total of about 10 to the 10th global households. This number represents about 1 percent of the 10 to the 12th nodes, which indicates that there should be enough space left for business, educational, research, government, military and other nodes connected to the future Internet.

One should be cautious, however, not to underestimate the possibility of multiple addresses that will be used at each node to specify different devices, processes, services, etc. For instance, it is very likely that more than one address will be used at each household for different devices such as the entertainment system (i.e., interactive multimedia "next generation" television(s)), the data system (i.e., the home personal computer(s)), and other new terminal devices that will emerge in the future (such as networked games, PDAs, etc.). Finally, the administration of the address space is of importance. If there are large blocks of assigned but unused addresses, the total number of available addresses will be effectively reduced from the 10 to the 12th nodes that have been originally considered.

3.2 Timescale

The cable industry is already making significant investments in plant upgrades, and the current estimates for the commercial deployment indicate that by the year 1998 tens of millions of homes will be served by interactive and integrated cable networks and services. This implies that during 1994 various trials will be conducted and evaluated, and the choices of technologies and products will be well under way by the year 1995. That is to say, critical investment and technological decisions by many of the cable operators, and their partners, will be made over the next 12 to 24 months.

These time estimates are tentative, of course, and subject to variations depending on economic, technical and public policy factors. Nonetheless, the definition of the IPng capabilities and the availability of implementations should not be delayed beyond the next year, in order to meet the period during which many of the early technological choices for the future deployment of cable networks and services will be made. The full development and deployment of IPng will be, of course, a long period that will be projected beyond the next year. Availability of early implementations will allow experimentation in trials to validate IPng choices and to provide early buy-in from the developers of networking products that will support the planned roll out.

It is my opinion that the effective support for high quality video and audio streams is one of the critical capabilities that should be demonstrated by IPng in order to capture the attention of network operators and information providers of interactive broadband services (e.g., cable television industry and partners). The currently accepted view is that IP is a great networking environment for the control side of an interactive broadband system. It is a challenge for IPng to demonstrate that it can be effective in transporting the broadband video and audio data streams, in addition to providing the networking support for the distributed control system.

3.3 Transition and deployment

The transition from the current version to IPng has to consider two aspects: support for existing applications and availability of new capabilities. The delivery of digital video and audio programs requires the capability to do broadcasting and selective multicasting efficiently. The interactive applications that the future cable networks will provide will be based on multimedia information streams that will have real-time constraints. That is to say, both the end-to-end delays and the jitter associated with the delivery across the network have to be bound. In addition, the commercial nature of these large private investments will require enhanced network capabilities for routing choices, resource allocation, quality of service controls, security, privacy, etc. Network management will be an increasingly important issue in the future. The extent to which the current IP fails to provide the needed capabilities will provide additional incentive for the transition to occur, since there will be no choice but to use IPng in future applications.

It is very important, however, to maintain backwards compatibility with the current IP. There is the obvious argument that the installed technological base developed around IP cannot be neglected under any reasonable evolution scenario. But in addition, one has to keep in mind that a global Internet will be composed of many interconnected heterogeneous networks, and that not all subnetworks, or user communities, will provide the full suite of interactive multimedia services. Interworking between IPng and IP will have to continue for a very long time in the future.

3.4 Security

The security needed in future networks falls into two general categories: protection of the users and protection of the network resources. The users of the future global Internet will include many communities that will likely expect a higher level of security than is currently available. These users include business, government, research, military, as well as private subscribers. The protection of the users' privacy is likely to become a hot issue as new commercial services are rolled out. The possibility of illicitly monitoring traffic patterns by looking at the headers in IPng packets, for instance, could be disturbing to most users that subscribe to new information and entertainment services.

The network operators and the information providers will also expect effective protection of their resources. One would expect that most of the security will be dealt at higher levels than IPng, but some issues might have to be considered in defining IPng as well. One issue relates, again, to the possibility of illicitly monitoring addresses and traffic patterns by looking at the IPng packet headers. Another issue of importance will be the capability of effective network management under the presence of benign or malicious bugs, especially if both source routing and resource reservation functionality is made available.

3.5 Configuration, administration and operation

The operations of these future integrated broadband networks will indeed become more difficult, and not only because the networks themselves will be larger and more complex, but also because of the number and diversity of applications running on or through the networks. It is expected that most of the issues that need to be addressed for effective operations support systems will belong to higher layers than IPng, but some aspects should be considered when defining IPng.

The area where IPng would have most impact would be in the interrelated issues of resource reservation, source routing and quality of service control. There will be tension to maintain high quality of service and low network resource usage simultaneously, especially if the users can specify preferred routes through the network. Useful capabilities at the IPng level would enable the network operator, or the user, to effectively monitor and direct traffic in order to meet quality and cost parameters. Similarly, it will be important to dynamically reconfigure the connectivity among end points or the location of specific processes (e.g., to support mobile computing terminals), and the design of IPng should either support, or at least not get in the way of, this capability. Under normal conditions, one would expect that resources for the new routing will be established before the old route is released in order to minimize service interruption. In cases where reconfiguration is in response to abnormal (i.e., failure) conditions, then one would expect longer interruptions in the service, or even loss of service.

The need to support heterogeneous multiple administrative domains will also have important implications on the available addressing schemes that IPng should support. It will be both a technical and a business issue to have effective means to address nodes, processes and users, as well as choosing schemes based on fair and open processes for allocation and administration of the address space.

3.6 Mobile hosts

The proliferation of personal and mobile communication services is a well established trend by now. Similarly, mobile computing devices are being introduced to the market at an accelerated pace. It would not be wise to disregard the issue of host mobility when evaluating proposals for IPng. Mobility will have impact on network addressing and routing, adaptive resource reservation, security and privacy, among other issues.

3.7 Flows and resource reservation

The largest fraction of the future broadband traffic will be due to real-time voice and video streams. It will be necessary to provide performance bounds for bandwidth, jitter, latency and loss parameters, as well as synchronization between media streams related by an application in a given session. In addition, there will be alternative network providers that will compete for the users and that will provide connectivity to a given choice of many available service providers. There is no question that IPng, if it aims to be a general protocol useful for interactive multimedia applications, will need to support some form of resource reservation or flows.

Two aspects are worth mentioning. First, the quality of service parameters are not known ahead of time, and hence the network will have to include flexible capabilities for defining these parameters. For instance, MPEG-II packetized video might have to be described differently than G.721 PCM packetized voice, although both data streams represent real-time traffic channels. In some cases, it might be appropriate to provide soft guarantees in the quality parameters, whereas in other cases hard guarantees might be required. The tradeoff between cost and quality could be an important capability of future IPng-based networks, but much work needs to be advanced on this.

A second important issue related to resource reservations is the need to deal with broken or lost end-to-end state information. In traditional circuit-switched networks, a considerable effort is expended by the intelligence of the switching system to detect and recover resources that have been lost due to misallocation. Future IPng networks will provide resource reservation capabilities by distributing the state information of a given session in several nodes of the network. A significant effort will be needed to find effective methods to maintain consistency and recover from errors in such a distributed environment. For example, keep-alive messages to each node where a queuing policy change has been made to establish the flow could be a strategy to make sure that network resources do not remain stuck in some corrupted session state. One should be careful, however, to assume that complex distributed algorithms can be made robust by using time-outs. This is a problem that might require innovation beyond the reuse of existing solutions.

It should be noted that some aspects of the requirements for recoverability are less stringent in this networking environment than in traditional distributed data processing systems. In most cases it is not needed (or even desirable) to recover the exact session state after failures, but only to guarantee that the system returns to some safe state. The goal would be to guarantee that no network resource is reserved that has not been correctly assigned to a valid session. The more stringent requirement of returning to old session state is not meaningful since the value of a session disappears, in most cases, as time progresses. One should keep in mind, however, that administrative and management state, such as usage measurement, is subject to the same conventional requirements of recoverability that database systems currently offer.

3.8 Policy based routing

In future broadband networks, there will be multiple network operators and information providers competing for customers and network traffic. An important capability of IPng will be to specify, at the source, the specific network for the traffic to follow. The users will be able to select specific networks that provide performance, feature or cost advantages. From the user's perspective, source routing is a feature that would enable a wider selection of network access options, enhancing their ability to obtain features, performance or cost advantages. From the network operator and service provider perspective, source routing would enable the offering of targeted bundled services that will cater to specific users and achieve some degree of customer lock-in. The information providers will be able to optimize the placement and distribution of their servers, based on either point-to-point streams or on multicasting to selected subgroups. The ability of IPng to dynamically specify the network routing would be an attractive feature that will facilitate the flexible offering of network services.

3.9 Topological flexibility

It is hard to predict what the topology of the future Internet will be. The current model developed in response to a specific set of technological drivers, as well as an open administrative process reflecting the non-commercial nature of the sector. The future Internet will continue to integrate multiple administrative domains that will be deployed by a variety of network operators. It is likely that there will be more "gateway" nodes (at the headends or even at the fiber nodes, for instance) as local and regional broadband networks will provide connectivity for their users to the global Internet.

3.10 Applicability

The future broadband networks that will be deployed, by both the cable industry and other companies, will integrate a diversity of applications. The strategies of the cable industry are to reach the homes, as well as schools, business, government and other campuses. The applications will focus on entertainment, remote education, telecommuting, medical, community services, news delivery and the whole spectrum of future information networking services. The traffic carried by the broadband networks will be dominated by real-time video and audio streams, even though there will also be an important component of traffic associated with non-time-critical services such messaging, file transfers, remote computing, etc. The value of IPng will be measured as a general internetworking technology for all these classes of applications. The future market for IPng could be much wider and larger than the current market for IP, provided that the capabilities to support these diverse interactive multimedia applications are available.

It is difficult to predict how pervasive the use of IPng and its related technologies might be in future broadband networks. There will be extensive deployment of distributed computing capabilities, both for the user applications and for the network management and operation support systems that will be required. This is the area where IPng could find a firm stronghold, especially as it can leverage on the extensive IP technology available. The extension of IPng to support video and audio real-time applications, with the required performance, quality and cost to be competitive, remains a question to be answered.

3.11 Datagram service

The "best-effort", hop-by-hop paradigm of the existing IP service will have to be reexamined if IPng is to provide capabilities for resource reservation or flows. The datagram paradigm could still be the basic service provided by IPng for many applications, but careful thought should be given to the need to support real-time traffic with (soft and/or hard) quality of service requirements.

3.12 Accounting

The ability to do accounting should be an important consideration in the selection of IPng. The future broadband networks will be commercially motivated, and measurement of resource usage by the various users will be required. The actual billing may or may not be based on session-by-session usage, and accounting will have many other useful purposes besides billing. The efficient operation of networks depends on maintaining availability and performance goals, including both on-line actions and long term planning and design. Accounting information will be important on both scores. On the other hand, the choice of providing accounting capabilities at the IPng level should be examined with a general criterion to introduce as little overhead as possible. Since fields for "to", "from" and time stamp will be available for any IPng choice, careful examination of what other parameters in IPng could be useful to both accounting and other network functions so as to keep IPng as lean as possible.

3.13 Support of communication media

The generality of IP should be carried over to IPng. It would not be an advantage to design a general internetworking technology that cannot be supported over as wide a class of communications media as possible. It is reasonable to expect that IPng will start with support over a few select transport technologies, and rely on the backwards compatibility with IP to work through a transition period. Ultimately, however, one would expect IPng to be carried over any available communications medium.

3.14 Robustness and fault tolerance

Service availability, end-to-end and at expected performance levels, is the true measure of robustness and fault-tolerance. In this sense, IPng is but one piece of a complex puzzle. There are, however, some vulnerability aspects of IPng that could decrease robustness. One general class of bugs will be associated with the change itself, regardless of any possible enhancement in capabilities. The design, implementation and testing process will have to be managed very carefully. Networks and distributed systems are tricky. There are plenty of horror stories from the Internet community itself to make us cautious, not to mention the brief but dramatic outages over the last couple of years associated with relatively small software bugs in the control networks (i.e., CCS/SS7 signaling) of the telephone industry, both local and long distance.

A second general class of bugs will be associated with the implementation of new capabilities. IPng will likely support a whole set of new functions, such as larger (multiple?) address space(s), source routing and flows, just to mention a few. Providing these new capabilities will require in most cases designing new distributed algorithms and testing implementation parameters very carefully. In addition, the future Internet will be even larger, have more diverse applications and have higher bandwidth. These are all factors that could have a multiplying effect on bugs that in the current network might be easily contained. The designers and implementers of IPng should be careful. It will be very important to provide the best possible transition process from IP to IPng. The need to maintain robustness and fault-tolerance is paramount.

3.15 Technology pull

The strongest "technology pull" factors that will influence the Internet are the same that are dictating the accelerated pace of the cable, telephone and computer networking world. The following is a partial list: higher network bandwidth, more powerful CPUs, larger and faster (static and dynamic) memory, improved signal processing and compression methods, advanced distributed computing technologies, open and extensible network operating systems, large distributed database management and directory systems, high performance and high capacity real-time servers, friendly graphical user interfaces, efficient application development environments. These technology developments, coupled with the current aggressive business strategies in our industry and favorable public policies, are powerful forces that will clearly have an impact on the evolution and acceptance of IPng. The current deployment strategies of the cable industry and their partners do not rely on the existence of commercial IPng capabilities, but the availability of new effective networking technology could become a unifying force to facilitate the interworking of networks and services.

3.16 Action items

We have no suggestions at this time for changes to the directorate, working groups or others to support the concerns or gather more information needed for a decision. We remain available to provide input to the IPng process.

4. Security Considerations

No comments on general security issues are provided, beyond the considerations presented in the previous subsection 3.4 on network security.

5. Conclusions

The potential for IPng to provide a universal internetworking solution is a very attractive possibility, but there are many hurdles to be overcome. The general acceptance of IPng to support future broadband services will depend on more than the IPng itself. There is need for IPng to be backed by the whole suite of Internet technology that will support the future networks and applications. These technologies must include the adequate support for commercial operation of a global Internet that will be built, financed and administered by many different private and public organizations.

The Internet community has taken pride in following a nimble and efficient path in the development and deployment of network technology. And the Internet has been very successful up to now. The challenge is to show that the Internet model can be a preferred technical solution for the future. Broadband networks and services will become widely available in a relatively short future, and this puts the Internet community in a fast track race. The current process to define IPng can be seen as a test of the ability of the Internet to evolve from its initial development - very successful but also protected and limited in scope - to a general technology for the support of a commercially viable broadband marketplace. If the Internet model is to become the preferred general solution for broadband networking, the current IPng process seems to be a critical starting point.

6. Author's Address

Mario P. Vecchi
Time Warner Cable,
160 Inverness Drive West
Englewood, CO 80112

Phone: (303) 799-5540
Fax: (303) 799-5651
EMail: mpvecchi@twcable.com