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Network Working Group                                        M. Vecchi
Request for Comments: 1686                            Time Warner Cable
Category: Informational                                    August 1994
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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.

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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