CIDR and the Evolution of the Internet Protocol

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Abstract

The tremendous growth of the Internet has resulted in several efforts addressing the need to be able to address and route the global public Internet. Many of these efforts call for large changes in the deployed Internet infrastructure. We believe a prudent course of action includes extending the usable life of IPv4 while evaluating the use of these new technologies. This requires incremental changes in the IPv4 routing technology base, but more importantly it will require additional coordination and management among the Internet service providers. We also believe that extending the life of IPv4 includes getting higher utilization of the IPv4 address space. Several strategies, mostly administrative in nature, are proposed to conserve the use of IP address space.

I. Introduction

The Internet is facing serious challenges with distinct (but interrelated) technical problems and several management problems which need to be addressed.

The three technical problems which need to be addressed are:

1. Routing table expansion beyond router capabilities.

2. Premature exhaustion of assigned IP network numbers due to inefficient allocation of the IPv4 address space.

3. IP's inability to address more than 4 billion hosts connected to a single public internet.

Each of these technical problems has separate time horizons and each is subject to a variety of solutions.

The need for global operational coordination with a systems perspective is largely unfulfilled in the current Internet. Internet addressing and routing requires significant multilateral management to insure effective operation of the Internet infrastructure.

Current "save the Internet" proposals (PIP[Francis 93], SIP[Deering 93], TP/IX[Ullman 93], TUBA[Callon 92][Katz 93]) attempt to solve all of the above problems with the application and deployment of new, immature and certainly untested technology. Furthermore, some of these proposals fail to recognize that the problems of building a large global public internet can not be solved strictly in the technical realm. Since the problem of routing table size may become serious in the near term (1-2 years), there is a perception that it is necessary to adopt one of the proposed new technologies as soon as possible.

We propose a two-pronged system approach to improve and enhance the current Internet. This approach combines technical and managerial aspects in a coherent fashion, addressing each of the above problems as they arise in an incremental manner. This greatly minimizes the risk of service disruption in the operational Internet and will allow time for much greater maturation of the proposed technologies and a better understanding of the requirements to be met.

II. CIDR as a solution to routing table size

The routing table size problem has several facets. A primary concern which led to the development of Classless Inter-Domain Routing (CIDR)[Fuller 92][Ford 93] is the imminent exhaustion of the class B address space. In the absence of CIDR, sites with more than 254 hosts need to advertise multiple class C networks into the Internet routing system. By using hierarchical routing, CIDR allows these sites to use a single prefix to advertise reachability of multiple class C networks, and subsequently permits full utilization of the class C address space with a minimum increase in routing table size.

CIDR can also be used recursively to hierarchically summarize routing information for multiple sites[Kleinrock 77]. CIDR summarization can be done along provider based, geographically based or other hierarchical lines. Thus, routing table growth can scale in proportion to the number of elements within the chosen hierarchy (e.g. number of providers) instead of to the number of sites. To achieve such scaling with CIDR requires address assignment along hierarchical boundaries, which will require additional

management of the address space.

III. Efficient use of address space

The class-oriented structure of IP addresses has led to fairly inefficient use of the IP address space. IP address space has been freely traded off for ease in routing administration. This tradeoff occurs in several ways:

1. Many sites receive far more address space than they need. Many sites with much less than 64 thousand hosts use a single class B address in place of multiple Cs.

2. Because of limited subnetting capabilities, many sites end up needing multiple network numbers (e.g. Many universities have several class B networks where they use 8 bit subnet masks with very low occupancy on most subnets.)

3. Many sites request additional network numbers simply to reduce the need to administratively coordinate within a campus.

4. Many sites using IP are not accessible on the public Internet yet they use a significant portion of the current address space. (e.g. out of 44,000 assigned network numbers only 25 percent are reachable through the Internet).

Since it is now clear that IP has become a key component of the global Internet, and the IP address space is an increasingly scarce resource, it is necessary to judiciously allocate and assign the IP address space. The various addressing registries of the Internet must now incorporate guidance regarding Internet routing issues into their IP address assignment policies. As part of CIDR deployment, such efforts have already started at the U.S. NIC [1] and the RIPE NCC [2], and CIDR addressing guidelines have been published[Gerich 92].

IV. Renumbering

The simplest hierarchy to use in a CIDR system is provider based addressing which allows hierarchical summarization of subscriber prefixes into a small number of routing entries. Provider based addressing is simple to administer since Internet subscribers will often get their addresses from a network service provider when they initially attach to the Internet.

When users switch providers, they will need to eventually change their addresses so that the routing system does not revert to "flat routing". Renumbering is often perceived as "impossible" to ask sites and Internet users to do. However, going beyond the perception we observe that most Internet users and systems use Internet Domain Names [Mockapetris 87] instead of addresses, limiting the exposure of host renumbering to system and network administrators. Internet users would certainly prefer name based systems which either autoconfigure from a network service or at least are more easily configured than today's systems. There should be a coordinated effort to make administration of Internet systems easier and at the same time to address some of the scaling issues of the Internet within the context of IPv4. These activities could take place in the Internet Engineering Task Force (IETF) within the Dynamic Host Configuration Protocol(DHCP) and Domain Name Service (DNS) working groups.

Renumbering of the current set of allocated class A, B and C network addresses will occur as necessary to increase the actual aggregation of network announcements. This will maximize the utility of the CIDR routing and addressing system. Renumbering will also recover significant amounts of unused IP address space, thus alleviating the problem of exhaustion of assigned IP network numbers. The combination of CIDR and renumbering makes it possible to use IPv4 until the total number of hosts approaches the practical limits of the 32 bit address field.

V. Network Numbers for Private Internets

Hosts within sites that use IP can be partitioned into 3 three distinct categories:

1. Hosts that do not require Internet access

2. Hosts that need access to a limited set of Internet services (e.g. E-mail) which can handled by application layer relays.

3. Hosts that need unlimited access to the Internet.

Only hosts in the last category require IP addresses that are globally unique. Hosts within the first and second categories may use IP addresses that are unique within a site, but may be globally non-unique. It is common for organizations to build private internets which have little or no hosts falling into the third category. Therefore, to conserve IP network address space utilization for the public Internet, we propose the allocation of specific IP network address blocks to be used by sites to identify hosts of type 1 or

[1] Network Information Center
[2] Network Coordination Center

2 within their private networks. These IP addresses will not be routed in the public Internet. Thus a site could assign two subnet addresses to each physical network. Systems either get a global address or a local-only address, depending upon what sort of access it needs. With the proposed scheme many large corporate sites (BBN, DEC, GE, IBM) can use a few class C network numbers from the global IP address space.

VI. Management as a Key Component

Routing of the Internet used to be quite simple when the Internet was a single community of interest network administered by a single entity. As the Internet has grown to serve many other communities in a production mode of operation, the problems of administering the Internet routing and addressing has become more difficult.

As noted above, many of the problems in deploying CIDR and securing maximal use of IPv4 technology are related to administrative issues, such as hierarchical assignment of addresses, renumbering sites as necessary, and management of routing databases[Adams 93][Bates 93] which contain route aggregation information. Multilateral coordination is just getting started in the Internet and the establishment of inter-provider operational procedures is underway. The problems of multilateral coordination will be present for any of the proposed IP "next generation" proposals and we need to carefully observe and learn from CIDR deployment and operation to help facilitate future deployments of new technology.

Problems in large scale internetworking require a two-pronged systems oriented approach including both technical and management elements. Experience with the current Internet, specifically the interdomain routing system engineering and management, shows that such an approach is necessary to deliver a workable solution. System-level interaction between technical and management components is required for a successful deployment of Internet technology. Currently, technical groups often know too little about actual operational issues, while the operational groups in turn often know too little about the feasibility of certain technologies. This state of affairs can be improved with better communication and interaction between these groups in a joint effort to reduce the risk of major operational problems in the Internet.

We observe that a key element to the success of any new strategy for the evolution of the Internet must address the issue of distributed management of the Internet system beyond simple addition of new technology to be deployed in the Internet. The Internet is beginning to move from centralized (e.g. NSFNET/MERIT) towards distributed management (e.g. an open Network Operations Forum (NOF)), with an according redistribution of responsibility among multiple participants. A small number of entities controlling the future of the Internet is anachronistic and reminiscent of the concept of a single global telephone company.

VII. CIDR Rollout Activities

The Internet community has already made significant plans for CIDR deployment laying the foundation for a successful roll out of BGP-4 when it becomes available during the summer of 1993.

- BGP-4 specification (IETF BGP working group)
- Commitment to implement BGP-4: ANS, Cisco, Proteon, Wellfleet, 3Com, BBN. (All of these companies participate in BGP-4 deployment coordination meetings.)
- Coordination and planning for BGP-4 deployment
  - U.S. Regionals workshop on CIDR
  - Special meeting by "backbone" providers (InterOP, DC 93)
  - IETF BGP deployment WG meetings
- Routing Database work: RIPE NCC and Merit.
- Routing Database Deployment: RIPE NCC, Merit, and CIX.
- Address assignment plans: U.S. Regionals and the U.S. NIC, RIPE NCC and EBONE, CIX, Japan, etc.
- Initial hierarchical allocation of IP addresses as blocks of class Cs is being done by the RIPE NCC, and the U.S. NIC in conjunction with the IP network providers in the U.S.

VIII. Conclusion

The Internet can evolve incrementally to address two of the major problems, routing table expansion and premature exhaustion of assigned IP network numbers. Small technological changes in the routing technology are being implemented by router vendors making BGP-4[Rekhter 92] available during Summer 1993 for deployment in the

Internet inter-domain routing system. [3] To effectively use BGP-4 will require additional administrative effort within the Internet. Most of this effort will be by Internet service providers, but the ability to reduce sites' efforts in changing addresses may require additional effort within the IETF.

CIDR and renumbering sites according to a CIDR management plan needs to be articulated to the Internet community as the most cost effective and risk adverse in contrast to installing new host and router technology throughout the Internet. The latter will be necessary only as the total number of hosts in the Internet approaches the limits of the 32 bit address field.

¿From the outset "saving the Internet" requires much more than a technical mechanism – it requires effective management. Deploying new or enhanced protocols to address the shortcomings of existing protocols is an important subset of the overall problem. However, such deployment can not occur in isolation and without proper development and deployment planning and management.

What began as an Arpanet research testbed has grown into a vast international fabric which must rely on stable, soundly-managed, underlying technology. Therefore, we need to focus on the stability of the operational environment of the existing and evolving Internet fabric. The current hype over the next generation of IP as an immediate requirement for a graceful infrastructural evolution is at best unnecessary, at worst dangerous, since it creates a poor public perception of the Internet and may lead to degraded Internet service. The next generation of IP is not really needed as urgently as some would like us to think. There is no reason to prematurely abandon the use of IPv4 until we can gain sufficient development and operational experience and develop consensus on a new network layer protocol, so as to address the problem of identifying more than 4 billion hosts in the public Internet.

The IAB/IESG/ISOC would err in making rash decisions regarding crucial changes in the Internet technology base without the development of adequate consensus from all affected communities (User, Operator, Developer). We must accept and cultivate the reality of the Internet as a cooperative enterprise and encourage coordination among entities participating in the growth and evolution of the Internet.

[3] In the appendix we detail a foundation which is being laid to these ends for the deployment of CIDR.

IX. Acknowledgements

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