CLASSLESS INTER DOMAIN ROUTING - CIDR

Marko Luoma
Helsinki University of Technology
Laboratory of Telecommunications Technology
Marko.Luoma@hut.fi

ABSTRACT

As the Internet evolved and become more familiar to people it become clear that internet would face several serious scaling problems. These included: exhaustion of class B addresses, routing information overflow and IP address space exhaustion. CIDR is a method to stem the tide of IP address allocation as well as routing table overflow. Basically, CIDR eliminates the concept of class A, B, and C networks and replaces this with a generalized "IP prefix".

TABLE OF CONTENTS

1. INTRODUCTION

As the Internet evolved and become more familiar to people it become clear that internet would face several serious scaling problems. These included:

- Exhaustion of the class-B network address space. One fundamental cause of this problem was/is the lack of a network class of a size that is appropriate for a mid-sized organization. Class-C, with a maximum of 254 host addresses, is too small, while class-B, which allows up to 65534 addresses, is too large to be densely populated. The result is inefficient utilization of class-B network numbers.
- Routing information overload. The size and rate of growth of the routing tables in Internet routers was beyond the ability of software (and people) to effectively manage. Size of routing tables was directly proportional to number of networks.
- Eventual exhaustion of IP network numbers.

It become clear that the first two of these problems were likely to become critical in the near term. Classless Inter-Domain Routing (CIDR) attempts to deal with these problems by defining a mechanism to slow the growth of routing tables and reduce the need to allocate new IP network numbers. It does not attempt to solve the third problem, which is of a more long-term nature, but instead endeavors to ease enough of the short to mid-term difficulties to allow the Internet to continue to function efficiently while progress is made on a longerterm solution (Ipv6).

1.1 Exhaustion of class B adresses

The problem of class B exhaustion has occurred simply because the class B address space is too large for many middle-sized organizations and the class C address space is rarely enough to fulfil networking requirements.

By the time problems started only the half of the total number of 16384 class B addresses are available. There is a total of about 2 million class C addresses and a small number of them were already allocated by service providers. A class B network would consist of a maximum of 65536 hosts and a class C network consist with a maximum of only 256 hosts. The classification of internet networks is not practicable since very few organizations have tens of thousands of hosts, but almost all organizations have lots more hosts than 256. It has been estimated that a network size consisting of about 4000 hosts is more suitable for organizations.

1.2 Routing information overload

The routing tables in the Internet have been growing as fast as the Internet and the router technology specifically and computer technology in general has not been able to keep pace. In December 1990 there were 2190 routes and 2 years later there were over 8500 routes. In July 1995 there are were over 29,000 routes, which require approximately 10 MB in a router with a single peer. Routers at interconnection points (or multi-homed hosts doing full routing with many peers) receive these routes from several peers, and need several dozen megabytes of RAM (and the appropriate CPU horsepower) to handle this. Routers with 64MB of memory have the capacity for approximately 60,000 routes after which some routes will just have to be left out of the global routing tables, and the more likely ones to be left out are routes covering small pieces of address space. [7]

2. CLASSLESS INTER DOMAIN ROUTING

IETF solution to fortcoming problems was CIDR. CIDR is an effective method to stem the tide of IP address allocation as well as routing table overflow. Basically, CIDR eliminates the concept of class A, B, and C networks and replaces this with a generalized “IP prefix”.

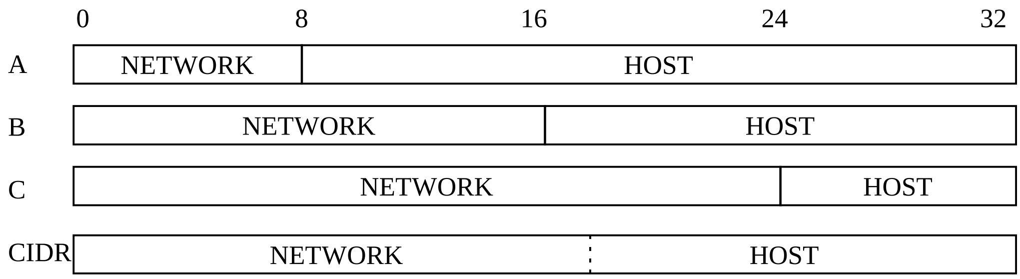

Fig 1: Classfull and Classless Network Numbering

CIDR can be used to perform route aggregation in which a single route can cover the address space of several “old-style” network numbers and thus replace a lot of old routes. This lessens the local administrative burden of updating external routing, saves routing table space in all backbone routers and reduces route flapping (rapid changes in routes), and thus CPU load, in all backbone routers. CIDR will also allow delegation of pieces of what used to be called “network numbers” to customers, and therefore make it possible to utilize the available address space more efficiently.

In practise, CIDR based address allocation means that instead of one class B network number a sequence of class C network numbers are assigned to an organization. A common network number and a mask pair represent a routing destination information stored in a routing table.

The purpose of the CIDR addressing scheme is to be a short-term solution before a long-term solution will be introduced. The CIDR proposes that IP addresses could be allocated topologically and some of them could be allocated to transit routing domains. [4]

Table 1: Address allocation according to RFC 1466

Multi-regional	192.0.0.0 - 193.255.255.255
Europe	194.0.0.0 - 195.255.255.255
Others	196.0.0.0 - 197.255.255.255
North America	198.0.0.0 - 199.255.255.255
Central/South America	200.0.0.0 - 201.255.255.255
Pacific Rim	202.0.0.0 - 203.255.255.255
Others	204.0.0.0 - 205.255.255.255
Others	206.0.0.0 - 207.255.255.255

Each block represents 131,072 addresses or approximately 6% of the total Class C address space.

3. AGGREGATION

The routing table aggregation is based on classless addresses. It means that a block of **continuous network numbers** have been assigned to a service provider. An organization gets a continuous sequence of network numbers from a service provider. A block of network numbers is represented as a single network number and a mask pair (IP prefix):

[xxx.xxx.xxx.xxx   zzz.zzz.zzz.zzz]

Bitwise logical AND operation on the IP-address and IP-mask component of a tuple yields the sequence of leftmost contiguous significant bits that form the IP address prefix. For example a tuple with the value [193.1.0.0 255.255.0.0] denotes an IP address prefix with 16 leftmost contiguous significant bits.

In aggregation a service provider advertises all the available addresses connected to it hierarchically at a lower level. The most straightforward case of this occurs when there is a set of routing domains that are all attached to a single service provider domain (e.g. regional network), and which use that provider for all inter-domain traffic. Each routing domain owns a prefix covering all connected subnetworks to them. The service provider advertises, based on the routing domains' prefixes, one or several continuous prefixes to the upper hierarchical level to which it has connected. This allows a hierarchical and recursive abbreviation of routing information and data reduction while advertising routing information.

This infers a super-networking idea and a decision of super-networking could be done based on topological or organizational information. The aggregation policy increases the hierarchy of network addressing since all sub-network level addresses must be known at a certain upper level. Each upper level node knows the address space on the lower levels.

3.1 Problem with multi-home organisations

Aggregations are not simple to implement, for example in the case of multi-homed routing domains. A multi-homed routing domain may consist of single-site campuses and companies that are attached to multiple backbones, large organizations that are attached to different providers at different locations in the same country, or multi-national organizations that are attached to backbones in a variety of countries worldwide.

In generally multi-homed routing domains are organisations that might have many service providers to connect them to the outside world.

In the case of a multi-homed organization, each service provider should advertise the same address space connected to them and the routing cost will not decrease.

In the case of changing the service provider, an organization should renumber the previously allocated address space to the new one given by the new service provider. Otherwise, traffic assigned to a client who has changed a service provider might go to an old service provider. If a client wants to keep the same addresses, the aggregation of the old service provider must be changed.

4. ROUTE ADVERTISEMENT

4.1 Rules for Route Advertisement

Following rules are stated to be enough in order to achieve all benefits from CIDR. [4]

1. Routing to all destinations must be done on a longest-match basis only. This implies that destinations which are multi-homed relative to a routing domain must always be explicitly announced into that routing domain - they cannot be summarized (this makes intuitive sense - if a network is multi-homed, all of its paths into a routing domain which is “higher” in the hierarchy of networks must be known to the “higher” network).
2. A routing domain which performs summarization of multiple routes must discard packets which match the summarization but do not match any of the explicit routes which makes up the summarization. This is necessary to prevent routing loops in the presence of less-specific information (such as a default route).

4.2 Example [4]

4.2.1 Network numbering

Block of 2048 class C network numbers beginning with 192.24.0.0 and ending with 192.31.255.0 allocated to a single network provider, “A”. A “supernetted eq. CIDR” route to this block of network numbers would be described as 192.24.0.0 with mask of 255.248.0.0.

This service provider connects six clients in the following order:

- “C1” requiring fewer than 2048 addresses (8 class C networks)
- “C2” requiring fewer than 4096 addresses (16 class C networks)
- “C3” requiring fewer than 1024 addresses (4 class C networks)
- “C4” requiring fewer than 1024 addresses (4 class C networks)
- “C5” requiring fewer than 512 addresses (2 class C networks)
- “C6” requiring fewer than 512 addresses (2 class C networks)

In all cases, the number of IP addresses “required” by each client is assumed to allow for *significant* growth. The service provider allocates its address space as follows:

- C1: allocate 192.24.0 through 192.24.7. This block of networks is described by the route 192.24.0.0 and mask 255.255.248.0
- C2: allocate 192.24.16 through 192.24.31. This block is described by the route 192.24.16.0, mask 255.255.240.0
- C3: allocate 192.24.8 through 192.24.11. This block is described by the route 192.24.8.0, mask 255.255.252.0
- C4: allocate 192.24.12 through 192.24.15. This block is described by the route 192.24.12.0, mask 255.255.252.0

- C5: allocate 192.24.32 and 192.24.33. This block is described by the route 192.24.32.0, mask 255.255.254.0
- C6: allocate 192.24.34 and 192.24.35. This block is described by the route 192.24.34.0, mask 255.255.254.0

Note that if the network provider uses an IGP which can support classless networks, he can (but doesn't have to) perform "supernetting" at the point where he connects to his clients and therefore only maintain six distinct routes for the 36 class C network numbers. If not, explicit routes to all 36 class C networks will have to be carried by the IGP. To make this example more realistic, assume that C4 and C5 are multi-homed through some other service provider, "B". Further assume the existence of a client "C7" which was originally connected to "B" but has moved to "A". For this reason, it has a block of network numbers which are allocated out "B"'s block of (the next) 2048 class C network numbers:

- C7: allocate 192.32.0 through 192.32.15. This block is described by the route 192.32.0, mask 255.255.240.0

For the multi-homed clients, we will assume that C4 is advertised as primary via "A" and secondary via "B"; C5 is primary via "B" and secondary via "A". To connect this mess together, we will assume that "A" and "B" are connected via some common "backbone" provider "BB".

4.2.2 Routing advertisements

To follow rule 1, "A" will need to advertise the block of addresses that it was given and C7. Since C4 is multi-homed and primary through "A", it must also be advertised. C5 is multi-homed and primary through "B". It need not be advertised since longest match will automatically select "B" as primary and the advertisement of "A's" aggregate will be used as a secondary.

Advertisements from "A" to "BB" will be:

- 192.24.12.0/255.255.252.0 primary (advertises C4)
- 192.32.0.0/255.255.240.0 primary (advertises C7)
- 192.24.0.0/255.248.0.0 primary (advertises remainder of A)

For "B", the advertisements must also include C4 and C5 as well as it's block of addresses. Further, "B" may advertise that C7 is unreachable.

Advertisements from "B" to "BB" will be:

- 192.24.12.0/255.255.252.0 secondary (advertises C4)
- 192.24.32.0/255.255.254.0 primary (advertises C5)
- 192.32.0.0/255.248.0.0 primary (advertises remainder of B)

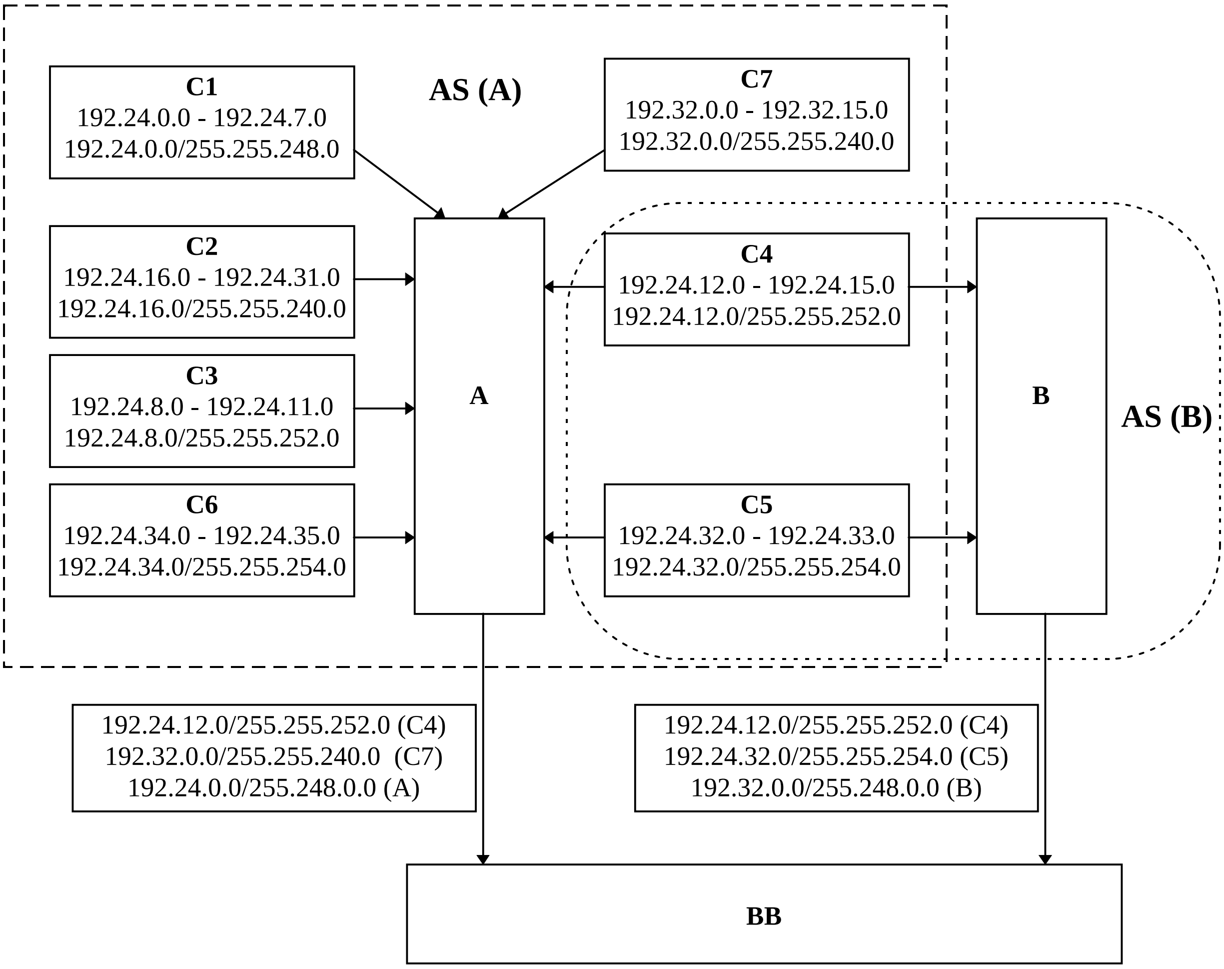

Fig 2: Route advertisement

If "A" loses connectivity to C7 (the client which is allocated out of "B's" space). In a stateful protocol, "A" will announce to "BB" that 192.32.0.0/255.255.240.0 has become unreachable. Now, when "BB" flushes this information out of its routing table, any future traffic sent through it for this destination will be forwarded to "B" (where it will be dropped according to rule 2) by virtue of "B's" less specific match 192.32.0.0/255.248.0.0. While this does not cause an operational problem (C7 is unreachable in any case), it does create some extra traffic across "BB"

5. INFORMATION EXCHANGE IN CIDR

5.1 Intra-domain

There are two ways to deal with interior (intra-domain) routing:

1. To use inter-domain protocols in intra-domain environment
2. To use routing protocols that support CIDR eq. OSPF, RIP II, Integrated IS-IS, and E-IGRP.

5.2 Inter-domain

The exterior (inter-domain) routing protocol that supports CIDR is BGP-4. Protocols like RIP, BGP-3, EGP, and IGRP do not support CIDR [6].

The primary function of a BGP speaking system is to exchange network reachability information with other BGP systems. This network reachability information includes information on the list of Autonomous Systems (ASs) that reachability information traverses. This information is sufficient to construct a graph of AS connectivity from which routing loops may be pruned and some policy decisions at the AS level may be enforced.

BGP-4 provides a new set of mechanisms for supporting classless inter-domain routing. These mechanisms include support for advertising an IP prefix and eliminates the concept of network "class" within BGP. BGP-4 also introduces mechanisms which allows aggregation of routes, including aggregation of AS paths. [10]

BGP-4 enhances the AS-PATH attribute to include sets of autonomous systems as well as lists. This extended format allows generated aggregate routes to carry path information from the more specific routes used to generate the aggregate. [11]

5.3 Internetworking with non-CIDR networks

At each phase during the transition to CIDR one of the essential aspects of the Internet operations will be the exchange of inter-domain routing information between CIDR-capable providers and CIDR-incapable provider.

When exchanging inter-domain routing information between a CIDR-capable provider and a CIDR-incapable provider, it is of outmost importance to take into account the view each side wants the other to present. This view has two distinct aspects:

- The type of routing information exchanged (i.e., Default route, traditional (non-CIDR) reachability information, CIDR reachability information)
- Routing information processing each side needs to do to maintain these views (e.g., ability to perform aggregation, ability to perform controlled de-aggregation)

The exchange of inter-domain routing information is expected to be controlled by bilateral agreements between the directly connected service providers. Consequently, the views each side wants of the other are expected to form an essential component of such agreements. To facilitate troubleshooting and problem isolation, the bilateral agreements should be made accessible to other providers. [9]

REFERENCES

/1/ Braun, Ford, Rekhter, CIDR and the Evolution of the Internet Protocol, Proc. INET '93. 5p.

/2/ RFC 1466, E. Gerich, "Guidelines for Management of IP Address Space", 26.5.1993. 10p.

/3/ RFC 1518, Y. Rekhter, T. Li, "An Architecture for IP Address Allocation with CIDR", 24.9.1993. 27p.

/4/ RFC 1519, V. Fuller, T. Li, J. Yu, K. Varadhan, “Classless Inter-Domain Routing (CIDR): an Address Assignment and Aggregation Strategy”, 24.9.1993. 24p.

/5/ RFC 1517, R. Hinden, “Applicability Statement for the Implementation of Classless Inter-Domain Routing (CIDR)”, 24.9.1993. 4p.

/6/ RFC 1817, Y. Rekhter, “CIDR and Classful Routing”, 4.8.1995. 2p.

/7/ CIDR FAQ v6, URL: http://www.ibm.net.il/~hank/cidr.html

/8/ *Christian Huitema*, Routing in the Internet, Prentice Hall, 1995.

/9/ RFC 1520, Y. Rekhter, C. Topolcic, “Exchanging Routing Information Across Provider Boundaries in the CIDR Environment”, 24.9.1993. 9p.

/10/ RFC 1771, Y. Rekhter, T. Li, “A Border Gateway Protocol 4 (BGP-4)”, 21.3.1995

/11/ RFC 1774, P. Traina, “BGP-4 Protocol Analysis”, 21.3.1995 10p.