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Supernetting: an Address Assignment and Aggregation Strategy

Status of this Memo

This memo provides information for the Internet community. It does not specify an Internet standard. Distribution of this memo is unlimited.

Abstract

This memo discusses strategies for address assignment of the existing IP address space with a view to conserve the address space and stem the explosive growth of routing tables in default-route-free routers run by transit routing domain providers.

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Acknowledgements

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   ROAD group with whom many of the ideas contained in this document
   were inspired and developed.

1.   Problem, Goal, and Motivation

   As the Internet has evolved and grown over in recent years, it has
   become painfully evident that it is soon to face several serious
   scaling problems. These include:

        1.   Exhaustion of the class-B network address space. One
             fundamental cause of this problem is the lack of a network
             class of a size which is appropriate for 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 to large to be widely allocated.

        2.   Growth of routing tables in Internet routers beyond the
             ability of current software (and people) to effectively
             manage.

        3.   Eventual exhaustion of the 32-bit IP address space.

   It has become clear that the first two of these problems are likely
   to become critical within the next one to three years. This memo
   attempts to deal with these problems by proposing a mechanism to slow
   the growth of the routing table and the need for allocating 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 longer-
   term solution.

   The proposed solution is to hierarchically allocate future IP address
   assignment, by delegating control of segments of the IP address space
   to the various network service providers.

   It is proposed that this scheme of allocating IP addresses be
   undertaken as soon as possible. It is also believed that the scheme
   will suffice as a short term strategy, to fill the gap between now

and the time when a viable long term plan can be put into place and
deployed effectively. It is believed that this scheme would be
viable for at least three (3) years, in which time frame, a suitable
long term solution would be expected to be deployed.

Note that this plan neither requires nor assumes that already
assigned addresses will be reassigned, though if doing so were
possible, it would further reduce routing table sizes. It is assumed
that routing technology will be capable of dealing with the current
routing table size and with some reasonably-small rate of growth.
The emphasis of this plan is on significantly slowing the rate of
this growth.

This scheme will not affect the deployment of any specific long term
plan, and therefore, this document will not discuss any long term
plans for routing and address architectures.

2.   Scheme Plan

There are two basic components of this addressing and routing scheme:
one, to distribute the allocation of Internet address space and two,
to provide a mechanism for the aggregation of routing information.

2.1. Aggregation and its limitations

One major goal of this addressing plan is to allocate Internet
address space in such a manner as to allow aggregation of routing
information along topological lines. For simple, single-homed
clients, the allocation of their address space out of a service
provider's space will accomplish this automatically - rather than
advertise a separate route for each such client, the service provider
may advertise a single, aggregate, route which describes all of the
destinations contained within it. Unfortunately, not all sites are
singly-connected to the network, so some loss of ability to aggregate
is realized for the non simple cases.

There are two situations that cause a loss of aggregation efficiency.

   o   Organizations which are multi-homed. Because multi-homed
         organizations must be advertised into the system by each of
         their service providers, it is often not feasible to aggregate
         their routing information into the address space any one of
         those providers. Note that they still may receive their
         address allocation out of a service provider's address space
         (which has other advantages), but their routing information
         must still be explicitly advertised by most of their service
         providers (the exception being that if the site's allocation
         comes out of its least-preferable service provider, then that

service provider need not advertise the explicit route -
longest-match will insure that its aggregated route is used to
get to the site on a non-primary basis). For this reason, the
routing cost for these organizations will typically be about
the same as it is today.

o   Organizations which move from one service provider to another.
        This has the effect of "punching a hole" in the aggregation of
        the original service provider's advertisement. This plan will
        handle the situation by requiring the newer service provider
        to advertise a specific advertisement for the new client,
        which is preferred by virtue of being the longest match. To
        maintain efficiency of aggregation, it is recommended that
        organizations which do change service providers plan to
        eventually migrate their address assignments from the old
        provider's space to that of the new provider. To this end, it
        is recommended that mechanisms to facilitate such migration,
        including improved protocols and procedures for dynamic host
        address assignment, be developed.

Note that some aggregation efficiency gain can still be had for
multi-homed sites (and, in general, for any site composed of
multiple, logical IP network numbers) - by allocating a contiguous
block of network numbers to the client (as opposed to multiple,
independently represented network numbers) the client's routing
information may be aggregated into a single (net, mask) pair. Also,
since the routing cost associated with assigning a multi-homed site
out of a service provider's address space is no greater than the
current method of a random allocation by a central authority, it
makes sense to allocate all address space out of blocks assigned to
service providers.

It is also worthwhile to mention that since aggregation may occur
at multiple levels in the system, it may still be possible to
aggregate these anomalous routes at higher levels of whatever
hierarchy may be present. For example, if a site is multi-homed to
two NSFNet regional networks both of whom obtain their address
space from the NSFNet, then aggregation by the NSFNet of routes
from the regionals will include all routes to the multi-homed site.

Finally, it should also be noted that deployment of the new
addressing plan described in this document may (and should) begin
almost immediately but effective use of the plan to aggregate
routing information will require changes to some Inter-Domain
routing protocols. Likewise, deploying the supernet-capable Inter-
Domain protocols without deployment of the new address plan will
not allow useful aggregation to occur (in other words, the

addressing plan and routing protocol changes are both required for
supernetting, and its resulting reduction in table growth, to be
effective.) Note, however, that during the period of time between
deployment of the addressing plan and deployment of the new
protocols, the size of routing tables may temporarily grow very
rapidly. This must be considered when planning the deployment of
the two plans.

Note: in the discussion and examples which follow, the network+mask
notation is used to represent routing destinations. This is used
for illustration only and does not require that routing protocols
use this representation in their updates.

2.2. Distributed allocation of address space

The basic idea of the plan is to allocate one or more blocks of
Class-C network numbers to each network service provider.
Organizations using the network service provider for Internet
connectivity are allocated bitmask-oriented subsets of the
provider's address space as required.

Note that in contrast to a previously described scheme of
subnetting a class-A network number, this plan should not require
difficult host changes to work around domain system limitations -
since each sub-allocated piece of the address space looks like a
class-C network number, delegation of authority for the IN-
ADDR.ARPA domain works much the same as it does today - there will
just be a lot of class-C network numbers whose IN-ADDR.ARPA
delegations all point to the same servers (the same will be true of
the root delegating a large block of class-Cs to the network
provider, unless the delegation just happens to fall on a byte
boundary). It is also the case that this method of aggregating
class-C's is somewhat easier to deploy, since it does not require
the ability to split a class-A across a routing domain boundary
(i.e., non-contiguous subnets).

It is also worthy to mention that once Inter-Domain protocols which
support classless network destinations are widely deployed, the
rules described by the "supernetting" plan generalize to permit
arbitrary super/subnetting of the remaining class-A and class-B
address space (the assumption being that classless Inter-Domain
protocols will either allow for non-contiguous subnets to exist in
the system or that all components of a sub-allocated class-A/B will
be contained within a single routing domain). This will allow this
plan to continue to be used in the event that the class-C space is
exhausted before implementation of a long-term solution is deployed
(there may, however, be further implementation considerations
before doing this).

Hierarchical sub-allocation of addresses in this manner implies
that clients with addresses allocated out of a given service
provider are, for routing purposes, part of that service provider
and will be routed via its infrastructure. This implies that
routing information about multi-homed organizations, i.e.,
organizations connected to more than one network service provider,
will still need to be known by higher levels in the hierarchy.

The advantages of hierarchical assignment in this fashion are

a)   It is expected to be easier for a relatively small number of
     service providers to obtain addresses from the central
     authority, rather than a much larger, and monotonically
     increasing, number of individual clients. This is not to be
     considered as a loss of part of the service providers' address
     space.

b)   Given the current growth of the Internet, a scalable and
     delegatable method of future allocation of network numbers has
     to be achieved.

For these reasons, and in the interest of providing a consistent
procedure for obtaining Internet addresses, it is recommended that
most, if not all, network numbers be distributed through service
providers.

3. Cost-benefit analysis

This new method of assigning address through service providers can be
put into effect immediately and will, from the start, have the
benefit of distributing the currently centralized process of
assigning new addresses. Unfortunately, before the benefit of
reducing the size of globally-known routing destinations can be
achieved, it will be necessary to deploy an Inter-Domain routing
protocol capable of handling arbitrary network+mask pairs. Only then
will it be possible to aggregate individual class-C networks into
larger blocks represented by single routing table entries.

This means that upon introduction, the new addressing plan will not
in and of itself help solve the routing table size problem. Once the
new Inter-Domain routing protocol is deployed, however, an immediate
drop in the number of destinations which clients of the new protocol
must carry will occur. A detailed analysis of the magnitude of this
expected drop and the permanent reduction in rate of growth is given
in the next section.

In should also be noted that the present method of flat address
allocations imposes a large bureaucratic cost on the central address

allocation authority. For scaling reasons unrelated to address space
exhaustion or routing table overflow, this should be changed. Using
the mechanism proposed in this paper will have the happy side effect
of distributing the address allocation procedure, greatly reducing
the load on the central authority.

3.1. Present Allocation Figures

   A back-of-the-envelope analysis of "network-contacts.txt"
   (available from the DDN NIC) indicates that as of 2/25/92, 46 of
   126 class-A network numbers have been allocated (leaving 81) and
   5467 of 16256 class-B numbers have been allocated, leaving 10789.
   Assuming that recent trends continue, the number of allocated
   class-B's will continue to double approximately once a year. At
   this rate of grown, all class-B's will be exhausted within about
   15 months.

3.2. Historic growth rates

MM/YY	ROUTES ADVERTISED		MM/YY	ROUTES ADVERTISED
Feb-92	4775		Apr-90	1525
Jan-92	4526		Mar-90	1038
Dec-91	4305		Feb-90	997
Nov-91	3751		Jan-90	927
Oct-91	3556		Dec-89	897
Sep-91	3389		Nov-89	837
Aug-91	3258		Oct-89	809
Jul-91	3086		Sep-89	745
Jun-91	2982		Aug-89	650
May-91	2763		Jul-89	603
Apr-91	2622		Jun-89	564
Mar-91	2501		May-89	516
Feb-91	2417		Apr-89	467
Jan-91	2338		Mar-89	410
Dec-90	2190		Feb-89	384
Nov-90	2125		Jan-89	346
Oct-90	2063		Dec-88	334
Sep-90	1988		Nov-88	313
Aug-90	1894		Oct-88	291
Jul-90	1727		Sep-88	244
Jun-90	1639		Aug-88	217
May-90	1580		Jul-88	173

Table I : Growth in routing table size, total numbers
Source for the routing table size data is MERIT

3.3. Detailed Analysis

There is no technical cost and minimal administrative cost
associated with deployment of the new address assignment plan. The
administrative cost is basically that of convincing the NIC, the
IANA, and the network service providers to agree to this plan,
which is not expected to be too difficult. In addition,
administrative cost for the central numbering authorities (the NIC
and the IANA) will be greatly decreased by the deployment of this
plan. To take advantage of aggregation of routing information,
however, it is necessary that the capability to represent routes
as arbitrary network+mask fields (as opposed to the current
class-A/B/C distinction) be added to the common Internet inter-
domain routing protocol(s).

3.3.1. Benefits of the new addressing plan

There are two benefits to be had by deploying this plan:

o   The current problem with depletion of the available class-B
     address space can be ameliorated by assigning more-
     appropriately sized blocks of class-C's to mid-sized
     organizations (in the 200-4000 host range).

o   When the improved inter-domain routing protocol is deployed,
     an immediate decrease in the number routing table entries
     followed by a significant reduction in the rate growth of
     routing table size should occur (for default-free routers).

3.3.2. Growth rate projections

Currently, a default-free routing table (for example, the routing
tables maintained by the routers in the NSFNET backbone) contains
approximately 4700 entries. This number reflects the current size
of the NSFNET routing database. Historic data shows that this
number, on average, has doubled every 10 months between 1988 and
1991. Assuming that this growth rate is going to persist in the
foreseeable future (and there is no reason to assume otherwise),
we expect the number of entries in a default-free routing table to
grow to approximately 30000 in two(2) years time. In the
following analysis, we assume that the growth of the Internet has
been, and will continue to be, exponential.

It should be stressed that these projections do not consider that
the current shortage of class-B network numbers may increase the
number of instances where many class-C's are used rather than a
class-B. Using an assumption that new organizations which formerly
obtained class-B's will now obtain somewhere between 4 and 16
class-C's, the rate of routing table growth can conservatively be
expected to at least double and probably quadruple. This means the
number of entries in a default-free routing table may well exceed
10,000 entries within six months and 20,000 entries in less than a
year.

Under the proposed plan, growth of the routing table in a
default-free router is greatly reduced since most new address
assignment will come from one of the large blocks allocated to the
service providers. For the sake of this analysis, we assume
prompt implementation of this proposal and deployment of the
revised routing protocols. We make the initial assumption that any
initial block given to a provider is sufficient to satisfy its
needs for two years.

Since under this plan, multi-homed networks must continue to be
explicitly advertised throughout the system (according to Rule#1
described in section 4.2), the number multi-homed routes is
expected to be the dominant factor in future growth of routing
table size, once the supernetting plan is applied.

Presently, it is estimated that there are fewer than 100 multi-
homed organizations connected to the Internet. Each such
organization's network is comprised of one or more network
numbers. In many cases (and in all future cases under this plan),
the network numbers used by an organization are consecutive,
meaning that aggregation of those networks during route
advertisement may be possible. This means that the number of
routes advertised within the Internet for multi-homed networks may
be approximated as the total number of multi-homed organizations.
Assuming that the number of multi-homed organization will double
every year (which may be a over-estimation, given that every
connection costs money), the number of routes for multi-homed
networks would be expected to grow to approximately 800 in three
years.

If we further assume that there are approximately 100 service
providers, then each service provider will also need to advertise
its block of addresses. However, due to aggregation, these
advertisements will be reduced to only 100 additional routes. We
assume that after the initial two years, new service providers
combined with additional requests from existing providers will
require an additional 50 routes per year. Thus, the total is 4700
+ 800 + 150 = 5650. This represents an annual grown rate of
approximately 6%. This is in clear contrast to the current annual
growth of 150%. This analysis also assumes an immediate
deployment of this plan with full compliance. Note that this
analysis assumes only a single level of route aggregation in the
current Internet - intelligent address allocation should
significantly improve this.

Clearly, this is not a very conservative assumption in the
Internet environment nor can 100% adoption of this proposal be
expected. Still, with only a 90% participation in this proposal by
service providers, at the end of the target three years, global
routing table size will be "only" 4700 + 800 + 145 + 7500 = 13145
routes -- without any action, the routing table will grow to
approximately 75000 routes during that time period.

4.   Changes to Inter-Domain routing protocols

   In order to support supernetting efficiently, it is clear that some
   changes will need to be made to both routing protocols themselves and
   to the way in which routing information is interpreted. In the case
   of "new" inter-domain protocols, the actual protocol syntax changes
   should be relatively minor. This mechanism will not work with older
   inter-domain protocols such as EGP2; the only ways to interoperate
   with old systems using such protocols are either to use existing
   mechanisms for providing "default" routes or b) require that new
   routers talking to old routers "explode" supernet information into
   individual network numbers. Since the first of these is trivial
   while the latter is cumbersome (at best -- consider the memory
   requirements it imposes on the receiver of the exploded information),
   it is recommended that the first approach be used -- that older
   systems to continue to the mechanisms they currently employ for
   default handling.

   Note that a basic assumption of this plan is that those organizations
   which need to import "supernet" information into their routing
   systems must run IGPs (such as OSPF[RFC1267]) which support classless
   routes. Systems running older IGPs may still advertise and receive
   "supernet" information, but they will not be able to propagate such
   information through their routing domains.

   4.1. Protocol-independent semantic changes

   There are two fundamental changes which must be applied to Inter-
   Domain routing protocols in order for this plan to work. First, the
   concept of network "class" needs to be deprecated - this plan assumes
   that routing destinations are represented by network+mask pairs and
   that routing is done on a longest-match basis (i.e., for a given
   destination which matches multiple network+mask pairs, the match with
   the longest mask is used). Second, current Inter-Domain protocols
   generally do not support the concept of route aggregation, so the new
   semantics need to be implemented mechanisms that routers use to
   interpret routing information returned by the Inter-Domain protocols.
   In particular, when doing aggregation, dealing with multi-homed sites
   or destinations which change service providers is difficult.
   Fortunately, it is possible to define several fairly simple rules for
   dealing with such cases.

   4.2. Rules for route advertisement

      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). Implementation note - one simple way to implement
this rule would be for the border router to maintain a "sink"
route for each of its aggregations. By the rule of longest
match, this would cause all traffic destined to components of
the aggregation which are not explicitly known to be
discarded.

Note that during failures, partial routing of traffic to a site which
takes its address space from one service provider but which is
actually reachable only through another (i.e., the case of a site
which has change service providers) may occur because such traffic
will be routed along the path advertised by the aggregated route.
Rule #2 will prevent any real problem from occurring by forcing such
traffic to be discarded by the advertiser of the aggregated route,
but the output of "traceroute" and other similar tools will suggest
that a problem exists within the service provider advertising the
aggregate, which may be confusing to network operators (see the
example in section 5.2 for details). Solutions to this problem appear
to be challenging and not likely to be implementable by current
Inter-Domain protocols within the time-frame suggested by this
document. This decision may need to be revisited as Inter-Domain
protocols evolve.

An implementation following these rules should also make the
implementation be generalized, so that arbitrary network number and
mask are accepted for all routing destinations. The only outstanding
constraint is that the mask must be left contiguous. Note that the
degenerate route 0.0.0.0 mask 0.0.0.0 is used as a default route and
MUST be accepted by all implementations. Further, to protect against
accidental advertisements of this route via the inter-domain
protocol, this route should never be advertised unless there is
specific configuration information indicating to do so.

Systems which process route announcements must also be able to verify
that information which they receive is correct. Thus, implementations
of this plan which filter route advertisements must also allow masks
in the filter elements. To simplify administration, it would be
useful if filter elements automatically allowed more specific network
numbers and masks to pass in filter elements given for a more general
mask. Thus, filter elements which looked like:

```
accept 128.32.0.0
accept 128.120.0.0
accept 134.139.0.0
accept 36.0.0.0
```

would look something like:

```
accept 128.32.0.0 255.255.0.0
accept 128.120.0.0 255.255.0.0
accept 134.139.0.0 255.255.0.0
deny 36.2.0.0 255.255.0.0
accept 36.0.0.0 255.0.0.0
```

This is merely making explicit the network mask which was implied by
the class-A/B/C classification of network numbers.

4.3. How the rules work

Rule #1 guarantees that the routing algorithm used is consistent
across implementations and consistent with other routing protocols,
such as OSPF. Multi-homed networks are always explicitly advertised
by every service provider through which they are routed even if they
are a specific subset of one service provider's aggregate (if they
are not, they clearly must be explicitly advertised). It may seem as
if the "primary" service provider could advertise the multi-homed
site implicitly as part of its aggregate, but the assumption that
longest-match routing is always done causes this not to work.

Rule #2 guarantees that no routing loops form due to aggregation.
Consider a mid-level network which has been allocated the 2048
class-C networks starting with 192.24.0.0 (see the example in section
5 for more on this). The mid-level advertises to a "backbone"
192.24.0.0/255.248.0.0. Assume that the "backbone", in turn, has been
allocated the block of networks 192.0.0.0/255.0.0.0. The backbone
will then advertise this aggregate route to the mid-level. Now, if
the mid-level loses internal connectivity to the network
192.24.1.0/255.255.255.0 (which is part of its aggregate), traffic
from the "backbone" to the mid-level to destination 192.24.1.1 will
follow the mid-level's advertised route. When that traffic gets to
the mid-level, however, the mid-level *must not* follow the route

192.0.0.0/255.0.0.0 it learned from the backbone, since that would
result in a routing loop. Rule #2 says that the mid-level may not
follow a less-specific route for a destination which matches one of
its own aggregated routes. Note that handling of the "default" route
(0.0.0.0/0.0.0.0) is a special case of this rule - a network must not
follow the default to destinations which are part of one of it's
aggregated advertisements.

4.4. Responsibility for and configuration of aggregation

The AS which owns a range of addresses has the sole authority for
aggregation of its address space. In the usual case, the AS will
install manual configuration commands in its border routers to
aggregate some portion of its address space. As AS can also delegate
aggregation authority to another AS. In this case, aggregation is
done in the other AS by one of its border routers.

When an inter-domain border router performs route aggregation, it
needs to know the range of the block of IP addresses to be
aggregated. The basic principle is that it should aggregate as much
as possible but not to aggregate those routes which cannot be treated
as part of a single unit due to multi-homing, policy, or other
constraints.

One mechanism is to do aggregation solely based on dynamically
learned routing information. This has the danger of not specifying a
precise enough range since when a route is not present, it is not
always possible to distinguish whether it is temporarily unreachable
or that it does not belong in the aggregate. Purely dynamic routing
also does not allow the flexibility of defining what to aggregate
within a range. The other mechanism is to do all aggregation based on
ranges of blocks of IP addresses preconfigured in the router. It is
recommended that preconfiguration be used, since it more flexible and
allows precise specification of the range of destinations to
aggregate.

Preconfiguration does require some manually-maintained configuration
information, but not excessively more so than what router
administrators already maintain today. As an addition to the amount
of information that must be typed in and maintained by a human,
preconfiguration is just a line or two defining the range of the
block of IP addresses to aggregate. In terms of gathering the
information, if the advertising router is doing the aggregation, its
administrator knows the information because the aggregation ranges
are assigned to its domain. If the receiving domain has been granted
the authority to and task of performing aggregation, the information
would be known as part of the agreement to delegate aggregation.
Given that it is common practice that a network administrator learns

from its neighbor which routes it should be willing to accept,
preconfiguration of aggregation information does not introduce
additional administrative overhead.

5.   Example of new allocation and routing

   5.1. Address allocation

   Consider the block of 2048 class-C network numbers beginning with
   192.24.0.0 (0xC0180000 and ending with 192.31.255.0 (0xC01FFF00)
   allocated to a single network provider, "RA". A "supernetted" route
   to this block of network numbers would be described as 192.24.0.0
   with mask of 255.248.0.0 (0xFFF80000).

   Assume this service provider connects six clients in the following
   order (significant because it demonstrates how temporary "holes" may
   form in the service provider's address space):

      "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 "supernet" 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
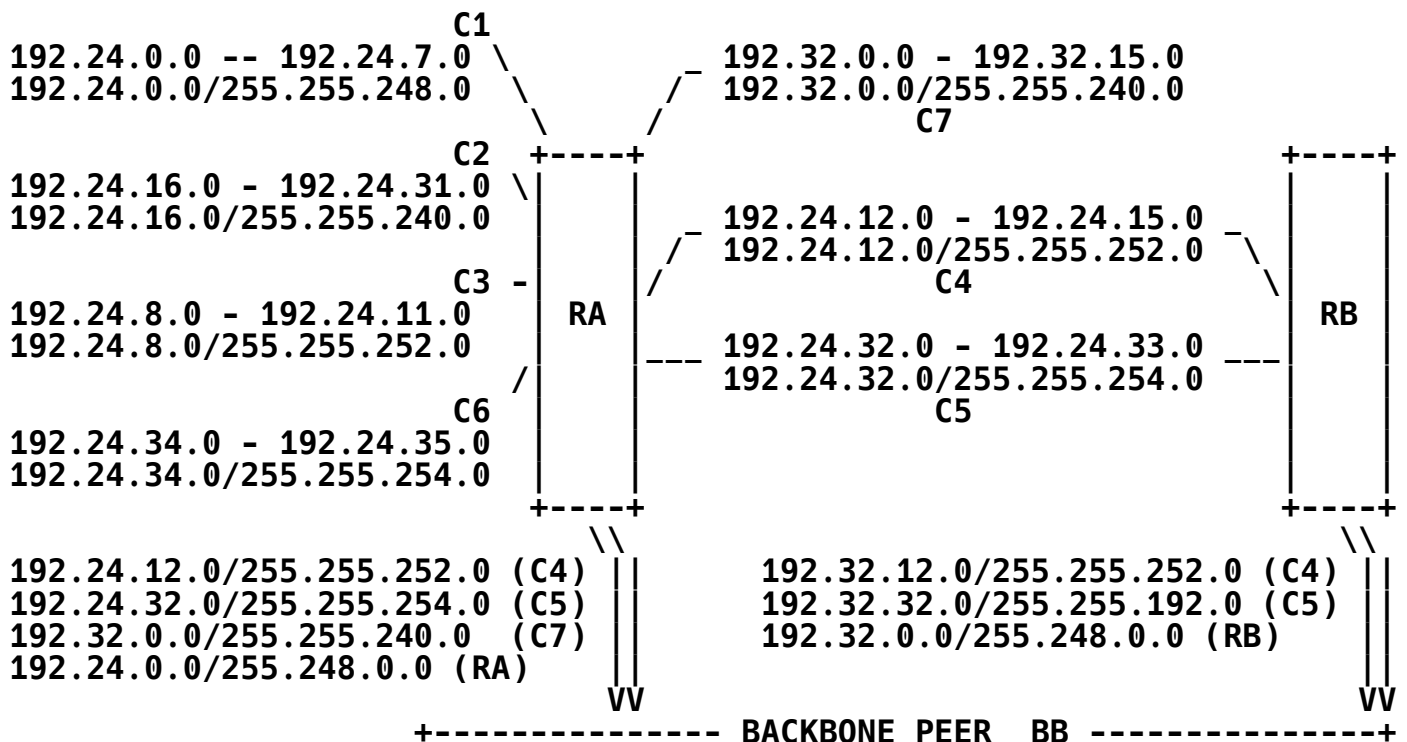   the route 192.24.34.0, mask 255.255.254.0

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, "RB". Further assume the
existence of a client "C7" which was originally connected to "RB" but
has moved to "RA". For this reason, it has a block of network numbers
which are allocated out "RB"'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 "RA" and secondary via "RB"; C5 is primary via "RB" and
secondary via "RA". To connect this mess together, we will assume
that "RA" and "RB" are connected via some common "backbone" provider
"BB".

Graphically, this simple topology looks something like this:

```
                              C1
192.24.0.0 -- 192.24.7.0  \          _  192.32.0.0 - 192.32.15.0
192.24.0.0/255.255.248.0   \      /     192.32.0.0/255.255.240.0
                            \    /                C7
                    C2    +----+                       +----+
192.24.16.0 - 192.24.31.0 \|    |                      |    |
192.24.16.0/255.255.240.0  |    |  _ 192.24.12.0 - 192.24.15.0 _  |    |
                           |    | /  192.24.12.0/255.255.252.0  \ |    |
                    C3 -   |    |/           C4                  \|    |
192.24.8.0 - 192.24.11.0   | RA |/                               | RB |
192.24.8.0/255.255.252.0   |    |___ 192.24.32.0 - 192.24.33.0 ___|    |
                        /  |    |    192.24.32.0/255.255.254.0      |    |
                    C6     |    |             C5                   |    |
192.24.34.0 - 192.24.35.0  |    |                                  |    |
192.24.34.0/255.255.254.0  |    |                                  |    |
                          +----+                       +----+
                            \\                            \\
192.24.12.0/255.255.252.0 (C4) ||   192.32.12.0/255.255.252.0 (C4) ||
192.24.32.0/255.255.254.0 (C5) ||   192.32.32.0/255.255.192.0 (C5) ||
192.32.0.0/255.255.240.0  (C7) ||   192.32.0.0/255.248.0.0 (RB)    ||
192.24.0.0/255.248.0.0 (RA)    ||
                              VV                            VV
          +-------------- BACKBONE PEER  BB --------------+
```

5.2. Routing advertisements

To follow rule #1, RA will need to advertise the block of addresses
that it was given and C7. Since C4 and C5 are multi-homed, they must
also be advertised.

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

```
    192.24.12.0/255.255.252.0 primary     (advertises C4)
    192.24.32.0/255.255.254.0 secondary   (advertises C5)
    192.32.0.0/255.255.240.0 primary      (advertises C7)
    192.24.0.0/255.248.0.0 primary        (advertises remainder of RA)
```

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

Advertisements from "RB" 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 RB)
```

To illustrate the problem alluded to by the "note" in section 4.2,
consider what happens if RA loses connectivity to C7 (the client
which is allocated out of RB's space). In a stateful protocol, RA
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 RB (where it will be dropped according to Rule #2) by
virtue of RB'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" (and may also
prove confusing to a network manager debugging the outage with
"traceroute"). A mechanism to cache such unreachability information
would help here, but is beyond the scope of this document (such a
mechanism is also not implementable in the near-term).

6. Transitioning to a long term solution

This solution does not change the Internet routing and addressing
architectures. Hence, transitioning to a more long term solution is
not affected by the deployment of this plan.

7. Conclusions

We are all aware of the growth in routing complexity, and the rapid
increase in allocation of network numbers. Given the rate at which
this growth is being observed, we expect to run out in a few short
years.

If the inter-domain routing protocol supports carrying network routes
with associated masks, all of the major concerns demonstrated in this
paper would be eliminated.

One of the influential factors which permits maximal exploitation of
the advantages of this plan is the number of people who agree to use
it. It is hoped that having the IAB and the Internet society bless
this plan would go a long way in the wide deployment, and hence
benefit of this plan.

If service providers start charging networks for advertising network
numbers, this would be a very great incentive to share the address
space, and hence the associated costs of advertising routes to
service providers.

8. Recommendations

The NIC should begin to hand out large blocks of class-C addresses to
network service providers. Each block must fall on bit boundaries
and should be large enough to serve the provider for two years.

Further, the NIC should distribute very large blocks to continental
and national network service organizations to allow additional levels
of aggregation to take place at the major backbone networks.

Service providers will further allocate power-of-two blocks of
class-C addresses from their address space to their subscribers.

All organizations, including those which are multi-homed, should
obtain address space from their provider (or one of their providers,
in the case of the multi-homed). These blocks should also fall on
bit boundaries to permit easy route aggregation.

To allow effective use of this new addressing plan to reduce
propagated routing information, appropriate IETF WGs will specify the
modifications needed to Inter-Domain routing protocols.
Implementation and deployment of these modifications should occur as
quickly as possible.

9. Bibliography

[RFC1247] Moy, J, "The OSPF Specification Version 2", January 1991.

10. Security Considerations

Security issues are not discussed in this memo.

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