Lecture Notes (04/09/02: First Half)

Network Design Priorities Summarized

1) Interoperability
2) Robustness
3) Scalability
4) Flexibility
5) Extensibility
6) Cost/Performance

It can be argued that robustness could be the prime consideration.

Robustness can be defined in a number of ways, e.g.

- Physical link between any two nodes should be able to ensure virtual connectivity of the nodes. Robustness could be measured as the likelihood of this requirement being fulfilled over a period of time.

- Or, it could be measured as the likelihood of connectivity of any two nodes over a period of time

- Or, it could be measured as the likelihood of client to host connection over a period of time.

It should be noted that if we emphasize on robustness maximally, other considerations may need to be compromised as extremely high levels of robustness are difficult to achieve in internetworking scenarios.

The time taken to re-establish the routing system after a failure can be a good measure of the robustness.

Role of routers

An important design consideration is how responsibilities are divided between routers and hosts.

It can be argued that the routers should do only what hosts cannot do.

Let us look at the pros and cons to shifting more responsibilities to the routers vs. hosts.

Router - they are fewer and possibly easier to update, they can be made more secure.
Hosts - they have more CPU cycles available, they are simpler and more predictable

For fast networks, routers have to process a packet in very few CPU cycles otherwise they will be overwhelmed with packets. The network can also be more scalable if hosts do more things and leave only the things they cannot do for the routers, so that the routers do not become the bottlenecks.

Historically hosts were more powerful and expensive machines than routers. (Hosts were mainframes while routers were minis.) Hence it made more sense to do more work at routers. The particular aspect has changed a great deal over the time. Now, routers are generally more powerful and expensive than hosts.

To add to this discussion, it would help to classify another set of nodes as 'servers', which carry out special purpose services. Examples of servers are - mail server, HTTP server, FTP server etc.

With respect to division of responsibilities, the current Internet works in the following way:

- Everything that can be done on the host is done on the host.
- Special services are served by special purpose servers
- Rest is done in the router

In such design, router has following essential things.

A router typically has a line card for each kind of network it supports. And, it has forwarding tables for routing.

If we consider a packet of 40 bytes, on a line card OC192 which is 10 GBps, router has barely 30 ns approximately to process the packet to keep up with the incoming packets. If we compare it to a typical DRAM access time of 200 ns, or to SDRAM access time of 1-2 ns, it is easy to see that there is not much room to do too many things of the router. This will become more and more true as the networks get faster and faster.

Hence it makes sense to do shift only the essential responsibilities to the router.

In addition, in today's world it is in fact easier to propagate changes to hosts, though they are more in number than routers. The users and software vendors for the host would usually have more incentive to switch to newer networking software to take advantage of newer features.

IP

IP is the interoperability layer between the networks.

IP header:

What all must IP header contain?

- IP version
- Destination address

Destination address is the global address of the destination host.

Consideration for address

1) How many bits should the address have?

How many hosts should we account for, considering that in foreseeable future every appliance can also have an IP address?

32 bits, (as in IPv4) can serve 4 billion hosts.
40 bits can serve about a trillion.

It would seem that 64 bits would to be sufficient for any imaginable future.

IP v6 though has 128 bit addresses.

2) Lookup of addresses for routing

An efficient lookup of IP addresses is a very important consideration when we consider such huge number of addresses.

Doing a lookup in a linear vector on the router is not practical given that router has very few cycles to complete the whole routing for a packet as discussed earlier.

To improve this situation, the addresses are organized in a tree. The efficiency is gained from the fact that addresses can be organized in such a way that large parts of the tree need not be searched. The tree can be collapsed to a low depth and the search only the branches matching the search address at a higher level need to be expanded.

Current IP addresses follow a hierarchy based on classes:

Class A: 7 bits for network address, 24 bits for the host address (meant for very large

networks)
Class B: 14 bits for network address, 16 bits fot the host address (meant for large networks)
Class C: 21 bits for network address, 8 buts for host address (meant for small networks)

The lookup tree is a very unbalanced tree, since class A addresses are very few, while class C addressed are too many. Looking up Class A addresses would not require too many comparisons.

Class C addresses will still need quite a few comparisons. An important thing to consider, though is that, even though there are about a billion hosts, the number of networks internet connects is only about 100k. Hence if addresses can be aggregated at the level of these networks, lookup will not be too expensive.

Routers at large Internet Service Providers (ISPs) can aggregate addresses at their level. The addresses ISPs provide to their customers can be in a close range. This works as long as the end host is given an IP address by only one ISP but it becomes a problem for multi-home hosts. These hosts acquire two or more different IP addresses from different ISPs.

Such factors are making routing entries grow by a factor of 2 every year and it is becoming a problem which has no direct solution, given the current addressing scheme.

In addition, things like IP mobility are difficult to support with the current addressing scheme.

Thus addressing scheme should be carefully considered for internetworking.