On Problems
Our finest plans have fallen
through, our airiest castles,
tumbled over by lines at first
we neatly drew, and later,
neatly stumbled over.
- Piet Hien

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Internet Addressing and Naming in a Tactical Environment

A basic premise in the Internet and Transmission Control Protocols is that addresses are unambiguous. An addressable object may own more than one address, but each address is unambiguous. The transformation from names to addresses might yield several addresses, but it has been assumed that this transformation would take place above the TCP and IP protocol layers [1,2].

Three realistic situations have been identified which suggest the need to re-think this position. The first situation was informally described by R. Tomlinson as a "network partitioning" problem in which a particular host, H in network N, is reachable from one gateway attached to network N but not another, because network N has become partitioned into two or more pieces. If the system of internet gateways in fact provides connectivity, it is desirable to find some way to route traffic to the gateway that can reach the destination host, even if this would require that traffic be routed out of network N, through networks A, B, and C, and back into network N again.

The second situation was described in a private note from W. Plummer and R. Tomlinson to the author and concerns hosts which are attached to more than one network. In the present paradigm, such a host has two distinct addresses, but might have only one name. Once a TCP connection is set up, for example, the connection ID consists of source and destination net and host addresses as well as source and destination port identifiers. Since a net and host address is bound to a particular connection to a given network, the failure of a particular interface can only be recovered by setting up a new TCP connection to an alternate destination or from an alternate source. Simultaneous recovery when both source and destination have alternate addresses could lead to synchronization problems if each site happens to choose a different destination on which to home during recovery. Depending on the subnet services, even hosts which are multi-homed onto the same net (e.g., ARPANET) may have different alternate addresses.

The third situation arises in connection with an advanced airborne packet radio application. It first emerged in conversations with Major L. Druffel of the DARPA/IPT office. In this case, long-range packet radios (200-300 miles) are installed in aircraft and on the ground at selected sites. The ground sites may or may not have connectivity with each other (e.g., through a wire network and gateways). While aircraft are aloft, they communicate with each other and the ground via packet radios. If we treat the ground packet radio networks as a single net

(for internet addressing purposes) and include the airborne packet radios as a part of that net, then this creates the partitioned network problem which was raised by R. Tomlinson.

If, on the other hand, each ground network is treated as a distinct network, the airborne packet radios would effectively join and depart from different nets, sometimes operating in radio connectivity with two of the distinct ground nets at the same time (during transition from one packet radio net to another). This model rapidly unravels into a classical can of worms, since the internet address of the airborne packet radio would need to change as it moves from one net to the next, leading to a problem related to the W. Plummer multi-homed internet host problem.

Furthermore, at the packet radio level, there is no built-in concept of which internetwork network identifier is associated with ARPANET, just as there is no such self-identification in the SATNET, ARPANET, LCSNET, etc. Xerox Parc has introduced network identification through the use of broadcast servers in each ethernet gateway which responds with the network ID to queries coming in on a given physical port.

The problem is compounded in a tactical ground environment when two mobile packet radio nets, each with their own network ID's and gateways to other nets (e.g., SATNET) suddenly move within radio range of each other. If they are to continue to be treated as distinct networks, then they must interface via gateways, and each must somehow ignore packets being sent by radios in the other network. Worse, there really should be a way to gateway the two nets together via radio, but this implies the existence of a radio link between gateway nodes - the radio link then needs to be treated either as a very special link between gateway halves (i.e., line of sight only). Alternatively, the two networks must somehow collapse into a single network with two identifiers (the dual of a host which is attached to two distinct nets).

As a strawman, I would like to offer an opinion as to the way in which these problems should be treated, for purposes of stimulating discussion in the internet working group.

1. If the packet radio networks (airborne or ground mobile) are operating on a common channel they should be treated as a single network. This creates a partitioned network problem which must be solved.

2. If the packet radio networks are operating in different frequency bands, then methods of connecting their gateways are needed. An obvious strategy is to attach a gateway to two packet radios, one operating on one net and the other in the second. Simultaneous

operation in both nets by a single radio is not presently feasible, but could be studied as a research problem.

3. Hosts which are deliberately multihomed on distinct networks should be able to recover from interface failures, but by mechanisms above the TCP/internet layer, not within them.

To deal with the partitioned network problem, it should be possible to broadcast (or send distinct copies of) a message from a host to all gateways attached to the net(s) the host interfaces with, requesting indications as to which gateway(s) are able to reach a given network. Using source routing, it should be possible to query the host by emitting packets which are forced to go through all gateways on the host's network to get to the desired destination. These queries would elicit responses which contain source routing information useful to the source. It isn't yet clear whether the source routing needed to achieve this capability needs to be used recursively to force traversal of all possible gateway paths into the destination network, but I suspect something like that is required (a sort of multi-network route-finding packet very analogous to a similar object described in the packet radio network protocols for stationless operation [3]).

An alternative strategy might be to attempt to maintain a model of the entire internetwork topology in each gateway and to respond to host queries about all known paths (sequences of nets and gateways) from the source net into the destination network. For even moderately rich network interconnection the computation to supply a response and/or the quantity of response data might be excessive.

A third possibility is to introduce knowledge of all hosts in all nets into each gateway and to perform routing updates based on host identifiers rather than network identifiers. This seems even more prohibitive than keeping track of internet topology in each gateway.

SUMMARY

The basic catch-22 in the airborne packet radio case is that we must either assume that all nets remain "connected" and therefore have the airborne radio join different nets (and have a higher level protocol for readdressing of TCP or internet packets). Or we must deal with the partitioned network problem. Since the packet radio network is designed to adapt to the appearance of new packet radios that have not appeared before, it seems natural to consider the combination of ground and airborne networks as a single network, possibly partitioned, with connectivity available via gateways to other networks. If we can solve the problem of routing "out of the network" to reach a disconnected partition, we can also look forward to providing increased robustness in wire nets through the use of satellite networks, for example.

The multi-homed internet host problem may arise in both the case of a conventional host and the case of a gateway connecting two or more nets. It appears to be most straightforward to retain multiple addresses for such hosts and to supply knowledge of the multiple addresses through internet name server services.

References

1. DARPA, Transmission Control Protocol, IEN No. 81, February 1979, NTIS Accession No. ADA 067072.

2. DARPA, Internet Protocol, IEN No. 80, February 1979, NTIS Accession No. ADA 067849.

3. R. Kahn, S. Gronemeyer, J. Burchfiel and R. Kunzelman, "Advances in Packet Radio Technology," IEEE Proceedings, Vol. 66, No. 11, Nov. 1978, Special Issue on Packet Communication Networks.