SOURCE ROUTING FOR CAMPUS-WIDE INTERNET TRANSPORT

by

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Abstract: For the internet addressing layer of a campus-wide local area network, a source routing mechanism may have several ad
versal or hierarchical target addresses. The campus environment requires many subnetworks connected by gateways, and it has relative
routing in this environment is simplicity of implementation of the gateways that interconnect subnetworks with consequent improveme
location, and overall management effort.

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shop.

Introduction

This paper proposes that for the internet addressing layer of a campus-wide local area network, the source routing mechanism sugge
may have several advantages over hop-by-hop routing schemes based on universal or hierarchical addresses. The campus environment,
quires many subnetworks connected by gateways, and it probably has a relatively loose administration. This research was supported by
United States Government and was monitored by the Office of Naval Research under Contract No. N00014-75-C-0661. The primary a
of implementation of the gateways that interconnect subnetworks with consequent improvement in cost, maintenance effort, recovery ti
fort. Secondary advantages of source routing when applied to the campus environment include: 1) a clearer separation of physical add
protocol design, 2) elimination of stability, oscillation, and packet looping considerations, 3) ability for a source to control precisely a r
sponse time, reliability, bandwidth, usage policy, or privacy), 4) deferment to a higher protocol level of the detailed design of the fragm
mediate networks with small maximum packet sizes, and finally, 5) the ability to accomodate both official and unofficial gateways betw

Two disadvantages of source routing are: 1) that the route used will tend to be relatively static and therefore cannot optimize use of
dynamic hop-by-hop route selection system, and 2) route selection must be accomplished somehow, and since this protocol level does r
must be designed to provide route selection. The argument made here is that the first disadvantage is not serious in an environment suc
communication can make optimization less important. The second disadvantage may be less serious than it appears when one consider
in any case, which service can also provide route selection service. In fact it may be possible to turn this need into an advantage, since
one of which is based on simple global or hierarchical network identifiers, while another, perhaps experimental or research service, pro
private route pattern.

This last ability to decouple target identifications and route selection from gateway implementation taken together with the other adv
in using source routes is improved modularity of network implementation.

This paper has three parts. The first explores the nature of the campus environment, especially its administrative properties. The sec
work using routing services. The final part discusses the advantages that source routing seems to provide when applied to the campus e
ing will find that the second section can quickly be skimmed; potentially novel observations are confined to the first and third sections.

I. What is a Campus Environment?

"The Campus Environment" is a name used here to identify a particular set of physical properties, geographical extents, data commu
needs for flexibility that characterize our own university campus. With only minor exceptions they equally apply to a corporate site, a g
be seven characteristic properties of this campus environment that provide a basis for design decisions for a data communication netwo
quite different from those of a single building, or of a nation-wide, common-carrier-based network. The seven properties are:

1) limited geographical extent,
2) up to several thousand nodes,
3) forces for both commonality and diversity,
4) multiple protocols,
5) confederated administration,
6) independently administered interconnections, and
7) gateways to other nets.

The following sections explain and discuss each of these properties in turn.

1) Limited geographical extent. The campus environment has a geographical extent beyond a single build
ary that permits transmission media to be installed without resort to a common carrier.

This first property is essential, so as to allow exploitation of low-cost, high-bandwidth communication technology. With current techno
cating over privately installed equipment and using common carrier facilities can be a factor between 10 and 100.

2) Up to several thousand nodes. Within this geographical area, a large number of nodes--that is, compute
Today the number of such nodes may be in the range of ten to one hundred. Looking ahead to the advent of desktop comp
thousand nodes by the end of the next decade.

The combination of the previous two properties seems to make it inevitable that local interconnection technologies such as the ETHER
PERCHANNEL [6], MITRENET [7], or the Cambridge Ring [8], cannot by themselves completely accomplish the required interconne
demonstrated have limitations on distance on the order of a thousand meters and limitations on node count on the order of a hundred no
attach clusters of nodes into subnetworks, for example all the nodes in a single building, and then install interconnections (gateway
pus, one might envision by 1990 as many as 100 subnetworks each comprising an average of, say, 50 to 100 nodes, thus linking up to 1
problem of how to route a message from a source node through a series of subnetworks and gateways, so that it ends up at a desired targ

3) Forces for both commonality and diversity. Administratively, there exist forces both for commo
The primary force for commonality is a desire to be able easily to set up communications between any pair of nodes on the campus. Th
er, data source, or data sink typically pre-determines the technology of the network to which it must be attached, because off-the-shelf n
one technology. Further, some applications may have special requirements for some connections (e.g., high bandwidth) that can be me
still need occasional "ordinary" connections to nodes elsewhere. Thus the emerging diversity of local networks will continue, and prob

4) Multiple protocols. Although there are several ongoing standardization efforts, the worldwide academic, co
anything resembling a consensus on how networks should be organized, how protocols should be layered or how functions
from obscure matters of taste, through fundamental technical disagreements about which requirements should have priority
communication technology is moving. Many different and competing standards have been proposed, and one can find in th
One must anticipate that these arguments will be reflected internally in the campus environment, in the form of a diversity
ment that any mutually consenting* set of nodes be able to carry on communication with one another using a protocol that

* Imagery borrowed from a Chaosnet working paper by David Moon.

The diversity of protocols arises for much the same reason as the previously-described diversity of network hardware. The foremost
it meets the immediate application requirement. Ability to communicate with other, not-yet-integrated, applications is a low priority co
particular supplier's collection of provincial protocols, the purchaser will tend to question them only if it appears that they might hampe
pone thinking about interconnection until some real requirement appears, and after the equipment and its protocols have been installed.

This protocol diversity suggests strongly that any network interconnection strategy that must be implemented today should have at th
complishes communication between any two nodes while making an absolute minimum number of assumptions about the higher-level
policy of network administration. Some typical assumptions that should be avoided unless an unusual opportunity can be taken are: w
routing should be optimized; fragmentation/reassembly strategy; flow control requirements; addressing plan; and particular network top

5) Confederated administration. Because a data communication network is a campus-wide service, there
terest to administer the entire network. This means that network administration will either be done by a haphazard confede
underfunded central service organization modeled on the one whose role is to minimize telephone costs.

In either case, this property places a requirement on the network interconnection technology that it be robust and self-surviving to every
complish and easy for individual users to participate in if they are so inclined, because trouble isolation and repair may involve multiple
important, so that operation can be completely unattended for long stretches of time. Although some central monitoring of network ope
design approach that requires close monitoring is undesirable.

6) Independently administered interconnections. The topology of subnetwork interconnection w
without.

This property arises from two needs: First, a "dependable" set of gateways that one can expect to exhibit predictable and stable propert
planned and administered set of gateways would provide this dependability. Second, whenever a node finds that for some reason it is at
some of its applications to serve also as a gateway between the subnetworks; yet it may not want to take on the official responsibility of
gateway that is not centrally administered may arise if some particular application needs, and has purchased the gateway equipment to s
of delay, reliability, bandwidth, or privacy. The person or organization that has purchased the special gateway equipment may not be pr
quirement is that a user may wish to avoid use of a sometimes troublesome gateway that is claimed by its owner to be perfectly operatin

7) Gateways to other nets. External, public data networks such as TELENET, the ARPANET, TYMNET, XT
nodes, and some of those nodes will serve as gateways between the campus network and the external networks. In some ca
link" in the campus net. In other cases, facilities within the campus net will set up communication paths to services having
Both kinds of cases require careful consideration of the interactions between internal and external network properties.

Note that the campus environment has all these properties only if we assume the technological opportunity mentioned in point one: tha
paths in the range from 1 to 10 Mbits/sec. between any two points within the campus. Availability of interconnect media and subnetwo
forms. Gateways that operate with such bandwidths may be harder to construct, and that concern is one of the considerations involved
can sustain these data rates for very long are likely to be rare; software often limits the rate at which a node can act as either a data sour
to be exploited in two ways:

1) to provide enough capacity to handle the aggregate demand of many lower-bandwidth sources and sinks o

2) non-optimal strategies that are relatively simple to implement or administer can be considered; it is not a r
timally utilized.

The availability of high bandwidth, together with lack of a requirement to use that bandwidth efficiently, is probably the most fundamer
work" and the commercial long-haul data communication network, a difference that can lead to significantly different design decisions.

II. How Source Routing Works

1. The basic mechanism. Source routing among a collection of subnetworks is a mechanism that comes into play at a relati
layer.* Figure one illustrates this layer arrangement. If one tried to interpret a collection of interconnected subnetworks according to t
somewhere in the "transport" layer. The lower layers, which we may collectively call the "local transport" layers, constitute a protocol
single ETHERNET or ring net. Routing within the local transport protocol is usually accomplished by physically broadcasting the pac
nizes its own local transport address at the front of the packet will receive it.

The intermediate, internet layer is a protocol for delivery of a packet between any pair of nodes on the campus. One starts a packet
transport address field, and some form of identification of the target node in what may be called the "target identification" field. The lo
which examines the target identification and determines what local transport address to use to get to the next gateway. In turn, the targe
gateways to determine which local transport address should be used for the next step of this packet's journey. This series of local trans
its journey to the target.

There have been suggested several alternatives for the interpretation of target identifiers by gateways ranging, on the one hand, from
tion of some route from the source to the target. Three possibilities along this spectrum are:

1) Unstructured unique identifier. Every node on the campus-wide net has as its target identifier a permanent unique iden
allow it to determine the appropriate next step in the route to every possible identified node. (Thus this approach is someti
most general form, the unique identifier provides no routing information whatsoever. The unique identifier may be interpr
identification of the point on the network to which the target node is attached, depending on the network's convention on w
reattached at a different place.

2) Hierarchical identifier. In this alternate form of hop-by-hop routing, the target identifier of each node is a multi-part fie
consist of an identifier of the subnetwork to which the node is attached and a node number (usually the local transport addr
identifer, each gateway has a set of tables or rules that allow it to determine the appropriate next step in the route to every p
subnetworks than nodes, these tables should be much smaller than in the case of the unstructured unique identifier. Reduct
identifier, and the argument can be extended to identifiers of more than two parts, network groups, and still smaller tables.
that identify parts of the network, this kind of network identifier is almost always thought of as identifying the network atta

3) Source route. The internet transport layer contains, in the place of the target identifier, a variable-length string of local
merely takes the next local transport address from the string, moves that address to the local transport protocol address fiel
gateway needs no knowledge of network topology, so the tables required for hop-by-hop routing vanish. A source route u
independently of what node is attached to that point. Any attempt to make an interpretation that a

source route identifies a node rather than an attachment point would be strained at best.

Note that if the network is arranged as a two-level hierarchy, with a single "supernet" acting as the only communication path among all identifier taken together with the local address of the nearest gateway to the supernet is an example of a source route and the gateways er can be used even if the network topology is not hierarchical, by providing an appropriate routing algorithm in the gateways. In that be directly usable as part of the route; even it might actually be interpreted or mapped by the final gateway.

Note also, that it is common for a single node to have several activities underway at once. For example, a time-sharing system may network for communication between their terminal and the time-sharing system. The receiving network software in the time-sharing sy tween the campus network on the one hand and the array of activities inside the node on the other. As a result it is commonly proposed particular activity within that node. This proposal usually takes the form of an additional field in a hierarchical identifier, known as a "s level of protocol should recognize this socket number, and how big it should be. For our purpose, it is sufficient to observe that the soc ing node.

The mechanics of operation of a source-routing gateway as a packet passes through are quite simple; this simplicity is the chief attra tailed approaches; to permit explicit discussion one implementation will be described here.* This implementation dynamically constru

* This implementation is only a slight variation of the one proposed by Farber and Vittal.

1) The internet source route field is structured as shown in figure two, with two one-octet numerical fields and a variable (of route. Each local transport address uses an integral number of octets, typically one or two. The first count is the numbe the next unused octet of the route. The first count remains constant for the lifetime of the packet; the second is updated at

2) A gateway receives a packet using the local transport protocol of one network (call it network A) and wants to send it ment, assume that a gateway interconnects exactly two nets; generalization for a multinet gateway involves a simple conce

3) The gateway parses the source route field using the "start of next local address" count to obtain the next step of the rou knowledge of how many octets of route are required by network B.) It extracts the appropriate octets and places them in th places those octets of the internet source route with its own local transport address on network B, thus contributing its part address" field by the number of octets it extracted from the route, and it invokes the local transport level to send the packet tion strategy assumes that all paths are bi-directional and that all local transport addresses on any single network are of the sum, that checksum must also be recalculated. Finally, the reverse route comes out upside down, and would have to be tur

4) If a gateway interconnects three or more subnetworks, it simply behaves as though it is itself a subnetwork with three route is interpreted as a local address on this hypothetical subnetwork. The reverse route is constructed as usual. (One sho step, so that expansion to three or more nets is easy and so that one can route packets to a gateway and back, for testing, as

The operation described above is repeated at every gateway, and may also be repeated one or more times inside the target node to dispa ilarly, when a packet originates, it may go through one or more route selection steps before it actually is placed on the first subnetwork. route system is a kind of electronically implemented step-by-step switch, with each subnetwork, multi-network gateway, or multi-activi cause it is electronically implemented and thus not restricted to ten-position mechanical switches, this step-by-step switch does not hav

2. _Where Routes Come From_. For source routing to work, the source of a message must somehow know what route to pla packet into the internet environment. This requirement superficially implies that every source of packets be very knowledgeable, which on the network would have to be able to create or deduce suitable routes. In fact, that implication is unwarranted--all that is really requ network to ask to obtain routes. Once a source has learned of a suitable route to a particular target, it can encache that fact and reuse it work or there is a reason for it to believe that a better route exists.

Thus route selection would be accomplished by consulting a _routing service_ somewhere in the network. A routing service sponse, or administrative convenience) specialized node whose function is to maintain an internal representation of the topology of net vice information about various subnetworks and gateways) and also to act as an identity resolver. The desired target must, of course, ha fier or hierarchical identifier earlier suggested as an alternative internet id. The routing service then implements a map from target iden

There are two independent dimensions along which this routing service may be more or less sophisticated: in its identifier-resolutio with, let us assume a particular fixed, fairly simple identifier resolution scheme--say a hierarchical identifier--with the understanding th tion. The routing choice mechanism, then, can range from a simple fixed table of routes from all possible sources to all possible targets al net topology) to a dynamic mechanism based on frequent exchanges of traffic statistics with gateways and other routing servers thro

Thus, to get started, a node that wants to originate messages needs to know one route: a route that can be used to send a request to a ble, though poor practice, to embed this "route to the nearest routing service" in the software of every node; a more general and flexible broadcast or a breath-of-life strategy to discover this one route. In the broadcast strategy, a node broadcasts on its local transport netwo For this particular broadcast route request, at least one gateway on every subnetwork is prepared to act as a rudimentary routing server. (say once every ten seconds) broadcasts over its local subnetworks a packet containing the route to the nearest routing service. A newl fore it can request its first route.

Having found a route to a routing service and then to a target node, if that node carries on more than one activity it may be necessar the target wants the source to identify the particular activity in which it is interested at the target. This negotiation probably takes plac in return a packet that contains some extra routing steps to be appended to the route originally obtained from the routing service. (Not on a negotiation that takes place in every such protocol; it is _not_ an extra step introduced by source routing.)

III. Advantages of source routes in the campus environment

1. Separation of routing from target identification. The main difference between source routing and its alte
of target identification are moved from the internet gateways to some other agent. In turn, this responsibility change allows the internet
plemented without freezing a particular form of network-wide identification of nodes or services. A commitment to a particular form o
identity resolution part of a routing service, and since it doesn't matter to a gateway where a route comes from (the gateway cares only
of identity resolution going on at the same time, perhaps implemented by different routing services. In practical situations there might
tion method implemented by standard routing services, and in addition some experimental or special-purpose routing services develope
with interactive resolution of catalogued service identities, or protocols that allow sending one packet to more than one target node. Th
inappropriate to embed now in the internet transport protocol layer on grounds of inexperience. But they can be tried in the environmen
disruption and without change to the gateways. It is even possible for one routing service to have a different view of the extent of the n
ping virtual networks are thus implementable using multiple source-route services. This feature might be used, for example, to segrega
that involve routes through external, tariffed, networks.* * Note that this separation of identity resolution from routing applies in both
points and the case where internet identifiers label nodes or services. In the latter case, one can imagine also an additional layer of bind
dresses) and the internet node and service identifiers; this additional layer of binding could be the function of a service similar to the ro
ty might have value in certain situations, one should understand that it is distinct from the modularity here imposed between routes and

At the same time, the source route field format places little constraint on the format of the local transport addresses for any particula
octets whose number is known by the gateway that moves the packet to that subnetwork. This flexibility means that paths can go almos
works no matter what their addressing or internal routing strategy, so long as at the far end of the outside network is a gateway that und

Separation of the mechanics of routing from the functions implemented by a labeling or addressing system has the advantage of clar
down to how much naming function should be embedded in the lowest protocol layers. For example, it is usually proposed that an extr
part of the internet address. This field is known as a "link" field in the ARPANET [10], the "channel" in X.25 [11], and the "socket" in
the Xerox PUP [13]. One argument develops over how big this field should be--just large enough to distinguish among the activities or
large enough to distinguish among all activities or connections the host will ever carry on. The former choice takes the view that the fie
choice makes the socket number a unique identifier, which is handling a labeling function for the host, perhaps allowing it to distinguish
superficially concerns whether this field can be interpreted in different ways by different higher-level protocols. This argument is really
ciently perform the fan-out mechanics required is the same one that should be interpreting the labeling properties of the field.

The source routing strategy finesses both these arguments in that it allows the design of the packet format at the level of the internet
sion about socket number size or position in the protocol layering. As many octets of route as the target host needs to distinguish amon
source route and learned as part of the initial negotiation with the target host using the initially obtained route to its negotiator. A uniqu
negotiation, and it can be included in a connection identifier field of the next higher level of protocol, to insure that packets arriving ove

2. Gateway simplicity and network maintenance. With the source routing scheme just described, a gateway m
the route octet count hasn't been exceeded) and it remembers nothing after the packet goes by. This simplicity of operation and lack of
gateway with a small amount of random logic and a pair of packet buffers interconnecting two local network hardware interfaces. Such
gram, has an exceptionally simple recovery strategy: a hardware reset to a standard starting state will always suffice. In practice, at lea
tistics and respond to trouble diagnosis requests, but the basic principle that recovery is trivial remains intact.

(There is one way in which a source-routing gateway is more complex than its hop-by-hop counterpart. Every packet that arrives ma
offset, so a small amount of lookup is needed to perform the forwarding operation. A related consequence is that higher-level protocols
tion within the packet.)

To create a gateway that can sustain a through transmission rate comparable to that of the subnetworks involved requires careful bud
bandwidth of 10 Mbits/sec. requires being able to pass twelve hundred fifty 1000-octet packets/second, leaving a time budget of only 8
used for the gateway, there must therefore be fewer than 400 instructions executed for each packet, with the implication that whatever r
source routing approach makes meeting such a budget a realistic possibility.

Maintenance is directly aided by having such a simple gateway mechanism. With little to do, there is little to go wrong, failures sho
straightforward. Even in the case where a gateway is actually implemented by software in a node attached to two local transport netwo
that the program required is short, the cycles required are few, and that therefore the program is not only likely to be trouble-free but als
supervisor, where it is less likely to fail because of interference by other programs in the same node. Perhaps even more important in th
routing approach means that the software required can be quick to implement.

3. Route Control. One of the more interesting opportunities that arises when source routing is used is that the node that is the s
the route through the internet that outgoing packets follow. This control can be applied to solve several problems, as follows:

a) Trouble location. If trouble develops in a network gateway, it will be noticed first as failure of packets routed through t
node that notices such a problem, one can route a test packet "out and back", through some set of gateways and back to the
steps in the route that failed, should quickly locate the troublesome gateway. One can also imagine extending this idea to n
check on the operation of the lower levels of that node's operating system. An interesting aspect of this approach to troubl
dertake network diagnosis; trouble location is not restricted to a network maintenance center that has some particular addre

b) Policy implementation: Some local networks may be paid for by a supporting organization that wants to have a say in

supposed to be restricted to government-sponsored business.) If such a network has gateways to two other networks, it cou
ets flowing between those networks. If source routing is used, the node that originates a packet can control whether the pa
tively, avoids that network. (Obviously, sophisticated help from routing services is needed to actually implement such a po

c) Class-of-Service implemention. There are a variety of properties that an internet connection can have, and that may be
probability of wiretapping, bandwidth. Again, assuming considerable knowledge on the part of a routing service, with sou
properties that are tailored to the application.

d) FIFO streams. Assuming that all gateways along a given route relay packets in the same order that they are received, i
packets will arrive at their target in the same order that they left the source, eliminating any need for the target to restore or
hop dynamic routing system, FIFO delivery cannot be easily insured, so the source and target must work harder if that is a

Finally, in an inter-network environment that includes both public and private gateways, the precise route control provided by source
ways can be used by their owners while being ignored by everyone else; flaky gateways can be bypassed by wary users no matter what

4. O t h e r o b s e r v a t i o n s. There are a variety of other observations that one can make about source routes. These are, in no pa

1) Source routing avoids several problems that can accompany more dynamic, highly optimal routing schemes. There is n
niques such as hop counts are not needed. There is little concern for startup transients, stability, or oscillation in the dynam
tistics among gateways is not involved, and one does not have to worry about the interaction between the reliability of that
ment that each gateway maintain a table that has a number of entries proportional to the size of the network.

2) Source routing is "compatible" with hop-by-hop routing in the following curious way: one can start with an existing co
ing, and add a routing service and an independent set of gateways that use source routing. If a packet is first sent to a hop-b
hop routing (and never encountering a source-route gateway). If, on the other hand, a packet is filled with a source route an
prescribed route. This observation encourages the experimental use of source routes, or their use ofr a narrow purpose, say
debted to Danny Cohen for this observation.)

3) Source routing is consistent with at least two proposed fragmentation/reassembly strategies. Fragmentation can be don
maximum packet size: by using the same route for all fragments of a given packet reassembly can be accomplished either a
node. Fragmentation can also be done by a fragmentation service, which might be a node whose address appears "in the m
tervening gateways. If it receives a packet that it believes is too large to get through some intermediate subnetwork, it can
a reassembly service on the other side of the bottleneck. Finally, one might successfully finesse fragmentation completely
that allows big packets, while sending small ones the short, desirable way.

4) In a manner similar to the fragmentation/reassembly servers just described, one can place other specialized services alo
not been explored, but it seems to represent an interesting opportunity.

5) Attachment of a single host to several subnetworks (the "multi-homing problem") is simplified. In a complex internet i
attachments to two or more different subnetworks of the internet, perhaps for added reliability or for assured bandwidth to
tachment points are functionally equivalent, then when another node tries to send a message to such a host, there is a quest
message should go. A hop-by-hop routing scheme in which gateways interpret internet identifiers would require that either
net identifiers (so the originator has the burden of choosing which internet identifier to use) or else a single internet identifi
and the gateways add this topological fact to their storehouse of routing knowledge and make the choice on the fly. With s
service, where the topological information is available to choose a route from the originator to the nearest attachment point
gateways need realize that the target has several attachment points.

In this last case, as in some others, one can argue that some of the apparent simplifications or advantages obtained by using source ro
over to the routing service. This argument is correct, but it underemphasizes two points:

1) Separation of two tangled problem areas, resolving the identity of a target node and routing, into two distinct and large
algorithms, and code. Modularity of network implementation is improved.

2) When one implements routing as a service supplied by a server, it becomes possible to introduce variations on the serv
server. When the function of routing is distributed among the gateways, changes in the service require changing all of the g
ardous. Again, modularity is the key consequence of using source routes.

C o n c l u s i o n s

The premise of our argument is that source routing is particularly well-suited to the campus environment. The argument goes as fol
width lines at low cost, since reliance on common-carrier offerings is not required and physical facilities are under administrative contro
source routing, that may waste some part of the communications capacity by not being optimal. At the same time, source routing may
ly exploit the available transmission bandwidth. The campus administrative environment calls for diversity in protocol, for which sourc
port protocol with a minimum amount of predetermined function that might constrain higher level protocol choices. The campus admin
tion, for which source routing caters by permitting precise control of complete routes for particular messages, and multiple strategies fo
quired. It also permits messages to flow through an internetwork arrangement despite some of its topology not being centrally planned
and source routing gateways are exceptionally simple, two properties that are important when one assumes a central administration tha
modularity of network implementation that source routing and routing services provide seems especially important in an environment t

Thus, from these arguments one can conclude that, at least for the campus-wide internetwork case, source routing is an attractive schem

We have concentrated on the application of source routing to the campus environment, without attempting to identify parallel situati important. For example, the British Post Office, in its recommended standard end-to-end transport protocol [14], suggests that source r tion of a local network, a public net, and another local net, because of the small likelihood that all of these separately administered netw

Finally, the remodularization of network function implied by source routing involves a substantially clever routing service. Although w sign, that design has not been sketched here; it remains an area of continuing investigation.

Acknowledgements

This paper records a series of intensive discussions with, among others, Kenneth Pogran and Noel Chiappa. It also borrows ideas ar project by Danny Cohen, Jon Postel, and John Shoch and from working papers of the M.I.T. Artificial Intelligence Laboratory Chaosne drafts were made by Danny Cohen and John Shoch. The basic idea of source routing and the mechanics of source route operation and Vittal in their 1973 paper; the present paper contributes only observations and implications for the special adminstrative environment by the simplicity of a source routing gateway and the notion of a routing service were suggested by Hopper and Wheeler [15].

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Captions for figures

Figure 1 -- Relation between local transport protocol, internet transport protocol, and other communicatio

Figure 2 -- Possible implementation of an internet source route.

Notes

Files for figures are located on Alto disk labelled "Muriel's NP Disk".

The files are called "zurich1.draw" and "zurich2.draw". These files must be run through the "redraw" program before use.

Biographical sketches for Saltzer, Reed, and Clark are not on-line.