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A Method for the Transmission of Internet
Packets Over AppleTalk Networks [MacIP]

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Abstract

   This Internet Draft describes an existing protocol for transporting
   IP packets over AppleTalk networks. It is intended to specify,
   standardize, and enhance existing implementations. Distribution of
   this memo is unlimited.

   This Internet Draft is a product of the Apple-IP Working Group of the
   Internet Engineering Task Force (IETF).

Table of Contents

   (To be generated and inserted later)

Overview

   There is much confusion over what MacIP really is, as it has grown by
   many small increments designed and implemented by at least as many
   people. There has been no central or formal design document, so each
   of the protocol additions and their effects are not well understood.
   We hope to dissect the anatomy of the current state of the art, and
   recommend a functional subset of the protocol features and a new

gateway architecture that will help provide services to multiple
zones more reliably.

The MacIP protocol is used to transport IP packets across AppleTalk
networks. There are many existing host and gateway implementations of
this protocol, and most of them have many slight differences.

We'll call the functional subset MacIP-1. It is our intention that
it is compatible with as many of the current implementations as is
practically possible. It also describes a set of existing features
that will not work except in specific topologies. A future document,
MacIP-2, will describe a protocol that provides the intended
features, but does so for all AppleTalk topologies.

The new proposed gateway architecture describes an Internal Virtual
MacIP (VIM) , which requires a gateway to maintain an internal
virtual network that has all zones that are supported in its zones
list. This does not require any modifications on existing MacIP host
implementations, and existing gateways will have a simple single-
point modification.

1.   Introduction

The goal of the MacIP architecture is to provide TCP/IP services and
connectivity to computers that are not directly connected to an IP
network, but are connected indirectly via an AppleTalk network.
Typically these are Apple Macintosh computers, but the use of MacIP
is not restricted to them.

IP hosts must be connected directly to appropriate media in order to
communicate with other IP hosts or gateways. All Macintosh computers
come equipped with LocalTalk, Apple Computer's medium speed network
media. LocalTalk is not capable of carrying IP directly. Thus,
MacIP gateways have been developed to provide IP front-end forwarding
agents on behalf of IP hosts embedded in AppleTalk networks.

It is recommended that hosts use this protocol only if they do not
have a direct connection; that is their network media does not
support IP. The details IP hosts directly connected to IP networks
are covered in other well known RFCs.

1.1.   Terminology and Topology

In this document, the term "MacIP" refers to the encapsulation
protocol and associated services. Specific parts of the protocol are
given more specific names as appropriate. In a "MacIP internet"
there are two distinct types of devices.

The first are termed "MacIP hosts", and are usually Apple Macintosh
computers. They are running applications over TCP/IP, and can use
MacIP to communicate between themselves within the confines of their
AppleTalk internet.

When communication is desired with common IP devices on IP supported
networks (hereafter called "IP hosts"), the services of the second
MacIP device, a "MacIP gateway", is required. A MacIP gateway
forwards IP datagrams between IP supported networks and MacIP devices
on AppleTalk networks, as well as provides other server-type
functions.

The term "MacIP Packets" specifically refers to IP datagrams
encapsulated in AppleTalk packets that are sent between the
forwarding modules in MacIP hosts and gateways.

The term "MacIP Range" refers to the set of IP addresses configured
into a MacIP gateway that are considered to belong to the MacIP hosts
being serviced by that MacIP gateway.

Other terms will be defined as they are used, and most appear in the
Glossary.

The AppleTalk protocols used by MacIP are detailed in section 8 which
describes DDP (Datagram Delivery Protocol), ATP (AppleTalk
Transaction Protocol) and NBP (Name Binding Protocol). If you are
not familiar with AppleTalk, then please read the relevant sections
in Inside AppleTalk [1].

1.2.   Intended Audience

It is expected that there are five different groups of people likely
to be reading this document: MacIP host implementors, MacIP gateway
implementors, system managers in trouble, the terminally curious, and
Jon Postel.

1.3.   Assumptions

This document assumes the reader is familiar with the AppleTalk suite
of protocols. AppleTalk is documented in "Inside AppleTalk" [1]. It
is also assumed that the reader is familiar with the IP suite of
protocols, particularly IP [2], IP over Ethernet [4], Ethernet ARP
[3], RIP [9], subnetting and routing [6], IP host requirements [10],
and as documented in other various RFC's.

This document is purposefully confined to the description of the two
port gateway, where one port is connected to an AppleTalk network and
one port is connected to a Ethernet IP network. This is for

descriptive simplicity and should not restrict implementations in any
way.

The described AppleTalk port of the gateway and of the host does not
need to be restricted to LocalTalk as AppleTalk may be transmitted
over other media, such as Ethernet (EtherTalk), Token Ring
(TokenTalk), a Serial connection (ARAP), or anything else.

1.4.   Structure of this Document

MacIP is a complex protocol; there are multiple modules in both the
gateway and the host. Some of them operate in a client/server mode.
Others operate peer-to- peer and/or peer-to-proxy.

The original protocol specification, MacIP-1 is described in sections
2 and 3. It begins with a description of the whole system, moves on
to detailed descriptions of the individual modules, then describes
the protocols used.

Section 4 discusses MacIP limitation, and recommends a subset of
features and the Virtual Internal MacIP architecture. These
limitations and recommendations are for informational purposes.

Section 5 provides a brief synopsis of AppleTalk, and discusses MacIP
required variations of the AppleTalk Name Binding Protocol, NBP.

Sections 6 and 7 provide protocol constant definitions and a
glossary.

Section 8 provides implementation notes on many of the previous
sections. Its section numbering is discontiguous, and follows which
previous section the note applies to. These notes are for
informational purposes.

2.   MacIP Protocol Overview

MacIP must satisfy requirements imposed by IP, AppleTalk (except
where noted), the Macintosh, and the MacIP gateway.

2.1.   Required Functionality

2.1.1. Basic Requirements

   IP connectivity is required between MacIP hosts embedded in an
   AppleTalk network, and IP hosts elsewhere on an IP internet.

```
              [ H1 ]            [ H2 ]        MacIP Hosts
                |                 |
                +-------+--------+             AppleTalk Net
                        |
  MacIP GW        [ GW1 ]          [ IP3 ] IP Host
                    ||                ||
                    ++=======++=====++     IP Ethernet
                            ||
  MacIP Host[ H4 ]             [ GW2 ]       MacIP GW
                |                 |
                +----------------+           AppleTalk Net
```
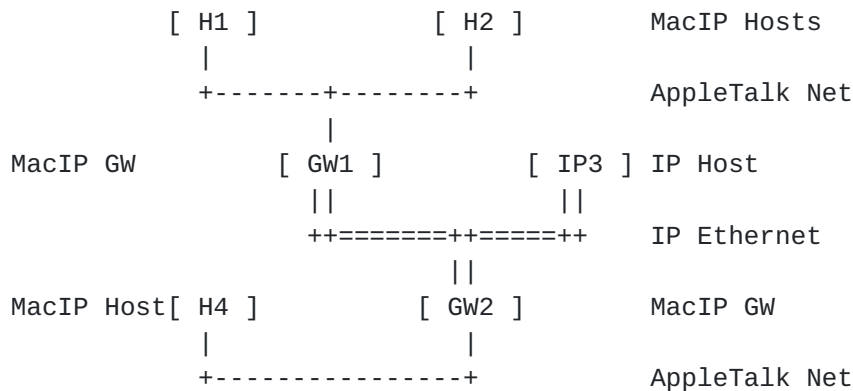
        Figure 1. Example MacIP Internet

    There are four different cases to consider in the internet shown in
   Figure 1.

        1.   Between a MacIP host and an IP Host (H1 and IP3 via
                GW1).

        2.   Between MacIP hosts on different AppleTalk networks via
                intervening MacIP gateways (H1 and H4 via GW1 and GW2).

        3.   Between MacIP hosts in the same zone connected to the
                same MacIP gateway (H1 and H2 via GW1).

        4.   Between MacIP hosts in the same zone without a MacIP
                gateway being present (H1 and H2 directly).

   Cases 1 and 2 are very similar. Given that MacIP to IP connectivity
   is established, there is no difficulty supporting MacIP to IP to
   MacIP. Cases 3 and 4 may appear identical, but are not. Traditional
   implementations require that MacIP packets must follow the most
   "efficient" route, and not go through the gateway when the hosts are

on the same network. The following is a simple requirement matrix.

```
                                        Local with
        From/To   Local   Remote  IP Host  No Gateway
        -----------------------------------------------
        Local   |  Yes  |  Yes  |  Yes  |   Yes   |
        Remote  |  Yes  |  Yes  |  Yes  |    -    |
        IP Host |  Yes  |  Yes  |   -   |    -    |
```

        Table 1. MacIP-1 Requirement Matrix

[2.1.2]. IP Requirements

In order to function as an IP host, a minimum of two things are
required:

    1.   An IP Address for the host.

    2.   A means by which to forward packets to the host.

 With these, an IP host can function on a point-to-point link. In
 order to function on a broadcast network (such as Ethernet or
 LocalTalk) the following is also required:

    3.   An Address Resolution scheme (ARP) to resolve IP
            addresses to native network addresses.

    4.   A subnet mask to allow local and remote routing
            decisions to be made.

    5.   Gateway address to send off-subnet packets to (more
            sophisticated routing is sometimes desirable, but not
            essential).

The MacIP protocol can provide all five, although the last two add
significant complexity. A variation on ARP provides this
functionality.

[2.1.3]. Macintosh Considerations

Macintoshes are mobile, and are often moved from one network to
another. The AppleTalk protocol handles this automatically without
requiring any user reconfiguration of the Macintosh. It would be
inconvenient to have to reconfigure the IP Protocol stack under these

circumstances. The MacIP protocol provides an automatic IP Address
Assignment protocol that can be used to circumvent the requirement
for reconfiguration when moved. IP addresses so assigned are called
"Dynamic" Addresses.

Because Macintoshes often are connected directly to Ethernet, the IP
protocol stacks usually support both direct Ethernet and MacIP modes
of connection. The MacIP protocol is modular and designed to attach
simply to an existing Ethernet implementation.

[2.2]().   **Protocol Relationships**

In order to provide the required functions, MacIP has the following
relationship to the other protocols in MacIP hosts and gateways:

```
            MacIP Host                      MacIP Gateway
       -------     -------
      | TCP |     | UDP |
      +-----+-----+-----+      ----------------------------
      |        IP        |<---->|            IP            |
      +-----------------+      +-------------------------+
      |      MacIP       |<---->|  MacIP   |  | Ethernet |
      +-----------------+      +----------+  -------------
      |     AppleTalk    |<====>| AppleTalk |
       ------------------        -------------
```
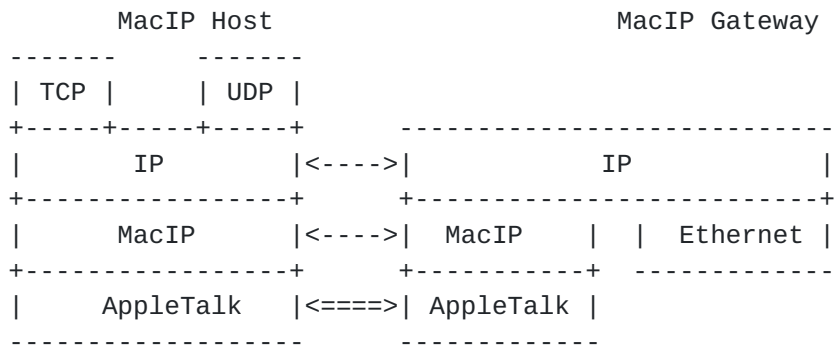
Figure 2. MacIP Host and Gateway Connections

MacIP acts as a Link-layer protocol to IP, while acting as a client
of all the session, transport and network layers of AppleTalk. This
should serve to warn readers of the complexities ahead:

```
        Layer Name        Protocol
                          -------     -------
        4 - Transport    | TCP |     | UDP |
                         +-----+-----+-----+
        3 - Network      |        IP        |
                         +-----------------+
        2 - Link to IP   |.................|
        5 - Session to   |      MacIP       |
            AppleTalk    +-----+-----.      |
```

```
         4 - Transport   | ATP | NBP |_____|
         3 - Network     | AppleTalk - DDP |
         2 - Link        | AppleTalk - LAP |
                         -------------------
```
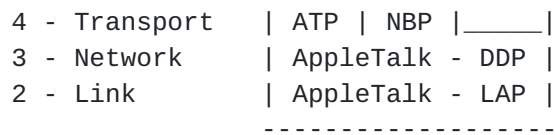
Figure 3. Relation Between IP and MacIP

[Phil doesn't like the above diagram. Shall it go in the appendix?]

2.3.   Protocol Mapping

MacIP uses the zone-wide protocol NBP to perform the ARP function.
This makes for a very simple ARP implementation on a Macintosh as
most of the code is already built in to the operating system. It
does lead to the following unfortunate restrictions:

   1.   There has to be one MacIP gateway per zone,

   2.   There can't be more than one MacIP gateway per zone, and

   3.   MacIP hosts can't use a MacIP gateway in a "remote"
          zone.

There have been many attempts to overcome the above restrictions, but
they are all "outside" of MacIP-1 and cause problems of their own.

2.4.   MacIP Functions and Services

MacIP provides address assignment, address resolution and packet
transport services.

2.4.1.   Address Assignment

The MacIP gateway contains an Address-Assignment module which is
configured with a set of IP addresses to assign to MacIP hosts. The
module advertises its presence on the network with NBP registration,
lookup, and confirmation. The MacIP gateway is discovered by a MacIP
host during the initialization of the MacIP host's protocol stack,
then an IP address can be requested and granted. MacIP also allows
for a MacIP host to be assigned a fixed or "Static" IP address within
a range of addresses known to the MacIP gateway.

2.4.2. Address Resolution

Ethernet-connected IP hosts use the Ethernet Address Resolution
Protocol (ARP) to discover the hardware address corresponding to a
required IP address. The AppleTalk NBP protocol provides similar
capabilities and is used to implement the address resolution function
in MacIP. This is referred to as NBP ARP.

When any device supporting MacIP acquires an IP address, it registers
it through its local NBP process. It is then visible to NBP ARP
requests from other MacIP devices. There is the added advantage of
possibly discovering configuration errors caused by duplicate IP
addresses, as NBP guarantees unique registration within the local
zone.

With Ethernet ARP, the "working range" of an ARP request is the IP
subnet, which corresponds to the "reach" of the Ethernet broadcast
packet. With NBP ARP, the "broadcast reach" corresponds to an
AppleTalk construct called a "Zone". A zone consists of one or more
AppleTalk networks, the actual topology of which is controlled by the
network administrator.

The zone that the MacIP gateway and the hosts are in is referred to
as the "MacIP zone". The zone that a particular device is in is

referred to as its "local zone".

Therefore there is a direct correspondence between an IP Subnet and
an AppleTalk Zone for NBP ARP. Unfortunately the same does not apply
for the delivery of any other sort of AppleTalk or MacIP packet, as
the "broadcast reach" corresponds to a single AppleTalk network.

2.4.3. Transport

Transport of IP datagrams over LocalTalk is achieved by encapsulating
them in Datagram Delivery Protocol (DDP) packets and sending them
over an AppleTalk internet. The destination device can be another
Macintosh computer supporting MacIP or a gateway. The latter can
either be explicitly selected or discovered through a proxy-based
process.

3.   MacIP Protocol Specifics

This section describes the MacIP protocol as originally implemented
and documented in the Stanford KIP gateway code. This forms the
simplest possible version of MacIP, and one which should be supported
by all host and gateway implementations.

3.1.   Gateway Addressing Styles

There are two alternative approaches to integrating an AppleTalk
network into an IP network. One approach involves treating the
AppleTalk network as an IP subnet, with the MacIP gateway assuming
the role of an IP router. The alternative is to allocate to the
AppleTalk network a small range of addresses "stolen" from the
Ethernet IP subnetwork that the MacIP gateway is connected to. In
this case, the MacIP gateway forwards IP packets to and from
AppleTalk.

The forwarding method is conceptually easier, and thus easier to
configure. No large range of subnet addresses needs to be calculated
and allocated to the AppleTalk network, and no changes need to be
made to the rest of the network.

The routing method is more difficult conceptually and, hence, harder
for an administrator to configure. It is, however, more consistent
with the requirements of many large sites, and can be more practical
in complicated networks. This is especially true if the MacIP
gateway will emit Routing Information Protocol (RIP, [9]) packets to
inform the Ethernet network of the MacIP AppleTalk subnet.

MacIP gateways conforming to MacIP-1 MAY implement either or both of
these styles. This doesn't affect MacIP hosts as they should not be

able to tell the difference.

3.1.1. MacIP Forwarding

When forwarding with the MacIP architecture, the AppleTalk network is
treated as an extension of the Ethernet IP network. This is done by
situating the "MacIP Range" within the range of IP addresses defined
by the Ethernet IP network. When a host on the Ethernet ARPs for an
IP address which is in the MacIP range, the gateway will answer,
performing the proxy ARP function [8].

For example, if the Ethernet has the IP subnet "192.9.200.0", then
the MacIP gateway might be configured to assign the addresses
"192.9.200.100" through "192.9.200.150" to MacIP hosts. The gateway

will respond to ARP requests on Ethernet to all these addresses, plus
its own IP address.

3.1.2. MacIP Routing

Routing via the MacIP protocol is straightforward from the
perspective of IP routing. The gateway is configured with two IP
addresses and subnet masks, one for the Ethernet and one for the
AppleTalk networks.

As the MacIP gateway is acting as an IP Gateway (and is thus
performing IP routing), it is necessary for the TCP/IP hosts on the
Ethernet side of the gateway be informed of the existence of the
subnet corresponding to the MacIP Range, and that the MacIP gateway
is the gateway to this subnet. This can be done via static routing
tables or via the RIP protocol. MacIP gateways MAY provide either a
full or conservative (the latter only advertises the MacIP subnet)
RIP implementation in the MacIP gateway.

3.2.   MacIP Initialization

3.2.1. Configuration Required For MacIP Hosts

The MacIP host requires an IP address for configuration. "Dynamic"
or "Static" addresses refer to the method by which the address is
acquired. A dynamic address is assigned from the MacIP gateway's
address range. A static address is assigned at the MacIP host, then
confirmed through the MacIP gateway.

3.2.2. MacIP Host Initialization

The initialization code is responsible for finding the MacIP
gateway's Address Assignment server using NBP, requesting "server"
information, acquiring an IP address, either from the address

assignment service or from a statically-configured address, and
registering the MacIP host's IP address with NBP.

3.2.2.1.   Locating the MacIP gateway's Address Assignment Server

The Address Assignment Service in the MacIP gateway [Server] is
assumed to have registered itself with NBP with a type of
"IPGATEWAY". The MacIP host initialization process uses NBP to
search for "=:IPGATEWAY@*", which performs a search for all Servers
in the same zone that the MacIP host is in. Under MacIP-1 the

implementation assumes that it will only receive one response from
one gateway. Multiple gateways in one zone are not covered in MacIP-
1.

3.2.2.2. Requesting Server Information

The MacIP host and the Server exchange information using a protocol
called "MacIPGP", described later. The MacIP host can optionally
send a MacIPGP SERVER request to the Server, and SHOULD then receive
a response packet. The information in the response packet is mainly
obsolete and not very useful, although the returned IP Broadcast
address might be usable from some gateways.

3.2.2.3. Requesting a Dynamic IP Address

If the MacIP host is not configured to use a Static IP address, it
sends a MacIPGP ASSIGN request to the Server. It will either respond
with an appropriate IP address or an error status and optional
message which should be displayed to the user. Errors at this point
are non-recoverable.

3.2.2.4. Registering the IP Address

The MacIP host registers its IP address through NBP. It MUST use its
IP address in dotted decimal notation as its NBP Name. This
representation is the four bytes of the IP address, in network order,
in decimal with no leading zeros and separated by periods. For its
NBP Type, the string "IPADDRESS" MUST be used. For example, to
register the IP address 131.161.1.2, the NBP registration would be
"131.161.1.2:IPADDRESS@*".

If the registration fails then it is an indication of a duplicate IP
address, a gateway, or a network misconfiguration. The failed
address MUST NOT be used. This SHOULD be clearly reported to the
user.

The MacIP host MUST register on DDP socket 72. Some current MacIP
gateway implementations assume that the MacIP host is using socket 72

whether it is or not, so using anything else is not advisable.

3.2.2.5 Closing Down

When the MacIP protocol stack closes down, it must remove its IP
address registration from NBP.

[3.2.3](#). Configuration Required For MacIP Gateways

A MacIP gateway has to be configured with an IP address, a subnet
mask and (possibly) a default gateway. It also needs to be
configured with the "range" of IP addresses that are to be allocated
to the MacIP hosts so that the gateway can provide address assignment
and forwarding service to its MacIP hosts.. The "union of all IP
addresses that can be assigned to MacIP hosts and that the MacIP
gateway is required to forward packets to" is called the "MacIP
Range". Historically, this is a single contiguous range, but
implementations are not confined to this.

This range contains a "Dynamic" and a "Static" range, either of which
may be empty. The "Dynamic" range consists of IP addresses that can
be allocated to MacIP hosts on request. The "Static" range consists
of IP addresses that can be configured into MacIP hosts that require
the same IP addresses all the time. The MacIP gateway will not
forward packets to a MacIP host that has an IP address outside of
this MacIP range.

[3.2.4](#). MacIP Gateway Initialization

The initialization code in a MacIP gateway is responsible for setting
up certain data structures used by other modules, registering the
Address Assignment server and certain IP addresses with NBP, and
performing an initial search for already- registered MacIP hosts.

[3.2.4.1](#).   Proxy ARP Initialization

If the MacIP gateway is configured in "forwarding" mode , then the
ARP module is initialized to respond to the "MacIP range" of IP
addresses in addition to other MacIP gateway addresses.

[3.2.4.2](#).   Registration of Address Assignment Server

The MacIP gateway MUST register itself through NBP, using the type
"IPGATEWAY", on DDP socket 72. It is necessary for the registration
to be unique in the zone, and early implementations guarantied this
by using as the NBP name field (which has to be unique), the dotted
decimal representation of their IP address.

[3.2.4.3](#).   Registration of IP Addresses

The IP addresses that the MacIP gateway has that are within the MacIP
Range SHOULD be registered with the NBP protocol on the gateway in
the same way that IP addresses are registered on MacIP hosts. This
guarantees that MacIP hosts will not succeed in registering the same
address in the same zone. Also, this makes the IP addresses visible
to both MacIP hosts (that may wish to send datagrams to these IP
addresses) and to network management software. If the registration
fails then MacIP MAY not be able to function on the gateway, and
appropriate actions should be taken. "Passive Registration" (section
5.3.2.1) SHOULD not be used.

3.2.4.4.   Reregistration Function

The MacIP gateway is responsible for assigning unique IP addresses to
MacIP hosts. If the gateway has been running, has assigned addresses
and is then restarted (or crashes), it is in danger of reassigning
the same addresses to other MacIP hosts. In order to recover the
previous assignments, the MacIP gateway uses NBP to search for
"=:IPADDRESS@*", which will locate all IP addresses registered with
NBP ARP in the zone. The NBP responses are directed back to the
Initialization module. Those discovered IP addresses that are within
the dynamic range assignable by the gateway can be used to initialize
the assignment table.

It is important that the MacIP gateway attempts to use the same
AppleTalk node address after a restart that it had before, as the
MacIP hosts will have the node address of the gateway stored in NBP
ARP tables and elsewhere. The gateway should not use a "random" node
address on restart.

3.3.   Proxy ARP

As mentioned in 4.1.1, when configured to act as a "Forwarding
Gateway", the MacIP gateway must perform Proxy ARP for the MacIP
Range of addresses. This is simply implemented by adding the MacIP
Range to the IP Address(es) that the MacIP gateway's Ethernet ARP
process will respond to. All IP addresses in the MacIP range are
proxied for, whether there are MacIP hosts using these IP addresses
or not as this simplifies the implementation.

Proxy ARP MUST be disabled when the MacIP gateway is configured to
act as a "Routing Gateway".

3.4.   NBP ARP - Address Resolution

Any MacIP device (host or gateway) can resolve an IP address to an

AppleTalk address by using NBP to search for the device that has that
IP address registered. The name is the requested IP address in
"dotted decimal" notation and the type is "IPADDRESS". NBP requires
repeat and delay specifications (the number of retries and the delay
between them). These should be set particularly leniently,
especially considering that MacIP may be running over WANs and/or
ARAP (Apple Remote Access Protocol). Recommended values are given in
section 10, "Definitions".

NBP ARP is functionally very similar to Ethernet ARP, and can often
be implemented by using the host or gateway Ethernet ARP code and
data structures. Both the MacIP host and gateway are assumed to
implement a cache for the addresses resolved by NBP ARP.

With Ethernet ARP, the "working range" of an ARP request is the IP
subnet, which corresponds to the "reach" of the Ethernet broadcast
packet. With NBP ARP, the "reach" corresponds to an AppleTalk
construct called a "Zone". A Zone consists of one or more AppleTalk
networks, the actual topology of which is controlled by the network
administrator.

There is therefore a direct correspondence between an IP Subnet and
an AppleTalk Zone, but ONLY when performing NBP ARP, and not when
routing certain packets such as those to an IP broadcast address,
such as might be used by RIP or RWHO.

3.4.1. NBP ARP - Details

The NBP ARP module is passed an IP address to resolve by the delivery
module. Resolution is first attempted by searching for a matching IP
address in the local ARP cache. A successful match should reset any
usage timers. If a no match is found, then the address has to be
searched for.

The search on the network is made by using NBP to send an NBP LookUp
to all devices in the MacIP zone. The entity-name in the LookUp is
the dotted-decimal representation of the IP address (see section
6.2.8). The entity type is "IPADDRESS". The entity zone is the MacIP
zone. The retry count and time is as specified in section 10.

The NBP ARP response carries the AppleTalk address of the
destination. The full AppleTalk address (net, node and socket -
socket 72 is not to be assumed) must be stored in the ARP cache
together with the IP address.

3.5.   Delivery

IP packets including the full IP header MUST be encapsulated in DDP

packets of type 22 (decimal). The source and destination sockets of
the packet are 72 (decimal) by convention.

The AppleTalk DDP protocol limits the data size of a DDP packet to
586 bytes, which is then the maximum possible Maximum Transmission
Unit (MTU) of the AppleTalk network when transporting IP datagrams.
The MTU of 576 is more commonly used so as to conform to the minimum
IP MTU.

The Ethernet network has an MTU size of 1486 bytes. The smaller MTU
size of AppleTalk requires that gateways must fragment Ethernet
packets bound for AppleTalk which are larger than the AppleTalk MTU
[3].

Packets received by the MacIP host MUST be dropped (not processed) if
the destination IP address does not match the IP address of the MacIP
host. No "IP Broadcast" destination addresses are allowed. This
function can be performed either by the Delivery or IP modules.

3.6.   MacIP Routing Decisions

MacIP's design imposes restrictions that renders MacIP hosts
incapable of correctly performing IP Broadcasts and of correctly
interpreting ICMP Redirects. Both of these features are required in
IP implementations. However, current MacIP host implementations do
attempt this, so the feature described in the following section was
developed.

3.7.   Gateway NBP Proxy ARP

In order to support the simple routing method used by the MacIP
client, it is necessary for there be a service in the MacIP
gateway that performs the equivalent of a "Proxy ARP" service, but
for all of its MacIP clients. The NBP Proxy ARP service must respond
to all NBP ARP requests for all IP addresses EXCEPT for the ones in
the MacIP range (those allocated to the MacIP clients).

NBP Proxy ARP MUST respond to NBP requests with the IP address being
requested, the type "IPADDRESS" and the AppleTalk net, node and
socket (72) address of the "Delivery" module. The NBP Proxy ARP
module MUST NOT respond to "wildcard" lookups for type "IPADDRESS".
NBP Proxy ARP has to be implemented on a "non-standard" NBP
implementation described in section 5.3 as "Conditional NBP" (CNBP)..

3.8.   MacIP Gateway Protocol

MacIPGP is a simple request-response protocol based on ATP (AppleTalk Transaction Protocol) ALO (at-least-once) transactions.

The MacIP host sends an ATP TREQ (ATP Request) packet to the AppleTalk address of the Address Assignment Server, and the MacIP gateway responds with an ATP TRSP (ATP Response) packet.

There are two defined functions which MacIP-1 uses. These are "get server info" (SERVER) and "assign IP address" (ASSIGN).

3.8.1. SERVER Function

The SERVER function returns a list of common server IP addresses, such as name server, file server and the broadcast address. These are usually defined as part of the gateway's configuration and simply passed on via the protocol without interpretation, so their specific contents is not part of the MacIP protocol. Most of these can be considered "obsolete". Their "usual" designation is detailed below.

3.8.2. ASSIGN Function

The ASSIGN function returns an IP address which can be used by the MacIP host to communicate with other IP hosts. The following is the description of the implementation in the December 1986 KIP code in the "ip.at" document.

The gateway is configured with a "Dynamic Range" range of IP addresses and maintains a table of these containing the fields:

  IP address; timer; flags; AppleTalk address (including socket);

When the MacIP Client sends an ASSIGN request to the gateway, the gateway searches the table described above. The service tries to reassign the same IP address to the same AppleTalk address if possible. Otherwise any free IP address is used. If an IP address is available, it is sent in an ASSIGN Reply packet, and the timer field of that table entry will be started.

Thereafter, every "Confirm Period" (60 seconds if not configurable), an "echo command"(NBP ARP Confirm) is sent to the client and the timer bumped. Echo replies received will restart the timer. If 5 periods pass with no replies received, that table entry will be available for potential reassignment. In making "new" table assignments the timer field is used to locate the oldest unused table entry. This increases the chances of a given MacIP host to keep

reusing its previous IP address assignment.

It is important to note that IP addresses assigned via the gateway
ATP protocol must be registered and resolved using the NBP ARP
technique.

3.8.3. ERROR Response

The MacIPGP protocol request return an error if a request other than
ASSIGN or SERVER is made. The ASSIGN response may return an error if
there are no Dynamic addresses available.

3.8.4. MacIPGP Packet Definitions

The complete MacIPGP packets consists of:

   1.   Data-link Header,

   2.   DDP Header,

   3.   ATP Header,

   4.   MacIPGP Header,

   5.   MacIPGP Data Packet (only on MacIPGP Response packets).

It has the format:


```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                                                               |
/                      Data Link Header                         /
|                                                               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                                                               |
/                         DDP Header                            /
|                                                               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
| ATP Control  | ATP Seq. No  |      ATP Transaction ID         |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                    ATP User Bytes - Ignored                   |
```

```
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                    MacIPGP Request or Response Code           |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                                                               |
/                    MacIPGP Data (variable length)            /
|                                                               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```
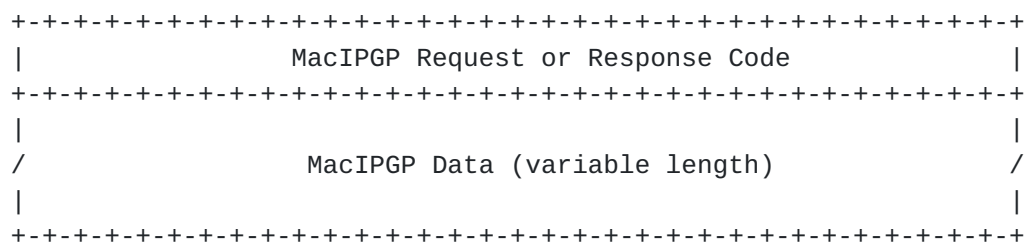
Figure 6. MacIPGP Packet

3.8.5. ATP Control Fields

The Control Info, Sequence Number and Transaction ID fields are
documented in Inside AppleTalk. The MacIP gateway returns these
fields as-is to the MacIP host except that the Control Info field is
changed from a TREQ to a TRSP.

3.8.6. ATP User Bytes

These four bytes are unused in MacIP-1 and can be expected to contain
random data.

3.8.7. MacIPGP Request and Response

If the ATP Control info is TREQ, then this is a packet from the MacIP
host to the gateway. The MacIPGP Data field is empty (zero length).
The defined values of the MacIPGP Request field are:

```
      Val.    Name    Meaning
      1       ASSIGN  Request assignment of Dynamic address.
      3       SERVER  Return Server Information.
      -1      ERROR   Only valid in MacIPGP Response packet.
```

ASSIGN is a request for the MacIP gateway to assign an IP address
from its configured "Dynamic Range" to the MacIP host. SERVER is a
request for the "Server Information" to be returned.

The MacIP gateway normally returns the packet as-is with the MacIPGP
Response field in the returned packet set to the MacIPGP Request
field in the received packet. If an error occurred, then the Response
field is set to "-1" (hex FFFFFFFF) with an optional zero-terminated

error string returned in the "Error Message" field. The length of
the data field of the returned ATP packet is 64 bytes plus the length
of the terminated error string. If the string is empty then 65 bytes
are returned.

3.8.8. MacIPGP Data Field

The MacIPGP Data Field is returned in MacIPGP Response packets. The
format is:

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                     Assigned IP Address                       |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                    Name Server IP Address                     |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                    Broadcast IP Address                       |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                    File Server IP Address                     |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|_                 Other IP Addresses (16 octets)            _|
|_                                                           _|
|_                                                           _|
|                                                             |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                    Error Message (NULL terminated)           |
/                    128 bytes maximum                         /
|                                                             |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```
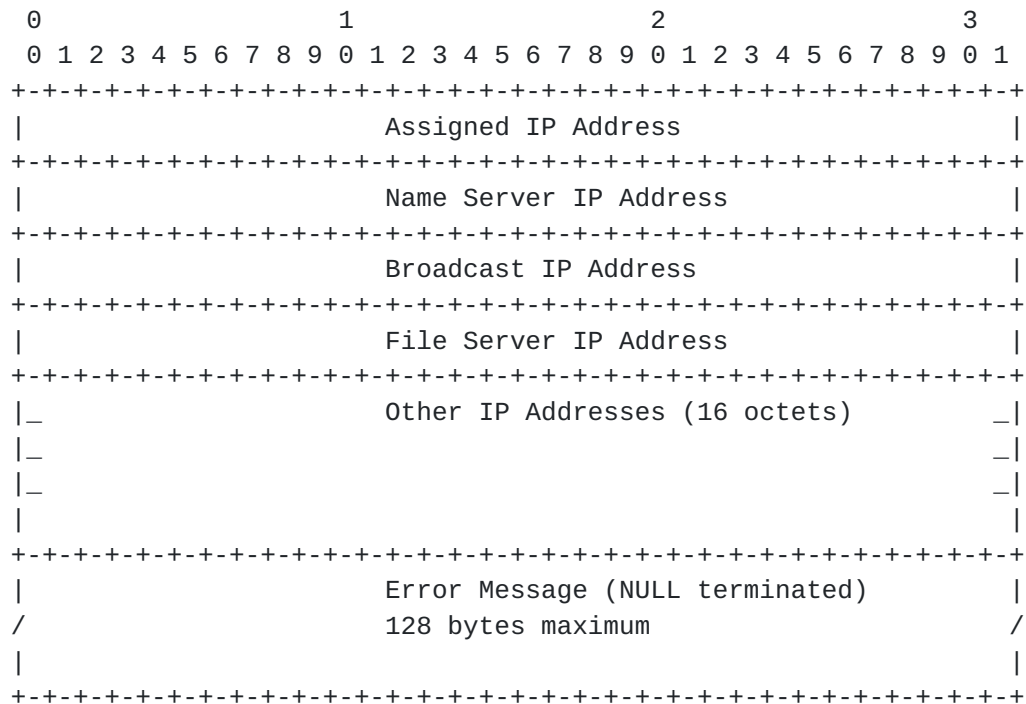
Figure 7. MacIPGP Data Field

Originally the Name-server, Broadcast, File-server and Other fields
were simply copies of configuration data transferred to the MacIP
gateway by the AppleTalk Administrative Daemon (atalkad). Their
meaning was thus a "private matter" between the administrator and the
MacIP host code in use, and did not involve the MacIP gateway at all.

It did not interpret or generate the data (except for the Broadcast
field which the MacIP gateway does use), it only transferred it.

Some manufacturers have changed this simple relationship by using the
atalkatab fields for gateway configuration and/or having the gateway
generate the data transferred to the MacIP host. Thus, the meaning
is unclear, and thus for MacIP-1, undefined.

3.8.8.1.   Assigned IP Address

This is the IP address assigned by the MacIP gateway to the MacIP
host. It is only returned in ASSIGN response packets. This field is
only valid in ASSIGN response packets.

3.8.8.2.   Name Server IP Address

This historically has been used to contain the IP address of an IEN-
116 Domain Name Server.

3.8.8.3.   Broadcast IP Address

This may be the Ethernet IP broadcast address which is only
"appropriate" for the MacIP hosts if the MacIP gateway is configured
in "Forwarding" mode. If it is in "Routing" mode, this field could
be anything. MacIP hosts MUST not rely on this data.

3.8.8.4.   File Server IP Address

Originally the address of EFS (Electronic File Server) included with
CAP v4 (Columbia AppleTalk Package). Obsoleted by AUFS.

3.8.8.5.   Other IP Addresses

Available for "private" use between consenting MacIP hosts and MacIP
gateway configurations. These may contain the "IPOTHER" fields from
the "atalkatab" file, but they may not.

3.8.8.6.   Error Message

If the returned MacIPGP Response code is -1, this may contain a 128-
byte maximum null-terminated error message. Otherwise it is a zero-
length null-terminated string (one byte of null).

3.8.9. Delivery Packets

If the Address Assignment Service does not have the same AppleTalk

address as the Delivery Module (as returned by NBP Proxy ARP), then
it may still receive delivery packets (IP packets of DDP type 22)
sent by MacIP hosts disobeying MacIP-1. For backward compatibility,
these packets SHOULD be forwarded to the Delivery module.

[4](#).   MacIP Limitations and Recommendations

The specification of MacIP imposes certain basic restrictions on
operations of both hosts and gateways, particularly on the allowable
network topology. Most MacIP gateway vendors have found different,
incompatible, and incomplete methods ways to work around these basic
protocol limitations.

This specification recommends methods for managing the restrictions
on both hosts and gateways. The host recommendations focus on the
routing decisions hosts are attempting, and the gateway recommends
that MacIP gateways reside on a virtual internal network. This
network's zones list contains all zones supported by the MacIP
gateway, and provides a more reliable mechanism for NBP ARP. This
gateway and topology architecture is referred to as Virtual Internal
MacIP (VIM).

[4.1](#).   MacIP Routing Decisions

MacIP 1 recommends that the MacIP host perform no IP routing
decisions whatsoever. There are many advantages to this requirement:

    1.   It simplifies the MacIP host implementation,

    2.   It minimizes the network-specific information that has
            to be sent to or configured into the MacIP host,

    3.   It allows for MacIP to be extended so that Hosts can use
            the services of a MacIP gateway from "out of zone".

Because of restrictions imposed by the design of MacIP, MacIP hosts
are incapable of performing IP Broadcasts and of correctly
interpreting ICMP Redirects, both of which would be expected of a
full IP implementation.

To be specific, it is mandatory that MacIP 1 Hosts should not do any
routing-related operations and should obey the following:

    1.   They must use NBP ARP to resolve all IP addresses, no
            matter what they are, even IP addresses that may be, or

are manifestly in another IP subnet or network, and
includes any possible broadcast IP addresses.

2.   They must ignore all subnet masks, network and subnet
        numbers and all possible "default gateway" addresses.

3.   They should not send IP Datagrams to either the
        AppleTalk or IP address of the Address Assignment Server
        (received as the "name" field of the NBP LookUp).

4.   They should ignore all ICMP Redirect messages and RIP
        packets that they may receive.

The simplest way to disable all off-host routing decisions in an
existing IP (or MacIP) implementation is to set the subnet mask to
"0.0.0.0", and to disable any other "special-case" or error-checking
code that may defeat the intention of this.

The MacIP host code should not assume that the Address Assignment
server and the NBP Proxy ARP module have the same socket address, or
even the same AppleTalk address, as it is permissible for them to be
implemented on different hardware and even on different networks.

4.2. Multiple Gateways in One Zone Limitation

As detailed in section 3.7 (Gateway NBP Proxy ARP), having multiple
MacIP gateways in the same zone will completely prevent MacIP hosts
in that zone from working. The following hacks have been invented to
get around this:

4.2.1. NBP Proxy ARP Directed Port

With this method, the MacIP gateway restricts the operation of NBP
Proxy ARP to requests received from networks connected via particular
physical ports, (usually the LocalTalk port, where the majority of
MacIP hosts usually are). This allows multiple MacIP gateways to
exist in the same zone as long as the network topology guarantees
that there is never more than one MacIP gateway's directed port on
one AppleTalk network. This approach also requires NBP (CNBP) in the
gateway to not answer NBP LookUps for "IPGATEWAY" unless they
originate from the same port that NBP Proxy ARP is enabled on. This
asymmetry plays havoc with network management; devices will be
visible depending on where in the AppleTalk topology devices are
looking from.

4.2.2. NBP Proxy ARP Hop Limit

The DDP Hop Count is available to the NBP Proxy ARP process. It can
refuse to answer any requests from MacIP hosts that aren't zero hops
away (directly connected). This solves some problems at the expense
of restricting the topology. It also will not work if two gateways
share a common network.

4.2.3. Friendly Requests - Dynamic

In this method, the NBP Proxy ARP module will only answer requests
from the SAME MacIP hosts that the Address Assignment module knows
about. The source AppleTalk address of the incoming NBP ARP is
compared against all entries in the Assigned Address table. If the
AppleTalk address is present (and the MacIP host is not registering
its own address), then the NBP Proxy ARP module responds.

This fails completely with MacIP hosts that have Static IP addresses,
as they aren't in the in the table.

4.2.4. Friendly Requests - Static

Various methods have been used to force friendly requests to work
with static hosts. In all cases the gateway has to somehow record the
AppleTalk addresses of MacIP hosts with static addresses. This table
has to be filled with periodic "Reregistration" calls (3.3.4.4), or
"directed wildcard NBP ARP" calls have to be issued to "suspected
hosts". VIM provides a superior solution.

4.2.5. NBP Proxy ARP Not Required

If the MacIP host disobeys MacIP-1 and sends all packets to the MacIP
gateway then NBP Proxy ARP may not be required, but MacTCP (Apple's
MacIP driver for the Macintosh) doesn't allow this.

4.2.6. Other Multiple Gateway Problems

Given a choice of multiple MacIP gateways, MacIP hosts will
invariably pick the worst possible one - the one "furthest away". To
date, MacIP hosts cannot select which MacIP gateway to attach
themselves to. Thus, it is a race condition for NBP responses to
return to the MacIP host. Generally, the first response received is
used. See section y.y.y "Out-of-order NBP" for a discussion.

.   **Out-of-Zone Limitation**

NBP ARP can only work between devices that are in the same zone. In
spite of this, most MacIP implementations try to allow the MacIP
hosts to be in a zone different to that of the MacIP gateway (the
MacIP zone). The problems for the MacIP host in the wrong zone are:

> 1.   Its NBP ARP Registration won't find duplicate IP
>   addresses,
>
> 2.   It can't answer NBP ARPs from other MacIP hosts,
>
> 3.   It can't answer NBP ARPs from the MacIP gateway,
>
> 4.   The gateway "reregistration" function can't find this
>   host.

The following "Out-of-Zone-Hacks" have been used in existing
implementations. We none of them, and suggest VIM instead (described
in the next sub-section).

. **Ask Address Assignment - Dynamic**

MacIP hosts that have requested Dynamic IP addresses have their
AppleTalk and IP addresses in the Address Assignment Module's table.
NBP ARP can be modified to check this table. This is a very
incomplete solution as it only solves problem (3) above, while
ignoring (1), (2) and (4). It can't work with Statically-addressed
hosts at all.

. **NBP ARP** Reverse Resolution

To allow Static-IP address MacIP hosts to operate out-of-zone, it is

possible for the MacIP gateway to "listen" for NBP ARPs (as it does
in 4.1.2 Friendly Requests). These may be the Static hosts attempting
to "register" their IP addresses in the zone of the MacIP gateway
(they should do this in order to discover duplicate registration, but
none do). It may be the Static hosts performing NBP ARP in the MacIP
gateway's zone. In either case, if the MacIP gateway doesn't find
the source AppleTalk address in the table, it then sends a "directed
wildcard NBP ARP" to the source AppleTalk address. Any response will
be directed by CNBP to the "reregistration" part of the
Initialization Module, and will serve to register the address for the
next time.

This fails to work for statically addressed hosts that are running an
IP service application. IP service applications tend not to send
unsolicited packets, and thus no address mapping exists, preventing
address resolution. It still doesn't solve problems (1) and (2)
either.

4.3.3. Glean From MacIP Packets

Some Static hosts may default to sending MacIP packets to the MacIP
gateway. The IP to AppleTalk address mapping can be "gleaned" from
these packets. There are two problems here. Firstly it is
computationally expensive to "glean" every MacIP packet. Secondly it
relies on the host sending the packet to the gateway, and not all do.
It doesn't work with hosts running a server application, as they
don't send any gleanable MacIP packets.

Gleaning can partly solve the problem that reregistration can't work
with out-of- zone hosts - the next MacIP packet from the MacIP host
after a gateway restart will update the table.

4.4.   Virtual Internal MacIP Recommendation

We recommend that MacIP gateways implement a virtual internal network
that has no physical port associated with it, but has a network range
and zones list. The zone list contains all the zones that MacIP
hosts are going to reside. Then, the MacIP gateway is made visible
in all of those zones by registering itself through NBP to all MacIP
hosts in those zones. If the MacIP Host is not in the same zone as
the MacIP Gateway, then you don't get in.

This simplifies everything back to "Classic 1986 MacIP" which we all
have code for. All existing MacIP host code works, both "in" and
"out-of" zone (because there aren't any out-of-zones). Pretty much
all of the existing MacIP Gateway code should be able to remain "as-
is" as well, and should be straight-forward to document and
instrument.

It is possible to make the "VIM zone list acquisition" automatic.
When a new "MacIP Zone" is found (by a MacIP host trying to
register), the gateway uses RTMP to "poison" the old VIM network
range (let's say it was AppleTalk network 10-10), creates a new VIM
network that overlaps the old one (say network 10-11) with all the
old zones and the new one in it, and then advertises that with RTMP.
Disabling "automatic zone list acquisition" counts as a marketable

"security feature".

We could then optionally add Phil Budne's idea of having MacIP
Gateways search for other MacIP Gateways (using NBP to look for
"=:IPGATEWAY@zzz"), and then send RIP packets to them - we've just
solved all of the tricky "RIP-in-MacIP" problems too.

For the "efficiency purists" who demand "minimum path" delivery
between MacIP hosts that are in different zones, that's now easy to
support too. In this case, NBP Proxy ARP would look in its mapping
table for the IP address in question, and use the mapped AppleTalk
address in the NBP Response's Entity address fields. This
effectivley provides an address translation service, or could be
considered NBP Proxy ARP redirect.

5.   AppleTalk Basics and Variations

For those not familiar with AppleTalk, this section gives a very
brief summary of the parts of AppleTalk used by MacIP. The reference
for AppleTalk is "Inside AppleTalk, Second Edition", published by
Addison Wesley.

5.1.   AppleTalk Addresses

Devices on an AppleTalk Internet are uniquely identified by a 16-bit
network number combined with an 8-bit node number. These addresses
are handled very similarly to the net and host part of a Class C IP
address. MacIP has no special requirements on AppleTalk addresses.

5.2.   AppleTalk Zones

AppleTalk networks are grouped together into named collections called
Zones. This is implemented in the routers responsible for the
network numbers by associating a Zone Name (or list of zones for
extended networks) with each network. Zone names form the user-
visible topology of AppleTalk Internets, hiding the actual network-
level topology.

5.3.   Name Binding Protocol

NBP provides registration and location services for named entities

within zones. A service entity begins by attempting to register a
"name" and a "type" with the local NBP software. NBP places the
name:type combination into a local registry, so their nodes may

locate it, and then (with the cooperation of the local router)
broadcasts "LookUp" packets on every network that is associated with
the host's zone. If the name:type is already registered in that or
some other host, a "LookUp Reply" packet will be received by NBP and
the registration attempt fails. Generally, the service will modify
the its name, and re-attempt registration. If no LookUp Replies are
received, then the registration is considered successful.

Once a name:type is registered, NBP will answer searches made by
other devices for that name:type, and will supply the AppleTalk
address (net:node:socket) of the registered entity. Wildcard LookUps
are permitted on both the name and type fields.

5.3.1. Strict NBP

The previously-described NBP is the type implemented by the Macintosh
Computer OS. It is characterized by "Active NBP Registration" where
NBP always performing a "uniqueness-search" on registration, and
"Unconditional NBP Replies" where NBP unconditionally answers all NBP
LookUps that match registered entities.

5.3.2. Loose NBP

There are a lot of ways to abuse NBP and to step outside the purposes
for which it was written. The following are some of the ways that
have been found to abuse it, collectively called "Loose NBP". The
problems caused are mainly those of confusion, both to network
managers and to network management software.

5.3.2.1.   Passive NBP Registration

Some NBP implementations perform "Passive NBP Registration" by
skipping the "uniqueness search". For the case of registering single
unique entities this can only be described as poor practice, as it
will fail to detect duplicate registration. It may also confuse
network managers who are monitoring the device to see if it is
working properly.

In the case of implementing NBP Proxy ARP it is impractical to
"Actively Register" the 4,261,412,864 IP addresses that the MacIP
gateway is proxying for.

5.3.2.2.   Conditional NBP Replies

NBP can also be abused to allow "Conditional NBP Replies" (CNBP)

where the generation of the NBP LookUp Reply does not depend solely
on the contents of the local NBP Registry, but depends on the
requesting device, or the particulars on what is being asked for.
This isn't possible on a Macintosh as NBP is built into the OS. Again
NBP Proxy ARP requires this.

5.3.2.3.   Out-of-order NBP

A packet monitor observing an NBP transaction would expect to see the
following operations in the following order, and may in fact depend
on the order to correctly report the operation:

   1.   MacIP host wishing to search for a particular named
           entity within its own zone sends NBP BrRq (Broadcast
           Request) to a local AppleTalk router,

   2.   The router rebroadcasts the NBP Query as an NBP LkUp
           (LookUp) on all networks in the requested zone,

   3.   One or more LkUp Replies are sent from the searched-for
           entity to the requesting host.

In the case of a MacIP host searching for a MacIP gateway there
exists a serious problem. The router that the MacIP host sent the
NBP BrRq to is likely to be the most appropriate MacIP gateway.
However while this router/gateway is busy performing step (2) above,
other MacIP gateways in the same zone are likely to be on step (3).
Current MacIP host code will use the first LkUp Reply and will thus
select the inappropriately "remote" gateway.

If the first router reverses steps (2) and (3) above, replying to the
request before rebroadcasting it, then the MacIP host will select it.
It looks weird on a packet monitor though.

5.3.2.4. Port Hopping

NBP is intended to allow a client to search for a service by name,
and to discover the network address which will be used for the
delivery of subsequent datagrams. In the case of a multi-port
service-provider, it is sensible to return the "nearest" AppleTalk
address to the client, in this case the address of the port that the
NBP Reply was returned to the client through. Unfortunately this
port (and address) may not be in the zone that the request was
originally made in. This causes no problems apart from confusion to
network managers again, and should probably be avoided for this
reason.

5.4.   DDP

The Datagram Delivery Protocol is close to the AppleTalk equivalent
of UDP/IP. It implements an "unreliable" Datagram Delivery service,
with the destination address being a socket at a specific net:node
address. DDP packets also have a "type" field which permits another
level of multiplexing on top of the socket multiplexor, but is often
used redundantly with the socket.

5.5.   ATP

The AppleTalk Transaction Protocol adds a request/response/timeout
and retry mechanism on top of DDP packet delivery. Transactions
commence with an ATP Request packet (TREQ) and must be answered by an
ATP Response (TRSP) or the requestor will retry and eventually time
out and report back an error to the client.

6.   Definitions

6.1.   AppleTalk Protocol constants

MacIP MTU   576 bytes

DDP constants
     MacIP packet type   22 (decimal) DDP
     ARP packet type   23 (decimal)

DDP ARP constants
     AppleTalk address type   3 (decimal)

NBP constants
     gateway object type   IPGATEWAY registered IP
     address object type   IPADDRESS LookUp retransmit
     count   4 tries LookUp retransmit interval   5
     seconds

6.2.   Gateway ATP Protocol Constants

ATP Protocol Constants
     ATP retransmit count   4 tries ATP retransmit
     interval   5 seconds

ATP request command codes
     ASSIGN   assign IP address   1 NAME   name
     server   2 (obsolete) SERVER get server
     info   3

ATP response codes
     SUCCESS   same as request code

[7](#). **Glossary**

MacIP
      The encapsulation protocol and associated services.

MacIP-1
      The original MacIP specification as implemented in the KIP code.

MacIP-2
      A future version of MacIP that will allow out-of-zone and
      multiple-gateway operation.

MacIP Host
      A device implementing the host-side of the MacIP protocol,
      usually an Apple Macintosh computer.

MacIP Gateway
      A device implementing the gateway-functions of the MacIP
      protocol. It converts between the MacIP transport-layer and
      those used by the other IP hosts, as well as provides other
      server-type functions.

IP Host
      An IP host on an IP internet, usually not using MacIP, but with
      which MacIP hosts can communicate.

MacIP Packets
      IP datagrams encapsulated in AppleTalk packets that are sent
      between the "Delivery" modules in MacIP hosts and gateways.

MacIP Network
      The collection of MacIP hosts and the MacIP gateway that are in
      direct communication with each other - similar to the concept of
      an IP Subnet.

MacIP Range
      The range of IP addresses configured into a MacIP gateway that
      are considered to belong to the MacIP hosts.

MacIP Dynamic Range
      The IP addresses in the MacIP range that are available for
      automatic assignment to MacIP hosts by the gateway MacIPGP
      module.

Dynamic Address
     An IP address assigned by a MacIP gateway from its Dynamic range
     for the use of a MacIP host.

MacIP Static Range
     The IP addresses in the MacIP range that are available for
     permanent assignment to MacIP hosts by the system administrator.

Static Address
     A fixed IP address assigned by the system administrator to a
     MacIP host. This address must be in the MacIP Static range of
     the host's MacIP gateway.

MacIP Zone
     The AppleTalk zone that the MacIP gateway is situated in, and
     which corresponds to the "reach" of the NBP ARP function.

Local Zone
     The AppleTalk zone that a MacIP host is in.

MacIP Routing Mode
     The MacIP gateway configuration where the MacIP network IP
     addresses are in a different subnet to that of the IP backbone,
     and where the MacIP gateway is acting as an IP router.

MacIP Forwarding Mode
     The MacIP gateway configuration where the MacIP network IP
     addresses are in the same subnet as the IP backbone, and where
     the MacIP gateway is performing Proxy ARP for the MacIP hosts.

In-Zone Mode
     The MacIP host configuration where the host is in the same zone
     as the MacIP gateway (the MacIP zone is the same as the Local
     zone).

Out-of-Zone Mode
     The MacIP host configuration where the host is in a different
     zone to the MacIP gateway (the MacIP zone is not the same as the
     Local zone).

MacIPGP
     The MacIP Gateway Protocol. Used to implement the address
     assignment service, and to forward other information.

NBP ARP
      Method for resolving an IP address into an AppleTalk address.
      Equivalent to Ethernet ARP.

NBP Proxy ARP
      Method by which the MacIP gateway answers NBP ARP requests for
      IP addresses of IP hosts.

NBP ARP Forwarding
      Method by which the MacIP gateway forward NBP ARP requests to
      MacIP hosts that ore located outside of the MacIP zone.

Proxy ARP
      Method by which the MacIP gateway responds to Ethernet ARP
      requests from IP hosts for IP addresses in the MacIP range.

VIM
      Virtual Internal MacIP. This refers to the proposed new MacIP
      gateway architcture. The gatweway implements an internal,
      virtual network, and associates itself with it. If the internal
      network's zones list contain more than one zone name, the MacIP
      gateway registers itself on all of them, providing gateway
      services to all MacIP hosts in those zones.

8. Implementation Notes

This section provides notes and insights to the reader. Its sections
numbers are organized to follow the preceding section numbers.

8.1.2   Intended Audience

It should be noted that members from the various groups mentioned
(host implementors, gateway implementors, system managers, and the
curious) have different preconceived notions about what comprises a
MacIP protocol system. Also, what is acceptable functionality in
undocumented limitations will differ between these groups, and
between members of the groups themselves. Careful attention must be
paid to the fact that TCP/IP is not AppleTalk, and AppleTalk is not
TCP/IP. There are some similarities that are close enough to conceal
the important differences. NBP is nothing like DNS. RIP is
different from RTMP. UDP isn't DDP. Mapping one protocol system to
another presents a significant challenge, and that is what we're
attempting with MacIP. It is very easy for things to go very wrong.

8.2.1.1 Basic Requirements

Implementing MacIP so as to fulfill this requirement as well as the
local with no gateway requirement (which is very rarely used in
practice) is one of the things that makes the protocol so complex.

8.2.3. Protocol Mapping

MacIP follows NBP ARP. The following are two obvious ways to "map"
IP onto AppleTalk at the transport level, but are not followed.

NBP ARP is used instead. This combines some of the worst features of

"Direct Mapping" and "Server Client" without sufficient advantages to
offset it. It also complicates implementation, documentation and
installation. But we're stuck with it.

8.2.3.1.   Direct Mapping

MacIP provides very similar capabilities to Ethernet and Ethernet
ARP, so one possible protocol mapping would be to treat each
AppleTalk network as an IP subnet, with IP addresses within each
subnet being resolved by an equivalent network-wide broadcast
protocol to Ethernet ARP. All routing would be performed by the
MacIP gateways, although the hosts would be required to perform
"this- subnet" type routing decisions.

This was actually implemented early on in the history of MacIP. It
has many advantages. It satisfies the "requirement matrix" of 2.1.1
and its similarity to IP makes it easily understandable and
documentable. The downside is that it requires every AppleTalk
router in an Internet to also be an IP router This complicates the
configuration of an Internet and also consumes IP address space at an
alarming rate. This isn't MacIP-1.

8.2.3.2.   Client-Server

An approach leading to a very simple implementation would be a strict
client- server one, such as the protocols that are already used to
implement DECnet, LAT and SNA services over AppleTalk. MacIP hosts
would use NBP to find the gateway(s) and then establish a "session"
which would allow the gateway to record the AppleTalk address of the
host so it would know how to route a packet back to them.

Advantages would be the ease of implementation, documentation and
debugging. The MacIP hosts wouldn't have to know anything about
routing - they would send all packets to the gateway. It would also
allow MacIP hosts that are anywhere on a large and complex AppleTalk
Internet to use a gateway no matter where it was - there would only
need to be one gateway. It would allow operation across AppleTalk
zones. The downside is that all traffic between two MacIP hosts on
the same network would have to pass through the gateway, and that the
gateway would be required for the protocol. This isn't MacIP-1
either, much the pity.

8.2.4.4.   MacIP Routing Decisions

8.2.4.4.1.   Routing in Standard IP Hosts

An IP host on a single point-to-point link only has one simple
routing decision to make when presented with an IP packet to forward:

     1. Is the destination IP address equal to my IP address?

If it is, the packet is sent "inwards". If not, it is sent out the
link. An IP host connected to single broadcast medium has another
two questions to answer:

     2. Is the destination address within "this" network/subnet?

If it is, the packet can be sent "directly" to the destination. If
it isn't, then the packet has to be sent via a gateway, often a
single "default gateway", the IP address of which is known.

     3. Is the destination address a Broadcast address?

In all cases ARP is used to resolve the selected IP address to a
hardware address. In case (3), ARP will substitute the appropriate
configured hardware broadcast address.

8.2.4.4.2.   Routing in MacIP Hosts

This "broadcast medium behavior" is insufficient for MacIP, as the
Address Assignment protocol sensibly and deliberately provides
neither the subnet mask nor default gateway information. This
behavior should not be defeated (by allowing manual entry of the
data) as it defeats the Macintosh "plug and play" requirement.

Even if Address Assignment did provide this information, the

disparity between the "reach" of NBP ARP and normal DDP broadcast
datagrams prevents a MacIP host from broadcasting an IP datagram to
all hosts in the zone. This is strictly not "required" by IP, but it
is certainly "expected" by some applications.

MacIP hosts SHOULD never perform any routing. This includes anything
to do with subnet masks, broadcast addresses, default gateways, RIP
or ICMP redirects.

8.3.2. MacIP Modules - Introduction

MacIP can be best understood and described if the various functions
are categorized into functional modules.

The following gives the relationship between the IP , MacIP and
AppleTalk modules in the MacIP host:

```
       ........................................
       :           IP Protocol Layer         :
       :.......... | ............. | .......:
                   |               |
       ........... | ............. | ........
       :  ---------+-------- ------+------   :
       :  | Initialization | | Delivery |   :
       :  ----+---------+--- -+--+--------   :
       :      |         |     |  |           :
       :  ----+----   ---+-----+- | MacIP    :
       :  | MIPGP*|   | NBP ARP | | Protocol :
       :  ----+----   -----+----- |          :
       :..... | ......... | .... | .........:
             |           |      |
       ...... | ........ | .... | ..........
       :  ----+----   -----+----   |         :
       :  | ATP  |   |  NBP  |   | AppleTalk:
       :  ----+----   -----+----   | Protocol :
       :      |           |      |          :
       :  ----+----------+------+--------   :
       :  | DDP (Datagram Delivery Proto)|  :
       :  ---------------+--------------   :
```

```
    :                    |                 :
    :  ---------------+--------------   :
    :  | LAP (Link Access Protocol) |   :
    :  ---------------+--------------   :
    :...............  | ...............:
                      |
    ...............   | ..................
    :        AppleTalk Hardware         :
    :..................................:
(*) "MIPGP" is short for "MacIPGP".
```
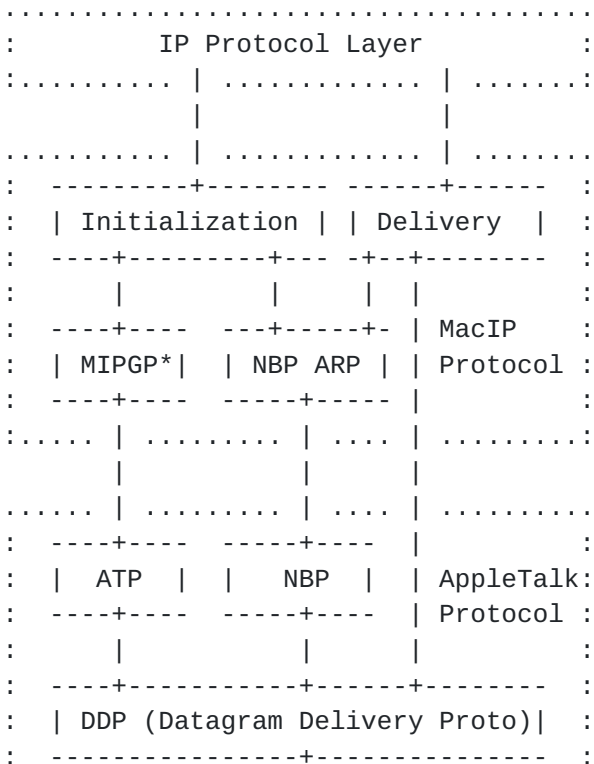
Figure 4. MacIP Host Implementation

The following gives the relationship between the IP , MacIP and
AppleTalk modules in the MacIP gateway:

```
     ....................................................
     :      IP Protocol Layer    +-----( IP Router )----+    :
     :.........  | ............  | .................... | ...:
                 |              |                       |
     ..........  | ...........  | .................     |
     :           |              |                 :     |
     :  ---------+-------- ------+------  MacIP    :     |
     :  | Initialization | | Delivery |  Protocol  :     |
     :  ----+------+------ --------+-+--           :     |
     :      |      |              | |             :     |
     :  ----+----- | ------------- | |    ---------  :     |
     :  | Assign | | | NBP Proxy | | |    | Proxy |  :     |
     :  ----+--+-- | ------+------ | |    |  ARP  |  :     |
     :      |   \__|___      |      | |    ----+----  :     |
     :      |      |   \     |     / |        |       :     |
     :  ----+----  | ---+--+-----+-- |        \       :     |
     :  | MIPGP |  | | NBP ARP      | |         |      :     |
     :  ----+----  | ---+---------- |          |      :     |
```
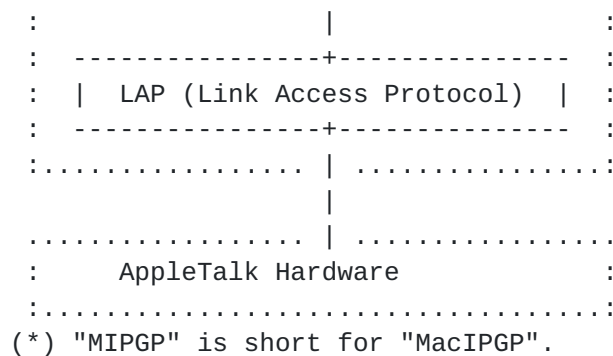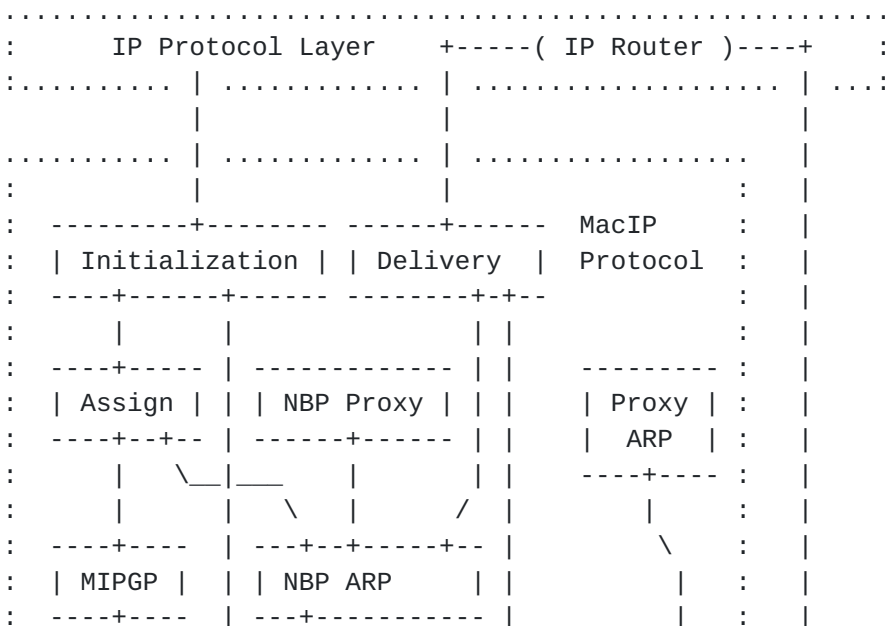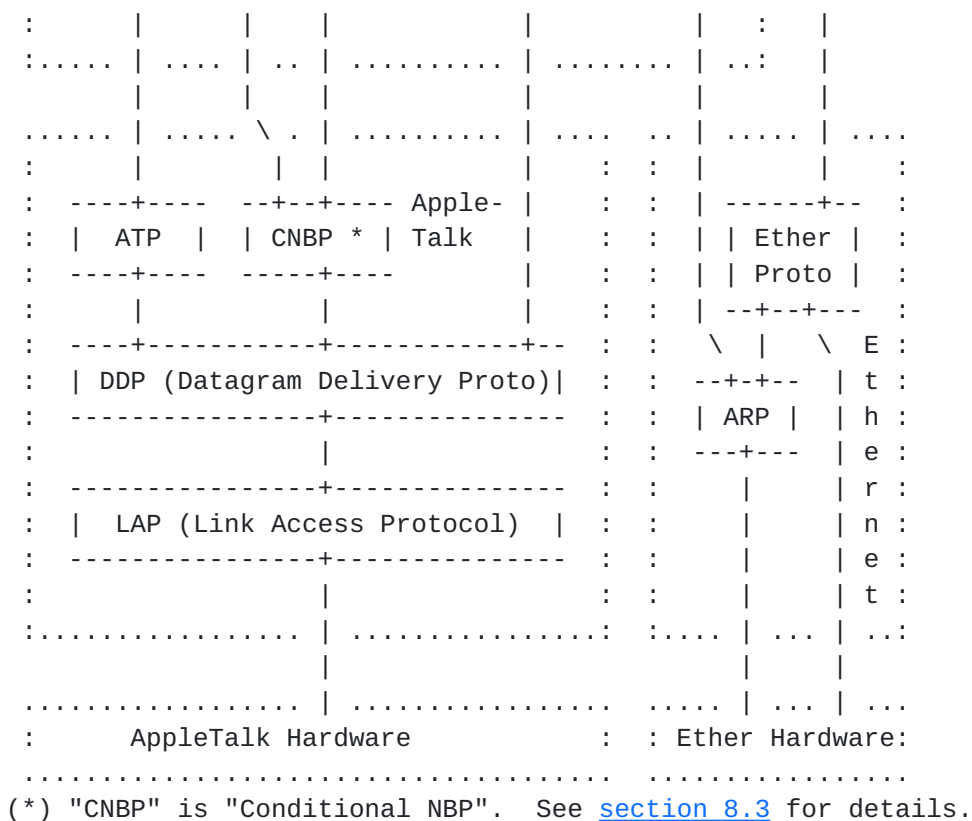
```
   :      |      |     |           |         |   :    |
   :..... |  .... | .. | .......... | ........ | ..:    |
          |      |     |           |          |       |
   ...... | ..... \ . | .......... | ....  .. | ..... | ....
   :      |       | | |           | :  :  |     |    :
   :  ----+----   --+--+---- Apple- |    :  :  | ------+--  :
   :  | ATP   |  | CNBP * | Talk  |    :  :  | | Ether |  :
   :  ----+----  -----+----       |    :  :  | | Proto |  :
   :      |          |           |    :  :  | --+--+---  :
   :  ----+----------+-----------+--  :  :   \ |   \  E :
   :  | DDP (Datagram Delivery Proto)| :  : --+-+--  | t :
   :  ---------------+--------------  :  : | ARP |  | h :
   :               |                :  : ---+---  | e :
   :  ---------------+--------------  :  :    |     | r :
   :  |  LAP (Link Access Protocol) | :  :    |     | n :
   :  ---------------+--------------  :  :    |     | e :
   :               |                :  :    |     | t :
   :................ | ...............:  :... |  ... | ..:
                   |                        |     |
   ................ | ...............  ..... | ... | ...
   :       AppleTalk Hardware         :  : Ether Hardware:
   ......................................  ................
   (*) "CNBP" is "Conditional NBP".  See section 8.3 for details.

   Figure 5.  MacIP Gateway Implementation
```

8.3.2.1. Configuration Required For MacIP Hosts

The terms static and dynamic SHOULD be used consistently in the user
interface.

If the host has multiple MacIP and/or IP interfaces, then a mechanism
is required to allow selection between them. It is important to
distinguish plainly between MacIP- based and "Native" IP connections.

8.3.2.2.1. Locating the MacIP gateway's Address Assignment Server

The implementation SHOULD not take any notice of the returned NVE
name field in the NBP response. However, it should be noted that
many implementations expect to find the IP address corresponding to
the Server in dotted decimal format.

The implementation SHOULD record the full AppleTalk address returned

in the NBP response (including the returned socket) and use it in
subsequent transactions with the Server. It SHOULD not simply assume
that the Server is on DDP socket 72. However, there are many existing
implementations that make this assumption.

8.3.2.4.2.   Registration of Address Assignment Server

Unfortunately many MacIP host implementations wrongly rely on the
name being an IP address, so for compatibility with these the use of
the IP address as the name is "recommended". A simple two-port MacIP
gateway configured in "forwarding" mode may only have one IP address
to use for this purpose, but a multi-IP-port MacIP gateway may suffer
an embarrassment of choices, so the question arises as to which IP
address to use for this purpose. Fortunately this choice can be
narrowed by the existence of bugs in some MacIP host implementations
that can require the name of the Server to be an IP address in the
same "subnet" as the IP address of the MacIP host. Good luck!

8.3.4.1.   NBP ARP - Details

The aging of ARP cache entries is required. The mobility of
Macintoshes makes this particularly important. Any algorithm may be
used as long it is at least as good as the following.

Each use of the ARP cache entry should reset a "usage" timer. When a
new entry is to be put into the cache, it might be full (or the
bucket associated with the hashing function might be full). The
entry with the oldest "usage" timer should be the one chosen to be
replaced.

ARP cache entries should be "confirmed" by sending a single NBP
Confirm directly to the AppleTalk address in the cache entry once a
minute. If no response is received after five requests the entry

should be deleted.

The NBP Cache should be capable of being flushed on request by other
modules.

8.3.5. Delivery

If the "Delivery" module experiences a hard error (the packet
transport code cannot transmit the packet, and returns an error) when
attempting to transmit a MacIP packet, then it is recommended that
the NBP ARP cache entry for the destination IP address should be

flushed and the transmit retried. This is to recover from MacIP
gateway restarts where the gateway has picked a different node
address to the one it previously had.

8.3.6. MacIP Routing Decisions

The requirement in section 3.6 that MacIP hosts should always use NBP
ARP for all destination IP addresses is widely disobeyed in actual
practice. Most MacIP host implementations disobey this fundamental
specification, as the requirements of being an IP host were not well
understood at the time.

It is thus expected that some MacIP-1 hosts will send some or all
packets directly to the AppleTalk address of the discovered MacIP
gateway for delivery. However it should be noted that if the MacIP
gateway restarts, it may acquire a different AppleTalk node address
to the one it had prior to the restart. If the host is sending MacIP
packets to the old gateway address, they will not be delivered. The
MacIP host SHOULD take measures to recover from this by following
address cache aging and updating algorithms as discussed in the Host
Requirements RFC [10]. This applies to NBP ARP caches as well.

8.3.7. Gateway NBP Proxy ARP

It is the implementation of this service that causes the most
problems in MacIP. If the NBP Proxy ARP module wrongly responds to
an IP addresses that is assigned to a MacIP host, then the response
from the gateway will look to the host attempting to register its
address as a duplicate registration.

This results in the restriction that with MacIP-1 there must never be
multiple MacIP gateways in the one zone configured with different
MacIP Ranges, as they will defeat registration attempts by MacIP
hosts that have been assigned addresses by another gateway. Then
again, two MacIP gateways can't be configured with the same MacIP
range, as normal IP routing (Routing case) and Proxy ARP (Forwarding
case) would fail to route packets under these circumstances.
Therefore there can't be more than one MacIP gateway in any one zone.

This is the "Multiple Gateways in the One Zone" problems, and will be
addressed later.

8.5.3. Name Binding Protocol

NBP can be though of implementing a form of "zone-wide broadcast".
The only thing that can be broadcast is a search for a named entity -

it is not possible to broadcast data-containing packets. This is
important when considering mapping one network protocol (such as IP)
onto an AppleTalk Internet.

It is not possible to discriminate a "registration attempt" NBP
LookUp from a "searching for" one. This makes the implementation of
NBP Proxy ARP far more difficult than you would first suspect.

9.   Issues

9.1   IP Routing Issues

Phil pointed out that we didn't discuss IP hop count or checksum
issues. Since we are subject to rfc1122 (naturally), should we still
discuss it? Furthermore, what do y'all think of bumping [or not
bumping] the hop count if we are just in 'forwarding mode'?

Also, Phil asked if forwarding gateways need to intercept ICMP
redirects. IP routers must ignore all ICMP redirects, as they're
meant to have their routing tables updated by a "more reliable"
method. Thus, all ICMP redirects MUST be ignored by the gateway, and
MacIP hosts SHOULD ignore all ICMP redirects too. Should this go
into this document? Where?

9.2   More Hacks

Jonathan described the following additional 'hacks'. Should they be
in this document, and if so, where?

(1) The EtherGate has one ethernet port and 2 localtalk ports. We
doclient IP address assignment out of a single range of addresses for
both localtalk ports. This means that besides it's usual
weirdnesses, we had to make NBP-proxy-ARP work across both localtalk
ports if they're in different zones. When a Mac tries to confirm
that it can use its IPADDRESS the EtherGate forwards the NBP Lookup
to the other port and changes the zone name. Yuck.

(2) When the EtherGate receives an NBP-ARP for an IPADDRESS not in
its client range and on the same (sub)net as the EtherGate itself, it
IP ARPs on the ethernet side to see if it can reach the IP host
before responding on the NBP side.

Would someone with a good familiarity of Proxy ARP routers like to
contribute - there may be some good practice in existing Proxy ARP
routers that we can adopt, copy, steal documentation from etc.

One last note, I assume the implementation notes will include hints
for the host (Mac client) implementor as well as the gateway
implementor? We should clearly point out pitfalls and suggestions
for both!

Any host-implementors like to contribute a few paragraphs?

9.3   MacIP Host Recommendations - Another Idea

From: Tom Evans

The MacIP _HOST_ doesn't need a "session" with anything.

Q. What is this "session" actually FOR?

A. It is established at MacIP Host startup for the sole purpose of
getting a Dynamic IP Address assigned.

Q. Does the MacIP Host have to MAINTAIN the "session" with the
Address Assignment Service?

A. NO.

Q. What is the ADDRESS of the IPGATEWAY?

A. I've been reading Radia's "Interconnections" too. By her
definition in section 2.3, an AppleTalk "address" doesn't fit her
definition of an "address". The node-part of an AppleTalk address
CHANGES.

So the "address" of the IPGATEWAY starts out as its NAME, which is
initially "=:IPGATEWAY@*" ("any gateway"). The MacIP Host picks a
particular one (which is now "aa.bb.cc.dd:IPGATEWAY@*"), which fits
the definition of a NAME (but has an IP ADDRESS embedded in it).
This is the only real "fixed" representation of the "address". The
AppleTalk address MAY CHANGE, so it shouldn't be stored. If the
IPGATEWAY is required for some reason, it should probably be searched
for again at the time that it is needed.

The IP Address ("aa.bb.cc.dd" above) is a better "fixed address" than
the AppleTalk address is. It can be resolved to an AppleTalk address
when required by existing (NBP ARP) code.

Q. "My code treats IPGATEWAY as a "default IP gateway", so I have to

keep its address".

A. XXXXXXXXXXX (removed by censors). Nothing else that I know of in a Mac stores AppleTalk addresses - they're too volatile. The LaserWriter driver stores the NAME of the printer. The AppleTalk address "A_Router" stored by any Mac is never more than 40 seconds old. ASP sessions store the AppleTalk address, but they're continuously maintained sessions that tell you when they break.

The logical thing to do is to store the MacIP Gateway's IP Address and NOT its AppleTalk Address. This will make a lot more sense in the host's existing IP Routing table after all. No "special case MacIP code" required in the IP layer.

Use NBP ARP to resolve ALL IP addresses passed down from the IP layer, including the one for the Default Gateway. The ARP/NBP-ARP code should have timeouts and confirmation. This will recover nicely if the IPGATEWAY changes its AppleTalk address, which it is "allowed" to do.

Q. How does the MacIP Gateway keep ITS session information (required for NBP Proxy ARP)?

A. By REREGISTRATION at gateway startup, by answering MacIPGP requests, by "tickling" them thereafter and by "probing" suspected "clients" that it receives NBP ARP requests from. It isn't the MacIP Host's problem.

So the MacIP Host shouldn't keep any information that it doesn't need to, and thus it shouldn't be in the MIB. If it is, then it should be the IP address that is stored and not the AppleTalk address.

Of course the above seems to be contradicted in the MacIP doc in sections 5.2.5 and 6.2 where it says that the MacIP Host should be able to receive multiple IPGATEWAY responses and then choose the "best" one. However, once the MacIP Host HAS an IP address, it doesn't need the Address Assignment Server anymore, and it should probably throw all the information away. So if the multiple gateway's addresses WERE accessible via SNMP, then they'd only be there for less than a second.

10. Acknowledgments

Bill Croft, for the initial implementation of this protocol in the SEAGATE gateway at Stanford University and for the documents provided with the KIP code.

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Brad Parker and Josh Littlefield. This document is directly based on theirs written in February 1990.

John Veizades, for a version of this document and for being the Chair of the Apple- IP working group.

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[12]. Expiration Date

   This Internet Draft will expire in May 1993.

[13]. Security

   This document does not discuss security in any manner.

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