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ARP and IP Broadcast over HIPPI-800

Status of this Memo

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Abstract

This document specifies a method for resolving IP addresses to ANSI High-Performance Parallel Interface (HIPPI) hardware addresses and for emulating IP broadcast in a logical IP subnet (LIS) as a direct extension of HARP. This memo defines a HARP that will interoperate between HIPPI-800 and HIPPI-6400 (also known as Gigabyte System Network, GSN). This document (when combined with RFC-2067 "IP over HIPPI") obsoletes RFC-1374.

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1. Introduction

The ANSI High-Performance Parallel Interface (HIPPI) is a dual simplex data channel. HIPPI can send and receive data simultaneously at 800 or 1600 megabits per second. Between 1987 and 1997, the ANSI X3T11.1 HIPPI working group (now known as NCITS T11.1) Standardized five documents that bear on the use of HIPPI as a network interface. They cover the physical and electrical specification (HIPPI-PH [1]), the framing of a stream of bytes (HIPPI-FP [2]), encapsulation of IEEE 802.2 LLC (HIPPI-LE [3]), the behavior of a physical layer switch (HIPPI-SC [4]) and the physical-level and optical specification (HIPPI-Serial [5]). HIPPI-LE also implies the encapsulation of Internet Protocol[5]. The reader should be familiar with the ANSI HIPPI documents. Approved ANSI NCITS

standards are available from ANSI (http://www.ansi.org). The working documents of the T11.1 working group may be obtained from the T11 web page (http://www.t11.org/).

HIPPI switches can be used to connect a variety of computers and peripheral equipment for many purposes, but the working group stopped short of describing their use as Local Area Networks. RFC-2067 [15] describes the encapsulation of IP over HIPPI-800. This memo takes up where the working group and RFC-2067 [15] left off and defines address resolution and LIS IP broadcast emulation for HIPPI-800 networks.

While investigating possible solutions for HARP it became evident that IP broadcast could easily be emulated for both HIPPI-800 and HIPPI-6400 hardware types. This is useful since HIPPI switches are not required to implement broadcast but many standard networking protocols rely on broadcast. This memo therefore further addresses the emulation of LIS IP broadcast as an extension of HARP.

2 Terminology

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in RFC-2119 [18].

3. Definitions

3.1 Global concepts used

In the following discussion, the terms "requester" and "target" are used to identify the port initiating the address resolution request and the port whose address it wishes to discover, respectively. If not all switches in the LIS support broadcast then there will be a HARP server providing the address resolution service and it will be the source of the reply. If on the other hand all switches support broadcast then the source address of a reply will be the target’s target address.

Values are decimal unless otherwise noted. Formatting follows IEEE 802.1A canonical bit order and and HIPPI-FP bit and byte order.

3.2 Glossary

Broadcast

A distribution mode which transmits a message to all ports. Particularly also the port sending the message.

Classical/Conventional

Both terms are used to refer to networks such as Ethernet, FDDI, and other 802 LAN types, as distinct from HIPPI-SC LANs.

Destination

The HIPPI port that receives data from a HIPPI Source.

HARP

HARP describes the whole set of HIPPI address resolution encodings and algorithms defined in this memo. HARP is a combination and adaptation of the Internet Address Resolution Protocol (ARP) RFC-826 [13] and Inverse ARP (InARP) [7] (see section 5). HARP also describes the HIPPI specific version of ARP [10] (i.e. the protocol and the HIPPI specific encoding).

HARP table

Each host has a HARP table which contains the IP to hardware address mapping of IP members.

HIPPI-Serial

An implementation of HIPPI in serial fashion on coaxial cable or optical fiber. (see [5])

HRAL

The HARP Request Address List. A list of ULAs to which HARP messages are sent when resolving names to addresses (see section 4.2).

Hardware (HW) address

The hardware address of a port consisting of an I-Field and an optional ULA (see section 6.2). Note: the term port as used in this document refers to a HIPPI port and is roughly equivalent to the term "interface" as commonly used in other IP documents.

Host

An entity, usually a computer system, that may have one or more HIPPI ports and which may serve as a client or a HARP server.

Port

An entity consisting of one HIPPI Source/Destination dual simplex pair that is connected by parallel or serial HIPPI to a HIPPI-SC switch and that transmits and receives IP datagrams.

PIBES

The Protocol for Internet Broadcast Emulation Server (see section 7).

Switch Address

A value used as the address of a port on a HIPPI-SC network. It is transmitted in the I-field. HIPPI-SC switches map Switch Addresses to physical switch port numbers. The switch address is extended with a mode byte to form an I-Field (see [4] and 6.2.2)

Source

The HIPPI port that generates data to send to a HIPPI Destination.

Universal LAN MAC Address (ULA)

A 48-bit globally unique address, administered by the IEEE, assigned to each port on an Ethernet, FDDI, 802 network, or HIPPI-SC LAN.

4. IP Subnetwork Configuration

4.1 Background

ARP (address resolution protocol) as defined in [12] was meant to work on the 'local' cable. This definition gives the ARP protocol a local logical IP subnet (LIS) scope. In the LIS scenario, each separate administrative entity configures its hosts and routers within the LIS. Each LIS operates and communicates independently of other LIS's on the same HIPPI network.

HARP has LIS scope only and serves all ports in the LIS. Communication to ports located outside of the local LIS is usually provided via an IP router. This router is a HIPPI port attached to the HIPPI network that is configured as a member of one or more LIS's. This configuration MAY result in a number of disjoint LIS's operating over the same HIPPI network. Using this model, ports of different IP subnets SHOULD communicate via an intermediate IP router even though it may be possible to open a direct HIPPI connection between the two IP members over the HIPPI network. This is a consequence of using IP and choosing to have multiple LIS's on the same HIPPI fabric.

By default, the HARP method detailed in section 5 and the classical LIS routing model MUST be available to any IP member client in the LIS.

4.2 HIPPI LIS Requirements

The requirement for IP members (hosts, routers) operating in a HIPPI LIS configuration is:

- All members of the LIS SHALL have the same IP network/subnet address and address mask [6].

The following list identifies the set of HIPPI-specific parameters that MUST be implemented in each IP station connected to the HIPPI network:

- HIPPI Hardware Address:

  The HIPPI hardware address of an individual IP port MUST contain the port's Switch Address (see section 9). The address SHOULD also contain a non-zero ULA address. If there is no ULA then that field MUST be zero.

- HARP Request Address List (HRAL):

  The HRAL is an ordered list of two or more addresses identifying the address resolution service(s). All HARP clients MUST be configured identically, i.e. all ports MUST have the same addresses(es) in the HRAL.

  The HRAL MUST contain at least two HIPPI HW addresses identifying the individual HARP service(s) that have authoritative responsibility for resolving HARP requests of all IP members located within the LIS.

  By default the first address MUST be the reserved address for broadcast, i.e. the address for "IP traffic conventionally directed to the IEEE 802.1 broadcast address: 0xFE1" [4]. The ULA for this HARP service entry SHALL be FF:FF:FF:FF:FF:FF.

  It is REQUIRED that the second address be the address for "Messages pertaining to (the) ... address resolution requests: 0xFE0" [4]. The ULA for this HARP server entry is 00:00:00:00:00:00.

Therefore, the HRAL entries are sorted in the following order:

```
  1st **  : broadcast address            (0x07000FE1 FF:FF:FF:FF:FF:FF),
  2nd **  : official HARP server address (0x07000FE0 00:00:00:00:00:00),
  3rd & on: any additional HARP server addresses will be sorted in
            decreasing order of the 12bit destination switch
            address portion of their I-Field (see section 6.2).
  ** REQUIRED
```

Within the restrictions mentioned above and in Section 6.2.2, local administration choose address(es) for the additional HARP services which they will put into the HRAL.

An example of such a list:

```
   1st entry: 0x07000FE1 FF:FF:FF:FF:FF:FF
   2nd entry: 0x07000FE0 00:00:00:00:00:00
   3rd entry: 0x07000001 <Alternate-HARP-server-ula>
   ...
```

Manual configuration of the addresses and address lists presented in this section is implementation dependent and beyond the scope of this memo.

5. HIPPI Address Resolution Protocol - HARP

Address resolution within the HIPPI LIS SHALL make use of the HIPPI Address Resolution Protocol (HARP) and the Inverse HIPPI Address Resolution Protocol (InHARP). HARP provides the same functionality as the Internet Address Resolution Protocol (ARP). HARP is based on ARP which is defined in RFC-826 [13]. Knowing the Internet address, conventional networks use ARP to discover another port's hardware address. HARP presented in this section further specifies the combination of the original protocol definitions to form a coherent address resolution service that is independent of the hardware's broadcast capability.

InHARP is based on the original Inverse ARP (InARP) protocol presented in [7]. Knowing its hardware address, InARP is used to discover the other party's Internet address.

This memo further REQUIRES the PIBES (see section 7 below) extension to the HARP protocol, guaranteeing broadcast service to upper layer protocols like IP.

Internet addresses are assigned independent of ULAs and switch addresses. Before using HARP, each port MUST know its IP and its hardware addresses. The ULA is optional but is RECOMMENDED if bridging to conventional networks is desired.

5.1 HARP Algorithm

This section defines the behavior and requirements for HARP implementations on both broadcast and non-broadcast capable HIPPI-SC networks. HARP creates a table in each port which maps the IP address of each port to a hardware address, so that when an application requests a connection to a remote port by its IP address, the hardware address can be determined, a correct HIPPI-LE header can be built, and a connection to the port can be established using the correct Switch Address in the I-field.

HARP is a two phase protocol. The first phase is the registration phase and the second phase is the operational phase. In the registration phase the port detects if it is connected to broadcast hardware or not. The InHARP protocol is used in the registration phase. In case of non-broadcast capable hardware, the InHARP Protocol will register and establish a table entry with the server. The operational phase works much like conventional ARP with the exception of the message format.

5.1.1 Selecting the authoritative HARP service

Within the HIPPI LIS, there SHALL be an authoritative HARP service. At each point in time there is only one authoritative HARP service.

To select the authoritative HARP service, each port needs to determine if it is connected to a broadcast network.

The port SHALL send an InHARP_REQUEST to the first address in its HRAL (0x07000FE1 FF:FF:FF:FF:FF:FF). If the port sees its own InHARP_REQUEST, then it is connected to a broadcast capable network. In this case, the rest of the HRAL is ignored and the authoritative HARP service is the broadcast entry.

If the port is connected to a non-broadcast capable network, then the port SHALL send the InHARP_REQUEST to all of the remaining entries in the HRAL. Every address which sends an InHARP_REPLY is considered to be a responsive HARP server. The authoritative HARP service SHALL be the HARP server which appears first in the HRAL.

The sequence of the HRAL is only important for deciding which address will be the authoritative one. On a non-broadcast network, the port is REQUIRED to keep "registered" with all HARP server addresses in the HRAL (NOTE: not the broadcast address since it is not a HARP server address). If for instance the authoritative HARP service is non-responsive, then the port will consider the next address in the HRAL as a candidate for the authoritative address and send an InHARP_REQUEST.

The authoritative HARP server SHOULD be considered non-responsive when it has failed to reply to: (1) one or more registration requests by the client (see section 5.1.2 and 5.2), (2) any two HARP_REQUESTs in the last 120 seconds or (3) if an external agent has detected failure of the authoritative HARP server. The details of such an external agent and its interaction with the HARP client are beyond the scope of this document. Should an authoritative HARP server become non-responsive, then the registration process SHOULD be restarted. Alternative methods for choosing an authoritative HARP service are not prohibited.

5.1.2 HARP registration phase

HARP clients SHALL initiate the registration phase by sending an InHARP_REQUEST message using the addresses in the HRAL in order. The client SHALL terminate the registration phase and transition into the operational phase, either when it receives its own InHARP_REQUEST or when it receives an InHARP_REPLY from at least one of the HARP servers and when it has determined the authoritative HARP service as described in section 5.1.1.

When ports are initiated they send an InHARP_REQUEST to the authoritative address as described in section 5.1.2. The first address to be tried will be the broadcast address "0x07000FE1 FF:FF:FF:FF:FF:FF". There are two outcomes:

1. The port sees its own InHARP_REQUEST: then the port is connected to a broadcast capable network. The first address becomes and remains the authoritative address for the HARP service.

2. The port does not receive its InHARP_REQUEST: then the port is connected to a non-broadcast capable network.

In the second case, the port SHALL choose the next address in the HRAL as a candidate for a authoritative address and send an InHARP_REQUEST to that address: (0x07000FE0 00:00:00:00:00:00).

- If the port receives its own message, then the port itself is the HARP server and the port is REQUIRED to provide broadcast services using the PIBES (see section 7).

- If the port receives an InHARP_REPLY, then it is a HARP client and not a HARP server.

In both cases, the current candidate address becomes the authoritative HARP service address.

If the client determines it is connected to a non-broadcast capable network then the client SHALL continue to retry each non-broadcast HARP server address in the HRAL at least once every 5 seconds until one of these two termination criteria are met for each address.

InHARP is an application of the InARP protocol for a purpose not originally intended. The purpose is to accomplish registration of port IP address mappings with a HARP server if one exists or detect hardware broadcast capability.

If the HIPPI-SC LAN supports broadcast, then the client will see its own InHARP_REQUEST message and SHALL complete the registration phase. The client SHOULD further note that it is connected to a broadcast capable network and use this information for aging the HARP server entry and for IP broadcast emulation as specified in sections 5.4 and 5.6 respectively.

If the client doesn't see its own InHARP_REQUEST, then it SHALL await an InHARP_REPLY before completing the registration phase. This will also provide the client with the protocol address by which the HARP server is addressable. This will be the case when the client happens to be connected to a non-broadcast capable HIPPI-SC network.

5.1.3 HARP operational phase

Once a HARP client has completed its registration phase it enters the operational phase. In this phase of the protocol, the HARP client SHALL gain and refresh its own HARP table which contains the IP to HW address mapping of IP members by sending HARP_REQUESTS to the authoritative address in the HRAL and receiving HARP_REPLYs. The client is fully operational during the operational phase.

In the operational phase, the client's behavior for requesting HARP resolution is the same for broadcast or non-broadcast networks.

The target of an address resolution request updates its address mapping tables with any new information it can find in the request. If it is the target port it SHALL formulate and send a reply message. A port is the target of an address resolution request if at least ONE of the following statements is true of the request:

1. The port's IP address is in the target protocol address field (ar$tpa) of the HARP message.

2. The port's ULA (if non-zero), is in the ULA part of the Target Hardware Address field (ar$tha) of the message.

3. The port's switch address is in the Target Switch Address field of Target Hardware Address field (ar$tha) of the message (see section 6.2.2).

4. The port is a HARP server.

NOTE: It is RECOMMENDED that all HARP servers run on a ports which each have a non-zero ULA.

5.2 HARP Client Operational Requirements

The HARP client is responsible for contacting the HARP server(s) to have its own HARP information registered and to gain and refresh its own HARP entry/information about other IP members. This means, as noted above, that HARP clients MUST be configured with the hardware address of the HARP server(s) in the HRAL.

HARP clients MUST:

1. When an interface is enabled (e.g. "ifconfig <interface> up" with an IP address) or assigned the first or an additional IP address (i.e. an IP alias), the client SHALL initiate the registration phase.

2. In the operational phase the client MUST respond to HARP_REQUEST and InHARP_REQUEST messages if it is the target port. If an interface has multiple IP addresses (e.g., IP aliases) then the client MUST cycle through all the IP addresses and generate an InHARP_REPLY for each such address. In that case an InHARP_REQUEST will have multiple replies. (Refer to Section 7, "Protocol Operation" in RFC-1293 [7].)

3. React to address resolution reply messages appropriately to build or refresh its own client HARP table entries. All solicited and unsolicited HARP_REPLYs from the authoritative HARP server SHALL be used to update and refresh its own client HARP table entries.

   Explanation: This allows the HARP server to update the clients when one of server's mappings change, similar to what is accomplished on Ethernet with gratuitous ARP.

4. Generate and transmit InHARP_REQUEST messages as needed and process InHARP_REPLY messages appropriately (see section 5.1.2 and 5.6). All InHARP_REPLY messages SHALL be used by the client to build or refresh its HARP table entries. (Refer to Section 7, "Protocol Operation" in [7].)

If the registration phase showed that the hardware does not support broadcast, then the client MUST refresh its own entry for the HARP server, created during the registration phase, at least once every 15 minutes. This can be accomplished either through the exchange of a HARP request/reply with the HARP server or by repeating step 1. To decrease the redundant network traffic, this timeout SHOULD be reset after each HARP_REQUEST/HARP_REPLY exchange.

Explanation: The HARP_REQUEST shows the HARP server that the client is still alive. Receiving a HARP_REPLY indicates to the client that the server must have seen the HARP_REQUEST.

If the registration phase shows that the underlying network supports broadcast, then periodic InHARP_REQUEST/InHARP_REPLY operations of step 4 are NOT REQUIRED.

5.3 Receiving Unknown HARP Messages

If a HARP client receives a HARP message with an operation code (ar$op) that it does not support, it MUST gracefully discard the message and continue normal operation. A HARP client is NOT REQUIRED to return any message to the sender of the undefined message.

5.4 HARP Server Operational Requirements

A HARP server MUST accept HIPPI connections from other HIPPI ports. The HARP server expects an InHARP_REQUEST as the first message from the client. A server examines the IP source address, the hardware source address of the InHARP_REQUEST and adds or updates its HARP table entry <IP address(es), switch address, ULA> as well as the time stamp.

A HARP server SHALL reply to HARP_REQUESTs and InHARP_REQUESTs based on the information which it has in its HARP table. The HARP server SHALL reply with a HARP_REPLY or a InHARP_REPLY, if it has the requested information in its tables; otherwise it SHALL reply with a HARP_NAK. The HARP server replies SHALL contain the hardware type and corresponding format of the request (see also section 6).

The following table shows all possible source address combinations on an incoming message and the actions to be taken. "linked" indicates that an existing "IP entry" is linked to a "hardware entry". It is possible to have an existing "IP entry" and to have an existing "hardware entry" but neither is linked to the other.

#	IP entry	HW entry	misc	Action
1	exists	exists	linked	*
2	exists	exists	not linked	*, a, b, e, f
3	exists	new	not linked	*, a, b, d, e, f
4	new	exists	not linked	*, c, e, f
5	new	new	not linked	*, c, d, e, f

Actions:
*: update timeout value
a: break the existing IP -> hardware (HW) - old link
b: delete HW(old) -> IP link and decrement HW(old) refcount, if refcount = 0, delete HW(old)
c: create new IP entry
d: create new HW entry
e: add new IP -> HW link to IP entry
f: add new HW -> IP link to HW entry

Examples of when this could happen (Numbers match lines in above table):

1: supplemental message

Just update timer.

2: move an IP alias to an existing interface

If the IP source address of the InHARP_REQUEST duplicates a table entry IP address (e.g. IPa <-> HWa) and the InHARP_REQUEST hardware source address matches a hardware address entry (e.g. HWb <-> IPb), but they are not linked together, then:
- HWa entry needs to have its reference to the current IPa address removed.
- HWb needs to have a new reference to IPa added
- IPa needs to be linked to HWb

3: move IP address to a new interface

If the InHARP_REQUEST requester’s IP source address duplicates a table entry IP address and the InHARP_REQUEST hardware source address does not match the table entry hardware address, then a new HW entry SHALL be created. The requestor’s IP address SHALL be moved from the original HW entry to the new one (see above).

4: add IP alias to table

If the InHARP_REQUEST requester's hardware source address duplicates a hardware source address entry, but there is no IP entry matching the received IP address, then the IP address SHALL be added to the hardware entries previous IP address(es). (E.g. adding an IP alias).

5: fresh entry, add it

Standard case, create both entries and link them.

A server MUST update the HARP table entry's timeout for each HARP_REQUEST. Explanation: if the client is sending HARP requests to the server, then the server SHOULD note that the client is still "alive" by updating the timeout on the client's HARP table entry.

A HARP server SHOULD use the PIBES (see section 7) to send out HARP_REPLYs to all hardware addresses in its table when the HARP server table changes mappings. This feature decreases the time of stale entries in the clients.

If there are multiple addresses in the HRAL, then a server needs to act as a client to the other servers.

5.5 HARP and Permanent ARP Table Entries

An IP station MUST have a mechanism (e.g. manual configuration) for determining what permanent entries it has. The details of the mechanism are beyond the scope of this memo. The permanent entries allow interoperability with legacy HIPPI adapters which do not yet implement dynamic HARP and use a table-based static ARP. Permanent entries are not aged.

The HARP server SHOULD use the static entries to resolve incoming HARP_REQUESTs from the clients. This feature eliminates the need for maintaining a static HARP table on the client ports.

5.6 HARP Table Aging

HARP table aging MUST be supported since IP addresses, especially IP aliases and also interfaces (with their ULA), are likely to move. When so doing the mapping in the clients own HARP table/cache becomes invalid and stale.

- When a client's HARP table entry ages beyond 15 minutes, a HARP client MUST invalidate the table entry.

- When a server's HARP table entry ages beyond 20 minutes, the HARP server MUST delete the table entry.

NOTE: the client SHOULD revalidate a HARP table entry before it ages, thus restarting the aging time when the table entry is successfully revalidated. The client MAY continue sending traffic to the port referred to by this entry while revalidation is in progress, as long as the table entry has not aged. The client MUST revalidate an aged entry prior to transmitting any non-address-resolution traffic to the port referred to by this entry.

The client revalidates the entry by querying the HARP server with a HARP_REQUEST. If a valid reply is received (e.g. HARP_REPLY), the entry is updated. If the address resolution service cannot resolve the entry (e.g. HARP_NAK, "host not found"), the associated table entry is removed. If the address resolution service is not available (i.e. "server failure") the client MUST attempt to revalidate the entry by transmitting an InHARP_REQUEST to the hardware address of the entry in question and updating the entry on receipt of an InHARP_REPLY. If the InHARP_REQUEST attempt fails to return an InHARP_REPLY, the associated table entry is removed.

6. HARP Message Encoding

The HARP Message is encapsulated over HIPPI-FP and HIPPI-LE headers. The HARP FP header values are to be set as defined in RFC-2067 "IP over HIPPI" [15]. The following sections detail the HIPPI-LE field contents and HARP message structure and contents. In a broadcast capable network the client MAY also support Type 1 and 6, Ethernet and IEEE 802 ARP packet formats.

6.1 HIPPI-LE Header of HARP Messages

The HIPPI message format for Internet datagrams shall conform to the HIPPI-FP [2] and HIPPI-LE [3] standards. The length of a HIPPI message, including trailing fill, shall be a multiple of eight bytes as required by HIPPI-LE. The HIPPI-LE header fields of HARP and InHARP requests and replies SHALL be:

FC (3 bits) SHALL contain zero.

Double-wide SHOULD be set according to HIPPI-LE [3]. This memo does NOT address the implications on HARP when this bit is set to 1 indicating the possibility of a port being able to accept 64-bit HIPPI connections.

Message_Type SHALL contain 0 to indicate a data message. HARP messages are identified using the Ethertype and the message type in the ar$op field of the HARP message.

Destination_Switch_Address, SHALL be the Switch Address of the destination port.

Destination_IEEE_Address SHALL be the ULA of the destination port, if known, otherwise zero.

Destination_Address_Type SHALL be 2, a 12-bit logical address. The behavior with type = 1, source routing, is NOT defined in this specification.

Source_Switch_Address in requests SHALL be the sender's Switch Address.

Source_IEEE_Address SHALL be the sender's ULA if known, otherwise zero.

Source_Address_Type SHALL be 2, a 12-bit logical address. The behavior with type = 1, source routing, is NOT defined in this specification.

6.1.1 IEEE 802.2 LLC

The IEEE 802.2 LLC Header SHALL begin in the first byte of the HIPPI-FP D2_Area.

The LLC value for SSAP-DSAP-CTL SHALL be 0xAA-AA-03 (3 bytes) indicating the presence of a SNAP header.

6.1.2 SNAP

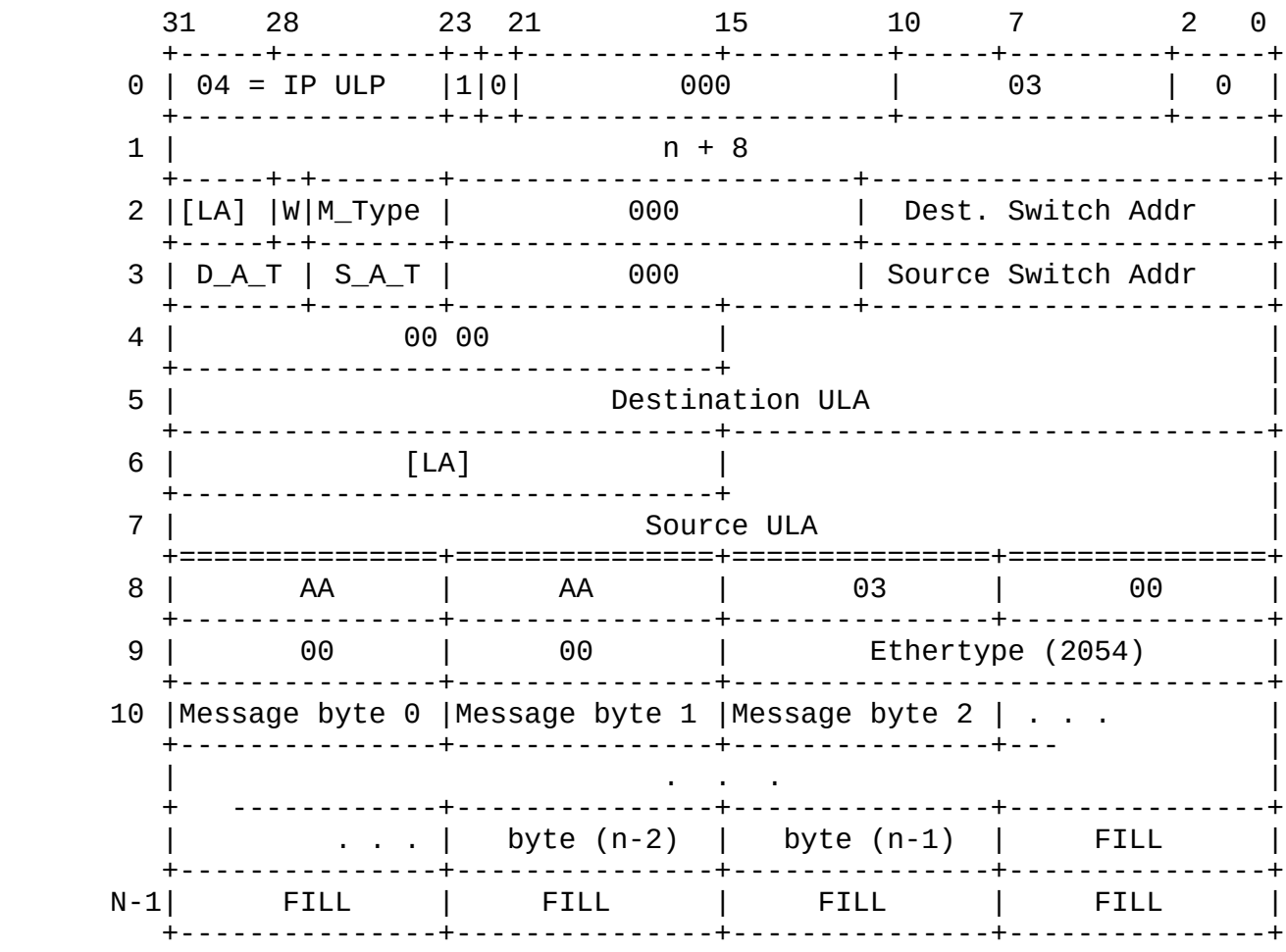
The OUI value for Organization Code SHALL be 0x00-00-00 (3 bytes) indicating that the following two-bytes is an Ethertype.

The Ethertype value SHALL be set as defined in Assigned Numbers [16]: InHARP = InARP = HARP = ARP = 2054 = 0x0806.

The total size of the LLC/SNAP header is fixed at 8-bytes.

6.1.3 HIPPI-LE header Diagram

HIPPI-LE header for HARP/InHARP PDUs:



HIPPI Message Format

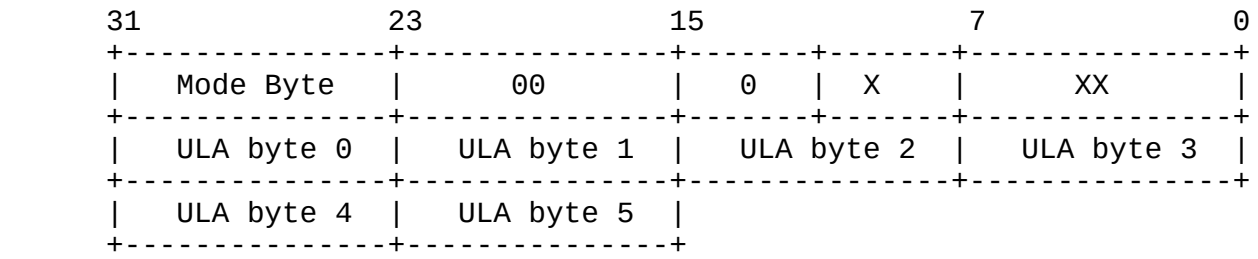
Words 0-1: HIPPI-FP Header
Words 2-7: D1_Area (HIPPI-LE Header)
Words 8-9: D2_Area (IEEE 802.2 LLC/SNAP)
Words 10-(N-1): D2_Area (HARP message)
(n+8) is the nb of bytes in the HARP message, incl. LLC/SNAP.
+====+ denotes the boundary between D1_Area and D2_Area.
[LA] fields are zero unless used otherwise locally.
Abbreviations:

"W"	= Double_Wide field	SHALL be 0
"M_Type"	= Message_Type field	SHALL be set according to HIPPI-LE
"D_A_T"	= Destination_Address_Type	SHALL be 2

"S_A_T" = Source_Address_Type SHALL be 2
[FILL] bytes complete the HIPPI message to an even number of 32 bit words. The number of fill bytes is not counted in the data length.

6.2 HIPPI Hardware Address Formats and Requirements

For HIPPI-800, the Hardware Address is a 10-byte unit that SHALL contain the Switch Address AND the ULA. The format of a hardware address is:



Where "XXX" is the 12 bit HIPPI logical address defined in HIPPI-SC [4]. Details on ULA see next section.

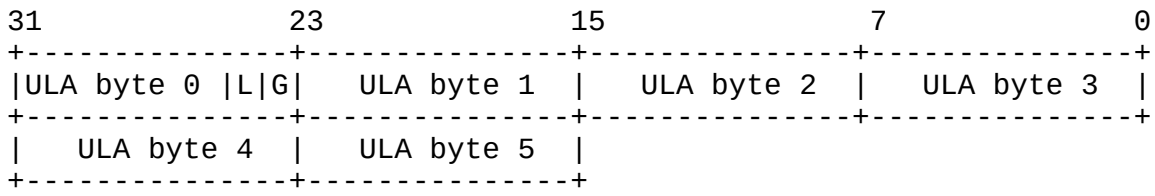
Two switch addresses are considered to be the same when they have the same 12 bit destination HIPPI logical address.

NOTE: In the case of HIPPI-6400, the hardware address is ONLY the 6-byte ULA. Therefore the length of the hardware address clearly defines which version of HIPPI is being used.

6.2.1 48-bit Universal LAN MAC Addresses

IEEE Standard 802.1A [11] specifies the Universal LAN MAC Address format. The globally unique part of the 48-bit space is administered by the IEEE. Each port on a HIPPI-SC LAN SHOULD be assigned a ULA. Multiple ULAs may be used if a port contains more than one IEEE 802.2 LLC protocol entity.

The format of the HIPPI hardware address within its HARP message follows IEEE 802.1A canonical bit order and HIPPI-FP bit and byte order. For example the requester’s ULA part of the HIPPI hardware address would decompose to:



Universal LAN MAC Address Format

L (U/L bit) = 1 for Locally administered addresses,
0 for Universal.
G (I/G bit) = 1 for Group addresses,
0 for Individual.

The use of ULAs is OPTIONAL, but RECOMMENDED. The use of ULAs is REQUIRED if a port wishes to interoperate with a conventional network.

ULAs may also be used by bridging devices that replace HIPPI hardware headers with the MAC headers of other LANs.

6.3 HARP and InHARP Message Formats

The HARP protocols use the HIPARP hardware type (ar$hrd) [16], protocol type (ar$pro), and operation code (ar$op) data formats as the ARP, and InARP protocols [15,7]. In addition, HARP makes use of an additional operation code for ARP_NAK introduced with [12]. The remainder of the HARP/InHARP message format is different than the ARP/InARP message format defined in [15,7,10] and it is also different from the format defined in the first "IP and ARP on HIPPI" RFC-1374 [14].

HARP messages SHALL be transmitted with the HIPARP hardware type code of 28 (decimal). Furthermore, HARP messages SHALL be accepted if received with hardware type codes of either 28, 1 or 6 (decimal).

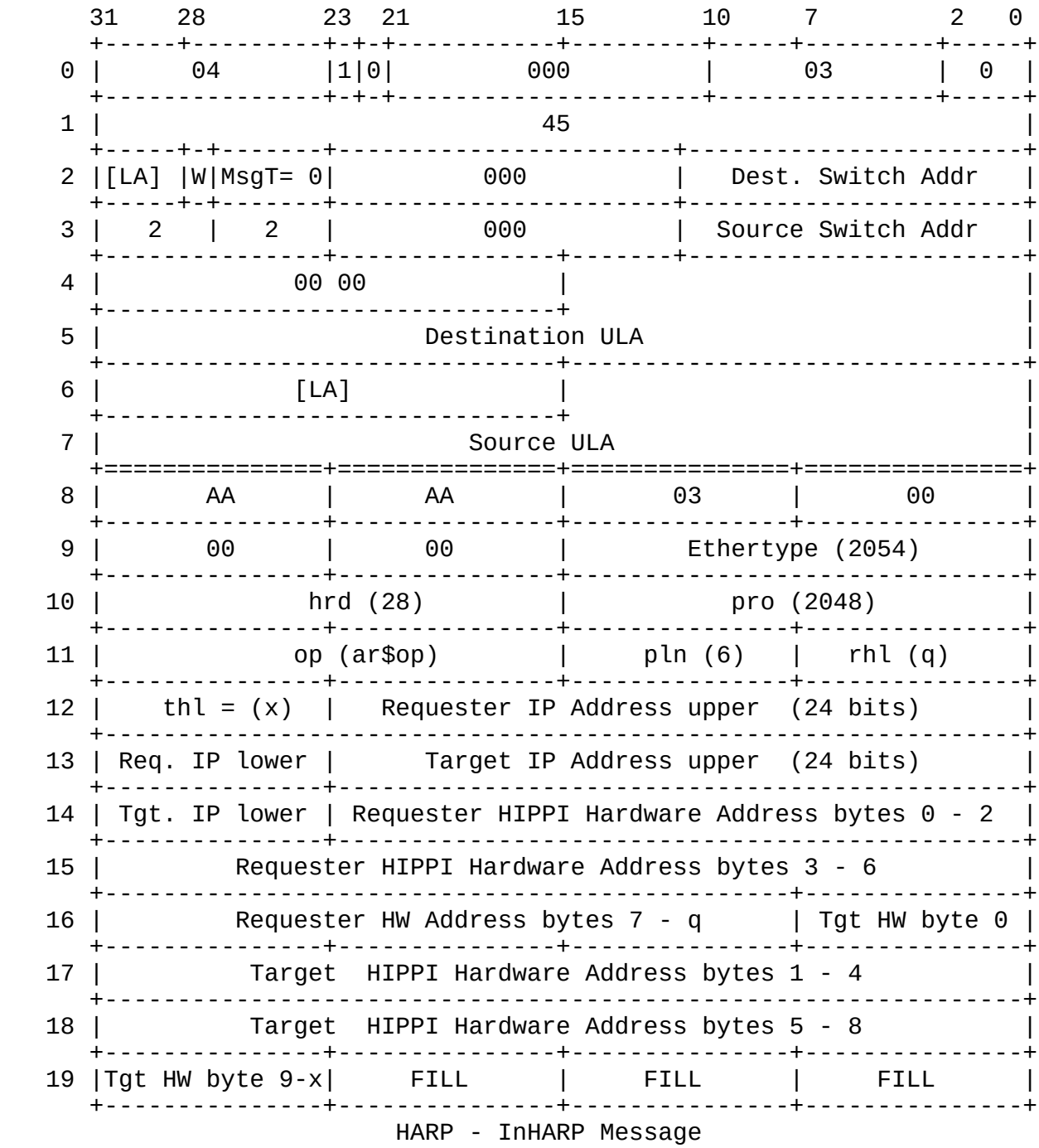
The HARP message has several fields that have the following format and values:

Data sizes and field meaning:

ar$hrd	16 bits	Hardware type
ar$pro	16 bits	Protocol type of the protocol fields below
ar$op	16 bits	Operation code (request, reply, or NAK)
ar$pln	8 bits	byte length of each protocol address
ar$rhl	8 bits	requester’s HIPPI hardware address length (q)
ar$thl	8 bits	target’s HIPPI hardware address length (x)
ar$rpa	32 bits	requester’s protocol address
ar$tpa	32 bits	target’s protocol address

```
     ar$rha  qbytes   requester's HIPPI Hardware address
     ar$tha  xbytes   target's HIPPI Hardware address

   Where :
     ar$hrd  - SHALL contain 28. (HIPARP)

     ar$pro  - SHALL contain the IP protocol code 2048 (decimal).

     ar$op   - SHALL contain the operational value (decimal):
               1  for   HARP_REQUESTs
               2  for   HARP_REPLYs
               8  for InHARP_REQUESTs
               9  for InHARP_REPLYs
               10 for   HARP_NAK

     ar$pln  - SHALL contain 4.

     ar$rln  - SHALL contain 10 IF this is a HIPPI-800 HW address
               ELSE, for HIPPI-6400, it SHALL contain 6.

     ar$thl  - SHALL contain 10 IF this is a HIPPI-800 HW address
               ELSE, for HIPPI-6400, it SHALL contain 6.

     ar$rha  - in requests and NAKs it SHALL contain the requester's
               HW address. In replies it SHALL contain the target
               port's HW address.

     ar$rpa  - in requests and NAKs it SHALL contain the requester's IP
               address if known, otherwise zero.
               In other replies it SHALL contain the target
               port's IP address.

     ar$tha  - in requests and NAKs it SHALL contain the target's
               HW address if known, otherwise zero.
               In other replies it SHALL contain the requester's
               HW addressA.

     ar$tpa  - in requests and NAKs it SHALL contain the
               target's IP address if known, otherwise zero.
               In other replies it SHALL contain the requester's
               IP address.
```

The format of the six bytes of the ULA SHALL be the same as required in the HIPPI-LE header (see section 6.2), except for the alignment of the ULAs with respect to the 32-bit HIPPI word, which is different between ARP and HIPPI-LE. No bit reversal is necessary as is required with FDDI.



HARP - InHARP Message

6.3.1 Example Message encodings:

```
HARP_REQUEST message
      HARP ar$op   = 1 (HARP_REQUEST)
      HARP ar$rpa  = IPy                HARP ar$tpa  = IPa
      HARP ar$rha  = SWy ULAy           HARP ar$tha  = 0 **
      ** is what we would like to find out

HARP_REPLY message format
      HARP ar$op   = 2 (HARP_REPLY)
      HARP ar$rpa  = IPa                HARP ar$tpa  = IPy
      HARP ar$rha  = SWa ULAa *         HARP ar$tha  = SWy ULAy
      * answer we were looking for

InHARP_REQUEST message format
      HARP ar$op    = 8 (InHARP_REQUEST)
      HARP ar$rpa   = IPy               HARP ar$tpa   = 0 **
      HARP ar$rha   = SWy ULAy          HARP ar$tha   = SWa ULAa
      ** is what we would like to find out

InHARP_REPLY message format
      HARP ar$op    = 9 (InHARP_REPLY)
      HARP ar$rpa   = IPs *             HARP ar$tpa   = IPy
      HARP ar$rha   = SWa ULAa          HARP ar$tha   = SWy ULAy
      * answer we were looking for
```

6.3.2 HARP_NAK message format

The HARP_NAK message format is the same as the received HARP_REQUEST message format with the operation code set to HARP_NAK; i.e. the HARP_REQUEST message data is copied byte for byte for transmission with the HARP_REQUEST operation code changed to the HARP_NAK value. HARP makes use of an additional operation code for HARP_NAK. Hence, HARP_NAK MUST be implemented.

6.3.3 Combined HIPPI-LE and HARP message addresses

The combined HIPPI-LE/HARP message contains ten addresses, two for the destination and two for the source of the message, three for the requester and three for the target:

```
Destination Switch Address  (HIPPI-LE)
Destination ULA             (HIPPI_LE)

Source Switch Address       (HIPPI-LE)
Source ULA                  (HIPPI-LE)
```

```
   Requester IP Address        (HARP)
   Requester ULA               (HARP)
   Requester Switch Address    (HARP)

   Target IP Address           (HARP)
   Target ULA                  (HARP)
   Target Switch Address       (HARP)
```

Examples:

The following relations are true for a HARP_REQUEST and InHARP_REQUESTs.

```
   LIS without broadcast -  Dest SW Addr   = HARP server SW Addr
   (with HARP server)       Dest ULA       = HARP server ULA
                            Source SW Addr = Requester's SW Addr
                            Source ULA     = Requester's ULA
```

7 Broadcast and Multicast

HIPPI-SC does not require switches to support broadcast. Broadcast support has therefore been absent from many HIPPI networks.

During its registration phase, every port, including HARP server(s), discover if the underlying medium is capable of broadcast (see section 5.1.2). Should this not be the case, then the HARP server(s) MUST emulate broadcast through an IP broadcast emulation server.

A HIPPI IP broadcast server (PIBES) is an extension to the HARP server and only makes sense when the LIS does not inherently support broadcast. The PIBES allows common upper layer networking protocols (RIP, TCP, UDP, etc.) to access IP LIS broadcast.

7.1 Protocol for an IP Broadcast Emulation Server - PIBES

To emulate broadcast within an LIS, a PIBES SHALL use the currently valid HARP table of the HARP server as a list of addresses called the target list. The broadcast server SHALL validate that all incoming messages have a source address which corresponds to an address in the target list. Only messages addressed to the IP LIS broadcast addresses, multicast address or 255.255.255.255 are considered valid messages for broadcasting. Invalid messages MUST be dropped. All valid incoming messages shall be forwarded to all addresses in the target list.

It is RECOMMENDED that the broadcast server run on the same port as the HARP server since this memo does not define the protocol for exchanging the valid HARP table. The default address to use for the broadcast address is the operational HARP server address.

7.2 IP Broadcast Address

This memo only defines IP broadcast. It is independent of the underlying hardware addressing and broadcast capabilities. Any port can differentiate between IP traffic directed to itself and a broadcast message sent to it by looking at the IP address. All IP broadcast messages SHALL use the IP LIS broadcast address or.

It is RECOMMENDED that the PIBES run on the same port as the HARP server. In that case, the PIBES SHALL use the same address as the HARP server.

7.3 IP Multicast Address

HIPPI does not directly support multicast address, therefore there are no mappings available from IP multicast addresses to HIPPI multicast services. Current IP multicast implementations (i.e. MBONE and IP tunneling, see [9]) will continue to operate over HIPPI-based logical IP subnets if all IP multicast packets are sent using the same algorithm as if the packet were being sent to 255.255.255.255.

7.4 A Note on Broadcast Emulation Performance

It is obvious that a broadcast emulation service (as defined in section 7.1) has an inherent performance limit. In an LIS with n ports, the upper bound on the bandwidth that such a service can broadcast is:

(total bandwidth)/(n+1)

since each message must first enter the broadcast server, accounting for the additional 1, and then be sent to all n ports. The broadcast server could forward the message destined to the port on which it runs internally, thus reducing (n+1) to (n) in a first optimization.

This service is adequate for the standard networking protocols such as RIP, OSPF, NIS, etc. since they usually use a small fraction of the network bandwidth for broadcast. For these purposes, the broadcast emulation server as defined in this memo allows the HIPPI network to look similar to an Ethernet network to the higher layers.

It is further obvious that such an emulation cannot be used to broadcast high bandwidth traffic. For such a solution, hardware support for true broadcast is required.

8 HARP for Scheduled Transfer Protocol[17]

This RFC also applies for resolving addresses used with Scheduled Transfer (STP) over HIPPI-800 instead of IP. This RFC's message types and algorithms can be used for STP (since STP uses Internet Addresses) as long as there is also an IP over HIPPI implementation on all of the ports.

9 Discovery of One's Own Switch Address

This HARP specification assumes that each port has prior knowledge of its own hardware address. This address may be manually configured, by means outside the scope of this memo or a port may discover its own logical address through the algorithm described below.

Ports are NOT REQUIRED to implement this switch address discovery protocol but are encouraged to do so since it reduces the administrative overhead. The algorithm presented in this section is based on John Renwick's work as detailed in RFC-1374 [14]. The concept of the discovery process is to scan all possible switch addresses. The messages that are received will be the ones containing one of our switch addresses.

If a port implements this algorithm it SHALL form a HIPPI-LE message as defined in HIPPI-LE: containing an Self_Address_Resolution_Request (see [3]) PDU Type, a Source_IEEE_Address and Destination_IEEE_Address (set to the correct ULA for the sender), and the Source_Switch_Address and Destination_Switch_Address.

This self address resolution message uses the same HIPPI-LE message format as described in HIPPI-SC and HIPPI-LE: the Self Address Resolution Request PDU and Self Address Resolution Response PDU type codes and no piggybacked ULP data. The HIPPI-LE header contents for the request are:

```
HIPPI-LE Message_Type is            = 3, Self Addr. Resolution Request
HIPPI-LE Destination_Address_Type   = 0 (undefined)
HIPPI-LE Destination_Switch_Address = X (X element scan range)
HIPPI-LE Source_Address_Type        = 0 (undefined)
HIPPI-LE Source_Switch_Address      = 0 (unknown)
HIPPI-LE Destination_IEEE_Address   = 0
HIPPI-LE Source_IEEE_Address        = my ULA
```

There is no D2 data; the message contains only the HIPPI-FP header and D1_Area with the HIPPI-LE header.

Ports SHALL start the scan with a configurable logical address (default 0x000) and increment the value for by one for each subsequent try. The port SHALL continue until it sees its own self address resolution request or it has reached the end, which may be another configurable value (default 0xFFF). It is RECOMMENDED that the range of addresses to scan be configurable since some networks have equipment that does not gracefully handle HIPPI-LE messages.

After a port sends the[se] request[s], two positive outcomes are possible:

- the port receives its own request(s), and obtains one of its own Switch Address, or
- the port receives an AR_S_Response with the Destination_Switch_Address filled in.

10 Security Considerations

HARP messages are not authenticated which is a potentially flaw that could allow corrupt information to be introduced into the server system.

There are other known security issues relating to port impersonation via the address resolution protocols used in the Internet [8]. No special security mechanisms have been added to the address resolution mechanism defined here for use with networks using HARP.

Not all of the security issues relating to ARP over HIPPI are clearly understood at this time. However, given the security hole ARP allows, other concerns are probably minor.

11 Open Issues

Synchronization and coordination of multiple HARP servers and multiple broadcast servers are left for further study.

12 HARP Examples

Assume a HIPPI-SC switch is installed with three connected ports: x, y, and a. Each port has a unique hardware address that consists of Switch Address (e.g. SWx, SWy, SWa) and unique ULA (ULAx, ULAy and ULAa, respectively). There is a HARP server connected to a switch port that is mapped to the address HWa (SWa, ULAa), this address is the authoritative HIPPI hardware address in the HRAL (HARP Request Address List).

The HARP server's table is empty. Ports X and Y each know their own hardware address. Eventually they want to talk to each other; each knows the other's IP address (from the port database) but neither knows the other's ULA or Switch Address. Both ports X and Y have their interfaces configured DOWN.

NOTE: The LLC, SNAP, Ethertype, HIPPI-LE Message Type, arhrd, arpro, ar$pln fields are left out from the examples below since they are constant. Likewise, ar$rhl = ar$thl = 9 are omitted since these are all HIPPI-800 examples.

12.1 Registration Phase of Client Y on Non-broadcast Hardware

Port Y starts: its HARP table entry state for the server: PENDING

1. Port Y initiates its interface and sends an InHARP_REQUEST to HWa after starting a table entry for HWa.

   ```
   HIPPI-LE Destination_Switch_Address = SWa
   HIPPI-LE Source_Switch_Address      = SWy
   HIPPI-LE Destination_IEEE_Address   = ULAa
   HIPPI-LE Source_IEEE_Address        = ULAy
   HARP ar$op                          = 8 (InHARP_REQUEST)
   HARP ar$rpa                         = IPy
   HARP ar$tpa                         = 0 **
   HARP ar$rha                         = SWy ULAy
   HARP ar$tha                         = SWa ULAa
   ** is what we would like to find out
   ```

2. HARP server receives Y's InHARP_REQUEST, it examines the source addresses and scans its tables for a match. Since this is the first time Y connects to this server there is no entry and one will be created and time stamped with the information from the InHARP_REQUEST. The HARP server will then send a InHARP_REPLY including its IP address.

   ```
   HIPPI-LE Destination_Switch_Address = SWy
   HIPPI-LE Source_Switch_Address      = SWa
   HIPPI-LE Destination_IEEE_Address   = ULAy
   HIPPI-LE Source_IEEE_Address        = ULAa
   HARP ar$op                          = 9 (InHARP_REPLY)
   HARP ar$rpa                         = IPs *
   HARP ar$tpa                         = IPy
   HARP ar$rha                         = SWa ULAa
   HARP ar$tha                         = SWy ULAy
   * answer we were looking for
   ```

3. Port Y examines the incoming InHARP_REPLY, completes its table entry for the HARP server. The client's HARP table entry for the server now passes into the VALID state and is usable for regular HARP traffic. Receiving this reply ensures that the HARP server has properly registered the client.

12.2 Registration Phase of Client Y on Broadcast Capable Hardware

If there is a broadcast capable network then the authoritative address in the HRAL would be mapped to the broadcast address, HWb = SWb, ULAb (likely 0xFE1 and FF:FF:FF:FF:FF:FF).

Port Y starts: its HARP table entry state for HWa: PENDING

1. Port Y initiates its interface and sends an InHARP_REQUEST to HWa, in this example the broadcast address, after starting a table entry.

```
HIPPI-LE Destination_Switch_Address = SWb
HIPPI-LE Source_Switch_Address      = SWy
HIPPI-LE Destination_IEEE_Address   = ULAb
HIPPI-LE Source_IEEE_Address        = ULAy
HARP ar$op                          = 8 (InHARP_REQUEST)
HARP ar$rpa                         = IPy
HARP ar$tpa                         = 0 **
HARP ar$rha                         = SWy ULAy
HARP ar$tha                         = SWb ULAb
** is what we would like to find out
```

2. Since the network is a broadcast network, client Y will receive a copy of its InHARP_REQUEST. Client Y examines the source addresses. Since they are the same as what Y filled in the InHARP_REQUEST, Y can deduce that it is connected to a broadcast medium. Port Y completes its table entry for HWa. This entry will not timeout since it is considered unlikely for a particular underlying hardware type to change between broadcast and non-broadcast; therefore this mapping will never change.

12.3 Operational Phase (phase II)

The Operational Phase of the HARP protocol as specified in this memo is the same for both broadcast and non-broadcast capable HIPPI hardware. The authoritative address in the HRAL for this example will be HWa: <SWa, ULAa> and IPs for simplicity reasons.

12.3.1 Standard successful HARP_Resolve example

Assume the same process (steps 1-3 of section 10.1) happened for port X. Then the state of X and Y's tables is: the HARP server table entry is in the VALID state. So lets look at the message traffic when X tries to send a message to Y. Since X doesn't have an entry for Y,

1. Port X connects to the authoritative address of the HRAL and sends a HARP_REQUEST for Y's hardware address:

```
HIPPI-LE Destination_Switch_Address = SWa
HIPPI-LE Source_Switch_Address      = SWx
HIPPI-LE Destination_IEEE_Address   = ULAa
HIPPI-LE Source_IEEE_Address        = ULAx
HARP ar$op                          = 1  (HARP_REQUEST)
HARP ar$rpa                         = IPx
HARP ar$tpa                         = IPy
HARP ar$rha                         = SWx ULAx
HARP ar$tha                         = 0 **
** is what we would like to find out
```

2. The HARP server receives the HARP request and updates its entry for X if necessary. It then generates a HARP_REPLY with Y's hardware address information.

```
HIPPI-LE Destination_Switch_Address = SWx
HIPPI-LE Source_Switch_Address      = SWa
HIPPI-LE Destination_IEEE_Address   = ULAx
HIPPI-LE Source_IEEE_Address        = ULAa
HARP ar$op                          = 2  (HARP_Reply)
HARP ar$rpa                         = IPy
HARP ar$tpa                         = IPx
HARP ar$rha                         = SWy ULAy *
HARP ar$tha                         = SWx ULAx
* answer we were looking for
```

3. Port X connects to port Y and transmits an IP message with the following information in the HIPPI-LE header:

```
HIPPI-LE Destination_Switch_Address = SWy
HIPPI-LE Source_Switch_Address      = SWx
HIPPI-LE Destination_IEEE_Address   = ULAy
HIPPI-LE Source_IEEE_Address        = ULAx
```

If there had been a broadcast capable HIPPI network, the target ports would themselves have received the HARP_REQUEST of step 2 above and responded to them in the same way the HARP server did.

12.3.2 Standard non-successful HARP_Resolve example

Like in 12.3.1, assume that X and Y are fully registered with the HARP server. Then the state of X and Y's HARP server table entry is: VALID. So lets look at the message traffic when X tries to send a message to Q. Further assume that interface Q is NOT configured UP, i.e. it is DOWN. Since X doesn't have an entry for Q,

1. Port X connects to the HARP server switch address and sends a HARP_REQUEST for Q's hardware address:

```
HIPPI-LE Destination_Switch_Address = SWa
HIPPI-LE Source_Switch_Address      = SWx
HIPPI-LE Destination_IEEE_Address   = ULAa
HIPPI-LE Source_IEEE_Address        = ULAx
HARP ar$op                          = 1  (HARP_REQUEST)
HARP ar$rpa                         = IPx
HARP ar$tpa                         = IPq
HARP ar$rha                         = SWx ULAx
HARP ar$tha                         = 0 **
** is what we would like to find out
```

2. The HARP server receives the HARP request and updates its entry for X if necessary. It then looks up IPq in its tables and doesn't find it. The HARP server then generates a HARP_NAK reply message.

```
HIPPI-LE Destination_Switch_Address = SWx
HIPPI-LE Source_Switch_Address      = SWa
HIPPI-LE Destination_IEEE_Address   = ULAx
HIPPI-LE Source_IEEE_Address        = ULAa
HARP ar$op                          = 10  (HARP_NAK)
HARP ar$rpa                         = IPx
HARP ar$tpa                         = IPq
HARP ar$rha                         = SWx ULAx
HARP ar$tha                         = 0 ***
*** No Answer, and notice that the fields do not get swapped,
    i.e. the HARP message is the same as the HARP_REQUEST
    except for the operation code.
```

If there had been a broadcast capable HIPPI network, then there would not have been a reply.

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14 Acknowledgments

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This memo is based on the second part of [14], written by John Renwick. ARP [13] written by Dave Plummer and Inverse ARP [7] written by T. Bradley and C. Brown provide the fundamental algorithms of HARP as presented in this memo. Further, the HARP server is based on concepts and models presented in [12], written by Mark Laubach who laid the structural groundwork for the HARP server.

15 Changes from RFC-1374 [14]

RFC-2067 obsoletes RFC-1374 but left ARP outside of its scope because there was not enough implementation experience. This memo is an effort to clarify and expand the definition of ARP over HIPPI as found in RFC-1374 such that implementations will be more readily possible, especially considering forward interoperability with HIPPI-6400.

The changes from RFC-1374 [14] are:

- A new message format to acknowledge the HIPPI hardware address format and to eliminate the requirement of HIPPI-LE ARP for HARP to function.

- Explicit registration phase.

- Additional message formats: InHARP requests and replies as well as HARP_NAKs.
- Details about the IP subnetwork configuration.
- Details about table aging.
- IP broadcast emulation.

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