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## Classical IP and ARP over ATM

### Status of this Memo

This document specifies an Internet standards track protocol for the Internet community, and requests discussion and suggestions for improvements. Please refer to the current edition of the "Internet Official Protocol Standards" (STD 1) for the standardization state and status of this protocol. Distribution of this memo is unlimited.

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## 1. ABSTRACT

This memo defines an initial application of classical IP and ARP in an Asynchronous Transfer Mode (ATM) network environment configured as a Logical IP Subnetwork (LIS) as described in Section 5. This memo does not preclude the subsequent development of ATM technology into areas other than a LIS; specifically, as single ATM networks grow to replace many Ethernet local LAN segments and as these networks become globally connected, the application of IP and ARP will be treated differently. This memo considers only the application of ATM as a direct replacement for the "wires" and local LAN segments connecting IP end-stations ("members") and routers operating in the "classical" LAN-based paradigm. Issues raised by MAC level bridging and LAN emulation are beyond the scope of this paper.

This memo introduces general ATM technology and nomenclature. Readers are encouraged to review the ATM Forum and ITU-TS (formerly CCITT) references for more detailed information about ATM implementation agreements and standards.

## 2. ACKNOWLEDGMENT

The authors would like to thank the efforts of the IP over ATM Working Group of the IETF. Without their substantial, and sometimes contentious support, of the Classical IP over ATM model, this updated memo would not have been possible. Section 7, on Default MTU, has been incorporated directly from Ran Atkinson's RFC 1626, with his permission. Thanks to Andy Malis for an early review and comments for rolc and ion related issues.

### 3. CONVENTIONS

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 [20].

### 4. INTRODUCTION

The goal of this specification is to allow compatible and interoperable implementations for transmitting IP datagrams and ATM Address Resolution Protocol (ATMARP) requests and replies over ATM Adaptation Layer 5 (AAL5)[2,6].

This memo specifies the stable foundation baseline operational model which will always be available in IP and ARP over ATM implementations. Subsequent memos will build upon and refine this model. However, in the absence or failure of those extensions, operations will default to the specifications contained in this memo. Consequently, this memo will not reference these other extensions.

This memo defines only the operation of IP and address resolution over ATM, and is not meant to describe the operation of ATM networks. Any reference to virtual connections, permanent virtual connections, or switched virtual connections applies only to virtual channel connections used to support IP and address resolution over ATM, and thus are assumed to be using AAL5. This memo places no restrictions or requirements on virtual connections used for other purposes.

Initial deployment of ATM provides a LAN segment replacement for:

- 1) Local area networks (e.g., Ethernets, Token Rings and FDDI).
- 2) Local-area backbones between existing (non-ATM) LANs.
- 3) Dedicated circuits or frame relay PVCs between IP routers.

NOTE: In 1), local IP routers with one or more ATM interfaces will be able to connect islands of ATM networks. In 3), public or private ATM Wide Area networks will be used to connect IP routers, which in turn may or may not connect to local ATM networks. ATM WANs and LANs may be interconnected.

Private ATM networks (local or wide area) will use the private ATM address structure specified in the ATM Forum UNI 3.1 specification [9] or as in the ATM Forum UNI 4.0 specification [19]. This structure is modeled after the format of an OSI Network Service Access Point Address (NSAPA). A private ATM address uniquely identifies an ATM endpoint.

Public networks will use either the address structure specified in ITU-TS recommendation E.164 or the private network ATM address structure. An E.164 address uniquely identifies an interface to a public network.

The characteristics and features of ATM networks are different than those found in LANs:

- o ATM provides a Virtual Connection (VC) switched environment. VC setup may be done on either a Permanent Virtual Connection (PVC) or dynamic Switched Virtual Connection (SVC) basis. SVC call management signalling is performed via implementations of the UNI 3.1 protocol [7,9].
- o Data to be passed by a VC is segmented into 53 octet quantities called cells (5 octets of ATM header and 48 octets of data).
- o The function of mapping user Protocol Data Units (PDUs) into the information field of the ATM cell and vice versa is performed in the ATM Adaptation Layer (AAL). When a VC is created a specific AAL type is associated with the VC. There are four different AAL types, which are referred to individually as "AAL1", "AAL2", "AAL3/4", and "AAL5". (NOTE: this memo concerns itself with the mapping of IP and ATMARP over AAL5 only. The other AAL types are mentioned for introductory purposes only.) The AAL type is known by the VC end points via the call setup mechanism and is not carried in the ATM cell header. For PVCs the AAL type is administratively configured at the end points when the Connection (circuit) is set up. For SVCs, the AAL type is communicated along the VC path via UNI 3.1 as part of call setup establishment and the end points use the signaled information for configuration. ATM switches generally do not care about the AAL type of VCs. The AAL5 format specifies a packet format with a maximum size of (64K - 1) octets of user data. Cells for an AAL5 PDU are transmitted first to last, the last cell indicating the end of the PDU. ATM standards guarantee that on a given VC, cell ordering is preserved end-to-end. NOTE: AAL5 provides a non-assured data transfer service - it is up to higher-level protocols to provide retransmission.
- o ATM Forum signaling defines point-to-point and point-to-point Connection setup [9, 19.] Multipoint-to-multipoint not yet specified by ITU-TS or ATM Forum.

An ATM Forum ATM address is either encoded as an NSAP form ATM EndSystem Address (AESAs) or is an E.164 Public-UNI address [9, 19]. In some cases, both an AESA and an E.164 Public UNI address are needed by an ATMARP client to reach another host or router.

Since the use of AESAs and E.164 public UNI addresses by ATMARP are analogous to the use of Ethernet addresses, the notion of "hardware address" is extended to encompass ATM addresses in the context of ATMARP, even though ATM addresses need not have hardware significance. ATM Forum NSAP format addresses (AESA) use the same basic format as U.S. GOSIP OSI NSAPAs [11]. NOTE: ATM Forum addresses should not be construed as being U.S. GOSIP NSAPAs. They are not, the administration is different, which fields get filled out are different, etc. However, in this document, these will be referred to as NSAPAs.

This memo describes the initial deployment of ATM within "classical" IP networks as a direct replacement for local area networks (Ethernets) and for IP links which interconnect routers, either within or between administrative domains. The "classical" model here refers to the treatment of the ATM host adapter as a networking interface to the IP protocol stack operating in a LAN-based paradigm.

Characteristics of the classical model are:

- o The same maximum transmission unit (MTU) size is the default for all VCs in a LIS. However, on a VC-by-VC point-to-point basis, the MTU size may be negotiated during connection setup using Path MTU Discovery to better suit the needs of the cooperating pair of IP members or the attributes of the communications path. (Refer to Section 7.3)
- o Default LLC/SNAP encapsulation of IP packets.
- o End-to-end IP routing architecture stays the same.
- o IP addresses are resolved to ATM addresses by use of an ATMARP service within the LIS - ATMARPs stay within the LIS. From a client's perspective, the ATMARP architecture stays faithful to the basic ARP model presented in [3].
- o One IP subnet is used for many hosts and routers. Each VC directly connects two IP members within the same LIS.

Future memos will describe the operation of IP over ATM when ATM networks become globally deployed and interconnected.

The deployment of ATM into the Internet community is just beginning and will take many years to complete. During the early part of this period, we expect deployment to follow traditional IP subnet boundaries for the following reasons:

- o Administrators and managers of IP subnetworks will tend to initially follow the same models as they currently have deployed. The mindset of the community will change slowly over time as ATM increases its coverage and builds its credibility.
- o Policy administration practices rely on the security, access, routing, and filtering capability of IP Internet gateways: i.e., firewalls. ATM will not be allowed to "back-door" around these mechanisms until ATM provides better management capability than the existing services and practices.
- o Standards for global IP over ATM will take some time to complete and deploy.

This memo details the treatment of the classical model of IP and ATMARP over ATM. This memo does not preclude the subsequent treatment of ATM networks within the IP framework as ATM becomes globally deployed and interconnected; this will be the subject of future documents. This memo does not address issues related to transparent data link layer interoperability.

## 5. IP SUBNETWORK CONFIGURATION

### 5.1 Background

In the LIS scenario, each separate administrative entity configures its hosts and routers within a LIS. Each LIS operates and communicates independently of other LISs on the same ATM network.

In the classical model, hosts communicate directly via ATM to other hosts within the same LIS using the ATMARP service as the mechanism for resolving target IP addresses to target ATM endpoint addresses. The ATMARP service has LIS scope only and serves all hosts in the LIS. Communication to hosts located outside of the local LIS is provided via an IP router. This router is an ATM endpoint attached to the ATM network that is configured as a member of one or more LISs. This configuration MAY result in a number of disjoint LISs operating over the same ATM network. Using this model hosts of differing IP subnets MUST communicate via an intermediate IP router even though it may be possible to open a direct VC between the two IP members over the ATM network.

By default, the ATMARP service and the classical LIS routing model MUST be available to any IP member client in the LIS.

## 5.2 LIS Configuration Requirements

The requirements for IP members (hosts, routers) operating in an ATM LIS configuration are:

- o All members of the LIS have the same IP network/subnet number and address mask [8].
- o All members within a LIS are directly connected to the ATM network.
- o All members of a LIS MUST have a mechanism for resolving IP addresses to ATM addresses via ATMARP (based on [3]) and vice versa via InATMARP (based on [12]) when using SVCs. Refer to Section 8 "LIS ADDRESS RESOLUTION SERVICES" in this memo.
- o All members of a LIS MUST have a mechanism for resolving VCs to IP addresses via InATMARP (based on [12]) when using PVCs. Refer to Section 8 "LIS ADDRESS RESOLUTION SERVICES" in this memo.
- o All members within a LIS MUST be able to communicate via ATM with all other members in the same LIS; i.e., the Virtual Connection topology underlying the intercommunication among the members is fully meshed.

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

- o ATM Hardware Address (atm\$ha). The ATM address of the individual IP station.
- o ATMARP Request Address list (atm\$arp-req-list): atm\$arp-req-list is a list containing one or more ATM addresses of individual ATMARP servers located within the LIS. In an SVC environment, ATMARP servers are used to resolve target IP addresses to target ATM address via an ATMARP request and reply protocol. ATMARP servers MUST have authoritative responsibility for resolving ATMARP requests of all IP members using SVCs located within the LIS.

A LIS MUST have a single ATMARP service entry configured and available to all members of the LIS who use SVCs.

In the case where there is only a single ATMARP server within the LIS, then all ATMARP clients MUST be configured identically to have only one non-null entry in atm\$arp-req-list configured with the same address of the single ATMARP service.

If the IP member is operating with PVCs only, then atm\$arp-req-list MUST be configured with all null entries and the client MUST not make queries to either address resolution service.

Within the restrictions mentioned above and in Section 8, local administration MUST decide which server address(es) are appropriate for atm\$arp-req-list.

By default, atm\$arp-req-list MUST be configured using the MIB [18].

Manual configuration of the addresses and address lists presented in this section is implementation dependent and beyond the scope of this document; i.e., this memo does not require any specific configuration method. This memo does require that these addresses MUST be configured completely on the client, as appropriate for the LIS, prior to use by any service or operation detailed in this memo.

### 5.3 LIS Router Additional Configuration

It is RECOMMENDED that routers providing LIS functionality over the ATM network also support the ability to interconnect multiple LISs. Routers that wish to provide interconnection of differing LISs MUST be able to support multiple sets of these parameters (one set for each connected LIS) and be able to associate each set of parameters to a specific IP network/ subnet number. In addition, it is RECOMMENDED that a router be able to provide this multiple LIS support with a single physical ATM interface that may have one or more individual ATM endpoint addresses. NOTE: this does not necessarily mean different End System Identifiers (ESIs) when NSAPAs are used. The last octet of an NSAPA is the NSAPA Selector (SEL) field which can be used to differentiate up to 256 different LISs for the same ESI. (Refer to Section 5.1.3.1, "Private Networks" in [9].)

## 6. IP PACKET FORMAT

Implementations MUST support IEEE 802.2 LLC/SNAP encapsulation as described in [2]. LLC/SNAP encapsulation is the default packet format for IP datagrams.

This memo recognizes that other encapsulation methods may be used however, in the absence of other knowledge or agreement, LLC/SNAP encapsulation is the default.

This memo recognizes that end-to-end signaling within ATM may allow negotiation of encapsulation method on a per-VC basis.



## 7. DEFAULT VALUE FOR IP MTU OVER ATM AAL5

Protocols in wide use throughout the Internet, such as the Network File System (NFS), currently use large frame sizes (e.g., 8 KB). Empirical evidence with various applications over the Transmission Control Protocol (TCP) indicates that larger Maximum Transmission Unit (MTU) sizes for the Internet Protocol (IP) tend to give better performance. Fragmentation of IP datagrams is known to be highly undesirable [16]. It is desirable to reduce fragmentation in the network and thereby enhance performance by having the IP Maximum Transmission Unit (MTU) for AAL5 be reasonably large. NFS defaults to an 8192 byte frame size. Allowing for RPC/XDR, UDP, IP, and LLC headers, NFS would prefer a default MTU of at least 8300 octets. Routers can sometimes perform better with larger packet sizes because most of the performance costs in routers relate to "packets handled" rather than "bytes transferred". So, there are a number of good reasons to have a reasonably large default MTU value for IP over ATM AAL5.

RFC 1209 specifies the IP MTU over SMDS to be 9180 octets, which is larger than 8300 octets but still in the same range [1]. There is no good reason for the default MTU of IP over ATM AAL5 to be different from IP over SMDS, given that they will be the same magnitude. Having the two be the same size will be helpful in interoperability and will also help reduce incidence of IP fragmentation.

Therefore, the default IP MTU for use with ATM AAL5 shall be 9180 octets. All implementations compliant and conformant with this specification shall support at least the default IP MTU value for use over ATM AAL5.

### 7.1 Permanent Virtual Circuits

Implementations which only support Permanent Virtual Circuits (PVCs) will (by definition) not implement any ATM signalling protocol. Such implementations shall use the default IP MTU value of 9180 octets unless both parties have agreed in advance to use some other IP MTU value via some mechanism not specified here.

### 7.2 Switched Virtual Circuits

Implementations that support Switched Virtual Circuits (SVCs) MUST attempt to negotiate the AAL CPCS-SDU size using the ATM signalling protocol. The industry standard ATM signalling protocol uses two different parts of the Information Element named "AAL Parameters" to exchange information on the MTU over the ATM circuit being setup [9]. The Forward Maximum CPCS-SDU Size field contains the value over the path from the calling party to the called party. The Backwards

Maximum CPCS-SDU Size Identifier field contains the value over the path from the called party to the calling party. The ATM Forum specifies the valid values of this identifier as 1 to 65535 inclusive. Note that the ATM Forum's User-to-Network-Interface (UNI) signalling permits the MTU in one direction to be different from the MTU in the opposite direction, so the Forward Maximum CPCS-SDU Size Identifier might have a different value from the Backwards Maximum CPCS-SDU Size Identifier on the same connection.

If the calling party wishes to use the default MTU it shall still include the "AAL Parameters" information element with the default values for the Maximum CPCS-SDU Size as part of the SETUP message of the ATM signalling protocol [9]. If the calling party desires to use a different value than the default, it shall include the "AAL Parameters" information element with the desired value for the Maximum CPCS-SDU Size as part of the SETUP message of the ATM Signalling Protocol. The called party will respond using the same information elements and identifiers in its CONNECT message response [9].

If the called party receives a SETUP message containing the "Maximum CPCS-SDU Size" in the AAL Parameters information element, it shall handle the Forward and Backward Maximum CPCS-SDU Size Identifier as follows:

- a) If it is able to accept the ATM MTU values proposed by the SETUP message, it shall include an AAL Parameters information element in its response. The Forward and Backwards Maximum CPCS-SDU Size fields shall be present and their values shall be equal to the corresponding values in the SETUP message.
- b) If it wishes a smaller ATM MTU size than that proposed, then it shall set the values of the Maximum CPCS-SDU Size in the AAL Parameters information elements equal to the desired value in the CONNECT message responding to the original SETUP message.
- c) If the calling endpoint receives a CONNECT message that does not contain the AAL Parameters Information Element, but the corresponding SETUP message did contain the AAL Parameters Information element (including the forward and backward CPCS-SDU Size fields), it shall clear the call with cause "AAL Parameters cannot be supported".
- d) If either endpoint receives a STATUS message with cause "Information Element Non-existent or Not Implemented" or cause "Access Information Discarded", and with a diagnostic field

indicating the AAL Parameters Information Element identifier, it shall clear the call with cause "AAL Parameters cannot be supported."

- e) If either endpoint receives CPCS-SDUs in excess of the negotiated MTU size, it may use IP fragmentation or may clear the call with cause "AAL Parameters cannot be supported". In this case, an error has occurred either due to a fault in an end system or in the ATM network. The error should be noted by ATM network management for human examination and intervention.

If the called endpoint incorrectly includes the Forward and Backward Maximum CPCS-SDU Size fields in the CONNECT messages (e.g., because the original SETUP message did not include these fields) or it sets these fields to an invalid value, then the calling party shall clear the call with cause "Invalid Information Element Contents".

### 7.3 Path MTU Discovery Required

The Path MTU Discovery mechanism is Internet Standard RFC 1191 [17] and is an important mechanism for reducing IP fragmentation in the Internet. This mechanism is particularly important because new subnet ATM uses a default MTU sizes significantly different from older subnet technologies such as Ethernet and FDDI.

In order to ensure good performance throughout the Internet and also to permit IP to take full advantage of the potentially larger IP datagram sizes supported by ATM, all router implementations that comply or conform with this specification must also implement the IP Path MTU Discovery mechanism as defined in RFC 1191 and clarified by RFC 1435 [14]. Host implementations should implement the IP Path MTU Discovery mechanism as defined in RFC 1191.

## 8. LIS ADDRESS RESOLUTION SERVICES

### 8.1 ATM-based ARP and InARP Equivalent Services

Address resolution within an ATM LIS SHALL make use of the ATM Address Resolution Protocol (ATMARP) (based on [3]) and the Inverse ATM Address Resolution Protocol (InATMARP) (based on [12]) and as defined in this memo. ATMARP is the same protocol as the ARP protocol presented in [3] with extensions needed to support address resolution in a unicast server ATM environment. InATMARP is the same protocol as the original InARP protocol presented in [12] but applied to ATM networks. All IP stations MUST support these protocols as updated and extended in this memo. Use of these protocols differs depending on whether PVCs or SVCs are used.

## 8.2 Permanent Virtual Connections

An IP station MUST have a mechanism (e.g., manual configuration) for determining what PVCs it has, and in particular which PVCs are being used with LLC/SNAP encapsulation. The details of the mechanism are beyond the scope of this memo.

All IP members supporting PVCs are required to use the Inverse ATM Address Resolution Protocol (InATMARP) (refer to [12]) on those VCs using LLC/SNAP encapsulation. In a strict PVC environment, the receiver SHALL infer the relevant VC from the VC on which the InATMARP\_Request or response InATMARP\_Reply was received. When the ATM source and/or target address is unknown, the corresponding ATM address length in the InATMARP packet MUST be set to zero (0) indicating a null length, and no storage be allocated in the InATMARP packet, otherwise the appropriate address field should be filled in and the corresponding length set appropriately. InATMARP packet format details are presented later in this memo.

Directly from [12]: "When the requesting station receives the In[ATM]ARP\_Reply, it may complete the [ATM]ARP table entry and use the provided address information. NOTE: as with [ATM]ARP, information learned via In[ATM]ARP may be aged or invalidated under certain circumstances." IP stations supporting PVCs MUST re-validate ATMARP table entries as part of the table aging process. See the Section 8.5.1 "Client ATMARP Table Aging".

If a client has more than one IP address within the LIS and if using PVCs, when an InATMARP\_Request is received an InATMARP\_Reply MUST be generated for each such address.

## 8.3 Switched Virtual Connections

SVCs require support from address resolution services for resolving target IP addresses to target ATM endpoint addresses. All members in the LIS MUST use the same service. This service MUST have authoritative responsibility for resolving the ATMARP requests of all IP members within the LIS.

ATMARP servers do not actively establish connections. They depend on the clients in the LIS to initiate connections for the ATMARP registration procedure and for transmitting ATMARP requests. An individual client connects to the ATMARP server using a point-to-point LLC/SNAP VC. The client sends normal ATMARP request packets to the server. The ATMARP server examines each ATMARP\_Request packet for

the source protocol and source hardware address information of the sending client and uses this information to build its ATMARP table cache. This information is used to generate replies to any ATMARP requests it receives.

InATMARP\_Request packets MUST specify valid address information for ATM source number, ATM target number, and source protocol address; i.e., these fields MUST be non-null in InATMARP\_Request packets.

This memo defines the address resolution service in the LIS and constrains it to consist of a single ATMARP server. Client-server interaction is defined by using a single server approach as a reference model.

This memo recognizes the future development of standards and implementations of multiple-ATMARP-server models that will extend the operations as defined in this memo to provide a highly reliable address resolution service.

#### 8.4 ATMARP Single Server Operational Requirements

A single ATMARP server accepts ATM calls/connections from other ATM end points. After receiving any ATMARP\_Request, the server will examine the source and target address information in the packet and make note of the VC on which the ATMARP\_Request arrived. It will use this information as necessary to build and update its ATMARP table entries.

For each ATMARP\_Request, then:

1. If the source IP protocol address is the same as the target IP protocol address and a table entry exists for that IP address and if the source ATM hardware address does not match the table entry ATM address and there is an open VC associated with that table entry that is not the same as the VC associated with the ATMARP\_Request, the server MUST return the table entry information in the ATMARP\_Reply, and MUST raise a "duplicate IP address detected" condition to the server's management. The table entry is not updated.
2. Otherwise, if the source IP protocol address is the same as the target IP protocol address, and either there is no table entry for that IP address, or a table entry exists for that IP address and there is no open VC associated with that table entry, or if the VC associated with that entry is the same as the VC for the ATMARP\_Request, the server MUST either create a new entry or update the old entry as appropriate and return that table entry information in the ATMARP Reply.

3. Otherwise, when the source IP protocol address does not match the target IP protocol address, the ATMARP server will generate the corresponding ATMARP\_Reply if it has an entry for the target information in its ATMARP table. Otherwise, it will generate a negative ATMARP reply (ATMARP\_NAK).
4. Additionally, when the source IP protocol address does not match the target IP protocol address and when the server receives an ATMARP\_Request over a VC, where the source IP and ATM address do not have a corresponding table entry, the ATMARP server MUST create a new table entry for the source information.  
Explanation: this allows old RFC 1577 clients to register with this ATMARP service by just issuing requests to it.
5. Additionally, when the source IP protocol address does not match the target IP protocol address and where the source IP and ATM addresses match the association already in the ATMARP table and the ATM address matches that associated with the VC, the server MUST update the table timeout on the source ATMARP table entry but only if it has been more than 10 minutes since the last update. Explanation: if the client is sending ATMARP requests to the server over the same VC that it used to register its ATMARP entry, the server should examine the ATMARP request and note that the client is still "alive" by updating the timeout on the client's ATMARP table entry.
6. Additionally, when the source IP protocol address does not match the target IP protocol address and where the source IP and ATM addresses do not match the association already in the ATMARP table, the server MUST NOT update the ATMARP table entry.

An ATMARP server MUST have knowledge of any open VCs it has and their association with an ATMARP table entry, and in particular, which VCs support LLC/SNAP encapsulation. In normal operation, active ATMARP clients will revalidate their entries prior to the server aging process taking effect.

Server ATMARP table entries are valid for 20 minutes. If an entry ages beyond 20 minutes without being updated (refreshed) by the client, that entry is deleted from the table regardless of the state of any VCs that may be associated with that entry.

## 8.5 ATMARP Client Operational Requirements

The ATMARP client is responsible for contacting the ATMARP service to both initially register and subsequently refresh its own ATMARP information.

The client is also responsible for using the ATMARP service to gain and revalidate ATMARP information about other IP members in the LIS (server selection overview is discussed in Section 8.6). As noted in Section 5.2, ATMARP clients MUST be configured with the ATM address of the appropriate server prior to client ATMARP operation.

IP clients MUST register their ATM endpoint address with their ATMARP server using the ATM address structure appropriate for their ATM network connection: i.e., LISs implemented over ATM LANs following ATM Forum UNI 3.1 should register using Structure 1; LISs implemented over an E.164 "public" ATM network should register using Structure 2. A LIS implemented over a combination of ATM LANs and public ATM networks may need to register using Structure 3. Implementations based on this memo MUST support all three ATM address structures. See Section 8.7.1 for more details regarding the ATMARP Request packet format.

To handle the case when a client has more than one IP address within a LIS, when using an ATMARP server, the client MUST register each such address.

For initial registration and subsequent refreshing of its own information with the ATMARP service, clients MUST:

1. Establish an LLC/SNAP VC connection to a server in the ATMARP service for the purposes of transmitting and receiving ATMARP packets.

NOTE: in the case of refreshing its own information with the ATMARP service, a client MAY reuse an existing established connection to the ATMARP service provided that the connection was previously used either to initially register its information with the ATMARP service or to refresh its information with the ATMARP service.

2. After establishing a successful connection to the ATMARP service, the client MUST transmit an ATMARP\_Request packet, requesting a target ATM address for its own IP address as the target IP protocol address. The client checks the ATMARP\_Reply and if the source hardware and protocol addresses match the respective target hardware and protocol addresses, the client is registered with the ATMARP service. If the addresses do not match, the client MAY take action, raise alarms, etc.; however, these actions are beyond the scope of this memo. In the case of a client having more than one IP address in the list, this step MUST be repeated for each IP address.

3. Clients MUST respond to ATMARP\_Request and InATMARP\_Request packets received on any VC appropriately. (Refer to Section 7, "Protocol Operation" in RFC 1293 [12].)

NOTE: for reasons of robustness, clients MUST respond to ATMARP\_Requests.

4. Generate and transmit address resolution request packets to the address resolution service. Respond to address resolution reply packets appropriately to build/refresh its own client ATMARP table entries.
5. Generate and transmit InATMARP\_Request packets as needed and process InATMARP\_Reply packets appropriately. InATMARP\_Reply packets should be used to build/refresh its own client ATMARP table entries. (Refer to Section 7, "Protocol Operation" in [12].) If a client has more than one IP address within the LIS when an InATMARP\_Request is received an InATMARP\_Reply MUST be generated for each such address.

The client MUST refresh its ATMARP information with the server at least once every 15 minutes. This is done by repeating steps 1 and 2.

An ATMARP client MUST have knowledge of any open VCs it has (permanent or switched), their association with an ATMARP table entry, and in particular, which VCs support LLC/SNAP encapsulation.

#### 8.5.1 Client ATMARP Table Aging

Client ATMARP table entries are valid for a maximum time of 15 minutes.

When an ATMARP table entry ages, an ATMARP client MUST invalidate the table entry. If there is no open VC server associated with the invalidated entry, that entry is deleted. In the case of an invalidated entry and an open VC, the client MUST revalidate the entry prior to transmitting any non address resolution traffic on that VC; this requirement applies to both PVCs and SVCs. NOTE: the client is permitted to revalidate an ATMARP table entry before it ages, thus restarting the aging time when the table entry is successfully revalidated. The client MAY continue to use the open VC, as long as the table entry has not aged, while revalidation is in progress.

In the case of an open PVC, the client revalidates the entry by transmitting an InATMARP\_Request and updating the entry on receipt of an InATMARP\_Reply.



In the case of an open SVC, the client revalidates the entry by querying the address resolution service. If a valid reply is received (e.g., ATMARP\_Reply), the entry is updated. If the address resolution service cannot resolve the entry (i.e., "host not found"), the SVC should be closed and the associated table entry removed. If the address resolution service is not available (i.e., "server failure") and if the SVC is LLC/SNAP encapsulated, the client MUST attempt to revalidate the entry by transmitting an InATMARP\_Request on that VC and updating the entry on receipt of an InATMARP\_Reply. If the InATMARP\_Request attempt fails to return an InATMARP\_Reply, the SVC should be closed and the associated table entry removed.

If a VC with an associated invalidated ATMARP table entry is closed, that table entry is removed.

#### 8.5.2 Non-Normal VC Operations

The specific details on client procedures for detecting non-normal VC connection establishment or closures, or failed communications on an established VC are beyond the scope of this memo. It is REQUIRED however, that the client MUST remove the associated ATMARP entry for a VC that fails to operate properly, as defined by the client, when the client closes that VC, when it releases its resources for a VC, or prior to any attempt to reopen that VC. This behavior specifically REQUIRES that the client MUST refresh its ATMARP table information prior to any attempt to re-establish communication to an IP member after a non-normal communications problem has previously occurred on a VC to that IP member.

#### 8.5.3 Use of ATMARP In Mobile-IP Scenarios

When an ATM LIS is used as the home network in a mobile-IP scenario, it is RECOMMENDED that the home agent NOT maintain long term connections with the ATMARP service. The absence of this VC will permit a mobile node's registration, upon its return to the home network, to immediately preempt the home agent's previous gratuitous registration.

#### 8.6 Address Resolution Server Selection

If the client supports PVCs only, the ATMARP server list is empty and the client MUST not generate any address resolution requests other than the InATMARP requests on a PVC needed to validate that PVC.

If the client supports SVCs, then the client MUST have a non-NULL atm\$arp-req-list pointing to the ATMARP server(s) which provides ATMARP service for the LIS.

The client **MUST** register with a server from atm\$arp-req-list.

The client **SHALL** attempt to communicate with any of the servers until a successful registration is accomplished. The order in which client selects servers to attempt registration, is a local matter, as are the number of retries and timeouts for such attempts.

#### 8.6.1 PVCs to ATMARP Servers

In a mixed PVC and SVC LIS environment, an ATMARP client **MAY** have a PVC to an ATMARP server. In this case, this PVC is used for ATMARP requests and responses as if it were an established SVC. **NOTE:** if this PVC is to be used for IP traffic, then the ATMARP server **MUST** be prepared to accept and respond appropriately to InATMARP traffic.

#### 8.7 ATMARP Packet Formats

Internet addresses are assigned independently of ATM addresses. Each host implementation **MUST** know its own IP and ATM address(es) and **MUST** respond to address resolution requests appropriately. IP members **MUST** also use ATMARP and InATMARP to resolve IP addresses to ATM addresses when needed.

**NOTE:** the ATMARP packet format presented in this memo is general in nature in that the ATM number and ATM subaddress fields **SHOULD** map directly to the corresponding UNI 3.1 fields used for ATM call/connection setup signalling messages. The IP over ATM Working Group expects ATM Forum NSAPA numbers (Structure 1) to predominate over E.164 numbers (Structure 2) as ATM endpoint identifiers within ATM LANs. The ATM Forum's VC Routing specification is not complete at this time and therefore its impact on the operational use of ATM Address Structure 3 is undefined. The ATM Forum will be defining this relationship in the future. It is for this reason that IP members need to support all three ATM address structures.

##### 8.7.1 ATMARP/InATMARP Request and Reply Packet Formats

The ATMARP and InATMARP request and reply protocols use the same hardware type (ar\$hrd), protocol type (ar\$pro), and operation code (ar\$op) data formats as the ARP and InARP protocols [3,12]. The location of these three fields within the ATMARP packet are in the same byte position as those in ARP and InARP packets. A unique hardware type value has been assigned for ATMARP. In addition, ATMARP makes use of an additional operation code for ARP\_NAK. The remainder of the ATMARP/InATMARP packet format is different than the ARP/InARP packet format.

The ATMARP and InATMARP protocols have several fields that have the following format and values:

Data:

ar\$hrd	16 bits	Hardware type
ar\$pro	16 bits	Protocol type
ar\$shtl	8 bits	Type & length (TL) of source ATM number (q)
ar\$sstl	8 bits	Type & length (TL) of source ATM subaddress (r)
ar\$op	16 bits	Operation code (request, reply, or NAK)
ar\$spln	8 bits	Length of source protocol address (s)
ar\$thtl	8 bits	Type & length (TL) of target ATM number (x)
ar\$stsl	8 bits	Type & length (TL) of target ATM subaddress (y)
ar\$tpln	8 bits	Length of target protocol address (z)
ar\$sha	qoctets	of source ATM number
ar\$ssa	roctets	of source ATM subaddress
ar\$spa	soctets	of source protocol address
ar\$tha	xoctets	of target ATM number
ar\$tsa	yoctets	of target ATM subaddress
ar\$tpa	zoctets	of target protocol address

Where:

ar\$hrd	-	assigned to ATM Forum address family and is 19 decimal (0x0013) [4].																									
ar\$pro	-	see Assigned Numbers for protocol type number for the protocol using ATMARP. (IP is 0x0800).																									
ar\$shtl	-	Type and length of source ATM number. See Section 8.7.4 for TL encoding details.																									
ar\$sstl	-	Type and length of source ATM subaddress. See Section 8.7.4 for TL encoding details.																									
ar\$op	-	The operation type value (decimal):																									
		<table border="0"> <tr> <td>ATMARP_Request</td> <td>=</td> <td>ARP_REQUEST</td> <td>=</td> <td>1</td> </tr> <tr> <td>ATMARP_Reply</td> <td>=</td> <td>ARP_REPLY</td> <td>=</td> <td>2</td> </tr> <tr> <td>InATMARP_Request</td> <td>=</td> <td>InARP_REQUEST</td> <td>=</td> <td>8</td> </tr> <tr> <td>InATMARP_Reply</td> <td>=</td> <td>InARP_REPLY</td> <td>=</td> <td>9</td> </tr> <tr> <td>ATMARP_NAK</td> <td>=</td> <td>ARP_NAK</td> <td>=</td> <td>10</td> </tr> </table>	ATMARP_Request	=	ARP_REQUEST	=	1	ATMARP_Reply	=	ARP_REPLY	=	2	InATMARP_Request	=	InARP_REQUEST	=	8	InATMARP_Reply	=	InARP_REPLY	=	9	ATMARP_NAK	=	ARP_NAK	=	10
ATMARP_Request	=	ARP_REQUEST	=	1																							
ATMARP_Reply	=	ARP_REPLY	=	2																							
InATMARP_Request	=	InARP_REQUEST	=	8																							
InATMARP_Reply	=	InARP_REPLY	=	9																							
ATMARP_NAK	=	ARP_NAK	=	10																							
ar\$spln	-	length in octets of the source protocol address. Value range is 0 or 4 (decimal). For IPv4 ar\$spln is 4.																									
ar\$thtl	-	Type and length of target ATM number. See Section 8.7.4 for TL encoding details.																									

`ar$tstl` - Type and length of target ATM subaddress. See Section 8.7.4 for TL encoding details.  
`ar$tpln` - length in octets of the target protocol address. Value range is 0 or 4 (decimal). For IPv4 `ar$tpln` is 4.  
`ar$sha` - source ATM number (E.164 or ATM Forum NSAPA)  
`ar$ssa` - source ATM subaddress (ATM Forum NSAPA)  
`ar$spa` - source protocol address  
`ar$tha` - target ATM number (E.164 or ATM Forum NSAPA)  
`ar$tsa` - target ATM subaddress (ATM Forum NSAPA)  
`ar$tpa` - target protocol address

### 8.7.2 Receiving Unknown ATMARP packets

If an ATMARP client receives an ATMARP message with an operation code (`ar$op`) for which it is not coded to support, it MUST gracefully discard the message and continue normal operation. An ATMARP client is NOT REQUIRED to return any message to the sender of the unsupported message.

### 8.7.3 TL, ATM Number, and ATM Subaddress Encoding

The encoding of the 8-bit TL (type and length) fields in ATMARP and In\_ATMARP packets is as follows:

MSB	8	7	6	5	4	3	2	1	LSB
+-----+-----+-----+-----+-----+-----+-----+-----+									
0		1/0		Octet length of address					
+-----+-----+-----+-----+-----+-----+-----+-----+									

Where:

bit.8 (reserved) = 0 (for future use)  
 bit.7 (type) = 0 ATM Forum NSAPA format  
               = 1 E.164 format  
 bit.6-1 (length) = 6 bit unsigned octet length of address  
                   (MSB = bit.6, LSB = bit.1) Value  
                   range is from 0 to 20 (decimal).

ATM addresses, as defined by the ATM Forum UNI 3.1 signaling specification [9], include a "Calling Party Number Information Element" and a "Calling Party Subaddress Information Element". These Information Elements (IEs) SHOULD map to ATMARP/InATMARP source ATM number and source ATM subaddress respectively. Furthermore, ATM Forum defines a "Called Party Number Information Element" and a "Called Party Subaddress Information Element". These IEs map to ATMARP/InATMARP target ATM number and target ATM subaddress, respectively.

The ATM Forum defines three structures for the combined use of number and subaddress [9]:

	ATM Number	ATM Subaddress
	-----	-----
Structure 1	ATM Forum NSAPA	null
Structure 2	E.164	null
Structure 3	E.164	ATM Forum NSAPA

ATMARP and InATMARP requests and replies for ATM address structures 1 and 2 MUST indicate a null or unknown ATM subaddress by setting the appropriate subaddress length to zero; i.e., ar\$sstl.length = 0 or ar\$stsl.length = 0, the corresponding type field (ar\$sstl.type or ar\$stsl.type) MUST be ignored and the physical space for the ATM subaddress buffer MUST not be allocated in the ATMARP packet. For example, if ar\$sstl.length=0, the storage for the source ATM subaddress is not allocated and the first byte of the source protocol address ar\$spa follows immediately after the last byte of the source hardware address ar\$sha in the packet.

Null or unknown ATM addresses MUST be indicated by setting the appropriate address length to zero; i.e., ar\$shl.length and ar\$thl.length is zero and the corresponding type field (ar\$sstl.type or ar\$stsl.type) MUST be ignored and the physical space for the ATM address or ATM subaddress buffer MUST not be allocated in the ATMARP packet.

#### 8.7.4 ATMARP\_NAK Packet Format

The ATMARP\_NAK packet format is the same as the received ATMARP\_Request packet format with the operation code set to ARP\_NAK, i.e., the ATMARP\_Request packet data is exactly copied (e.g., using bcopy) for transmission with the ATMARP\_Request operation code changed to ARP\_NAK value.

#### 8.7.5 Variable Length Requirements for ATMARP Packets

ATMARP and InATMARP packets are variable in length.

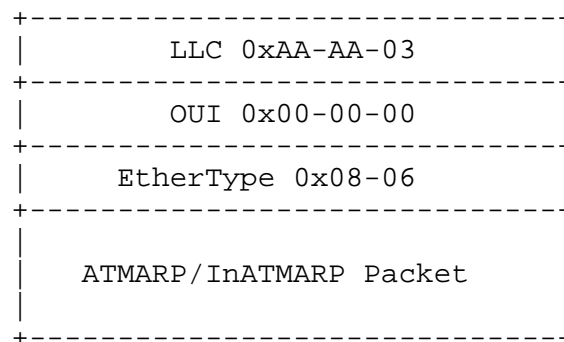
A null or unknown source or target protocol address is indicated by the corresponding length set to zero: e.g., when ar\$spln or ar\$tpn is zero the physical space for the corresponding address structure MUST not be allocated in the packet.

For backward compatibility with previous implementations, a null IPv4 protocol address may be received with length = 4 and an allocated address in storage set to the value 0.0.0.0. Receiving stations MUST be liberal in accepting this format of a null IPv4 address. However, on transmitting an ATMARP or InATMARP packet, a null IPv4 address MUST only be indicated by the length set to zero and MUST have no storage allocated.

## 8.8 ATMARP/InATMARP Packet Encapsulation

ATMARP and InATMARP packets are to be encoded in AAL5 PDUs using LLC/SNAP encapsulation. The format of the AAL5 CPCS-SDU payload field for ATMARP/InATMARP PDUs is:

Payload Format for ATMARP/InATMARP PDUs:



The LLC value of 0xAA-AA-03 (3 octets) indicates the presence of a SNAP header.

The OUI value of 0x00-00-00 (3 octets) indicates that the following two-bytes is an EtherType.

The EtherType value of 0x08-06 (2 octets) indicates ARP [4].

The total size of the LLC/SNAP header is fixed at 8-octets. This aligns the start of the ATMARP packet on a 64-bit boundary relative to the start of the AAL5 CPCS-SDU.

The LLC/SNAP encapsulation for ATMARP/InATMARP presented here is consistent with the treatment of multiprotocol encapsulation of IP over ATM AAL5 as specified in [2] and in the format of ATMARP over IEEE 802 networks as specified in [5].

Traditionally, address resolution requests are broadcast to all directly connected IP members within a LIS. It is conceivable in the future that larger scaled ATM networks may handle ATMARP requests to destinations outside the originating LIS, perhaps even globally; issues raised by ATMARPing outside the LIS or by a global ATMARP mechanism are beyond the scope of this memo.

#### 9. IP BROADCAST ADDRESS

ATM does not support broadcast addressing, therefore there are no mappings available from IP broadcast addresses to ATM broadcast services. Note: this lack of mapping does not restrict members from transmitting or receiving IP datagrams specifying any of the four standard IP broadcast address forms as described in [8]. Members, upon receiving an IP broadcast or IP subnet broadcast for their LIS, MUST process the packet as if addressed to that station.

This memo recognizes the future development of standards and implementations that will extend the operations as defined in this memo to provide an IP broadcast capability for use by the classical client.

#### 10. IP MULTICAST ADDRESS

ATM does not directly support IP multicast address services, therefore there are no mappings available from IP multicast addresses to ATM multicast services. Current IP multicast implementations (i.e., MBONE and IP tunneling, see [10]) will continue to operate over ATM based logical IP subnets if operated in the WAN configuration.

This memo recognizes the future development of ATM multicast service addressing by the ATM Forum. When available and widely implemented, the roll-over from the current IP multicast architecture to this new ATM architecture will be straightforward.

This memo recognizes the future development of standards and implementations that will extend the operations as defined in this memo to provide an IP multicast capability for use by the classical client.

#### 11. SECURITY CONSIDERATIONS

Not all of the security issues relating to IP over ATM are clearly understood at this time, due to the fluid state of ATM specifications, newness of the technology, and other factors.

It is believed that ATM and IP facilities for authenticated call management, authenticated end-to-end communications, and data encryption will be needed in globally connected ATM networks. Such future security facilities and their use by IP networks are beyond the scope of this memo.

There are known security issues relating to host impersonation via the address resolution protocols used in the Internet [13]. No special security mechanisms have been added to the address resolution mechanism defined here for use with networks using IP over ATM.

## 12. MIB SPECIFICATION

Clients built to this specification MUST implement and provide a Management Information Base (MIB) as defined in "Definitions of Managed Objects for Classical IP and ARP Over ATM Using SMIPv2" [18].

## 13. OPEN ISSUES

- o Automatic configuration of client ATM addresses via DHCP [15] or via ATM UNI 3.1 Interim Local Management Interface (ILMI) services would be a useful extended service addition to this document and should be addressed in a separate memo.
- o ATMARP packets are not authenticated. This is a potentially serious flaw in the overall system by allowing a mechanism by which corrupt information may be introduced into the server system.

## 14. REFERENCES

- [1] Piscitello, D., and J. Lawrence, "The Transmission of IP Datagrams over the SMDS Service", STD 52, RFC 1209, March 1991.
- [2] Heinanen, J., "Multiprotocol Encapsulation over ATM Adaptation Layer 5", RFC 1483, July 1993.
- [3] Plummer, D., "An Ethernet Address Resolution Protocol - or - Converting Network Protocol Addresses to 48.bit Ethernet Address for Transmission on Ethernet Hardware", STD 37, RFC 826, November 1982.
- [4] Reynolds, J., and J. Postel, "Assigned Numbers", STD 2, RFC 1700, July 1992.
- [5] Postel, J., and J. Reynolds, "A Standard for the Transmission of IP Datagrams over IEEE 802 Networks", STD 43, RFC 1042, February 1988.



- [6] CCITT, "Draft Recommendation I.363", CCITT Study Group XVIII, Geneva, 19-29 January 1993.
- [7] CCITT, "Draft text for Q.93B", CCITT Study Group XI, 23 September - 2 October 1992.
- [8] Braden, R., "Requirements for Internet Hosts -- Communication Layers", STD 3, RFC 1122, October 1989.
- [9] ATM Forum, "ATM User-Network Interface (UNI) Specification Version 3.1.", ISBN 0-13-393828-X, Prentice-Hall, Inc., Upper Saddle River, NJ, 07458, September, 1994.
- [10] Deering, S., "Host Extensions for IP Multicasting", STD 5, RFC 1112, August 1989.
- [11] Colella, R., Gardner, E., and R. Callon, "Guidelines for OSI NSAP Allocation in the Internet", RFC 1237, July 1991.
- [12] Bradely, T., and C. Brown, "Inverse Address Resolution Protocol", RFC 1293, January 1992.
- [13] Bellovin, Steven M., "Security Problems in the TCP/IP Protocol Suite", ACM Computer Communications Review, Vol. 19, Issue 2, pp. 32-48, 1989.
- [14] Knowles, S., "IESG Advice from Experience with Path MTU Discovery", RFC 1435, March 1993.
- [15] Droms, R., "Dynamic Host Configuration Protocol", RFC 1541, March 1997.
- [16] Kent C., and J. Mogul, "Fragmentation Considered Harmful", Proceedings of the ACM SIGCOMM '87 Workshop on Frontiers in Computer Communications Technology, August 1987.
- [17] Mogul, J., and S. Deering, "Path MTU Discovery", RFC 1191, November 1990.
- [18] Green, M., Luciani, J., White, K., and T. Kuo, "Definitions of Managed Objects for Classical IP and ARP over ATM Using SMIPv2", RFC 2320, April 1998.
- [19] ATM Forum, "ATM User-Network Interface (UNI) Specification Version 4.0", ATM Forum specification af-sig-0061.000, <ftp://ftp.atmforum.com/>, July, 1996.

[20] Bradner, S., "Key words for use in RFCs to Indicate Requirement Levels", BCP 14, RFC 2119, March 1997.

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## APPENDIX A - Update Information

This memo represents an update to RFC 1577 and RFC 1626. The following changes are included in this memo:

- o Pointer to Classical MIB I-D for setting of variables
- o Single ATMARP server address to ATMARP server list, configurable via the MIB.
- o RFC 1626 text replaces MTU section
- o Client registration procedure from In\_ATMARP to first ATMARP\_Request
- o Clarification of variable length ATMARP packet format
- o Clarification of ARP\_NAK packet format
- o Clarification of InATMARP packet format for null IPv4 addresses
- o Clarification on ATMARP registration and use of InATMARP\_Reply for clients having more than one IP address in a LIS

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