**Address Resolution Protocol**

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The **Address Resolution Protocol** (**ARP**) is a [communication protocol](https://en.wikipedia.org/wiki/Communication_protocol) used for discovering the [link layer](https://en.wikipedia.org/wiki/Link_layer) address, such as a [MAC address](https://en.wikipedia.org/wiki/MAC_address), associated with a given [internet layer](https://en.wikipedia.org/wiki/Internet_layer) address, typically an [IPv4 address](https://en.wikipedia.org/wiki/IPv4_address). This mapping is a critical function in the [Internet protocol suite](https://en.wikipedia.org/wiki/Internet_protocol_suite). ARP was defined in 1982 by [RFC](https://en.wikipedia.org/wiki/RFC_(identifier)) [826](https://tools.ietf.org/html/rfc826),[[1]](https://en.wikipedia.org/wiki/Address_Resolution_Protocol#cite_note-1) which is [Internet Standard](https://en.wikipedia.org/wiki/Internet_Standard) STD 37.

ARP has been implemented with many combinations of network and data link layer technologies, such as [IPv4](https://en.wikipedia.org/wiki/IPv4), [Chaosnet](https://en.wikipedia.org/wiki/Chaosnet), [DECnet](https://en.wikipedia.org/wiki/DECnet) and Xerox [PARC Universal Packet](https://en.wikipedia.org/wiki/PARC_Universal_Packet) (PUP) using [IEEE 802](https://en.wikipedia.org/wiki/IEEE_802) standards, [FDDI](https://en.wikipedia.org/wiki/FDDI), [X.25](https://en.wikipedia.org/wiki/X.25), [Frame Relay](https://en.wikipedia.org/wiki/Frame_Relay) and [Asynchronous Transfer Mode](https://en.wikipedia.org/wiki/Asynchronous_Transfer_Mode) (ATM).

In [Internet Protocol Version 6](https://en.wikipedia.org/wiki/IPv6) (IPv6) networks, the functionality of ARP is provided by the [Neighbor Discovery Protocol](https://en.wikipedia.org/wiki/Neighbor_Discovery_Protocol) (NDP).



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**Operating scope**

The Address Resolution Protocol is a [request-response](https://en.wikipedia.org/wiki/Request-response) protocol whose messages are encapsulated by a link layer protocol. It is communicated within the boundaries of a single network, never routed across internetworking nodes. This property places ARP into the [link layer](https://en.wikipedia.org/wiki/Link_layer) of the [Internet protocol suite](https://en.wikipedia.org/wiki/Internet_protocol_suite).[[2]](https://en.wikipedia.org/wiki/Address_Resolution_Protocol#cite_note-2)

**Packet structure**

The Address Resolution Protocol uses a simple message format containing one address resolution request or response. The size of the ARP message depends on the link layer and network layer address sizes. The message [header](https://en.wikipedia.org/wiki/Header_(computing)) specifies the types of network in use at each layer as well as the size of addresses of each. The message header is completed with the operation code for request (1) and reply (2). The payload of the packet consists of four addresses, the hardware and protocol address of the sender and receiver hosts.

The principal packet structure of ARP packets is shown in the following table which illustrates the case of IPv4 networks running on Ethernet. In this scenario, the packet has 48-bit fields for the sender hardware address (SHA) and target hardware address (THA), and 32-bit fields for the corresponding sender and target protocol addresses (SPA and TPA). The ARP packet size in this case is 28 bytes.

|  |  |  |
| --- | --- | --- |
| Internet Protocol (IPv4) over Ethernet ARP packet | | |
| **Octet offset** | **0** | **1** |
| **0** | Hardware type (HTYPE) | |
| **2** | Protocol type (PTYPE) | |
| **4** | Hardware address length (HLEN) | Protocol address length (PLEN) |
| **6** | Operation (OPER) | |
| **8** | Sender hardware address (SHA) (first 2 bytes) | |
| **10** | (next 2 bytes) | |
| **12** | (last 2 bytes) | |
| **14** | Sender protocol address (SPA) (first 2 bytes) | |
| **16** | (last 2 bytes) | |
| **18** | Target hardware address (THA) (first 2 bytes) | |
| **20** | (next 2 bytes) | |
| **22** | (last 2 bytes) | |
| **24** | Target protocol address (TPA) (first 2 bytes) | |
| **26** | (last 2 bytes) | |

Hardware type (HTYPE)

This field specifies the network link protocol type. Example: Ethernet is 1.

Protocol type (PTYPE)

This field specifies the internetwork protocol for which the ARP request is intended. For IPv4, this has the value 0x0800. The permitted PTYPE values share a numbering space with those for [EtherType](https://en.wikipedia.org/wiki/EtherType).[[3]](https://en.wikipedia.org/wiki/Address_Resolution_Protocol#cite_note-3)[[4]](https://en.wikipedia.org/wiki/Address_Resolution_Protocol#cite_note-4)[[5]](https://en.wikipedia.org/wiki/Address_Resolution_Protocol#cite_note-5)

Hardware length (HLEN)

Length (in [octets](https://en.wikipedia.org/wiki/Octet_(computing))) of a hardware address. Ethernet address length is 6.

Protocol length (PLEN)

Length (in octets) of internetwork addresses. The internetwork protocol is specified in PTYPE. Example: IPv4 address length is 4.

Operation

Specifies the operation that the sender is performing: 1 for request, 2 for reply.

Sender hardware address (SHA)

Media address of the sender. In an ARP request this field is used to indicate the address of the host sending the request. In an ARP reply this field is used to indicate the address of the host that the request was looking for.

Sender protocol address (SPA)

Internetwork address of the sender.

Target hardware address (THA)

Media address of the intended receiver. In an ARP request this field is ignored. In an ARP reply this field is used to indicate the address of the host that originated the ARP request.

Target protocol address (TPA)

Internetwork address of the intended receiver.

ARP protocol parameter values have been standardized and are maintained by the [Internet Assigned Numbers Authority](https://en.wikipedia.org/wiki/Internet_Assigned_Numbers_Authority) (IANA).[[6]](https://en.wikipedia.org/wiki/Address_Resolution_Protocol#cite_note-6)

The [EtherType](https://en.wikipedia.org/wiki/EtherType) for ARP is 0x0806. This appears in the Ethernet frame header when the payload is an ARP packet and is not to be confused with PTYPE, which appears within this encapsulated ARP packet.

**Example**

Two computers in an office (Computer 1 and Computer 2) are connected to each other in a [local area network](https://en.wikipedia.org/wiki/Local_area_network) by [Ethernet](https://en.wikipedia.org/wiki/Ethernet) cables and [network switches](https://en.wikipedia.org/wiki/Network_switches), with no intervening [gateways](https://en.wikipedia.org/wiki/Gateway_(telecommunications)) or [routers](https://en.wikipedia.org/wiki/Router_(computing)). Computer 1 has a packet to send to Computer 2. Through [DNS](https://en.wikipedia.org/wiki/DNS), it determines that Computer 2 has the IP address 192.168.0.55.

To send the message, it also requires Computer 2's [MAC address](https://en.wikipedia.org/wiki/MAC_address). First, Computer 1 uses a cached ARP table to look up 192.168.0.55 for any existing records of Computer 2's MAC address (00:eb:24:b2:05:ac). If the MAC address is found, it sends an Ethernet [frame](https://en.wikipedia.org/wiki/Frame_(networking)) with destination address 00:eb:24:b2:05:ac, containing the IP packet onto the link. If the cache did not produce a result for 192.168.0.55, Computer 1 has to send a broadcast ARP request message (destination FF:FF:FF:FF:FF:FF MAC address), which is accepted by all computers on the local network, requesting an answer for 192.168.0.55.

Computer 2 responds with an ARP response message containing its MAC and IP addresses. As part of fielding the request, Computer 2 may insert an entry for Computer 1 into its ARP table for future use.

Computer 1 receives and caches the response information in its ARP table and can now send the packet.[[7]](https://en.wikipedia.org/wiki/Address_Resolution_Protocol#cite_note-7)

**ARP probe**

An **ARP probe** is an ARP request constructed with an all-zero SPA. Before beginning to use an IPv4 address (whether received from manual configuration, DHCP, or some other means), a host implementing this specification must test to see if the address is already in use, by broadcasting ARP probe packets.[[8]](https://en.wikipedia.org/wiki/Address_Resolution_Protocol#cite_note-8)

**ARP announcements**

ARP may also be used as a simple announcement protocol. This is useful for updating other hosts' mappings of a hardware address when the sender's IP address or MAC address changes. Such an announcement, also called a **gratuitous ARP** message, is usually broadcast as an *ARP request* containing the SPA in the target field (TPA=SPA), with THA set to zero. An alternative way is to broadcast an *ARP reply* with the sender's SHA and SPA duplicated in the target fields (TPA=SPA, THA=SHA).

The *ARP request* and *ARP reply* announcements are both standards-based methods,[[9]](https://en.wikipedia.org/wiki/Address_Resolution_Protocol#cite_note-9)[[10]](https://en.wikipedia.org/wiki/Address_Resolution_Protocol#cite_note-10) but the *ARP request* method is preferred.[[11]](https://en.wikipedia.org/wiki/Address_Resolution_Protocol#cite_note-11) Some devices may be configured for the use of either of these two types of announcements.[[12]](https://en.wikipedia.org/wiki/Address_Resolution_Protocol#cite_note-12)

An ARP announcement is not intended to solicit a reply; instead, it updates any cached entries in the ARP tables of other hosts that receive the packet. The operation code in the announcement may be either request or reply; the ARP standard specifies that the opcode is only processed after the ARP table has been updated from the address fields.[[13]](https://en.wikipedia.org/wiki/Address_Resolution_Protocol#cite_note-13)[[14]](https://en.wikipedia.org/wiki/Address_Resolution_Protocol#cite_note-14)[[15]](https://en.wikipedia.org/wiki/Address_Resolution_Protocol#cite_note-15)

Many operating systems issue an ARP announcement during startup. This helps to resolve problems which would otherwise occur if, for example, a [network card](https://en.wikipedia.org/wiki/Network_interface_controller) was recently changed (changing the IP-address-to-MAC-address mapping) and other hosts still have the old mapping in their ARP caches.

ARP announcements are also used by some network interfaces to provide load balancing for incoming traffic. In a [team](https://en.wikipedia.org/wiki/NIC_teaming) of network cards, it is used to announce a different MAC address within the team that should receive incoming packets.

ARP announcements can be used in the [Zeroconf](https://en.wikipedia.org/wiki/Zeroconf) protocol to allow automatic assignment of a [link-local IP addresses](https://en.wikipedia.org/wiki/Link-local_address) to an interface where no other IP address configuration is available. The announcements are used to ensure an address chosen by a host is not in use by other hosts on the network link.[[16]](https://en.wikipedia.org/wiki/Address_Resolution_Protocol#cite_note-16)

**ARP mediation**

**ARP mediation** refers to the process of resolving Layer-2 addresses through a [virtual private wire service](https://en.wikipedia.org/w/index.php?title=Virtual_private_wire_service&action=edit&redlink=1) (VPWS) when different resolution protocols are used on the connected circuits, e.g., [Ethernet](https://en.wikipedia.org/wiki/Ethernet) on one end and [Frame Relay](https://en.wikipedia.org/wiki/Frame_Relay) on the other. In [IPv4](https://en.wikipedia.org/wiki/IPv4), each [Provider Edge](https://en.wikipedia.org/wiki/Provider_Edge) (PE) device discovers the IP address of the locally attached [Customer Edge](https://en.wikipedia.org/wiki/Customer_Edge) (CE) device and distributes that IP address to the corresponding remote PE device. Then each PE device responds to local ARP requests using the IP address of the remote CE device and the hardware address of the local PE device. In [IPv6](https://en.wikipedia.org/wiki/IPv6), each PE device discovers the IP address of both local and remote CE devices and then intercepts local [Neighbor Discovery](https://en.wikipedia.org/wiki/Neighbor_Discovery_Protocol) (ND) and [Inverse Neighbor Discovery](https://en.wikipedia.org/wiki/Inverse_Neighbor_Discovery) (IND) packets and forwards them to the remote PE device.[[17]](https://en.wikipedia.org/wiki/Address_Resolution_Protocol#cite_note-17)

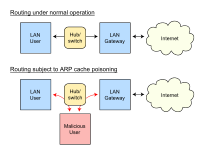
**Inverse ARP and Reverse ARP**

**Inverse Address Resolution Protocol** (**Inverse ARP** or **InARP**) is used to obtain [network layer](https://en.wikipedia.org/wiki/Network_layer) addresses (for example, [IP addresses](https://en.wikipedia.org/wiki/IP_address)) of other nodes from [data link layer](https://en.wikipedia.org/wiki/Data_link_layer) (Layer 2) addresses. It is primarily used in [Frame Relay](https://en.wikipedia.org/wiki/Frame_Relay) ([DLCI](https://en.wikipedia.org/wiki/DLCI)) and ATM networks, in which Layer 2 addresses of [virtual circuits](https://en.wikipedia.org/wiki/Virtual_circuit) are sometimes obtained from Layer 2 signaling, and the corresponding Layer 3 addresses must be available before those virtual circuits can be used.[[18]](https://en.wikipedia.org/wiki/Address_Resolution_Protocol#cite_note-18)

Since ARP translates Layer 3 addresses to Layer 2 addresses, InARP may be described as its inverse. In addition, InARP is implemented as a protocol extension to ARP: it uses the same packet format as ARP, but different operation codes.

The [Reverse Address Resolution Protocol](https://en.wikipedia.org/wiki/Reverse_Address_Resolution_Protocol) (Reverse ARP or RARP), like InARP, translates Layer 2 addresses to Layer 3 addresses. However, in InARP the requesting station queries the Layer 3 address of another node, whereas RARP is used to obtain the Layer 3 address of the requesting station itself for address configuration purposes. RARP is obsolete; it was replaced by [BOOTP](https://en.wikipedia.org/wiki/BOOTP), which was later superseded by the [Dynamic Host Configuration Protocol](https://en.wikipedia.org/wiki/Dynamic_Host_Configuration_Protocol) (DHCP).[[19]](https://en.wikipedia.org/wiki/Address_Resolution_Protocol#cite_note-19)

**ARP spoofing and Proxy ARP**

[](https://en.wikipedia.org/wiki/File:ARP_Spoofing.svg)

A successful [ARP spoofing](https://en.wikipedia.org/wiki/ARP_spoofing) attack allows an attacker to perform a [man-in-the-middle attack](https://en.wikipedia.org/wiki/Man-in-the-middle_attack).

Main article: [ARP spoofing](https://en.wikipedia.org/wiki/ARP_spoofing)

Main article: [Proxy ARP](https://en.wikipedia.org/wiki/Proxy_ARP)

Because ARP does not provide methods for authenticating ARP replies on a network, ARP replies can come from systems other than the one with the required Layer 2 address. An ARP *proxy* is a system which answers the ARP request on behalf of another system for which it will forward traffic, normally as a part of the network's design, such as for a dialup internet service. By contrast, in ARP *spoofing* the answering system, or *spoofer*, replies to a request for another system's address with the aim of intercepting data bound for that system. A malicious user may use ARP spoofing to perform a [man-in-the-middle](https://en.wikipedia.org/wiki/Man-in-the-middle) or [denial-of-service](https://en.wikipedia.org/wiki/Denial-of-service) attack on other users on the network. Various software exists to both detect and perform ARP spoofing attacks, though ARP itself does not provide any methods of protection from such attacks.[[20]](https://en.wikipedia.org/wiki/Address_Resolution_Protocol#cite_note-grc-20)

**Alternatives to ARP**

IPv6 uses the [Neighbor Discovery Protocol](https://en.wikipedia.org/wiki/Neighbor_Discovery_Protocol) and its extensions such as [Secure Neighbor Discovery](https://en.wikipedia.org/wiki/Secure_Neighbor_Discovery), rather than ARP.

Computers can also maintain lists of known addresses, rather than using an active protocol. In this model, each computer maintains a database of the mapping of [Layer 3](https://en.wikipedia.org/wiki/Layer_3) addresses (e.g., [IP addresses](https://en.wikipedia.org/wiki/IP_addresses)) to [Layer 2](https://en.wikipedia.org/wiki/Layer_2) addresses (e.g., [Ethernet](https://en.wikipedia.org/wiki/Ethernet) [MAC addresses](https://en.wikipedia.org/wiki/MAC_addresses)). This data maintained primarily by the interpreting ARP packets from the local network link. Thus, it is often called the *ARP cache*.

Traditionally, other methods were also used to maintain the mapping between addresses, such as static configuration files,[[21]](https://en.wikipedia.org/wiki/Address_Resolution_Protocol#cite_note-21) or centrally maintained lists.

Since at least the 1980s,[[22]](https://en.wikipedia.org/wiki/Address_Resolution_Protocol#cite_note-22) networked computers have a utility called 'arp' for interrogating or manipulating this table.[[23]](https://en.wikipedia.org/wiki/Address_Resolution_Protocol#cite_note-23)[[24]](https://en.wikipedia.org/wiki/Address_Resolution_Protocol#cite_note-24)[[25]](https://en.wikipedia.org/wiki/Address_Resolution_Protocol#cite_note-25)

**ARP stuffing**

Embedded systems such as networked cameras[[26]](https://en.wikipedia.org/wiki/Address_Resolution_Protocol#cite_note-26) and networked power distribution devices,[[27]](https://en.wikipedia.org/wiki/Address_Resolution_Protocol#cite_note-27) which lack a user interface, can use so-called *ARP stuffing* to make an initial network connection, although this is a misnomer, as ARP is not involved.

This is a solution to an issue in network management of consumer devices, specifically the allocation of IP addresses of ethernet devices where:

1. the user doesn't have the ability to control [DHCP](https://en.wikipedia.org/wiki/DHCP) or similar address allocation protocols
2. the device doesn't have a user interface to configure it with
3. the user's computer can't communicate with it because it has no suitable IP address.

The solution adopted is as follows:

* The user's computer has an IP address *stuffed* manually into its address table (normally with the *arp* command with the MAC address taken from a label on the device)
* The computer sends special packets to the device, typically a [ping](https://en.wikipedia.org/wiki/Ping_(networking_utility)) packet with a non-default size.
* The device then adopts this IP address
* The user then communicates with it by [telnet](https://en.wikipedia.org/wiki/Telnet) or [web](https://en.wikipedia.org/wiki/Http) protocols to complete the configuration.

Such devices typically have a method to disable this process once the device is operating normally, as it is vulnerable to attack.

**Standards documents**

* [RFC](https://en.wikipedia.org/wiki/RFC_(identifier)) [826](https://tools.ietf.org/html/rfc826) - Ethernet Address Resolution Protocol, Internet Standard STD 37.
* [RFC](https://en.wikipedia.org/wiki/RFC_(identifier)) [903](https://tools.ietf.org/html/rfc903) - Reverse Address Resolution Protocol, Internet Standard STD 38.
* [RFC](https://en.wikipedia.org/wiki/RFC_(identifier)) [2390](https://tools.ietf.org/html/rfc2390) - Inverse Address Resolution Protocol, draft standard
* [RFC](https://en.wikipedia.org/wiki/RFC_(identifier)) [5227](https://tools.ietf.org/html/rfc5227) - IPv4 Address Conflict Detection, proposed standard

**See also**

* [ARP spoofing](https://en.wikipedia.org/wiki/ARP_spoofing)
* [Arping](https://en.wikipedia.org/wiki/Arping)
* [Arptables](https://en.wikipedia.org/wiki/Arptables)
* [Arpwatch](https://en.wikipedia.org/wiki/Arpwatch)
* [Bonjour Sleep Proxy](https://en.wikipedia.org/wiki/Bonjour_Sleep_Proxy)
* [Cisco HDLC](https://en.wikipedia.org/wiki/Cisco_HDLC)
* [Neighbor Discovery Protocol](https://en.wikipedia.org/wiki/Neighbor_Discovery_Protocol)
* [Proxy ARP](https://en.wikipedia.org/wiki/Proxy_ARP)

**References**

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  *Braden, R. (October 1989).* [*"RFC 1122 - Requirements for Internet Hosts -- Communication Layers"*](http://tools.ietf.org/html/rfc1122)*. Internet Engineering Task Force.*

  [IANA ARP - "Protocol Type"](https://www.iana.org/assignments/arp-parameters/arp-parameters.xhtml)

  [IANA - Ethertype values](https://www.iana.org/assignments/ethernet-numbers/ethernet-numbers.xhtml)

  [RFC](https://en.wikipedia.org/wiki/RFC_(identifier)) [5342](https://tools.ietf.org/html/rfc5342)

  [*"Address Resolution Protocol (ARP) Parameters"*](https://www.iana.org/assignments/arp-parameters/arp-parameters.xhtml)*. www.iana.org. Retrieved 2018-10-16.*

  Chappell, Laura A. and Tittel, Ed. *Guide to TCP/IP, Third Edition*. Thomson Course Technology, 2007, pp. 115-116.

  *Cheshire, S. (July 2008).* [*IPv4 Address Conflict Detection*](https://tools.ietf.org/html/rfc5227)*. Internet Engineering Task Force.* [*doi*](https://en.wikipedia.org/wiki/Doi_(identifier))*:*[*10.17487/RFC5227*](https://doi.org/10.17487%2FRFC5227)*.* [*RFC*](https://en.wikipedia.org/wiki/RFC_(identifier))[*5227*](https://tools.ietf.org/html/rfc5227)*.*

  *Perkins, C. (November 2010).* [*"RFC 5944 - IP Mobility Support for IPv4, Revised"*](https://tools.ietf.org/html/rfc5944#section-4.6)*. Internet Engineering Task Force. A gratuitous ARP MAY use either an ARP Request or an ARP Reply packet. [...] any node receiving any ARP packet (Request or Reply) MUST update its local ARP cache with the Sender Protocol and Hardware Addresses in the ARP packet [...]*

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  [RFC 2002 Section 4.6](http://tools.ietf.org/html/rfc2002#section-4.6)

  [RFC 2131 DHCP – Last lines of Section 4.4.1](http://tools.ietf.org/html/rfc2131#section-4.4.1)

  [RFC](https://en.wikipedia.org/wiki/RFC_(identifier)) [3927](https://tools.ietf.org/html/rfc3927)

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**External links**

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|  | Wikiversity has learning resources about [***Address Resolution Protocol***](https://en.wikiversity.org/wiki/Address_Resolution_Protocol) |

* [ARP Sequence Diagram (pdf)](http://www.eventhelix.com/RealtimeMantra/Networking/Arp.pdf)
* [Gratuitous ARP](https://wiki.wireshark.org/Gratuitous_ARP)
* [ARP-SK ARP traffic generation tools](https://web.archive.org/web/20090903074149/http:/sid.rstack.org/arp-sk/)
* [Sample Capture file from WireSharkWiki](https://wiki.wireshark.org/SampleCaptures#head-2fb4a82886c1d8c722134b44461e22e5f7f54b32)