- IP- Internet Protocol
  - Addressing Scheme
  - Address Resolution
  - Datagram Forwarding
  - Encapsulation, Fragmentation & Reassembly
- TCP- Transmission Control Protocol
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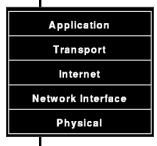
  - Reliability: ordering, missing data handling

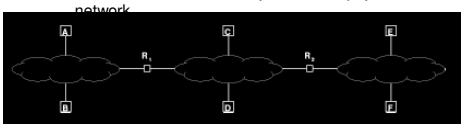


How Data is Forwarded?

- To create an illusion of large uniform network software works with IP addresses. It puts data into packet and specifies the IP address of the destination.
- TCP/IP software in each host (or router) looks into the destination address and decides the next-hop. This next hop is also IP address.
- Unfortunately, IP addresses are virtual and cannot be used to reach the next-hop across a physical network.
- A frame sent across a physical network must have a physical address.

Address Resolution

- Translation from IP address to hosts physical address is known as address resolution.
- Address resolution is always local to a physical network.



A to B: Protocol Software resolves B's address.
A to D: Protocol Software on A determines R1 is the next hop's IP address. A resolves R1's address. Protocol Software on R2 resolves D's address.

Address Resolution Techniques

- Depends on Physical Network Technology.
- Three main types:
  - Table Lookup
  - Closed form Computation
  - Message Exchange

AR by Table Lookup

IP Address	Hardware Address
197.15.3.2	0A:07:4B:12:82:36
197.15.3.3	0A:9C:28:71:32:8D
197.15.3.4	0A:11:C3:68:01:99
197.15.3.5	0A:74:59:32:CC:1F
197.15.3.6	0A:04:BC:00:03:28
197.15.3.7	0A:77:81:0E:52:FA

Address binding table.

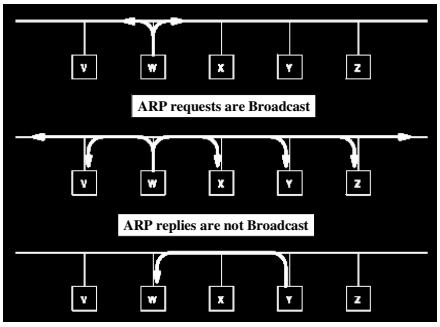
Direct lookup table in array.

AR with Message Exchange

- Send a request for physical address.
  - Broadcast to all
  - Send to designated server.
  - Broadcast to designated servers.
- Receive message with physical address.
  - The actual owner of the IP address replies
  - or a server replies.

TCP/IP can use any of the three methods. However, to guarantee that all computers agree on the exact format and meaning of messages the suit includes ARP.

ARP Message Delivery



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ARP Message Format

- ARP protocol is general and can handle any-to-any translation.

1 FOR ETHERNET

0	8	16	24	31
HARDWARE ADDRESS TYPE		PROTOCOL ADDRESS TYPE		
HADDR LEN	PADDR LEN	OPERATION		
SENDER HADDR (first 4 octets)				
SENDER HADDR (last 2 octets)		SENDER PADDR (first 2 octets)		
SENDER PADDR (last 2 octets)		TARGET HADDR (first 2 octets)		
TARGET HADDR (last 4 octets)				
TARGET PADDR (all 4 octets)				

x0800 FOR IP

1 for REQ
2 for RES

TCP/IP to Ethernet ARP message format

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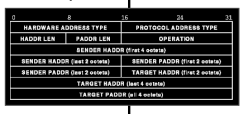
Sending ARP Message

- Encapsulation (in Ethernet Frame)

- How do the computers know if the Ethernet data is ARP?
  - Type 0x806!
- How do the computers know if it is a request or a response?
  - Need to open packet and check OPERATION field.



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Flashback: Ethernet

- Preamble 64 (8 octates) '10101010..' synchronizes hardware.

Preamble	Dest. Address	Source Address	Frame Type	Data In Frame	CRC
8	6	6	2	46 - 1500	4

Header

- 48 bits static destination and source address.
- 16 bit frame type describe content forms.
  - 0800 IP Version 4
  - **806 Internet ARP**
- 46-1500 byte data.
- 32 bit CRC.

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Caching ARP Address

- 1 communication = 3 messages (2 ARPs)
- Caching is done:
  - but only in memory.
  - ARP maintains a small memory
  - Entries are deleted if not used for more than 20 min.
  - For new address oldest is removed.

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Processing ARP Message

- ARP specifies the following actions for the receiver of ARP messages:
  - Extract senders address binding. Update own cache only if it is there.
  - Check the OPERATION field. Request or response?
  - If response, (the receiver must be the target), add the entry.
  - If request, check TARGET PAADR, if this is the target send ARP response.
    - Reverse sender & target fields. Insert own physical address in SENDER HADDR.
  - After sending, if the receiver is target, add the senders binding in own cache.

Why broadcast receivers don't record the senders binding, but only the target receiver records it?

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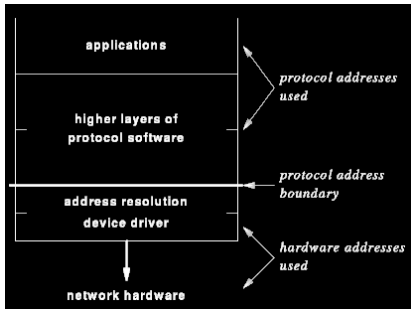
IP and Hardware Address Boundaries



INTERNET ENGINEERING

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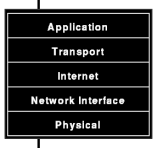

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IP Packets

- Physical Networks differ in the format, size, transmission mechanism of packets. If applications have to be aware of these diversities than application developed for one physical network technology will not work for other.
- IP therefore creates a definition of virtual packets which all applications can use. IP software takes the responsibility of adapting to specific underlying network technology.
- IP packets are virtual. They never travel across a network intact.
- IP offers communication mechanism for both connectionless and connection-based services.

INTERNET ENGINEERING

IP Datagram

- IP packets are called IP datagram.

- IP datagrams can be of variable size 1-64K octates.
- IP datagram header contains information to route the packet across internet.
- IP datagrams are encapsulated in frames before they are transmitted over any Network.

The address that appears in datagram header is different from the address that appears in frame header.

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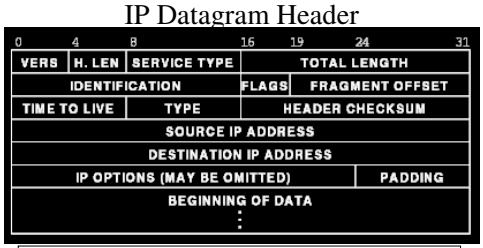
IP Datagram Header



VARS=IP version, H.LEN=how many 32 bit segments in header
SEVICE TYPE= min delay or max capacity path?
TOTAL LENGTH= HEADER+DATA octates.
TIME TO LIVE=maximum allowable hops (0-255)
HEADER CHECKSUM= 1's complement sum
OPTIONS=optional, without it LEN=H.LEN=5,
PADDING=0's to meet 32 bit boundary

IP does not take responsibility of: duplication, out-of-order, corrupt data or lost datagram problems.

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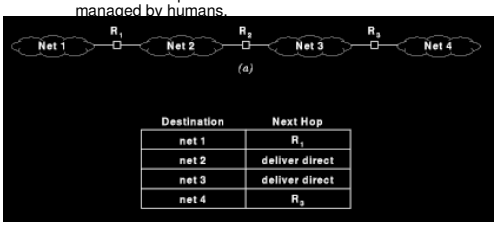
IP Datagram Forwarding: Concept

- Each router sends forwards it to next router. They maintain a simple table which can also be managed by humans.



- R2's routing table

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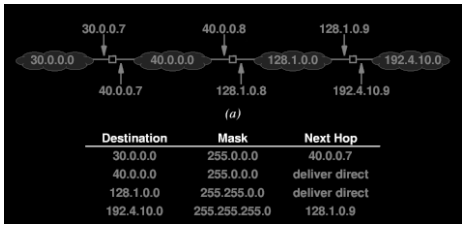
IP Datagram Forwarding: Example

- The IP tables are a little complicated. It uses Masks.



(a)

Destination	Mask	Next Hop
30.0.0.0	255.0.0.0	40.0.0.7
40.0.0.0	255.0.0.0	deliver direct
128.1.0.0	255.255.0.0	deliver direct
192.4.10.0	255.255.255.0	128.1.0.9

- R2's routing table