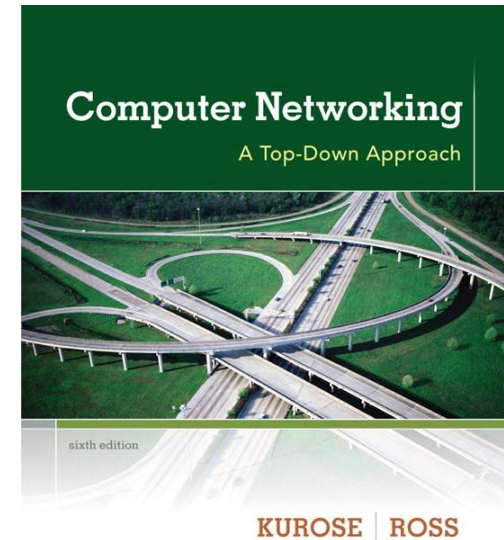


Chapter 5

Link Layer



*Computer
Networking: A Top
Down Approach
6th edition
Jim Kurose, Keith Ross
Addison-Wesley
March 2012*

Chapter 5: Link layer

our goals:

- ❖ understand principles behind link layer services:
 - error detection, correction
 - sharing a broadcast channel: multiple access
 - link layer addressing
 - local area networks: Ethernet, VLANs
- ❖ instantiation, implementation of various link layer technologies

Link layer, LANs: outline

5.1 introduction, services

5.2 error detection,
correction

5.3 multiple access
protocols

5.4 LANs

- addressing, ARP
- Ethernet
- switches
- VLANs

5.5 link virtualization:
MPLS

5.6 data center
networking

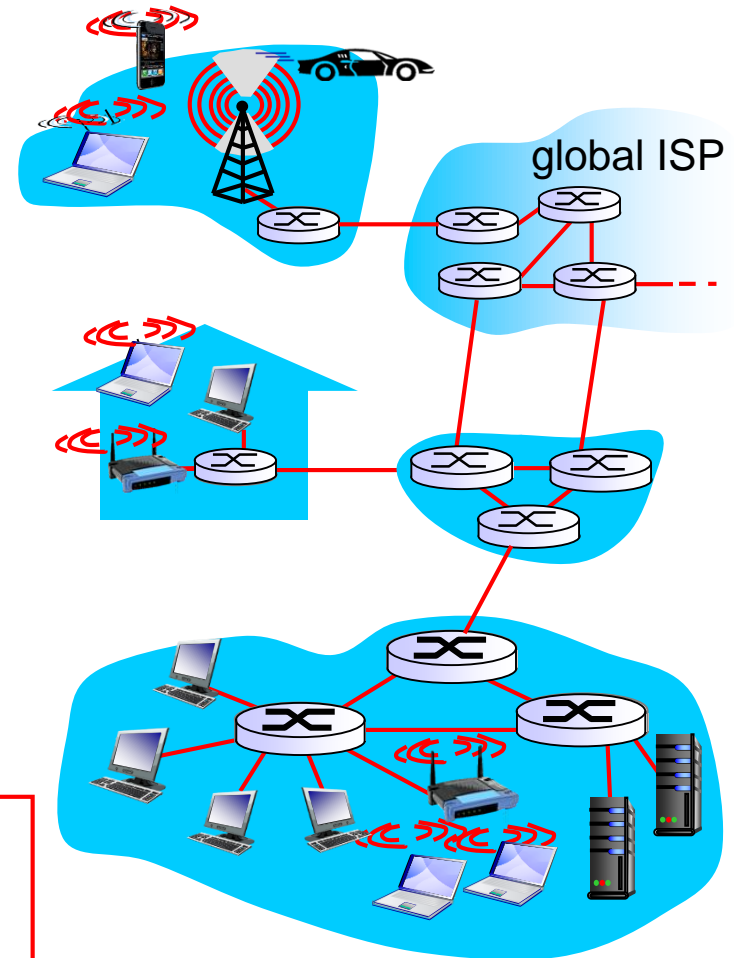
5.7 a day in the life of a
web request

Link layer: introduction

terminology:

- ❖ hosts and routers: **nodes**
- ❖ communication channels that connect adjacent nodes along communication path: **links**
 - wired links
 - wireless links
 - LANs
- ❖ layer-2 packet: **frame**, encapsulates datagram

data-link layer has responsibility of transferring datagram from one node to *physically adjacent* node over a link



Link layer: context

- ❖ datagram transferred by different link protocols over different links:
 - e.g., Ethernet on first link, frame relay on intermediate links, 802.11 on last link
- ❖ each link protocol provides different services
 - e.g., may or may not provide rdt over link

transportation analogy:

- ❖ trip from Princeton to Lausanne
 - limo: Princeton to JFK
 - plane: JFK to Geneva
 - train: Geneva to Lausanne
- ❖ tourist = **datagram**
- ❖ transport segment = **communication link**
- ❖ transportation mode = **link layer protocol**
- ❖ travel agent = **routing algorithm**

Link layer services

❖ *framing, link access:*

- encapsulate datagram into frame, adding header, trailer
- channel access if shared medium
- “MAC” addresses used in frame headers to identify source, dest
 - different from IP address!

❖ *reliable delivery between adjacent nodes*

- we learned how to do this already (chapter 3)!
- seldom used on low bit-error link (fiber, some twisted pair)
- wireless links: high error rates
 - **Q:** why both link-level and end-end reliability?

Link layer services (more)

❖ *flow control:*

- pacing between adjacent sending and receiving nodes

❖ *error detection:*

- errors caused by signal attenuation, noise.
- receiver detects presence of errors:
 - signals sender for retransmission or drops frame

❖ *error correction:*

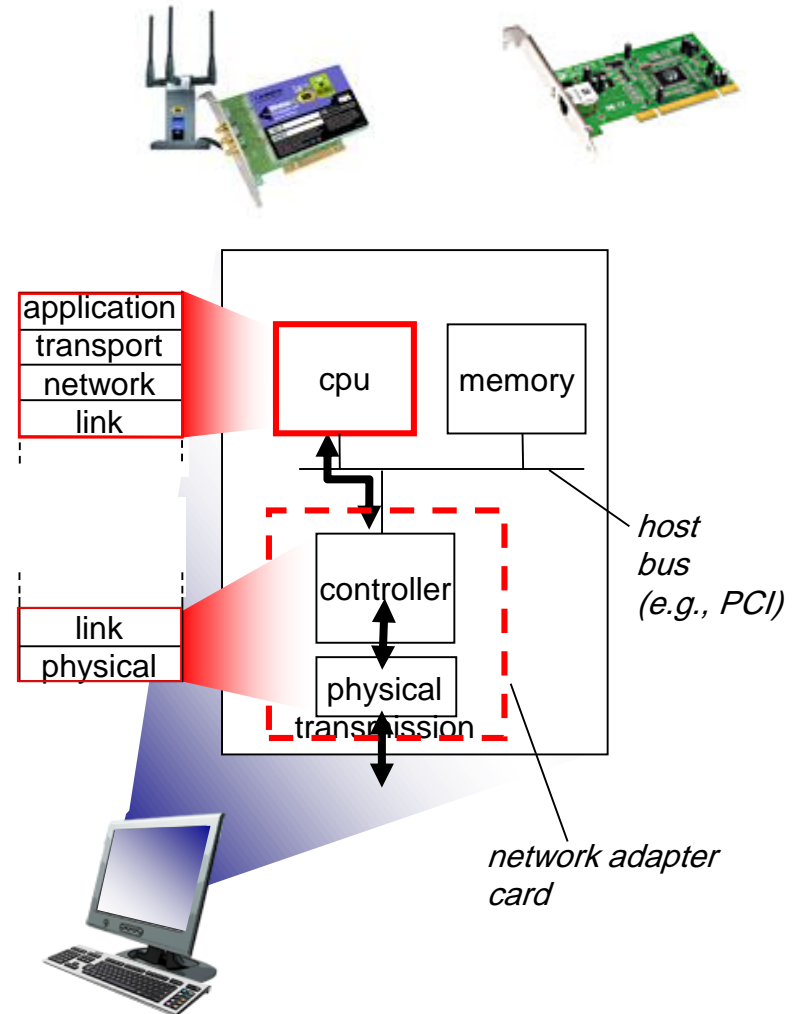
- receiver identifies *and corrects* bit error(s) without resorting to retransmission

❖ *half-duplex and full-duplex*

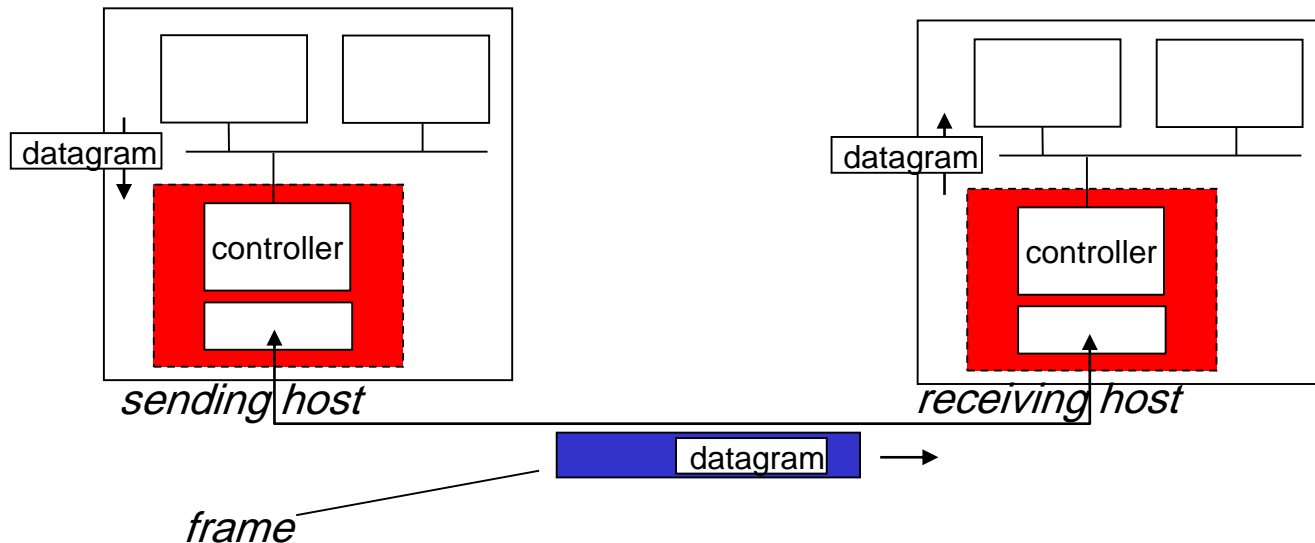
- with half duplex, nodes at both ends of link can transmit, but not at same time

Where is the link layer implemented?

- ❖ in each and every host
- ❖ link layer implemented in “adaptor” (aka *network interface card* NIC) or on a chip
 - Ethernet card, 802.11 card; Ethernet chipset
 - implements link, physical layer
- ❖ attaches into host's system buses
- ❖ combination of hardware, software, firmware



Adaptors communicating



❖ sending side:

- encapsulates datagram in frame
- adds error checking bits, rdt, flow control, etc.

❖ receiving side

- looks for errors, rdt, flow control, etc
- extracts datagram, passes to upper layer at receiving side

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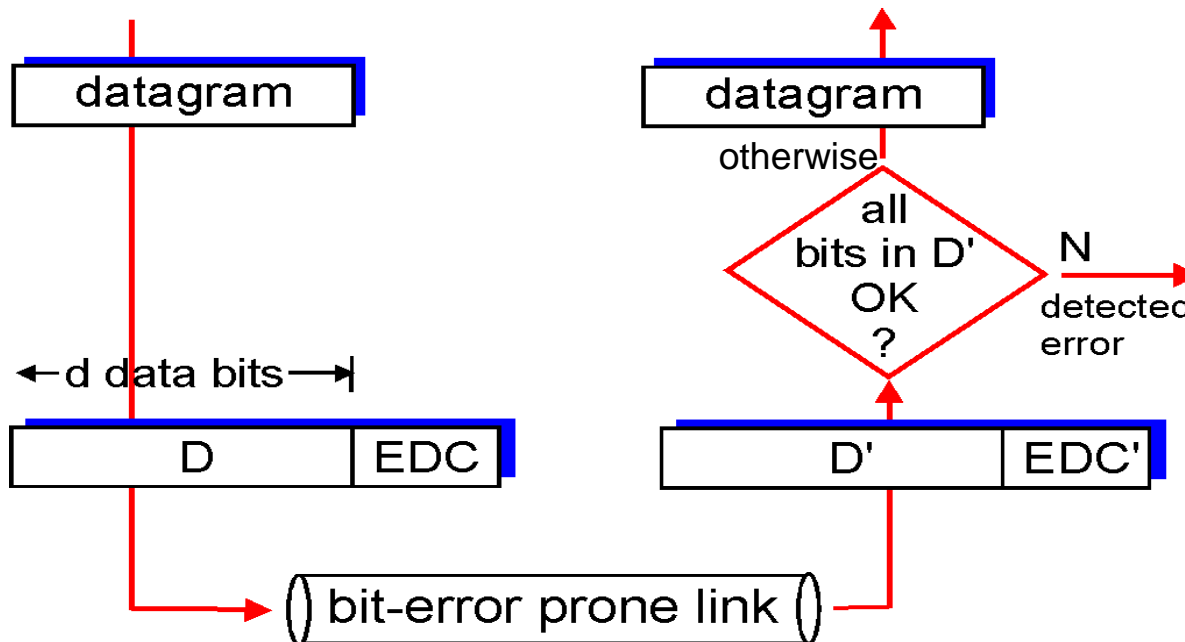
5.7 a day in the life of a
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Error detection

EDC= Error Detection and Correction bits (redundancy)

D = Data protected by error checking, may include header fields

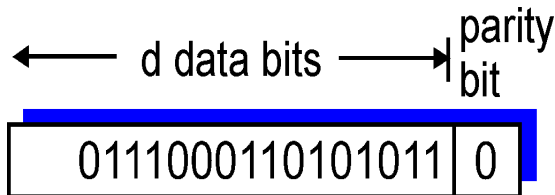
- Error detection not 100% reliable!
 - protocol may miss some errors, but rarely
 - larger EDC field yields better detection and correction



Parity checking

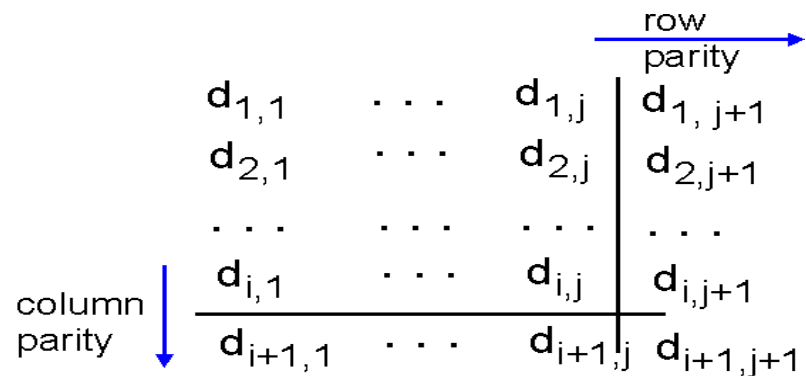
single bit parity:

- ❖ detect single bit errors



two-dimensional bit parity:

- ❖ detect and correct single bit errors



1	0	1	0	1	1
1	1	1	1	0	0
0	1	1	1	0	1
0	0	1	0	1	0

no errors

1	0	1	0	1	1
1	1	1	1	0	0
0	1	1	1	0	1
0	0	1	0	1	0

parity error

*correctable
single bit error*

Internet checksum (review)

goal: detect “errors” (e.g., flipped bits) in transmitted packet
(note: used at transport layer *only*)

sender:

- ❖ treat segment contents as sequence of 16-bit integers
- ❖ checksum: addition (1’s complement sum) of segment contents
- ❖ sender puts checksum value into UDP checksum field

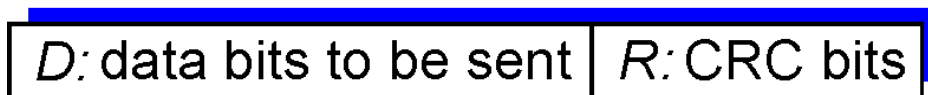
receiver:

- ❖ compute checksum of received segment
- ❖ check if computed checksum equals checksum field value:
 - NO - error detected
 - YES - no error detected.
But maybe errors nonetheless?

Cyclic redundancy check

- ❖ more powerful error-detection coding
- ❖ view data bits, **D**, as a binary number
- ❖ choose $r+1$ bit pattern (generator), **G**
- ❖ goal: choose r CRC bits, **R**, such that
 - $\langle D, R \rangle$ exactly divisible by G (modulo 2)
 - receiver knows G , divides $\langle D, R \rangle$ by G . If non-zero remainder: error detected!
 - can detect all burst errors less than $r+1$ bits
- ❖ widely used in practice (Ethernet, 802.11 WiFi, ATM)

← d bits → ← r bits →



*bit
pattern*

$$D * 2^r \text{ XOR } R$$

*mathematical
formula*

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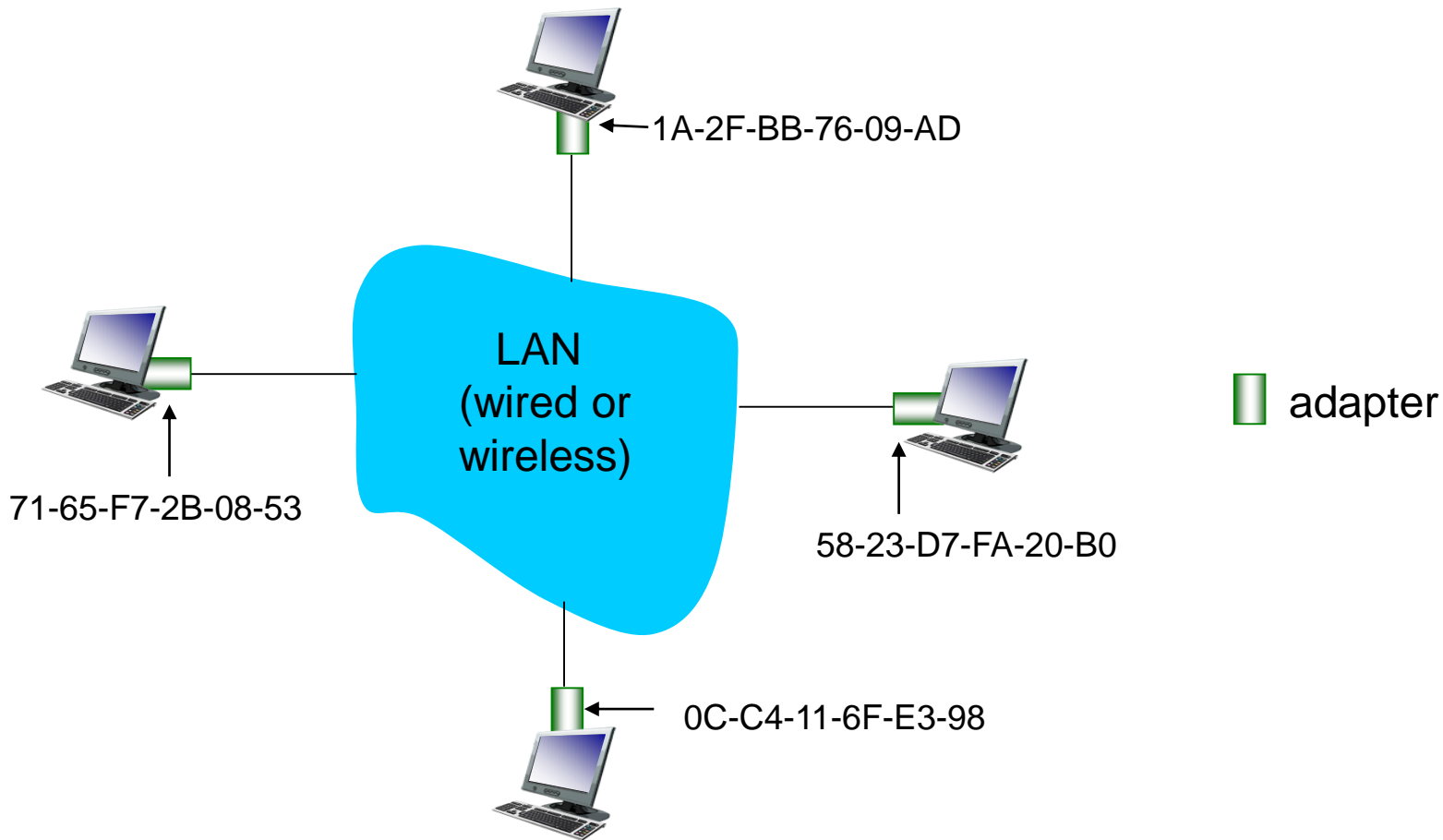
MAC addresses and ARP

- ❖ 32-bit IP address:
 - *network-layer* address for interface
 - used for layer 3 (network layer) forwarding
- ❖ MAC (or LAN or physical or Ethernet) address:
 - function: *used ‘locally’ to get frame from one interface to another physically-connected interface (same network, in IP-addressing sense)*
 - 48 bit MAC address (for most LANs) burned in NIC ROM, also sometimes software settable
 - e.g.: 1A-2F-BB-76-09-AD

hexadecimal (base 16) notation
(each “number” represents 4 bits)

LAN addresses and ARP

each adapter on LAN has unique *LAN* address

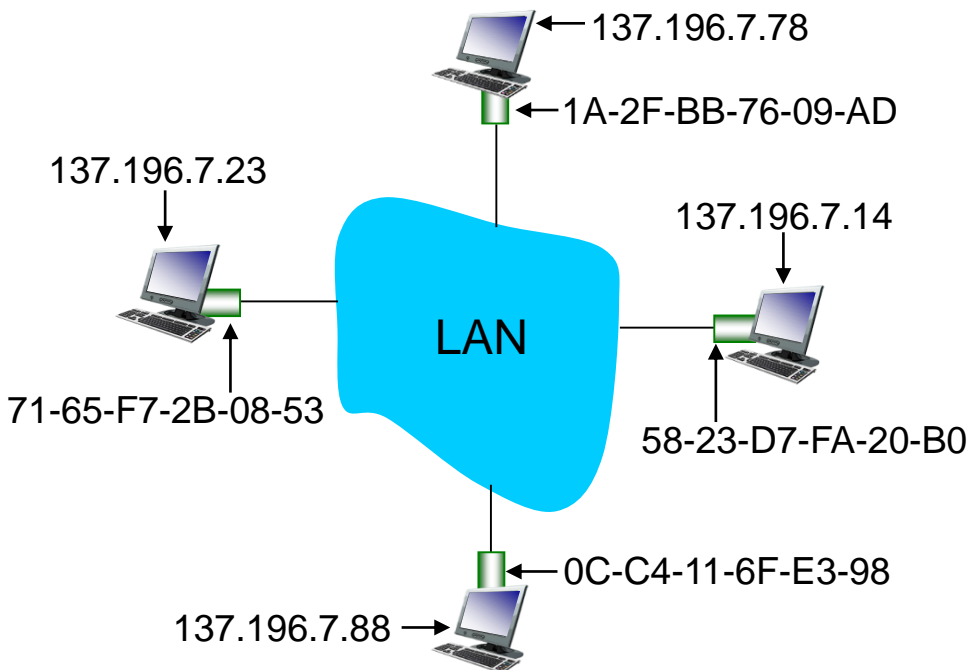


LAN addresses (more)

- ❖ MAC address allocation administered by IEEE
- ❖ manufacturer buys portion of MAC address space (to assure uniqueness)
- ❖ analogy:
 - MAC address: like Social Security Number
 - IP address: like postal address
- ❖ MAC flat address → portability
 - can move LAN card from one LAN to another
- ❖ IP hierarchical address *not* portable
 - address depends on IP subnet to which node is attached

ARP: address resolution protocol

Question: how to determine interface's MAC address, knowing its IP address?



ARP table: each IP node (host, router) on LAN has table

- IP/MAC address mappings for some LAN nodes:
< IP address; MAC address; TTL >
- TTL (Time To Live): time after which address mapping will be forgotten (typically 20 min)