COMP28411 Computer Networks

Nick Filer - Link Layer and Physical Layer

Tuesday	25/11 LL – 1 of 4 –	Introduction
Thursday	27/11 LL - 2	- Switches, Routing and Medium Access
Thursday	4/12 LL - 3	- Framing, Ethernet, ATM Point-2-Point Protocol
Tuesday	9/12 PL – 4 of 4	- Physical Layer and Wireless
	2 and 4/12	- Error Detection Workshop

Some material from:

Kurose & Rose – Chapter 5 + Slides

Lecture Summary

- Link Layer
  - Services
  - Where implemented
  - Packet Encapsulation – reminder
  - Flow Control
  - Link layer addressing
  - Mapping IP to/from MAC addresses.
  - Hubs and Switches

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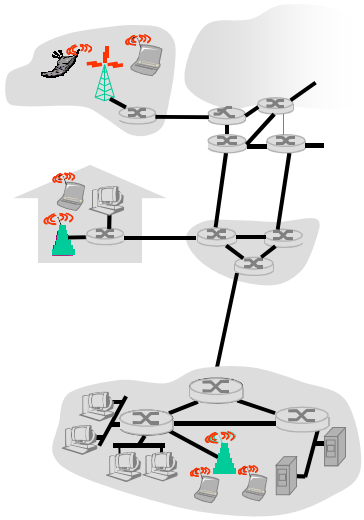
Link Layer Overview

- **Terminology**
  - Hosts and Routers/Switches/Hubs are **NODES**.
  - Communications channel between nodes is a **LINK.**
  - Layer 2 packets are a **FRAME**
- **Responsibility**
  - Node to adjacent node transfer of layer 3 **datagram** over **link**.
  - Uses Layer 1 (Physical) methods to move **frames between directly interconnected hosts**.



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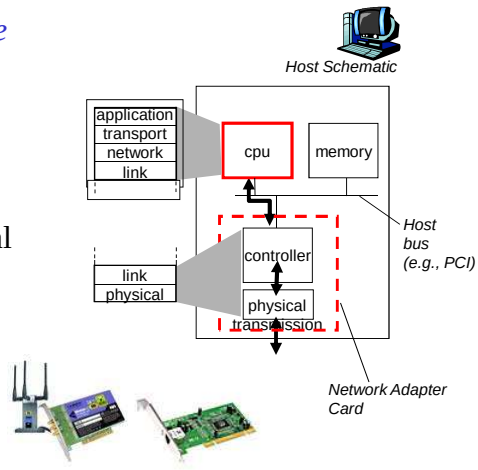
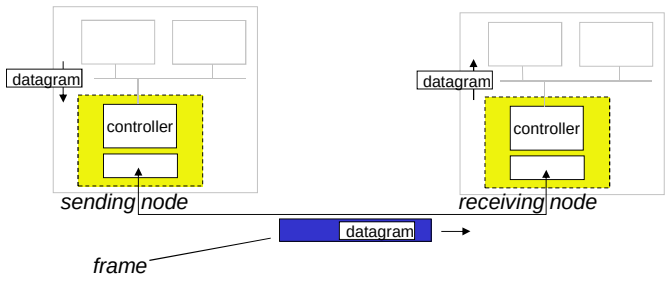
Where is the link layer implemented?

- In every node.
- Link layer implemented in "adaptor" (*network interface card* NIC)
  - Ethernet card, PCMCIA/Express cards, 802.11 card
  - Implements link, physical layer
- Attaches into node's system buses
- Combination of hardware, software, firmware.

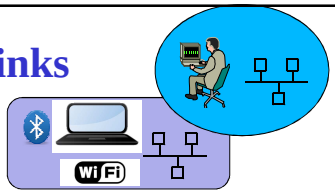


Adaptors Communicating



- Sending side:
  - Encapsulates datagram in frame.
  - Adds error checking bits, flow control, etc.
- Receiving side
  - Looks for errors, flow control, etc.
  - Extracts datagram, passes to upper layer at receiving side.

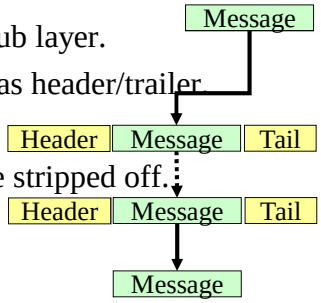
Virtual Links



- **Alternatives:**
  - My computer talks Ethernet (Layer 2 + 1) .
  - My laptop talks either Ethernet, WiFi (Layer 2 + 1) or Bluetooth.
- **My Broadband (Last Mile Connection over telephone or cable) has:**
  - **IP input over Ethernet or WiFi**. Both IEEE 802.xx standards.
  - **ADSL2 physical layer** with **Asynchronous Transfer Mode (ATM)** at the data-link layer.
  - **VDSL** (very high bit rate DSL) **over fibre**. Often **PPPoE**.
  - On ADSL the ATM (layer 2) carries Point to Point Protocol over ATM (**PPPoA**) – also layer 2!.
    - Outside Europe many use PPPoE (Ethernet)
    - The PPP (layer 2) carries IP packets .
- We regard the PPPoA/E as providing a **virtual link**.
  - To higher layers it appears as a complete network.

Encapsulation Review ?

- Protocol data + control is sent to host's sub layer for processing.
- Treated as a black box of bytes at next sub layer.
- Each layer adds control + data for itself as header/trailer.
- Process is repeated at each layer.
- At destination, each layer's additions are stripped off.
  - So acts as multiplexor/demultiplexor.



Ethernet Frame Structure

Preamble	Start of frame delimiter	MAC Destination	MAC Source	Ethertype or Length	Data + Padding	CRC32	Interframe Gap
7 lots of 10101010	10101011	6 Octets	6 Octets	2 Octets	46-1500 Octets	4 Octets	12 Octets

IP Packet or other goes in here

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A2

Flow Control

- Is an optional service! Not always implemented at this layer.
- Purpose ?:
  - _____
- Handshake:
  - Exchange stop/start messages.
    - Hardware: Request to Send/Clear To Send (RTS/CTS), Data Set Terminal Ready (DSR/DTR)
    - Software: X-ON/X-OFF
- Open-Flow:
  - By prior reservation – using Connection Admission Control (CAC)
  - To work must over resource – redundancy.
- Closed-Loop:
  - Some way of reporting resource availability and resource needs.
    - Ethernet PAUSE frame sent to special multicast address 01-80-C2-00-00-01 with 16 bit time request in 512 bit time quanta's.
  - Asynchronous Transfer Mode (ATM) has Available Bit Rate (ABR) guarantees minimum bit rate and reports congestion.

e.g. for real-time constant bit rate traffic.

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LAN/MAC Addresses

- 32-bit IP address:
  - *Network-layer* address.
  - Used to get datagram to destination IP subnet .
  - At least partially geographical and part ID.
- MAC (or LAN or physical or Ethernet) address:
  - Function: *Get frame from one interface to another physically-connected interface (on the same network).*
  - 48 bit (6 byte) MAC address (for most LANs)
    - Moving towards 64 bit in IPv6 network cards. Compatibility?
    - Burned in Network Interface Card (NIC) ROM, also sometimes software settable.
    - 3 Bytes Organization Identifier + 3 bytes NIC Identifier.
    - 2^{48} or 281,474,976,710,656 unique addresses, Expected to last until year 2100. Used in most IEEE 802 networks (Ethernet, WiFi), Bluetooth, …..
    - Does it matter if MAC addresses are re-used? _____

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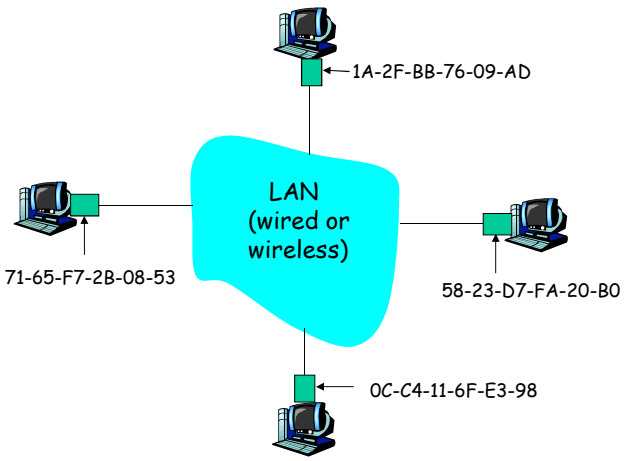
LAN Addresses

Each adapter on LAN has unique LAN address.



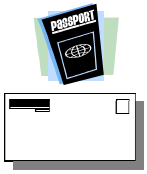
Ethernet
Broadcast address =
FF-FF-FF-FF-FF-FF

= Adapter

Not all systems have BROADCAST e.g. ATM.

LAN Address (more)

- MAC address allocation administered by IEEE
- Manufacturer buys portion of MAC address space (to assure uniqueness).
- Analogy:
  - (a) MAC address: like Passport Number or social security or National ID card.
  - (b) IP address: like postal address



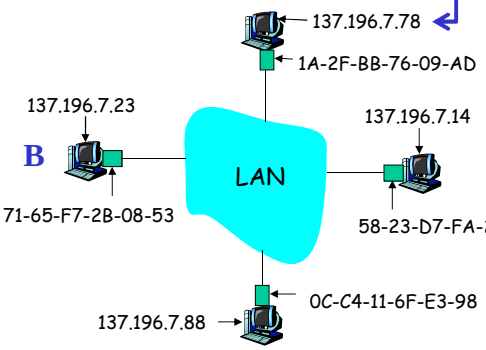
- MAC flat address `gives` portability
  - Can move LAN card from one LAN to another
  - Switches auto-adapt to new card
- IP hierarchical address NOT portable
  - Address depends on IP subnet where node is attached (geography/location).
  - IP routing depends on attachment to network

A1

ARP: Address Resolution Protocol

Question: How to determine MAC address of B knowing B's IP address?

You should know this already!



- Each IP node (host, router) on LAN has an ARP table.
- ARP 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).

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Switch & Hubs

- Older networks were **Half-Duplex**, wires were shared by many machines. They used Hubs.
- Modern networks are **Full-Duplex** over **unshared point-2-point wires**. They use Switches.
  - Switches are Link-layer device: Smarter than hubs, take ***active* role**.
    - Store + forward frames.
    - Examine incoming frame's MAC address, selectively forward frame to one-or-more outgoing links when frame is to be forwarded on segment, uses collision avoidance techniques to access segment.
  - *Transparent*
    - Hosts are unaware of presence of switches.
  - *Plug-and-play, self-learning*
    - Switches do not need to be configured.
      - **Remember that routers do need configuration!**

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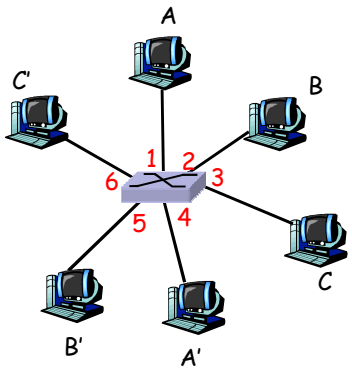
Switch: Allows Multiple Simultaneous Transmissions

- Hosts have dedicated, direct connection to switch.
- Switches buffer (queue) packets.
- Ethernet protocol used on *each* incoming link, but no collisions; full duplex.
  - Each link is its own collision domain.
- *Switching:* A-to-A' and B-to-B' simultaneously, without collisions.
  - Not possible with dumb hub.

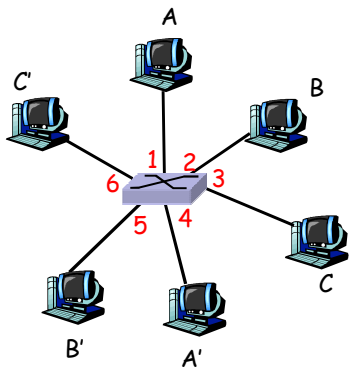


Switch with six interfaces (1,2,3,4,5,6)

Print Version - A2

Switch Table

- *Q:* How does switch know that A' is reachable via interface 4 and B' reachable via interface 5?

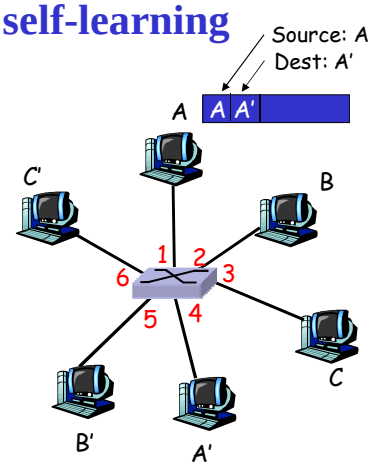


Switch with six interfaces (1,2,3,4,5,6)

A3

Switch: self-learning

- Switch learns which hosts can be reached through which interfaces
  - When a frame is received, the switch "learns" the location of the sender: Incoming LAN segment.
  - Records sender/location pair in switch table.
  - Example: Sending A ➔ A' via switch.



Which network protocol probably initiates self-learning?

MAC addr	interface	TTL
A	1	60

Switch table (initially empty)

Switch: Frame Filtering/Forwarding

When frame is received:

1. Record link associated with sending host.
2. Index switch table using MAC dest address.
3. IF entry found for destination THEN {

```
        IF Destination is on segment from which frame arrived
          THEN Drop the frame
             ELSE Forward the frame on interface indicated
        }
      ELSE Flood
```

forward on all but the interface on which the frame arrived

This is a simplification? **What actually happens?** Try Wikipedia Switch page.

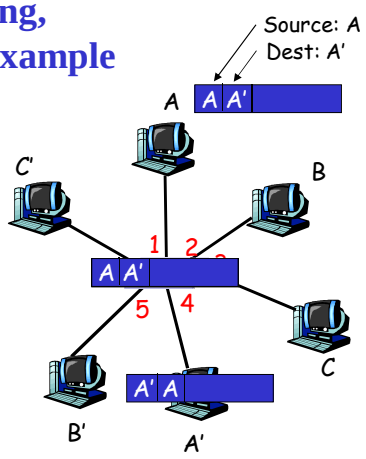
A6

Self-learning, Forwarding: Example

- Example:
  - Sending A ➔ A' via switch.
  - Then a frame A' ➔A.
- Frame destination unknown:

  flood
- Destination A location known:

  Selective send

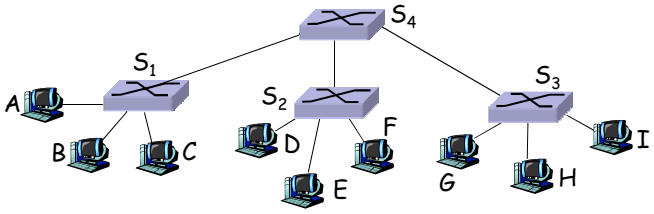


MAC addr	interface	TTL
A	1	60
A'	4	60

Switch table (initially empty)

Interconnecting Switches

- Switches can be connected together



- *Q:* Sending from C to I ➔
  How does S_1 know to forward frame destined to I via S_4 and S_3?
- *A:* Self learning! (works exactly the same as in single-switch case!)

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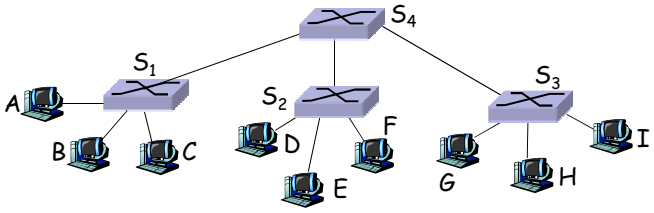
Self-learning Multi-Switch Example

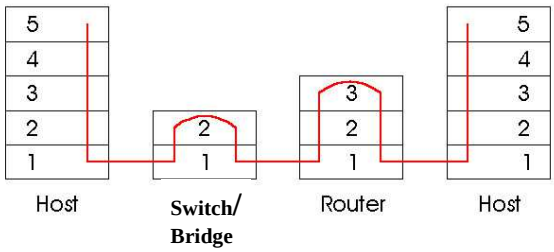
Suppose C sends frame to I, I responds to C – ***Q:*** How learn how to do it?



- ***Q:*** Show switch tables and packet forwarding in S_1, S_2, S_3, S_4

Switches vs. Routers

- Both are store-and-forward devices
  - Routers: network layer devices (examine network layer headers)
  - Switches are link layer devices – sometimes called **bridges**.
- Routers maintain routing tables, implement routing algorithms
- Switches maintain switch tables, implement filtering, learning algorithms
- Bridges  connect separate switched networks or sub-nets together at layers 1 and 2.



Lecture Summary

- Link Layer is concerned with node to node communications.
- It is normally implemented in hardware but may be soft coded
  - Services
  - Where implemented
  - Packet Encapsulation – reminder
  - Flow Control
  - Link layer addressing
  - Address Resolution
  - Hubs and Switches
- Next:
  - More on addresses and Sharing a network Link Layer Routing (between switches)
  - Multiple access – sharing a network.
  - Collisions and channel partitioning.
  - Random Access protocols

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Questions ?

- What information passes between:
  - The network layer and the link layer?
  - The link layer and the physical layer?
- If the transport layer can do error checking, why is error detection and correction important at the link layer?
- The network layer has the full address for the datagram, why doesn't the link layer use network addresses?
- What extra hardware is needed to implement a full-duplex link compared to a half-duplex link?
- If data is buffered at other layers, why does the link layer also do buffering?
  - Why does the network layer buffer?
  - Do you think the physical layer buffers? Why or why not?
- Why do you think IPv4 addresses were 32 bits whereas Ethernet MAC addresses were 48 bits?
  - Why are IPv6 IP addresses 128 bits whereas the IPv6 MAC address equivalent is 64 bits?
- What is “Inverse ARP” (InARP)? Why is it used?

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