Computer Networks
COL 334/672

Local Area Network

Tarun Mangla

Slides adapted from KR

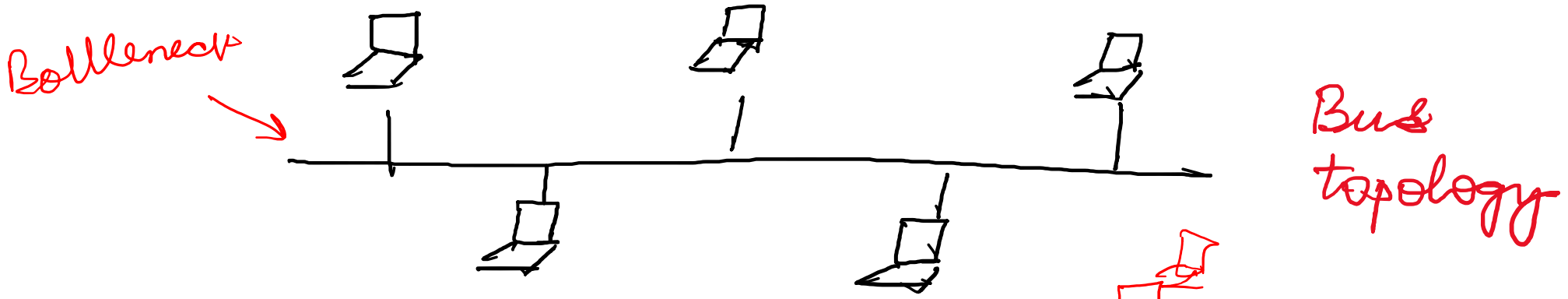
Sem 1, 2024-25

Recap

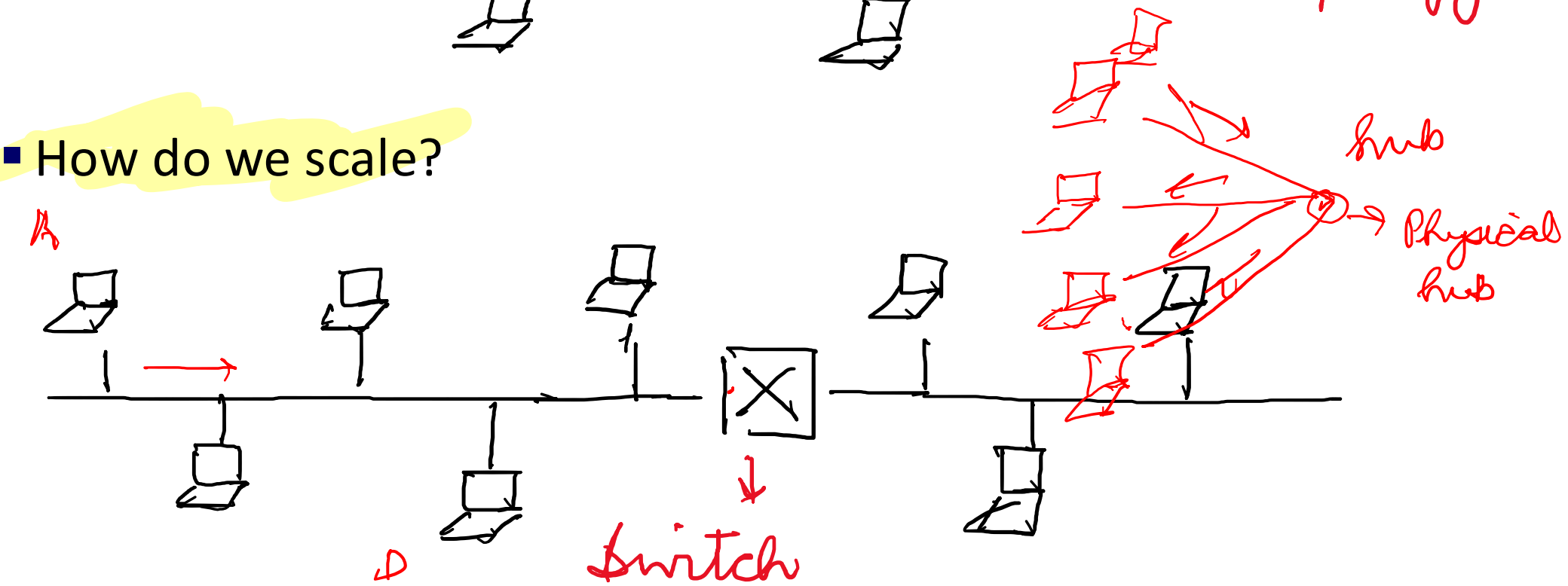
- Link-layer services
  - Framing
  - Error detection
  - Reliability
  - Medium Access Control (MAC)
- Ethernet protocol

So Far..

- We know how to communicate in case of a multiple-access link

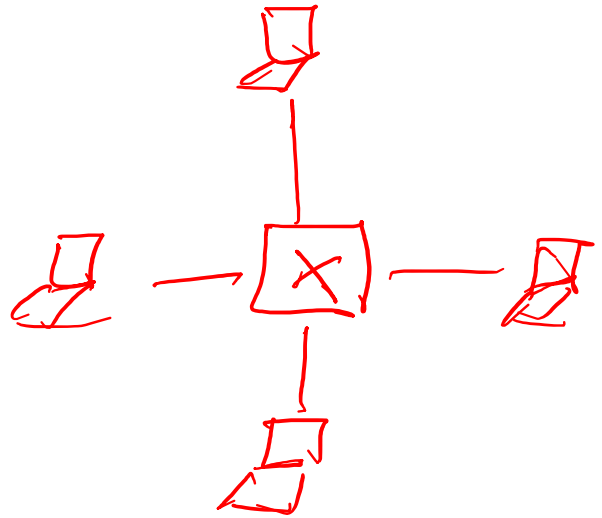


- How do we scale?



Switched Network

- Star topology
- Switches in both link layer or L2 (Ethernet protocol) and network layer or L3 (IP)
- Use store and forward approach
- L3 switches are also called routers, while L2 switches are also called bridges, ethernet switches
- **This lecture**: L2 switches or bridges or ethernet switch

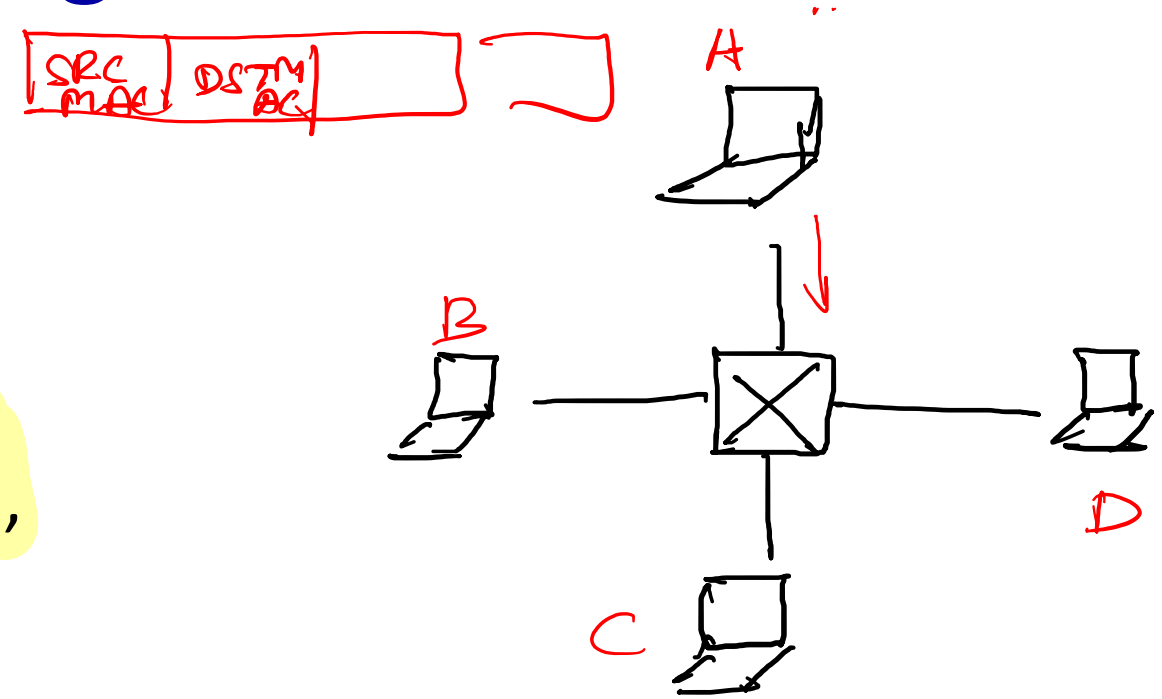


How does L2 switching work?

Requirement 1: Addressing

- Need a way to identify end nodes
- Ethernet uses a 48-bit MAC address burned in NIC ROM, also sometimes software settable
- E.g., 1A-2F-BB-76-09-AD

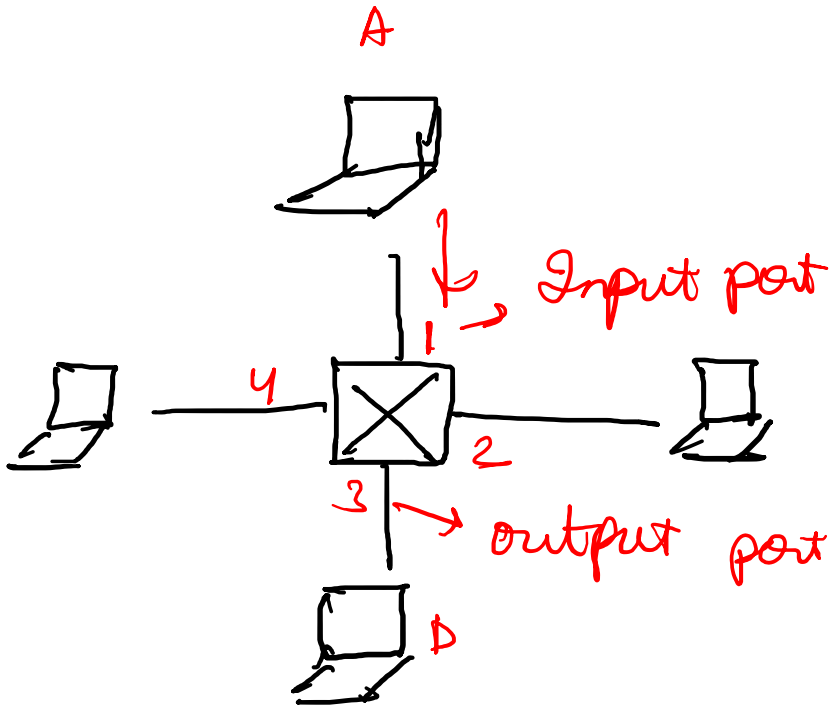
hexadecimal (base 16) notation
(each "numeral" represents 4 bits)



How does L2 switching work?

- **Requirement 1:** Addressing

- **Requirement 2:** Need a way to identify input and output ports on switch
  - Using a number
  - Name of the host it leads to

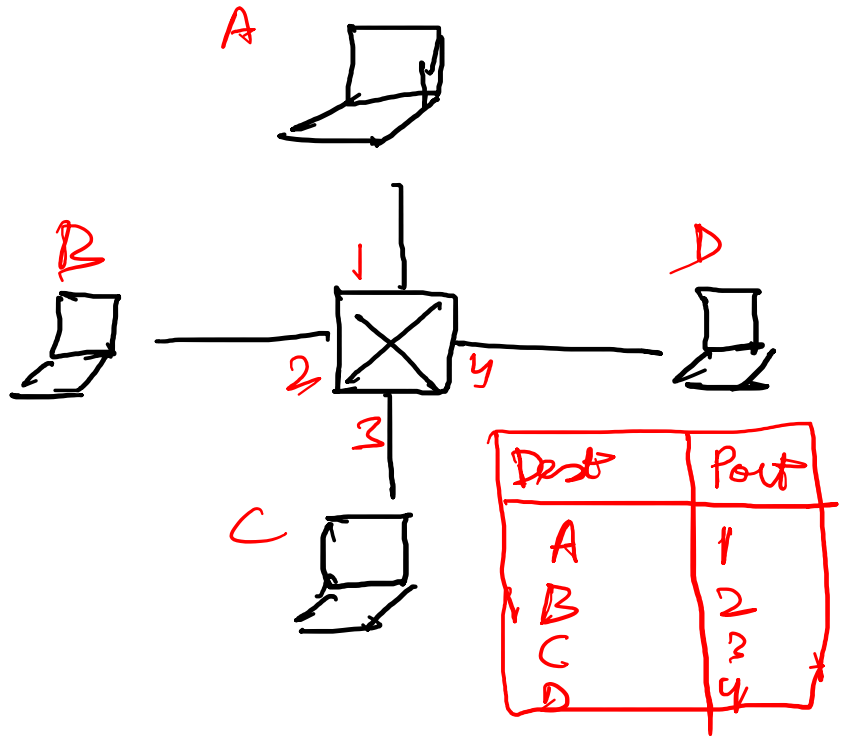


How does L2 switching work?

- **Requirement 1:** Addressing

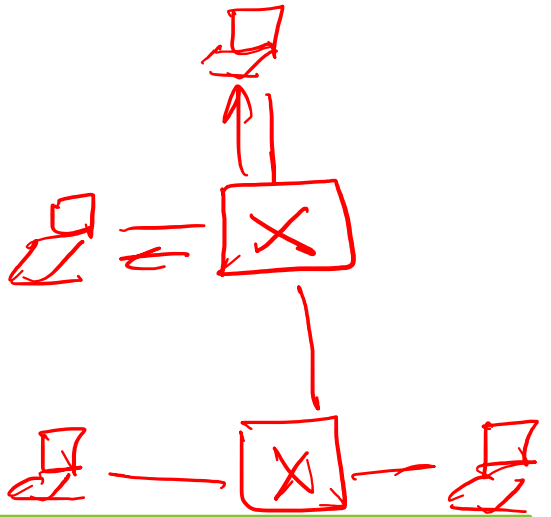
- **Requirement 2:** Need a way to identify input and output ports on switch

- **Requirement 3:** Switching or forwarding
  - Moving packet from its input port to the appropriate output port
  - Forwarding table: map of destination address to output port



How does L2 switching work?

- **Requirement 1:** Addressing
- **Requirement 2:** Need a way to identify input and output ports on switch
- **Requirement 3:** Switching or forwarding → data plane
- **Requirement 4:** Need algorithms to fill the forwarding table, also known as routing → control plane



L2 switch
-> Addressing
-> Port-Device mapping
-> Forwarding/switching
→ Routing

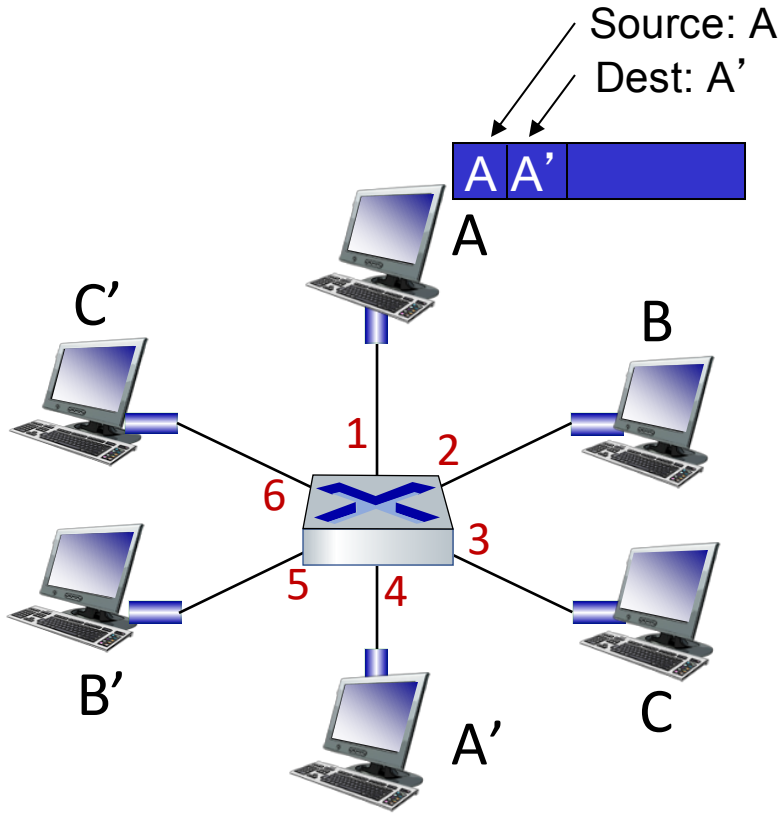
PAER

L2 Routing

- Using static tables added by network administrator
  - Difficult to support dynamic addition of nodes (end-hosts and switches)

L2 Routing: Self-learning Switch

- switch *learns* which hosts can be reached through which interfaces
  - when frame received, switch "learns" location of sender: incoming LAN segment
  - records sender/location pair in switch table



MAC addr	interface	TTL
A	*1*	*60*

Switch table (initially empty)

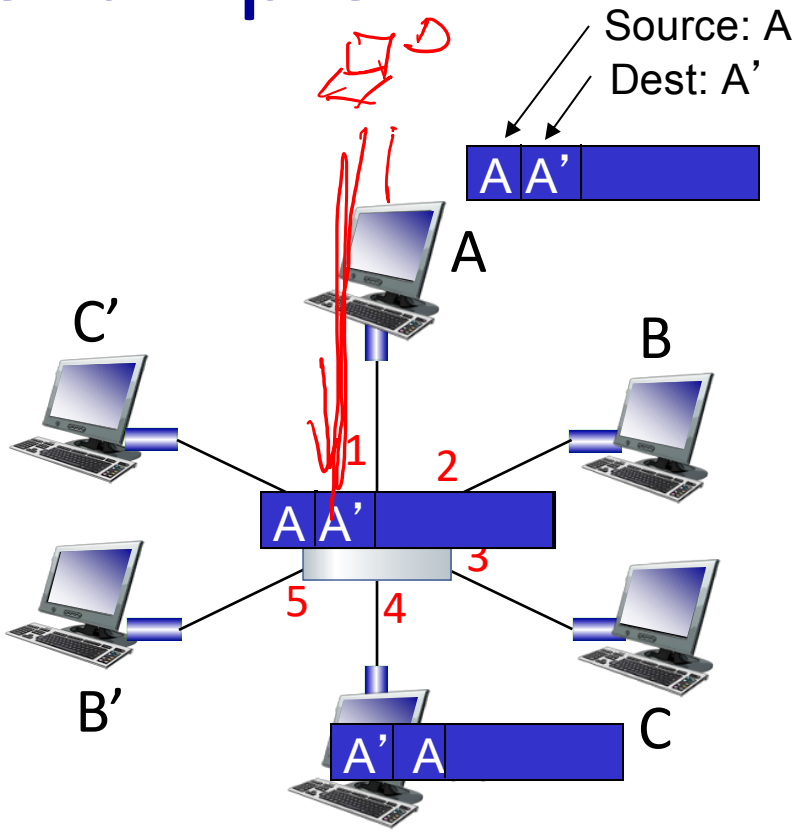
L2 Routing: Self-learning Switch

when frame received at switch:

1. record incoming link, MAC address of sending host
2. index switch table using MAC destination address
3. if entry found for destination
   then {
   if destination on segment from which frame arrived
      then drop frame
      else forward frame on interface indicated by entry
   }
   else flood /* forward on all interfaces except arriving interface */

Self-learning, Forwarding: example

- frame destination, A', location unknown: flood
- destination A location known: selectively send on just one link

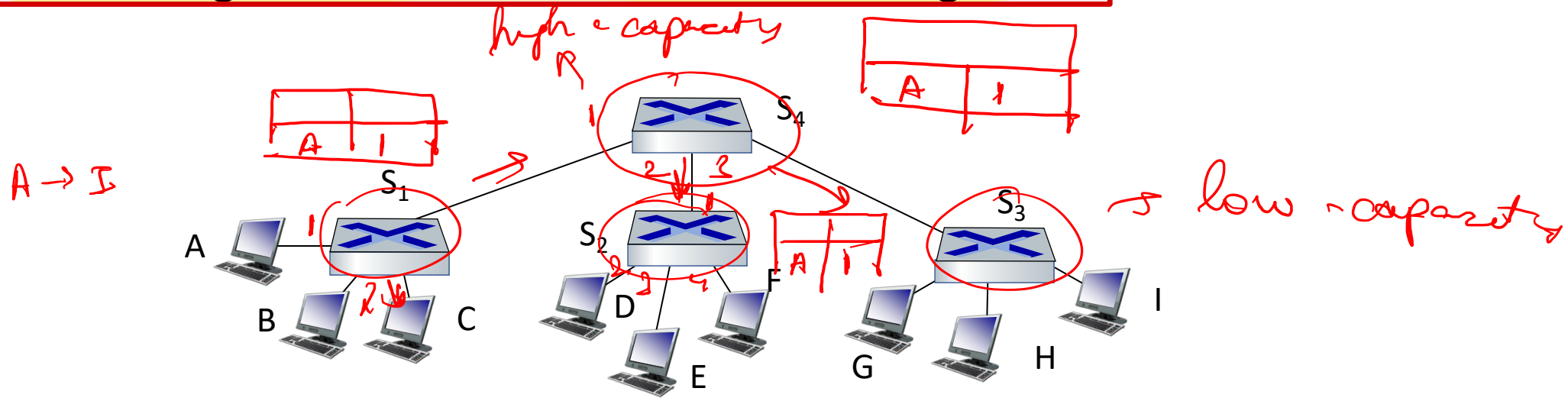


MAC addr	interface	TTL
A	*1*	*60*
A'	*4*	*60*

switch table (initially empty)

Interconnecting switches

self-learning switches can be connected together:



Self learning! (works exactly the same as in single-switch case!)

Q: show switch tables and packet forwarding in S_1, S_2, S_3, S_4

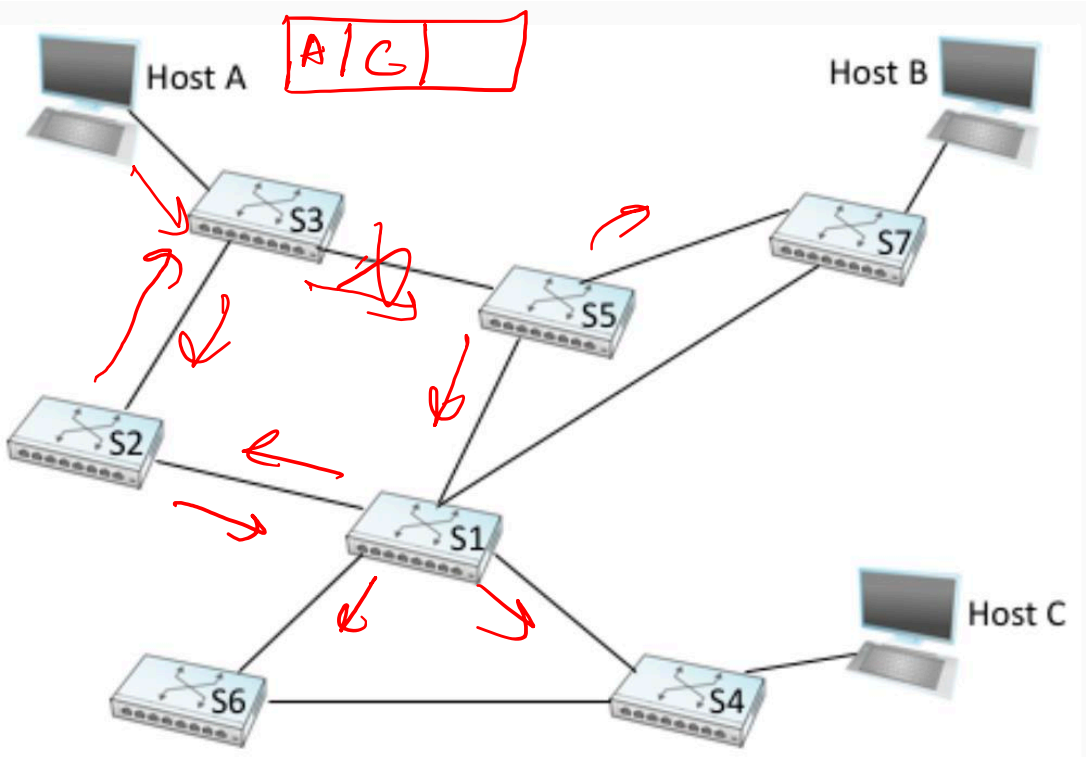
What happens in case of a loop?

- Packets will loop in both direction at S1, S4, and S6

- Why would switched Ethernet have loop?
  - Redundancy
  - By accident: network managed by more than one admins

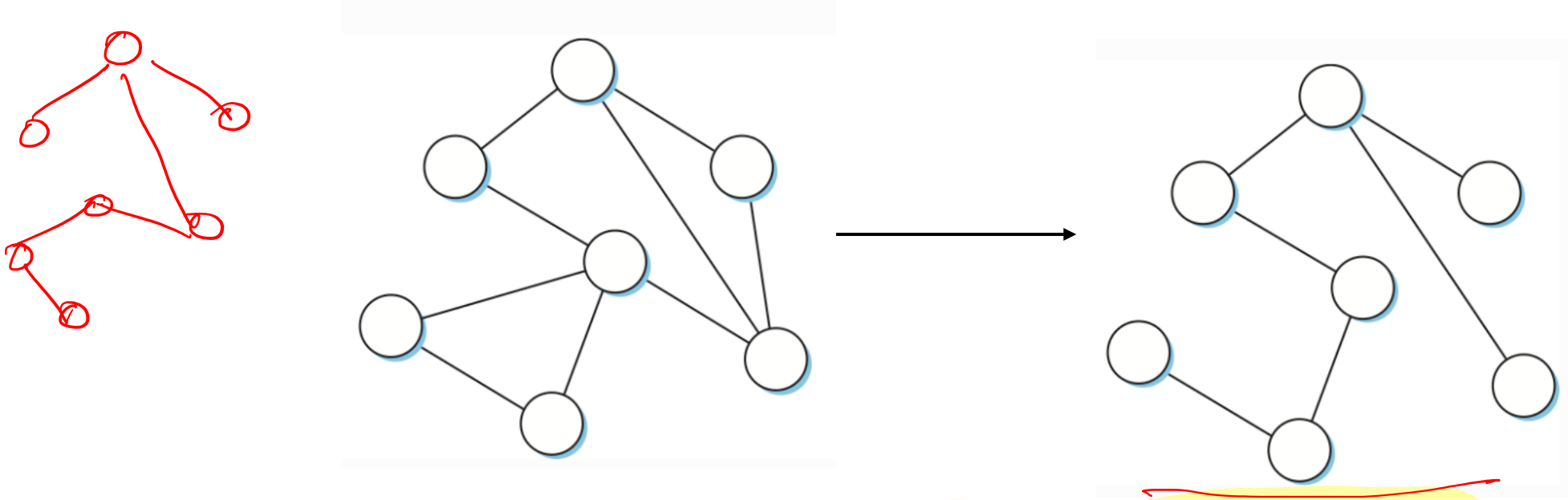
- Loops are a waste of network bandwidth, but increase reliability

- How do we prevent packets from looping?



Break the Loop!

- **Idea**: Create a logical spanning tree in the network
  - Spanning tree: subgraph that covers all vertices but contains no cycles
  - Switches will only forward on ports lying on the spanning tree



- **Challenge:** Need to create the same spanning tree in a distributed manner

Spanning Tree Protocol

- Invented by Radia Perlman from DEC

Algorhyme

I think that I shall never see
A graph more lovely than a tree.

A tree whose crucial property
Is loop-free connectivity.

A tree which must be sure to span
So packets can reach every LAN.

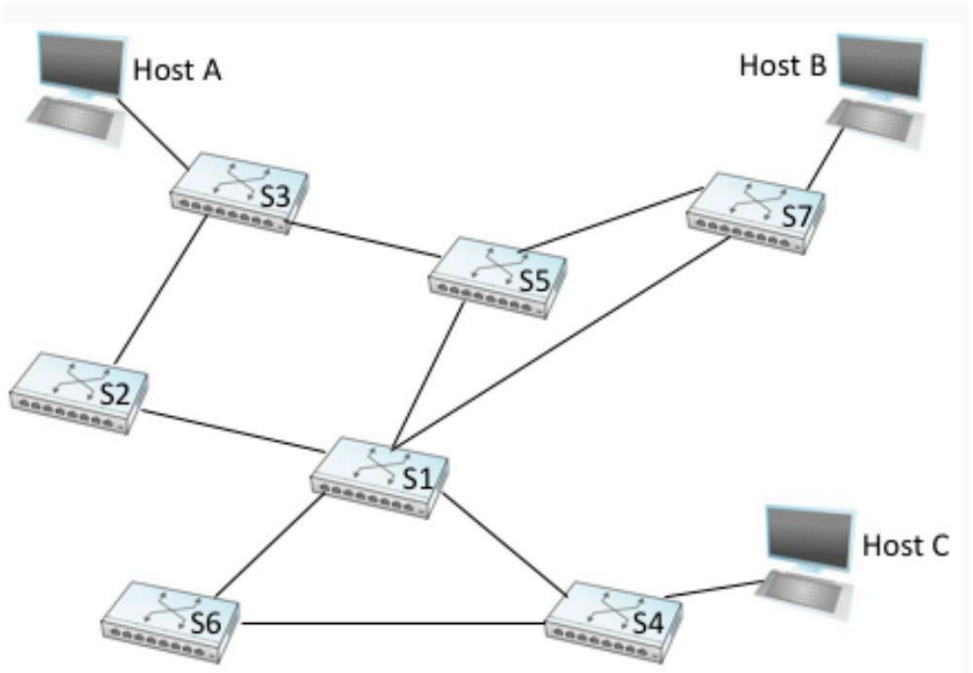
First the Root must be selected.
By ID it is elected.

Least cost paths from Root are traced.
In the tree these paths are placed.

A mesh is made by folks like me
Then bridges find a spanning tree.

Spanning Tree Protocol

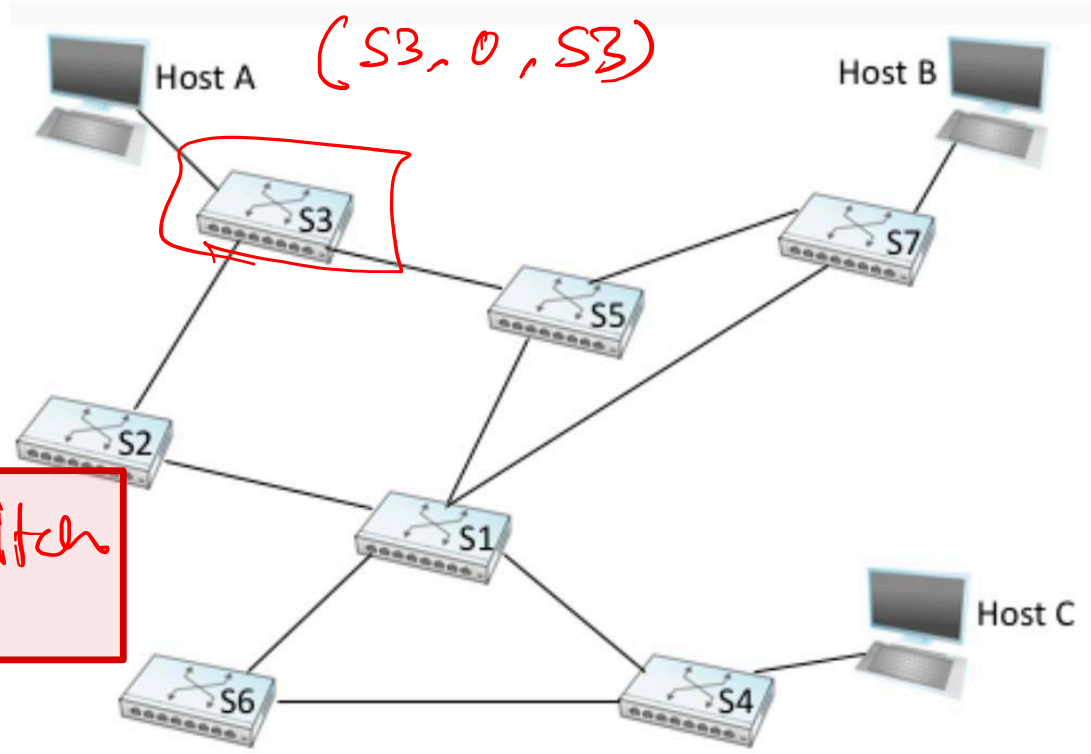
- **Algorithm**
  - Elect the switch with smallest ID as the root of the spanning tree
  - Identify port that is closest to the root and assign it as a root port
  - In case of a tie, select the port with smaller switch ID
  - Any port that is not root port is disabled



- How is it exactly done?

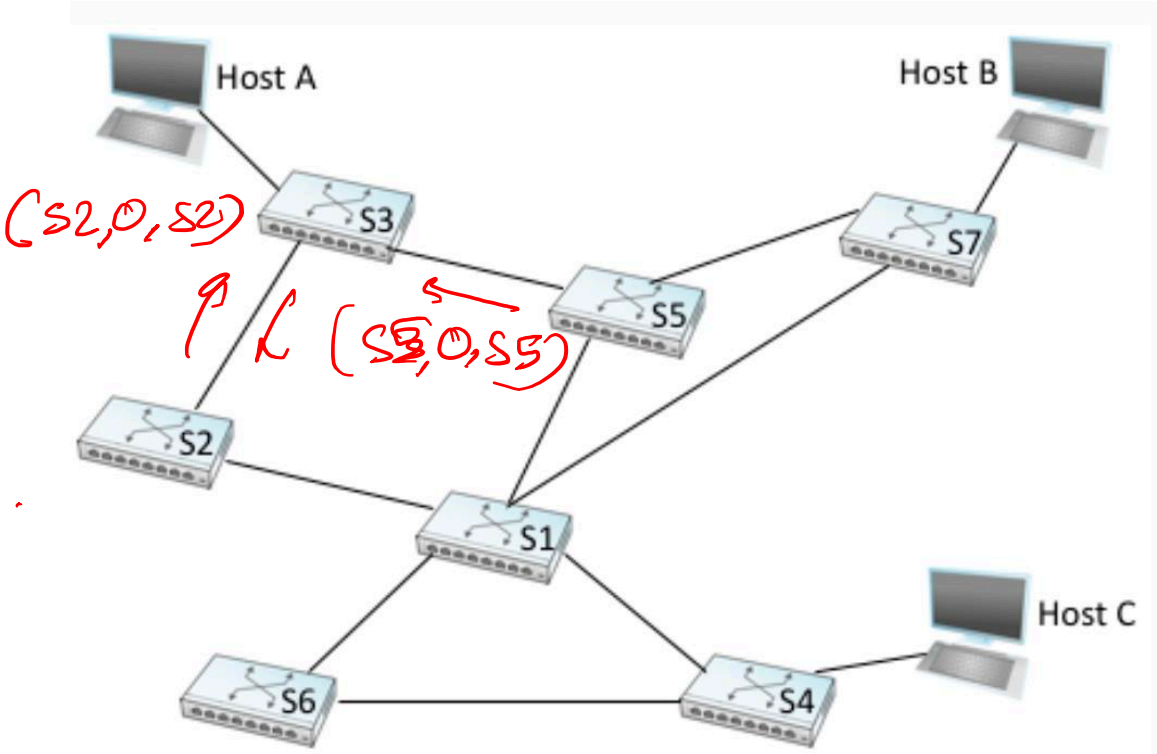
SPT (Details)

- Each bridge has an ID
  - 8 bytes: 2 bytes configurable, 6 bytes of MAC address
- Bridge X announces its bridge ID to its neighbors along with distance to root
  - (Y, d, X)



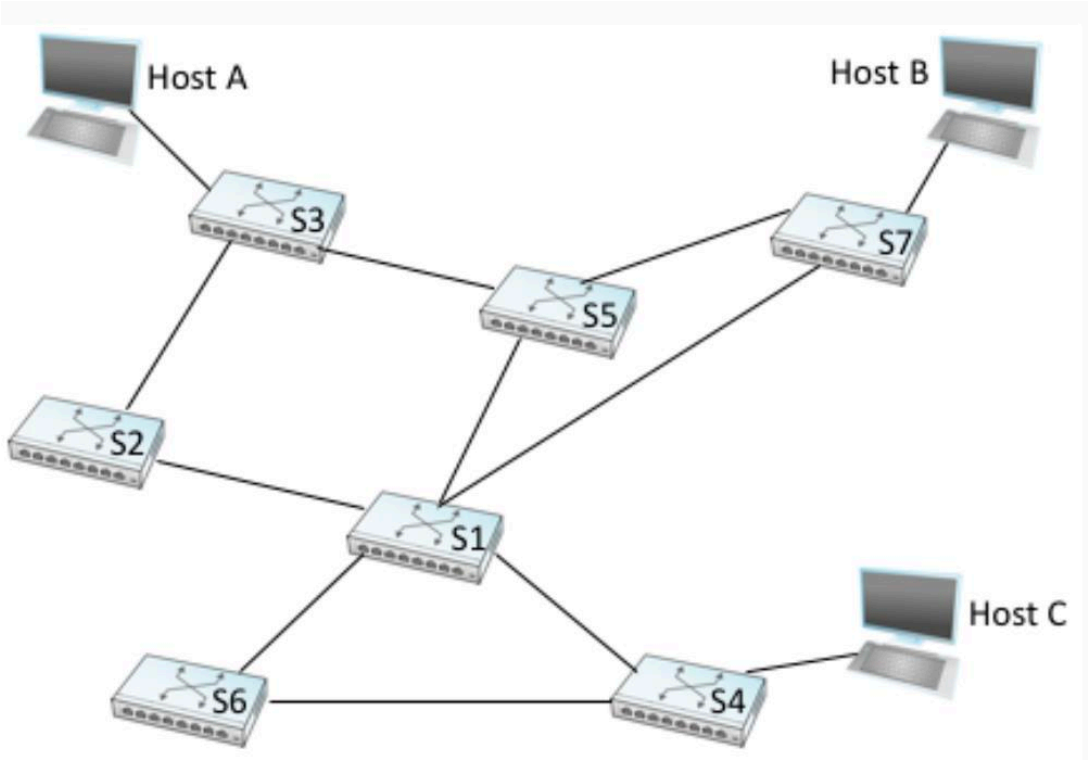
SPT (Details)

- Each bridge has an ID
  - 8 bytes: 2 bytes configurable, 6 bytes of MAC address
- Bridge X announces its bridge ID to its neighbors along with distance to root
  - (Y, d, X)
- Stop generating configuration messages as root node
  - When receives message from a smaller switch ID



SPT (Details)

- Each bridge has an ID
  - 8 bytes: 2 bytes configurable, 6 bytes of MAC address
- Bridge X announces its bridge ID to its neighbors along with distance to root
  - (Y, d, X)
- Stop generating configuration messages
  - When receives message from a smaller switch ID
- Stop sending on a port
  - Message from a switch that is closer to root or
  - Equally far from from the root but with smaller ID



Conclusion

- Link layer services
  - Framing
  - Error detection
  - Reliability
  - Medium Access Control (MAC)
- Ethernet protocol
- Forwarding in an Ethernet switched network
- A lot of interesting things happening at L2
  - MPLS, VLAN
  - Data center networks
  - ..