CS 4410
Operating Systems

Networking:
Network Layer

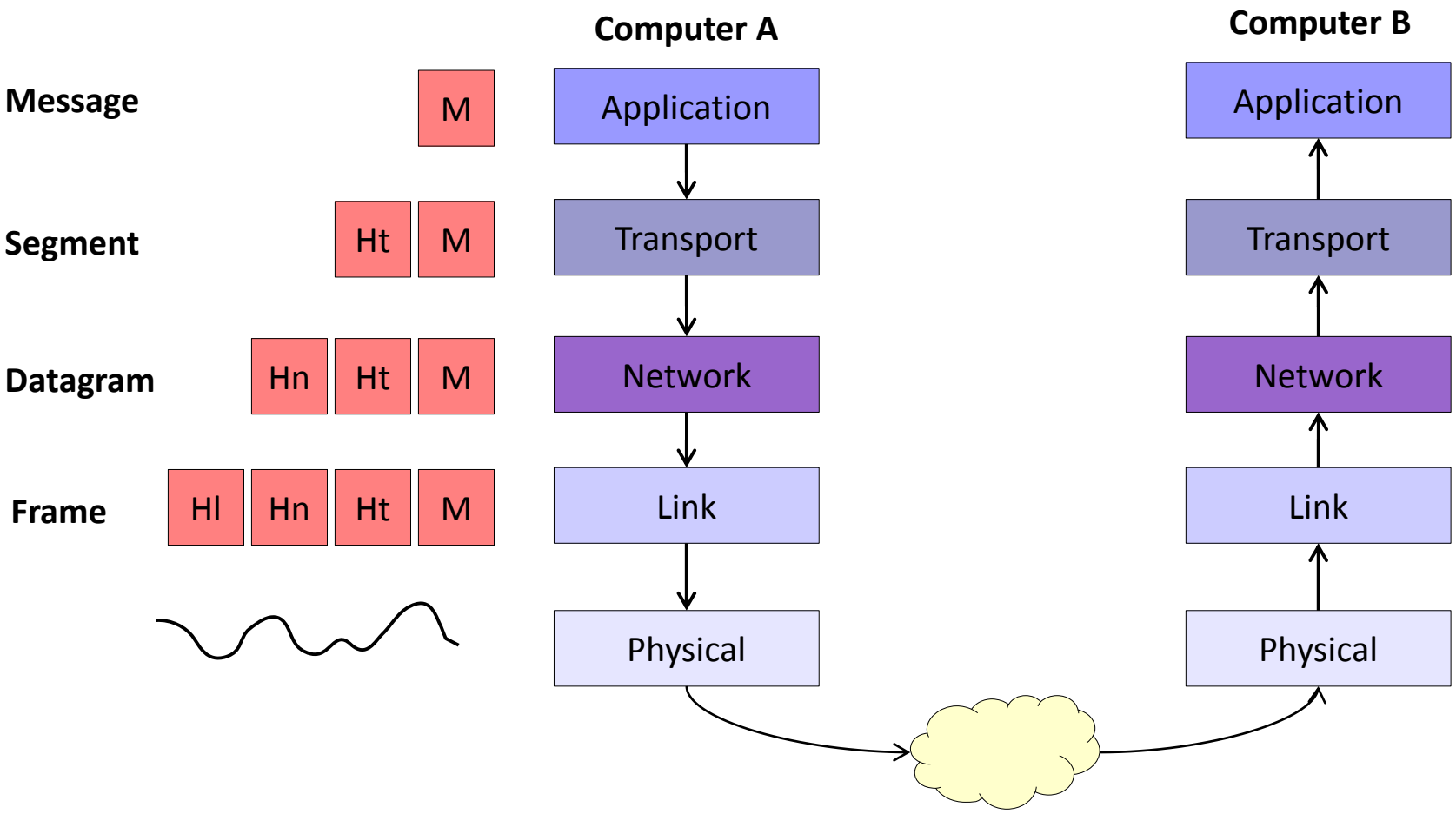
Summer 2016

Cornell University

Today

- How can two computers communicate in a WAN?

Protocol Stack



WAN

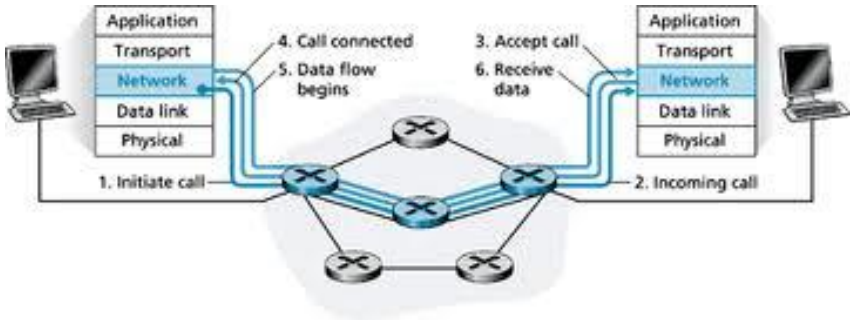
- Usually, thousands of computers need to be interconnected.
- The capabilities that LANs offer cannot support larger networks.
- We need more services than the Link Layer offers.
  - Why?
  - Clever Naming
  - Efficient forwarding/routing of messages.

Network Layer

- Mission: Transfer messages from the **source-computer** to the **destination-computer**.
  - Attention: this is different from the mission of the Link Layer.
- Services:
  - Forwarding / Routing
  - Guaranteed delivery, bandwidth, etc
  - Security
  - Not all the protocols support these services.
- The Network Layer protocol depends on the kind of network we want to built:
  - Virtual-circuit networks
  - Datagram networks
- Necessary network device:
  - Router: It knows where to forward the message.

Network Layer

- **Virtual-circuit networks**
  - 3 phases
  - Establish a virtual circuit.
    - The Network Layer finds the path from the source to the destination.
    - Reserve resources for the virtual circuit.
  - Transfer data
    - Packets pass through the virtual circuit.
  - Destroy virtual circuit.
    - Release resources.
  - Disadvantages?
- **Datagram networks**
  - Every packet has the destination address and it is routed independently in the network.
  - The router uses the destination address to forward the packet towards the destination-computer.



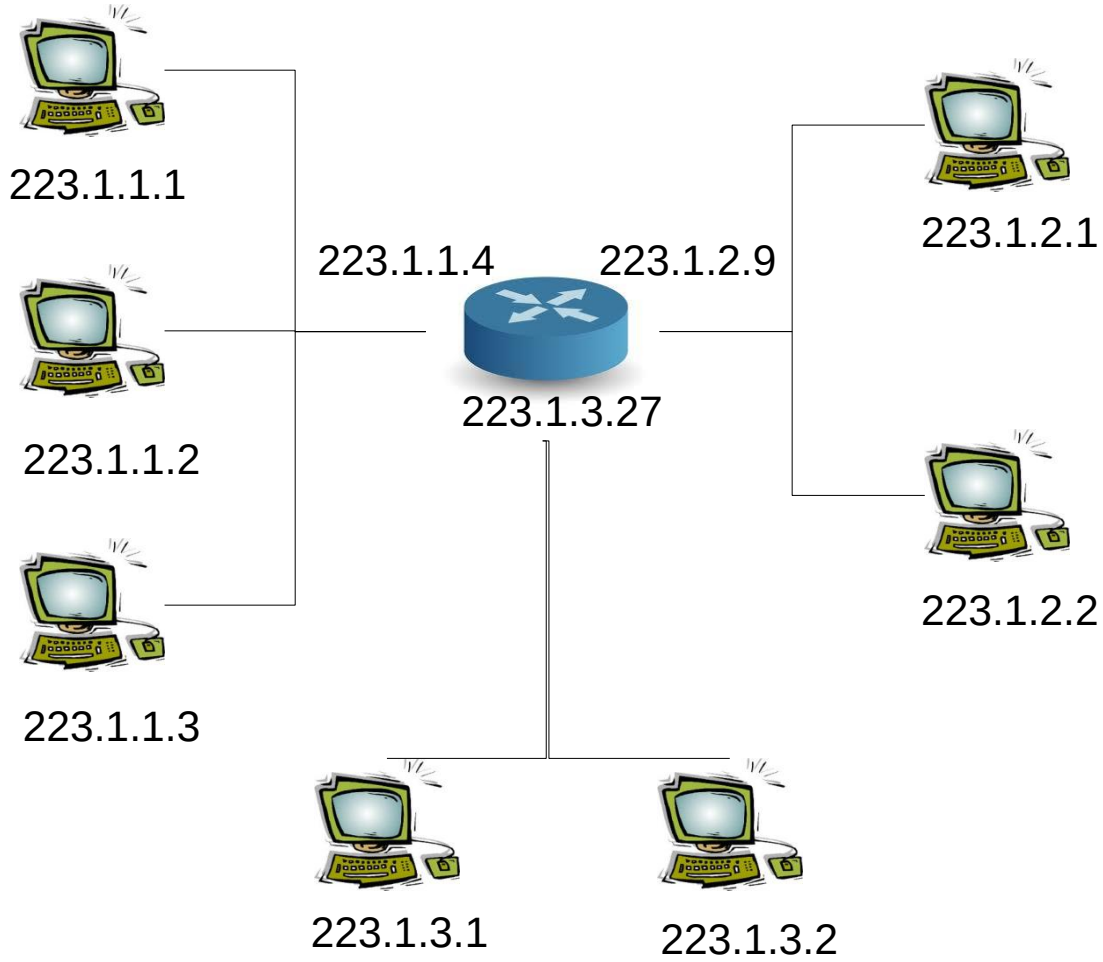
IP

- Network Layer Protocol for the Internet:
  - Internet Protocol
- For Datagram networks.
- IPv4, IPv6
- Datagram structure:

Version	Header Length	Type of service	Length	
Identification			Flags	Fragment Offset
Time to live		Protocol	Header Checksum	
Source IP Address (32-bit)				
Destination IP Address				
Options				
Data				

Naming

- All the computers in the Internet have one or more IP addresses.
- For IPv4:
  - 32 bits
  - Dotted-decimal notation (Ex: 147.76.89.4)
  - Contain information about the subnetwork in which a host belongs.
    - Example: For the address 140.251.27.18 we know that:
      - It belongs to a host in Cornell, as Cornell gives addresses of the form 140.251.xxx.xxx. → subnetwork address 140.251.0.0/16, mask 255.255.0.0
      - It belongs in host in Linguistics Department, as the addresses of this department is 140.251.27.xxx. → subnetwork address 140.251.27.0/24, mask 255.255.255.0
      - The number 18 distinguish this host from other hosts in the same subnetwork of Linguistics.
- Assigned by a DHCP server in the subnetwork.
  - Dynamic Host Configuration Protocol
  - Every computer that is inserted in the subnetwork, communicated with the DHCP server to obtain an IP address.



What happens when 223.1.1.1 wants to send a packet to 223.1.3.2 ?

Forwarding

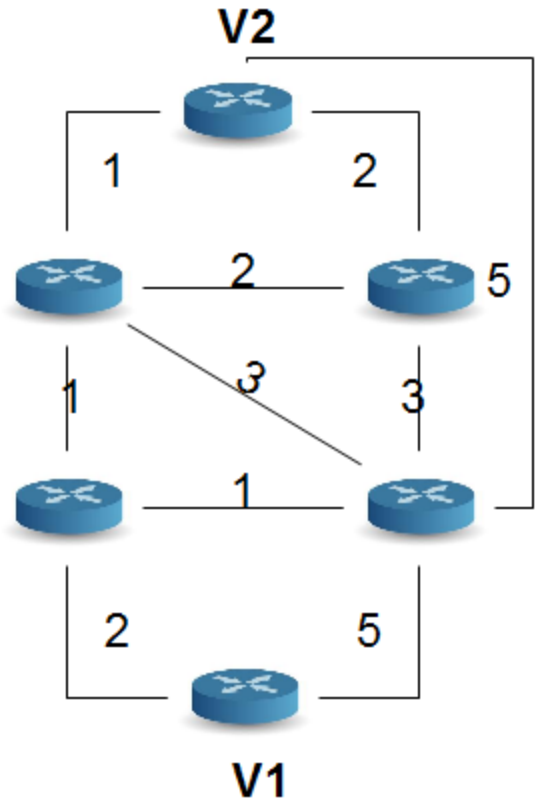
- Each router has a **routing table**.
- The routing table is an array of triples (at least).
- Each tuple has:
  - **Subnetwork id, subnetwork mask, gateway**
- So, the routing table of the previous example is:
  - 223.1.1.0, 255.255.255.0, 0
  - 223.1.3.0, 255.255.255.0, 1
  - 223.1.2.0, 255.255.255.0, 2
- When a datagram is received, all the subnetwork masks are applied to its IP address (binary AND operation) to find the subnetwork in which the destination belongs.
- So, a datagram with destination to 223.1.3.2 is forwarded to gateway 1.

Forwarding

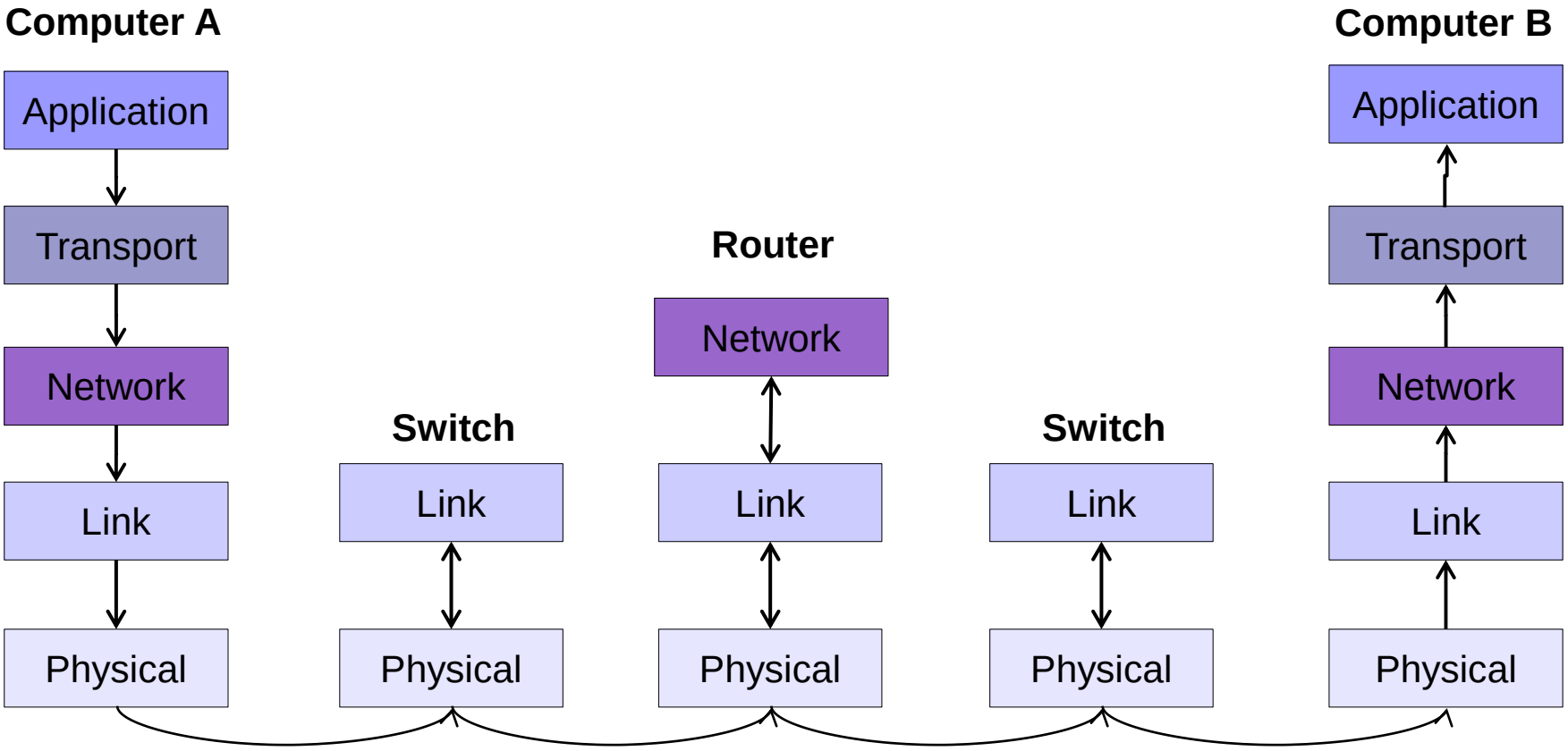
- Even though we know the destination IP, we do not know the MAC address of 223.1.3.2, in order the packet to go from the gateway 1 to the destination.
- With the **ARP** protocol the router asks which node of one subnetwork has the needed IP.
- The destination replies with its MAC address.
- Finally, the packet can be sent to the destination.

Routing Algorithms

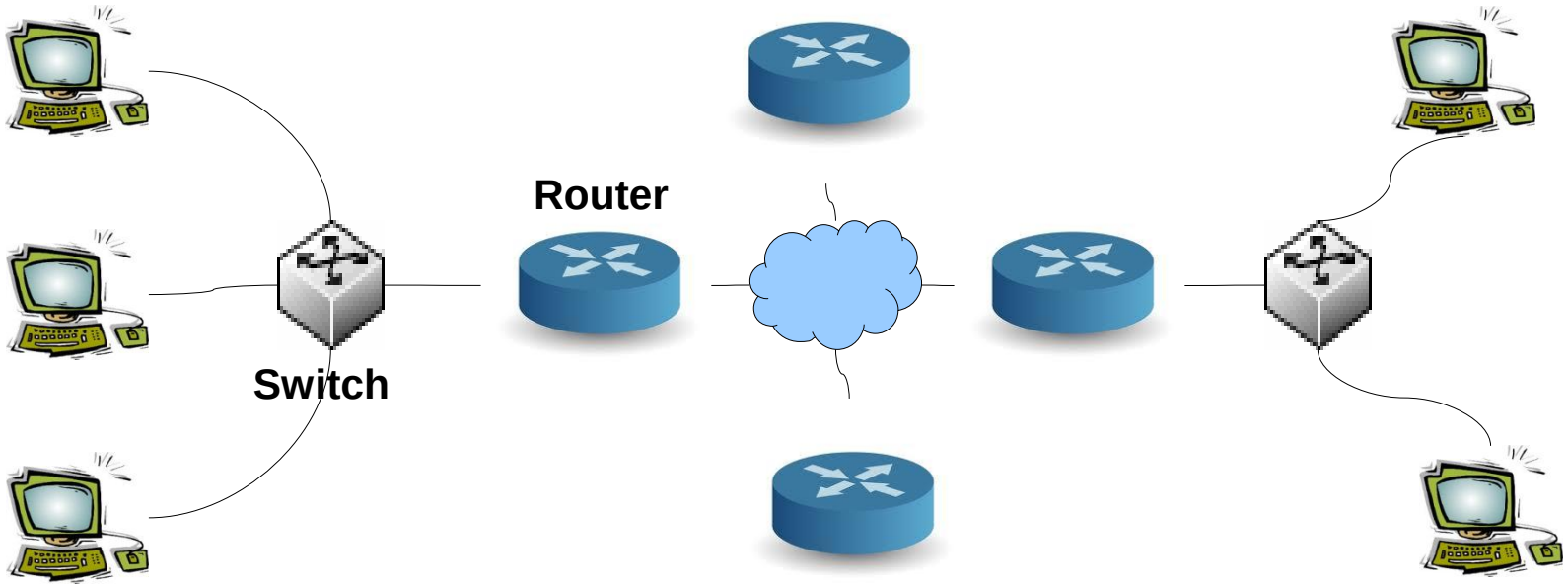
- How does the router construct its routing table?
- The routing path should be the shortest path from the source to the destination.
- General problem:
  - Graph (V, E)
  - V is the set of routers.
  - E is the set of links between the routers.
  - Each edge has a cost related to the distance.
  - If the source is attached to the router V1 and the destination to the router V2, what is the shortest path between V1 and V2?



Network Layer



Network Layer



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Coming up…

- Next lecture: Routing algorithms