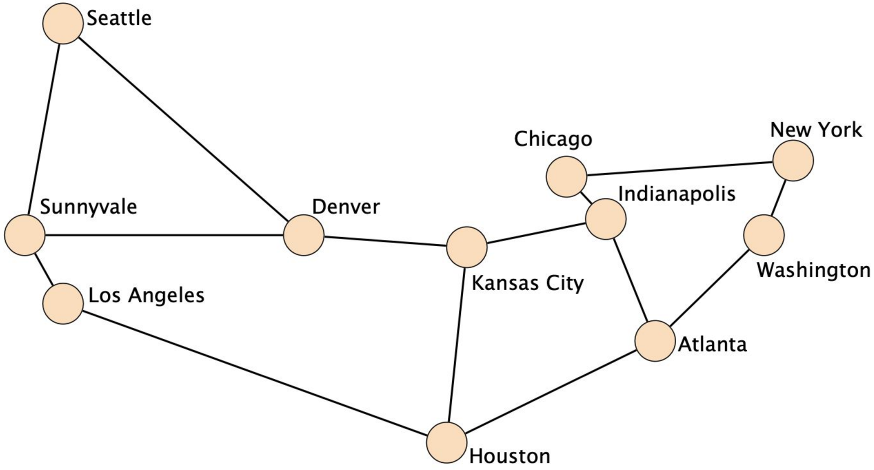
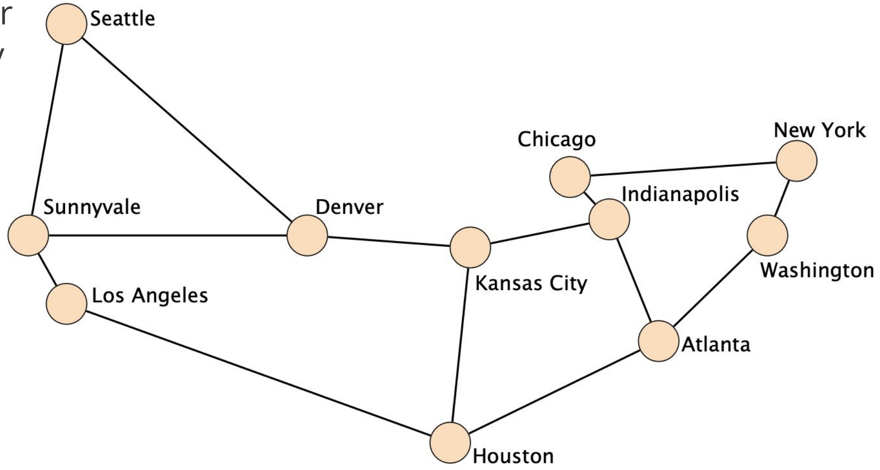
Link Weight Configurations

- The Abilene network was a high-performance backbone network in the US. You are the network operator in charge and you have to configure the link weights in the network. Initially, all links have a weight of one and routers will always use the shortest-path available to reach a destination.



Link Weight Configurations

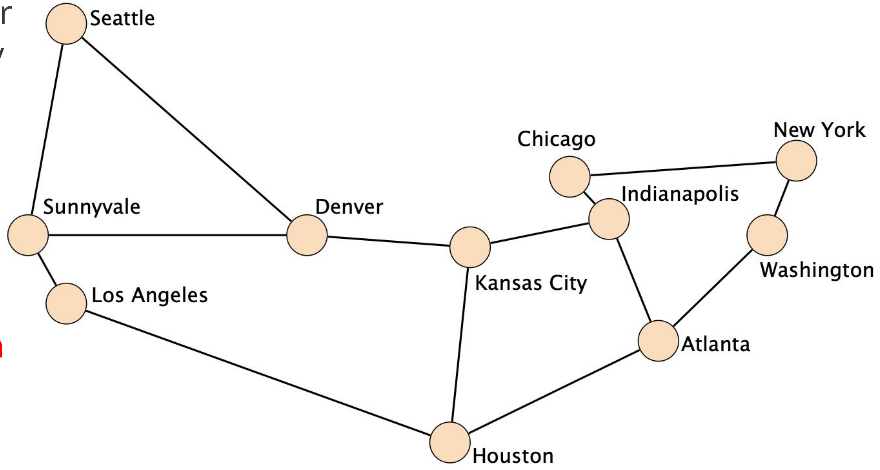
Is it possible to configure the link weights such that the packets sent by the router located in Los Angeles to the router located in New York follow one path while the packets sent by the router located in New York to the router located in Los Angeles follow a completely different path?



Link Weight Configurations

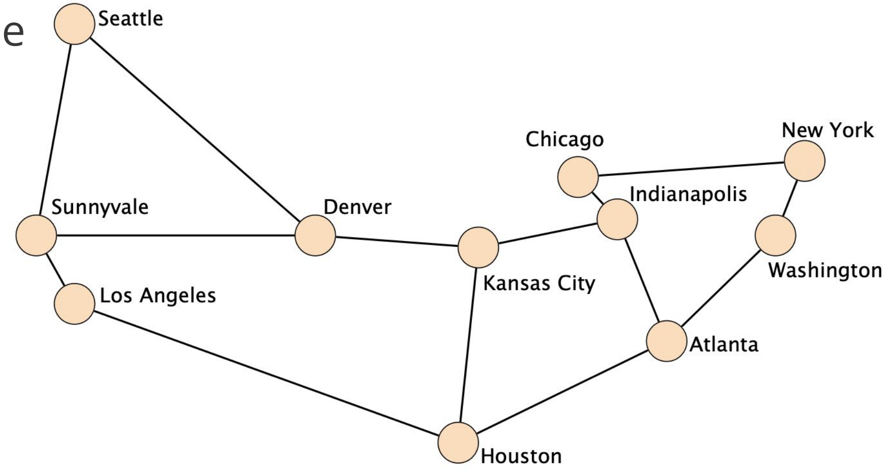
Is it possible to configure the link weights such that the packets sent by the router located in Los Angeles to the router located in New York follow one path while the packets sent by the router located in New York to the router located in Los Angeles follow a completely different path?

Solution: Not possible. We consider only links which have the same weight in both directions. If the two routers would use different paths for the two traffic directions, the two paths would need different total weights. That implies that one path is shorter and one router is not using the shortest-path available. A contradiction to our initial assumption.



Link Weight Configurations

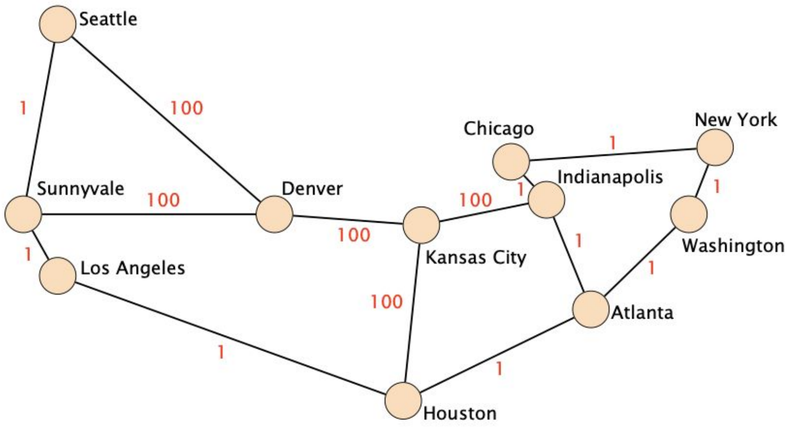
Assume that the routers located in Denver and Kansas City need to exchange lots of data on the direct link. Can you configure the link weights such that the link between these two routers does not carry any packet sent by any other router in the network?



Link Weight Configurations

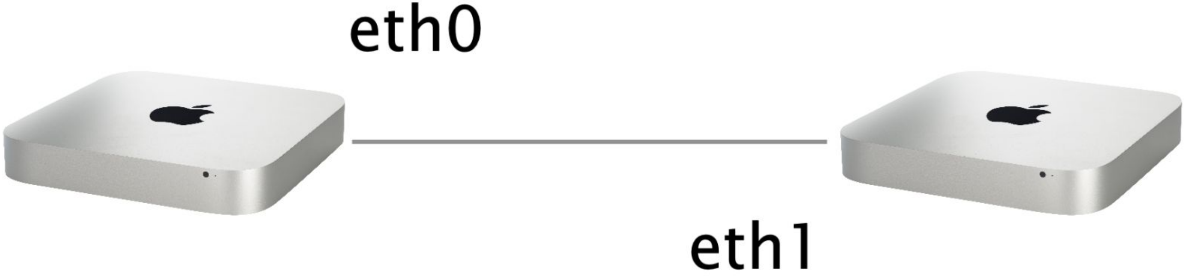
Assume that the routers located in Denver and Kansas City need to exchange lots of data on th direct link. Can you configure the link weights such that the link between these two routers does not carry any packet sent by any other router in the network?

Solution:



Link Layer

How do local computers communicate?



Link Layer

1. What is a link?
2. How do we share a network medium?
3. How do we identify link adapters?
4. What is Ethernet?
5. How do we interconnect segments at the link layer?

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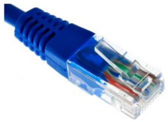
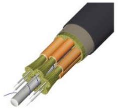
Link Layer

Link Communication medium and Network adapter

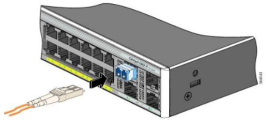
Wifi



Ethernet



Fiber



Link Layer

terminology:

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

Link layer has responsibility of transferring datagram from one node to physically adjacent node over a link

Link Layer

- datagram transferred by different link protocols over different links:
  - e.g., WiFi on first link, Ethernet on next link
- each link protocol provides different services
  - e.g., may or may not provide reliable data transfer 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 in frame headers identify source, destination

- reliable delivery between adjacent nodes
  - seldom used on low bit-error links
  - wireless links: high error rates
  - Question: why both link-level and end-end reliability?

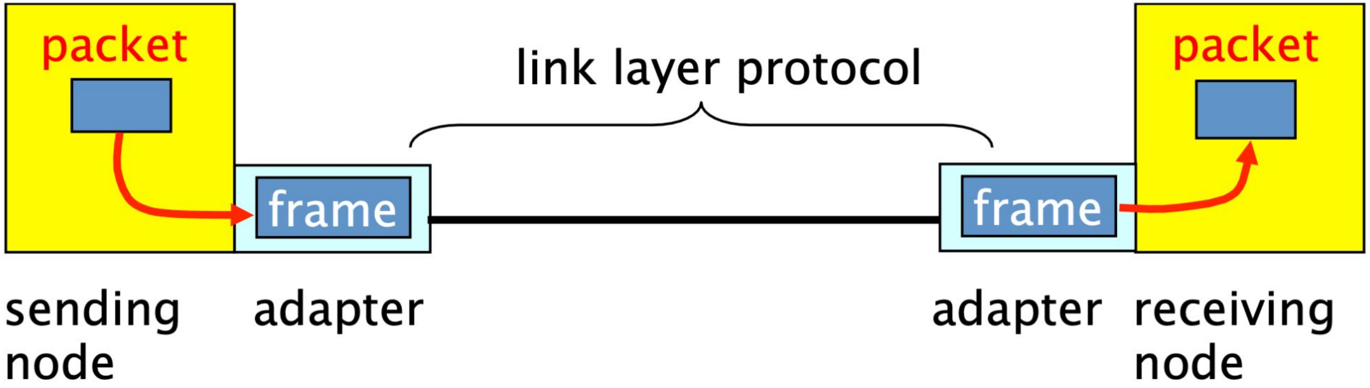
Link Layer Services

- flow control:
  - pacing between adjacent sending and receiving nodes
- error detection:
  - errors caused by signal attenuation, noise.
  - receiver detects errors, signals retransmission, or drops frame
- error correction:
  - receiver identifies and corrects bit error(s) without 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?

- each-and-every host
- link layer implemented in *network interface card* (NIC) or on a chip
  - Ethernet, WiFi card or chip
  - implements link, physical layer
- attaches into host’s system buses
- combination of hardware, software, firmware

Network Adapters Communicate via the Medium



sending side:

- encapsulates datagram in frame
- adds error checking bits, reliable data transfer, flow control, etc.

receiving side:

- looks for errors, reliable data transfer, flow control, etc.
- extracts datagram, passes to upper layer at receiving side

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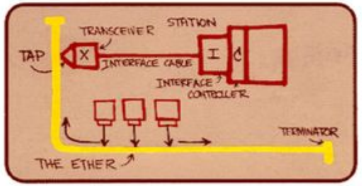
Some Mediums are Multi-Access (>1 Host can Communicate at a Time)

Wireless
networks

Satellite
networks



original Ethernet
networks

Cellular
networks

Multi-Access Problem - Collisions

Problem

collisions lead
to garbled data

Solution

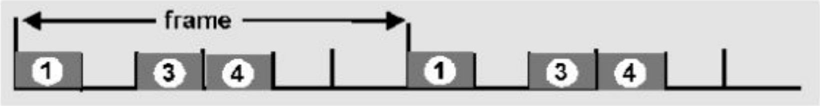
distributed algorithm
for sharing the channel

When can each node transmit?

There are Effectively Three Ways to Manage Multiple Access

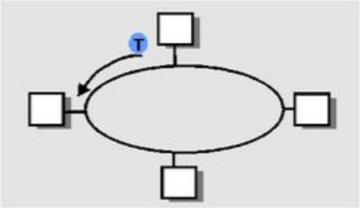
Divide the channel into pieces

either in time or in frequency



Take turns

pass a token for the right to transmit



Random access

allow collisions, detect them and then recover

There are Effectively Three Ways to Manage Multiple Access

channel partitioning, by time, frequency or code

- Time Division, Frequency Division

taking turns

- polling from central site, token passing
- Bluetooth, FDDI, token ring

random access (dynamic),

- ALOHA, S-ALOHA, CSMA, CSMA/CD
- carrier sensing: easy in some technologies (wire), hard in others (wireless)
- CSMA/CD used in Ethernet
- CSMA/CA used in 802.11

Carrier Sense Multiple Access

simple CSMA: listen before transmit:

- if channel sensed idle: transmit entire frame
- if channel sensed busy: defer transmission

human analogy: don't interrupt others

CSMA/CD: CSMA with collision detection

- collisions detected within short time
- colliding transmissions aborted, reducing channel wastage
- collision detection easy in wired, difficult with wireless

human analogy: the polite conversationalist

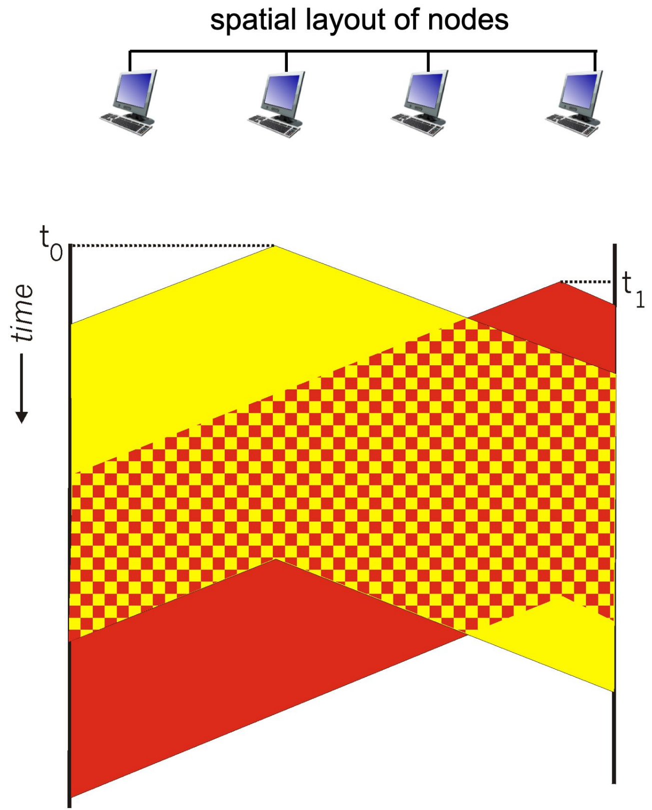
Pure CSMA

collisions can still occur with carrier sensing:

- propagation delay means two nodes may not hear each other's just-started transmission

collision: entire packet transmission time wasted

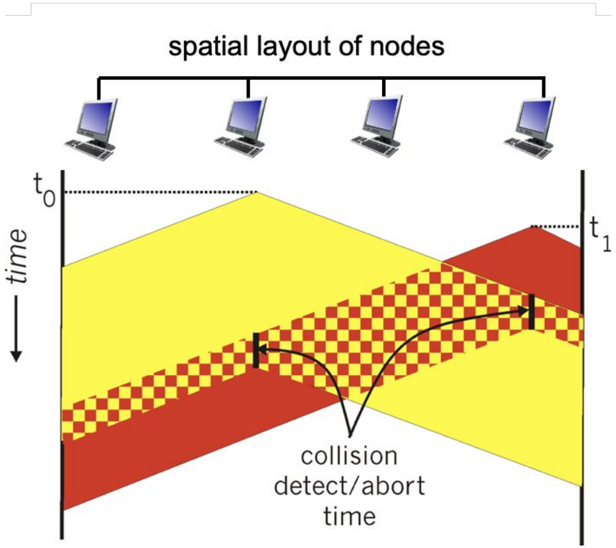
- distance & propagation delay play role in in determining collision probability



CSMA/CD

CSMA/CD reduces the amount of time wasted in collisions

- transmission aborted on collision detection



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Medium Access Control addresses

MAC Addresses

identify the sender & receiver adapters

- used on a link

are uniquely assigned

- hard-coded into the adapter when built

use a flat space of 48 bits

- allocated hierarchically

MAC Addresses are Hierarchical

34:36:3b:d2:8a:86

The First 24 bits Represent the Vendor

`34:36:3b:d2:8a:86`

Apple, Inc.
1 Infinite Loop
Cupertino CA 95014
US

see http://standards-oui.ieee.org/oui/oui.txt

The Second 24 bits are Assigned by the Vendor to the Adapter

34:36:3b:**d2:8a:86**

assigned by Apple
to my adapter

If all bits are Set, it's a Broadcast Address

`ff:ff:ff:ff:ff:ff`

enables to send a frame to
all adapters on the link

By Default, Adapters only Decapsulates Frames Addressed to the Local MAC or the Broadcast Address

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Workaround is promiscuous mode: enables to decapsulate everything, independently of the destination MAC

Why Do We Need MAC Addresses (and not just use IPs)?

Adapters must be identified during bootstrap

need to talk to an adapter to give it an IP address

Network Adapter Bootstrap

Two problems to solve:

1. Who am I? How do I acquire an IP address?

2. Who are you? Given an IP, how do I find which MAC to send to?

Network Adapter Bootstrap

Two problems to solve:

1. Who am I? How do I acquire an IP address?
   Dynamic Host Configuration Protocol

2. Who are you? Given an IP, how do I find which MAC to send to?
   Address Resolution Protocol