

# Internet Routing

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# Outline

1 Overview

2 Routing Information

3 Internet Routing Protocols

- ▶ Routing information. It is about network information sources. Routing information typically have information about network topology and delay
- ▶ Routing algorithms. They are the algorithms used to make a routing decision based on routing information.
- ▶ Routing protocols. They specify formats, syntax, and timing of information exchange for routing.

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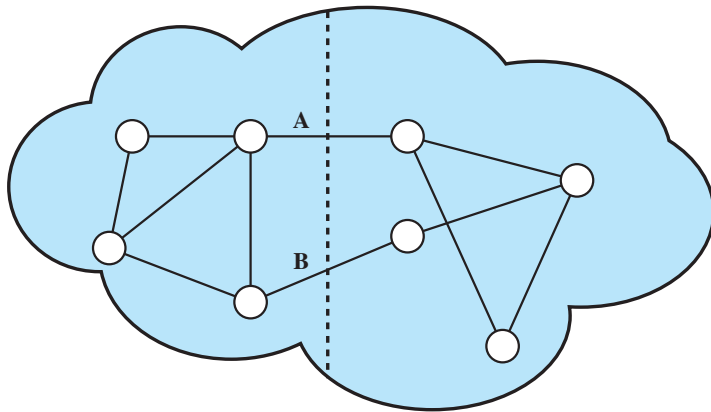
## How to assign a cost to a link?

Below are some examples,

- ▶ Using queue length of a link (see the example in Figure 19.4<sup>1</sup>).
  - ▶ It does not consider link bandwidth
  - ▶ Processing time also impacts queue length
  - ▶ It responds slowly to congestion and delay increases
  - ▶ It can also vary rapidly, which results in thrashing
- ▶ Measuring delay directly (by recording arrival time, departure time, and arrival time of acknowledgement)
  - ▶ The estimated delay does not correlate well with actual delay experienced by a packet under heavy load.
  - ▶ Example. Figure 19.7 <sup>1</sup>
- ▶ Estimating the link utilization (based on queueing models)

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<sup>1</sup>William Stallings. *Data and Computer Communications*. 10th. USA: Prentice Hall Press, 2013. ISBN: 0133506487.

Figure 19.7<sup>2</sup>

**Figure 19.7 Packet-Switching Network Subject to Oscillations**

<sup>2</sup>William Stallings. *Data and Computer Communications*. 10th. USA: Prentice Hall Press, 2013. ISBN: 0133506487.

# Estimating Link Utilization

1. Estimate utilization

$$\rho = \frac{2(T_s - T)}{T_s - 2T} \quad (1)$$

2. Apply exponential averaging

$$U(n+1) = \alpha \rho(n+1) + (1 - \alpha)U(n) \quad (2)$$

where  $\alpha$  is typically  $\frac{1}{2}$ .

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# Autonomous System (AS)

- ▶ The Internet is an internetwork consisting of networks that are independently controlled and managed.
- ▶ As part of the design of the Internet, the Internet composes of autonomous systems(AS).
- ▶ An AS has the following characteristics.
  - ▶ An AS is an internetwork managed by a single organization.
  - ▶ An AS has a group of routers exchanging routing information via a common routing protocol
  - ▶ Except in times of failure, an AS is connected, i.e., there is a path between any pair of routers within.
  - ▶ An AS is identified by an AS number (public AS numbers, like IP addresses are assigned by the Internet Assigned Number Authority)

# Interdomain and Intradomain Routing

- ▶ Intradomain routing. Routing among routers within an autonomous system.
  - ▶ Interior router protocol
  - ▶ Distance-vector and link-state routing
    - ▶ Distance-vector. Routers exchange distance-vector containing path costs with their neighbors
    - ▶ Link-state. Routers propagate link states containing path costs with all the other routers (via flooding).
- ▶ Interdomain routing. Routing among routers in different autonomous systems.
  - ▶ Exterior router protocol (ERP)
  - ▶ Path vector routing
    - ▶ Link cost estimation unreliable crossing multiple autonomous systems
    - ▶ Autonomous systems may use different metrics and have different restrictions or prohibitions.
    - ▶ Flooding is unmanageable.

# Link-State Routing

- ▶ Let's examine how it works
- ▶ Let's set it up on an internetwork

# Border Gateway Protocol (BGP)

Let's examine how it works.