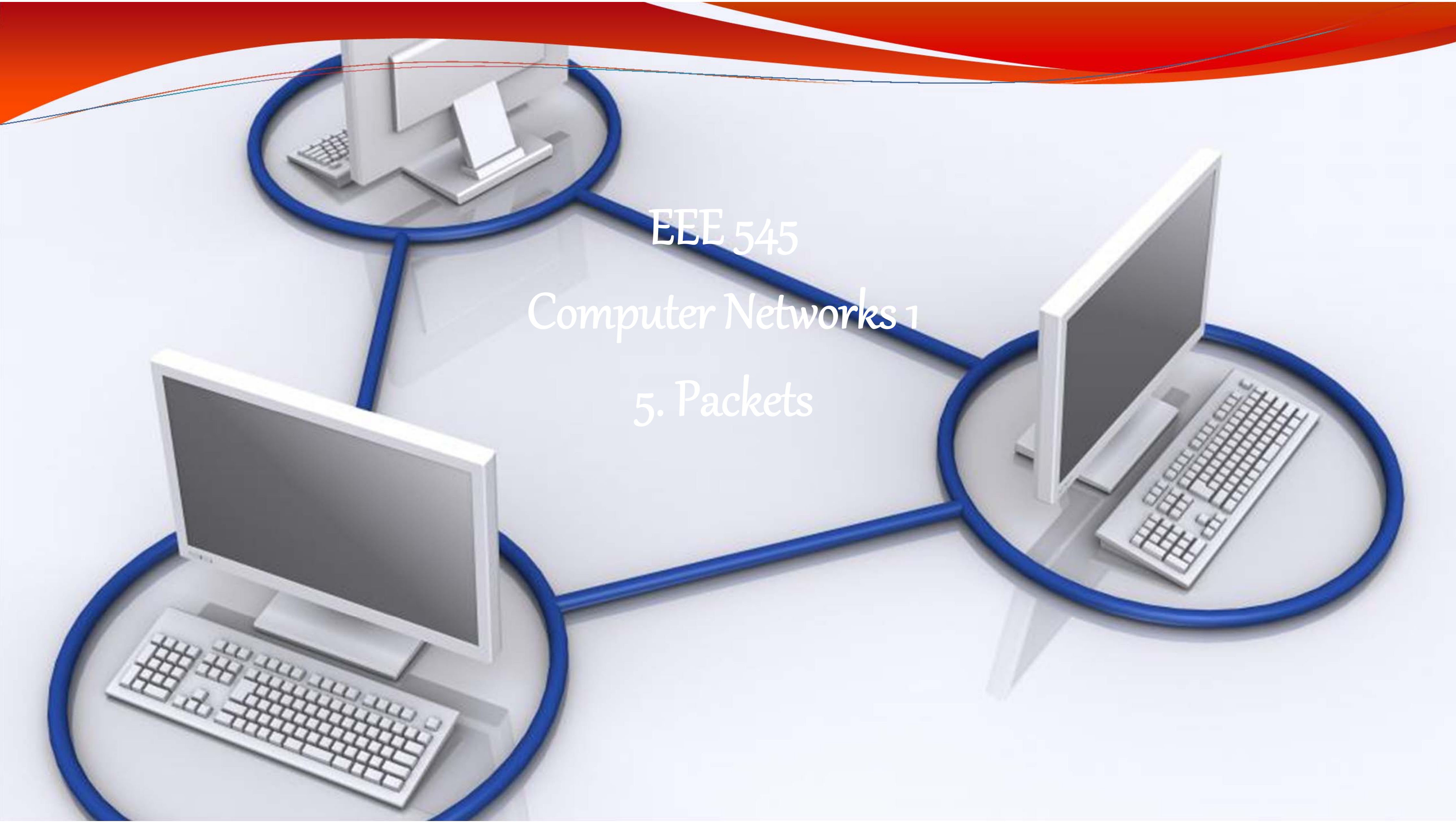


EEE 545

Computer Networks 1

5. Packets

5.1 Packet Delay

- There are several contributing sources to the delay encountered in transmitting a packet. On a LAN, the most significant is usually what we will call **bandwidth delay**: the time needed for a sender to get the packet onto the wire. This is simply the packet size divided by the bandwidth, after everything has been converted to common units (either all bits or all bytes).
- For a 1500-byte packet on 100 Mbps Ethernet, the bandwidth delay is 12,000 bits / (100 bits/µsec) = 120 µsec.

5.1 Packet Delay

- There is also **propagation delay,** relating to the propagation of the bits at the speed of light (for the transmission medium in question). This delay is the distance divided by the speed of light; for 1,000 m of Ethernet cable, with a signal propagation speed of about 230 m/µsec (v=**0.77c**), the propagation delay is about 4.3 µsec.
- That is, if we start transmitting the 1500 byte packet of the previous paragraph at time T=0, then the first bit arrives at a destination 1,000 m away at T = 4.3 µsec, and the last bit is transmitted at 120 µsec, and the last bit arrives at T = 124.3 µsec.

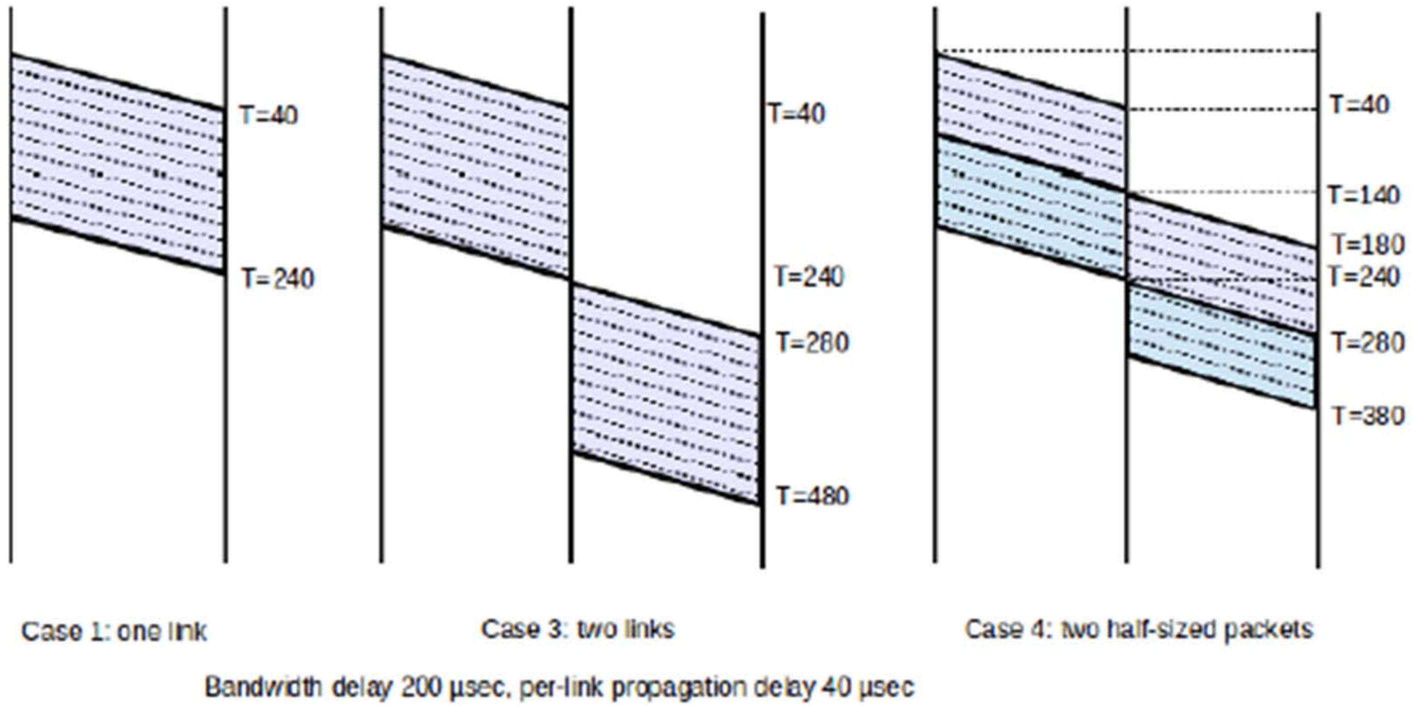
5.1.1 Delay Examples

- **Case 1:** A--------------B
- • Propagation delay is 40 µsec
- • Bandwidth is 1 byte/µsec (1 mB/sec, 8 Mbit/sec)
- • Packet size is 200 bytes (200 µsec bandwidth delay)
- Then the total one-way transmit time is 240 µsec = 200 µsec + 40 µsec
- **Case 2:** A---------------------------------B
- Like the previous example except that the propagation delay is increased to 4 ms
- The total transmit time is now 4200 µsec = 200 µsec + 4000 µsec.

5.1.1 Delay Examples

- **Case 3:** A-------------R--------------B
- We now have two links, each with propagation delay 40 µsec bandwidth and packet size as in Case 1
- The total transmit time for one 200-byte packet is now 480 µsec = 240 + 240. There are two propagation delays of 40 µsec each; A introduces a bandwidth delay of 200 µsec and R introduces a store-and-forward delay (or second bandwidth delay) of 200 µsec.
- **Case 4:** A-------------R--------------B
- The same as 3, but with data sent as two 100-byte packets
- The total transmit time is now 380 µsec = 3x100 + 2x40. There are still two propagation delays, but there is only 3/4 as much bandwidth delay because the transmission of the first 100 bytes on the second link overlaps with the transmission of the second 100 bytes on the first link.

5.1.1 Delay Examples



- These ladder diagrams represent the full transmission; a snapshot state of the transmission at any one instant can be obtained by drawing a horizontal line. In the middle, case 3, diagram, for example, at no instant are both links active.

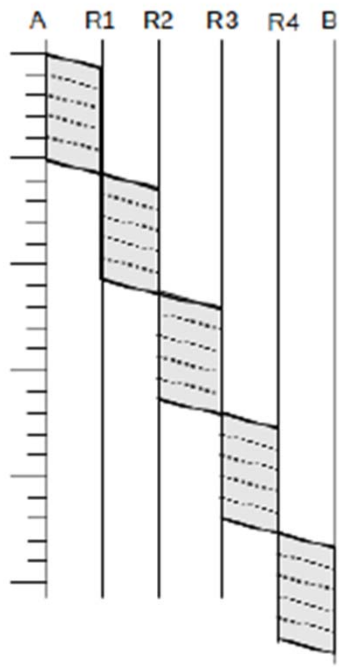
5.3 Packet Size

How big should packets be? Should they be large (eg 64 KB) or small (eg 48 bytes)?

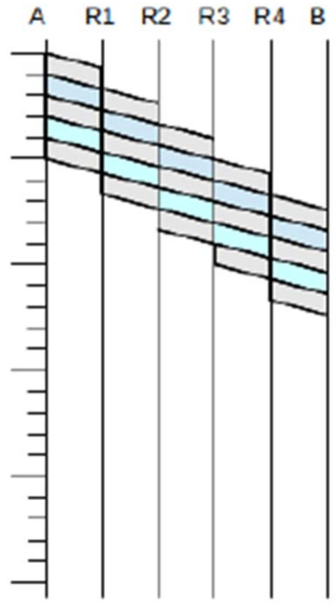
- The Ethernet answer to this question had to do with equitable sharing of the line: large packets would not allow other senders timely access to transmit. In any network, this issue remains a concern.
- On the other hand, large packets waste a smaller percentage of bandwidth on headers. However, in most of the cases we will consider, this percentage does not exceed 10%. **It turns out that if store-and-forward switches are involved, smaller packets have much better throughput.**

5.3 Packet Size

- As an example of this, consider a path from A to B with four switches and five links:
- A-----R1-----R2-----R3-----R4-----B
- Suppose we send either one big packet or five smaller packets. The relative times from A to B are illustrate in the following figure:



One large packet over five links



Five smaller packets over five links

5.3.1 Error Rates and Packet Size

- For example, suppose that 1 bit in 10,000 is corrupted, at random, so the probability that a single bit is transmitted correctly is 0.9999 (this is much higher than the error rates encountered on real networks). For a 1000-bit packet, the probability that every bit in the packet is transmitted correctly is (0.9999)^1000, or about 90%. For a 10,000-bit packet the probability is (0.9999)^10,000 = 37%. For 20,000-bit packets, the success rate is below 14%.
- Now suppose we have 1,000,000 bits to send, either as 1000-bit packets or as 20,000-bit packets. Nominally this would require 1,000 of the smaller packets, but because of the 90% packet-success rate we will need to retransmit 10% of these, or 100 packets.

5.3.1 Error Rates and Packet Size

- **Moral:** Choose the packet size small enough that most packets do not encounter errors.
- To be fair, very large packets can be sent reliably on most cable links (eg TDM and SONET). Wireless, however, is more of a problem.

5.4 Error Detection

- The basic strategy for packet error detection is to add some extra bits – formally known as an error-detection code – that will allow the receiver to determine if the packet has been corrupted in transit.
- A corrupted packet will then be discarded by the receiver; higher layers do not distinguish between lost packets and those never received. While packets lost due to bit errors occur much less frequently than packets lost due to queue overflows.
- Intermittent packet errors generally fall into two categories: low-frequency bit errors due to things like cosmic rays, and interference errors, typically generated by nearby electrical equipment. Errors of the latter type generally occur in bursts, with multiple bad bits per packet. Occasionally, a malfunctioning network device will introduce bursty errors as well.