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Network Metrics

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Network Metrics

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- Types of Errors
- Performance Measures

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Reliability

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- Most users expect the network to deliver their data to the Application Layer without error
  - All the data that was sent is received ("all received")
  - Within a unit of data, order is preserved ("in order")
  - The data is not garbled ("no bit errors")
- This means that lower layers must, as far as is feasible, try to prevent errors, and detect and correct errors that do occur

What kinds of errors might occur?

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- Bit errors
  - random or bursts
  - errors in data can often be fixed
  - errors in header info can lead to strange effects
- Packet-level errors
  - delayed due to congestion
  - lost/mis-routed
  - out of order
- Link and node failures
  - short and long-term
  - unexpected start-up problems

Detection and correction?
That will be a major goal of the protocols we will discuss

Performance measures: Talking about the performance of a link

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- A common measure of link performance is the amount of time required to transfer a packet from one end to the other
- Delay = Propagation delay + Transmit delay + Queuing time
  - Propagation delay = time to send a signal end to end
  - Transmit delay = time to stream all bits of a packet onto the link
  - Queuing time = time the packet is delayed (buffer, queue, etc)

An analogous situation: water in a pipe

- each gallon of water takes a finite amount of time to traverse the pipe, depending on the pipe's length (propagation delay)
- the pipe can deliver a certain number of gallons per second, depending on the pipe's size (transmit delay)
- water may be stored temporarily in a reservoir (queuing time)

Progation delay (aka "latency")

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- = time it takes for the elictrical or optical signal to be sent from the sending end of the link to the receiving end
- Propagation delay = L / c
  - L = Length of the link (m)
  - c = Speed of light in the medium the link is made from (m/s)
    - Free space: 3.0×10^8 m/s
    - Copper: 2.3×10^8 m/s
    - Optical fiber: 2.0×10^8 m/s

Example:

Latency of a 100Km copper link

$= 100 \times 10^3$ m / 2.3 x 108 m/s

$= 10^{-3} / 2.3$ s

$= 0.43 \times 10^{-3}$ s = 430 usec

Transmit delay

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- = time it takes to stream the bits of the packet onto the link
- Transmit delay = p / bw
  - p = number of bits in the packet
  - bw = bandwidth of the link (bps)

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Link bandwidth

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- Some types of link technologies and designs can handle more bits per second (bps) than others
- Bandwidth of a link = the specified max rate in bps at which the link can accept binary data
  - (Remember: rates expressed using powers of 10, not 2)

Example:

If bandwidth = 100Mbps ($10^2 \times 10^6$ bps = 10^8 bps) then:

- The link can accept 10^8 bits in a second, including both data and "overhead" bits
- When data is being streamed onto the link, a new bit can be handled each 10^{-8} seconds (10 nsec)
- It will take n x 10^{-8} sec to stream an n-bit packet onto the link (this is the Transmit delay for the packet)

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Queuing delay

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- = time packet is delayed in a buffer or queue
- Depends on the specific situation -- hard to generalize accurately
- We will normally ignore queuing delay in calculating link delay, but *don't forget it is there*.

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An example link delay calculation

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What is the minimum link delay for a 1MB packet sent from New York City to San Francisco (4800 Km) over a 10Mbps fiber link?

Prop delay = L / c
= 4800 Km / c_in_fiber
= 4.8×10^6m/2×10^8m/s
= **24 msec** (the "standard" US coast-to-coast delay)

Transmit delay = p / bw
= (1×2^{20} bytes x 2^3 bits/byte) / (10×10^6 bps)
= 2^{23} / 10^7 sec
= **839 msec**

Delay = 24 + 839 msec
= **863 msec**

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Other performance metrics: RTT

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- Round-trip time (RTT) = network delay associated with sending a message and receiving a reply or acknowledgement
- RTT = 2 x Propagation delay
- Note that this is a Best-Case time that considers the newtrok delay only: it ignores processing and buffering times at each end
- Frequently used in rough performance measures

Example

A Mars rover is controlled from Earth. What is the minimum lag time between the time that a rover sensor detects a problem and a responsive control command can be received?

Assume Earth-Mars distance ~= 80×10^6 Km = 8×10^{10} m
Then L = $8 \times 10^{10} / 3 \times 10^8$ = 266 sec
RTT = 532 sec ~= 9 minutes

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Another type of measure: How many bits can a wire "hold"?

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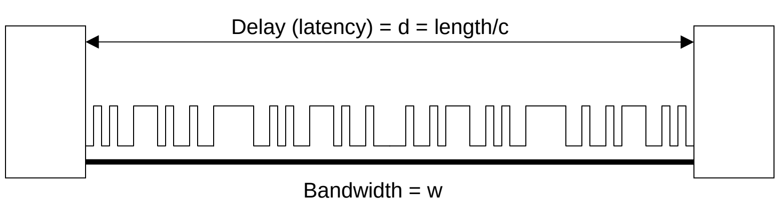

Sender starts a sending stream of bits at time t = 0

The first bit reaches the receiver at time t = d

The sender will send a bit each 1/w seconds

So, by time t = d,
the sender has sent d/(1/w) = dw bits

These dw bits are "in flight" somewhere between the sender and the receiver

Example:

How much data stays in flight on a Coast-to-coast 100Mbps Fiber link?

Delay ~= 24ms
\# bits in flight = 24ms x 100Mbps
= 2.4×10^6 bits
or about 290KB

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delay x bandwidth product

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- = the maximum number of bits that can be in transit on the link simultaneously ("in flight")
- Sometimes used as a measure of the link's capacity
- Maintaining dxb bits in flight is called "keeping the pipe full"

> **Example**
> A 100Mbps link with a latency of 10 msec carries streaming data from a sensor to a computer. When the computer's receive buffer is full, it sends a PAUSE signal to the sensor. Any data in flight at that time cannot be received and must be re-sent after the PAUSE is removed. What is the minimum amount of data that would have to be re-sent after a PAUSE?
>
> dxb product = 100×10^6 bps x 10×10^{-3} sec = 10^6 bits = 122 KB

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Other performance metrics: jitter

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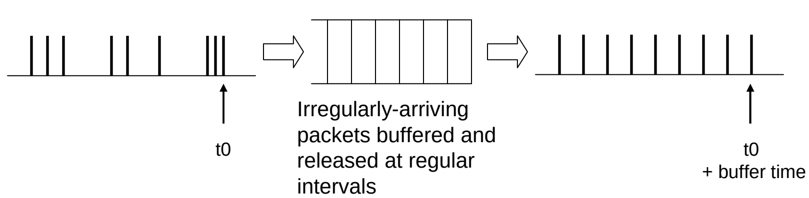
- Jitter = irregularity in delay between packets in a datastream

- A critical problem in streaming media (often resolved by buffering)



Traffic profiles

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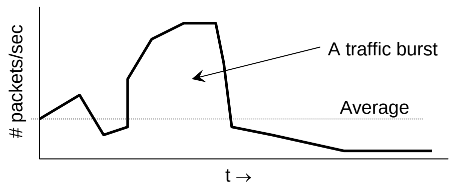
- Most real network traffic is bursty:



- Knowing the average load is good, but is of limited usefulness -- we need to know the traffic "profile"
- Average loads usually don't kill networks, bursts kill networks