Performance Metrics

- bandwidth (throughput)
- latency (delay)
- Bandwidth –
  - single physical link
  - logical process to channel
- Definition of bandwidth: Number of bits transmitted/second
Width of Bit and Bandwidth

1 sec

Each bit – 1 $\mu$s wide

1 sec

Each bit – 0.5 $\mu$s wide

$\Rightarrow$ Large Bandwidth
Performance Metrics

- Latency: How long a message takes to travel from one end of the network to another
- Speed of light
- Propagation delay

- Vacuum: $3 \times 10^8$ m/sec
- Cable: $2.3 \times 10^8$ m/sec
- Fiber: $2.0 \times 10^8$ m/sec
Performance Metrics

- Amount of time to transmit a unit of data
  - Network Bandwidth
  - Size of Packet
- Queuing delays
- (storing and forwarding at switches)
- Latency = propagation delay + transmit time + queue
- Propagation delay = distance / speed of light
- Bandwidth + latency = performance characteristics of a network
Performance Characteristics

- channel could be 1 Mbps / 100 Mbps
- Application behave different
  - across the continent
  - across the room
- Round trip time:
  - 1 Mbps - 100ms
  - 100 Mbps - 1ms
Performance Characteristics

Example:
- Channel Capacity: 1x10 Mbps
- Datalength: 10 bits
- Transmit time = 10 \text{ microseconds}
- Channel = 100 Mbps bits / sec
- Transmit time = 0.010 \text{ microseconds}
Performance Characteristics

- RTT = 100 ms, 1 ms
- Latency = 100 + 10 \times 10^{-3}
  = 100.010 ms
- Latency = 1 + 10 \times 10^{-3}
  = 1.001 ms
  - Latency dominated by RTT.
Performance Metrics

- Large files
  - Image of size $25 \times 10^6 \times 8$ bits
  - Channel Capacity $10 \times 10^6$ bits/s
  - Time taken to transmit image 20 s
  - Suppose RTT = 1 ms
    - Latency = 20.001 sec
  - Suppose RTT = 100 ms
    - Latency = 20.1 sec
- Bandwidth dominates latency
Performance Metrics

• Large Latency
  – Example: CPU = 200x10^6 instructions/s
  – Latency 100ms, for 5000 miles

\[
\frac{200 \times 10^6 \times 0.1}{1} = 20 \times 10^6 \text{ instr / sec}
\]

\[
\Rightarrow \frac{20 \times 10^6}{5 \times 10^3} = 4000 \text{ instr / mile}
\]
Performance Metrics

• 4000 instr / mile is lost
  – Is it worth going across network?
  – Bandwidth wasted
  – Solution
    • Treat the channel as pipe
Network as Pipe

• The pipe holds data
Network as a Pipe

- **Example**
  - Latency - 50 ms
  - BW - 50 Mbps

- **Pipe can hold**
  - $50 \times 10^{-3} \times 50 \times 10^6$ bits of data
  - Bandwidth wasted if sender does not fill the pipe
Throughput

- **Throughput:**
  - Transfer Size / Transfer Time
- **Transfer Time**
  - RTT + (Transfer Size / BW)
- **If RTT large, increase in BW does not reduce transfer time**
Throughput

• Example:
  – Latency: 100ms
  – Channel Capacity: 1 Mbps, 1 Gbps
  – Data: 10 MB
  – On 1 Mbps channel
    • Time taken = 80.1s
  – On 1 Gbps channel
    • Time taken = 0.180s
Throughput

• Throughput for 1 Mbps channel
  – \(80/80.1 \text{ Mbps} = 99.87 \text{ Mbps} \Rightarrow \text{very efficient}\)
  \(\Rightarrow \text{reaches channel capacity}\)

• Throughput for 1 Gbps channel
  – \(80/0.180 \text{ Mbps} = 444.4 \text{ Mbps} \Rightarrow \text{very inefficient}\)
  \(\Rightarrow \text{very low compared to channel capacity}\)
Throughput

- Stream of packets – 1 Mbps channel
Throughput

- Single packet - 1 Gbps channel