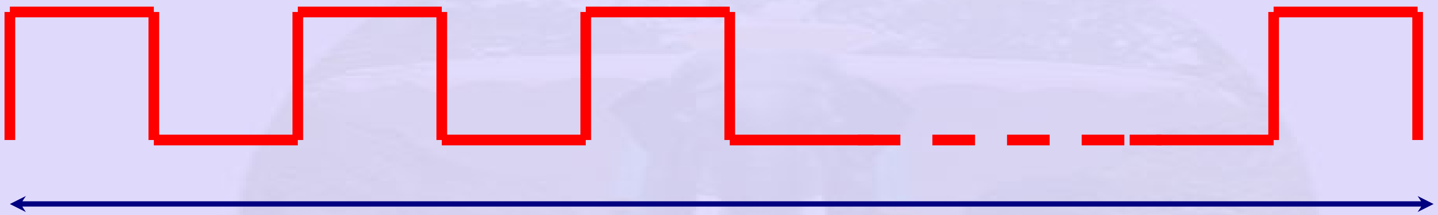
# Performance Metrics

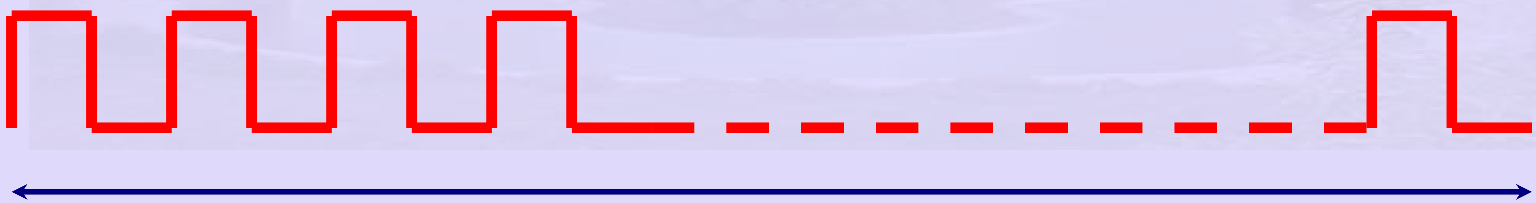
- bandwidth (throughput)
- latency (delay)
- Bandwidth –
  - single physical link
  - logical process to channel
- Definition of bandwidth: Number of bits transmitted/second

# 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 — cable — fiber
- $3 \times 10^8$ m/sec — $2.3 \times 10^8$ m/sec — $2.0 \times 10^8$ 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 *microseconds*
  - Channel = 100 Mbps bits / sec
  - Transmit time = 0.010 *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 = $200 \times 10^6$ instructions/s
  - Latency 100ms, for 5000 miles

$200 \times 10^6$ - 1

? - 0.1

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

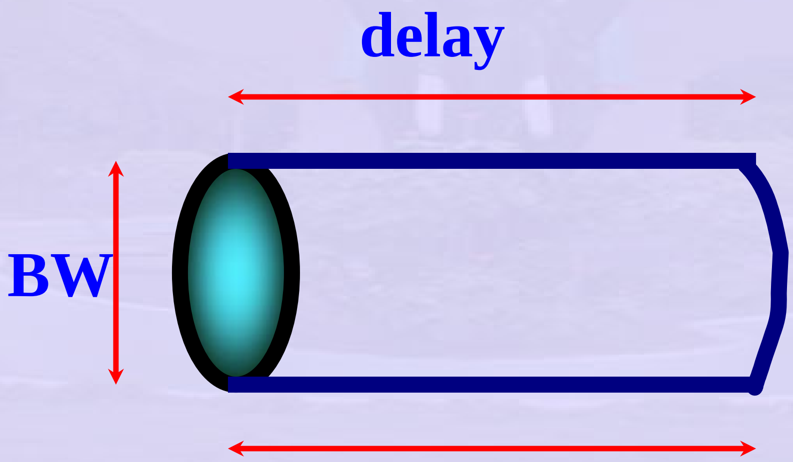
$$\Rightarrow \frac{20 \times 10^6}{5 \times 10^3} = 4000 \text{ instr /mile}$$

# 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

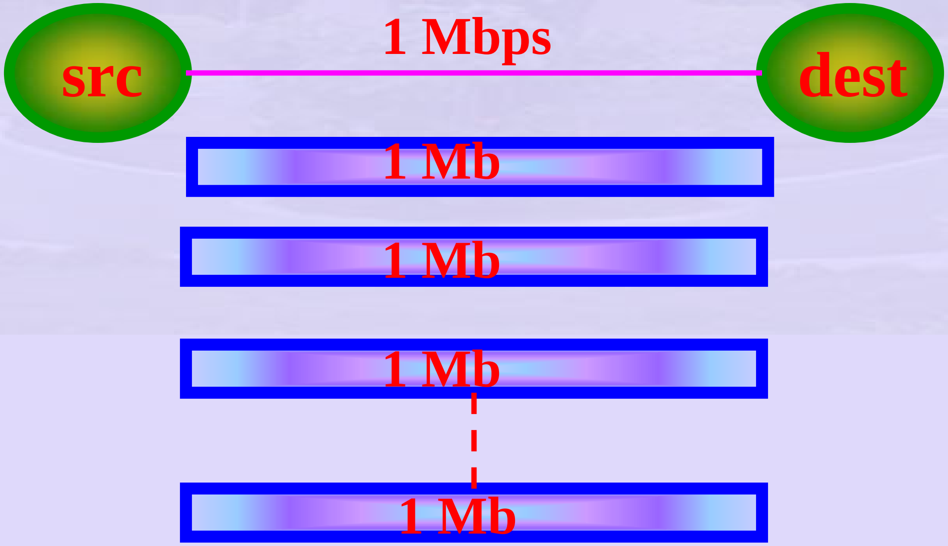
- Example:
  - Latency: 100ms
  - Channel Capacity: 1 Mbps, 1 Gbps
  - Data: 10 MB
  - On 1 Mbps channel
    - Time taken = 80.1s
  - On 1 Gbps channel
    - Time taken = 0.180s

# Throughput

- Throughput for 1 Mbps channel
  - 80/80.1 Mbps = 99.87 Mbps → very efficient → reaches channel capacity
- Throughput for 1 Gbps channel
  - 80/0.180 Mbps =444.4 Mbps → very inefficient → very low compared to channel capacity

# Throughput

- Stream of packets – 1 Mbps channel



# Throughput

- Single packet - 1 Gbps channel