Methods for Understanding Networks

- **Measure**
  - gather data from a real network
  - e.g., ping www.ru
  - realistic, specific

- **Simulate**
  - run a program that pretends to be a real network
  - e.g., NS network simulator, Nachos OS simulator
  - between the other two

- **Model**
  - write some equations from which we can derive conclusions
  - general, may not be realistic

- Usually use combination of methods
Usually favor plausibility, tractability over realism
- better to have a few realistic conclusions than none (could not derive) or many conclusions that no one believes (not plausible)
Single Link Packet Delay Model

- Predicts time for packets to traverse a single link

**Terminology**

- bandwidth (capacity, throughput): bits/second that link can deliver
- delay (latency, Round Trip Time (RTT)/2): measured in seconds

**total delay across link =**

load independent delay + load dependent delay

- load dependent delay = queueing delay + …
- load independent delay = transmission delay + fixed delay
  - transmission delay = packet size / link bandwidth
  - fixed delay = propagation delay + …
    - propagation delay = distance / speed of signal in medium
Multiple Link, Single Packet

\[
t_l^0 = t_0^0 + \sum_{i=0}^{l-1} \left( \frac{s_i^0}{b_i} + d_i \right)
\]

- \(s_i^0\) is size of packet \(i\)
- \(b_j\) is bandwidth of link \(j\)
- \(t_i^j\) is time packet \(i\) arrives at link \(j\)
Multiple Link, Multiple Packets of Same Flow

\[ t_l^k = t_0^k + \sum_{i=0}^{l-1} \left( \frac{s_i^k}{b_i} + d_i + q_i^k \right) \]

\[ q_l^k = \max\left(0, t_{l+1}^{k-1} - d_l - t_l^k\right) \]
Packet Delay Model Characteristics

**Limitations**
- No packet loss
- No load dependent delays from other flows
- No route changes
- does not model many other situations that occur less frequently

**Advantages**
- relatively easy to work with
- realistically predicts behavior in an unloaded network