Reliable Transport Layer over Wireless Link

Performance and Capacity Planning

Wire vs. Wireless

- Wire channels are:
  Reliable (loss rate 10^-16)
  High bandwidth
  Stability
- Wireless channels are:
  Unreliable (loss rate 10^-2 – 10^-6)
  Low bandwidth
  Instability

Wire vs. Wireless

- Key algorithms of TCP protocol rest on features of **wire channels**
- Data loss means network congestion
- Channel performance is fixed
- Significant change in RTT means congestion
- Channel set is uniform ('in some sense')

Wire vs. wireless

- Reality of wireless links
- Data loss **may** signal congestion
- Significant change in RTT **may** signal congestion
- Channel performance varies during connection lifetime

Wire vs. wireless

- Reliable transport layer adaptation for wireless links property is **open problem**
- Analyst can do capacity planning for the case basing on the state-of-art of TCP performance understanding

TCP performance state-of-art

- TCP is sophisticated instance
- TCP realizes several algorithms (Slow Start, Congestion Avoidance, Fast Retransmit and Recovery, Exponential back off etc.)
- TCP performance is a function of many parameters (segm. loss probability, receiver adv. window, e2e path bottleneck throughput and workload, RTT distribution etc.)

TCP performance state-of-art

- ‘Root square’ low formulae used in IETF documents.
- Simple formula (S. Floyd) Only Congestion Avoidance Algorithm. No back off and timeouts.

$$T \approx \frac{C}{\sqrt{p}}$$

TCP performance state-of-art

- Another 'root square' formula which counts timeouts

$$T = \frac{MSS}{RTT\sqrt{1.33p} + RTOp(1+32p)\min[1,3\sqrt{.75p}]}$$

For simple formula

$$C = 0.93\frac{MSS}{RTT}$$

TCP performance state-of-art

- ‘Root square’ lows break down as segment loss probability *p* approaches to zero
- Researches are topical
- For other models see ACM and IEEE publications

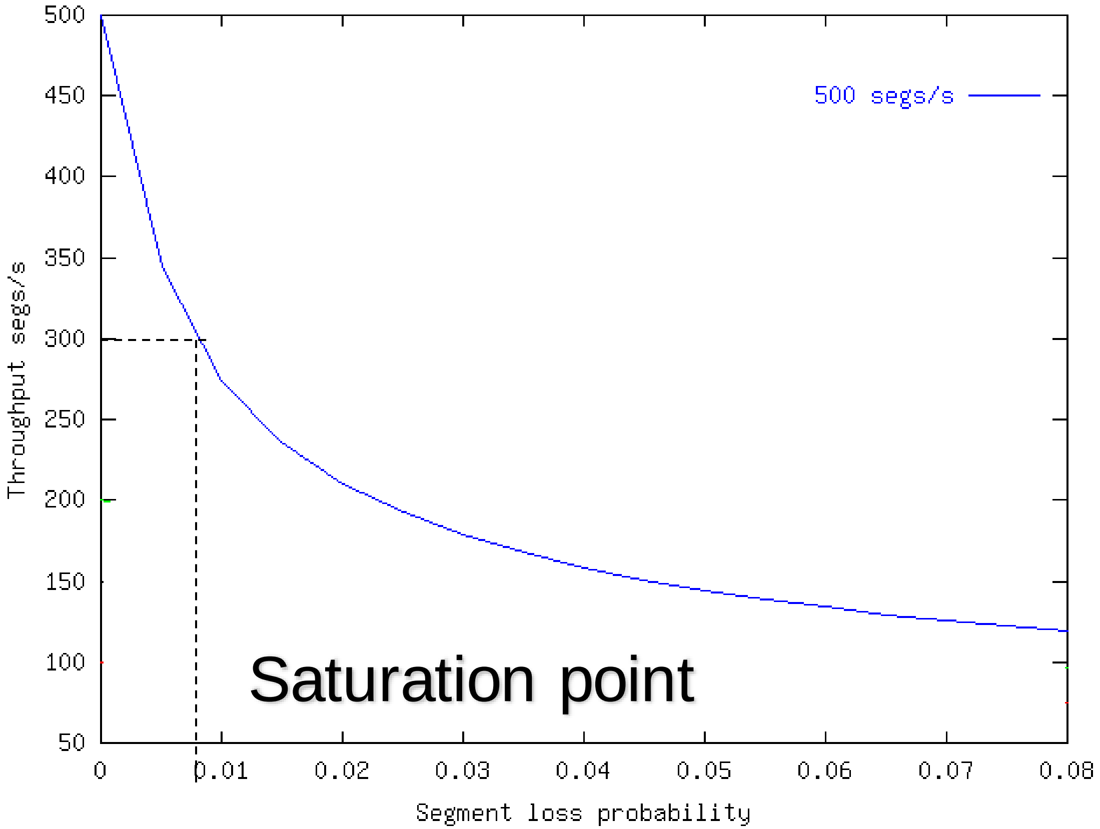
Capacity planning at transport

- Formulae are calculation for a single TCP connection.
- If path carries many TCP connections, each will follow formulae independently
- Input parameters are: segment loss probability, average RTT duration, average RTO duration

Capacity planning at transport

- Define input parameters
- Use formulae and get throughput forecast
- Use the forecast for capacity planning process

Capacity planning at transport



Capacity planning example

- Designer invents new wireless link which losses 1% of IP packets
- This link layer is used in the internet on a path which otherwise had RTT of 80 msec
- Designer is interested in understanding performance of TCP over this link
- WLAN gives 2 Mbit/s

Capacity planning example

- Define MSS=1000 bytes (remove 40 bytes for TCP/IP headers)
- Define RTT=120 msec (80 msec for internet part, plus 20 msec each way for the new wireless links)
- Define p=0.01

Capacity planning example

- Simple formula gives

$$T = \frac{0{,}93 \cdot 1000 \cdot 8\text{bits}}{0{,}120\,\text{sec} \cdot \sqrt{0{,}01}} = 620\text{kbit/s}$$

- More complex one provides

$$T = 402.9\text{kbit/s}$$

Metrics of TCP performance

- **Throughput** is considered at per-flow base. Transport level combines maximizing throughput with congestion avoidance
- **Delay** per-packet vs. inter-packet
- **Packet loss rates.** We distinguish packet loss and loss events

Metrics of TCP performance

- **Response** to sudden changes or to transient events
- **Minimizing oscillations** in throughput or in delay. This has clear trade off with the previous one
- **Fairness** and **convergence** times (to fairness). Max-min fairness, epsilon fairness, proportion fairness, etc.

Metrics of TCP performance

- **Robustness** for challenging **environments**
- **Robustness to failures** and to misbehaving users
- Internet architecture has valued robustness over efficiency, e.g., when there are tradeoffs between robustness and the throughput, delay, and fairness metrics

Metrics of TCP performance

- **Energy consumption:** In mobile environments the energy consumption for the mobile end-node can be a key metric
- **Goodput:** For wireless networks, goodput can be a useful metric, where goodput is defined as the fraction of useful data from all of the data delivered. High goodput indicates an efficient use of the radio spectrum

Metrics of TCP performance

- **Deployability** in the current internet
- Metrics for **specific types** of transport. QoS-enabled environments or for below-best-effort traffic
- **User-based** metrics. Application-specific utility