Analysis of TCP Westwood+ in high speed networks

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Outline

- TCP Westwood.
- Stochastic model.
- Stability conditions.
- Explicit throughput expression.
- Numerical results.

TCP Westwood+

- Proposed improvement of TCP's window control.
- Absense of losses: Standard additive increase, β.
- At loss event: New window size based estimated bandwidth.
- State variables: Window W, bandwidth estimate B.
- Parameter: Filter coefficient $\alpha = 0.9$.

Link model

- High speed link.
- Random i.i.d. delays, e.g., due to local retransmissions.
- Poisson loss process, independent of delay process.
- Loss indicator: $Z_n = 1$ if loss occurs during roundtrip n.

Stochastic matrices

$$\begin{pmatrix} X_{n+1} \\ B_{n+1} \end{pmatrix} = A_n \begin{pmatrix} X_n \\ B_n \end{pmatrix} + C_n \quad A_n = \begin{pmatrix} \overline{Z}_n & Z_n \\ \overline{\alpha}\overline{Z}_n \frac{\mathrm{RTT}_{\mathrm{min}}}{RTT_n} & \alpha\overline{Z}_n + Z_n \end{pmatrix}$$

$$X_n = W_n/\mathrm{RTT}_{\mathrm{min}} \qquad C_n = \begin{pmatrix} \frac{\beta\overline{Z}_n}{\mathrm{RTT}_{\mathrm{min}}} \\ 0 \end{pmatrix}$$

Main object of study: $E[A_n]$

Explicit throughput computation

Constants p and q computed from the delay and loss processes.

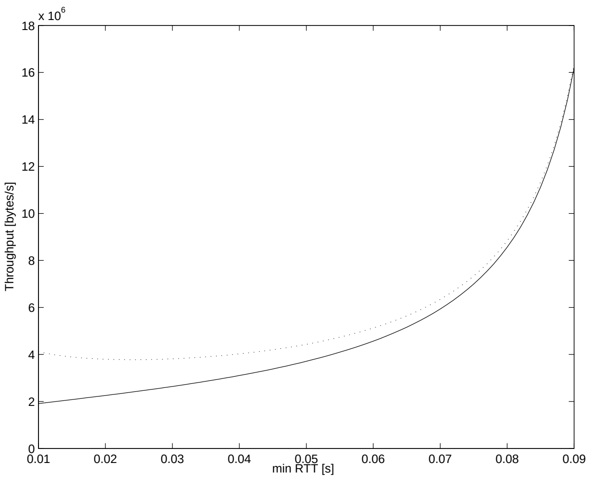
$$E[A_n] = \begin{pmatrix} \overline{p} & p \\ \overline{\alpha} q \mathrm{RTT}_{\min} & \alpha + \overline{\alpha} p \end{pmatrix} \qquad E[C_n] = \begin{pmatrix} \frac{\beta p}{\mathrm{RTT}_{\min}} \\ 0 \end{pmatrix}$$

Theorem: Finite throughput iff $\alpha < 1$ and $E[\mathrm{RTT}_n] > \mathrm{RTT}_{\min}$.

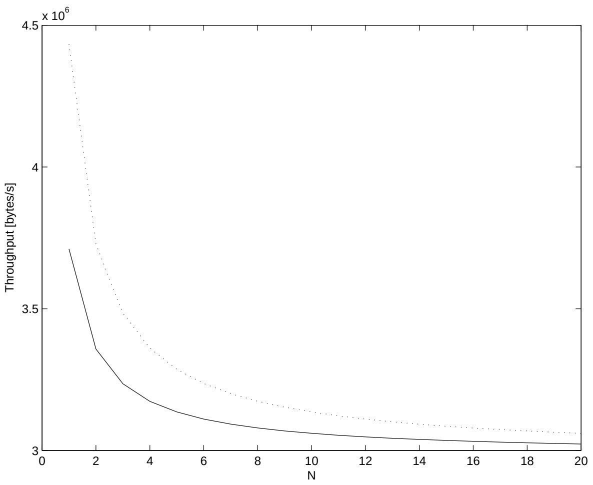
$$\text{Throughput} = (1,0)\big(I - E[A_0]\big)^{-1} E[C_0] \frac{\mathrm{RTT}_{\min}}{E[\mathrm{RTT}_0]}$$

Does not depend on α.

Influence of RTT_{min}



Influence of RTT variance



Conclusions

- Constant RTT and Poisson losses $\Longrightarrow$ TCP Westwood+ can saturate links of arbitrary high capacity.
- Stochastic i.i.d. and Poisson losses $\Longrightarrow$ finite stationary throughput with TCP Westwood+.
- Stationary throughput is independent of the α filter parameter.