Performance of TCP Congestion Avoidance Algorithm

Olga Bogoiavlenskaia

Petrozavodsk State University

Key words: Telecommunication, performance, transport layer protocol

Performance of TCP

Defining a Task:

- Flow and Congestion control are paramount problems for Internetworking.
- The control is performed by transport layer protocols (such as TCP). The protocols provide decisive contribution in internetworking reliability, stability and performance
- New applications demand new level of control and design.

Areas of demand:

- Wireless connection (slow and unreliable link)
- Multimedia applications (Huge amount of traffic)
- ‘Traditional networking’ as well

Performance of TCP

Aims of the research

- Evaluation of TCP performance
- Revealing the factors at the bottom of TCP behavior

The object of research

Congestion Avoidance Algorithm i.e. Additive Increase Multiplicative Decrease (AIMD) Algorithm

Key methods

The model of congestion avoidance and the resulting algorithms are based on the apparatus of Markov processes analysis.

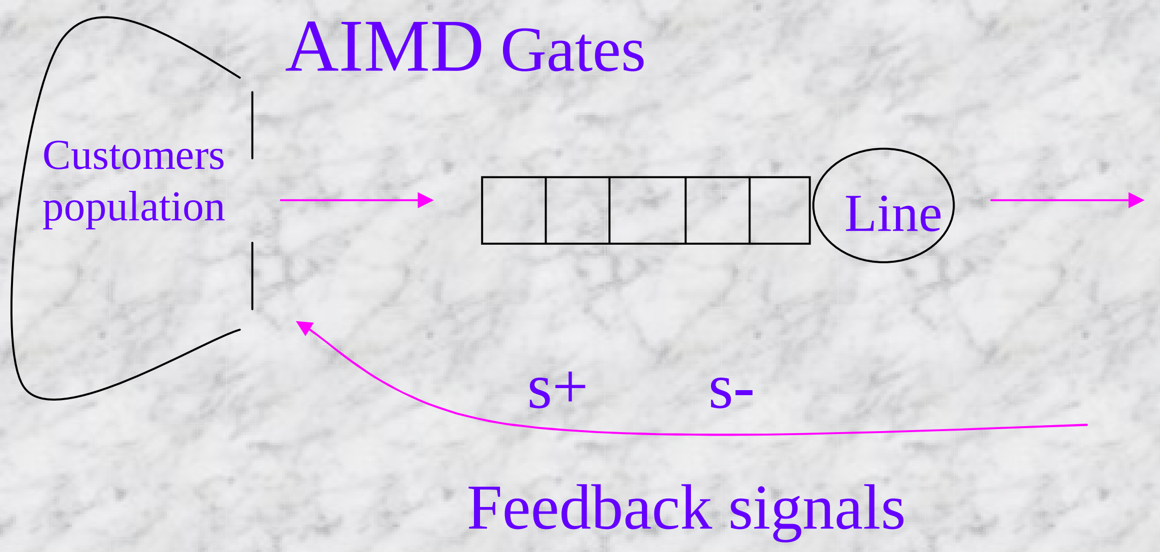
Detailed Technology Description

Assumptions of the model

- TCP segments are lost independently. The segments loss probability is p
- Congestion window size growth is limited by particular value w_{max}
- Throughput also is limited by the capacity of the first hop link L
- We consider only AIMD portion of TCP congestion control
- Round Trip Time is random variable which depends on congestion window size. It is described by its distribution function.

TCP sender's behavior

W/2 ⟵ W ⟶ W+1/W



Detailed Technology Description

Main definitions

$w(t)$ - congestion window size

τ_i - moment when interger part of $w(t)$ changes

$w_i = w(\tau_i)$ is Markov chain

$\{w(t)\}_{t>0}$ is semi Markov random process

Let $P_w(t) = \mathrm{P}(w(t) = w)$ and $\alpha_w = \mathrm{E}(\tau_{i+1} - \tau_i \mid w(\tau_i) = w)$

δ_w be RTT at window size w, $R_w(t)$ be pdf of RTT

L is throughput upper limit, $t_0 = 1/L$

π_w steady state distribution of the chain $\{w_i\}$

Detailed Technology Description

Congestion window size

Theorem 1. If δ_w have finite expectations then

$$P_w(t) \xrightarrow[t \to \infty]{} \frac{\alpha_w \pi_w}{\sum_{i=2}^{w_{\max}} \alpha_i \pi_i}$$

Here π_w are solutions of the corresponding Kolmogorov equations. We have found for them effective and simple recurrent form.

Detailed Technology Description

Congestion window size

Theorem 2. Distributi on π_w sutisfies following relations

$$\pi_i = \pi_j K_i,$$

where

$$K_{w_{\max}} = \frac{F_{w_{\max}-1}}{1 - f_{w_{\max}}},$$

$$K_i = F_{i-1}, \qquad j < i < w_{\max}$$

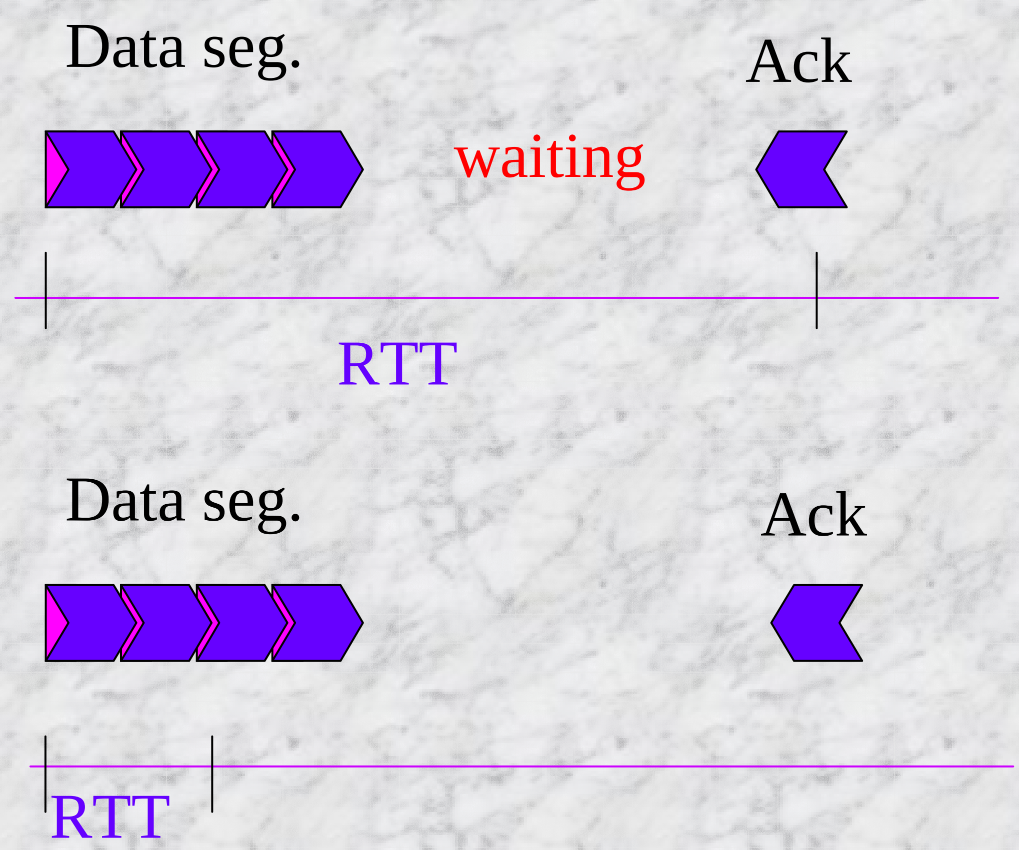
$$K_{i-1} = \frac{1}{f_{i-1}}\left(K_i - \left(K_{2i}(1 - f_{2i}) + K_{2i+1}(1 - f_{2i+1})\right)\right) \quad i < j.$$

Here f_i and F_i are the functions of p,

and $j = \lfloor w_{\max} / 2 \rfloor$

Detailed Technology Description

Throughput Evaluation



$wt_0 < RTT$

$wt_0 > RTT$

Detailed Technology Description

Throughput Evaluation

$N(t)$ is number of TCP segments sent up to the moment t

Then we calculate thorughput as

$$T = \frac{N(\tau_{i+1}) - N(\tau_i)}{\tau_{i+1} - \tau_i}$$

If $x < L$ its pdf function is

$$F_T(x) = \mathrm{P}(T < x) = \mathrm{P}(w = 2)\mathrm{P}(RTT > 2/x) + \mathrm{P}(w = 3)\mathrm{P}(RTT > 3/x) + \dots$$
$$+ \mathrm{P}(w = w_{\max})\mathrm{P}(RTT > w_{\max}/x)$$

Let P_w be the limit defined by theorem1

$$F_T(x) = 1 - \sum_{w=2}^{w_{\max}} P_w R_w(\frac{w}{x}) \text{ and } F_T(L) = 1$$

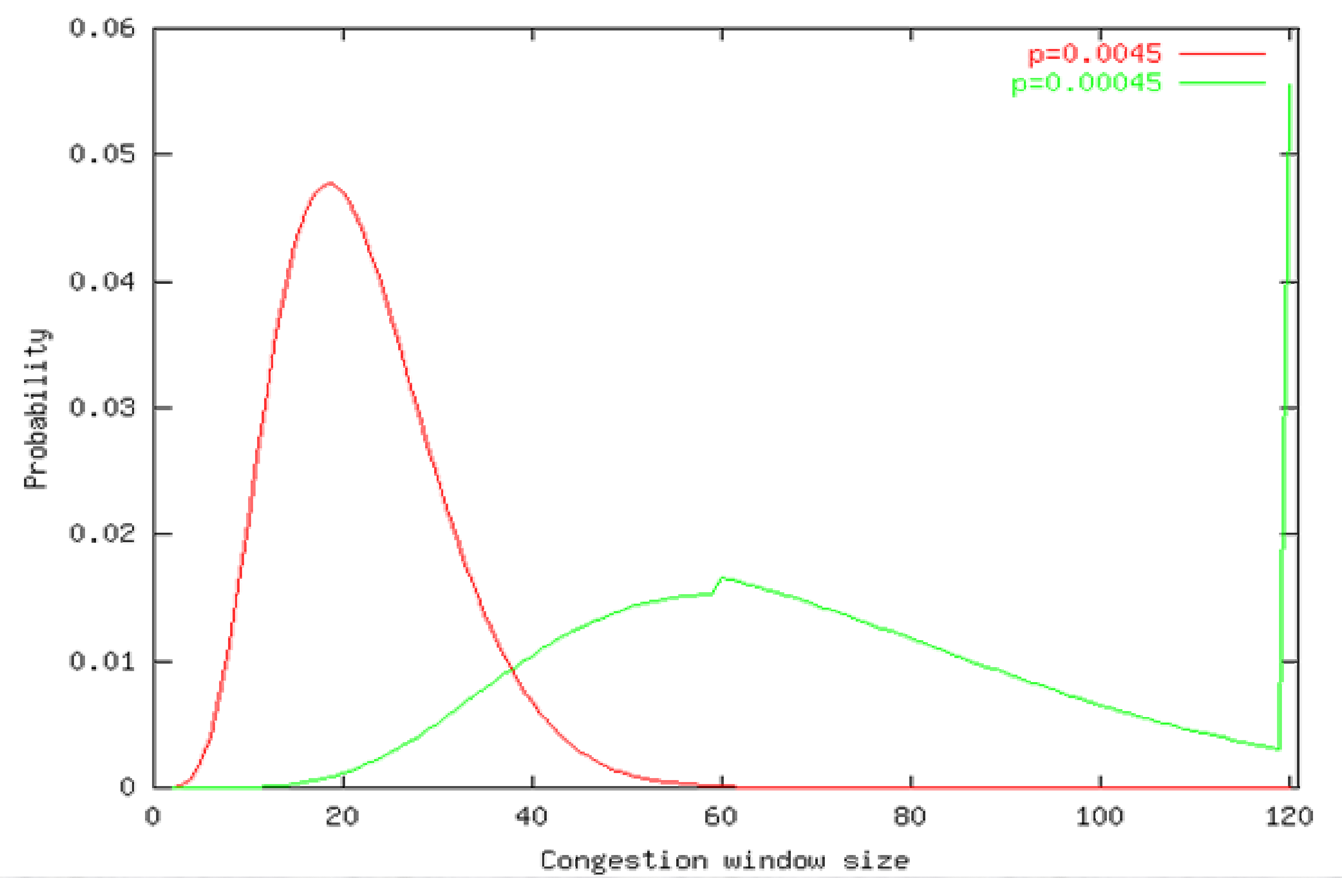
Application Areas

- Performance analysis and Capacity planning for the Networking environments
- QoS control (at the end-user level and at the routers)
- TCP-unfriendly flows detection
- Traffic engineering and protocols design

Main Results

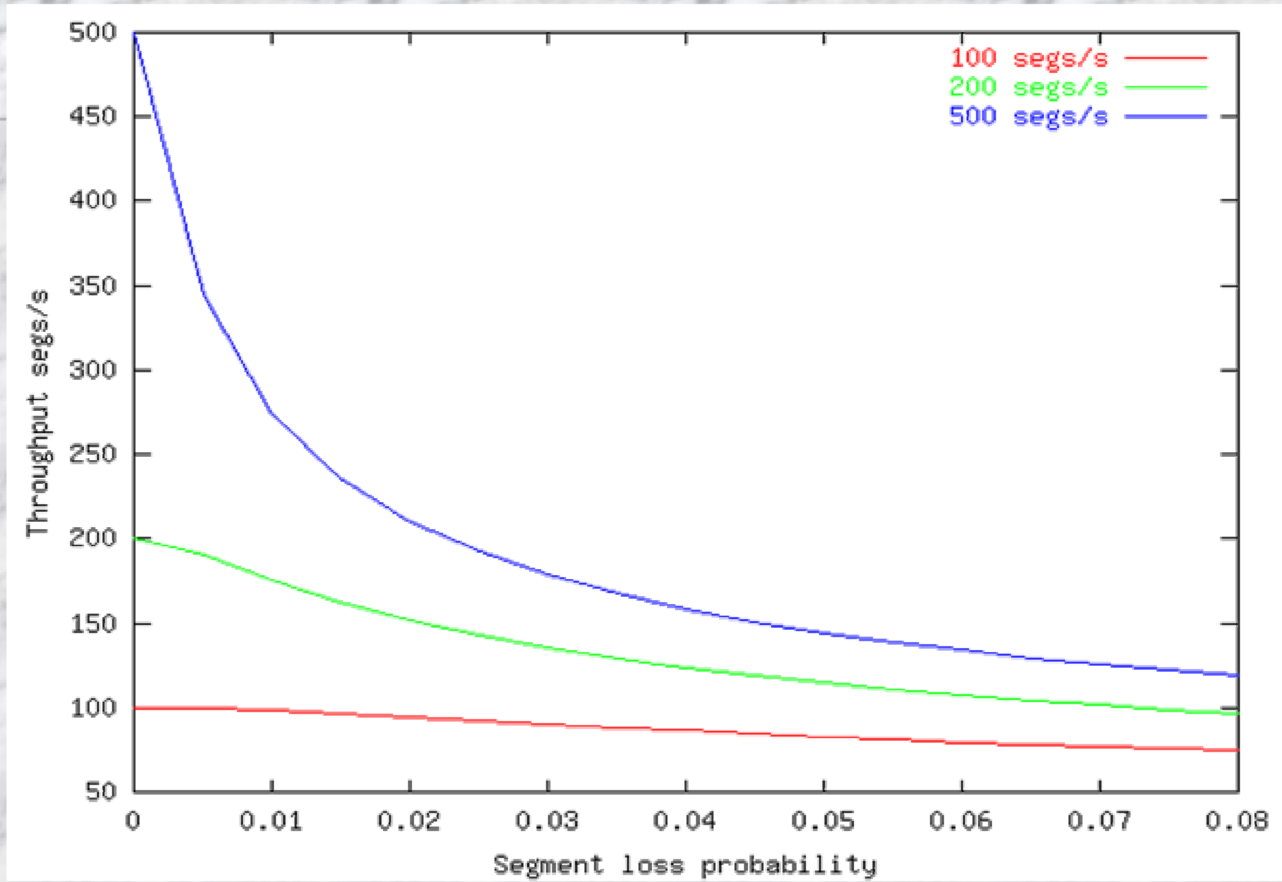
- The new detailed model of TCP Congestion Avoidance is developed
- The distributions of TCP Congestion Avoidance window size and throughput are obtained in effective explicit form.
- Polynomial algorithms computing TCP performance metrics are developed by further processing of the distributions

Numerical Examples



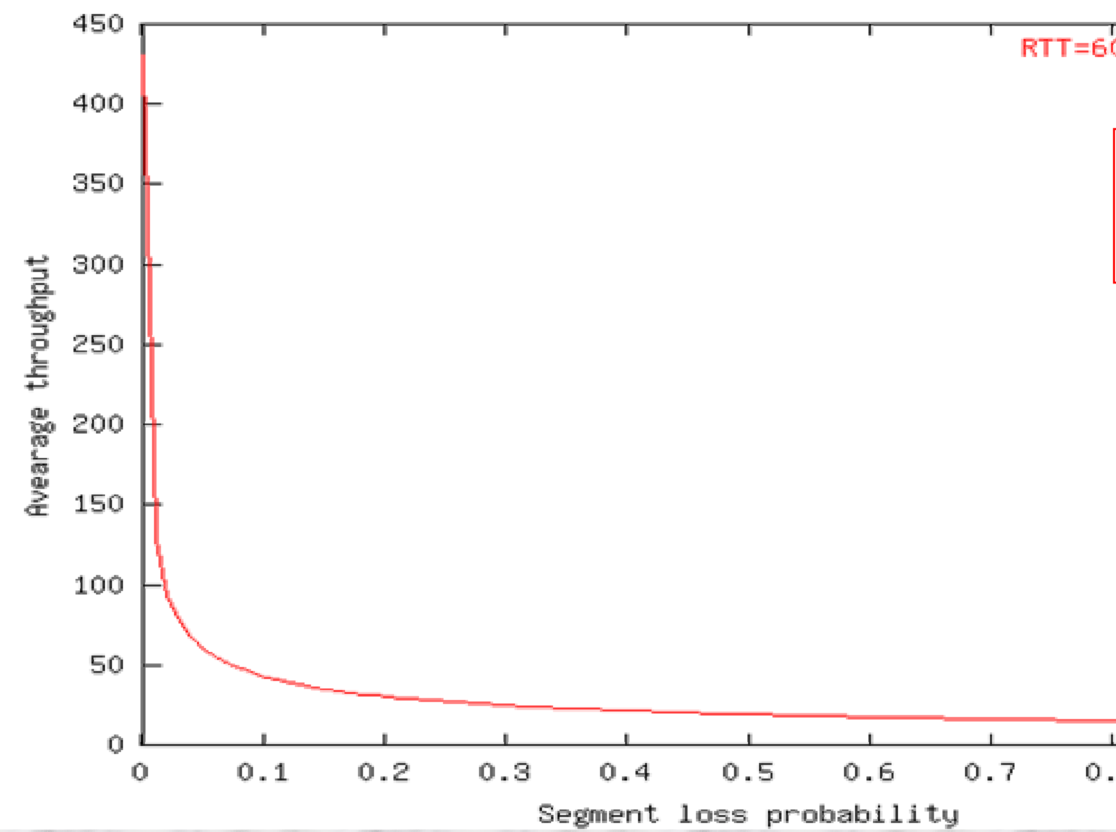
Congestion window size distribution. W_{max}=120 segs

Numerical Examples



TCP throughput expectation for different links. Wmax=70 segs

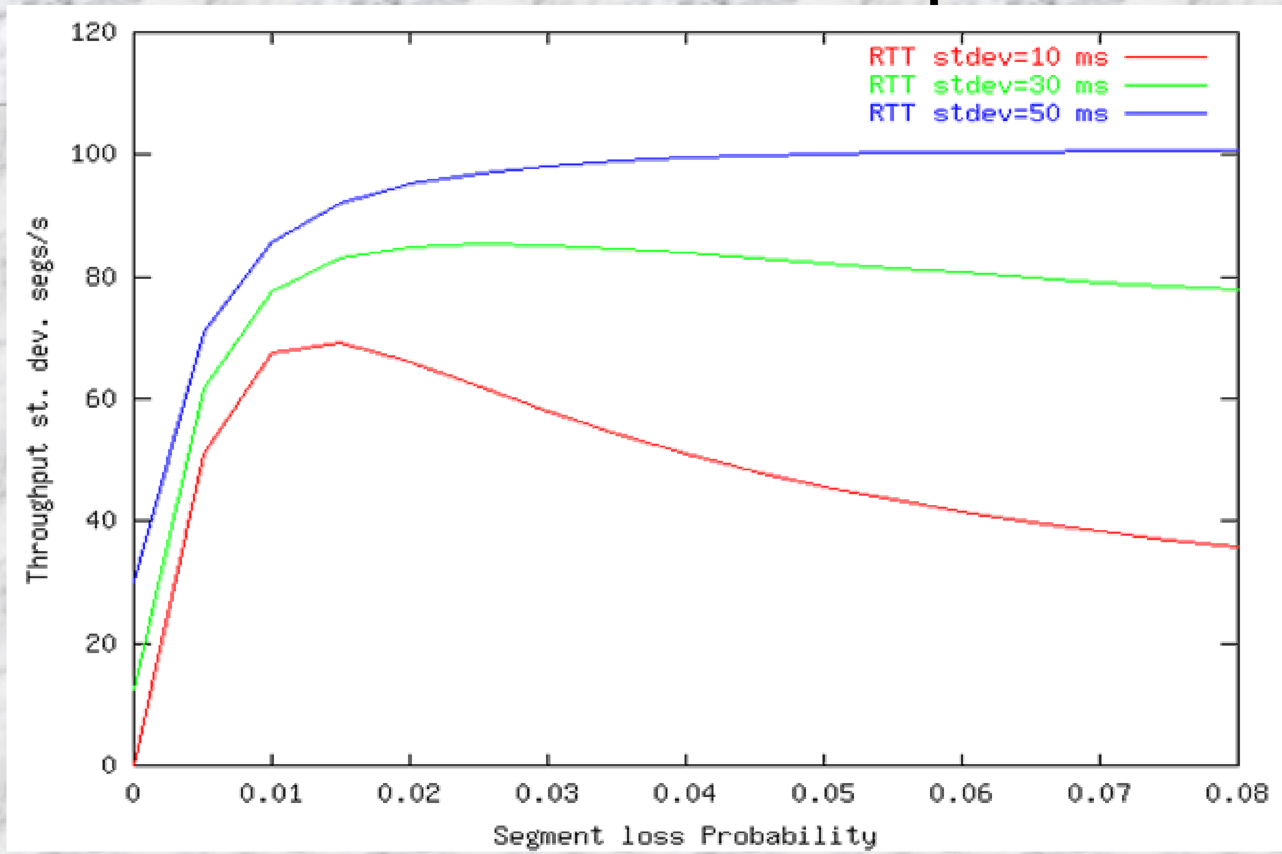
Numerical Examples



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

Root square low for TCP throughput
(S. Floyd, D. Towsely and others)

Numerical Examples



Influence of RTT std. dev. on TCP throughput std. dev.
Link capacity is 300 seg/s, Wmax=50 segs

Conclusion

- At the moment only our approach yields distributions of AIMD window size and throughput
- Currently published estimations of average TCP throughput (two most referenced of them belong to S. Floyd and D. Towsely group), e. g., ‘root square low’, have unrealistic behavior, infinite error, and take RTT as an independent deterministic variable.
- Experimental validation of the model have been done with Dept. of CS of the University of Helsinki, Finland. I appreciate Prof. T. Alanko, M. Kojo and P. Sarolahti for providing of experimental environment, support and multiple useful discussions.