Variance Estimation for Networking Congestion Avoidance Algorithm.

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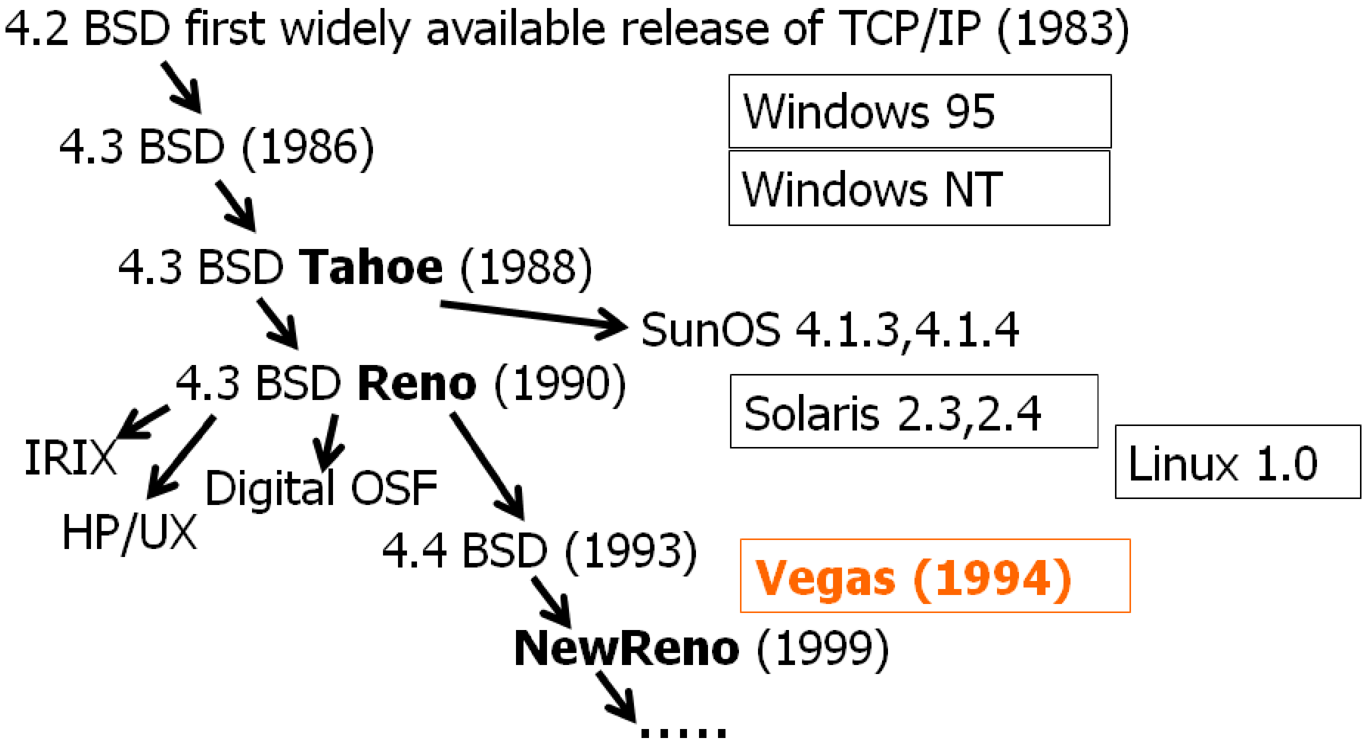
TCP Congestion Control

- The paradigm of Distributed Control in Packet Switching Network
- Transmission Control Program, 1974.
- Congestion collapse
- Variance not important yet

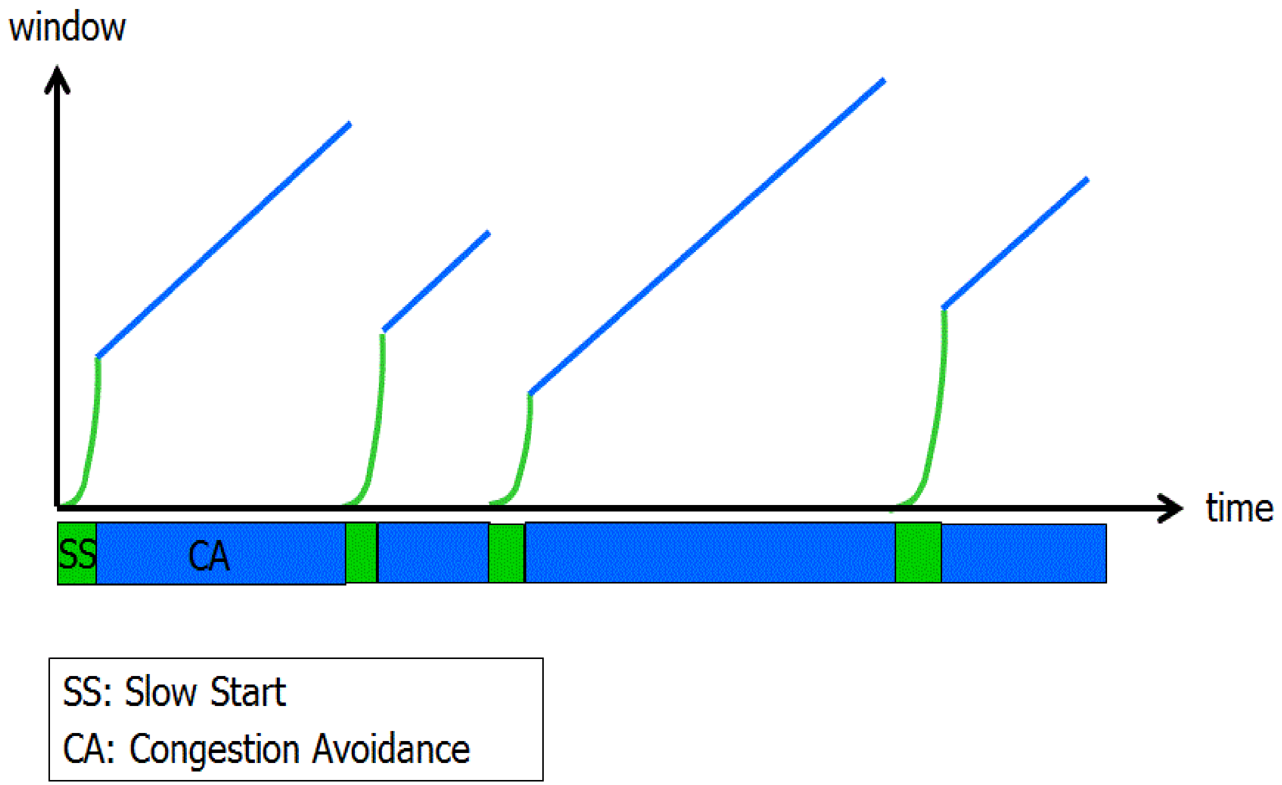
TCP versions

- *TCP is not perfectly homogenous (200+)*



Example of Tahoe Trajectory

TCP Tahoe (Jacobson 1988)



TCP Congestion Control Development

- Jitter sensitive applications
- TCP vs UDP
- High BDP links utilization vs Congestion Control
- Best effort vs QoS guarantees

Variety of Experimental Versions

- TCP CUBIC - cubical growth period. RTT independent
- High Speed TCP (HSTCP), S. Floyd 2003. Congestion Avoidance coeff. of linear growth and multiplicative decrease are convex functions of current window size
- Scalable TCP (STCP) T. Kelly, 2003. Decreases time of data recovery
- H-TCP, Hamilton Institute, Ireland, 2004. Intended for links with high BDP value. Uses RTT size to react on losses
- TCP Hybla 2003-04. Developed for satellite links. Scales throughput to mimic NewReno and utilize link at the same time.

Variety of Experimental Versions

- TCP Westwood, 2001. Tries to identify the reason behind losses. Developed for wireless links.
- TCP-Illinois uses dynamic function for defining Congestion Avoidance parameters
- TCP-LP (Low Priority)
- TCP-YeAH

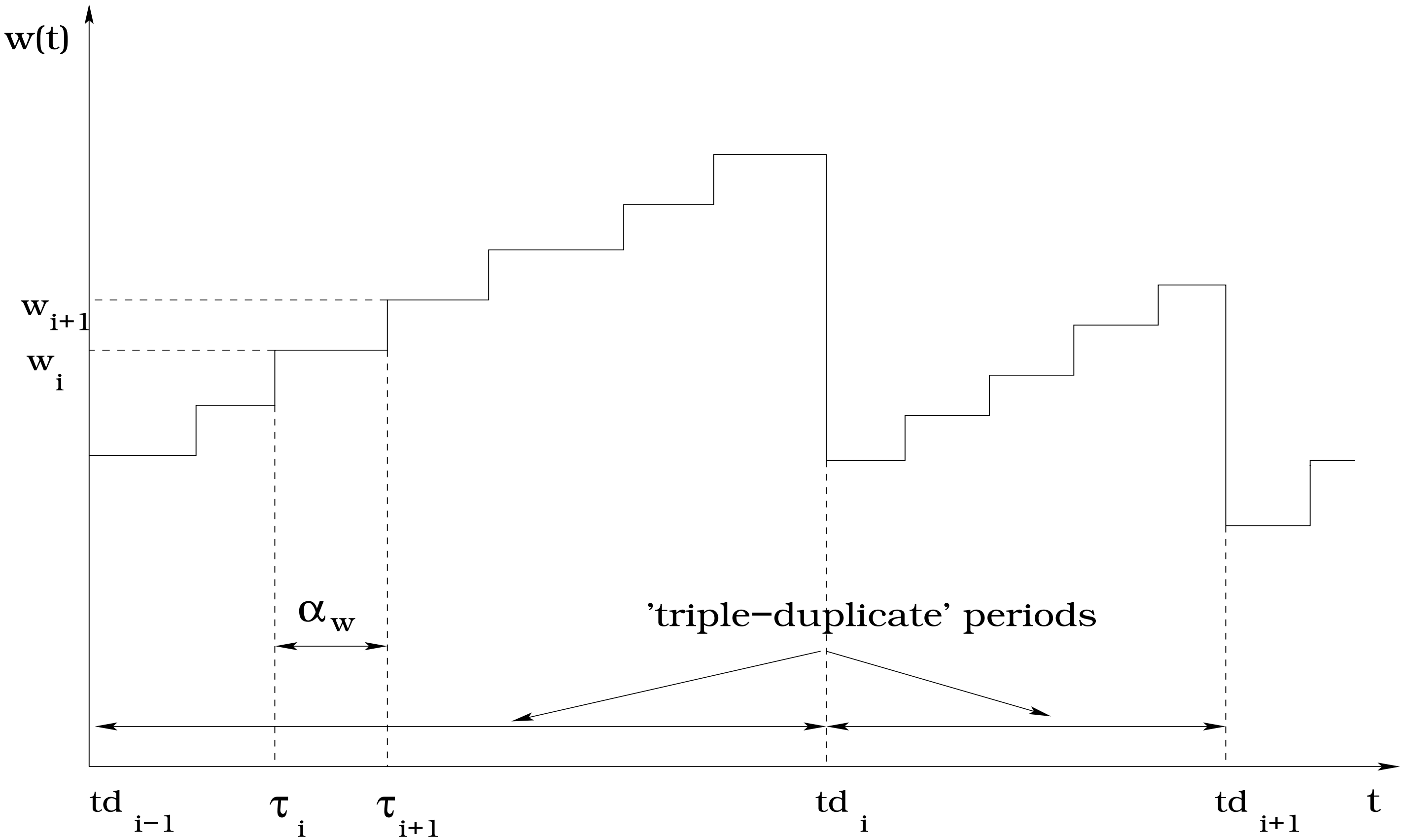
TCP Variance

- Why important?
- A lot of models of average window size — Reno, NewReno, CUBIC
- Asymptotic studies etc.

D. Towsley group for $p > 0.025$

$$T = \frac{MSS}{RTT\sqrt{\frac{2p}{3}} + RTOmin(1, 3\sqrt{\frac{3p}{8}})p(1 + 32p^2)} \tag{1}$$

TCP NewReno 'Saw'



Variance evaluation

- Altman E., Avrachenkov K., Barakat C. A Stochastic model of TCP/IP with Stationary Random Losses, Proceedings of ACM SIGCOMM'00. Stockholm, 2000. pp. 231-242.
- Some 'popular' assumptions provide difficulties in estimating TCP variance, e.g.
- Variance is $Var[X] = E[X^2] - (E[X]^2)$
- Root square lows are derived thorough Goelders's inequality i.e.

$$E[X] \leq \sqrt{E[X^2]}$$

Variance estimation

- Using geometrical considerations one get from TCP 'saw'

$$X_{n+1}^2 = \alpha X_n^2 + 2bS_n,$$

- Expanding, one gets

$$X_{k+n}^2 = 2b \sum_{i=0}^{n} \alpha^{2i} S_{k+n-i}$$

or

- $X_{k+n} = \sqrt{2b \sum_{i=0}^{n} \alpha^{2i} S_{k+n-i}}$

Variance estimation

$$E[X_{k+n}] = E\left[\sqrt{2b\sum_{i=0}^{n}\alpha^{2i}S_{k+n-i}}\right] \leq \sqrt{2b}\sum_{i=0}^{n}E\left[\sqrt{\alpha^{2i}S_{k+n-i}}\right]$$

Now when $n \to \infty$ one gets the following

$$E[X] = \lim_{n\to\infty} E[X_n] \leq \lim \sqrt{2b}\sum_{i=0}^{n}E\left[\sqrt{\alpha^{2i}S_i}\right] =$$

$$\frac{\sqrt{2b}}{1-\alpha}E[\sqrt{S_n}]$$

For $b = 1$ and $\alpha = \frac{1}{2}$ and hence

$$E[X] \leq 2\sqrt{2}E[\sqrt{S_n}]$$

Variance evaluation

Now we have two estimations of sliding window size expectation

- $E[X] \le A = \sqrt{\frac{8}{3}E[S_n^2]}$
- $E[X] \le B = 2\sqrt{2}E[\sqrt{S_n}]$

Reminder.

If $B < A$ then it could be used for estimation variance

$$Var[X] \le A^2 - B^2.$$

This holds if

$$E[\sqrt{S_n}] < \sqrt{\frac{E[S_n]}{3}}.$$

Variance evaluation. Examples

Lets p.d.f. of S_n is $F(x) = 1 - e^{\lambda x}$ then

$$E[S_n] = \frac{1}{\lambda}$$

and

$$E[\sqrt{S_n}] = \frac{\sqrt{\pi}}{2}\sqrt{\frac{1}{\lambda}}.$$

Condition does not hold.

Variance evaluation. Examples.

Lets p.d.f of S_n is Pierson root square distribution then its moments can be calculated through Γ-function and

$$E[S_n] = 2^{\frac{1}{2}} \frac{\Gamma(\frac{n+1}{2})}{\Gamma(\frac{n}{2})}$$

and

$$E[\sqrt{S_n}] = 2^{\frac{1}{4}} \frac{\Gamma(\frac{2n+1}{4})}{\Gamma(\frac{n}{2})}.$$

The result depends on parameter n. Condition holds for e.g. $n = 10$.

Variance evaluation

Notice that

$$\lim_{n\to\infty} E[X_n^2] = \lim_{n\to\infty} E[X_{n+1}^2]$$

and

$$\lim_{n\to\infty} E[X_n^2] = \frac{2bE[S_n]}{1-\alpha^2}.$$

Hence there might take place

$$\lim_{n\to\infty} E[X_n] = \sqrt{\frac{2b}{1-\alpha^2}}E[\sqrt{S_n}].$$

GetTCP kernel level monitor for OS Linux

Conclusion

- The Development of Congestion Control schemes is considered
- The importance of TCP variance evaluation is demonstrated
- Possible approaches to the problem are analyzed
- Variance estimation is proposed