Finnish-Russian University of Cooperation in Telecommunications
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Fuzzy logic queue discipline processing over bottleneck link

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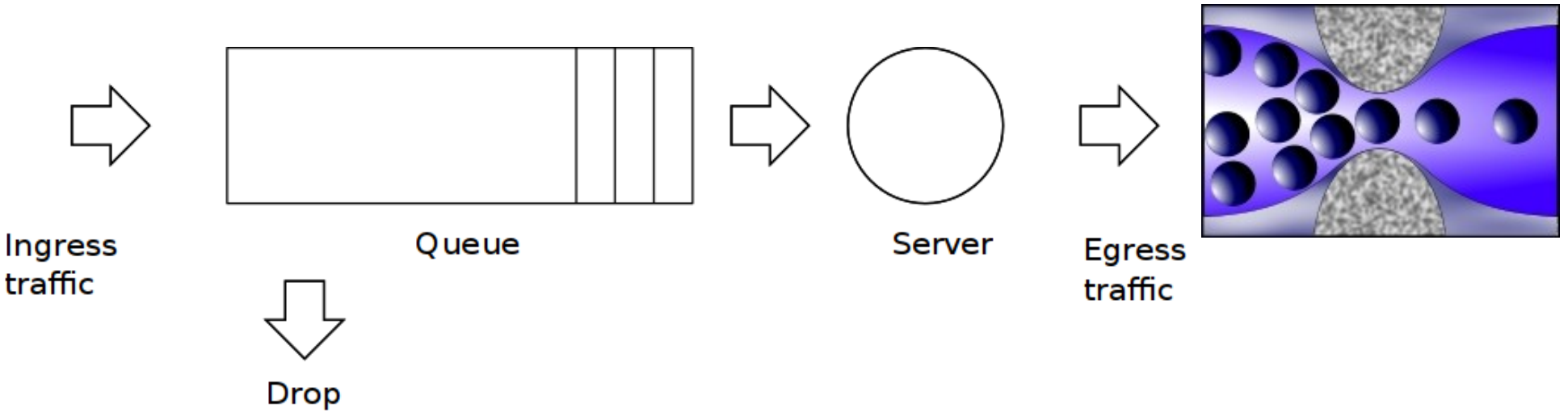
Queue management techniques

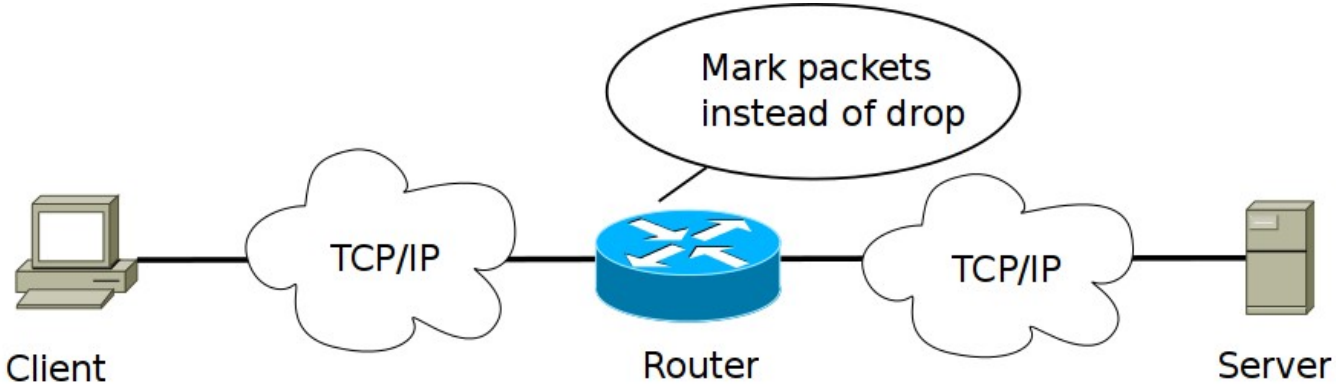


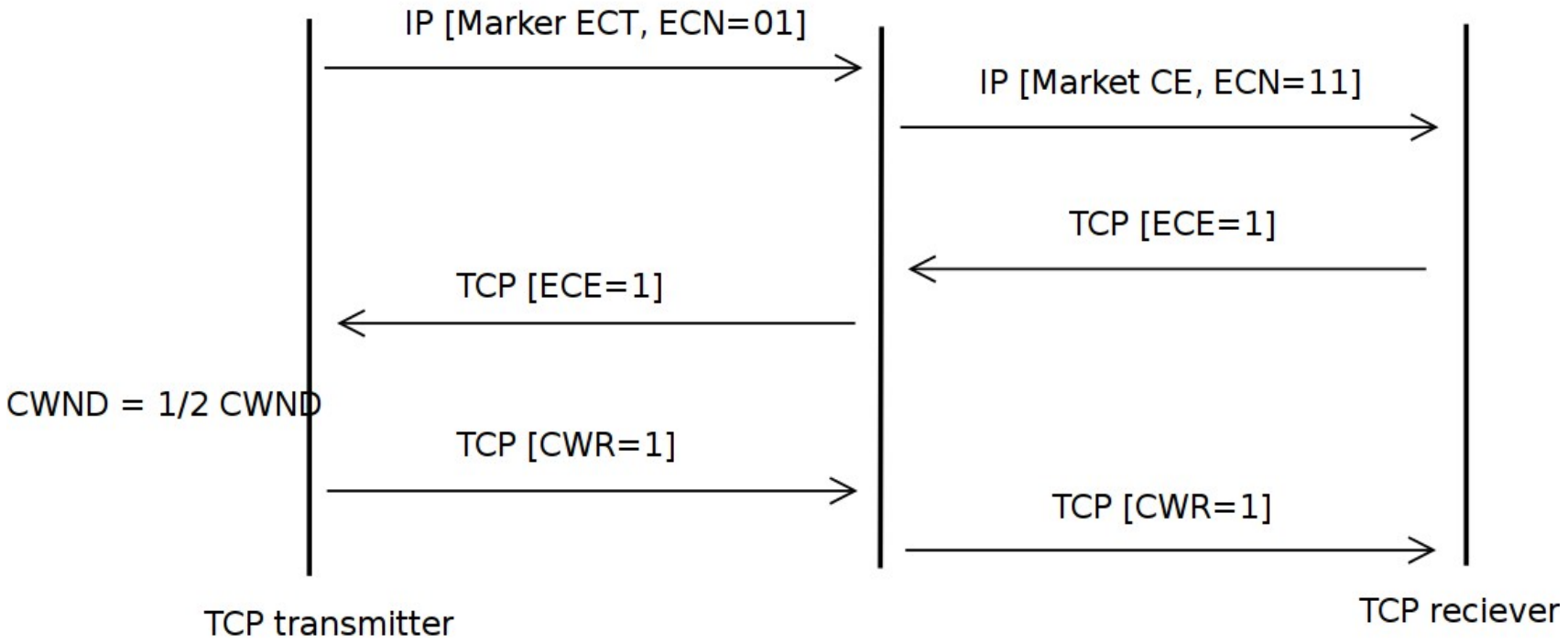
- Passive technique Drop Tail

Active management [4]:

- Random Early Detection (RED), *S.Floyd, V.Jacobson, 1993 [2]*
- Adaptive RED, *S.Floyd, 2001*
- Proportional Integral (PI), *C.V.Hollot, V.Misra, 2002*
- Random Exponential Marking (REM), *S.Athuraliya, 2001*
- Adaptive Virtual Queue (AVQ), *S.Kunniuyr, 2004*
- Fuzzy Explicit Marking (FEM), *C.Chrysostomou, 2009 [3]*

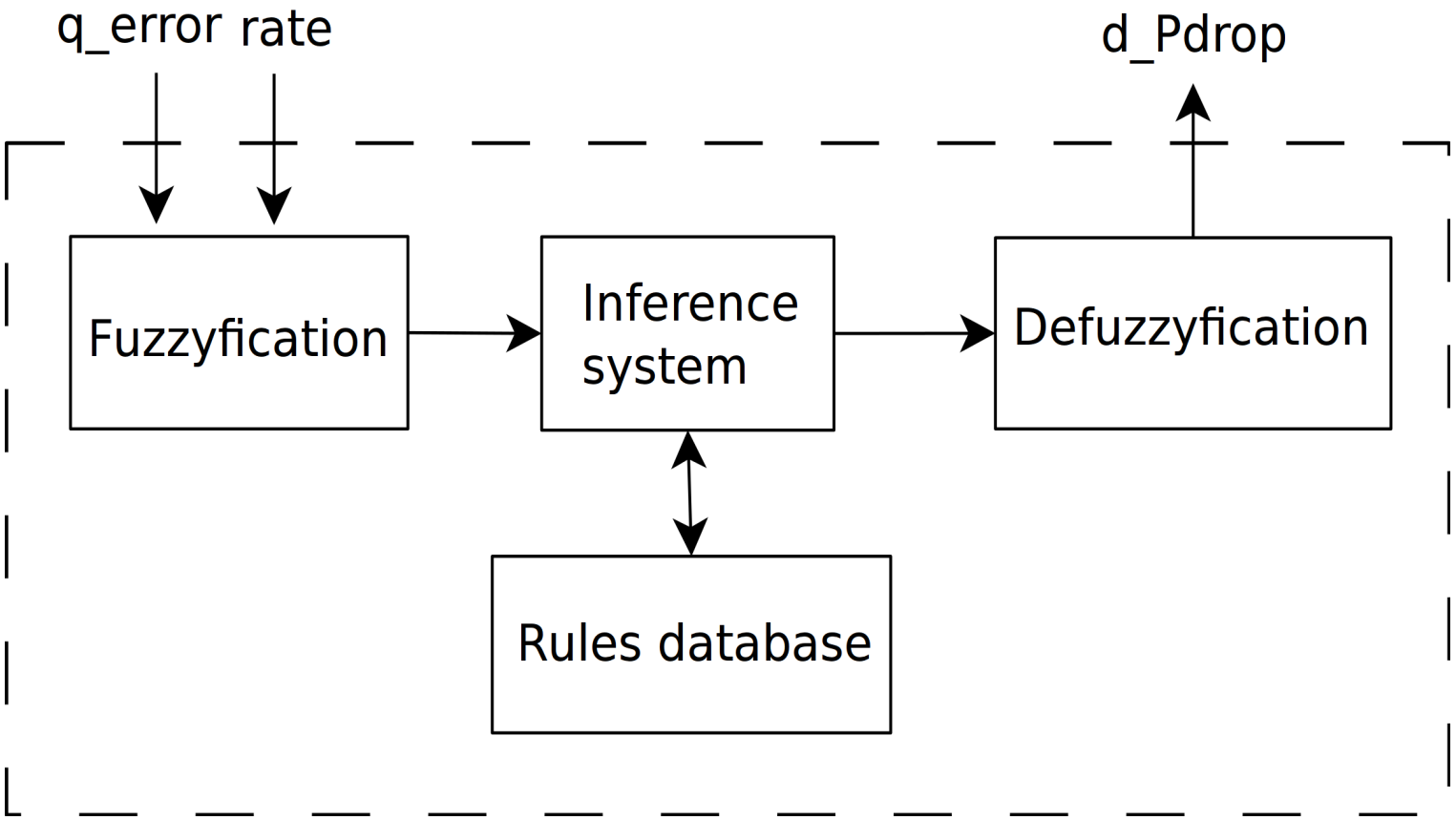
ECN (Explicit Congestion Notification, RFC-3168)





ECN [1] is supported by most popular OS (Windows, Linux, MacOS, FreeBSD)

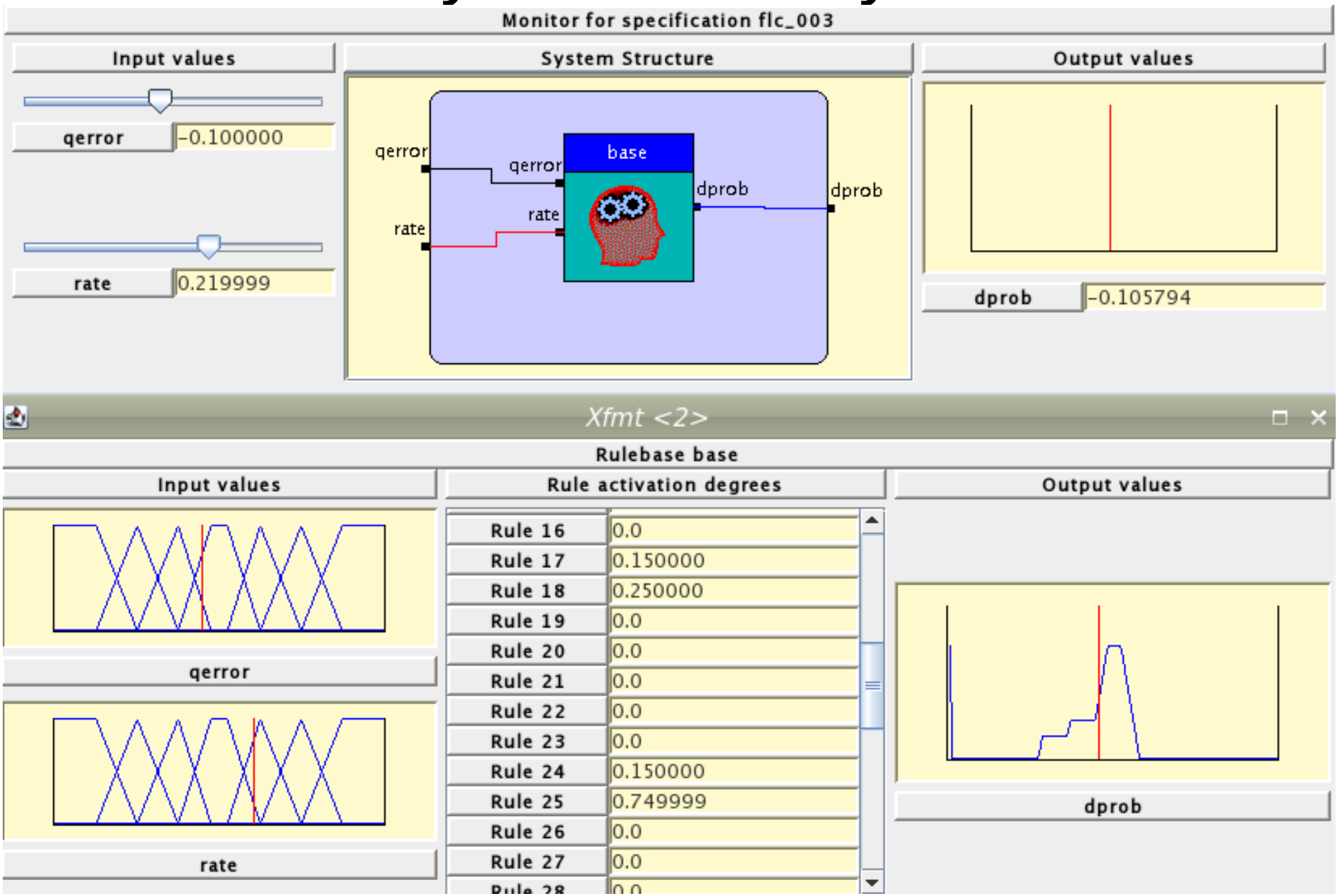
Fuzzy Logic Controller (FLC)



Two inputs:
q_error — queue length error
rate — relative rate (intensity)

One output:
d_Pdrob — drop probability increment

Fuzzy inference system



Xfuzzy 3.0 software

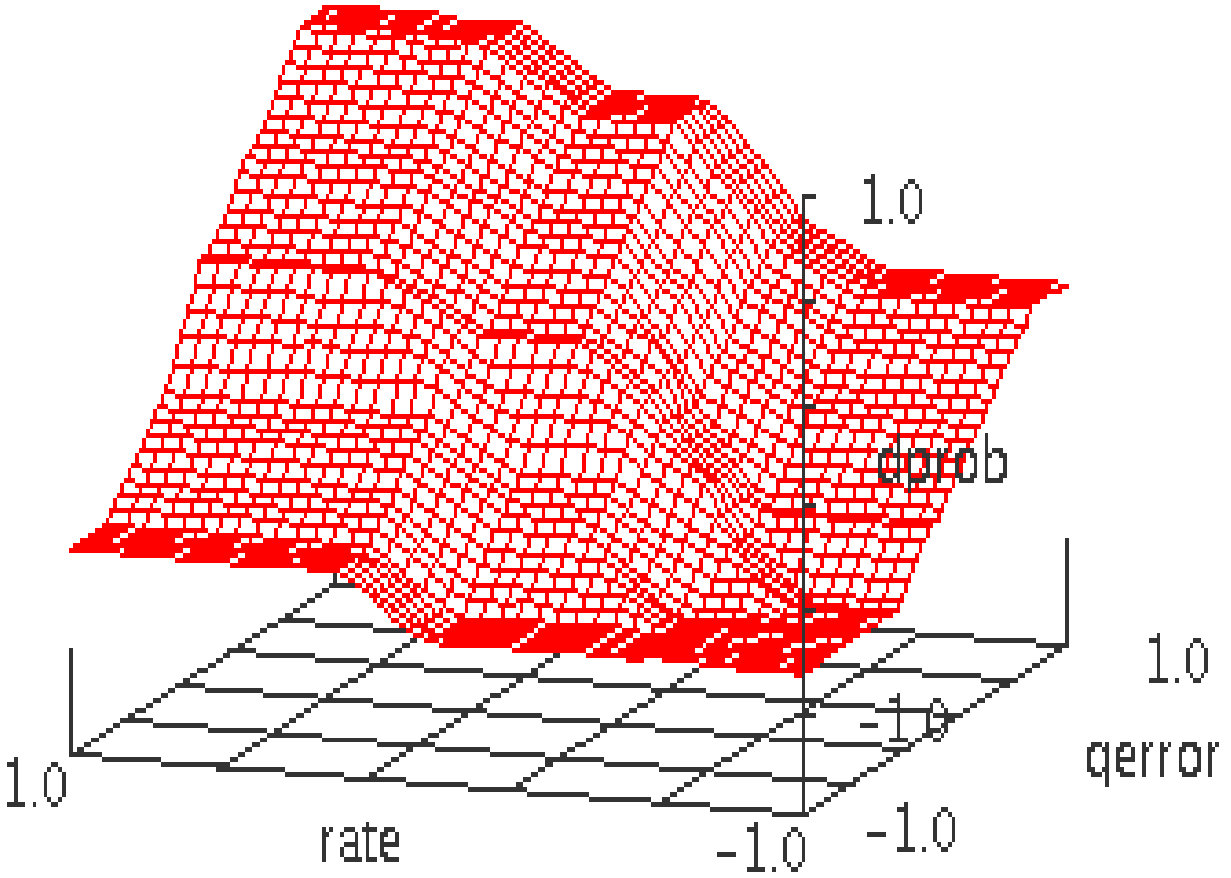
Rules database

qerror \ rate	nh	nb	ns	z	s	b	h
nh	nh	nh	nh	nh	nb	nb	nb
nb	nh	nh	nb	nb	ns	ns	ns
ns	nh	nb	ns	ns	nt	nt	nt
z	nb	nb	nt	z	z	t	t
ps	ns	ns	nt	t	t	s	s
pb	nt	nt	z	s	s	b	b
ph	z	z	t	b	b	h	h

Z — zero
N — negative
P — positive
V — very
S — small
B — big
H — huge
T — tiny

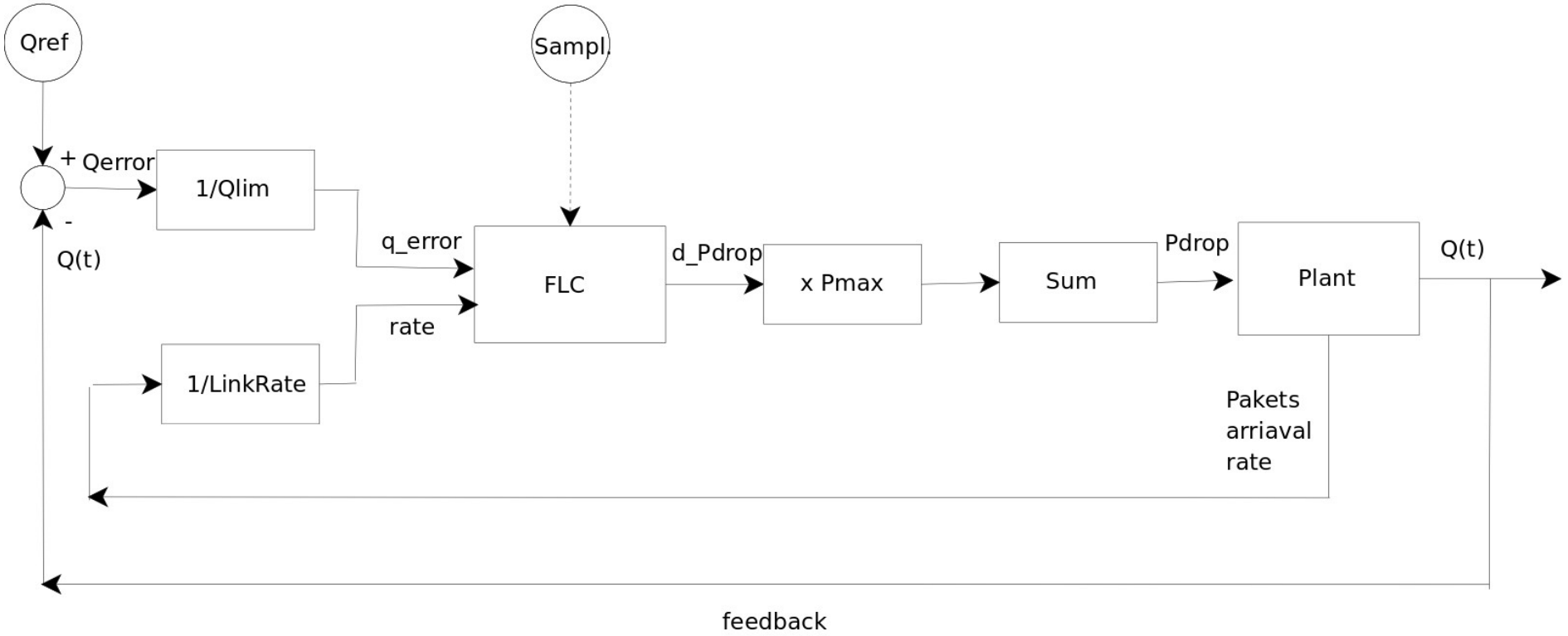
FLC response surface

Dependance of output value *dprob* from input values values (*qerror* and *rate*)



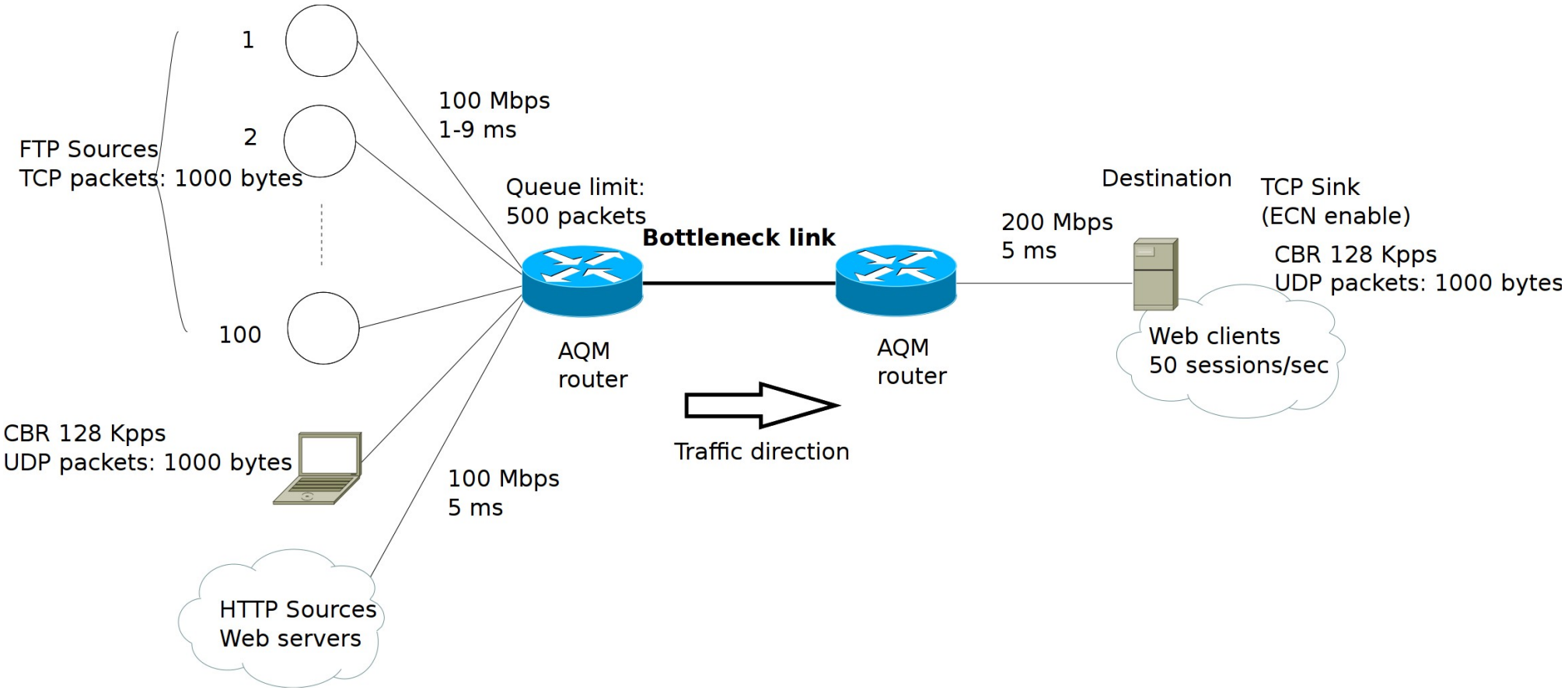
dprob — drop probability increment
qerror — queue length error
rate — relative rate

FLC system architecture



Q(t) — current queue length
Qlim — maximal queue size (500 packets)
Qref — target (reference) queue length (300 packets)
LinkRate — bandwidth (Mbps)
Sampl. — sampling rate (6 msec)
Pmax — maximal drop probability increment for the sampling period (8E-5)

Network simulation diagram (NS-2)

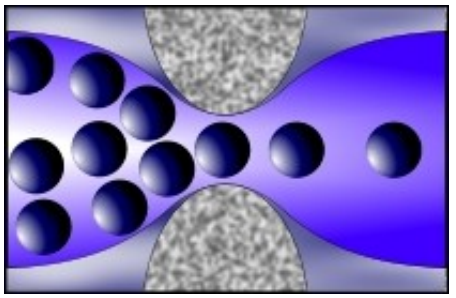


Simulation of 3 types of traffic:

1. Long-live TCP connections (FTP)
2. Short-live TCP connections (HTTP)
3. Unmanaged constant bitrate traffic (CBR/UDP)

Simulation parameters

Queue discipline: **FLC**
Target queue length: 300 packets
Maximal queue size: 500 packets

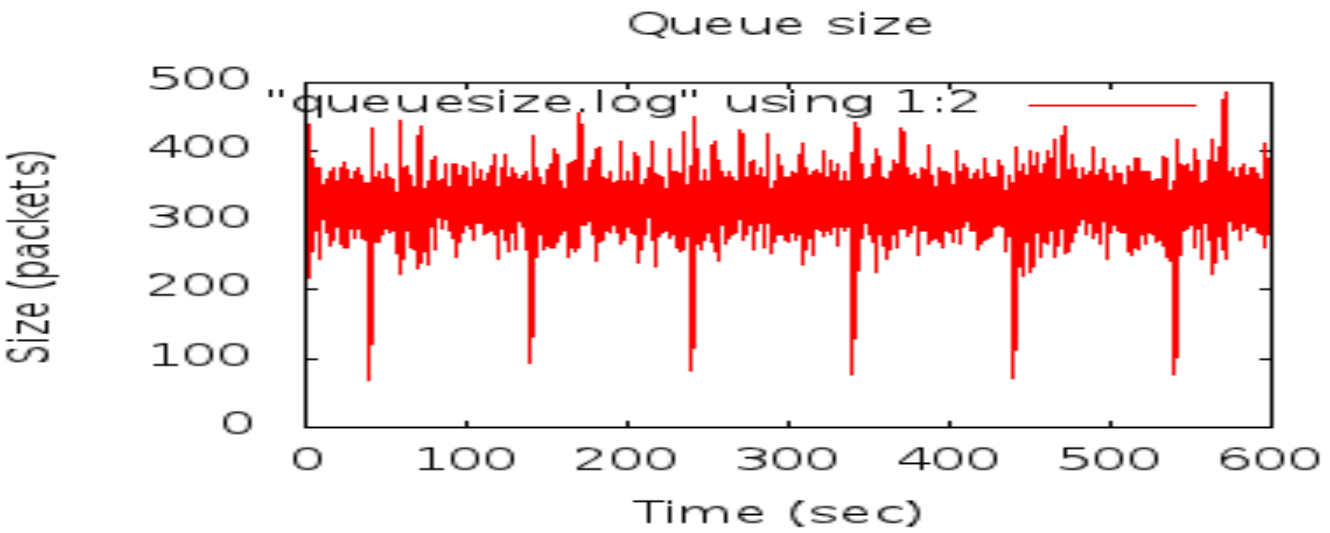


Bottleneck link bandwidth, Mbps: 10, 20, 35, 50
Link delay, msec: 5, 10, 20, 50, 100
Totally: 20 experiments

Test scenario:
Simulation time: 600 seconds continuously.
FTP (100 sources), HTTP (50 new sessions per second) and CBR/UDP (128 Kbps) traffic are started at the beginning

Six repeated intervals by 100 sec of each one are simulated network dynamics:
1. At time of 40 sec — 50 FTP sources stop transmission;
2. At time of 70 sec — these 50 FTP sources continue transmission again.

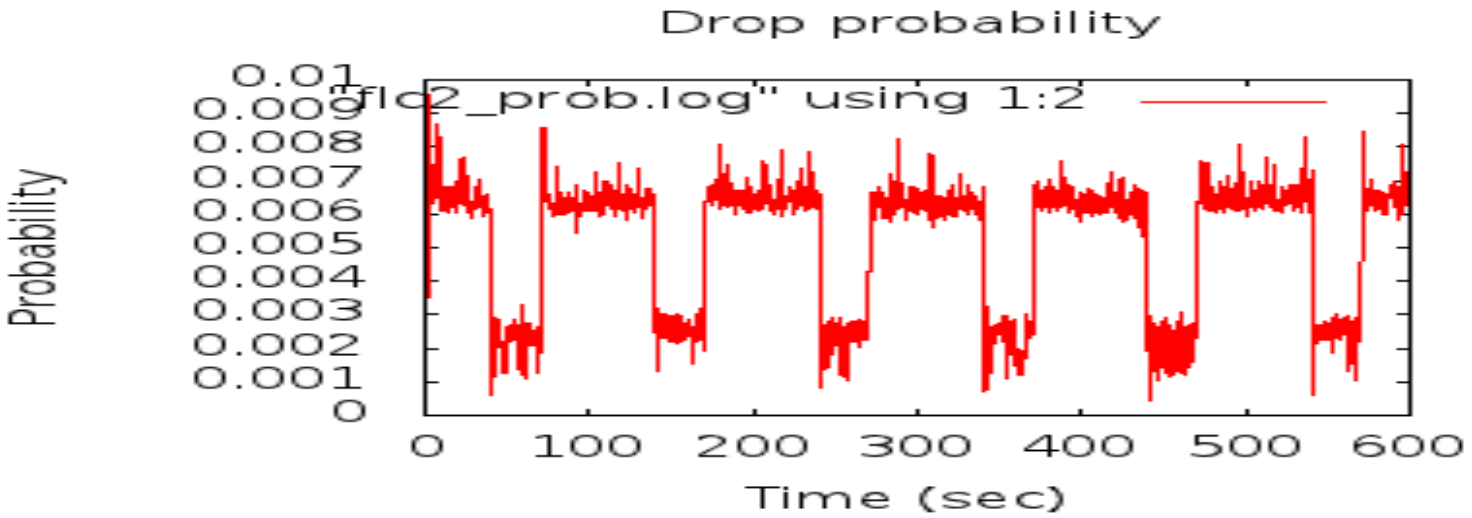
Queue length evaluation



Bandwidth:
50 Mbps

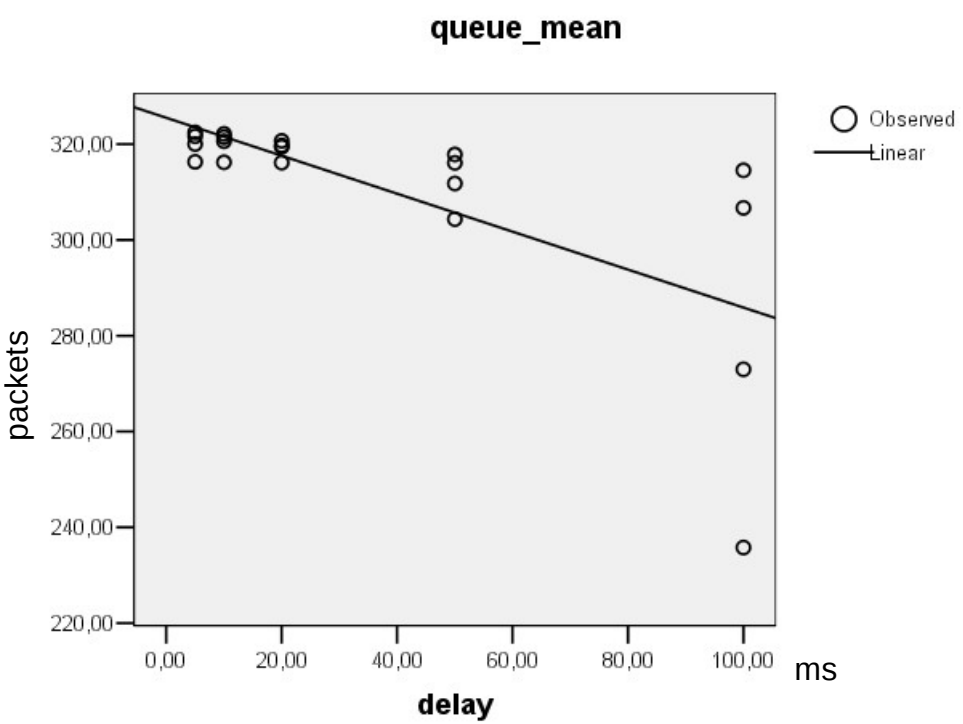
Delay:
5 msec

Drop probability evaluation

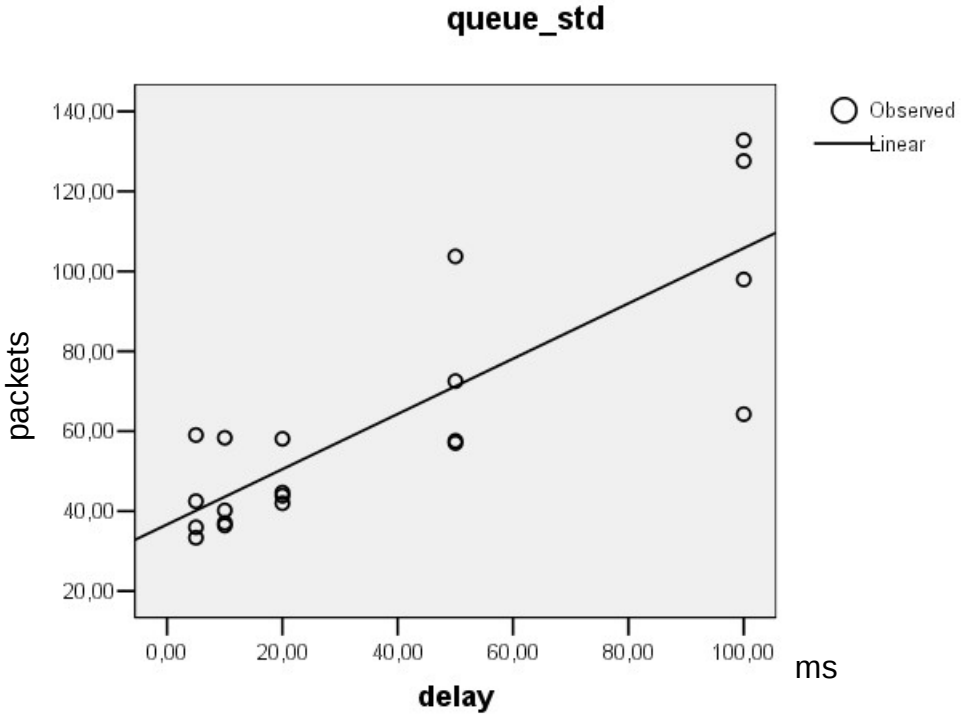


FLC method automatically adjust drop/mark probability in order to keep the target queue length

Regression analysis

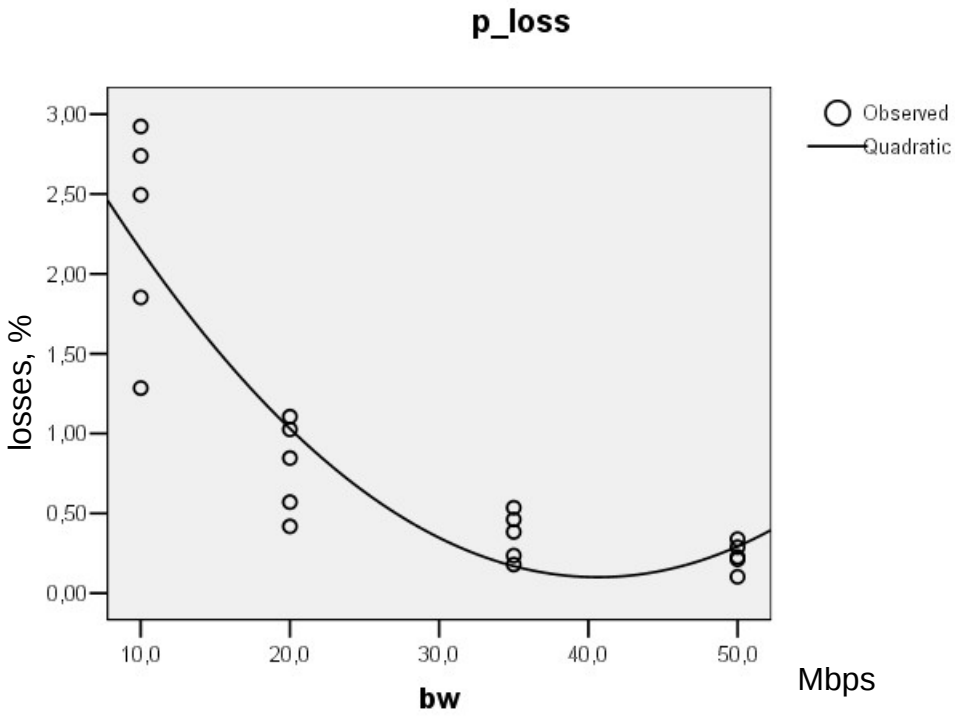


Dependence of average queue length *queue_mean* (packets) from link delay (ms)

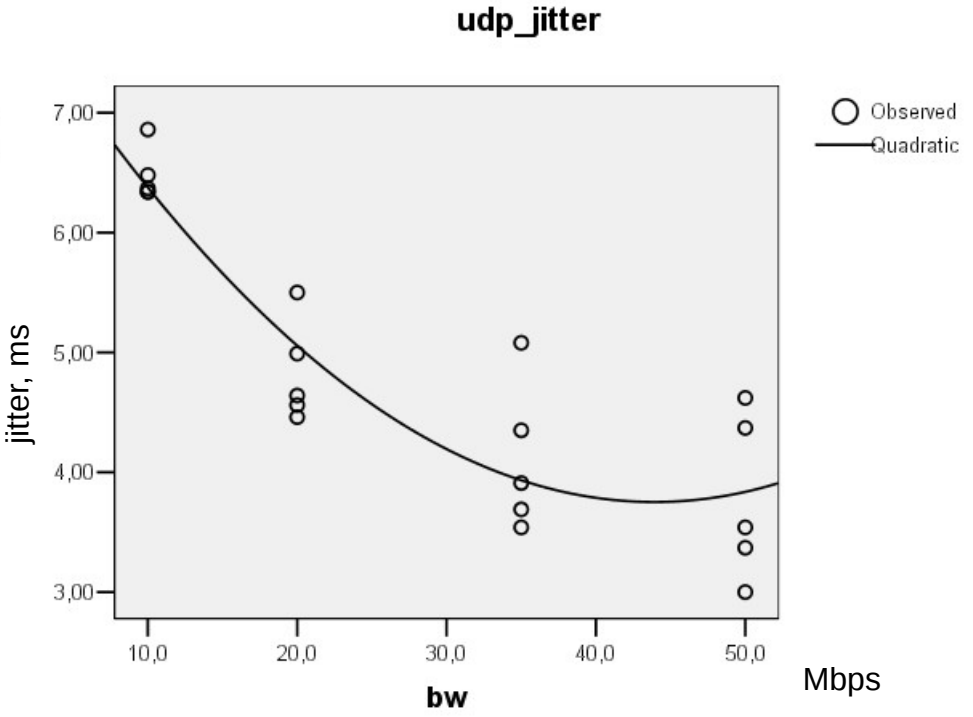


Dependence of standard deviation of queue length *queue_std* from link delay (ms)

Regression analysis (cont.)

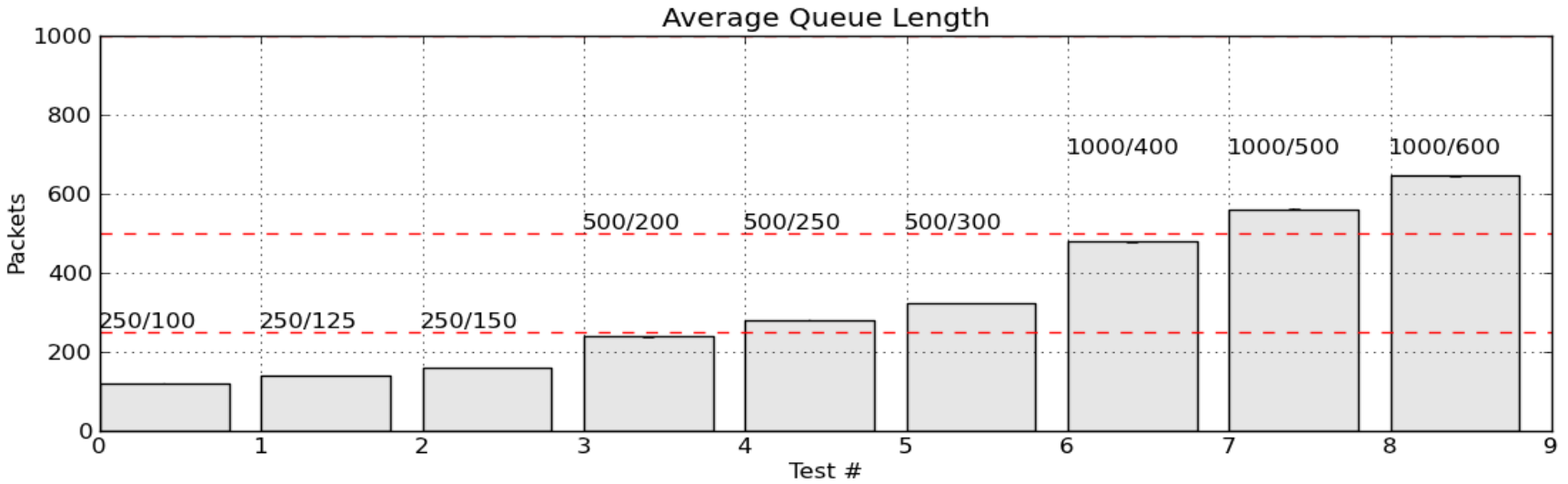


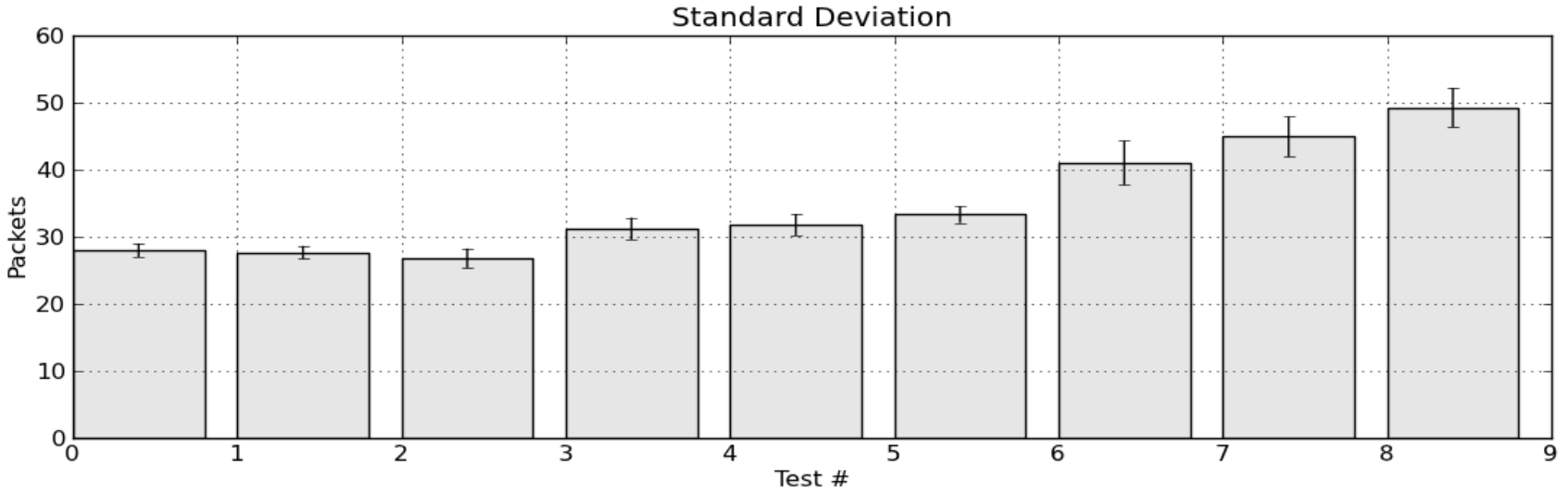
Dependence of percentage of packets loss *p_loss* (%) from link bandwidth *bw* (Mbit/s)



Dependence of jitter of UDP packets *udp_jitter* (ms) from link bandwidth *bw* (Mbit/s)

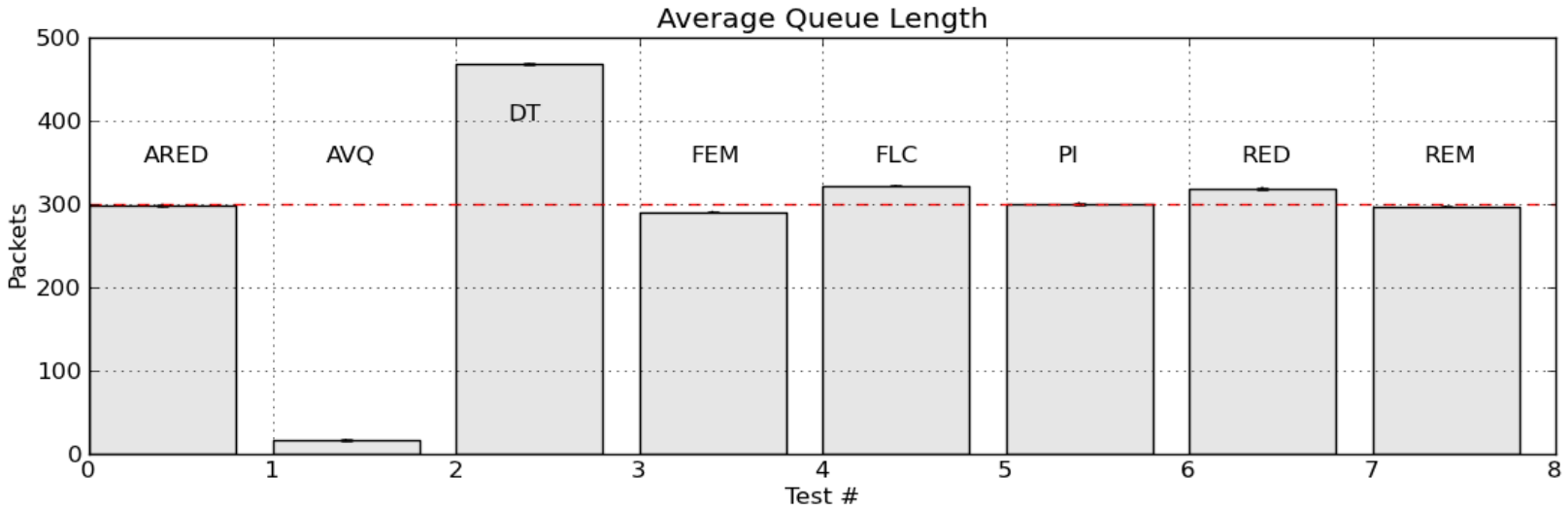
Average queue length and standard deviation for the different maximal and target queue length

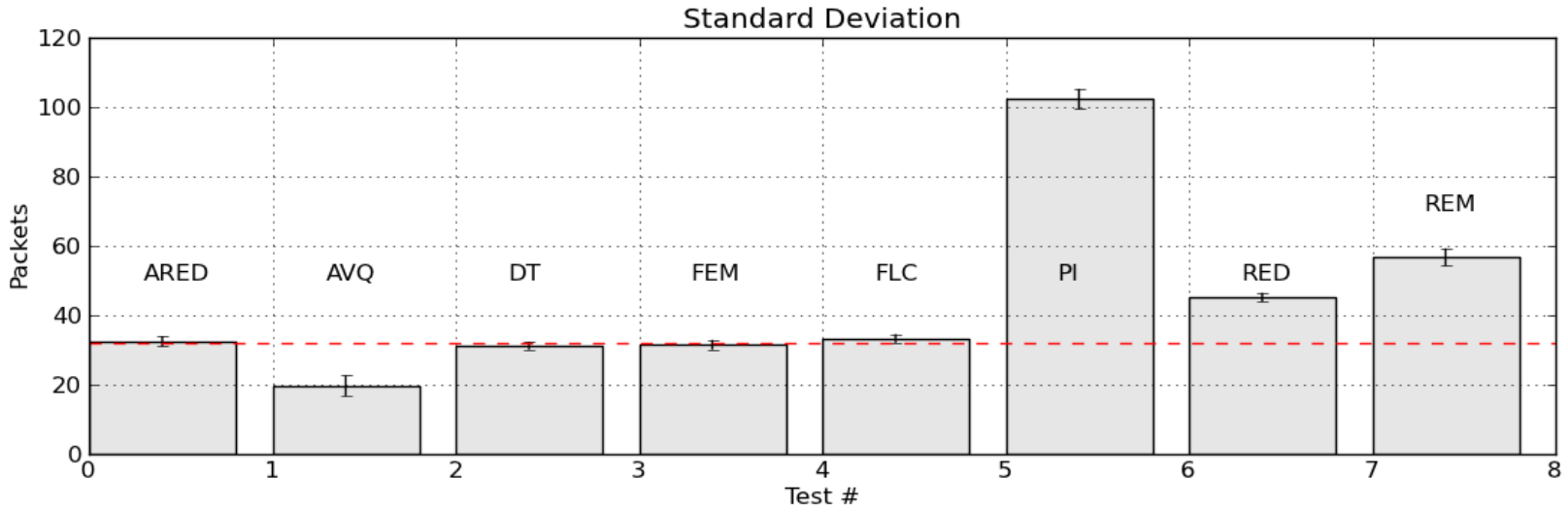




Legend: Maximal/Target queue length

Average queue length and standard deviation for the different queue management discipline



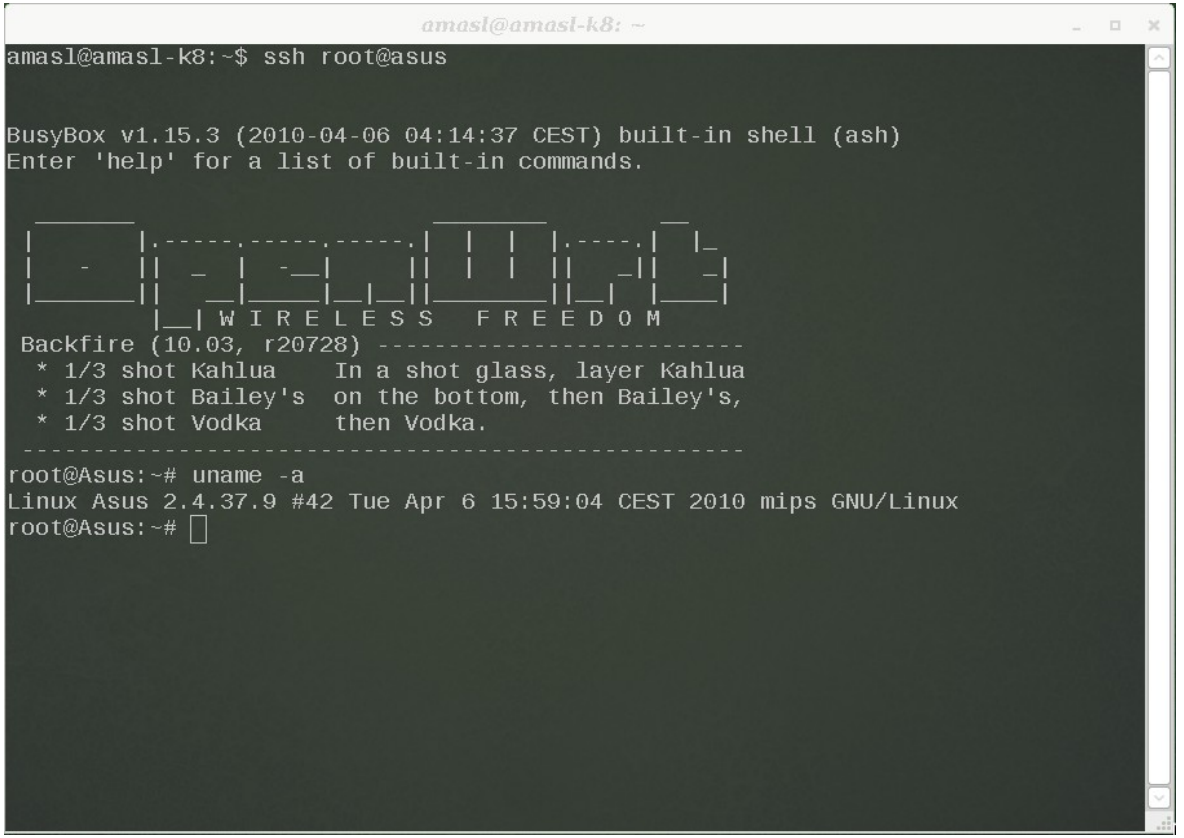


Bandwidth:
50 Mbps

Delay:
5 msec

Further work:
FLC implementation on a free source Linux-router

Free open source Linux software - OpenWRT (openwrt.org) for wide range routers from different vendors



Conclusion

A queue management mechanism based on fuzzy logic controller could effectively keep the queue length around a given value in a complex traffic condition with non-linear dynamics.

References

[1] K. Ramakrishnan, S. Floyd, D. Black, The Addition of Explicit Congestion Notification (ECN) to IP // RFC-3168, Sep. 2001.

[2] S. Floyd, V. Jacobson, Random Early Detection gateways for Congestion Avoidance // IEEE/ACM Transactions on Networking, V.1 N.4, August 1993, p. 397-413.

[3] C. Chrysostomou, A. Pitsillides, Y.A. Sekercioglu, Fuzzy explicit marking: A unified congestion controller for Best-Effort and Diff-Serv networks // Computer Networks 53 (2009), p. 650-667.

[4] A.G. Maslennikov, Active queue management techniques for routers // Network-Journal. Theory and practice, No.2 (19) 2011. http://network-journal.mpei.ac.ru

[5] The Network Simulator, NS-2, http://nsnam.isi.edu/nsnam/

Thank you for your attention!

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