Business from technology

Delay Based Packet Size Control in Wireless Local Area Networks

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Outline

- Motivation for the packet size control
- Aim of the paper
- Congestion control and prevention in WLANs
- Proportional-integral-derivative packet size controller
- Fuzzy packet size controller
- Network simulations
- Results
- Conclusions
- References

Motivation for the packet size control

- In contention-based MACs (e.g. WLAN's CSMA/CA MAC in DCF mode), the packet interval is dependent on the packet length
- if packet size is reduced
  - packet transmission interval and channel access time is decreased
  - channel reservation competition is increased
  - □ may lead to the network congestion and decreased throughput of the network.
- if packet size is increased
  - packet interval becomes longer and the number of packets sent from the source is reduced
  - channel reservation competition is decreased
  - □ increase the probability of packet errors due to bit errors, which decreases throughput.

□ Tranceivers' packet sizes should be controlled according to prevailing network conditions to achieve maximum throughput and minimum delay.

Aim

- We introduce and compare developed PID (Proportional, Integral, Derivative) and fuzzy control systems, which regulate packet sizes of User Datagram Protocol (UDP) based traffic on WLANs according to prevailing network conditions.
- The target of the developed controllers is to optimize packet size for the prevailing connection for higher throughput, and to fulfil the overall delay requirement of real-time traffic.

Congestion control in WLANs

Congestion:

- a condition of severe delay caused by an overload of datagrams at the network
- occurs when the load on the network is temporarily greater than the resources
- in WLAN, congestion typically arises when several nodes try to send at the same time

In a congested state one can either:

- increase resources
- decrease load
- reduce channel access competition
- do traffic shaping

Solutions for congestion problems can be divided into two main categories:

- open loop (problems are attemped to be solved beforehand by good (pre)design) and
- closed loop (solutions are based on feedback information) control
  - traffic or system monitoring to detect when and where congestion occurs
  - transferring of information to places where action should happen and
  - adjusting the system accordingly
- The developed PID and fuzzy control systems belong to the closed loop category

Proportional-integral-derivative (PID) packet size controller

Widely used feedback mechanism:

- calculates an error value as the difference between a measured variable and a desired setpoint
- attempts to minimize the error by adjusting the process control inputs:
  - the proportional value determines the controller's reaction to the current error
  - the integral value determines the reaction based on the sum of recent errors
  - the derivative value defines the reaction to the rate at which the error has been changing
- the weighted sum of these three actions is used to adjust the process

In the developed PID controller the input values are:

- one-way delay error (Ed= proportional value = delay - set value (100 ms))
- sum of the recent errors (Id = integral value)
- the change of error (ΔEd = derivative value)
- and the output value of the controller is the change of the packet payload size
- The developed controller can be presented in the equation form as follows: $Pi(t) = Kp \times Ed(t) + Ki \times \int Ed(t)\, dt + Kd \times \Delta Ed(t)/dt$,

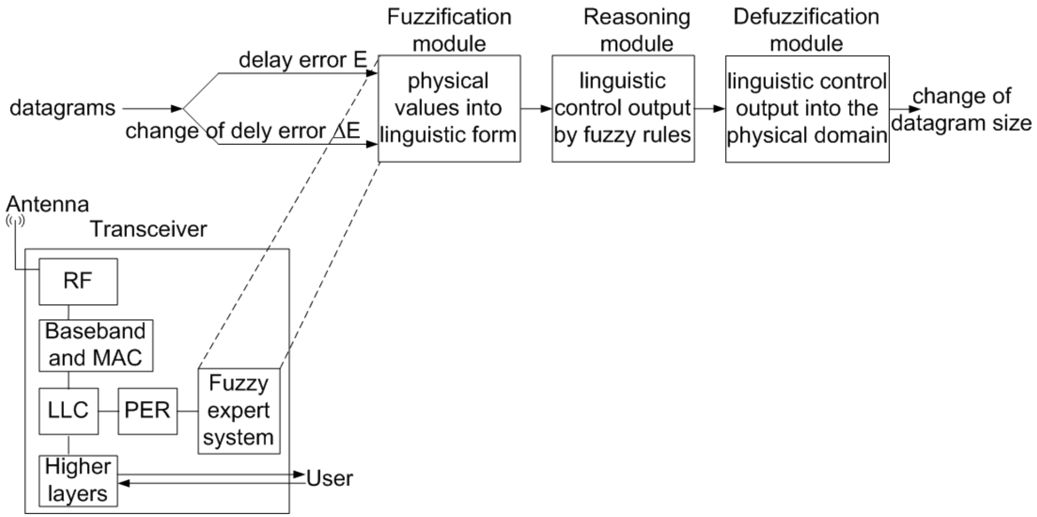
where Pi is the change of the packet payload size, Kp (=0.75) is a proportional amplifier, Ki (=0.20) is an integration amplifier, Kd (=0.1) is a derivation amplifier, and t is time

Fuzzy proportional-integral-derivative packet size controller

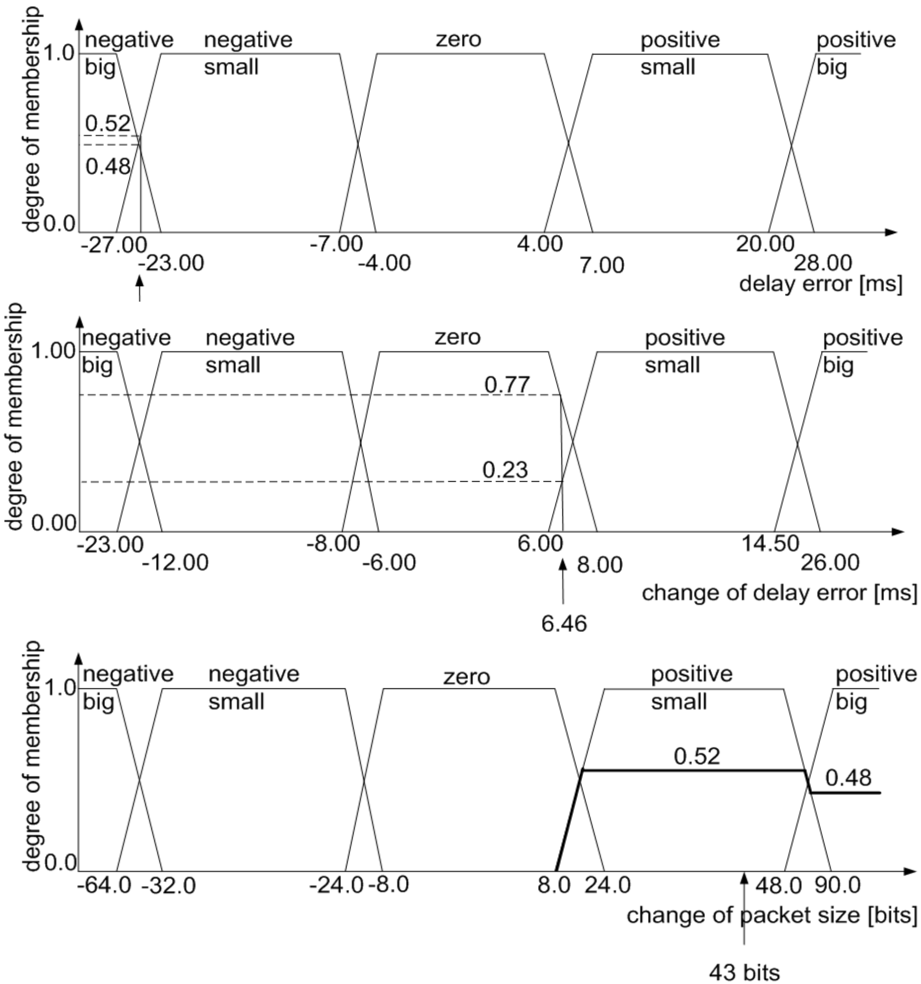
In the developed FPID controller input values are:

- one-way delay error (Ed= proportional value = delay - set value (100 ms)) = proportional part
- change of error (ΔEd = derivative value) = derivative part

- and the output value of the controller is the change of the packet payload size = integral part



Fuzzy membership functions



Mapping of the linguistic relations to the linguistic equations

mapping of the linguistic relations to the linguistic equations

error (E) \ change of error (ΔE)	NB	NS	ZE (0.77)	PS (0.23)	PB
PB	NS	NB	NB	NB	NB
PS	ZE	NS	NS	NS	NB
ZE	PS	ZE	ZE	ZE	NS
NS (0.52)	PB	PS	PS	PS	ZE
NB (0.48)	PB	PB	PB	PB	PS

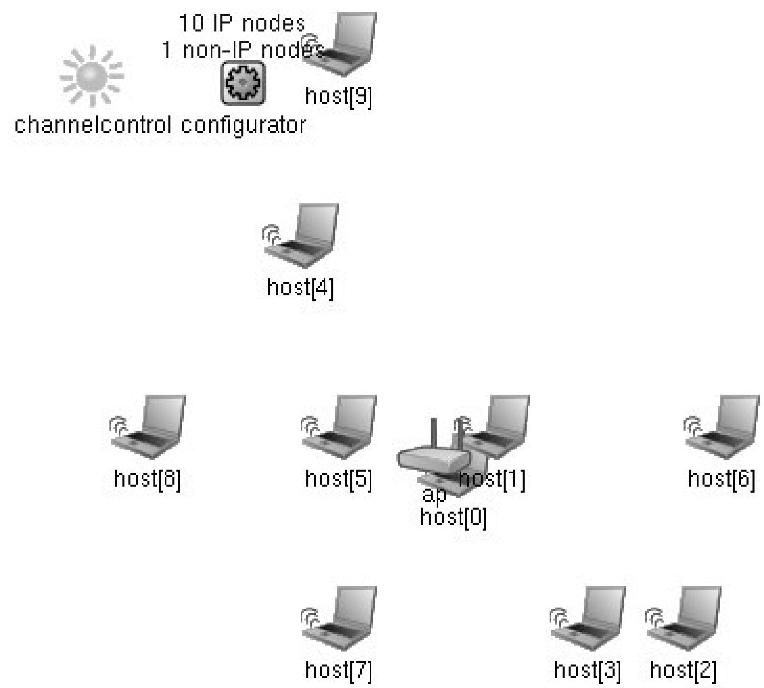
⇨

error (E) \ change of error (ΔE)	-2	-1	0	1	2
2	-1	-2	-2	-2	-2
1	0	-1	-1	-1	-2
0	1	0	0	0	-1
-1	2	1	1	1	0
-2	2	2	2	2	1

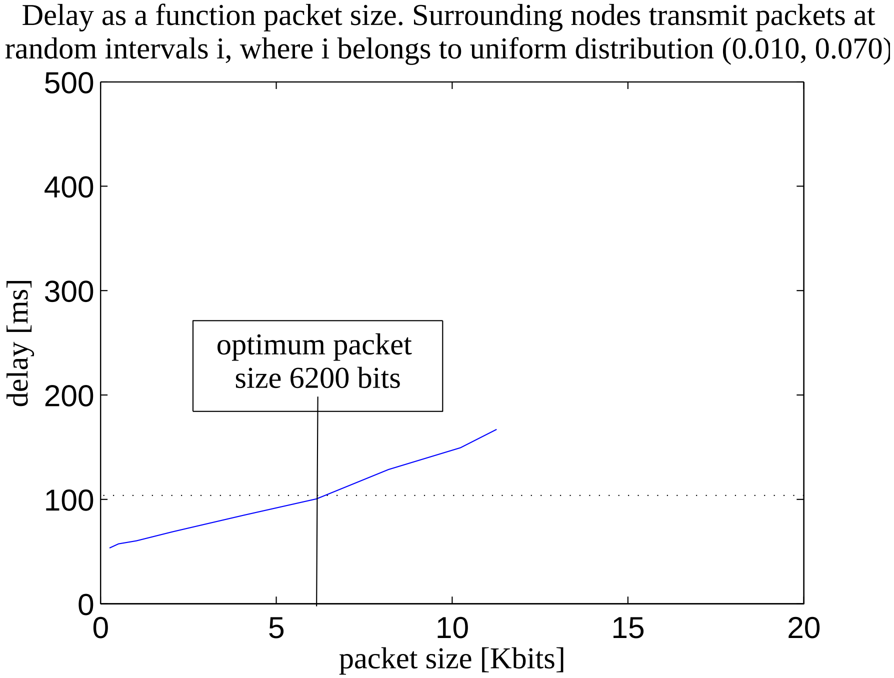
IF E IS NB at the grade of membership 0.48 AND
E IS NS at the grade of membership 0.52 AND
IF ΔE IS ZE at the grade of membership 0.77 AND
ΔE IS PS at the grade of membership 0.23
THEN change of *packet size* IS PS at the grade of membership 0.52
AND change of *packet size* IS PB at the grade of membership 0.48

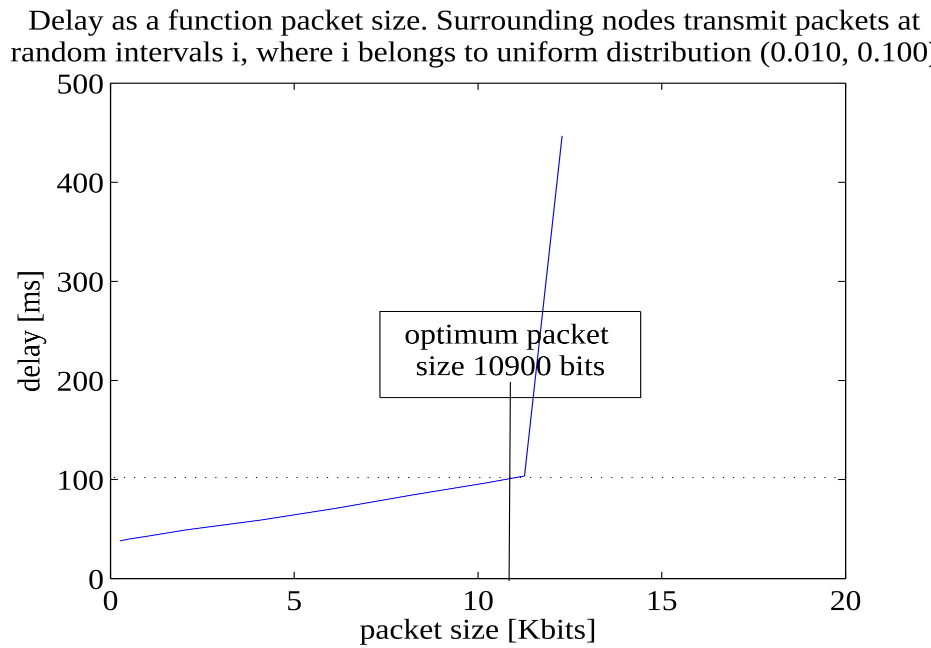
Simulation model

- OMNeT++ 4.0 together with the INETMANET framework was used
- One 802.11b AP and 10 wireless hosts in infrastructure mode
- The monitored and adapted traffic was between Host[1] and Host[0]
  - Host[1] sent one UDP packet every 1 ms
  - Initial packet size 256 bits
  - Host[0] measured the delay for the packets, calculated the optimal packet size, and reported it to Host[1] after every 200 packets
- Other wireless hosts created the background traffic



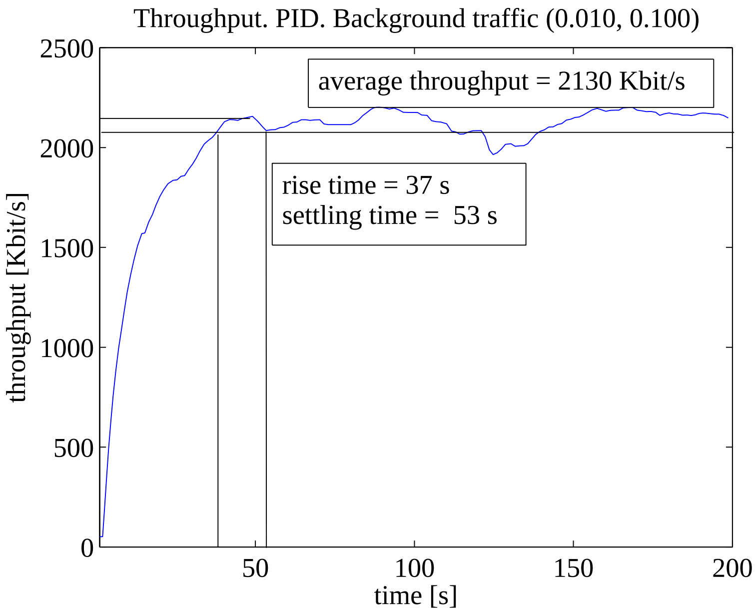
Delay as a function of packet size

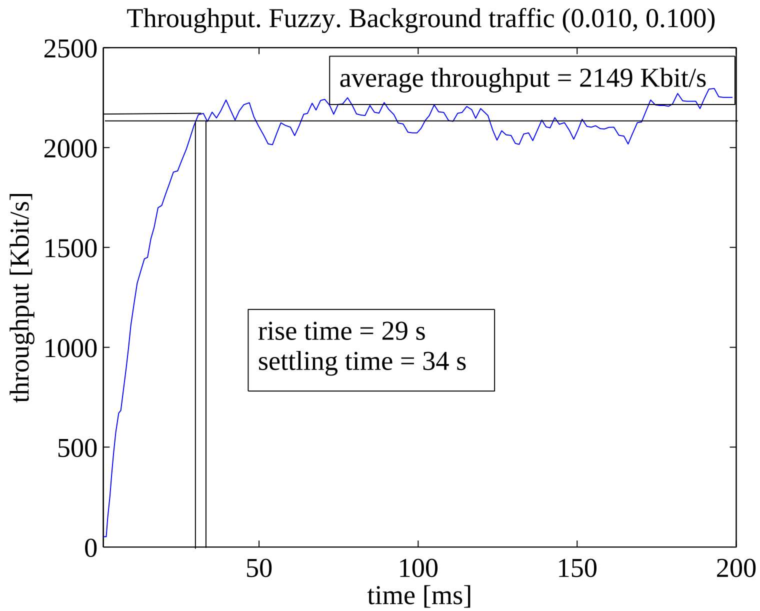




The optimum packet size value depends on the amount of traffic on the network. Figures above presents delay as a function of packet size, when surrounding nodes transmit packets at random intervals i, where i □ [0.010 s, 0.070 s] and, when i □ [0.010 s, 0.100 s]. The optimum values are 6200 bits and 10900 bits, respectively.

Throughput





- Figures above present throughput as a function of time, when the packet size was adjusted by the fuzzy and PID controller and the surrounding nodes transmit packets at random intervals i, where i □ [0.010 s, 0.010 s]. With the fuzzy controller average throughput is a bit higher and the rise and settling time are shorter than with the PID controller.

Throughputs and corresponding averaged packet sizes with different amount of background traffic

Background traffic	Optimized fixed packet size [bits]	FPID average packet size [bits]	PID average packet size [bits]	Throughput fixed packet size [Kbit/s]	Throughput FPID packet size [Kbit/s]	Throughput PID packet size [Kbit/s]
(0.010,0.100)	10900	10552	10538	1518	2149	2130
(0.010,0.090)	9750	9366	9324	1285	1907	1874
(0.010,0.085)	8800	8897	8455	1180	1804	1763
(0.010,0.080)	8200	8276	7876	1051	1686	1593
(0.010,0.075)	7100	7103	7034	900	1457	1429
(0.010,0.070)	6200	6207	5793	715	1255	1175

Averaged packet sizes and respective throughputs when the packet transmission interval of surrounding nodes is varied from i □ [0.010 s, 0.070 s] to i □ [0.010 s, 0.100 s]. Throughputs with FPID and PID controlled packet sizes are significantly higher than with the optimally chosen fixed packet sizes which is probably due to controllers ability to fastly adapt to prevailing channel conditions and exploit available transmission capacity.

Response times

The average (averaged over the different amount of disturbing background traffic of surrounding nodes) rise and settling times were 41.5 s and 53.2 s for FPID controller and 58.5 s and 78.3 s for PID controller.

Background traffic	Rise time FPID [s]	Rise time PID [s]	Settling time FPID [s]	Settling time PID [s]
(0.010,0.100)	29	37	34	53
(0.010,0.090)	47	88	58	123
(0.010,0.085)	42	62	60	71
(0.010,0.080)	38	53	44	72
(0.010,0.075)	60	63	63	79
(0.010,0.070)	33	48	60	72

Conclusions

- This paper considered FPID and PID control systems:
- regulate tranceivers' packet sizes for prevailing network conditions
- located at user terminals
- validated by simulating real-time UDP traffic in WLAN with OMNeT++ network simulator
  - The approach and techniques are easily applicable for other packet switched access networks, too

- The results proved that with FPID and PID controlled packet sizes:
- throughputs are significantly higher than with the optimally chosen fixed packet sizes
- the prevailing optimum level is achieved very fast and accurately

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