

# Analysis and Improvement of Transport Protocol Fairness

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# Overview

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- Congestion
- Congestion control
- Quantitative qualification of fairness
- The *Balancer* method
- Future research



# Congestion I

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- Bandwidth demand often exceeds available capacity
  - Traffic peaks that exceed capacity
  - Congestion control mechanisms are necessary
- Solution: buffering (e.g. FIFO), or packet drop
  - Packets are dropped when FIFO is full
  - Assumption: after a packet drop sending rate is decreased, which causes decreasing of queue



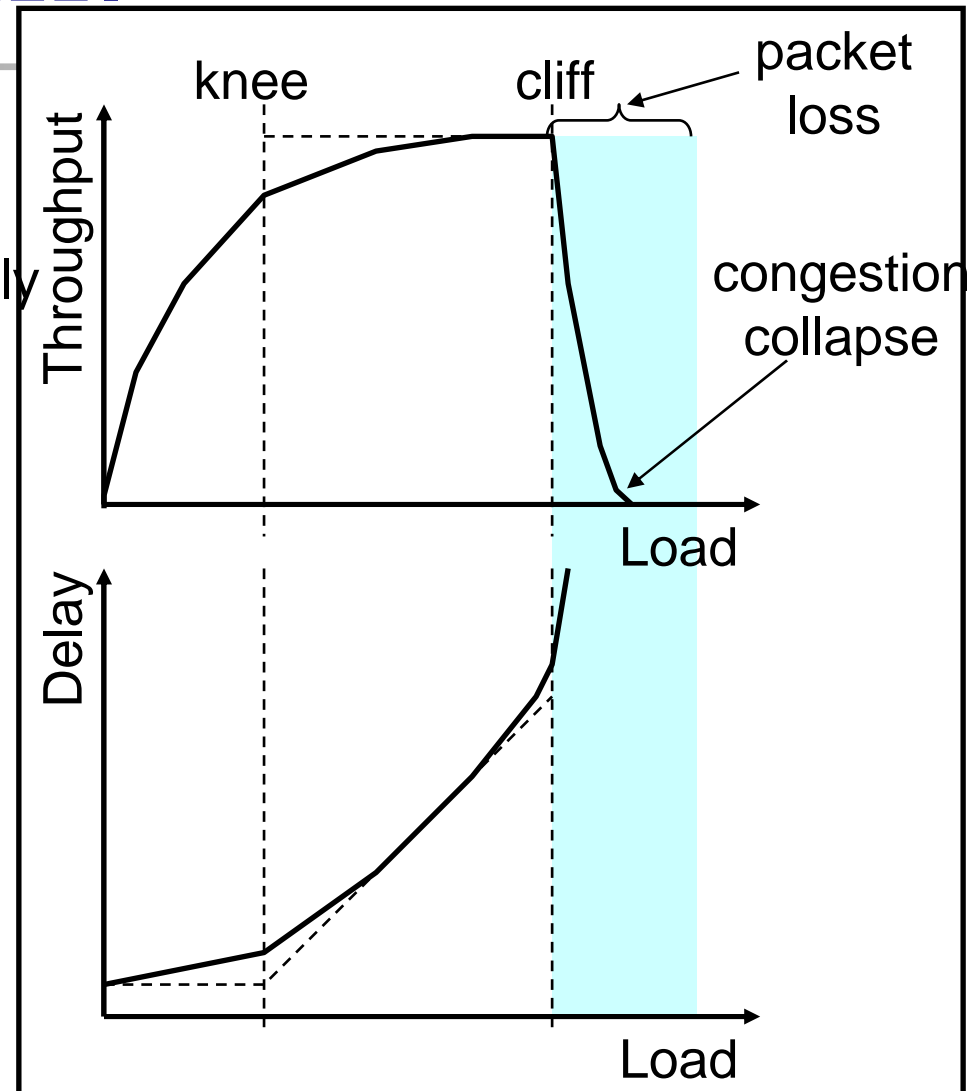
# Congestion II

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- Congestion causes the growth of queue length
  - Increasing delay and drop rate
- The goal of congestion control:
  - Optimal utilization of network resources
  - Best possible throughput
  - Low delay and packet drop rate
  - Fairness

# Congestion III.

- knee – point after which
  - throughput increases very slowly
  - delay increases fast
- cliff – point after which
  - throughput starts to decrease very fast to zero (congestion collapse)
  - delay approaches infinity
- Note (in an M/M/1 queue)
  - $\text{delay} = 1/(1 - \text{utilization})$



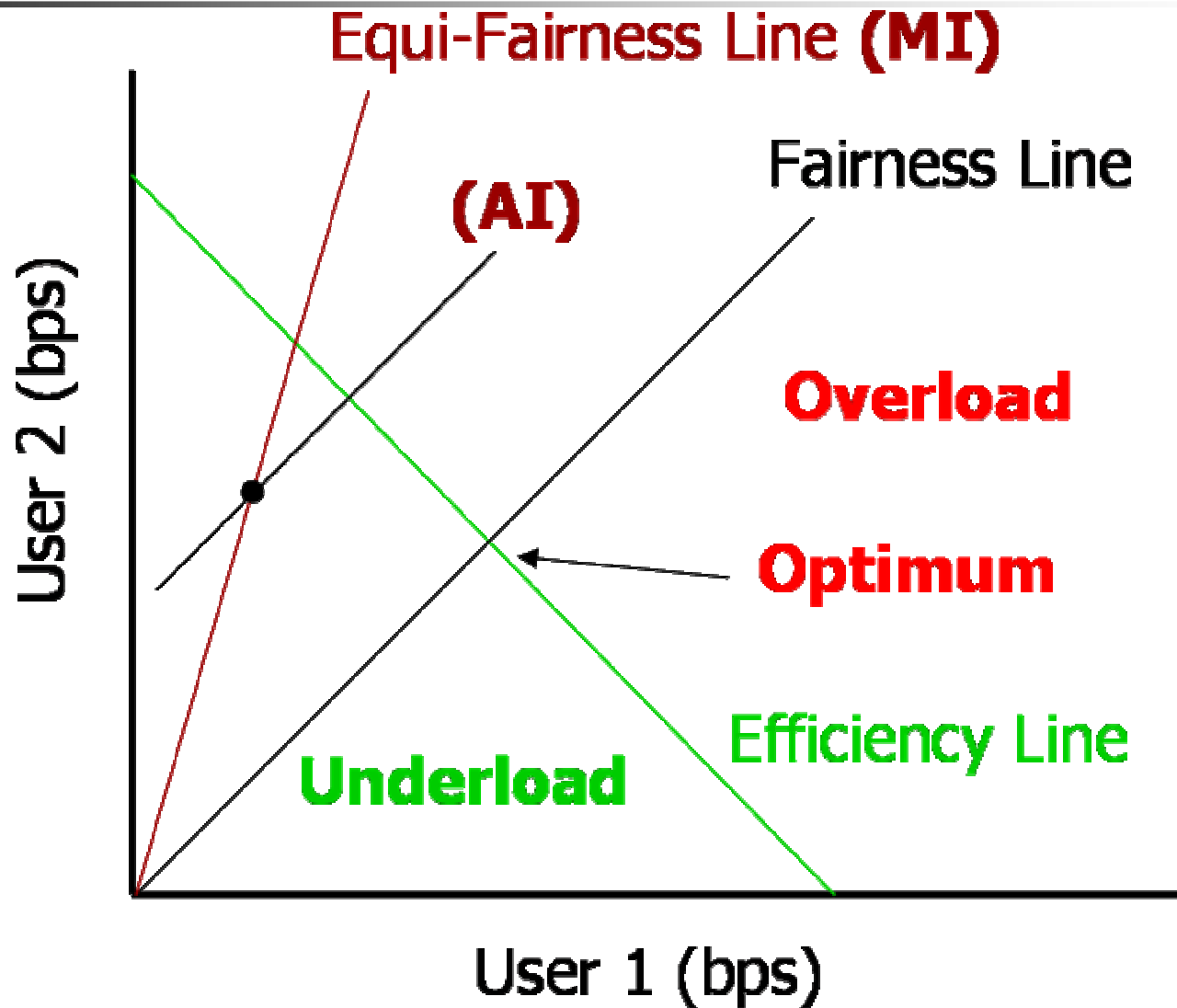


# Congestion control I.

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- Basically reactive methods
- Closed loop control of control theory
- Measure and feed back network parameters (reactiveness)
- Measurement
  - At the receiver (implicit feedback)
  - On routers
- Intervention
  - At the sender or on routers
- AIMD

# Congestion control II.



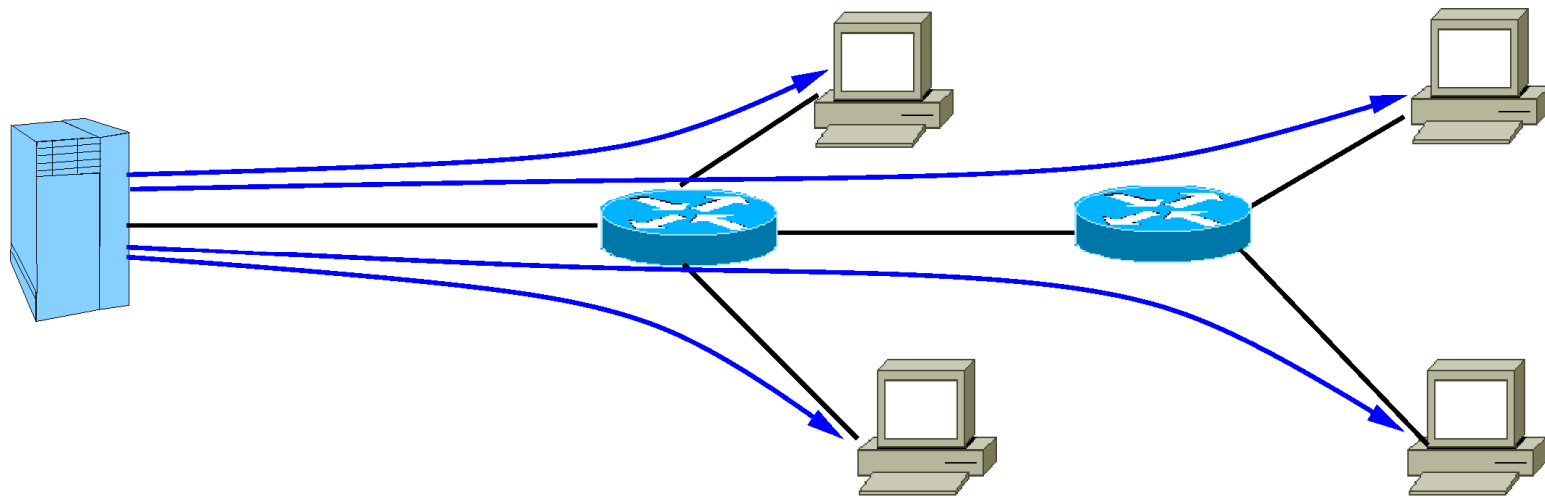


# Congestion control III.

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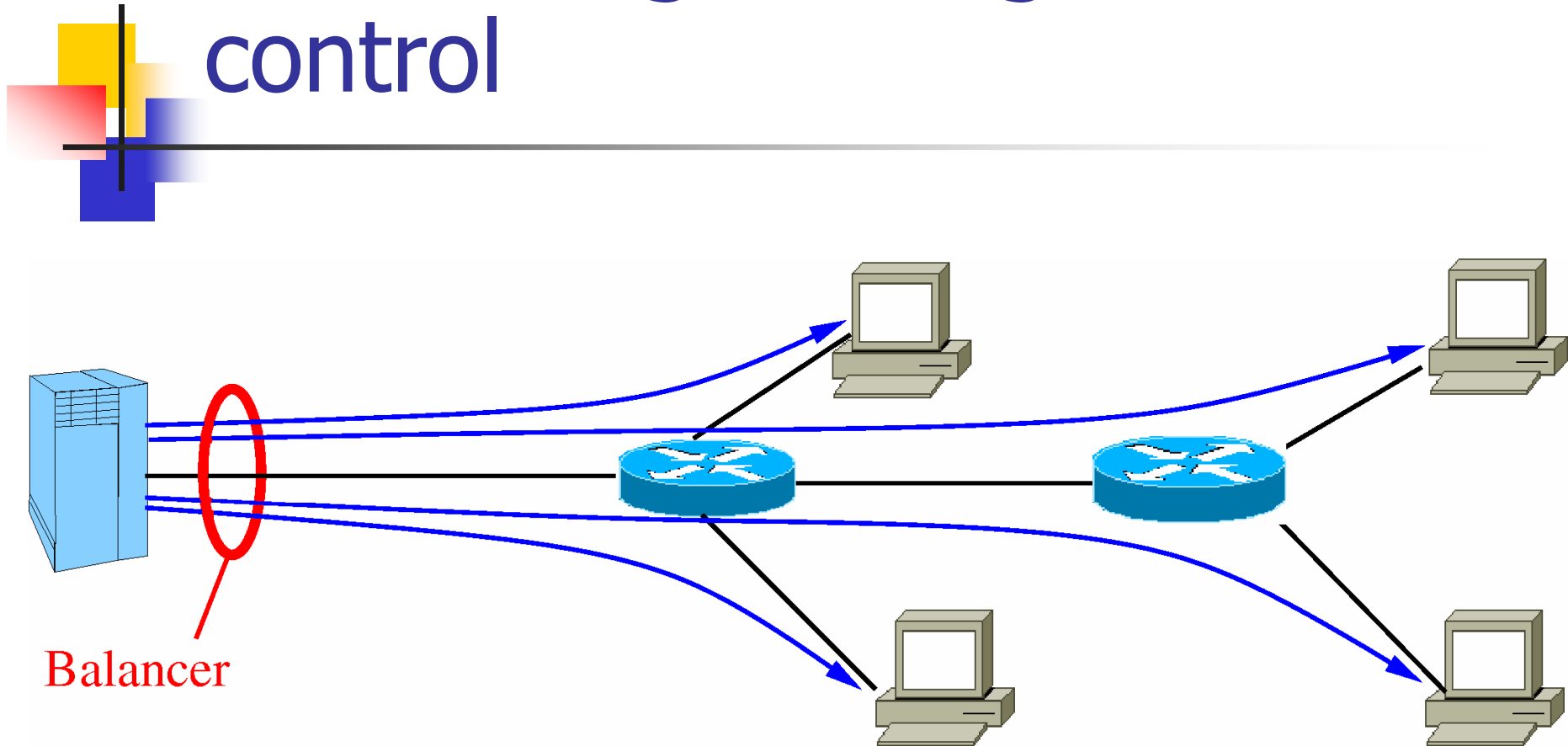
- Basic traffic control on the Internet: end to end method
  - Measurement of parameters at the receiver,
  - Traffic control at the sender
- End to end method is scalable
- Basis of feedback: packet drop rate or delay information
  - This assumes that the main source of packet loss is congestion

# Traditional end to end transport layer congestion control



- *Problem:* efficiency of congestion control is limited at high traffic network segments

# Fine-tuning of congestion control



- Fine-tuning of congestion control methods at the endpoints



# The *Balancer* method

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- Problem with concurrent flows' fairness
  - Control mechanisms are based on per flow feedback
  - Traditional AIMD converges to optimum point slowly
- Measuring the fairness of the bandwidth share using fairness measures
- For this we need a protocol analysis system
  - *SimCast*



# The essence of the Balancer method

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- Extension of existing congestion control mechanisms
- Endpoint control method
- Fairness based feedback
- Uses inter-flow feedback, rather than per flow feedback
  - Global knowledge
- Fairness is especially important at the neighborhood of high traffic servers
- Modification of DCCP/TFRC congestion control in the *SimCast* simulation environment
- TCP based implementation is in progress

# Qualification of protocol fairness



- Raj Jain's fairness index:

$$F = \frac{\left( \sum_{i=1}^{i=N} x_i \right)^2}{N \times \sum_{i=1}^{i=N} (x_i)^2}$$

- Usable for small number of flows
- Independent of scale and measure
- Maps fairness values to the (0,1] interval
- Positive correspondence higher fairness value – better fairness
- Can be calculated from the *coefficient of variation* directly




# The developed control method

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$$B_i = \frac{1}{F_i} = \frac{x_f}{x_i}$$

- The controlled global F fairness index will be optimal (1 in our case) if the per flow fairness index ( $F_i$ ) is close to 1
- **Proportional control of control theory**
  - Stable
  - Does not depend on the previous fairness values
  - Simple model
- $B_i$  is the control factor of the  $i$ -th flow



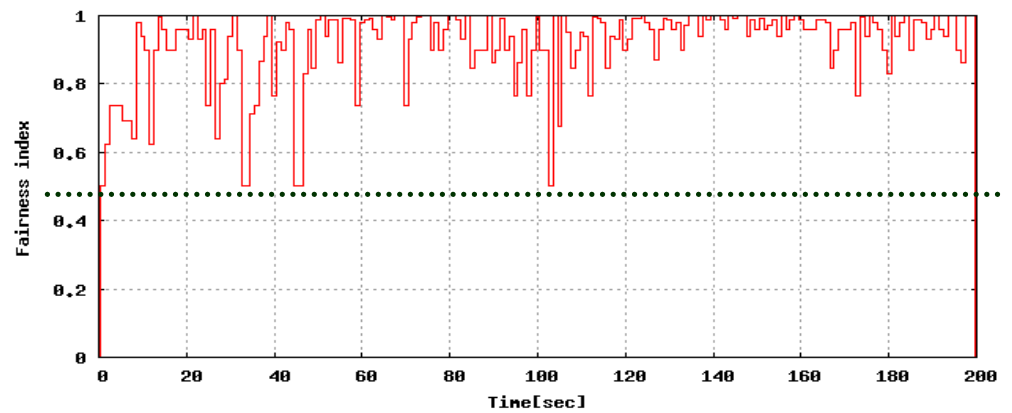
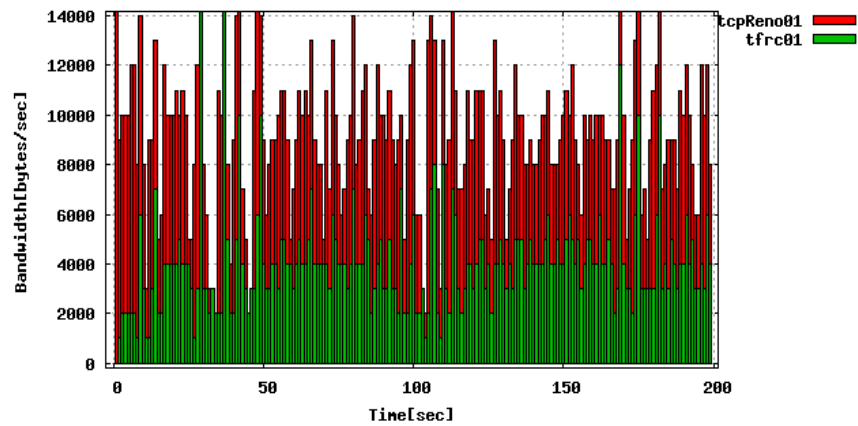
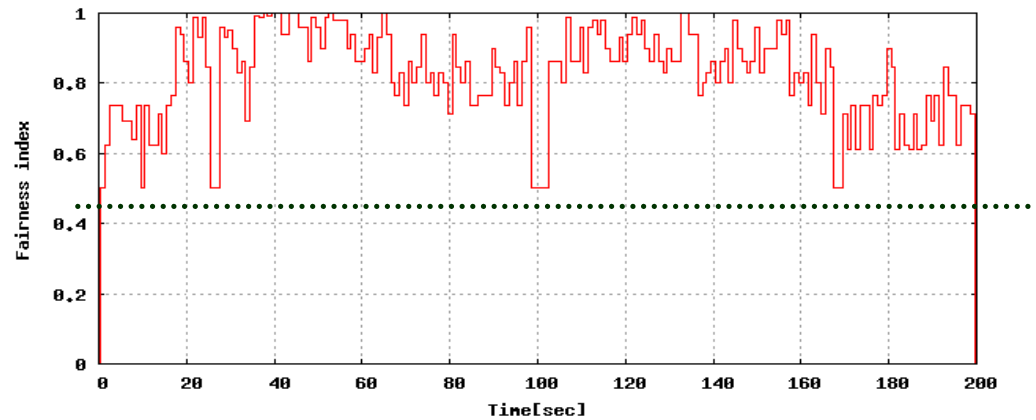
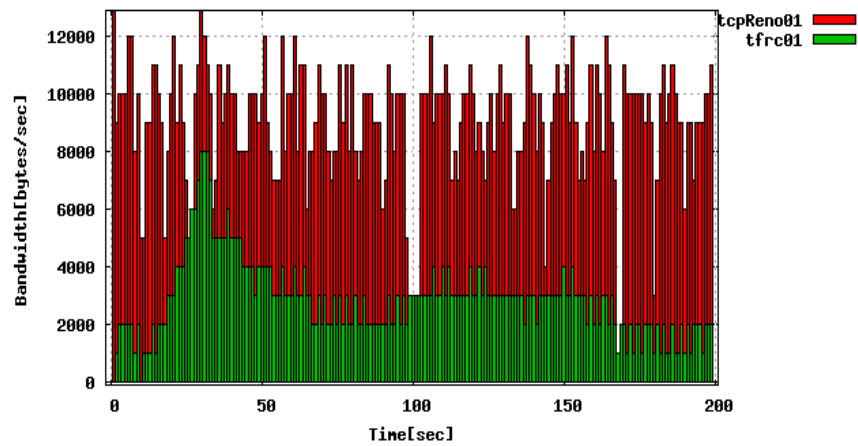
# Effect of the method – circumstances of an example simulation

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- Simulation based results - *SimCast*
- Host-Router-Router-Host topology
- *TCP Reno* and *TFRC* protocol entities
- Bandwidth: 80 kbit/sec
- Control frequency: 0.5 sec
- Packet size: 1000 bytes



# Simulation results of the method



# Simulation results of the method



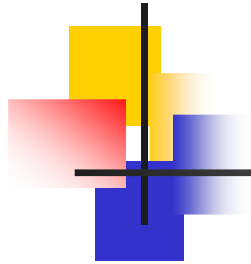
	Time required to reach the threshold value of 0.9 [sec]	Mean value of the fairness index samples
Uncontrolled case	17.0	0.82428
Controlled case	8.5	0.91685



# Directions of future research

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- Application of more complex control theoretic models
  - „PID” control – improvement of transient behavior
- Application of the *Balancer* method for TCP and other window based protocols using window size modification
- Take new aspects of protocol qualification into account in the control mechanism
- Investigation of topology dependent effects of control
- More detailed analysis of short and long term fairness



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Thank you for your attention!