# Unbalanced Traffic and the RPR Fairness Algorithm

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http://www.ece.rice.edu/networks/

# Outline

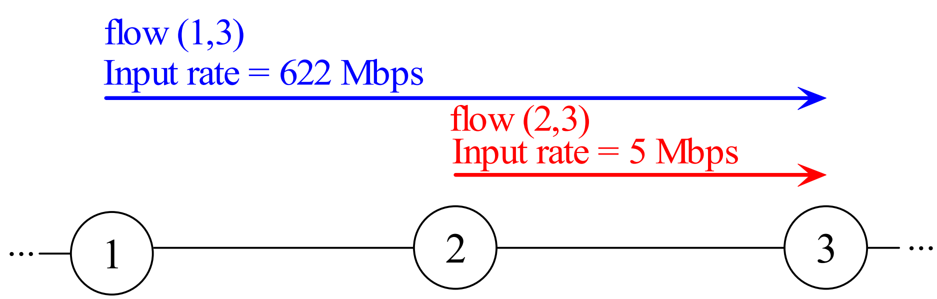
- Unbalanced traffic
  - What is it, why should we care?
- Throughput oscillations
  - Conditions
- Modeling RPR under unbalanced traffic
- Throughput loss due to oscillations
- Ongoing research
  - Impact of TCP

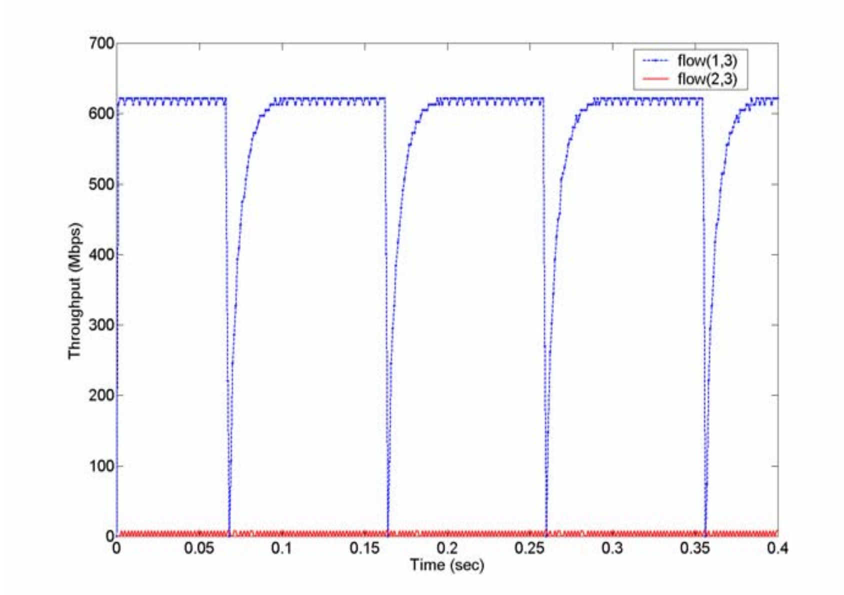
Should we try to avoid oscillations? Are they worth avoiding?

# Unbalanced Traffic

## (Unbalanced Traffic with Unbalanced Inputs)

Permanent oscillations with constant rate unbalanced inputs



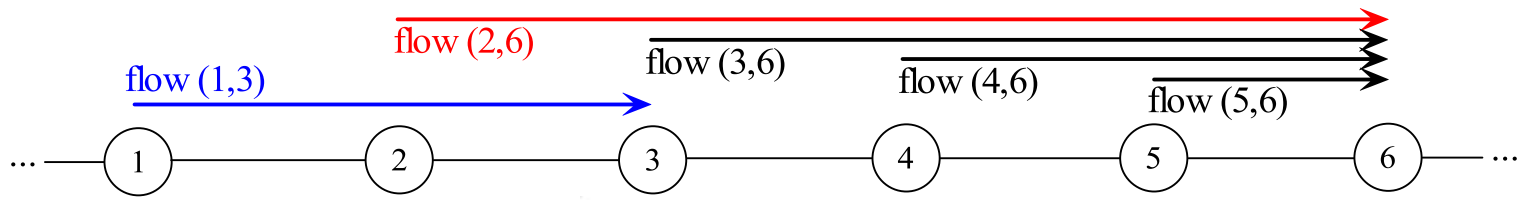




RPR-Aggressive Mode

Throughput loss is 15%

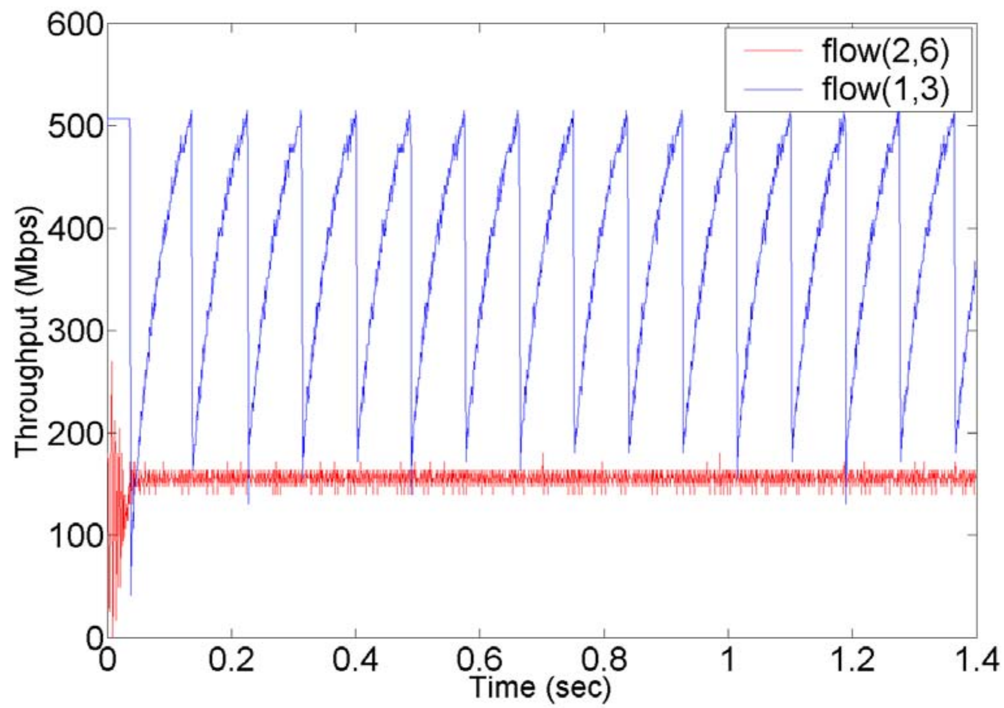
**Unrealistic scenario**

# Upstream Parallel Parking Lot
## (Unbalanced Traffic with Balanced Inputs)




- Permanent oscillations
  - Even with identical input rates
  - Throughput loss is 14%

- Many scenarios can result in traffic imbalances, thus permanent oscillations




RPR-Aggressive Mode

# RPR Oscillations

- Permanent oscillations for many scenarios with unbalanced traffic
  - Unbalanced targeted fair rates

> Illustrations: *Annex I.3 Fairness scenarios*
>
> Precise definition:
>
> http://www.ece.rice.edu/networks/RIAS

- Adverse effects
  - Throughput degradation
  - Increased delay jitter

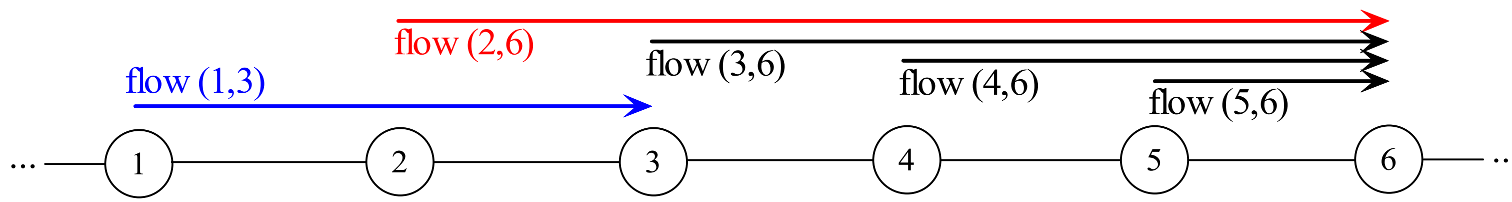
- Key issue

  AM: *add_rate*

  CM: *C/number_of_active_stations*

  } does not accurately reflect the congestion status

# Oscillation Conditions – Aggressive Mode

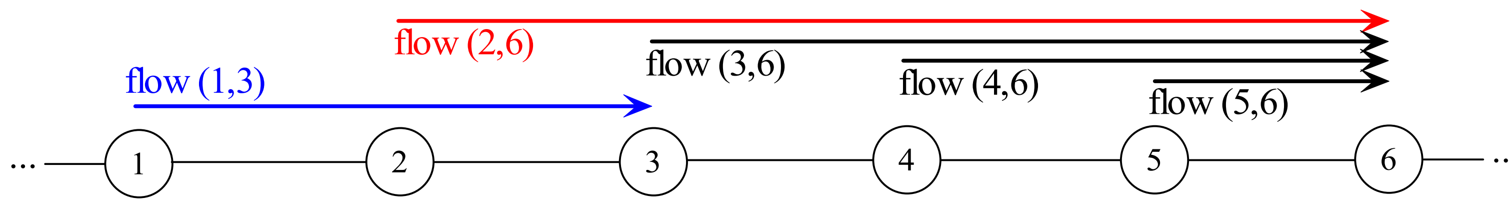



Flow (1,3) demand = 1
Flow (1,3) fair rate = ¾

Flow (2,6) demand = 1
Flow (2,6) fair rate = ¼

Flow (1,3) has demand and fair rate larger than minimum fair rate (demand) at congested link with unbalanced traffic

# Oscillation Conditions – Aggressive Mode

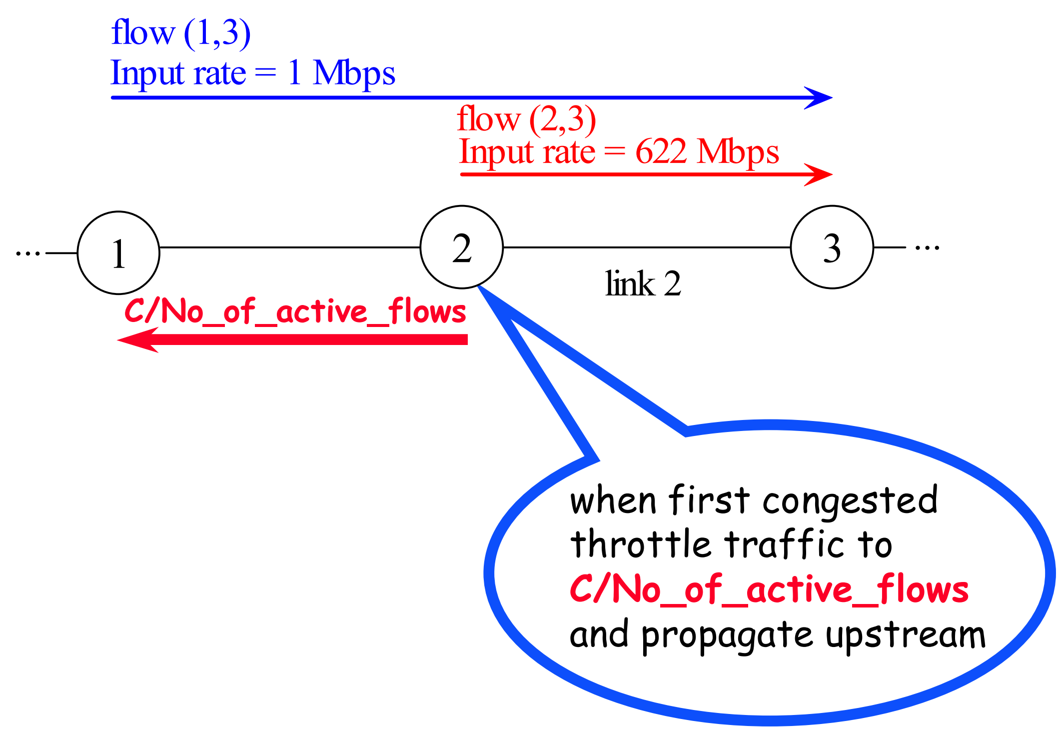



***Proposition 1:*** For a given fair rate matrix R, demanded rates r, and congested link j, permanent oscillations will occur in RPR-AM if there is a flow (n,i) crossing link j such that following two conditions are satisfied:

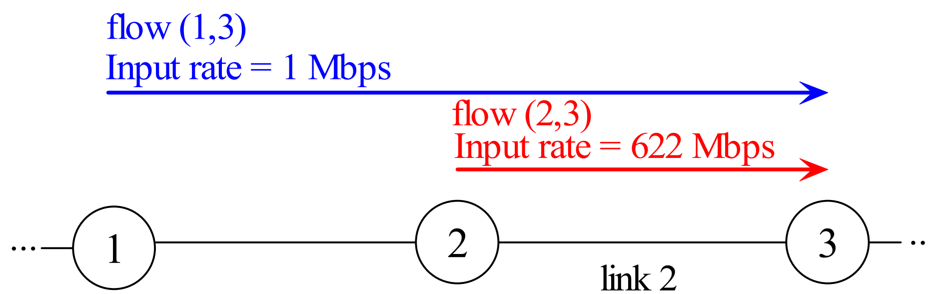
$$r_{osc} = \min_{n<k\leq j, l>j} \min(r_{kl}, R_{kl}) < R_{ni}$$

$$r_{osc} < r_{ni}$$

# Oscillation Conditions – Conservative Mode
## (Example)



# Oscillation Conditions – Conservative Mode
## (Example)




Flow (1,3) demand = 1 Mbps < C/2

Rate at link 2 after first congestion:
622/2 +1 (Mbps) < low_threshold

# Oscillation Conditions – Conservative Mode

***Proposition 2:*** For a given fair rate matrix R, demanded rates r, and congested link j, let $n_a$ denote the number of active flows on link j, and $n_g$ denote the number of flows crossing link j that have both demand and targeted fair rate greater than $C/n_a$. Ignoring low pass filtering and propagation delay, permanent oscillations will occur in RPR-CM if there is a flow (n,i) crossing link j such that the following two conditions are satisfied

$$\min(r_{ni}, R_{ni}) < \frac{C}{n_a}$$

$$n_g \frac{C}{n_a} + S_s < low\_threshold$$

where $S_s = \sum_{k \le j, l > j, \min(R_{kl}, r_{kl}) < \frac{C}{n_a}} \min(r_{kl}, R_{kl})$

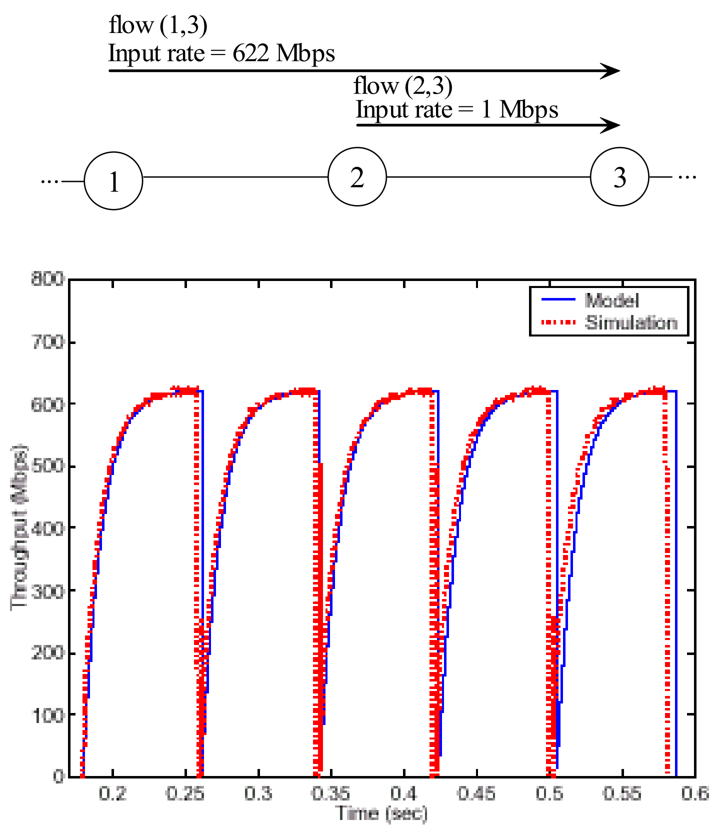
# Oscillation Conditions – Conservative Mode

***Proposition 2:*** For a given fair rate matrix R, demanded rates r, and congested link j, let $n_a$ denote the number of active flows on link j, and $n_g$ denote the number of flows crossing link j that have both demand and targeted fair rate greater than $C/n_a$. Ignoring low pass filtering and propagation delay, permanent oscillations will occur in RPR-CM if there is a flow (n,i) crossing link j such that the following two conditions are satisfied

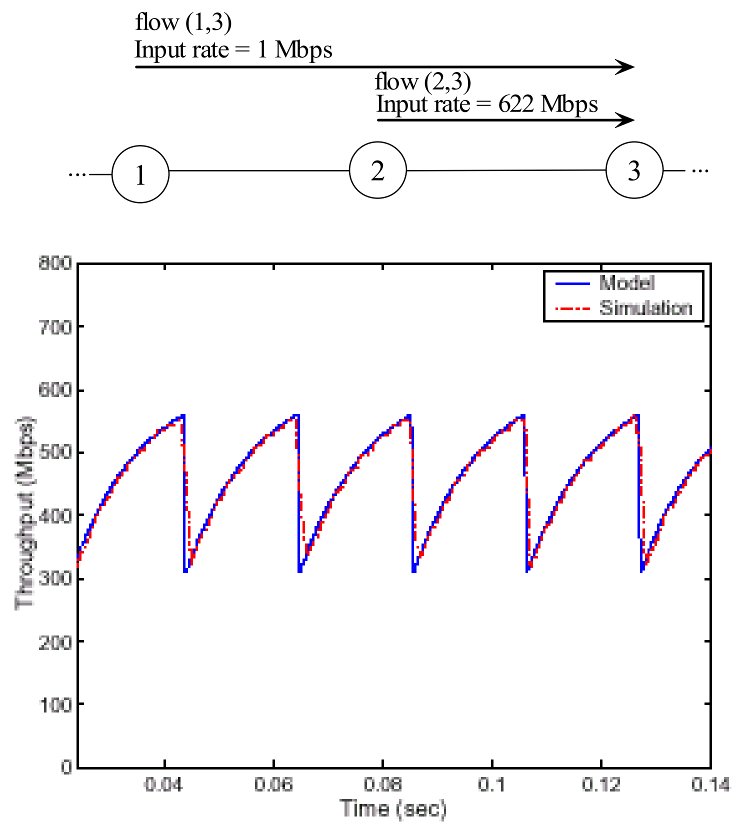
V. Gambiroza, P. Yuan, L. Balzano, Y. Liu, S. Sheafor, and E. Knightly, ``Design, Analysis, and Implementation of DVSR: A Fair, High Performance Protocol for Packet Rings," to appear in *IEEE/ACM Transactions on Networking*.

# Modeling RPR Oscillations
## (Analytical and Simulation Results)

Model accurately matches simulation




Aggressive Mode




Conservative Mode

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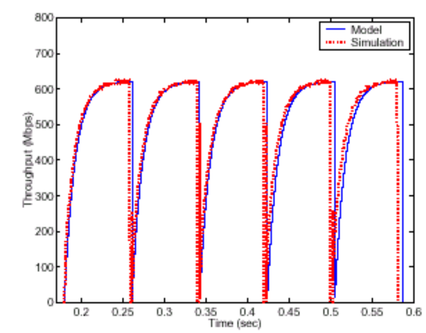
# Modeling Throughput Loss

- Oscillation results in throughput loss



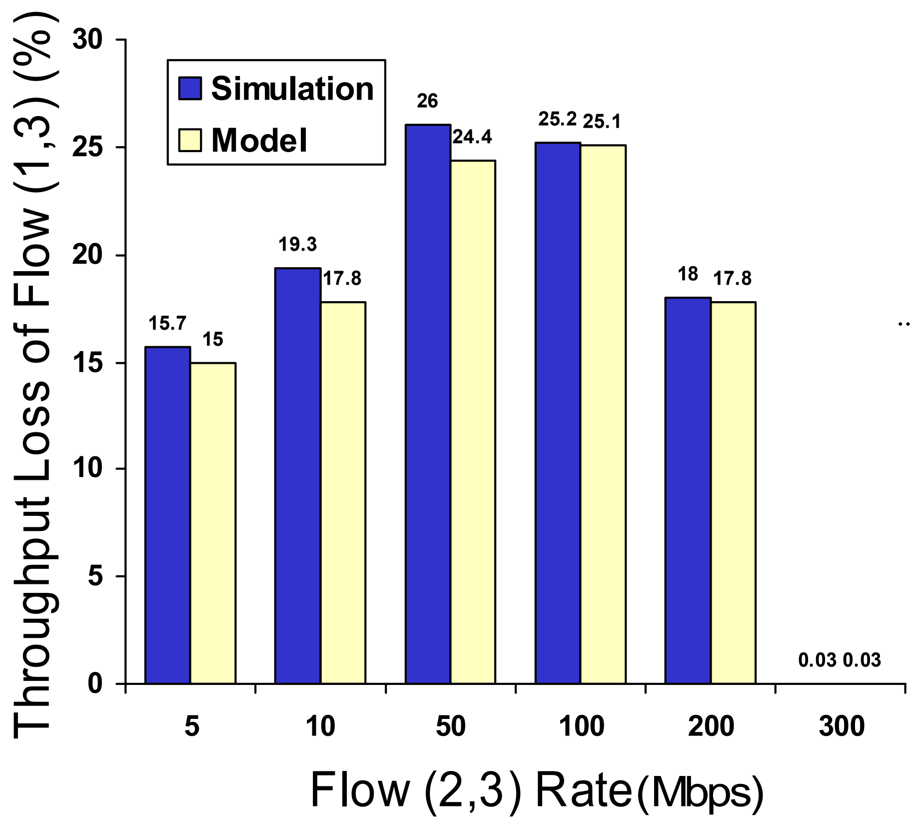

- Knowing exact rates during one cycle we can write expression for throughput loss

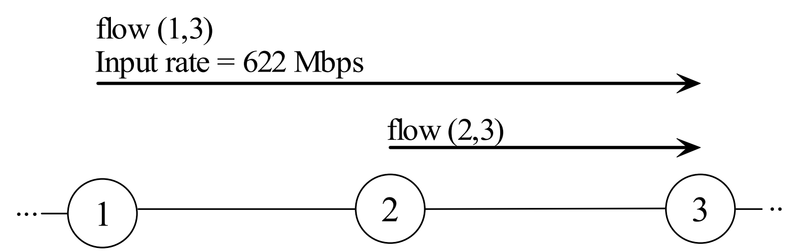
$$\rho_{loss} = \frac{1}{N} \sum_{k=0}^{k=N} (R - r_k)$$

where N is the number of rate updates in one cycle

# Throughput Loss – Analytical and Simulation Results
## (RPR - Aggressive Mode)

Model matches simulation within 2%




Throughput loss as high as 26%

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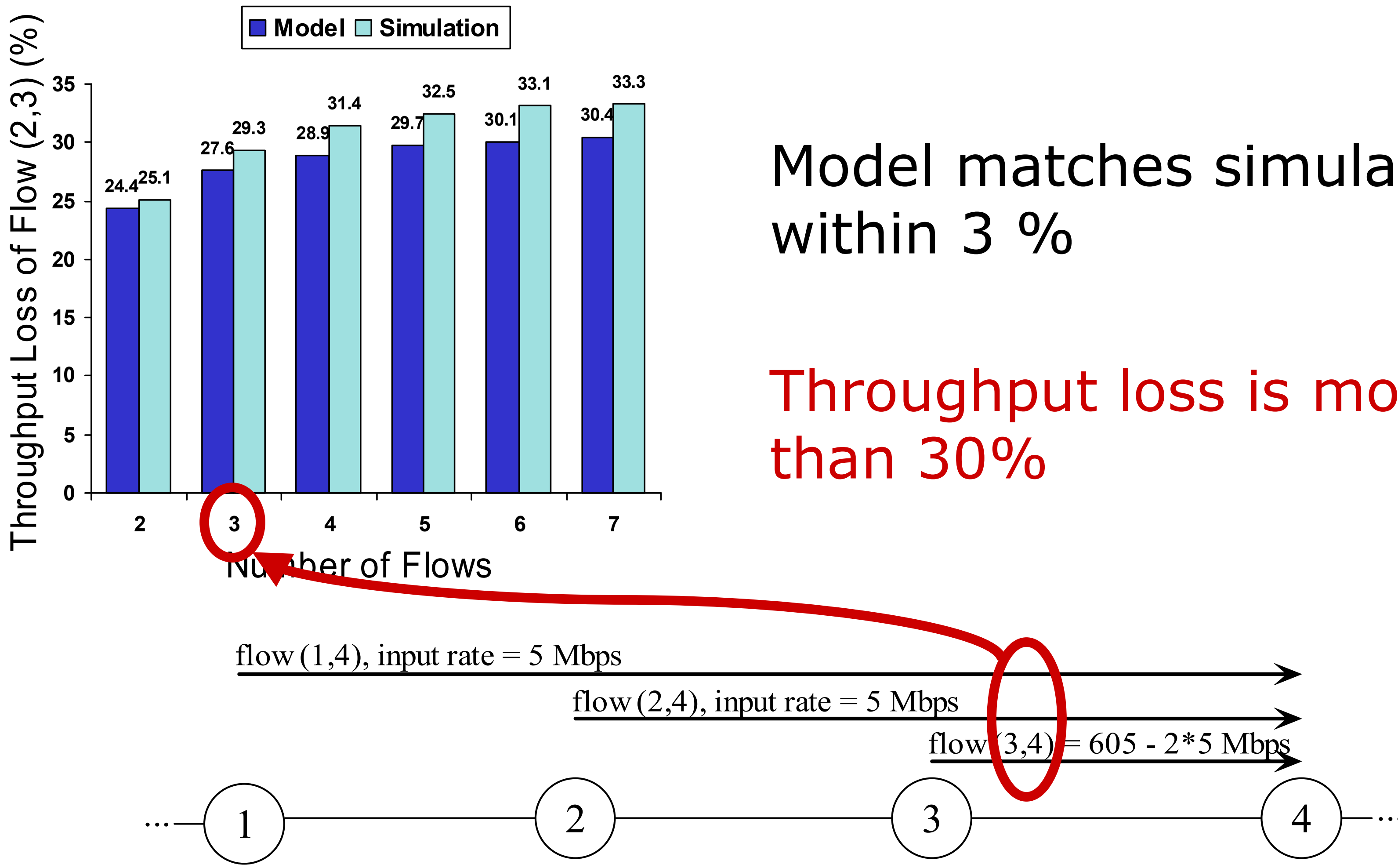
# Throughput Loss – Analytical and Simulation Results
## (RPR - Conservative Mode)

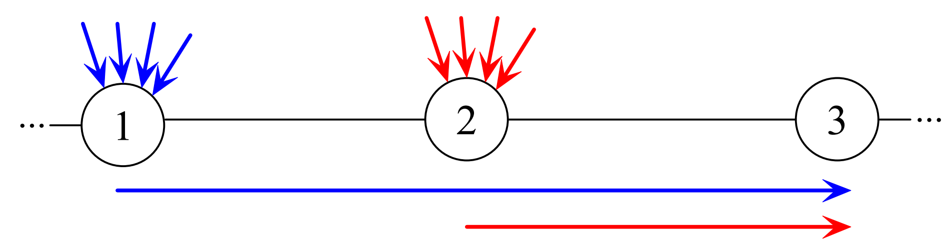



Model matches simulation within 3 %

Throughput loss is more than 30%

# Ongoing Research
# Impact of TCP

- Similar oscillations occur with TCP
- Parameters of interest
  - Maximum window size - number of packets source is allowed to send without ACK
  - STQ size
  - Ingress buffers
  - Level of aggregation



# Conclusions

- RPR can permanently oscillate in a wide range
  - Root cause is unbalanced traffic (fair rates)
- Throughput loss more than 30% with constant rate flows
  - We need to address the problem
  - Similar oscillations with TCP flows
    - Problem much more complex

- Possible solutions
  - Generalize RPR feedback information
  - Avoid unbalanced traffic with careful traffic engineering

# Future Work

- Modeling RPR
  - What other aspects of the RPR-fa can we model?
    - Convergence time
    - Feedback control with non-FIFO scheduling?

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