A Game-Theoretic Approach Towards Congestion Control in Communication Networks

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INTRODUCTION(1/3)

- Network Congestion Control
  - User-end：end-to-end congestion control(e.g. TCP)
  - Router or Switch：resource sharing policy(e.g. RED, ECN…)
- Most of the end-to-end congestion control are *“voluntary”*.
- During congestion, router and switch mechanisms can *“absolutely”* determine the sharing of resources.

INTRODUCTION(2/3)

- The authors using a game-theoretic approach can show that all current router and switch mechanisms either *“encourage“* congestion or *“oblivious“* to it.
- The authors also show that in the presence of selfish users, all such scheme will inevitably lead to *“congestion collapse“*.

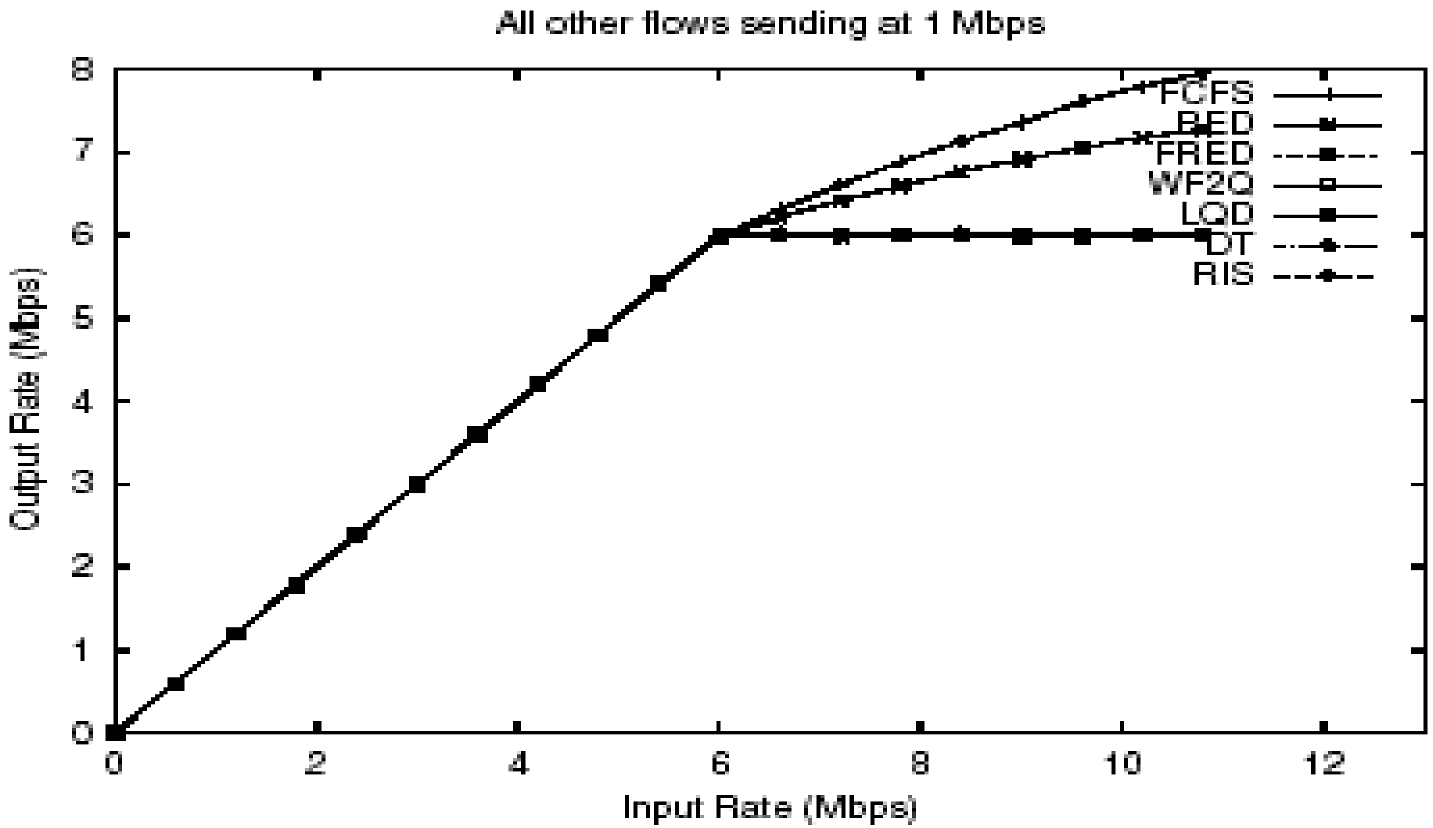
INTRODUCTION(3/3)

- The authors of this paper propose a game-theoretic approach towards congestion control which is called *“DWS”* .
- The crux of the approach is to deploy buffer management policies at switches and routers that *“punish misbehaving flows”* and *“encourage well behaved flows”* .

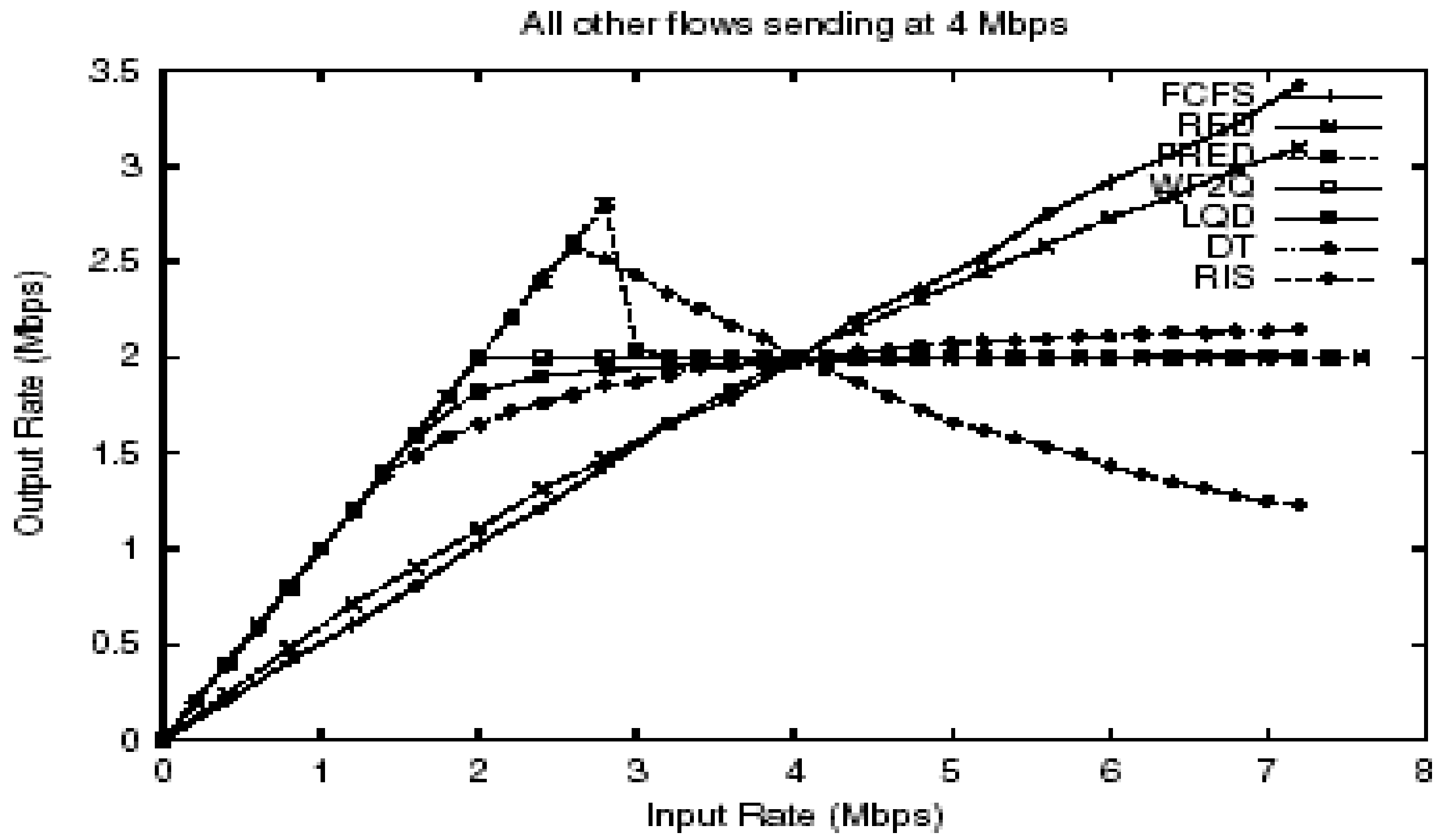
CURRENT CONGESTION CONTROL POLICIES(1/4)

Legend	Queuing discipline	Buffer management policy
FIFO	FIFO	Shared buffers, drop tail
DT	FIFO	Dynamic threshold
RED	FIFO	Random early drop
WF2Q	Worst case fair weighted fair queuing	Per flow buffers, drop tail
LQD	FIFO	Longest queue tail drop
FRED	FIFO	Flow RED
RIS	Rate inverse scheduling	Per flow buffers, drop tail

CURRENT CONGESTION CONTROL POLICIES(2/4)



CURRENT CONGESTION CONTROL POLICIES(3/4)



CURRENT CONGESTION CONTROL POLICIES(4/4)

- For FIFO, RED, and DT resource sharing policies, the only Nash Equilibrium is when the input rates approach infinity. Which can *"encourage congestion causing behavior."*
- For WF2Q, LQD, and FRED, where each user's input rate is more than fair rate constitutes a Nash Equilibrium. Which are *"oblivious to congestion causing behavior."*

DWS(DIMISHING WEIGHT SCHEDULERS)

- It is provided in the Appendix.
- If a flow is experiencing losses, then decreasing the flow’s input rate by a sufficiently small amount will either increase its output rate, or leave it unchanged.
- If a flow is not experiencing losses, then increasing the flow’s input rate by a sufficiently small amount will either increase its output rate, or leave it unchanged.

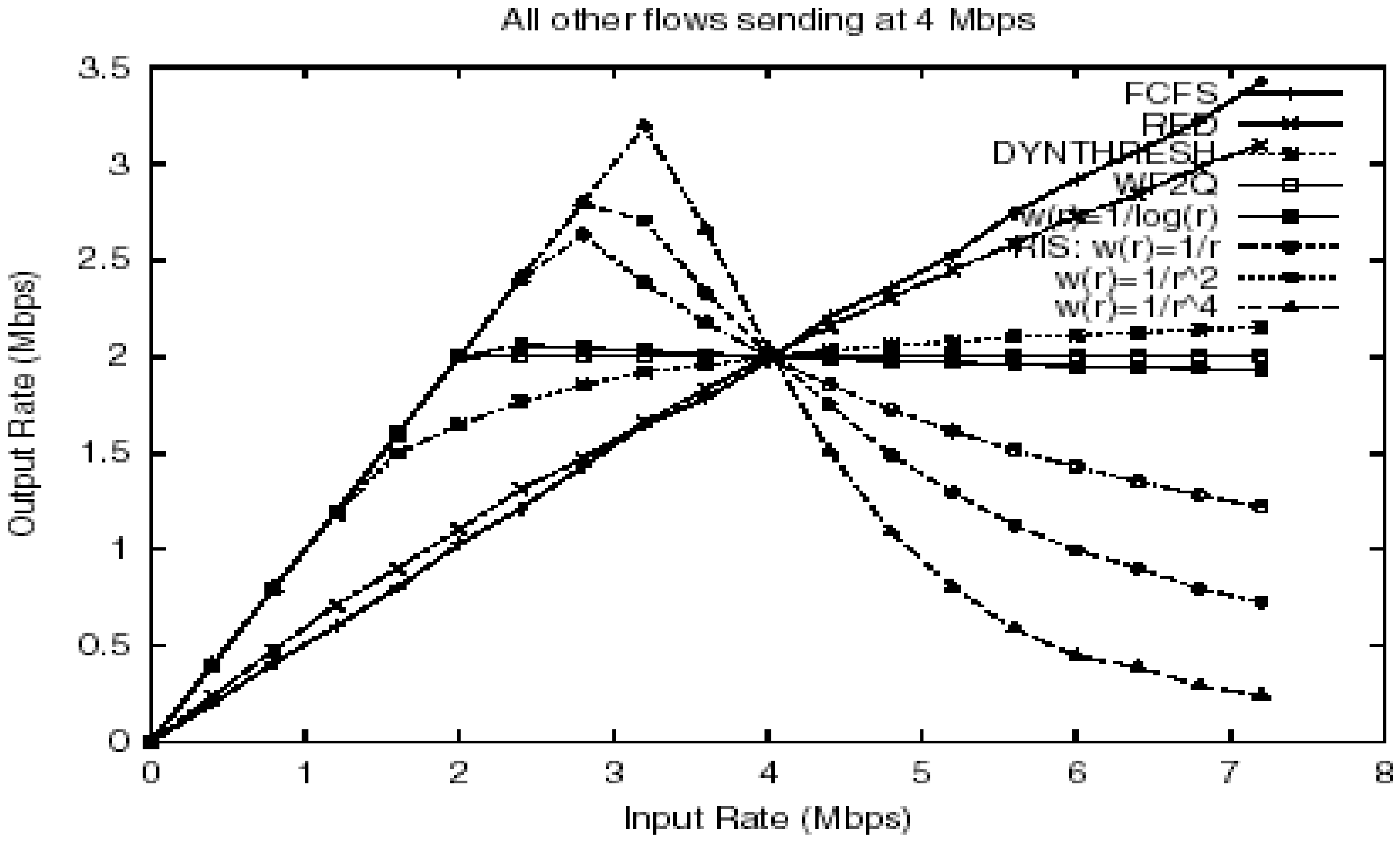
PROPERTIES OF DWS

- Single link：
  - With DWS scheduling, the fair rate is *“the unique”* Nash Equilibrium for the system.
  - For DWS scheduling, Nash Equilibrium and Stackelberg Equilibrium *“coincide”*.
- Arbitrary network of links：
  - *“The max-min fair rates”* constitute a Nash as well as Stackelberg Equilibrium which there are no losses in the system.

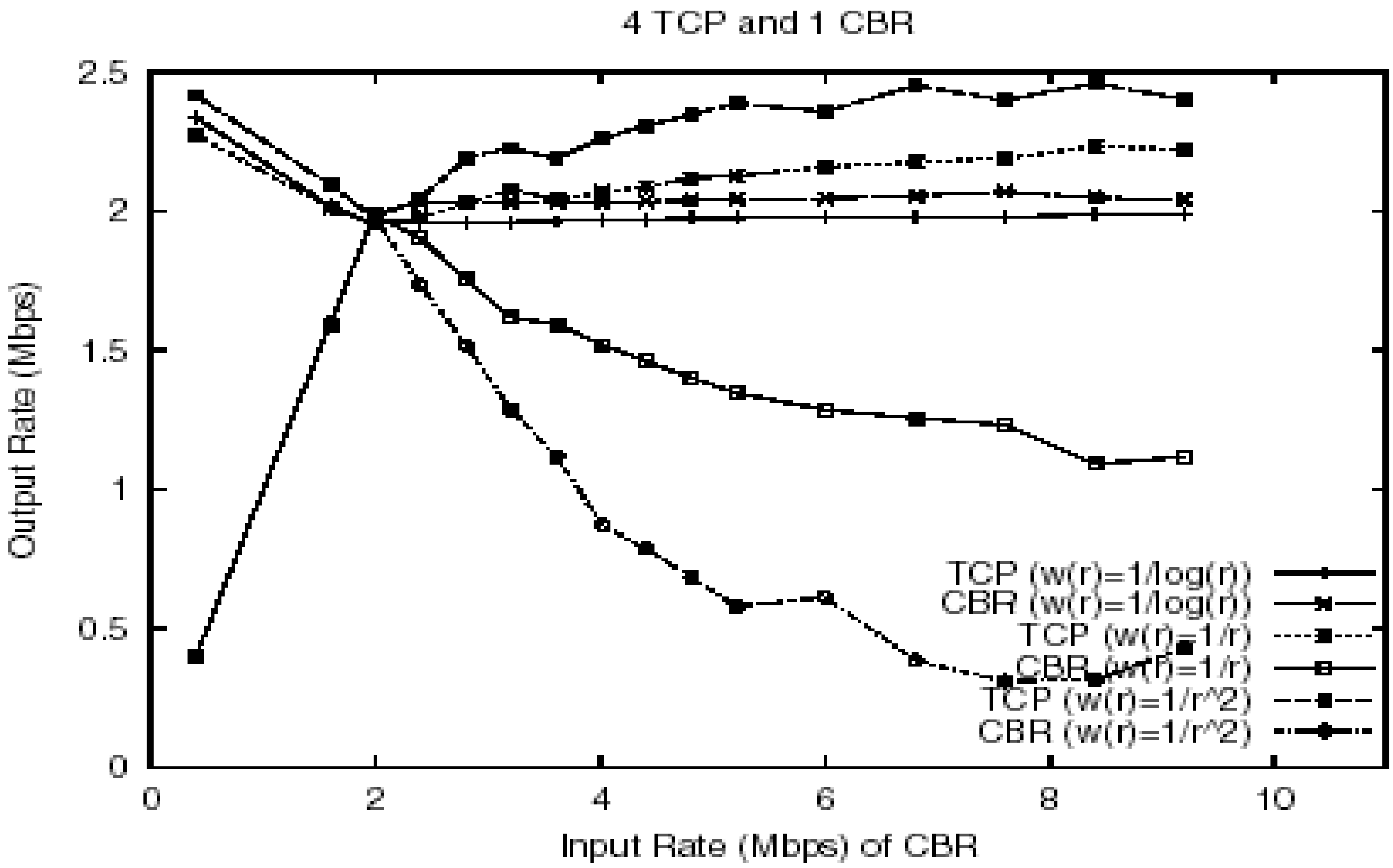
SIMULATION RESULTS(1/7)

- The previous section imply that *“the best behavior”* for a user is to send traffic at its *“max-min fair rate”*. However, a user will not know its max-min fair rate.
- If a link with DWS scheduling is modeled as a game, then TCP-like end user algorithms seem to be reasonable rules to play the game.
- The authors illustrate that *“TCP indeed converge to their max-min fair rate”*.

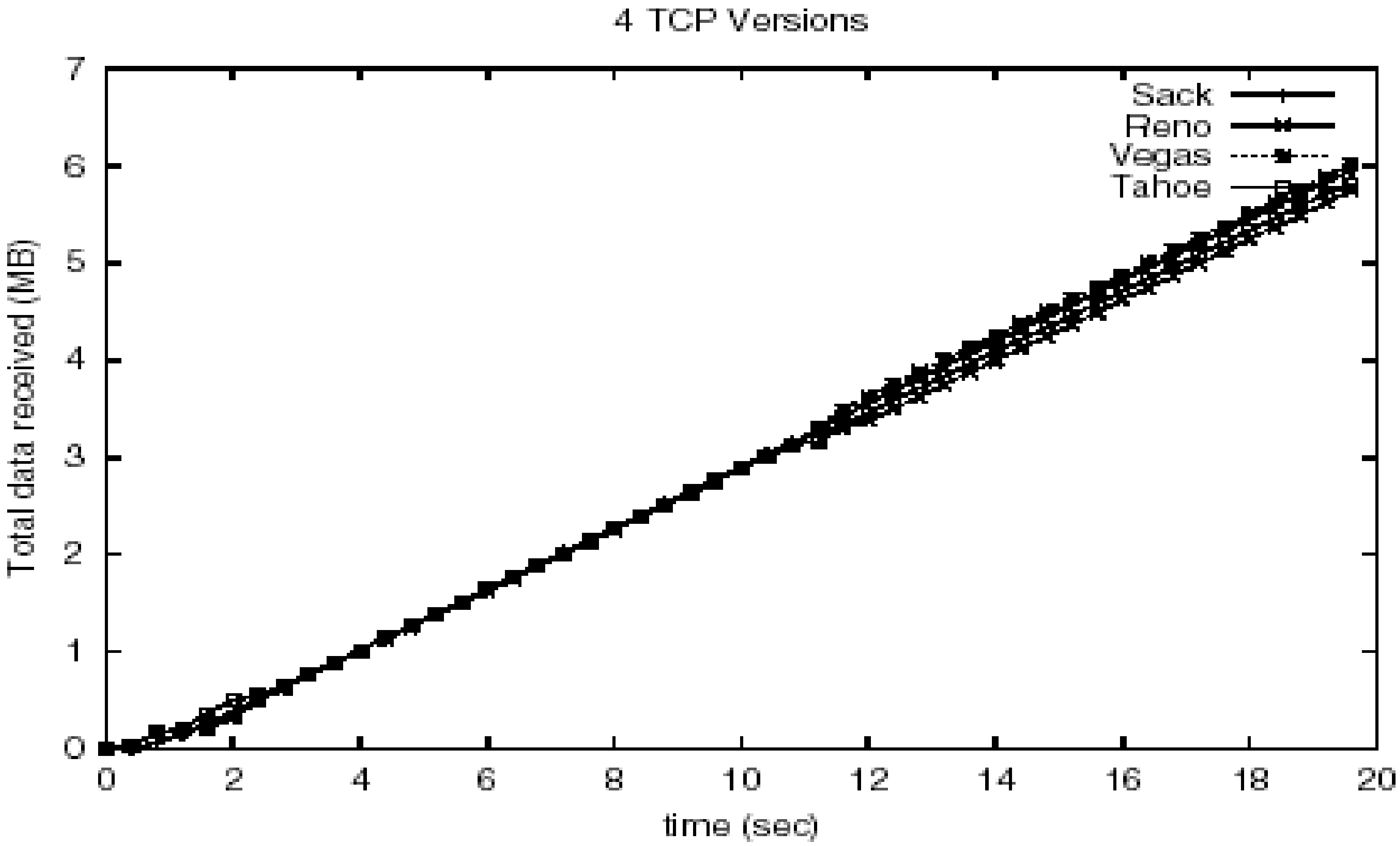
SIMULATION RESULTS(2/7)



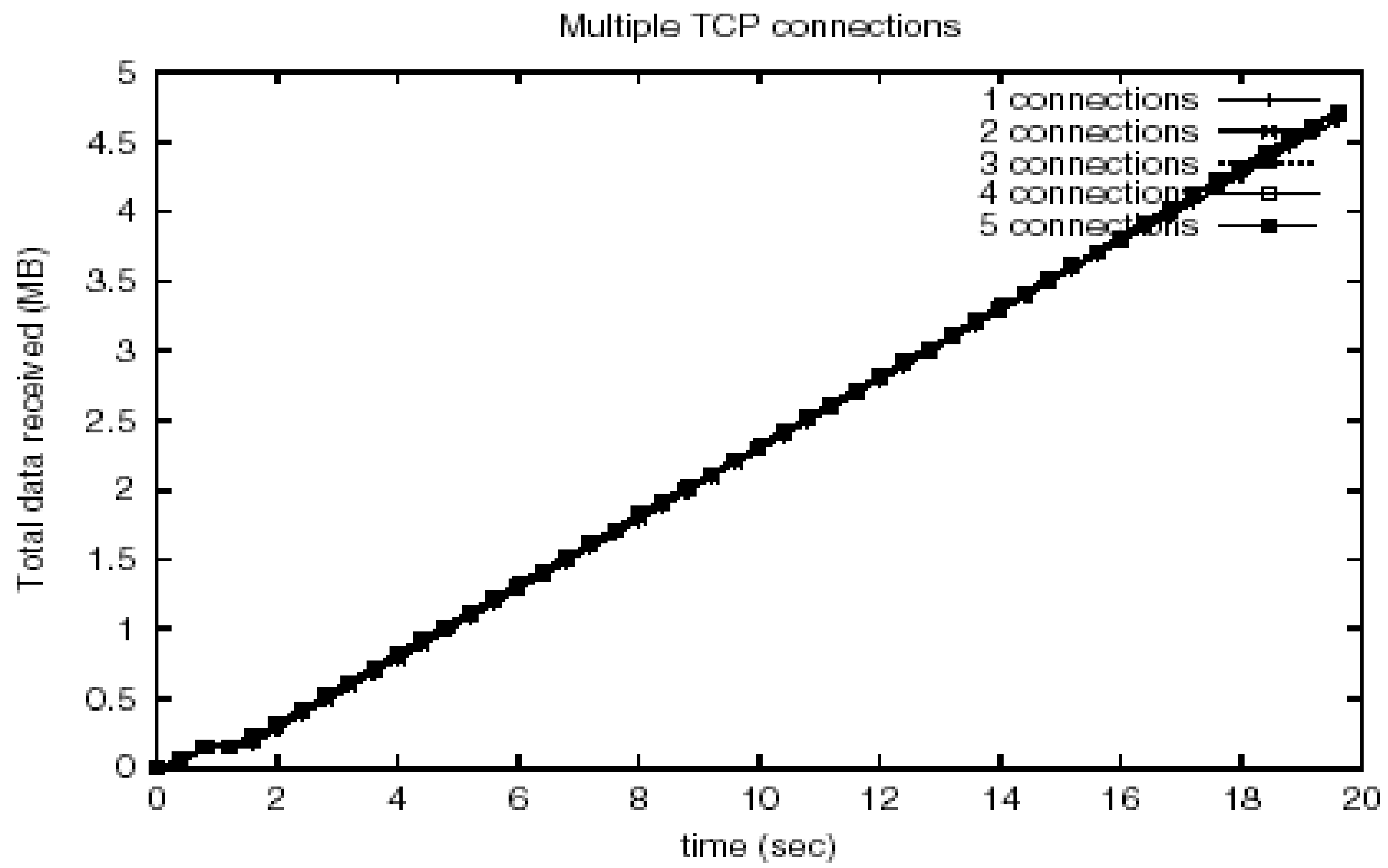
SIMULATION RESULTS(3/7)



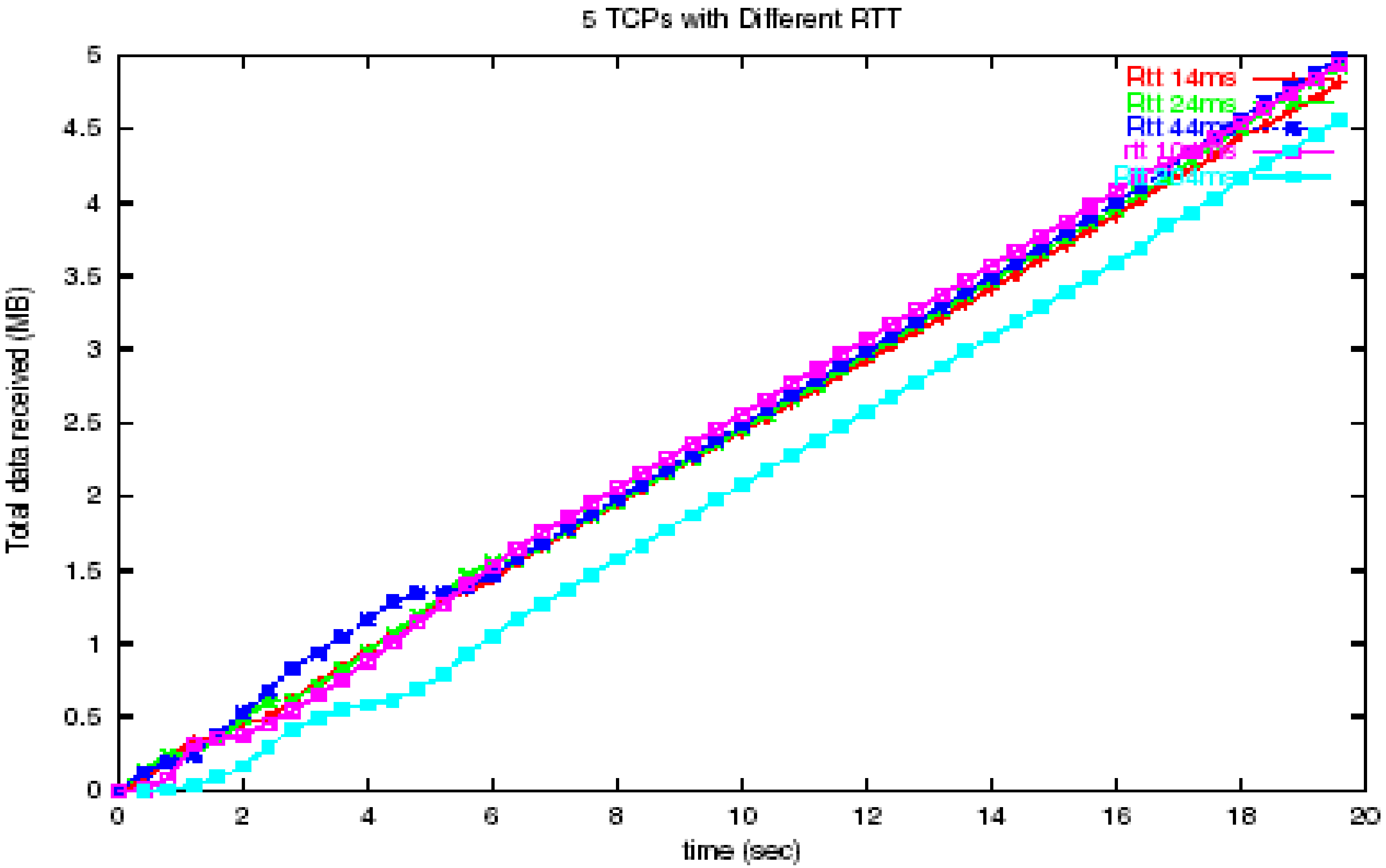
SIMULATION RESULTS(4/7)



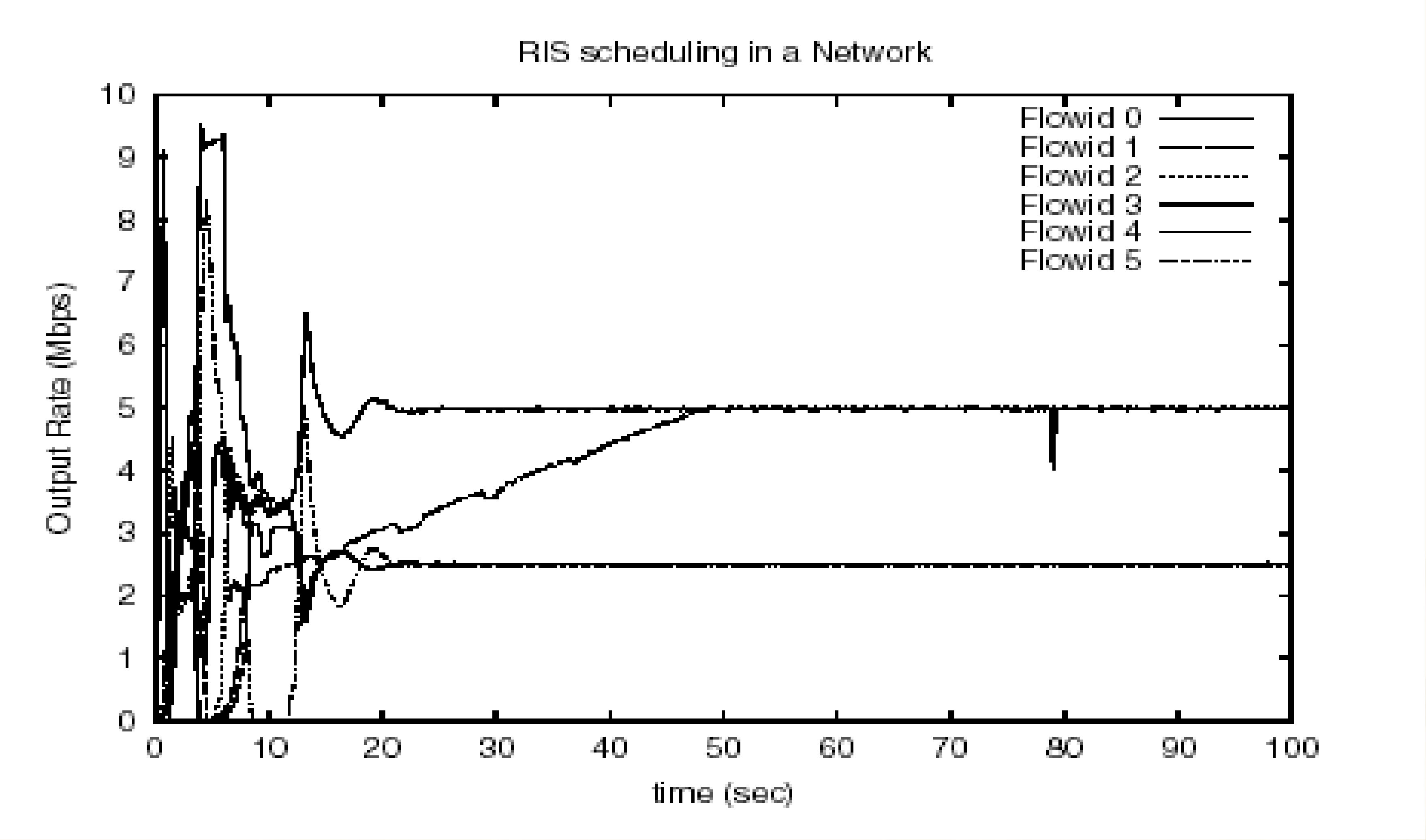
SIMULATION RESULTS(5/7)



SIMULATION RESULTS(6/7)



SIMULATION RESULTS(7/7)



CONCLUSIONS(1/5)

- Using the techniques of game theory, the authors showed that “*the current congestion control mechanisms*” in the router or switch either “encourage congestion causing behavior” or *“are oblivious to it”*.
- The authors proposed a scheduling algorithm by the name *“DWS”* and showed that it *“encourage congestion avoiding behavior”* and *“punish behaviors that lead to congestion”*.

CONCLUSIONS(2/5)

- The authors showed that for a single link with DWS scheduling, *“fair rates constitute the unique Nash and Stackelberg Equilibrium”*.
- They also showed that for an arbitrary network with DWS scheduling at every link, *“the max-min fair rates constitute a Nash as well as Stackelberg Equilibrium”*.

CONCLUSIONS(3/5)

- Although the max-min rate constitute Nash and Stackelberg Equilibrium, it is not clear how users can estimate their max-min fair rates.
- For above, *"a decentralized distributed scheme is required"*. It must be stable and will indeed converge to the max-min fair rates when DWS are deployed in the network.

CONCLUSIONS(4/5)

- Using simulations the authors showed that in a network with DWS, most of the TCP variants are able to estimate their max-min rate well, *“irrespective of their versions and RTT”*.
- They also showed that with DWS, *“the TCP users indeed get rewarded in the presence of unresponsive CBR flows”* which get punished.

CONCLUSIONS(5/5)

- The proposed model requires per-flow queuing and scheduling in the core routers, which may not be very easy to implement.
- However, this paper presents a significantly different view of resource sharing and congestion control on communication networks.