



# **Pricing Models for Differentiated QoS**

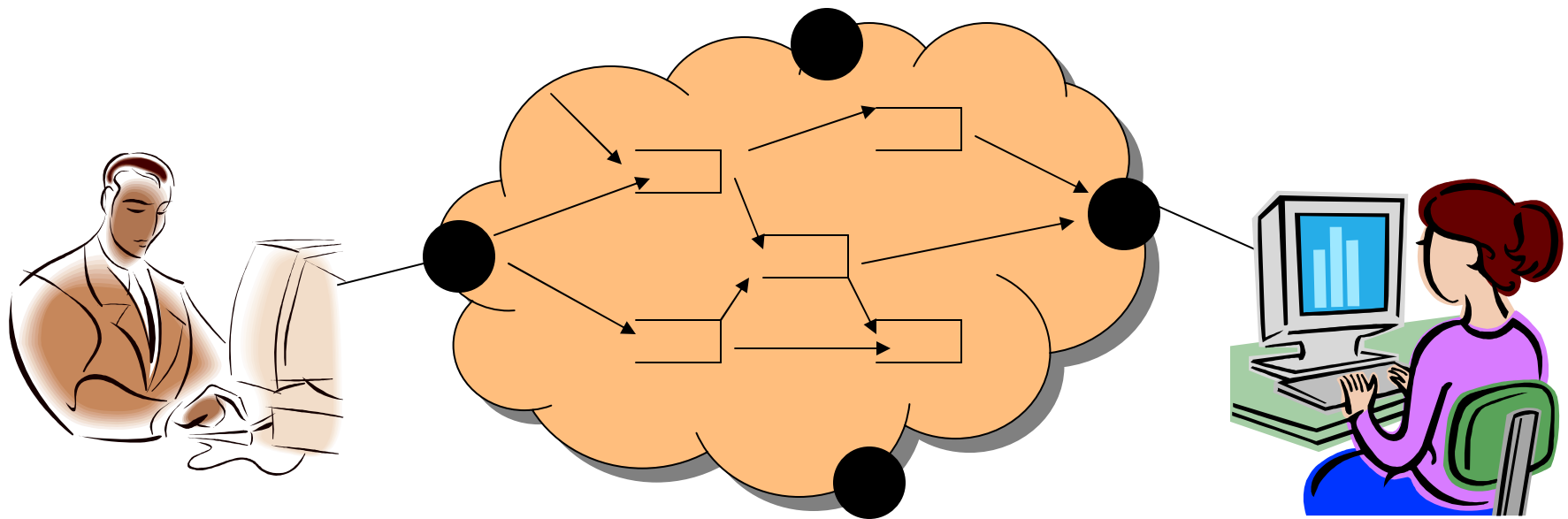
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**Shweta Saraf**

**EE 650**

# Why Differentiated QoS?

- In order to achieve better than the best effort QoS
- Different priority classes are employed at the edge of Internet





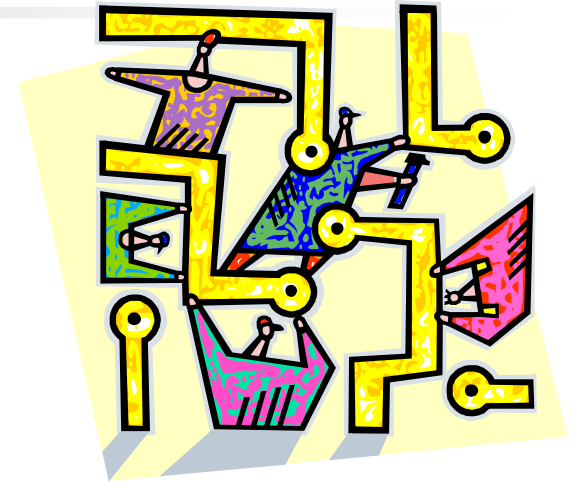
# Existing Pricing Models

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- Pricing schemes for guaranteed services through resource reservation - **RSVP** protocol [Paschalidis and Tsitsiklis, 2000].
- **Paris Metro Pricing** [Odlyzko, 1999], consists in partitioning the network into several logical subnetworks, each subnetwork working as the current one, but with different access charges.
- **Cumulus Pricing** analysed in [Reichl and Stiller, 2001] where positive or negative points are awarded depending on the respect of the predefined contract.
- **Priority Pricing** [Cocchi et al., 1991] among different classes (at the packet level)
- Pricing using **Non Cooperative Game** [Marbach, 2001]
- Pricing based on transfer rates and shadow prices [Kelly et al., 1998].

# Marbach's Model

- Prices per sent-packet are static
- Time discretized in slots
  - higher priority classes served first
  - packets not served in a slot are lost
- Analysis by a non-cooperative game, where each user chooses the allocation among classes which maximize his net benefit
- Proof of existence and uniqueness of an equilibrium



# Marbach's Model (continued)

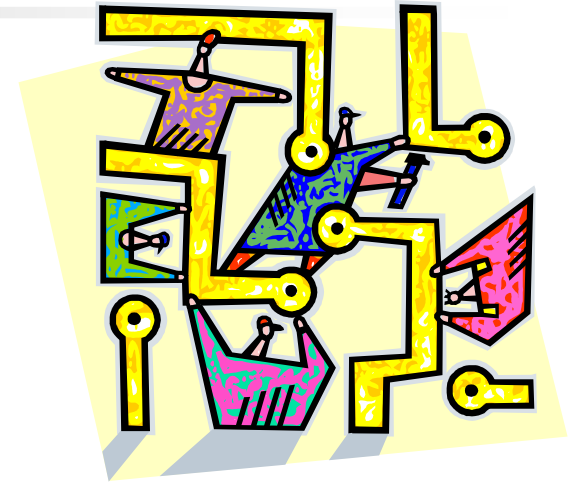
- User r throughput is:

$$x_r = \sum_{i=1}^n d_r(i) P_{tr}(i, d)$$

- User r chooses allocation, such that:

$$d_r^* = \operatorname{argmax}_{d_r} (U_r(x_r) - \sum_{i=1}^n d_r(i) u_i)$$

- Analyzes only a single link model
- Iterative algorithm proposed to establish equilibrium involves complex mathematical analysis



# EE650 Project

- A simplified approach to Marbach's Model
- Analyzing for simple network topologies
- Establishing conditions for Nash equilibrium with suggested model





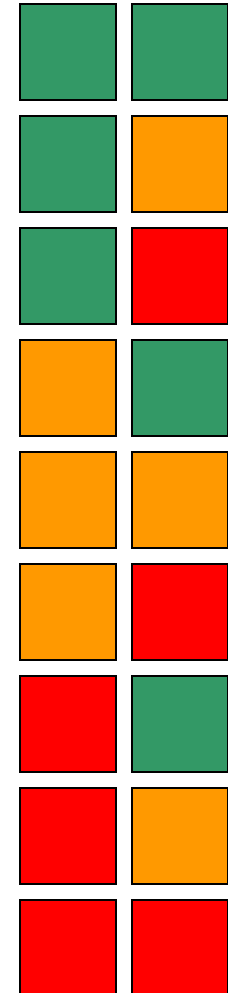
# The Model

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- Pricing is implemented at packets by marking them with low, medium and high priority (red, orange and green)
- Priority imposed at two levels
  - Priority for admittance
  - Priority for service
- If packets belong to the same priority level, they follow FIFO

# Pricing

- Depending on the type of service the packets are marked
- This allows nine level pricing scheme
- Here the first row column indicates **priority of admittance** and second column indicates **priority of service**
- The services utilized by the user can be assigned these priorities depending on the sensitivity to the delay



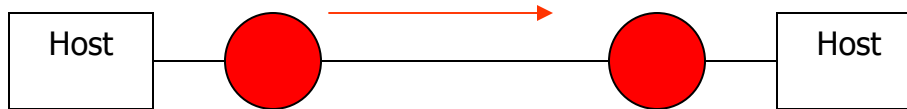


# Analysis

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- $t_i$  - Type of the service received by the  $i$ th user
- $P_i(t_i)$  – Performance for  $i$ th user with service  $t_i$
- Utility = Performance - Cost
- $U_i = P_i(t_i) - C_i$
- $\sum P_i(t_i(\sigma_{\max})) \geq \sum P_i(t_i(\sigma))$
- $\sigma$  represents Nash Equilibrium if for all  $I$  and  $\sigma$ ;  $U_i(\sigma) \geq U_i(\sigma / \sigma')$

# Network Topology & Traffic



## Different Types of Traffic

1. Voice
2. MPEG
3. FTP
4. Telnet
5. Email



# Simulation Results

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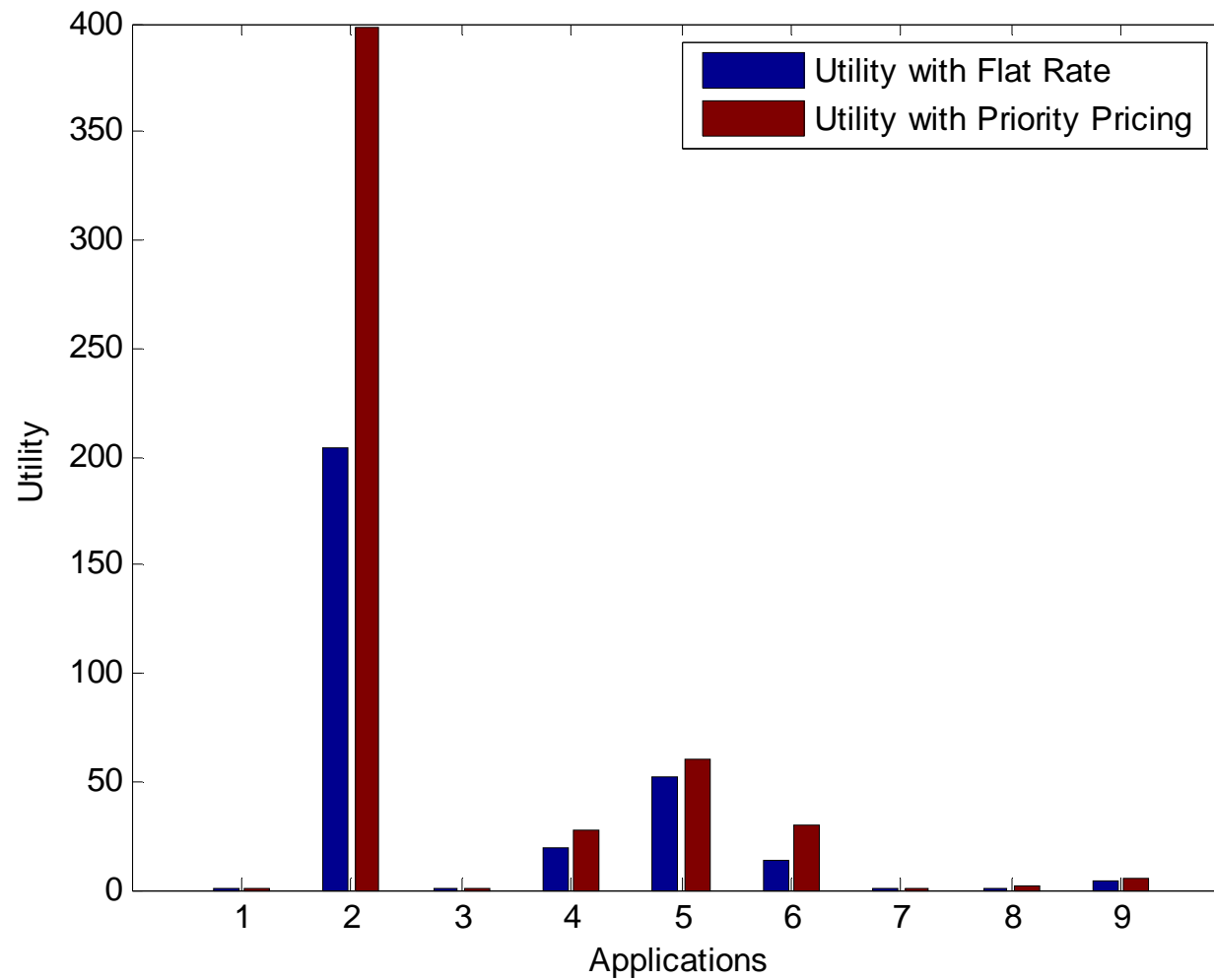
**Assumption:** The traffic flows are with normal link having a delay of 1ms and bandwidth of 10Mbps.

Traffic load on Network:

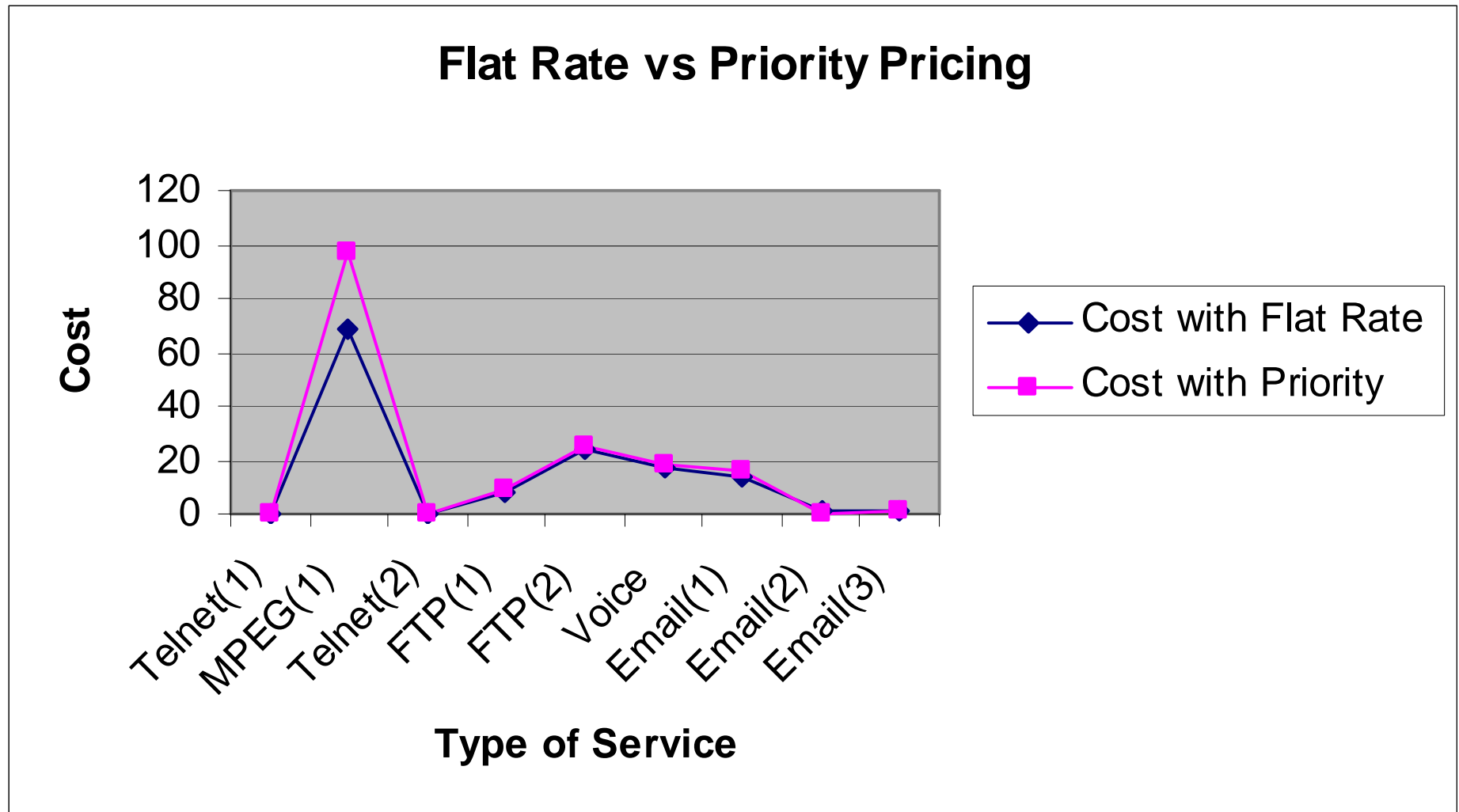
Traffic Load in KBs

Telnet(1)	0.005
MPEG(1)	12000
Telnet(2)	100
FTP(1)	500
FTP(2)	1000
Voice	12
Email(1)	5
Email(2)	100
Email(3)	15

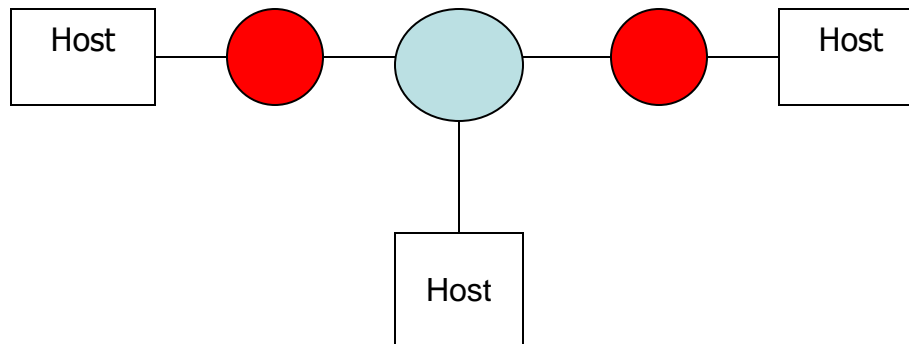
# Simulation Results



# Comparison with Flat Rate Pricing

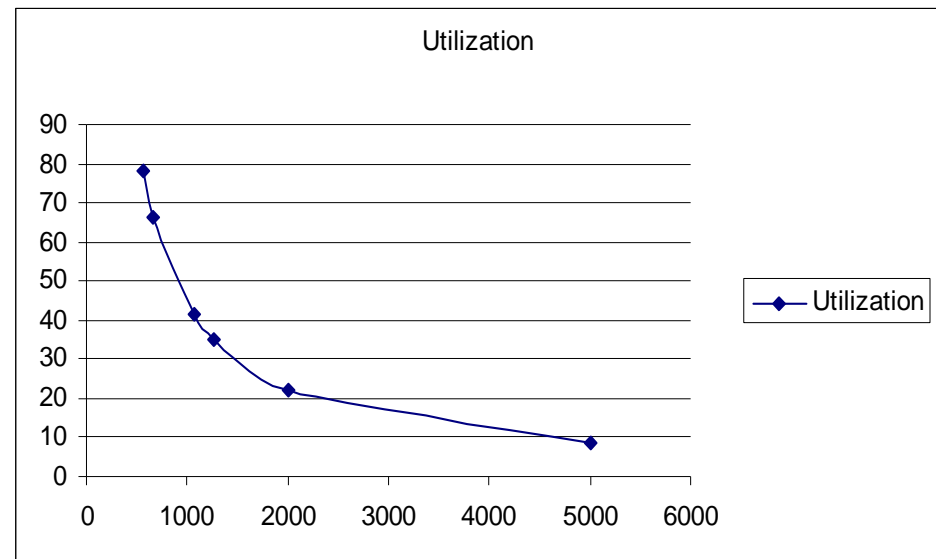


# Another Network Topology

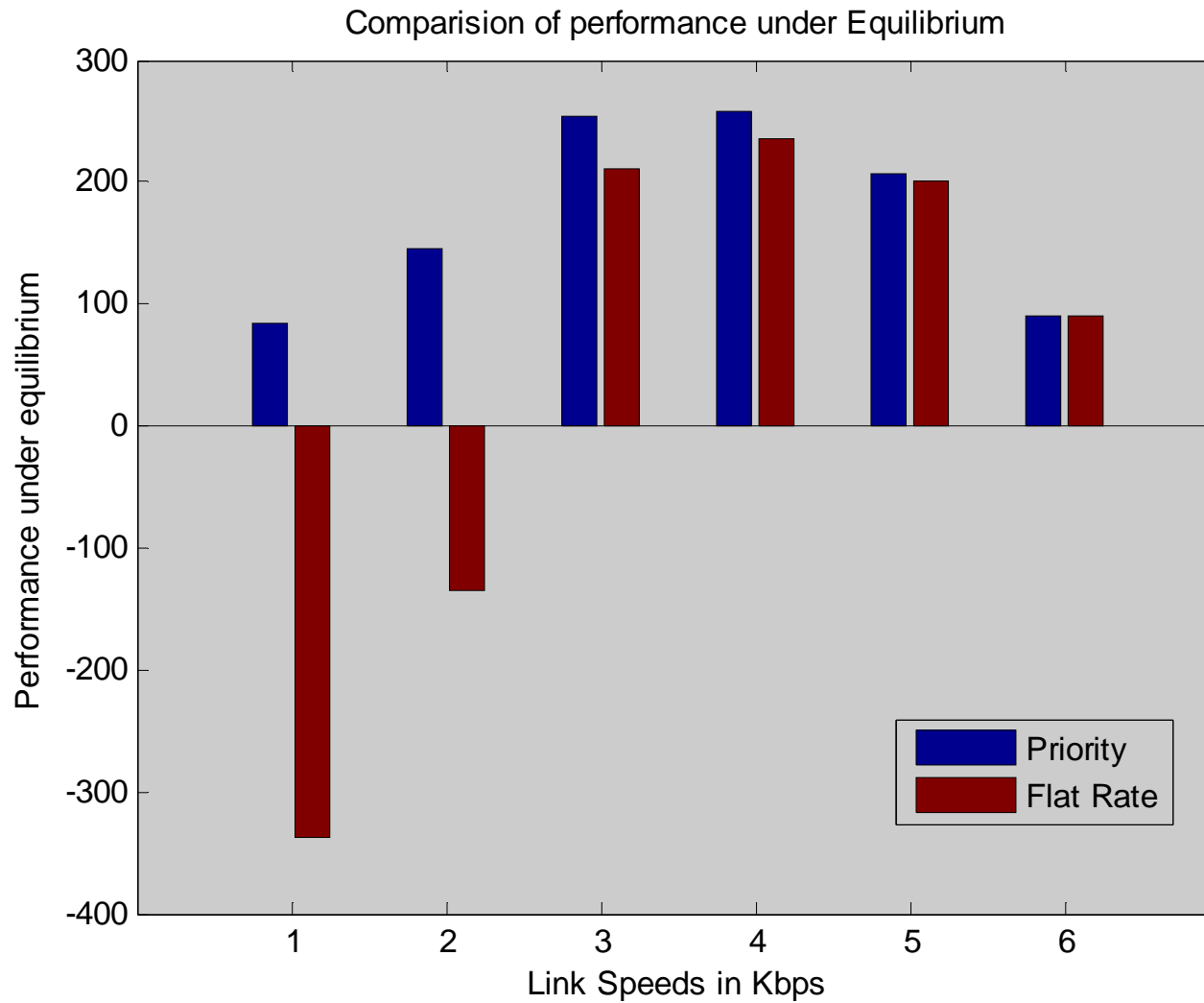


Equilibrium conditions over various link speeds

Link Speed	Utilization	Priority
570	78.01	GGGOR
670	66.37	GGGOO
1070	41.56	GGOOR
1270	35.01	GOOOR
2000	22.23	GOORR
5000	8.89	GOROR



# Simulation Results





# Conclusions

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- The pricing did help to achieve better utility function and hence better QoS.
- The cost of pricing scheme is comparable to Flat Rate and shoots high only for high priority, high traffic applications.
- Nash Equilibrium exists for certain range of pricing scheme.
- As the link speeds increase the utilization of network decreases under equilibrium.



# Future Work

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- To carry out more simulations for different topologies
- To introduce higher level pricing scheme
- To establish conditions in order to maintain equilibrium when the pricing policy is changed
- To consider the effect of feedback mechanism on prices instead of static prices



# References

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# Thank You

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