# Applying Repeated Games to Networking Problems

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## 1. OVERVIEW

In our research, we examine the impact of applying repeated game models to networking problems. Repeated interactions are prevalent in networking applications and well-studied in Economic literature. Here, we present the results of applying repeated game models to two well-known results. The first is the celebrated strategyproof routing mechanism of Feigenbaum *et al* (FPSS) [1]. The second is application overlay application trees. In both we find, through counter-examples, that the traditional models are unsatisfactory. However, from this negative result we find two *positive results* in the repeated framework. As such the contributions of our work are:

1. The application of repeated games to two well understood problems and recognized results.
2. The conclusion that the FPSS model is not strategyproof in a repeated environment, a significant problem for a routing protocol.
3. Analysis of the equilibrium conditions, which provide an understanding of the relationship between system parameters and the outcome. This in turn provides useful insights into how such systems should be built.

## 2. LEAST COST PATH ROUTING

The FPPS mechanism for inter-domain routing is strategyproof – each network bids truthfully. The mechanism pays a node k, on the Least Cost Path (LCP) from s to t, *(Cost_of_LCP(s,t)_Without_k - Cost_of_LCP(s,t)_With_k)+* $cost_k$. For example, in Fig. 1, node A, on the LCP from s to $t_1$, is paid: $(1+10)-(1+1)+1=10$. However, this mechanism is *not strategyproof in the repeated game.* In Fig. 1, A and B both can (implicitly) collude to bid higher, for example, 20. Now each is paid $(20+10)-(20+1)+20=29$.

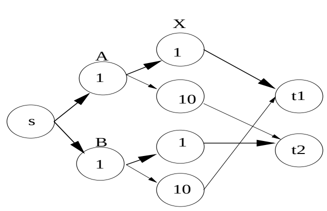
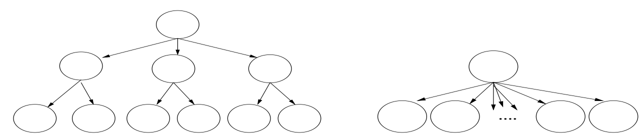



**Figure 1: FPSS not Strategyproof when Repeated**

To better understand this overcharging, we develop a formal model of the game and analyze its equilibrium. This requires us to examine several modeling questions involving equilibria notions and classes of protocols. The model then enables us to deterime the impact of the properties of the protocol on the resulting price. Several of the conclusions, summarized in Table 1 are quite surprising. For example, it matters if we use Mega*bits* or Mega*bytes* – and further that decreasing the period of the protocol may increase price.

**Table 1: Impact of Parameters on Overcharging**

| As *[Variable]* Increases | Impact on Overcharging |
|---|---|
| $N$ : Number of players | Decreases |
| $b$ : Minimum bid size | Increases |
| $d$ : Period of the protocol | Decreases |
| $D$ : Stability period of topology | Increases |



(a) Efficient Topology (b) Selfish Users

**Figure 2: Selfish Users Lead to a Different Topology**

## 3. APPLICATION OVERLAY TREES

Application overlays have been proposed as a way of achieving the benefits of IP multicast. In practice, as discussed [2], the utility of a node decreases as it moves away from the source and also as it supports more children. Instead of topologies as in Fig. 2a, sufficiently greedy users will produce Fig. 2b.

In our research, we build a model of this interaction where users' greed is tempered by their desire for the network to continue to exist. With this model we solve for the equilibrium conditions and simulate the interactions on a BRITE-generated network topology. In our model, users' greed is tempered by their desire to ensure the network's continued existence, which in turn is a function of its efficiency. This allows us to determine the relationship of parameters such as the cost of adding children or $\delta$, the patience level, on network efficiency and maximum size. In turn we are again able to make recommendations for system design.

## 4. REFERENCES

[1] J. Feigenbaum, C. Papadimitriou, R. Sami, and S. Shenker. A BGP-based mechanism for lowest-cost routing. In *Proceedings of the 2002 ACM Symposium on Principles of Distributed Computing*, 2002.

[2] L. Mathy, N. Blundell, V. Roca, and A. El-Sayed. Impact of simple cheating in application-level multicast. In *Proc. of IEEE Infocom*, 2004.