A Microeconomic Approach to Intelligent Resource Sharing in Multiagent Systems

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We have analyzed characteristics of sharable resources and developed techniques for intelligently sharing resources—specifically, communication channels—among agents in multiagent systems. Our techniques allow agents to nearly optimize their communication behavior in a distributed fashion, involving the use of a microeconomic pricing system based on economic laws of supply and demand and trading among agents in real-time. Our analyses are based on three measures of performance: fairness of resource allocation, utilization of resources, and waiting time for resources.

Our initial analysis indicates that *fairness* and *utilization* conflict under any statically-defined resource allocation policy. Suppose that two agents, a and b attempt to send an infinite number of messages through the shared communication channel with probability, called *transmission-potential*, P_a and P_b, respectively. The utilization of the channel is $P_a(1-P_b)+P_b(1-P_a)$. On the one hand, with a fair policy ($P_a = P_b$), the *maximum* utilization, .5, occurs at $P_a = P_b = .5$. On the other hand, with a biased policy ($P_a = 1-P_b$), the *minimum* utilization, .5, occurs at $P_a = 1 - P_b = .5$. From this analysis, we conclude that when there are infinite messages to send, the best "fair" allocation of potentials corresponds to the worst "unfair" allocation.

Utilization, however, is not the only interesting parameter. The mean message delay is also important for timely communication. Unfortunately, high utilization and low delay are inherently in conflict. For example, if one agent alone has all the potential, the channel utilization is maximized to 1 (assuming infinite pending messages), but the mean message delay is infinite. The simplest way to overcome this problem is to alternate transmission potentials between the two agents, so they take turns with the channel.

Simply swapping 1/0 potentials works very well with infinite messages, but if we relax this assumption, some bandwidth of the channel may be wasted because the agent may have no message to send while it is holding all the potential. Rather than having some static "turn-taking" behavior, the system would be more adaptive if agents could "trade" potential as needed. Our approach is thus to have an agent *trade* surplus transmission-potential if another agent is willing to purchase more potential. In our model, each agent pays to deliver messages, where the *price* of the channel changes based on current supply and demand, and what an agent can afford to send is limited by its initial budget, its regular (periodic) income, and its previous spending history. Thus, if multiple agents want to send, no agent can afford to hold the entire transmission-potential all the time. Moreover, as needs to send fluctuate, agents can trade transmission-potential for their mutual benefit. To identify such trades, each agent periodically announces information about its *B*udget for the next period, its transmission *C*apacity calculated in budget units, and the budget it needs to send all expected *M*essages for the next period. We have developed heuristic criteria for trading decisions based on the BCM information. For example, if an agent has $C > M > B$, it has sufficient transmission capacity C to send all messages M, but its budget B is insufficient to use all of its capacity. Hence the agent should trade away some of its unusable capacity to increase its budget. If $(C-M) \leq (M-B)$, the best deal for the agent is selling $(C-B)/2$, thereby increasing its budget by that much.

Our preliminary evaluations have highlighted how, with fair incomes among agents, agents that are more taciturn receive higher utility when they do communicate—selling their usual silence leaves them with a high budget to get messages through when they need to. A more talkative agent, however, has greater access to the channels most of the time. Our approach is relatively cheap and simple, and thus applicable for dynamic real-time communications where other market-oriented mechanisms requiring equilibration among agents would be infeasible. Our model, however, needs to be extended to provide heuristics in cases with more than two agents, and to be enhanced to ensure truthful information revelation.

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