A Quantitative Analysis of the Contract Net Protocol

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The Contract Net Protocol (CNP) [Smith, 1980] assigns a subtask to agents which are involved in multiagent problem solving. Although the logical aspects of the negotiation protocol have been analyzed, the properties of protocol dynamics remain unclear. This paper introduces our quantitative analysis of protocol dynamics which is essential for constructing continuous realtime applications.

We carried out a simulation which based on queueing theory to practice the purpose described above. Two kinds of agent, *manager* and *contractor*, exist within the simulation. Managers provide tasks to contractors which undertake them as follows: first, when a task arrives, the manager responsible for it announces it with a bidding deadline to all of contractors immediately; second, each contractor selects from all the announced tasks, the one that best matches its own standards, and bids for it; finally, the manager chooses the most appropriate bid, and awards it to that agent; a manager can make multiple announcements simultaneously while a contractor can bid for only one task at a time. Each manager and contractor has a evaluation function f_i and g_j, respectively. Manager i awards a bidder that achieves $\max_j[f_i(j)]$ and contractor j selects a task that achieves $\max_i[g_j(i)]$. The f_i and g_j is generated as a list containing the natural numbers from 1 to 100. The service time for a task and the bidding period is fixed at 1 and 0.1 respectively. We say managers or contractors are homogeneous when $f_{i_1}(j) = f_{i_2}(j)$ or $g_{j_1}(i) = g_{j_2}(i)$, otherwise heterogeneous. The manager utility and the contractor utility is respectively calculated by $\frac{1}{cn_m}\sum_{i=1}^{n_m}\sum_{j=1}^{c} f_i(j)$, wherein c is the number of the concluded contracts awarded by manager i, n_m is the number of managers, and $\frac{1}{tn_c}\sum_{j=1}^{n_c}\sum_{i=1}^{t} g_j(i)$, wherein t is the number of tasks served by contractor j, n_c is the number of contractors.

We obtained the following results from the simulation: the contractor utility increases along with the system load while the manager utility decreases (figure 1a); when the number of agents increases, the contractor utility rises while the manager utility does not change (figure 1b); the uniformity of agents causes the concentration of bids and awards, and thus decreases the manager and the contractor utility (figure 1c). In conclusion, the initiative shifts from managers to contractors as the system load increases. However, the changes of utilities are not symmetrical when both the parameters of the number of agents and the uniformity of agents change.

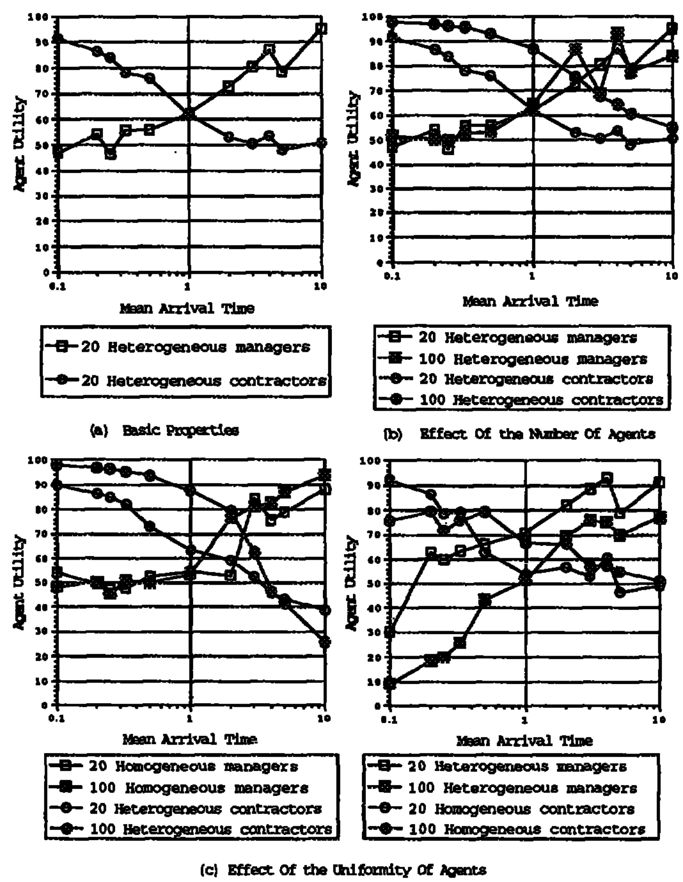

Figure 1: Simulation Results

[Smith, 1980] R. G. Smith, "The Contract Net Protocol: High-Level Communication and Control in a Distributed Problem Solver," *IEEE Trans on Computers*, Vol. 29, No. 12, pp. 1104-1113, 1980.