Theoretical Evaluation of Ring-Based Architectural Model for Middle Agents in Agent-Based System

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Abstract. Ring-based architectural model is usually employed to promote the scalability and robustness of agent-based systems. However there are no criteria for evaluating the performance of ring-based architectural model. In this paper, we introduce an evaluation approach to comparing the performance of ring-based architectural model with other ones. In order to evaluate ring-based architectural model, we proposed an application-based information-gathering system with middle agents, which are organized with ring-based architectural model and solve the matching problem between service provider agents and requester agents. We evaluate the ring-based architectural model with performance predictability, adaptability, and availability. We demonstrate the potentials of ring-based architectural model by the results of evaluation.

1 Introduction

The organizational structure and coordination mechanism of an agent-based system determine the interaction performance among agents. Organizational structure presents the interrelationship among agents in a system. The organizational structures have been modeled into four types, namely, Peer-to-Peer (P), Tree (T), Grouping with facilitator (F), and Ring (R) in practical agent-based systems [3]. Coordination mechanism is the protocols to manage inter-dependencies between the activities of agents. Coordination mechanisms have been classified into five patterns, namely, Direct search (D), Matchmaker (M), Broker (B), Contract-net (C), and Token Ring (TR) [3]. Twelve architectural models for agent-based systems have been proposed by combination of the organizational structures (OS) and coordination mechanisms as shown in Table 1.

Table 1. Practical architectural models

OS	D	M	B	C	TR
P	P-D	-	-	P-C	P-TR
F	-	F-M	F-B	F-C	-
T	-	-	T-B	T-C	-
R	-	R-M	R-B	R-C	R-TR

A key issue concerning agent-based systems with middle agents is how to organize requester agents, middle agents, and service provider agents so that the requester agents can receive appropriate services quickly and efficiently. The combination of R-M and R-TR architectural models can solve the problem because they concentrate on the features of middle agents [3]. However there are no criteria for evaluating the performance of ring-based architectural model. In this paper, we introduce an evaluation approach to comparing the performance of ring-based architectural model with other ones. In order to evaluate ring-based architectural model, an application-based information-gathering system from websites is designed. We evaluate the practical architectural models with performance predictability, adaptability, and availability. We demonstrate the potentials of ring-based architectural model by the result of evaluation.

The remaining sections of this paper are organized as follows: Section 2 chiefly presents the related work about this research. Section 3 introduces the evaluation approach. Section 4 concludes the paper.

2 Review of related work

The evaluation paradigms of agent-oriented technology might be categorized into three levels: agent coordination level, individual agent behavior level, and agent-oriented methodology level. Bourne et al. proposed a formal framework within which autonomous agents could dynamically select and apply different mechanisms to coordinate their interactions with one another [1]. Agents used the task attributes and environmental conditions to evaluate which mechanism maximized their expected utility. Mali et al. defined power, usefulness, flexibility, modularity, and reliability to evaluate properties of agent behavior sets [4]. Cernuzzi et al. proposed a framework for evaluating methodologies, so that agent-based system designers and authors of agent-oriented methodologies might carry out the evaluation and accumulation of experience [2]. However the framework lacks enough accurate methods to evaluate every attribute. Our research promotes the interaction attribute of the attribute tree of the framework.

3 Evaluation of Ring-Based Architecture

We evaluate the ring-based architectural model with performance predictability, adaptability, and availability. The performance predictability can be measured by complexity and efficiency of the system. Adaptability is measured by extendibility of the system. (Note that all following comparisons are based on Lee and Kim's research at Korea University).

3.1 Complexity

Complexity measures the number of links among agents or middle agents in organizational structure. The more the number of interactions between agents is, the

more complex agent-based system is. If agent-based system is designed by using the peer-to-peer structure, the complexity of the system will be highest because agents in peer-to-peer structure are fully connected. Complexity (C) is defined as following.

C = Number of links among agents

For each organizational structure, the detail formula for the complexity is different. The formulae for each structure are defined as following (C_p means the complexity of peer-to-peer structure; C_f means the complexity of grouping with facilitator structure; C_t means the complexity of tree structure; C_r means the complexity of ring structure).

$C_p = n(n-1)/2$

where n is the number of agents.

$C_f = f(f-1)/2+\sum(n_i(n_i+1)/2)$

where f is the number of middle agents; n_i is the number of agents under the $_i$th middle agent.

$C_t = sum(in\text{-}degree(f_i), out\text{-}degree(f_i))$

where f_i means $_i$th middle agent (i = 1,2…n); n is the number of middle agents in the tree structure.

$C_r = N_f+N_s+2m+mN_s+\sum(n_i(n_i-1)/2)$

where N_f means the number of middle agents; N_s means the number of service provider agents; n_i means the number of requester agents in $Group_i$ (i = 1,2…m; m is the number of groups).

According to the case study (the system includes 9 agents and 4 middle agents) in our research, the Cr is 26, which is worse than Tree (less than 20) but better than Peer-to-Peer and Grouping with facilitator (between 30 to 70).

3.2 Efficiency

Efficiency measures the number of links from service request to completion of the service. Efficiency (E) is defined as following.

E = Number of interactions until completion after receiving request

The formulae for each structure are defined as following (E_p means the efficiency of peer-to-peer with contract-net coordination mechanism; E_f means the efficiency of grouping with facilitator; E_t means the efficiency of tree structure with broker coordination mechanism; E_r means the efficiency of ring structure).

$E_p = (n-1)*3+1$

where n is the number of agents.

$E_f = N_l+N_f+N_r$

where N_l is the number of interactions among agents under a local middle agent; N_f is the number of interactions among local middle agents; N_r is the number of interactions among agents under the remote middle agent.

$E_t = N_l+N_f+N_r$

where N_l is the number of interactions between agents and local middle agent; N_f is the number of interactions between local middle agent and global agent; N_r is the number of interactions between remote middle agent and agents under it.

$E_r = N_l+N_f+N_r+N_s$

where N_l is the number of interactions among agents under a group; N_f is the number of interactions between agent and its middle agent; N_r is the number of

interactions among middle agents; N_s is the number of interactions between requester agent and service provider agent.

According to the case study, the E_r is 20, which is better than Tree, Peer-to-Peer and Grouping with facilitator (Between 30 to 50).

3.3 Extendibility

Extendibility is to evaluate the adaptability of agent-based system. When a new type of service request is introduced into the system, it is necessary to reconfigure the existing system. Reconfiguration includes change, replacement, deletion and addition of agent or middle agent. Extendibility (EL) measures the resources that need to add an agent or middle agent to the existing system. It is defined as following.

EL = Number of links that need to add agent or middle agent

The formulae for each structure are defined as following (EL_p means the extendibility of peer-to-peer structure; EL_f means the extendibility of grouping with facilitator structure; EL_t means the extendibility of tree structure; EL_r means the extendibility of ring structure).

$EL_p = n$

where n is the number of agents.

$EL_f = n+1$ (if an agent is added) or

$EL_f = 2$ (if a middle agent is added)

where n is the number of agents under the middle agent.

$EL_t = 1$

$EL_r = n$ (if a requester agent is added) or

$EL_r = 4$ (if a pair of middle agents are added) or

$EL_r = 1$ (if a service provider agent is added)

where n means the number of requester agents in the group.

According to the case study, the most EL_r is 4, which is worse than Tree (1) but better than Peer-to-Peer and Grouping with facilitator (7, 12 respectively). From this measure, we can reason whether an organizational structure can be easily extend. Ring structure is more scalable than peer-to-peer and grouping with facilitator.

3.4 Availability

When agent or middle agent is abnormal, agent-based system may occur erroneous behaviors. The abnormal situations can be occurred by fault or malicious action. If local middle agent in tree structure is abnormal, agents under the middle agent cannot act and consequently the availability of system decreases. Availability (A) is defined as following.

$A = (C-F)/C$

where: *C means Complexity;*

F = Number of links connected to abnormal agent or middle agent.

The formulae for each structure are defined as following (A_p means the availability of peer-to-peer structure; A_f means the availability of grouping with facilitator; A_t means the availability of tree structure; A_r means the availability of ring structure).

$A_p = (C_p – F_p)/C_p$

$F_p = n\text{-}1$

where n is the number of agents.

$A_f = (C_f – F_f)/C_f$

F_f = sum(the number of peer middle agents, the number of agents connected to the fault middle agent)

$A_t = (C_t – F_t)/C_t$

$F_t = 1$ (If an agent is abnormal) or

F_t = sum(in-degree(f_i), out-degree(f_i)) (If a local middle agent is abnormal) or

$F_t = C_t$ (If global middle agent is abnormal)

where f_i means $_i$th middle agent ($_i$ = 1,2…n); n is the number of middle agents in the tree structure; out-degree(f_i) includes all offspring links of f_i.

$A_r = (C_r – F_r)/C_r$

$F_r = n_i$ (If a requester agent is abnormal) or

$F_r = 4$ (If a middle agent is abnormal) or

$F_r = 1$ (If service provider is abnormal)

where n_i means the number of requester agents in $Group_i$ (i = 1,2…m; m is the number of groups).

According to the case study, the least A_r is 0.85, which is similar with Tree, Peer-to-Peer and Grouping with facilitator (Between 0.8 to 0.9). If the coordinator in ring structure is abnormal, A_r will decrease to a lower point (about 0.65). However, the coordinator can be automatically regenerated if it is abnormal.

4 Conclusion

Although the extendibility and availability are not better than tree structure, these factors can be improved by organizing the agents in a group (application) when the application is designed. The result of this research shows that the ring-based middle agent architectural model can be used as a basis for the agent-based systems that need to use middle agents.

References

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