A Taxonomy of Middle-agents for the Internet*

H. Chi Wong and Katia Sycara
The Robotics Institute
Carnegie Mellon University
Pittsburgh, PA, 15213
hcwong@cs.cmu.edu, katia@cs.cmu.edu

Abstract

Like middle-men in physical world, middle-agents assist in locating and connecting the ultimate (information or goods) provider with the ultimate requester in the electronic world.

In this paper, we identify a basic list of dimensions along which middle-agents can differ from one other, and derive a taxonomy.

1 Introduction

In an open multi-agent system, there are two types of agents: *end-agents* and *middle-agents*, henceforth denoted by *MAs*. End-agents act as *providers* when they offer services; and *requesters* when they need them. MAs exist to enable interactions among end-agents.

Different systems define their MAs differently. For example, facilitators in Genesereth's federated systems [3] and SRI's Open Agent Architecture [5], and matchmakers and brokers in Retsina [6] all differ in their interactions with providers and requesters. In [2], it was shown that different types of MAs exhibit different characteristics in terms of privacy, robustness, adaptiveness, etc. Thus, which type of middle-agent to use in a system depends on the requirements of the application. It is therefore essential that we identify different design possibilities for MAs, and investigate the properties they satisfy.

In this paper, we take a first step towards a comprehensive and systematic study of MAs. We first identify a list of dimensions along which MAs can differ and possible values for these dimensions, and then derive a taxonomy. We focus on capability-based MAs involved in agent location and transaction intermediation here.

*This work is supported by ONR contract N00014-96-1222, DARPA contract F30602-98-2-0138.

2 The Model

In capability-based coordination, providers specify services they provide in *capabilities*. Being able to provide weather forecast is an example of a capability. Capabilities are sometimes accompanied by *service parameters*, which specify conditions under which services are offered. Price and quality of service are both examples of service parameters. Requesters specify services they need in *requests*. Requests can be accompanied by *preferences*, which are counterparts of service parameters.

In our model, agents communicate via message passing, and are capable of intelligent internal processing.

3 A Taxonomy of MAs

To find agents with desired capabilities, end-agents can send ('push') information about themselves to the MA, or ask ('pull') the MA about what is available in the system. Thus, the first dimension that characterizes a MA is *P1) Who sends information to MAs?* The answer can be either providers or requesters. Providers and requesters need to complement each other: if providers 'push', requesters 'pull'; and vice-versa.

The second question to ask is *P2) How much information is sent to the MA?* There are two possibilities: only capabilities/requests, or parameters/preferences as well.

The third question to ask is *P3) What happens to the information MAs receive?* It can be broadcast or kept in a local database.

If the information MAs receive is stored in the MAs' databases, the following question arises: *P4) How is the content of the database used?* It can be browsed or queried. If it is browsed, then the 'puller' receives the content of the whole database. Otherwise, the 'puller' gets only a subset of the information in the database, determined by what is specified in the query.

0-7695-0625-9/00 $10.00 © 2000 IEEE

This leads us to the fifth dimension: *P5) How much information is specified in a query to the MA?* One can specify only the essential information - capabilities/requests; or provide service parameters/preferences as well.

Finally, *P6) Does the MA intermediate transactions* between end-agents? MAs may intermediate transactions to implement anonymity of the parties involved in a transaction; to guarantee fairness; or to collect affidavits for possible future disputes.

The above 6 dimensions and their respective values give rise to a taxonomy of MAs. This taxonomy includes different variants of MAs known in the literature. Matchmakers [2] (Fig. 1) and facilitators [5]

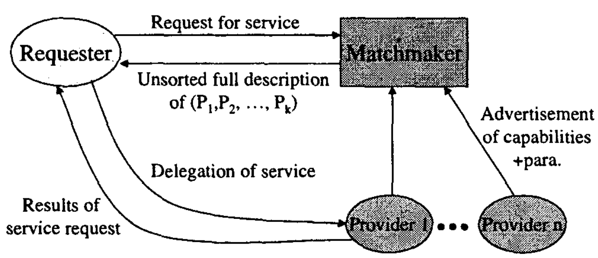
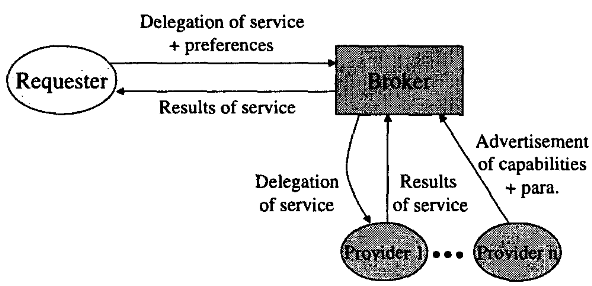


Figure 1. Matchmaker.

(Fig. 2) are two examples. Note that facilitators differ from matchmakers in that they intermediate transactions.

Figure 2. Facilitator.



One of the factors that may determine a user's preference of one type of MAs over the others is the issue of privacy. For example, a 'puller' that browses a MA's database does not reveal information about itself when it browses. If it queries, however, the information specified in the query is revealed. And, depending on the amount of information one specifies in a query, a greater or lesser amount of privacy is guaranteed.

Also, different types of MAs presuppose different local processing. For example, if a MA's database is to be browsed, then no major processing is required of it. But, if it can be queried, then it needs a matching engine capable of filtering out database entries that match the specification provided in the query.

The set of dimensions identified here may not be complete or unique, but they constitute a basic set in characterizing typical location and transaction interactions.

4 Conclusion

This work is significant for several reasons. First, MAs are becoming common in open multi-agent systems, making inroads even in the commercial world [1]. Second, this taxonomy will enable a comprehensive study of different performance characteristics of different types of MAs, which will provide designers of multi-agent systems with the knowledge they need to choose the type of MA that best satisfy the requirements of their application. Third, as systems using different MAs are being asked to inter-operate, knowledge of their workings and protocols could expedite the integration process. Finally, this work may provide the first step towards standardization.

To our knowledge, no one has presented such a comprehensive and systematic taxonomy for MAs. The only other similar effort [2] focuses on quantitative performance comparisons between matchmakers and brokers.

For future work, we plan to investigate MAs in our taxonomy with respect to characteristics such as privacy, robustness, and load-balacing. We also plan to expand our taxonomy to include other types of mediating agents, such as inter-operators [4].

References

[1] Jini connection technology. http://www.sun.com/jini/.

[2] K. Decker, K. Sycara, and M. Williamson. Middle-agents for the internet. In *Proc. IJCAI-97*, Jan. 1997.

[3] M. Genesereth. An agent-based framework for interoperability. In J. M. Bradshaw, editor, *Software Agents*, pages 317–345. AAAI Press, 1997.

[4] J. Giampapa, M. Paolucci, and K. Sycara. Agent interoperation across multi-agent system boundaries. To appear in Agents 2000.

[5] D. Martin, A. Cheyer, and D. Moran. The open agent architecture: A framework for building distributed software systems. *Applied Artificial Intelligence*, 13(1-2):92–128, 1999.

[6] K. Sycara, A. Pannu, M. Williamson, D. Zeng, and K. Decker. Distributed intelligent agents. *IEEE Expert*, pages 36–46, Dec. 1996.