

## Chapter 2

# Semantic Web Agents

**Abstract** Agent denotes the piece of software that possesses the properties of autonomy, social ability, reactivity, proactivity, temporal continuity, and goal-orientedness. Multi-agent system consists of a number of agents which are capable of interacting with each other. In these systems, the agents are capable to cooperate, coordinate, and negotiate with each other. Various activities in the Semantic Web based systems are performed by Semantic Web agents. The inter-agent dependencies among these agents are managed using the process of negotiation. Negotiation is the process by which a group of agents come to a mutually acceptable agreement on some matter. In this chapter, a general introduction to the terms agents, multi-agent systems and negotiation has been given.

**Keywords** Agents • Multi-agent systems • Negotiation

### 2.1 Semantic Web Agents

Although there is no universally accepted definition of the term Agent (Wooldridge 2002), there are some of the similar definitions available in the literature. As per (Wooldridge 2002), an agent is a computer system that is situated in some environment and that is capable of some autonomous action in this environment in order to meet its design objective. An agent basically has two important capabilities. Firstly, agents are capable of autonomous action to some extent and hence are capable of deciding for themselves what they need to do in order to satisfy their design objectives. Secondly, agents are capable of interacting with other agents by exchanging data and they can engage with other agents in some social activities such as coordination, cooperation, negotiation etc. According to (Antoniou and Harmelen 2004), agent is a piece of software that

works autonomously and proactively. Agent denotes a software-based computer system that has following properties (Wooldridge 2002; Kappel et al. 2006):

- **Autonomy:** operates without direct intervention of human and having self-control over its actions and internal states.
- **Social ability:** has ability to interact with other agents and humans using some agent communication language.
- **Reactivity:** has ability to perceive its environment and respond in timely fashion to the occurring changes.
- **Proactivity:** exhibition of goal-directed behavior by taking initiative.
- **Temporal continuity:** continuously running process either in active or in sleeping state in background.
- **Goal orientedness:** capable of handling complex and high-level tasks by taking decision on how much a task is best split into smaller sub-tasks and in which order and in what way these sub-tasks need to be performed.

Among others, some of the activities performed by the Semantic Web agent are (Antoniou and Harmelen 2004):

- Receiving some tasks and preferences from the service requester.
- Seeking information from the Web sources.
- Communicating with other agents.
- Comparing information about user requirements and preferences.
- Selecting certain choices.
- Giving answer to the service requester or user.

Some of the technologies used by Semantic Web agent are (Antoniou and Harmelen 2004):

- *Ontologies* are used to assist in Web searches. These are also used to interpret the retrieved information and to communicate with other agents. It uses meta-data for identifying and extracting information from Web sources.
- *Logic* is used for processing of retrieved information and drawing a conclusion.
- *Agent communication languages* are used for communicating with other agents.
- *Formal representation* is needed for representing the cognitive parameters such as belief, desire, intention etc. of agents.
- *Negotiation* is the process by which a group of agents reach to a mutually acceptable agreement on some matter such as price, quality etc. It is the process of making a joint decision by two or more parties (Jennings et al. 2001). In general, before selecting a certain agent for taking its service, the requester agent negotiate with it over various service parameters such as price, quality etc. to reach at a mutually acceptable agreement.

## 2.2 Multi-Agent Systems

As the technology matures and addresses increasingly complex applications, the need for systems that consist of multiple agents that communicate in a peer-to-peer fashion is becoming apparent (Sycara 1998). Multi-agent systems are systems composed of multiple interacting computing elements known as agents. Multi-agent system consists of a number of agents which are capable of interacting with each other by exchanging messages through some computer network infrastructure. In these systems, mostly the agents are acting on behalf of users and are having very different goals and motivations. They are capable to cooperate, coordinate and negotiate with each other (Wooldridge 2002). Following are some of the characteristics of multi-agent systems (Sycara 1998):

- Each agent has incomplete information or capabilities for solving the problem. Thus, it has a limited viewpoint.
- There is no system global control.
- Data are decentralized.
- Computation is asynchronous.

Multi-agent system technology is capable of enhancing the performance of systems along the following dimensions (Sycara 1998):

- *Computational efficiency.* These systems exploit the concurrency of computation and communication is kept minimal.
- *Reliability.* These systems provide graceful recovery of component failures. As agents with redundant capabilities or appropriate inter-agent coordination are found dynamically.
- *Extensibility.* As the number and the capabilities of agents working on a problem can be altered.
- *Robustness.* These systems are capable of tolerating uncertainty.
- *Maintainability.* Multi-agent system is easier to maintain because of its modularity.
- *Responsiveness.* Due to its modular nature, these systems can handle anomalies locally.
- *Flexibility.* Agents with different abilities can adaptively organize to solve the problem.
- *Reuse.* Functionally specific agents can be reused in different agent teams.

## 2.3 Negotiation

Negotiation is a form of decision-making where two or more parties jointly search a space of possible solutions with the goal of reaching a consensus (Rosenschein and Zlotkin 1994). Negotiation is the process by which a group of agents come to a

mutually acceptable agreement on some matter. In this process, agents first verbalize demands and then move toward an agreement through a process of concession formation or search for new alternatives (Muller 1996; Zhang et al. 2005). There are mainly three approaches to the automated negotiation i.e. Game theoretic approach, Heuristic approach, and Argumentation-based approach (Jennings et al. 2001). Multi-agent systems can have either competitive behavior or cooperative behavior. In the competitive behavior, the participating agents are self interested and their activities may be conflicting with the activities of other agents. In cooperative environment, the activities of agents are such that they are mutually cooperating each other to reach the final goal. Negotiation is required in both of these environments. So, negotiation in multi-agent systems can be either competitive negotiation or cooperative negotiation. In competitive negotiation, the agents are self-interested and each one tries to maximize its local utility. In cooperative negotiation, the agents try to maximize their global utility. There can be different degree of cooperation in the cooperative negotiation. The two extremes are: global cooperation and local cooperation. In global cooperation, an agent, while making its local decision, tries to maximize the global utility function that takes into account the activities of all the agents in the system. Whereas, in local cooperation, two or more agents negotiating over an issue try to find a solution that increases the sum of their local utilities, without taking into account the rest of the agents in the system (Zhang et al. 2005). Various activities in the Semantic Web based systems such as seeking information from the Web sources, receiving tasks and preferences from the person, comparing information about user preferences etc. are performed by Semantic Web agents. The inter-agent dependencies among these agents are managed using the process of negotiation.

Following are some of the important topics related to automated negotiation:

*Negotiation protocols* are the set of rules governing the interaction process. It includes the permissible types of participants, negotiation states, the events causing negotiation states to change, and the valid actions of the participants in particular state (Jennings et al. 2001, Lomuscio et al. 2000).

*Negotiation objects* define the range of issues over which the agreement must be reached. It may contain a single issue such as price or multiple issues such as price, quality, time etc. The participants can have the flexibility to change the values of the issues in the negotiation object and even the participants might be allowed to dynamically alter the structure of negotiation object (Jennings et al. 2001; Lomuscio et al. 2000). The negotiation approach having multiple issues as the negotiation objects is called as multi-attribute negotiation. This type of negotiation process is widely used in the real-life scenario also.

*Decision making models* are employed by the participants to act in line with the negotiation protocol for achieving their objectives. The sophistication of the model is influenced by the negotiation protocol, nature of negotiation object, and by the range of operations that can be performed on it (Jennings et al. 2001, Lomuscio et al. 2000).

*Negotiation strategy* species the sequence of actions usually containing offers and responses that agent plans to make during the negotiation process. The choice

of the negotiation strategy to use is a function of specifics of the negotiation scenario and the negotiation protocol to use. Thus, the strategies performing well with certain protocols may not do so with others (Lomuscio et al. 2000).

*Negotiation mechanism* consists of a negotiation protocol and negotiation strategies for the involved agents. A negotiation mechanism should have computational efficiency, communication efficiency, individual rationality, distribution of computation, and Pareto efficiency. The parameters based upon which negotiation can take place are categorized into many characteristics such as cardinality of negotiation, agent characteristics, environment and goods characteristics, event parameters, information parameters, and allocation parameters (Lomuscio et al. 2000).

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