Chapter 6

CONCLUSIONS AND FUTURE WORK

6.1 CONCLUSIONS

This thesis has presented MAFSW, a Multi Agent Framework which provides complete communication solution for Multi-agent systems operating in Semantic Cyberspace. Although the initial stirrings of SW were experienced back in 2001, but complete transformation requires many issues to be addressed. It was analyzed that agent technology provided the underlying thrust for SW and helped in conceiving the idea of a web which will be much more than the information portals, but MAS had not only been suffering from problems of ontology mapping desired to communicate with other MAS in order to share knowledge among themselves but also in addition to the need for efficient fault-tolerance, there had been lack of strong and efficient security mechanisms.

The in-depth literature survey was carried out and the vital analysis of the same raised the following major shortcomings in the field of Semantic Web.

- Lack of standard Ontology Mapping Mechanism in homogeneous and heterogeneous domains.
- Lack of secure communication strategy.
- Inefficient strategies for communication security.
- Inefficient strategies for ensuring fault-tolerance in communicating MAS.
• Lack of mechanisms for handling uncertainty in user queries.

A graved study of above shortcomings, led to the design of following adaptable, efficient, robust, scalable and secure intelligent frameworks:

1. An Agent-based Framework for providing ontology mapping in both homogeneous and heterogeneous domains of MAS called “INTELLIGENT AND ADAPTIVE MAPPING MECHANISM FOR MULTI AGENT INTERFACE (IAM3I)”.

2. An Agent-Oriented Secure Communication Strategy termed as “CONTRACT NET TRUST ESTABLISHMENT PROTOCOL (CNTEP)”.

3. A security engine to ensure security at all stages of interactions among MAS called “Elliptical Curve Cryptography based Security Engine for Multi Agent Systems Operating in Semantic Cyberspace”. It initially gets the trust established among the communicating counterparts and once trust is established, provides security of communicated messages by encrypting them using Elliptical Curve Cryptography technique.

4. For providing efficient fault-tolerance to MAS a strategy called “Adaptive and Automated Fault-Tolerance for MAS” was also proposed.

5. A framework for handling uncertainty in user queries using fuzzy logic at ontology level called “FUZZY INTEGRATED ONTOLOGY MODEL: THE FIOM”.

6. Although individual frameworks were evaluated during their implementation phases, however the overall system was integrated and hence evaluated in “THE EVALUATION OF MULTIAGENT FRAMEWORK FOR SEMANTIC WEB”.

The proposed concept is an extension of, rather than a replacement for, the existing mechanisms. The Intelligent multiagent framework provides a novel approach for providing ontology mapping in same or different domains by delegating the ontology mapping task completely to agents. Also, the extension mechanism employed in this strategy allows mapping of concepts which are otherwise unknown in a domain
vocabulary. The framework follows the modular approach. The significant achievements of the proposed design are listed as under:

- **A Standardized Ontology Mapping Mechanism in Homogeneous or Heterogeneous Domains:** The proposed ontology mapping layer eliminates human intervention required for mapping in earlier proposed techniques by delegating the mapping task entirely to intelligent agents. Secondly, the utilization of ontology extension or intension mechanisms makes this strategy unique in itself and allows mapping of ontologies possible in similar or different domains.

- **Secure Communication Strategy:** Conventionally, MAS follow Contract Net Protocol for communication among one another. Although, CNP focuses on and provides facilities for most of the issues related to agent communication, however it failed to establish trust among communicating agents. This work provided a new version of existing CNP termed as **Contract Net Trust Establishment Protocol (CNTEP)**, which provides the ability to establish trust among communicating agents.

- **Efficient Security Engine:** Encryption of communicated messages and agent code is frequently used as one of the few measures to ensure security in communication. Traditionally, encryption follows DH, DSA and RSA algorithms. In contrast the proposed security engine makes use of Elliptical Curve Cryptography technique for the encryption of messages and agent code, which is not only novel but also is efficient in terms of time and space complexity.

- **Adaptive and Automated Fault-Tolerance:** Dynamic replication of all agents is considered to be the most robust fault-tolerance approach, but it results in very expensive and complex systems. The strategy proposed in this work provides a unique approach to establish equilibrium between static and dynamic replication based on criticality of an agent which in turn is based upon the cardinality of an agent computed using Emergent Graph Structure.
• **Fuzzy Integrated Ontology Model:** Semantic web is meant to provide context based and intelligent results to the users. But naïve users usually provide incomplete and uncertain inputs to the search engine, and search engines are unable to handle that uncertainty since they are supported by ontology databases working on crisp logic. Thus, integration of fuzzy logic in semantic web at ontology level has improved the way inputs are processed and more useful results could be provided to the users.

### 6.2 FUTURE SCOPE

The work contained in the thesis had made an attempt to answer the questions, which emerged as a result of literature survey. While designing the solutions for these questions, some new issues related to maintenance and survival of deployed agents in semantic cyber space has emerged as a big challenge. The other challenges include:

- **How can the inherent interdependence between agents be managed effectively?**
  The interdependence among agents depends on various factors. For example, when agents work towards to achieve a shared goal, then challenge is to assimilate agents in an interacting team through communication, coordination and negotiation. However, if agents don’t share a goal or they are destructive in nature, then challenge is to manage and minimize the negative effects of inter-agent communication and coordination. Since agents are inherently autonomous and self motivated, thus there must be some way to guard them from getting destructive.

- **What type of organizational structure i.e. layered, hierarchical, mesh etc. is appropriate?**
  The structure varies depending on the task complexity, executing environment, goals to be achieved, reliability and moreover, on the intelligence of agents. For example, if an environment makes communication
difficult, a distributed structure or more autonomy may be desirable. However, if the agents are able to perform the task in a simple way, they may exist on their own.

- **What and how much capabilities should be delegated to the agents?**

The designed agents are usually smaller in size but they differ in the capabilities they have, to achieve a goal. Some agents are simple such that their control remains withheld with the system itself but some agents are more critical and rational that has special problem-solving knowledge and lie closer to human intelligence spectrum. Such agents are designed to be intelligent, having learning capabilities however *they must not reveal future predictions* to unauthorized users. Human intelligence needs to be duplicated to agents. For example, whether an agent should have the ability to radically change another agent's behavior (e.g., turning a trusted agent into malicious one), modification of an agent’s code by some malicious user. Agent gains information about other agents’ activities by using platform services, and then it might eavesdrop on their communications.

In general, other significant research issues include simplified and interactive communication interfaces so that knowledge available on the web can be easily made available to the users. With the increase in the interest of people towards internet surfing, there is strong desire to have personalized and intelligent delivery of information. Agent architectures also require to be modified to incorporate mechanisms to predict agent behavior and preventing them from turning malicious. Future will surely bring complete transformation of WWW into Semantic Web but it will require much more adaptation of user interests towards searching and contexts of information desired.