Chapter-1

INTRODUCTION

1.1 Motivation

The last decade has seen an exponential growth in computing and the use of Internet. The rapidly evolving network and computer technology, coupled with the expansion of services and information available, is moving towards a new era of mobile and ubiquitous computing. The devices are no longer isolated; rather they are distributed in nature. In the upcoming era, new paradigms are required for building distributed systems and applications, with autonomy and social ability, like software agents.

A software agent can be defined as a program or an independent module which works or executes in order to accomplish the goals assigned by its creator or user. Software agents need a supporting platform on which the agents can be created, managed and executed. This underlying middleware or platform is defined as Multi-Agent System.

The mobile agent technology is playing a key role in driving research activities in agent related research community. It possesses the capability to revolutionize the methodology in which distributed applications are designed and deployed [1]. The mobility feature highlights the flexible behavior [2] in multi agent systems, in which various interactive components as well as protocols are involved in order to address heterogeneous
functionalities. The fundamental properties of mobile agents are capability to move across various hosts and autonomous operations at remote hosts.

Major research is being undertaken in domain of teamwork among software agents, highlighting various coordination and collaboration strategies. However, very limited work is being done for teamwork among mobile agents. Mobile agents are special types of software agents which demand extra capabilities and features in traditional design of communication and coordination as well as goal sharing and task accomplishment.

The ontology based policy technique is a strong candidate strategy to address major issues in teamwork among mobile agents. The term “Policy” is defined as per current environment or relevant context [3]. Policy is a rule based expression or statement which is linked to constituent conditions and actions [4]. Policy based systems have been actively used in domains of management and security related functions.

Ontology can be described as meta-data or domain concepts and its relationships. The ontologies are used for sharing of domain knowledge and expressing data in specified schema. Ontologies [5] can also be defined as formal specifications of domain knowledge. It is a constituent part of building semantics infrastructure in multi agent systems and semantic web. Ontologies provide support for interoperation and definition of domain data in multi-agent systems. Ontology based systems facilitate in runtime reconfiguration and information sharing among software agents in distributed architecture. Additionally,
it simplifies the policy engineering problems [6] like authoring, conflict resolution and deployment.

Ontology based policy techniques can improve the task execution efficiency of mobile agents by providing a flexible approach for creation and execution of tasks. It adds reusability, customizability and flexibility. This technique can help to incorporate teamwork support in multi-agent systems by reducing the middleware support as teamwork will be the need of future especially for complex applications in the future arena.

1.2 Problem Statement

Mobile agent is a new paradigm for building distributed systems. The existing approaches are more oriented towards building inherent mobility mechanism in multi agent systems as compared to enhancing the individual characteristics of mobile agents. Additionally, there is no consensus on a conceptual framework for building mobility characteristics in multi-agent systems. As the applications are becoming more complex and distributed, mobile agents require more efficient teamwork mechanisms. More autonomous coordination and cooperation is required in order to execute the assigned tasks. These circumstances introduce new issues such as knowledge sharing, expression of domain data and tasks execution mechanisms in the distributed environment. There is a need to enhance the mobile agent basic structure and fundamental capabilities like intelligence, autonomy, proactive and social behavior [7] in addition to its inherent mobility potential.
Furthermore, there is no clear understanding of the new abstractions offered by this paradigm. Achieving mobility in software agents is a complex process which requires developer’s extensive role in defining when and where to move which components under varying operating conditions. Additionally, there is a need to analyse possible techniques to carry preferences and goals by agents during mobility operations. Also there is a need to explore the possibility of making groups of agents with varying combination of core properties like mobility, rationality, behaviours etc. in order to find out the ways of achieving goals in collaboration with each other. In collaboration architecture, agents need to share with each other their specializations, knowledge, goals and dynamic parameters. The problems are: change in environment, change in goals to-be-achieved and their priorities. Also the approach needs to be formalized in order to enhance the modelling and reliability aspects.

1.3 Research Hypothesis and Questions

The aim of this research is to explore the limitations in domain of teamwork among mobile agents and highlight its potential capabilities through employing ontology based policy strategy. The hypothesis is stated as follows,

“Goal oriented ontology based policies technique can address the major issues of task definition and execution in dynamic teamwork architecture of mobile agents.”
The following research questions originate from the hypothesis statement, which have been explored and addressed in this thesis.

- What are the limitations in execution as well as coordination and cooperation of mobile agent applications?
- Which teamwork strategy is more efficient among mobile agents when they are distributed on multiple machines?
- How interactions among mobile agents influence the performance of teamwork architecture especially in scenario of distributed infrastructure?
- Why mobile agent applications are tightly constrained with multi agent system?
- How can an ontology based policies approach address the limitations and improve the overall architecture?

![Figure 1.1 Action Research with Iterative Approach](image-url)
1.4 Research Methodology

The methodology revolves around paradigm of action research in order to investigate the above mentioned research questions. As per action research methodology, the work is planned, designed and developed, evaluated and re-visited. The flow of activities is described in figure 1.1 and figure 1.2 which classifies the research work in five phases.

- In first phase, research domain and problem statement is analyzed in context of research questions. In addition, background study and state of the art literature review is done to familiarize with latest trends and techniques in research domain.

- In second phase, an efficient teamwork architecture has been proposed in the domain of multi-agent systems, which is based on honey-bee teamwork strategy especially for mobile agents. Two major teamwork paradigms are considered. In first case, the primary goal is shared through team leader approach while in second case members are assigned the goal and they perform their respective tasks in coordination and collaboration with each other. The evaluation is made for both paradigms when the teams are distributed on multiple machines and overhead of inter-machine communication is analyzed.

- In third phase, another contribution is proposal of ontology based goal oriented policies technique where policies are made of various tasks and conditions in a tree like structure. Each primary goal is divided to sub-goals which are associated
with respective sub-tasks. These are joined together in policies form where a particular goal triggers the associated list of conditions and actions. These policies are represented in ontologies form using OWL [8] which is standardized by W3C. It provides higher flexibility as compared to tightly constrained traditional
approaches. These ontology based policies are published and accessed as well as manipulated by mobile agents using URI through Protégé [9] and Jena [10] APIs.

• In fourth phase, the proposed work is discussed and analyzed by designing a novel application in domain of disaster management systems called as Earthquake Management System (EMS). This application is based on concept of utilizing the autonomous and intelligent nature of software agents in order to fulfill the demand of quick response activities from start of earthquake to other relief efforts. The major modules are used as the proof of concept application for teamwork and ontology based goal oriented policies research work. The proposed application is modeled using formal method techniques of Pi-Calculus [11-14] and Pi-ADL [15-16, 93] in order to analyze the specifications and working behavior.

• In last phase, research activities are concluded by discussing the research outcome and highlighting the future directions.

1.5 Thesis Outline

The thesis highlights the honey-bee teamwork architecture as well as ontology based policy framework for mobile agents in multi-agent systems. The literature review is presented in chapter 2 where a review of teamwork efforts is highlighted along with their limitations in context of mobile agents. Also, various generic policy based techniques are discussed and later relevant ontology based work is highlighted.
In chapter 3, an efficient teamwork strategy is proposed after discussing two major paradigms of team leader and non-team leader approaches. The Honey-Bee teamwork strategy is discussed and mapped with mobile agent operations. Chapter 4 describes the ontology based policy architecture where goal oriented task based policies concept is proposed. The classification of policies as well as its role in mobile agent operations is presented and later its representation in ontologies form is discussed.

Chapter 5 presents the formal approach towards design, modeling and analysis of agent based disaster management systems. An Earthquake Management System (EMS) is proposed which is composed of software agents. Additionally, the roles of agents along with major activities are analyzed using formal methods. In Chapter 6, the implementation of proof of concept application is discussed along with modeling and specification of earthquake management system in pi-calculus and pi-ADL.

In Chapter 7, the evaluation is presented firstly about the teamwork strategies and then by using the ontology based policies approach. The evaluation is highlighted in context of agents’ execution on multiple machines and inter-machine communication aspect. Also the formal verification work is described in later part of the chapter.

Chapter 8 provides the discussion and critique about the results obtained as well as the overall analysis of proposed work in context of research domain. Conclusion and Future work is highlighted in Chapter 9.