A Novel and Seamless Approach for Vertical Handover
Using Agent-Based Middleware in 4G

1. Introduction

The telecommunications industry has witnessed an ever accelerated growth of the usage of mobile communications. The first generation (1G) was voice-centric and used analog signaling, while real revolution began with the birth of second-generation (2G) technologies in which the systems are digital with 10 kbps data transfer rate. Later on 2G was enhanced to 2.5G which provided Global Packet Radio Service (GPRS) and Enhanced Data Rate for Global Evolution (EDGE) packet switching technologies. Further, considering the heavy demand of high-bandwidth multimedia applications, third-generation (3G) was designed to support integrated services, such as video, audio, high speed internet connection, and video conferencing etc. Further works are going on in the direction of enhancing 3G to 4G as the present age communication infrastructure involves systems such as GSM, CDMA, Wireless LAN, etc., which are used to provide different services, and the desire is to integrate all existing and newly developed wireless communication systems instead of developing new uniform standard to replace existing technologies. Such a network shall promise seamless handover and best connected service, combining multiple radio access interfaces (such as WLAN, Bluetooth, GPRS, UMTS, WiMAX, CDMA) into a single network that subscribers may use.

The most important research issue is “Anytime and Anywhere communication”. This is accomplished with handoff procedure, where handoff is the process of shifting the channel i.e. frequency, time slot, spreading code, or combination of them, associated with the current network connection while data transmission is in progress. It is often initiated either by crossing a network boundary or by a drop in quality of the signal in the current channel. Handoff has been divided into two broad categories namely, Horizontal and Vertical Handoffs. In contrast to horizontal handoff where in, a mobile node moves around from one access point to another access point supporting the same network technology, while vertical handoff process allows the mobility of mobile node among access points supporting different network technologies. Further, the horizontal handoff decision mainly depends on the
quality of channel and resources available in the target cell and is finally executed if the Received Signal Strength (RSS) from a neighboring base station exceeds the RSS from the current base station. In vertical handover mobile node moves over heterogeneous networks, which provide different type of features such as the access network bandwidth, better QoS, cell coverage and an efficient interface management for mobile node with multiple wireless interfaces etc. In order to continue receiving services while roaming heterogeneous networks, each device shall be provided with a compatible Mobile IPv6 protocol.

Mobile IPv6 protocol was introduced by the Mobile IP Internet Engineering Task Force (IETF). MIPv6 follows the Host based movement; various messages are exchanged between a mobile node and a home agent which leads to inefficient utilization of resources such as bandwidth, time and battery etc. Enhanced version of the same known as PMIPv6 (Proxy Mobile IPv6) supports network based mobility without requiring the participation of the Mobile Node in mobility task. It also reduces the limitation of the link bandwidth and terminal power. PMIPv6 is employed for heterogeneous networking environment supporting various access network technologies such as 3G/4G cellular network, WLAN and WiMAX network. In host-based mobility, the communication was direct between home agent and mobile node, where as in PMIPv6, Mobile Access Gateway (MAG) was incorporated that took over the responsibility of mobile node thereby overcoming the limitation of the link bandwidth and terminal power. Though PMIPv6 is able to reduce handover latency but is still suffering from lots of other drawbacks. Some of drawbacks are a) increase in frequency of packet loss, b) routing path of data between two nodes becoming too complicated because of overlapping effect, and c) overloading of MAG as the number of mobile nodes becomes large.

Although, researchers had been trying to sort out the above stated issues, however no solution has been proposed at the time of listing. Due to the above stated limitations, the need for a new solution is apparent and hence current research work aims to propose the incorporation of mobile agent in PMIPv6 domain. Next section elaborates the motivation behind injecting mobile agents in vertical handover process.
2. Motivation behind using Mobile Agents

The idea of injecting mobile agents was implemented after scrutinizing the literature thoroughly. It was discovered that mobile agents can greatly reduce battery consumption, and communication cost, especially over low bandwidth links. This has been made possible by moving processing functioning to agents rather than bringing the data to central processor. Mobile agent is a program that acts on behalf of a user or another program and is able to migrate from host to host on a network under its own control. Some of the features like autonomy, ability to migrate from one node to another node, persistent, reactive in nature, carrying logic and data, performing actions on behalf of the user of mobile agents will definitely enhance the performance of network management software. Making use of these significant features of mobile agent, following are the challenges that are required to be met in order to find optimal solution for the shortcomings listed above.

3. Challenges in Designing an Intelligent Framework

The main issue is to design an intelligent agent framework which is capable of selecting the best available network as compared to the current. It also initiates the handover process on the behalf of MAG. The need of the handover is also looking for an automatic solution in critical situations. The smart agents should also be capable of gathering information of neighboring network so that an instant action can be taken in case of handover. The proposed intelligent multi agent framework contributes uniquely towards smooth functioning of highlighted issues.

- **Seamless Handoff Initiation and Binding Updates:** Intelligent agent approach must be capable of seamless handover for initiating binding updates on the behalf of MAG. The main idea was to reduce the handover latency and packet loss during handover.

**Solution:**

“An Agent based Smart Solution for Vertical Handover in 4G” is being proposed. The idea is to amalgamate intelligent agents named $\text{M}_{\text{Nagent}}$, $\text{MAG}_{\text{agent}}$ and $\text{LMA}_{\text{agent}}$ in PMIPv6 domain and handover the decision
making ability to agents. The main objective is to reduce handover latency and packet loss. This is successfully achieved by assigning duties to the proposed agents. MAG\textsubscript{agent} maintain MNlog of all the visited mobile nodes, to avoid repetitive Authentication, Authorization and Accounting part. MAG\textsubscript{agent} also forward buffered data to new MAG in case of handover. Both processes significantly reduce the handover latency and packet loss in PMIPv6.

- **Mobile Agent based Emigration Framework**: An intelligent framework is required which can switch to less power demanding network in case of critical situations like low battery status of mobile device.

**Solution:**

Another approach “Mobile Agent based Emigration Framework (MAEF) in 4G” was proposed to overcome the loss of packet especially when the remaining time of current transaction is more than the remaining battery life (RBL) of current device. The framework proactively migrate data from one network to another using intelligent agents. However, if no suitable network is found then it gives an option of moving data from current device to other alternative device. MAG\textsubscript{agent} retrieves the bandwidth of available networks and migrate the current mobile node to available network in case the device is running out of battery.

- **Automatic Switch to Preferred Network**: An intelligent network selection mechanism which helps mobile users to choose the best available network that suits user’s needs and is able to change dynamically with the change in conditions.

**Solution:**

“A Novel Approach for Always Best Connected for Future network” selects the best available network on the basis of seven factors. These factors includes cost of service, data transfer rate, mobility of node, signal strength, network traffic, security and drainage rate of battery. MAG\textsubscript{agent} populate the
sorted list and handover the same to MN\textsubscript{agents}, which further uses this list to arrange the preference list and identifies the always best connected network.

- **Load Reduction and Load Balancing of Network:** Developing a scheme to reduce the load of MAG and hence balance the load in PMIPv6 domain.

  **Solution:**

  “**A Load Reduction and Balancing Scheme for MAG Operating in PMIPv6 Domain**” scheme provides the solution of load reduction and balancing mechanism for MAG. In fact, when more than the desired number of mobile nodes is attached to the PMIPv6 domain including a particular MAG, it gets overloaded, causing the end-to-end transmission delay. Since the number of mobile users and the associated applications are increasing exponentially, the problem stated above is obvious. The work proposes two algorithms initially for reducing the load & later for balancing the load, if still required. The work proposes mathematical equations that are able to compute the reduction in load & hence the amount of load to be balanced.

- **Deployment of a Trusted Security Engine:** Implementing trust based security model in the proposed agent based solution.

  **Solution:**

  In the proposed work mobile agents travels from one system to another in a network, they transfer their code, data and execution state. Therefore, reliability is a vital issue for deploying the mobile agent system. The reliability can be gained by implementing trust certificate for mobile agents. A **New Reliability Model for Evaluating Trustworthiness of Intelligent Agents in Vertical Handover** is being proposed to add Trust Certificate to all agents. The trust certificate has been weighted on the basis of Direct Experience, Third Party References, Confidentiality, Persistence Execution Trust etc. The unique contribution of this part is to compute reliability and then generate trust certificate which has been mathematically simulated & is consistent with existing models.
4. Organisation of The Research Work

The thesis has been divided into six broad chapters as listed below:

**Chapter 2** provides an overview of PMIPv6 domain and Software Agents. The chapter discusses the applications and challenges in the field of Vertical Handover in PMIPv6 environment. The chapter further discusses the challenges in deploying intelligent agents.

**Chapter 3** the detailed review of the literature of PMIPv6, vertical handover and the role of intelligent agent in telecommunication has been provided. The survey done highlights the major issues and the potential solutions that have been done so far to achieve the stated issues.

**Chapter 4** explains the proposed Intelligent Agent Framework for Proxy Mobile IPv6 (IAF-PMIPv6). The chapter begins with deployment of agents at different level of PMIPv6 domain. It has been divided into four major parts ensuring the description of challenges and their proposed solutions. The proposed work has been simulated, evaluated and analyzed and the results have been presented in this chapter.

**Chapter 5** explains the trustworthiness of all the deployed agents. In the proposed framework every agent populated with trust certificate based on various parameters that may affect the performance of any participating agent.

**Chapter 6** concludes the thesis by summarizing the work and throwing light on the future scope for the expansion of current work.
List of Publications


