Chapter 1

Introduction
Chapter Overview

This chapter introduces the research work and describes the motivation behind pursing it with respect to the current trends. It defines the research scope and points out the basic objectives of the research in brief. It also presents the outline of the work and the flow of the dissertation.

1.1 Research Motivation

In the recent past, the subscriber base of mobile phone users has increased multifold. Along with this phenomenal increase in users, even requirements of the users have changed drastically. Current users look for internet connectivity, email access, instant messaging, and music downloads, online gaming etc. As a result, provision of resources, of the cellular network, needs to be performed optimally, in real time as well as keeping quality of service in purview. Thus resource management becomes a crucial task in cellular networks.

Service Level Agreement (SLA) [1, 2] is defined as a pact between the Service Providers (SP) and the Network Providers (NP) or between the SP and the customers specifying service guarantee in terms of service parameters, acceptable/unacceptable service levels, and action to be taken in special cases and penalties incurred by SP in case this guarantee of specified Quality of Service (QoS) is not met. This SLA concept plays a very important role as it is the means to guarantee the QoS provided to the customers in response to the level of service to which they have subscribed. Hence there is a need to introduce effective SLA-QoS based policies as part of the radio resource management.

Call admission control (CAC) [3, 4, 5] is a fundamental mechanism used for QoS provisioning in a network by limiting the number of call connections into the networks in order guarantee connection level QoS parameters such as new call blocking probability and handoff blocking probability, packet level QoS parameters such as delay, jitter, packet loss for various classes of traffic. Dynamic CAC schemes [5] consider mobility patterns based on velocity, distance and direction of the movement of mobile terminal while making call admission decision in a cell. While admitting calls to a cell, if
information about ongoing calls in the adjacent (neighbouring) cells is available, to it, it can derive the impact of neighbouring ongoing calls on its own call admission and do resource allocation for handoff calls in advance. This ensures certain level of QoS in terms of call dropping probabilities. In case of congestion in the network or QoS degradation, channel borrowing schemes [6] could be implemented. This kind of distributed traffic information exchange between cells requires cooperation from adjacent cells. Thus, the motivation of the research comes from the requirement to model dynamic call admission as a Multi Agent System (MAS) [7, 8] for cellular networks.

A multi agent system is a set of agents [9, 10], which are autonomous, social, reactive, proactive software components, which interact, collaborate, cooperate or even negotiate with each other and with the environment to solve a particular problem in a coordinated manner. A MAS solves problems that are beyond the individual capabilities or knowledge of each agent. These problem-solving agents are autonomous and can be heterogeneous in nature.

The properties of cellular network such as; an individual cell having limited viewpoint of the network, no global system control and asynchronous computations make them most suitable for modeling as a multi tier multi agent based SLA system for resource management.

Our work proposes to model cells of cellular network as hybrid agents and form a MAS of neighbouring cell agents (cluster), which interact and share their ongoing call information to maintain the QoS within the permissible limits defined in SLA.

1.2 Research Scope

The research extends the agent based model of IST (Information Society Technology) project ‘Shuffle’ [11, 12]. The ‘Shuffle’ project presented a multi layered model of hybrid agents by classifying them according to their responsibilities. The work offered business models for network provider, service provider and customers and the relationships between these actors. However, it had following limitations:
1. It only offered the hypothesis that the agents could control SLAs at cell level. Performance evaluation of the MAS for call admission control was absent.

2. The QoS guarantee was limited to only Resource Plane, not making it granular at cell level.

3. The Planning Layer of the hybrid agent did not accommodate new traffic patterns or real time traffic.

4. SP-NP negotiation for NP selection though explained in detail, NP-Cell interaction and Cell-Cell interaction were missing.

The work proposed in this thesis extends ‘Shuffle’ project, and aims at addressing the issues mentioned above. The sub goals of the research are as follows:

1. To implement cell level SLA-QoS provisioning, a new cell/connection level layer needs to be introduced which should handle call admission control, complete with channel borrowing. This layer should be fully compatible with the ‘Shuffle’ model and agents modeled in this layer should interact with existing agents through vertical interaction.

2. The Multi Agent based Call Admission Control (MA-CAC) policies in Local Planning Layer, should consider different classes (voice/data) of traffic and mobility patterns (high/low) of mobile user along with priority and non-priority handoff traffic.

3. The research should present performance evaluation of MA-CAC strategies, in terms of connection level parameters such as new call blocking probability, handoff call blocking probability, effect of queue on blocking probability.

4. Congestion control through channel borrowing strategies should demonstrate the effectiveness of using socially intelligent agent based MAS.

5. The work should establish the affect of degree of distribution of agents in MAS based interaction in terms performance parameters.
The following section presents the research done towards meeting these sub goals.

### 1.3 Outline of the Research

To meet the above mentioned goals the research extended the ‘Shuffle’ model and redesigned the architecture. It introduced a new plane called *Connection Plane* and designed cell as a new *Network Provider Cell Agent (NPCA)* residing in this plane. The *Network Resource Provider Agent (NPRA)* in *Resource plane* also was redesigned to bring resource management at cell level. These agents were designed as layered hybrid agent, having ‘Cooperative’, ‘Local Planning’ and ‘Call Establishment’ layers. The agents demonstrate the capability of interacting with other agents in distributed manner through the functionality of ‘Cooperative Layer’ giving rise to multi agent based interaction.

According to the degree of distribution of agents, the interaction amongst agents was classified as vertical (centralised) or horizontal (distributed), based on which two service architectures were realized. These two service architecture were then compared for reactivity, responsiveness, utilization of resources, communication overhead, sustainability, scalability, robustness and modifiability to establish the effect of degree of distribution of agent on system performance for cellular networks.

The decision of which CAC or channel borrowing policies/schemes needed to be implemented in Connection Plane, by the NPCA, was based on the requirement of QoS specified for the traffic conditions, mobility pattern and traffic classes etc. The work evaluated various MA based CAC (MA-CAC) schemes which vary in there cutoff thresholds, mobile user velocity, traffic class mix for cell parameters to establish suitability of a scheme.

CAC also used the concept of Social Welfare for channel borrowing through MAS of socially intelligent agents to handle congestion. The results established the relationship between the social attitude of an agent towards the other agents, and the fairness of resource distribution.
The research aims at helping in building knowledge for choosing the correct multi agent based CAC and channel borrowing scheme, along with the most suitable service architecture for required SLA-QoS and traffic conditions for a cellular network.

The simulations were carried out in Java Agent DEvelopment framework (JADE) [13], Foundation for Intelligent Agent (FIPA) [14] compliant open source framework.

1.4 Organization of the Dissertation

Chapter 2 gives an overview of evolution of cellular networks and presents cellular concepts. It presents the review of different call admission control and dynamic channel borrowing schemes for resource management. The chapter introduces agents and multi agent systems with their various models and available platforms for implementation and typically discusses JADE in detail.

Chapter 3 presents the design of the proposed multi agent based cellular network model, which is the extension of ‘Shuffle’ model, its architecture and its components along with interaction model and its performatives.

Chapter 4 presents the analytical models of Multi Agent based Call Admission Control (MA-CAC) namely; Static Cutoff Priority , Dynamic Cutoff Priority, Mobility Based Channel Reservation (Integral, fractional) CAC schemes for single class as well multi class (priority, non priority) traffic. Also analytical model for MAS of socially intelligent agent based Dynamic Channel Borrowing schemes (MA-DCB) for congestion control. It also presents qualitative analysis of parameters used for comparing the two proposed service architectures, Centralised Service Architecture and Distributed Service Architecture.

Chapter 5 presents the simulation model i.e. the traffic model, system model and the agent model used in the research. The important processes of validation and verification, essential when using simulation-based research, are presented with the results. It also gives the results that show the system performance of the two MAS based service architectures.
Chapter 6 narrates the entire journey. It analyzes and discusses the results obtained at different level of work.

Chapter 7 presents the conclusions and future perspective of the work along with detailed list of contributions. The author’s papers publications are listed in section 7.3.5 and can be referred in appendix C.