Toward Cognitive Radio Handover Management
Based on Social Agent Technology for Spectrum Efficiency Performance
Improvement of Cellular Systems

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Abstract— Interference and delay are considered as the main reasons limiting the capacity and increasing the new call blocking probability in the cellular systems. The Probability of handover failure is considered a common criterion for performance evaluation of handovers in cellular systems. In this paper we discuss and analyze cognitive radio handover managements based on social agent technology in cellular systems.

Keywords— Cognitive radio, handover, social agent

I. INTRODUCTION

Handover is a basic mobile network capability for dynamic support of terminal migration. Handover Management is the process of initiating and ensuring a seamless and lossless handover of a mobile terminal from the region covered by one base station to another base station. In this paper we consider the handover call blocking probability in cellular systems. Various resource allocation strategies are proposed to optimize the resource allocation in cellular system by reducing the call blocking probability [5-6, 8] in cellular systems. The call blocking probability is often measured in terms of two blocking probabilities, the arriving call blocking probability, and the handover blocking probability. Analyses and studies in [9-11] show that the call blocking probability in handover is caused by two main parameters, interference and delay. Interference leads to missed and blocked calls due to errors in the digital signaling. Between transmitter (Base Station, BS) and receiver (Mobile Station, MS), the channel is modeled by several key parameters. These parameters vary significantly with the environment (urban, rural, mountains). There are different type of interference that when not minimized, decreases the ratio of carrier to interference power at the periphery of the cells, causing diminished system capacity, more handover [4], and more dropped calls. To reduce the handover blocking probability in cellular systems has been proposed various schemes as, prioritized handover schemes and handover with queueing [4]. In some application fields like real-time communication and industrial automation is needed to ensure a seamless and lossless handoff. Which means the handover latency should be zero. For efficient handover management, we introduce cognitive radio approach that is expected to perform more significant role in the view of efficient utilization of the spectrum resources in the future wireless communication networks. The spectrum utilization efficiency is defined as the ratio of information transferred to the amount of spectrum utilization. Our approach is reactive approach, in that it enables, via negotiation, learning, reasoning, prediction, active sense, identification, changes in the base station’s parameter to meet the new services requirements in modern wireless networks and future challenges in cellular systems. A major challenge with cognitive radio approach is to be done in near real-time and to keep up with an ever changing RF environment without overly computationally complex. The paper is organized as follows: Section II introduces the system model and the social agent strategies. Section III discuss and analyze the handover call blocking probability based on simulation results and section IV concludes the paper.

II. SYSTEM MODEL

A cellular network consists of an array of cells. We partition the cellular network to clusters. For each cell we set a social agent, as depicted in Figure 1. By using radio cognitive approach we aim to achieve an optimal network capacity, minimizing interference to other signals and to reduce messages complexity and channel acquisition delay that are considered the main reasons to block the new calls. A radio cognitive approach may be able to sense the current spectral environment, and have information of past transmitted and received packets along with the power, bandwidth, and modulation. By considering all this, it makes better decisions about how to best optimize for some overall goal. Under heavy traffic load, and if a vacant channel is not found, the social agent then tries to obtain an exclusive channel by optimization of channel distribution based on iterative swapping scheme [12]. In which the social agent changes the channel distribution anew. We partition the set of channels into active and passive channels. The active channels are defined as the channels, which can be used by own cell. Furthermore the active channels can be simultaneously used in
different cells without any interference if they are a minimum reuse distance ($D_{\text{min}}$) apart from each other [12]. The passive channels are defined as the channels, which can be used by neighbor cells. Furthermore, the free channel will be expressed as 1 and the busy channel will be expressed as 0. The set of channels are classified and assigned uniform to cells in real-time.

A. Social Agent Negotiation Strategy
Compared to the traditional negotiation strategy that offers high messages complexity as described in figure 2, we are interested in applications where negotiation between social agents serves to solve the resource allocation problem in cellular systems. Furthermore we anticipate concern the feasibility of reaching an allocation of resources that is optimal from a social point of view. Social agents often need to interact in order to improve their performance. One type of interaction that is gaining an increasing interest is dynamic negotiation. The goal of negotiation is the maximization of the utility of a future decision. In distributed dynamic environment, each cell has an objective that specifies its intention to acquire a free channel for call establishment. That objective should be achieved in a certain amount of time, specified by a deadline. Negotiation stops when this deadline is reached.

B. Social Agent Decision Strategy
In this phase the agent deals with handover request as illustrates in Figure 3. The social agent’s decision about the handover process is focused on quality of service requirements (e.g. signal power, signal-to-noise ratio and delay). The signal-to-noise ratio (SNR or S/R) defined as the ratio of a signal power to the noise power corrupting the signal. The social agent estimates the SNR and then determines to carry out the handover or not. Furthermore the agent collects information about the adjacent cells. Based on of the collected information from the adjacent cells, the agent determines the next handover cell. The handover based on SNR can be divided into two main categories:
1) The first scenario is based on received SNR from the base station only. This method decides handoff when the SNR from current station is smaller than another station. This kind of method is simple but will take place repeated or unnecessary handoff.
2) The second scenario is based on relative SNR with threshold. In this approach, handoff is initialed when the average SNR falls below a certain threshold value. This method can avoid unnecessary handoff when the current station signal is still satisfactory.

C. Social Agent Reasoning Strategy
The radio approach draws its decision based on employing a cost function [13]. The resource agent allocates to a request, the channel of which the cost function is minimal. The cost function basically computes the interference level. The cost functions can be collectively expressed in a general expression:

$$J_k = \sum_{i \in I_c} (C_{ki}q_{ki})$$

(1)

Where,

$J_k$ is the channel interference cost unit for the $k$-th channel,
$I_c$ denotes the set of co-channel interference cells related to cell $C$. $C_{ki}$ denotes the binary status of $I_c$ which signifies that

$$C_{ki} = \begin{cases} 
0, & \text{channel } k \text{ causes no interf. in cell } i \\
1, & \text{channel } k \text{ causes interf. in cell } i 
\end{cases}$$

$q_{ki}$ is used to reflect the interference between the interfering cell $i$ and cell $C$. Therefore, any available channel having minimum value of $J_k$ is to be allocated to a new call arising in cell $C$. To obtain an optimal reasoning, the social agents consider aggregation rules that enable the social agents to change the currently held reasoning upon acquiring new information. Information and actions that affect the social agent decision in handover process are described below.

- Handover process starts if the mobile station receives a weak SNR.
- Mobile station moves to neighbor cell that have the highest number of free channel to ensure that the call is not blocked.
• Chooses channel with the lowest interference from the set of free channels. \( \text{channel}(k) = \arg \min_k I_k \)

• Using iterative swapping scheme to avoid high interference.

\[
\begin{align*}
&i = 0 \\
&\text{FOR } i = 1 \text{ to } k \text{ DO} \\
&\quad r_i(t) = \text{choose } (V) \\
&\text{ENDDO} \\
&\text{FOR } i = 1 \text{ to } k \text{ DO} \\
&\quad C_i = \phi \\
&\quad x = \arg \min_{v \in V} d(r_i(t), v) \\
&\text{ENDDO} \\
&\text{UNTIL } (\forall r_i : d(r_i(t), r_i(t-1)) < \varepsilon, t > t_{\text{max}}) \\
&\text{return } (r_1(t), \ldots, r_k(t))
\end{align*}
\]

### D. Social Agent Learning Strategy

To reduce the call blocking probability in handover process, the social agent has to update and change it sequence beliefs (local information) related to channel state in adjacent cells. Updating the social agent sequence beliefs of new channel set based on interaction between active and passive channels. The interaction between the cells is based on many-to-many negotiation. The many-to-many negotiation is based on XOR.

### E. Social Agent Beliefs

The new call in cell is blocked when there are no more free channels in the cell or the QoS requested cannot be provided as the SIR is under a given threshold SIR\(_{\text{tgt}}\). By computing the call blocking probability in handover process, we consider four social agent decision scenarios that are described below.

1) Probability (Approve, SNR > SNR\(_{\text{tgt}}\))
2) Probability (Reject, SNR < SNR\(_{\text{tgt}}\))
3) Probability (Approve, SNR < SNR\(_{\text{tgt}}\))
4) Probability (Reject, SNR > SNR\(_{\text{tgt}}\))

From social agent view point, there are two kinds of decision. Good decision, B(1) and bad decision, B(0). The mentioned four scenarios can be expressed in binary information as follow: B(1,1), B(0,0), B(1,0), B(0,1). For resource assignment denotes by \( x_i \), where \( x_i \in \{1,0\} \), \( x_i = 1 \), and \( x_i = 0 \), denote, respectively, approval and rejection of a resource assignment. The vector \( x = (x_1, \ldots, x_k) \) is referred to as the decision profile of the social agents. The decisional skill of the social agent is parameterized by the probabilities \( p^1_i \) and \( p^2_i \). That he makes the right decision concerning the resource acquisition and disapprove to assign resource that cause interference. Which mean, \( p^1_i = \text{Pr}(1:1) \) and \( p^2_i = \text{Pr}(0:0) \). We assume that, for any \( i \), \( \text{Pr}(0:1) = 1 - p^1_i \), \( \text{Pr}(1:0) = 1 - p^2_i \). For a given rule \( f \), the social agent approves to assign a channel or reject it with probability \( \prod f(j) : 1 \) and \( \prod f(j) : 0 \). Where \( \prod f(j) : 1 = \text{Pr}\{x \in X(1:j) : 1\} \) and \( \prod f(j) : 0 = \text{Pr}\{x \in X(0:j) : 0\} \). Since \( f \) is a decisive aggregation rule, we obtain that,

\[
\begin{align*}
\text{Pr}\{x \in X(0,f) : 1\} = 1 - \prod f(j) : 1 \\
\text{Pr}\{x \in X(1,f) : 0\} = 1 - \prod f(j) : 0
\end{align*}
\]

Our focus is the maximization of expected quality of grades (profit) \( E \) over the set \( F \) of all decisive aggregation rules.

\[
E = \alpha \prod f(j) : 1 \prod f(j) : 0 + (1-\alpha) \prod f(j) : 0 \prod f(j) : 1
\]

\( \alpha \) is the proportion of good decision for each social agent. Where \( 0 < \alpha < 1 \). The individual and collective behaviors of the social agent are reflected in its decisions and performances in the system.

### F. Interference Area Identification

In a mobile system, since the mobile stations can move between cells, the number of mobile stations within a cell at a given time can never be known exactly in advance. However, we can estimate roughly the location of the mobile stations. To avoid the call blocking by handover, it is important to identify the interference area. The interference area can be considered as the node of decision to hand over to a new cell. Denote \( P_t \) as the transmitter power of the base station, \( G \) the antenna gain, \( d \) the distance between the transmitter and receiver and \( N_0 \) as the thermal noise power. Generally, then, the received signal-to-noise ratio (SNR) at the \( k \)-th user in cell-1 is given by

\[
\gamma_{k(d)} = \frac{P_t(d)}{N_0}, \quad \gamma_{k(d)} = \frac{P_t(d)}{N_0}, \quad \ldots, \quad \gamma_{k(d)} = \frac{P_t(d)}{N_0}
\]

for \( j = 1, \ldots, k \). The signal-to-noise ratio (SNR or S/R) \( \gamma_k \) defined as the ratio of a signal power to the noise power corrupting the signal. Hence, following Markovian analysis, the social agent can predict the average blocking probability of user \( k \) being served by the base station based on calculation of the interference area for cell \( i \), which is greater...
than a given target value for cell $i$, $\gamma_{i}^{tg}$. This blocking probability is:

$$P_{b} = \frac{1}{n} \sum_{k=1}^{n} \delta_{k}$$

Where $\delta_{k} = \begin{cases} 1 & (\gamma_{k} - \gamma_{i}^{tg}) < 0 \\ 0 & \text{Otherwise} \end{cases}$

G. Active Sense Environment

In sense environment the radio cognitive approach takes in consideration the following parameters, propagation model, traffic model and amount of the information. This represents the maximum amount of information that can be conveyed through a communications channel. From an information theoretic perspective, a communications channel is responsible for passing data between two points, and will likely add some sort of noise to be original signal. In other words, the original signal reception is possible only when the relation of energy per bit $E_{b}$ to noise spectral density $N_0$ is appropriate. Low value of $E_{b}/N_0$ will cause the receiver to be unable to decode the received signal, while a high value of the energy per bit in relation to noise will be perceived as interference for other users of the same radio channel. For example, for CDMA systems, the bit energy-to-interference-and-noise-spectral density ($E_{b}/N_0$) is SINR multiplied by the number of information bits modulated by the spreading code, whereas the carrier-to-interference-and-noise-power ratio (CIR or C/I) is equal to ($E_{b}/N_0$) divided by the length of the spreading code. The ratio $E_{b}/N_0$ is given by

$$E_{b}/N_0 = G_p (C/I)$$

Where $G_p$ is the processing gain, and the ratio $C/I$ of the user is given by

$$C/I = \frac{P}{E(I)}$$

To calculate the received signal-to-noise ratio (SNR) at the kth user is given by

$$\gamma_{k}(r_{k}) = \frac{P_{r}G_{r}(r_{k})}{N_0}$$

For our purposes we focus on the Shannon Theorem, which states for additive white Gaussian noise (AWGN) channel. The channel capacity is given by

$$C = W \log_{2}(1 + \xi \gamma_{k})$$

Where $\xi$ is the bit error rate.

III. SIMULATION RESULTS

The radio cells treat licensed users, other unlicensed radio networks, interference, and noise all as interference affecting the signal-to-interference ratio (SIR). Higher interference yields lower SIR, which means lower capacity is achievable for a particular signal bandwidth and Interference in the radio channel and reduces the quality of the transmission. There are different quantities that measure the quality as signal-to-interference ratio (SIR) and the bit-error rate (BER). SIR, referred to also as signal-to-interference-and-noise ratio (SINR) to emphasize the presence of background noise, is the ratio between the power of the desired signal and the power of the interference (plus noise). In figure 4, two different mobile radio systems are illustrated. Mobile station $MS_A$ is located at the cell boundaries of system $A$, however very close to base station $BS_B$. Due different reasons like receiving a weak SNR (finding the mobile station in rural area) or due interference that may occur at base station $BS_A$ from base station $BS_B$. To maintain a reliable connection between the user and the base station, the SIR at the receiver should be no less than some threshold that corresponds to QoS requirement such as the bit error rate. Figure 5 shows that the received signal to interference ratio varies greatly over the duration of the simulation. Figure 6 describes the average received power by the users. Figure 7 describes the social agent strategy that may agree on a deal to exchange some of the resources they currently hold, in order to increase the social agent utility. The social agent utility is increased when the social agent owns a resource $r \in R$ according to the aggregation rule 2.3.iii. Figure 8 describes the bandwidth efficiency. Figure 9 describes the blocking probability related to the SNR.
IV. CONCLUSION

In this paper we have presented the principles of handoff procedures and described some of the procedures used in various types of systems. Furthermore we have proposed a radio cognitive for handover management to reduce the interference which is sourced by channel acquisition in cellular system. In general, there are different reasons that caused the interference in cellular system, such as power which is also an important resource. Allocation of power in the proper channels can increase capacity and avoid interference.

REFERENCE