A Novel Connectivity Control Scheme for Next Generation Wireless System by using Short Coverage Antennas

Shubhajeet Chatterjee[1]
Soumyanil Banerjee [2]
Arijit Mondal [3]
Joydeep Saha[4]

Department of Electronics and Communication Engineering, Institute of Engineering & Management,
Saltlake, Kolkata-700091, India

E-mail: 1chatterjeeshubhajeet@gmail.com .
2 soumya_nil@yahoo.com.
3amondal29@yahoo.com .
4joydeepsaha007@gmail.com

Abstract – **Connectivity control technique in next generation wireless system is a burning issue of research. Throughout the last few years plenty of researches had been done to obliterate the connection failure problem by implementing several channel allocation schemes. In this paper, we propose a new scheme of connectivity control by implementing some Short Coverage Antennas (SCA) in the cell. If the channels of the Base Station (BS) are not free then the call request of the Mobile Station (MS) is served by the closest SCA of the MS. The MS, being connected with the SCA, will send its request for a free channel to the new BS within fixed time intervals and when it will find free channels are available in BS it will automatically connect with it, rejecting the connection of the SCA. This process effectively reduces the connection failure problem.**

Keywords- Next Generation Wireless Systems (NGWS), Mobile computing, Mobility Management, Handover, BS (Base Station), MS (Mobile Station), IEEE802.11.

1. INTRODUCTION

Handoff has become an essential criterion in mobile communication system especially in urban areas, owing to the limited coverage area of Access Points (AP). Whenever a MS move from current BS to a new BS it requires handoff. For successful implementation of seamless Voice over IP communications, the handoff latency should not exceed 50ms. But measurements indicate MAC layer handoff latencies in the range of 400ms which is completely unacceptable and thus must be reduced for wireless networking to fulfill its potential. With the advent of real time applications, the latency and packet loss caused by mobility became an important issue in Mobile Networks. The most relevant topic of discussion is to reduce the IEEE 802.11 link-layer handoff latency. IEEE 802.11 MAC specification [1] defines two operation modes: ad hoc and infrastructure mode. In the ad hoc mode, two or more stations (STAs) recognize each other through beacons and hence establish a peer-to-peer relationship. In infrastructure mode, a BS provides network connectivity to its associated STAs to form a Basic Service Set (BSS). Multiple APs form an Extended Service Set (ESS) that constructs the same wireless networks.

Handover: When a MS moves out of reach of its current BS it must be reconnected to a new BS to continue its operation. The search for a new BS and subsequent registration under it constitute the handover or handoff process which takes enough time (called handoff latency) to interfere with proper functioning of many applications. As the handoff and handover are same in meaning, we will use these terms alternatively in our discussion [15].

The handoff procedure consists of three logical phases where all communication between the mobile station undergoing handoff and the APs concerned is controlled by the use of IEEE802.11 management frames.

Scanning: When a mobile station is moving away from its current AP, it initiates the handoff process when the received signal strength and the signal-to-noise-ratio have decreased significantly. The STA now begins MAC layer scanning to find new APs. It can either opt for a passive scan (where it listens for beacon frames periodically sent out by APs) or chose a faster active scanning mechanism wherein it regularly sends out probe request frames and waits for responses for T_{MIN} (min Channel Time) and continues scanning until T_{MAX} (max Channel Time) if at least one response has been heard within T_{MIN}. Thus, $n*T_{MIN} \leq$ time to scan n channels $\leq n*T_{MAX}$. The information gathered is then processed so that the STA can decide which AP to join next. The total time required until this point constitutes 90% of the handoff delay.

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Authentication: Authentication is necessary to associate the link with the new AP. Authentication must either immediately proceed to association or must immediately follow a channel scan cycle. In pre-authentication schemes, the MS authenticates with the new AP immediately after the scan cycle finishes. IEEE 802.11 defines two subtypes of authentication service: ‘Open System’ which is a null authentication algorithm and ‘Shared Key’ which is a four-way authentication mechanism. If Inter Access Point Protocol (IAPP) is used, only null authentication frames need to be exchanged in the re-authentication phase. Exchanging null authentication frames takes about 1-2 ms.

Re-Association: Re-association is a process for transferring associations from old AP to new one. Once the STA has been authenticated with the new AP, re-association can be started. Previous works has shown re-association delay to be around 1-2ms. The range of scanning delay is given by:-

N × Tmin _ Tscan _ N × Tmax

Where N is the total number of channels according to the spectrum released by a country, Tmin is Min Channel Time, Tscan is the total measured scanning delay, and Tmax is Max Channel Time.

Channel Distribution: IEEE802.11b and IEEE802.11g operates in the 2.4GHz ISM band and use 11 of the maximum 14 channels available and are hence compatible due to use of same frequency channels. The channels (numbered 1to14) are spaced by 5MHz with a bandwidth of 22MHz, 11MHz above and below the center of the channel. In addition there is a guard band of 1MHz at the base to accommodate out-of-band emissions below 2.4GHz. Thus a transmitter set at channel one transmits signal from 2.401GHz to 2.423GHz and so on to give the standard channel frequency distribution as shown in.

It should be noted that due to overlapping of frequencies there can be significant interference between adjacent APs. Thus, in a well configured network, most of the APs will operate on the non-overlapping channels numbered 1, 6 and 11, as shown in figure 1 .

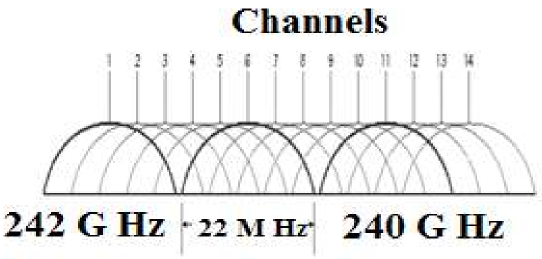

Figure 1

Channel allocation refers to division of a given radio spectrum into a set of disjoint channels, which can be used simultaneously while minimizing interference in adjacent channels by good channel separation. There are three ways in which channel allocation is mainly done. They are:

a) Fixed Channel Allocation scheme
b) Dynamic Channel Allocation scheme
c) Hybrid Channel Allocation scheme

Fixed Channel Allocation: Here, a set of channels is permanently allocated to each cell of the system. It has certain advantages like maximum channel reusability, low computational effort required and low call setup delay. It performs better under heavy traffic. However, it has low flexibility in channel assignment and high forced call termination probability.

Dynamic Channel Allocation:

Here, all free channels are allocated to a central pool. As new calls arrive in the system, channels are allocated dynamically to complete these calls. When the call is completed, the channel currently being used is returned to the central pool. They may be of two types:

i. *Centralized Dynamic Channel Allocation:*

Here, the first free channel that satisfies the reuse distance is selected. For a given reuse distance, all the cells that satisfy minimum reuse distance are termed co-channel cells. When a cell needs to support a new call, a free channel is selected so as to maximize the number of members in the co-channel set.

ii. *Distributed Dynamic Channel Allocation:*

They are primarily based on three factors: co-channel distance, signal strength measurement and signal-to-noise interference ratio.

Hybrid Channel Allocation:

Each cell is exclusively allotted a fixed number of channels. Request for a channel in the dynamic channel set is initiated only if all the channels in the fixed set are pre-occupied. It has been observed that keeping the ratio of fixed channels to dynamic channels at 3:1, hybrid allocation leads to better service than fixed channel allocation up to 50%. Beyond this load, fixed channel schemes perform better.

We have organized the rest part of this paper as follows. Sec 2 describes the related works, Sec 3 describes our proposed approach. The simulation results are given in Sec 4 and finally concluding remarks are presented in Sec5.

2. RELATED WORKS

In last few years, many researches had been done to develop a user friendly channel allocation. The simplest way of channel allocation is “Guard channel” allocation where the handoff call is given more priority than the new calls by reserving a fixed number of channels for them [1]. In [2], only the new voice calls are buffered in queue whereas in [3], both new call and handoff call are allowed to be queued. Author of [4] proposed a handoff scheme with two level priority reservation. Higher priority is given to the handoff call because termination of ongoing call is more annoying than the new one [5]. All of the above researches are based on voice cellular system. But due to the rapid development in wireless communication, the effect of non-real-time service needs to be taken in consideration [6]. Author in [7] proposed a method where only data service handoff requests are allowed to be queued where as a two dimensional traffic model for cellular mobile system is proposed in [8]. Some algorithms also proposed for multimedia users with fixed bandwidth requirement in [9]. In [10] author used a two dimensional Markov chain to propose a new approximation approach that reduces the computational complexity. Authors of [11] propose a dynamic channel allocation i.e. no fixed channel among the cells where all channels are kept in a central pool and will be assigned dynamically when the new calls will arrive. In [12], authors proposed a non-preemptive prioritization scheme for access control in cellular networks.

3. PROPOSED WORK

In this paper we propose a novel connection control protocol to improve Next GenerationWireless Communication. Here we improve the connectivity of the network by implementing short coverage antennas in the cell.

We divide our proposed work into four sections:

1. Circular cell coverage concept.
2. Short coverage antenna approach.
3. Connection Control
4. Comparison with Previous Works

3.1. Circular cell Coverage Concept

Due to fading of signal strength (*fast fading* due to scattering from interfering objects & s*low fading* due to long term spatial and variations, inversely proportional to the square of the distance) it is consider that each base station or antenna services a circular area (depending on the height of the antenna and power of its signal) beyond which signal strength becomes lower than usable levels. But for the presence of obstacles (like buildings, mountains) an exact circular cell area cannot be obtained. For this reason here topological concept is used which helps to consider the coverage area as a circle of radius *Ri* for the *ith* AP, as shown in Figure 2.

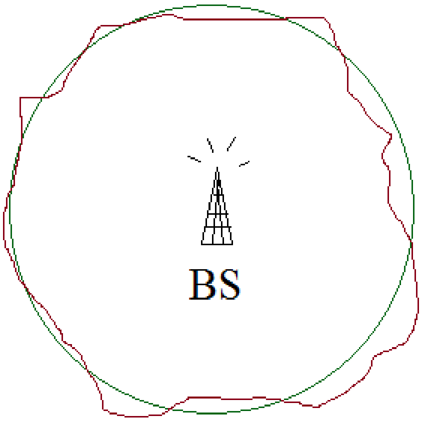

Figure 2

3.2. Short Coverage Antenna (SCA) Approach

Here, we attempts to reduce handover connection failures without significant increase in blocking probability of new calls. A Mobile Station (MS) on entering a new BS requests a channel from the Base Station (BS) for continuing the existing call. However, if no such free channels are available, then a handoff failure is said to occur, i.e. an existing call is dropped. Similarly a new call also blocked when all channels of the BS is busy. This failure probability may be reduced if the call request (i.e. handoff call and new call) is served by aShort Coverage Antenna (SCA) of the cell (as shown in figure 3) closest to the MS, when no free channel from BS is available.

If we consider the radius of the circular cell is "R" and the range of SCA is "r", then

Area of the main cell = $\prod R^2$

Area of the auxiliary cell= $\prod r^2$

Let N number of SCA is required to cover the whole area of the main cell.

So, $\prod R^2 = N \prod r^2$

So, $r=R/\sqrt{N}$

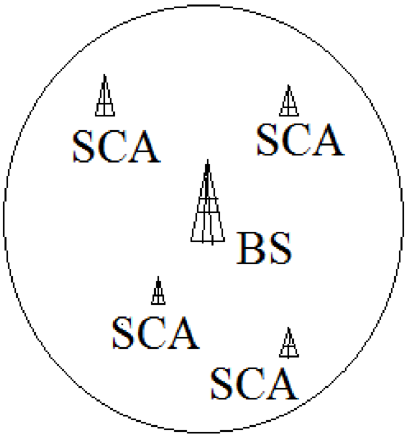

Figure 3

The main purpose of the SCA is to provide channels for the incoming calls in its area. SCA can provide a limited number of channels. So, to avoid the unnecessary congestion in SCA, the MS which is occupying a channel of it, will try to changeover to a channel under the BS at the earliest possible opportunity.

The MS will send its request to the BS at every fixed time interval (say t) and when it will find a free channel in BS, it will connect itself with the BS rejecting the SCA connection. Thus the BS and SCA both channels are required to update after this fixed time interval t.

T is chosen heuristically as,

$$\mathbf{T} = \frac{\mathbf{k} * \mathbf{v}}{\mathbf{N}}$$

Where

k= network constant and it depends upon traffic load, available channels and the topography of the cell.

v= velocity of MS

N= number of SCA

To make the process more economy friendly, we can optimize the number of SCAs depending upon the call arrival rate. The number of SCA required for a cell can be given as,

$$N = \frac{(\alpha h + \alpha 0) * \mu}{s}$$

Where,

α_h= Handoff call arrival rate

α_o= New call arrival rate

μ= average call duration

S= total number of channels in SCA.

This N number of SCAs can be placed arbitrarily in the cell maintaining a fixed and equal distance d,

$$r < d < \frac{R}{N}$$

Now according to call arrival rate, the number of SCA is varied as shown below in figure 4 and figure 5.

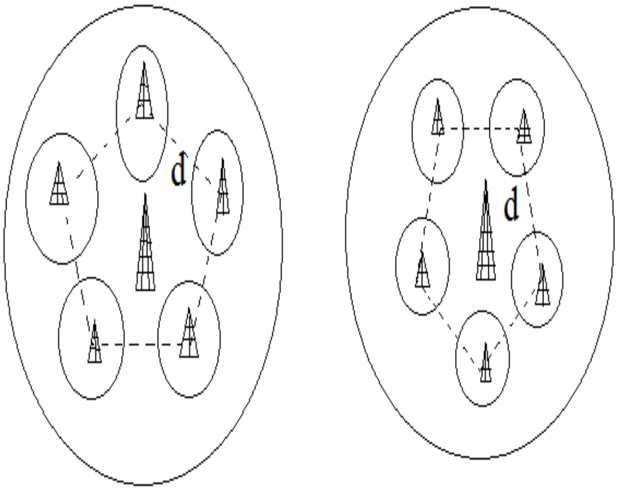

Figure 4: High Call Arrival Rate

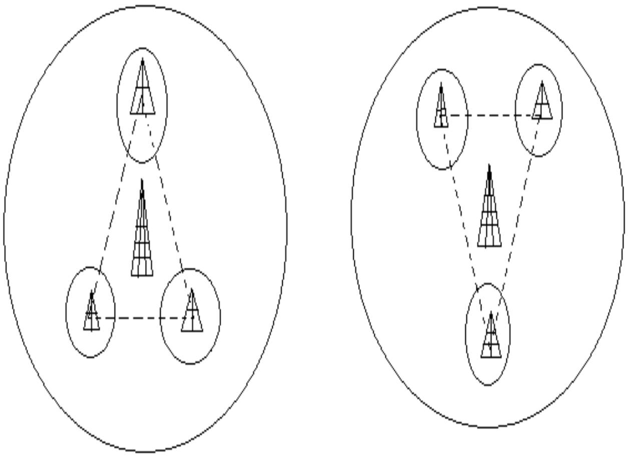

Figure 5: Moderate Call Arrival Rate

3.3. Connection Control

When a call (handoff or originating) is requested to the BS, it will allocate a channel for that call from its given radio spectrum. If it does not have any free channel in its given spectrum then it will send a failure notice to the MS. On receiving this failure notice, MS will search for a SCA to continue its connectivity. The nearest SCA will be the best SCA from the aspect of the received signal strength as refer to [6], more on nearest stations having better signal strengths due to their advantage in competing for the wireless channel. The positions of SCA are known parameter and the position of MS can be obtained by using GPS (Global Positioning System) or any other sensor technology. From this positional data we can find out the distance (di) between MS (x_{MS},y_{MS}) and SCA (x_{SCA},y_{SCA}) as,

$$di = \sqrt{(xMS - xSCA)^2 + (yMS - ySCA)^2}$$

From the value of di we can find out the nearest SCA. Now the MS will be connected with this SCA and it will continuously send its request to the BS for a free channel after every fixed time interval. When a free channel will be available in BS it will be allocated for this call. When the multiple numbers of calls will request for free channel, the channels will be given in order of first come first serve.

We can apply this proposed method in practical purposes by using the following algorithm.

```
/* Total number of channels in the radio spectrum given to the Base Station (BS) is N */
/* Total number of channels occupied in BS is c */
/* velocity of MS is v*/
/* Network Constant = k */

1.  W=N-c
2.  If w≠0
                    */when a free channel will be available in BS/*
3.  The BS will allocate a channel for the incoming call.
4.  Else
                    */when any free channel is not available in BS/*
5.  Get the positional data of MS with help of GPS.
6.  $di = \sqrt{(xMS - xSCA)^2 + (yMS - ySCA)^2}$
                    */Find out the distance (di) between MS ($x_{MS}$,$y_{MS}$) and SCA ($x_{SCA}$,$y_{SCA}$)./*
7.  Choose the SCA whose di value is minimum.
8.  Connect the MS with this SCA.
9.  Set a timer with the T value.
    $T = \frac{k * v}{N}$
10. Start the timer.
11. If timer T=0.
12. Connect the MS with the BS.
                    */when a free channel will be available in BS/*
13. Else
14. Go to step 9.
                    */when any free channel is not available in BS/*
14. End
15. End
```

This will effectively reduce the connection failure probability.

3.4. Comparison with previous works

It may be noted here that for the last few years plenty of researches had been done to improve connectivity issue. Compared to those few research works our proposed method is a completely new idea. To reduce call dropping and call blocking probability some researcher uses special channel allocation technique which are much sophisticated to apply in real field [18]. Some research works also proposed to use WLAN at the handoff region which is quite expensive [19].

Whereas, in our proposed method we use some SCAs to work as a substitute of the BS which are low costs (as the SCA has small signal coverage area thus it requires small battery power) and the application of this method in real field is also not a sophisticated one as we have seen in above algorithm. Thus, the proposed model is low cost, less sophisticated and efficient for connection control.

Now let us simulates it to see if it actually works out in real field.

4. SIMULATION RESULT

In this section we will evaluate the performance of our approach by using Global Mobile Information System Simulator (GloMoSim). For our simulation, we consider a cellular system of cell size 1 km. and the BS can provide 5 channels i.e. 5 subscribers (including handover and originating call) can be connected at a time. The number of Short Coverage antenna in the cell is 4 and the number of incoming call is 11.The mean call duration time is assumed to be 120 seconds. Here we consider Dynamic channel allocation algorithm [14] and guard channel algorithm [13] to compare our proposed work with existing schemes.

Here we consider following antenna specification:

Base Station antenna specification(Fiberglass Rodome, Base Station Antenna)
Frequency Range : 2.4-2.483 GHz
Gain: 18 dBi.
Max input Power/Transmitter power:115dBm/ 35 dBm
Antenna height: 30m
Polarization: vertical
Short Coverage Antenna specification (Fiberglass Rodome, wireless antenna)
Frequency Range : 2.4-2.483 GHz
Gain: 10dBi.
Max Power: 50dBm
Antenna height: 10 m
Polarization: vertical
Cell phone antenna specification (2.4GHz Omni Directional wireless antenna)
Frequency Range : 2.4-2.483 GHz
Gain: 7 dBi.
Max Power: 31dBm
Antenna height: .6 m
Polarization: vertical

Figure [6] shows the call dropping probability, i.e. the handoff failure probability for these three schemes. Here we can see that for the guard channel technique the call dropping probability is zero up to a certain traffic load as few numbers of channels are especially reserved for the handoff calls and after that it increases towards 1. For dynamic channel allocation scheme the call dropping probability is initially a small nonzero finite value and then increases rapidly towards 1.It can be observed that as the BS can provide 5 number of channels, in both of these techniques the call dropping probability increases very rapidly when the traffic load becomes more than 5. Whereas, in our approach it is less than 0.1 up to the traffic load of 8 and after that it increase rapidly. As the 4 SCA can provide 4 channels for the subscriber, the network can support up to a traffic load of 8.

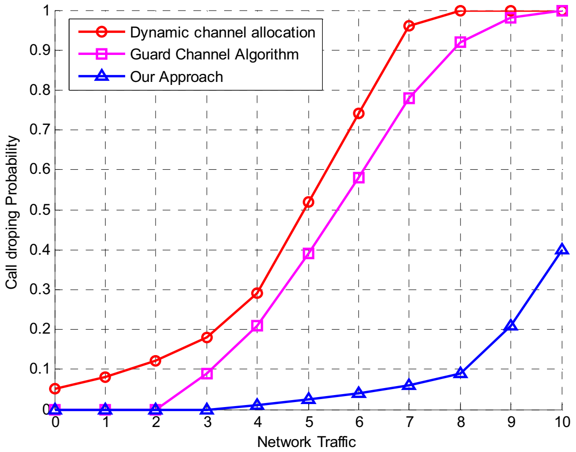

Figure 6

Figure [7] shows the call blocking probability, i.e. the originating or new call blocking probability for these three schemes. Here we can see that for the guard channel technique the call blocking probability is initially zero and then increases very rapidly towards 1. For dynamic channel allocation scheme the call blocking probability is initially a small nonzero finite value and then increases rapidly towards 1.It can be observed that as the BS can provide 5 number of channels, in both of these techniques, the call blocking probability increases very rapidly when the traffic load becomes more than 5. Whereas, in our approach it is less than 0.2 up to the traffic load of 8 and after that it increase rapidly. As the 4 SCA can provide 4 channels for the subscriber, the network can support up to a traffic load of 8.

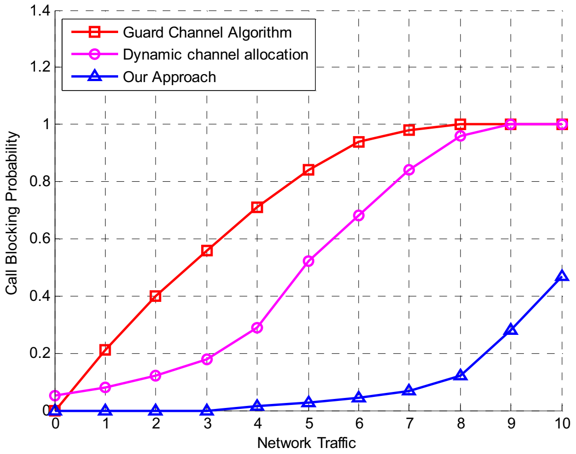

Figure 7

To further explain the practicability of our scheme we calculate the completed call ratio which is defined as the following and is closely related with the throughput of the system.

$$\text{Completed Call Ratio} = 1 - \frac{\text{number of blocked or dropped calls}}{\text{total number of arrived calls}}$$

Our SCA based scheme is compared to the Dynamic Channel Allocation strategy and Guard channel strategy with respect to the completed call ratio as shown in Fig. 8. The simulation result shows the significant improvement of our approach.

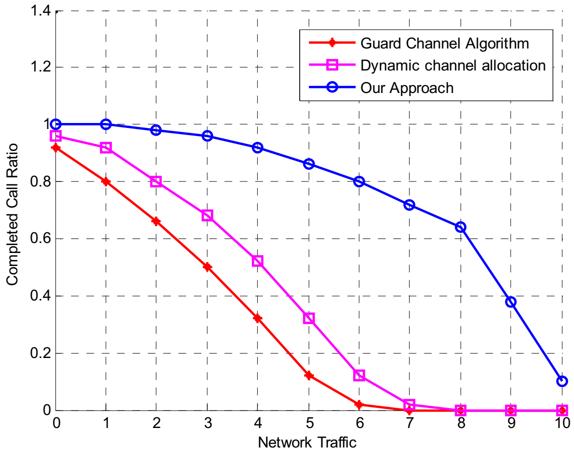

Figure 8

5. CONCLUSION

As we have already seen above, model simulations give favourable results for our new approach. Also the simplicity and flexibility of the proposed method point to diverse fields of implementation with the help of appropriate improvements and modifications. For example, though we have been able to reduce handoff failure we do not consider whether the handoff was at all necessary in the first place, i.e. ping-pong effects can significantly increase the number of false handoffs taking place. As the number of SCA will increase the possibility of ping pong effect will also increase.

Also, our approach may result in handoff failure when all the channels of the nearest SCA will be busy.

Such limitations can be effectively eliminated using mobility measurements of the STA involved in handoff. We can also improve the traffic distribution between SCA and BS. We intend to take up this matter in future studies.

However if we neglect those few special cases, our proposed method is flawless and effective for practical purpose

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