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Adjusting Blocking Probability of Handoff Calls in Cellular Mobile Communication

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Abstract

The problem of handoff calls management in cellular mobile communication is discussed. A simple but efficient design of a cellular network for a small area is proposed so as to keep blocking probability of handoff calls (B_H) below a pre-defined margin. The non-prioritized scheme of managing handoff calls for a single traffic system is used here to find the blocking probability. Xie and Kuek's traffic model is used to predict the teletraffic parameters. The value of B_H is calculated using MATLAB for different values of parameters so as to find the minimum number of channels requiredso as to keep B_H below 5%.

Keywords

Cellular Mobile, Handoff Call, Blocking Probability, Traffic Model, Channel

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1. Introduction

The cellular concept is the major breakthrough over the earlier mobile radio system. A cellular network consists of numbers of cells which isthe basic geographical service area of a wireless communication system. Each cell is allocated a band of frequencies and served by base station consisting of transmitter, receiver and control unit. Frequency reuse is the core concept of the cellular mobile radio system, where users in different geographic locations (different cells) may simultaneously use the same frequency channel. By limiting the coverage area to within the boundaries of a cell, the same group of channels may be used to cover different cells that are separated from one another by distances large enough to keep interference levels within tolerable limits [1].

When a mobile station (MS) moves into a different cell while a conversation is in progress, the Mobile switching center (MSC) automatically transfers the call to a new channel belonging to the new base station (BS). This transferring operation not only involves identifying a new base station, but also requires that the voice and control signals be allocated to channels associated with the new base station.This process of transferring channel is called handoff [2-4].Thus, Handoff is needed in two situations where the cell site receives weak signals from the mobile unit: (1) at the cell boundary, say, -100 dbm which is the level for requesting a handoff in a noise limited environment and (2) when the mobile unit is reaching the signal-strength holes within cell site.

Handoffs are broadly classified into two categories—hard and soft handoffs. In this paper, we will focus primarily on the hard handoff. In a hard handoff, under the control of the MSC, the BS hands off the MS's call to another cell and then drops the call., the link to the prior BS is terminated as the user is transferred to the new cell's BS; the MS is linked to no more than one BS at any given time. Hard handoff is primarily used in FDMA (frequency division multiple access) and TDMA (time division multiple access), where different frequency ranges are used in adjacent channels in order to minimize channel interference [2, 4]. So when the MS moves from one BS to another BS, it becomes impossible for it to communicate with both BSs (since different frequencies are used). Figure 1 illustrates hard handoff between the MS and the BSs.

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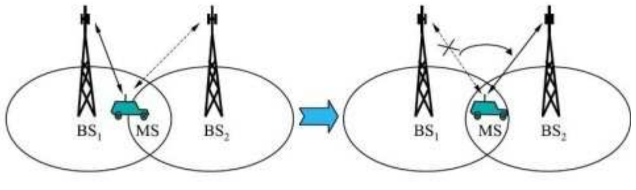

a. Before handoff b. After handoff

Fig. 1. Hard handoff between the MS and BS [4].

Measurement of handoff criteria and taking a handoff decision may be performed either by MS itself or by BS (associated with MSC) or by both MS and BS together. Depending on this, main handoff detection strategies are Mobile controlled handoff (MCHO), Network controlled handoff (NCHO) and Mobile assisted handoff (MAHO) [5-7].

A handoff may be intra-system where the same MSC manages the entire process or it may be intersystem handoff where two MSCs are involved in handoff processing. In each of these cases the handoff processing is completed in three steps: handoff detection, then assignment of channels and finally transfer of radio link [2, 4, 6].

Processing handoffs is an important task in any cellular radio system. Even, some handoff strategies prioritize handoff requests over call initiation requests when allocating unused channels in a cell site [3, 5]. Handoffs must be performed successfully and as infrequently as possible, and should be imperceptible to the users. In order to meet these requirements, system designers must specify an optimum signal level at which to initiate a handoff. Once a particular signal level is specified as the minimum usable signal for acceptable voice quality at the base station receiver (normally taken as between –90 dBm and –100 dBm), a slightly stronger signal level is used as a threshold at which a handoff is made. This margin cannot be too large or too small. If it is too large, unnecessary handoffs will burden the MSC, and if it is too small, there may be insufficient time to complete a handoffbefore a call is lost due to weak signal conditions. Therefore, the margin is chosen carefully to meet these conflicting requirements [8].

Figure 2 illustrates a handoff situation and Fig 2(a) demonstrates the case where a handoff is not made and the signal drops below the minimum acceptable level to keep the channel active. This dropped call event can happen when there is an excessive delay by the MSC in assigning a handoff or when the threshold is set too small for the handoff time in the system. Excessive delays may occur during high traffic conditions due to computational loading at the MSC or due to the fact that no channels are available on any of the nearby base stations (thus forcing the MSC to wait until a channel in a nearby cell becomes free) [8].

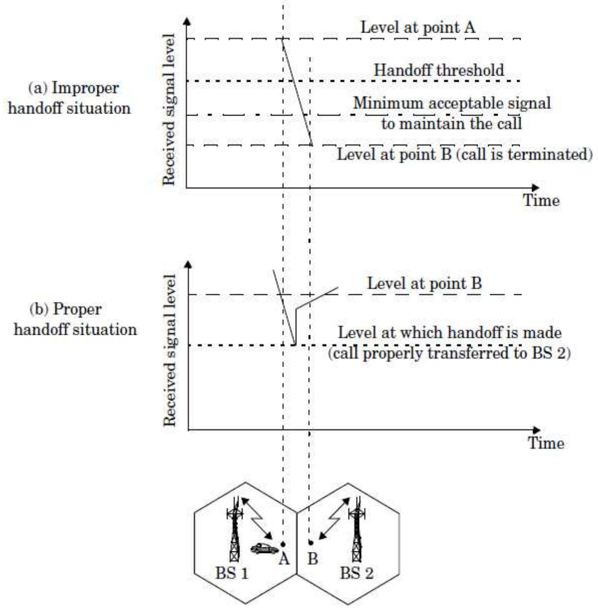

Fig. 2. Showing (a) Improper and (b) Proper handoff situation at cell boundary [8].

The value of implementing handoff is dependent on the size of the cell. For example, if the radius of the cell is 32 km, the area is 3217 km^2. Aftera call is initiated in this area there is little chance that will dropped before the call is implemented as a result of a weak signal at the coverage boundary. Even for 16 km radius cell handoff may not be needed. If a call is dropped in fringe area, the customer simply redials and reconnects the call.

Poorly designed handoff schemes tend to generate very heavy signalling traffic and, thereby, a dramatic decrease in quality of service (QoS) [3-6]. The reason why handoffs are critical in cellular communication systems is that neighbouring cells are always using a disjoint subset of frequency bands. So negotiations must take place between the mobile station (MS), the current serving base station (BS), and the next potential BS. Other related issues, such as decision making and priority strategies during overloading, might influence the overall performance. Drop of handoff call is never appreciated from user’s end and thus, researchers in this field always find effective methods to reduce blocking of handoff requests in a cellular network.

One way to solve this handoff problem is to design a network with optimum number of channelsfor the BS of each cell so that it may handle handoff calls in addition to newly originating calls satisfactorily. Optimum number of channels will reduce overloading on networkdue to handoff requests and consequently network will not refuse or delay inprocessing handoff requests.

Our intention here is to propose a simple but efficient design of a cellular mobile network using suitable traffic model and channel assignment scheme. The proposed design parameters will be calculated in MATLAB using suitable assumptions for necessary tele-traffic and network parameters. Our objective will be to find minimum number of required channel to keep the blocking probability of handoff calls below a presetacceptable margin.

2. Method

At first, to find the probability of requiring a handoff, we can carry out a simple simulation. Suppose that a mobile unit randomly initiates a call in a 16 km (10mi) cell. The vehicle speed is also randomly chosen between 8 and 96 km/h (5 to 60mi/h). The direction is randomly chosen to be between 0 and 360, and then the chance of reaching the boundary is dependent on the call holding time.

Table I. Probability of handoff in a 10 mi area.

Handoff Probability (%)	Call length (min)
11.3	1.76
18	3
42.6	6
59.3	9

Table I summarizes the results. If the call holding time is 1.76 min, the only chance of reaching the boundary is 11%. If the call holdingtimeis3 Min the chance of reaching the boundary is 18%. Now we may debate whether a handoff is needed or not. In rural areas, handoff may not be necessary. However, commercial mobile units must meet certain requirements and handoff s may be necessary at that time.

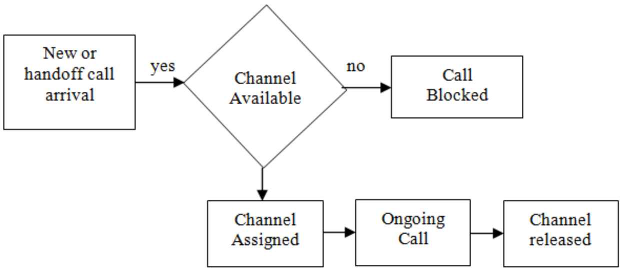

Fig. 3. Flowchart for non-prioritized scheme.

Now we will proceed with our objective which is design the proposed network that can handle handoff calls with minimum blocking probability, first we need to select suitable traffic model and channel assignment scheme to be used in our design.

2.1. Chosen Traffic Model

It is important to establish a traffic model before analyzing the performance of any mobile cellular radio system. Several traffic models have been proposed by many authors based on different assumptions on user's distribution in the cell and their mobility. Notable traffic models are Hong and Rappaport's traffic model [3], Steele's traffic model [9], Xie and Kuek's traffic model [10] and Zeng et al.'s approximated traffic model [11].

From these, Xie and Kuek's traffic model [10] is smart enough as it uses simple approximation but can give acceptable accuracy. Moreover, it is observed that the probability of handoff in Hong and Rappaport's traffic model is a pessimistic one, because the speed distribution of handoff calls are not the same as the overall speed distribution of all mobile users. Steele's traffic model is not adaptive for an irregular cell and vehicular users. Zeng et al.' s approximated traffic model is very close to Xie and Kuek's traffic model and actual deviation of their model from Xie and Kuek's traffic model is relatively small when the blocking probability of originating calls and the forced termination probability of handoff calls are small [4]. Hence, Xie and Kuek's traffic model is preferred here for predicting and calculating necessary tele-traffic parameters.

2.2. Chosen Channel Assignment Scheme

At a busy BS, call attempts that fails because there are no available channels are called blocked calls. Handoff requests that must be turned down because there are no available channels are called forced terminations. It is generally believed that forced terminations are less desirable than blocked call attempts.

Several channel assignment strategies have been developed to reduce forced termination at the cost of increasing the number of lost or blocked calls. Established channel assignment schemes are the non-prioritized schemes, the reserved channel schemes and the queuing priority schemes [3-5]. The non-prioritized scheme for a single traffic system (such as either a voice or a data system) is chosen here, as it is quite straight forward, uses lesser assumptions and involves simpler algorithm in network design layer [3]. It does not require some reserved or dedicated channels to serve handoff requests like prioritized scheme and thus optimize the use of each channel.

The block diagram of non-prioritized scheme is presented in Fig. 3. In the non-prioritized scheme, a handoff call is handled exactly in the same manner as a new call; that is the handoff call is blocked immediately if no channel is available.A blocked handoff request call can still maintain the communication via current BS until the received signal strength goes below the receiver threshold or until the conversationis completed before the received signal strength goes below the receiver threshold.

Some standard and well accepted assumptions in teletraffic analysis are made here to start the proposed network design with minimum blocking probability of handoff calls. Let us assume a system which has many homogeneous cells, with each having S channels. The channel holding time has an exponential distribution with mean rate μ. Both originating and handoff calls are generated in a cell according to Poisson's processes, with mean rates λ_o and λ_H, respectively [9-11].

Following parameters are defined here as follows:

E [C]: The average number of calls in a cell

S: The number of channels in a cell

Bo: Blocking probability

λ_o: The arrival rate of originating calls

λ_H: The arrival rate of handoff calls

$1/\mu_c$: The average call duration

$\mu_{c\text{-dwell}}$: The outgoing rate of mobile users

T: The average channel holding time in a cell

Xie and Kuek's traffic model assumes a uniform density of mobile users throughout an area and that a user is equally likely to move in any direction with respect to the cell border. From this assumption, the arrival rate of handoff calls is [10],

$$\lambda_H = E[C]\mu_{c-dwell} \tag{1}$$

and the average channel holding time T in a cell is,

$$\overline{T} = \frac{1}{\mu_c + \mu_{c-dwell}} \tag{2}$$

Now, a Single Traffic (either a voice or a data system) non-prioritized handoff Schemes assumes that all *S* channels are shared by both originating and handoff request calls and both kinds of requests are blocked if no free channel is available.

The blocking probability B_O for an originating call in such a system is found from Erlang-B formula [4],

$$B_o = P(S) = \left\{ \frac{\dfrac{(\lambda_o + \lambda_H)^S}{S!\mu^S}}{\displaystyle\sum_{i=0}^{S} \frac{(\lambda_o + \lambda_H)^i}{i!\mu^i}} \right\} \tag{3}$$

As, in thenon-prioritized schemes,a handoff call is handled exactly in the same manner as a originating call, the blocking probability B_H of a handoff request is equal to blocking probability B_O for an originating call, i.e.,

$$B_H = B_o$$

Here, the target is to find blocking probability (B_H) of handoff calls for different value of average no of calls E [c] and number of channels in a cell (S) so that minimum number of required channels can be determined within 5% blocking probability, which we set here as the tolerable margin. Clearly, the value of number of channels, S, cannot be calculated directly from Eq. 3, except following a complex numerical techniques or by using suitable software. Here, MATLAB program is used to find the minimum required number of channels within preset acceptable margin of blocking probability. Following steps were carried out through MATLAB to achieve this design goal:

Step-1: Initial values of E (c) and S were assumed for a small area.

Step-2: Suitable and reasonable values for λo, $1/\mu_c$ and $\mu_{c\text{-dwell}}$ for such an area are assigned.

Step-3: The arrival rate of handoff calls (λ_H) is calculated from Xie and Kuek's traffic model.

Step-4: The blocking probability of handoff calls B_H (=B_O) is calculated from Erlang-B formula using rest other parameters.

Step-5: Finally, the values of all the variables were changed within reasonable limit maintaining their mutual dependence and then the above steps were repeated to find an acceptable set of values to keep the value of B_H below 5%.

3. Results

Following above steps and using the chosen traffic model and channel assignment schemes, blocking probably of handoff calls were calculated using MATLAB for different values of associated network parameters.

Table II. MATLAB Result.

E[c]	λ_O	λ_H	$\lambda_H + \lambda_O$	S	B_O
800	80	13	93	89	0.1064
800	80	13	93	90	0.099
800	80	13	93	91	0.0919
800	80	13	93	95	0.0658
800	80	13	93	97	0.0543
800	80	13	93	98	0.049
800	80	13	93	99	0.0448
1000	100	16	116	110	0.1051
1000	100	16	116	112	0.093
1000	100	16	116	115	0.0759
1000	100	16	116	120	0.051
1000	100	16	116	123	0.0385
1500	150	25	175	135	0.2449
1500	150	25	175	136	0.2396
1500	150	25	175	137	0.2344
2000	200	33	233	120	0.4894
2000	200	33	233	125	0.4683
2000	200	33	233	130	0.4473
2300	230	38	268	120	0.5552
2300	230	38	268	123	0.5441
2300	230	38	268	125	0.5368

Here, the outgoing rate of mobile users is assumed as 10% of the average number of call in a cell who may require handoff. This is a fair assumption for small semi-urban residential area. The minimum number of required channels to keep blocking probability of handoff call below 5% is determined after analyzing the MATLAB result.

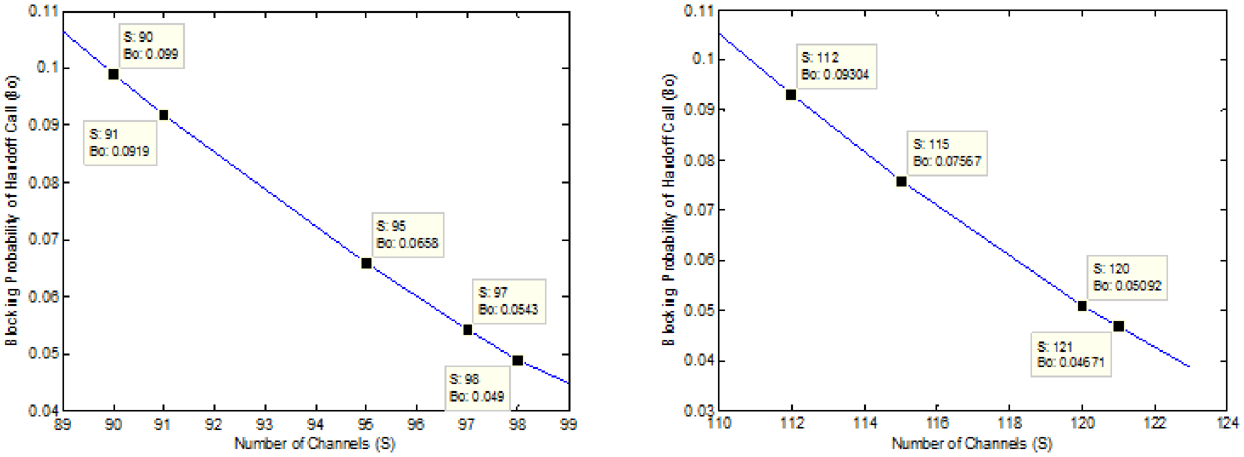

Fig. 4. Number of channel (S) vs Blocking probability (B_o) for two different cases, a) E(c)=800 and b) E (c) = 1000.

From the MATLAB result, as shown in Table II, it has been observed that for any fixed value of E[c], the more we reduce the number of channels, blocking probability (B_o) increases which is quite logical as it means less number of channels are serving higher number of users which increases blocking of new handoff requests. For maintaining blocking probability below 5%, S need to be increased up to a particular value. MATLAB result tells that for an area with 800 average number of calls/minute, the minimum required number of channels is 98 with blocking probability 4.9 % (<5%). If the average number of calls/minute is increased to 1000 and the program is repeated then minimum required channels are found to be 123 with blocking probability 3.85%. Thus, the minimum required number of channels to serve required number of calls in a cell with blocking probability below 5% can be found from this approach.Figure 4 (a) and (b) represents the plot of calculated blocking probability (B_0) vs number of channels (S). It can be clearly observed from this figure how locking probability reduces with the increase of number of channel, as expected. The minimum number of required channel for any acceptable blocking probability margin can be found from this curve.

4. Conclusions

The necessity of efficient management of handoff calls for uninterrupted service in cellular mobile communication is discussed. A simple but efficient design of cellular network for a small area is proposed, to reduce blocking probability of handoff calls below a pre-defined margin. 10% of the users are inassumed in mobility in any direction who may require handoff. Xie and Kuek's traffic model and the non-prioritized scheme of managing handoff calls is used here to find the blocking probability. Calculation using MATLAB is performed for different values of the parameters so as to find the minimum number of channels required to keep the blocking probability below 5%. From the MATLAB result, the minimum number of required channels with 800 calls/min and 1000 calls/min was found to be 98 and 123, respectively, with blocking probability 4.9% and 3.85%, respectively.

5. Future Work

The approach taken in this work can be extended to design cellular networkswithhigher number of originating calls to serve a densely populated area (which will obviously require higher number of minimum required channels and increased calculation time) within same margin of blocking probability of handoff calls.Some network parameters used here can be altered suitably, depending on area or user's behaviours. For example, for a busy or commercial area, mobility of the users may be higher than 10%,thus handoff requestsmay increase. Similarly, the tolerable margin for blocking probability of handoff calls may be set above or below 5% to optimize the satisfaction of specific class of users depending on their priority. The approach used here can also be extended by using any other traffic model instead of Xie and Kuek's traffic model and using prioritized scheme instead of non-prioritized scheme for managing handoff calls though in that case the network parameters, assumptionsand corresponding results may vary significantly.

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