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Improving Handoff Call Handling in Future Mobile Networks with Location Tracking

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Abstract: This study aims to incorporate location tracking of Mobile Terminals (MTs) for wireless resource management in contrast to existing schemes employing signal strength patterns and signal arrival timing characteristics. The incorporation of location information in Handoff (HO) call handling under heterogeneous traffic conditions can provide better efficiency and Quality of Service (QoS) guaranties. As present results confirm, a HO call handling scheme that takes into account the Received Signal Strength (RSS), speed and call type of users to prioritize HO requests reduces the blocking probability of HO calls, detects false HOs and provides better resource utilization performance as compared to Non Priority and First In First Out HO queuing schemes.

Key words: Quality of service, location tracking, queuing schemes, sorted handoff queue, blocking probability, dropping probability

INTRODUCTION

Wireless resources must be provided for a Mobile Terminal (MT) to continue an ongoing call as it crosses-over the coverage area or cell of its Host Base Station (HBS) to move in a new cell. This process is referred to as Handoff (HO). Traditionally, HOs have been associated with the received signal strength (pilot strength) from HBS (host node) in different network architectures. The successful completion of a HO is pivotal for network performance in terms of user-perceived and network-estimated Quality of Service (QoS). Next Generation Networks (NGNs) promise a large cellular coverage area, new services and higher system capacity without compromising the QoS (Zhu *et al*., 2004). These goals require an optimized spectrum efficiency and reduction in important QoS parameters such as handoff call dropping probability (P_d) and new call blocking probability (P_b). Spectrum efficiency can be achieved through load balancing of available channel capacity with efficient channel allocation schemes such as Fixed Channel Allocation (FCA), Dynamic Channel Allocation (DCA) and hybrid schemes. On the other hand, QoS can be improved by reducing cell size and providing better channel reuse over a large coverage area through handoff and new call queuing (Ma *et al*., 2006; Pandey *et al*., 2007; Louvros *et al*., 2007). Although, a single FIFO queue for HO management in a given coverage area, comprising of several Base Stations (BS) having heterogeneous traffic, is the simplest to implement and is cost effective but it would result in higher P_d values unless separate queues are provided for voice or data calls. Also a fast HO call may be left waiting before many slow HO calls are assigned channels in their respective target BSs. User activity is also known to be focused around certain 'hot spots' and the use of a single queue to manage HO requests from hot and cold spots together would lower QoS further.

Another solution for QoS improvement is to incorporate additional information in HO decision process such as MT location tracking with or without embedded hardware. Global Positioning System (GPS) has already been adapted for tracking in mobile environments for next generation network architectures and several schemes are presented to use mobility information in Quality of Service (QoS) improvement. However it demands additional hardware at user end and hence, would require more time to be globally adapted (Sadoun and Al-Bayari, 2007; Sotelo *et al*., 2007). A parallel dimension of research had been mobile terminal tracking through signal characteristics. The most common non-GPS solutions for mobile positioning are: (1) Cell-ID (taking into consideration cell size and timing advance), (2) Time of Arrival (ToA), (3) Angle of Arrival (AoA) and (4) Enhanced Observed Time Difference (EOTD); all make use of the wireless telecommunications system itself (Zaidi and Mark, 2005). Particle and Kalman filtering has been employed to obtain a tracking accuracy of 2 to

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3 min in Mihaylova *et al*. (2007) and Zaidi and Mark (2005), while tracking schemes for Multiple Input Multiple Output (MIMO) and UMTS communication systems are presented by Li *et al*. (2007) and Ahonen and Eskelinen (2003). The incorporation of above mentioned schemes at both network end (i.e., BS) and handset end (i.e., MT) is now realizable due to significant hardware (processing and storage) and software developments.

In our previous research, it was shown that using location coordinates for mobility prediction obtained through onboard GPS can improve QoS and reduce the number of false HO requests results in better resource utilization and increased channel capacity. It was also proposed that a GPS enabled MT should communicate mobility information with HBS for possible HO only when its RSS is below a certain threshold level to reduce the control channel communication and HO requests should be prioritized depending on a MT's need and urgency of HO (Khan and Sha, 2006). In the present research, we wish to extend this idea to resource management, provide HO algorithm details and analysis in anticipation of an increased interest in this important and to our knowledge, less explored dimension of efficient resource management research.

MATERIALS AND METHODS

If we are provided with an estimated location of a MT, the process of HO can be made more robust, quick and reliable (Chang and Leu, 2004; Khan and Sha, 2006). Therefore, a new resource management scheme that accounts for user speed, call type and depreciation in RSS by assuming that location information about a subscriber is available to HO manager (which can be run at BS or MSC under different network tier configurations) is required to prioritize HO requests in NGNs.

USING MOBILITY PREDICTION IN RESOURCE MANAGEMENT

We intend to highlight the importance of mobility information in resource management. In order to handle limited wireless resources efficiently, we must formulate a way to reduce pre-reservation time for HO requests and the average time spent in queue waiting for resources. For this purpose, we must establish the actual need of HO and an estimated time before the MT must complete HO. Elimination of false HO requests would allow more new calls to be served and overall channel utilization would improve (Khan *et al*., 2008).

Figure 1 shows a mobility prediction scheme based on very simple linear extrapolation to predict the future location of a MT given its current coordinates and heading. It is assumed that MT has its current location

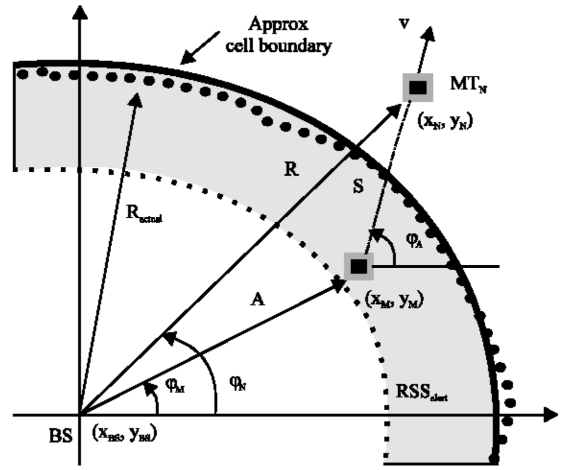

Fig. 1: Estimating mobility and target base station by linear extrapolation

information available through any tracking scheme (x_M, y_M). If MT maintains its current speed (v) and direction (φ_A) for a certain time duration T_{UPDATE} (say 1min), its extrapolated location is predicted to be (x_N, y_N) and its direction with respect to HBS would be φ_N. Assuming T_{UPDATE} to be small enough, we imply that direction of motion φ_A remains constant and MT's speed can be calculated by using present coordinates (x_M, y_M) and last recorded value (x_{M-1}, y_{M-1}):

$$v = \frac{S}{T_{UPDATE}} = \frac{\sqrt{(y_M - y_{M-1})^2 + (x_M - x_{M-1})^2}}{T_{UPDATE}} \quad (1)$$

The extrapolated coordinates (x_N, y_N) can be calculated as:

$$x_N = x_M + S.\cos\varphi_A, \quad y_N = y_M + S.\cos\varphi_A \quad (2)$$

Following from (1) and (2), we can calculate the distance and direction of MT's extrapolated position from HBS (R), which is very useful in establishing the requirement of handoff.

$$R = \sqrt{(y_N - y_{BS})^2 + (x_N - x_{BS})^2}$$
$$\tan\varphi_N = \frac{y_N - y_{BS}}{x_N - x_{BS}}, \quad (3)$$
$$t_{REMAIN} = \frac{|R_{AVERAGE}\cos\varphi_N - A\cos\varphi_M|}{v}$$

Here, $R_{AVERAGE}$ is the average radius of host base station's coverage area in direction φ_N, calculated by averaging distances reported by previously handedoff MTs in this particular direction and A is the actual distance of MT from Host BS. Distance (R) and angle (φ_N) are very important in establishing average cell radius and target BS of mobile terminal as well as the time remaining before Handoff. If distance (R) is found to be equal or greater than the average cell boundary reported by previously handed-off mobile terminals, MT under consideration is in dire need of handoff. On the other hand, if calculated distance is less than the average reported cell boundary, MT is left on alert. Remaining time to handoff is calculated for every MT in RSS_{ALERT} zone. Handoff requests can be ordered according to t_{REMAIN} and target BS can be identified by matching φ_M with a short table containing the directions of neighboring BSs (for hexagonal cells, each BS would have 6 neighboring BSs).

HANDOFF URGENCY BASED RESOURCE MANAGEMENT SCHEME (HUB)

Proposed HUB scheme is intended to address the need for resources by multimedia and voice traffic having different bandwidth requirements. In order to accommodate heterogeneous traffic with different originating call types (voice or data) and user mobility (slow and fast) we introduce a Call Type Factor (CTF). The network administrator can set it for a specific time interval depending upon the amount and type of traffic in a given area. For instance, CTF for voice calls may be set higher than data calls during lunch intervals and conversely, multimedia calls may get precedence during weekends and holidays to cater for different amount and types of traffic. The need and urgency of handoff for any MT depends upon user mobility and resultant depreciation in RSS. In proposed scheme, Urgency of HO (U_{HO}) for n subscribers in a given coverage area at a particular time instance t is calculated as:

$$U_{HO}(i,t) = \Delta RSS(i,t) \times speed(i,t) \times CTF(i,t),\ [i = 1, 2, ..., n; t \neq 0] \quad (4)$$

Change in RSS (ΔRSS) from HBS at a given time t is calculated if the RSS is above some preset threshold level RSS_{TER}, necessary to continue an on going call, according to following relation:

$$\Delta RSS(i,t) = RSS(i,t) - RSS(i,t-1), \\ [i = 1, 2, ..., n; t \neq 0; RSS(i,t) > RSS_{TER}] \quad (5)$$

Speed of a MT is also taken into account in Eq. 4 as it is likely that fast moving users would require a channel in target BS more urgently as compared to a slow user.

U_{HO} represents the need of a MT to complete HO to its target BS within the HO completion window and accounts for the nature and mobility of introduced traffic. Using the above parameters also ensures the elimination of false handoff requests from MTs in the cellular overlap region. During subsequent updates in U_{HO} values any such false HO request would be assigned a lower U_{HO} and hence, would be denied resource allocation, resulting in better channel utilization and efficiency. The algorithm is listed as below:

- In the case of a HO request, if no channels are available in Target Base Station (TBS) and a slot is available in HO Queue, HO call is queued. On the other hand, if no empty slot is available in HO Queue, a MT would continue its call in Host Base Station (HBS).
- At every update instance, the call with maximum U_{HO} (which would also be positioned at the first slot in sorted HO queue) is given precedence over other queued HO calls as well as the new call requests for the provision of wireless resources.
- New calls are serviced as long as BW is available at HBS otherwise, they are blocked.
- A HO call leaves the system in four cases: (1) it gets forcefully terminated due to RSS depreciation, (2) it gets an empty slot in HO Queue at next update instance, (3) HO request gets dropped while waiting in sorted queue for its turn to be serviced or (4) Updated value of U_{HO} is lower than preset threshold, HO request is considered a false alarm in this case and MT is removed from HO queue to make room for more HO requests. Condition 3 is highly unlikely in proposed scheme as a HO call with rapidly depreciating RSS would essentially have a higher U_{HO} and hence, is more likely to be serviced ahead of other queued HO requests.
- At every update instance, U_{HO} parameter for all queued calls is updated and queue is sorted accordingly.

To evaluate the performance of proposed scheme, we compare it with two existing resource management schemes: (1) Non Priority Scheme (NPS) that does not assign any particular priority to HO calls and instead, shares the available resources among new calls and HO calls on first come first served basis and (2) First-In-First-Out (FIFO) scheme which queues all HO requests in a queue to improve p_d metric.

In NPS, a new call (voice or data, fast or slow user) attempts to acquire any free channel in its Host Base Station (HBS). If all the channels in HBS are busy, new call is blocked. Similarly, HO call is attempted at Target Base Station (TBS). If there are no resources available to service the HO request, MT requesting HO remains with its HBS. A HO call leaves the system in two cases: (1) it gets forcefully terminated due to depreciation of Received

Signal Strength (RSS) below a certain threshold level required to continue the call and increases the overall dropping probability or (2) it competes again with other HO requests for any free resources on the next update instance and gets a free channel in TBS. After a successful HO, resources are freed in the HBS and TBS becomes the HBS for the said MT.

For FIFO scheme, in the case of a HO request if no channels are available in TBS and a slot is available in HO Queue, HO call is queued. On the other hand, if no empty slot is available in HO Queue, a MT would continue its call in HBS. New calls are serviced as long as BW is available at HBS otherwise they are blocked. A HO call leaves the system in three cases: (1) it gets forcefully terminated due to RSS depreciation, (2) it gets an empty slot in HO Queue at next update instance or (3) HO request gets dropped while waiting in FIFO queue for its turn to be serviced. At every update instance, calls waiting in HO Queue are given precedence over new call requests for the provision of wireless resources.

SIMULATION SETUP

The arrivals of new fast and slow calls in cells are generated through a Poisson process with parameter λ (calls/sec) with Q fast calls and 1-Q slow calls in the network, respectively. Uniform fluid-flow model is used to represent user mobility and the simulation setup is shown in Fig. 2. The rate at which a mobile crosses a microcell boundary is given by $\eta = V L/\pi S$, where L is the perimeter of a cell, V is the average velocity of the user and S is the cell area (Rappaport, 2001). The cell-dwelling time of a mobile in a microcell is exponentially distributed with the mobility parameter η (cell crossings/sec).

The total (new-call plus handoff-call) call-holding time is assumed to have an exponential distribution with a mean of $1/\mu$sec. The cell-dwelling time of a call in a microcell is therefore exponentially distributed with

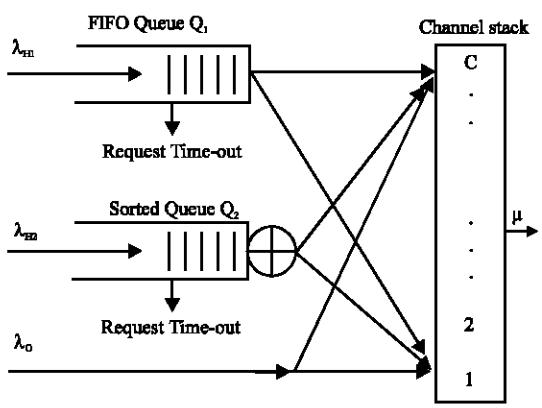

Fig. 2: FIFO and HUB queuing schemes for a given coverage area

parameter $\eta+\mu$. There are two ways in which a call exits a cell: (1) there is a handoff with probability $P_{HO} = \eta/(\eta+\mu)$ and (2) the call completes with probability $1\text{-}P_{HO}$. Maximum number of channels available (BW) in each Base Station (BS) is 150. We simulated a test area covered by five BSs each having coverage area with radius 200 m. The mean user mobility for a slow user is assumed to be 3.5 kmph (2.25 mph), which is the average walking speed of a human being. For a fast user, the mean mobility is assumed to be 35 kmph, which is the average automobile speed in a busy urban area. Therefore, η_s = 0.0030946 (cell crossings/sec) for slow users and η_f = 0.030947 (cell crossings/sec) for fast users. For short calls, a mean call-holding time of 2 min is used, while long calls are assumed to hold for 5 min, on average. Traffic λ is taken equal to 1.0 calls/sec. Each simulation experiment is conducted for 10,000 serviced calls and queue size is fixed to 5 for results presented in following section. The comparison is based on the following performance metrics.

Blocking probability: Total blocking probability is defined as the ratio of the total new calls blocked to the total number of new-call attempts.

Dropping probability: Total dropping probability is the ratio of the total number of calls that got dropped while attempting a handoff to the total number of successful new-call attempts.

Channel utilization: It is the ratio of channel occupancy time to the total simulation duration.

RESULTS

Figure 3 presents the comparison of three schemes in terms of blocking and dropping probability. As we are testing the system under high traffic conditions (1 call/sec) in a single tier network, the blocking probability converges to zero beyond the provision of 100 channels in every BS. However, the trends are quite visible and typical i.e. $P_{b\text{-}HUB} > P_{b\text{-}FIFO} > P_{b\text{-}NPS}$. Proposed scheme has the highest dropping probability for any given number of available channels but the gap narrows as the system achieves equilibrium and/or low traffic conditions. FIFO achieves very competitive results with NPS which achieves the lowest blocking probability metric under simulated conditions as it does not assign any priority to HO calls. Dropping probability comparison reveals that proposed scheme outperforms NPS and FIFO queuing scheme with a wide margin i.e. $P_{d\text{-}HUB} << P_{d\text{-}FIFO} < P_{d\text{-}NPS}$. The effectiveness of distributing wireless resources to the

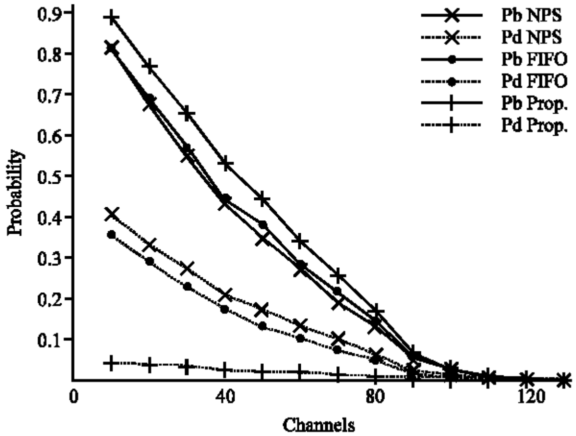

Fig. 3: Blocking and dropping probability comparison with traffic 1 call/sec

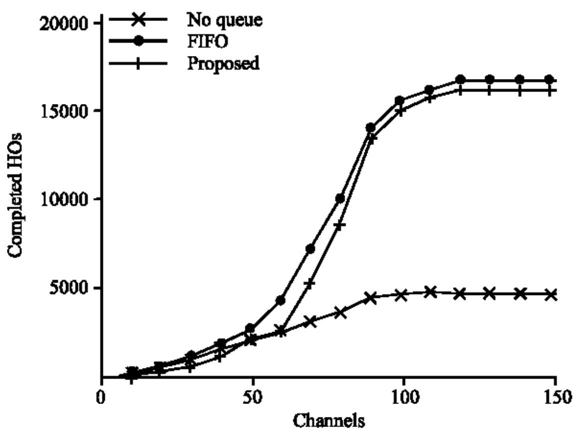

Fig. 4: Total number of completed handoffs for 10,000 new-call arrivals

Table 1: False handoff requests detected by proposed scheme

Channels (BW)	Handoff detected
10	408
20	778
30	991
40	1060
50	1137
60	1046
70	925
80	629
90	490
100	304
110	300
120	311
130	307
140	308
150	305

most in need HO users is evident in Fig. 3 especially for an over populated system with less available BW. The gap in performance decreases with an increase in available channels as more HO and new calls can be serviced then.

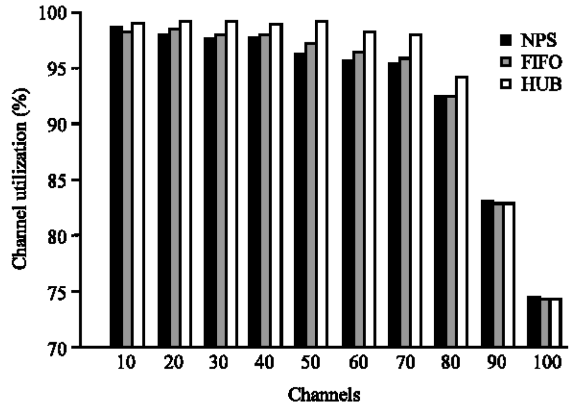

Fig. 5: Channel utilization comparison

Analysis of results for total completed HOs during an entire run for varying system capacity reveals a very interesting scenario. NPS fails to adapt to high traffic conditions and hence does not accept significant number of HO calls in all the test runs. On the other hand, FIFO scheme shows the most completed HOs while proposed scheme follows a little behind as shown in Fig. 4. Another important aspect is the decrease in total number of HOs by our scheme without any increase in dropping probability. This signifies a definite QoS improvement as more channels are made available for originating calls and HO requests.

Together with results in Fig. 4, we can see that proposed HO management scheme is able to detect false HOs at different channel capacity values. Referring to Table 1, the initial rise in the number of detected false HOs as BW is increased from 10 to 50 channels complements the fact that more new calls get channels and consequently would request HOs depending on their respective dwell time and RSS values. The reason for the decrease in detected false HOs for BW = 50 to 100 is again dependent on the channel capacity. As BW increases more HO calls can be serviced without the need for them to wait in queue for their turn. This limits the effectiveness of proposed false HO detection procedure in HUB scheme.

Our scheme gives the best channel utilization performance under high traffic and low capacity conditions by efficient management of resources. Figure 5 shows the comparison of three schemes at different available bandwidth. The biggest improvement is for BW = 50 to 80. However, the gap narrows as more channels are available to handle incoming new call and handoff traffic.

CONCLUSIONS

Performance comparison of handoff management schemes in terms of QoS parameters indicates that queuing handoff requests by estimating mobility and call type can definitely improve blocking probability metric with a little increase in new call dropping probability. Proposed HUB scheme has been shown to be capable of handling heterogeneous traffic type and mobility, as well as the elimination of false handoffs within the cellular overlap area. It also provides better resource utilization in high traffic conditions. However, further investigation is required for the reduction of new call blocking as well. Also, the effect of queue size on comparative system performance is desired to further validate the effectiveness of proposed scheme. As wireless networks are evolving towards multi-tier architecture, the adoption of proposed scheme at individual tiers can improve QoS significantly, however this is left as a future work. Similarly, the claim for minimal control communication requires further verification as this feature is dependent on network architecture, protocols used and desired QoS. An envisioned resource management scheme for multi-tier topology and heterogeneous traffic with location tracking is realizable but dependent upon hardware innovations.

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