Mobility Prediction Based Resource Reservation for Handoff in Multimedia Wireless Cellular Networks

Maher Al-Sanabani, Shamala Subramaniam, Mohamed Othman, and Zuriati Zukarnain
Department of Communication Technology and Networks, University Putra Malaysia, Malaysia

Abstract: *In this paper, a mobility predictive based resource (bandwidth) reservation is proposed to provide flexible usage of limited resource in wireless cellular networks. Currently, multimedia communications is urgently expected in wireless networks. That as there is more and more high speed applications that emerge for wireless networks. One of the most important and complicated issues is the Quality of Service (QoS) in next wireless networks. In other words, the problem to maintain the playing continuity of multimedia streams during handoff is hard for solution. Hence, in this paper, the scheme is proposed to provide high accurate prediction of next crossing cell that Mobile Terminal is going to, in order to avoid too early or over reservation resulting in a waste of resources. The amount of bandwidth to be reserved is dynamically adjusted according to the current position and extrapolated direction of Mobile Terminal. An admission control scheme is also considered to further guarantee the QoS of real time traffic. The performance of system is evaluated through discrete event simulation of realistic wireless cellular environment. Simulation results show that the proposed scheme as compared to the existing schemes is efficient to reduce the New Call Blocking Probability and the Handoff Call Dropping Probability of real time traffic. In addition, it is efficient to reduce the number of terminated ongoing calls of non-real time traffic and the cancels reservation that increase the system bandwidth utilization.*

Keywords: *Wireless cellular networks, mobility prediction, resource reservation, handoff and quality of service.*

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1. Introduction

The evolving trends in Wireless Cellular Networks (WCN) have caused multimedia communications to be researched in an in-depth manner. This is the consequence of the rapidly increasing number of high-speed applications with different Quality-of-Service (QoS) and their respective traffic profiles. Among the critical issues to be addressed is the QoS in the third-generation (3G) and beyond WCN. Guaranteeing the QoS of multimedia traffic, which is classified as real-time and non-real-time and the continuity of multimedia streams during a handoff are areas of challenge. Integration of Call Admission Control (CAC) and bandwidth reservation avoid long latency of path rebuilding and ensured QoS. However, pure bandwidth reservation may lead to an inefficient bandwidth utilization and increase of New Call Blocking Probability (NCBP) in WCN. To reduce unnecessary bandwidth reservations, the predictive bandwidth reservation can be incorporated to enhance pure bandwidth reservation. This would avoid premature or over-estimated reservation which, results in a waste of reservation.

User mobility information, defined as the probability that a mobile user will reside in a particular cell at future moments, is the key information to obtain accurate estimation of resource demands at future time [8]. An inaccurate knowledge or lack of user mobility information may result in an inaccurate resource estimation, which would further lead to the underutilizing or overloading of the available network resources. In the former case, some calls that otherwise should be admitted may be rejected, while in the latter case, the handoff call dropping rate may be unacceptably high.

In order to guarantee QoS requirements over the lifetime of a connection and to maintain maximum resources utilization, it is highly desirable for the system to know in advance the mobility information of a mobile user. User mobility information plays an important role in mobility management and network resource management. A CAC scheme incorporating mobility information can determine whether there are enough resources available in cells along the path of the mobile and reserve resources accordingly [14]. Therefore, the guaranteed QoS can be achieved if enough bandwidth is reserved before entering a new cell and if a system makes exact prediction of next crossing cell that Mobile Terminal (MT) is going to. When the system fails to predict a MT's target cell the previously reserved bandwidth become waste. In such situation, a system should release previously reserved bandwidth.

In this paper, a 3-zone cell structure is adopted. In the proposed scheme, the target cell is predicted by Received Signal Strength (RSS) measurement from current position and extrapolation path of the MTs when it is in the Reservation Zone (RZ) and Handoff Zone (HZ) and is leaving the Non Reservation Zone (NRZ). The amount of bandwidth to be reserved in the target cell is dynamically adjusted to reflect the mobility condition of MT. A CAC scheme is also adopted to achieve lower connection blocking and dropping probabilities and better bandwidth utilization.

The rest of this paper is organized as follows. Section 2 describes the related work. The proposed mobility-prediction scheme is presented in section 3. The system environment and simulation results are provided and discussed in section 4, where performance measures of the proposed scheme are investigated. The paper is concluded in section 5.

2. Related Work

Resource reservation issues have been addressed in several literatures extensively [10, 1]. In most of these work, the target cell is defined using the random walk model i.e., probabilistic [10] or history profile of moving MTs i.e., dynamic [1]. Although the random walk model is often adopted in Personal Communication Services (PCS) networks, MTs explicitly exhibit some degree of regularity in the mobility pattern, i.e., non-random travelling pattern.

In [2], a method to estimate user mobility based on an aggregate history of handoff times in a cell was developed. This method has been used to predict probabilistically mobiles' directions and handoff times in a cell and then an admission call algorithm has been provided based on the calculated target reservation bandwidth. The method provided in [2] depends on the length of the periodic observation windows with which the estimation is based on. The Base Station (BS) of a cell should keep track of each active user in its cell. Regardless of the huge load of computations needed, this method provides a realistic estimation of the target cells. In this scheme, the prediction is used to reserve bandwidth, but the amount of bandwidth to be reserved is dynamically adjusted according to the time-varying traffic pattern and the observed handoff dropping events. An adaptive algorithm for controlling the mobility estimation time window to prevent over-reserving bandwidth is also used.

In [13] a reservation algorithm which utilizes MT movement prediction based on the previous local mobility patterns in each cell was proposed. The system accumulates the statistics of transition probability information in the cell. Whilst [2, 13] utilized the aggregate history of MTs movements from the previous cell to the current cell as the means to make next cell prediction.

A mobile motion prediction algorithm, which is based on the user's movement history, was proposed in [7]. The user movements consist of regular and random components that can either be matched with circle/track patterns or simulated by the Markov chain model. The user prediction is highly accurate with regular movements but decreases linearly with increasing random component.

A shadow cluster that defines the area of influence of an MT (i.e., a set of BSs to which the MT is likely to attach in the near future) was proposed in [6]. Like a shadow, this set moves along with the MT, integrating new base stations while leaving the old ones as they come under and out of the MT's influence. Each BS in the shadow cluster foresees the MT's arrival and reserves resources for it. A close association exists between the MT's arrival prediction and reservation of resources for it. The accuracy of the MT's path prediction determines the number of BSs that reserve resources, and consequently determines the overall system efficiency.

In [8], a hierarchic position prediction algorithm was proposed. This scheme is based on the user's movement history and instantaneous Received Signal Strength Indicator (RSSI) measurements of surrounding cells. User's movement can be mapped into previous mobility patterns, with matching operations such as insertion, deletion and changing. Inter-cell movements can be also estimated by current location, velocity and cell geometry. Prediction remains reasonably accurate (75%) despite the influence of random movements.

In [9, 5], a MT should make a reservation at any neighbouring BS where the signal strength that the MT receives from the BS is greater than a pre-defined threshold. If a MT can receive a strong signal from a BS, the MT must be close to the BS. Therefore, the MT may soon handoff to the BS. While in [3], each BS stores a map of the signal strength at any point in the cell. When making calculations the BS uses this map to determine accurately where the MT is located. A weakness of this scheme is that it makes advance reservations in three cells and all schemes makes the reservation in shadow cluster/most likely cluster that yield to wastage of resources. Ideally, advance reservations should be made in one cell.

3. Description of Proposed Mobility Prediction Scheme

In current mobile cellular system, the distance between the MT and a known BS is practically observable. Such information is inherent in the forward link RSS of a reachable BS [8]. Thus, this RSS can be used to predict the MT movement as presented in [3]. From field measurements, a few points with known values of RSS are chosen as anchor points within the cell. Based on the RSS from the user and the RSS at the user from neighbouring BSs, the anchor point closest to the user is computed. Then, the location of the MT is predicted relative to its closest neighbouring anchor point whose coordinates are assumed to be known. As a result of this approach, three neighbouring cells closest to the current location of the MT can also be determined. The neighbouring BS, from which the RSS is the highest, is most likely the closest neighbouring cell of the user. After the BS detects that a MT has entered the RZ (by comparing its RSS with certain thresholds), it instructs the MT to send the RSS measurements from all the neighbouring BSs and the corresponding cell ids. The representation of RZ and HZ is shown in Figure 1.

To determine the cell coverage, zone coverage, and (RZ, HZ), the propagation model proposed by [12, 4] is adopted where the RSS from a particular cell $cell_i$, can be expressed as

$$RSS = - 10\gamma \; x \; \log (d_i) \qquad (1)$$

where γ is the propagation path-loss coefficient, typically, $\gamma = 2$ for highways and $\gamma = 4$ for micro-cells in a city. d_i represents the distance of the transmitter to the MT between the MT and BS of $cell_i$, which can be further expressed in terms of the MT's position ($x(t)$, $y(t)$) at time t and the location of BS (a_i, b_i)

$$d_i = [(x(t) - a_i)2 + (y(t) - b_i)2]1/2 \qquad (2)$$

This MT coordinate position then can be used to determine the location of MT in the cell. Similar to [3] we also propose a RZ to predict the neighbour cell a MT is likely to move to (see Figure 1). But unlike [3] where the reservation is performed to three cells, the proposed system performs a bandwidth reservation to one predicted destination cell only. The next section discusses the details of the proposed algorithm to enhance mobility prediction utilizing directions are an integral index.

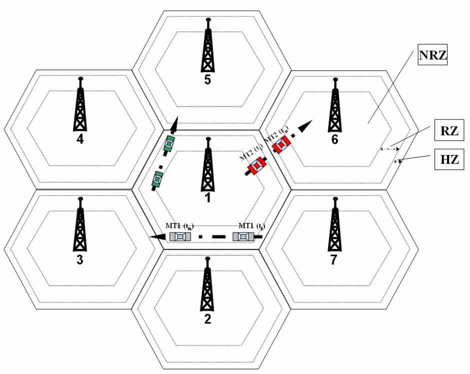

Figure 1. Reservation and false reservation.

3.1. The Cell Geometry

The cell boundary is approximated by using M points surrounding a BS. It is arranged in such a way that the radial lines drawn from the BS to these points are spaced at regular angles $\theta^o = 360^o / M$ apart (see Figure 2). We shall refer to these points as Boundary Cell Points (BCPs). These points are represented in polar coordinates as (R_n, $n\theta^o$); n=0, 1….M-1, where R_n is the radial distance of the n^{th} point from the BS. The polar axis could be chosen to point towards any arbitrary magnetic direction. The region around each BS is divided into M sectors, where the nth sector spans from azimuth $n\theta^o$ to $(n+1)\theta^o$; n=0, 1….M-1. In order to compute the BCPs, R_n is obtained as the distance of this position point from the BS where this distance is the radius of the cell. The sector with two BCPs (R_n, $n\theta^o$), (R_{n+1}, $(n+1)\theta^o$) and their corresponding most likely target handoff cell T_{cell} are stored in a table located at each BS. The number of entries in the table is equal to the number of BCPs M. The choice of M should depend on the size of actual BS coverage area in hexagonal shape.

A 3-zone cell structure is adopted. In the proposed scheme, the target cell is predicted by RSS measurement from current position and extrapolation of the direction MT when it is in the RZ and HZ and is leaving the NRZ. The amount of reserved bandwidth in the target cell is dynamically adjusted to reflect the mobility condition of MT.

3.2. The Prediction Algorithm

The algorithm presented here is assigning the delegating prediction responsibility to the BS instead of delegating the prediction responsibility to individual MTs. This reduces the computational power requirement at the MTs, which could be more attractive since battery power limitation and component cost are major concerns for mobile device manufacturers. Also, the BS should be able to handle this additional computational requirement without any difficulty.

For every active MT in the cell, the BS performs a series of simple calculations as α (azimuth of MT's position from BS where $0^o \leq \alpha < 360^o$), β (azimuth of MT's estimated direction of travel, where $0^o \leq \beta < 360^o$) and γ (azimuth of MT's projected position from BS at time Ω, where $0^o \leq \gamma < 360^o$). Specifically, a line segment is extrapolated from the MT's current location in its estimated direction of travel by a distance equal to the product of Ω and the MT's current speed (see Figure 2). This represents the path that would be travelled by the MT if it were to maintain its current speed and direction. The line segment is to be tested for any intersection with the BCPs. If an intersection is found, the BCPs that contain this intersection point is determined, which we shall refer to it as the sector while the crresponding target handoff cell is predicted to be the T_{cell} associated with the sector. When the base station detects that a MT has entered the RZ and HZ (by comparing its RSS with certain thresholds) for reducing computation and signalling overhead, In the proposed scheme, bandwidth reservation decisions are based on if current position and extrapolation of the direction MT in the same sector.

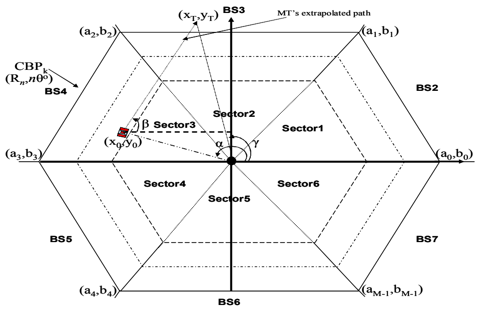

Figure 2. Boundary cell points and determines direction of MT.

To illustrate the mobility prediction of proposed scheme, we compare the scheme with mobility prediction scheme based on location of MT that depend on closer distance of MT to BSs [5] which called MPS-L. When the MT is within a certain distance from the next cell, the current BS sends a reservation request to the new BS in order to pre-allocate a bandwidth for expected handoff event. A reservation may be deemed invalid at later time, which is called a false reservation. In this case, cancellation of reservation must be sent to de-allocate the reservation. Since the false reservations increases signalling traffic in WCN and waste bandwidth resources, it is desired that to be reduced as much as possible.

The Contrast to [5], the proposed scheme, determination of when a reservation request should be sent by the BS of a cell where an MT is currently located to the BS of the next targeted cell that the MT is heading to, is done based on a real time analysis of user mobility information such as the RSS measurement and current direction of this MT.

An assumption that the WCN has a two-dimensional (2-D) topology in which each cell has exactly six neighbouring cells is made. The reservation and cancellation mechanism is illustrated in Figure 1 which shows a small portion of a WCN. Handoff occurs when the MT reaches the boundary of the current cell. Figure 1 gives an example of when a reservation and a cancellation may occur. Suppose at t_i, the MT1 is in RZ in cell 1 and it is close to cell 2. As a result, the BS in cell 1 sends a reservation request to cell 2 on behalf of MT1.Assume at a later time t_n, the BS in cell 1 detects the MT1 is closer to BS in cell 3. Thus the BS in cell 1 needs to send a cancellation to the BS in cell 2, as well a new reservation request to BS in cell 3 because the information of MT1 changes. Also, at t_i, the MT2 is in RZ in cell 1 and it is close to cell 6. As a result, the BS in cell 1 sends a reservation request to cell 6 on behalf of MT2 at a later time t_n, the MT2 is in HZ or RZ in cell 6 and it is closer to the old BS in cell 1. Thus the BS in cell 6 needs to send a reservation request to BS in cell 1.Based on this example the waste of bandwidth reservation caused by a false reservation is evident. In this research, the reductions of these limitations are reduced by the defining direction of the MT as an integral factor in reservations. Thus, reducing false reservation by a substantial amount observed from the simulation conducted.

3.3. Call Admission Control and Bandwidth Reservation

The proposed research has adopted the CAC scheme of [11]. The CAC determines the acceptance or rejection of a call. There are two steps taken before admitting a call. First, when the resource is underutilized, all incoming calls are admitted. Secondly, when the resource is fully utilized, only new high priority calls will be admitted, while ongoing lower priority calls would receive a reduced or forcedly terminated service. For example, When the CAC receives a new real time Constant Bit Rate (CBR) call; the CAC compares the average required bandwidth of the MT to the available bandwidth of the network. If the required bandwidth is less than or equal to the available bandwidth; the new call is accepted. Otherwise, the system will check the priority level of all the ongoing connections. If the priority level of the ongoing connections is less than CBR priority, the bandwidth reallocation algorithm for non-real-time Unspecified Bit Rate (UBR) traffic will be invoked and executed to get additional bandwidth. Then, a new available bandwidth is obtained, and it is compared to the bandwidth desired. If the new available bandwidth is still less then the bandwidth required, the bandwidth reallocation algorithm for real-time Variable Bit Rate (VBR) traffic is called. This algorithm will reduce the bandwidth allocation for real-time VBR traffic to be given to the new CBR call. Once the new available bandwidth is sufficient, the new call is accepted. Otherwise, the new call is rejected.

The application priority is maintained and checked to determine the need for bandwidth reservation. If the MT connection is real-time traffic (i.e., VBR or CBR) and it has crossed the RZ, the bandwidth reservation algorithm is invoked. On the other hand, if the MT connection type is non real-time, the MT position will be ignored until it enters the HZ. When it does, the reservation algorithm is invoked. The determination of the amount of bandwidth to be reserved depends on the bandwidth required by the traffic. For example, CBR traffic has only one bandwidth requirement. Therefore, its specific amount of bandwidth will be reserved in the destination cell. In the case of real-time VBR traffic, two bandwidth requirements is utilized, which are the minimum and the average required bandwidth. At first the system will request for the average bandwidth required. If the available bandwidth is sufficient, bandwidth reservation takes place in the destination cell. Otherwise, the system requests for the minimum bandwidth required. If the available bandwidth can satisfy the bandwidth requirements, the reservation is successful; otherwise, the reservation fails, which may lead to handoff drop.

4. Performance Evaluation

In this research, the accuracy of prediction metric to evaluate the proposed prediction scheme is introduced. During an on-line compute RSS measurement, the current position and the direction of MT, the predictor is given a chance to predict the target cell that the MT will move to. There are two possible outcomes for this prediction, when compared to the actual target cell: correct and incorrect. We define the accuracy of a predictor for a system to be the fraction of target cells for which the predictor correctly identified the target cell.

Two additional performance measures of the proposed scheme are utilized. The parameters are based on the QoS parameters which are NCBP and HCDP. The bandwidth utilization is also measured to illustrate how the system is able to maintain the efficient bandwidth utilization while attempting to strike a balance between these two QoS parameters (NCBP and HCDP).

In each cell, the BS is responsible for connection setup, CAC, call termination, bandwidth reallocation and bandwidth reservation for new and handoff calls. In most of the simulation results that follows, the performance measures are plotted as a function of the call arrival rate. The call arrival rate is the arrival rate of new calls measured as the average number of new call requests per second per cell. Before proceeding, we first describe the simulation model that is used in this paper.

4.1. Simulation Model

A discrete-event simulation model for a wireless cellular network environment in a 2-D topology in which each cell has exactly six neighbouring cells is extensively developed using C++.

4.1.1. Multimedia Services Model

The representations of the multimedia applications are based on the call duration, bandwidth requirement and the class of service. The classification strategy is adopted from [10]. The different application groups include real time CBR, real time VBR, and data traffic sources UBR. The six applications are carefully chosen for a simulation; they are typical traffic seen in wireless networks and their respective parameter values are chosen from Table 1. The bandwidth required of the call is assumed to follow a geometric distribution between the minimum and average values. The call duration for each MT is exponentially distributed with rates equal to μ. The values closely represent realistic scenarios shown in the Table 1.

4.1.2. Cell and Traffic Model

The simulated area consists of omni-cells and has a uniform geographic distribution. It is assumed that a BS is located in the centre of a hexagonal. Fixed channel allocation is assumed in the system. The maximum bandwidth capacity for each BS is set to 30 Mbps and the maximum amount of bandwidth that can be reserved for handoff requests per cell is limited to 20% from the maximum bandwidth capacity per cell.

Calls requests are generated according to a poisson process with rate λ_{new} (calls/second/cell) in each cell of different the traffic classes where the probability of a call belonging to traffic classes 1,2..or 6 are generated with equal probability and appear anywhere in the cell with an equal probability. The parameters values used in the simulation shown in Table 1.

4.1.3. Mobility Model

Three parameters for mobility model are considered, the initial position of a mobile, its direction and its speed. A newly generated call can appear anywhere in the cell with an equal probability. When a new call is initiated, a mobile is assigned a random initial position derived from a uniform probability distribution function over the cell area. The MT coordinate position can be used to determine the location of a MT in the cell. When the BS detects whether a MT has entered the RZ and HZ (by comparing its RSS with certain thresholds), the current BS sends a bandwidth request to the new BS (one of the neighbouring cells of current cell) that the MT heading to is determined in order to pre-allocate a bandwidth for expected handoff event. A mobile can travel in one of 8 directions with equal probability. Since MTs are free to move in any direction, therefore, newly established connections have equal probability of ending up in any cell of its six neighbouring cells. The user movement pattern is considered as 75%D; directional that means MT can not change its direction as long lifetime of connection. And as 25%R random that means MT can change its direction every 1sec, movement pattern because the MTs explicitly exhibit some degree of regularity in the mobility pattern. A mobile is assigned a random direction upon entering a cell. A constant randomly selected speed is assigned to a mobile when it enters a cell either at call initiation or after handoff. The system interval for checking the RSS measurement and current position of MT is assumed to be performed every Probing time interval while extrapolation path or the direction of MT when MT in RZ and HZ in the cell for reducing the signalling traffic.

Table 1. Multimedia traffic and simulation parameters used in simulation.

Traffic Type-Class No.	Type of Media	Bandwidth Requirements Avg.	Bandwidth Requirements Min.	Duration of Call Avg.	Priority
1-CBR-1	Voice service and audio phone	30 Kbps	30 Kbps	3 min	6 *(Highest)*
2-CBR-2	Video-phone and video-conference	256 Kbps	256 Kbps	5 min	5
3-VBR-3	Interactive multimedia and video on demand	3 Mbps	1 Mbps	10 min	4
4-UBR-1	Email ,paging and fax	10 Kbps	5 Kbps	30 sec	3
5-UBR-2	Remote login and data on demand	256 Kbps	64 Kbps	3 min	2
6-UBR-3	File transfer and retrieval service	5 Mbps	1 Mbps	2 min	1

Description	**Value**	**Description**	**Value**
Number of cells	64(8x8) Warp around	Probing time interval	1 sec
Cell radius	200m	The probability of moving direction	(0.75) Forward (0.25) Changing the direction
TD-RZ	50m	Direction of mobile	8 directions with 6 neighbouring
TD-HZ	10m	Speed of mobile	2 m/s – 20 m/s
Max. bandwidth capacity of cell	30 Mbps		

4.2. Results and Discussions

The proposed algorithm is able to improve the rate of false reservation as dual parameters are utilized for the prediction purpose. The consequence of this achievement is shown in Figure 3 whereby the number of cancelled reservation is lower for the proposed scheme as compared to the MPS-L scheme which utilizes location of the MT as a deciding uni-parameter for reservation.

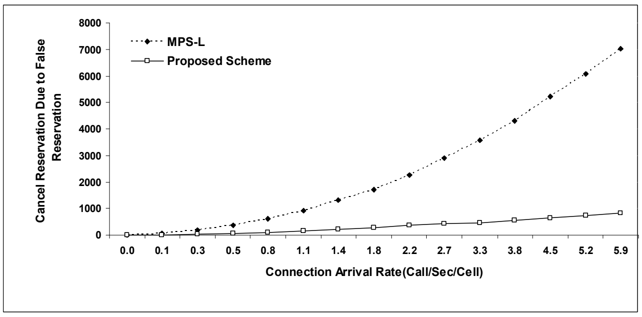

Figure3. Cancel reservation due to false reservation.

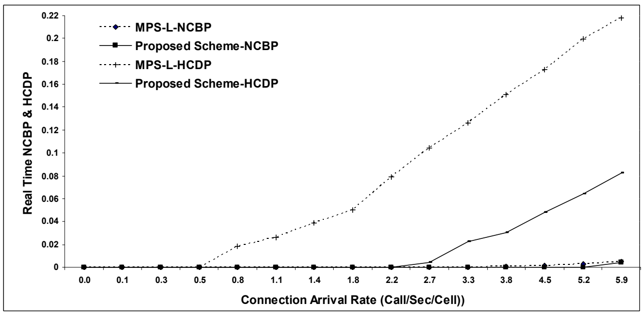

Figure 4. Real-time NCBP and HCDP.

Figures 4-6, displays the correlation between the impact of real-time and non real-time priority on the NCBP and HCDP. Although the MPS-L scheme has better performance in the context of non-real time traffic, the proposed scheme is able to control this reduction of performance. The control is based on a balance in the trade-off between NCBP, HCDP and the termination of non real-time call due to pre-emption by real-time traffic. This enables the proposed scheme to achieve lower NCBP, HCDP for real-time traffic and improve non real-time traffic in terms of terminating the call in the presence higher priority real-time traffic.

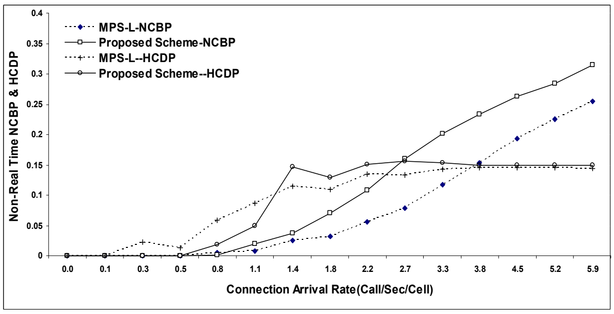

Figure 5. Non-real-time NCBP and HCDP.

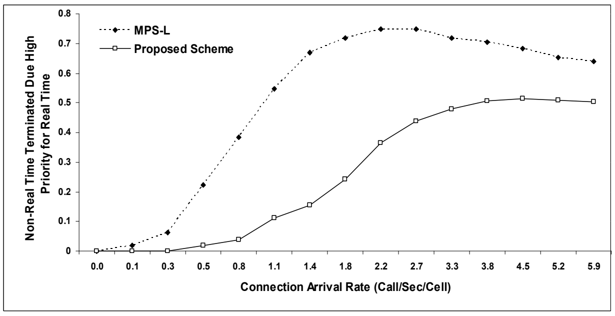

Figure 6. Non-real-time terminated due to high priority for real time.

Figure 7 shows the bandwidth utilization of the MPS-L scheme and proposed scheme. The bandwidth utilization is the ratio between the amount of bandwidth used by ongoing connections and the total bandwidth capacity of the network. In this Figure, we find that the proposed scheme produce higher bandwidth utilization than that MPS-L. This is due to the fact that as less false bandwidth reservation, less new and Handoff call connections that are attempting to get connections get denied.

Figure 8 shows the accuracy of target cell prediction for MPS-L scheme and proposed scheme. The accuracy of cell prediction is the probability of correct or accurate prediction of the next destination cell the MT is going to move to. As shown in Figure 8 proposed scheme performs higher precision than MPS-L as expected.

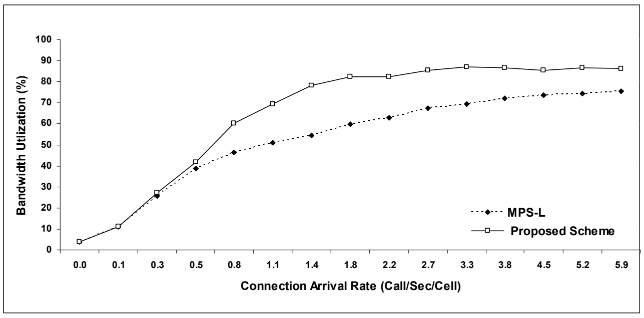

Figure 7. Bandwidth utilization.

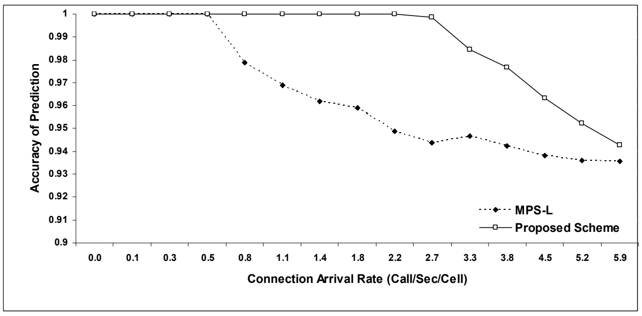

Figure 8. The accuracy of target cell prediction.

5. Conclusions

This paper has presented an enhanced resource reservation scheme based on a predictive model. The proposed scheme is able to produce a higher accuracy for the estimation of target cell, whilst reducing the signalling traffic in WCN and the false reservations that wasted bandwidth resources. Subsequently, decreasing the NCBP and HCDP for real time traffic, terminated calls of non real time traffic and increase the system bandwidth utilization. The main factor which enables an improved algorithm is the integration of the direction of the MT to complement the reservation based solely on the location of the MT within a cell.

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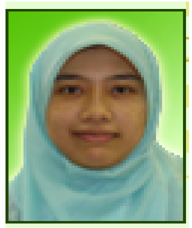
Maher Al-Sanabani received the BS degree in computer science from Yarmouk University, Jordan, in 1996. The MS degree from University of Technology, Iraq in 2002. Currently, he is a PhD candidate at faculty of Computer Science and Information Technology, University Putra Malaysia (UPM). His research interests are communication networks with emphasis on providing QoS assurance in high-speed multimedia, resource and mobility managements in 3G-4G mobile radio systems.

Shamala Subramaniam received the BS degree in computer science from UPM, in 1996, MS from UPM, in 1999, and PhD from UPM, in 2002. Her research interests are computer networks, simulation and modeling, scheduling and real time system. She already published several journal papers.

Mohamed Othman received his PhD from National University of Malaysia with distinction (Best PhD thesis in 2000 awarded by Sime Darby Malaysia and Malaysian Mathematical Society). In 2002 and 2003, he received gold medal award for research development exhibition. His main research interests are in the field of parallel and distributed algorithms, high speed computer network, network management (security and traffic monitoring) and scientific computing. He already published several journal papers. He is also an associate researcher and coordinator of high speed machine at institute of mathematical science, UPM.



Zuriati Zukarnain is head of Department of Communication Technology and Networks, UPM. She received the BSE degree in (Hons) major in Physics from UPM, in 1997, MS in information technology, UPM, 2000, PhD degree in quantum computation and information from University of Bradford, United Kingdom, 2006. Her research interests are quantum computation, quantum information and communication (entanglement, teleportation), computer networks and distributed computing. She already published several journal papers.