An Adaptive Handoff Algorithm with Accumulated Attempts of User Mobility for Supporting QoS in Wireless Cellular Networks

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Summary
As the number of mobile users in cellular systems increases, the user mobility becomes the dominating factor for guaranteeing quality of services (QoS). In order to support QoS for mobiles in cellular systems, the concept of accumulated user mobility is combined with the handoff algorithm to reduce the amount of reserving channels (codes) for handoff calls and increase the total carried traffic load. There are many factors that affect the QoS for a handoff algorithm and the mobile velocity, average call duration time, average cell dwell time, and handoff probabilities for each adjacent cell are most frequently mentioned. Thus, the mobile velocity is considered and formulated by the relational function of extenics that is similar to a fussy theory and first applied in wireless networks by this paper. With the cell approaches, the call duration time, etc. can be obtained from user profile and be applied to calculate the handoff attempts of each adjacent cell in current cell. By the accumulated handoff attempts of the six adjacent cells, the appropriate amount of channels (codes) can be reserved for handoff beforehand, and the required QoS is preserved during handoffs occurring. Since both QoS and the number of reserved channels (codes) are the considered issues in the proposed scheme, better system utilization can be achieved.
Key words:
user mobility, QoS, accumulated, handoff, extenics

1. Introduction

Due to the rapid evolution of mobile communications, the applications are also accompanied to vary from voice data which is low demand of bandwidth to multimedia services that are high demand of bandwidth. In such a large number of bandwidth demand for multimedia services in mobile cellular systems, the most important issue is to support quality of service (QoS) for subscribers. As a result of the increase in mobile velocity and limited radio spectra, it is difficult to allocate suitable bandwidth for mobiles before handoff to the appropriate cell. In order to increase the system capacity, the cell size will be mutated from micro-cell to pico-cell in future cellular systems, and the dwell time in a certain cell for all of the call duration will become smaller than before. Because the handoff frequencies that are affected by the cell size increase progressively, mobiles maybe come through performance degradations. As the user mobility is variable, it became more complex to predict the appropriate cell for handoff. The past research [1] showed the impact of mobility on cellular network and provided a modeling method for configuring cellular networks to study the dynamics of mobility, and there are also many researches [2, 3] focusing on user mobility prediction for providing accurate information for handoff and call admission control algorithm. Therefore, an effective handoff algorithm should think over the user mobility for supporting QoS.

The call blocking probability (CBP) and resource utilization should be also mentioned simultaneously while the QoS is considered for an effective handoff algorithm. There are so many studies [4, 5] which focused on the issue of QoS guarantee, and the effective user mobility and resource management is also mentioned in [6] at the same. The improvement of radio bandwidth is always thought as a dynamic channel (code) allocation problem in past literatures. For reducing the call dropping rate (CDR), the reservation schemes were proposed in the studies [7-9]. However, seldom literature has been developed to satisfy both issues of CDP and CBP at the same time. Although both prioritized channel assignment schemes for accommodating handoff attempts and optimization studies for assigning channels to priority classed have been proposed in the reference study [10], the user mobility has been considered a crucial factor for affecting traffic performance in the cellular networks.

To overcome both the emergency problem of demand of extensive bandwidth for multimedia services and the increase velocity of mobiles are appropriate bandwidth allocation for guaranteeing QoS and significantly progressive the resource utilization. Thus, if the prediction information of user mobility is applied suitably for channel (code) allocation in wireless cellular networks, the resource utilization will be improved obviously. Moreover, multimedia services will be the major trend for next generation mobile communications, so bandwidth requirements will also increase rapidly. Although it can be solved by reducing the size of cell radius, it will also increase handoff times simultaneously. For example, in the size of cell radius about 40m environment, the subscriber that move in the speed of 100km per hour, the handover will occur in every 1.44 second.

With a view to solving the QoS problem, a proper handoff algorithm that could reserve the required bandwidth in advance for the mobile in the predicted cell should be proposed. There two approaches, which are cell approaches making use of global knowledge of users traffic flows in a particular cell and user approaches relying on the knowledge users mobility in short or long term, focuses on the subject of handoff prediction, but the resource utilization is not so satisfied. In this paper, therefore, accumulated user mobility is applied to the handoff algorithm which formulates the user velocity by extenics [11] and is combined with the profile concept of cell approaches for solving this problem. The proposed scheme does not intend to predict the accuracy movement of mobile but calculate the accumulated attempts of the adjacent cells that are adjacent ones for current cell according to the uses of user profiles, user regular routines information, and the speed of mobile movement.

2. Extenics

In the real word, there are many existing unsolvable problems that can be changed into solvable through some transformation methods. For example, it is impossible for utilizing a steelyard to weigh an elephant. However, the well-known story about “Tsao Chung weighs an elephant” that revealed a possible way of solving this weighing problem happened in ancient China. Thus, there has been an interest in the research of Extension Engineering, which is motivated by the potential benefits of Extension Set Theory. The Extension Set Theory, called Extenics [11], is developed for solving conflicts in problems or providing equivalent solutions. Problems are solved with experiences by human. Some of them can be applied with straightforward thoughts, but there still leaves conflicts and incompatible parts that cannot be solved. Equivalent solutions are needed to transform the original problem to another. However, *Laplace Transform* is a good example. In our proposed method, the extended relational function and extension set are used to define the threshold dynamically in the speed of mobile movement.

For the Cantor set, a datum or element either belongs to a set or not. But there is something different in innate characteristics that do not belong to the sets. For example, as shown in Figure 2.1, the qualified work-pieces that have been processed by a lathe are specified with a diameter of $50 \pm 0.1mm$. Processed work-pieces may be divided into two portions, i.e., qualified and unqualified. For the unqualified work-pieces, some have diameters d >50.1*mm*, and some have d < 49.9*mm*. The diameters d >50.1*mm* are called wasted products. However, the latter can be transformed into qualified ones if reprocessing the work-pieces is allowed. Obviously, although both the wasted and re-workable products are not qualified, they are essentially different. Thus, the extenics was proposed to solve such a kind of problems. The extended relational function is defined to quantify the relationship between an element and a set. The range of extended relational function is $(-\infty,+\infty)$ which means that an element belongs to any set with a certain degree. In the universe of discourse U shown in Fig.2.1, we define an extended relational function by $k(x) \in (-\infty,+\infty)$ for any $x \in U$.

(1) If $k(x) \geq 0$, such as the qualified products, then it belongs to the positive set, $X = \{x \mid k(x) \geq 0, x \in U\}$.

(2) If $k(x) < -1$, such as the unqualified products, then it belongs to the negative set, $\overline{X}$ = $\{x \mid k(x) < -1, x \in U\}$.

(3) If $k(x) = 0$, such as the critical products, then it is called the zero point.

(4) If $-1 \leq k(x) < 0$, such as the re-workable products, then it belongs to the extension set, $\underline{X} = \{x \mid -1 \leq k(x) < 0, x \in U\}$.

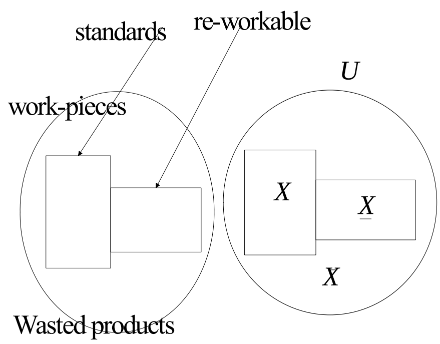


Figure 2.1: The concept of Extension set.

Based on the concept of extenics, the relation function is applied to formulate the mobile velocity that is one of the dominated factors for calculating the accumulated handoff attempts in the proposed scheme.

3. The Proposed Method

In order to analyze user mobility, the mobile speed is viewed as the most important factor that should be considered firstly. Thus, we make efforts in the acquisition of user velocity and its formulation. According to the free space propagation of radios [12], the distance between the base station and the mobile can be calculated by the received radio power of mobile. The speed can be obtained roughly by dividing the displacement in a time period.

3.1 Formulating of User Velocity

Although it is very complex to model the mobile velocity into an equation expression, we reference to the method of modeling the relational function in the Extenics [11] for reducing the complexity. Wu adjust the original relational function to formulate the speed of mobile movement in wireless cellular networks. Because the mobile velocity maybe experience from stationary to maximum limit of velocity that can be achieved by available vehicles, three kinds of movement speed defined in Table 1 for the purpose of simplification. The handoff probability is very low except only just along the edge of two cells when a pedestrian take a walk around no matter urban area or suburbs. Because the handoff probability is very low, the definition value of relational function is modified to be 0.

In contrast to pedestrian, vehicles mobility can be classified into two classes; one is that vehicles move in the speed between 5km/hr and 50 km/hr around urban area, and the other is that vehicles move in the speed of faster than 50 km/hr around suburbs. The first case can be regarded as extension part for Extenics, because the speed of vehicles may be almost approaching to pedestrian velocity for a traffic jam and faster than 50 km/hr when the traffic is smooth. In the other case, because the vehicles move in the speed of faster than 50 km/hr, the handoff probability occur will be very high and the definition value of relation function will always be greater than 1. One limitation for model the ormula *k(v)* is that the divisor $V_{limited}$ is the velocity limitation for the adopted mobile communication. Once the velocity is higher than the one that can be supported by the adopted system, the service will not be obtained again.

Table 1: Definition of relational function

	Potential category of traffic	Definition of velocity function k(v)
Speed ≤ 5 km/hr	Pedestrians	k(v) = 0
5 km/hr < Speed ≤ 50 km/hr	Vehicles in urban area	k(v) = (v – 5) / (50 – 5)
Speed >50 km/hr	Vehicles in suburbs	k(v) = 1 + (v – 50) / $V_{limited}$

3.2 Formulating of Accumulated User Mobility

The proposed scheme is suitable for the traditional honeycomb, and the area of geometry for each cell is equal. The service area is cover by *k*k* cells, shown as Figure 3.1, and the fixed channel assignment strategy that means equal capacity for each cell is adopted. Based on the honeycomb structure, the potential cells of handoff have only six adjacent ones. For cell 'a', illustrated in Figure 3.2, may handoff to the cell which is adjacent with cell 'a', such as 'b', 'c', 'd', 'e', 'f', or 'g'.

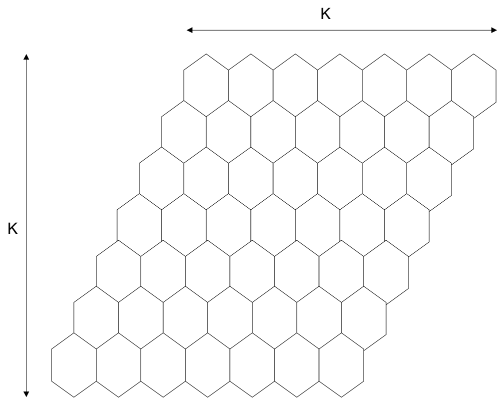


Figure 3.1: An illustration for a service area of *k*k* cells.

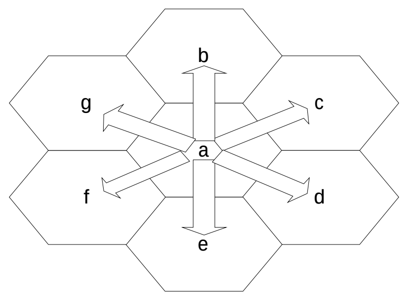


Figure 3.2: The possible handoff cell for cell 'a'.

For the proposed method, cell 'a' is as an initial point to calculate the potential handoff attempts that are defined by the accumulation function of weight for each adjacent cell. In order to define the accumulation function of weight, we find out that the affecting factors for handoff are movement speed, call duration time, and user regular routes that can be represented by the handoff probabilities.

The movement speed is defined by velocity function, and the potential probability of movement for each cell can be obtained by analyzing user regular routes.

To obtain the movement probability for each mobile in each cell, a profile-based method of user approaches [13] is applied to observe and record the mobile habits for a periodic time in each cell. By the profile-based method, two phases are required: the phase one learns the user's mobility and every move of the user is recorded; the second phase selects a cell which the algorithm looks for recorded transitions in its base. The proposed scheme reduces the recording information of cell by modifying data structure of the reference [10], and the necessary information of cell for each mobile is described as follows:

- ***i***: the current cell number.
- T_{dwell_avg}: the average dwell time in a cell for a mobile call.
- T_{dwell_min}: the minimum dwell time in a cell for a mobile call.
- $P_{move(j)}$: the probability of handoff to cell *j*, and *j* is the adjacent cell.

To calculate the accumulation attempts of handoff in each cell, an accumulation function is defined and formularized as the Eq. (1), where the weight factors *w_of_v(w)*, *w_of_t(w)* and *w_of_mp(w)* are represented weight of velocity function, weight of the average dwell time and weight of move probability, respectively. The portion of each weight factor stands for the dominant portion for the handoff and can be adjusted dynamically by *imf_v(m)*, *imf_t(m)*, and *imf_mp(m)* according to the real situation. Furthermore, the summation of the three weight factors is equal to 1, shown as Eq. (2).

$$A(w) = k(v) * w\_of\_v(w) * imf\_v(m) + w\_of\_t(w) * imf\_t(m) + w\_of\_mp(w) * imf\_m(m) \quad (1)$$

$$imf\_v(m) + imf\_t(m) + imf\_mp(m) = 1 \quad (2)$$

3.3 The Proposed Handoff Algorithm

Based on the past literatures, many channel allocation schemes have been proposed for handoff such as fully shared scheme (FSS), guard channel scheme (GCS) and so on. In order to guarantee the call dropping probability (or called QoS) below a certain level, the guard channel scheme is usually applied for handoff. The proposed method which applies accumulated user mobility can be composed of two phases: Phase 1 is a learning phase that is responsible for collecting user profile by user approaches and recording to the corresponding data structure; the major duty of phase 2 is to calculate the total accumulation attempts of the adjacent cell according to the defined accumulations function of weight. For simplification, the proposed method considers recording the data of user profile of each cell for each mobile by modifying the data structure of the reference research [14], and the two phase's handoff algorithm (TPHA) is summarized as follows.

TPHA (Two Phase's Handoff Algorithm)
Begin
Phase 1:
Begin
Learn user profile;
Record user profile to database;
End Phase 1;
Phase 2:
Begin
Choose mobile information from database;
*Select the current cell number **i** and get the corresponding information;*
***If** $T_{dwell\_avg} >= T_{call\_avg}$*
*$w\_of\_t_i(w)$ = HIGH; /*Set the value of $w\_of\_t(w)_i$ to HIGH*/*
Else
*$w\_of\_t_i(w)$ = LOW; /*Set the value of $w\_of\_t(w)_i$ to LOW*/*
***EndIf**;*
***While** (j ∈ A, A is the set of adjacent cells of cell i)*
Begin
$w\_of\_m_j(w) = P_{move(j)}$; / Set the $w\_of\_m_j(w)$ to be the value of moving probability from cell (i) to cell(j); */*
/ Calculate the accumulation attempts from cell **i** to cell **j***/*
$A_j(w) = k(v) * w\_of\_v_i(w) * imf\_v(m) + w\_of\_t_i(w) * imf\_t(m) + w\_of\_mp_j(w) * imf\_mp(m)$;
*/*Sum up $A_k(w)$ in cell **j**, (**k** is the adjacent cells of cell **j**) */*
$\tilde{A}_j(w) = \sum A_k(w)$;
*/*Reserve the necessary resource and adjust the number of guard channel in cell **j** by total accumulation attempts of mobility $\tilde{A}_j(w)$*/*
*GCS_num = Total channels - $\tilde{A}_j(w)$ * **Predict_basis**;*
*Prepare handoff to the cell **j**;*
***EndWhile**;*
End Phase 2;
End TPHA;

In the phase 1, user profile is learning by applying user approach in [14]. During the learning phase, each move of user is recorded. For a certain cell, therefore, the movement probability of the adjacent cells can be obtained with its own handoff times divided by the total handoff times in current cell.

In phase 2, the value of *w_of_t* is set by comparing T_{dwell_avg} with T_{call_avg}, and the value will be set either "**LOW**" or "**HIGH**", where "**LOW**" and "**HIGH**" are adjustable definition constants. Moreover, the calculation of accumulated mobility attempts in current cell triggers off the calculations of total accumulated mobility attempts in the six adjacent cells which are illustrated in Figure 3.3, and the total accumulated mobility attempts of weight can be as the factor for adjusting the number of channels in the six adjacent cells, where "**Predict_basis**" is the critical value which can be adjusted according to the quality of service. The most difference among the proposed method and the past literatures is the adaptive threshold for the number of guard channels by using the total accumulated mobility attempt "$\tilde{A}_j(w)$"

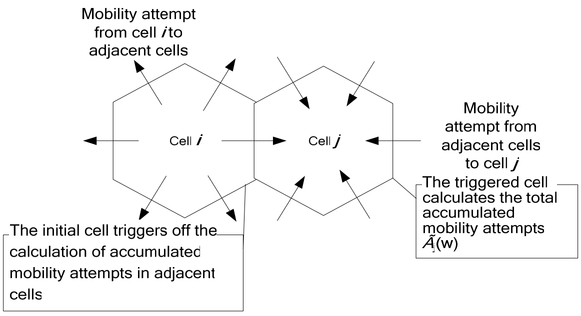


Figure 3.3: An illustration for calculating total accumulated mobility attempts.

4 Performance Evaluations

In performance evaluation, the terms of dropping probability of handoff calls, blocking probability of a new call, and channel utilization are compared between predicted handoff and unpredicted handoff. Besides, the number of guard channels for predicted handoff calls are dynamically adapted and also shown in the experimental results.

4.1 Simulation Assumptions

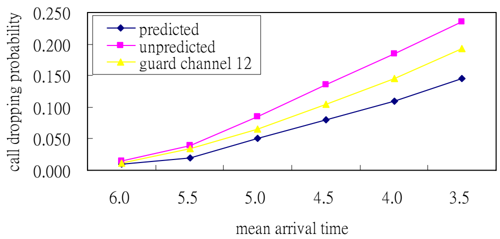
The number of mobiles in our simulation is bigger than the channels in cell so that the traffic model to the cell can be approximated as a Poisson process [14] [15], and other related parameters are shown as follows.

- λ: call arrival rate according to Poisson process of rate λ.
- μ: the mean completion time that are assumed to follow exponential distribution with mean of $1/\mu$ [8].
- θ: the portable mobility and the dwell time is assumed to be exponential distribution with mean of $1/\theta$.

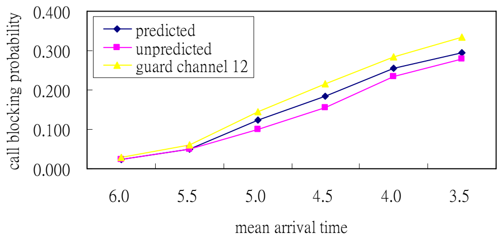
In our experiments, the mean of call holding time $1/\mu$ is 6 min, and the mean of dwell time $1/\theta$ is 3 min. The number of cells is 6*6 for a given service area, and the channel capacity of each cell is 30 channels. For the general experimental assumptions, the handoff calls are 50% of total calls, and predicted handoff calls are 50% of handoff calls. Besides, bandwidth requirement for any kind of call request is all the same to be one channel required.

4.2 Simulation analysis

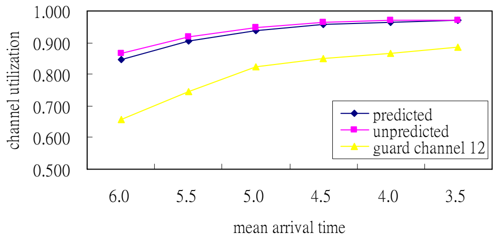
For demonstrating the performance of the proposed scheme, there will be two simulation cases analyzed in this paper. First, the unpredicted method that assigns required channels for any kind of call request immediately once if there are enough number of channels, the proposed method, and the guard channel policy with twelve fixed channels reserved are compared in term of call blocking probability, call dropping probability, and channel utilization. The simulation results show that the proposed method has the best performance for call dropping probability among the three comparison targets, illustrated in Figure 4.1 (a), and the proposed method can almost achieve the same performance as unpredicted one for call blocking probability and channel utilization, shown as Figure 4.1. (b) - (c). The proposed method is compared with the guard channel policy that reserves twelve channels steadily for the reserved number of channels. Figure 4.2 shows that the reserved number of guard channels for the proposed method is adjustable dynamically within the simulation process, so the proposed method can maintain better utilization than the other.



(a) Call dropping probability



(b) Call blocking probability



(c) Channel utilization

Figure 4.1: Simulation results for three methods.

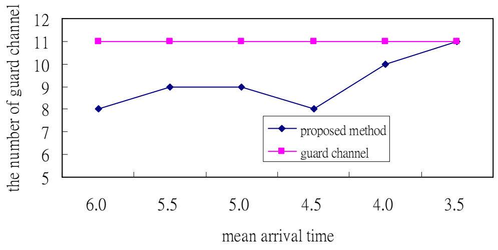


Figure 4.2: The comparison for the number of guard channels.

5. Conclusions

In this paper, a new concept that uses accumulated user mobility is applied for the prediction of handoff attempts, and the extenics is also introduced and applied to formulate the mobile velocity in the relational function. The accumulated user mobility that is derived from the speed of movement, dwell time, and move probability, is applied for adjusting the number of guard channels dynamically. The proposed scheme reserves the necessary number of channels for handoff calls and reduces the number of guard channels which can increase the utilization, hence, the call dropping probability can be decrease and QoS is also guaranteed.

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