Resource Management Scheme Based on Position and Direction for Handoff Control in Micro/Pico-Cellular Networks

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Abstract. We propose a handoff control scheme to accommodate mobile multimedia traffic based on the resource reservation procedure using the direction estimation. This proposed scheme uses a novel mobile tracking method based on Fuzzy Multi-Criteria Decision Making (FMCDM), in which uncertain parameters such as Pilot Signal Strength (PSS), the distances between the Mobile Terminal (MT) and the Base Station (BS), the moving direction, and the previous location are used in the decision process using the aggregation function in fuzzy set theory. In performance analysis, our proposed scheme provides a better performance than the previous schemes.

Keywords: Handoff control, FMCDM, position and direction method.

1 Introduction

With the proliferation of various wireless services such as forthcoming Fifth Generation (5G), Wireless Local Area Network (WLAN), and Personal Area Network (PAN), etc, next generation wireless communication systems are considered to support various types of high-speed multimedia traffic with packet switching at the same time. To do that, more upgraded Quality of Services (QoS) and system capacity are needed. Due to the limitations of the radio spectrum, the next generation wireless networks will adopt micro/pico-cellular architectures for various advantages including higher data throughput, greater frequency reuse, and location information with finer granularity. In this environment, because of small coverage area of micro/pico-cells, the handoff rate grows rapidly and fast handoff support is essential [1].

These limitations call for the development of new frameworks and approaches to meet the specific challenge of supporting adaptive QoS in a controlled manner, despite frequent and random mobility of the Mobile Terminal (MT) and the dynamically changing network resource availability. Adaptive QoS issues relate to how handoff must be managed and carefully controlled in order to minimize session

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dropping due to insufficient resource available in the new cell [2]. As MTs move around, the network must continuously track them down and discover their new locations in order to be able to deliver data to them. Especially wireless radio resources availability varies frequently as MTs move from one access point to another [2-3].

Majority of the previous schemes to support mobility make a reservation for resources in adjacent cells [4-5]. The reserved resource approach offers a generic means of improving the probability of successful handoffs by simply reserving the corresponding resources exclusively for handoff sessions in each cell. The remaining resource can be equally shared among handoff and new sessions. The penalty is the reduction in the total carried traffic load due to the fact that fewer radio resources are granted to new sessions. Also, these techniques cause a waste of resources since it is regardless of the direction of MTs. Therefore, previous methods for predicting and reserving resources for future handoff sessions do not seem to be suitable for mobile multimedia networks. The amount of resources required to successfully perform handoff may vary arbitrarily over a wide range in mobile multimedia networks [6-12].

2 Defining Location in FMCDM

Fig. 1 shows how our scheme divides a cell into many blocks based on the signal strength and then estimates the optimal block stepwise where the MT is located using the FMCDM.

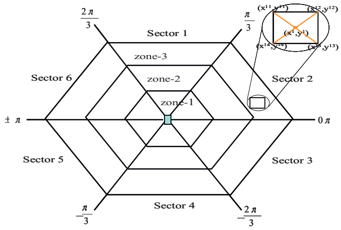

Fig. 1 Sector, Zone and Block

The location of a MT within a cell can be defined by dividing each cell into sectors, zones and blocks and relating these to the signal level received by it at that point. It is done automatically in three phases of sector definition, zone definition and block definition. Then the location definition block is constructed with these results. They are performed at the system initialization before executing the location estimation. The sector definition phase divides a cell into sectors, and assigns a sector number to blocks belonging to each sector. The zone definition phase divides each sector into zones, and assigns a zone number to blocks belonging to each zone. The block definition phase assigns a block number to each block. In order to indicate the location of each block within a cell, 2-dimensional vector (i.e., distance d, angle a) is assigned to each block. After the completion of this phase each block has a set of block information. Three classified zones are used to predict the handoff probability of MTs as shown in the Fig. 1. One cell is consists of zone-1 as a base station coverage, zone-2 as a candidate coverage, and zone-3 as a handoff coverage. However, although a MT moves within the same zone, MT's neighboring cells can be changed. Therefore, to identify them, each zone is partitioned in to six directions which can be easily archived by the pilot signal strength. The sectors are used to know that MT's moving direction is changed. Based on the above location definition method, each block is given his location information which consists of one center point (xi, yi) and four of area point (xij, yij) as shown in Fig. 1. By comparing the location information of each block and the position information of the MT, the position of the MT within a cell is estimated. The set of block information is called the block object. The block object contains the following information: the sector number, the zone number, the block number, the vector data (i.e., distance d, angle a), the maximum and the minimum values of the average Pilot Signal Strength (PSS) for the Line of Sight (LOS) block.

3 Mobile Tracking in FMCDM

3.1 Fuzzy multi-criteria decision parameters

In our paper, the received signal strength, the distance between the MTs and the BS, the previous location, and the moving direction are considered as decision parameters. The received signal strength has been used in many schemes, but it has very irregular profiles due to the effects of radio environments. The distance is considered because it can explain the block allocation plan; however, it may also be inaccurate due to the effect of multi-path fading, etc. It is not sufficient by itself. We consider the previous location. It is normally expected that the estimated location should be near the previous one. Therefore, if the estimated location is too far from the previous one, the estimation may be regarded as inaccurate. We also consider the moving direction. Usually the MT is most likely to move forward, less likely to move rightward or leftward, and least likely to move backward more than one block. The low-speed MT (i.e., a pedestrian) has a smaller moving radius and a more complex moving pattern, while the high-speed MT (i.e., a motor vehicle) has a larger radius and a simpler pattern.

In mobile tracking using FMCDM, the decision function D is defined by combining the degree of satisfaction for multiple evaluation parameters, and the decision is made on the basis of his function. The evaluation parameter can be seen as a proposition. A compound proposition is formed from multiple evaluation parameters with a connective operator, and the total evaluation is performed by totaling the values for the multiple parameters with connective operators. In this method errors in the evaluation parameters impose milder changes on the total evaluation value than in binary logics. This method can also consider multiple inaccurate and insufficient evaluation parameters simultaneously and can compensate for them. This results in the optimal decision.

3.1 Membership function

The membership function with a trapezoidal shape is used for determining the membership degree of the MT because it provides a more versatile degree between the upper and the lower limits than the membership function with a step-like shape. Let us define the membership functions for the PSSs from neighboring BSs. The membership function of PSS_i, $\mu_R(PSS_i)$, is given by Eq. (1). PSS_i is the signal strength received from the BS_i, s_1 is the lower limit, and s_2 is the upper limit. 2 *PSS* values are used for forming the membership function with a trapezoidal shape and for determining the membership degree of estimated signal strength.

$$\mu_R(PSS_i) = \begin{bmatrix} 0, & PSS_i < s_1 \\ 1 - \dfrac{PSS_i - s_1}{|s_2 - s_1|}, & s_1 \le PSS_i \le s_2 \\ 1, & PSS_i > s_2 \end{bmatrix} \tag{1}$$

Now we define the membership function of the distance. The membership function of the distance $\mu_R(D_i)$ is given by Eq. (2), where D_i is the distance between the BS_i and the MT [13]. Also, d_1 is the upper limit, and d_2 is the lower limit.

$$\mu_R(D_i) = \begin{bmatrix} 1, & D_i < d_1 \\ 1 - \dfrac{|D_i - d_2|}{|d_1 - d_2|}, & d_1 \le D_i \le d_2 \\ 0, & D_i > d_2 \end{bmatrix} \tag{2}$$

The membership function of the previous location of the MT $\mu_R(L_i)$ is given by Eq. (3), where L_i is its current location, $E_1,\cdots,E_4$ is the previous location [14]. The previous location is defined by comparing the vector information of previous block and that of the estimated block. These 4 values are used for forming the membership function with a trapezoidal shape and for determining the membership degree of estimated current location as shown in the following figure. In other words, if a current location estimated is too far away from previous location (that is, if the membership degree is too small), it is likely that we have incorrect location estimated.

$$\mu_R(L_i) = \begin{bmatrix} 0; & L_i < E_1 \\ 1 - \dfrac{L_i - E_1}{E_2 - E_1}, & E_1 \le L_i \le E_2 \\ 1, & E_2 \le L_i \le E_3 \\ 1 - \dfrac{L_i - E_3}{E_4 - E_3}, & E_3 \le L_i \le E_4 \\ 0, & L_i > E_4 \end{bmatrix} \tag{3}$$

The membership function of the moving direction $\mu_R(C_i)$ is given by Eq. (4). C_i is the moving direction of the MT, $PSS_1,\cdots,PSS_4$ is the PSS, and o_i the physical difference between the previous location and the current one. These 4 values are used for forming the membership function with a trapezoidal shape and for determining the membership degree of estimated moving direction. The moving direction C_i is defined by comparing the vector information of previous block and that of the estimated block.

$$\mu_R(C_i) = \begin{bmatrix} 0, & C_i < PSS_1 \\ 1 - \dfrac{C_i - PSS_1}{PSS_2 - PSS_1}, & PSS_1 \le C_i \le PSS_2 \\ 1, & PSS_2 \le C_i \le PSS_3 \\ 1 - \dfrac{C_i - PSS_3}{PSS_4 - PSS_3}, & PSS_3 \le C_i \le PSS_4 \\ 0, & C_i > PSS_4 \end{bmatrix} \tag{4}$$

3.2 Location estimation

Most of the FMCDM approaches face the decision problem in two consecutive steps: aggregating all the judgments with respect to all the criteria and per decision alternative and ranking the alternatives according to the aggregated criterion. Also our approach uses this two-steps decomposition [15].

Let J_i (i $\in \{1, 2, \ldots, n\}$ be a finite number of alternatives to be evaluated against a set of criteria K_j (j=1, 2, …, m). Subjective assessments are to be given to determine (a) the degree to which each alternative satisfies each criterion, represented as a fuzzy matrix referred to as the decision matrix, and (b) how important each criterion is for the problem evaluated, represented as a fuzzy vector referred to as the weighting vector.

$$\mu = \begin{bmatrix} \mu_R(PSS_{11}) & \mu_R(D_{12}) & \mu_R(L_{13}) & \mu_R(C_{14}) \\ \mu_R(PSS_{21}) & \mu_R(D_{22}) & \mu_R(L2_{23}) & \mu_R(C_{24}) \\ \mu_R(PSS_{31}) & \mu_R(D_{32}) & \mu_R(L_{33}) & \mu_R(C_{34}) \\ \cdots & \cdots & \cdots & \cdots \\ \mu_R(PSS_{n1}) & \mu_R(D_{n2}) & \mu_R(L_{n3}) & \mu_R(C_{nm}) \end{bmatrix} \tag{5}$$

Each decision problem involves n alternatives and m linguistic attributes corresponding to m criteria. Thus, decision data can be organized in $m \times n$ matrix. The decision matrix for alternatives is given by Eq. (5). The weighting vector for evaluation criteria can be given by using linguistic terminology with fuzzy set theory [16]. It is a finite set of ordered symbols to represent the weights of the criteria using the following linear ordering: Very high $\geq$ high $\geq$ medium $\geq$ low $\geq$ very low. Weighting vector W is represented as Eq. (6).

$$W = (w_i^{PSS}, w_i^{D}, w_i^{L}, w_i^{C}) \tag{6}$$

3.2.1 Sector estimation based on multi–criteria parameters

The decision parameters considered in the Sector Estimation step are the signal strength, the distance and the previous location. The MT is estimated to be located at the sector neighboring to the BS whose total membership degree is the largest. The sector estimation is performed as follows.

Procedure 1: Membership degrees are obtained using the membership function for the signal strength, the distance and the previous location.

Procedure 2: Membership degrees obtained in Procedure 1 for the BS neighboring to the present station are totalized using the fuzzy connective operator as shown in Eq. (7).

$$\mu_i = \mu_R(PSS_i) \cdot \mu_R(D_i) \cdot \mu_R(L_i) \tag{7}$$

We obtain Eq. (8) by imposing the weight on μ_i. The reason for weighting is that the parameters used may differ in their importance.

$$\omega\mu_i = \mu_R(PSS_i) \cdot W_{PSS} + \mu_R(D_i) \cdot W_D + \mu_R(L_i) \cdot W_L, \tag{8}$$

Where W_{PSS} is the weight for the received signal strength, W_D for the distance, and W_L for the location. Also $W_{PSS} + W_D + W_L$ is 1, W_{PSS} is 0.5, and W_D and W_L are 0.3, 0.2, respectively.

Procedure 3: Blocks with the sector number estimated are selected from all the blocks within the cell for the next step of the estimation. Selection is done by examining sector number in the block object information.

3.2.2 Zone estimation based on multi-criteria parameters

The decision parameters considered in the zone estimation step are the signal strength, the distance and the moving direction. From the blocks selected in the sector estimation step, this step estimates the zone of blocks at one of which the MT locates using the following algorithm.

Procedure 1: Membership degrees are obtained using the membership function for the signal strength, the distance and the moving direction.

Procedure 2: Membership degrees obtained in Procedure 1is totalized using the fuzzy connective operator as shown in Eq. (9).

$$\mu_i = \mu_R(PSS_i) \cdot \mu_R(D_i) \cdot \mu_R(C_i) \tag{9}$$

We obtain Eq. (10) by imposing the weight on μ_i .

$$\omega\mu_i = \mu_R(PSS_i) \cdot W_{PSS} + \mu_R(D_i) \cdot W_D + \mu_R(C_i) \cdot W_C \tag{10}$$

Where W_{PSS}, W_D, and W_C are assumed to be 0.6, 0.2, 0.2, respectively.

Procedure 3: Blocks which belong to the zone estimated above are selected for the next step. It is done by examining the zone number of the blocks selected in the sector estimation.

3.2.3 Zone estimation based on multi-criteria parameters

The decision parameters to be considered in the block estimation step are the signal strength, the distance and the moving direction. From the blocks selected in the zone estimation step, this step uses the following algorithm to estimate the block in which the MT may be located.

Procedure 1: Membership degrees are obtained using the membership function for the signal strength, the distance and the moving direction.

Procedure 2: Membership degrees obtained in procedure 1 are totalized using the fuzzy connective operator as shown in Eq. (11).

$$\mu_i = \mu_R(PSS_i) \cdot \mu_R(D_i) \cdot \mu_R(C_i) . \tag{11}$$

We obtain Eq. (12) by imposing the weight on μ_i .

$$\omega\mu_i = \mu_R(PSS_i)\cdot W_{PSS} + \mu_R(D_i)\cdot W_D + \mu_R(C_i)\cdot W_C \quad (12)$$

Where W_{PSS}, W_D, and W_C are assumed to be 0.6, 0.1, 0.3, respectively.

Procedure 3: The selection is done by examining the block number of the blocks selected in the zone estimation

4 Resource Reservation and Allocation in Direction Prediction

We have a resource management structure to efficiently accommodate multimedia sessions, in which **rs-part** can be reserved only for real-time sessions and temporarily occupied by non-real-time sessions, **ns-part** can be used only for non-real-time sessions and **ss-part** can be reserved by real-time sessions and temporarily occupied by non-real-time sessions depending on the needs. The size of **ss-part** is adapted according to the transmission rate of real-time sessions. A boundary line between two parts is decided on **ss-part**. Namely, the **ss-part** is temporarily occupied by non-real-time sessions during a time interval T_i and is updated at T_{i+1}. The amount of the reserved resources for each session can be adjusted periodically and allocated only to same applications. The basic rule for resource allocation is to allocate the resources corresponding to the minimum transmission rate to all sessions.

Each session needs to have the primary resources, which are a part of reserved resources in real-time sessions and corresponds to Minimum Transmission Rate (MiTR) in non-real-time sessions. If the allocation of the primary resources should not be done, a session request is blocked. If the transmission rate of the primary resources allocated to a real-time session is less than Average Transmission Rate (AvTR), the supplementary resources are allocated and reserved for the session. In case of non-real-time sessions the primary resources corresponding to MiTR are allocated and the supplementary resources are temporarily allocated on the basis of the bursts of real-time sessions.

The BS reserves only the resources corresponding to the minimum transmission rate to the MT. Based on the location and the direction of the MT within a cell, the resource reservation is performed with the following orders: unnecessary state, not necessary state, necessary state, and positively necessary state. If the reservation variable for the MT is changed, the reservation is canceled and the resources have to be released with the reverse order and returned to the pool of available resource.

5 Performance Evaluation

5.1 Simulation Model

The simulation model is based on a B3G system proposed from ETRI [17] as shown in Table 1, which is implemented using MOBILESimulatorV6. The simulation model composed of a single cell, which will keep contact with its six neighboring cells. Each cell contains a BS, which is responsible for the session setup and tear-down of new applications and to serve handoff applications. The moving path and the

MT velocity are affected by the road topology. The moving pattern is described by the changes in moving direction and velocity. In our study we assume that the low speed MTs, the pedestrian, occupy 60% of the total population in the cell and the high-speed MTs, the vehicles, 40%. Vehicles move forward, leftward/rightward and U- Turn. The moving velocity is assumed to have the uniform distribution. The walking speed of the pedestrian is 3~5 *Km/hr*, the speed of the private car and the Taxi 50~120 Km/hr, and the bus 20~90 Km/hr. The speed is assumed to be constant during walking or driving. Fig. 3 shows the blocks and moving path on the road within a square cell. The black circle indicates the branch of the road, and the shaded areas are blocks that the road passes through. Each block is a square and its side is assumed to have the length of 30 m. The time needed for a high speed MT to pass through a block is calculated from the crossing time of a block $BT = r / \upsilon$ where r is the length of a road segment crossing at each block and v is the MT speed. As shown in Fig. 4, the crossing time of a block is dependent on r. In order to reflect more realistic information into our simulation, it is assumed that the signal strength is sampled every 0.5 sec, 0.2 sec, 0.1 sec, 0.1 sec and 0.04 sec for the speed of 10km/h, 20km/h, 50km/h, 80km/h and : 120km/h, respectively.

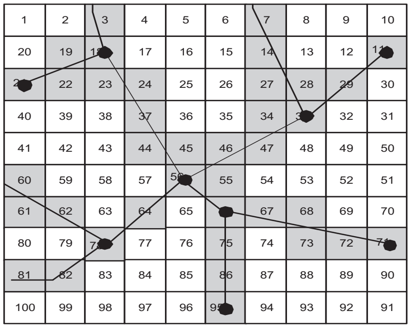

Fig. 3 Blocks and moving path on the road

We consider the following simulation parameters regarding the received signal strength. The mean signal attenuation by the path-loss is proportional to 3.5 times the propagation distance, and the shadowing has a log-normal distribution with a standard deviation of $c = 6dB$.

5.2 Numerical Results

The results of from Fig. 4 to Fig .5 show the comparison between the proposed Directional Reservation scheme and the previous resource reservation schemes that mobile tracking is not applied. Assuming that thirty sessions with MiTR are accepted regardless of service type, Fig. 4 shows the results for an average percentage of resource utilization as a function of sessions arrival with priority to handoff sessions over new sessions, in which the resources occupied by the non-real-time sessions are not considered as an appraised target that is how many non-real-time sessions is multiplexed to the reserved resources by the real-time sessions. The resource utilization for the proposed Directional Reservation scheme is increased up to 25% at average and peak arrivals, than that for Fixed Reservation method and Statistic Reservation method. In Fig. 5, the comparison of transmission delay of the three schemes is plotted against the number of sessions. It is observed that as the number of sessions increase, the proposed Directional Reservation scheme provides a noticeable improvement over the conventional schemes for real-time sessions, while slightly degrading the performance for the non-real-time sessions.

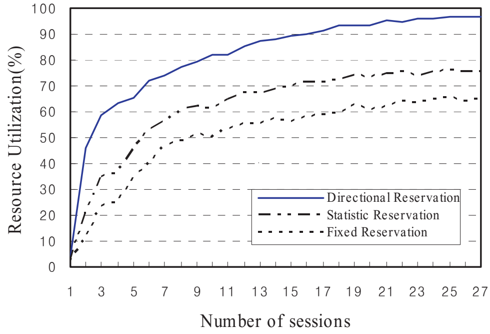

Fig. 4 Comparison of resource utilization

In case that traffic load is over 20, results demonstrate that the delay of the proposed scheme has decreased to about 300ms and 500ms as compared to the Statistic Reservation scheme and Fixed Reservation scheme, respectively.

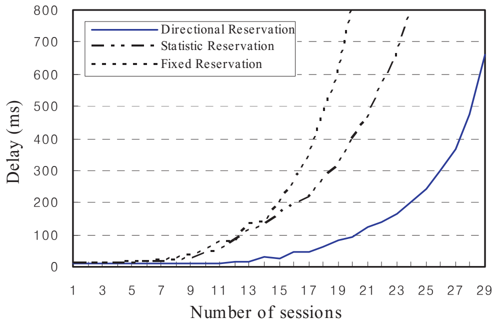

Fig. 5 Comparison of transmission delay

6 Conclusions

This paper is to address the problem of guaranteeing an acceptable level of QoS requirements for MT users as they move from one location to another. This is achieved through reservation variables such as the current location and the moving direction that is presented with a set of attributes that describes the user mobility. In this scheme, MTs are classified according to their reservation variables.

The proposed scheme shows a great improvement of the resource utilization and the dropping rate of handoff sessions. It is because our resource reservation scheme is more adaptive than previous schemes. In the proposed scheme, radio resources are classified as ones having priority to the new sessions and ones having priority to the handoff sessions based on reservation variable. Using this, we improve the dropping rate for the handoff sessions by dynamically adjusting the amount of the reserved resources according to the amount of occupied resources.

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