Resource Reservation and Allocation Based on Direction Prediction for Handoff in Mobile Multimedia Networks

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Abstract. Future mobile communication systems can support not only voice but also multimedia applications such as data, image and video. It requires greater resources than voice-oriented mobile system. If handoff events are occurred during the transmission of multimedia, the efficient resource allocation and handoff procedures are necessary to maintain the same QoS of transmitted multimedia traffic because the QoS may be defected by some delay and information loss. This paper proposes a resource reservation and allocation scheme to accommodate multimedia traffic based on the direction estimation in mobile multimedia networks. This scheme estimates the position of mobiles based on a two step estimation comprised of sector estimation, zone estimation. With the position information, the moving direction is determined.

1 Introduction

The explosive growth of Internet access in parallel with the technological advances in mobile communications has motivated mobile computing and multimedia applications in wireless mobile networks. A Key characteristic of multimedia services is that they require different Quality of Service (QoS) guarantees. Due to the limitations of the radio spectrum, the wireless systems use microcellular architectures in order to provide a higher capacity. Because of small coverage area of micro-cells, network resources availability varies frequently as users move from one access point to another [1]. In order to deterministically guarantee QoS support for a mobile unit, the network must have prior exact knowledge of the mobile's mobility. Majority of the existing schemes to support mobility make a reservation for resources in adjacent cells. However these techniques cause a waste of resources since it is regardless of the direction of mobiles. Also, existing methods for predicting and reserving resources for future handoff calls 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 a mobile multimedia network. For example, data and video applications may adapt to different service quality levels and consequently

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may accept different levels of resources in order to ensure a successful handoff [2][3][4]. In this paper, we consider a mobile network supporting diverse traffic characteristics of voice, data, and video applications. Since the connections can now differ in the amount of resources required to meet their QoS needs, the question is how should a base station dynamically adapt the amount of resources reserved for dealing with handoff requests. In this paper, the handoff requests for real-time connections are handled based on the direction prediction and the resource reservation scheme. The resources in the estimated adjacent cells should be reserved to guarantee the continuity of the real-time connections. If handoff requests are occurred during the transmission of multimedia traffic, the efficient resource allocation and handoff procedures are necessary to maintain the same QoS of transmitted multimedia traffic because the QoS may be defected by some delay and information loss. This paper proposes a handoff scheme to transmit multimedia traffic based on the resource reservation using direction estimation.

2 Direction Prediction Method

Figure 1 shows how our scheme divides a cell into many zones based on the signal strength, and then estimates the optimal zone stepwise where the mobile is located. This process is based on a two step location estimations which determines the mobile position by gradually reducing the area of the mobile position [5][6]. This scheme is implemented as an estimator into the base station. The estimator is started with a timer, and then the estimation is performed sequentially in two steps. The estimator first estimates the location sector in the sector estimation step, then estimates the location zone in the zone estimation step, and then finally estimates mobile's direction.

2.1 Sector Estimation

The sector estimation, the first step of the location estimation, is done in the following procedure.

A. All the neighboring base stations transmit pilot signals periodically.
B. The demodulator of the mobile measures PSSs of neighboring base stations.
C. The mobile sends PSMM (Pilot Strength Measurement Message) to the base station.
D. The estimator in the base station compares the received strengths of the pilot channels with each other and chooses the sector neighboring to the base station of the greatest signal strength as the sector at which the mobile locates.
E. The sector number is registered to the object information.

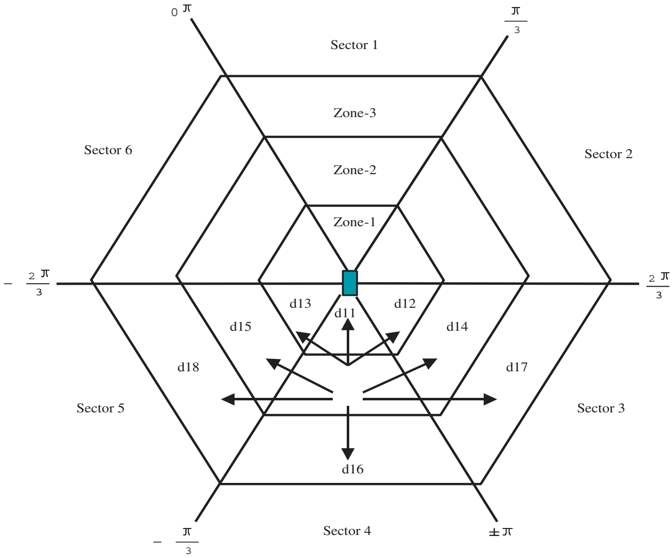

Fig. 1. Sector, zone and a mobile's moving direction

2.2 Zone Estimation

Each cell is divided into n zones with each zone classified by PSS. The following LOS algorithm summarizes the zone estimation procedure for LOS model.

1. Select each threshold considering PSS.
2. In order to map the signal strength onto the direction information, determine the distance function for each threshold with Equation(1).

$$\begin{gathered} P_A(d) = k_1 - k_2(d) + u(t) \\ P_B(d) = k_1 - k_2(D - d) + \upsilon(t) \end{gathered} \qquad (1)$$

   In Equation (1) D indicates the distance between two base stations, and d the distance between the base station A and the mobile. k_1 is proportional to the transmission power of the station and k has the offset value depending the radio propagation environment. Two random signals $u(t)$, $\upsilon(t)$ which indicate the power distributions of signals received at the distance d respectively from the station A and from the station B have i.i.d (identical independent distribution) with Gaussian distribution of $N(\mu(d), \sigma)$. The average value of the received signal at the specific location, $\mu(d)$, is determined by the path-loss component proportional to the distance and σ is assumed to be same. The changes in the LOS are depicted by k_2.

3. Classify zones using the distance function.
4. Assign the zone number and the PSS threshold to all divided zones.

Using the sector of blocks selected in the sector estimation, the zone estimation, the second step of the location estimation, estimates the zone of blocks at one of which the mobile locates. It is done in the following procedure.

A. The base station transmits the pilot signal periodically.
B. The demodulator of the mobile measures the signal strength of the pilot channel of the base station in which it is.
C. The mobile sends PSMM to the base station.
D. The estimator estimates the zone using the LOS algorithm.
E. The estimated zone number is registered to a zone object.

2.3 Direction Estimation

The estimator estimates a sector in the sector estimation step and a zone in the zone estimation step respectively, and then finally computes mobile's direction using the vector information between the estimated location and the previous one. In order to indicate the location of each zone within a cell, we use the vector data which is obtained by converting the rectangular coordinate of the zone to the polar coordinate with the origin of the base station [5]. Each vector has the information on a distance and an angle. The polar coordinate indicates the location by the distance from the origin to the mobile and the angle from the positive horizontal axis toward counter-clockwise. In our study we need the direction information to identify the sector relative to the base station and the relative position of a zone so we use the polar coordinates converted from the rectangular coordinates.

A mobile's direction is classified based on the movement into the upper zone (d11, d12 and d13), lower one (d16, d17 and d18) and the same one (d14 and d15), as shown in Figure 1. The moving radius of a mobile toward the upper from the lower zone becomes wider, while the moving radius of a mobile toward the lower zone becomes narrower. That is, the direction prediction for a mobile toward his BS is difficult more than mobiles toward his cell boundary. Therefore, for a mobile toward the upper zone it is efficient to increase the number of cells within his moving radius that is expected to be handed off, and to decrease the number of cells in case of a mobile toward the lower zone. Figure 2 shows the direction estimation algorithm based on the above conditions.

2.3.1 Resource Reservation for Low-Speed Mobiles

The moving radius and the moving pattern of a mobile has different characteristics according to the speed of the mobile. That is, a low-speed mobile (a pedestrian) has a smaller moving radius and a more complex moving pattern, while a high-speed mobile (a motor vehicle) has a larger radius and a simpler pattern. Using those characteristics, reservation variables such as the current position and the moving direction of a mobile are defined, and the neighboring cells that need to reserve resources are decided. In the case of low-speed mobiles,

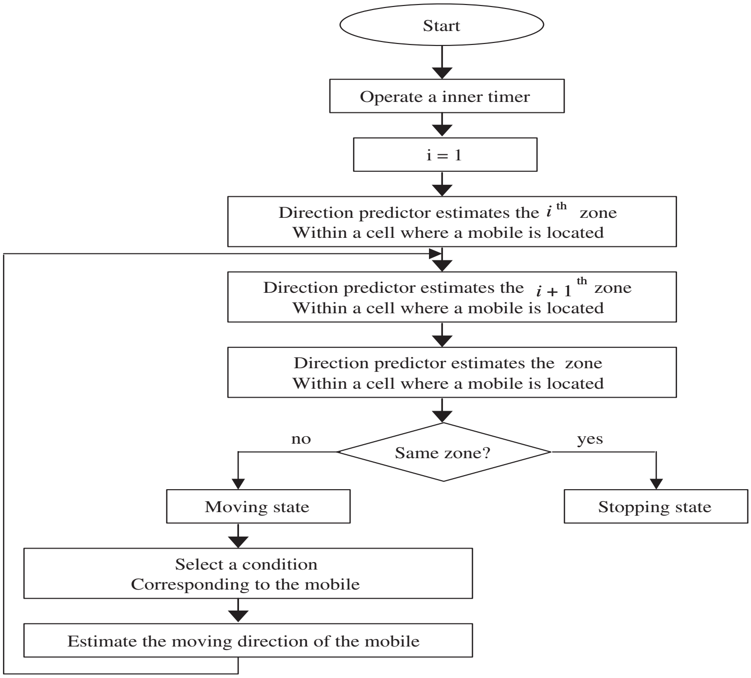

Fig. 2. Direction estimation algorithm

the result of the direction estimation can vary significantly due to two factors. First, the current position is considered. This is because the moving radius of low-speed mobiles is narrow, therefore, whether the handoff is done or not can be estimated according to his current position. Second, the moving direction is considered. The reason of using this factor is that the handoff attempt of the mobiles moving toward the inside of cell is decreased, while the handoff attempt of the mobiles moving toward the outside of cell is increased. The location zone is estimated in the sector and the zone estimation, and then based on the location of the estimated zone and the predicted direction, cells in the neighborhood are ranked according to the likelihood that the mobile will move into these cells. Cells needed to reserve the resource is decided by the sector estimation, and the resource reservation for the cells is done using the current position estimated by the zone estimation. Mobiles moving toward the upper zone need not reserve the resource. The resources for mobiles moving toward the lower zone are reserved only in case their estimated position is zone-3. Resource reservation conditions based on the reservation variable for a low-speed mobile is as follows.

– Condition 1: if the current position is zone-1, the reservation is not made regardless of its moving direction.

- Condition 2: if the current position is zone-2 and its movement is done from zone-1, the reservation is not made.

- Condition 3: if the current position is zone-2 and its movement is done from zone-3, the reservation is made to the maximum two cells.

- Condition 4: if the current position is zone-3 and its movement is done from zone-2, the reservation is made to the maximum one cell.

2.3.2 Resource Reservation for High-Speed Mobiles

The reservation variable for fast-speed mobiles is the moving direction. If the mobiles move fast, the feasibility of performing a handoff is expected to be higher; therefore the reservation is needed regardless of their current position within cell. Since the mobility of the fast-speed mobiles has a varying randomness, a cluster of cells that is reflective of the user mobility is needed to reserve the resources. Resource reservation conditions based on the reservation variable for a high-speed mobile is as follows.

- Condition 1: If the mobile moves from zone-1 to zone-2 within the same sector, the resources are reserved for three cells that is reflective of the moving direction.
- Condition 2: If the mobile moves from zone-2 to zone-3 within the same sector, the resources are reserved for one cell that is reflective of the moving direction.
- Condition 3: If the mobile moves from zone-3 to zone-2 within the same sector, the resources are reserved for five cells that is reflective of the moving direction.
- Condition 4: If the mobile moves from zone-1 to zone-2 within the same sector, the resources are reserved for three cells that is reflective of the moving direction.
- Condition 5: If the mobile moves from zone-1 to zone-2 within the other sector, the resources are reserved for three cells that is reflective of the moving direction.
- Condition 6: If the mobile moves from zone-2 to zone-3 within the other sector, the resources are reserved for one cell that is reflective of the moving direction.
- Condition 7: If the mobile moves from zone-3 to zone-2 within the other sector, the resources are reserved for five cells that is reflective of the moving direction.
- Condition 8: If the mobile moves from zone-2 to zone-1 within the other sector, the resources are reserved for five cells that is reflective of the moving direction

3 Direction Prediction Based Resource Reservation and Allocation

3.1 Resource Reservation and Allocation Structure

A real-time mobile performs resource reservation for hand-off, and a set of the reserved resources can be occupied temporally by non-real-time mobiles within the target cell. On the order hand, a non-real-time mobile doesn't perform resource reservation for handoff, and its resource allocation request is buffered in the waiting queue of the target BS during handoff duration time and is given the priority based on the service demand time. If the reserved set is returned because the corresponding real-time mobile is handed off, the priority of the request becomes the lowest lank. This strategy is explained in Figure 3.

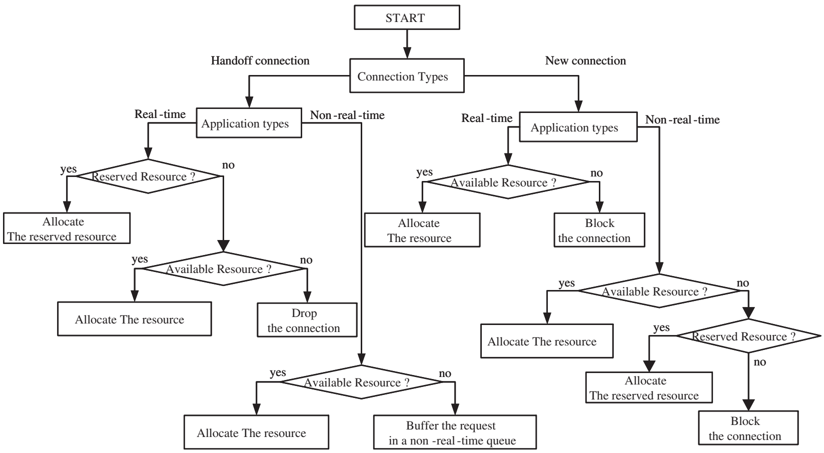

Fig. 3. Admission control for multimedia connections

3.2 Resource Reservation Procedure

The base station reserves only the resources corresponding to the minimum transmission rate to the mobile. Based on the location and the direction of the mobile within a cell, the resource reservation is performed with the following order: unnecessary state, not necessary state, necessary state, and positively necessary state. If the reservation variable for the mobile is changed, the reservation is canceled and the resources have to be released with the reverse order and returned to the fool of available resource. The set of the reserved resources have its priorities depending on whether it can be allocated to new connections or not: a real-time handoff connection (priority 1), a non-real-time handoff connection (priority 2) and a non-real-time new connection (priority 3).

- *Unnecessary State*
  The resource reservation needs not be performed.
  This state corresponds to the resource reservation condition 1 and 2 for low-speed mobiles.

- *Not Necessary State*
  A set of the reserved resources corresponds to priority 3.
  If any resources are available in each of the estimated cells, the resources are then reserved for each of the mobiles. A set of the reserved resources can be occupied by the new connections if enough resources are not available for a new connection in each of the estimated cells.
  If there are any resources available to support the reservation in the estimated cell, and a moving connection competes with a new connection for the resources, the resources are occupied with the following order: a real-time handoff connection, a real-time new connection, a non-real-time handoff connection, and a non-real-time new connection.
  If no resources are available, the reservation is not done.
  This state corresponds to the resource reservation condition 3, 7 and 8 for fast-speed mobiles.

- *Necessary State*
  A set of the reserved resources corresponds to priority 1.
  If there is no enough resource available to accommodate a new connection, a set of the reserved resources for real-time handoff connections can be occupied by non-real-time new connections.
  If there are resources available to support the reservation in the estimated cell, and a moving connection competes with a new connection for the resources, the order of occupying the resources is the same as Not Necessary State.
  If no resources are available for the reservation in the estimate cell, the shared part resources are allocated and reserved for a real-time connection.
  This state corresponds to the resource reservation condition 4 for low-speed mobiles.
  This state corresponds to the resource reservation condition 1, 4, 5 and 8 for fast-speed mobiles.

- *Positively Necessary State*
  The reserved resources correspond to priority 1.
  New connections cannot occupy the reserved resources.
  In case of a moving connection competes with a new connection for resources in the estimated cell, the resources are occupied with the following order: a real-time handoff connection, a non-real-handoff connection, a real-time new connection and a non-real-time new connection.
  If no resources are available for the reservation in the estimate cell, the shared part resources can be allocated and reserved for both real-time connections and non- real-time connections.

This state corresponds to the resource reservation condition 4 for low-speed mobiles.
This state corresponds to the resource reservation condition 2 and 6 for fast-speed mobiles.

4 Simulation Model and Result

The proposed scheme is compared with two different methods to evaluate the performance.

Method 1: there is resource reservation. The resources are reserved exclusively for handoff connections in each cell. The remaining resources can be equally shared among handoff and new connections. This method is called Fixed_Res.
Method 2: the resources are reserved dynamically based on the current connections in the neighboring cells. This method is called Dynamic_Res.

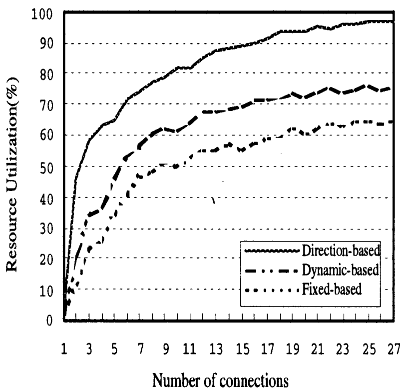

Fig. 4. Comparison of resource utilization

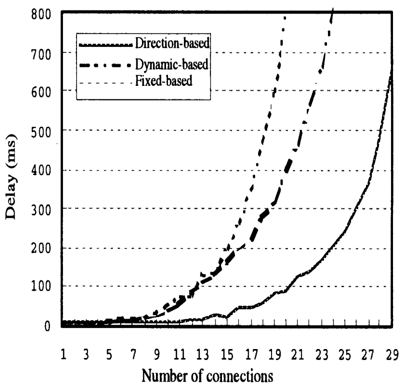

Fig. 5. Comparison of transmission delay

The simulation model composed of a single cell, which will keep contact with its six neighboring cells. Each cell contains a base station, which is responsible for the connection setup and tear-down of new applications and to serve handoff applications. 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 $\sigma = 6dB$. A value of the received signal strength less than -16 dB is regarded as an error, which is therefore excluded from the calculation. Figure 4 shows the results for an average percentage of resource utilization as a function of connections arrival with priority to handoff connections over new connections. The resource utilization for

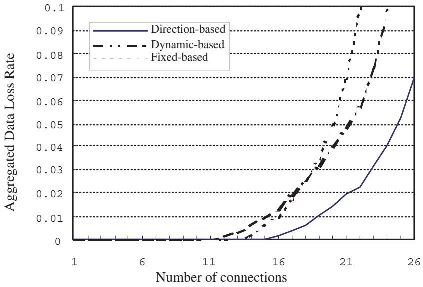

Fig. 6 Comparison of aggregated data loss rate

the Direction-based is increased up to 25 arrival, than that for Fixed and Dynamic. This improvement may be caused since the Direction-based allocates the reserved resources not only real-time handoff connections but also non-real-time new connections. In Figure 5, the comparison of transmission delay of the three schemes is plotted against the number of connections. From the figure, we can see the performance of the direction-based is up to 2.5 times better than that of the conventional schemes. This is because non-real-time connections can adaptively occupy the reserved resources for real-time connections, and we can prevent the performance degradation due to queueing of non-real-time connections.

Figure 6 shows the aggregated data loss rate. It is observed that as the number of connections increase, direction-based provides a noticeable improvement over the conventional schemes for real-time connections, while slightly degrading the performance for the non-real-time connections.

5 Conclusion

This main paper is to address the problem of guaranteeing an acceptable level of QoS requirements for mobile 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, mobiles are classified according to their reservation variables. Based on reservation variables a scheme that provides predictive QoS guarantees in mobile multimedia networks is proposed. The proposed scheme shows a great improvement of the resource utilization, the delay and the data loss. It is because our resource reservation scheme is more adaptive than existing resource reservation schemes. In our scheme, resources are classified as ones having priority to the new calls and ones having priority to the handoff calls based on reservation variable. We improve the dropping rate for the handoff connections by dynamically adjusting the amount of the reserved resources according to the amount of occupied resources. The determination of the optimal direction should be studied consecutively. Also further researches are required on their implementation and applications to the handoff and resource allocation strategies.

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