A Flexible Bandwidth Allocation Scheme Using Specified Duration Based Data Acquisition in Heterogeneous Networks

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Abstract

Measurement and data acquisition get the most accurate indicator, in mobile communication network. Channel occupancy for each cell shows the proportion of current traffic. In addition, call duration is another important target, which more precise estimate the users' usage situation in heterogeneous networks. A Flexible Bandwidth Allocation Scheme (FBS) using specified duration based data acquisition improves the quality of services (QoS) in heterogeneous networks. The FBS reduces the weight call loss probability (CLP) and improves performance in resource allocation and wireless channel utilization. Simulation results demonstrate the effectiveness of the scheme.

Keywords: *Data Acquisition, Heterogeneous Networks, Flexible Bandwidth Allocation Scheme*

1. Introduction

Heterogeneous Networks provide seamless coverage services with the low propagation delay, low-power terminals and the good QoS. GSM networks with 3G networks are classic examples of heterogeneous networks. Call Dropping Probability (CDP) and Call Blocking Probability (CBP) are important indexes for heterogeneous networks. Furthermore, it should be noted that blocking a handover call is more unsatisfying to the user than blocking a new call; more attention has been paid to the handover issue.

Many schemes to address the Call Admission Control (CAC) strategy and Channel Resources issue of heterogeneous network have been proposed. One of noticeable schemes is the Dynamic Handover Priority (DHP) scheme [1,2]. DHP proposes a Channel-Locking Mechanism and defines two kinds of users, one is the priority users or DHP users, and another is the regular users. The locked channels are reserved for the DHP users to avoid calls' dropping. DHP has low system complexity and low call dropping probability. The disadvantage of DHP is the channel utilization rate is low.

The Time-based Channel Predictive Control (TCPC) [3] is proposed recently to improve the channel utilization rate when handovers happen in system. It reserves the channel for a priority user during a suitable time interval in the cell. The channel can be used by other users in other time interval. The Dynamic Time-based Channel Resources Control (DTCRC) mechanism is based on the TCPC. It divides traffic flows into two classes, the stream flow and the elastic flow. The transmission rates of elastic flows are Flexible in order to improve the whole channel utilization of the mobile communication system. These schemes improved the channel utilization rate while demanded a higher system complexity and longer processing time.

The Flexible Bandwidth Scheme (FBS) is proposed in this paper to balance the channel utilization rate and the system complexity. In the scheme, the bandwidth resource of a cell is divided into two states according to the traffic load. In low traffic load state, the main purpose of the system is to decrease the system complexity and processing time; and in high traffic load state, the main purpose of the scheme is to improve the bandwidth utilization rate, and provide the services for more users.

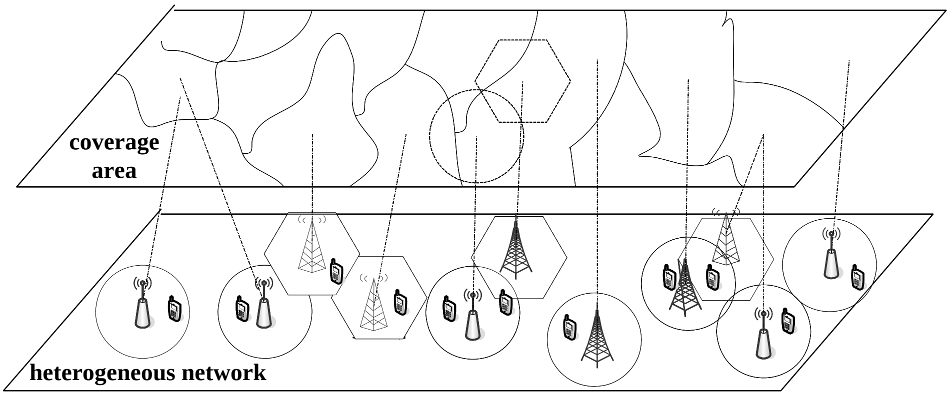


Figure 1. Heterogeneous networks and their coverage area.

In addition, heterogeneous networks are a huge system due to its low propagation delay and good QoS. However, the growth of mobile broadband services so that there is a shortage of wireless bandwidth resource. A new scheme which provides better services to use limited resources becomes a general demand. The real-time priorities of ongoing services are adjusted with the change of bandwidth occupancy rate. In accordance with the protocols, an ongoing service sends Measurement Reports (MR) to the base station every 480ms. The information in the MR includes traffic type, call duration and channel occupation.

Many schemes to address the bandwidth allocation strategy and Channel Resources issue of heterogeneous network have been proposed. One of noticeable schemes is the Max-Min fair bandwidth allocation algorithms, before packet transmission, an input port claims portion of the bandwidth of each output port for its traffic. However, since each input and output has only local bandwidth information, it does not know how much bandwidth other input claimed at a specific output. [4]For the under-utilized case, clearly, the unused bandwidth should be allocated to make full use of the transmission capacity, and it has to be carefully handled to allocate the leftover bandwidth in a fair manner. For the over-utilized case, it is also necessary to fairly scale down the claimed bandwidth of each user to make the scheme feasible. [5]Another bandwidth allocation scheme based on games considers the problem for a consumer multi-provider system, where a consumer may have access to only a subset of all providers. [7] A user demands bandwidth from the base stations it has access to by submitting bids. Once the bidding process is complete, a base station distributes its bandwidth to the users in proportion to their bids. Because all the data needed for this scheme that stays in MR. The data acquisition server takes the supplied MR and looks it up in a large table of E1 addresses to a data format. Great capacity database is built of MRs and the data real-time analysis becomes a challenge and the second step in this system.

Table 1. Information of Measurement Result.

field name	data type	values range	frame name
Time	date/time	18decimal	Measurement Result
TEI	tinyint	0-127/7bits	Measurement Result
CI_Num	big int	0 ~ 4294967295/4 bytes	Config File
CI_Name	varcha	100bytes	Config File
BTS_Num	bigint	0 ~ 4294967295/4 bytes	Config File
BTS_Name	varchar[50]	100bytes	Config File
Latitude	float	±1.175494E-38 ~ ±3.402823E+38/4bytes	Config File
Longitude	float	±1.175494E-38 ~ ±3.402823E+38/4bytes	Config File
BSC_Num	bigint	0 ~ 4294967295/4 bytes	Config File
BSC_Name	varchar[50]	100bytes	Config File
LAC	bigint	0 ~ 4294967295/4 bytes	Config File
MSC_Name	varchar[50]	100bytes	Config File
Channel_type	tinyint	0-31/5bits	Measurement Result
Time_slot_num	tinyint	0-7/3bits	Measurement Result
Measurement_result_num	tinyint	0-255/8bits	Measurement Result
RXLEV_all_up	tinyint	0-63/6bits	Measurement Reasult
RXLEV_subset_up	tinyint	0-63/6bits	Measurement Reasult
RXQUAL_subset_up	tinyint	0-7/3bits	Measurement Reasult
RXQUAL_all_up	tinyint	0-7/3bits	Measurement Reasult
BS_Power	tinyint	0-31/5bits	Measurement Reasult
MS_Power	tinyint	0-31/5bits	Measurement Reasult
DTX	bit	0-1/1bits	Measurement Reasult
RXLEV_FULL_down	tinyint	0-63/6bits	Measurement Reasult
RXLEV_SUB_down	tinyint	0-63/6bits	Measurement Reasult
RXQUAL_FULL_down	tinyint	0-7/3bits	Measurement Reasult
RXQUAL_SUB_down	tinyint	0-7/3bits	Measurement Reasult
RXLEV_NCELL_i(1-	tinyint	0-63/6bits	Measurement Reasult

6)			
BCCH_FREQ_NCELL_i(1-6)	tinyint	0-31/5bits	Measurement Reasult
BSIC_NCC_NCELL_i (1-6)	tinyint	0-7/3bits	Measurement Reasult
BSIC_BCC_NCELL_i (1-6)	tinyint	0-7/3bits	Measurement Reasult
Timing_advance	tinyint	0-63/6bits	Measurement Reasult

Measurement results
RXLEV-FULL-SERVING:43
RXLEV-SUB-SERVING:44
RXQUAL-FULL-SERVING:1
RXQUAL-SUB-SERVING:0
BA-USED:1
DTX:Used
Measurement results(MEAS-VALID):Valid
Number of neighboring cell measurements:6

NCEll	RXLEV-NCELL	BSIC-NCELL	BCCH-FREQ-NCELL
1	42	23	03
2	40	27	00
3	32	22	01
4	32	45	06
5	29	41	02
6	25	27	07

Figure 2. A data format of Measurement Result Sample.

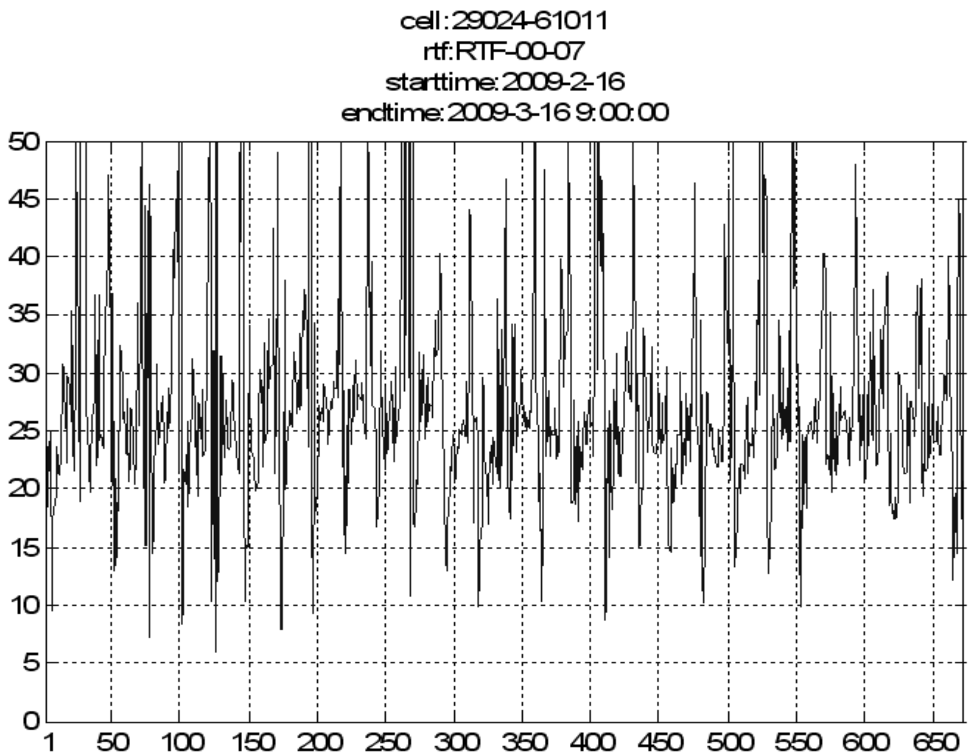
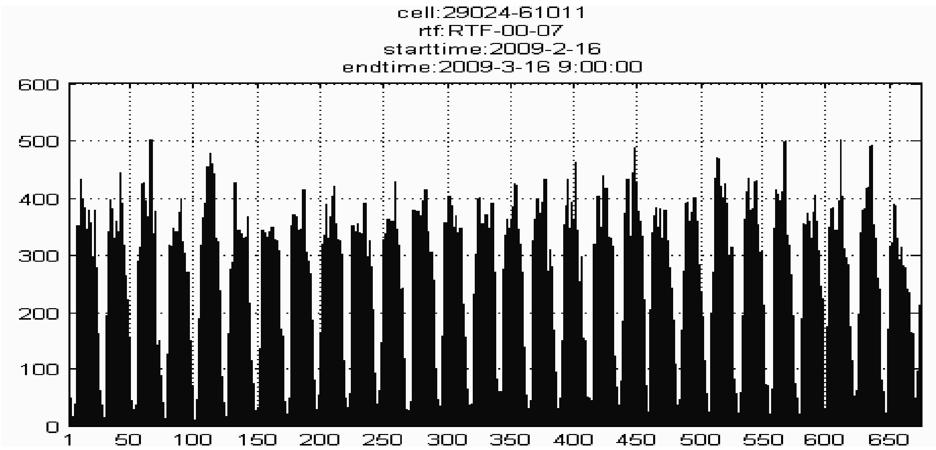
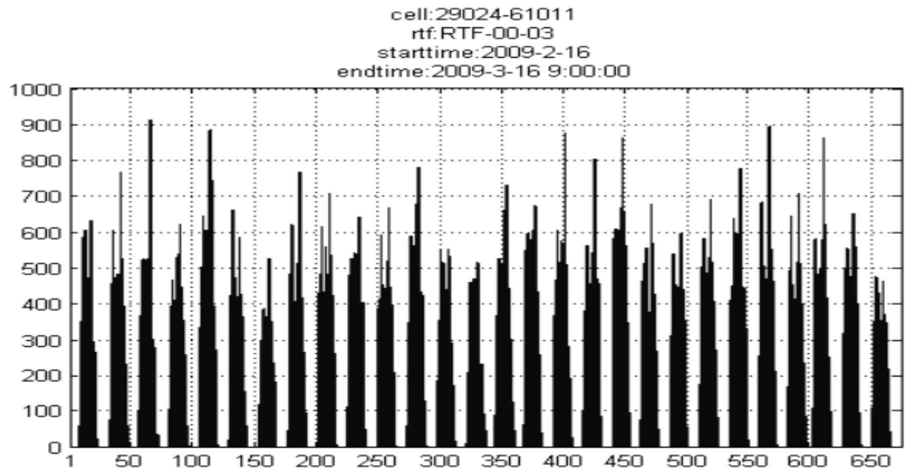


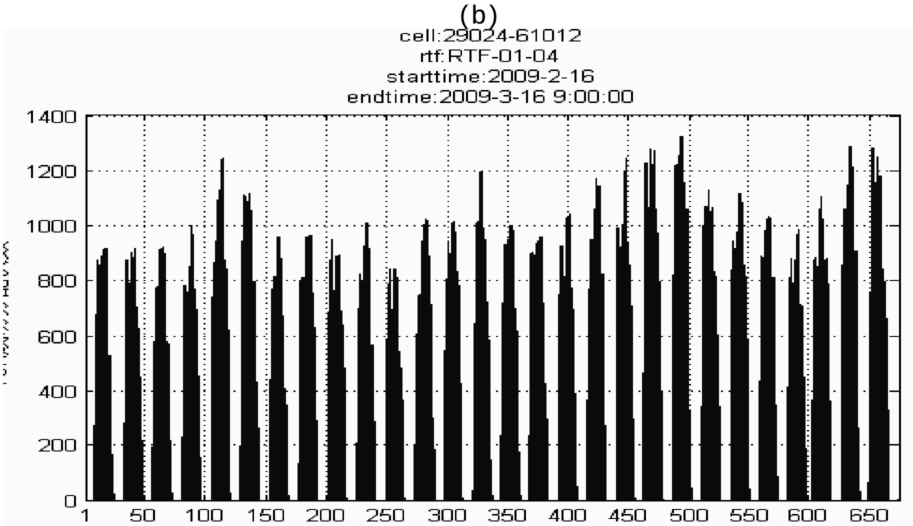
Figure 3. Call duration data acquisition Samples.



(a)



(b)



(c)

Figure 4. The number of TCH channel allocation.

Bandwidth Allocation Schemes for a multi-services heterogeneous network must guarantee the potentially different QoS requirement. The transmission rates of elastic flows are Flexible in order to improve the whole channel utilization of the mobile communication system [8]. These schemes improved the channel utilization rate while demanded a higher system complexity and longer processing time.

There is little influence on the quality degree of data service when bandwidth changed within a certain range. Therefore, when there is not enough bandwidth in the system, the bandwidth of data service can be reduced and transferred to the handoff calls. The dropping probability is reduced while the quality of service (QoS) is reduced little. But if the bandwidth grade of ongoing calls is decreased too much, there will be significant influence on their QoS. For different service types, the relationships between the QoS and bandwidth used are different. Through the MR real-time analysis, we get the corresponding parameters of current channel occupancy rate. Resource scheduling among the ongoing calls is feasible.

2. Related Work

2.1. Road Monitoring

Intelligent transportation systems [11] have been proposed and built to leverage computing and communication technology for various purposes: traffic management, routing planning, safety of vehicles and roadways, emergency services, etc.

There has been much work on systems for traffic monitoring, both in the research world and in the commercial space. Many of these systems leverage vehicle-based GPS units (e.g., as in GM's OnStar [12]) that track the movement of vehicles and report this information back to a server for aggregation and analysis. For instance, CarTel [14] includes a special box installed in vehicles to monitor their movements using GPS and report it back using opportunistic communication across a range of radios. This information is then used for applications such as route planning.

Recent work on Surface Street Traffic Estimation [15] also uses GPS-derived location traces but goes beyond just estimating speed to identifying anomalous traffic situations using both the temporal and spatial distributions of speed. For instance, the authors are able to distinguish between traffic congestion and vehicles halting at a traffic signal.

There has also been work on leveraging mobile phones carried by users as traffic probes. Smith et al. [16] report on a trial conducted in Virginia in 2000, which was based on localizing mobile phones using information gathered at the cellular towers.

2.2. Cellular Localization

Several positioning techniques working within cellular networks have been developed, and they can be divided into: Satellite-based, ranging, direction-finding, and range-differencing.

Much of the activities in the area of wireless positioning have been driven by the 1996 Report and order of the Federal Communications Commission (FCC) [17]. Since then, different positioning systems working within a cellular network have been developed [18-20]. Parameters that are often measured and used for location include received signal strength (RSS), angle-of-arrival (AoA), time-of-arrival (ToA) and time differences of arrival (TDoA).

Direction finding and ranging methods perform well in environment characterized with LOS. In dense urban area, additional algorithms should be added which deal with non-line-of-sight (NLOS). Moreover, these methods require additional equipment for their implementations (directional antennas at every base station (BS) for AoA and very accurate clock for ranging methods).

Fingerprint localization methods perform relatively better in urban area compared to other methods. Moreover, this approach does not require any additional equipment for its implementation to the existing cellular networks.

Fingerprinting techniques have appeared to perform better in environment with severe multipath propagation characteristics and NLOS [21]. However, fingerprint-based techniques suffer from poor performance if the stochastic effect in the fingerprint is not reduced. In [22] the author reduced the stochastic effect by averaging RSS.

There are two main processing methods for fingerprinting techniques: database and NN (neural network). Since our purpose is to detect subscribers in the road, ignoring large area of resident, we present a quick algorithm to match characteristic fingerprint.

3. System Structure

The GSM specifications allow the MS (Mobile Station) to report signal strength measurements on the serving and the six strongest neighboring cells (the neighboring cell's BCCH beacon frequency). The measurement result is contained in MR (measurement report) transported between Abis interface. Obtaining MR, we can establish RSS fingerprint database. The system structure is show as Fig. 2.

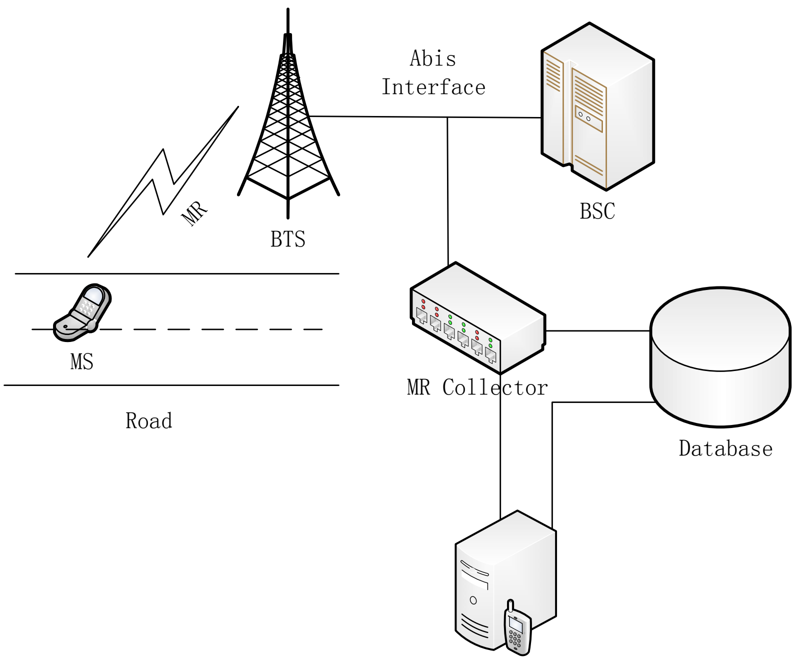


Figure 5. System structure

To build RSS fingerprint database, we collected RSS information with GPS, as show in Fig.3. Real pedestrian-style and drive-style handset measurements were taken with a Sony-Ericsson handset T68 connected to an Ericsson TEMS data collection unit. At the same time, we collected E1 signaling information in BSC machine room, as show in Fig. 3.

Figure 6. Sony-Ericsson handset T68 and GPS receiver

Figure 7. Sony-Ericsson handset T68 and GPS receiver.

4. Bandwidth Resource Analysis

Based on the MR real-time analysis that the bandwidth of an ongoing call is Flexible during its lifetime, the bandwidth used by the call is divided into different grades according to their magnitude. The set of the different bandwidth grades is denoted as $G = \{g_1, g_2, ..., g_n\}$. In the notation, the lowest bandwidth, g_1 is the amount of bandwidth which support the minimum information transmit rate required for the call to be admitted; the highest bandwidth, g_n , is the maximum bandwidth a call used. $g_1, g_2, ..., g_n$ is an increasing sequence. The bandwidth of an ongoing call is adjusted in its bandwidth grade set $\{g_1, g_2, ..., g_n\}$ according to the number of calls in the cell.

The bandwidth resources of the system are divided into two sets: the reserved bandwidth, which is reserved for handoff call specially; the non-reserved bandwidth, which can be used by new call and handoff call. When a new connecting request is sent to the network, the classes of the service and its bandwidth set are transmitted to the network as well. The network assigns the bandwidth as much as possible to accept the call. Only when the available non-reserved bandwidth is less than the demand of the minimum bandwidth grade $g1$, the new connecting request will be blocked.

When handoff call arrives, they can use the total idle bandwidth of the network. The network assigns bandwidth as much as possible to the handoff calls. If the available idle bandwidth is less than the demand of the minimum bandwidth, the network will lower the bandwidth grade of the ongoing call to release some bandwidth resources in order to satisfy the lowest bandwidth requirement of the handoff calls. The bandwidth resources will be released when the calls is finished, and then is assigned to the ongoing calls which are served with lower bandwidth grade in order to improve their QoS.

Let C represents the set of on-going calls, Let b_t^i and b_{t+1}^i represents the bandwidth assigned to call $i(i \in c)$ at time t and the next time $t+1$ respectively. Let y_i be the bandwidth lowered of the ongoing call i . That is $y_i = b^i{}_t - b_{t+1}^i$. Let $y = \sum_{i \in c} y_i$. Let u_i represents the QoS, it increases with the bandwidth the relate call used. Let B denotes the total bandwidth the handoff calls need. Let p_{hf} represents the handoff dropping probability of the handoff calls. It is assumed that QoS of the heterogeneous network U is the function of QoS and handoff calls dropping probability. It is expressed as:

$$U = \sum_{i \in c} u_i(b_{t+1}^i) - \gamma p_{hf} \tag{1}$$

Where γ is a parameter indicating the influence of the handoff call dropping probabilities on the QoS. Lowering the ongoing call's bandwidth for handoff call can reduce the dropping probability, but the QoS of the ongoing call will decrease. Our main aim is to maximize the system's QoS which belongs to the classical constrained nonlinear optimization problems, and can be formulated as follows:

$$\max\ U = \sum_{i \in c} u_i(b_{t+1}^i) - \gamma p_{hf} \tag{2}$$

$$b_{t+1}^i = b_t^i - y_i \tag{3}$$

$$\sum_{i \in c} y_i \le B \tag{4}$$

$$b_{t+1}^i \ge \min b_i, \qquad \text{for all } i \in C \tag{5}$$

Constraint (4) ensures that the sum of the lowered bandwidth of the ongoing calls cannot exceed the amount of total bandwidth that all the handoff calls need. Constraint (5) indicates the bandwidth left for call i must be higher than the lowest bandwidth it needs, and $\min b_i$ is the lowest bandwidth call i requests.

5. Flexible Bandwidth Scheme

The strategy of FBS is described in this section. In FBS, two traffic load states of cells are defined. One state is the Channel Low-Occupancy Rate, called CLOR state; the other is Channel High-Occupancy Rate, called CHOR state. The switch of the two states is determined by a channel occupancy rate threshold. Two classes of calls, voice calls and non-real-time calls are considered in FBS.

A. CLOR state

When the traffic load of a cell is in CLOR state, it means that the traffic load of this cell is not high. For a voice call, the DHP method is adopted. When a voice call sets up in a given cell C_i of the heterogeneous network, a bandwidth reservation request is sent to the first two cells to be visited by the user, the cell C_i and the cell C_{i+1}. The system will judge whether there is enough idle bandwidth for this new call, the occupied bandwidth includes the ongoing calls in C_i and the locked bandwidth for the voice calls in cell. If the condition of bandwidth of the two cells is satisfied, the new call will be admitted. And in the sequent cell C_{i+1} that the call may enter, the sufficient bandwidth will be reserved. When the call enters the sequent cell C_{i+1}, it occupies the locked bandwidth reserved before for itself; and a reservation request is immediately sent to the next cell C_{i+2}, when the bandwidth is enough in C_{i+2}, it is locked to reserve for this call.

Such processes happen sequentially until the call terminate. In order to decrease the complexity of the system, there isn't a bandwidth locking waiting queue in each cell.

For a non-real-time call, a gradational method is used, the transmission rate of the non-real-time call in a given cell divides into five grades, and the transmission rate of the higher grade is twice over the lower grade. When a non-real-time call sets up in the cell C_i, the system will first inquire the non-real-time call grade of this cell, and then judge that if there is enough bandwidth for the call with this rate of the grade in this cell. If the bandwidth is enough, the call will be admitted, otherwise, the grade of service of this cell will be decreased. After the decreasing procedure, the bandwidth is judged again. If the bandwidth is still not enough, then the decreasing process will be repeated until the call get the bandwidth needed. If the grade of this cell is the lowest grade and there is still not enough bandwidth for this call, the call will be rejected. Figure 5 shows the flowchart of the Call Admission Control (CAC) strategy for a non-real-time call.

Because of the simple strategy of the CAC and the bandwidth reservation for channel resources predictive control, the complexity of the CLOR state is low. The system can admit the new call to access more quickly.

B. CHOR state

In this state, we assume that the user's terminal has the positioning facility to receive its position information. For a voice call, TCPC method is adopted. When a voice call sets up in a given cell C_i of the cell, the system judge that whether there is enough bandwidth in the temporary cell 1 [x-R, x] and the temporary cell 2 [x, x+R], x is position of the new voice call's user, R is the size of a cell, these are showed in Figure 2. If the bandwidth is enough, this call will be admitted to access; otherwise the call will be blocked. When this call is admitted, a bandwidth reservation request is sent to the cell C_{i+1}, the reservation time interval is [T_{iR} , T_{2R}], where T_R is the time of this voice call user reaching the boundary of cell C_i and C_{i+1}, and T_{2R} is the time that the user reaches the boundary of cell C_{i+1} and C_{i+2}. At the time of each voice call's handover, a handover request is sent to the next cell immediately, to reserve the time interval [T_{iR+R} , T_{iR+2R}].

For a non-real-time call, we used the same strategy as that of the CLOR state. The transmission rate of the call is Flexible according to the traffic in the cell. There won't be a bandwidth reservation for this class of calls.

In CHOR state, the main goal is how to provide services for users as many as possible; in requital for that the cost is the more processing time and the complexity of system.

According to the above, the scheme proposed can be more efficient in CLOR state. For CHOR state, the higher utilization of bandwidth has been obtained.

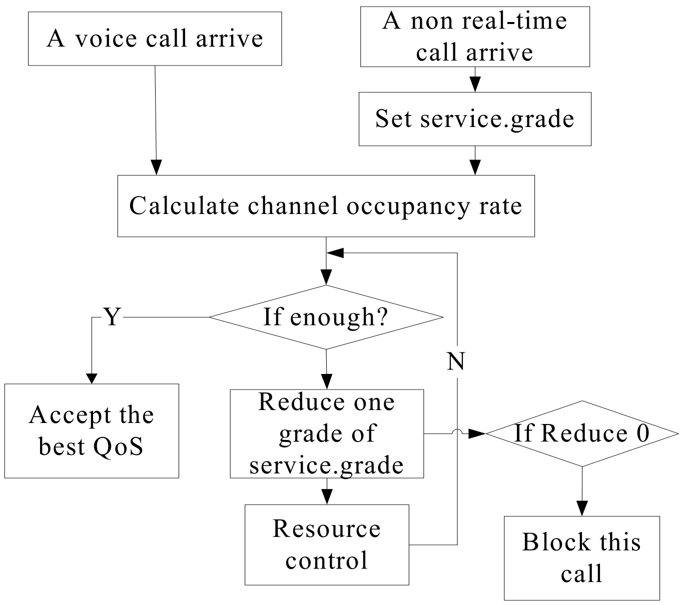


Figure 8. Flowchart of CAC for a non-real-time call

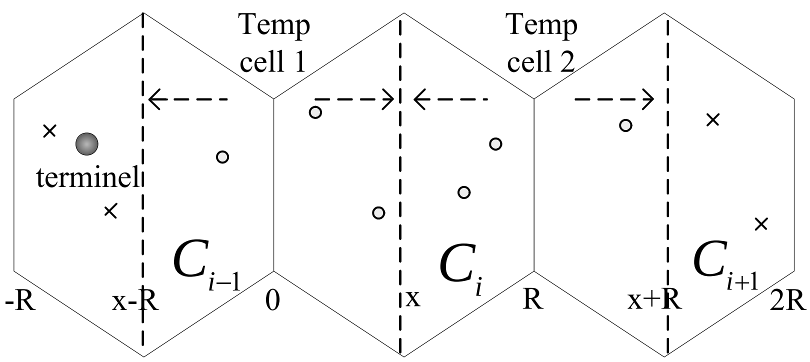


Figure 9. CHOR state voice call CAC.

6. Analysis of the Proposed Scheme

6.1. Basic Assumption

Two guidelines of the channel resources predictive control in heterogeneous network were considered in the study, the Call Blocking Probability (CBP) and the Call Dropping Probability (CDP). CBP is the parameter for the new call, and CDP is the parameter for the handover call. The cell of heterogeneous network is single-aspect. Let us assume that the bandwidth resource of the exact cell of the heterogeneous network is a constant, we use B to denote it. And RATE_V denotes the transmission rate of the voice call, it is a constant. RATE_D denote the transmission rate of the non-real-time call, there are five grades of RATE_D.

6.2. Evaluation

In the study, the classical traffic assumptions are considered. The new calls are assumed to arrive according to the Poisson process, λ_c and λ_d are respectively the mean arrival rate of the voice new calls and the non-real-time new calls. And the calls durative times are assumed to be according to the exponential process, $1/\mu_c$ and $1/\mu_d$ are respectively the mean serving time of the voice calls and the non-real-time calls. We only need to analyze the new call blocking rate of the cell in CHOR state. A cell of this system is modeled by the Markov chain corresponding to the M/M/N/N queue. In this model, if there are new calls blocked, the grade of RATE_D is certainly down to the first grade according to the rule aforementioned; N is the voice call and the non-real-time call users' number. Let Π_k be the marginal probability to have k users occupying resources. Given the uniform users' distribution position and the uniform arrival of the users in a cell, p_k is the new call blocking probability with the condition of k users in cell C_i, p_k can be derived as follows (only the values of the steady states be considered). Let t denote the initial offset of a new call arrival, and v the actual configuration when a new call arrives.

$$p_k = \frac{1}{\sqrt{R^2+1}} \int_{x=0}^{R} \sum_{l,m=0}^{N} P(N \mid v) dx \tag{6}$$

With, v = {t = x, users number in C_{i-1} = l, users number in C_i = k, users number in C_{i+1} = m} as the Figure 2 shows.

Since PASTA stands, the probability of the new calls blocking P_b is:

$$P_b = \sum_{k=0}^{N} \Pi_k \, p_k \sqrt{1-p_k^{\,2}} \tag{7}$$

From the equation above, it can be seen that the probability of new calls blocking depends on the steady state probabilities of the Markov chain.

7. Simulation Results

Simulation experiments have been carried out. Suppose that the simulated heterogeneous network to be an orbicular shape area of 3 cells. All handovers are considered to be the same. In the simulation model of the proposed scheme, there are two classes of users, the voice call users and the non-real-time call users. For comparing the performance of the proposed scheme, the TCPC scheme have also been simulated.

The simulation also gets the CBP and the CDP. Figure 7 and Figure 8 show the CBP and CDP curves of the proposed scheme's performance and that of TCPC and Figure 9 shows the BUR curves of FBS scheme's performance and that of TCPC.

- The new call arrivals are assumed to obey Poisson process with the parameter λ, it is a Flexible.
- The user call duration is exponentially distributed. The mean duration time of the voice call is 180s, and the mean duration time of the non-real-time call is 300s. The voice call users belong to class 1 users, the proportion of it is 40%, and the non-real-time call users belong to class 2 users, the proportion is 60%.
- The threshold of the state is that the bandwidth which has been occupied is 80% of the bandwidth in the cell.

According to the results, the FBS reduces the CBP with respect to TCPC schemes, and has better performance of CDP than TCPC. The complexity of FBS is close to the DHP scheme, and is lower than the TCPC. So the proposed scheme has both good performances in complexity and guide lines of channel resources predictive control.

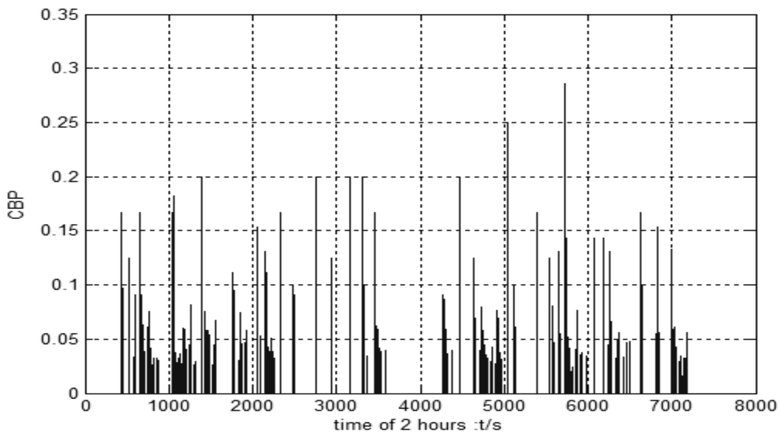


Figure 10. CBP for FBS in 2 hours.

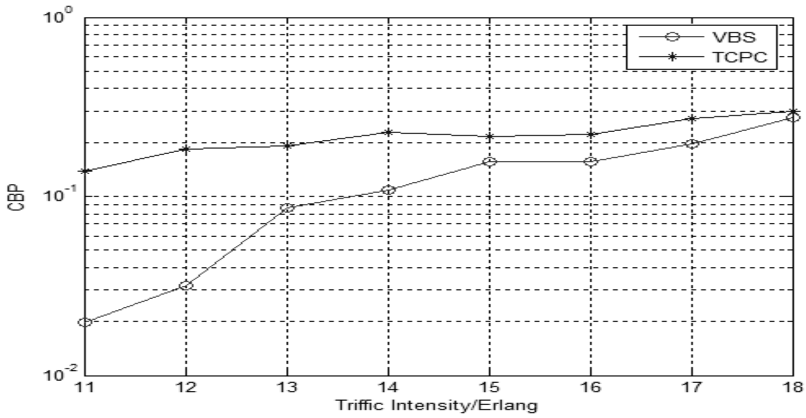


Figure 11. CBP for FBS and TCPC schemes

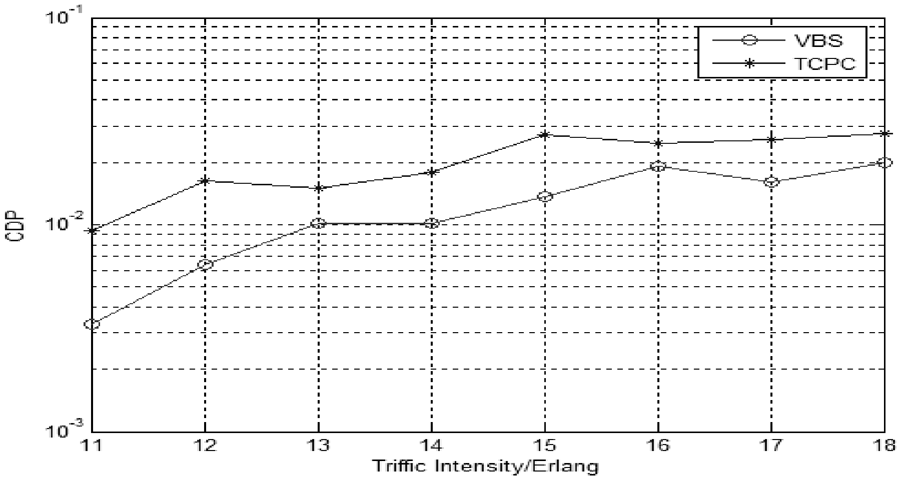


Figure 12. CDP for FBS and TCPC schemes

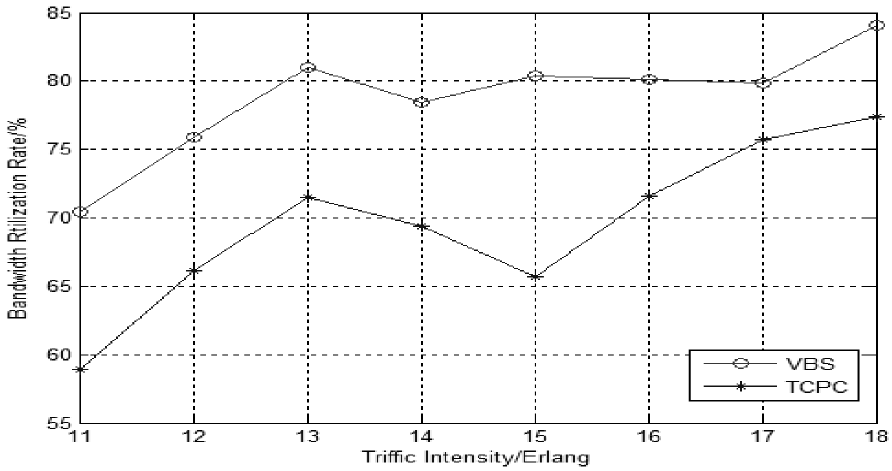


Figure 13. Bandwidth Utilization Rate for FBS and TCPC schemes

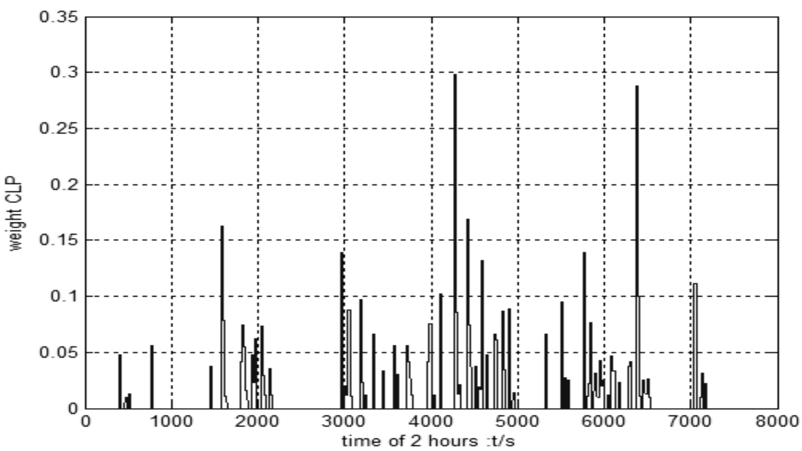


Figure 14. Weight CLP in 2 hours

- New call blocking probability is recorded as CBP and handoff call dropping probability is recorded as CDP. As we know, CDP impacts on the QoS greater than CBP. The weight call loss probability(WCLP) is:

$$WCLP = \alpha \cdot CBP + \beta \cdot CDP \tag{7}$$

  The Parameters α and β are assigned 1 and 2.
- Standardized QoS is decided by weight call loss probability, channel occupancy rate and average Service Level.

The simulation results show the effectiveness of QoS-adaptive Bandwidth Allocation Scheme.

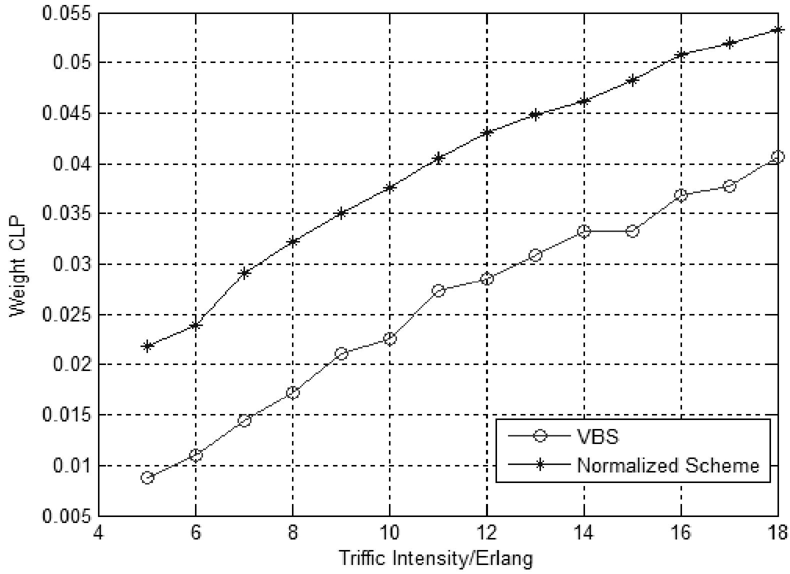


Figure 15. Weight CLP Analysis

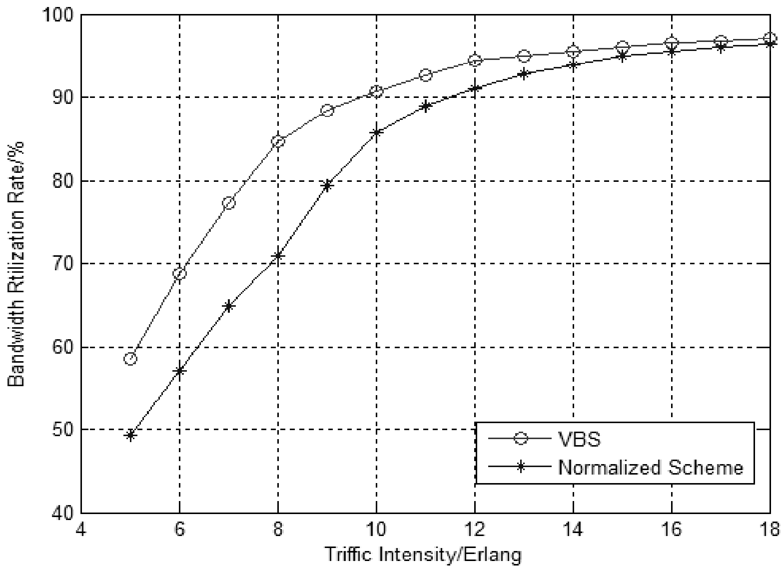


Figure 16. Bandwidth Utilization Rate Analysis.

Table 2. Average QoS Level comparison

Traffic Intensity	4	6	8	10	12	14	16	18
Average QoS Level/BAS	g_5	g_5	g_4	g_3	g_2	g_1	g_1	g_1
Average QoS Level/QBAS	g_5	g_5	g_5	g_5	g_4	g_3	g_2	g_1

8. Conclusions

A new Flexible Bandwidth Scheme (FBS) for channel resources predictive control in heterogeneous network was proposed in this paper. FBS defines two traffic load states of cells, the CLOR state and the CHOR state. In CLOR state, the main purpose of the scheme is to decrease the system complexity and processing time; and in CHOR state, the main purpose of the scheme is to improve the bandwidth utilization rate, and provide the services for more users. Compared with TCPC, the simulation results demonstrate the effectiveness of FBS.

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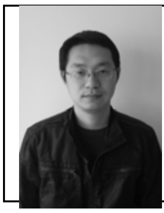

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