IJCSI International Journal of Computer Science Issues, Vol. 8, Issue 3, No. 2, May 2011
ISSN (Online): 1694-0814
www.IJCSI.org

Generalized Bandwidth Adaptive System for Multimedia Transmission in Multi-Cell Wireless Networks

O. Said[1] and A.Tolba[2]

[1] Computer Science, Taif University, College of Computers and Information Technology
Taif, 888, KSA

[2] Computer Science, King Saud University, Riyadh Community College
Riyadh, 11437, KSA

Abstract

In this paper, a novel system, which adapts a bandwidth by dynamic extracting the excess bandwidth not only from one cell but also from other cells in the cellular wireless networks, is presented. The proposed system manages the multimedia sessions to redistribute the new QoS parameters values in case of notable changes or network starvation. The performance analysis shows that our proposed system impacts the old trials and decreases the drop probability of new and handoff calls in multi-cell wireless networks.

Keywords: *QoS, Multimedia Communication, Wireless Networks, Multi-Cell Networks.*

1. Introduction

Low cost and high capacity of the Wireless Local Area Networks (WLANS) make them more popular. Even though the Quality of Services (QoS) in wireless networks is a challenging problem due to the limited bandwidth, wireless networks are expected to support multimedia services with guaranteed QoS for diverse traffic types (video, voice, and data). QoS support in wireless networks as well as in wireline has been a key hot area of research for some time with improvements in the Medium Access Control (MAC) protocol as the key way to resolve the problem. This paper concerns with the multimedia QoS problem at mobile multi-cell WLANs [1, 2, 3]. In this paper a Generalized Bandwidth Adaptive System (GBAS), in which the bandwidth is extracted from the lazy cells and borrowed to the starved cells over mobile WLANs, is proposed. The computation, related to the extraction process, is done in real-time without affecting the multimedia transmission or the system efficiency.

This paper proceeds as follows; in Section 2, the problem formulation is introduced. In Section 3, the previous trials approaches are showed briefly. In Section 4, our proposed system is demonstrated. In Section 5, how our system recovers the bandwidth lack for new and handoff calls in multi-cell mobile WLANs in addition to system simulation and performance evaluation, are showed. Finally, conclusion and future work are stated in Sections 6 and 7.

Both Authors are Assistant Professors, Computer Science Department, College of Science, Menoufia University, Menoufia, Egypt

2. Problem Formulation

The New Call Blocking Probability (NCBP) and Handoff Call Dropping Probability (HCDP) [1, 2, 3] can express about the QoS requirements in WLANS. When a user requests a new connection, a new call is initiated, and when an active user moves from one cell to another neighboring cell, a handoff call occurs. Thus, the NCBP is defined by the probability of a new arriving call that is rejected while the HCDP is defined by the probability that a handoff attempt fails. The multimedia QoS guarantees in wireless networks is a great challenge due to the bandwidth limitation and the huge number of handoff events. When a user handoffs to a new cell, there may not be sufficient bandwidth to support his call. Based on the nature of the service, there are two possibilities in this situation. The first possibility is a non-adaptive service (fixed bandwidth for each call), the call will be dropped. The second possibility is a local adaptive QoS; the call may not be dropped but will suffer bandwidth degradation.

3. Related Work

There are many research work have been introduced in the topic of adaptive multimedia in cellular WLANS [4, 5]. The trial at [4] obtained the optimal bandwidth allocation over the entire network under a condition of continuous value of bandwidth. However, this trial is impractical due to its signaling overload. The trial at [5] proposed an adaptive multimedia model that guarantees only the upper bound of cell overload probability. Also, practical bandwidth values of adaptive multimedia is more likely to be discrete than continuous at [6]. However, bandwidth limitation is not considered. In addition, the trials are for [7, 8, 9, 10, 11, 12, 13] that proposed a bandwidth adaptive frameworks to extract the exceeded bandwidth from the cell calls. These trials are considered local solutions i.e. the operations are done internally at the cell and this makes the adaptation process restricted with a limited exceeded bandwidth. The last trial at [14], which used the tiered schemes idea with expert systems techniques, is complex and didn't consider the processes complexity in its evaluation.

4. Our proposed system

The infrastructure of our proposed system contains two major components. The first one is the system adaptation component, which adapts the bandwidth to serve new and handoff calls. The second one is the system management component, which controls the new additive agents and redistributes the new QoS parameters in case of notable changes.

4.1 System adaptation approach

Our system considers a wireless network with a multi-cell infrastructure. The system supports mobile users running multimedia applications that demand a wide range of bandwidth. The multimedia call bandwidth can be dynamically adapted not only over one cell but also over the system cells. There are two types of connections that share the bandwidth of each cell: new and handoff. We assume that the bandwidth of a call is variable during a multimedia session and can be assigned depending on its need using QoS requirements. We assume that the system calls have different classes. Each call has three bandwidth variables. These variables are B_{min}, B_{nor}, and B_{max}. B_{min} is a minimum required bandwidth value at which the call can be accepted. B_{nor} is the bandwidth value at which the call can proceed without degradation. B_{max} is the maximum value of bandwidth assigned for each cell call. In our system, we consider video and audio calls. Also, we assume that the system uses a variable channel allocation i.e. each cell has a total bandwidth that can be determined using the technique at [15].

For each system cell, the calls share the bandwidth. Each call takes the value B_{max} if available bandwidth is sufficient otherwise each call takes B_{nor}. Our considered case is not sufficient bandwidth for handoff or new calls. In this case, a bandwidth for selected number of calls equal X should be decreased from B_{max} to B_{nor} or from B_{nor} to B_{min}. The selection process depends on the call priority. Hence, the bandwidth of X calls is decreased gradually and extracted. Consequently, we should test if the extracted bandwidth equals the B_{min} of new or handoff calls or not. If yes, the decreasing process is stopped and the new starved call can be served. If no, the decreasing process is continued till the extracted bandwidth covers the need of starved calls. If the internal extraction process is finished without covering the need of bandwidth for the starved calls, the external bandwidth extraction process is fired and the system starts to test the neighbor cells. Every time, a new bandwidth for each cell should be extracted and kept using the second management component, see the next sub section. In case of bandwidth need for a cell, the system should borrow an exceeded bandwidth from another cell till the call(s) is served and the system reassigned the same borrowed value to the donor cell. The donor cell is a cell that provides the starved cell with the required bandwidth. The borrowing process is accomplished using the techniques at [16, 17]. It's preferable that the donor cell is one from the recipient cell neighbors. The borrowing process is completed by the management cell in the WLAN. This management cell uses a database file to store the transactions that occurred during our system, see Figs. 1, 2.

4.2 System management approach

To manage the proposed bandwidth adaptive system, a management sub-system should be introduced. The proposed management sub-system depends on the intelligent multi-agent system idea. In details, the system contains three agents to complete the communication between the wireless network cells as regards the bandwidth integration. This technology is used in our system due to multimedia transmission sensitivity and its capabilities in firing when an important system action is done as well as an agent dynamic reaction. The main target of our system is to make the network cells as one cell in the bandwidth resources. Hence, any bandwidth decreasing in one cell should be recovered internally by the same cell. If the internal recovering process is failed the external recovering process is fired and the donor cell is selected (neighbor cell or far cell). For data sensitivity, the bandwidth recovery operation should be done before the cell received new or handoff calls.

In the following subsections, the proposed management system components description and how they work are demonstrated.

4.2.1 The proposed management system components

Our management system contains three components that are called analyzer, detector, and connector. These terms and the communication between them are used and defined at [18].

The Analyzer: The analyzer is a software component. It is used to watch the bandwidth value of each depository by using the tool at [15]. This depository target is to keep the exceeded bandwidth. In our system each cell has one depository. The watching operation means that the analyzer should be fired when it finds that a cell depository is empty or about to be empty. Also, the function of analyzer is to store the history of each cell in adaptive system. This history contains number of parameters like the number of internal and external adaptation process, the number of new and handoff calls. These collected data are used as a feedback that will be functioned at a bandwidth redistributed operation. Each group of cells has one analyzer. The number of cells per group depends on the efficiency of the analyzer.

The Detector: The detector is a software component. It is used to find a starved cell. This is done as follows; the detector sends a value of a cell depository to the analyzer. When a cell makes huge number of adaptations to serve its new and handoff calls, the detector should inform the analyzer with the situation to provide this cell with additional bandwidth. Each cell contains one detector.

The Connector: Also, the connector is a software component. It is used to connect the analyzer with the detector when an urgent action, like large number of dropping new or handoff calls and adaptation processes, is done. The connector is used to find a suitable donor cell in a real time processing. The connector has a dynamic table that contains the cells which can be used as a donor for each system cell. For system simplicity, it's preferable to find a neighbor cell to act as a donor. Most of the connector table is filled using the routing table of wireless network and the QoS manager that extracts the bandwidth of each cell.

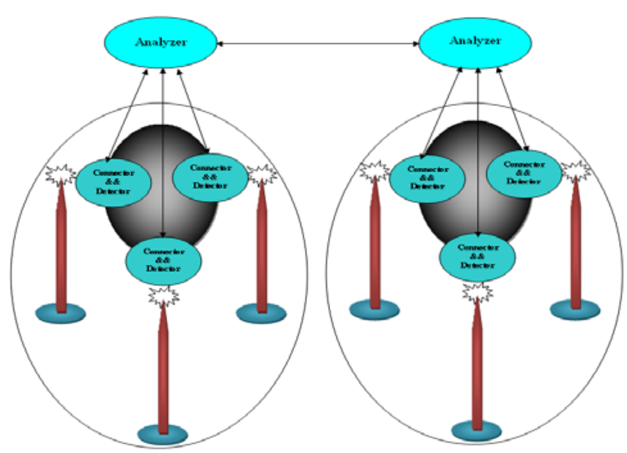

Fig. 1. How the proposed system works.

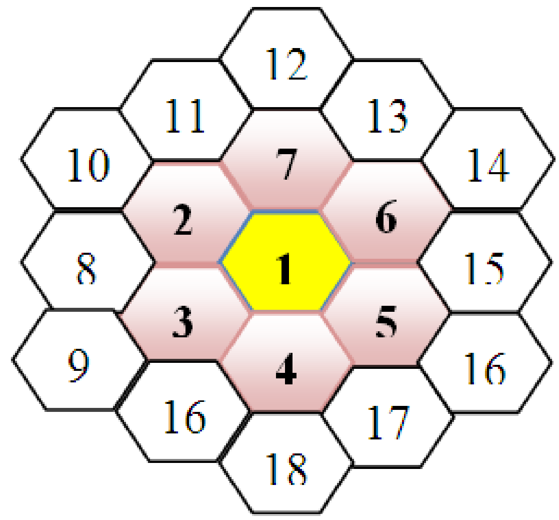

Fig. 2. Example about how the donor cell is selected

4.2.2 How the proposed management system works

At the start, the QoS manager of mobile wireless networks distributes the bandwidth on the system cells. Consequently, the cell receives and serves the calls (new or handoff). Each interval time or at a notable transaction, the detector sends to the analyzer the value of each notable changed depository. The analyzer keeps these values and extracts the starved or near to starvation cells. Hence; the connector starts the recovery process. The analyzer sends the depository values of neighbors to the connector. Hence, the connector selects a donor cell and a borrow amount of bandwidth that is sufficient for the call(s) service. The sufficient bandwidth can be determined by the connector using the QoS parameters and requirements. The connector stores in its memory the addresses of starved and donor cells and a value of borrowed bandwidth. For system reliability factor, the connector should provide the starved cell with more than required bandwidth (if available). The detector continues to provide and alarm the analyzer with starved cells in the system. The analyzer saves these data that will be used as a system feedback, see algorithms 1 and 2.

It's notable that our proposed system has a huge number of control messages. This can be considered as a system drawback especially at the bandwidth limitation state. To recover this drawback, two techniques are used. The first technique is to borrow a bandwidth from lazy cells and seize it to the control messages. The cell that handles low number of calls is considered a lazy cell. The second technique is to make a cumulative message idea in case of no lazy cells. We use a mixture of two techniques to reach the highest efficiency.

- **Algorithm 1**

1. Suppose that each cell in the system has a bandwidth called B_{total}
2. For I = 1 to m
   2.1 Each call in the cell consumes its required bandwidth.
   2.2 Reps_Value [i] = $B_{total} - n*B_{consumed}$.
   2.3 If Reps_Value [i] = 0
      2.3.1 If there are calls having a bandwidth equals B_{max}
         2.3.1.1 For J = 1 to max[i] (number of B_{max} calls at cell i)
            2.3.1.1.1 Reps_Value [i] = Reps_Value [i] + $B_{max[J]} - B_{nor[J]}$
      2.3.2 Else If there are calls having a bandwidth equals B_{nor}
         2.3.2.1 For J = 1 to nor[i] (number of B_{nor} calls at cell i)
            2.3.1.2.2 Reps_Value [i] = Reps_Value [i] + $B_{nor[J]} - B_{min[J]}$
      2.3.3 Else If there are calls having a bandwidth equals B_{min}
         2.3.3.1 Algorithm 1 is fired.
3. End of the algorithm.

- **Algorithm 2**

1- For I = 1 to m
   1.1 The cell[i] received a new call
   1.2 If the n_{reqb} < Reps_value [i]
      1.2.1 The call is served
      1.2.2 Reps_Value [i] = Reps_Value [i] - n_{reqb}
   1.3 Else If the n_{reqb} = Reps_value [i]
      1.3.1 The call is served
      1.3.2 Reps_Value [i] = 0
      1.3.3 The detector alarms the analyzer; hence the analyzer informs the connector
      1.3.4 The connector starts to fill the Reps_value [i] for future calls.
   1.4 Else If the n_{reqb}> Reps_Value [i] (Starvation Case)
      1.4.1 The internal recovery failed
      1.4.2 The connector connects to the neighbors of the starved cell
      1.4.3 The connector borrows the required bandwidth from the donor cell.
      1.4.4 The connector stores the address of the starved cell, donor cell and the borrowed value
      1.4.5 Reps_Value [i] = Reps_Value [i] + $Borrow_{Bandwidth}$.
      1.4.6 The call is served.
      1.4.7 Reps_Value [i] = Reps_Value [i] + $Borrow_{Bandwidth} - n_{reqb}$
      1.4.8 The connector extracts a bandwidth from the starved cell and provides the donor with the same borrowed bandwidth consequently; the system returns to the previous state.
2. End of the algorithm.

4.3 System statistical analysis

The adaptability can be defined with the number of adaptation times occurred in the system [12, 13]. This variable should be calculated in our system to determine the effect of extension process. The adaptability value equals one minus the summation of bandwidth divided by the total bandwidth for each cell. The above assumption (B_{min}, B_{nor}, and B_{max}) can be used to calculate the total consumption bandwidth by the system cells. The total consumption bandwidth for the system is a summation of consumption bandwidth per cell. The consumption bandwidth per cell is a summation of number of B_{min} active users multiplied by B_{min} bandwidth plus the B_{nor} active users multiplied by B_{nor} bandwidth plus the B_{max} active users multiplied by B_{max} bandwidth. Equation 1 calculates the total allocated bandwidth.

$$B_{Allocated_{Total}} = \sum_{k=1}^{n} \left(\sum_{i=1}^{max\_cell} X_i b_i + \sum_{j=1}^{nor\_cell} X_j b_j + \sum_{z=1}^{mini\_cell} X_z b_z \right) \quad \text{Equation 1}$$

$$x = 1 - \sum_{k=1}^{n} \frac{B_{Allocated_k}}{C_k} \quad \text{Equation 2}$$

5. Performance Evaluation

The most simulation parameters are used to show the effect of the system extension on the bandwidth allocation for new and handoff calls, see table 1. In the following subsections the simulation setup and simulation results are demonstrated.

5.1 Simulation setup

This subsection describes our simulation setup. The cellular network contains 50-cell that is configured with different traffic conditions. The diameter of each cell is 1 km. The base station resides at the center of each cell. The total capacity of each cell is C_i, i= 1 to number of cells and scaled with Bandwidth Unite (BU). Audio and video streaming service with three adaptive bandwidth levels are tested. The call arrival process for new and handoff calls is assumed to follow a Poisson distribution with rates λ_{nc} and λ_h, respectively. The handoff call arrival rate is proportional to the new call arrival rate and this is determined by $\lambda_h = 0.75\ \lambda_{nc}$. The call holding time is assumed to follow an exponential distribution with mean $1/\mu$ [13]. There are three parameters are considered for the mobility factor, the initial position, the direction, and the speed of a mobile. When a new call is initiated, a random initial position, which derived from a uniform probability distribution function over the cell area, is assigned to a mobile. For handoff calls, when the handoff event is scheduled, the initial position of a mobile is determined. A mobile direction is assigned upon entering a cell. The mobility scenario is modeled in Fig. 3. When a mobile enters a cell, a constant randomly selected speed is assigned to it. The mobile speed is obtained from a uniform probability distribution function ranging between V_{min} and V_{max}. Most of these simulation parameters are used in [12, 13]. Number of calls (X) that is selected to decrease its bandwidth from B_{max} to B_{nor} or from B_{nor} to B_{min} is assumed to follow the exponential distribution.

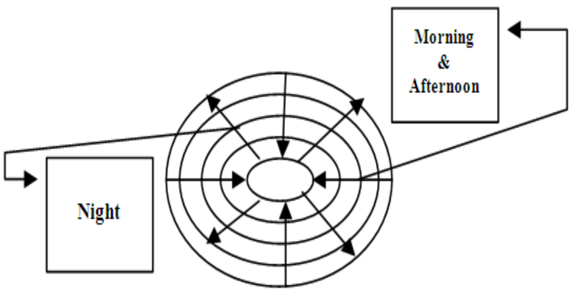

Fig. 3. The signal distribution likes the rush and the evening hours.

Table 1: Simulation parameters

Parameter	**Value**	**Unite**
Total Bandwidth	1024	BU
Cell Diameter	1	Km
Average B_{min}	3	BU
Average B_{nor}	6	BU
Average B_{max}	9	BU
$Bandwdith_{requested}$	Random (5-10)	BU
New call arrival rate	$\lambda_{nc} = \lambda$	Call/Sec
μ^{-1}	5000	sec
V_{min}	10	Km/hr
V_{max}	60	Km/hr
T_{sim}	10000	sec
Number of Cells	50	unite

It was stated at [13] that the average residence time for a new call, t_{nc}, is given by:

$$t_{nc} = \frac{8RE[1/V]}{3\pi} \qquad \text{Equation 3}$$

While the average residence time of a handoff calls, th is given by:

$$t_h = \frac{R\pi}{2E[V]} \qquad \text{Equation 4}$$

Where R is the radius of the cell and V is the average speed of a mobile in the cell. Therefore, the handoff rate of new calls, h_{nc} equals 1/ t_{nc} and the handoff rate of handoff calls, h, equals 1/ t_h.

In the performance evaluation, the proposed system GBAS, the Bandwidth Adaptive Framework (BAF), and the QoS_AMS algorithm are compared as regards the following parameters; the NCBP, the HCDP and the bandwidth utilization. The bandwidth utilization is defined as the ratio of a bandwidth which is used by completely serviced calls to the total bandwidth capacity.

5.2 Simulation results

5.2.1 NCBP evaluation

Fig. 4 shows a comparison between the QoS_AMS algorithm, the BAF algorithm, and the GBAS as regards NCBP (β value is fixed and equals 50%). It's notable that the generalization process for the AMS algorithm decreases the number of blocking new calls. This decrease is due to the dynamic allocation for the exceeded bandwidth internally at the cell and externally outside cells. Also it's notable that the NCBP at the three models increase as the arrival rate increases but the GBAS is lower than two other algorithms, AMS and BAF.

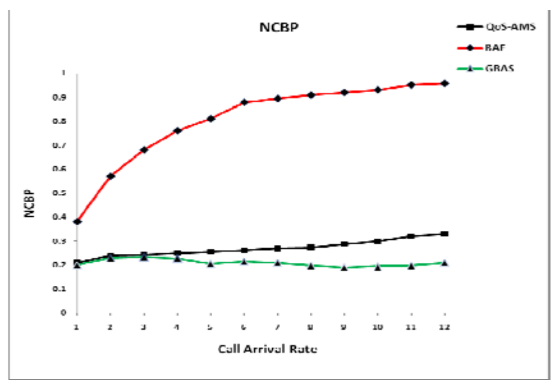

Fig. 4. NCBP Evaluation

In case of the adaptability ratio of the system has a large value than a predefined value β, the adaptability ratio during the bandwidth adaptation procedure is calculated and activating the ABA algorithm [11, 12, 13] for new calls. This step should be done before deciding to reject a new call or accept it.

5.2.2 HCDP evaluation

Fig. 5 shows a comparison between the QoS_AMS algorithm, the BAF algorithm, and the GBAS as regards

HCDP (*β* value is fixed and equals 50%). It's notable that the generalization process for the QoS-AMS algorithm decreases the number of blocking handoff calls. This decrease is due to the dynamic allocation for the exceeded bandwidth internally at one cell and externally over the system cells. Also, it's notable that the HCDP percentage is less than the NCBP percentage. This is due to the huge number of handoff calls that move through the system cells with fast speed. The huge number and fast speed means more computation to extract a bandwidth and serve handoff calls. Hence, the GBAS model gives more priority for handoff calls in case of limited bandwidth. Also, it's obvious that the three algorithms provide a best performance and the GBAS surpasses the two algorithms science when the system has a limited bandwidth. This is because the GBAS model uses the bandwidth of lazy cells.

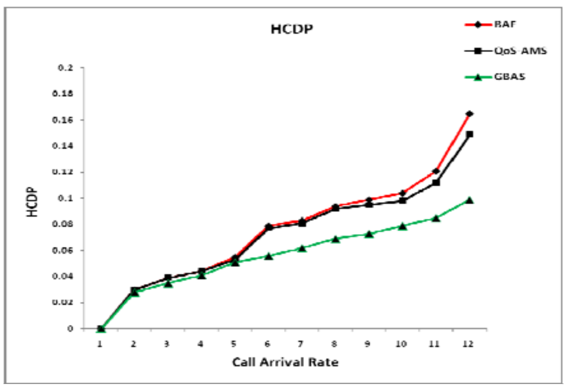

Fig. 5. HCDP Evaluation

5.2.3 *NCBP evaluation with varying β value*

Fig. 6 shows the effect of varying β value on the NCBP. It's notable that the decrease in β value means decrease in the NCBP. This is due to the increase of adaptation processes when the β value is decreased. Also, the decrease of NCBP gets smaller with higher arrival rate of incoming calls.

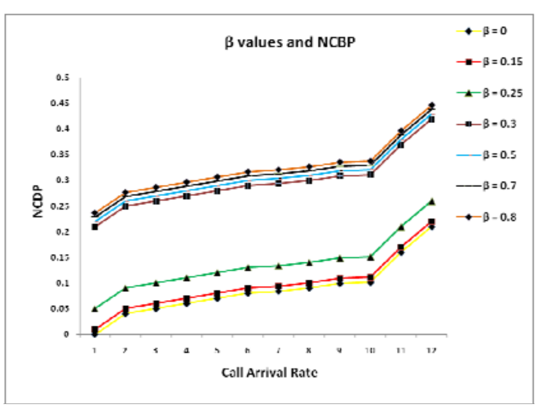

Fig. 6. Effect of varying β value on the NCBP

5.2.4 *HCDP evaluation with varying β value*

Fig. 7 shows the effect of varying β value on the HCDP. It's notable that the decrease in β value means decrease in the HCDP. This is due to the increase of adaptation processes when the β value is decreased. Also, the HCDP is decreased as the call arrival rate is increased. In a low rate of incoming calls, for instance 0.4, the increase in HCDP is small compared to the decrease of NCBP. This means that the QoS improvements for new calls do not result in a significant decay in the QoS of handoff calls. Also, it's obvious that the HCDP is sudden increases as the arrival call notably increases and β = 0.15 and 0.25. This is due to the sudden stop of our model that results a zero borrowed bandwidth.

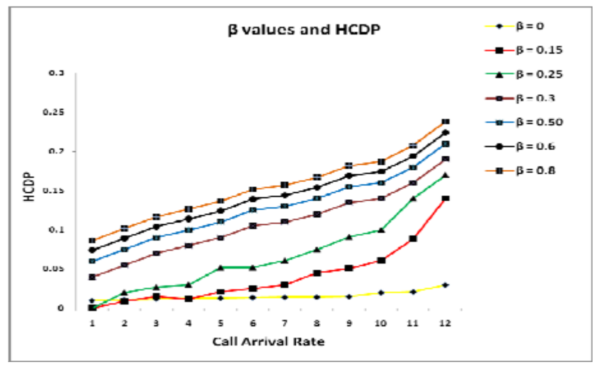

Fig. 7 Effect of varying β value on the HCDP

5.2.5 *Bandwidth utilization*

Fig. 8 clearly shows the bandwidth utilization versus the offered load for QoS-AMS framework and BAF as opposed to GBAS. Clearly, the bandwidth utilization of the GBAS framework outperforms that of the QoS-AMS and BAF. This is due to the usage of the GBAS that utilizes the adaptability ratio measure and allows the system intelligently adjusting the bandwidth of ongoing calls internally and externally which results a near zero HCDP and a reduced NCBP. Therefore, more calls are able to successfully complete their connection sessions which results in better bandwidth utilization.

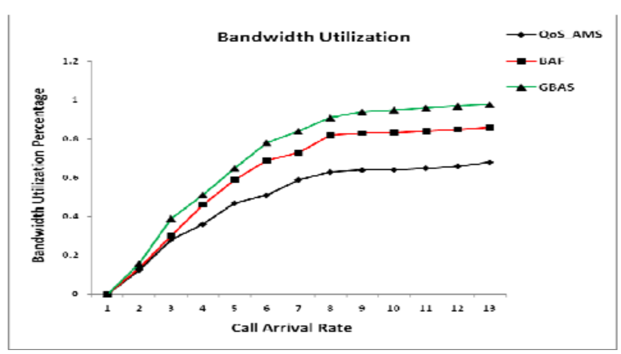

Fig. 8. Bandwidth Utilization

6. Conclusion

In this paper, a Generalized Bandwidth Adaptive System (GBAS) is proposed. The framework consists of two main components: bandwidth allocation algorithm and system management component. The first component is used to adapt the bandwidth internally over one cell and externally over the system cells (if required). The second component is used to manage the new additive software to work in harmony with other old components. The framework is designed for wireless cellular networks that support real-time adaptive multimedia services. Our experiments contained audio and video streams. The simulation results showed an improvement and reduced values for the connection-level QoS parameters: HCDP and NCBP comparable with BAF and QoS-AMS. The requirements of the mobile users are satisfied. Moreover, the results ensure efficient utilization of bandwidth that is highly desirable by service providers.

7. Future work

In our experiments, a special type of video (JPEG) is examined. So, we will run the GBAS on other video types such as MPEG. Hence, we will go to the standardization.

References

[1] Zhijun Y., Dongfeng Z., 2008. QoS Support Polling Scheme for Multimedia Traffic in Wireless LAN MAC Protocol. Elsevier Tsinghua Science & Technology, 13(6): 754-758.

[2] Sanabani, M., Shamala, S., Othman, M., Zukarnain, Z., 2006. QoS Provisioning for Adaptive Multimedia Services in Wireless/Mobile Cellular Networks. International Conference on RF and Microwave, PutraJaya, Malaysia, p.381 - 385.

[3] Kumar, A., 2007. Introduction to Streaming and Mobile Multimedia., Mobile TV, p. 63-98

[4] Bharghavan,V., Lee, K., Lu, S., Ha, S., Dwyer, D., Li, J., 1998. The TIMELY adaptive resource management architecture. IEEE Personal Communications Magazine, 5(8): 20-31.

[5] Kwon, T., Choi, Y., Bisdikian, C., Naghshineh, M., 2003. QoS provisioning in wireless/mobile multimedia networks using an adaptive framework. Kluwer Wireless Network, 9(1): 51-59.

[6] Talukdar, A., Badrinath, B., Acharya, A., 1998. Rate adaptation schemes in networks with mobile hosts. ACM/IEEE International Conference of MobiCom, Dallas, USA, p.169-180.

[7] Changyuan, L., Hongzhi W., 2009. A Dynamic Bandwidth Allocation Based Call Access Strategy of Wireless Multimedia Service. International Workshop on Intelligent Systems and Applications,Wuhan,China, p.1-4.

[8] Wen-Yu C., Hai-Bo Y., 2008. A Hierarchical QoS Framework for Wireless Multimedia Network. International Conference on Communications, Circuits and Systems (ICCCAS), China, p.732-736.

[9] Huang, c., Chuang, y., 2007. A Self-Adaptive Bandwidth Reservation Scheme For 4G Mobile WIMAX. International Workshop on Cross Layer Design (IWCLD '07), Jinan, China, p.55 - 59.

[10] Hyukmin S., Sanghoon L., 2006. Bandwidth and region division for broadband multi-cell networks.IEEE Communications Letters, 10(5):360 - 362.

[11] Nasser, N., Hassanein, H., 2004. Connection-level Performance Analysis for Adaptive Bandwidth Allocation in Multimedia Wireless Cellular Networks. IEEE International Conference of Performance Computing and Communications (IPCCC), Arizona, USA, p.61-68.

[12] Nasser, N., 2005. Real-Time Service Adaptability in Multimedia Wireless Networks. Q2SWinet'05, Montreal, Canada, p.144- 149.

[13] Nasser, N., 2009. Service Adaptability in Multimedia Wireless Networks. IEEE Transactions on Multimedia, 11(4): 786-792.

[14] Huanga, C., Shena, H., Chuangb, Y., 2010. An adaptive bandwidth reservation scheme for 4G cellular networks using flexible 2-tier cell structure. Elsevier Transaction on Expert Systems with Applications, 37(9): 6414-6420.

[15] Mingzhe, C., Kinicki, R., 2008. WBest: A bandwidth estimation tool for IEEE 802.11 wireless networks. 33rd IEEE Conference on Local Computer Networks, Montreal, Canada, p374-381.

[16] Jau-Yang, C., Hsing-Lung, C., 2007. Service-Oriented Bandwidth Borrowing Scheme for Mobile Multimedia Wireless Networks. Auswireless Conference. http://epress.lib.uts.edu.au/dspace/handle/2100/131

[17] Kuang, L., Hsu-Sheng,T., Yu-Hang S., 2009. Tiered bandwidth reservation scheme for multimedia wireless networks. Transaction in Wireless Communications & Mobile Computing, 9(7): 1005-1016.

[18] Said, O., Bahgat, S., Ghonemy, S., Elawady, Y., 2009. Analysis, Design and Simulation of a New System for Internet Multimedia Transmission Guarantee. IJCSIS, 5(1):77-86.