GBAS: Generalized Bandwidth Adaptation System for Enhancing Multimedia Transmission Over Multi-Cell Wireless Networks

(Extended Version)

O. Said
Information Technology Department, College of Computers and Information Technology, Taif Univerity
Taif, Elhawya, 888, KSA.

Abstract— ***Nowadays, multimedia Quality of Services (QoS) is considered a very important research issue. In cellular infrastructure wireless networks, a user can move from one cell to another. Hence; a large number of handoff events may occur during a typical session. In case of running multimedia applications with a limited bandwidth, new, handoff, and waiting calls may be dropped. This paper proposes enhancements for the Generalized Bandwidth Adaptation System which is used for multimedia transmission over multi-cell wireless networks and demonstrated by the author in a previous work. Our proposed extended system monitors the multimedia sessions to create the new bandwidth values in case of significant changes or calls starvation. The enhancement criteria are done over three interlocutors. The first one is to add some new features such as distance between cells, waiting calls, starved calls bandwidth considerations and call prioritization technique. The second one is to recover some drawbacks such as huge number of management messages. The third one is to make some old issues more scalable such as normal degree division to be multi-values and starting with minimum degree bandwidth. Also, statistical analysis for the enhanced version is demonstrated. Furthermore, a simulation environment to test our proposed system is constructed. Finally, comparing these results with the old trials results is demonstrated to make sure that our proposed system enhances other old trials.***

Keywords- Cellular Wireless Networks; Adaptive Bandwidth, Multimedia Communication; Mobile Communication.

I. INTRODUCTION

Nowadays, the use of mobile communications has a notable growth around the world. The mobile multimedia QoS is becoming extremely important due to the development of integrated services which support video and audio in mobile communication systems. The bandwidth is considered as one of the most precious QoS parameters in wireless systems. An efficient call admission control (CAC) scheme is used to maximize the bandwidth utilization [1]. Most previous proposed approaches only consider non-adaptive traffic and non-adaptive networks (i.e. cannot change the bandwidth of ongoing calls). However, in recent years, there is a notable instability of link bandwidth in wireless networks, which makes the development of adaptive multimedia services urgently needed. Meanwhile the bandwidth of a connection can be dynamically adjusted [1, 2].

This paper proceeds as follows; in Section II, the research problem is briefly defined. In Section III, the close related works are demonstrated. Our proposed system is discussed in Section IV. In Section V, advantages of our system over other systems are introduced. In Sections VI and VII conclusion and future work are stated.

II. PROBLEM DEFINITION

There are two types of calls in multi-cell wireless networks; new and handoff. A new call starts when a user requests a new mobile connection, and a handoff call occurs when a user changes his position from one cell to another one. The QoS requirements in multi-cell wireless networks can be expressed by New Call Blocking Probability (NCBP) and Handoff Call Dropping Probability (HCDP) [1, 3, 4]. The NCBP is the probability of rejecting new arriving calls. The HCDP is the probability of fail handoff attempt. The bandwidth limitation with huge number of handoff events makes the multimedia QoS guarantees in multi-cell wireless networks an enormous challenge. When a user call is transformed to a new cell, it may face a problem of insufficient bandwidth. In this case, there are two possibilities which are based on the required service nature. The first possibility is fixed bandwidth for each call (non-adaptive service), which leads to call dropping. The second possibility is local adaptive service which may lead to call dropping or call distortion due to the bandwidth shortage. In this paper, a new system for bandwidth adaptation over a multi-cell network wide range is introduced. Our proposed system is introduced to enhance the Generalized Bandwidth Adaptation System (GBAS) system [5] efficiency. Hence, the enhancements can be considered as a new version.

III. RELATED WORKS EVALUATION

There are several adaptive multimedia approaches in multi-cell wireless networks [6, 7]. These approaches only consider the HCDP reduction. Kwon et al. [7] guarantees the cell overload probability upper bound. Furthermore, adaptive multimedia practical bandwidth values are mostly discrete [8, 9]. This work didn't consider bandwidth degradation. Bharghavan et al., [7] introduced an approach to provide the multi-cell wireless network with optimal and continuous bandwidth value assumption. This work has signaling overload and can be considered impractical. There are several schemes for adaptive multimedia services. Talukdar et al. [10] differentiated between overload and fairness of the network in bandwidth adaptation issue, but did not consider maximizing multi-cell wireless network utilization. In Kwon et al [11] a near optimal scheme is proposed having the same shortage like the framework proposed in [10]. Zaruba et al. [12] assume that future arrivals and departures are known hence; the optimal call-mix selection to maximize the total network revenue is found. However it may not be realistic in practice. The frameworks, which are proposed in [13, 14], studied one type of adaptive traffic and it is not easy to extend these schemes in case of multiple traffic types. [15 to 20] generally focused on the QoS problems in case of multimedia communication in multi-cell wireless networks. Nidal [21] proposed a Bandwidth Adaptive Framework (BAF) which extracts the excess bandwidth from the cell calls. However, the operations in BAF are internally executed at the cell which makes the adaptation process restricted with a limited exceeded bandwidth. So, the Nidal trial is considered a local solution. Huanga, et al. [22] trial is considered as a special purpose solution due to the limited experimental environment and assumptions. The last trial in this research, which is proposed by Said et. al. [3], is a system to adapt the multimedia in multi-cell networks globally. This system enhanced the bandwidth over the network cells but still has some drawbacks, including huge number of management messages which may consume a bandwidth, the distance between the cells are not considered, some functions for old GBAS system components can be neglected for simplicity, the simulation environment is executed over one multimedia compression, the normal bandwidth for multimedia applications is one value and this may not be realistic, the waiting calls are not considered, and there is no cell prioritization technique.

IV. The Proposed System Infrastructure

Three main subsections are introduced. The first one is the idea of adaptation process and its formulated algorithm. The second subsection, related to the management issue, demonstrates the components of our system. These components contain agents, some features of network management technologies, and collection of software executed strategies. Furthermore, a prioritization technique, which determines the first served cell and call. The third subsection discusses the enhancements which are provided by the new GBAS system.

A. The idea of adaptation process

The system supports mobile users running multimedia applications, which require extremely flow of bandwidth. This paper considers a multi-cell wireless network infrastructure. In our system, available bandwidth should be adapted not only between one or two system cells but also in a wide range (the entire system cells) provided that it should be stable. In addition, the distance between the system cells should be considered. New, Handoff, and Waiting are three types of mobile calls which require normal bandwidth. But, when these calls run multimedia applications, the state will be completely different due to an extremely huge required bandwidth for these types of applications. The waiting calls can be defined as the calls which open the connection without data transmission. These types of calls can be considered as helpful or overload calls. The helpful case occurs if the user pauses the multimedia session, and the bandwidth, which is assigned for this call, can be timely extracted for other starved call. The overload case occurs when the multimedia session is active without sender or receiver reactions.

In our system, the bandwidth of each call is changed within a multimedia session and can be assigned using QoS parameters. Each call has two main bandwidth constant parameters and one variable parameter. The two fixed parameters, whose values are not within the single multimedia application, are called BW_{Lower} and BW_{Upper}. The variable parameter, which may take more values in the multimedia session, is called BW_{Normal}. BW_{Lower} is the minimum required bandwidth value at which the session can be accepted for the users without data loss. BW_{Upper} is the maximum value of bandwidth assigned for each cell call. BW_{Upper} is not a fixed value because it depends on the type of multimedia compression. BW_{Normal} is the bandwidth value at which the call can proceed without degradation. BW_{Normal} is a key factor for our new bandwidth adaptation system, because it may take multi values in the same multimedia session. So, there are n values for BW_{Normal} (i.e. $BW_{Normal\ (1)}$ to $BW_{Normal\ (n)}$). The degrees of normal bandwidth state is useful in case of multimedia applications which require a dynamic bandwidth allocation. Many of these applications may need minor exceeding in bandwidth to work in normal state. This will make our system more precious by collecting these pieces of bandwidth which may help in starved call states, see Fig. 1.

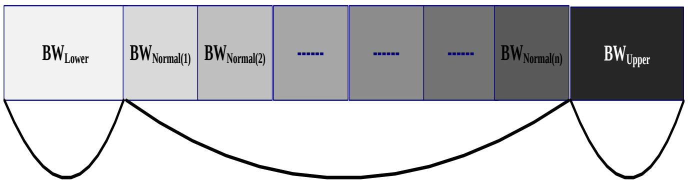


Figure 1: The bandwidth Degrees

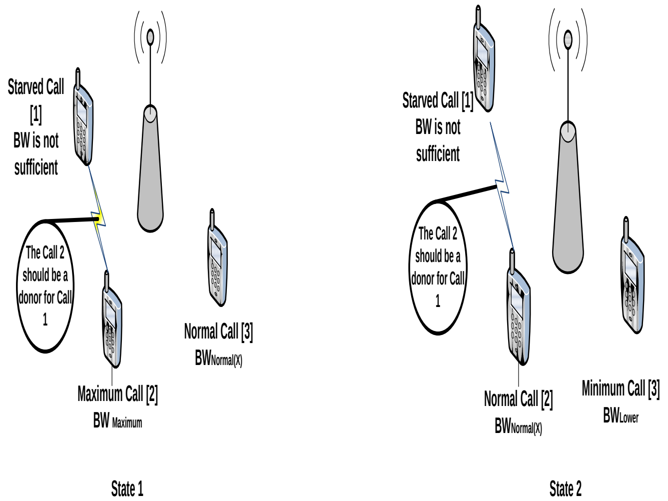
The video and audio calls should be considered in our system to be generalized. Furthermore, our system uses a variable channel allocation which means that the total bandwidth for each system cell should be determined using the technique at [22]. Hence, it's easy to calculate the total bandwidth of the entire system cells using equations number 1 and 2.

$$BW(j) = \sum_{j=1}^{m} Call(j) \qquad \text{Equation 1}$$

$$BW_{System} = \sum_{i=1}^{n} (BW(i)) \qquad \text{Equation 2}$$

where, j is the number of calls per cell and i is the number of cells in the system. At the start of the system, the total bandwidth should be calculated using above equations. This bandwidth should be distributed among the system cells. Each call on the system should take the *minimum required* bandwidth (BW_{Lower}) by which the user can start his call. The bandwidth per cell should be evaluated after the starting of a multimedia session. The starved calls in each cell in our system should be determined using the central agent (see subsection C below). Hence, the bandwidth of these starved calls is evaluated as regards its sufficient bandwidth, which is defined as the maximum of normal bandwidth degree ($BW_{Normal\ \mathbf{(n)}}$) by which the required bandwidth is determined. Each call can take the maximum bandwidth (BW_{Upper}) provided that, there are no starved calls and the reserved bandwidth is sufficient to recover the future starved calls which may appear in the next time of multimedia session.

There are four main states in this situation. The first one occurs when the cell contains three types of calls (BW_{Upper}, BW_{Lower}, $BW_{Normal\ (x)}$ where x is a normal degree value) and starved call. This case is easy to solve by selecting a donor call from the maximum bandwidth calls. The second case occurs when the cell contains two types of bandwidth degrees (BW_{Lower}, $BW_{Normal\ (x)}$ where x is a normal degree value) with starved call. Also this case is easy to solve using the same strategy of the state one. The third case occurs when the cell contains only lower bandwidth (BW_{Lower}) calls with starved call, which can be recovered internally. This state is difficult to solve. The last one occurs when the system cell contains a lower bandwidth calls which cannot be recovered internally and should be recovered externally, see Fig. 2. Our system is concerned with the last two states (3^{rd} and 4^{rd}), see Fig. 3. First, the predictor agent should predict the problem occurrence which may produce the third and fourth states. If the predictor agent fails to detect these states, the central agent should test the reserved bandwidth, if it's sufficient to recover or not. If not sufficient, the central agent should fire a request message and send it to neighbor cells asking for recovery. The central agent should select the cell which makes an overlapped area, see Fig. 3. If there are no overlap areas, the signal power of the most neighbor cell should be increased to create this area. The central agent starts to borrow the required bandwidth and recover the starved calls. For more specific steps, see subsection 4.2.



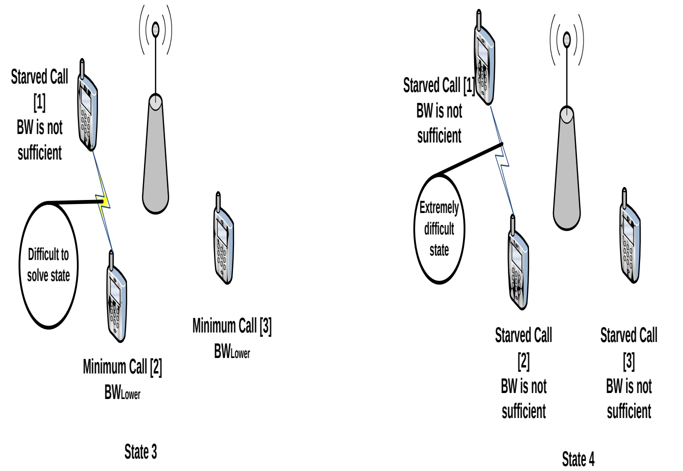


Figure 2: The four call states

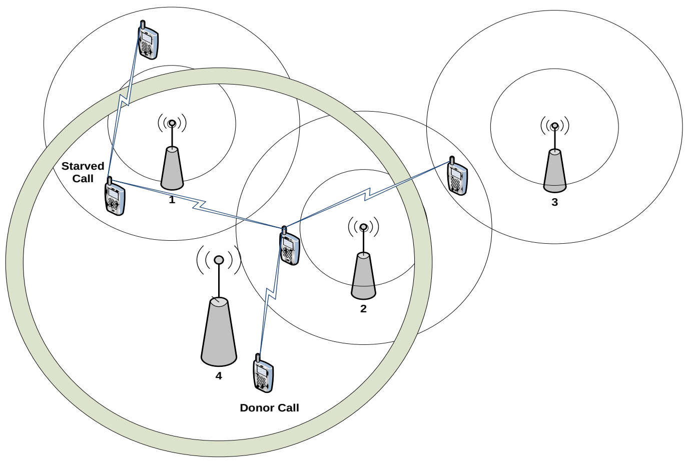


Figure 3: The solution of state 3 and state 4

B. Adaptation algorithm

TABLE I. LIST OF PARAMETERS

Symbol	Meaning
c	The number of cells
u	The number of cells getting the maximum bandwidth degree.
nd	The number of cells getting the normal bandwidth specific degree.
L	The number of cells getting the low bandwidth degree.
B_s, B_L, B_{nd}, B_u	Bandwidth for starved, low, normal, maximum calls respectively.
S	The reserved bandwidth in each cell.
R_B	Requested bandwidth.
S_j	The reserved bandwidth in the cell j.

1. The bandwidth is distributed on the system cells depending on the number of calls in each cell. These parameters may be accessed from the network history registration file.
2. S = 0 // There is no reserved bandwidth
3. For i = 1 to c
{
// The maximum bandwidth collection (From Maximum state to Normal state)
For j = 1 to m
S = S + B[i] - Bn.
If S = > R_B, the starved calls will be served.
Else: Go to the Normal calls part
// The Normal bandwidth collection (From Normal degree state to different Normal degree state)
For j = 1 to (nd +m)
For h = 1 to (nd +m)
S = S + B_{nd}[j][h] - B_{nd}[j][h+1].
If S = > R_B, the starved calls will be served.
Else Go to the external recovery part
// The external recovery, we supposed that each cell is numbered sequentially),
For j = (z+1) to a (z is the cell number and a is the number of this cell neighbors)
If Sj > = R_B
1. The donor cell is captured
2. The z cell will borrow the bandwidth.
3. The starved calls will be served.
Else: The same external recovery steps are done for other cells in the network until the required bandwidth is extracted.
}

C. How the system is managed

To accomplish the proposed bandwidth adaptation process, a management approach should be introduced. The intelligent multi-agent is the infrastructure of our management approach. In details, the cooperation between the cells for bandwidth adaptation is accomplished using three main software agents. This technology is used in our system due to the agent dynamic reaction as well as multimedia transmission sensitivity and its capabilities in firing when an important action appears. The main target of our system is to make the network cells as one cell as regards bandwidth resources. Each cell tries to recover the bandwidth decreasing which may occur during the multimedia session in the cell calls. This type of bandwidth recovery process is called local. If the local recovery fails to provide the calls with required bandwidth, the external recovery process should be executed. The external recovery means that each cell extracts the excess bandwidth to recover the starved cell calls. It's well known that the multimedia data needs real-time procedures, which makes the suggested process dynamically fired in case of handoff or new calls.

- *The proposed management system components*

Our management system contains three agents, which are called Central Agent, Revealer Agent, and Predictor Agent. These terms are defined as follows:

The Central Agent: This agent monitors the quantity of bandwidth in each cell using technique [15]. The central agent should visit each system cell to upgrade its bandwidth value. During the central agent trip, if it finds a critical case such as no spare bandwidth in a cell, it should construct its plan to recover this case externally by other cells (neighbors or faraway). Also, the central agent saves some parameters about the system cells, calls, and bandwidth consumption within intervals determined by the system manager. This information are number of new, waiting, and handoff calls, each executed multimedia application data, the consumed bandwidth for each call, and the number of internal and external adaptation processes. These parameters are used to help system manager in decision making in addition to bandwidth redistribution. The central agent is a software package designed to serve the system cells (i.e. one package for the multi-cell wireless network). Also, the central agent should visit each cell in order to decrease the number of management messages.

The Revealer Agent: This agent is an inactive (i.e. it is fired only if the central agent hangs up suddenly). So, it can be considered as a spare of the central agent. This is for fault tolerance factor in addition to alleviate or decrease the number of management messages, which may increase the system efficiency. When the central agent visits a system cell, it takes the values of required parameters (as stated above) and the revealer agent should not change its status. After, the central agent leaves this cell, the revealer agent should change its state to active till the next visiting of the central agent. At this moment, the revealer agent should alarm the central agent to revisit this starved cell, which may indicate that the collected parameter values are changed. The revealer agent may stay in an active state limited interval because the central agent should visit the system cells periodically.

The Predictor Agent: the predictor agent is used to analyze the database constructed by the central agent, and extract some factors like starved cells. The predictor agent can predict the cells, which will require an extra bandwidth. In rush hours, there are some cells, which have a huge number of calls, either new, handoff, or waiting should require bandwidth to serve these calls. If the system waits until the problem occurs and tries to solve it, the adaptation efficiency will be decreased and some calls may be dropped. The predictor agent function is to make an early alarming for the central agent to provide the starved cells with required bandwidth in accurate time.

- *The prioritization technique.*

The central agent should determine the starved cell, which should be served firstly. The revealer agent should provide the central agent with the permanently starved cells. In addition, the predictor agent should provide the central agent with the cells which may be starved. Hence, the central agent should select the starved cell depending on the difference between its basic bandwidth and consumption bandwidth as well as the predictor information. If this difference is less than zero, the cell can be considered as a starved. Hence, the starved cells are arranged in ascending order and saved in memory prioritized queue. Consequently, the central agent uses this queue to select the starved cell which will be served firstly.

D. The enhancements which are provided by our new version

1. *Degrees of normal bandwidth*
   The degrees of normal state will be useful for accurate bandwidth adaptation. Each piece of bandwidth may be shared to change state of starved call (i.e. from starved to normal) especially in rush hour periods.
2. *Each call starts with minimum bandwidth and increases gradually*
   When the system calls start with minimum required bandwidth, the probability to serve more number of starved calls is increased.
3. *The distance between the system cells is considered.*
   This distance is very urgent parameter. The mobile signal may be degraded due to the long distance trip. So, the donor cell should be a neighbor of borrowed cell or each cell should increase its power to recover a wide range area. In addition, it's preferable on the overlap area between cells
4. *The components of our system.*
   The new system changes some functions for each software agent, which shares in the management operation, and adds some other components like the predictor agent, which increases the system efficiency due to the decrease of management message number and this will be proved in the implementation issue.
5. *The prioritization technique.*
   The new system uses this technique to select the prioritized cell which will be served. This technique is used when the total bandwidth cannot recover all the starved cells and it must select the poorest ones. This technique can use a queuing theory [23] to determine which starved call is served firstly.
6. *More accuracy in bandwidth calculation*
   In the old version the starved calls bandwidth were not considered in the calculation. In the new version the bandwidth, which is assigned for each call, is calculated. This makes the bandwidth allocation and extraction more accurate and increases the reserved bandwidth.
7. *The old model algorithm is adapted*
   The two algorithms in the old version are adapted to be in one algorithm. Furthermore, some upgrades are done to decrease the complexity. This issue will be proved in the simulation step (see section V).
8. *There are some new specs in the donor cells which are defined as follows;*
   - Should be in the neighbors for distance factor.
   - Should have the sufficient required bandwidth for it and for the borrow cell.
   - It's recommended that the donor cell signal recovers the starved call. So, it's preferable to select the cells overlap region.
9. The simulation results proved that the total efficiency of the new GBAS system is higher than the old one, see section VI.

V. 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_{Lower}, B_{Normal}, and $B_{Maximum}$) 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_{Lower} active users multiplied by B_{Lower} bandwidth plus the B_{Normal} active users multiplied by B_{Normal} bandwidth plus the $B_{Maximum}$ active users multiplied by $B_{Maximum}$ bandwidth. Equation 3 calculates the total allocated bandwidth. In addition, the starved calls bandwidth is considered and added to equation 4.

$$Allocated\ bandwidth = = \sum_{G=1}^{C}\Big(\sum_{i=1}^{U} B[i]_{Upper} * Call[i]_{Upper} + \sum_{i=1}^{N} B[i]_{Normal} * Call[i]_{Normal} + \sum_{i=1}^{L} B[i]_{Lower} * Call[i]_{Lower} + \sum_{i=1}^{S} B[i]_{Starved} * Call[i]_{Starved}\Big) \quad \text{Equation 3}$$

$$\mathrm{B} = 1 - \sum_{\mathrm{G}=1}^{\mathrm{C}} \frac{\text{Allocated Bandwdith}}{\text{Total Bandwdith}} \quad \text{Equation 4}$$

VI. SIMULATION, RESULTS, AND DISCUSSION

In this section, a simulation environment is constructed to test our new GBAS as regards old GBAS, Bandwidth Adaptive Framework (BAF), and QoS_AMS. The waiting calls in our simulation test are used to serve the handoff and new starved calls. To get an accurate refine results between the four systems, most of simulation environment, which is constructed in old GBAS, will be reconstructed in new GBAS test but under JPEG and MP4. The simulation parameters are 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 [3].

A. Simulation environment

Our simulation environment parameters can be stated as follows,

1. The diameter of each cell is 2 km to create more overlap regions, which helps the starved calls in selecting other cells with new bandwidth channels.
2. The cellular network contains 100 cells that are configured with different traffic conditions.
3. The base station resides at the center of each cell.
4. The total network bandwidth should be divided on the network cells. The total capacity of each cell is C_i, i= 1 to number of cells and scaled with Bandwidth Unit (BU).
5. JPEG and MP4 multimedia streaming service with two adaptive bandwidth levels; B_{Upper} and B_{Lower} and n adaptive normal degrees B_{Normal} are tested.
6. The call arrival process for new, handoff, and waiting calls is assumed to follow a Poisson distribution with rates λ_{nc}, λ_h, and λ_w respectively.
7. $\lambda_h = 0.75*\lambda_{nc}$ and $\lambda_w = 0.05*\lambda_h$.

8. The call holding time is assumed to follow an exponential distribution with mean 1/μ [13].
9. The mobility factor, the initial position, the signal direction, and the speed of a mobile are four considered parameters.
10. A cell area uniform probability is used to determine a random initial position for a mobile in case of new call initiation.
11. For handoff calls, when the handoff event is scheduled, the initial position of a mobile is determined.
12. A mobile direction is assigned upon entering a cell.
13. When a mobile enters a cell, a constant randomly selected speed is assigned to it. This speed is obtained from a uniform distribution function with maximum and minimum values.
14. Number of calls (X) that is selected to decrease its bandwidth from B_{Upper} to B_{Normal} or from B_{Normal} degree to another normal degree or to B_{Lower} is assumed to follow the exponential distribution.
15. The average residence time for new calls, t_{nc}, is calculated using equation 5, the residence time of handoff calls, t_h, is calculated using equation 6, and the residence time for waiting calls, t_w is calculated using equation 7.

$t_{nc}= \frac{8RE_{\frac{1}{V}}}{3\pi}$ Equation 5, $t_h= \frac{R\pi}{2EV}$ Equation 6, $t_w= \mathbf{0.05} * \frac{R\pi}{2EV}$ Equation 7.

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.
16. The simulation style is a mixture between rush hour period in a crowded downtown and highways see Fig. 4.

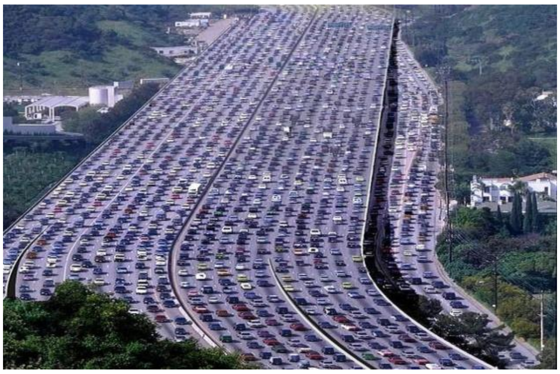


Figure 4: Mixture between rush hour period in a crowded downtown and highways [24].

B. Results and Discussions

- *NCBP system comparison*

Fig. 5.a and Fig. 5.b demonstrate the results of the new GBAS version, the old GBAS version, the QoS_AMS algorithm, and the BAF algorithm as regards NCBP (*β* value is fixed and equals 50%) and under JPEG and MP4 test. It's notable that the probability of blocking new calls in case of the new GBAS system is the lowest one. This is due to the normal degree services which are used to provide new calls with required bandwidth. This required bandwidth is collected from the differences between normal degrees. In addition, the differences of upper degree services when it transfer to normal degree services or less contributes to increase the reserved bandwidth. When the adaptability ratio of the system has a large value than a predefined value β, the adaptability ratio during the bandwidth adaptation procedure should be calculated by activating the new GBAS system algorithm for new calls. This step should be done before deciding to reject a new call or accept it.

- *HCDP system comparison*

Fig. 5.c and Fig.5.d demonstrate the results of the new GBAS version, the old GBAS version, the QoS_AMS algorithm, and the BAF algorithm as regards HCDP (*β* value is fixed and equals 50%). In some intervals, it's notable that the probability of blocking new calls in case of the new GBAS system is the lowest one. The difference between new and old GBAS versions in HCDP comes from the new adaptation algorithm which starts the calls service with minimum degree service which gives high chance to complete handoff calls without starvation. Also, it's notable that from point 3 to point 5 on the arrival rate axis the number of handoff dropping calls for old version is less than the new version. After this point, the efficiency of our system becomes higher. This is due to the arrival rate which is a variable parameter in our simulation environment. There is an inverse relationship between the arrival rate and the efficiency of old and new GBAS systems. Furthermore, it’s obvious that the four algorithms provide the best performance and the new GBAS version surpasses the three algorithms when the system has a limited bandwidth. This is because the new GBAS model uses the bandwidth of lazy cells as well as it benefit with minimal exceeded bandwidth for each cell call which increases the reserved bandwidth.

- *NCBP evaluation with varying β value*

Fig. 5.e, Fig. 5.f, and Fig. 5.g show the effect of varying β value on the NCBP as regards the new GBAS version under JPEG and MP4 tests as regards the old GBAS, the BAF, and the QoS_AMS. Generally, 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. As regards the comparison between the systems, the NCBP is decreased in most values of β in case of new GBAS version. This means that the enhancements, which are constructed in the new system, are effective and increase the number of served calls in most system cells. Furthermore, at the arrival rate percentage point the β has different values with fixed NCBP, which means that the new system can keep the state of call serves in different positions with different required bandwidth and under more than multimedia compression types.

- *HCDP evaluation with varying β value*

Fig. 5.h, Fig. 5.i, and Fig. 5.j show the effect of varying β value on the HCDP as regards new GBAS version under JPEG and MP4 tests as regards the old GBAS, the BAF, and the QoS_AMS. 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, 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 increased as the arrival call notably increases at some values of β. This is due to the sudden stop of our model that results a zero borrowed bandwidth. As regards the comparison between the systems, the HCDP is decreased for most values of β in case of new GBAS version

- *Bandwidth Utilization of new and old GBAS versions.*

Fig. 5.k and Fig. 5.l clearly show the bandwidth utilization versus the offered load for the new GBAS as opposed to the old GBAS, QoS_AMS framework, and BAF. Clearly, the bandwidth utilization of the new GBAS framework outperforms that of the old GBAS version, QoS_AMS, and BAF. This is due to the usage of the new GBAS that utilizes the adaptability ratio measure and allows the system to intelligently adjust 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. Also, the efficient collection of bandwidth both small or large values and starting each call with minimal bandwidth increases the system reserved bandwidth. Hence; the number of starved calls, which are served, is increased.

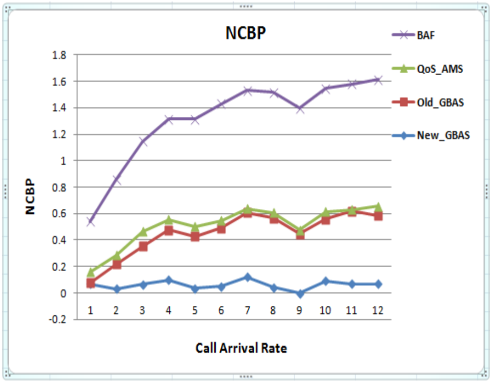


Figure 5. (a): The NCBP evaluation for four models under JPEG test

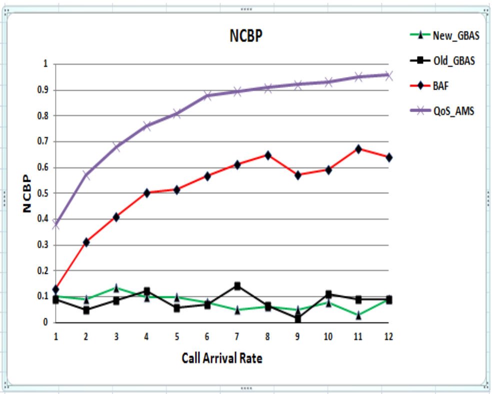


Figure 5. (b): The NCBP evaluation for four models under JPEG test

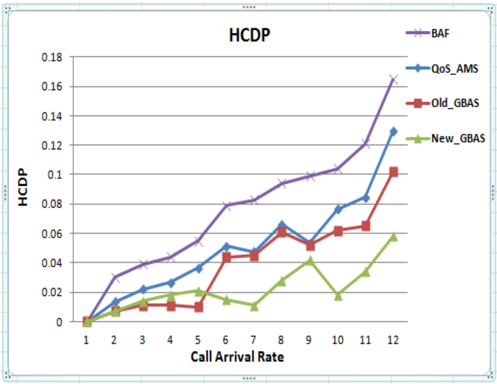


Figure 5. (C): The HCDP evaluation for four models under JPEG test

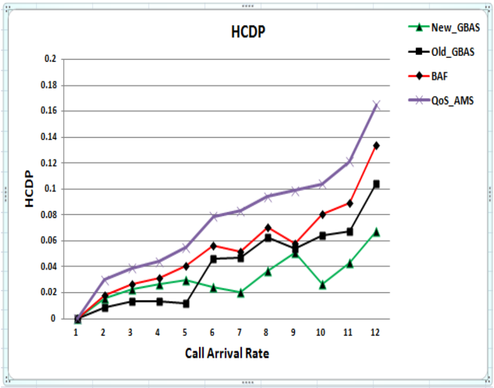


Figure 5. (D): The HCDP evaluation for four models under JPEG test

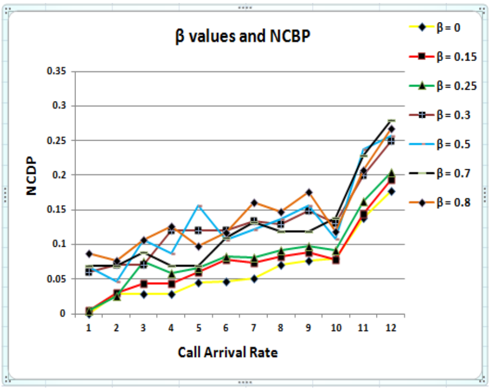


Figure 5. (E): Effect of varying β value on the NCBP under JPEG test.

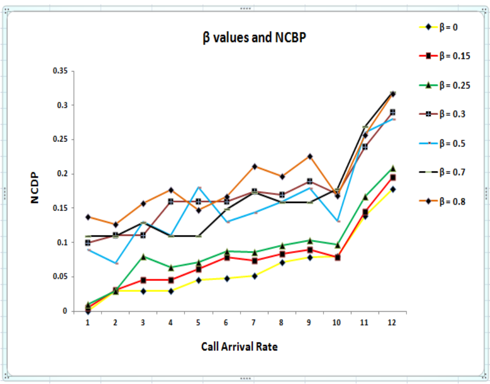


Figure 5. (F): Effect of varying β value on the NCBP under MP4 test.

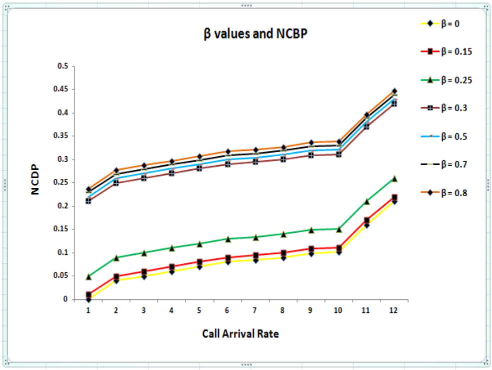


Figure 5. (G): Effect of varying β value on NCBP for the old GBAS.

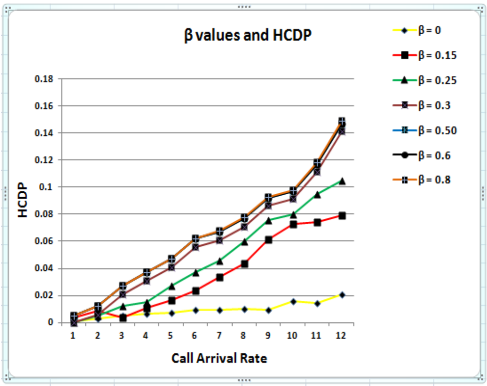


Figure 5. (H): Effect of varying β value on the HCDP under JPEG test.

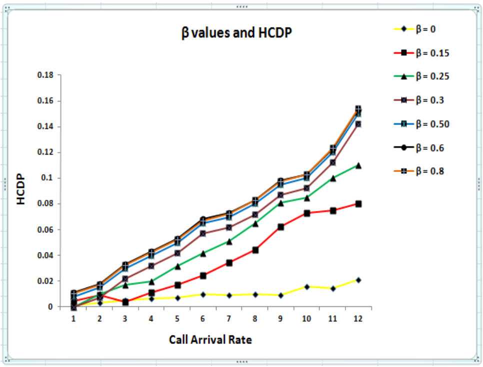


Figure 5. (I): Effect of varying β value on the HCDP under MP4 test.

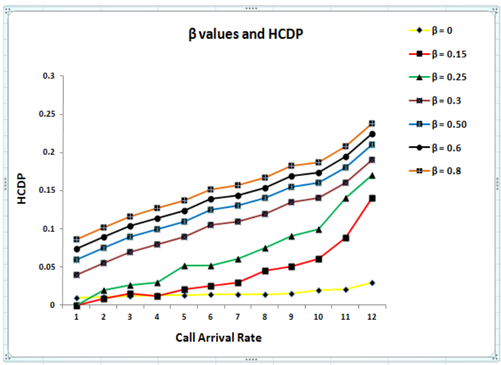


Figure 5. (J): Effect of varying β value on the HCDP for the old GBAS.

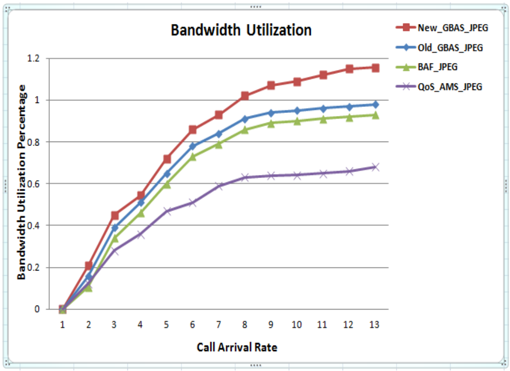


Figure 5. (K): Bandwidth utilization under JPEG test.

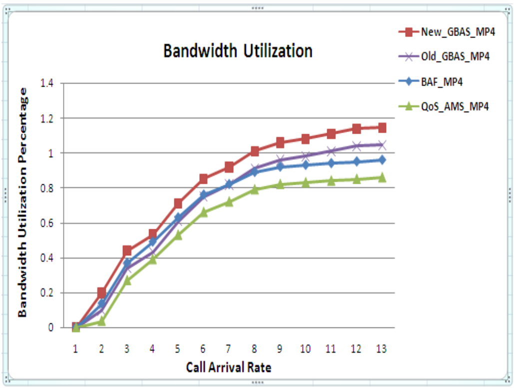


Figure 5. (L): Bandwidth utilization under MP4 test.

VII. Conclusion

In this paper, enhancements for the GBAS system are proposed. Some new features such as distance between cells, waiting calls, and starved calls bandwidth considerations, in addition to prioritization technique for selecting the first served call, are demonstrated. Furthermore, the old version drawbacks such as huge number of management messages are recovered. Also, some old issues are upgraded to be more scalable such as normal degree division to be multi-values. The statistical analysis for the proposed enhanced GBAS version is introduced. In addition, a simulation environment is constructed to test our proposed enhancements. The simulation results proved that our system enhancements outperform the multimedia transmission over multi-cell network by decreasing the NCBP with approximately 40% and HCDP with 46.5 % under JPEG test comparable with the old, the BAF, and the QoS_AMS. As regards MP4 test, the NCBP is decreased by 38.9 and HCDP is decreased by 43.2 comparable with the old, the BAF, and the QoS_AMS.

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