CHAPTER V

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Exponential growth in the number of subscribers of mobile communication services has prompted service providers to maintain high level of QoS. QoS performance is usually measured in terms of the $\boldsymbol{Pcb}$ *and* $\boldsymbol{Pcd}$ *parameters. Recently, HAPs are being explored to deploy mobile communication services due to various advantages.*

This chapter begins with introduction CAC techniques and the QoS requirements. It also introduces the basic theory bandwidth reservation scheme and bandwidth degradation scheme in detail to deliver the desired QoS. This chapter describes how an analytical model can be developed by using Markov chain model for performance evaluation. It also discusses the bandwidth reservation and bandwidth degradation schemes. Under the bandwidth reservation scheme, we allocated dedicated bandwidth to each category of service. Consequently, when a new call request arrives and when there are no more channels available, in that particular class; we use the 'adaptive degradation scheme' under which the allocated bandwidth of each channel is reduced slightly and additional channels are created and hence allocated to the new call request.

It is shown that the proposed bandwidth reservation and bandwidth degradation schemes in conjunction with CAC technique, significant improved for bandwidth utilization has been obtained over preferred category of committed QoS and the connections services enjoy more available bandwidth with improve in the $\boldsymbol{Pcb}$ *and* $\boldsymbol{Pcb}$*.*

5.1. Introduction

In the present scenario, the life of every person is very much affected by two objects i.e. mobile and computers. These two objects have changed the way of communication. Exponential increase in the number of users has resulted into large demand of high quality of wireless communication services. This requirements lead to the development of more innovative communication infrastructures. Terrestrial and satellite systems are established to provide communication services to the users. Overcoming the shortcomings of both terrestrial and satellite systems is the only innovative way to provide cellular communications services via HAP [156].

There are two types of requested call namely new requested call in same cell and hand-off requested call. Hand-off takes place when the user movement from original cell to new cell. Predication user mobility remains very challenging task due to fuzziness of human mobility patterns [187-189]. The call of this new user may get dropped due to insufficient bandwidth of new cell to avoid the congestion state. Therefore, it is the responsibility of network service provider to reserve the required bandwidth for each admitted call.

When requested new connection occurs, CAC takes a decision whether to accept the connection or not [124]. This decision will be based on the current network load and the bandwidth required by the connection during its lifetime. Further, considering that call-drop during hand-off is more annoying, higher priority is given to connection request due to handoff [190]. CAC increases the efficiency of the system by determining the optimal number of new user connections and by minimizing the call-drop during hand-off [191].

During the last two decades, CAC has been receiving attention due to its central role for QoS provisioning in terms of signal quality, Pcb and Pcb, packet delay, loss rate, transmission rate etc. [192]. Furthermore, a good CAC algorithm should be adaptable to implement any changes in the service management policy with low computational complexity [193]. A good CAC algorithm should also be capable to handle bandwidth with much flexibility. It is also designed to fulfill the objectives of minimizing the signal exchange between HAP and terrestrial segments as well as to reduce the delay of requested connection [194].

CAC alone cannot guarantee the required QoS without the support of bandwidth degradation [195], scheduling [196] and bandwidth reservation scheme [197]. Loung et al. (2006) have proposed an approximation method to calculate the guard channel based CAC algorithm for use in HAPs networks which keep the Pcd under predefined threshold while approaching the maximum bandwidth reservation [198]. Kalikivayi et al. (2008) and Haitang et al. (2005) proposed a CAC scheme that assigns highest priority to Unsolicited Grant Service (UGS) flows and aims to maximize bandwidth utilization by using bandwidth borrowing and reduction methods [199, 200]. In their proposal, while bandwidth borrowing and reduction helps accept more connections, the QoS of the ongoing real-time Polling Service (rtPS) and non real-time Polling Service (nrtPS) connections must be guaranteed.

Further, dynamic bandwidth reservation has been proposed in [201]. The authors focused on UGS flows by assigning higher priority to the flows. The scheme divides the scheduling services to UGS and Non-UGS (rtPS, nrtPS and Best Effort (BE)) service types.

In this chapter, we have proposed an advanced CAC technique. The proposed technique has been analyzed by modeling the CAC by using Markov Chain model for its performance evaluation. Accordingly, for the delivery of committed QoS, in different priority classes of users, two schemes viz. 'bandwidth reservation' and 'bandwidth degradation' have been integrated with CAC. Therefore, in this contribution, we have considered four types of service classes belonging to high/ low priority user: (i) Unsolicited Grant Services (UGS) – as high priority users, (ii) real time Polling Service (rtPS) – low priority users, (iii) non-real time Polling Service (nrtPS) - low priority users and (iv) *Best Effort (BE) – low priority. We have proposed that 'bandwidth reservation' scheme and 'bandwidth degradation scheme' can be augmented through real-time channel state information obtained from the CAC, to manage and regulate incoming and outgoing calls as shown in Figure 5.1. Here, different bandwidths can be reserved according to the priority for each type of service category. Further, bandwidth degradation scheme can be used to create extra channels for use in a higher priority category by degrading the channel bandwidth of lower priority user category.

*Best Effort (BE) services are designed for applications with no rate or delay requirements e.g. HTTP etc. and therefore has not been considered our study, yet it has been included for sake of completeness.

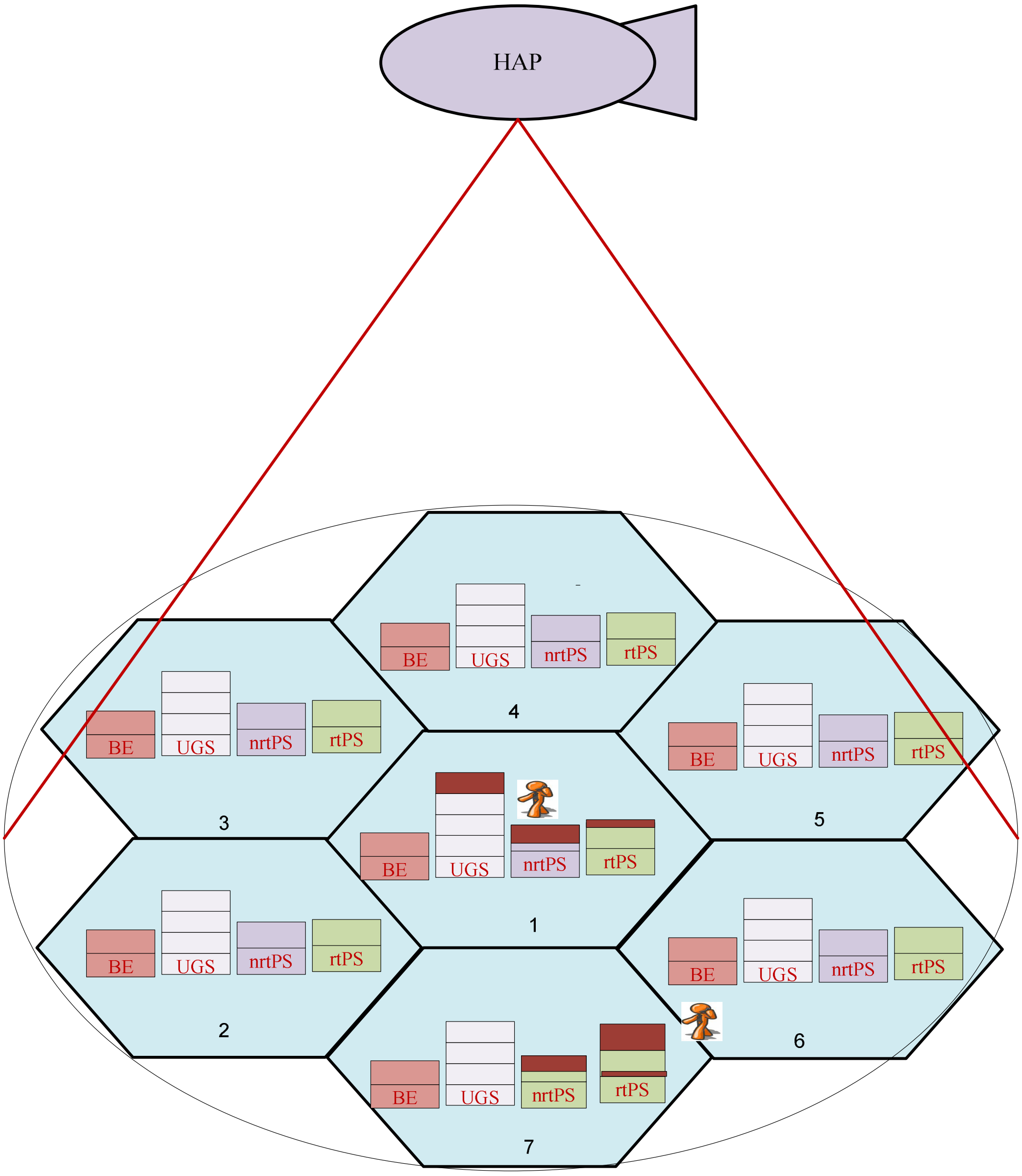

Figure 5.1 Channel Reservation and Bandwidth Degradation supporting CAC

5.2. Call Admission Control Technique

CAC is a technique to provide QoS in any wireless network depend on available bandwidth in cell. Available bandwidths in each cell are channelized and Pcb and Pcd are the relevant QoS parameters which are measured [202]. When a requested new connection is blocked, this service is known as call blocking and its probability is known as Pcb. When the user moves from one cell to another cell, this service is known as call dropping and its probability is known as Pcd, it needs to request connection from the cell into which user is entering. A successful hand-off needs sufficient number of available allocated bandwidths at the destination cell.

CAC keeps a track of available channels as allocated to respective cells. CAC take decision while ensuring that (i) the acceptance of this new-call does not affect the QoS of other already accepted calls, in that service category and (ii) the desired QoS is also delivered as requested by this call, so admitted.

The role of CAC is to regulate the total number of calls in each cell, under each service category. When considering CAC algorithms for HAP, we note that the unique characteristic of HAP is that all BS are collocated. This means that information about the current interference conditions within the cells can be exchanged between base stations with minimal signaling overheads and delay. Hence, distributed global CAC techniques can be implemented more efficiently and jointly for HAP and terrestrial system. In fact, the above characteristic of HAP allows the implementation of more integration, so that interference is managed centrally rather than at individual BS.

A good CAC can achieve many desirable features. Some of the desirable features of CAC are as following [203] such as speed, accuracy, stability of QoS and easy to configurable to accommodate additional services. QoS is the ability to provide different priority to different applications, or users. The implementation of efficient CAC algorithms is useful to prevent congestion and guarantee target QoS. Telecommunication network can be divided into three parts, core network, and radio access network and user equipment. Core network provides the function related to transport, manage, and interconnect with other networks.

Radio access network is set of radio network subsystem used to allow connection between UE and the core network as shown in Figure 5.2. It composes of a radio network control and set of nods B. the function of radio access network are admission control, congestion control, broadcasting control, radio link encoding, hand-off, control and management. Each radio network subsystem manages set of cells through radio network controller which is used to manage mobility management, call processing, radio resource management, link maintenance, hand-off control, traffic concentration, support of mobile services.

The BS is located in the HAP payload and the HAP is used for carrying a set of electronic equipment (antennas, transceivers...) as shown in Figure 5.2. This payload basically consists of a set of antennas (also RNC and Node B equipment) as shown in, each one pointing to different points over the earth. It can also be used as a combined radio network control and Node B [204]. The HAP concentrates the traffic of all users inside the HAP coverage, and forwards it to the terrestrial radio network control. This radio network control could be in the payload of HAP or in a terrestrial node, depending on the role of the platforms in the network.

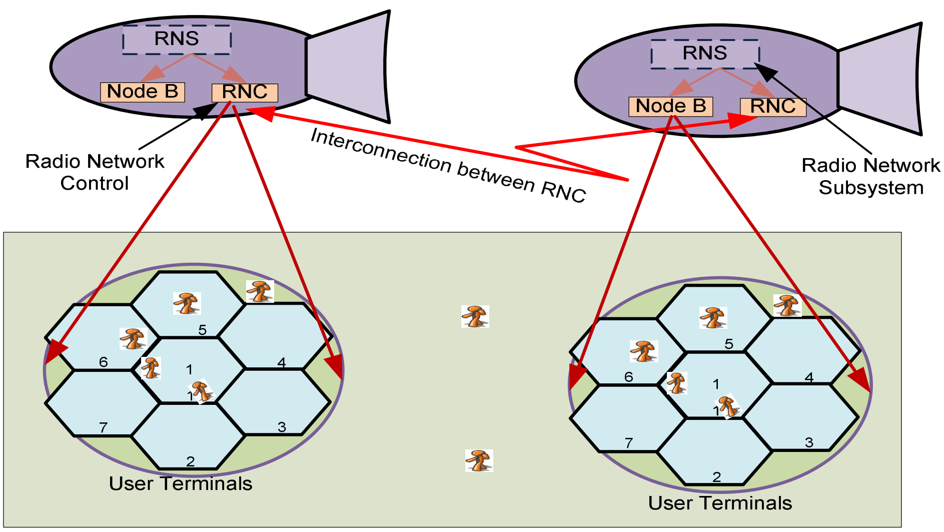

Figure 5.2 CAC Implimented in HAP

5.3. CAC Principles

The aim of CAC algorithms should be to keep the dropping probability under a predefined threshold while minimizing the blocking probability and maximizing the bandwidth reservation at the same time. Dropping probability is the probability that a request for hand-off is rejected, while blocking probability is the probability that a new connection is blocked. So, CAC needs to use both the system and user characteristics to manage the available bandwidth, monitor the system's available capacity, accommodate the new call requests and at same time ensuring the QoS of existing calls.

Analysis of CAC algorithms for QoS guarantees hinges on several design principles and techniques. These principles and techniques help the design of better CAC algorithms in the future. The CAC algorithms developed are designed to manage channel allocations such that QoS constraints for distinct service call types are satisfied. Two main schemes have been used to reservation channels (partitioning channel) and setting threshold. Second scheme is degradation scheme. The idea behind degradation is to increase the number of accommodation connection while reservation channel is to satisfy stringent QoS constraints of some service call types. While this technique is very powerful to satisfy stringent QoS constraints, it reduces channel utilization.

Furthermore, a good CAC algorithm for parameters .i.e Pcd and Pcb should be very flexible to any changes in the service management policy and should have very low computational complexity. It can achieve many desirable features. Some of the desirable features of CAC are as following [203]:

- Speed: the decision to admit or block a connection should be fast for minimizing setup process time.

- Accuracy: CAC technique should ensure connection QoS both in the uplink and downlink.
- Environment: CAC should be adaptable even in minimum capacity. It must provide an acceptable and stable QoS in various environments.
- QoS stability: network performance should be maintained continuously to ensure user satisfactory.
- Reconfiguration: CAC technique should be easily configurable to accommodate additional services with different QoS requirements.

5.4. CAC and QoS Requirement

CAC determines the extent to which network bandwidths are utilized and whether the promised QoS parameters are actually delivered or not.

5.4.1. Bandwidth Degradation

Wireless communication networks must guarantee the QoS requested by users, which includes minimizing dropping and blocking call. But, increasing the admitted number of users shall pressurize network to maximize the revenue [205]. Bandwidth degradation scheme is an important resource management in wireless communication networks. As the number of hand-offs and new calls increase in a cell the requirement of bandwidth increases and finally become insufficient to accept the requested call.

In brief as user requests a call and in case there is no enough bandwidth to satisfy this call then this call will complete with other connected calls. So here bandwidth degradation plays a major role, i.e. bandwidth degradation is used to degrade some of the bandwidth of admitted users under condition that minimum sufficient bandwidth required by a user is allocated, such that QoS is maintained efficiently. Its main characteristic is that it is able to provide higher priority to hand-off calls as compared to new calls in addition to increase the capacity.

Actually there are maximum and minimum bandwidths allocated to every connected user. Degradation can be calculated by subtracting maximum and minimum level bandwidth [195]. This can be explained as follows:

1. If new call request arrives and bandwidth requested is more than available bandwidths, then ongoing calls are degraded to average level as shown in Figure 5.3 (fulfil minimum required bandwidth).
2. If handoff call arrives and bandwidth requested is more than available bandwidth, then ongoing calls are degraded to minimum level as shown in Figure 5.3 (more than sufficient BW).

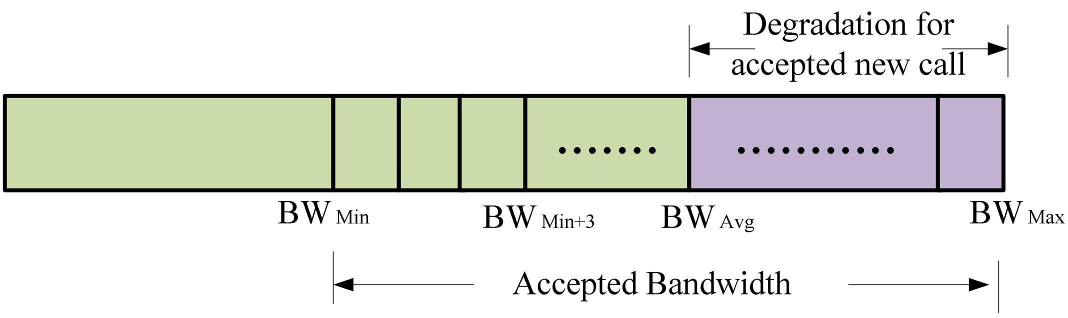

Figure 5.3 Bandwidth Degradation

5.4.2. Bandwidth Reservation

The main and basic technique involved in bandwidth reservation is the dynamic adjustment of bandwidth reserved for hand-off according to the arrival intensity of new connection and hand-off connection. This scheme is used to increase the number of admission opportunities for new coming connections and guarantee QoS for hand-off calls. Bandwidth reservation analyze the behavior of hand-offs and new connections in order to ensure the promising QoS. The amount of reserved bandwidth is allocated based on the incoming and outgoing behavior of hand-off connections to make the resource utilization more efficient [206].

Wireless communications possess some challenges such as scarce bandwidth, dynamic channel qualities, and diverse user demands which are solved by the combination of CAC and bandwidth reservation. Integration of CAC and bandwidth reservation avoids long latency of path rebuilding and guaranteed QoS. Bandwidth reservation is used to provide flexible usage of limited channel in wireless cellular. This work of CAC is taken over at BS. The role of CAC is to estimate whether a remained bandwidth in the cell can provide the required bandwidth of new connections without violating QoS of already admitted users. However, pure bandwidth reservation for hand-off may increase efficiency of hand-off but, lead to an inefficient channel utilization and increase of new call blocking probability.

Bandwidth reservation is used to prioritize the Unsolicited Grant Service (UGS) connections. Degradation scheme is the method of decreasing the Bandwidth allocated to the admitted connections in order to accommodate more number of connections. In this study the performance of the CAC scheme is evaluated in terms of QoS parameters like blocking probability, dropping probability and bandwidth utilization.

Each cell has its own channels, where channel unit is a minimum bandwidth that required for allocated Ms. Each Ms has to submit a report of the service that includes the required channel. The CAC in the BS Ensures the requirement of QoS and keep the channel for user until finish his call. CAC used for comparison the required channel and the available channel of the cell. If new request call is less than available channel the channel is allocated for this call, it keeps channel until the call is finished in the cell or the user moves out of the cell. And if the available channel is sufficient, the new call is accepted otherwise the new call is rejected.

The new requested call is accepted only if the summation of channel utilized and channel required for the new request call is less than the total number of channels which given to the cell.

Usually, there are two types of call in wireless networks, Viz, new calls and hand-off calls. The new call is the one which just started but hand-off call is call which is already ongoing but is moving on to new cell. Accepted the request new call for new call or hand-off call is depending on the available of channel in the cell. During the process of hand-off, the call may not able to gain channel in new cell for continuing service due to limited channels. This will lead to dropping call. Thus hand-off calls assigned higher priority, because users tend to be more sensitive to call dropping than to call blocking.

Channel reservation is varying the sized of channel based on the demand of users as shown in Figure 5.4, and the reservation is success only when available free channels are sufficient. Therefore, integration of CAC and channel reservation avoids long latency of path rebuilding and guaranteed QoS. Based on available channel in cell along with reserved channel, CAC can determine whether call accept or reject.

Figure 5.4 Different Channels for Different Services

5.4.3. QoS Requirements

QoS is related to user's mobility. To provide QoS in various types of multimedia applications class like application for transferring voice, call, video and other kinds of data. To guarantee QoS and achieve high bandwidth utilization, the main approach of admission control is to assign a constant bandwidth and an effective bandwidth to a class of calls [5].

A cell is provided with four distinct service classes. These services class are explained in [207], UGS, rtPS, nrtPS, and BE as shown Figure 5.5 and comparison between different services in Table 5.1. Allocation channels are the one for daily general services but channel reservations are one which are just used for some special function or services like some channels are reserved while mobile hand-offs occurs

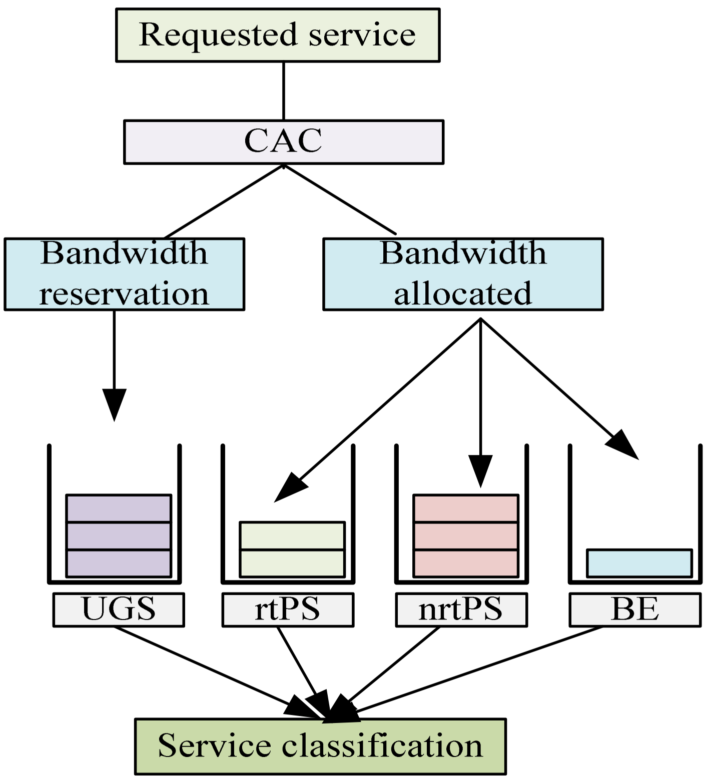

Figure 5.5 Classification of Services

Table 5.1 Services and QoS Parameters

Services	QoS Parameters	Applications
Unsolicited Grant Service (UGS)	Maximum Sustained Rate Maximum Latency Tolerance Jitter Tolerance	VoIP
Real-time Polling Service (rtPS)	Minimum Reserved Rate Maximum Sustained Rate Maximum Latency Tolerance Traffic Priority	Stream Audio or Vidio
Non Real-time Polling Service (nrtPS)	Minimum Reserved Rate Maximum Sustained Rate Traffic Priority	File Transfer Protocal
Best Effort Service (BE)	Minimum Reserved Rate Traffic Priority	Data transfer,Web browsing etc.

The performance of CAC depends on the effectiveness of resource allocation. Giving knowledge of the amount of channel, resource allocation determines the maximum number of calls of each class that can be supported while satisfying all the QoS constraints:

1) UGS supports constant bit rate (CBR) such as Voice over Internet Protocol (VoIP) without silence suppression. It also supports real time traffic with fixed size data packets on a periodic basis. It granted periodically without a polling-request procedure and thereby reducing the latency.
2) rtPS supports real time traffic with variable size data packets such as MPEG video on periodic basis generate at Variable Bit Rate (VBR). The rtPS is suitable for connections carrying services like VoIP or video streaming services.
3) nrtPS supports delay tolerant traffic that requires a minimum serviced rate. The nrtPS are favorable for network services with variable rates like File Transfer Protocol (FTP) and Hypertext Transfer Protocol (HTTP).

4) BE supports in regulating data services. The main aim of BE is to accommodate data streams that have no lower limit of service requirement.

There are two important dynamic parameters in the analysis of service provided, they are: 1. Minimum Reserved Traffic Rate (MRTR) and 2. Maximum Sustained Traffic Rate (MSTR). MRTR used to define the minimum rate reserved for the connection whereas MSTR used to specify the peak information rate of the service.

UGS connections have only one kind of QoS requirements which is MSTR whereas rtPS, and nrtPS connections have both kinds of QoS requirements MRTR and MSTR. BE connections have only one kind of QoS requirements which is MSTR. The connections of UGS and rtPS are easily dropped or blocked because they have QoS requirements on Latency. Hence, Hand-off connections must be given higher priority than new connections. Hand-off without interruption is very important for real-time services, but is not critical for non real-time services [7]. To reduce the dropping and blocking probabilities of non real time connections, queuing schemes is required [208]. So whether the connection is a new or a hand-off from other cells, the priorities of UGS and rtPS are higher than those of nrtPS and BE.

The UGS connection is accepted only when its MSTR is not larger than the remaining bandwidth, the connection of rtPS or nrtPS is accepted when their MRTR are satisfied, and BE connection is always admitted. i.e. Minimum bandwidth is required for each service class. When the requested connection is admitted, it will take specific amount of bandwidth until the connection is complete or hand-off occurs to another cell.

5.5. Proposed CAC

CAC function is to regulate the total utilized bandwidth, the total number of calls passing a specific point per unit time. Therefore, different services need different bandwidth for their satisfying QoS. Several steps are followed in the adopted CAC technique to guarantee QoS, they are: 1. Manage and regulate incoming calls, 2. Reserve and degrade bandwidth, 3. Decide whether the new requested connection accepted or rejected 4. Minimize Pcb and Pcd, 5.Maximize the bandwidth utilization so as to guarantee QoS. Figure 5.6 is the block diagram of the proposed admission control scheme. Bandwidth reservation is used to prioritize the UGS connections. Degradation is the method of decreasing the bandwidth allocated to admit connections in order to accommodate more number of connections.

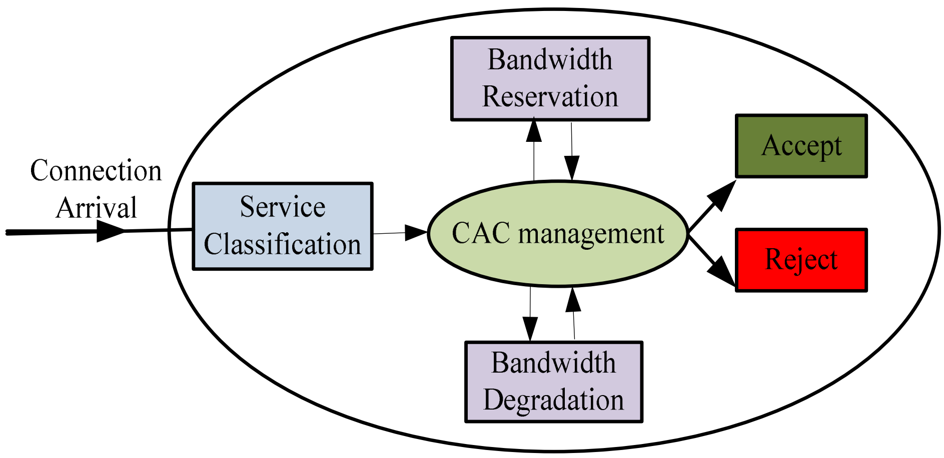

Figure 5.6 Framework of CAC

Our proposed CAC technique is used for maximizing bandwidth utilization. Therefore, it is possible for any service connection to receive some bandwidth from existing connection which doesn't have higher priority service class without any drop of already admitted connections. Allocated bandwidth for rtPS and nrtPS connections is varied between MRTR and MSTR but reserved bandwidth for UGS connections is represented by MSTR.

Bandwidth cannot be borrowed from UGS class because of its higher priority. Therefore, UGS connections can borrow bandwidth partially from existing rtPS and nrtPS connections belonging to the same HAP cell; whereas rtPS bandwidth can borrow from existing nrtPS connections. But nrtPS cannot borrow from any existing nrtPS connections.

The most important concern in CAC technique is to guarantee QoS of different type of connections, to increasing the successful of connection probability and at the same time, to optimize the bandwidth utilization. To guarantee QoS, the delay of the rtPS connections must be satisfied by using Equation (5.1) [209].

$$Bs_i \leq [\ (m_i - 1) * (1 + C_{nrtPS}/C_{rtps}) * r_i * f \qquad \text{Equation (5.1)}$$

$$m_i = d_i/f \qquad \text{Equation (5.2)}$$

Where Bs_i Bucket size of connection i , f is duration of a timeframe (ms) which includes downlink and uplink subframe, d_i is maximum delay requirement of a connection (ms), r_i is the average data rate of connection i , C_{rtps} is total amount of bandwidth allocated to rtPS connections and C_{nrtPS} is total amount of bandwidth allocated to nrtPS.

5.6. Algorithm of CAC Technique

CAC is used with bandwidth reservation and bandwidth degradation schemes to enhance QoS as shown in Figure 5.7. When new requested call is received CAC will determine either hand-off request call from another HAP cell or new request call in same HAP cell.

In case of hand-off request connection of UGS connection arrives to HAP cell with request bandwidth B_{rUGS}, the CAC in HAP checks whether the remaining bandwidth is sufficient or not. If yes then it will check whether the delay guarantee are satisfied or not by using Equation (5.1**)** and if satisfied admit the connections, else reject. If the remaining bandwidth in UGS less than B_{rUGS}, then perform degradation on nrtPS class in steps until maximum degradation step is reached. If this degradation is satisfy the required bandwidth for B_{rUGS}, then check the delay guarantee using Equation (5.1**)** and if satisfied admit the connections, else reject. If degradation of nrtPS doesn't satisfy the requested connectionB_{rUGS}, then perform degradation on rtPS class in steps until maximum degradation step is reached. If this degradation is satisfy the required bandwidth for B_{rUGS}, then check the delay guarantee using Equation (5.1**)** and if satisfied admit the connections, else reject. If the maximum step degradation in nrtPS and rtPS are not satisfying the required bandwidth then reject the connection.

If a newly originated UGS connection arrives at the HAP with requested bandwidth equal to B_{rUGS}, the CAC at the HAP checks whether the remaining bandwidth in UGS class greater than the required bandwidth B_{rUGS}, then it will check whether the delay guarantees using Equation (5.1**)** and if satisfied admit the connection. Else reject the connection. If remaining bandwidth is less than the required bandwidth B_{rUGS} , then degrade the bandwidth allocated to nrtPS connections in steps maximum degradation steps is reached. After degradation, if bandwidth B_{rUGS} is satisfied then check whether delay guarantees using Equation (5.1**)** and if satisfied admit the connection, else reject the connection. If the maximum step degradation in nrtPS is not satisfying the required bandwidth, then reject the connection.

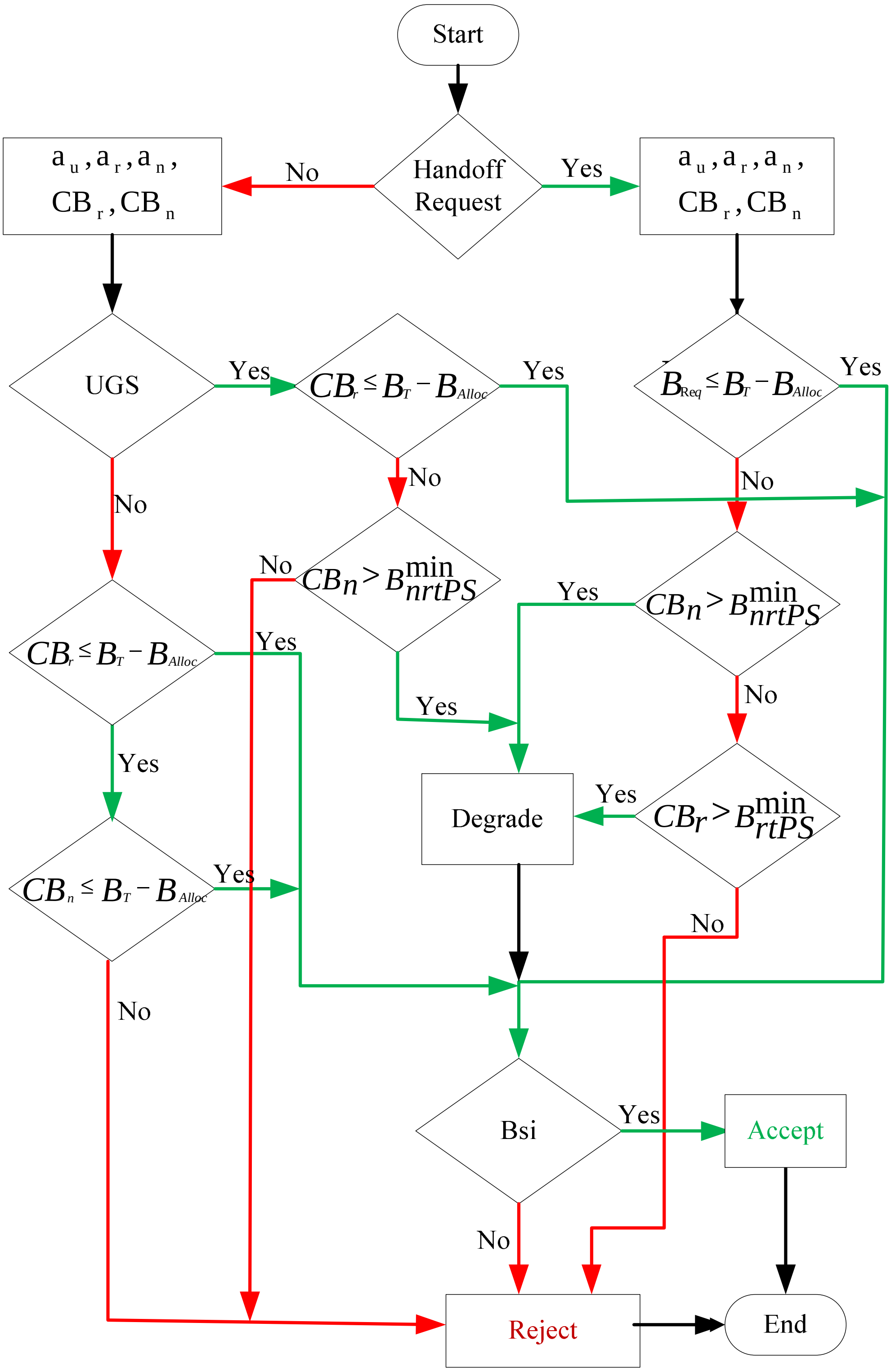

Figure 5.7 CAC Algorithm

5.7. Analytical Model of a HAP Station as a Markov Chain Model

The performance evaluation of the CAC techniques is discussed in this chapter and obtained by ergodic Markov Chain as shown in Figure 5.8. In this scenario, we consider a single BS in HAP coverage and the user will request bandwidth from this BS. There are three type of services is considered for request connections which are UGS, rtPS, and nrtPS. CAC technique in that BS will only accept the connection if there is sufficient BW, to accommodate the connection and provide sufficient QoS, otherwise the connection reject.

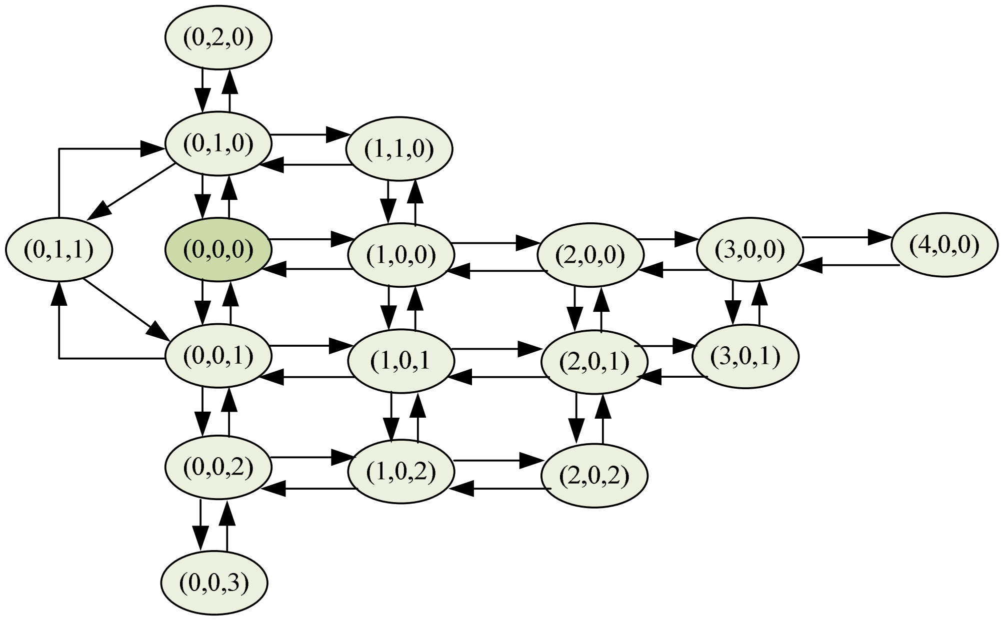

Figure 5.8 State Diagram Using an Ergodic Markov Chain

Represent state is given by $s = (n_u, n_r, n_n)$ based on number of accepted connection. Where $n_u, n_r,$ and n_n represent currently accepted connection of UGS, rtPS and nrtPS respectively. The arrival intensity of new requested connection of UGS, rtPS and nrtPS are assumed to be Poisson with λ_U, λ_r , and λ_n , respectively and the service time is assumed to be exponentially distributed with mean $1/\mu_u$, $1/\mu_r$ and $1/\mu_n$ respectively.

The steady state probabilities for each state s in the above example can be obtained as follows. Assume that the steady state probability of state $s = (0,0,0)$ in the above example be $\pi_{(0,0,0)}$. The steady state balance equation of the state $s = (0,0,0)$ can be observed in Figure 5.8.

$$\pi_{(0,0,0)}(\lambda_u + \lambda_r + \lambda_n) = \mu_u \pi_{(1,0,0)} + \mu_r \pi_{(0,1,0)} + \mu_n \pi_{(0,0,1)} \qquad \text{Equation (5.3)}$$

Similarly, we can get the steady state balance equations of all the states s in the state space S. If there are n numbers of states, we get n dependent steady state balance equations.

The performance evaluation of the CAC techniques is discussed in this chapter and obtained by Ergodic Markov Chain. Blocking and dropping probabilities are considered in as parameter for satisfy QoS of UGS, rtPS, and nrtPS service connection.

5.7.1. Calculation of Bandwidth Utilization

Bandwidth utilization is the average ratio of the used bandwidth to the total bandwidth. Formally, it can be calculated as:

$$BW_U = \sum_{\pi = S} (\pi_u B_u + \pi_r B_r + \pi_n B_n)\pi_s / B \qquad \text{Equation (5.4)}$$

Where $B_u, B_r,$ and B_n are the bandwidth requirements of the UGS, rtPS, and nrtPS connections respectively. π_s is the steady state probability of the state s, where B is the total bandwidth available at the BS. For performance evaluation of the proposed CAC scheme each BS is modeled using a Markov chain [210, 211]. The arrival process of the hand-off and newly originated UGS, rtPS, and nrtPS connections is Poisson with rates λ_{hu} , λ_{hr} ,λ_{hn},λ_{ou}, λ_{or} and λ_{on} respectively, where the subscript h represents hand off connections and the subscript o represents newly originated connections in a cell. Therefore the total arrival rate of the connection requests at the BS is equal sum of all the individual arrival rates of all the connections i.e. $\lambda_T = \lambda_{hu} + \lambda_{hr} + \lambda_{hn} + \lambda_{ou} + \lambda_{or} + \lambda_{on}$.

The service times of UGS, rtPS and nrtPS connections are exponentially distributed with mean $1/\mu_u$, $1/\mu_r$ and $1/\mu_n$, respectively. Each BS can be modeled as five dimensional Markov chain n_u, n_r, n_n, B_r, and B_n.The steady state probability of state $s = (n_u, n_r, n_n, B_r, B_n)$ is $\pi_{(n_u,n_r,n_n,B_r,B_n)}$. The state Space S for all possible Markov states is define based on the proposed CAC technique as given by:

$$S = \{s = (n_u, n_r, n_n, B_r, B_n) \mid n_u * n_r * n_n * B_r * B_n \leq B \wedge (B_r \geq B_r^{min}) \wedge (B_n \geq B_r^{min}\}$$ Equation (5.5)

For a given state $s = (n_u, n_r, n_n, B_r, B_n)$, the state transition occurs when a new request is accepted or an on-going connection terminates. Where B_r^{min} represented MSTR allocated rtPS connection.

$$\lambda_{tu} = \begin{cases} \lambda_{hu} + \lambda_{ou}, & \text{if } (n_u + 1)B_u + n_r * B_r^{max} + n_n * B_n^{min} < B \\ \lambda_{hu} & \text{otherwise} \end{cases}$$ Equation (5.6)

$$\lambda_{tr} = \begin{cases} \lambda_{hr} + \lambda_{or}, & \text{if } n_u * B_u + (n_r + 1) * B_r^{max} + n_n * B_n^{max} < B \\ \lambda_{hr}, & \text{otherwise} \end{cases}$$ Equation (5.7)

$$\lambda_{tn} = \begin{cases} \lambda_{hn} + \lambda_{on}, & \text{if } n_u * B_u + n_r * B_r^{max} + (n_n + 1) * B_n^{max} < B \\ \lambda_{hr}, & \text{otherwise} \end{cases}$$ Equation (5.8)

$$\pi_{(n_u,n_r,n_n,B_r,B_n)} = \begin{cases} 1, & (n_u, n_r, n_n, B_r, B_n) \epsilon S \\ 0, & \text{Otherwise} \end{cases}$$ Equation (5.9)

$$\sum_{s \epsilon S} \pi_{(n_u,n_r,n_n,B_r,B_n)} = 1$$ Equation (5.10)

Where B_n^{max} and B_r^{max} represent MRTR and MRTR allocated for rtPS, respectively. Considering the normalizing condition (equation above) and using recursive algorithm, the steady state probability of each state can be obtained [211]. Using the steady state probabilities of all the states the following performance parameters can be obtained.

5.7.2. Calculation of New Connection Blocking Probability

The new connection probability is the probability of blocking a new request for connection. The blocking probability of a new arriving UGS request connection is the sum of all the steady state probabilities of the states $s = (n_u, n_r, n_n)$ in the state space S for which there is no transition to the state $s = (n_u + 1, n_r, n_n)$. So the blocking probability of new UGS requests is equal to the sum of the steady state probabilities of the states (4,0,0) ,(1,1,0), (0,2,0), (0,1,1), (0,0,3), (2,0,2), and (3,0,1). In similar manner the blocking probabilities of rtPS and nrtPS connections can be calculated. The new Pcb of UGS, rtPS, and nrtPS connections can be calculated as follows. Pcb for UGS connection is given by:

$$\sum_{s \in S} \pi_{(n_u, n_r, n_n, B_r, B_n)} \qquad \text{Equation (5.11)}$$

$$S = \{s = (n_u, n_r, n_n, B_r, B_n) \mid (n_u + 1)B_u + n_r * B_r + n_n * B_n^{min} > B\} \qquad \text{Equation (5.12)}$$

Where B_n^{min} is MSTR allocated for nrtPS. Also Pcb for rtPS can be given by:

$$\sum_{s \in S} \pi_{(n_u, n_r, n_n, B_r, B_n)} \qquad \text{Equation (5.13)}$$

$$S = \{s = (n_u, n_r, n_n, B_r, B_n) \mid n_u * B_u + (n_r + 1) * B_r + n_n * B_n > B\} \qquad \text{Equation (5.14)}$$

As well as Pcb for nrtPS is given by:

$$\sum_{s \in S} \pi_{(n_u, n_r, n_n, B_r, B_n)} \qquad \text{Equation (5.15)}$$

$$S = \{s = (n_u, n_r, n_n, B_r, B_n) \mid n_u * B_u + n_r * B_r + (n_n + 1) * B_n > B\} \qquad \text{Equation (5.16)}$$

5.7.3. Hand-off Connection Dropping Probability

The Hand-off connection dropping probability is the probability of dropping a hand-off connection request for admission into the network. The Pcd of UGS, rtPS and nrtPS connections can be calculated as follows. Pcd for UGS is given by:

$$\sum_{s\epsilon\, S} \pi_{(n_u,n_r,n_n,B_r,B_n)} \qquad \text{Equation (5.17)}$$

$$S = \{s = (\, n_u, n_r, n_n, B_r, B_n) \mid (n_u + 1) * B_u + n_r \ * \ B_r^{min} + n_n * B_n^{min} > B\,\} \qquad \text{Equation (5.18)}$$

Furthermore, Pcd for rtPS is given by:

$$\sum_{s\epsilon\, S} \pi_{(n_u,n_r,n_n,B_r,B_n)} \qquad \text{Equation (5.19)}$$

$$S = \{s = (\, n_u, n_r, n_n, B_r, B_n) \mid n_u * B_u + (n_r + 1) \ * \ B_r^{min} + n_n * B_n^{min} > B\,\} \qquad \text{Equation (5.20)}$$

Finally, Pcd for nrtPS is given by:

$$\sum_{s\epsilon\, S} \pi_{(n_u,n_r,n_n,B_r,B_n)} \qquad \text{Equation (5.21)}$$

$$S = \{s = (\, n_u, n_r, n_n, B_r, B_n) \mid n_u * B_u + n_r * \ B_r^{min} + (n_n + 1) * B_n^{min} > B\,\} \qquad \text{Equation (5.22)}$$

5.8. Result and Discussion

The result is shown the important of using bandwidth reservation and bandwidth degradation schemes with help of CAC to improve excellently the bandwidth utilization of HAP. Degradation is done to allow more hand-off connections and higher priority connections to be accommodated. It can be observed that the Pcd of hand-off connections is very low and at same time the Pcb is decreased.

Figure 5.9, Figure 5.10 and Figure 5.11 are shown Pcb and Pcd of UGS, rtPS and nrtPS respectively. Since the two schemes differ only in the method of degradation, the Pcb and Pcd of all services are improved as indicated in Figure 5.9, Figure 5.10 and Figure 5.11, respectively. Figure 5.12 is shown bandwidth utilization is greatly increased. It is quite evident from the Figure 5.12

that with adaptive degradation the bandwidth utilization of the system is excellent when the network is stressed.

Briefly, the priority order of all of the types of class in figures below is shown Pcd UGS < Pcd of rtPS and Pcd of nrtPS. On the other hand, Pcb of new originated UGS is < Pcb of new originated rtPS and Pcb of new originated nrtPS. The proportional bandwidth degradation scheme thus not only increased the total number of calls admitted, but also gave different priorities to different kinds of class categories, which represents a trade-off between guarantee QoS and high bandwidth utilization.

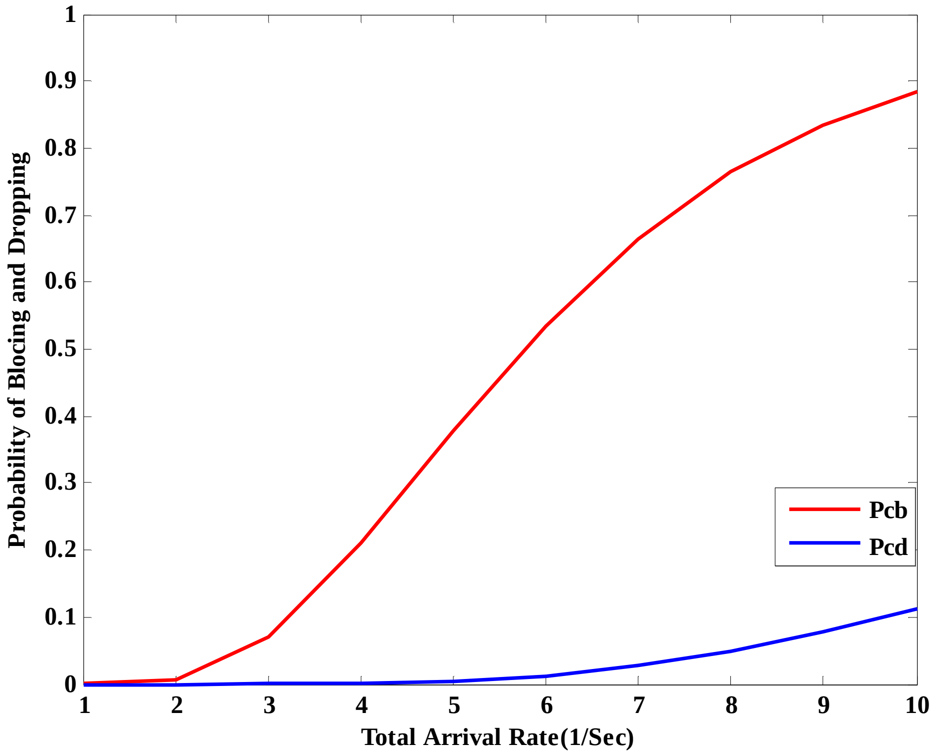

Figure 5.9 Dropping and Blocking Probability of UGS Connections

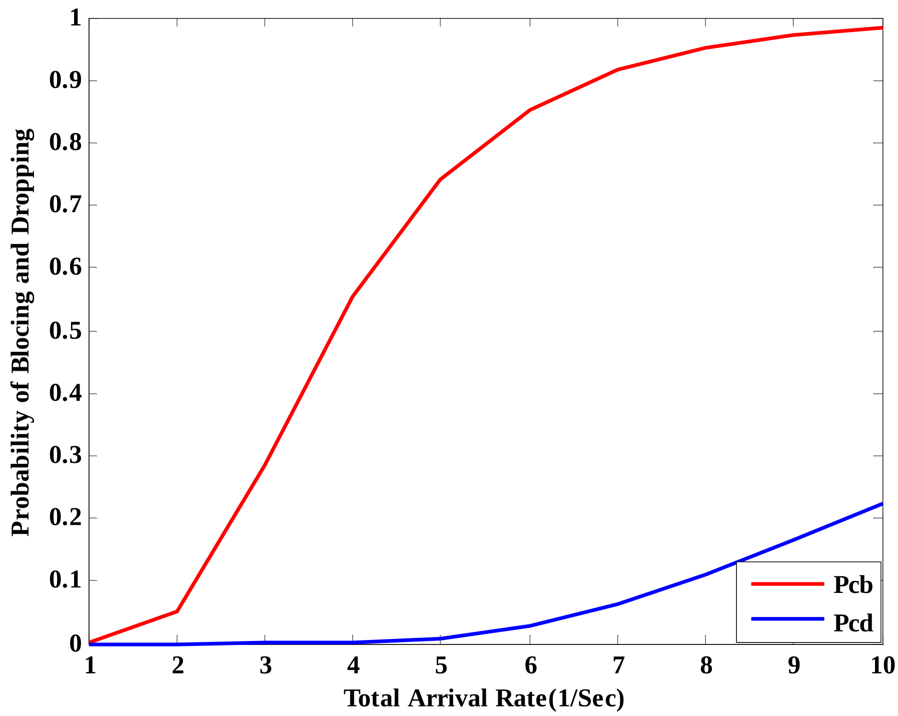

Figure 5.10 Dropping and Blocking Probability of rtPS Connections

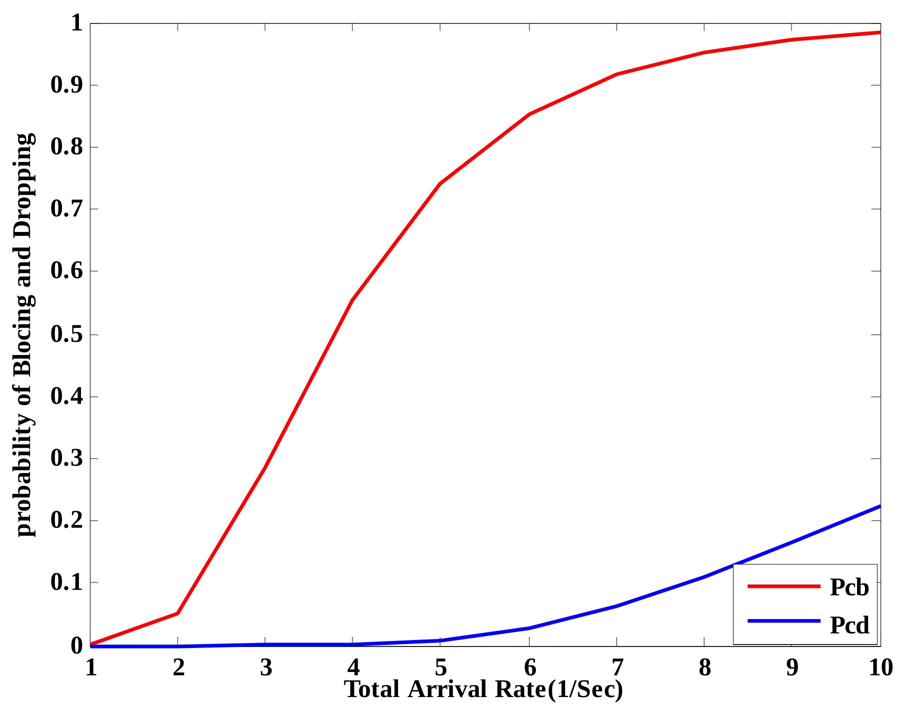

Figure 5.11 Dropping and Blocking Probability of nrtPS Connections

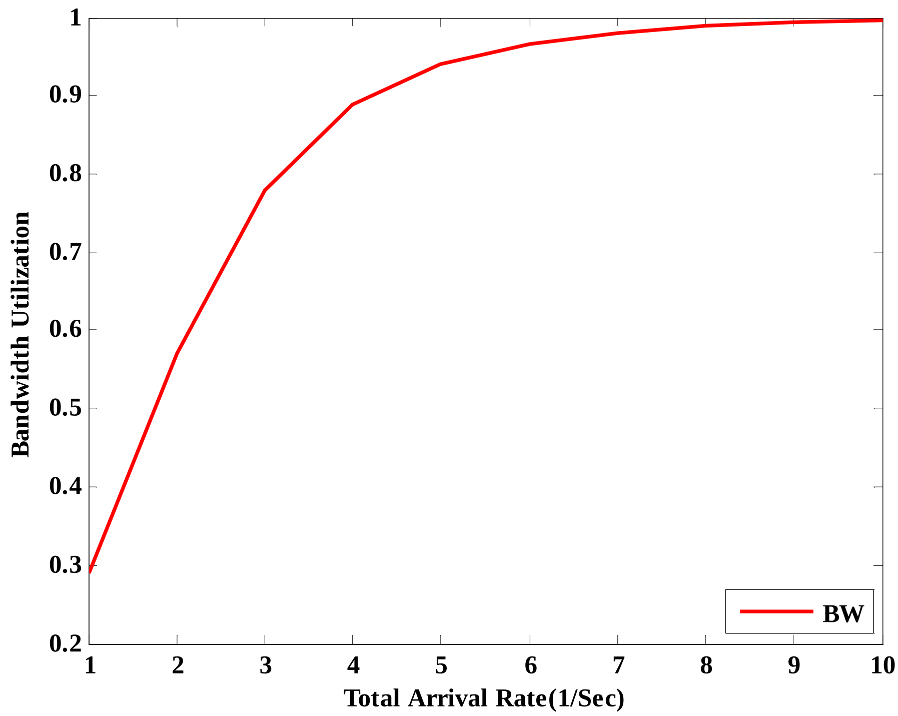

Figure 5.12 Bandwidth Utilization of the System

With this technique, the higher priority category achieves lower probability of call block and call drop. When the total arrival rate is varied between 0 to 10 (1⁄Sec), the maximum Pcd reaches 0.114 for higher priority class (i.e. UGS) Page 11 of 14 while it reaches up to 0.225 in case of low priority class (i.e. rtPS and nrtPS). On the other hand, for higher values of total arrival rate, Pcb rises up to 0.884 (for UGS) and 0.984 (for rtPS and nrtPS), respectively. As well as at maximum arrival rate, the bandwidth utilization reaches to 0.9858.

5.9. Conclusion

Efficient wireless networks resource utilization with QoS guarantees in the next high bandwidth of wireless cellular networks poses great challenges due to scarce radio bandwidth. Efficient CAC is important for the efficient utilization of the limited bandwidth. In this chapter, CAC technique is proposed to provide efficient bandwidth utilization with both bandwidth and delay guarantees. The adaptive degradation has small effect on the dropping and blocking probability of all services but it addressed the most important issue of communication which is efficient utilization of the limited scarce bandwidth. The proposed technique may be considered as an optimal technique in terms of the bandwidth utilization. The novelty of the work lies within the scope of analyzing the follow services using Markov chain model in an integrated way for HAP.

The simulation results show the use of bandwidth reservation and bandwidth degradation schemes with help of CAC not only keeps the bandwidth utilization at a maximal level, but also provides a reasonable priority order of new requested call in same cell and hand-off requested call of different service classes. Moreover, these two schemes improve Pcb as well Pcd of each kind of classes. The results also indicate that the bandwidth utilization has also increased significantly with help bandwidth degradation scheme.