A Call admission Control Algorithm to Enhance the Network Management in Heterogeneous Wireless Networks

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Abstract - *Next generation wireless networks are heterogeneous in nature. As various communications are available, the infrastructure enables the devices to run applications diverse bandwidth and network connectivity problem. So, to attain seamless connectivity and ensure the required Quality of Service (QoS) heterogeneous networks came into existence. Heterogeneous Wireless Network (HWN) is a network which consists of various Radio Access Technologies (RAT's) and different cell type network to provide reliability, increasing coverage and spectrum efficiency. The several problems which must be addressed are QoS, handoff, mobility and interference. Call admission control (CAC) mechanisms plays an role to provide QoS as different RAT's coexists and to ensure that the data traffic (voice and video) does not use all the bandwidth and cause other important data to experience dropped packets. This paper illustrates a CAC algorithm and Bandwidth level degradation (BLD) algorithm for adaptive bandwidth management for HWN's with requirements of CAC algorithms. In the algorithm, it separates the incoming traffic for each class and prioritizes the handoff calls over the new calls to guarantee QoS requirements of accepted calls, reduce call blocking probability and handoff call dropping probability and to maintain efficient network utilization.*

Key Words: **Quality of service (QoS), Heterogeneous Wireless Networks (HWN), Call Admission Control (CAC), Adaptive Bandwidth Management, Radio Resource Management, Call drop.**

1. INTRODUCTION

It is foreseen that next generation wireless network will be heterogeneous in nature. Heterogeneous Wireless Networks (HWNs) shown in fig-1 are the combination of various radio access technologies and different cell types The term Radio access Technology was traditionally used in mobile communication network interoperability, the different radio access technologies are Bluetooth, Wi-Fi, and 3G, 4G or LTE, WiMax etc.. The term is used when a user device selects between the types of RAT available in the network being used to connect to the Internet. One of the example is, this is often performed similar to access point selection in IEEE 802.11 (Wi-Fi) based networks. The different cell types arte micro cell, pico cell, micro cell, hemto cell etc. These networks provide ubiquitous access with high rates for users who, through multimode terminals, will be able to connect with the most appropriate RAT.

The benefits of HWNs are

- Increase in reliability
- Improved spectrum efficiency
- Increased coverage

There are several problems still to be solved in heterogeneous wireless networks such as

- Determining the theoretical capacity of HWNs
- Interoperability of technology
- Handover
- Mobility
- Quality of Service / Quality of Experience
- Interference between RATs

When a user sends a request for services such as voice, video, and web browsing, the call admission control (CAC) algorithm plays a major role, the basic function is to decide whether a handoff call or new call can be accepted into a resource-constrained network without violating the service commitments made to already admitted calls.

1.1 Call Admission Control

Call admission control (CAC) algorithm is one of the key radio resource management strategies [1], which plays an important role, by defining how the radio resources have to be efficiently shared among users in the network. In homogeneous networks like cellular networks with single radio access technology like GSM, CDMA, Wi-Fi etc., the CAC algorithms decide whether or not an incoming service request made by a user is accepted according to an admission constraint. If the condition is satisfied, the incoming service request will be accepted, otherwise, it will be blocked [2].

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As day by day many electronic gadgets are invented and no. of users are increasing , these provide many different types of user friendly applications ,the single RAT doesn't provide the services to the all call whether it is handoff call or new call especially in crowed areas. So, the solution is to deploy HWNs with the vision of next generation wireless networks has led to the development of new CAC algorithms specifically designed for heterogeneous wireless networks with adaptive bandwidth management.

In this paper, a new call admission control is designed with adaptive bandwidth management which not only decides whether the incoming service should be accepted or not but also selecting in which of the available RATs, a incoming service request has to be accommodated shown in fig-2.

In other words, The CAC manages the access to network resources to ensure certain level of QoS in the heterogeneous environment.

New call requests are accepted only when enough resources are granted for meeting the QoS constraints.

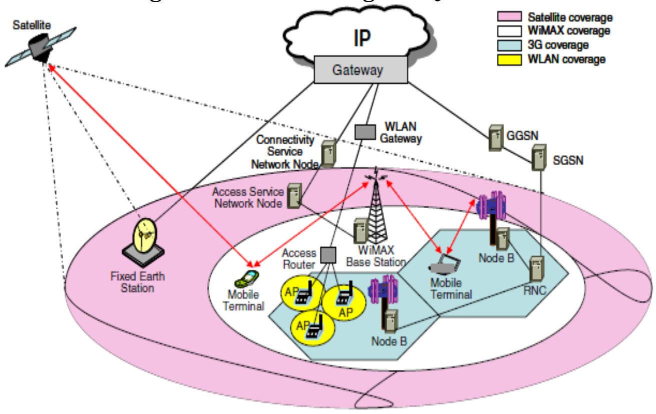

Fig-1: An example of Heterogeneous Wireless Network

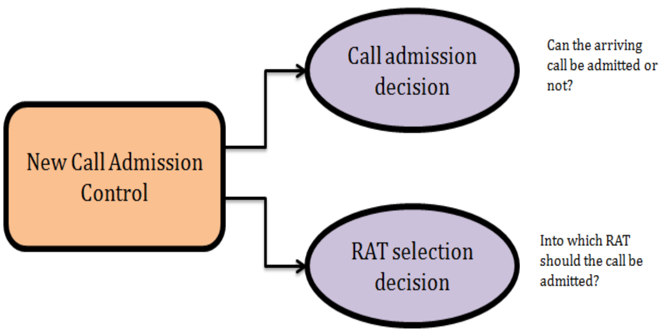

Fig-2: New Call Admission Control Algorithm

As mentioned earlier, the main goal is to use the network's resource efficiently and effectively by reducing call blocking probability and handoff call dropping probability.

1.2 Benefits of CAC algorithms

CAC algorithms are necessary for

- Efficient utilization of radio resources
- Consistent provisioning of QoS across different RATs,
- Overall stability of network
- Enhancement of users' satisfaction
- Increase in operators' revenue.

1.3 Requirements of CAC algorithms

It is desirable that a CAC algorithm meets certain requirements in order to have the benefits given above

1.3.1 Multi-service

Next generation wireless network should support multiple classes of services (voice, video, video and audio streaming, web browsing, etc.). Supporting these services in heterogeneous wireless networks will enhance users' satisfaction because different users have different service requirements. By supporting multiple services will increase operators' revenue. Therefore, CAC algorithms need to support multiple services.

1.3.2 Efficiency

Performance of CAC algorithms is measured in a number of ways such as radio resource utilization, new call blocking probability, handoff call dropping probability, outage probability, average delay, packet loss probability, operators' revenue, and users' satisfaction. CAC algorithms must be efficient in achieving the designed goals. Generally, an efficient CAC algorithm will guarantee the QoS requirements of accepted calls and achieve high radio resource utilization.

1.3.3 Simplicity

The implementation cost and scalability problem require that a CAC algorithm be as simple as possible. A simple algorithm will have a low computational overhead and therefore will not incur additional delay in the network. However, an overly simple CAC algorithm may not achieve high radio resource utilization. For good quality of service and efficient radio resource utilization, a sophisticated CAC algorithm is required to support multiple services, especially in a scenario where users are dynamically roaming across different access networks. Therefore, there is a tradeoff between simplicity and the efficiency of CAC algorithms.

1.3.4 High-execution speed

Call admission control algorithms operate in real-time. Therefore, the execution speed should be very high so that they do not cause additional delay in the network. High execution speed of CAC algorithms will enhance QoS in the heterogeneous wireless network.

1.3.5 Scalability

As, there is an increase in the demand for multimedia data services in recent years. This increase in demand is likely to grow at a faster pace in the future due to advances in multimedia distribution services. Therefore, the overall system capacity of heterogeneous wireless networks must be expandable in terms of the number of subscribers supported, data rate, and geographical coverage. A CAC algorithm must be able to accommodate increase in capacity or size of individual RATs. It must also accommodate the integration of other access networks. Moreover, exchange of a large amount of information among base stations of different RATs may exert a significant overhead cost in a heterogeneous wireless network as the size of the network increases. Therefore, CAC algorithms must minimize the amount of information exchange in heterogeneous networks.

1.3.6 Stability

It is necessary that CAC algorithms ensure overall stability of the heterogeneous wireless network. Instability refers to a situation where certain RATs suddenly become overloaded whereas some other RATs with overlapping coverage are underutilized. In which case, it may be necessary to move some subscribers back and forth from the suddenly overloaded RAT to the underutilized RAT. A major disadvantage of instability is increase in frequency of vertical handoff (i.e., handoff between two different RATs), thereby reducing the overall efficiency of the network. Therefore, it is desirable that a CAC algorithm ensures overall stability of the heterogeneous wireless network.

2. PREVIOUS WORK

Proposed research tried to overcome the blocking problem in wireless networks by offering admission control algorithms that are split into two groups. The first group focuses on the CAC in homogeneous network to determine if an arriving call can be admitted or not in the network, as in [3, 4].

While the second group as in [5, 6] focuses on more sophisticated CAC algorithms for heterogeneous networks to restrict the access to the network based on the available resources in order to prevent network congestion and QoS deterioration. In [3], an adaptive CAC algorithm is considered for LTE network (Long Term Evolution). This approach supports a resource block reservation algorithm to adapt calls resources. However, the problem with this scheme is of some kind of satisfaction level for the users. It puts some served connections to their minimum data rate to maximize the network capacity. In [4], the authors propose a QoS approach for adaptive CAC scheme for multiclass service wireless cellular networks using call bandwidth borrowing and call preemption techniques. However, the execution of this scheme consumes an amount of time that could increase the handoff latency. Moreover, the bandwidth adaptation algorithm is not effective because the same call can undergo successive resources degradations which can increase blocking probability.

Authors in [5] propose a CAC algorithm depending on the mobility. They introduce the concept of guard channels to give priority to handoff calls over new calls. In this policy, a set of channels called the guard channels are permanently reserved for handoff calls. In [6], a novel joint group call admission control algorithm (JGCAC) is proposed. The proposed algorithm is developed to distribute users into different networks to avoid network congestion, meanwhile, user satisfaction is considered to provide better service experience. Authors in [7,8] provide a survey of recent works in HWNs. These works included CAC algorithms, RAT selection schemes and scheduling.

3. PROPOSED SCHEME

3.1 System model and assumptions

Here, we considered a heterogeneous wireless network, which consists of j RATs coexisting in the same area. They have the capability to operate in 3GPP LTE, WiMAX and Wi-Fi interfaces. We assume that the multiservice heterogeneous network traffic is classified into three main traffic classes of calls. Each class is characterized by radio bandwidth requirement, arrival distribution, and channel holding time. The first class belongs to real-time intolerant traffic, such as Voice over IP (VoIP). The second class belongs to real-time tolerant traffic, such as video streaming. The third class belongs to non real-time traffic, such as Data on Demand (DoD) service.

In most cases, the bandwidth requirements of multimedia applications are characterized to be tolerable and adaptable to transient fluctuations in the QoS. Therefore, the bandwidth requirements for these applications may vary from their minimum to their maximum. Accordingly, we assume that the real-time intolerant class (RT-INTLR) has the highest priority, followed by the calls of the real-time tolerant class (RT-TLR), then the calls of the non real-time class (NRT). Moreover, we assume that each User Equipment (UE) communicates to the network a service contract that determines the contractual constraints for the required service. The entire QoS parameters forming the descriptor of traffic are

Traffic profile = {$BW_{max,i}$; $BW_{req,i}$; $BW_{min,i}$; $D_{max,i}$; C_i ; K_i }

Where:

- $BW_{max,i}$ -Denotes the maximum required bandwidth for the call i,
- $BW_{req,i}$ -Denotes the required bandwidth for the call i,
- $BW_{min,i}$ -Denotes the minimum bandwidth for the call i,
- $D_{max,i}$ -Denotes the tolerable maximum delay for the call i,
- C_i -Denotes the type of call (i.e. handover call (HC) or new call (NC)),
- K_i - Denotes the type of service for the call i.

3.2 Scheduling of users

In, Heterogeneous wireless networks they support different type of applications with various constraints such as delay. To provide some guarantees of service towards a data flow, this approach for admission control is responsible for limiting the timeout for connection requests in the queue of packets. As mentioned above, the multiservice traffic is classified into three main classes of traffic: INTLR (Real-Time- Intolerant),RT-TLR (Real-Time Tolerant) and NRT (Non Real Time).Thus, the data flow of the RT-INTLR class is real-time type whose time requirements are strict. Calls in this class have the highest priority, followed by calls in the RT-TLR class which are more tolerant to changes in the timeout. NRT calls have the least priority. The proposed approach treats the types of calls differently the priority is given to handoff call over new call in admission. Preference for handover calls over new calls decreases the handover call blocking.

3.3 Proposed call admission control

After receiving quality of service profiles, the proposed CAC algorithm separates the incoming traffic into classes and it distinguishes between types of calls (NC and HC). We assume that all types of applications have a QoS request, including a delay constraint to respect, both for real time applications and for non-real-time applications. Fig-4 gives the detailed explanation about proposed CAC algorithm and it is common for both Handoff call and New call but the priority is given to handoff call. At the arrival of QoS requests, the proposed CAC algorithm accepts or rejects such calls based on the application requirements (in terms of bandwidth required) and available bandwidths in the system. If the CAC estimates that resources defined in the network do not reach the predefined threshold capacity associated with the type of application requested, then these calls will be accepted by allocating the resources requested.

In the ideal case, all calls in a cell should be allocated with the maximum bandwidth (BW_{max}) whenever possible. However, if the cell is over-loaded, some of the calls in the cell might receive a bandwidth lower than the requested bandwidth.

If the CAC estimates that the maximum capacity of the bandwidth associated to a traffic class is reached, calls requesting this type of application will be storing them in specific queues. For this, we propose three different queues (for each class of service) for each type of call. The delay $D_{r,i}$ of requesting a service i depends on the transmit time $T_{t,i}$ and the reception time $T_{r,i}$ of the request. The request which have the minimum tolerated delay and does not exceed the tolerable maximum delay will be treated first.

$$D_{r,i} = T_{r,i} - T_{t,}i \qquad (1)$$

The CAC algorithm is as follows

STEP 1 : Arrival calls with the required parameters like $BW_{max,i}$;$BW_{req,i}$; $BW_{min,i}$; $D_{max,i}$; C_i ; k_i.
STEP 2: All RATs are sorted and the least loaded is selected.
STEP 3: The call type (NC or HC) is determined.
STEP 4: QoS call (NRT or RT-TLR or RT-INTLR) is determined.
STEP 5: If the resources are sufficient then the call is accepted; else the condition $D_{r,i}<D_{max,i}$ is checked. If true then proceed to next step, else the call is rejected.
STEP 6: If the condition is satisfied then the call with the minimum tolerated delay is checked and Bandwidth Level Degradation algorithm (BLD) is used.
STEP 7: If sufficient resources are present then call is accepted; else the condition $D_{r,i}<D_{max,I}$ is checked again. If true then the call is redirected to another RAT.
STEP 8: If still no resources are available at the expiration of the delay the call will be rejected.
STEP 9: The details of each RAT in the network will be sent in the form of beacon messages with an interval of time which is predefined. These are received by the device by which it can be easily connected to the available best RAT for its requirement of the type of service requested. Here, we will consider multiple criteria parameters of each RAT which helps to improve the network utilization to a more extent.

3.4 Bandwidth adaptation algorithm

As the resource management is one of the most important issue bandwidth degradation is used to maximize the resource management of a cell without increasing the blocking or dropping probability. When the requested bandwidth exceeds the maximum available unused bandwidth within the cell, then the role of bandwidth degradation algorithm is essential. The concept used here is that when the network is overloaded then some of the bandwidth allocated to ongoing calls can be degraded to free bandwidth so as to accept more new and

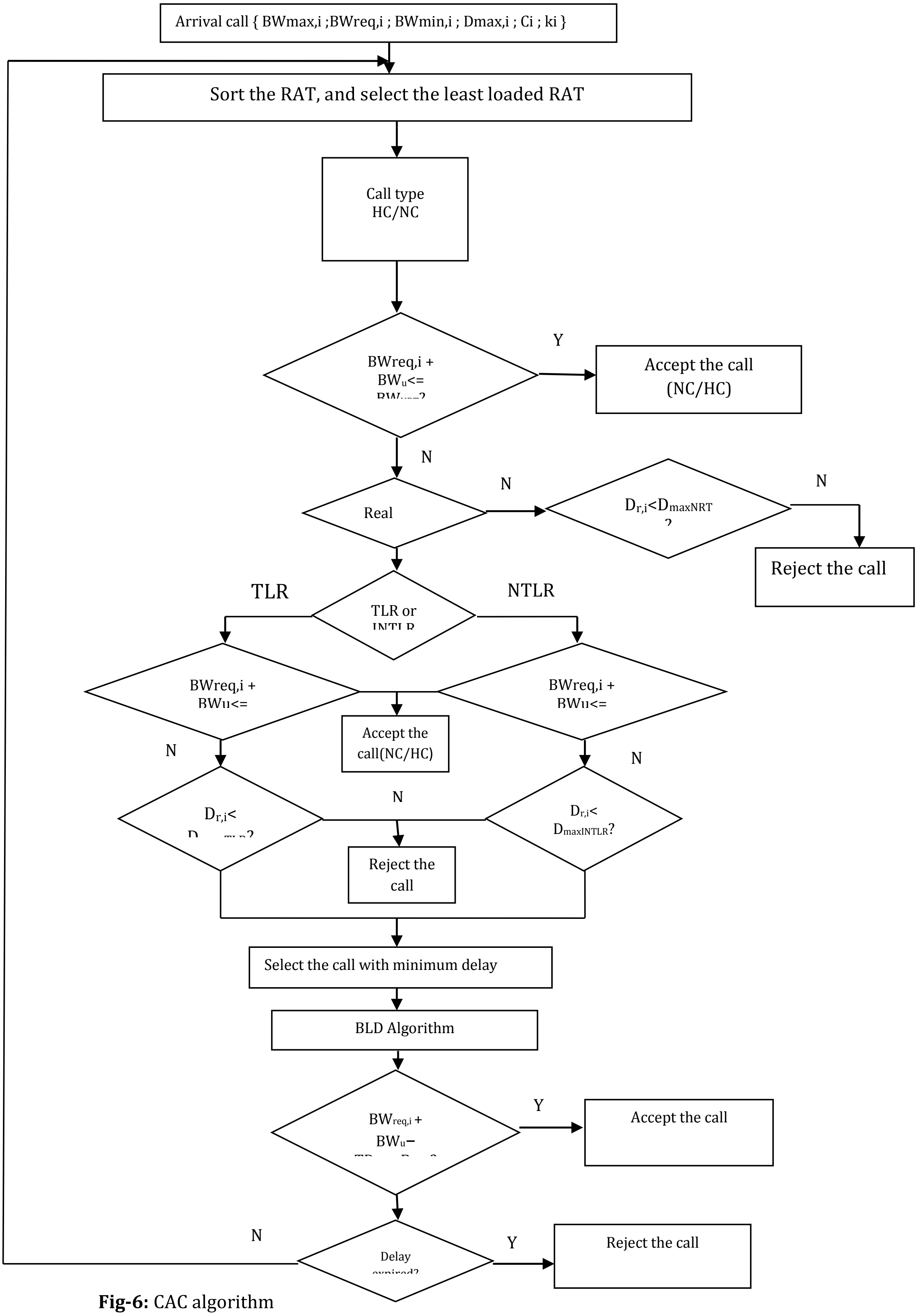

Fig-6: CAC algorithm

handoff calls. In designing the bandwidth degradation algorithm, we assume that a service with degraded QoS is better than an outright rejection of service requests. This algorithm is triggered when is triggered when the currently available bandwidth is insufficient to accept the arrived call, via levels of degradation, we progressively reduce the resources of some selected active calls in order to free enough resources to accommodate incoming calls. Liberated bandwidth should be added to the available bandwidth.

The BLD algorithm starts processing active calls and carrying non-real time applications, and if necessary it passes treating active calls and carrying real time tolerant applications. First, all calls from the same class are sorted in descending order of their bandwidths. Then the algorithm starts to reduce a bandwidth rate of each call c_j belonging to a set of calls D that have the highest bandwidth level (l_i). If at this level of degradation, released resources are greater than those requested, then the call will be accepted and the requested resource will be allocated.In the opposite case, by finding that the collected resources do not satisfy the constraints required by the arrived call, the set of degraded class D is updated to handling calls with the next highest level l_{i+1}. The procedure continues with the same pace to collect the requested resources, by satisfying that all calls in the set D will not be degraded more than the limit level of degradation. Accordingly, a call is removed from the set D if its bandwidth reaches $BW_{req,i}$ level in case of acceptance of a NC and $BW_{min,i}$ level in case of acceptance of a HC. The algorithm is stops if D becomes empty and there is no call to add.

In order to prioritize handover calls over new calls, the rate degradation of active calls will depend on the kind of call arrived. The following equations explain the rate degradation to accommodate an arrived call:

$$TD_h = \sum_{c_j \in D} \propto \%(BW_{asg,c_j} - BW_{min,c_j}) \qquad (2)$$

$$TD_n = \sum_{c_j \in D} \beta\%(BW_{asg,c_j} - BW_{min,c_j}) \qquad (3)$$

Here, we have:

- TD_h: The degradation rate of resource to accommodate the arrived handover call.
- TD_n: The degradation rate of resource to accommodate the arrived new call.
- BW_{asg,c_j}: The bandwidth assigned to a call c_j.
- α,β: The degradation factors.
- BW_c: The bandwidth call.
- BW_u: The used bandwidth.
- $BW_{thr,k}$: The threshold value of the resource reserved for applications of class k.

Now, we will consider two cases .In the first one if the available resources in the network are sufficient then the call will be easily acceptable in to the network else, high priority calls are accepted.

- $BW_{tot,j}$: The total resource capacity in the RAT_j .
- $BW_{avail,j,t}$: The available resource in the RAT_j at time t.
- $BW_{u,j,t}$: The used resources at time t.
- $BW_{asg,i,j,t}$:The assigned resource by the RAT_j to call i at time t.
- n: The total number of ongoing calls in the RAT_j at time t.

If we consider a least loaded cell, here the resource available will be sufficient to the requested service. For this the following condition must be satisfied

$$D_{r,i} < D_{max,i} \text{ And } BW_{req,i} + BW_{u,j,t} \le BW_{thr,k} \quad (4)$$

If the cell is loaded,
The call is accepted if the following condition is satisfied

$$D_{r,i} < D_{max,i} \text{ And } BW_{req,i} - TD_n \le BW_{thr,k} \qquad (5)$$

For handoff call,

$$D_{r,i} < D_{max,i} \text{ And } BW_{req,i} - TD_h \le BW_{thr,k} \qquad (6)$$

4. PERFORMANCE EVALUATION

4.1 Simulation parameters

Here, we investigate the performance of our proposed algorithm for heterogeneous wireless networks via simulation analysis using NS2 (Network Simulator 2) that allows modeling of heterogeneous wireless networks. In the network WiMax, 3GPP LTE Network, IEEE 802.11n WLAN are integrated in heterogeneous environment full radio coverage of the studied area. The service requests will be generated in a random manner because in real time the requests are random and can be generated at any time so, Poisson process with a mean arrival rate of λ (calls/s)is used. The channel holding times are exponentially distributed. Three types of traffic were considered: VoIP, Video streaming and Data on Demand. The mobility model used is Random Walk model. The system parameters used are shown in Table 1.

4.2 Simulation Results

The proposed CAC algorithm is compared with homogeneous wireless network [1] and heterogeneous wireless networks. Fig-5 shows the New Call Blocking Probability (NCBP) and Handoff Call Dropping Probability (HCDP) for non real time applications.

We notice an increase in NCBP and in HCDP following the increase in number of users in the network throughout the simulation analysis results. This can be justified by the increase in the number of resource blocks occupied causing the loading of the network. As shown in the Fig-5 and 6, we can see that the intervention of our algorithm enhances the values of blocking probabilities for both types of calls. By comparing the curves of the two schemes, we observe that the NCBP and the HCDP of the three Curves become non zero at different points; indeed, for our proposed CAC scheme Starting from the values of 2 users/second that the NCBP and the HCDP surpass zeros respectively.

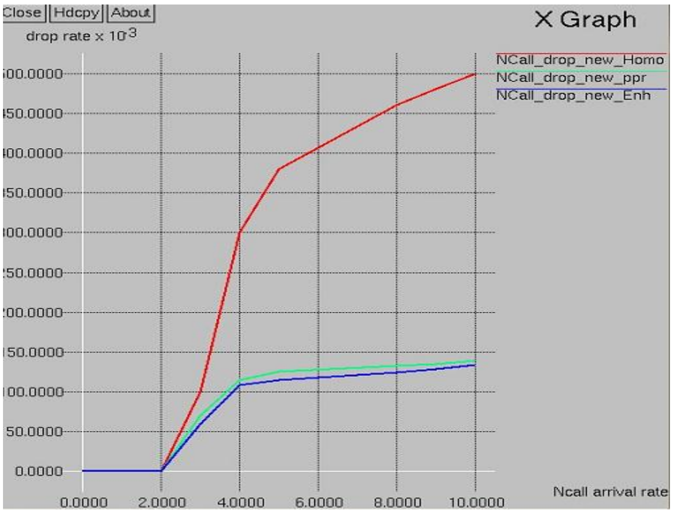

Fig-5: New call blocking probability for Non Real time service

If we observe the three curves, as homogeneous can only support single RAT it cannot support present generation requirements so both NCBP and HCDP are more compared to other two curves of HWNs as seen in fig-5 and fig-6.

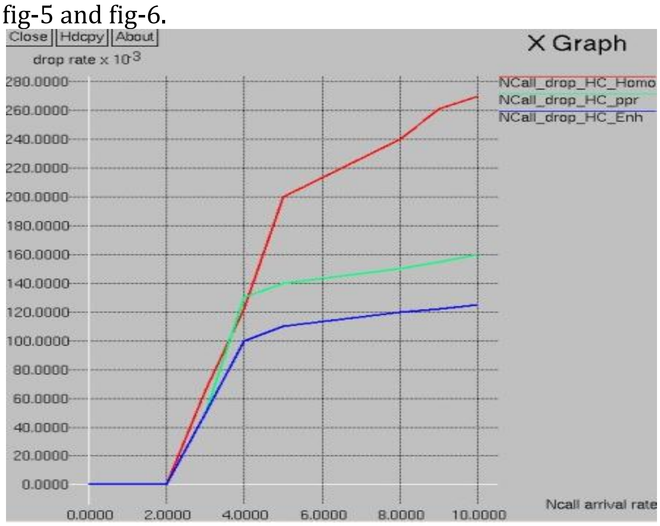

Fig-6: Handoff call dropping probability for Non Real time service

It can be seen that if we compare the curves of the two HWNs the curve of existing technique [3] is little more compared to proposed technique as we are considering multiple criteria selection and the user will receive the beacon messages by which the user can easily be connected to the RAT which give allocate the sufficient resources for the requested service.

The proposed BLD algorithm reduces progressively the number of resources of some selected active calls to collect the resources requested by incoming calls. Hence, our proposed CAC can accommodate more arrival calls compared to the CAC scheme in [3].

Table-1: Simulation Parameters

Parameters	Values
3GPP LTE System bandwidth WiMax System bandwidth	20 Mhz (100 RBs; 180 khz per 1RB) 30 Mhz (150 RBs;250 khz per 1RB)
VoIP : (RB_{max} ; RB_{req} ; RB_{min} ; D_{max})	1RB ; 1RB ; 1RB ; 300ms
Video streaming : ($RB_{max,}$; RB_{req} ; RB_{min} ; D_{max})	2RB ; 1RB ; 1RB ; 1500ms
Data on demand : ($RB_{max,}$; RB_{req} ; RB_{min} ; D_{max})	3RB ; 2RB ; 1RB ; 10000ms
Average connection holding time: VoIP; Video; Data	3min; 5min ; 9min
Simulation time	30min

Fig- 7 and fig-8 depicts the new call blocking probability and handoff call dropping probability versus call arrival rate demanding the real time intolerant traffic.

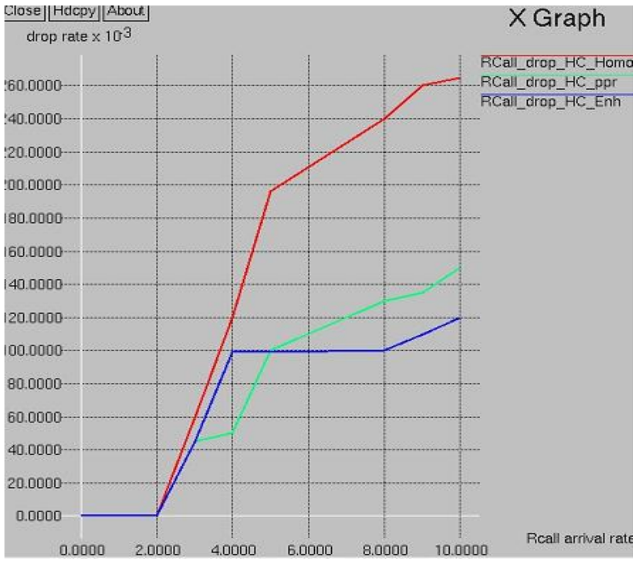

Fig-7: Handoff call dropping probability for Real time intolerant service

If the 3GPP LTE network cannot accommodate new calls then WiMax will allocate the resources if the users are under its coverage area. During handoff process, the other RAT will accommodate the resources to the mobile user. Suppose consider a case where a RAT1 is providing the resources to maximum no. of users it can accommodate then if a new user is requesting a service and it is not under the coverage of other RATs then, according to our algorithm if other users are under RAT2 coverage area then they will be connected to it while RAT1 will consider the new request else the call will be dropped in worst conditions.

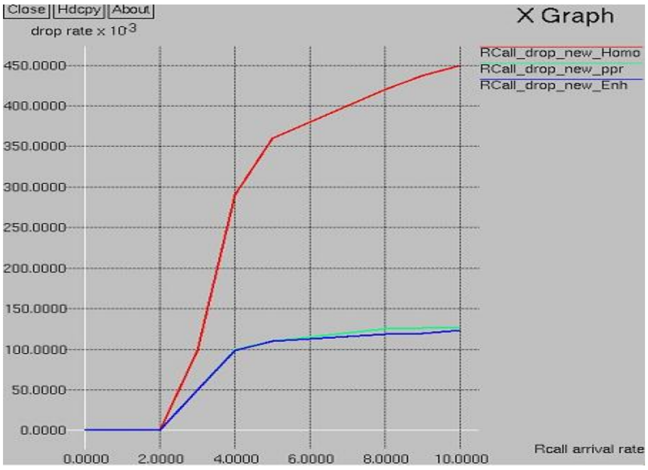

Fig-8: New call blocking probability for Real time intolerant service

5. Conclusion

As the homogeneous networks doesn't support the present wireless generation requirements, the heterogeneous wireless networks can overcome the issues which provide reliability, improves spectrum efficiency. A new CAC algorithm is introduced with adaptive bandwidth management which helps to meet the QoS requirements of present generation wireless networks. In future, as the next generation wireless network will be user-centric, users' preferences for a particular RAT will be considered in making call admission decisions.

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