Survey of Call Admission Control in Femtocell Network

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ABSTRACT: This paper talks about a call admission control method for integrated macrocell-femtocell base stations. Femtocell base stations are home base stations whose coverage area is very small. They are specially designed for indoor coverage and are used for home, office and apartment. Traditional call admission control methods can't directly apply on integrated macrocell-femtocell network as we have three different access modes called Open access, closed access & hybrid access mode in femtocell network which are absent in cellular network. For better access control, integrated macrocell femtocell network needs some modifications in traditional approach. In Open Access, the femtocell provide services to all users who come across its coverage area whereas closed access mode only register users can access femtocell services. On the hybrid access mode, service for both registered subscribers and non-registered subscribers is allowed and high priority is given to registered users. In this paper, we will discuss various existing call admission control algorithms for the integrated macrocell-femtocell network.

KEYWORDS: Femtocell Network, Call Admission Control, Handover Management, Femtocell Access Modes

I. INTRODUCTION

Capacity demands of modern mobile telecommunication networks have increased tremendously over past few years & it is kept on growing. Global Mobile Data Traffic Forecast by Cisco says that, At the end of 2016 mobile data traffic has reached to 7.2 exabytes per month & which will be around 49 exabytes per month by 2021 [1]. One of primary & major contributor for this tremendous global mobile data traffic is smart phones or other smart wireless devices which are using mobile networks worldwide. As per International Telecommunication Union research, with smartphone user data capacity is consumed on an average five times more than standard mobile phone users. Smartphone penetration is growing 30% per year and capacity demand increased by 70-200% per annum. Current traditional cellular network is already facing network capacity crisis issue so it is not able to deal with this data explosion & lot of users are left unsatisfied. Latest wireless technologies such as WCDMA, LTE etc. are not able to use advance application in effective manner just because of lack of resource availability.

Due to this capacity issue, development of new innovative technology concept has grown interest. Small cell design is one of such technology which helps us achieve better system capacity, better indoor coverage and higher data rate etc. Pico cell, femtocell are few examples of small cells. Femtocell is low power & less expensive way-out for achieving higher data rate. Research on wireless usage says that more than 70%- 75% data transactions & 30-40% voice calls are originated indoor. It will be great relief to service operator, if we offload this indoor traffic. The ability to offload a large amount of traffic to femto cellular networks from macro cellular networks is the most important benefit of the femtocell macrocell integrated network architecture. Femtocell network will also help to reduce the investment capital, the maintenance expenses, and the operational costs and improve the reliability of the cellular networks [3].

Femtocells are home base stations which are connected to the core network of cellular network via internet access technologies like DSL (Digital Subscription Line) and cable. Femtocells are a less expensive and faster way to offer

capacity and coverage to indoor premises like homes and offices. Call Admission control in integrated macrocell & femtocell is difficult due to following reasons:

1) Femtocell & macrocell network works on licensed spectrum & forms two tier heterogeneous network
2) Multiple femtocells are deployed over once macrocell coverage area
3) Femtocell has three different access mode called open, close & hybrid access mode.

Conventional call admission control algorithms used in macrocell cannot well satisfy the access modes efficiently in hierarchical macro/femto cell network [4]. In this Paper, We will discuss various approaches used for call admission control proposed by various authors in integrated macrocell- femtocell network. Section 2 highlights Call admission control Concept in femtocell network and related work. Section 3 discusses integrated macrocell femtocell network architecture which wills talk about important entities & network elements used in integrated femtocell & macrocell. Finally Section 4 has detailed survey of various existing call admission control algorithms &paper concludes with highlights & lowlights of proposed algorithms.

II. RELATED WORK

Ensuring the Quality of service of network and individual connection by appropriately managing the network resources is the basic idea of Call Admission control. Efficient Call Admission Control policy needs to have below characteristics [7]:

- For Handoff and new calls of different service class, CAC should establish a robust priority assigning mechanism
- It should have low call blocking probability
- Allocate resources fairly
- Achieve a high network throughput and
- Avoid congestion
- Maintain the planned coverage

Call admission control is defined as a technique which provides quality-of-service in a network by limiting the access to network resources [8]. Call admission control (CAC) is first control function imposed on a user for QoS provisioning. Due to limited and variable resources and user mobility, the design of call admission control algorithms for mobile cellular networks is challenging [8]. Fig. 2 helps us understand the basic concept of call admission control.
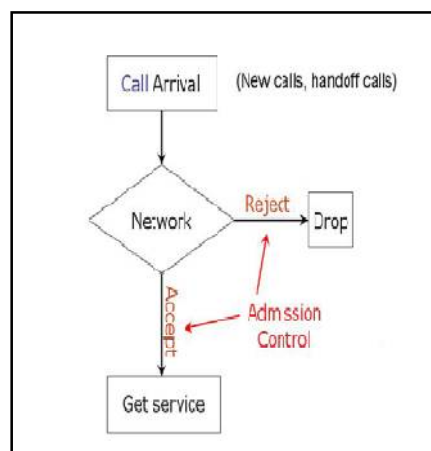

Fig. 2.The CAC decision process

When a user requests a new connection, what the CAC does is to calculate the amount of resources required by
(i) The users already in the system and
(ii) The pending user.

If the sum of the two is not larger than the total capacity, then the user's request will be acknowledged; otherwise, the request will be rejected.This is equivalent to first reserving resources for the admitted users and then checking if the remaining resources are sufficient to support the new connection.Different telephone operator decides required Call Admission control policy according to the needs of customer. The decision process of call admission control can often be formulated in a high level representation called the CAC policy. Let's see few call admission control approaches defined by various research authors in forth section.

III. INTEGRATED MACROCELL FEMTOCELL NETWORK
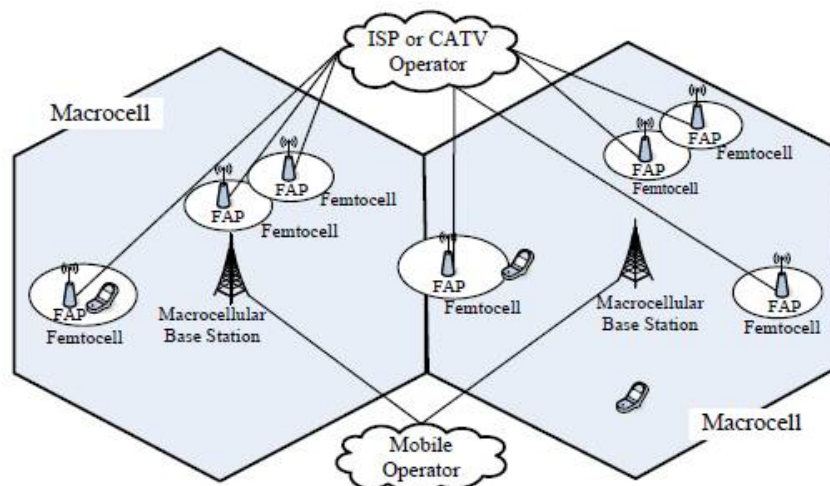
Source: Network Evolution and QoS Provisioning for Integrated Femtocell/Macrocell Networks [5]

Fig. 1.Integration of a macrocellular network with femtocells

Fig 1 shows integration of macro cellular network with femtocell. We need unique architecture for connecting femtocells to operator cellular networks. Integrated Macrocell-Femtocell network architecture should fulfill the security needs of operators and mobile users and also support the deployment of scalable femtocell networks that can serve millions of subscribers. The femtocell network architecture is designed to allow plug-and-play simplicity to install femtocells to ordinary consumers. Zero-touch service activation by the user is also supported by significant adaptive and self-organizing capabilities built into this architecture. Emergency calling services with the same accuracy and reliability as fixed-line emergency calling are also supported by femtocell network architecture, which can be delivered to mobile devices inside buildings [6].

Femtocell network architecture includes 3 key network elements and 2 network entities to support communication between femtocell & macrocell. Key network elements of femtocell network architecture are Femtocell access point, security gateway & Femtocell device management system. The primary node of femtocell network is femtocell Access point. It works as base station & base station controller in femtocell and communicate with the operator core network via the Internet. Network node of this architecture is Security gateway. Secure Internet connection between femtocell users and the mobile operator core network is maintained by security gateway. Femtocell device management system is third node & is located in operator network. Provisioning, activation and operational management of femtocells using industry standards such as TR-069 is done by femtocell device management system. It Ensures scalability & manages all online communication devices. We have two more entities which support femtocell network for actual call transactions along with above explained three network elements. Femtocell networks uses below two entities to enable communication between femtocell & macrocell.
1) Femtocell Convergence Server (FCS), Femtocell Network Gateway (FNG) for circuit switched calls
2) Packet data serving node PDSN or xGSN for packet calls

Femtocell network support 3 different access modes. To determine the service quality of femto users and the revenue of network operators, these three different access modes of a femtocell network plays a crucial role. The behavior of a femtocell is based on the access mode being adopted. Handover mechanism, interference management, security and resource management's metrics as well get influenced by access mode used by femtocell network [27]. Below are different access modes of femtocell network [27]:

1) *Close access Mode*: This mode provides access to only registered users. The CSG manager adds, removes and views the list of registered users. The only drawback of this mode is inefficient use of spectrum reserved for CSG in case there are very less registered Members.
2) *Open Access Mode*: In this, Access provided to all users. It's simple & no additional configuration is needed. Capacity of the FAP and the capacity of the backhaul connection are limiting factors for this mode.
3) *Hybrid Access Mode*: It is combination of close & open mode. Few resources are reserved for registered user & rest can be accessed by all who come across femtocell coverage area.

Due to this three different access modes, call admission control in femtocell network required special attention & careful design. Let's see basic call admission control concept before leading to actual survey of various call admission control strategies for femtocell network.

IV. SURVEY OF HANDOVER DECISION ALGORITHMS FOR FEMTOCELL

This section summarizes the main Call Admission Control strategies used for femtocell network, in current literature. Normally Call Admission control policies are divided in to two categories called Deterministic Call Admission Control and Stochastic Call Admission Control. QoS parameters are ensured with 100% confidence with deterministic call admission control [26]. Extensive knowledge of the system parameters such as user mobility is required for deterministic call admission control. On the other hand,QoS parameters are ensured with some probabilistic confidence in stochastic CAC. These schemes can achieve a higher utilization than deterministic approaches, by relaxing QoS guarantees [26]. CAC schemes can also be classified as proactive or reactive call admission control. Proactive call admission control is parameter-based admission control strategy whereas reactive is measurement-based. In proactive schemes [23], some predictive/analytical assessment of the QoS constraints is done &based on its result the incoming call is admitted or rejected. In reactive schemes [24], the incoming call might start transmission by transmitting some probing packets or using reduced power before the admission controller decides to admit or reject the call based on the QoS measurements during the transmission attempt at the beginning.Various other classification of call admission control strategies are investigated in the literature. As seen in last section, for femtocell network we have three different access modes so we have CAC classification based on access modes too. For Hybrid access mode, guard channel CAC policy is used & few channels are reserved for registered users. In this higher priority is given to registered users. For closed access CAC, first subscriber authentication is done and only registered users gets access to the service. Non-registered user gets rejected by this admission control approach. For open access call admission control, the users request gets addressed when we have required channels available. It does not require any special admission control approach just like closed & hybrid access mode. In this article, Various Call admission control policies proposed by various authors are classified based on below criteria

A. Threshold Based CAC
B. QoS Based CAC
C. Handoff Prioritized CAC
D. Soft Computing Based CAC

A. *THRESHOLD BASED CAC*

In 2013, Jie Wang and YangfanQiuintroduced a new call admission control (CAC) strategy for LTE femtocell networks [9]. This new approach supports diverse bandwidth requirements and multimedia services with different classes of traffic. In their work, they have taken care of subscriber authentication and queuing admission control. Here, Subscriber authentication is based on thresholds. When demand for physical resource block (PRB) service i is less then available PRB in the network then that subscriber is authenticated & his demand is addressed. The condition for admission can be expressed as follow:

$$PRB_i^{demand} \leqq PRB_i^{avail}$$

After this, Queuing concept is used for different class of services. Here all resources are distributed into subsets on a queue for different class of service. Few resources are reserved for best effort class service and public resources are used for real-time traffic. Demand of any class of service compared with its capacity threshold & call admission decision is taken. Fig. 3 shows Flowchart for this approach
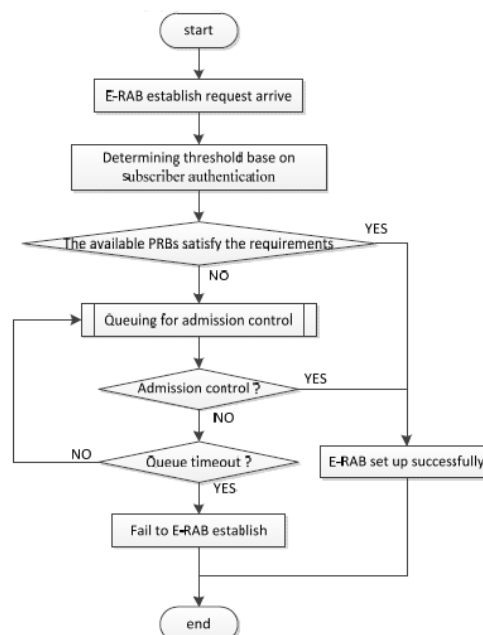

Fig. 3.Threshold Based CAC by Jie Wang and YangfanQiu

Jin-Seok Kim and Tae-Jin Lee propose a CAC mechanism taking into consideration of residence time in a cell [17]. Author consider the user type, the received signal level, the duration a UE maintains the signal level above the threshold level, the signal to interference level and the capacity (bandwidth) that one femtocell can accept. If the received signal level from the femtocell is higher than the threshold, the FGW checks whether the UE is preregistered or part of close subscriber group. If the UE is pre-registered, then call request is addressed. If the UE is not pre-registered, UE must stay in the femtocell area for the threshold time interval (T) during which a signal level is higher than the threshold signal level before continuing to the call admission control procedure. Thus the threshold time interval can reduce the number of unnecessary handovers. Call admission Control approach follows below psedocode

```
If (femtocell registered user or non-registered user)
    If (Femtocell registered user)
        If (RSSI > Threshold RSSI) &
        If (SNR > Threshold SNR) then
            Check Free channel
                If free channel available then
                    Accept registered users Call
                Else
                    Reject registered users Call
        Endif
        Endif
    else
        Reject non-registered users Call
    Endif
End
```

Fig. 4.Threshold Based CAC by Jin-Seok Kim and Tae-Jin Lee

B. *QOS BASED CAC*

Cristian Olariu, John Fitzpatrick, Philip Perry and Liam Murphy proposed QoS based call admission control policy for LTE femtocell network [10]. In their work, they have investigated the issue of maintaining call quality. In this approach, CAC decision is based on average call quality. This approach first calculates call quality for voice calls &Mean Opinion Score (MOS) for VoIP call is done. If average call quality for new call is less than 3.8 then no new call is accepted to maintain call quality. Quality rating is defined as good when it is more than 4 & any call quality less than that is poor. This is again part of threshold based CAC approach but here author considered quality threshold instead of capacity.The flowchart in Figure 5 describes the decision process.
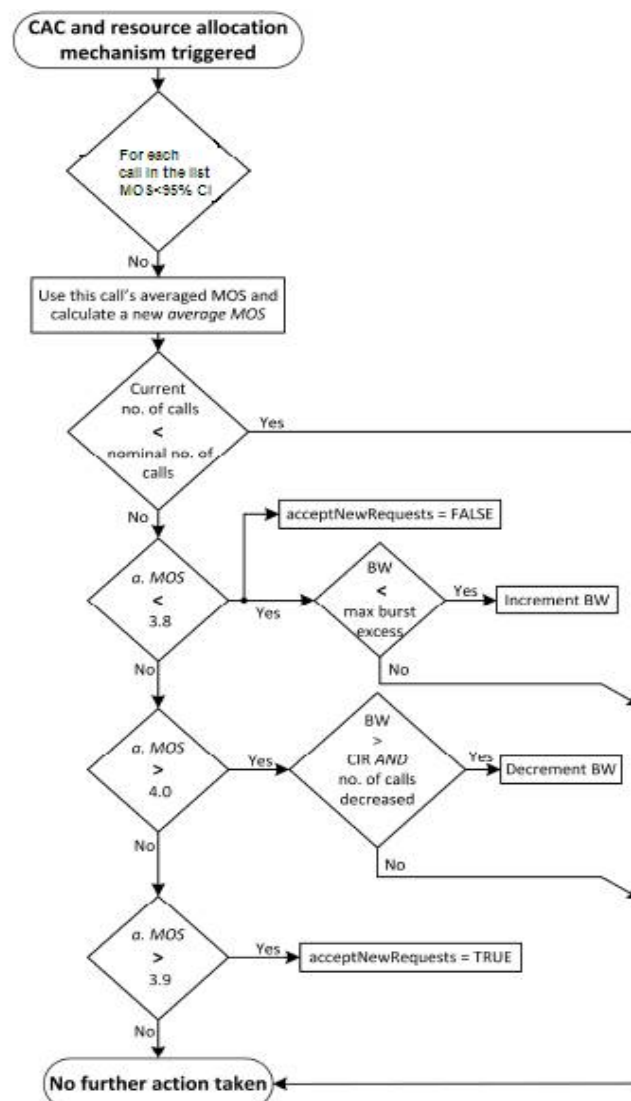

Fig. 5.QoS Based CAC by Cristian Olariu, John Fitzpatrick, Philip Perry and Liam Murphy

S. A. El-Dolil, A. Y. Al-nahari, M. I. Desouky and F. E. Abd El-samie proposed a model to investigate the received power based Multi-Cell Admission Control when multimedia traffic is considered with different QoS requirements. Fast power control is used with admission control after a new user is admitted to bring the system to a new equilibrium state in which every user try to reach its target signal to interference ratio. In their paper, they investigated trade-off in

the uplink direction using power-based Multi-Cell Admission Control (MC-AC) algorithm [19]. Proposed admission control algorithm estimates the increase in the total received power due to a new user and decides to accept or reject this user according to the current system state. Below Admission control condition is used in this approach

$$\Lambda_{est}^{own} < \Lambda th - \Lambda hr = \Lambda_{target}$$

Where,

Λ_{est}^{own} = Estimation of noise rise at the own cell after the new user has been admitted

Λhr = Head room parameterset as a safety margin to compensate for the estimation errors

Λth = Threshold noise rise

When Noise rise is below Λ_{target} after power control then call can be accepted else call is rejected.

S.-E. Elayoubi, T. Chahed, and G.He'buterne developed a novel CAC algorithm that combines the efficiency of Interference-call Admission Control and the simplicity of the number of user based call admission control approach, and that functions on both dedicated and shared channels [20]. In their article, the impact of other-cell interference on the capacity of a DS-CDMA cellular system is studied and analytical model introducing the inter-cell interference in the SIR expressions is developed. For the downlink, they focused on the conventional receiver because multiuser detection is not usually used in the mobile station and obtained the other-cell interference and the SIR.Using these expressions, CAC algorithm for UMTS, based on the notion of effective bandwidth is developed. Compared to classical Interference-call Admission Control algorithms, this CAC algorithm achieves better performance, by decreasing the dropping rate, and is simple to implement. To take advantage of the existence of two types of channels, namely dedicated and shared ones for the transport of real-time and non-real-time traffic, respectively, new strategy insures the priority of real-time calls on elastic ones and maximizes the resource utilization by squeezing elastic flows in the available resources.

C. HANDOFF PRIORITIZED CAC

In 2016, RadhiaKhdhir, Kais Mnif, Khitem Ben Ali and LotfiKammoun proposed CAC scheme which gives priority of Handoff Calls without neglecting the new calls requirements [11]. Depending on QoS parameters, two service classes for the coming calls are identified & higher priority is given to handoff calls. Guard channel policy is used for prioritizing handoff calls. Proposed CAC algorithm steps are explained as below:

1) Calls arrive specifying their QoS parameters.
2) Verify New call (NC) or Handoff calls (HC)
3) If the number of PRBs is sufficient then the call is accepted.
   Else
   a. Checkleng$HC<\rho HC$ Where, lengHC=The length of HC queue&ρHC = The threshold size of the HC queue. If true then proceed to next step, else the call is rejected.
   b. If this call is HC, then proceed to next step.
4) Verity type of Evolved Packet System bearer (GBR and NGBR classes)
5) Compare PRB demand for each class. If it is less than max allowed channels for that class.Then,
   a. For the NCs, If no resources are available the call is rejected, else the call is accepted.
   b. For the HCs, proceed to next step
6) Check $RB_{min}<RB_{avail,}$ If condition is true accept HC else Reject

O. A. Ojesanmi and R. F. Famutimi also proposed similar concept of prioritizing handoff calls [12]. It uses concept of preemption for prioritizing handoff calls. It improved system efficiency & guarantees QoS requirement but it has inefficient resource utilization and increased blocking probability of a new call. Fig. 6 shows Flowchart for this approach.
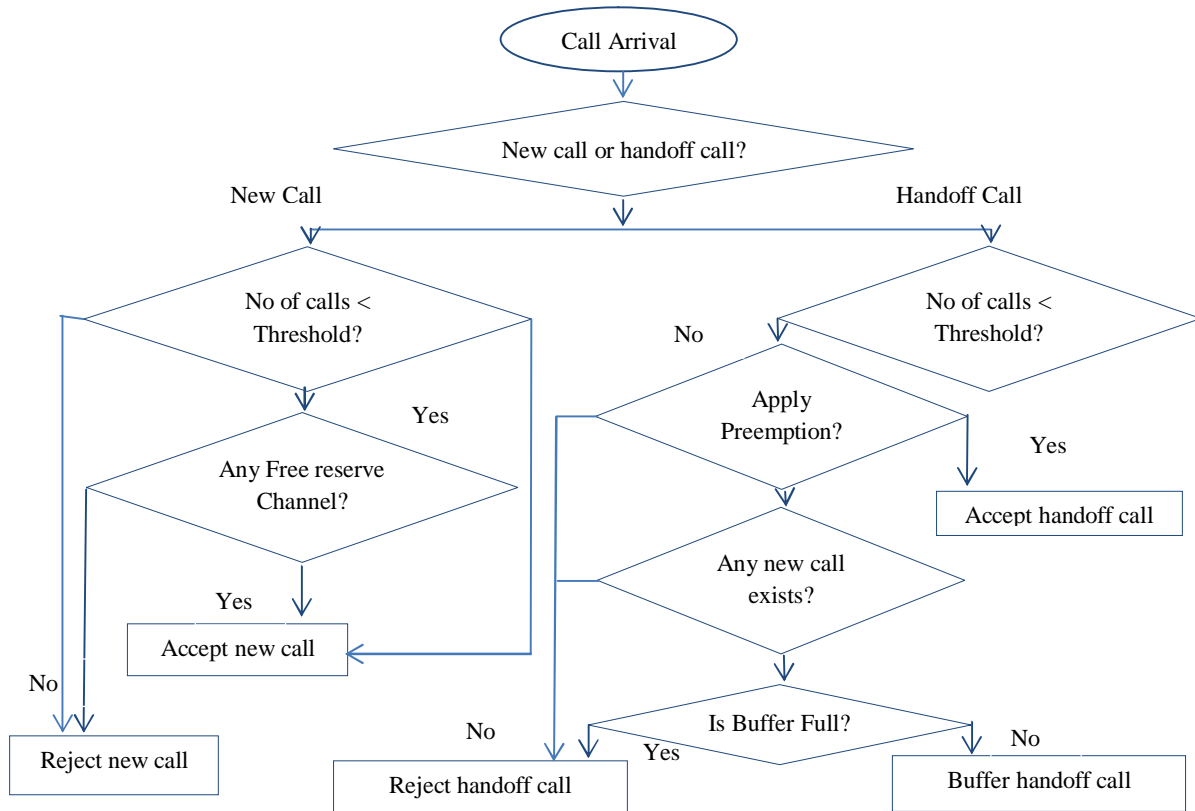
Fig. 6.Handoff Prioritised CAC by O. A. Ojesanmi and R. F. Famutimi

   T.O Oyebisi and O.A Ojesanmi proposed a new handoff prioritized CAC policy for wireless mobile multimedia networks [13]. It uses dynamic guard channel allocation scheme. This scheme guarantees QoS for both new and handoff calls. In this scheme author has introduced buffer concept to deal with real-time multimedia traffic. With this scheme call requests are queued until resources will be available later, if there are no available resources. Below fig 7 shows psudocode for this approach.

```
If (incoming request is new call or handoff call)
    If (there is a free channel) then
      allocate the free channel
    else
      If (handoff calls)
    put in a buffer
          If (there is free channel again)
      allocate the free channel to handoff call
        else
            Ignore request
          Endif
    else
          Ignore request
    endif
    ignore request
    End.
```

Fig. 7.Handoff Prioritised CAC by T.O Oyebisi and O.A Ojesanmi

Adaptive CAC framework for wireless cellular networks is proposed by N. Omheni, A. Gharsallah, F. Zarai and M. S. Obaidat[14]. Separation between the incoming traffic for each class is taken into consideration in this scheme. It prioritizes handoff calls over the new calls using reserved channels for handoff. It uses similar concept for call admission control as it is explained in psudocode of handoff prioritised CAC in fig 7. Hamid Beigy and M. R. Meybodi introduced a multi-threshold guard channel policy for call admission control [16]. There are N class of calls in the network and we use multiple thresholds for different classes & access N class of calls. Author gives analgorithm to find the optimal number of guard channels that minimizes the blocking probability of calls. It uses markov chain model for admission control. Total channels are divided into 2 subset (Tk< T_N). A callfrom class k or new calls (for k = 1... N) will be acceptedwhen the number of busy channels are smaller thanTk'& similarly class N or handoff calls will be accepted when the number of busy channels are smaller than T_N. Fig. 8 shows psedocode for this approach.

```
If (incoming request is new call or handoff call)
If (new call) then
      Capacity Demand <Tk,
      Accept new call
   Else
      Reject new call
   If (handoff calls)
      Capacity Demand < T_N,
         Accept handoff call
   Else
            Reject handoff call
endif
endif
End.
```

Fig. 8.Handoff Prioritised CAC by Hamid Beigy and M. R. Meybodi

D. SOFT COMPUTING BASED CAC

SunethNamal, KavehGhaboosi, Mehdi Bennis, Allen B. MacKenzie and MattiLatva-aho introduced an algorithm based on Reinforcement Learning for slot allocation to the traffic streams on different sub-carriers to be employed by each femtocell access point in order to mitigate the interference among femtocells and the underlaid macrocell [18]. To allocate sub-carriers to an incoming traffic, a femtocell maintains a counter for each sub-carrier and stochastically counts it down using the outage probability perceived on the sub-carrier. The traffic is assigned to a set of sub-carriers, for which the counter reaches zero within a predefined time interval. Once traffic streams are assigned to the sub-carriers, each femtocell access point independently runs an algorithm based on reinforcement learning to perform slot allocation for the traffic streams in each sub-carrier, which is meant for further interference mitigation among femtocells and the underlaid macrocell.Proposed admission control mechanism, is entirely stream oriented, which allows users to have more than one simultaneous traffic streams with different QoS requirements and makes the accounted system model be closer to the practical networks.

Mahesh G, Yeshwanth S andManikantan U V reviewed various Soft Computing (SC) techniques likeFuzzy Logic (FL), Neural Networks (NN) and GeneticAlgorithms (GA) for call admission control design [15]. Calldropping or rejection can be reduced to a greater extent by using soft computing Call admission control, which will help to have betterQuality of Service in the sphere of wirelesscommunications.Mahesh G, Yeshwanthand Dr.Gowrishankar proposed one fuzzy logic based CAC policy which addresses QoS issue in femtocell network. In this scheme, total bandwidth is divided into three parts viz. platinum gold and silver class [28]. Fig. 9 shows flowchart of Fuzzy logic based CAC
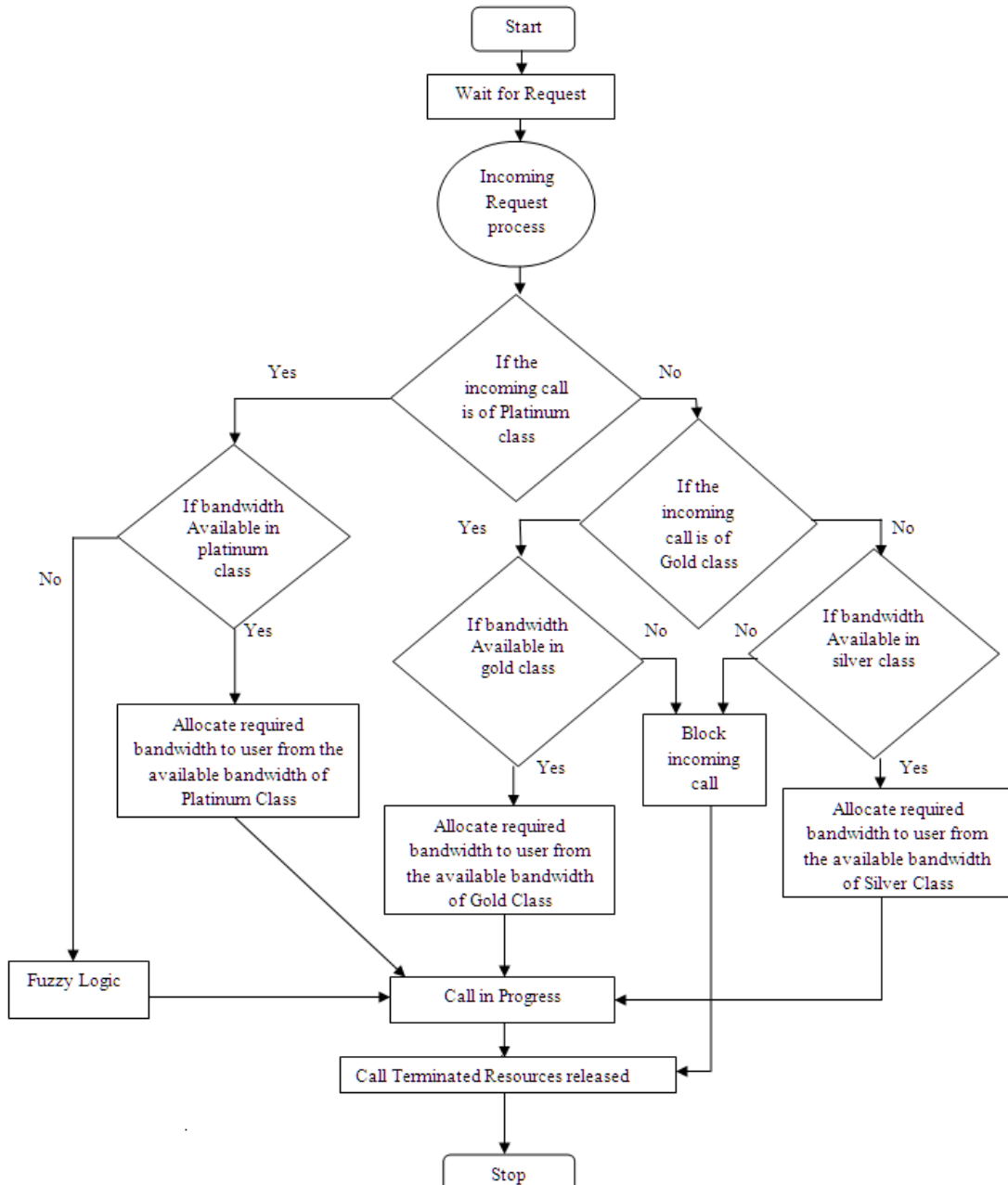
Fig. 9.Handoff Prioritised CAC by Mahesh G, Yeshwanth and Dr.Gowrishankar

V. CONCLUSIONS

The task of ensuring the admission of more user calls in spite of having limited radio resources is a challenging task in any wireless network. Femtocells have very small coverage area & they work in same licensed spectrum as macrocell hence call admission needs to be handled very carefully. Various access modes in femtocell even add difficulty level in the task of admission control. The quality of ongoing calls should be maintained by the admission strategy adopted for better resource utilization.In this paper, various call admission control algorithms are studied. Base ideas behind call admission strategy defined by various authors are discussed.

To develop novel approach of call admission control in two tire macrocell-femtocell networks, we need to focus on various CAC decision parameters, system model assumptions, QoS requirements and key features of algorithms. Even though huge research is going on admission control in integrated macrocell femtocell network, few issues left unsolved in this area. This comprehensive survey of Call admission control algorithms will give base to future research work in this field.

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BIOGRAPHY

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Sachin Gengaje has received his B.E. and M.E. degree in Electronics Engineering. He later his Ph.D from Bharti Vidyapeeth deemed University. There he pursued research on Image processing. He has huge industry as well as teaching experience in wireless communication and Image processing Domain. Dr. Sachin Gengaje is an author of numerous technical papers in the field of image processing, wireless communication. He is head of electronics department and professor since long. He has organised several national level conferences and technical events. His interests include: mobile and wireless biologically-inspired networks, femtocell network, Image Processing.