CALL ADMISSION CONTROL: A SURVEY

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Abstract
Availability and effective allocation of radio resources is one of the major challenges in addressing Quality of Service (QoS) in Cellular and wireless networks. This is as result of the mobility of users. Call Admission Control (CAC) is one of the major approaches to solving the challenges of scarce and efficient allocation of radio resources. Due to the characteristics of the mobile cellular networks, that is, the mobility of subscribers, randomness of the traffic demand, designing CAC systems is not an easy task. In this Survey, the different types of CAC algorithms and schemes were classified. The classification and discussion was carried out based on the nature of the network (homogeneous and heterogeneous), Conventional and Unconventional, Traditional CAC and Joint CAC etc., in order to have a good understanding of different CAC schemes in mobile cellular networks.

Keywords: CAC, Congestion, Handoff, JCAC, QoS

Introduction
The determination of optimal system parameters to match real traffic conditions is one of the major challenges of cellular mobile networks. The performance of the access network (i.e. radio part) broadly determines the performance of the entire mobile cellular network. The reduction in congestion, call drops, overload, and handover failure go a long way to improve the performance of the access network (Nurboja and Lipovac, 2013). Having a high QoS in mobile cellular network is a great challenge. The reasons for such a major challenge are the scarcity of radio resources, mobility of subscribers, and randomness of the traffic. Scarcity and inefficient radio resource allocation will ultimately lead to network congestion. Congestion is bound to occur in a scenario whereby the available link capacity is less than the input rate:

$$\sum \text{Available Link Capacity} < \text{Input Rate} \quad (1)$$

By regulating the traffic flow in network nodes, saturation or over loading can be avoided. This is one of the objectives of congestion control and avoidance. Various congestion control systems achieve this objective by matching the available link capacity to the input rates.

Congestion has adverse effect on the mobile cellular network. Some of the effects are high rate of queuing which results into increased delay, reduction in throughput which is caused by loss of packets and the buffer overflow (Emmadi &Venkatesh, 2004; Jain,1996).
Congestion Control in Cellular Network can be approached from two perspective; Call level Controls and Cell level Controls. Call level controls prevent congestion by not allowing new

calls or connections into the network unless the network has sufficient capacity to support them. Call Admission Control (CAC) is one of the call level control approach to congestion control. At the Cell level, the input rates of the different traffic sources are controlled in order to avoid and reduce congestion. Traffic policing, Leaky bucket, traffic shaping are examples of the Cell levelcongestion control (Heo, Byun, Lee, Sung & Lee, 2000). The focus of this work will be on CAC as a Congestion control technique.

In order to achieve a high QoS in cellular network, the importance of CAC cannot be over emphasize. It controls the access to network resources so as to avoid congestion of the network and degradation of radio resources available to subscribers who are already connected which may lead to call drop. In wireless networks, another dimension is added: Call connection or call dropping is possible due to the users' mobility.

The CAC system accepts the request by a new call on the basis that there are radio resources that are idle and will not adversely affect the QoS of call that have been accepted. In the design of an efficient CAC scheme, call blocking and call dropping parameters have to be taken into consideration. There must be a balance in between the two parameters.

CAC schemes were designed for the first and second generation of mobile cellular systems where primarily for the single service, that is voice. Whereas the CAC schemes for third generation mobile systems are much more complex. This is as result of the multi-service (video, data and voice) environment of the third generation (Fang & Zhang, 2002;Hu & Sharma, 2003;Majid &Boutaba, 2006;Leong &Zhuang, 2002; Ahmed, 2005; Patil &Deshmukh, 2013).

Basic Concepts

CAC is the process of regulating new calls and handoff calls into a resource-constrained wireless networks so that a high QoS is guaranteed. The mobile cellular network is a resource constrained network. Bearer modification, handoff call arrival and new call arrival are mainly the occurrences that initiate a process of CAC algorithms as shown in Figure 1 (Leong & Zhuang, 1996). When a mobile subscriber wants to communicate with another subscriber, the mobile terminal will request for radio resources from the base station it hears well. If a channel is available, the base station grants it and a new call originates. The process of moving between cells when a subscriber (Party A) is already connected to Party B is called a "handoff". During this process the mobile terminal requests resources from the base station in the cell it is moving to (Majid & Boutaba, 2006).

The service request of a mobile user may be denied or agreed to. When the service request is denied, this is generally known as Call Blocking. The Probability that a users' request will be blocked is called the Call Blocking Probability (P_b). Availability of radio resources will determine the success of a handoff call. The Probability of a handoff failure is otherwise known as the handoff failure probability (P_f). When there is no available resources for the call to handoff to a new a cell, the user's call will be terminated. This is known as Call Drop. Theprobability of the call dropping is otherwise known as Call Dropping Probability (P_d).

Subscribers find call drop more irritating than the request for a new call being blocked. In most CAC schemes, new calls have lesser priority than handoff calls in the bid to access resources. This will result to an increase in the new call blocking rate (Majid & Boutaba, 2006; Leong & Zhuang, 2002; Ahmed, 2005; Patil & Deshmukh, 2013; Leong & Zhuang, 1996; Perros &Elsayed, 1996).

A widely accepted way of prioritizing handoff calls over new calls is to allot apart of the available resources in each cell to be for handoffs only. If we represent the handoffs during a call by *H*, being a random variable, therefore

$$p_d = 1 - (1 - p_f)^H \tag{2}$$

Therefore,

$$p_d = 1 - \sum_{h=0}^{\infty} (1 - p_f)^h \Pr(H = h) \tag{3}$$

The Call Blocking Probability (P_b), Call Completion Probability (P_c) and Call Drop Probability (P_d) are all related as shown in equation 4.

$$P_c = (1 - P_b)(1 - P_d) \tag{4}$$

However, Call Blocking and Call Dropping are key parameters that affect the Quality of Services of Cellular Networks, Figure 2 clearly depicts this. These two parameters are addressed in virtually all CAC algorithms.

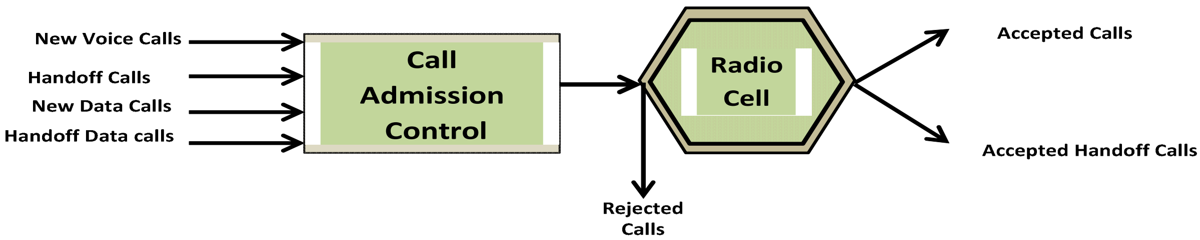

Figure 1: A Typical System Traffic Model under CAC

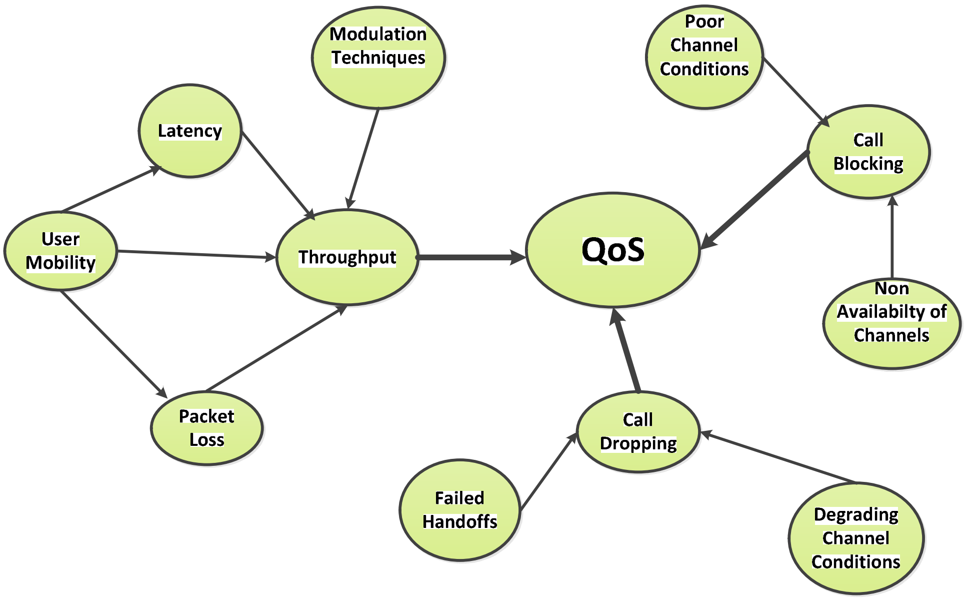

Figure 2: Factors affecting QoS

Channel Assignment Schemes

There are three (3) categories of Channel Assignment Schemes. Namely: (1) Fixed Channel Allocation (FCA); (2) Dynamic Channel Allocation (DCA); (3) Hybrid Channel Allocation (HCA). The simplest strategy (FCA) is to permanently allot radio channels to cells in a manner that the channel reuse constraint can never be violated even if all channels of all cells are used simultaneously. The common fundamental idea in all FCA schemes is the perdurable assignment of a set of radio resources to each cell. In the basic FCA strategy, a new call or a handoff call can only be handled if the idle radio resources are available in the cell; otherwise, the call should be blocked. In FCA systems, the role of MSC is restricted. The MSC is to update the new BS about handoff requests, and to receive a acceptance or denial message from the new base station, with respect to the handoff. Though FCA strategies are not complex, they do not adjust to the dynamic nature of mobile traffic. An unfavorable quality of FCA schemes is that whenever the number of calls is greater than the number of assigned channels, calls will be blocked irrespective of whether neighbouring base stations do have free radio resources (Katzela & Naghshineh, 1996; Mishra & Saxena, 2012; Katzis,Pearce & Grace, 2004; Tokpo Ovengalt, Djouani & Kurien, 2014).

To overcome the limitations of FCA, another strategy called dynamic channel allocation (DCA) (Majid & Boutaba, 2006; Mishra & Saxena, 2012; Katzis, Pearce & Grace, 2004), in which Channels are dynamically assigned to the cells are used. Contrasts to FCA, in DCA available radio resources are reserved in a global pool and from there channels are allocated to the cells on demand as per their need.

The idea of DCA is that base stations attempt to retain channel user pattern similar to FCA, in as much as it in consonance with the existing traffic distribution. In general, requirements of a good DCA scheme is to take care of two aspects-- first is to maximize channel uses by maximizing the reuse of various channels in the system; second during dynamic system implementation minimum information exchange among base stations should be less. Hence, the DCA strategy should maintain, as far as possible, the maximum packing of channels. In an ideal DCA, at any time, a call request should be satisfied, provided that the sufficient channels are available in the system in any cell. Such an ideal DCA is impractical because, It requires online modification of the carrier-to-cell assignment in the entire networkand hence, turning up into a considerably large signaling overhead. In a pure DCA scheme, it is assumed that the whole set of channels belongs to a common pool and the allocations are performed on a call-by-call basis according to certain frequency reuse criteria, frequency usage and future call blocking probability (Mishra & Saxena, 2012; Katzis, Pearce & Grace, 2004).

Another scheme of channel allocation is called hybrid channel allocation (HCA), is a unification of DCA and FCA schemes. HCA schemes combine the advantages of both DCA and FCA. HCA scheme allocates some channels statically and other channels dynamically. This scheme, the channels are separated into fixed and dynamic sets. The FCA schemes assign the fixed set to each cell, while the different base stations share the dynamic set of channels. Different types of DCA schemes can apply in the process of allocation of channel for dynamic sets. When a mobile subscriber requests for a channel for its call, and all the channels in the fixed set are busy, then a request from the dynamic set is made. The proportion of the number of fixed and dynamic channels is a major factor in deciding QoS of the system in HCA (Mishra & Saxena, 2012; Katzis, Pearce & Grace, 2004).A comparison of the three (3) allocation schemes is shown in Table 1.

Table 1: Comparison of the FCA, DCA and HCA Schemes (Mishra & Saxena, 2012)

Performance Metrics	FCA	DCA	HCA
Channel Allocation	Do not change during processing of calls	Changes Dynamically	Changes Dynamically
Minimum Reusable Distance	Follow	Follow	Follow
Complexity	Less	More	Moderate
Uniform Traffic Distribution	Good	Not Good	Not Good
Non Uniform Traffic Distribution	Not Good	Good	Good
Implementation Cost	Low	High	Moderate
Role of MSC	Less	More	Moderate
Channel Utilization	Less	More	More
Flexibility	Less	More	Moderate
Awareness of Network	Full	Partial	Partial
Efficiency	More	Less	Less

Classification of CAC Schemes

CAC can be categorized based on the nature of the cellular Networks. Cellular Networks can be viewed from the perspective of Homogeneous (HMN) and Heterogeneous Networks (HTN). HMN employ the use of Traditional CAC schemes. The CACs for HMN determine the acceptance of rejection of a new call or handoff call into the HMN network.

Heterogeneous network architectures i.e beyond the third generation networks (B3G) require more than the single solution provided by traditional CAC meant for homogeneous systems. The restriction (single solution) of traditional CAC schemes galvanizes the advancement of the Joint Call Admission Control (JCAC) algorithms for HTN. In HTN, no single radio access technologies (RAT) can deliver a universal coverage and constant high levels of QoS over various spaces like offices, homes etc. as clearly shown in Figure 3. Hence, the concurrent use of diverse RATs calls for the use of Joint Radio Resource Management (JRRM). JRRM intensify high QoS, effective and efficient utilization of radio resources. One of the well-known JRRM techniques in B3G network is the JCAC.

Furthermore, the JCAC determines the best RAT that will suite a new or handoff call request. This is pictorially represented in Figure 4. The base station that has the strongest signal strength serves a mobile terminal in HMN. While in HMN, signals that have weak strengths from other base stations are considered inimical i.e. interference. Whereas in HTN, signals with weak strengths can be maximized for high performance. In HTN intelligent resource coordination among base stations and exceptional server selection furnish appreciable gains in terms of high throughput and superb user experience as compared to a conventional approach of deploying cellular network infrastructure (Qualcomm, 2011; Ramesh Babu, Gowri & Satyanarayana, 2009; Falowo & Chan, 2006b; Falowo & Chan, 2008; Pacheco-Paramo, Pla, Casares-Giner & Martinez-Bauset, 2011; Liu, Zhou, Pissinou & Makki, 2011; George & Adalla, 2014;Falowo & Chan, 2007; Suleiman, Chan & Dlodlo, 2006).In (Majid & Boutaba, 2006; Kolate, Patil & Bhide, 2012) Traditional CACs was categorized into: Deterministic Call Admission Control and Stochastic Call Admission Control.

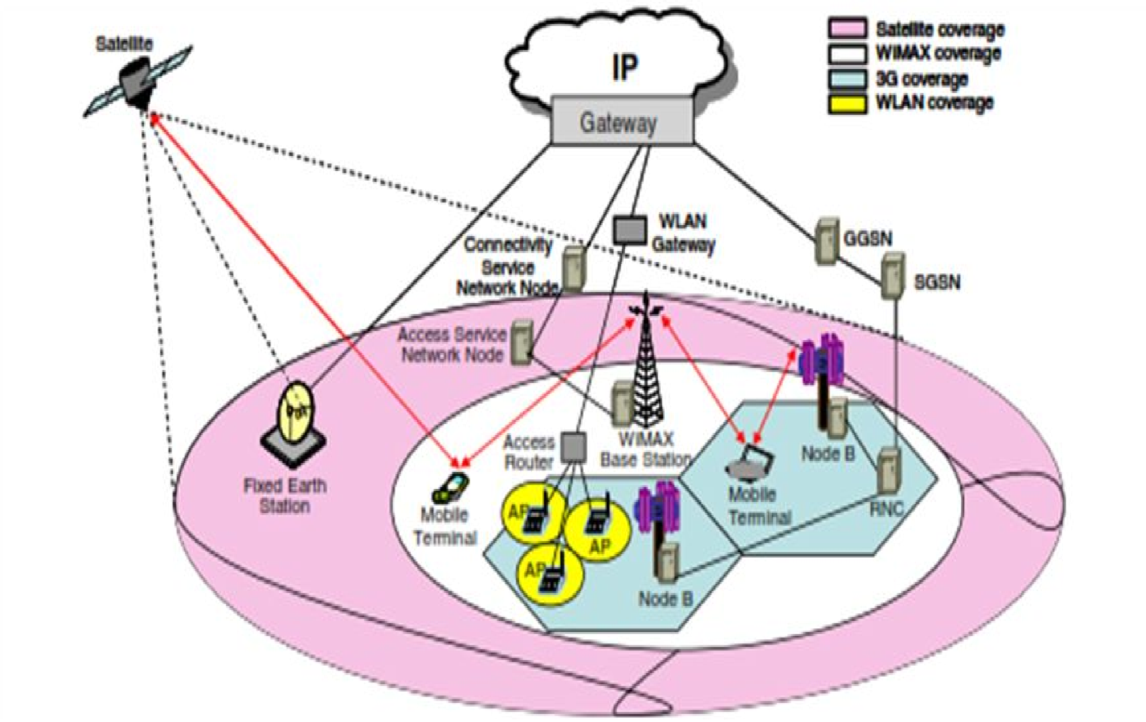

Figure 3: An Example of Heterogeneous Network (Source: Falowo & Chan, 2008a)

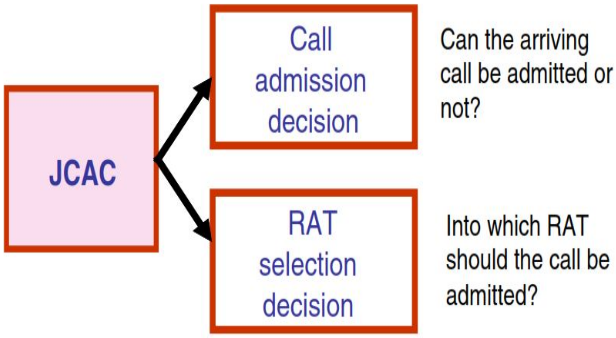

Figure 4: Basic function of JCAC (Source: Falowo & Chan, 2008a)

Deterministic and Stochastic CAC

Deterministic CAC: In Deterministic CAC schemes, there is a call for comprehensive knowledge of the system parameters such as the mobility of the user, or sacrifice the scarce radio resources to satisfy the deterministic QoS bounds. The system parameters required are vendor or equipment dependent which might be hard to come by. In deterministic CAC, QoS parameters are guaranteed with hundred percent confidence (Kolate, Patil & Bhide, 2012; Tostes, Duarte-Figueiredo & Zarate, 2011).

Stochastic CAC: In recent times, the research focus is majorly on Stochastic CAC because it is vendor or operator independent and thereby requires less knowledge of the system parameters. High QoS is not hundred percent guaranteed but it is probabilistic. Stochastic schemes can deliver an appreciable level of utilization than the deterministic schemes by relaxing show QoS conditions (Kolate, Patil & Bhide, 2012).In the rest of this paper, we discuss each category in detail. In some cases, we will further expand this basic classification.

However, in (Tostes, Duarte-Figueiredo & Zarate, 2011), the classification in (Majid & Boutaba, 2006) and (Kolate, Patil & Bhide, 2012), that is Deterministic and Stochastic CAC were further re-categorised into Conventional and Unconventional CAC. The conventional CACs use prioritization of calls, resources reservation and borrowing of channels. The CACs that apply computational intelligence methods associated with the traditional techniques are classified as unconventional CACs. Among the methods used, there are the artificial neural networks, fuzzy logic, genetic algorithms and statistical methods. Figure 5 shows a classification of Traditional CAC schemes for cellular networks.

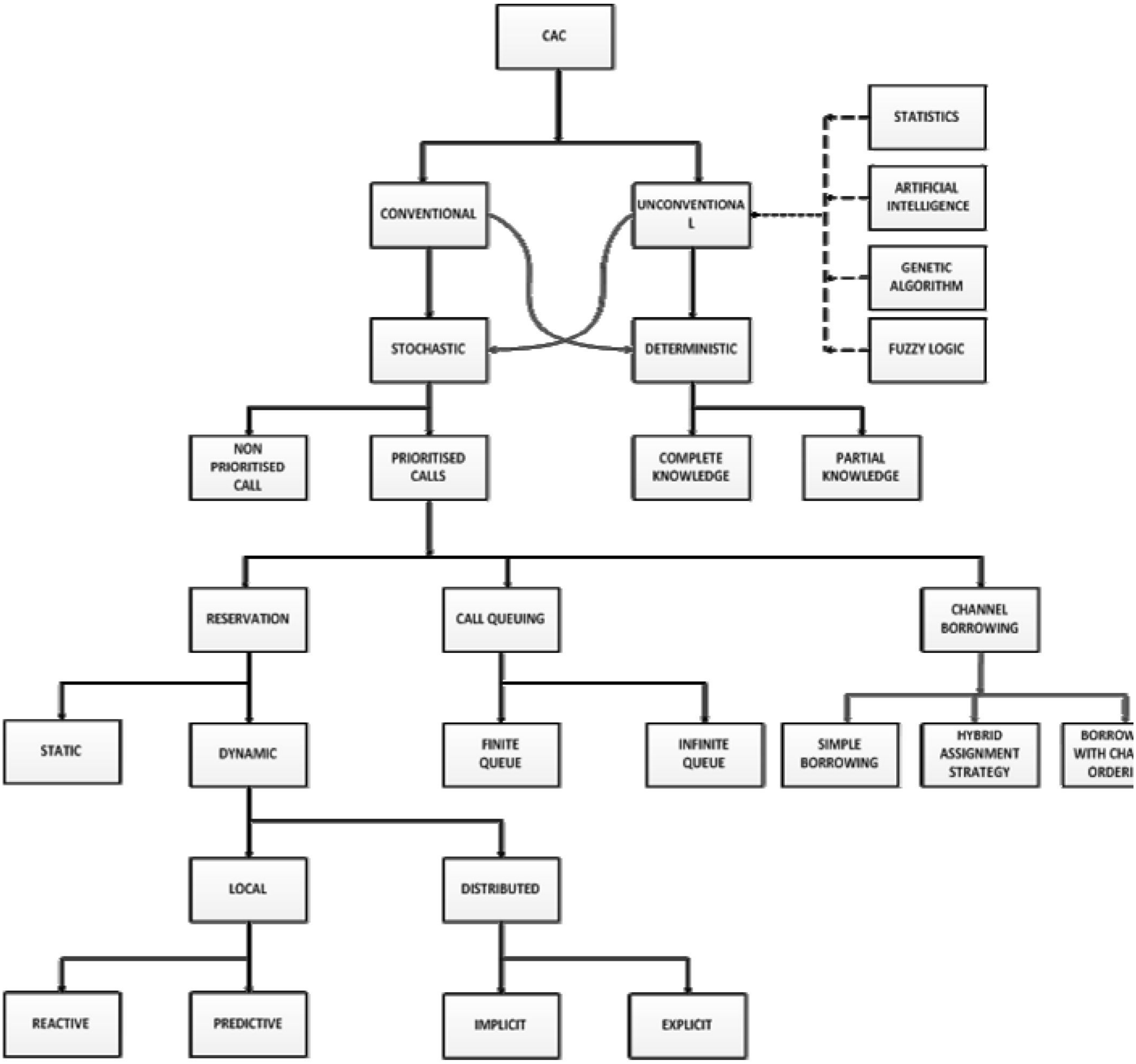

Figure 5: Traditional CAC Classification

Channel Borrowing Schemes

Channel Borrowing (CB) is a melding of DCA and FCA. A channel set is normally allotted to each cell (like in FCA). In CB, a cell borrows radio resources i.e. channels from other cells to integrate the incoming new or handoff calls, in as much as the borrowed channels do not interfere with the ones used by existing calls (at this point it works like DCA). Otherwise the call is blocked. The channel borrowing schemes are more flexible in the sense that by "moving" (borrowing) channels from less busy cells to more busy cells, a balanced performance throughout in the system can be achieved. Borrowing a channel *x* carries a penalty: cells that were originally allocated this channel *x*, may not be able to use this channel, since they may be within the co-channel interference range of the cell that borrowed the channel. Thus the decreased blocking probability at the cell that borrowed a channel is obtained at the cost of decreasing the capacity of other cells, which in turn causes QoS degradation in these cells. The basic channel borrowing strategy gives better performance (lower rate of call blocking) than FCA strategy under light and moderate traffic conditions, especially under unbalanced traffic.

Call Queuing

In Call Queuing the admission controller keeps trail of the free channels available for all the three user classes. When a user call of a particular class requests for a channel, the admission controller admits the user call request only if there are free channels available for that particular user class else the user call requests is queued. The admission controller does this process without disturbing the QoS of the existing user calls in the system. The main idea in this model is to minimize the denial of service at any point of time. Delaying the service by a small time is considered better than not providing service at all. Hence in this model if a class of users finds that all channels belonging to its class are occupied, and then instead of dropping the call they are queued in appropriate queue class (Mahesh, Gowrishnkar & Ramesh Babu, 2012). However the bearable time spent in queues is a distinctive parameter. The impatience of users by reneging of new and handoff calls that has been queued greatly affects performance of queuing schemes. Queuing schemes in times past have been employed in circuit-switched voice calls. It is quite challenging to implement queuing schemes multiple service environment. The blocking Probability of an Originating call i.e. new call (B_n) and also the blocking Probability of a handoff request (B_h) are given by the following expression (Sindal & Tokekar, 2012).

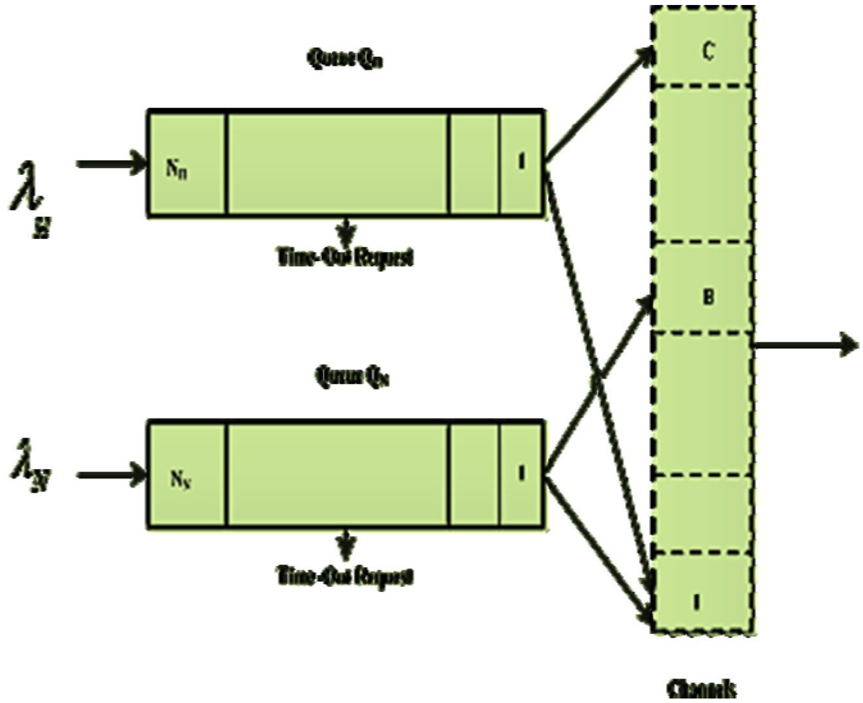

Figure 6: Model of the Complete Queuing CAC Scheme (Source: Sindal & Tokekar, 2012)

$$B_n = \sum_{i=B}^{C+N_H} p(i, N_N) \quad (5)$$

$$B_h = \sum p(C + N_H, j) \quad (6)$$

Reservation Schemes

In the early 1980s, the concept of guard channels was brought about as a CAC schemes. Guard Channel schemes prioritize handoffs over the new calls. The GC allots a group of radio channels on a permanent basis to specifically attend to handoff calls. For a cellular network having *C* number of channels in a cell, the GC allots a class of channels, *C-T* to handle handoff calls. Where *T* is a threshold set for channel occupancy. Whenever *T* is exceeded, new calls will be rejected by the GC until the utilization of the channel goes below the *T*. Generally the assumption is the arrival process of handoff and new calls is poisson in nature. Let the arrival rate of new call and handoff call be denoted by v and λ. The call holding time and cell residency for both types of call is exponentially distributed with mean $1/\mu$ and $1/\eta$ respectively.

Therefore

$$\rho = (\lambda + v) / (\mu + \eta) \quad (7)$$

Where ρ stands for the intensity of the traffic or otherwise traffic intensity

The traffic intensity characterizes the condition of a cell with respect to number of channels that are not in idle mode in the cells. The continuous time markov chain having *C* states can be employed to model the channel occupancy which is related to the traffic intensity. This is shown in Figure 7. From the markov chain it is easy to derive the steady-state probability P_n, that *n* channels are busy (Majid & Boutaba, 2006)

$$P_n = \begin{cases} \left(\dfrac{\rho^n}{n!}\right) P_0, & 0 \le n \le T \\ \rho^T \left(\dfrac{v^{n-T}}{n!}\right) P_o, & T \le n \le C \end{cases} \quad (8)$$

where

$$P_0 = \left[\sum_{n=0}^{T} \frac{\rho^n}{n!} + \rho^T \sum_{n=T+1}^{C} \frac{v^{n-T}}{n!} \right]^{-1} \quad (9)$$

And then $P_b = \sum_{n=T+1}^{C} P_n$ and $P_f = P_C$

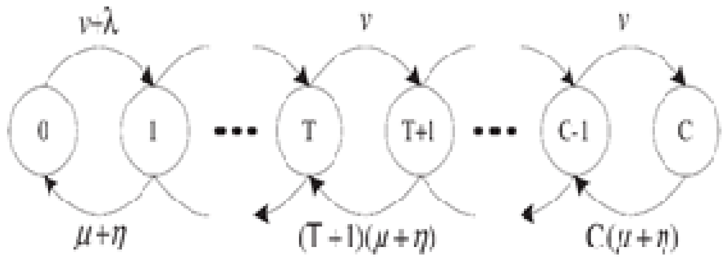

Figure 7: State Transition of the Guard Channel Scheme

The major challenge with GC schemes is the determination of maximum number of channels reserved as GC. Moderately choosing the number of GC can adversely affect the CAC effectiveness by increase of the P_d. Hence there is a need for the compromise between minimizing P_d and minimizing P_b.

Static Reservation Schemes

In (Hong & Rappaport, 1986), permanent channels were reserved for handoffs, which gave handoff calls priority over new calls. The Static reservation of channels reduced the handoff blocking in comparison with CACs without priority calls. The call drop probability decreases drastically when comparisons is done with probability of blocking new calls even as the number of guard channel is increased.

Poor utilization of resources of one of the limitations of the static schemes. To overcome this limitation, the allocation of guard channel is made to be dynamic in relation to the real traffic conditions and the rate of call drops as proposed in different dynamic reservation techniques. The reserved channels will increase whenever the probability of call drop P_d increases. Similarly, the reserved channels will decrease in number when the there is a dip in the probability of call drop P_d(Majid & Boutaba, 2006; Katzela & Naghshineh, 1996; Tostes, Duarte-Figueiredo & Zarate, 2011; Bozkurt, Akdeniz & Ucar, 2010; Tripathy, Sharma & Talhi, 2009; El-Dolil, Al-nahari, Desouky &Abd El-samie, 2007; Hong & Rappaport, 1986).

Dynamic Reservation Scheme

Dynamic reservation can be categorized into: Local and Distributed schemes. In local schemes, local information is used in the determination of the estimates of each cell and this is what used in adjusting the reservation threshold (Majid & Boutaba, 2006). Local schemes though are not complex by design and implementation; they have a drawback of not being up to date with traffic changes in the network, in other words they are deficient when it comes to network-wide information.

In Majid and Boutaba (2006), local schemes were further classified into reactive and Predictive techniques. In reactive approaches, the CAC adjust the decision parameters because of trigger events like arrival of new and handoff call, acceptance or denial of requests.

In Predictive techniques, the CAC is able to foretell events that will happen later, and then adapt before they occur so as to avoid service deterioration and in essence poor QoS By using modeling techniques on the information resident in eachcell, predictive schemes can determine the global condition of the network (Majid & Boutaba, 2006).

Distributed Schemes

Cells in distributed schemes collect network information in cooperation with other neighbouring cells. The information gathered is then used in adjusting the reservation threshold. Though distributed schemes have complex design, high signaling overhead; they have the ability to keep track of network–wide information.

In Distributed Call Admission Schemes (DCA), information sharing among neighbouring cells is done periodically and not on the instance of a call. The DCA decision is based on real time traffic information, unlike the predictive schemes that rely much on computational prediction (Naghshimeh & Schwartz, 1996; Si Wu & Wong, 1998).

As the load increases, DCA becomes unstable and the dropping probability dips. In Levine, Akyildiz and Naghshineh (1997) the concept of shadow cluster was proposed to address the limitation of DCA. In shadow cluster, all active mobile terminal influences the cells in their surroundings of its current location and also along the path they travel. The shadow cluster make use of the traffic distribution and pattern information; bandwidth demand of each mobile terminal. It is an adaptive and proactive scheme; hence reservation of resources is done spontaneously. The use of shadow cluster reduced the number of handoff failures and also there was also a reduction in drop of already connected calls. This scheme is well suited or small cell sizes, which require an appreciable number of handoff for average call duration. The shadow cluster concept is distributed in nature (Levine, Akyildiz & Naghshineh, 1997).

Classification of JCAC

In Suleiman, Chan and Dlodlo (2006) a hierarchical approach to JCAC, it was categorized into two; namely, horizontal call admission control (HCAC) and vertical call admission control (VCAC).

HCAC decides whether or not to admit a certain call to the access network. In the case of access technologies where there are multiple cells, the HCAC in a cell periodically shares traffic information with HCACs in neighbouring cells to predict future traffic conditions. In such cases, it dynamically adjusts threshold values using the knowledge of the current traffic condition in its domain and neighbouring cells.

In addition, HCAC respond to the VCAC queries of call denial or acceptance and also queries related to the determination of the network status. This is done by updating the VCAC periodically.

The HCAC can be deployed in either of two modes: centralized or decentralized. In the centralized mode, for each access network an HCAC protocol that manages its admission will reside in the central RRM. For example, if there are 3 access networks that an RRM controls, then there will be three HCACs in it. In the decentralized mode, there will be anHCAC in each access network. There are many advantages that the latter alternative offers over the first one. For example, it prevents waste of resources

VCAC controls inter domain admission policy to distribute calls among the different access networks that are integrated at a certain area. The VCAC is triggered by three events: new call, necessary handoff and desirable handoff. In the case of a new call, VCAC queries all the HCACs that are close to the subscriber in order to determine traffic information. The query results are used to determine the best access network that meets the call requirement of the subscriber. Not all access networks are necessarily available to a service type at a certain location. Hence, when a user travel through the HTN, there is a chance that the access network to which the mobile terminal (MT) is connected is not available at certain locations. In this case, the HCAC will know that a vertical handoff is necessary and it informs the VCAC about this situation. Then the VCAC will choose the best access network to admit this call.

For the desirable handoff scenario, Even though the VCAC considers load balance when it admits new calls, because of departures of calls, load imbalance occurs. The VCAC periodically examines the traffic conditions of the different access networks using the report that it receives from individual HCACs. When the load imbalance approaches a certain threshold, the VCAC will decide to choose some mobile terminals from the heavily loaded networks and connect them to lightly loaded ones (Suleiman, Chan & Dlodlo, 2006; Falowo & Chan, 2008).

In Falowo and Chan (2007), Falowo and Chan (2012), Reddy and Teja (2013) JCAC Algorithms were classified into eight; namely Random-Selection Based JCAC, Service-Class-Based JCAC, Load-Based JCAC, Path-Loss-Based JCAC, Service-Cost-Based JCAC, Layer-Based JCAC and RAT-Duplexing-Technique Based JCAC, Terminal-Modality-Based JCAC Scheme.

Random Selection Based JCAC

An available RAT is selected randomly on the arrival of a vertical handoff or new call. If an HTN has J number of RATs, the odds of choosing a particular RAT is then given as 1/J. The random selection based JCAC is not complex by design and its implementation is easy. Moreover, the P_b and P_d are high. It also suffers setbacks because of the unfairness in the selection of resources (Falowo & Chan, 2012; Reddy & Teja, 2013).

Service-Class-Based JCAC

In this JCAC type, the classes of service (video, voice, data etc.) determine whether a call is admitted into a RAT. The different types of RAT are best suited for certain service class. The process of mapping the RATs to service class is direct, which then lead to an unbalanced traffic load distribution across the different RATs. It also suffers setbacks because of the unfairness in the selection of resources (Falowo & Chan, 2008; Falowo &Chan, 2012; Reddy & Teja, 2013)

Load Based JCAC

In load based JCAC algorithm calls are admitted into a RAT based on the load in the RAT, it uniformly distributes load over all the RATs present in the heterogeneous network. Specifically it selects the RAT with the lowest load. A load based JCAC algorithm will lead to inequality in distribution of radio resources among heterogeneous mobile terminals because not all terminals support all the available RATs (Falowo & Chan, 2008;Falowo & Chan, 2012; Reddy & Teja, 2013; Suleiman, Chan & Dlodlo, 2006).

Path Loss Based JCAC

In path loss based JCAC algorithms, calls are admitted based on measurements of path loss taken in the cells of each RAT. The RATs individually have a mechanism to measure the path loss and this JCAC algorithm makes decisions based on the path loss. The RAT that suffers the least path loss will be selected first. Path loss based JCAC algorithms are unfair in the distribution of radio resources across heterogeneous mobile terminals (Reddy & Teja, 2013; Suleiman, Chan & Dlodlo, 2006).

Service-Cost-Based JCAC

In Falowo and Chan (2008), Reddy and Teja (2013, Suleiman, Chan and Dlodlo (2006), Service-cost-based JCAC schemes base the decision of mapping an incoming call to a RAT on cost. The least expensive RAT is selected in order for the subscriber to enjoy a cheaper tariff in the HTN. The cost of RATs differs from one another. The scheme can be unfair in the distribution of radio resources across heterogeneous mobile terminals.

Layer- Based JCAC

In layer based JCAC, the RATs in the HTN are logically arranged in layers. Call admission is then based on these layers. If a call request is directed to a layer and the request is not accepted, the JCAC algorithm then redirects the request to the next available layer. Layer-based JCAC schemes are grossly unfair in the distribution of radio resources.

Rat-Duplexing-Technique Based JCAC

In this scheme, symmetry calls are admitted into non-flexible RATS while asymmetry calls are admitted into flexible RATs and by so doing there will be reduction in P_b and P_d respectively (Falowo & Olowole, 2011).

Terminal-Modality-Based JCAC

In Falowo and Chan (2012), Reddy and Teja (2013) P_b and P_d for mobile terminals with single mode capability are significantly higher than those of multiple-mode terminals in a HTN. Hence the terminal –modality- based JCAC scheme admits calls based on the following key parameters; RAT terminal support index, mobile terminal modality, and network load. This algorithm reduces the value of P_b and P_d and at the same time it is fair in the distribution of radio resources across heterogeneous mobile terminal in a HTN.

Conclusion

A CAC scheme decides to accept or deny a call depending on network conditions, regarding availability of channels, signal power and quality of service. Its greatest difficulty is the knowledge of which call request to accept and the ones to be blocked, due to numerous parameters involved in the CAC's decision. The CAC's main challenge is to accept as much as it can and at the same time maintaining high network performance. CAC techniques can either be approached from the Traditional or Joint approach i.e JCAC. The traditional CAC schemes are deployed in homogeneous networks, while the JCACs are deployed in heterogeneous networks i.e 3G and beyond. CAC mechanisms can also be conventional or Unconventional. The conventional ones use deterministic or stochastic techniques. The CAC schemes that apply computational intelligence methods associated with the traditional techniques are classified as Unconventional CACs.

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