A SURVEY ON CALL ADMISSION CONTROL SCHEMES IN LTE

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ABSTRACT

The growing number of mobile users with diverse applications such as VoIP, video, internet surfing etc. has made LTE networks to adopt a CAC strategy in order to ensure the quality of service (QoS) requirements of these applications. Over the years, several CAC schemes have been proposed to either accept or reject service requests. This paper presents a survey of these schemes under four different classes. The classes are: Bandwidth Reservation (BR), Bandwidth Degradation (BD), BR and BD and Non-BR and Non-BD (NBR-NBD). In each of the classification, the operation procedure, strengths and weaknesses of each scheme has been discussed. Furthermore, a comparative analysis of these schemes is also presented. The analysis provides insight into the challenges in the design of CAC by highlighting open research issues for future directions.

KEYWORDS

Call Admission Control, LTE, bandwidth degradation, bandwidth reservation, survey, CAC

1. INTRODUCTION

Wireless technologies have witnessed a great deal of evolution over the past two decades from the first generation (1G) to the present fourth generation (4G) and much anticipated fifth generation (5G) of wireless technologies due to the increase in mobile devices and consequently user mobility support as well as the need for cheaper internet services. However, as the cost of these services lowered, the demand further increased due to the lowering price of mobile and smart devices. The evolution of these devices and the Internet has witnessed a corresponding evolution in wireless network technologies as well. These technologies support multimedia driven applications such as voice over Internet protocol (VoIP), video streaming, internet surfing, and online gaming etc. with most of these applications having quality of service (QoS) requirements constraints [1]. The desire to meet these constraints led to the development and deployment of recent 4G wireless technologies like Long-Term Evolution (LTE) network [2].

The LTE network was first rolled out in 2004 by the third-generation partnership project (3GPP) group with the core objectives of achieving higher data-rate, lower latency, improved system capacity and extended coverage [3]. In order to meet these objectives despite the scarcity of resources in wireless networks, the LTE network deploys a set of radio resources management techniques to effectively manage these resources [4]. These techniques consist of scheduling and dynamic allocation of resources to user equipment (UEs), radio bearer control, radio mobility control and radio admission control (RAC). The RAC popularly known as a call admission control (CAC) scheme which admits or rejects a new connection request if the required QoS of the new connection request will be met without lowering that of the ongoing calls [5,6]. Several researches on CAC have been conducted for QoS provisioning.

This paper presents a state-of-the-art survey of CAC schemes in LTE networks. These schemes are classified and discussed. The comparative analysis of these schemes is also presented with the aim of identifying current challenges for future research. The rest of this paper is organized as follows: section II presents an overview of the LTE network, in Section III, an overview of CAC is presented, section IV presents a state-of-the-art survey of CAC schemes. Comparative analysis of the various schemes is presented in section V and we conclude the paper in section VI.

2. OVERVIEW OF LTE NETWORK

The LTE network is built on three major technologies: Orthogonal Frequency Division Multiple Access (OFDMA), Single-Carrier Frequency Division Multiple Access (SCFDMA) and Multiple Input Multiple Output (MIMO) [7]. The OFDMA is deployed for downlink communication. It is an enhanced air access technology that divides the frequency bandwidth into narrow orthogonal sub-parts known as sub-carriers with each subcarrier comprising of data carriers, pilot carrier, and a Data Counter (DC). The SCFDMA technology on the other hand is employed for uplink communication. It assigns a single communication channel to multiple users and was chosen to reduce Peak to Average Ratio (PAR). The technology benefits the mobile devices because it ensures better transmit power efficiency and reduces cost of the power amplifier. The MIMO technology minimizes the effects of noise and improves link reliability during data transmission. In this technology, a transmitter sends multiple streams on multiple transmit antennas with a single stream following different paths to reach multiple receivers thereby allowing the use of superior signal processing techniques for cancelation of errors.

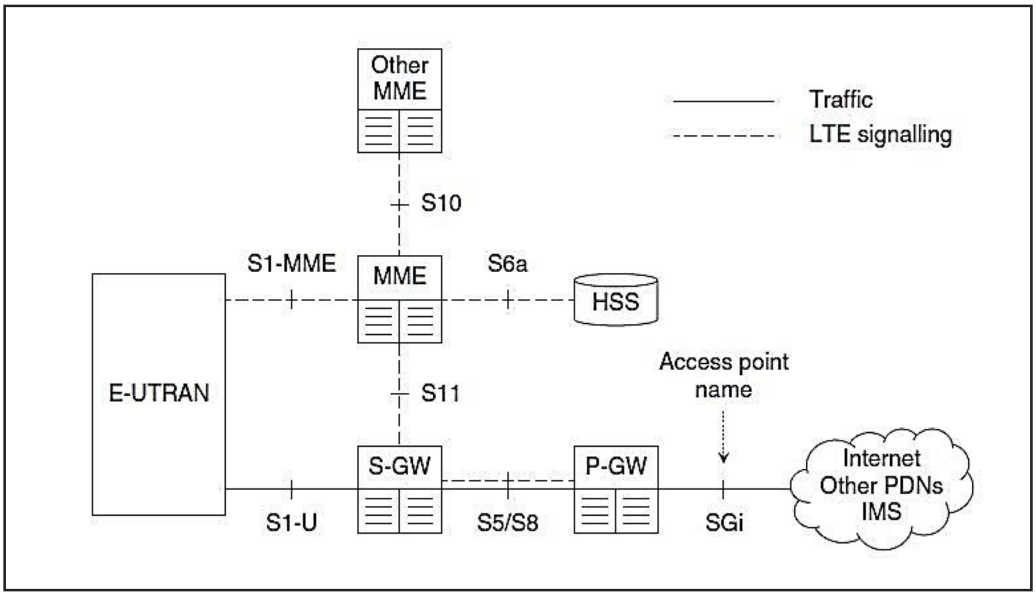

Figure 1: LTE Architecture [8].

The architecture of LTE consists of two parts (see Figure 1), the evolved packet core (EPC) and evolved universal terrestrial radio access network (E-UTRAN) [7]. EPC is the core network that controls the activities of the user equipment (UE). It consists of mobility management entity (MME), home subscriber system (HSS), serving gateway (SGW) and public data network gateway (PGW) [9]. The MME processes the signaling between the UE and core network (CN). It is responsible for mobility control of the UE. MME connects to the SGW and eNodeB through S11 and S1-MME interfaces respectively and with other MMEs through the S10 interface. The SGW anchors all user packets of mobile UE and sends same to the appropriate destination. It connects to eNodeB and PGW through S1_u and S5/S8 interfaces. The PGW serves as the link between the network and outside world. It provides address (allocates IP) to the UE and connects to other IP networks through SGi interface. HSS is a component that contains subscription data of the UE as well as stores user authentication data and subscription status. It connects to MME through S6a interface.

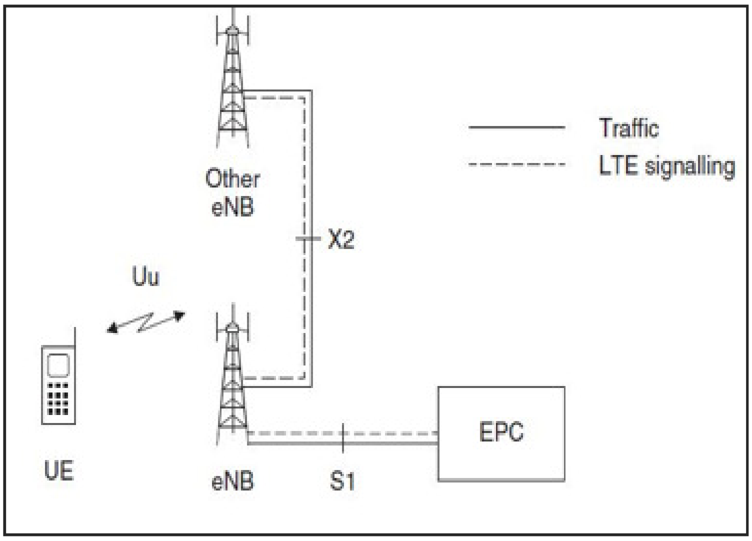

Figure 2: Components of the E-UTRAN [8]

The E-UTRAN forms the second part of the LTE architecture which consists of evolved Node Base Station (eNodeB) as the only component as shown in Figure 2. The eNodeB links the UE with CN and connects to the CN through S1-MME and S1_U interfaces to link with MME and SGW components respectively. It connects to the UE and neighboring eNodeBs through LTE Uu and X2 interfaces respectively.

As physical radio resources are shared among connected users, the eNodeB performs radio resource management (RRM) functions for smooth operation of the LTE networks [12]. These RRM techniques include scheduling, power saving, congestion control and call admission control. Scheduling is the allocation of shared physical resources among users. It is the means of assigning resources to users for QoS guaranteeing. LTE employs discontinuous reception to reduce power consumption while call admission control serves as the gateway into the network.

3. OVERVIEW OF CALL ADMISSION

Call admission control (CAC) is a process of accepting new call requests or handoff call requests into the network while regulating the quality of service (QoS) of already admitted or active calls. CAC ensures that a certain level of QoS is maintained for real time (RT) and non-real time (NRT) call requests in the network. The objective of CAC is to ensure efficient resource allocation and monitor the resource utilization when network is congested. Is also manages the bandwidth with respect to the total number of available call requests in the base station.

Call requests are usually classified into new call (NC) and handoff call (HC). NC is a type of call request that is requesting for a new connection into the network while HC is an ongoing or active call that needs to be transferred from one cell to another without compromising the QoS of already admitted calls. Process of transferring an active or ongoing call from one cell to another is referred to handover or handoff procedure. Handoff procedure ensures the stability of active calls with required QoS. It also ensures load balancing in a wireless system as well as guaranteeing the stability of service.

Admission control is always performed when a UE starts communication with eNodeB either through a new call or a handoff call or a new service request by the UE [10]**.** When the UE intends to establish a connection with the eNodeB, it sends a request for resource allocation, and the admission controller at radio network controller (RNC) handles the request. For real time (RT) call requests, if connection causes excessive interference to the system, the request will be denied. Otherwise resources will be allocated for that connection. For NRT connection requests, the optimum scheduling of the packets must be determined after the admission of the call.

Basic Call Admission control (BCAC) is a static CAC scheme [11]. The decision for the acceptance or rejection of a call request depends only on the availability of network resources. This means that, call requests are only admitted into the network when the requested resources are less than or equal to the available network resources, otherwise the call request is rejected. Figure 3 describes the operation of BCAC scheme.

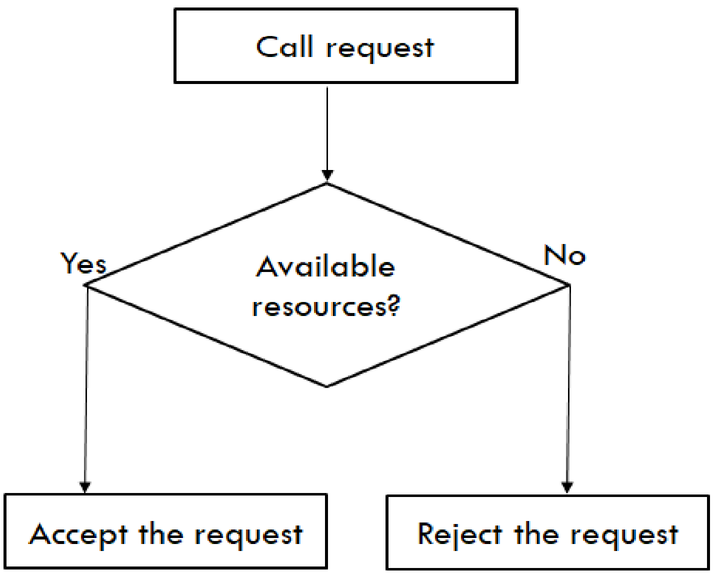

Figure 3: Description of Basic CAC scheme [11]

The design of CAC for a fixed network is simple, as the call admission is based on the available resources and QoS requirements of the new calls as shown in Figure 3 above. In the mobile environment however, the design is more complicated than that of a fixed network, as the eNodeB may reserve some bandwidth to admit the handoff calls. The design of a CAC scheme depends on some parameters such as availability of resources, quality of network parameters, quality policies, call prioritization, mobility management, and optimization methodologies etc. CAC schemes have been categorized in different ways by different researchers. In this paper, the CAC schemes are classified into the following categories; Bandwidth reservation (BR) schemes, Bandwidth Degradation (BD) schemes, Bandwidth Reservation-Bandwidth Degradation (BR-BD) schemes and Non-bandwidth reservation and Non-bandwidth degradation (NBR-NBD) schemes as shown in Figure 4.

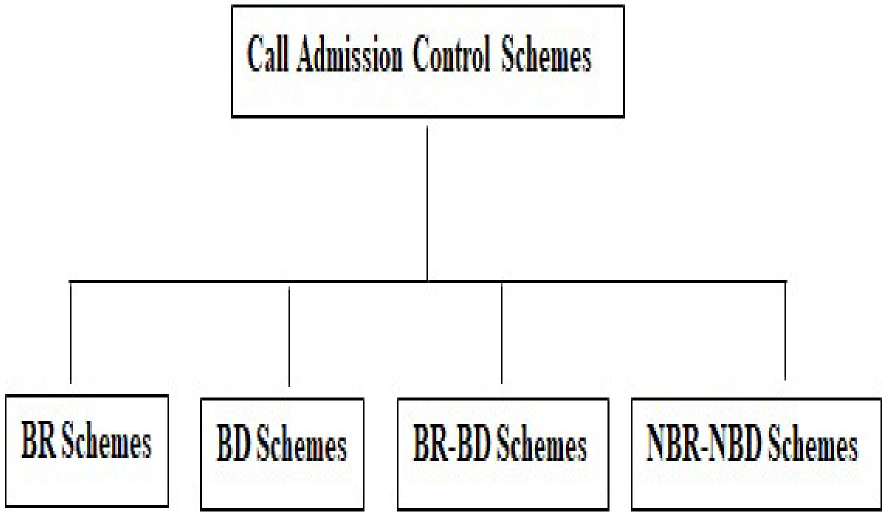

Figure 4: Categorization of CAC schemes

4. SURVEY ON CAC SCHEMES

This section presents a survey on existing CAC schemes which are classified into four: Bandwidth Reservation (BR), Bandwidth Degradation (BD), BR and BD (BR-BD) and Non-BR and Non-BD (NBR-NBD). These classifications are discussed and reviewed as follows:

4.1. Bandwidth Reservation (BR) Schemes

The BR schemes reserve certain amount of resources for Handoff Calls (HCs) and share the remaining resources to New Calls (NCs) and HCs. The schemes are reviewed as follows:

In [13], a Guard Channel (GC) scheme was proposed to ensure low Handoff Call Dropping Probability (HCDP). The GC scheme reserves a certain amount of resources for the exclusive use of handoff calls. The scheme blocks a new call if the number of available resources is less than the amount of resources required by the incoming call while a handoff call is dropped if and only if no channel is available. It decreases the HCDP but increases the NCBP due to higher priority given to HCs.

[14] proposed a Fractional Guard Channel (FGC) or Thinning Scheme-I algorithm to minimize NCBP. The FGC scheme uses a reserved fraction of a total network resource for HCs and shares the remaining resources between NCs and HCs. The scheme admits NCs based on a certain probability (a non-increasing function of the number of occupied channels) and HCs as long as there is a free channel. It decreases the NCBP but wastes network resources by reserving fixed amount of resources that might not be fully utilized.

A Uniform Fractional Guard Channel (UFGC) scheme was also proposed by [15] to reduce NCBP. The UFGC scheme is a variant of the FGC scheme that reserves a non-integral number of resources for HCs. The scheme employs an acceptance probability which is a constant probability that is independent of the number of occupied channels and arrival rate to accept NCs. It decreases NCBP and decreases HCDP under low traffic arrival rate but increases HCDP under heavy traffic because of insufficient reserved resources.

In [16], a New Call Bounding (NCB) scheme was proposed to limit the number of NCs in the network. The NCB scheme reserves resources for HCs and sets a threshold (maximum number of NCs to be admitted) beyond which NCs cannot be admitted. The scheme accepts a NC if the threshold is not exceeded but HCs are only blocked if all channels are occupied [17]. It decreases HCDP and thus ensures QoS of ongoing calls. However, the scheme greatly increases NCBP due to the threshold value used and also wastes network resources as the reserved resources may be more than the HC traffic.

To ensure better QoS, a Limited Fractional Guard Channel (LFGC) scheme was proposed in [18]. The LFGC scheme varies the number of channels reserved for HCs in a fraction of one based on channel occupancy. The scheme uses two parameters: the number of guard channels (T) and the NC acceptance probability (βl). Initially, T→1, βl→0 and T is continuously incremented by 1 until the required QoS is met. The scheme achieves better QoS and decreases NCBP but increases HCDP due to failure to consider channel utilization [19].

[17], proposed a CAC with Resource Reservation scheme for Multi-service OFDM Networks to ensure QoS of ongoing calls. The scheme reserves extra resources at the point of admission that every admitted user may consume during call holding. The scheme enhances the QoS of all ongoing calls. However, it wastes network resources because of the advanced reservation technique.

The Queuing principle was proposed in [20] to reduce excessive call blocking and waste of network resources. The principle reserves a set of channels for HCs and accepts NC requests when the remaining available resources are sufficient. It queues NCs instead of out rightly blocking them but drops HCs when resources are insufficient. The scheme decreases NCBP but increases HCDP under heavy traffic scenarios.

In [21], a novel advanced resource reservation-based CAC (AR-CAC) scheme was proposed to ensure guaranteed QoS. The AR-CAC scheme, groups calls based on priority as: advanced calls, HCs and new immediate calls and then sets a threshold for all the three class of calls. The scheme reserves resources for advance calls for future use and queues HCs when all the channels are occupied. It admits a HC whenever some resources (sub-channels) are released and the delay time-out of a HC in queue has not reached, but services the HCs on a FIFO basis if they are many on the queue. The scheme admits a new immediate call if the sum of the resources it requires and that of existing calls is less than or equal to the threshold set for new calls else it is rejected. Furthermore, it sets a minimum start time in order to differentiate immediate calls from advance calls and a maximum book-ahead start time calls beyond which calls are rejected so as to limit the number of advance calls. The scheme decreases HCDP and thus ensures better QoS but increases NCBP and inefficiently utilizes network resources because the resources reserved for the advance calls may not be fully utilized.

[8] proposed a Bandwidth Reservation CAC (BRCAC) and a Dynamic CAC (DCAC) to ensure fair allocation of resources during the busy hour. The BRCAC scheme maps incoming call requests to the following service classes: voice GBR, non-voice GBR and non-GBR. The scheme dynamically adjusts the amount of reserved resources for voice GBR calls based on traffic intensity of the VoIP calls. The DCAC scheme prioritizes VoIP calls during busy hour and employs an outage probability for non-VoIP calls. This probability depends on the arrival rate of VoIP requests as well as the available bandwidth. It is set to zero when the network has enough resources to admit all call requests. These schemes reduce HCDP and thus greatly improve the QoS for voice traffic. However, the schemes are unfair to non-voice calls because of the outage probability used and inefficiently utilize network resources because channel quality is ignored.

A Ring Based CAC (RCAC) Scheme was proposed in [22] to improve resource utilization. The RCAC reserves a certain amount of resources for HCs based on current mobility prediction. It rejects a call if the available resources at the particular node are not sufficient for the call else it checks if there are free resources in the Most Likely Cell-Time (MLCT) of the UE. The MLCT is a cluster of time units that shows when and where a mobile UE is most likely to visit in the future [23]. The RCAC scheme uses information from the MLCT to predict the mobility of users by checking the availability of free resources in MLCT of the mobile UE. It enhances network resource utilization and lowers the HCDP. However, the scheme wastes resources because there is uncertainty in its mobility prediction that may lead to over reservation of resources.

In order to reduce NCBD and HCDP [24], a CAC algorithm for high speed vehicular communication systems was proposed. The scheme reserves resources for ongoing calls and NCs. It calculates the resources required by an incoming request as well as available resources of the network. Based on the calculated information, if the available reserved resources for either HC or NC are more than or equal to the requested resources, the call is admitted else it is rejected. The scheme is fair and decreases both HCDP and NCBP. However, the scheme inefficiently utilizes resources because some amount of the reserved resources may be left unutilized.

[25] proposed an Adaptive CAC Algorithm based on RB allocation to ensure better resource utilization. The scheme classifies incoming call requests into RT and NRT and reserves a certain amount of resources for RT calls while the remaining resources are used for NRT calls. It adjusts the amount of reserved resources for RT calls based on current traffic conditions. It queues NRT calls when resources are insufficient due to their insensitivity to delay. The scheme is easy to implement and decreases NCBP. It also decreases resource wastage by adaptively adjusting the amount of reserved resources based on traffic. However, it increases HCDP because handoff scenario is ignored.

To guarantee QoS of RT and NRT calls, [26] proposed a novel resource allocation scheme. The scheme employs two strategies: the first reserves resources for calls in mobility in order to limit the number of calls in the network and reduce the probability of block and loss while the second strategy dynamically assigns the reserved resources to RT calls in migration and the remaining to NRT calls. The scheme guarantees throughput for all admitted calls and decreases HCDP but increases the NCBP when the number of calls in mobility increases.

4.2. Bandwidth Degradation (BD) Schemes

The BD schemes degrade resources already allocated to low priority calls in order to admit more users into the network. The schemes are reviewed as follows:

[27], proposed a Fairness-Based Preemption Algorithm (FBPA) to ensure fairness. The FBPA performs preemption in two phases: partial and full. In the partial preemption phase, low priority calls and overprovisioned resources of high priority calls are preempted to their respective GBR. At the full preemption phase, all the resources allotted to low priority calls are degraded in order of priority when the resources acquired after the partial preemption are insufficient. After the full preemption, if the resources are inadequate, the call is rejected. The scheme improves preemption fairness. However, it wastes network resources because it degrades all ongoing calls irrespective of the amount of resources required by the incoming call. A Priority-Scaled (PS) preemption technique that employs ARP was proposed in [28], to ensure fairness among Low Priority Preemptible Active Bearers (LP-PABs). The scheme employs a Priority-Scaled (PS) Minimum QoS Preemption Algorithm (PS-MQPA) and a Total Preemption Algorithm (TPA). The PS-MQPA preempts resources from LP PABs based on their priorities (the lower the priority, the more the resources that will be preempted from it). It computes two parameters: R_{Total} and R_{Min} when a NC arrives where R_{Min} is the amount of resource that can be

freed by reconfiguring or preempting all LP-PABs to their minimum QoS requirements and R_{Total} is the resources that can be obtained by TPA. The algorithm rejects a NC if R_{Total} is not sufficient to meet its QoS requirements. If after the preemption of the PS-MQPA, the resources are still not enough, the TPA preempts all the resources from LPPABs. The scheme decreases HCDP for LP-PABs but limits the QoS of higher priority calls to their minimum service rates because of the preemption algorithm used.

In order to optimize system capacity while guaranteeing QoS for all service classes, a novel Radio Admission Control (RAC) scheme was proposed in [29]. The scheme categorizes services into three groups where group 1 comprises of services whose resources can be preempted, group 2 and 3 represent non-pre-emptible. It degrades low priority calls to their respective GBR whenever the resources are insufficient and adds the degraded resources to the Complete Sharing (CS) resource pool, so that the resources can be allocated to any NC. The scheme maximizes system capacity and maintains QoS of all admitted users but is unsuitable to HCs because the handoff scenario is ignored.

In [30], a Persistent Scheduler Based Call Admission scheme known as Utility Based Scheduling and Call Admission Control (UBSCAC) was proposed to schedule resources to RT and NRT users. The UBSCAC scheme classifies service type as VoIP and video. The scheme uses Received Signal Strength (RSS) value to estimate a channel as good or bad. It dynamically reserves resources for VoIP services, video services and calls with bad channels based on traffic density. Furthermore, the scheme allocates resources to the RT and the NRT users based on the highest marginal utility function where marginal utility refers to the gain in the utility function when resources are allocated to a user compared to the utility of the user before the allocation of the resource. Finally, the scheme degrades calls with bad channels to admit RT and NRT calls when there are insufficient resources. The scheme improves HCDP and resource utilization but it is unfair to calls with bad channel.

A CAC scheme based on adaptive bandwidth allocation was proposed in [23] to reduce call dropping. The scheme assigns resources to NCs and HCs based on traffic class. It degrades varying amount of resources from NRT calls in order to admit more calls into the network depending on whether the requesting call is either a HC or a NC. The scheme decreases HCDP while it maintains bandwidth utilization. However, the scheme increases NCBP due to the higher priority attached to HCs.

[31] proposed a Utility Based Scheduling and CAC (UBSCAC) scheme to ensure service differentiation. The scheme classifies call requests into NC and HC call requests and the type of service as RT and NRT. The scheme estimates a channel as either good or bad based on the RSS value. It allocates resource to VoIP-HCs and video-HCs based on traffic density and the tolerance of limit (TOL), respectively. The scheme computes utility function according to the channel condition in order to assign resources to NCs. It uses highest marginal utility function to schedule channels for RT and NRT users. In the case of insufficient resources, the scheme degrades the resources of users with bad channels to admit more HCs into the network. The scheme improves HCDP and resource utilization but it is unfair to calls with bad channel.

In [32], an Extensive DBA-CAC Mechanism was proposed to reduce HCDP while ensuring QoS. The scheme uses a handoff procedure based on load balancing to prioritize HCs over NCs and queues calls when resources are insufficient. It employs DBA to predict the amount of resources to be reserved in advance for a call based on its past behavior. The DBA utilizes an arrival algorithm to degrade resources from NRT calls for queued NCs and HCs. Similarly, it employs a departure algorithm to upgrade resources of ongoing calls when a call is completed. The scheme lowers NCBP, ensures efficient handover and improves resource utilization. However, the scheme is unfair because it degrades low priority flows.

A Fair Intelligent (LTE-FIAC) scheme was proposed in [33] to ensure fairness among calls of different priority class and flows at the same priority level. The LTE-FIAC deploys the ideas of Complete Sharing (CS) and Virtual Portioning (VP). The scheme uses a variable size degradation step to degrade varying quantity of resources from admitted calls with low priority in order to admit a call with higher priority. It reduces blocking probability and guarantees fairness among flows at the same and different priority levels. However, the scheme degrades low priority calls to admit those of higher priority, thus increasing the blocking probability of low priority calls. It also fails to consider the handoff scenario, which leads to an increase in the handoff dropping probability.

In [34], a Fuzzy-based decisive approach for call admission control in the LTE networks was proposed to provide QoS Guarantees. The scheme employs the amount of available resources in the network to prioritize users based on the user categorization, QoS requirements, and traffic maximum delay tolerance. It also categorizes the users as Golden and Silver corresponding to RT and NRT services respectively and dynamically adjusts priority of the user based on the user's categorization. Furthermore, when a when a request with higher priority arrives, the scheme totally or partially preempts existing connections depending on the amount of resources required by the new connection and increases the resources allocated to users when the channel condition of the users deteriorates. The scheme ensures QoS for users. However, the total preemption of low priority users will greatly increase their dropping rates. Also, increasing the resource allocation to users with poor channel condition will reduce resource utilization as resources allocated to such users may end up being wasted.

4.3. BR and BD (BR-BD) Schemes

The BR-BD schemes reserve resources and also degrade already admitted low priority calls to admit more calls into the network. The schemes are reviewed as follows:

To reduce handoff blocking probability, [35] proposed an adaptive CAC scheme. The scheme classifies incoming call requests into NRT, Real Time Tolerant (RT-TLR) and Real Time Intolerant (RT-INTLR). It also prioritizes service classes as NC¬NRT, HC-NRT, NC-TLR, HC-TLR, NC-INTLR, HC-INTLR. The scheme adaptively reserves resources for HCs according to service contract. It degrades calls with resources greater than their minimum requirements and low priority (NRT) calls to admit HCs if resources are inadequate. However, if both procedures fail to yield the required amount of resources, the HC is dropped. In addition, the scheme queues NCs into three different queues (NRT, RT-TLR and RT-INTLR) when resources are insufficient. The scheme degrades NRT calls to accommodate the queued NCs based on their latency and if it fails, then the NC is blocked. The scheme lowers NCBP and maintains efficient resource utilization. However, it increases the delay of NCs because of the queuing mechanism used and it is also unfair to NRT calls under insufficient resources.

[36] proposed a Dynamic Bandwidth Adaptation supported Adaptive CAC Mechanism to reduce the HCDP while ensuring QoS. The scheme determines an incoming call's service type as either RT or NRT if the resources are insufficient and further classifies the call as HC or NC. It also reserves resources for HCs based on current network load and queues calls when resources are insufficient. Furthermore, it uses a dynamic bandwidth adaptation mechanism to degrade resources assigned to NRT calls to admit queued NCs and HCs as well as reassign unused network resources. It decreases HCDP and NCBP but it is unfair to NRT calls as it services queued calls based on latency.

An Adaptive CAC scheme was proposed to reduce HCDP in [37]. The scheme classifies service classes into NRT, Real-Time Intolerant (RTINTLR) and Real-Time Tolerant (RTTLR) service. These classes are also prioritized as: None Real Time NC (NC-NRT)/Non-Real Time HC (HC-

NRT)/Tolerant NC (NC-TLR)/Tolerant HC (HC-TLR)/Intolerant NC (NC-INTLR)/Intolerant HC (HC-INTLR). It employs a dynamic reservation algorithm that gives a threshold resource block capacity for each service class. These thresholds are dynamically tuned based on the cell state and level of the blocking call's type. The scheme queues NCs when resources are insufficient and degrades calls with the largest allocated bandwidth greater than their minimum required resources (RB_{min}) and the lowest priority (NRT) to their RB_{min} under insufficient resources in order to accept more calls. It improves resource utilization as well as decreases NCBP for VoIP calls and HCDP. However, the scheme inefficiently utilizes network resources due to its failure to consider channel quality.

In [38], a Flexible CAC with Pre-emption (FCAC_P) was proposed to support multimedia services. The FCAC_P first classifies incoming call requests into RT and NRT users, then estimates the channel quality based upon the RSS value, finally identifies the call as either NC or HC. The scheme dynamically reserves resources for both RT and NRT calls based on current network load. It accepts a NRT call irrespective of the channel quality if the amount of reserved resources for NRT calls is sufficient else the call is blocked. It drops HCs with bad channel and classifies RT calls with good channels as either RT HC or RT NC when resources are insufficient. The scheme automatically accepts RT HCs while the RT NCs are accepted with a certain probability. The scheme sets a threshold (non-pre-empted NRT calls) and pre-empts old ongoing NRT calls and those that have not been pre-empted to free resources for RT. The scheme decreases the NCBP for high priority calls and increases throughput. However, it increases the NCBP and is unfair to low priority calls because of its pre-emption mechanism.

A multiservice CAC (MSCAC) scheme was proposed in [39] to support multimedia services. The MSCAC scheme classifies multimedia services into three: conversational (RT e.g. VoIP), streaming (RT e.g. video) and best effort (NRT e.g. FTP) and associates each service with a queue. The scheme reserves resources for VoIP HCs based on traffic rate of VoIP calls and divides the remaining into two parts: BE and public resources (used by BE, video and new VoIP calls). It rejects an incoming call if its queue is full and drops queued calls that exceed their delay time-out. The MSCAC preempts the public reserved resources to service VoIP HCs calls when resources are inadequate. The scheme guarantees low blocking probability for all class types and also reduces wastage of resources. However, it is unfair to NCs as it reserves resources for and also preempts resources reserved for NCs to service VoIP HCs.

[40] proposed an Efficient Channel State Based CAC (CBECAC) for Non-Real-time traffic to ensure resource utilization. The CBECAC scheme comprises of three phases: call classification, channel state estimation and call admission control. In the call classification phase, incoming call requests are classified as either NC or HC (and HCs are prioritized over NCs) with each class further classified as RT (VoIP) and BE (video) (prioritizes VoIP over video). In the channel estimation phase, the scheme estimates a channel as either good or bad based on the RSS value. In the call admission control phase, the scheme dynamically reserves resources for VoIP, video and calls with bad channel based on traffic density. It degrades resources reserved for bad channels to admit other calls when resources are insufficient. The scheme improves resource utilization but it is unfair to NCs due to the level of priority given to HCs.

In [41], an Adaptive CAC Scheme based on higher order Markov chains was proposed to effectively handle NCBP. The scheme deploys the Markov chain model for resource allocation and the PRB allocation algorithm to intelligently tune the allocation. It also reserves resources for HCs based on traffic load and uses the remaining resources to accept all calls. Furthermore, it degrades low priority calls under insufficient resources in order to accept more calls. The scheme NCBP for each class of traffic and maintains resource utilization. However, it is unfair to low priority calls because of degradation scheme used.

An Adaptive Call Admission Control with Bandwidth Reservation was proposed in [42] improve resource utilization and prevent starvation of BE connections. The scheme dynamically reserves resources for handoff connections base on handoff traffic intensity. Also, it admits real time (RT) and non-real time (NRT) connections with their maximum and minimum required resources respectively. When resources are insufficient, it deploys a BD mechanism to degrade the RT calls. However, if the degraded resources are not sufficient to admit the new request, the connection is dropped. The scheme reduces the blocking and dropping rates. However, it reduces throughput of RT connections due to the BD mechanism that performs degradation before determining if the degraded resources are sufficient or not. Thus, prompting a call to be dropped when the degraded resources are not enough to admit the requesting call even after reducing the transmission rate of existing RT connections.

4.4. Non-BR and Non-BD (NBR-NBD) Schemes

The NR-ND schemes neither reserve for future use nor degrade resources already allocated to ongoing calls. These schemes are reviewed as follows:

A Resource-estimated Call Admission Control (RECAC) Algorithm was proposed by [43] to guarantee QoS. The RECAC scheme estimates the amount of PRBs required by an incoming call based on information about its service type and Modulation and Coding Scheme (MCS). The scheme accepts a call if the amount of available resources is higher than the minimum amount of resources required by the incoming call. This scheme lowers average packet delay as well as NCBP. However, it reduces resource utilization because it admits calls according to minimum data rate requirements. Furthermore, the scheme increases HCDP because code rate for HCs are worse than those for NCs at their request time.

In [44], Neural Network (NN) and Bayesian network (BN) based CAC algorithms were proposed to optimize the network performance. The NN scheme estimates the QoS of all ongoing GBR calls and if it is greater than or equal to a given threshold, an incoming call is accepted else rejected while the BN scheme estimates the probability distribution of the QoS of all ongoing calls and accepts an incoming call if the probability that the QoS of all ongoing GBR calls is greater than or equal to a given minimum system QoS threshold value. Both schemes adaptively adjust resource allocation based on user mobility and channel condition. Comparatively, NN CAC scheme outperforms the BN CAC scheme in terms of prediction accuracy but the BN CAC scheme has a lower error rate compared to the NN CAC scheme. These schemes ensure QoS and efficiently utilize resources. However, the schemes may lead to waste of resources when calls that can probably be accepted are rejected because of the QoS threshold used for the BN scheme as well as the probability used by the BN scheme.

A fuzzy based call admission control scheme was proposed to improve QoS in [45]. The fuzzy based scheme admits calls base on the network condition as well as the number of available channels. The scheme also estimates the channel condition of calls and performs channel aggregation and assigns resources to the meet the demand of either a NC or a HC. If, however the resources are inadequate, the call is queued and retried four times after which it is dropped/blocked. The scheme achieves greater user satisfaction and better QoS. However, it inefficiently manages network resources because it has difficulty in determining very low and high channel conditions.

In [46], a Hybrid Adaptive Call Admission Control Mechanism was proposed to reduce HCDP. The mechanism uses the resource block strategy to allocate the resources based on the call type i.e. NC or HC. It employs the following parameters: maximum number of RBs required, minimum number of RBs required, number of required RBs, tolerable maximum delay and latency to prioritize calls. The scheme also queues calls when resources are insufficient and introduces expiration delay to reject calls that exceed their delay time-out. The scheme reduces the HCDP and improves resource utilization. However, the scheme increases NCBP and cannot guarantee QoS when the channel condition varies because it only takes into account the priority of a call at the time of admission.

[47] proposed a Delay-aware Call Admission Control (DA-CAC) Algorithm to ensure QoS for various classes of traffics. The DA-CAC scheme employs statistical data on packet delay and current PRB utilization. The scheme also deploys a dynamic moving-window average method as average connection holding time which consists of several sub-windows where the size of a sub-window is the interval between consecutive call requests. The scheme rejects some calls in order to prevent congestion in the network. It lowers packet delay for each service class and also decreases HCDP. However, the scheme decreases resource utilization and average data rate due to its policy of rejecting some call requests to avoid congestion. In addition, it also increases NCBP.

A QoS based call admission control and resource allocation mechanism was proposed in [48] to avoid congestion and ensure QoS. The scheme employs a voice monitor to monitor on-going calls, measure the real time voice call quality and determine when problems occur. It dynamically assigns resources based on measurements taken from actual ongoing VoIP calls (changes in call quality) rather than voice probing streams. The scheme leads to high voice call quality and improves resource utilization. However, it is unsuitable for multi-service networks because it only considers voice calls.

In [49], a delay aware user classification and adaptive resource reservation-based call admission control (DA–UC-ARR) scheme was proposed to efficiently control resource utilization. The DA–UC-ARR scheme is divided into two sub-schemes: user categorizing-based CAC with adaptive resource reservation (UC-ARR) and delay aware and user categorizing-based CAC with adaptive resource reservation (DA–UC-ARR). The UC-ARR scheme classifies users' requests into Golden (G) and Silver (S) and the type of services per user as RT and NRT and adaptively reserves virtual resources for G RT, S RT, G NRT and S NRT. It admits a call request if the available resources are adequate else it is stored in its queue and the request with the least Adaptive Priority (AP) value is served first. The AP is calculated based on the total number of resources currently used by all users belonging to that service class and user type and the number of virtual reserved RBs for call belonging to that class and user type. A queued request is dropped if its queuing time limit is exceeded. The DA–UC-ARR operates just like the UC-ARR but additionally uses maximum delay tolerance to calculate the AP value. The scheme maximizes throughput, ensures QoS and decreases computational complexity. However, the scheme is unfair to NRT and silver users due to the prioritization policy used.

5. COMPARATIVE ANALYSIS OF CAC SCHEMES

Table 1 provides a comparative analysis of the various CAC schemes in LTE networks with regards to their type, adaptability, strengths and weaknesses. The type consists of four classes: CAC with BR, CAC with BD, CAC with BR and BD (BR-BD) and CAC with Non-BR and Non-BD (NBR-NBD).

The CAC schemes with BR proposed in [8, 13-18, 20-22 and 24-26] reserve resource blocks (RBs) for HCs or high priority calls. The schemes proposed in [13-18, 20, 21, 24, 26] reserve fixed amount of RBs. These schemes provide QoS for high priority calls but waste RBs due to the fixed reservation used as some resources may be left unused. The schemes proposed in [22, 25] dynamically reserve RBs by adjusting the amount of reserved resources for high priority calls based on traffic conditions and service contracts in order to efficiently utilize the resources.

Although these schemes have higher resource utilization compared to the fixed reservation, the scheme in [22] inefficiently manage resources due to uncertainty in mobility prediction. In addition, these schemes degrade QoS requirements of higher priority calls as reserved resources may be insufficient when their traffic increases.

The BD schemes proposed in [23, 27-34] are designed to improve the resource utilization. These schemes degrade low priority calls in order to accommodate more calls in the network. Most of these schemes [23, 27-32] degrade a fixed amount of resources from low priority calls to improve resource utilization but the schemes are unfair due to degradation procedures used. The scheme in [33] employs variable sized degradation to address unfairness issue but has poor QoS and inefficiently utilizes resources due to failure to consider channel condition during the life time of calls. Also, the scheme in [34] employs full and partial degradation to admit high priority connections.

The BR-BD schemes proposed in [35-41] are designed to enhance QoS requirements of high priority calls and resource utilization. These schemes reserve resources for calls of high priority and degrade low priority calls in order to admit more calls when resources are insufficient. These schemes improve resource utilization and QoS requirements. However, these schemes are unfair due to the degradation policies used.

Similarly, NBR-NBD schemes proposed in [42-49] are designed to address unfairness problem and ensure QoS for admitted calls. These schemes neither reserve nor degrade already assigned resources but achieve fairness and QoS for admitted calls except for scheme in [44] that have poor QoS because it only considers the channel quality of calls once (when they are admitted) and scheme in [48] that is unfair due to the prioritization policy used. Furthermore, the schemes in [42, 45, 47, 48] also achieve efficient resource utilization but schemes in [42, 44, 46] inefficiently utilize resources.

Table 1. Comparative analysis Of the various CAC schemes.

Scheme	Adaptability	Class	Strength	Weaknesses
Bandwidth Reservation CAC (BR CAC) and Dynamic CAC (DCAC) schemes 8]	Fixed and Adaptive	BR	-Improved QoS for voice traffic -low HCBP	-underutilization of network resources -unfair to non-voice calls
Guard Channel (GC) [13]	Fixed	ll	It decreases HCDP	V- very high NCBP - - resource wastage
fractional guard channel (FGC) [14]	Fixed	ll	-low NCBP	-increased HCDP -Low resource utilization
Uniform Fractional Guard Channel (UFGC) [15]	Fixed	ll	-improved resource utilization -low HCDP and NCDP	-high HCDP under high traffic arrival rate
New Call Bounding (NCB) [16]	Fixed	ll	-Improved QoS for ongoing calls -low HCDP	-increased NCBP -resource wastage
Call Admission Control with Resource	Fixed	ll	-enhanced QoS for ongoing calls	- resource waste

Reservation (CAC-RR) [17]				
Limited Fractional Guard Channel (LFGC) [18]	Fixed	II	-minimizes NCBP -improves QoS	-increases HCDP -does not consider channel utilization
Queuing principle [20]	Fixed	II	-decreases NCBP	-increases HCDP
advance resource reservation-based CAC (AR-CAC) [21]	Adaptive	II	-Lower HCDP -ensures QoS	-inefficient utilization of resources -increased NCBP
Ring Based Call Admission Control (RCAC) Scheme [22]	Adaptive	II	-low HCDP -efficient resource utilization	-resource waste due to uncertainty mobility prediction
CAC algorithm for high vehicular speed communication [24]	Fixed	II	-fairness in admission -low HCDP and NCBP	-inefficient utilization of resources
Adaptive Connection Admission Control Algorithm based on RB allocation [25]	Adaptive	II	-decreases resource wastage -easy to implement -decreases NCBP	-increases HCDP
novel resource allocation scheme [26]	Fixed and adaptive	II	-guarantees throughput for all -decreases HCDP	-increases NCBP
Fairness-Based Pre-emption Algorithm (FBPA) [27]	Adaptive	BD	-fairness in pre-emption -maintains HCDP and NCBP	-resource wastage
priority-scaled (PS) pre-emption technique using Allocation and Retention Priority (ARP) [28]	Adaptive	II	-decreases HCDP	-decreases QoS
radio admission control (RAC) scheme [29]	Adaptive	II	-maintains QoS -better resource utilization	-not suitable for HCs
Persistent Scheduler Based Call Admission scheme [30]	Adaptive	II	-improves HCDP -improves resources utilization	-is unfair to calls with bad channel
CAC scheme based on Adaptive Bandwidth Allocation [23]	Adaptive	II	-lower HCDP -reduced handovers -maintains resource utilization	-increased NCBP
Utility Based Scheduling and CAC scheme [31]	Adaptive	II	-improves HCDP and resource utilization	-unfair to calls with bad channel
Extensive DBA-CAC Mechanism [32]	Adaptive	II	-low HCDP and NCBP -Better resource utilization	-unfair treatment of calls
Fair Intelligent (LTE-FIAC) scheme [33]	Adaptive	II	-Lower NCBP -fair share of resources	-low QoS

Fuzzy-based decisive CAC [34]	Adaptive	ll	- QoS assurance	-Increased dropping rate of low priority connections -reduced system resource utilization -
Adaptive CAC scheme [35]	Adaptive	BR-BD	-Lowers call blocking probability -Maintains efficient resource utilization	-increases delay of NCs -is unfair to NRT calls
Dynamic Bandwidth Adaptation supported Adaptive CAC Mechanism [36]	Adaptive	ll	-decreases HCDP -decreases NCBP	-unfair NRT calls
Adaptive call admission control scheme [37]	Adaptive	ll	-improve resource utilization -decreases HCDP -decreases call blocking for VoIP	-inefficiently utilizes network resources
Flexible Call Admission Control scheme with Preemption [38]	Adaptive	ll	-reduced NCBP for high priority calls -high throughput	-unfairness to low priority calls -increases NCBP for low priority calls
Multiservice CAC (MSCAC) [39]	Adaptive	ll	-low blocking probability for all calls - ensures resource utilization	-unfair to NRT calls
Efficient Channel State Based Call Admission Control (CBECAC) for Non-Real calls [40]	Adaptive	ll	-better resource utilization -low HCDP	-unfair to BE services
Adaptive CAC Scheme based on Markov Model and [41]	Adaptive	ll	-maintains resource utilization -lowers blocking probability for all calls	-unfairness
Adaptive CAC With Bandwidth Reservation [4]	Adaptive	ll	-reduces CBP, CDP	-inefficient resource utilization - reduced throughput
Resource-estimated Call Admission Control (RECAC) Algorithm [43]	Adaptive	NBR-NBD	- low average packet delay - Low NCBP	-increased HCDP -reduces resource utilization
Neural Networks (NNs) and Bayesian networks (BNs) based CAC	Adaptive	ll	-ensure QoS -efficient utilization of resources	-may waste resources due to threshold and

schemes [44]				probabilistic approach used
fuzzy based CAC scheme [45]	Adaptive	ll	-greater user satisfaction -better QoS	-inefficient management of resources
Hybrid Adaptive Call Admission Control Mechanism (HA-CAC) [46]	Adaptive	ll	-low HCDP -improves resource utilization	-increases NCBP -cannot guarantee QoS when channel condition varies
Delay-aware Call Admission Control Algorithm (DA-CAC) [47]	Adaptive	ll	-lowers packet delay -decreases HCDP	-inefficient utilization of resources -low data rates -increases NCBP
QoS based CAC and resource allocation mechanism [48]	Adaptive	ll	-ensures high voice quality -improves resource utilization	-unsuitable for multiservice networks
delay aware user classification and adaptive resource reservation-based CAC (DA–UC-ARR) scheme [49]	Adaptive	ll	-maximizes throughput -decreases computational complexity -ensures QoS	-unfair to NRT calls

5. CONCLUSIONS

In this paper, a review of the existing CAC schemes in LTE network is presented. The schemes are classified into four: Bandwidth Reservation (BR), Bandwidth degradation (BD), BR and BD and bandwidth non-BR and non-BD (NBR-NBD). In each of the class, several CAC schemes have been presented by highlighting the operation, strengths and weaknesses of each scheme. Finally, an analysis of these classes is presented in order to provide open issues for future research. In the future, the researchers hope to comparatively evaluate the performance of some of these schemes to gain more insight into their performance under certain network conditions

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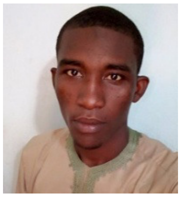

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