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CALL ADMISSION CONTROL FOR WIRELESS BROADBAND NETWORKS: KEY PROCEDURES AND MECHANISMS

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Abstract

Radio Resource Management (RRM) techniques are used in wireless broadband networks to improve the utilization of network resources and guaranteeing the Quality of Service (QoS) of different users. Call Admission Control (CAC) is one of such techniques that has the responsibility of deciding which call connection to be accepted or rejected by the network. CAC has been in existing since during the 2G network era and several schemes have been proposed by different researchers. This paper gives an overview of how CAC procedure works in 2G, 3G, 4G and 5G networks. Basic Call Admission Control scheme (BCAC), Multi-Service Call Admission Control (MS-CAC) and Enhanced Adaptive Call Admission control (EA-CAC) schemes were discussed as the schemes proposed for 2G, 3G and 4G networks respectively. Finally, the paper discusses the CAC procedure for 5G networks by explaining all the steps involved for a CAC scheme's decision taking

Keywords: *Radio Resource Management, RRM, Call Admission Control, CAC, QoS.*

I. Introduction

Quality of Service (QoS) provisioning for different category of users has always been the major concern of wireless broadband networks. Different wireless broadband technologies have been evolving for the purpose of satisfying users need such as high demand for multimedia services like voice, data, video etc. (Odinma, Oborkhale and Kah, 2007). Other factor that leads to the evolution of broadband networks include mobility, due to the fact that wireless mobile professionals or users always demand access to their corporate network remotely anywhere and anytime.

Wireless broadband networks are broadly categorized into two: Fixed and Mobile Wireless networks. Fixed wireless broadband technologies can be seen as high-speed networks that connects stationary locations and are intended to serve nomadic users (Odinma*et.al, 2007*). Examples of such technologies are Wireless Fidelity (Wi-Fi), Wireless Interoperability Microwave Access (WiMax) etc. Unlike the fixed wireless broadband network, a mobile broadband technology is designed with the feature and capability of mobility and can be covers more distance than the fixed wireless networks (Mishra, Maurya and Gaur, 2012). In mobile broadband networks such as 3G and 4G, network resources are mostly scare due to high number of users therefore there is a need for an efficient radio resource management (RRM) technique that will ensure effective utilization of the available network resources to ensure that users has a good experience while using the network (Kolate, Sonawane and Bhide, 2012).

RRM is the system-level control of co-channel interference and radio transmission characteristics in a wireless communication system. RRM techniques are used to improve the utilization of radio resources of the wireless network (Kandaraj, Adlen, Jean and Cesar, 2011). Some of the RRM techniques are: packet scheduling, call admission control, power control and handoff control. This paper will focus on Call Admission Control (CAC) which is a technique which QoS in a network by restricting the access to network resources such as bandwidth, frequency bands etc.

The rest of the paper is organised as follows: Next section presented and overview of wireless broadband networks Section III gave a highlight on Call admission control which discussed how CAC procedure is done in 2G, 3G, 4G and wireless networks. Finally, section IV concludes the paper.

II. Wireless Broadband Networks

This section will give an overview of the evolution of wireless broadband technologies. It shows the different wireless technologies that evolved from the first generation (1G) upto the fifth generation (5G). Figure 1 shows the evolution of wireless broadband technologies.

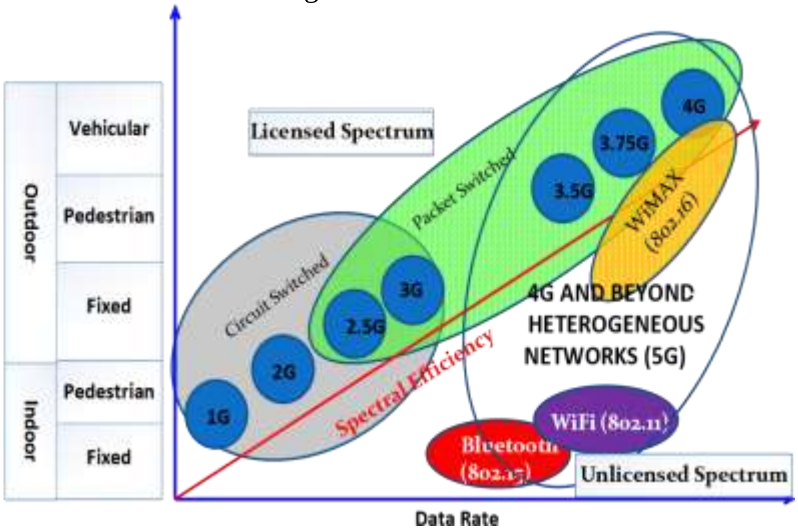

Figure 1: Evolution of wireless technologies (Gupta & Jha, 2015).

It can be seen from figure 1 that 1G and 2G networks uses circuit switching while 3G technologies uses both circuit and packet switching. The next generation networks i.e. 3.5G to 5G utilizes packet switching.

1G has a data rate upto 2.4kbps. The major technologies during the 1G era were Advanced Mobile Phone System (AMPS), Total Access Communication System (TACS) etc. some of the major drawbacks of 1G are reckless handoff, inferior voice association and with no security since voice calls are stored and played in a radio towers due to vulnerability of the calls from unauthorized parties.

Digital technology was used in 2G. Global System for Mobile Communications (GSM) was the first 2nd generation system. It was used for voice communication and has data rate upto 64kbps. The radio signals in 2G were low thereby the batteries of the systems last longer. 2G also supports short message service (SMS) and email services among others.

2.5G systems generally uses 2G system framework and integrates packet switching together with circuit switching. It has a data rate upto 144kbps. Most common 2.5G technologies are GPRS, Enhanced Data rate for GSM Evolution (EDGE) and Code Division Multiple Access (CDMA) 2000. 2.5G is mostly seen as an improvement of the 2G network.

The 3G transmits data upto 2Mbps and it has high mobile access to service based on Internet Protocol (IP). Wide Code Division Multiple Access (WCDMA) and Universal Mobile Telecommunication System (UMTS) are some of the major 3G systems. Some evolving technologies such as High-Speed Uplink/Downlink Packet Access (HSUPA/HSDPA) and Evolution Data Optimized (EVDO) gave birth to a technology between the 3G and 4G known as 3.5G and 3.75G which can transmit data upto 5-30Mbps. One of the disadvantages of 3G systems is that they require more power than 2G system.

4G technology is seen as the descendant of the 2G and 3G standards. It provides services such as voice, data and multimedia services at a very high speed compared to 2G and 3G. Applications designed for 4G are multimedia messaging services (MMS), digital video broadcasting (DVB), video chat etc. Long Term Evolution (LTE) and WiMAX are the major technologies in 4G networks.

The 5G cellular network is designed to address six challenges that were not effectively addressed in the 4G network. There challenges are: higher capacity, higher data rate, low end-to-end latency, massive device connectivity, reduced cost and consistent quality of experience provisioning. 5G is expected to transmit data upto 10-50Gbps (Gupta & Jha, 2015). Table 1 below summarized the evolution of wireless technologies.

Table 1: Evolution of Wireless Technologies (Gupta &Jha, 2015)

<table>
<tr><th>Gen.</th><th colspan="2">Access Technology</th><th>Data Rate</th><th>Applications</th></tr>
<tr><td>1G</td><td colspan="2">Advanced Mobile Phone Service (AMPS) (Frequency Division Multiple Access (FDMA))</td><td>2.4 kbps</td><td>Voice</td></tr>
<tr><td rowspan="2">2G</td><td colspan="2">Global Systems for Mobile communications (GSM) (Time Division Multiple Access (TDMA))</td><td>10 kbps</td><td rowspan="4">Voice + Data</td></tr>
<tr><td colspan="2">Code Division Multiple Access (CDMA)</td><td>10 kbps</td></tr>
<tr><td rowspan="2">2.5G</td><td colspan="2">General Packet Radio Service (GPRS)</td><td>50 kbps</td></tr>
<tr><td colspan="2">Enhanced Data Rate for GSM Evolution (EDGE)</td><td>200 kbps</td></tr>
<tr><td rowspan="2">3G</td><td colspan="2">Wideband Code Division Multiple Access (WCDMA) / Universal Mobile Telecommunications Systems (UMTS)</td><td>384 kbps</td><td rowspan="4">Voice + Data + Video calling</td></tr>
<tr><td colspan="2">Code Division Multiple Access (CDMA) 2000</td><td>384 kbps</td></tr>
<tr><td rowspan="2">3.5G</td><td colspan="2">High Speed Uplink / Downlink Packet Access (HSUPA / HSDPA)</td><td>5-30 Mbps</td></tr>
<tr><td colspan="2">Evolution-Data Optimized (EVDO)</td><td>5-30 Mbps</td></tr>
<tr><td rowspan="2">3.75G</td><td colspan="2">Long Term Evolution (LTE) (Orthogonal / Single Carrier Frequency Division Multiple Access) (OFDMA / SC-FDMA)</td><td>100-200 Mbps</td><td rowspan="2">Online gaming + High Definition Television</td></tr>
<tr><td>Worldwide Microwave Access (WIMAX)(Scalable Orthogonal Frequency Division Multiple Access (SOFDMA))</td><td>Interoperability for Fixed WIMAX</td><td>100-200 Mbps</td></tr>
<tr><td rowspan="2">4G</td><td colspan="2">Long Term Evolution Advanced (LTE-A) (Orthogonal / Single Carrier Frequency Division Multiple Access) (OFDMA / SCFDMA)</td><td>DL 3Gbps
UL 1.5Gbps</td><td rowspan="2">Online gaming + High Definition Television</td></tr>
<tr><td>Worldwide Interoperability for Microwave Access (WIMAX)(Scalable Orthogonal Frequency Division Multiple Access (SOFDMA))</td><td>Mobile WIMAX</td><td>100-200 Mbps</td></tr>
<tr><td>5G</td><td colspan="2">Beam Division Multiple Access (BDMA) and Non- and quasi-orthogonal or Filter Bank multi carrier (FBMC) multiple access</td><td>10-50 Gbps (expected)</td><td>Ultra High definition video + Virtual Reality applications</td></tr>
</table>

Network resources are mostly very scare due to higher demands from network users for different services. An efficient radio resource management technique needs to be deployed in order to manage the available network resources.

Radio resource management (RRM) is the system-level control of co-channel interference and radio transmission characteristics in a wireless communication system. RRM techniques are used to improve the utilization of radio resources of the wireless network. (Kandaraj, Adlen, Jean and Cesar, 2011). To ensure efficient use of radio resources, several techniques are used as part of RRM to provide the users with a service following the configured QoS parameters. The main RRM techniques in LTE are; packet scheduling, call admission control, power control and handoff control (Kandaraj*et al*, 2011). This paper will concentrate on call admission control, we will discuss how call admission control procedure works in different broadband networks.

III. Call Admission Control (CAC)

Call admission control (CAC) is a process of accepting new calls (connection request) or handoff calls in a network while regulating the quality of service (QoS) of existing or active calls without degrading any call drop connection (Maniru, Aminu, Abubakar, Ahmed and Abdulhakeem, 2019). Maniru, Aminu, Abdulhakeem& Solomon (2020) defined Call admission control (CAC) as a process of accepting new calls or handoff calls in a network while regulating the QoS of existing or active calls without degrading any call drop.

CAC is a radio resource management (RRM) technique and has a direct impact on QoS for individual connection and the overall system efficiency (Raymond, Rob, Riccrado and Mitsuhiro, 2010). Call requests are normally classified as New Call (NC) and Handoff Call (HC). NC is a type of call that is requesting for a new connection or requesting to be connected into the network while HC is an ongoing or active call that needs to be transferred from one cell to another and still maintain its connection (Maniru, Aminu, Abubakar, Ahmed and Abdulhakeem, 2021).

The major objective of CAC is to ensure efficient resource allocation and to monitor the resource utilization in the high volume of traffic. CAC determines the condition for accepting or rejecting an NC or HC into the network based on pre-defined criteria such as availability of network resources, network channel condition, etc. to guarantee the QoS parameters without affecting the existing calls (Faouzi, Khitem, Mohammed and Lotfi, 2012).

CAC was introduced during the second generation (2G) era of networks and it has got a lot of attention by several researchers. The next section presents how CAC works in 2G networks.

CAC Procedure in 2G networks

The CAC procedure that was used in the 2G networks was known as Basic Call Admission control (BCAC) which is a static call admission control scheme (Belghith, Turki, Cousin and Obaidat, 2016). The decision for the acceptance and rejection of a call request depends only on the availability of network resources. 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. Therefore, the BCAC scheme only depends on availability of network resources as an admission criterion and it also treats all classes of calls in the same manner without considering a higher priority of lower priority call request. Figure 2 describes the operation of the BCAC scheme.

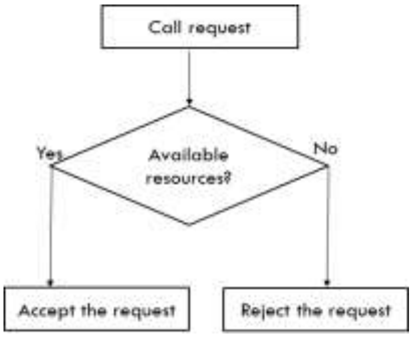

Figure 2: Description of Basic CAC scheme

The BCAC does not consider the type of call request i.e. either a real time or non-real time, all call requests are given same priority. It employs a first come first serve approach for admission.

CAC Procedure in 3G Networks

The CAC procedure that was first proposed in 3G networks was the Multi-Service call admission control (MSCAC). The procedure defines two types of service class which are the Real Time (RT) and Non-real Time (NRT). RT are for conventional and streaming calls while NRT were for Best Effort calls. The MSCAC procedure divides the network resources into two parts i.e. one part for RT and the other part for NRT call requests (Belghith, Turki, Cousin and Obaidat, 2016). The procedure or scheme accepts an NRT call request only if there are enough available resources in the NRT calls part. Similarly, it accepts an RT call request only of there are available resources in the RT calls part otherwise the call request is rejected.

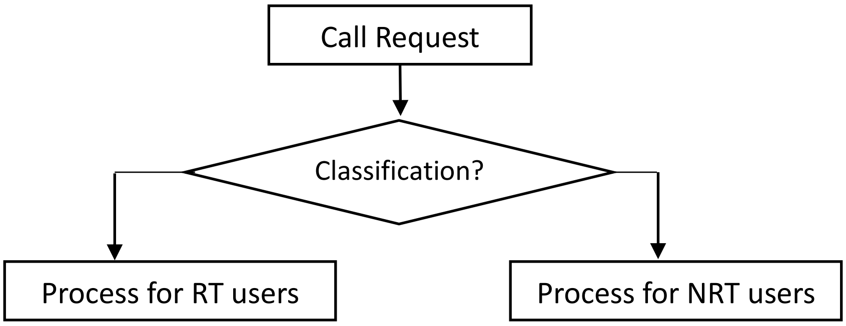

Figure 3: MSCAC Classification of call requests

Figure 3 shows the description of how MSCAC classifies call requests. MSCAC is said to be an improvement of the BCAC because the MSCAC classifies calls into two different categories and also divide the network resources into two parts thereby giving the opportunity to admit different types of calls especially in a situation where different kind of calls are requesting for admission. But in a situation where there is a frequent arrival of one type of call e.g. RT calls and all resources meant for RT are exhausted, then any RT call that arrive will be blocked. Resources meant for the other type of call i.e. NRT are then wasted because there is no NRT call to be admitted while the RT calls cannot be admitted with the resources meant for NRT call requests.

CAC Procedure in 4G networks

In 4G, specifically in the LTE system, CAC process is always performed when a UE starts communication with the eNodeB either through a new call or a handoff call or a new service request by the UE (Ayaz, Chowdhry, Baloch, and Pathan, 2006).

When the UE wants to establish a connection with the eNodeB, it sends a request for resource allocation, admission control at eNodeB handles the request. For 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 the NRT connection request, the optimum scheduling of the packets must be determined after the admission of the call. Call admission control is located at layer 3 i.e. network layer in the evolved Node B (eNB) and is used for setup of both new user and handoff users (Mamman, 2018).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. (Mohammed, 2005).

Several CAC schemes have been proposed for LTE networks, some of the schemes focused on improving the utilization of network resources while some focused on QoS requirements for different calls. A comprehensive survey on different call admission control scheme in LTE was present by Solomon, Abdulhakeem, Aminu, Maniru&Zaharadeen (2019). This paper will give a brief description of one of the CAC scheme proposed for LTE networks which is Enhanced Adaptive Call Admission Control (EA-CAC) Scheme for LTE network.

The EA-CAC scheme was proposed by Maniru*et.al* (2021) with the aim of improving the QoS of calls and also increasing the throughput of RT calls without sacrificing the performance of NRT calls. The EA-CAC scheme introduced a prior-check mechanism that ensures bandwidth to be degraded from admitted calls will be enough to admit the requested calls. It further employed an adaptive degradation procedure that will degraded admitted calls one class after the other i.e. NRT class first before RT class. Figure 4 shows the description of how EA-CAC operates.

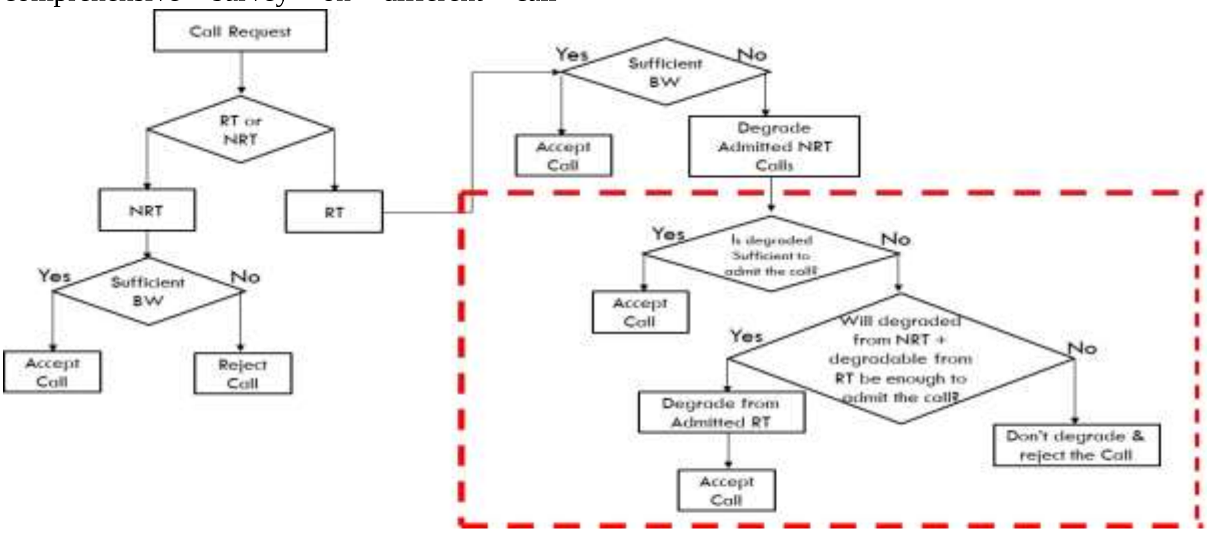

Figure 4: Diagrammatic Description of the EA-CAC Scheme

The scheme starts by categorizing call requests as either RT or NRT before checking for the admission criteria. It admits an NRT call request if the requested bandwidth is less than or equal to the available bandwidth otherwise the call is rejected. On the other hand, the EA-CAC admits the RT call request if the requested bandwidth is less than or equal to the available bandwidth otherwise it degrades admitted NRT calls. Then it will sum the degraded bandwidth with the available bandwidth and then try to admit the call. If the bandwidth is enough, the call is then admitted otherwise, the scheme checks if the degradable bandwidth from RT calls plus the available bandwidth will be enough to admit the call, it will then degrade the admitted RT calls and then admit the call otherwise it will not degrade the RT calls thereby rejecting the call. The EA-CAC reduces bandwidth wastage and also increases the throughput of RT calls without sacrificing the performance of NRT calls.

CAC Procedure in 5G networks

Call Admission Control (CAC) in 5G networks is a critical mechanism that ensures efficient resource utilization and maintains the Quality of Service (QoS) by deciding whether a new call or service request can be admitted into the network. The procedure for CAC in 5G networks involves several steps, including resource allocation, QoS management, and decision-making processes (Al-Maitah*et al., 2018)*. Below are the steps followed by every CAC scheme for 5G networks:

1. **Service Request Initiation:** A user equipment (UE) initiates a service request, which could be a voice call, data session, or any other service requiring network resources.The request includes details about the required QoS, such as latency, bandwidth, and priority level.

2. **QoS Class Identifier (QCI) Mapping:** The network maps the service request to a specific QoS Class Identifier (QCI). QCIs are predefined classes in 5G that represent different types of services with specific QoS characteristics (Slalmi, *et al., 2018)*.

3. **Resource Availability Check:** The 5G network checks the availability of necessary resources (e.g., bandwidth, processing power) to fulfill the QoS requirements of the requested service.

   This involves analyzing current network load, ongoing sessions, and the capacity of the serving base station (gNB).

4. **Decision-Making Process:** Based on the resource availability and QoS requirements, the network makes a decision:

   i. Admit the call: If resources are sufficient, the network admits the call or service request.

   ii. Deny the call: If resources are insufficient, the request is denied to prevent network congestion and maintain the QoS for existing sessions.

   iii. Queue the call: In some cases, the network may queue the request, waiting for resources to become available (Al-Rubaye, *et al*., 2018)

5. **Resource Allocation:** If the call is admitted, the network allocates the required resources to the UE and establishes the necessary connections. This may involve setting up bearers, which are logical channels that carry the traffic with the agreed QoS parameters.

6. **Ongoing Monitoring:** After the call or service is admitted, the network continuously monitors the session to ensure that the QoS requirements are being met.If network conditions change (e.g., increased load or mobility of the UE), the network may adjust resources dynamically or even re-evaluate the admission decision (Slalmi, *et al., 2020)*

7. **Handling Overload and Congestion:** If the network becomes overloaded or congested, it may trigger preemption mechanisms to free up resources. This could involve dropping lower-priority sessions or redistributing resources among active sessions.

8. **Termination of Service:** Once the service or call is completed, the network releases the allocated resources, making them available for other users or services.

9. **Feedback Loop:** The network uses feedback from ongoing sessions to refine future CAC decisions, adjusting thresholds and parameters based on real-time performance data.

IV. Conclusion

In this paper, an overview of wireless broadband networks was given by highlighting how the different technologies evolved from 1G up to the current 5G. It further gave an overview of one of the major radio resource management techniques which is aimed at improving the utilization of network resources and guaranteeing the QoS of different network users. The paper then highlights some of the call admission control procedures that were proposed for 2G, 3G and 4G wireless networks. It was seen clearly that CAC procedure in 3G was an improvement of the

CAC procedure in 2G, likewise that of 4G was an improvement of 3G CAC procedure. Few admission criteria were considered in 2G and more criteria were considered in 4G and 5G, this is as a result of the improvement in various aspects of the broadband technologies such as data rate, frequency band, bandwidth etc.

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