Network Congestion Management Using Call Admission Control

O.A. Alimi, Meera K. Joseph, and A.O. Akinlabi

Abstract**—**Call Admission Control schemes have been used extensively in improving mobile network quality. Signal quality degradation, interference and network congestion has been a real issue for Global System for Mobile Communication (GSM) as the number of mobile users increased rapidly. It has been an issue in providing a decent Quality of Service (QoS) to the network users especially during the period of high network traffic. It is essential to maintain a certain level of quality in handling mobile network congestion. Fortunately, Call Admission Control is a strategy that can provide credible QoS by limiting the number of connections into the cellular network thereby reducing network congestions, dropping of calls, interference and other QoS problems. In this paper, we discuss issues around mobile network congestion, overview of congestion management schemes, attributes and benefits of Call Admission Control (CAC). We also highlight different handoff schemes. We simulated a typical CAC scheme comparing the new call blocking probability and handoff call probability.

Keywords**—** Call Admission Control, Handoff, Mobile Network Congestion, Quality of Service (QoS).

I. Introduction

Call Admission Control (CAC) is a strategy that centers on limiting the number of mobile networks users so as to suppress traffic congestion, call blocking, call dropping as well as providing a good (QoS) to network subscribers [2]. It has been used widely for mobile network congestion management and improving the Quality of Service. CAC schemes consider the network users in the adjacent cells, as well as users in the particular cell being under consideration, in order to decide whether to admit or block the new call [6]. Advances in technologies has made it possible for handy computers and devices including notebooks and tablets to have wireless interfaces hence allowing massive networked communication and mobility. This trend has led to massive mobile congestion, hence making mobile network congestion a key issue. The main objective of this paper is to discuss the concept of Call Admission Control (CAC) and its use in managing network congestion. The other sub-objectives are: to discuss the different types of Handoff schemes [1]. The remainder of this paper is coordinated as follows: Section II provides insight into issues around network congestion. In section III, overview of Call Admission Control, its attributes and benefits will be discussed. In Section IV we will discuss how CAC can be used to handle network congestion and a simulation result will be provided to illustrate a typical bandwidth reservation based CAC scheme. We discuss the conclusions and future research work in section V.

O. A. Alimi is an MTech student at the University of Johannesburg

M. K. Joseph is a senior lecturer at the Department of Electrical and Electronic Engineering Technology at the University of Johannesburg, South Africa.

A. O. Akinlabi is a DPhil student at the University of Johannesburg, South Africa. He completed MTech at the University of Johannesburg.

II. Issues Around Network Congestion

The problem of network congestion is a network managerial issue that affects the Quality of Service (QoS) rendered by a network. Basically over-utilization of a node in a network can lead to short span of resources or malfunctioning. Interference is a serious problem associated with network congestion. Therefore congestion control is of utmost importance for the sustainability of the mobile networks. Token Banks, Automatic Call Gapping, channel borrowing, cell-splitting and development of micro-cells, among others are the conventional methods to manage call congestion [2]. These principles are either to reject excessive traffic to prevent overload from occurring or diverting excess load if overload occurs.

TABLE I
COMPARING VARIOUS MOBILE CONGESTION MANAGEMENT SCHEMES

Congestion management methods	**Congestion Parameters**		
	New Call Blocking	***Handoff Blocking***	***Resources Management***
Cell splitting	Moderate	High	Low
Channel Allocation using channel borrowing	High	Moderate	Moderate
Priority Token Bank	High	High	Moderate
Call Gapping	High	low	High
CAC	Low	Low	High

Table I shows the new call blocking probability, handoff call blocking probability and network resources management for various mobile congestion management schemes. Call Admission Control (CAC) is adjudged the best because it provides massive reduction in handoff call blocking and new call blocking. Also it is a simple and reliable method. CAC performance depends mostly on the efficiency and effectiveness of resources allocation.

III. OVERVIEW OF CALL ADMISSION CONTROL (CAC)

Initiating new users into the system typically intensify the rate of interference in the network [10]. CAC scheme provide a suitable means of accommodating / blocking prospective callers based on the network condition. Resources allocation is a paramount feature of the CAC scheme. The core focus of Call Admission Control scheme is safeguarding ongoing calls by denying new users once there is no available channel to cater for the new calls as they approach the network. Due to the ever growing network subscribers and the relative limited resources in the network, Call Admission Control is essential in order to maintain a good QoS in terms of Connection Level, Packet Level and Packet Loss. QoS parameter in terms of packet level includes Delay and Jitter experience by the network users.

The basis of CAC is such that; assuming there are (N-1) ongoing calls in the network when the N^{th} new user approaches the network, it considers the available resources in the network. If there is enough resources to admit the N^{th} user such that it will not compromise the QoS requirement status of the ongoing (N-1) users as well as the incoming N^{th} user, then N^{th} user will be admitted into the network. Otherwise N^{th} user will be blocked and denied connection to the network. Literarily, the aim of CAC is to efficiently allocate network resources to users in order to produce a reasonable QoS.

Literally, the QoS achieved is an indicator that decides the competency of an industry [9]. QoS in mobile network considers features which include blocking probabilities, receptiveness, interference level, connection consistency and quality of connection.

Mobile network users basically expect that they derive maximum satisfaction from the network service since they are paying for it. However, providing a decent and sufficient QoS to the mobile users has always been a tedious task for the network providers. The number of users is not proportional to the number of network facilities especially during period of high network traffic. This imbalance hence leads to traffic congestion, call blocking, call dropping and hence poor QoS.

QoS requirement can either be at the call level or at cell level [5]. QoS requirement at cell level includes New Call Blocking Probability and Handoff Blocking Probability whereas QoS requirement at call level includes error rate, packet delay, audio and video synchronization as well as packet loss. However, in order to differentiate QoS requirement at cell level from QoS at call level, the QoS at cell level is sometimes referred to as Grade of Service (GoS).

In different countries, there are regulatory bodies to checkmate network providers and influence them to provide satisfactory Quality of Service for their users. The organizations employ diverse QoS factors which include Successful Call Completion Rate (SCCR) [17], Signal-to-interference Ratio (SIR) [16] and Answer Seizure Ratio (ASR) [18] among others. These factors are employed to control and regulate the service offered to network users. Table II shows the basic characteristics and features of the QoS factors and how they affect the QoS.

TABLE II
COMPARING VARIOUS MOBILE CONGESTION MANAGEMENT SCHEMES

QoS Factors	Characteristics/ Description	How it affect QoS
SCCR	No of calls completely served to completion per unit time by each cell	High CCR implies high QoS, high call arrival rate and high new calls blocking and low handoff blocking.
SIR	Measured at base station. It is the ratio of the desired mobile's signal power to the sum of the power from all other mobiles.	Low SIR yield low new call blocking probability and low handoff call blocking probability
ASR	It depends more on users behaviour, far end switch congestion	High ASR yields decent QoS

However, network users are more concerned about the connection level i.e. how easy it is, to initiate and get connected into the network, the quality of the voice call and the call retain ability based on the users' mobility.

The verdict making on acceptability or reject ability of a call in ancient networks like AMPS and GPRS is easy to make since the usable number of channels are known. Where as in CDMA and NGWN, the total amount of callers cannot state the available space in the network. New user will get allocation only if it will not affect the customers already in the network.

Call Admission Control scheme considers the network users in the adjacent cells, as well as users in the particular cell being under consideration, in order to decide whether to admit or block the new call [6]. The admission decision in Call Admission Control is made in real time making the process efficient without the involvement of network call processor. Furthermore, Call Admission Control scheme decreases handoff call dropping probability as well as system overload probability to a predefined level irrespective of the numbers of pending users and ongoing calls. However, Call Admission Control is however complicated in new generation wireless networks majorly as a result of the fact that users are mobile and fluctuating quality of network link and nodes. Call admission control (CAC) is a means of minimizing New Call Blocking Probability (NCBP) and Handoff Call Dropping Probability (HCDP) [4].

CAC schemes are simple and reliable means of managing network congestion. They yield less programming difficulties and allows multiple connection requests to be handled simultaneously. Also it tolerates less power consumption [13].

Call Admission Control is one of the most efficient methods for optimal management of network resource [8]. When a new user initiate a call in one cell, the new call will trigger a request for a channel in the cell. If there is no available free channel, the call will relocate to neighboring cell, if it hit a dreadlock in the neighboring cell, the call will be blocked.

A. Attribute of Call Admission Control

In homogenous networks, CAC controls the number of network users in the network. Call Admission Control considers the total number of calls in the system in order to make a verdict on either accepting or rejecting the new call. In a situation where the new users eclipse the cell capacity threshold, the new users will be blocked from gaining access into the network. Contrarily, the new users will be admitted into the network. For handoff calls, an ongoing call will be rejected only if there is no channel for it to be admitted to, in the new cell it is migrating to. However, the decision on whether to admit or reject calls in Call Admission Control is made in real time making the process highly dynamic and reliable.

B. Benefits of Call Admission Control

The key purpose of CAC algorithm is to limit the interference level in the network by monitoring the number of new calls and handoff calls that are being accepted or rejected [13].

Call Admission Control is an efficient means of managing radio resources in wireless networks [12]. Proper resource management and utilization are vital techniques for improving the QoS. CAC schemes performs the resources utilization effectively by allowing or denying connection requests into the network based on the situation in the network.

Call Admission Control scheme reduce the System Overload Probability to a low level irrespective of the numbers of pending users and ongoing calls. The effectiveness of resources allocation determines the performance of a CAC scheme [7]. This advantage make CAC scheme a very effective means to maximizing the effectiveness of the network system.

However, Call Admission Control scheme is not effective in handling heterogeneous wireless networks due to the movement of users as well as varying quality of network link and nodes. CAC algorithms do not consider the inter-layer issues that are known with heterogeneous and overlay networks [14]. Decision making on either admitting or rejecting calls, voice or data in heterogeneous networks is challenging and tedious for CAC schemes as a result of multiple conflicting parameters. This is basically due to the complexity of heterogeneous wireless networks. Furthermore, Call Admission Control scheme is peculiar to voice traffic especially wireless mobile network and in VoIP (voice over internet protocol). In an event of data congestion in a network node, queuing, and buffering manages the situation.

But overall, CAC is a decision making scheme that is processed even before a call is made into the system and it is sorely built on availability of resources to cater for the call in order to deliver a credible QoS that will favor network users [11].

IV. THE USE OF CALL ADMISSION CONTROL TO HANDLE NETWORK CONGESTION

As shown in fig. 1, when a call (either new call or handoff call) try to access the network, the request will be granted access only if there is available bandwidth to cater for the request. And if there is no available channel to cater for the call request, the call will be blocked/dropped.

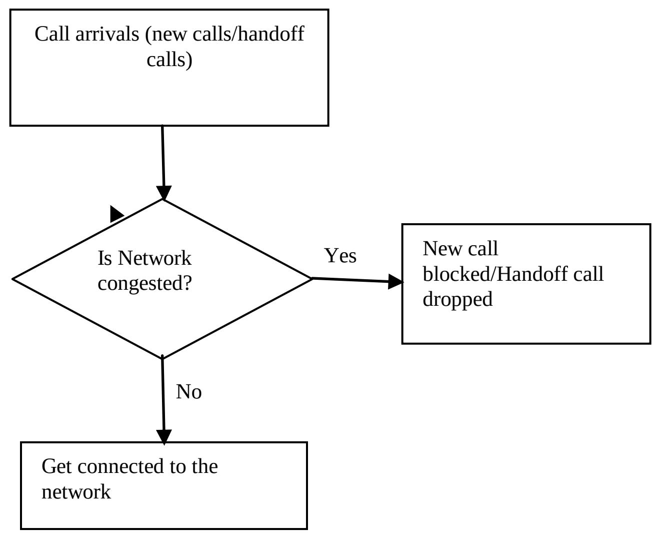

Fig. 1 Call admission control illustration

Furthermore, Call Admission Control dwindle the Handoff Call Dropping Probability due to the fact that high priority is accorded to handoff calls over new calls in the cell capacity. Higher priority is typically accorded handoff calls with respect to new calls due to user sensibility and irritability to their ongoing calls being terminated. CAC algorithm work in such a way that it controls the reception of new calls as well as the reservation of some time slots purposely for handoff calls [5]. Hence, in CAC, the probability of handoff calls being dropped is lower compared to the probability of new calls being blocked.

New Call Blocking Probability (PB) is the probability that a new call request will be blocked once there is no more capacity in a given coverage cell to cater for the request [20].

Handoff Call Dropping Probability (PD) is the probability that a handoff call request will be dropped once there is no more capacity in the cell the call is moving into [20]. The condition for PB and PD is given as [19] as in (1):

$$b + \sum ((b \times n) + (b \times h)) > C \qquad (1)$$

Where C denotes cell Capacity, b denotes bandwidth, n denotes number of new calls and h denotes that of handoff calls. A threshold for new call (Tn) is set for the maximum capacity that can be occupied by new calls. Once the threshold is reached and exceeded, new call blocking will commence.

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The threshold for new calls is defined by the constraint [19] as in (2):

$$b + \sum ((b \times n) > Tn \qquad (2)$$

Where Tn denotes threshold for new calls and Th denotes threshold for handoff calls. The threshold (Th) is set for the maximum capacity that can be occupied by handoff calls. Once the threshold is reached and exceeded, handoff call dropping will commence. The threshold for handoff calls is defined by the constraint [19] as in (3):

$$b + \sum (b \times h) > Th \qquad (3)$$

From fig. 2, a simulation is carried out using MATLAB to illustrate a typical bandwidth reservation based CAC scheme. Parameters used (Table III) for the simulation includes two cells of the same capacity but different threshold levels for new calls and handoff calls.

TABLE III
PARAMETERS USED FOR SIMULATION

Cell	Threshold capacity for new calls (Tn)	Threshold capacity for handoff calls (Th)	Summation of Call arrival rate	Bandwidth (b)
A	15	20	24	2
B	10	20	24	2

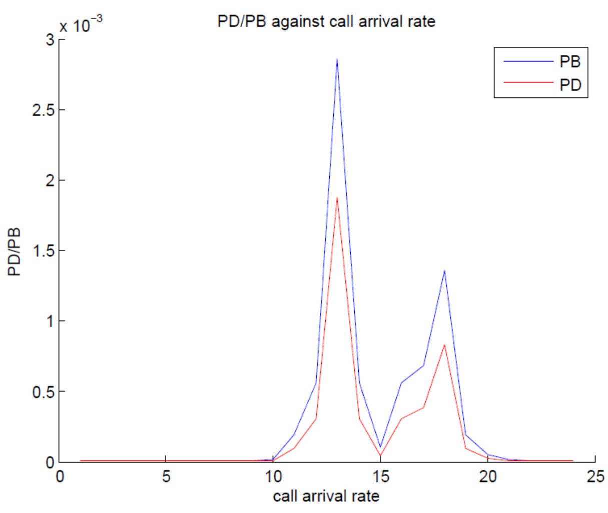

Fig. 2 Blocking probabilities as a function of call arrival rate.

There are two bandwidth per each cell. The CAC scheme compensate massively for handoff calls over new calls due to some bandwidth being reserved solely for handoff calls. From the simulation as shown in fig. 2, it is shown that Handoff Call Blocking Probability (PD) is slightly lower compared to New Call Blocking Probability (PB). This is one of the main characteristics of CAC schemes, it compensates for handoff calls more compared to new calls.

In wireless network, users' mobility tends to complicate the network system. Handoff happens when a current user in the network migrates from its cell into alternative cell due to the mobility of the mobile user [3]. Handoff enables mobile users to maintain their connectivity while migrating between cells. Managing handoff calls is a key issue in mobile networks. Cellular Network supports the handoff of users between various wireless technologies [1]. During the process of handoff, mobile users instantly adjust its power to the nearest cell with least transmission power in the mobile station. During this transition process, the call may get dropped. A current user of the network may be dropped due to inadequate bandwidth to support it in the cell it is migrating to. Handoff call blocking refers to blocking of ongoing calls due to the mobility of the user. As shown in fig. 3, a user that is connected to Cell A will move to Cell B due to his/her mobility. However, if there is no available channel to accommodate the user in Cell B, the user will be blocked.

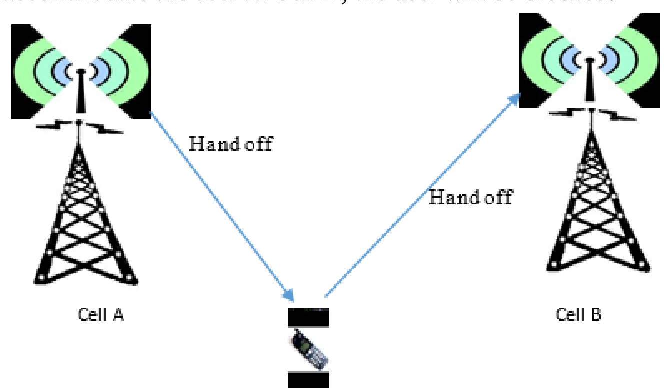

Fig. 3 Schematic illustration of a Handoff.

Handoff schemes can be classified according to the way the call is being handed off as well as the manner in which new channels are being arranged [8]. At call level, Soft Handoff and Hard Handoff are the classes of handoff schemes.

A. Soft Handoff

In this particular class, a mobile terminal uses multiple radio links to connect with the network via different base stations. The overlapping areas between several cells start the handoff process shortly before the actual handoff occurs. The old channel will be released only after the new channel has allocated a space for the ongoing call. Two channels are simultaneously used for a single call, hence reducing call dropping. In soft handoff, it involves a conditional choice on whether to hand off. The decision depends on the pilot signal strength from the cells involved [15]. Some of the mobile communication that uses soft handoff are the new generation CDMA-based system.

B. Hard Handoff

In the hard handoff class, the mobile terminal only communicates with a base station for the duration of the handoff process. The disengaging channel is disconnected before the new channel pick up the call. Hence, there is a probability of little disruption of ongoing calls during the transition [1]. Also there is a possibility of the call to be forcibly terminated if the old channel is disengaged earlier before the handoff transition. In a situation whereby there is an available channel, a handoff may fail once the link transfer response is slow. Second generation GSM mobile systems use the Hard Handoff scheme. However, both new call blocking and Handoff call blocking occurs as a result of channels unavailability.

V. Conclusion

Cellular networks users expect credible Quality of Service (QoS). The desired QoS can be achieved using Call Admission Control (CAC) scheme. This is done by restricting incoming and ongoing calls to the network. The QoS performances relate to both new call blocking and handoff call blocking. In our paper we highlighted CAC as an efficient scheme for handling congestion in homogenous mobile networks. We simulated a typical CAC scheme comparing the new call blocking probability and handoff call probability. Future research will focus on how CAC can be fully utilized for handling congestion in heterogeneous mobile networks.

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Mr. O.A. Alimi is a registered M.Tech. student in Electrical and Electronic Engineering at University of Johannesburg. He completed his B.Tech degree in Electronic and Electrical Engineering from Ladoke Akintola University of Technology, Oyo state, Nigeria in 2011. His research interest is in wireless networks.

Mr. A.O Akinlabi is a registered DPhil in Electrical and Electronic Engineering student and Senior Tutor at the University of Johannesburg (UJ). He completed his M.Tech degree from UJ and B.Tech degree in Electrical and Electronic Engineering Technology in 2007 from Nigeria. For academic excellence, he has the best paper award from IMECS. His research interest focuses in the field of communications and power distribution and generation, interference management, power generation and distribution. The major focus is to improve in both the lack of industrialization and infrastructure in remote areas

Dr. Meera K. Joseph received the degrees of DPhil. Engineering Management from the University of Johannesburg (UJ) in 2013 and M.C.A in 1997 from the Bangalore University, India. Many postgraduate students completed Masters degree under her supervision and she has many IEEE international conference papers, international journal papers and book chapters to her credit. Her research interests include Information and Communication Technology for Development, Smart Grids, Cloud Computing and Computer Networks. She works as a Senior Lecturer at UJ and she is a Professional Member of IITPSA.