



ENHANCED CONTROL STRATEGY FOR HIGH SPEED WIRELESS NETWORKS

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Abstract:

In 4G cellular networks, call admission control (CAC) has a direct impact on quality of service (QoS) for individual connections and overall system efficiency. Reservation-based CAC schemes have been previously proposed for cellular networks where a certain amount of system bandwidth is reserved for high-priority calls, e.g., hand-off calls and real-time new calls. Traditional reservation-based schemes are not efficient for 4G vehicular networks, as the reserved bandwidth may not be utilized effectively in low hand-off rates. We propose a channel borrowing approach in which new best effort (BE) calls can borrow the reserved bandwidth for high-priority calls. Later, if a hand-off call arrives and all the channels are busy, it will pre-empt the service of a borrower BE call if there exists any. Our focus in this paper is on the system modeling and performance evaluation of the proposed scheme. We present two system models that approximate the operation of the proposed scheme. For these models, we derive the CBP and CDP analytically. It is shown that our analytical results are very close to the ones obtained from simulations.

Key Words: Long-Term Evolution, High-Speed Wireless Communication, Mobile Phones, Data Terminals, GSM/EDGE & UMTS/HSPA.

1. Introduction:

The evolution of vehicular networks is aimed to support non-safety multimedia applications which require high-speed Internet for mobile users [1-9]. Fortunately, the telecommunication industry landscape for cellular networks is growing rapidly from 2G to 4G to accommodate the increasing usage of multimedia applications and users' mobility. In 4G, Worldwide Interoperability for Microwave Access (WiMAX) and Long-Term Evolution (LTE) are two emerging broadband wireless technologies aimed to provide high-speed Internet of 100Mbps at a vehicular speed of up to 350 km/h [1, 2]. Recently, research on the performance evaluation and improvement of 4G/5G vehicular networks has been under the focus of researchers in the field of vehicular networking [10-15]. In 4G vehicular networks, call admission control (CAC) is considered as one of the radio resource management (RRM) functionalities and has a direct impact on quality of service (QoS) for individual connections and overall system efficiency.

The goal of the CAC mechanism is to regulate the admission of new users, while controlling the quality of current connections without any call drops. In the traditional mobile networks, e.g., cellular and vehicular networks, CAC schemes have been designed to handle the voice traffic. On the other hand, design of practical and efficient CAC schemes for 4G vehicular networks [16-21]. Challenging task due to the heterogeneous nature of multimedia traffic, user mobility, etc. However, CAC design is left open for innovation in 4G wireless network standards, such as WiMAX and LTE.

In the design of CAC schemes, the most common QoS parameters for performance evaluation are call blocking probability (CBP) and call dropping probability (CDP). Call blocking means denying new calls due to insufficient bandwidth in the network or the QoS requirements. Call dropping means dropping an existing call during a hand-off process due to users' mobility (vehicular or pedestrian). Forced termination of a call in progress is more frustrating than blocking a new call. As a result, hand-off calls are treated differently by being given higher priority over new calls in cellular/vehicular networks. Particularly, we may either reserve certain amount of channels from the total available channels in a cell for hand-off calls or dynamically allocate channels for an individual cell, based on the time-varying status of vehicular traffic. The amount of channel reservation for handoff calls is mostly based on users' mobility pattern, i.e., using vehicular traffic modeling that aggregates variables such as traffic density, mean speed, etc.

In various research efforts on mobile cellular networks, the hand-off call arrival rate can be derived from the mobility model. CAC designs based on mobility and traffic models will be depended on the assumptions made in modeling of the users' mobility and traffic pattern. In vehicular networks, due to the fast movement of vehicles, the variation range of hand-off rates is large. A good CAC design for 4G vehicular networks should be robust enough to support a vast range of hand-off rates [22-24]. This motivates us to

propose a CAC scheme which is robust enough to support a vast range of hand-off rates. We will propose a CAC scheme that irrespective of the traffic model and mobility pattern can improve the CBP considerably while not affecting CDP over a large range of hand-off rates. This motivates application of the proposed scheme for 4G vehicular networks.

2. Literature Survey:

Guard Channel-based call admission control strategies are a classical topic of exhaustive research in cellular networks (Lunayach et al., 1982; Posner & Guerin, 1985; Hong & Rappaport, 1986). Guard channel-based strategies reserve an amount of resources (bandwidth/number of channels/transmission power) for exclusive use of a call type (i.e., new, handoff, etc.), but they have mainly been utilized to reduce the handoff failure probability in mobile cellular networks. Guard Channel-based call admission control strategies include the Conventional Guard Channel (CGC) scheme¹ (Hong & Rappaport, 1986), Fractional Guard Channel (FGC) policies² (Ramjee et al., 1997; Fang & Zhang, 2002; Vázquez-Ávila et al., 2006; Cruz-Pérez & Ortigoza-Guerrero, 2006), Limited Fractional Guard Channel scheme (LFGC) (Ramjee et al., 1997; Cruz-Pérez et al., 1999), and Uniform Fractional Guard Channel (UFGC) scheme³ (Beigy & Meybodi, 2002; Beigy & Meybodi, 2004). They have widely been considered as prioritization techniques in cellular networks for nearly 30 years because they are simple and effective resource management strategies (Lunayach et al., 1982; Posner & Guerin, 1985; Hong & Rappaport, 1986). In this section, both a comprehensive review and a comparison study of the different approximated mathematical analysis methods proposed in the literature for the performance evaluation of Guard-Channel-based call admission control for handoff prioritization in mobile cellular networks is presented.

- ✓ The general guidelines of the model presented in most of the listed references are adopted to cast the system considered here in the framework of birth and death processes.
- ✓ A homogeneous multi-cellular system with S channels per cell is considered. It is also assumed that both the unencumbered call duration and the cell dwell time for new and handed off calls have negative exponential probability density function (pdf).
- ✓ Hence, the channel holding time is also negative exponentially distributed. $1/\mu_n$ and $1/\mu_h$ denote the average channel holding time for new and handed off calls, respectively.
- ✓ Finally, it is also assumed that new and handoff call arrivals follow independent Poisson processes with mean arrival rates λ_n and λ_h , respectively.
- ✓ In general, the mean and probability distribution of the cell dwell time for users with new and handed off calls are different (Posner & Guerin, 1985; Hong & Rappaport, 1986; Ramjee et al., 1997; Fang & Zhang, 2002).
- ✓ The channel occupancy distribution in a particular cell directly depends on the channel holding time (i.e.: the amount of time that a call occupies a channel in a particular cell). The channel holding time is given by the minimum of the unencumbered service time and the cell dwell time.
- ✓ On the other hand, the average time that a call (new or handed off) occupies a channel in a cell (here called effective average channel holding time) depends on the channel holding time of new and handed off calls and its respective admission rate.

3. Proposed Systematic Approach:

A new call belongs to one of the traffic classes defined in the network. Other than the new call arrivals, there exist hand-off calls which are generated in a cell due to the mobility of users into the cell. Note that the hand-off calls have the same traffic classification. Assuming a wireless network with N traffic classes, the Markov modeling of the system will end up to a Markov chain with $2 \times N$ -dimensional state space which makes it unfeasible to analyze mathematically. To show the effectiveness of our proposed reservation-based CAC scheme and to provide an analytical performance evaluation for it, we consider a 4G wireless network with two main priority traffic classes. In our model, we assume that the high-priority class contains only the hand-off calls that is coming from other cells in the cellular network. We may also categorize the real-time new calls in the current cell into this class.

The low-priority class contains the new calls generated in the current cell. We assume that the new calls are subcategorized to non-real-time (nRT) new calls and best effort (BE) new calls. Examples of nRT and BE calls are non-real time multimedia traffic (e.g., YouTube video) and web traffic, respectively. Example of real-time traffic is live broadcasting. It is assumed that the arrival processes of hand-off, nRT, and BE calls are Poisson distributed with parameters λ_H , λ_{nRT} , and λ_{BE} , respectively. We further assume that the service processes of the hand-off, nRT, and BE calls are exponentially distributed with parameters μ_H , μ_{nRT} , and μ_{BE} , respectively. The system bandwidth is channelized, and the number of channels (bandwidth units) in the system is C . Note that C is not the network capacity in terms of amount of served traffic (which is dependent on the users' wireless channel model and interference). In this model, C denotes the number of physical network resources in a cell which should be allocated to the arriving calls, e.g., number of physical resource blocks in an LTE network.

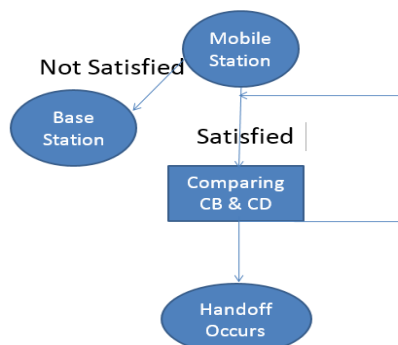


Figure 1: Flowchart of the Proposed Method

We build our channel borrowing idea on the *new call bounding scheme* proposed, and henceforth, we call this CAC as the conventional scheme. We first review the new call bounding scheme and then explain how we incorporate our channel borrowing approach in this scheme.

4. Result Analysis and Discussions:

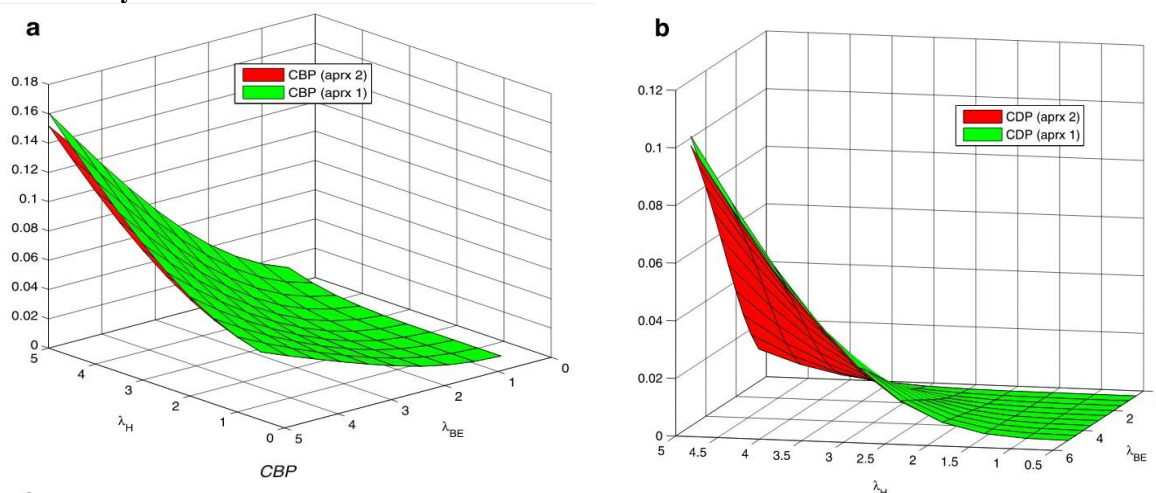


Figure 2: Simulation results of the Proposed Method

5. Conclusion:

A hand-off arrival call can pre-empt the service of a borrower BE call, and the pre-empted BE calls are stored in a queue to resume their service in future. Moreover, we modeled the channel borrowing scheme using a mixed loss-queuing system and introduced two system approximations for the proposed borrowing scheme to simplify the mathematical analysis. By using simulations and numerical analysis, we showed that the two approximations result in very close CBP and CDP values with respect to the actual CBP and CDP values. Furthermore, it was shown that channel borrowing decreases CBP considerably while it only increases CDP slightly. In our study, the number of reserved channels for high-priority calls, i.e., T , is assumed to be fixed. Optimization of T with respect to the number of users in the cell and the arrival rate of high-priority calls can be considered as a future work in this area of research.

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