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Application of support vector machines to bandwidth reservation in sectored cellular communications ☆

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Abstract

Many mechanisms based on bandwidth reservation have been proposed in the literature to decrease connection dropping probability for handoffs in cellular communications. The handoff events occur at a much higher rate in sectored cellular networks than in traditional cellular systems. An efficient bandwidth reservation mechanism for the neighboring cells is therefore critical in the process of handoff during the connection of multimedia calls to avoid the unwillingly forced termination and waste of limited bandwidth in the sectored cellular communications, particularly when the handoff traffic is heavy. In this paper, a self-adaptive bandwidth reservation scheme, which adopts support vector machines technique, is proposed to reduce the forced termination probability. Meanwhile, a channel-borrowing technique is used to decrease the new call-blocking probability of real-time traffic. The simulation results show that the proposed scheme can achieve superior performance than the representative bandwidth-reserving schemes in sectored cellular networks in the literature when performance metrics are measured in terms of the forced termination probability and the new call- blocking probability.

Keywords: Bandwidth reservation; Wireless networks; Sectored antenna; Quality of service; Support vector machines

1. Introduction

With the increasing demand for the provision of the multimedia services in wireless networks, a great deal of attention is being paid to resource allocation for providing seamless multimedia access in the next generation mobile communication networks (Lin and Chlamtac, 2001; Tripathi et al., 1998). However, how to allocate and use the limited bandwidth in a wireless environment efficiently is a challenging issue due to the existence of some bandwidth intensive multimedia applications and client mobility.

There are two important quality-of-service (QoS) parameters considered in wireless networks, namely the handoff-dropping probability (CDP) and new call-blocking probability (CBP). Handoff is a mechanism that a mobile host (MH) is transferred from one base station (BS) to another during an ongoing call and the desired bandwidth should be allocated in the new cell in order to provide QoS guarantee for multimedia traffic. The CDP denotes the likelihood that an ongoing call is forced to terminate during a handoff process when the allocated resources in the new cell are degenerated to an unacceptable level, while the CBP represents the possibility that a new connection request is denied admission into the cellular networks. Accordingly, one of the most important QoS issues in providing multimedia traffic in wireless networks is to reduce handoff drops caused by lack of available bandwidth in the new cell while maintaining high bandwidth utilization and

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low new call-blocking rate. This QoS issue is even more important in dense urban areas whereby microcellular networks or the BS sectorization is widely employed to provide greater traffic capacity in a given area than traditional macrocellular networks or nonsectorized layouts (Clark et al., 1997; Jiang and Rappaport, 1994) due to much higher frequencies for handoff events. In recent years, a variety of resource reservation algorithms have been proposed to process handoff to ensure satisfactory reception quality in cellular networks (Liu et al., 1998; Lee et al., 2000, 2001; Boumerdassi and Beylot, 1999; Oliveira et al., 1998; Levine et al., 1997; Malla et al., 2001; Sherif et al., 2000; Kuo et al., 2001; Wu et al., 2000; Ei-Kadi et al., 2002). Among them, Oliviera et al. suggested reserving some bandwidth in the target cells and the neighboring cells at the same time. However, their scheme was unable to adapt to the abrupt oscillation of bandwidth requirement and bandwidth utilization was deteriorated as well (Oliveira et al., 1998). Levine et al. presented a shadow cluster scheme to reserve resources with neighboring cells by exchanging information related to the movement pattern and position (Levine et al., 1997). However, the scheme introduces too many communication overheads among the BSs of the cellular system. Malla et al. (2001) proposed a scheme based on max–min fairness protocol to provide QoS guarantees in wireless multimedia network. In spite of potentially improving both the CBP and the CDP in this scheme, the users might be subjected to significant bandwidth fluctuations. Lee et al. presented a handoff management scheme using simultaneous multiple bindings that reduces packet loss and generates negligible delays due to handoff in IP-based third-generation cellular systems (Lee et al., 2000). The CDP is probably reduced whereas the bandwidth levels of ongoing multimedia traffic are also degraded. Kuo et al. took use of the knowledge of staying time, available time, and the class of the MH to develop a resource semi-reservation scenario and it turns out to be idealistic since the speed of the MH is difficult to detect accurately (Kuo et al., 2001). The traffic in a wireless system is first divided into two classes, which are voice calls and video calls by Wu et al. (2000). Then a channel borrowing scheme is proposed to allow voice calls to borrow channels from those pre-allocated to video calls temporarily. Although the CBP for the voice calls is reduced, the issue of improving the CDP during the handoff is not addressed. The work proposed by Ei-Kadi et al. borrowed bandwidth from multimedia connections for supporting the new calls or handoff connections because multimedia connections can tolerate and gracefully adapt themselves to transient fluctuations in QoS (Ei-Kadi et al., 2002). The borrowed bandwidth is returned to the original connections as soon as possible to satisfy the QoS requirements. There is 15% of bandwidth reserved exclusively for multimedia handoff connections. Thus, if a new call or handoff call requests for bandwidth, the scheme by Ei-Kadi et al. (2002) tries to borrow bandwidth from other existing connections first. If the borrowed bandwidth is insufficient for the request, the connection will try to use the bandwidth in the reservation pool. If there is no enough bandwidth, the connection will be dropped.

Although much attention has been paid to process the handoffs by using bandwidth reservation schemes in the traditional cellular systems, sectorized layouts in the future cellular systems, to the best of our knowledge, have never been considered in the literature. In sectored cellular systems, directional antennas are used to divide a cell into several sectors. In three-sectored cellular systems, three-directional antennas are used at the center of each cell to provide 360° of coverage. Although the three-directional antennas can be angled to improve traffic cover and meet other network design objectives, the azimuths of three antennas are assumed to be 0, 120, 240, respectively, in this work to simplify the design of the proposed algorithm. Fig. 1 shows an example of 120° antenna cellular system, where the alphabets A, B, C, D, E, F, and G denote the seven cells in a cluster.

Support vector machines (SVMs) have been successfully applied in many areas, such as time series prediction (Cao and Tay, 2003; Van Gestel et al., 2001; Zhu et al., 2002; Raicharoen et al., 2003), Internet traffic prediction, call classification for AT&T's natural dialog system, multi-user detection and signal recovery for a code division multiple access (CDMA) system, etc. (Gong and Kuh, 1999; Chen et al., 2001; Haffner et al., 2003; Kuh, 2001; Hasegawa et al., 2001). Moreover, there are lots of solutions on VLSI chips which allow the SVM to be hardware computed, and high speed

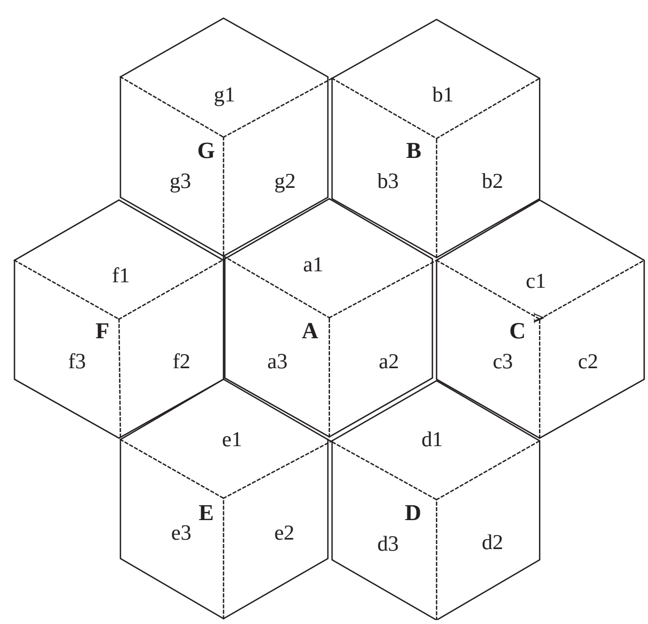

Fig. 1. Cluster of seven cells in three-sectored cellular systems.