Computers and Electrical Engineering 56 (2016) 205–221

Contents lists available at ScienceDirect

Computers and Electrical Engineering

journal homepage: www.elsevier.com/locate/compeleceng

Handover management framework for WiMAX Point-to-Multi-Point networks☆

L. Rajya Lakshmi*, Vinay J. Ribeiro, B.N. Jain

Department of Computer Science and Engineering, Indian Institute of Technology Delhi, Hauz Khas, New Delhi 110016, India

ARTICLE INFO

Article history:
Received 28 May 2014
Revised 7 December 2015
Accepted 7 December 2015
Available online 31 December 2015

Keywords:
IEEE 802.16 networks
Base station cooperation
Handover management
Call admission control
Quality of service (QoS)
Markov model

ABSTRACT

In this paper, a distributed base station cooperation-based handover management method is proposed for WiMAX Point-to-Multi-Point networks to provide quality of service to handover nodes. Moreover, a delay reduction method is proposed to reduce the packet delivery delays during handover. A Call Admission Control (CAC) algorithm is proposed to handle handover calls of various service classes fairly, according to their priorities. A bandwidth borrowing scheme is proposed to reduce the handover call dropping probabilities of various service classes while not starving the ongoing calls of lower priority service classes. A Markov model is developed to analyze the proposed CAC method and to obtain the approximate handover call dropping probabilities of various service classes. Simulation experiments are conducted to establish the performance advantages of the proposed handover management and CAC methods.

1. Introduction

WiMAX (Worldwide Interoperability for Microwave Access) is a Broadband Wireless Access (BWA) technology and it is based on the IEEE 802.16 standard. It provides high data rate services to last mile users. It supports two modes of deployment: Point-to-Multi-Point (PMP) and mesh mode [1]. In the PMP mode all Mobile Nodes/Subscriber Stations (MNs/SSs) are under the direct coverage of the Base Station (BS), whereas in the mesh mode, SSs/MNs, using their mesh connectivity property establish a wireless mesh among themselves to help each other in the data transmission and to extend the coverage area of the network.

In order to capture the Quality of Service (QoS) requirements of various user applications and to provide prioritized data transmission, WiMAX defines five service classes namely Unsolicited Grant Service (UGS), extended real-time Polling Service (ertPS), real-time Polling Service (rtPS), non-real-time Polling Service (nrtPS) and Best Effort (BE). These service classes differ in their QoS parameters. UGS calls require fixed bandwidth allocations at regular intervals. BE service calls can access the radio resource if and only if some bandwidth remains after the completion of the bandwidth allocation of the other four service classes. The service class priorities of UGS, ertPS, rtPS, nrtPS and BE are 1, 2, 3, 4 and 5, respectively.

Handover management is an important research problem related to WiMAX networks. Consider the network diagram shown in Fig. 1. Assume that a mobile node MN_1 is currently under the coverage area of BS_1 and moving towards the coverage area of BS_2. As MN_1 moves away from BS_1 and towards BS_2, it might happen that some time before the handover, during the handover and some time after the handover, none of the base stations (neither BS_1 nor BS_2) could be able to provide the full required data

☆ Reviews processed and approved for publication by the Editor-in-Chief Prof. Manu Malek.

* Corresponding author. Tel.: +91 1126561540.
E-mail address: rajya99@gmail.com (L. Rajya Lakshmi).

http://dx.doi.org/10.1016/j.compeleceng.2015.12.004
0045-7906/

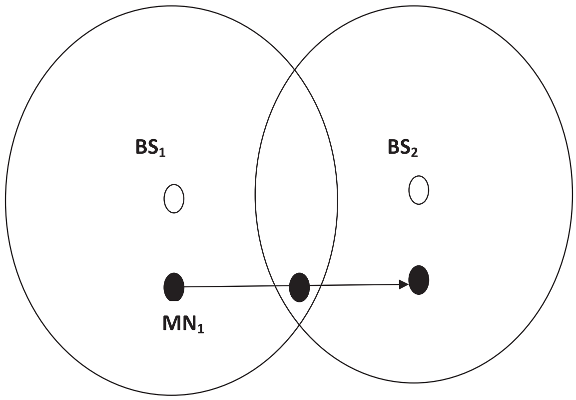

Fig. 1. Handover in WiMAX.

rate to MN_1. As MN_1 moves away from BS_1, the signal strength (*SigS*) it receives from BS_1 decreases. As a result BS_1 adopts a more robust level of Modulation and Coding Scheme (MCS) with a lower data rate to ensure error free data reception at MN_1. After its handover, MN_1 is at the border of the coverage area of BS_2. Similar to BS_1, BS_2 also adopts a more robust MCS level with a lesser data rate. As a result the QoS requirements of MN_1 are not fulfilled during the handover and for some time before and after the handover. In the remaining discussion, the two BSs involved in the handover of an MN are called as the old_BS and the new_BS. Old_BS is the currently serving BS of the MN and the new_BS is its serving BS after the handover. Also, the words “calls” and “flows” are used interchangeably.

The IEEE 802.16e amendment [2] of the IEEE 802.16 standard [1] gives a break-before-make hard handover protocol and this protocol does not provide QoS to MNs during their handover. In the literature some research contributions try to improve the performance of the handover method given in the IEEE 802.16 standard. Some methods [3] try to reduce the scanning delay of MNs by ensuring that the QoS requirements of the MNs can be fulfilled with the bandwidth available at the target BSs. According to these methods, data transmission to an MN takes place either through the old_BS or new_BS. But none of them [3,4] addresses the issue mentioned above. Consider a situation where neither the old_BS nor the new_BS can support the QoS requirements of the MN but both of them together can support. In such situations, if both the BSs participate in the data transmission, then they can support the QoS-constrained service flows of the MN. For that, the two BSs involved in the MN’s handover should coordinate in terms of the bandwidth allocations they make to the QoS-constrained flows of the MN.

Assume that the data rate requirement of a flow of an MN is b kbps. Further assume that the old_BS as well as the new_BS can provide only the data rate of $b/2$ kbps to the MN. In such a situation, both the old_BS and new_BS together transmit data to the MN. The old_BS provides the data rate of $b/2$ kbps and the new_BS provides the remaining data rate, that is, $b/2$ kbps to the MN to support its QoS requirements.

Cooperation between the old_BS and the new_BS of an MN can be achieved in two ways: centralized and distributed. Centralized Base Station Cooperation (BSC) is used in the literature for load balancing [5], throughput enhancement [6,7], capacity gain [8] and handover [9]. In a centralized cooperation method, a central controller handles all issues related to the handover and instructs actions to the BSs to provide QoS to the MN’s flows. It has *SigS* information of the BSs involved in the handover. Based on that information, it performs scheduling and generates universal uplink map (UL-MAP) and downlink map (DL-MAP) for all BSs involved in the handover [5]. Different from this method, the present paper proposes a distributed BSC method for WiMAX PMP networks, since a distributed approach is more practical and scalable than a centralized solution.

The most difficult part of the distributed solution is: the two BSs have to place their bandwidth allocations in the subframes (uplink and downlink) in such a way that the handover MNs should be able to switch to the respective channels of the BSs to avail their bandwidth allocations.

A novel delay reduction algorithm is another important contribution of this paper. It uses the fragmentation facility that is available in WiMAX to reduce the packet delivery delays during handover.

Another issue that contributes towards the QoS provisioning during handover is admission control of handover calls. Call Admission Control (CAC) module of a BS admits the calls of MNs that handover from the neighboring BSs. Some methods [10,11] are proposed in the literature for CAC in WiMAX PMP networks. These methods treat handover calls of various service classes equally. However, it is very important to provide certain priority to the handover calls of higher priority service classes. The CAC method proposed in this paper, admits handover calls of various service classes according to their priorities.

Some bandwidth borrowing schemes [10,12] are proposed to borrow bandwidth from the lower priority calls such as nrtPS and BE calls when sufficient free bandwidth is not available for admission of handover calls of higher priority service classes. These methods may lead to the starvation of nrtPS and BE calls when the handover call arrival rates of higher priority classes are high. The present paper proposes a bandwidth borrowing scheme which does not starve the ongoing calls of nrtPS and BE service classes.