ARTICLE IN PRESS

Computer Networks xxx (2015) xxx–xxx

Contents lists available at ScienceDirect

Computer Networks

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

PRIME: A partial path establishment based handover management technique for QoS support in WiMAX based wireless mesh networks

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

Department of Computer Science and Engineering, IIT Delhi, New Delhi 110016, India

ARTICLE INFO

Article history:
Received 19 May 2014
Received in revised form 11 February 2015
Accepted 17 March 2015
Available online xxxx

Keywords:
WiMAX
Wireless mesh networks
Handoff
QoS
Crossover node
Markov model

ABSTRACT

In this paper, we propose a novel handover management technique called PaRtIal path establishment based handover Management tEchnique (PRIME) for WiMAX based wireless mesh networks (WMNs). Different from the currently existing methods for WiMAX networks, PRIME addresses handover management in WiMAX WMNs deployed with distributed scheduling. In these networks, to continue the quality of service (QoS) constrained flows to a mobile node (MN) after its handover, a new path with the required bandwidth and which passes through its new base station (BS) needs to be established as quickly as possible. To address that issue, PRIME handles re-routing and scheduling issues of a handing over MN together. To provide lossless and seamless service, PRIME tries to establish new path(s) in the wireless mesh with the required bandwidth to the MN before it enters into the coverage area of the new BS. The present paper proposes a novel crossover node based partial path establishment algorithm to establish new path(s) which support QoS requirements of handoff calls. To analyze the performance of PRIME, the present paper proposes a multi-dimensional Markov model. Unlike previous models which analyze the performance of wireless networks, our proposed model represents nodes in terms of the number of transmission and reception available slots. The theoretical upper and lower bounds on the call dropping probabilities of handoff calls are obtained. To study the performance advantages of PRIME, we devise another handover management method called RFPHMT which does not use the concept of crossover base station in the new path establishment of a handing over node. The performance of PRIME and RFPHMT are compared in terms of call dropping probabilities and call setup delays. PRIME shows superior performance than RFPHMT. For a random topology, at a high call arrival rate of 1/2000 (calls/milliseconds), the handover call dropping probability of PRIME is 40% less than that of RFPHMT. The call dropping probabilities of PRIME with the simulations are always within the theoretical bounds which proves that the obtained bounds are close to the real call dropping probabilities.

1. Introduction

Wireless mesh networks (WMNs) are a promising technology to deliver various emerging wireless services to end users in a cost-effective manner. They are scalable, reliable and address the high bandwidth needs of current and future wireless applications. Two types of nodes exist in these networks: mesh routers/base station (MRs/BSs) and mesh clients [1]. MRs/BSs establish a wireless mesh among themselves which acts as a backbone of a WMN. The coverage area of a WMN can be extended by adding more MRs/

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

http://dx.doi.org/10.1016/j.comnet.2015.03.013
1389-1286/

Please cite this article in press as: L. Rajya Lakshmi et al., PRIME: A partial path establishment based handover management technique for QoS support in WiMAX based wireless mesh networks, Comput. Netw. (2015), http://dx.doi.org/10.1016/j.comnet.2015.03.013

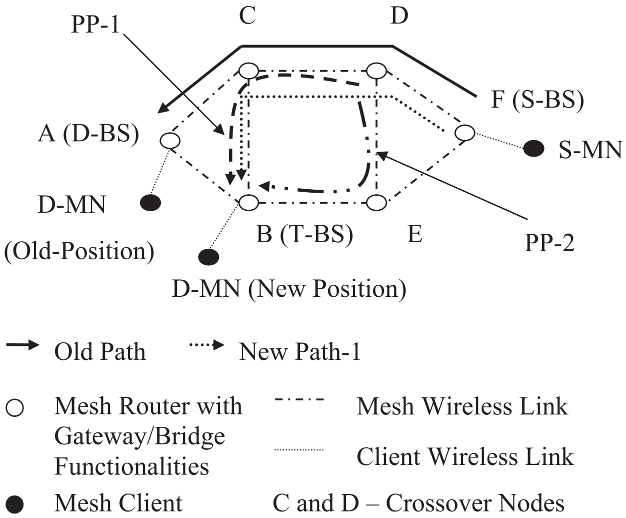

Fig. 1. A sample network diagram to explain notations.

BSs to the existing network. Mesh clients access services by getting connected to one of the MRs/BSs. They can be easily deployed and used in emergency situations, disaster affected areas etc. to mention a few.

A wireless backbone is an important part of a WMN. One of its responsibilities is the backhaul networking to deliver quality of service (QoS) constrained services to users while addressing fairness issues. Till now many WMNs are deployed worldwide and most of them are IEEE 802.11 based WMNs [27,28]. Analysis in previous work [26] revealed that the IEEE 802.11 MAC is not suitable for the backhaul networking. In contrast, IEEE 802.16 technology, which consists of TDMA (time division multiple access) MAC, distributed scheduling among the nodes, more capacity and capability to provide fairness to network flows, is a promising technology for backhaul networking in WMNs. WiMAX WMN architecture considered in this paper (see Fig. 1) consists of a wireless mesh among the WIMAX base stations; clients can access the network services by connecting to one of the BSs.

Two types of scheduling methods can be used in WiMAX mesh networks: centralized and distributed. With centralized scheduling, the BS is responsible for all scheduling tasks. With distributed scheduling, nodes coordinate with their two-hop neighbors to come up with a collision free schedule. In this paper, we consider WiMAX WMNs deployed with distributed scheduling.

Handover management is an important research issue related to any wireless network. Even though many mobility management methods are developed for other wireless networks, the handover management in TDMA WiMAX WMNs deployed with distributed scheduling has not been addressed before. The present paper proposes a novel method for handover management in these networks. In TDMA WiMAX WMNs, data transmission between a source S-MN (see Table 3 for the list of notations) and a destination D-MN (a flow) takes place through a multihop path between them. During the establishment of the flow, the required bandwidth is reserved at all the nodes along a multihop path between S-MN and D-MN. Assume that the destination node D-MN (see Fig. 1) handovers from the coverage area of its currently serving BS (D-BS) to the coverage area of some other BS (T-BS). In order to continue the QoS-constrained[1] flow between nodes S-MN and D-MN after D-MN's handover, a new route (R_n) from S-MN to D-MN needs to be established before the handover of D-MN. R_n should pass through T-BS and the required bandwidth must be available along that path. To achieve that, one simple solution is to start new path establishment from the source S-MN. In that case, the route re-discovery delay might cause interruption to the services flowing to D-MN. In addition to that, some packets may get lost during the handover process. Hence, we need an algorithm which finds new path(s) for D-MN with the required bandwidth as quickly as possible. To address that issue, this paper proposes a crossover node based partial path establishment algorithm for TDMA WiMAX WMNs.

There are many research papers that discuss various issues related to WiMAX WMNs deployed with distributed scheduling. Various scheduling and call admission control methods are developed for TDMA WiMAX WMNs. A survey on these methods is given in [29]. But none of these works addresses end-to-end QoS guarantees to flows. An analysis [30] of the research activities by the standardization groups reveals that the IEEE 802.16 based TDMA WMNs are still active in the research community. Hence it is very important to address the issue of preservation of end-to-end QoS requirements of the flows of handover nodes.

The partial path establishment method proposed in this paper tries to utilize the old path of an MN after its handover. This is the first novel quality of the proposed method. It tries to find a node which is on the old path and which has a route to the target BS of the MN with the required bandwidth. Such a node is called a crossover node of the old path and new path of the MN. In Fig. 1,

[1] QoS-constrained flow requires certain bandwidth allocation along its path.