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A new efficient cross-layer relay node selection model for Wireless Community Mesh Networks[☆,☆☆]

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ABSTRACT

Current networking technologies are not perfectly equipped to support Quality of Service (QoS), which is vital for real-time multimedia applications in Wireless Community Mesh Networks (WCNs). Therefore, there is a need to devise innovative routing algorithms to support QoS on top of existing standards. Thus, this paper presents a cross layer relay node selection model for routing protocols in order to offer optimal routes to real-time applications. To the best of our knowledge, our two proposed routing metrics, *Packet Priority-Oriented routing metric (PPO)* and *Packet Priority-oriented QoS routing metric (PP-QoS)*, are the first to provide differentiated priorities and service levels to applications with different needs. *PPO* considers the application priority. Moreover, *PP-QoS* also considers the channel busy level to improve the performance of path selection. The simulation confirms the superiority of the proposed model against a number of existing counterparts.

1. Introduction

Today, broadband Internet is used by billions of people worldwide [1]. It has become a major avenue for everyday life. With the huge increasing demand of the Internet of Things (IoT) and the Internet, it is anticipated that wireless applications will continue to grow, including but not limited to Voice over Internet Protocol (VoIP), video streaming, online gaming, and real-time multimedia streaming. The provisioning of broadband access to citizens and communities has been a strategic objective for organizations and governments worldwide to avoid or mitigate the digital divide and promote the quality of life.

Wireless Community Mesh Networks (WCNs), also known as wireless community networks, stand as a cost-effective, ubiquitous broadband connectivity offering a wide range of services in a given geographical area and have attracted tremendous research efforts [2–20]. Due to the desirable characteristics of WCNs, including multi-hop routing, auto-configuration, low cost, and easy deployment, they are a perfect fit for new users seeking convenient and affordable Internet access. There are various mesh devices, including personal computers, smart phones, and other smart devices such as smart TVs. Although WCNs can offer network connectivity, it is obvious that the bandwidth is still not sufficient to satisfy the transmission of

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high-definition multimedia applications and real-time applications. To solve this problem, we observe that among a wide range of applications, real-time applications require low latency and high data rates, e.g., video chat applications; other applications such as web browsing, however, require relatively much lower communication quality. Therefore, there has been an array of important works providing quality of service (QoS) to end users in WCN, such as the proposals from [4,10,15].

In this paper, we propose two new routing metrics, namely, the *Packet Priority-Oriented routing metric* (*PPO*) and *Packet Priority-oriented QoS routing metric* (*PP-QoS*), to enhance the QoS of WCNs. Our schemes are based on the different communication demands of WCN applications, indirectly providing superior paths in order to provide QoS provisioning services to real-time applications. This mechanism also allows Internet service providers (ISPs) to control the distribution of traffic load in the gateway. It is worth indicating that this paper is an expanded version of a paper presented at IEEE IUCC-2015 [18].

The remainder of this paper is organized as follows. Section 2 shows the current state of the art. Section 3 presents a list of related work. In Section 4, the proposed solution is introduced, after which the implementation of the solution and its simulation results are shown in Sections 5 and 6, respectively. Section 7 concludes the paper and indicates the future working direction.

2. State of the art

Due to the use of unlicensed spectra and the absence of centralized management, WCN is vulnerable to interference and congestion that can greatly degrade the quality of service (QoS). Thus, there have been many attempts to improve the QoS provisioning in WCNs [16]. The majority relay node of the offered solutions, however, are limited to the physical or MAC layers. In particular, QoS route selection schemes have not yet been explored. To fill in this gap, this paper proposes a relay node scheme with the capacity of offering adaptive quality guarantees for QoS-aware streams under the umbrella of both unicast and group communication patterns.

The selection of a relay node scheme plays an important role in ensuring the quality of a route. In this respect, routing metrics are applied in the routing protocols to judge the quality and suitability of the available paths. Existing routing protocols use only the number of hops, delay, interference, bandwidth, etc., omitting the variety of the application requirements/demands. A relay node approach usually considers limited routing metrics while selecting the best path between the source and destination. Although there is a wide variety of relay nodes mechanisms that deploy different routing metrics, including the most recently proposed ones such as *IAR* [20], the selection of the optimal routes depending on the sensitivity of the applications to communication quality has not been introduced in WCNs. Indeed, the routing design of QoS-aware relay nodes based on the required QoS provisioning level is still in its infancy.

3. Related work

In this section, we review some well-known routing metrics and then present the functionality of each routing metric and its ability to satisfy the requirements of efficient WCNs.

Hop Count is widely used in existing protocols such as AODV [21], Dynamic Source Routing (DSR) [22], and Destination-Sequenced Distance-Vector (DSDV) [23]. Simply, a routing protocol with the *Hop Count* metric finds the routing path with the minimum distance, i.e., the hop number. It does not consider other issues such as interference, transmission rates, and packet loss ratios. Therefore, the *Hop Count* metric may result in poor performance, especially in regard to delivering QoS-aware applications.

***Expected Transmission Count* (*ETX*)** [23,24] estimates the expected number of MAC layer transmissions for the wireless links along with the packet loss rate. The advantages of *ETX* are the reduced probing overhead and non-self-interference, as the delay is not measured. *ETX* cannot measure the cause of data rate in the delivery ratio, however, and it does not consider the transmission rate. Furthermore, unicast probing of *ETX* is not accurate, especially in collective communication patterns.

***Interference-Aware Routing Metric* (*IAR*)** [20] is designed for WCNs to use the MAC layer information to detect the channel busy level. The IAR of a link is

$$IAR(l) = \frac{1}{1 - a_{ub}} \times \frac{S}{B}$$

$$a_{ub} = \frac{T_{Wait} + T_{Collision} + T_{Backoff}}{T_{Wait} + T_{Collision} + T_{Backoff} + T_{Success}}$$

where T_{Wait}, $T_{Collision}$, $T_{Backoff}$, and $T_{Success}$ are the time spent in the *Wait, Collision, Backoff* and *Success* states, respectively, in the MAC level. a_{ub} is the percentage of time spent in the *Wait, Collision* and *Backoff* states. Thus, the smaller the *IAR* of a path is, the less busy it is.

In addition, there are a number of routing metrics that are intended to improve the route selection on the basis of *ETX*. For example, ***Expected Transmission Time* (*ETT*)** [2] considers the differences in link transmission rate by measuring the expected time duration for the successful transmission of a packet at link *l* in MAC layer. ***Expected Forwarded Counter* (*EFW*)** [2] considers the packet forwarding possibility of a relay node. Thus, EFW detects the misbehaving nodes. ***Energy-Load Aware Routing Metric* (*ELARM*)** [13] enables the routing protocol to select the best route based on link stability and

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