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Opportunistic routing with admission control in wireless ad hoc networks

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ABSTRACT

It is challenging to provide QoS in wireless ad hoc networks, one of the main problems that affects QoS in wireless ad hoc networks is the multi-hop nature of the network. In the traditional routing, if one node at the optimal path is broken because of congestion or exhaustion of available energy, the whole path will be broken, and the source must re-route again. Opportunistic routing (OR) is an efficient approach to solve this problem, which can improve performance of system. However, it is difficult to provide better QoS in OR due to the uncertainty of forwarding paths. In the meanwhile, existing OR protocols rarely consider providing service for different types of flows, and many of them cannot make a tradeoff between opportunistic path and limited resources of nodes. Therefore, in this paper, we present a novel Opportunistic Routing scheme which considers Admission Control of nodes for the different types of flows, namely ORAC. ORAC scheme first exploits a new flow admission control scheme which is based on bandwidth, backlog traffic and residual energy of nodes to select forwarding candidates. And then, ORAC uses a novel forwarding scheme to provide services for multiple different types of flows. In this way, ORAC scheme can reduce the network congestion, and protect from any changes of traffic load for established routes. Thus, it can provide better QoS for flows. Our extensive simulation results demonstrate that the proposed scheme ORAC can achieve better network performance compared to existing OR schemes in terms of average delay, flow acceptance ratio and system throughput, routing overhead and energy consumption.

1. Introduction

With the development of wireless ad hoc networks, to provide better QoS for these types of networks is a meaningful and important issue. And this issue has been concerned by more and more researchers. Existing works on this topic have targeted toward several areas, such as QoS routing [1,2], QoS MAC [3], and QoS cross layer design [4–6]. Despite the research efforts, there has been no perfect solution in guaranteeing any form of hard QoS in wireless ad hoc networks. Even formal QoS standards such as IEEE 802.11e [7] (for MAC layer) have been criticized on its lack of QoS support for multi-hop wireless networks. One of the reasons why QoS provisioning in wireless ad hoc networks is more challenging as compared to centralized wireless networks is its multi-hop nature. In multi-hop wireless ad hoc networks, packets can be forwarded via intermediate nodes from the source to the destination without centralized coordination. And many traditional routing protocols fail to use the broadcast nature of wireless networks and spatial diversity by choosing a fixed path as similar to wired links. When the current path is broken, the source will re-route again, and end-to-end QoS is difficult to guarantee.

Opportunistic routing (OR) [8] is an attempt to address the above mentioned problem. OR exploits an elegant way to utilize the broadcast nature of wireless links to achieve cooperative communication at the link layer and networks layer of static multi-hop wireless networks. Therefore, the network throughput can be improved, and the transmission delay can be reduced by using the OR mechanism. Because OR has many characteristics, several representative works on OR have been proposed, such as [8–14]. In [8], Biswas et al. first proposed the Extremely Opportunistic Routing (ExOR) [8], which integrates routing and MAC protocol to increase the throughput in multi-hop wireless networks. However, ExOR's forwarding paths can easily diverge, and the metric for selecting candidate nodes only employs Expected Transmission

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Count (ETX) [15]. These factors make it unclear how well ExOR supports multiple simultaneous flows.

Then, MAC-Independent Opportunistic Routing and Encoding (MORE) [9], Cumulative Coded ACKnowledgments (CCACK) [10] and the scheme in [11] combine OR and network coding [16] to increase the end-to-end throughput. The characteristics of them are: MORE is an intra-session network coding scheme, CCACK adopts a cumulative coded acknowledgment scheme that allows nodes to acknowledge network coded traffic to their upstream nodes, and the scheme of [11] presents potential benefits of forwarding schemes that combine OR and NC, and gives a theoretical optimal scheme to provide a lower bound on the expected number of transmissions, when traffic on a bidirectional unicast connection between two nodes is relayed by multiple common neighbors.

Simple Opportunistic Adaptive Routing (SOAR) [12] adaptively selects forwarding nodes and uses priority-based timers to service for multiple simultaneous flows in wireless mesh networks. Coordinated Opportunistic Routing Protocol for Wireless Mesh Networks (CORP-M) [13] uses a region based OR scheme to select the next forwarder, and the nodes in the region nearer to the destination with higher priority. In addition, Wang et al. proposed a Cooperative Opportunistic Routing in Mobile Ad hoc Networks (CORMAN) [14], which extends the application environment of OR from static multi-hop wireless networks to mobile ad hoc networks.

However, these protocols do not consider how to provide a better QoS guarantee for different requirements under resource constraints. In the meantime, in real networks, the bandwidth, the buffer and the energy of nodes are limited in many cases. If we do not consider these factors, it may result in network congestion and high packet loss, and then, QoS is unable to be guaranteed.

Of course, there are some routing schemes under networks resources constraints have been proposed. In [17], Ergin et al. presented an admission control and routing mechanism for multi-rate wireless mesh networks, and their admission control scheme is based on available bandwidth estimation. Moreover, Gao et al. [18] discussed the multi-rate any path routing scheme, which provides a bandwidth reservation for traffics. In addition, Zhao et al. [19] proposed Bandwidth-aware OR with considering Admission Control named BOR/AC in mesh networks. In congestion control aspect, Naghshvar et al. [20] proposed an OR scheme with considering congestion diversity. In energy efficiency aspect, Mao et al. [21] presented the energy efficient OR scheme. However, these protocols can only consider single type of resource for the network nodes.

In summary, these existing works in OR do not consider different types of traffic flows, i.e., some traffics are audio or video, and others are data, with different QoS requirements. And the real time requirements (audio and video flows) should be given higher scheduling priority than the non-real time requirements (data flows). Especially for the situation that the networks resources (energy, bandwidth and buffer) are limited, how to design a better admission control scheme for OR is a challenging but deserving research issue. For example, in military communication, the devices of military can establish communication through wireless ad hoc networks. And these devices are installed the audio sensor and camera, which can collect the local audio and video information and send them to the other nodes through ad hoc networks, but these devices may have limited resources. Hence, to design an efficient routing scheme for this situation is important. Our previous work [22] considers this problem in the Ad hoc On-demand Distance Vector routing (AODV) [23]. However, AODV is a traditional routing protocol by choosing a fixed path, which does not efficiently utilize the broadcast nature of wireless networks. To the best of our knowledge, there is no related work on OR about QoS with admission control for different types of flows. This is the motivations of our paper.

Therefore, we jointly consider the OR scheme and admission control, which is an efficient way to provide QoS in wireless ad hoc networks. First, OR is a cooperative routing, which forward each packet to multiple one-hop neighbors by using the broadcast nature of wireless networks. When the current path is broken, or part of messages does not successfully deliver to the destination, the potential neighbor forwarders which have received the messages can cooperatively forward packets. Second, we exploit the node's admission control scheme before traffic admitting, which take the available bandwidth, the residual energy and backlog traffics of nodes into account. If a constructed route happens to involve some congested nodes, the packets along this route may be dropped, in the meantime, affecting the existing flows passing through the congested nodes, resulting in more control packets being created due to local route repair, etc. Therefore, the ideal case is to minimize such situations as much as possible through proper flow admission, and the likelihood of congested routes can be reduced through the implementation of the flow admission control scheme, so as to provide a better QoS for flows.

In this paper, we propose a novel OR scheme joint with admission control for different priority flows in wireless ad hoc networks, named as ORAC (Opportunistic Routing with Admission Control). By considering the node's available bandwidth, residual energy and backlog in buffer before selecting the candidates, ORAC is able to improve the network performance for different traffics. The contributions of our work can be concluded as follows.

(1) As far as we know, for different priority of traffics, ORAC is the first opportunistic routing scheme, which comprehensively considers various kinds of node's resources when admitting a new flow in wireless ad hoc networks. The advantage of ORAC is that it can guarantee QoS for different types of flows, especially for multiple simultaneous flows.
(2) ORAC scheme contains two modules: First, a comprehensive admission control module is proposed, which is used to decide whether a coming data flow can be accepted or not for some nodes during route discovery. Second, the novel candidate selecting scheme and prioritization policy are proposed in opportunistic forwarding module. For different types of flows, we can select different forwarding nodes and candidates list according to our forwarding scheme, so as to guarantee QoS for different requirements.
(3) We extensively evaluate the performance of ORAC. First, we present the average delay and cumulative percentage of delay with (ORAC)/without (ExOR) admission control. The simulation results show that ORAC can improve the performance compared with ExOR for multiple simultaneous flows. In addition, we compare ORAC with BOR/AC, in terms of flow acceptance ratio, system throughput, average delay, normalized routing overhead, and energy consumption of nodes. The simulation results show that our ORAC scheme can achieve better performance than BOR/AC.

The rest of the paper is organized as follows. In Section 2, we present our flow admission control model in ORAC, which includes available bandwidth module, backlog traffic module and energy consumption module. In Section 3, we propose our forwarding scheme in ORAC for different priorities of flows. In Section 4, we show the simulation results. Section 5 gives the conclusion of our paper.

2. Flow admission control model in ORAC

In this section, we describe a new scheme joint flow admission control with OR. The purpose is to provide a proper method to