A Study on Congestion Routing in Ad hoc Networks

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Abstract: This paper focuses on congestion control over multihop, wireless networks. In a wireless network, an important constraint that arises is that due to the MAC (Media Access Control) layer. Many wireless MACs use a time-division strategy for channel access, where, at any point in space, the physical channel can be accessed by a single user at each instant of time. In this paper, we develop a fair hop-by-hop congestion control algorithm with the MAC constraint being imposed in the form of a channel access time constraint, using an optimization based framework. In the absence of delay, we show that this algorithm is globally stable using a Lyapunov function based approach. Next, in the presence of delay, we show that the hop-by-hop control algorithm has the property of spatial spreading. In other words, focused loads at a particular spatial location in the network get "smoothed" over space. We derive bounds on the "peak load" at a node, both with hop-by-hop control, as well as with end-to-end control, show that significant gains are to be had with the hop-by-hop scheme, and validate the analytical results with simulation.

Keywords: Control theory, Mathematical programming optimization

A mobile ad hoc network (MANET) is a collection of randomly moving wireless devices (also called nodes) within a particular area. Unlike in cellular networks, there is not any fixed base-stations to support routing and mobility management. The wireless mobile devices are

equipped with wireless transmitter and receivers that allow them to communicate with each other without the help of wired base-stations. Since each transmitter has a limited

effective range, distant nodes communicate through multihop paths with other nodes in the middle as routers. These networks are particularly suitable for emergency situations like

warfare, floods and other disasters where infrastructure networks are impossible to operate. Routing is one of the core problems for data exchange between nodes in networks. Many

routing protocols have been proposed for wireless networks, such as Dynamic Source

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Routing protocol (DSR) [1], Ad hoc On-Demand Distance Vector (AODV) protocol [2], Temporally Ordered Routing Algorithm (TORA) [3] which establish and maintain routes on a best effort service. These protocols do not consider quality of service of the routes they generate. No guarantees or predictions can be given here on when a node is allowed to send. For quality-of-service (QoS) routing, it is not sufficient to only find a route from a source to one or multiple destinations. This route also has to satisfy one or more QoS constraints, mostly, but not limited to, bandwidth or delay. To guarantee these constraints after a route was found, resource reservations on the participating nodes are made. Quality of service is more difficult to guarantee in ad hoc networks than in most other type of networks, because the wireless bandwidth is shared among adjacent nodes and the network topology changes as the nodes move. A number of QoS routing protocols with distinguishing features have been proposed in recent years. Most of QoS routing protocols are the extensions of existing best-effort

routing protocols, so they can be also classified into two different categories: table-driven (proactive) and on-demand (reactive). In proactive protocols, all the nodes need to maintain the routing information in the network and update it periodically even if they need to communicate or not. These protocols have the advantage that new communications with

arbitrary destinations experience minimal delay, but suffer the disadvantage of the additional control overhead to update routing information at all nodes. On the contrary, in reactive protocols, routes are discovered between source and destination pair only when data is to be sent. These protocols often have reduced overhead and consume much less bandwidth than proactive protocols, but they typically experience a long delay for discovering a route to a destination prior to the actual communication. In this paper, a few of the reactive QoS routing protocols have been discussed which provide QoS using different approaches. The strengths and weaknesses of these QoS routing protocols have also been summarized. Finally, a comparison of the routing protocols has been done so as to explore the future areas of work.

II. SURVEY OF QOS ROUTING PROTOCOLS

Many routing protocols belonging to different QoS philosophies have been proposed in the literature. A fairly comprehensive overview of the QoS support in networking was provided by Chen in 1999 [4]. Chakrabarti and Mishra [5] later summarized the important QoS related issues in MANETs in 2001 and their conclusions highlighted several significant

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points in MANET research. It includes admission control policies and protocols, QoS robustness and QoS preservation under failure conditions. In 2004, Al-Karaki and Kamal [6] published a detailed overview and the development trends in the field of QoS routing. QoS routing solutions were categorised into various types of approaches: Flat, Hierarchical, Position-based and power aware QoS routing. Some of the important areas such as security and multicast routing which require further research attention were highlighted. Reddy et al. [7] provided another survey about the issues and solutions pertaining to QoS in a mobile ad hoc network. He provided a thorough overview of some of the widely accepted MAC and routing solutions for providing better QoS in MANETs. Asokan [8] mainly looked at the problem of QoS provisioning in the perception of network layer. He provided a detailed survey of QoS routing protocols in MANETs and concluded that new protocols having multiple constraints like throughput, end-to-end delay, jitter, and energy metrics need to be developed to satisfy the rigid QoS requirements of the multimedia applications. Though sufficient works on the survey of QoS routing protocols in MANETs have been done, it seems less satisfactory in terms of analyzing the QoS routing protocols based on the different approaches like multipath, cross layer, stability, bandwidth reservation and load balancing.

Related work:

The work of [12], [2] provides an optimization based framework for Internet congestion control and derives a differential equation based distributed solution. Works of [13], [1], [14], [3], [15], [16] study the stability of such end-to-end controllers in the presence of feedback delay.

In [8], [17], [7], [9], using a simulation based approach, the authors provide hop-by-hop control algorithms and show that the hop-by-hop schemes react faster than end-to-end schemes, thus reducing buffer requirements. In [10], the author proposes a framework for congestion control and routing based on pushback, where-in, queue buildup at a down-stream node causes upstream nodes to decrease rate and use alternate paths. This has been extended to the multicast case in [11]. Related work includes [18], where the authors consider max-min fair scheduling in the context of a wireless network using a similar model as that considered here for media access control (MAC). The authors develop a token based local scheduling policy at each node to ensure max-min fairness. This paper differs in that we develop rate based (end-to-end and hop-by-hop) controllers with the objective of (weighted) proportionally-fair resource

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allocation among users, and with MAC constraints. We derive explicit bounds on queue lengths in the presence of propagation delay, both with an end-to-end and hop-by-hop scheme, and demonstrate spatial spreading with hop-by-hop control.

II. CONGESTION ADAPTIVE ROUTING (CRP)

In CRP, every node appearing on a route warns its previous node when prone to be congested. The previous node then uses a "bypass" route bypassing the potential congestion to the first non-congested node on the route. Traffic will be split probabilistically over these two routes, primary and bypass, thus effectively lessening the chance of congestion occurrence. CRP is on-demand and consists of the following components: (1) Congestion monitoring, (2) Primary route discovery, (3) Bypass discovery, (4) Traffic splitting and congestion adaptivity, (5) Multi-path minimization, and (6) Failure recovery. A. Congestion Monitoring A variety of metrics can be used for a node to monitor congestion status. Chief among these are the percentage of all packets discarded for lack of buffer space, the average queue length, the number of packets timed out and retransmitted, the average packet delay, and the standard deviation of packet delay. In all cases, rising numbers indicate growing congestion. Any of these methods can work with CRP in practice. We further classify the congestion status at a node into 3 levels: "green", "yellow", and "red". A node is said to be "green" if it is far from congested, "yellow" if likely congested, or "red" if most likely or already congested. As later discussed, a bypass is a path from a node to its next green node. The next green node is the first green node at least two hops away downstream on the primary route. B. Primary Route Discovery To find a route to the receiver, the sender broadcasts a REQ packet toward the receiver. The receiver responds to the first copy of REQ by sending toward the sender a REP packet. The REP will traverse back the path that the REQ previously followed. This path becomes the primary route between the sender and the receiver. Nodes along this route are called primary nodes. To reduce traffic due to route discovery and better deal with congestion in the network, we employ two strategies: (1) the REQ is dropped if arriving at a node already having a route to the destination, and (2) the REQ is dropped if arriving at a node with a "red" congestion status.

CONCLUSION:

We have proposed a congestion-aware routing protocol for mobile ad hoc networks (CARM). CARM utilizes two

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mechanisms to improve the routing protocol adaptability to congestion.

Firstly, the weighted channel delay (WCD) metric is used to select high throughput routes with low congestion. The second mechanism that CARM employs is the avoidance of mismatched link data-rate routes via the use of effective link datarate categories (ELDCs). In short, the protocol tackles congestion via several approaches, taking into account causes, indicators and effects. The decisions made by CARM are performed locally. Our simulation results demonstrate that CARM outperforms DSR due to its adaptability and robustness to congestion.

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