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Minimization of Congestion in Mobile Ad-Hoc Network

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Abstract: Congestion causes transmission delay, packet loss, wastage of time and energy during congestion recovery. Routing protocol adaptive to mobile ad-hoc networks congestion status can greatly improve network performance. Present work proposes a congestion-adaptive routing protocol for mobile ad -hoc networks (CRP), whereas in the reported designs, routing is not congestion-adaptive. Routing allows congestion to happen which is detected by congestion control. When new route is required, dealing with congestion in this reactive manner results in longer delay, unnecessary packet loss and requires significant overhead. This problem becomes more significant especially in large-scale transmission of heavy traffic such as multimedia data, where congestion is more probable and the negative impact of packet loss on the service quality is of more significant.

Keywords: ad-hoc network, routing, congestion-aware, congestion-adaptive, multihop.

I. INTRODUCTION

Congestion occurs in ad-hoc networks with limited resources. In such a network, packet transmission frequently suffers from collision, interference, and fading, due to shared radio and dynamic topology. Transmission errors burden the network load. Recently, there is an increasing demand on supporting multimedia communications in ad-hoc networks. The massive real-time traffics are in bursts, bandwidth intensive, and congestion liable. Congestion in ad-hoc networks leads to packet loss, band-width degradation, and essential wastage of time and energy for congestion recovery. Congestion-aware routing protocol can preemptively settle congestion through bypassing the congested links.

It is believed that a large portion will be ad-hoc connections, which will open many opportunities for MANET applications. To prepare for such promising future, routing is an important issue in need of a solution that not only works well with a small network, but also sustains efficiency and scalability as the network gets expanded and the application data gets transmitted in larger volume. Since mobile nodes have limited transmission capacity, they mostly intercommunicate by multi-hop relay. Multi-hop routing is challenged by limited wireless bandwidth, low device power, dynamically changing network topology. To overcome these problems, many routing algorithms in MANETs were proposed. Network is a collection of mobile nodes which forms a temporary network without the help of central administration or standard support devices regularly available in conventional networks. Mobile ad-hoc wireless networks have the ability to establish networks at anytime, anywhere to possess the assurance of the future. These networks do not depend on normal hardware because it makes them ideal candidate for rescue and emergency operations. The constituent wireless nodes of these network build, operate and maintain these networks. Each node needs the help of its neighboring nodes to forward packets because these nodes usually have only a limited transmission range. A homogeneous ad-hoc network suffers from poor scalability because the network performance is degraded quickly as the number of nodes increases. The nodes are usually heterogeneous in realistic ad-hoc networks. For example, in a battlefield network, portable wireless devices are carried by soldiers and more powerful and reliable communication devices are carried by vehicles, tanks, aircraft and satellites. These devices/nodes have different communication characteristics in terms of transmission power, data rate, processing capability, reliability, etc. Hence it would be more realistic to model these network elements as different types of nodes.

The following are the general causes of congestion:

1. The throughput of all nodes in a particular area gets reduced because many nodes within range of one another attempt to transmit simultaneously, resulting in losses.
2. The queue or buffer used to hold packets to be transmitted may overflows within a particular node. This is also the cause of losses.

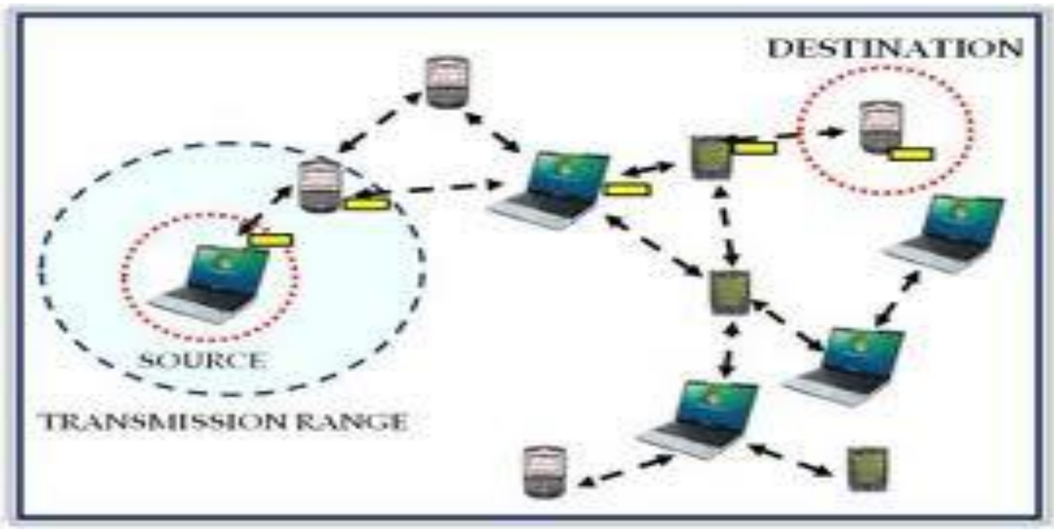
Therefore, for overcoming these issues with the help of simulation following stages are proposed.

1. To find out the congestion which might occur on a particular node with the help of data retention and data rate at which data is passing through the node.
2. To bypass the data, if congestion occurs on a node before reaching the node in congestion, so that time loss to reach destination will be decreased.

II. ROUTING IN MANET

Mobile Ad-hoc networks are self-organizing and self-configuring multi-hop wireless networks, where the structure of the network changes dynamically. This is mainly due to the mobility of the nodes. Nodes in these networks utilize the same random access wireless channel, cooperating in an intimate manner to engaging themselves in multi-hop forwarding. The node in the network not only acts as hosts but also as routers that route data to/from other nodes in network. In mobile ad-hoc networks there is no infrastructure support as in the case with wireless networks and since a destination node might be out of range of a source node transferring packets; so there is need of a routing procedure. This is always ready to find a path so as to forward the packets appropriately between the source and the destination. In the case of ad-hoc networks, each node must be able to forward data for other nodes. This creates additional problems along with the problems of dynamic topology which is unpredictable.

Congestion non-adaptiveness in routing in MANETs may lead to the following problems:



III. TYPES OF MANETS ROUTING PROTOCOL

Classification of routing protocols in mobile ad-hoc network can be done in many ways, but most of these are done depending on routing strategy and network structure. The routing protocols can be categorized as flat routing, hierarchical routing.

A. Flat Routing Protocols

Flat routing protocols are divided mainly into two classes; the first one is proactive routing protocols and other is reactive (on-demand) routing protocols.

1. ProActive / Table Driven routing Protocols

Proactive MANETs protocols are also called as table-driven protocols and will actively determine the layout of the network. Through a regular exchange of network topology packets between the nodes of the network, at every single node an absolute picture of the network is maintained. There is minimal delay in determining the route. This is especially important for time-critical traffic. When the routing information becomes worthless quickly, there are many short-lived routes that are being determined and not used before they turn invalid. Therefore, another drawback resulting from the increased mobility is the amount of traffic overhead generated when evaluating these unnecessary routes. The portion of the total control traffic that consists of actual practical data is further decreased. Lastly, if the nodes transmit infrequently, most of the routing information is considered redundant. The nodes, however, continue to expend energy by continually updating these unused entries in their routing tables as mentioned, energy conservation is very important in a MANET system design. Therefore, this excessive expenditure of energy is not desired. Thus, proactive MANET protocols work best in networks that have low node mobility or where the nodes transmit data frequently.

2. Reactive (On-Demand) protocols

Portable nodes- Notebooks, palmtops or even mobile phones usually compose wireless ad-hoc networks. This portability also brings a significant issue of mobility. This is a key issue in ad-hoc networks. The mobility of the nodes causes the topology of the network to change constantly. Keeping track of this topology is not an easy task, and too many resources may be consumed in signaling. Reactive routing protocols were intended for these types of environments. These are based on the design that there is no point on trying to have an image of the entire network topology, since it will be constantly changing. Instead, whenever a node needs a route to a given target, it initiates a route discovery process for discovering out a pathway . Reactive protocols start to set up routes on-demand. The routing protocol will try to establish such a route, whenever any node wants to initiate communication with another node to which it has no route. This kind of protocols is usually based on flooding the network with Route Request (RREQ) and Route reply (RERP) messages. By the help of Route request message the route is discovered from source to target node; and as the target node gets a RREQ message it send RERP message for the confirmation that the route has been established. This kind of protocol is usually very effective on single-rate networks. It usually minimum the number of hops of the selected path.

3. Hybrid Routing Protocols

Since proactive and reactive protocols each work best in oppositely different scenarios, hybrid method uses both. It is used to find a balance between both protocols. Proactive operations are restricted to small domain, whereas, reactive protocols are used for locating nodes outside those domains.

B. Hierarchical Routing Protocol

It maintains a hierarchical topology, where elected cluster-heads at the lowest level becomes member of the next higher level. On the higher level, super-clusters are formed, and so on. Nodes which want to communicate to a node outside of their cluster need their cluster-head to forward their packet to the next level, until a cluster-head of the other node is in the same cluster. The packet then travels down to the destination node.

IV. Properties of Ad-Hoc Routing Protocols

i) Distributed operation: The protocol should be distributed. It should not be dependent on a centralized controlling node. This is the case even for stationary networks. The dissimilarity is that the nodes in an ad-hoc network can enter or leave the network very easily and because of mobility the network can be partitioned.

ii) Loop free: To improve the overall performance, the routing protocol should assuare that the routes supplied are loop free. This avoids any misuse of bandwidth or CPU consumption.

iii) Demand based operation: To minimize the control overhead in the network and thus not misuse the network resources the protocol should be reactive. This means that the protocol should react only when needed and should not periodically broadcast control information.

iv) Security: The radio environment is especially vulnerable to impersonation attacks so to ensure the wanted behavior of the routing protocol we need some sort of security measures. Authentication and encryption is the way to go and problem here lies within distributing the keys among the nodes in the ad-hoc network.

v) Power conservation: The nodes in the ad-hoc network can be laptops and thin clients such as PDA_s that are limited in battery power and therefore uses some standby mode to save the power. It is therefore very important that the routing protocol has support for these sleep modes.

vi) Multiple routes: To reduce the number of reactions to topological changes and congestion multiple routes can be used. If one route becomes invalid, it is possible that another stored route could still be valid and thus saving the routing protocol from initiating another route discovery procedure.

V. System Design

A. Primary Route Discovery

The sender discovers the route to the receiver in a simple way. It broadcasts an REQ packet toward the receiver. The receiver responds to the first copy of REQ by sending back an 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.

Estimation of MAC Overhead

In this network, we consider IEEE 802.11 MAC.It has the packet sequence as request-to-send (RTS), clear-to-send (CTS), and data, acknowledge (ACK). The amount of time between the receipt of one packet and the transmission of the next is called a short inter frame space (SIFS). Then the channel occupation due to MAC contention will be

$$C_{occ} = t_{RTS} + t_{CTS} + 3t_{SIFS}$$

Where t_{RTS} and t_{CTS} are the time consumed on RTS and CTS, respectively and t_{SIFS} is the SIFS period.

Then the MAC overhead OHMAC can be represented as

$$OH_{MAC} = C_{occ} + t_{acc}$$

Where t_{acc} is the time taken due to access contention.The amount of MAC overhead is mainly dependent upon the medium access contention, and the number of packet collisions. That is, OH_{MAC} is strongly related to the congestion around given node.

Route Request

We now calculate the node weight metric NW which assigns a Cost to each link in the network. The node weight NW combines the link quality L_a , MAC overhead OH_{MAC}. For an intermediate node i with establish transmission with several of its neighbours. The NW for the link from node i to a particular neighboring node is given by, NW = $(L_a * D_{rate}) / (OH_{MAC} * D_{avg})$

Let us consider the route

$$S \text{--->} N1 \text{->} N2 \text{->} N3 \text{->} D$$

To initiate congestion-aware routing discovery, the source node S sends a RREQ. When the intermediate node N1 receives

RREQ packet, it first estimates all the metrics. The node $N1$ then calculates its node weight NW_{N1} using

$$NW_{N1}$$

$RREQ_{N1} \rightarrow N_2$

N2 then calculate its weight NW_{N2} in the same way and adds it to the weight of N1. N2 then forward the RREQ packet with this added weight.

$$NW_{N1}+NW_{N2}$$

$RREQ_{N2} \rightarrow N_3$

Finally the RREQ reaches the destination node D with the sum of node weights

$$NW_{N1}+NW_{N2}+NW_{N3}$$

$RREQ_{N3} \rightarrow D$

Route Reply

The destination node D sends the route reply packet RREP along with the total node weight to immediate upstream node $N_{3.}$

$$NW_{N1}+NW_{N2}+NW_{N3}$$

$RREP_D \rightarrow N_3$

Now N3 calculates its cost C based on its information from RREP as,

$C_{N3}= (NW_{N1}+ NW_{N2}+ NW_{N3})-(NW_{N1}+ NW_{N2})$

B. Congestion Monitoring

When the number of packets coming to a node exceeds its carrying capacity, the node becomes congested and starts losing packets. We can use a variety of metrics at a node to monitor congestion status. For instance, we can be based on 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.

C. Bypass Discovery

A primary node periodically broadcasts a UDT (update) packet with TTL = 1. The UDT packet contains the node's congestion status and a set of tuples [destination R, next green node G, distance to green node m], each for a destination appearing in the primary routing table. The purpose is that, when a node N receives a UDT packet from its next primary node N_{next} regarding destination R, N will be aware of the congestion status of N_{next} and learn that the next green node of N is G, which is m hops away on the primary route. This information is crucial in case a bypass is needed.

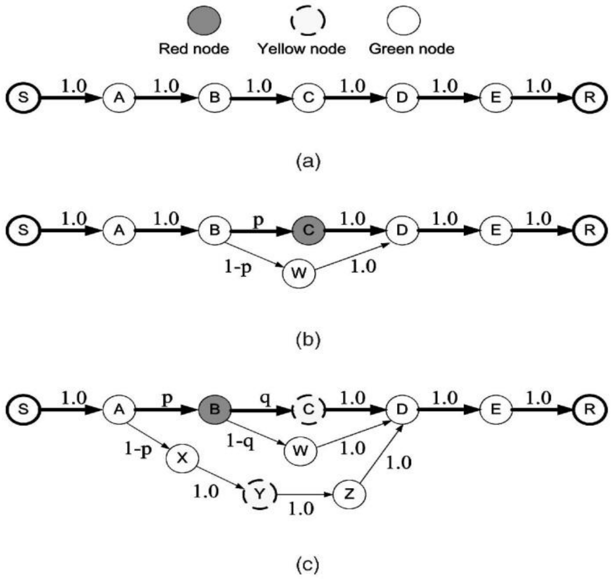


Fig. Use of Bypassing Method

VI. Conclusion

This work proposes a congestion-adaptive routing protocol for MANETs. A key in CRP design is the bypass concept. A bypass is a sub-path connecting a node and the next non-congested node. Part of the incoming traffic will be sent on the bypass, making the traffic coming to the potentially congested node less. The congestion may be avoided as a result.

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