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An Analytical study on Simple packet forwarding rules for controlling congestion in Mobile Ad-Hoc Networks

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ABSTRACT

Mobile ad hoc networks are collections of mobile nodes that can dynamically form temporary networks without the need for pre-existing network infrastructure or centralized administration. These nodes can be arbitrarily located and can move freely at any given time. Hence, the network topology can change rapidly and unpredictably. Because wireless link capacities are usually limited, congestion is possible in MANETs. Hence, balancing the load in a MANET is important since nodes with high loads will deplete their batteries quickly, thereby increasing the probability of disconnecting or partitioning the network. Here a load balancing protocol is proposed to improve the network throughput, decrease average end-to-end delay and reduce congestion in ad hoc networks. This scheme is applied as an extension on top of existing load balanced routing protocols. Simulation results obtained using ns-2 network simulation platform show a 20-25% improvement in packet delivery ratio and average end-to-end delay.

Keywords: MANET, Congestion, Load balancing, Network Throughput.

INTRODUCTION

Mobile ad hoc networks (MANETs) are collections of mobile nodes that can dynamically form temporary networks on the fly without the need for pre-existing network infrastructure or centralized administration. They have desirable features such as fast deployment and the ability to communicate while on the move. Over the years, numerous routing protocols have been developed for ad hoc mobile networks. These can be categorized into table-driven and on demand routing. Table-driven routing protocols maintain consistent, up-to-date routing information in each node by propagating route updates throughout the whole network. Although a route to every other node is always available, such protocols incur signalling traffic and power consumption overhead. On the other hand, on-demand routing protocols do not maintain routing information at every node. They create routes only when desired by the source. So that on demand routing protocols can perform better than table-driven protocols in MANETs. Several ad hoc routing protocols use route hop count as the routing metric. Although it is intuitive and simple, it does not consider link capacity.

In shortest path routing, nodes on the shortest path will get more heavily loaded than others since they are frequently chosen as the routing path. Having a heavy load can exhaust a node‘s resources such as bandwidth, processing power, battery energy, and memory storage. Furthermore, if one of the heavily loaded nodes is congested, it can lead to packet loss and buffer overflow, resulting in longer end-to-end delay, degradation in throughput, and loss of transport connections. Hence, it is important that some form of load balancing is present in the network. Most of the loads balancing protocols are on-demand-based protocols; that is, they combine load balancing strategies with route discovery. A route with the least load among multiple possible routes from source to destination is usually chosen. The existing Load-Aware On-Demand Routing (LAOR) is delay based. It is an extension of ad hoc on-demand distance vector (AODV) routing.

It has two phases: route discovery and route maintenance. LAOR achieves load balancing by minimizing the estimated total route delay and route hop count. A node initiates route discovery by sending a route request (RREQ) when it does not have a valid route to the destination. Intermediate nodes that receive the RREQ message update the total delay to RREQ and the routing table. Unlike AODV, if an intermediate node receives a duplicate RREQ with a smaller total delay and hop count, it updates this route in the routing table. The destination node then sends a reply message (RREP) when it receives the first RREQ. If duplicate RREQs received at the destination node have smaller total delay and hop count than previous ones, it sends an RREP message to the source node to change the chosen route immediately. When the source node receives the RREP, it initiates data packet transmission. This approach reduces delay due to the efforts made in selecting the best route.

Load balanced ad hoc routing protocols use different load metrics:

- Active path: This refers to the number of active routing paths supported by a node. Generally, the higher the number of active routing paths, the busier the node since it is responsible for forwarding data packets from an upstream node to a downstream node.

- Traffic size: This refers to the traffic load present at a node and its associated neighbors (measured in bytes).

- Packets in interface queue: This refers to the total number of packets buffered at both the incoming and outgoing wireless interfaces.

- Channel access probability: This refers to the likelihood of successful access to the wireless media. It is also related to the degree of channel contention with neighboring nodes.

- Node delay: This refers to the delays incurred for packet queuing, processing, and successful transmission. Existing load balanced ad hoc routing protocols use the above-mentioned load metrics to model load. In a broader context, the term load can be interpreted as:

- Channel load: Represents the load on the channel where multiple nodes contend to access the shared media.
- Nodal load: Relates to a node's activity. Specifically, it refers to how busy a node is in processing, computation, and so on.

- Neighboring load: Represents the load generated by communication activities among neighboring nodes.

Figure 1: Example of MANET

CONGESTION PROBLEM

In a network with shared resources, where multiple senders compete for link bandwidth, it is necessary to adjust the data rate used by each sender in order not to overload the network. Packets that arrive at a router and cannot be forwarded are dropped, consequently an excessive amount of packets arriving at a network bottleneck leads to many packet drops. These dropped packets might already have travelled a long way in the network and thus consumed significant resources. Additionally, the lost packets often trigger retransmissions, which mean that even more packets are sent into the network. Thus network congestion can severely deteriorate network throughput. If no appropriate congestion control is performed this can lead to a congestion collapse of the network, where almost no data is successfully delivered.

a) Priority of Traffic

Generally in QoS provisioning, the bandwidth is allocated first to the higher priority traffic in preference and then allocated to the lower priority traffic. The lower priority traffic can utilize the bandwidth only after the utilization of the higher priority traffic. If a high priority flow's traffic pattern satisfies the behavior described in the service agreement, its packets should be delivered in preference to other packets with lower priorities. On the other hand, flows with lower priorities should use as much bandwidth as possible after the transmission requirements of higher priority flows.

b) QOS Provisioning Challenges in MANETs

Due to several problems, QOS provisioning in MANETs is much complicated when compared to wired networks. The following are some of the main QOS provisioning and maintenance problems in MANETs.

• It requires knowledge of the available bandwidth, which is difficult to be accurately estimated in a dynamic environment.

• Bandwidth reservation has to be made through negotiation between neighbors within two to three hops other than only the direct neighbors sharing the same channel, and this needs signaling message exchanges between them. Moreover, when the neighbor moves out of the reservation area of the node, the reserved bandwidth in a neighbor should be released through some mechanism. Hence, an extra control overhead will be introduced by these signaling messages and consumes limited bandwidth and energy.

• The reserved bandwidth over the entire duration of an active session cannot be guaranteed. Some of the reserved bandwidth might be stolen by the oncoming node, if a communicating node moves towards a node which has reserved some bandwidth for flow(s). The reserved bandwidth over the link between them might be unavailable or the link might be broken, if two nodes on the end of a link move away from each other.

• In MANETs, due to the dynamic topology, there is no clear definition of what is core, ingress or egress router. Since all the nodes in the network cooperate to provide services, there is no clear definition of a Service Level Agreement (SLA). On the other hand, an infrastructure network where the services to the users in the network are provisioned by one or more service providers.

• Since the wireless bandwidth and capacity in MANETs are affected by interference, noise and multi-path fading, it is limited and the channel is not reliable. Moreover, the available bandwidth at a node cannot be estimated exactly because it involves in a large variations based on the mobility of the node and other wireless device transmitting in the vicinity etc.

RELATED WORK

Yao-Nan Lien et al proposed a new TCP congestion control mechanism by router-assisted approach. Their proposed TCP protocol, called TCP Muzha uses the assistance provided by routers to achieve better congestion control. To use TCP Muzha, routers are required to provide some information allowing the sender to estimate more accurately the remaining capacity over the bottleneck node with respect to the path from the sender to the receiver. With this information, TCP Muzha will be able to enhance the performance of both TCP and network. Wei Sun et al [8] have compared the general AIMD-based congestion control mechanism (GAIMD) with Equation-based congestion control mechanism (TFRC TCP-Friendly Rate Control) over a wide range of MANET scenario, in terms of throughput fairness and smoothness. Their results have shown that TFRC and GAIMD are able to maintain throughput smoothness in MANET, but at the same time, they require only a less throughput than the competing TCP flows. Also their results show that TFRC changes its sending rate more smoothly than GAIMD does, but it gets the least throughput compares with TCP and GAIMD.

Yung Yi et al have developed 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, they have shown that their algorithm is globally stable using a Lyapunov-function-based approach. Next, in the presence of delay, they have shown that the hop-by-hop control algorithm has the property of spatial spreading. Also they have derived 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.

Umut Akyol et al have studied the problem of jointly performing scheduling and congestion control in mobile adhoc networks so that network queues remain bounded and the resulting flow rates satisfy an associated network utility maximization problem. They have defined a specific network utility maximization problem which is appropriate for mobile adhoc networks. They have described a wireless Greedy Primal Dual (wGPD) algorithm for combined congestion control and scheduling that aims to solve this problem. They have shown how the wGPD algorithm and its associated signaling can be implemented in practice with minimal disruption to existing wireless protocols.

S.Karunakaran et al have presented a Cluster Based Congestion Control (CBCC) protocol that consists of scalable and distributed cluster-based mechanisms for supporting congestion control in mobile ad hoc networks. The distinctive feature of their approach is that it is based on the self-organization of the network into clusters. The clusters autonomously and proactively monitor congestion within its localized scope.

S. Venkatasubramanian et al proposed the QoS architecture for Bandwidth Management and Rate Control in MANETs. The bandwidth information in the architecture can be used for QoS capable routing protocols to provide support to admission control. The traffic is balanced and the network capacity is improved as the weight value assists the routing protocol to evade routing traffic through congested area. The source nodes then perform call admission control for different priority of flows based on the bandwidth information provided by the QoS routing. In addition to this, a rate control mechanism is used to regulate best-effort traffic, whenever network congestion is detected. In this mechanism, the packet generation rate of the low-priority traffic is adjusted to incorporate the high-priority traffic.

R.Mynuddin Sulthani et al proposed a joint design of reliable QoS architecture for mobile adhoc networks. In the reliable multipath routing protocol, dispersion and erasure code techniques are utilized for producing replicated fragments for each packet, to enhance reliability. Then messages with good delivery probability are identified and transmitted through the paths with high average node delivery index. While it receives an assured number of fragments, destination can recover the original packet. Next, a call admission control (CAC) scheme has been developed, in which, the calls are admitted based on the bandwidth availability of the path. Once congestion occurs, the best effort traffic is rate controlled, to free bandwidth for the real-time flows.

Lijun Chen et al proposed the joint design of congestion control, routing and scheduling for ad hoc wireless networks. They formulate resource allocation in the network with fixed wireless channels or single-rate wireless devices as a utility maximization problem with schedulability and rate constraints arising from contention for the wireless channel. We also extend the dual algorithm to handle the network with time-varying channel and adaptive multi-rate devices, and surprisingly show that, despite stochastic channel variation, it solves an ideal reference system problem which has the best feasible rate region at link layer. In future, they will extend the results to networks with more general interference models and/or node mobility and further will enhance the performance gain from cross-layer design involving link layer.

Xuyang Wang et al proposed a cross layer hop by hop congestion control scheme to improve TCP performance in multihop wireless networks which coordinates the congestion response across the transport, network, and transport layer protocols. The proposed scheme attempts to determine the actual cause of a packet loss and then coordinates the appropriate congestion control response among the MAC network, and transport protocols.

RESULTS AND EVALUATIONS

In this section, benefits of proposed load balancing protocol are shown by comparing the simulation results with LAOR. Analysis of the protocol is done by studying the efficiency of routing metrics like throughput and packet delivery ratio. Energy efficiency of our protocol is evaluated using energy metrics average energy consumed variance and network lifetime. Throughput is the rate at which a computer or network sends or receives data. It is a good measure of the channel capacity of a communication link. It is usually rated in terms of how many bits they pass per second(Bit/s). In our project, throughput is the amount of data moved successfully from one node to another node in a given time period. In the existing system, initially the nodes spend much time in finding the node to communicate, so throughput is decreased at the beginning of data transmission.

A. Simulation Scenario This protocol is simulated using ns2 which supports complete physical, data link and MAC layer models for simulating wireless ad hoc networks. We have constructed a 100 X 100 m mobile ad hoc network of 50 nodes randomly placed, which can be simulated in ns-2.33. These nodes correspond to the mobile nodes. For the traffic model, we consider constant bit rate (CBR) data sources each sending packets at a fixed rate of 4 packets/sec. The data packet size is 512 bytes.

B. Simulation Results We compare three performance metrics for evaluations:

1) Throughput: is the average rate of successful message delivery over a communication channel.

2) Packet delivery ratio: The measured ratio of the number of data packets delivered to the destinations to the number of packets generated by all traffic sources.

3) Energy: Energy plays a major role in the lifetime of a mobile ad hoc network. Fig 2 shows the throughput. Throughput is the rate at which a computer or network sends or receives data. It is a good measure of the channel capacity of a communication link. It is usually rated in terms of how many bits they pass per second(Bit/s). Here,

throughput is the amount of data moved successfully from one node to another node in a given time period. In the existing system, initially the nodes spend much time in finding the node to communicate, so throughput is decreased at the beginning of data transmission. Fig 3 shows the energy. Energy plays a major role in the lifetime of a mobile ad hoc network. From the graph, it is clear that energy is reduced considerably. Thus, our proposed system is energy efficient when compared to the existing system as described earlier. The sudden increase and decrease in these graph means that the load may vary from one region to another region according to the number of nodes. Fig 4 shows the packet delivery ratio.

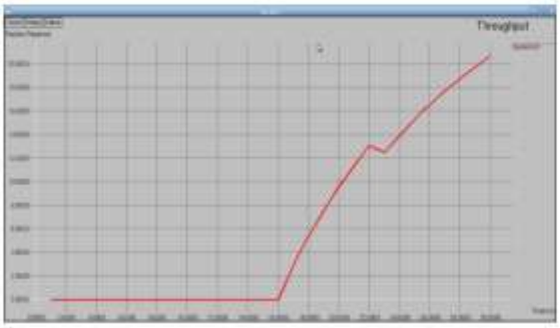

Figure 2: Graph Showing Throughput

Figure 3: Graph Showing Energy

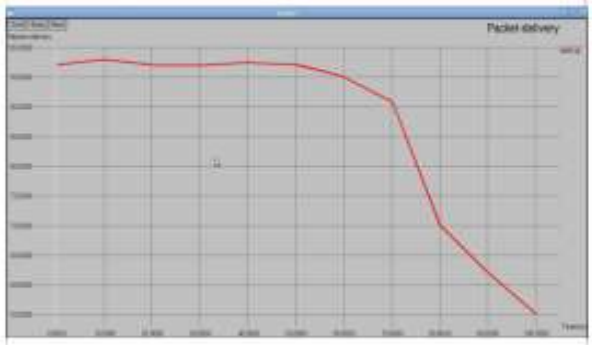

Figure 4: Graph showing Packet Delivery Ratio

CONCLUSION

In this paper, the existing LAOR protocol is compared with the proposed load balancing protocol. While offering better representation of actual load, LAOR incurs higher complexity in capturing load information. Comparing the operations of protocols, only the proposed protocol achieves load balancing during route maintenance. Other protocol balances load only during route discovery. In wired networks, multicast is used very rarely, because it is often not supported by the network. But in mobile ad-hoc networks, where the network can be tailored to the application and bandwidth is especially scarce, it might in fact turn out to be vital for group communication scenarios. Congestion control for these non-unicast communication scenarios is also an open research issue.

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