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EFFICIENT GROUP COMMUNICATIONS IN MOBILE AD HOC NETWORKS

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ABSTRACT

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Due to variable and unpredictable characteristics of wireless mobile computing device, efficient support of group communications is very challenging issue for most Mobile Ad-hoc Networks (MANETs). Recently several prominent broadcast routing protocols in MANETs are emerging for supporting Quality of Service (QoS) aware group communication. In MANETs Quality of Service (QoS) requirements can be quantified in terms of Packet delivery ratio (PDR), delay, packet drop probability, routing overhead, MAC overhead, throughput and bandwidth etc. This paper provides an in-depth study of many-to-many communication in MANETs. We evaluate the various Quality of Service (QoS) metrics of broadcast routing protocols, focusing on the effects of number of data senders. BCAST protocol is used as broadcast protocol. A detailed simulation model with MAC and physical layer models is used to study the interlayer interactions and the QoS implications. Simulation result shows that BCAST performs well in most cases and is more suitable for real time multimedia communication.

Keywords: Mobile Routing protocols, MANETs, QoS, BCAST, Random way point model

INTRODUCTION

During recent years, with the advent of new universal technologies and proliferation of portable mobile computing devices, the importance of mobile and wireless ad-hoc networks have raised. These recent revolutions have been generating a renewed and growing interest in the research and development of MANETs in group communications. A mobile ad hoc network is a self organizing network comprising a set of wireless mobile computing devices that move around freely and can able to communicate among themselves using wireless radios, without the aid of a pre-existing base station or infrastructure (Holland, et al.2002). Each mobile computing device participating in this network can act as a sender, as a receiver and as a router at the same time and able to build, operate and maintain these networks at anytime, anywhere. Due to limited radio propagation range of these wireless devices, distant nodes communicate through multi-hop paths.

In MANET group communications issues differ from those in wired environments for the following reasons: The wireless communication medium has variable and unpredictable characteristics and the signal strength and propagation fluctuate with respect to time and environment resulting disconnection of the network at any time even during the data transmission period. The strength of the received signal depends on the power of the transmitted signal, the antenna gain at the sender and receiver, the distance between the two nodes, the obstacles between them, and the number of different paths the signals travel due to reflection. Further more, node mobility creates a continuously changing communication topology in which routing paths break and new ones form dynamically (Prasant, et al. 2004). Since MANETs have limited channel bandwidth availability and low battery power, their algorithms and protocols must conserve both bandwidth and energy. Wireless devices usually use computing components such as processors, memory, and I/O devices, which have low capacity and limited processing power. Thus, their communications protocols should have lightweight computational and information storage (Prasant, et al. 2004).

Network-wide broadcasting, which attempts to deliver packets from a source node to all other nodes in the network, serves an important function in MANETs. It is a basic mode of operation in wireless medium that provides important control and route establishment functionality for a number of unicast and multicast protocols. When designing broadcast protocols for ad hoc networks, developers seek to reduce the overhead such as collision and retransmission or redundant retransmission, while reaching all the network's nodes (Tanenbaum, et al. 2003, Forouzan, et al. 2000). Although a wireless signal broadcast causes more contention and collisions in the shared wireless channel, it also allows a single transmission to reach multiple neighboring nodes. In practice, the scope of the broadcast is limited to a broadcast domain. Broadcasting is largely confined to local area network (LAN) technologies, most notably Ethernet and Token Ring, where the performance impact of broadcasting is not as large as it would be in a wide area network. Because Broadcasting is used to carry huge amount of traffic and requires more bandwidth, neither X.25 nor frame relay supply a broadcast capability, nor Internet explicitly support broadcasting at the global level (Forouzan, et al. 2000).

Classification of routing protocols

In MANET Routing protocols can be classified into different categories depending on their desirable properties. Various prominent methods of classification have been suggested in the literature (Feeney, et al.1999, Hong, et al. 2002, Kuosmanen, 2002). One way is to classify them according to the network topology that they form as *hierarchical or flat ro*uting. In hierarchical routing the network is organized in the form of a tree and nodes are

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grouped, some nodes are selected as group leaders that take more responsibilities than others where as in flat routing every node plays an equal role independently and take the same responsibility. This classification is typical physical. When we consider the routing protocols that conFigure and maintain networks, classification can be done according to the way they establish routes to the destinations. We can group them into *pro-active* or *re-active*. In pro-active routing protocols, the nodes in a wireless ad hoc network keep track of up-to-date routing information to all possible destinations through periodic updates of routing table so that when a packet needs to be forwarded, the route is already known and can be used immediately where as in reactive routing protocols, nodes attempt to build a route when needed i.e. when a node wants to send packets to some destination but has no routes to the destination, it initiates a route discovery process within the network We can also group them as *hop-by-hop* where routers choose on next hop forwarding advertising only the path that they are using. *Source* routing is an alternative to hop-by-hop routing whereby, routes are determined by the originator of the source.

In-group oriented communication system, routing protocols can be classified into three main categories [7] based on the number of senders and number of receivers in MANETs. Protocols can be assumed to operate at *Unicast, Multicast or Broadcast situations.* In unicast routing the communications are referred as one-to-one i.e. a separate transmission stream from source to destination for each recipient. Multicast communications are both one-to-many and many-to-many traffic pattern i.e. to transmit a single message to a select group of recipients where as in broadcast routing communications is one-to-all traffic pattern. In this paper, this category of the classification, this is more relevant to our goal and is considered.

Broadcast routing protocols

BCAST is an optimized scalable broadcast routing protocol (Kunz, 2003). It keeps track of one-hop and two-hop neighbor knowledge information exchanged by periodic "Hello" messages. Each "Hello" message contains the node's IP address and list of known neighbors. When a node receives a "Hello" packet from all its neighbors, it has two-hop topology information i.e. only packets that would reach additional neighbors are re-broadcast. For example if a node says *B* receives a broadcast message from another node say *A*, it knows all neighbors of *A*. If *B* has neighbors not covered by *A*, it schedules the broadcast packet with a random delay. During this delay, if *B* receives another copy of this broadcast from *C*, it can check whether its own broadcast will still reach new neighbors. If this is no longer the case, it will drop the packet. Otherwise, the process continues until *B*'s timer goes off and *B* itself rebroadcasts the packet.

The determination of Random delay time is very critical. To solve this problem a dynamic strategy is suggested (Kunz, 2003). Each node searches its neighbor table for the maximum neighbor degree of any neighbor node, say *MAX*. If its own node degree is N, it calculates the random delay as *MAX/N.* In reliable BCAST, every node also buffers the most recent *X* packets. *X* can be any arbitrary number, to keep the memory requirement at each node low; set *X* to a small number. This basic mechanism improves the packet delivery ratio in BCAST.

When a node receives a packet with sequence number *N* from source node *A*, it checks whether it also received packet *N*-1 from the same source. If not, it issues a one-hop broadcast to the neighbors, asking for retransmission of this packet by sending Negative Acknowledgement, NACK(N-1, A) message. Each neighbor, upon receiving the NACK packet, will check its local buffer and if they have this packet buffered, will schedule a retransmission. To reduce collisions, the NACKs and the packet retransmissions are jittered randomly by few milliseconds. In addition, NACKs have a timeout mechanism associated with them, so even if a NACK or retransmission is lost, packets can be recovered. NACKs are reissued up to a certain maximum number of attempts. In order to reduce network traffic, nodes with pending packet retransmissions will cancel their retransmission if they overhear another node *C* re-broadcasting that packet. This is based on the assumption that the requesting node will receive this packet as well, satisfying the NACK. This is arguably not guaranteed to be the case, when a node *C* could be out of reach of the requesting node, broadcasting packet *N* for other reasons. However, with multiple NACK attempts (spaced apart multiple seconds), eventually only nodes that received a NACK will attempt to re-transmit a packet. Since they received the NACK, and packets are retransmitted with little additional delay, it is reasonable to assume that the requesting node, in turn, will receive their transmission. If a sequence of packets is lost, this NACK mechanism also recovers from this by backtracking.

In this paper we attempted to present an overview of BCAST routing protocols. QoS metrics measurement of BCAST protocol is based on Shadowing radio propagation model and Random way point mobility model. The simulation is carried out using ns-2 network simulator.

Simulation model

Simulation is the research tool of choice for a majority of the mobile ad hoc network community. A detail simulation model based on NS-2 (Fall, et al. 2008) is used to implement DSR and BCAST routing protocols. NS-2 is a discrete event packet-level simulator with CMU's Monarch group's mobility extensions, which include implementations of models of signal strength, radio propagation, wireless medium contention, capture effect, and node mobility. A simulation model with MAC and physical models are used to study the interlayer interaction and their performance. An unslotted carrier sense multiple access (CSMA) technique with collision avoidance (CSMA/CA) is used to transmit the data packets. The radio model uses characteristics similar to a conventional radio interface, Lucent's WaveLAN. WaveLAN is modeled as a shared-media radio with nominal bit rate of 2Mb/s and radio range of 250m.

Radio Propagation Model

The shadowing propagation model (Fall, et al. 2008) is used in this simulation study. It attempts more realistic situation than free space and two-ray models. It takes into account multi-path propagation effects. Both free space and two-ray models predict the mean received signal strength as a deterministic function of distance and consequently represent communication radius as an ideal circle. But in realistic environment, when the fading effects are considered it can be seen that, the received power at a certain distance is a random variable. Hence shadowing model is widely used in real environment. The available parameters that are used in our simulation code are shown in Table 1.

Table 1. Different parameters of Radio Propagation Model

Parameters	Value	Comment
Transmission Range	250m	Fixed (Considered)
Frequency	$914 \times 10^{6}\ Hz$	Fixed (Considered)
Path Loss Exponent	2.0	Fixed (Considered)
Standard Deviation	4.0	Fixed (Considered)
Reference Distance	1.0m	Fixed (Considered)
CPThreshold	10.0 Watt	Fixed (Considered)
RXThreshold	6.76252×10^{-10}	Calculated
CSThrehold	2.88759×10^{-11}	Calculated (RXThreshold*0.0427)
Power (Pt)	0.28183815 Watt	Fixed (Considered)
System Loss	1.0	Fixed (Considered)

Traffic and Mobility Model

In this paper we are using traffic based on Continuous bit rate (CBR) traffic sources. The source-destination pairs are spread randomly over the network. Only 512- byte data packets are used. The number of source destination pairs and the packet sending rate in each pair is varied to change the offered load in the network. A mobility model accurately represents the movement of mobile nodes in MANET. *Random waypoint mobility* model *(*RWM) is used in this simulation study (Heng, 2001). The model includes networks with 50 mobile nodes placed on a site with dimensions 1500×300 meters. Each packet starts its journey from a random location to a random destination with a randomly chosen speed (uniformly distributed between 0–20 m/s). Once the destination is reached, another random destination is targeted after a pause time and then repeats the process. The pause time, which affects the relative speeds of the mobiles, is also varied. Each simulation is run for 200 simulated seconds. Five randomly generated scenarios are run for each parameter combination, and each point in the graphs is the average results of these five scenarios. Identical mobility and traffic scenarios are also used across protocols to gather fair results. In RWM model, *Pause Time* and *Max Speed* of a mobile are the two key parameters that determine the mobility behavior of nodes. If the node movement is small and the *Pause Time* is long, the topology of Ad Hoc network becomes relatively stable. On the other hand, if the node moves fast and the pause time is small; the topology is expected to be highly dynamic.

Performances metrices:Protocol performance will be evaluated using the following important metrics

Packet Delivery Ratio (PDR): The ratio between the number of packets originated by the application layer CBR sources and the number of packets received by the CBR sink.

Packet Latency: This includes all possible delays caused by buffering during route discovery, queuing delay at the interface queue, retransmission delays at the MAC, propagation and transfer times (Marina, et al. 2003).

Packet loss percentage*:* This is defined as the percentage of data packets dropped in the network either at the source or at intermediate nodes (Marina, et al. 2003).

Normalized MAC Load (NML): The number of routing, Address Resolution Protocol (ARP), and control packets (e.g., RTS, CTS and ACK) transmitted by the MAC layer, including IP/MAC headers for each delivered data packet (Jayakumar, et al. 2007). It considers both routing overhead and the MAC control overhead. This metric also accounts for transmission at each hop.

SIMULATION RESULTS

The result of this simulation study is considered by varying number of data senders:

EFFECT OF NUMBER OF SENDERS ON QOS METRICS

To investigate the effect of number of senders on the performance of DSR and BCAST, the data send rate and number of data receivers are kept constant at 2 pkts/s and 20 respectively. The numbers of data senders are increased from 1 to 10 and several performance metrics are measured. For the fairness of protocols comparison and network performance, each ad hoc routing protocol is run over the same set of scenarios. Simulation parameters for the different Senders Scenarios are shown in Table 2.

Table 2. Effect of number of senders on qos metrics

Parameter	Value
Number of senders	1, 2, 5, 7 and 10
Number of receivers	20
Pause Time	0 m/s
Max. Speed	20 m/s
Antenna Range	250 m
CBR Rate	2 packets/sec.
Simulation Time	200 s

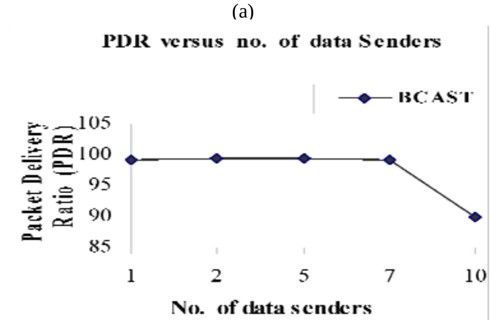
Packet Delivery Ratio (PDR) and latency results as a function number of senders

The simulation results for PDR and data latency of DSR and BCAST routing protocols are given in Figure 1.

From Figure 1(a) it is observed that with increasing number of senders, the PDR of BCAST protocol is high and relatively consistent. A relatively high PDR is a desirable property for the scalability of Ad Hoc routing protocols. This is because that BCAST has less redundancy and dynamically selects only a subset of nodes to re-broadcast a packet. It keeps 2-hop neighbor topology information and each node also buffers most recent few packets. A NACK based retransmission scheme of BCAST protocol further increase PDR.

From Figure 1(b) it is observed that the average packet latency of BCAST increases slowly with increasing number of data senders. BCAST protocol performs better than DSR in this case. Since BCAST maintains broadcast connections and keep two hops topology information, the average packet delay is significantly lower. Lower packet latency is the desirable property for real-time multimedia applications.Because these applications can tolerate loss but very sensitive to delay. Hence BCAST is more effective for real time multimedia communication.

(a)



(b)

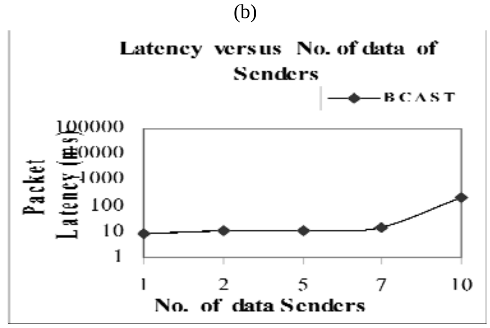


Figure1. PDR (a), Latency (b) results as a function of Number of Senders

NML results as a function number of senders

The simulation results for NML are given in Figure 3.
From Figure 2 it can be observed that the normalized MAC load of BCAST is lower, hence provides good performance. Since in BCAST all MAC transmissions are multicast, it generates only fraction of MAC layer control packets (RTS, CTS and ACK). This effect results lower transmission collision and offers high packet delivery guarantee.

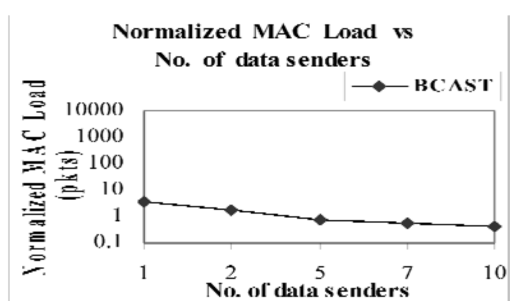


Figure 2. NML results as a function of Number of Senders

Packet loss percentage results as a function number of senders

The simulation result for packet loss probability is given in Figure 3.

From Figure 3 it is observed that with increasing number of data senders, the probability of data packets loss percentage either at the source or the intermediate nodes increases slowly. Though BCAST performs well, some packet losses can be explained by transmission collisions. This value is significantly lower, since the protocol implementation takes great care to avoid such collision by randomly jittering re-broadcasts by 10 ms.

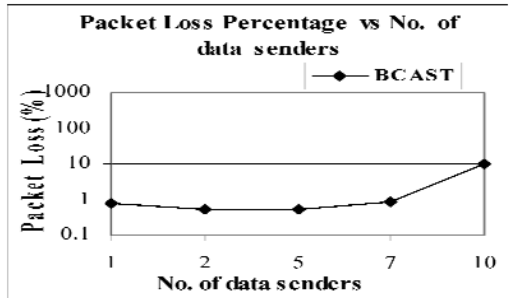


Figure 3. Packet loss percentage results as a function of Number of Senders

There are number of alternatives when delivering data from one or more senders to a group of receivers such as setting up dedicated unicast connections from each sender to each receiver, employing a multicast protocol and broadcasting packet to every node. The network must meet QoS requirements while transporting a packet stream from source to destination. This paper measures various QoS matrices of BCAST routing protocol over group communication in MANETs. BCAST is an optimized neighbor knowledge based broadcast protocol provides robust performance with less delay time (minimizes network congestion and keeps two hop neighbor information) and less traffic overhead (partial source route) in terms of PDR, latency, normalized routing and MAC load, packet drop probability. The simulation result shows that the broadcast protocol BCAST work very well in most scenarios and are more robust even with high traffic environments. Due to low latency and high PDR it is more useful in real time multimedia applications.

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