ANALYSIS OF NEIGHBOR KNOWLEDGE BASED BCAST PROTOCOL PERFORMANCE FOR MULTIHOP WIRELESS AD HOC NETWORKS

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ABSTRACT

Reliable group communication is a challenging issue for most Mobile Ad-hoc Networks (MANETs) due to dynamic nature of wireless mobile nodes, group key establishment and management, ensuring secure information exchange and Quality of Service (QoS) in data transfer. Recently multicast and broadcast routing protocols are emerging for supporting QoS aware group communication. In MANETs QoS requirements can be quantified by a set of measurable pre-specified service attributes such as packet delivery ratio, end-to-end delay, packet loss probability, network control overhead, throughput, bandwidth, power consumption, service coverage area etc. In this paper, the performance of a neighbor knowledge based broadcast protocol is analyzed using different QoS metrics (packet delivery ratio, end-to-end delay, packet loss probability and network control overhead). BCAST is used as broadcast protocol. The performance differentials are analyzed using NS-2 network simulator for varying number of data senders (multicast group size) and data sending rate (offered traffic to the network) over QoS aware group communication. Simulation results show that BCAST performs well in most cases and provides robust performance even with high traffic environments.

KEYWORDS

MANETs, Broadcast, BCAST, Random way point model, QoS.

1. INTRODUCTION

Recent advances in technology have provided portable mobile computing devices with wireless interfaces that allow network to support group oriented communication among mobile users. The resulting technology influence mobile users no longer necessary to maintain continuous network connectivity regardless of fixed physical location and enables almost nonrestricted node mobility. It is argued that future wireless communication will be converged to be more ad hoc and reconfigurable [1]. A mobile ad hoc network (MANET) is a self organizing network comprising a set of wireless mobile nodes that move around freely and can able to communicate among themselves using wireless radios, without the aid of any centralized administration [2]. In ad hoc networks all nodes are mobile and can be connected dynamically in an arbitrary manner and can act as sender, receiver and even as a router at the same time.

Ad hoc routing protocols can be classified into three main categories based on the number of senders and receivers in group computing environment: Unicast, Multicast and Broadcast routing

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protocols [3],[4],[5]. In unicast routing the communication is simply 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 selective group of recipients where as in broadcast routing communications is one-to-all traffic pattern. It is a basic mode of operation in wireless medium that provides important control and route establishment functionality for a number of on-demand 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 [6].

Reliable Broadcasting in Ad-hoc networks poses more challenges than the one in wired networks for the following reasons: node mobility, temporary network partition and scarce system resources. The wireless medium has variable and unpredictable characteristics of the signal strength and the propagation fluctuate with respect to time and environment resulting in disconnection of the network at any time [7]. 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 mobile nodes, the obstacles between them, and the number of different paths the signals travel due to reflection. Since MANETs have limited channel bandwidth availability and low battery power, their algorithms and protocols must conserve both bandwidth and energy [7]. Further node mobility also creates a continuously changing communication topology in which existing routing paths break and new ones form dynamically. In a low mobility environment, tree-based schemes such as minimal connected dominating set (MCDS) are better in reducing resource consumption. In a high mobility situation, simple flooding is the only way to achieve the full network coverage; that is, the broadcast packet is guaranteed to be received by every node in the network, providing there is no packet loss caused by collision in the MAC layer [1].

Broadcast protocols can categorize into four families: simple flooding, probability based method, area based method and neighbor knowledge based methods [8]. In simple flooding, source node first broadcasting a packet to all neighbors. It is forwarded by every neighbor in the network exactly once until all reachable network nodes have received that packet. Though simple flooding ensures the entire coverage, it has the largest forward node set and may cause broadcast storm problem in the network. Probability and area-based methods are proposed to solve the broadcast storm problem [9]. In these schemes, each node will estimate its potential contribution to the overall broadcasting before forwarding a broadcast packet. If the estimated contribution is lower than a given threshold, it will not forward the packet. However, the estimation methods are some time inaccurate and cannot ensure the full network coverage. Neighbor Knowledge Methods maintain state on their neighborhood, via "Hello" packets, which is used in the decision to rebroadcast. A small set of forward nodes is selected to avoid flooding in the whole coverage. Basically, the forward node set forms a connected dominating set (CDS). A node set is a dominating set if every node in the network is either in the set or the neighbor of a node in the set. The challenge is to select a small set of forward nodes in the absence of global network information.

In this paper, a reliable neighbor Knowledge based broadcast routing protocol over QoS aware group communication in multi-hop mobile Ad-hoc network is simulated and its performance is analyzed in terms of four QoS metrics such as packet delivery ratio, end-to-end delay or jitter, packet loss probability and network control overhead varying multicast group size (number of data senders) and data sending rate over QoS aware group communication.

The rest of this paper is organized as follows. Related works in the relevant field are discussed in section 2. In section 3 neighbor Knowledge based broadcast routing algorithm is discussed briefly. The network topologies together with simulation parameters are presented in section 4.

Quality of Service (QoS) metrics used in this study is mentioned in section 5. Simulation results are discussed in the same section 6. Finally, the recommendations for future work in this area and concluding remarks are provided in section 7.

2. RELATED WORKS

Presently significant research is undertaken to analyze the performance of different prominent unicast, multicast and broadcast routing protocols in mobile ad hoc environment. Perkins et al [10] studied and implemented unicast version of on-demand AODV and compared it with DSR protocol with respect to QoS parameter considering a multi-hop wireless ad hoc environment under diverse network scenarios through simulation.

A framework to evaluate the impact of three classes of unicast proactive, reactive and hybrid MANET routing protocols namely AODV, Optimized Link State Routing (OLSR) protocol, and Dynamic Zone Topology Routing Protocol (DZTR) presented in [11]. They investigated the effect of packet delivery ratio, Normalized control overhead and Delay with respect to the different node scenarios. Their simulations results show that AODV and DZTR are more scalable than OLSR.

Authors in reference [12] analyzed two on-demand multicast routing protocols one tree based MAODV protocol and other mesh based On Demand Multicast Routing Protocol (ODMRP). They investigated the effect of packet delivery ratio and latency with respect to the network traffic, the node speed, as well as the area and antenna range for different simulation scenarios. Reference [13] proposed an enhanced Multicast Ad-hoc On-demand Distance Vector Routing protocol called E-MAODV and compared with the original MAODV. In this work two prominent metrics control overhead and total overhead was considered for performance comparison.

The existing broadcasting schemes are categorized into four families, performed comprehensive comparison of protocols from each family through simulator and conducted an in-depth analysis of the performance under a wide range of parameters in [8]. Their simulation results show that all protocols will eventually suffer from low packet delivery ratio as the mobility rate increased. In [1] authors proposed a general framework for broadcasting in ad-hoc networks that uses self-pruning techniques to reduce the number of forward nodes and provided a performance analysis of broadcast protocols based on this self-pruning in highly mobile networks. A comparative simulation study reveals that the self-pruning scheme in general is more efficient in reducing the forward node set than existing schemes that ensure the broadcast coverage.

3. NEIGHBOR KNOWLEDGE BASED BROADCAST ROUTING PROTOCOL

BCAST [14] is a neighbor Knowledge based broadcast routing protocol. It uses Scalable Broadcast algorithm (SBA) [9]. In BCAST, each node keeps knowledge of their neighbor’s within a 1-hop and 2-hops radius that is achieved 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 packet from another node A, it knows all neighbors of A. If B has additional neighbors not covered by A, it schedules the broadcast packet for delivery with a uniform random delay called Random Assessment Delay (RAD). During this delay, if node B receives another copy of this broadcast from another neighbor 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 (RAD expires) and B itself rebroadcasts the packet.

The determination of Random delay time is very critical. To solve this problem a dynamic strategy is suggested [9], [14]. The strategy defines a technique which consists in re-adjusting the RAD according to the degree of the node concerned and the maximum degree of its neighbors. Specifically each node searches its neighbor table for the maximum neighbor degree of any neighbor node, say d_{MAX}. If its own current node degree is N, it calculates the random delay as d_{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 further performance of 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 say 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. With this NACK based scheme, the packet delivery ratio can be improved. However, there are still sources of packet loss that a NACK-based scheme cannot completely avoid problems due to the NACK mechanism itself and long-lived network partitions.

4. SIMULATION MODEL

This section describes the simulation tools and parameters chosen to simulate the routing protocol.

4.1 Simulation Environment

To investigate the performance of BCAST, simulation environment is created using network simulator (NS-2). 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 [11],[12]. The extensions include a set of mobile Ah-hoc routing protocols as well as an 802.11 MAC layer and a radio propagation model. The simulation environment used the following parameters:

- Simulation Area: 1500×300 m^2
- Number of wireless mobile nodes: 50
- Simulation duration: 200 sec
- Number of repetitions: 5
- Radio propagation modes: Shadowing propagation model (more realistic path loss model than free space or two-ray models used in more realistic environment).

- Mobility model: Random waypoint model with 0 m/s pause time and 20 m/s maximum node speed
- Physical/Mac layer: IEEE 802.11 at 2 Mbps, 250 m transmission range
- CBR parameters: packet size = 256 bytes, interval = 0.50 ms, random = 1 and destination address = 0xE000000
- Each receiver is a multicast group member but the sender does not join a multicast group member except for the case of 50 receivers because all nodes are group members. All receivers join a single multicast group at the beginning of the simulation.

4.2 Radio Propagation Model

The shadowing propagation model is used in this simulation study. 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 [12]. The parameters used in our simulation code are shown in Table 1.

4.3 Traffic and Mobility Model

In this simulation, continuous bit rate (CBR) traffic is used. 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.

Nodes in the simulation area move according to mobility model. Random waypoint mobility model (RWM) is used in this simulation study [13]. This model includes networks with mobile nodes placed on a site with chosen dimensions. Each packet starts its journey from a random location to a random destination with a randomly chosen speed. Once the destination is reached, another random destination is targeted after a pause time and then repeats this process. The pause time, which affects the relative speeds of the mobiles, is also varied. 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 Ah-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.

Table 1. Parameters used in simulation

Parameters	Value	Comment
Transmission Range	250m	Fixed (Considered)
Frequency	914×10^{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)

5. PERFORMANCES PARAMETERS

The performance of BCAST protocol is evaluated using the following important QoS metrics

- Data Packet Delivery Ratio (PDR)
- End-to-End Delay (EED)
- Normalized Control overhead (NCO)
- Data packet Loss Probability (PLP)

PDR is the number of packets received by the destination to those generated by the CBR source. The EED represents the average delay experienced by each packet when traveling from to destination due to buffering during route discovery, queuing delay at the interface queue, retransmission delays at the MAC, propagation and transfer times. NCO presents the ratio of the number of control packets transmitted through the network to the number of data packets successfully transmitted. It considers routing overhead and the MAC control overhead (ARP packets and control packets such as- RTS, CTS and ACK). Data Packet Loss Probability is defined as the percentage of data packets dropped in the network either at the source or at intermediate nodes.

6. SIMULATION RESULTS AND DISCUSSIONS

The results of this simulation study are separately considered into two sections.

- Varying multicast group size (number of data senders)
- Varying data sending rate (offered traffic to network)

6.1 Effect of Number of Data Senders

In this section, the data sending rate and number of data receivers is kept constant at 2 packets/sec. and 20, respectively. The number of data senders is increased from 1 to 10 and PDR, EED, NCO and PLP are estimated and plotted into graphs. For the fairness of protocol comparison and network performance, Ad-hoc routing protocol is run over the same set of scenarios. Table 2 shows simulation parameters for different senders scenarios.

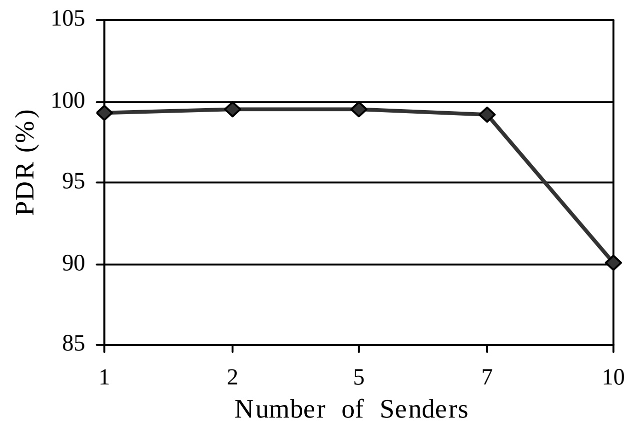
Table 2. Simulation parameters for the different senders scenarios.

Parameter	Value
Number of senders (variable)	1, 2, 5, 7 and 10
Number of receivers (keep constant)	20
Pause Time	0 m/s
Max. Speed	20 m/s
CBR Rate (constant)	2 packets/sec.

The simulation results for the PDR and EED as a function of number of data senders are shown in Fig. 1. From Fig. 1(a) it is observed that with increasing number of senders, the PDR of BCAST protocol is very high and relatively consistent. This is because that BCAST has less redundancy and it dynamically selects only a subset of nodes to rebroadcast 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. A relatively high PDR is a desirable property for lossless multimedia applications.

From Fig. 1(b) it is seen that the average EED of BCAST is low and nearly constant (increases very slowly) with increasing multicast group size (number of data senders). Since BCAST maintains broadcast connections and keep 2-hops topology information, the average packet EED is significantly low. Lower packet latency is the desirable property for real-time applications as these applications can tolerate loss but very sensitive to delay.

The simulation results for NCO and PLP are given in Fig. 2. From Fig. 2(a) it is seen that the normalized NCO load of BCAST protocol is low and nearly constant (decreases slowly), which indicates good performance of the protocol. As in BCAST all MAC transmissions are multicast, it generates only a fraction of MAC layer control packets (RTS, CTS and ACK) resulting in lower transmission collision and offers high packet delivery guarantee. Some NCO causes due to exchanging periodic "HELLO" messages.



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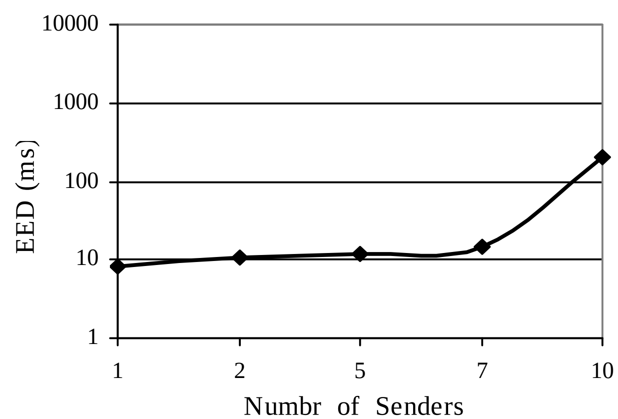
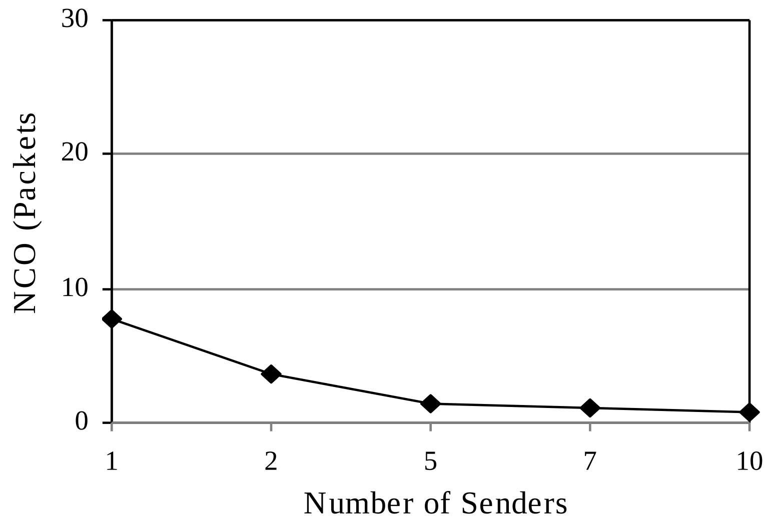


(b)

Figure 1. (a) PDR and (b) EED simulation results as a function of number of data senders.

Figure 2(b) shows that the percentage of data packet loss probability is low and increases very slowly with increasing number of data senders either at the source or the intermediate nodes. Though BCAST performs well, the occurrence of some packet losses can be explained by transmission collisions. The protocol implementation takes great care to avoid such collision by random jittering rebroadcasts by 10 ms interval. While a sequence of packets is lost, NACK mechanism of BCAST also recovers this by backtracking.



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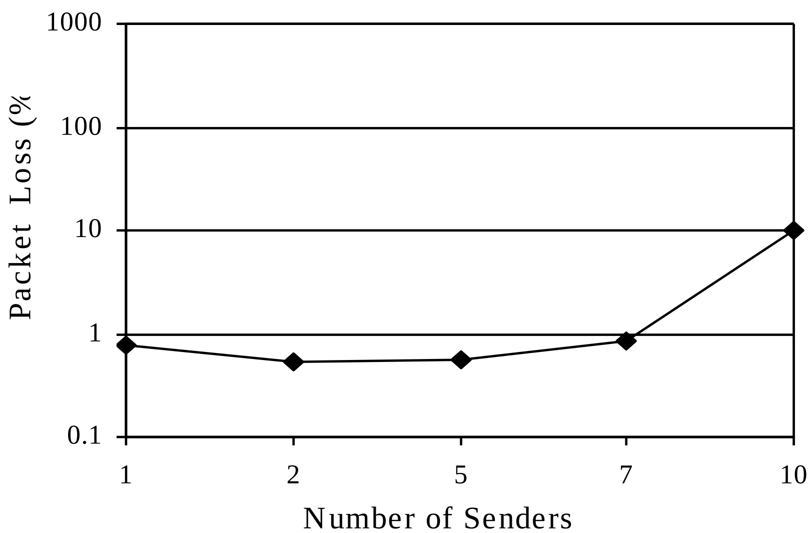


(b)

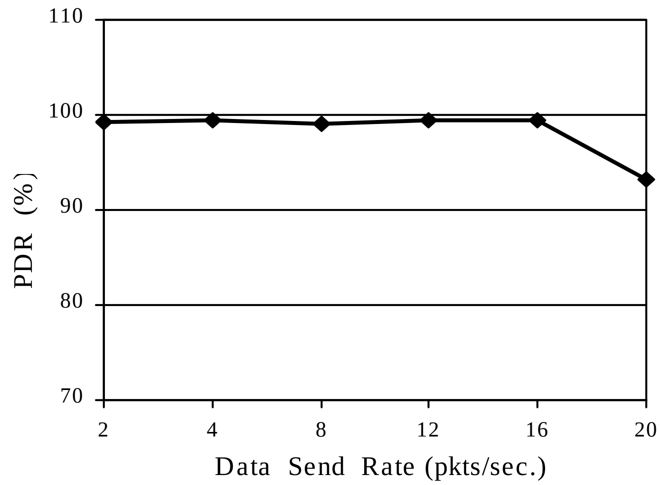
Figure 2. (a) NCO and (b) PLP simulation results as a function of number of data senders.

6.2 Effect of data sending rate

In this section, to investigate the effect of data sending rate or offered traffic in the network, number of data senders and data receivers are kept constant at 1 and 30, respectively. The data send rate is increased and several QoS metrics are measured and plotted into graphs. The simulation parameters considered for performance evaluation are given in Table 3.

Table 3. Simulation parameters for different data sending rate s scenarios.

Parameter	Value
Number of senders (constant))	01
Number of receivers (constant)	30
Pause Time	0 m/s
Max. Speed	20 m/s
CBR Rate	2, 4, 8, 12, 16, 20 packets/sec.



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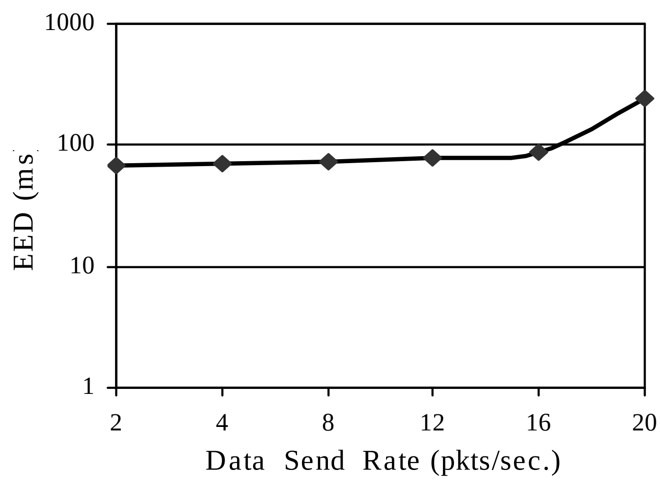

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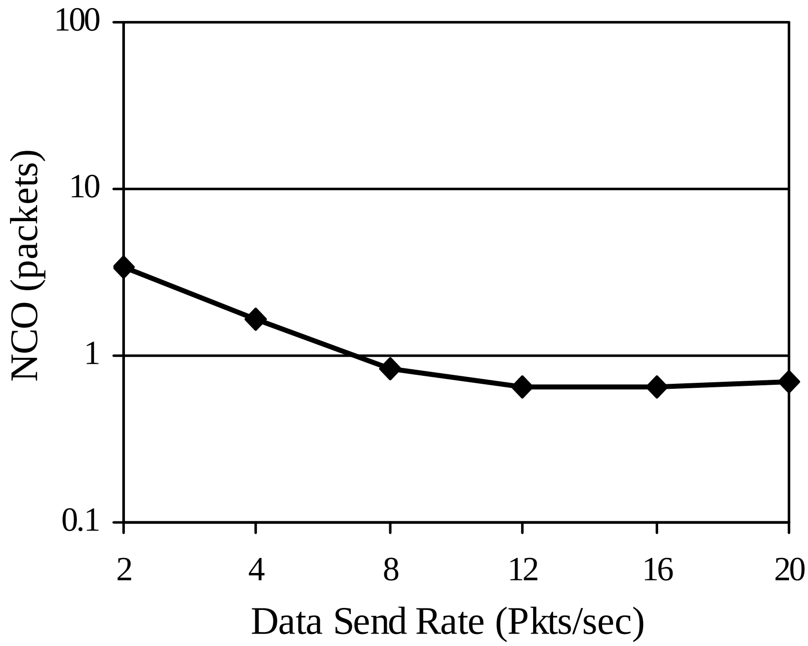

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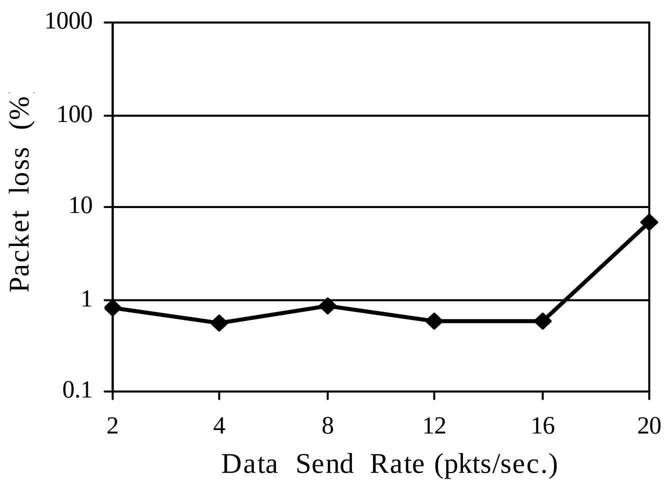

(d)

Figure 3. (a) PDR , (b) EED, (c) NCO and (d) PLP results as a function of data sending rate.

The simulation results for PDR, EED, NCO and PLP as a function of data send rate are given in Fig. 3. From Fig. 3(a), it is observed that with increasing the data send rate, the PDR performance of BCAST protocol is high and relatively constant. Even if the data rate is increased, the more packets are injected into the network before processing the previous data which overwhelm the queue and hence more data packets may be lost unexpectedly, the BCAST performance does not decay. This is due to the fact that BCAST uses scalable broadcast algorithm (SBA) and all mobile nodes have knowledge of their neighbors within a two hop radius which reduces number of broadcast packets in the network and is observed that with increasing data send rate, the EED, NCO and PLP of BCAST protocol varies in a similar way as for the case of the effect of number of data senders (Section 6.1).

7. CONCLUSIONS

In this paper, we have analyzed the performance of neighbor knowledge based BCAST routing protocol over group communication in Mobile Ad-hoc Networks (MANETs) using four important QoS metrics such as data packet delivery ratio, end-to-end delay, normalized control overhead and data packet loss probability for varying number of data senders (multicast group size) and data sending rate (offered traffic to the network). Simulation results show that the broadcast protocol BCAST for multi-hop wireless ad-hoc networks works very well in most scenarios and provides robust performance with less delay time and less traffic overhead even with high traffic environments.

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