Data Rate Adaptation Strategy to Avoid Packet Loss in MANETs

Muhammad Saleem Khan[1(✉)], Mohammad Hossein Anisi[2], Saira Waris[1], Ihsan Ali[2], and Majid I. Khan[1]

[1] Department of Computer Science, COMSATS Institute of Information Technology, Islamabad, Pakistan
skhan.ciit@gmail.com, syra054@yahoo.com, majid_iqbal@comsats.edu.pk

[2] Faculty of Computer Science and Information Technology, University of Malaya, Kuala Lumpur, Malaysia
anisi@um.edu.my, ihsanalichd@siswa.um.edu.my

Abstract. Due to mobile and dynamic nature of MANETs, congestion avoidance and control is a challenging issue. Congestion mainly occurs due to the phenomena where data arrival rate is higher than the transmission rate of data packets at a particular node. Congestion results in high packet drop ratio, increased delays and wastage of network resources. In this paper, we propose data rate adaptation technique to avoid packet loss. Proposed technique is based on the analysis of queue length of the forwarding nodes, number of source nodes forwarding data through a particular forwarding node, and rate of link changes. In the proposed strategy, queue length of forwarding nodes is communicated periodically to the neighbor nodes. Keeping in view the queue length of forwarding node, the sending node adapts its sending data rate to avoid congestion and to ensure reliable data communication. Results show that proposed strategy improves network performance as compared to the static data rate adaptation strategy in terms of packet delivery ratio upto 15% and reduces packet loss due to interface queue overflow upto 14%, respectively.

1 Introduction

Due to mobility, lack of continues end-to-end connectivity, and dynamic network topology, reliable data delivery becomes a challenging task in Mobile Ad Hoc Networks (MANETs). When source node transmits data packets to the destination, any intermediate node can suffer from congestion due to limited resources. Congestion will prompt high packet loss, long delays, and wastage of network resources [1,2]. The reasons for packet loss may be due to node mobility, non-availability of next hop nodes, interface queue overflow, and so on. As multiple sources are sending frequent data, queue of forwarding node may overflow causing packet drops which leads to degradation of the network performance. Therefore, an efficient congestion control mechanism is of vital significance in networks like MANETs. Existing conventional congestion control mechanisms are unable to

J. Ferreira and M. Alam (Eds.): Future 5V 2016, LNICST 185, pp. 57–66, 2017.
DOI: 10.1007/978-3-319-51207-5_6

cope with the congestion in MANETs due to many inherent challenges like high node mobility and continuous changes in the topology of network.

Various techniques have been proposed to avoid packet loss, such as adapting alternate route, routing Using bypass concept, on-demand multicast, and so on. These schemes find the alternate path in case of congestion at nodes in the current path. However, run-time calculation of alternate path is overhead in the aforementioned schemes. Moreover, congestion reports used in alternate route adaptation techniques may be delayed which can effect the network performance. Similarly, sending control packets for congestion notification is an itself overhead for a congested network.

To avoid the packet loss due to interface queue overflow, there is a strong need of mechanism which adapts the data rate at source nodes based on the run-time network conditions. In this paper, we propose Data Rate Adaptation Strategy (DRAS) to avoid packet loss due to interface queue overflow. The proposed DRAS avoids congestion before it actually happens.

The rest of the paper is organized as follows. Section 2 presents related work. Section 3 describes our proposed technique. Performance evaluation is discussed in Sect. 4 and finally conclusion and future work is presented in Sect. 5.

2 Related Work

Packet loss due to congestion or queue overflow is a severe problem in MANETs. Based on the methodology used to avoid congestion, these schemes can be classified as alternate path based [3–5], data rate adaptation based and pausing control messages. In this work, we present the data rate adaptation based techniques, as our work is more related with this type of category. In the following, we discuss these schemes in details.

In [6], authors proposed a technique to control congestion in wireless sensor networks. Their technique calculates rate of sending packets, compare it to sending rate of parent node and downstream the smaller one. By rate of sending data, they get mean rate of packet generation of all nodes. They can reduce this rate if queue of node is full to minimize the congestion which results in packet loss reduction and hence, increases network performance. In [7] data rate is increased if 10 consecutive successful transmissions are done and decreased after 2 consecutive transmission failures. Success and failure is evaluated on the basis of received ACK packets. This scheme is not taking into account the reason of transmission failure. In [1,10,11] data rate is adapted for end-to-end congestion control. In end-to-end congestion control mechanism, ACK packets, sent by destination node, are used to communicate congestion message to the source nodes. A novel Rate-Based Congestion Control (RBCC) and EXplicit rAte-based flow ConTrol (EXACT) techniques are proposed, in [1,10] respectively, based on end-to-end congestion control mechanism. Technique which assists routing nodes named Explicit.

Another way of providing feedback to source node is explicit congestion notification (ECN) in header of the packet. Technique proposed in [12,13] are using the congestion notifications to avoid packet loss. In these techniques, once the data has reached, the router calculates the load factor for all the links and congestion region is identified on the basis of load factor. Moreover if calculated load factor is comparatively higher, then congestion status is updated by overwriting ECN bits. Technique proposed in [13] uses two ECN bits for improving results. In this technique, data rate is changed by a static factor. Another technique in which successful packet transmission and buffer threshold both are considered is additive increase and multiplicative decrease (AIMD) scheme [14] is proposed. In this scheme, for every successful packet transmission, data rate is increased with increasing parameter and continue until buffer threshold is received from other side and data rate is decreased when packet transmission failed. Failure of data transmission is measured by not receiving ACK packets. Due to congested route, delivery of ACK packet might be delayed that cannot represent the actual status of route.

Queue based data rate adaptation is done in [15–18]. These techniques uses queue length as a parameter to judge congestion. Probability of accessing the communication channel is calculated by each node based on the number of unsuccessful transmissions in [18]. In addition, each node receives a hello message periodically from its neighbors containing the channel access probability, transmission rate and the estimated traffic load. Reinforcement learning is used by each node to analyze the channel access probability. Thus, previous actions are used to decide either it is necessary to update the transmission rate or not. Negative impact of updating the transmission rate unnecessarily is mitigated using this technique. Furthermore, this technique also take in account the load on each node calculated by its queue length and then this information is used to decide whether to increase, decrease or keep its transmission rate. In this paper, no specific mechanism is discussed about factor by which data rate is increased or decreased. We assume it a static factor.

To adapt data rate at sender node, a technique is proposed in [15]. This technique is based on queue length analysis at intermediate nodes. One of the basis shortcomings of the aforementioned technique is that data rate is adaptation is fixed and static without analyzing the run-time network conditions.

To summarize, the proposed techniques are based on static data rate adaptation mechanism. Congestion notification messages are used to propagate information. Using congestion notification on congested route is an overhead for the network. To overcome the limitation of proposed techniques, we have proposed congestion avoidance strategy based on the dynamic rate adaptation for MANETs. Proposed strategy avoids the packet loss caused specifically due to interface queue (IFQ) overflow by dynamically adapting data rate at intermediate nodes on the basis of current queue size.

3 Data Rate Adaptation Strategy (DRAS)

Techniques using data rate adaptation at source node with static factor results in wastage of network resources. To avoid the negative influence of these techniques on network, a dynamic and adaptive data rate adaptation strategy is proposed to avoid packet loss caused due to interface queue overflow in MANETs. In this scheme, unlike feedback based rate adaptation, data rate is adapted dynamically by considering the network parameters having significant influence on data rate. In this paper, we have first identified the network parameters that are critical in order to adapt the data rate, and analyze their relationship to the network dynamics. Then, we discuss how such topology parameters affect the data rate.

3.1 Data Rate Adaptation and Network Parameters

In proposed technique we have identified various network parameters that have significant effect on data rate of nodes. Packet loss caused due to interface queue overflow is influenced by the factor of mobility, queue length and number of source nodes. We are using term queue length for consumed buffer space of a node.

Queue Length: Increased queue length results in high packet loss ratio so data rate is to be reduced with the increased queue length to avoid packet loss caused due to interface queue overflow. So, the relation between queue length and data rate is defined as:

$$DR \propto \frac{1}{QL}, \tag{1}$$

where QL represents queue length and DR is data rate.

Queue length is being used as data rate adaptation parameter and varies between its minimum and maximum values. When queue is empty it has minimum value and maximum value denotes to value of queue when queue is full. On the basis of this maximum and minimum value, following formula helps us to find optimal rate adaption value at any node N with respect to queue length.

$$\rho = 1 - \frac{QL_N}{QL_{max}}, \tag{2}$$

where QL_N is current queue length of node and QL_{max} is maximum queue size of a node.

According to above equation, the maximum value of queue length results lowest rate adaptation factor, i.e. 0, while the minimum value of queue length results in the higher rate adaptation factor with respect to queue length parameter, i.e. 1, where, DR is data rate and SN is number of source nodes.

Number of Sources: Number of source nodes is another parameter for data rate adaptation. When there are no source nodes, it has minimum value and a node has maximum number of source nodes if all one-hop neighbors are sending data to it. The relation between number of source nodes and data rate adaptation factor can be written as:

$$DR \propto \frac{1}{SN}, \tag{3}$$

To find the optimal rate adaptation value at node N for avoiding packet loss caused due to queue overflow with respect to number of source nodes, we use the following equation:

$$\sigma = 1 - \frac{Sources_N}{nb_{max}}, \tag{4}$$

where $Sources_N$ is current number of source nodes of a node N and nb_{max} is maximum possible source nodes of a node N.

According to above equation, the maximum value of number of source nodes results in lowest rate (i.e., 0), while the minimum value of number of source nodes results in the highest rate adaptation (i.e., 1).

Rate of Link Changes: Number of link changes shows the mobility of network. High mobility means node has less interaction time to exchange their packets. So, data rate should be higher that allows node to transfer its messages to other nodes in less time. This may over burden the queue of receiving nodes that may results in drop of packets. To avoid this problem, data rate is adopted keeping queue size of forwarding node in account. Mathematical relation between link changes and data rate can be written as:

$$DR \propto LC, \tag{5}$$

where DR is data rate and LC is number of link changes.

Number of link changes is an important parameter for data rate adaptation. LC has minimum value when no node movement. Similarly, a node has maximum number of link changes if all 1-hop and 2-hop neighbors of that node have changed their position. The optimal value for data rate adaptation factor with respect to the link change rate is formulated as follows:

$$\varepsilon = \frac{LC_N}{N_O}, \tag{6}$$

where LC_N is current number of link changes of a node and N_O is maximum possible number of link changes in a particular node's neighborhood.

According to above equation, the maximum value of number of link changes results in highest rate adaptation, i.e. 1, while the minimum value of number of link changes results in the lowest, i.e., 0.

3.2 Mathematical Model

We can combine the equations introduced so far into a mathematical model to compute data rate adaptation factor ϖ to avoid packet loss caused due to interface queue overflow. By combining Eqs. 2, 4, and 6, we obtain:

$$\varpi = \frac{(\alpha\rho + \beta\sigma + \gamma\varepsilon)}{(\alpha + \beta + \gamma)}, where\ \alpha + \beta + \gamma = 3. \tag{7}$$

In Eq. 7, α, β, and γ are the weights assigned to each data rate adaptation parameter, discussed previously. As we are considering every parameter equally important for data rate adaptation, weights assigned to each parameter is equal, i.e. 1.

4 Performance Evaluation

In this section, we present the simulation setup, performance metrics, and simulation results to evaluate the proposed scheme in comparison to the protocol without rate adaptation mechanism. Proposed technique is evaluated on Network Simulator (NS2). The Optimized Link State Routing (OLSR) protocol is used as routing protocol. Table 1 shows the simulation parameters.

Table 1. Simulation parameters

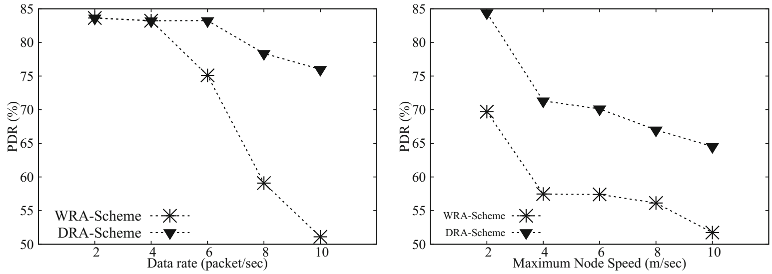
Parameter	Value
Simulation time	1000 s
Number of nodes	50
Network size	1000 m × 1000 m
Transmission range	250 m
Packet size	512 b
Queue length	50
Mobility model	Random way point
Traffic type	Constant bit rate (CBR)
Max speed	1–10 m/s
Source-destination pairs	10–50%
Data rate	2–10 packets/sec

We have evaluated our proposed scheme referred as "DRA" in graphs in comparison to a protocol without any data rate adaptation strategy referred as "WRA". The proposed scheme is evaluated under two network performance parameters, i.e., under varying data rate and node speed.

4.1 Packet Delivery Ratio (PDR)

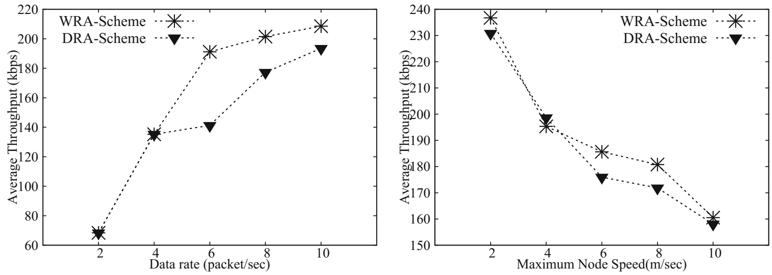
Figure 1a shows the effect of increasing data rate on PDR. As data rate increases, chances for packet loss are higher because queues of forwarding node overflows frequently. So, delivery probability decreases with increased data rate. The WRA scheme is not adapting any strategy to avoid packet loss, that is why it holds lower PDR as compared to the DRA scheme. As shown in figure, the DRA scheme has higher PDR comparatively as in this scheme data rate is adapted efficiently to avoid packet loss.

Similarly, Fig. 1b shows the effect of node mobility on PDR. Increased mobility results in frequent forwarding node queues overflow as nodes change their position frequently and forwarding nodes need to store packets for longer in their queues. So, the chances of packet loss become higher. As there is no data rate adaptation technique in the WRA scheme, with increasing mobility there is



(a) (b)

Fig. 1. Effect of data rate and node speed on PDR



(a) (b)

Fig. 2. Effect of data rate and node speed on throughput

more packet loss which cause lower PDR. As shown in Fig. 1b, the DRA scheme has more PDR as compared to WRA as in this scheme data rate is adapted efficiently to avoid packet loss.

4.2 Throughput

As data rate increases, throughput is also increasing because increased data rate means number of packets generated per unit time increases. As shown in Fig. 2a, WRA shows highest throughput as compared to the DRA scheme because it sends data with constant data rate without taking congestion in account. If congestion occurs, WRA do not have any mechanism to deal with such situation. On the other hand, proposed mechanism adds more parameters and adapts data rate in a better way. In adaptation phase, DRA is not utilizing whole bandwidth of the channel which results in decreased throughput that is why throughput in DRA scheme is slightly lower as compared to the WRA scheme.

Similarly, for increasing node mobility means nodes are mobile and change their position frequently. Forwarding nodes do not find the destination node and unable to deliver packets frequently that is why throughput decreases with increasing node mobility as shown in Fig. 2b. WRA shows highest throughput as compared to the DRA scheme because it sends data with constant data rate without taking congestion into the account. Due to data rate adaptation mechanism in the DRA scheme, the data rate is decreased at the source node to avoid packet loss causing under utilization of the channel bandwidth, hence lower throughput in this case.

4.3 End-to-End Delay

End-to-end delay increases with increased number of packet loss as packet loss results in large number of re-transmissions, hence increases end-to-end delay. In WRA scheme, as packet loss is high, so they result in long end-to-end delays as shown in Fig. 3a. Proposed scheme reduces delivery delay because data rate is efficiently adapted which low packet loss. Moreover, as DRA scheme is adapting data rate to avoid packet loss which means smaller number of packets in network will be communicated, hence avoid congestion. As congestion is avoided, so end-to-end delay also decreases in proposed scheme due to smaller number of re-transmissions for lost packets.

Similalry, Fig. 3b shows the impact of mobility of average end-to-end delay. Due to high mobility, data is not delivered to distant nodes. Where as, data is delivered speedily to nearer nodes that is why end-to-end delay decreases with increased mobility. Proposed scheme reduces delivery delay as compared to the WRA scheme as shown in Fig. 3b because data rate is efficiently adapted which reduces packet loss. Hence, large number of re transmissions are not required which effects end-to-end delay positively.

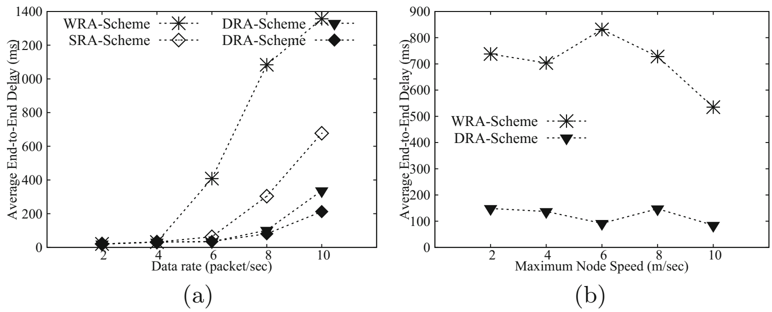
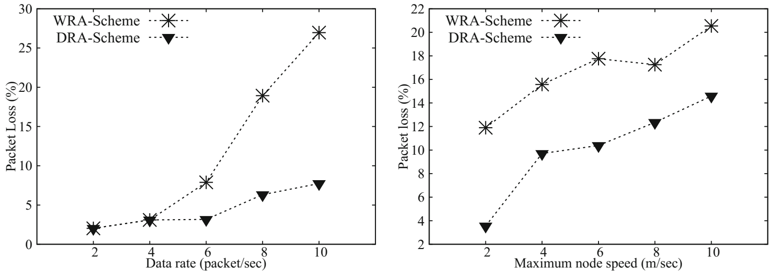


Fig. 3. Effect of data rate and node speed on end-to-end delay

4.4 Packet Loss

As shown in Fig. 4a packet loss due to interface queue overflow increases with the increased data rate because queues of forwarding node overflow due to high data rate. Moreover, Fig. 4a shows that packet loss in WRA scheme are higher as this scheme does not consider any strategy to avoid packet loss. But on the other hand, DRA scheme adapts data rate efficiently by considering mobility



(a) (b)

Fig. 4. Effect of data rate and node speed on packet loss

factor and number of source nodes along with queue length which causes smaller packet loss in proposed scheme.

To analyze the impact of node mobility on packet loss, Fig. 4b packet loss with increasing node mobility. For increasing node mobility, forwarding node queues are overflow as nodes change their position frequently and forwarding nodes need to store packets for longer in their queues. Moreover, Fig. 4b shows that packet loss in WRA scheme are higher as this scheme does not consider any strategy to avoid packet loss. But on the other hand, the DRA scheme adapts data rate efficiently based on multiple network factors to avoid packet loss.

5 Conclusion and Future Work

In this paper, we proposed a technique to adapt data rate of the sender node based on the run time network conditions around forwarding nodes using different network dynamics. Proposed technique is based on the analysis of queue length of the forwarding nodes. We have simulated our proposed technique in NS-2 and achieved better results in terms of packet delivery ratio and average end-to-end delay in comparison to the static rate adaptation technique.

As currently, the data rate is adapted at source nodes by shifting the congestion effect immediately from forwarding nodes to the source node. In future, we plan to adapt the data rate at intermediate nodes based on the mentioned parameters by buffering the data packets in queues up to bearable threshold, and then gradually shift the effect of rate adaptation to the source nodes. We also plan to evaluate the proposed scheme in VANETs scenario to under different performance metrics to check the compatibility and scalability of the proposed scheme in high dynamic environment.

Acknowledgment. The work reported in this paper has been partially supported by Higher Education Commission (HEC), Pakistan, and the University of Malaya under grant RG325-15AFR.

References

1. Chen, K., Nahrstedt, K., Vaidya, N.: The utility of explicit rate-based flow control in mobile ad hoc networks. IEEE Wireless Communications and Networking Conference, vol. 3, pp. 1921–1926 (2004)
2. Deshmukh, V.S., et al.: A survey of congestion control in proactive source routing protocol in mobile ad hoc networks. COMPUSOFT **3**(12), 1350 (2014)
3. Yaghmaee, M.H., Adjeroh, D.A.: Priority-based rate control for service differentiation and congestion control in wireless multimedia sensor networks. Comput. Netw. **53**(11), 1798–1811 (2009)
4. Hussain, A., Zia, K., Farooq, U., Ahmed, S.: PLP-A packet loss prevention technique for partitioned MANETs using Location-Based Multicast (LBM) Algorithms. In: National Conference on Emerging Technologies (2004)
5. Kumaran, T.S., Sankaranarayanan, V.: Early congestion detection and adaptive routing in MANET. Egypt. Inform. J. **12**(3), 165–175 (2011)
6. Ee, C.T., Bajcsy, R.: Congestion control and fairness for many-to-one routing in sensor networks. In: Proceedings of the 2nd ACM International Conference on Embedded Networked Sensor Systems, pp. 148–161 (2004)
7. Camp, J., Knightly, E.: Modulation rate adaptation in urban and vehicular environments: crosslayer implementation and experimental evaluation. IEEE/ACM Trans. Netw. **18**(6), 1949–1962 (2010)
8. Chevillat, P., Jelitto, J., Barreto, A.N., Truong, H.L.: A dynamic link adaptation algorithm for IEEE 802.11 a wireless LANs. In: IEEE International Conference on Communications (ICC 2003), vol. 2, pp. 1141–1145 (2003)
9. Xi, Y., Kim, B.S., Wei, J.B., Huang, Q.Y.: Adaptive multirate auto rate fallback protocol for IEEE 802.11 WLANs. In: IEEE Military Communications Conference (MILCOM 2006), pp. 1–7 (2006)
10. Senthilkumaran, T., Sankaranarayanan, V.: Dynamic congestion detection and control routing in ad hoc networks. J. King Saud Univ. Comput. Inf. Sci. **25**(1), 25–34 (2013)
11. Zhai, H., Chen, X., Fang, Y.: Rate-based transport control for mobile ad hoc networks. In: IEEE Wireless Communications and Networking Conference, vol. 4, pp. 2264–2269 (2005)
12. Manikandan, K., Durai, M.A.S.: Active queue management based congestion control protocol for wireless networks. Int. J. Enterp. Netw. Manag. **6**(1), 30–41 (2014)
13. Tiwari, S.K., Rana, Y.K., Jain, A.: An ECN approach to congestion control mechanisms in MANETs. Netw. Complex Syst. **4**(6), 18–22 (2014)
14. Mishra, T.K., Tripathi, S.: Explicit throughput and buffer notification based congestion control: a cross layer approach. In: Eighth International Conference on Contemporary Computing (IC3), pp. 493–497 (2015)
15. Thakur, S., Gupta, M.: Mitigating congestion using data rate control for MANETs (2014)
16. Rahman, K.C., Hasan, S.F.: Explicit rate-based congestion control for multimedia streaming over mobile ad hoc networks. Int. J. Electr. Comput. Sci. IJECS-IJENS **10**(04), 28–40 (2010)
17. Benslimane, A., Rachedi, A.: Rate adaptation scheme for IEEE 802.11-based MANETs. J. Netw. Comput. Appl. **39**, 126–139 (2014)
18. Al-Saadi, A., Setchi, R., Hicks, Y., Allen, S.M.: Multi-rate medium access protocol based on reinforcement learning. In: IEEE International Conference on Systems, Man and Cybernetics (SMC), pp. 2875–2880 (2014)