Efficient Multipath Routing Protocol with Quality of Service for Mobile Adhoc Networks

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Abstract*—Design of multipath routing schemeis a challenging task as its topology is very dynamic in mobile adhoc network (MANET) environments. Providing reliability is more important while designing the routing protocol. Hence, multipath routing protocol which is based on Quality of Service parameters is proposed in this paper. The QoS parameters considered are delay, bandwidth and hop count. Different types of traffic such as real-time traffic and non-real-time traffic are considered. In order to improve reliability by reducing number of retransmissions, an additional packet is generated in the case of non-real time traffic and multiple description coding is used in the case of real-time traffic. The proposed algorithm, MRQ is simulated using NS-2 and compared with the existing competing schemes – QAMR and RA-MDC. Simulation results proved that the perfomance of our scheme is better in terms of End-to-End delay, packet delivery ratio, Peak Signal Noise Ratio (PSNR) and retransmissions ratio metrics.

Keywords: *Multipath, Multiple description coding, MANET, routing*

1. Introduction

The nodes in the Mobile Ad-hoc network (MANET) are dynamic in nature and also self-organized. MANET is an infrastructureless network. Each node in the network can behave both as a router which forwards the packets and general device which transmits and receives packets. The mobile nature of the nodes in the MANET makes the network to dynamically changing its topology. The disadvantages of the nodes in the MANET are the low available powerand limited bandwidth. Hence, there is a requirement of routing protocol which utilizes the power and bandwidth effectively [7].

In general, the routing protocols are categorized based on routing information update mechanism into proactive, reactive and hybrid routing protocols. In proactive routing protocols, all the nodes in the network maintain the topology information using routing table. Examples incldue Optimized Link State Routing Protocol (OLSR), and Destination Sequence Distance Vector (DSDV). As the MANET topology is very dynamic,proactive routing protocols do not apt for MANET. On the other hand, the reactive routing protocols determine the routes when required and is most suitable for MANET. Examples incldue Dynamic Source Routing (DSR), and Ad-hoc On-demand Distance Vector Routing (AODV). However, the reactive routing protocols experience delay during route discovery process when compared to proactive routing protocols.The hybrid routing protocols combine the properties of proactive and reactive routing protocols. Zone Routing protocol (ZRP) is an example on these. The routing protocols can be also be classified based on the usage of temporal data as selection based on past history or prediction, usage of particular resources as flooding, and power, and topology information organization as flat routing and hierarchical routing [1]. They can also be categorized as single path routing and multipath routing. The multipath routing may be alternate path routing or parallel path routing. Our traditional circuit switched telephone network uses an alternate path routing. Hence, one of the paths acts as main path and others as secondary. The main path is only used for transmission. When failure occurs in main path then the one of secondary paths is used for transmission. In parallel path routing, more than one path is used to transmit the packets from source to destination where the maintenance of flow control plays a major role.

In single path routing, the time for route discovery process is less, but frequency of this process is high when compared to multipath routing. Multipath routing helps in enhancing the reliability. The multiple paths determined will be definitely more. Hence, multipath routing protocols considers either node disjoint paths or link disjoint paths. Node disjoint paths have the intersection of nodes set of all possible paths as NULL set. Similarly, edge disjoint paths have the intersection of edge set of all possible paths as NULL set. In other words, no node or edge is in common to any of the 2 possible paths respectively [5]. Ad-hoc on demand Multipath Distance Vector (AOMDV) is a link disjoint routing protocol which is an extension of AODV to determine multiple paths. DSR is extended to determine multiple paths as Split Multipath routing (SMR) [6]. The node disjoint paths guarantee failure

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介绍了很多routing策略的分类，优缺点
说明multipath routing是最合适的，但是contribution?

independence whereas link disjoint paths cannot. But at the same time node disjoint paths cannot guarantee transmission independence. Transmission independence is the interference less transmission of packets from source to destination [2]. The various parameters to be considered for guaranteeing the transmission independence are coupling [3] and correlation [4]. To make the multipath routing efficient, a process of controlling the traffic among various paths is mostly required.

Multipath routing is chosen as it is most appropriate in the case of MANET because of its high density of nodes.

The rest of the paper is organized as follows. Related work in this area is presented in Section 2, wheile the proposed work, MRQ, is explained in section 3. Results are discussed in section 4 and the paper is concluded in section 5.

2. Related work

In [7], the authors modified AOMDV and proposed a Maximally Spatial Disjoint Multipath routing protocol (MSDM). The paths which are determined using MSDM will be alienatedspatially and extremely disjoint. As they are spatially alienated, the collisions are avoided and this makes the simultaneous transmissions easy and comfortable using various determined paths. The authors modified the RREQ packet format to include the details of the nodes along the path from source to destination in order to verify the disjointness of the paths. In addition two tables referred as Seen RREQ and Replied RREQ table are maintained. The spatial separateness of the paths helps in reducing the collisions, which in turn reduces the end-to-end delay. The filtering process of RREQ packets helps in decreasing the discovery overhead. The authors evaluated the performance of the proposed algorithm by calculating throughput also.

In wireless sensor network, energy is the main issue to be considered while designing the protocols. The important concern of multipath routing protocols is the load balancing. Hence the routing protocol which could find the paths with minimum energy and load to be distributed optimally among various paths is required. The authors in [8] proposed a cross layer based routing protocol for wireless sensor networks. The cross layer is designed between MAC layer and the network layer. With the help of the information given by the MAC layer, the network layer selects the forwarding nodes which are used for less time. This helps in determining the energy efficient paths and balances the energy depletion throughout the network. The performance is evaluated both analytically and experimentally. The number of the times the network is getting partitioned is less using the proposed protocol [8]. Hence it increases the lifetime of the network.

In [9], the authors proposed a fault-aware multipath routing in combination with the flow control for vehicular ad-hoc networks. A leaky path prototype is established by exemplifying the consequences of faults on every link of the network. The effect of the fault correlation amid multiple paths of routing on activestreams is calculated with the help of a cost function. The proposed algorithm is based on the above two concepts, leaky path prototype and cost function. This algorithm helps in enhancing the throughput of the network. A new distributed approach is proposed, which is used to regulate the speed at which transmission need to take on each path. The testing is carried out in the presence of malicious nodes and shown better throughput.

In MANET, the nodes are mobile in nature, have restricted power and less storage space. The nodes in the MANET communicate among themselves without the help of any backbone infrastructure. The nodes in the network may leave or new nodes may join at any point of time. As the nodes in MANET keep moving, the topology of the network changes dynamically and very frequently. A particular source and destination pair can have multiple possible paths to communicate to each other. When using the multiple paths, then reliability and load balancing need to be considered while designing a routing protocol. In [10] various limitations like energy conservation, reliability, Quality of Service (QoS) and load balancing are considered for the discussion while proposing a multipath routing protocol.

In [11], Disjoint Inter domain Multipath routing protocol is proposed. This protocol identifies two nodes which can determine disjoint paths simultaneously. The rules for choosing disjoint paths are deliberated by presenting novel ideas as combining paths and circle notation [11]. A multipath routing protocol which is based on network coding and is on demand in nature is proposed in [12]. The main goal of the proposed algorithm in [12] is to enhance the guarantee delivery of packets. The mesh structure is used to determine multiple paths without an overhead of the control packets in [13].

A graph based multipath routing protocol is proposed in [14] in which a graph is used to determine multiple paths from source to destination. RREQ packets are transmitted including the information related to the network topology in the form of graph to the destination while the intermediate or forwarding nodes keep updating the graph. When the destination receives multiple RREQs it determines various link disjoint paths and transmit the acknowledgement or RREP packets using the determined multiple paths to the source. Local graph search algorithm is used to determine link disjoint paths. This protocol is the extension of dynamic source routing.Disjoint pathset selection protocol is proposed in [15]. It is proposed to optimally select the set of routes that can make the multipath routing protocol efficient. The Cache and Multipath routing protocol is presented in [16]. It incorporated caching of packets to enhance the reliability of the network and follows round robin process of allocating the traffic along the various paths.

3. Multipath Routing based on QoS Parameters (MRQ)

Sample mobile ad-hoc network is shown in Fig. 1. The information that can be transmitted from the source node to destination node can be real-time or non-real-time. When the transmission is non-real time traffic, multiple paths are determined and an additional packet is computed based on the original packets for every path and when the transmission is real time traffic, multiple description coding is used.First, we describe the process of determining the multiple paths using the proposed algorithm. Then multiple description coding is applied for real-time traffic and an additional packet is generated for non-real-time traffic before starting the transmission.

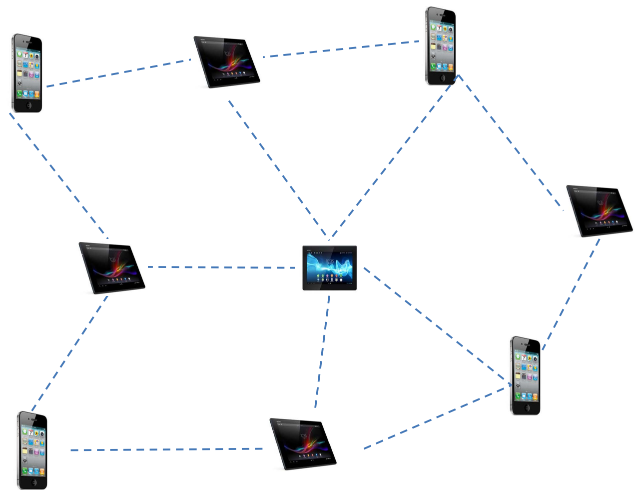

Fig. 1 Sample MANET

3.1 Determination of Multiple Paths

The QoS parameters – delay, bandwidth and hop count are considered to determine the efficient paths for transmission. Let d_i, b_i, hc_i represent the delay, bandwidth and hop count of the path p_i and d_{th}, b_{th}, hc_{th} be the threshold values of delay, bandwidth and hop count. First determine the various possible paths from the source node to the destination node.The next forwarding node is selected based on its available energy /battery power. If the available energy is not sufficient to transmit the required number of packets, then the corresponding node will be rejected for forwarding the packets. Then delay, bandwidth and hop count are determined for each path. The delay of the path is sum of the delay at all nodes and the delay of all the links in the path. The bandwidth of the path is the minimum bandwidth among all the links in the path.
Let there be 'N' nodes and 'L' links in the path. Then,
$d_i = \sum_{j \in N} d_{n_j} + \sum_{k \in L} d_{l_k}$, where d_{n_j} is the delay of node 'j' and d_{l_k} is the delay at link 'k'
$b_i = \min(b_{l_1}, b_{l_2}, ..., b_{l_L})$, where b_{l_1} the bandwidth at link1, b_{l_2} is the bandwidth at link2 and so on
And the hop count, $hc_i = N$.
Let g_d, g_b and g_{hc} be the goodness values of delay, bandwidth and hop count and are calculated as shown below:

$$g_d = \frac{d_{th} - d_i}{d_{th}}$$

$$g_b = \frac{b_i - b_{th}}{b_{th}}$$

$$g_{hc} = \frac{hc_{th} - hc_i}{hc_{th}}$$

Let the reward and penalized parameter be $G = g_d + g_b + g_{hc}$
The goodness value of the path is initialized with G. If the transmission is successful the goodness value is increased by the G, otherwise it is decreased by G. The path with highest G value is used for transmitting the non-real-time traffic. The paths whose G is greater than G_{th} are selected for transmitting real-time traffic. After determining the paths for transmission, network coding or multiple descriptions coding is applied.
In our proposed method, an additional packet is transmitted for 'n' packets. i.e, after transmitting 'n' packets an additional packet is transmitted which is computed by performing XOR with already transmitted 'n' packets. This process helps in reducing the overhead, which normally appears in the network coding but still reliability increases. If any of the 'n' packets is not received by the destination node then it can be obtained with the help of an additional packet and may be other packets.
For example,
Let P_1 = 10101011, P_2 = 10100110, P_3 = 11001001 and P be an additional packet.
Hence $P = P_1 \oplus P_2 \oplus P_3$= 11000100
If P_2 is not received, then P_2 can be reconstructed $P_2 = P_1 \oplus P \oplus P_3$.
Number of retransmissions is reduced with the help of this procedure andhence energy can be conserved.

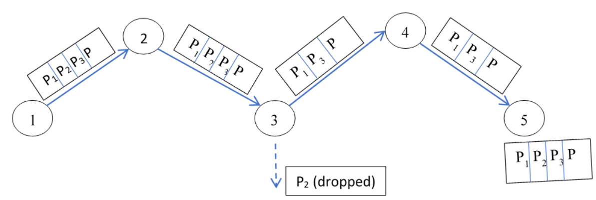

Fig. 2 Transmission of Non-real time Traffic

3.2 Multiple Description Coding

The number of multiple paths determined decides the number of descriptions to be generated for the real-time traffic to be transmitted. The packet is used to generate the descriptions which are independently encoded. Spatial poly-phase down sampling is used to generate descriptions. H.264 encoding technique is used for encoding the descriptions. These encoded descriptions are transmitted using multiple paths towards destination. At the destination node, the encoded descriptions are decoded and all the descriptions are combined to obtain the packet almost or equal to the original packet. This process helps in receiving the packets without error as the error may not be in the same position for all the descriptions. Hence, the original packet can be obtained with high quality.

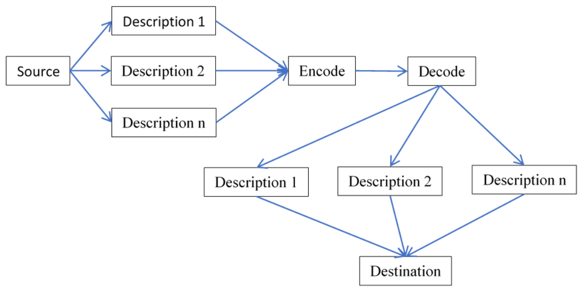

Fig. 3 Multiple Description coding for real-time traffic

3.3 MRQ Algorithm

1. For non-real time traffic:
   a. Call Multi-path discovery process
   b. Select the path with high goodness value
   c. Compute an additional packet using XOR
   d. Transmit all the packets including an additional packet
2. Else
   a. Call Multi-path discovery process
   b. Generate descriptions.
   c. Encode the descriptions
   d. Transmit all the descriptions using multiple paths.
   e. Decode the descriptions
   f. Combine the descriptions to obtain the original packet

3.3.1 Multi-path discovery process

1. Determine neighbouring nodes based on the available energy
2. Determine the possible multiple paths – M
3. For i = 1 to M
   a. Calculate d_i, b_i and hc_i
   b. Calculate g_d, g_b and g_{hc}
   c. $G = g_d + g_b + g_{hc}$
   d. If $G > G_{th}$ then
      i. $P = P \cup \{p_i\}$
4. Return P (Set of Multiple paths)

4. Results and Discussions

The proposed algorithm is simulated using ns-2 tool. The proposed algorithm is compared with QAMR [17] and RA-MDC [18]. The proposed algorithm is evaluated using the end-to-end delay, packet delivery ratio, Peak Signal to Noise Ratio (PSNR) performance metrics.
End-to-End Delay: The average time taken for the packet to be received by the destination node.

$$End-to-End\ Delay = \frac{\sum receiving\ time - sending\ time}{Total\ Number\ of\ Packets}$$

Packet delivery ratio (PDR): Ratio of the number of packets successfully received by the destination node to the total number of packets sent by the source node.

$$Packet\ Delivery\ Ratio = \frac{Number\ of\ Packets\ received\ by\ destination}{Number\ of\ Packets\ send\ by\ source}$$

Peak Signal to Noise Ratio (PSNR) [19]: It is an estimate of the quality level of reformation of the original data.

PSNR is defined in dB as:

$$PSNR = 10\log_{10}\left(\frac{MAX^2}{MSE}\right)$$ Where,

MAX =Image's maximum pixel value
MSE – Mean Squared Error = $\frac{1}{mn}\sum_{i=0}^{m-1}\sum_{j=0}^{n-1}[I(i,j)-K(i,j)]^2$

Retransmissions Ratio: The number of packets to be retransmitted by the source when compared to the total number of packets transmitted by the source.

$$Retransmissions\ Ratio = \frac{Number\ of\ packets\ retransmitted}{Total\ Number\ of\ Packets\ transmitted}$$

The NS-2 Parameters used in the simulation of the proposed algorithm is shown in Table 1.

Table 1: Simulation Parameters

Parameter	Values
Transmission range of each node	300 Meters
MAC Layer Protocol	IEEE 802.11
Traffic Pattern	CBR
Data Packet Size	1024 Bytes
Simulation Area	1000 M * 1000 M
Number of Nodes	75
Mobility	0-60 m/s
Simulation Time	500 sec
Mobility Model	Random waypoint mobility model
QoS threshold set	Bandwidth, Delay, Hop Count
Threshold limits	Bandwidth threshold (min 5Mbps) Delay Threshold (max. 100msec) Hop Count threshold (max. 15)

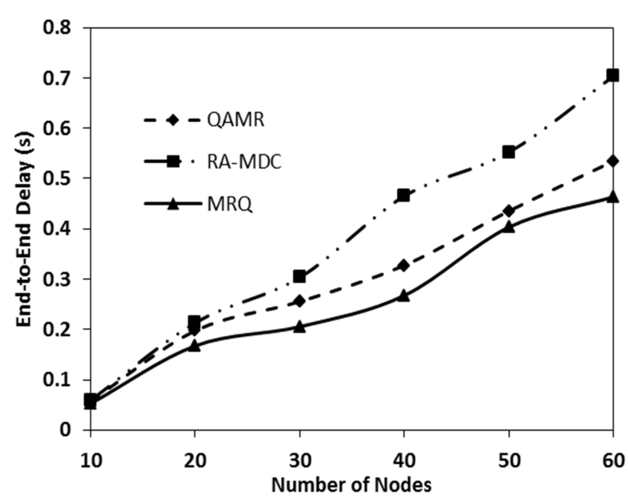

Fig. 4 Comparison of QAMR, RA-MDC and MRQ in terms of End-to-End Delay

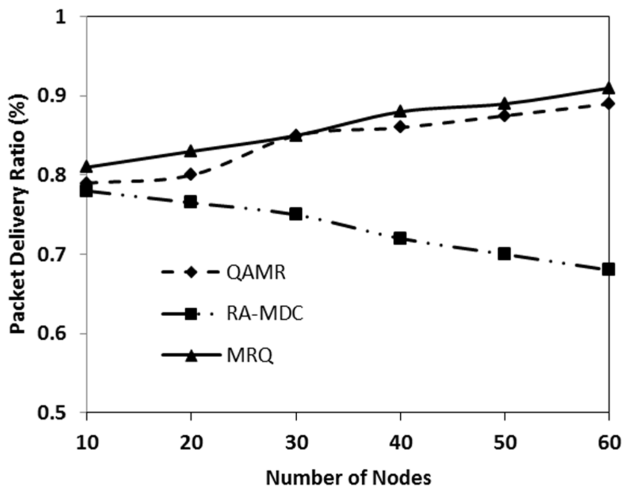

Fig. 5 Packet Delivery Ratio vs Number of Nodes

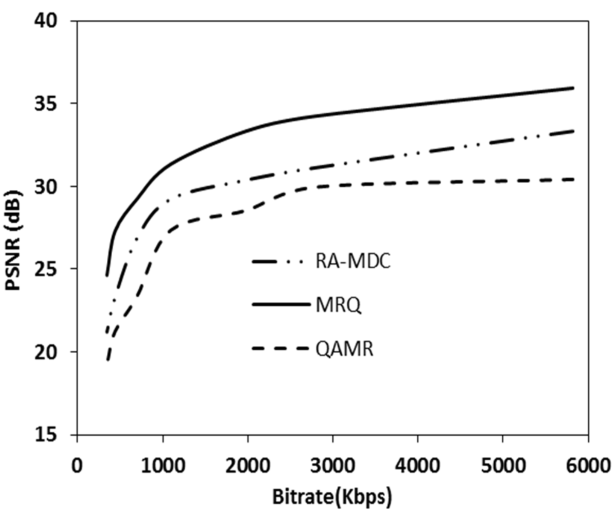

Fig. 6 Comparison of QAMR, RA-MDC and MRQ in terms of PSNR

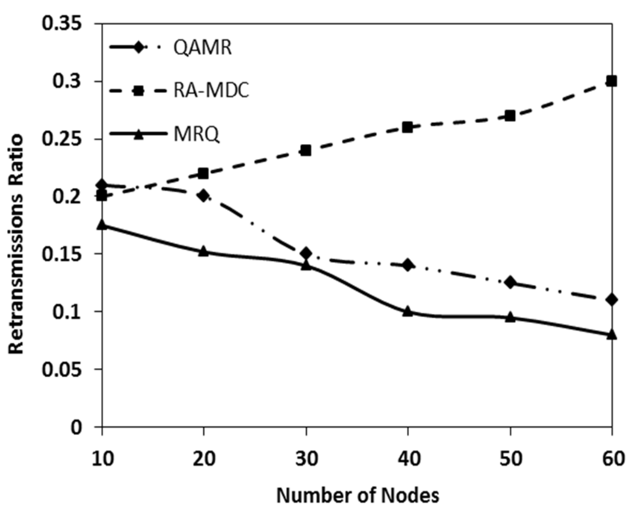

Fig. 7 Comparison of QAMR, RA-MDC and MRQ in terms of Retransmissions Ratio

The simulation results are shown in Figs. 4-7 and it can be observed that the proposed algorithm MRQ performs better when compared to the legacy systems like QAMR and RA-MDC. The MRQ performs better in terms of End-to-End delay as shown in Fig.4 because the path determination for either real-time or non-real-time traffic is dependent on the hop count and the delay of each link involved in the path to be selected. As the proposed algorithm, MRQ is selecting the paths which have links with less delay and less number of nodes, the time taken for the transmission of packets to the destination is less.The MRQ is able to achieve better packet delivery ratio as shown in Fig. 5as it determines the paths using the goodness value of the path and the neighbours are determined based on the available energy. As the path determination is dependent on the bandwidth, it reflects the performance in terms of packet delivery ratio. When bandwidth is sufficient there is a possibility of less congestion and hence there is a high probability of delivering the packets successfully to the destination. The packet delivery ratio is increasing in the case of QAMR as ant colony optimization is incorporated in it and also in the case of MRQ as the goodness parameter helps in making the good selection of the paths among the possible paths. The increment in the packet delivery ratio in QAMR and MRQ is only to a certain limit till the optimization point is reached. But in the case of RA-MDC, the packet delivery ratio is decreasing as it is using any optimization technique. The high value of PSNR indicates the good quality of received data by the destination. The Coastguard video sequence in the CIF format [10] is considered in the case of real-time traffic. The PSNR of QAMR is less because it does not use any technique or procedure to make the received data improve its quality and it concentrates only on optimizing the routing path. The multiple description coding is followed by RA-MDC in order to improve PSNR. The proposed algorithm, MRQ is optimizing the path and also incorporated MDC in order to enhance the received data quality. Hence MRQ shows better PSNR as shown in the Fig. 6 when compared to QAMR and RA-MDC. In general, the packets are retransmitted which are dropped or not received by the destination. The packet delivery ratio decreases and number of retransmissions or retransmission ratio increases as the number of packet drops increases. But this number of retransmissions is decreased by using an additional packet in the case of non-real-time traffic and MDC in the case of real-time traffic. Hence, MRQ shows good performance in terms of retransmissions ratio when compared to QAMR and RA-MDC.

5. Conclusions

In this paper a multipath routing protocol which is based on improving the QoS parameters – bandwidth, delay and hop count is proposed for MANET. Various real-time traffic and non-real-time traffic types are considered. An additional packet is generated using the original packets such that any lost packet is recoverable from the other packets for the non-real-time traffic. Multiple description coding is used for real-time traffic. The consideration of bandwidth and strong neighbours in the path determination increases the packet delivery ratio. The delay and hop count steps in the path discovery process reduces the end-to-end delay. PSNR is improved by using the MDC and hence can reduce the retransmissions. The proposed algorithm, MRQ is implemented using NS-2 and evaluated using the performance metrics of packet delivery ratio, end-to-end delay, PSNR and retransmissions ratio. The results are compared with QAMR and RA-MDC and show improved performance.

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