ETX METRIC FOR EXTREMELY OPPORTUNISTIC ROUTING TO IMPROVE THE PERFORMANCE OF HYBRID WIRELESS NETWORKS

Sumathy S[1*], Dr.R Saravanan[1]

School of Information Technology and Engineering, VIT University, Vellore - 632014, Tamilnadu, India
ssumathy@vit.ac.in

ABSTRACT

Mobility in wireless networks has paved way for a new paradigm of communication in this era. Exploiting the optimal routing technique for hybrid wireless networks which brings in a balance of the overheads in infrastructure based and infrastructure less network is essential. Routing protocol design for hybrid wireless network is critical in order to improve the performance and reliability of the network. Opportunistic Routing (OR) technique attempts to deal with unreliable transmissions by utilizing the broadcast nature of the wireless medium. Due to multi-hop nature of ad hoc networks, Opportunistic Routing provides lesser throughput than expected when minimum hop count metric is used. To combat the above limitations, an Extremely Opportunistic Routing(ExOR) scheme with Expected Transmission count(ETX) metric is proposed and implemented in a hybrid scenario. The simulation study reveals that this routing technique efficiently utilizes resources and improves the end-to-end throughput and packet delivery ratio in hybrid wireless networks.

Keywords

ExOR, ETX, Throughput, Ad hoc networks, Hybrid networks

1. INTRODUCTION

Wireless networks are group of nodes which communicate with each other over the wireless media. Many cities and public places have deployed wireless networks to provide internet access to residents and local businesses. Ad hoc networks can be formed with portable devices like laptop computers, personal digital assistants(PDA's) and mobile phones can communicate among themselves through multihop links without any fixed infra structure. Ad hoc [Infra structure less] networks are a category of wireless networks, whose decentralized nature, minimal configuration and quick deployment make them suitable for applications ranging from emergency situations like natural disasters, military sensing, disaster rescue, traffic monitoring, tracking, etc. In infrastructure based networks there exists a continuous path between the source and the destination once the connection is established and at times traffic overflow in these networks lead to congestion during the transmission of data. Information loss occurs if the connection is lost due to environmental impacts.

Hybrid wireless networks are integration of both 'ad hoc – infrastructure less' and 'Wireless – Infrastructure based' networks. Brust, Rothkugel define hybrid wireless networks as "multi-hop wireless networks combined with a backbone network" where the term "hybrid" stands in direct relation to the fact that different communication technologies are used to create such a network.

Hybrid wireless network combine the advantages of ad-hoc networks and infrastructure based architecture as both paradigms are complementary. Use of base station in hybrid wireless network localizes the ad hoc traffic, which avoids the overwhelming burden of relaying packets between source and destination. Infra-structure less networks exploit the multi-hop forwarding of data packets between the source and destination through the candidate relay sets[neighbour nodes]. The neighbour nodes that would participate in relaying is determined based on the link bandwidth. The focus is to efficiently utilize the resources like bandwidth for efficient delivery of the data to the destination, which results in high throughput compared to traditional routing protocols.

A hybrid network is formed by placing a sparse network of base stations in an ad hoc network. The use of base stations is to avoid overwhelming burden of relaying packets between source and destination by the mobile nodes. Unlike traditional wireless routing protocols which use a single predetermined path, opportunistic routing explicitly takes advantage of the broadcast nature of wireless communications by using a set of relay nodes to opportunistically perform packet forwarding**.** Opportunistic routing technique chooses a path dynamically on per-transmission basis to forward a packet to the next node. Expected Transmission Count (ETX) is the routing metric used by OR to choose Candidate Relay Sets (CRS). It minimizes the expected total number of packet transmissions required to successfully deliver a packet to the destination [2].

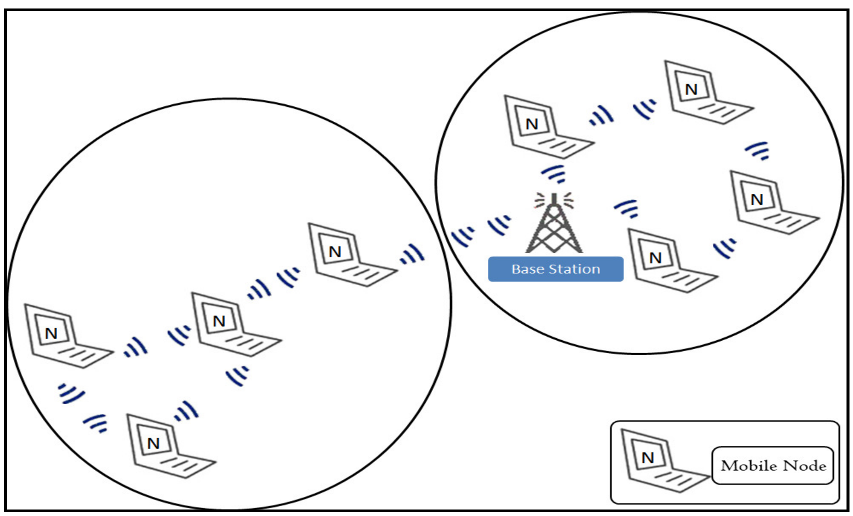

Fig. 1 Hybrid Wireless Network Scenario

In Hybrid wireless networks [Fig. 1], wireless nodes communicate with each other through multi hop ad hoc transmissions and nodes within the coverage range of a Base Station (BT), communicate with the BT using single-hop infrastructure mode. In Opportunistic Routing, nodes in the network are cooperative and forward each other's packets to their destinations [4]. The node nearer to the destination node becomes the potential forwarder node. This work attempts to provide focus on exploiting opportunistic routing protocol with expected transmission count metric in hybrid wireless networks.

Assumptions concerning the behaviour of the nodes and base stations that participate in hybrid networks are as follows:

- Wireless nodes and Base stations are randomly located.
- Wireless nodes have the same set of transmission rates and equivalent ranges.

- Each wireless node could connect to at most one BT.
- Each node is identified by a unique ID within the network.

The proposed work is organized as follows: Section 2, explains the use of Extremely Opportunistic Routing scheme in comparison with traditional routing protocols. Section 3, depicts ExOR protocol's design aspects. Section 4, describes the performance (evaluation criteria) of ExOR routing protocol and discussion on implementation details of the proposed work in hybrid wireless networks in comparison with ad hoc networks. Section 5 provides the conclusion of the work.

2. EXTREMELY OPPORTUNISTIC ROUTING TECHNIQUE

2.1. Opportunistic Routing Principles

OR scheme extends the concept of Geographical routing [4]. As in geographical routing, OR uses the node available in the transmission range in order to forward the packet. This node availability reduces the overhead of finding the node information frequently in the network as followed by traditional proactive routing schemes [5]. The performance of the network may go down because of routing loops and inconsistency of the network. Opportunistic routing scheme chooses each hop of a packet's route after the transmission for the present hop, to reflect on which intermediate node has actually received the transmission to make better progress [5]. This provides higher throughput than the traditional routing, since each transmission may have more independent chances of being received and forwarded [1][14]. The nodes are organized in a tree structure in order to avoid the participating nodes in forming loops.

Traditional routing protocols follow the concept of routing similar to wired networks by abstracting the wireless links as wired links, and find the shortest, least cost, or highest throughput paths between a source and the destination [4]. When a packet is unicast to a specific next-hop node, all neighboring nodes in the communication range of the sender receives the packet and make use of the successful reception on the neighboring nodes instead of retransmitting the packet and saves the bandwidth [3]. In opportunistic routing protocols, all neighboring nodes that are closer to the destination may overhear a data packet, and may be a candidate to forward the packet to its destination. But, among all the candidate nodes that receives a packet, the potential candidate node with better link quality that is nearer to the destination alone forwards the packet.

2.2. ExOR Principles

ExOR forwards each packet through sequence of nodes, deferring the choice of each node in the sequence until after the previous node has transmitted the packet on its radio. ExOR determines which node, of all the nodes that successfully received the transmission, is the closest to the destination; the closest node transmits the packet. A distributed MAC protocol allows recipients to ensure that only one of them forwards the packet. The inter-node delivery rates are used to determine which recipient is likely to be the better useful forwarder node.

ExOR and MORE (MAC independent Opportunistic Routing and Encoding) are few existing opportunistic routing protocols [6]. MORE protocol is independent of MAC and network layer. This protocol randomly mixes packets before forwarding, in order to ensure that routers that hear the same transmission do not forward the same packet. The other advantage is, it does not need any special scheduler to coordinate the routers and can run directly on top of 802.11 [8]. The proposed scheme (ExOR) with ETX for hybrid wireless network, which is an integration of MAC and network layer [5] choose the path dynamically on a per transmission basis.

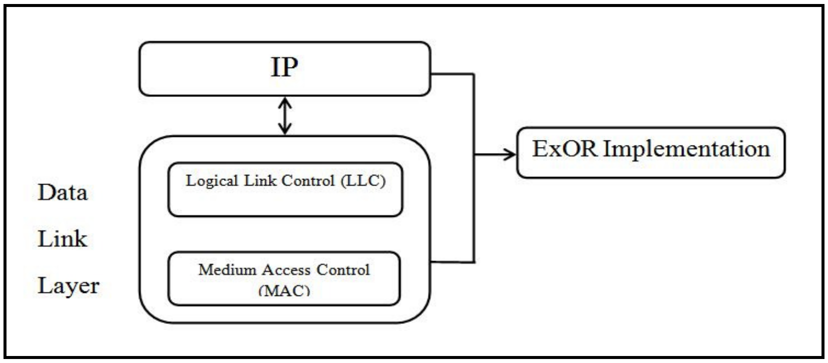

Figure 2. Layered Architecture of ExOR

3. SYSTEM DESIGN

- Routing Methodology in ExOR
- ExOR Protocol's design
- ETX Metric

3.1 Routing Methodology in ExOR

A source node S that intends to forward a packet to a destination node D broadcasts the packet in the network. Though a sub-set of the nodes receive the packet, only the node closer to the destination rebroadcasts the packet. Further, the nodes that receive the second transmission broadcast the packet in turn to the nearest receiver. This procedure is followed until the packet reaches the destination node [3].

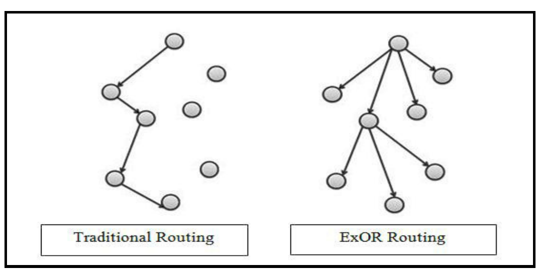

Figure 3. Traditional Routing and ExOR Routing Methodologies

3.2 Extremely Opportunistic Routing (ExOR) Protocol's Design

Extremely Opportunistic Routing (ExOR) is a combination of routing protocol and media access control which follows a simple rule that, "Of all the nodes that were able to successfully decode the transmission, the one that is closest to the destination should forward it on". ExOR achieves high throughput in lossy wireless links and chooses paths dynamically on a per transmission basis. When each time a packet is forwarded, ExOR selects a set of next hop forwarding candidates nodes. These set of candidate nodes are called as Candidate Relay Sets [CRS]. ExOR basically increases the forwarding capability and hence reliability reducing the retransmission cost.

3.2.1 Design Challenges

Although simple to define, the rule is quite difficult to implement in a Hybrid network. ExOR's design has the following challenges:

- The nodes should agree on which subset of them receives the packet. An agreement protocol should decide the candidate node that would forward the packet. i.e., the node closest to the ultimate destination that receives a packet should forward it.
- ExOR must have a Cost metric to move a packet from source to destination on per transmission basis.
- In a large dense network there is a penalty for using too many nodes as potential forwarders, since the costs of agreement grow with the number of participants. ExOR must choose only the most useful nodes as participants in large networks.
- ExOR must avoid simultaneous transmissions to minimize collisions.

The design is achieved with the following inclusions such that each node participating in ExOR routing uses the header format as given in Fig.4 [5].

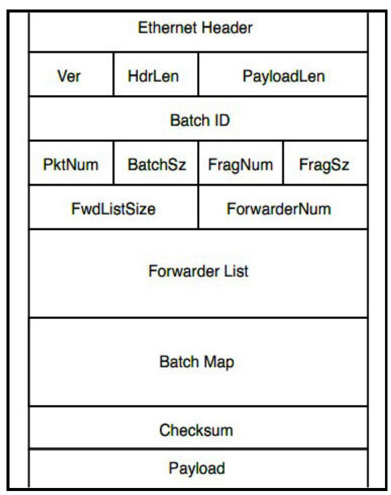

Figure 4. ExOR packet Header format [5]

Batch Preparation:

The source node chooses a unique batch ID and selects a Forwarder List for a batch of packets all destined to the same destination node. The source does this by adding an ExOR header to each packet of the batch, containing the batch ID and a forwarder list.

Forwarder List:

The forwarder's list is specified by the source based on the expected cost and priority from each node in the list to the destination. The cost metric is calculated by counting both hops and retransmissions from the source to the destination. The cost metric ETX is used to find the path between the source and the destination with higher throughput.

Packet Reception:

For every entry in the batch map of the packet, the node compares the corresponding entry with its local batch map, and replaces the later entry with highest priority.

Scheduling Transmissions:

ExOR attempts to schedule high priority nodes to be sent first that helps avoid collision to forward one packet at a time from the subset of nodes.

3.3 ETX Metric Design

3.3.1 General

Expected transmission count (ETX) is a metric that finds high throughput paths on multi-hop wireless networks incorporating the effects of link loss ratios and interference among the successive links of a path. However, the minimum hop-count metric regardless of large differences in throughput, chooses different paths of same minimum length. This metric also account to issues like interference between successive hops among multi-hop paths. ETX metric provides better improvement for paths with two or more hops, suggesting that transmission count offers increased benefit as networks grows larger and paths become longer.

3.3.2 Metric Calculation

The ETX of a route is a sum of the expected transmission count for each link in the route between the source and destination. The ETX of the link is calculated using the forward (d_f) and reverse (d_r) delivery ratios of the link [2]. The forward delivery ratio (d_f) is the measured probability that a data packet successfully arrives at the recipient. The reverse delivery ratio (d_r) is the probability that the ACK packet is successfully received. ExOR uses only the forward delivery ratio (d_f) of the ETX metric. The metric is applied for the route with hop count of more than two to achieve better delivery ratio.

The delivery ratios d_f and d_r are measured using dedicated link probe packets at an average period. Delivery ratio from the sender at any time t during the last w seconds is calculated as:

$$r(t) = \frac{\text{count}(t-w,t)}{w/\tau} \qquad (1)$$

Count (t-w, t) is the determined with the number of probes received during the window w, and w/τ is the number of probes that should have been received. The advantage of using this metric is to scale down many alternate routes and determine a better route to forward the data from source to destination.

4. Performance Evaluation

A well designed hybrid topology combines two or more network topologies together, and strengthens the speed, reliability, efficiency, etc. This implementation would be applicable in various applications like mobile learning, disaster management, group communication among similar interest groups and so on. ExOR routing protocol with ETX metric is implemented using the network simulator [NS2] by extending and incorporating the ExOR protocol in hybrid scenario. The QoS parameters like packet delivery ratio and throughput for hybrid wireless networks using ExOR routing protocol is obtained and compared with that of the ad hoc wireless networks. It is observed that considerable improvement in throughput and packet delivery ratio is achieved in hybrid network and the comparison results are shown in figures 6 and 8.

4.1 Methodology

This section covers the implementation of the proposed protocol design of ExOR incorporating ETX metric for hybrid networks. The protocol is built in C++ that is included in the NS2. The code has been implemented such that it corresponds well to the design aspects of the chosen scenario. NS2 has many built-in routing protocols such as AODV, DSDV, and DSR etc. NS2 is open source and has a feature of adding new protocol. NS2 supports to analyse the new routing protocol incorporated and it is very useful to various research groups to propose new protocols in the area of wireless networks.

Network topologies are simulated and trace files generated are analysed using ‘Awk’ Script. AWK is a data driven programming language designed for processing text based data, either in files or data streams. Using Awk script, the data points for packet delivery ratio and throughput for ad hoc wireless and hybrid networks has been calculated. The values thus computed are used to visualize the results graphically using ‘Gnuplot’, an interactive data plotting program mainly intended for depicting the scientific data.

4.2 Packet Delivery Ratio

The packet delivery ratio is the proportion of the number of packets received by the destination to the number of packets sent by the source.

$$\text{Packet Delivery Ratio} = \frac{\sum \text{Packets received by Destination}}{\sum \text{Packets sent by Scurce}} \qquad (2)$$

4.2.1 Determining the Packet delivery ratio

The hybrid wireless networks are simulated using the following simulation environment in ns2. The network area of 200 m x 200 m with 4 wired nodes, 14 wireless ad hoc nodes and 2 base stations are assigned. The initial range for the nodes is assumed as 100 m. Movement of nodes and data transfer takes place according to the change in the topology using the random way point mobility pattern. Simulation is carried out with different simulation times of 30, 60, 90, 120, 150, 180 seconds and the packet delivery ratio is calculated for both ad hoc and hybrid scenarios as given in Table 1. It is observed that the packet delivery ratio for hybrid network is better than that in ad hoc network.

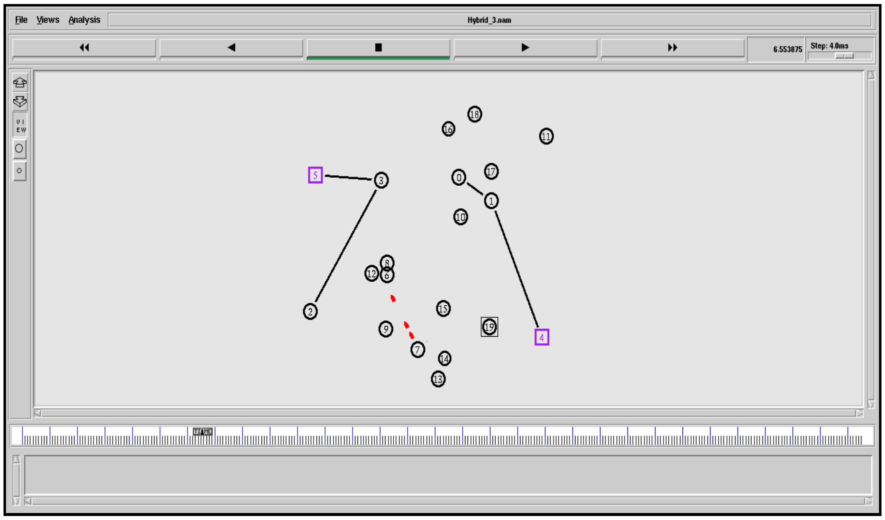

Figure 5. Scenario: To determine Packet delivery ratio

Table 1. Data points used for plotting: Packet delivery ratio in Ad hoc and Hybrid Wireless Network

ExOR \ Time (Sec)	30	60	90	120	150	180
Ad Hoc	95.3714	97.4854	98.1968	98.5709	98.7386	98.9302
Hybrid	99.1089	99.395	99.4889	99.4837	99.4814	99.4863

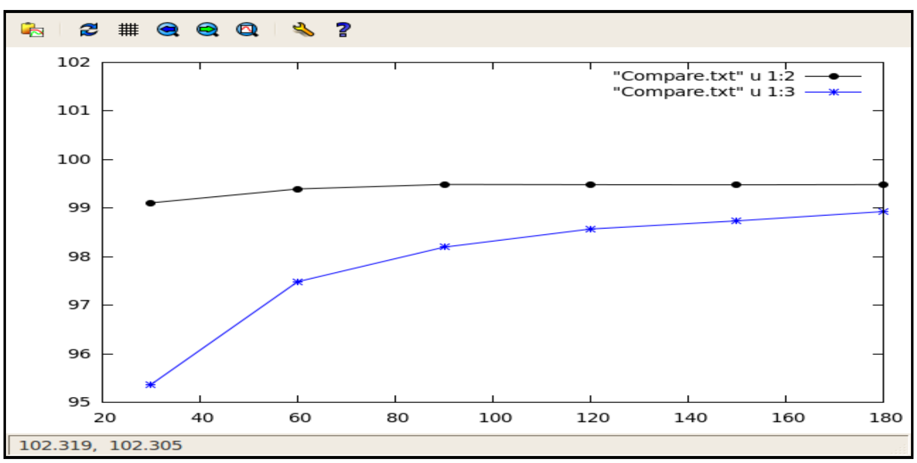

Figure 6. Comparison of Packet Delivery Ratio: Ad hoc and Hybrid Wireless Networks using ExOR Routing Protocol

4.3 Throughput

Throughput refers to the total amount of bytes being transferred over a particular time.

4.3.1 Throughput Calculation

Hybrid wireless networks are simulated using a network area of 150 m x 150 m with 4 wired nodes, 14 wireless ad hoc nodes and 2 base stations. The initial range for the nodes is assumed as 100 m. Movement of nodes and data transfer takes place according to the change in the topology using the random way point mobility pattern. Simulation is carried out with different simulation times of 30, 60, 90, 120, 150, 180 seconds and the throughput is calculated for both ad hoc and hybrid scenarios as given in Table 2.

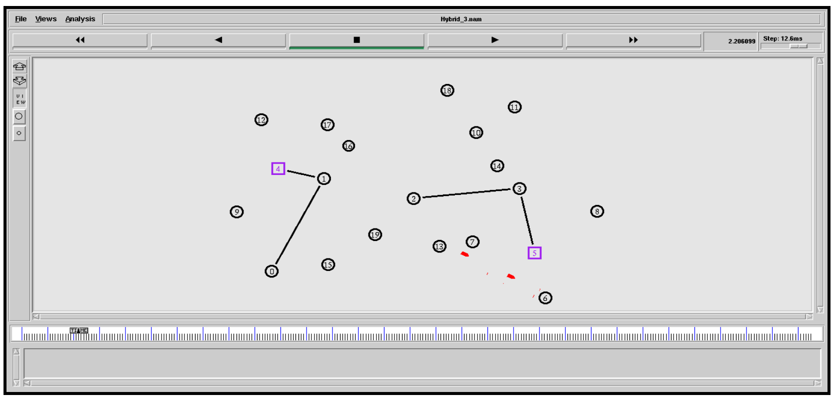

Figure 7. Scenario: To determine Throughput

Table 2. Data points used for plotting: Throughput in Ad hoc and Hybrid Wireless Network

Time (Sec) / ExOR	30	60	90	120	150	180
Ad Hoc	615.42	631.42	635.28	637.59	639.17	648.55
Hybrid	812.53	825.52	828.54	833.54	831.25	838.61

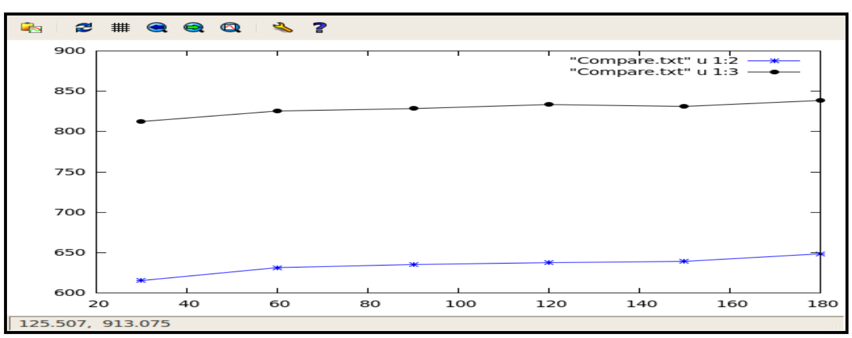

Figure 8. Comparison of throughput: Ad hoc and Hybrid Wireless Network using ExOR Routing Protocol

5. CONCLUSIONS

Extremely Opportunistic Routing (ExOR), an integrated routing protocol takes the advantage of long-distance but lossy links which is not addressed by the traditional routing protocols. ExOR protocol is implemented using Expected Transmission Count (ETX) Metric that finds the optimal path with higher throughput in hybrid wireless networks which increases the performance considerably. The packet delivery ratio and throughput is calculated using different simulation times for ad hoc as well as hybrid networks. Simulation results prove that there is about 20 to 30% increase in packet delivery ratio and throughput taking into account the routing overhead in Hybrid wireless network when compared to that of ad hoc wireless networks. This implementation would be applicable in various areas like mobile learning applications, group learning/communication and in other time critical applications like disaster management, military environment and so on. Moreover, this approach shall support applications that would require to be deployed in hybrid environment in a cost effective manner. Further enhancement to this work would be to incorporate trust among the nodes participating to forward information in the hybrid network which would address the security aspects as it's an essential component for any wireless network.

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