Survey and Analysis of various Routing Techniques and Metrics in Wireless Networks

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ABSTRACT
The focus of this paper is to survey the use of EXOR routing scheme and routing metrics to be applied in hybrid wireless networks over the traditional unicast routing protocols used for mobile ad hoc networks. On performing a thorough analysis of various literatures, it is proposed that use of EXOR with ETX metric in hybrid wireless networks would give a better throughput than that of the traditional unicast routing protocols for ad hoc networks. This survey would be a great source of information for researches with focus in hybrid networks.

General Terms
Wired networks, Wireless networks, Ad Hoc networks, Hybrid networks

Keywords
Throughput, Routing, Metric, EXOR, ETX, EOTX, MORE

1. INTRODUCTION
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. Secured transmission of the information is not guaranteed as hackers would interrupt in the intermediate nodes.

Wireless networks have become an attractive communication paradigm in this era. Many cities and public places have deployed wireless networks to provide internet access to residents and local businesses. To deploy wireless networks, routing protocol design is critical in terms of performance and reliability of wireless networks.

An ad hoc wireless network (Figure1) is a category of wireless networks. These are based on the principle of multi hop relaying and are capable of operating without the support of any fixed infrastructure and can be deployed rapidly and inexpensively even in situations with geographical or time constraints. These wireless networks are useful in many application domains. The extensive use of wireless networks in various application domains has become a point of motivation for researches to study the behaviour of these networks.

Much of the recent works in ad hoc routing protocols for wireless networks have focused on dealing with mobile nodes, rapidly changing topologies and scalability. Less attention has been paid to find high quality paths in the face of lossy wireless links.

Recent studies show that ad hoc networks provide less throughput due to inefficient utilization of resources. It poses many challenges in the transmission of data. Transmission of data mainly depends on efficient routing schemes.

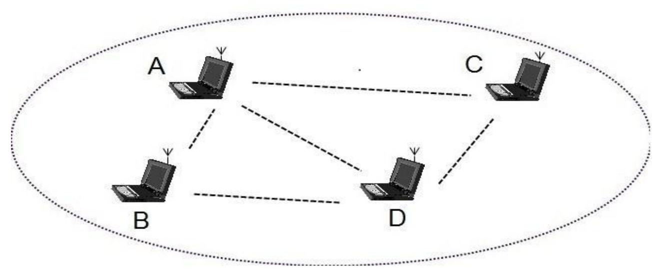

Figure 1. Ad Hoc Network

Routing in multi hop wireless networks presents a great challenge due to the following facts:

- Wireless links are not reliable because of channel fading.
- Available channel rates may be different at different link as link quality depends on distance and the path loss between neighbors.
- Since wireless medium is broadcast in nature, the transmission on one link may interfere with transmissions on other neighboring links.

Hybrid Wireless Networks (Figure 2), which is an integration of wired and wireless networks, uses base stations to avoid over whelming burden of relaying packets between source and destination if required. Efficient utilization of the resources results in high throughput in hybrid wireless networks compared to other networks. This leads to the careful study of Hybrid Wireless Networks and various strategies.

A hybrid network is formed by placing a sparse network of base stations in an ad hoc network. These base stations are assumed to be connected by a high bandwidth wired network and act as relays for wireless nodes. They present a trade-off between traditional cellular networks and pure ad hoc networks in that, data may be forwarded in a multi hop fashion or through the infrastructure.

The proposed solution shall overcome the limitations of routing in wireless networks with base stations (infrastructure) support in ad hoc environment.

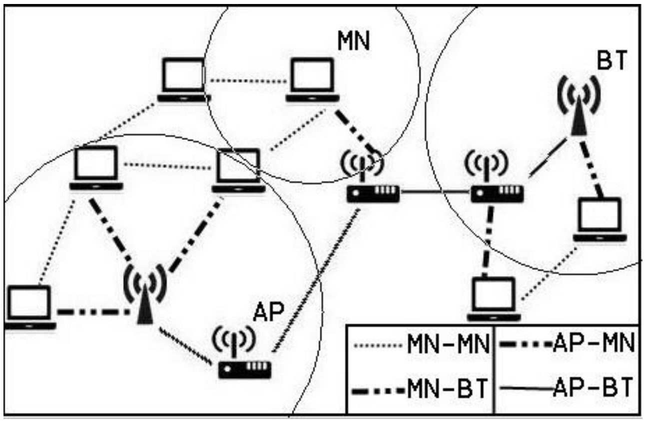

Figure 2. Hybrid Wireless Network

EXOR routing scheme adaptable in ad hoc network is incorporated to hybrid network with ETX metric. The addition of base stations in hybrid wireless network improves the throughput. ETX is the metric used by EXOR to find the paths with highest throughput. Minimal configuration and quick deployment make them suitable for emergency situations like natural disasters or military conflicts.

2. LITERATURE SURVEY

2.1 Sanjit Biswas and Robert Morris [5] discuss on ExOR, an integrated routing and MAC protocol. Traditional routing protocols choose the best sequence of nodes between the source and destination in order to forward each packet.

ExOR broadcasts each packet, choosing a receiver to forward only after learning the set of nodes which actually is intended to receive the packet. It ensures that only the best receiver of each packet forwards it, in order to avoid duplication. When a node has a packet to be delivered to the destination, nodes run a protocol to discover and agree on which nodes in the subset would forward the packet during routing. Again, the nodes that receive the second transmission agree on the closest receiver, which broadcasts the packet in turn.

This paper gives two reasons as to why EXOR would provide more throughput than traditional routing. Traditional routing would route all the data through the same intermediate nodes. But using ExOR, each of the source's transmissions is likely to be received by at least one intermediate node. Another reason is that it takes advantages of transmissions that reach unexpectedly far or fall unexpectedly short leading to decrease in delivery probability with distance. ExOR increases the total network capacity as well as individual connection throughput based on the metric.

The challenges faced by the ExOR's design proposed in [5] are,

- The nodes must agree on which subset of them should receive each packet.
- The node 'closer' to the ultimate destination should be the one that forwards the packet.
- ExOR must choose only the most useful nodes as forwarders.
- ExOR must avoid simultaneous transmissions by different nodes to minimize collisions.

ExOR operates on batches of packets. All ExOR packets are broadcasts. Source node includes a list of candidate forwarders in each packet, prioritized by the estimated cost to the destination. The EXOR packet format includes Node State, Packet Format, Batch Preparation, Forwarder List, Packet Reception, Scheduling Transmissions and Completion of transmission.

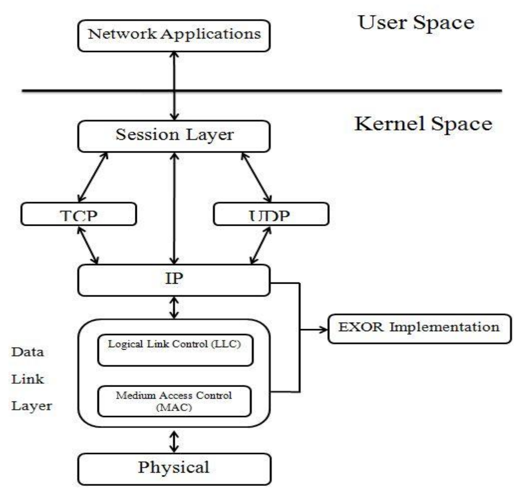

Figure 3. Layered Architecture – EXOR Implementation

Traditional routing would forward data through some sub sequence of the chain whereas ExOR uses the nodes that are instantly available for routing. This improves performance by taking advantage of long-distance but loss links which would otherwise have been avoided by traditional routing protocols. The forwarders go through the priority list until the destination has 90% of the packets. The remaining packets are transferred with traditional routing. ExOR's acknowledgements prevent unnecessary retransmissions, increasing throughput by nearly 35%.

2.2 Rahul C. Shah et al [4] compares geographic routing and opportunistic routing. Different opportunistic routing protocols have been proposed. These protocols exploit the redundancy among nodes by using a node that is available for routing at time of packet transmission. This mitigates the effect of varying channel conditions and duty cycling of nodes that make static selection of the routes not feasible. [4] Provides a systematic performance evaluation, taking into account different node densities, channel qualities and traffic rates to identify the cases when opportunistic routing makes sense. The metrics used are power consumption at the nodes, average delay suffered by packets and throughput of the protocol. This paper also addresses optimal operation points for opportunistic routing that minimizes the power consumption at the nodes.

The traditional approach to design routing protocols for sensor networks is to decouple the routing layer from the MAC layer, which results in poor quality paths which have low availability, low reliability and high energy consumption. To alleviate these shortcomings, the concept of OR has been proposed in [4].

The distinguishing characteristic of Geographic routing protocols is the use of node location information to route packets geographically towards the destination by forwarding to a neighbor that is located farthest towards the destination node. The Opportunistic routing protocols extends the idea of geographic routing, and use some node that is awake and available for routing at the time the packet needs to be transmitted which avoids overhead. The way it works is by integrating the network layer and MAC layers so that the network layer passes down a set of candidate forwarders and the MAC layer takes a final decision on which node to use as a forwarder depending on current connectivity.

Greedy forwarding, which is a common part of all geographic protocols, is compared with region based opportunistic routing. The solution results of this compared protocols shows that OR is suitable for higher node densities which gains about 10% improvements in power and 40 % in delay.

2.3 Kai Zeng et al [3] propose the idea of Opportunistic routing (OR), which deals with unreliable transmissions by exploiting the broadcast nature and spatial diversity of the wireless medium. The performance of OR in multi rate scenario and throughput bound of OR has been analyzed. The concept based on Concurrent Transmitter Sets (CTS) which captures the transmission conflict constraints of OR is proposed.

Traditional routing protocols for multi hop wireless networks followed the concept of routing in wired networks by abstracting the wireless links, and for finding the shortest, least or higher throughput paths between the source and destination. This abstraction resulted in lesser throughput.

When a packet is unicast to a specific next hop node of the sender, all the neighboring nodes in the range of the sender will overhear the packet. It is likely that some of the neighbors may receive the packet correctly when the specified next hop node doesn't receive. The innovative thought was "Can we make use of the successful receptions of this neighboring nodes instead of re transmitting the packets on the specified link to save precious band width and energy?" Inspired by this idea a new routing paradigm called Opportunistic routing has been proposed in [3].

Conservative CTS (CCTS) and Greedy CTS (GCTS) laid the foundation of computing end to end throughput. CCTS is defined as set of transmitters, when all of them are transmitting simultaneously and all links associated with them are still usable. CCTS requires all opportunistic receivers to be interference free for one transmission. This limitation results in lower bound of end to end capacity. So to get maximum end to end throughput, GCTS is used. GCTS is defined as set of transmitters when all of them are transmitted simultaneously, with at least one link associated with each transmitter is usable.

Generally, low rate communication covers a long transmission range while high rate communication covers short range. This rate - distance diversity trade off directly affects the throughput of OR.

[3] Also proposes a rate selection scheme and compares the throughput capacity of multi - rate OR with single-rate OR. A simulation result shows that OR has great potential to improve end-to-end throughput and system operating at multi-rates achieve higher throughput than that operating at any single rate.

2.4 Yanhua Li et al [8] analyses the type of routing metrics used for selecting the forwarder lists for designing the opportunistic routing scheme and also proposes the STR (Successful Transmission Rate) routing metric and FORLC (Fair Opportunistic Routing with Linear Coding) routing scheme which uses the STR metric and improves network performance, in terms of throughput and the packet transmission cost.

Traditional routing protocols are based on single best path to deliver the packets. Multi – path routing protocol is an improvement to single hop routing protocol by selecting multiple paths to deliver the packets, increasing the delivery ratio and also avoiding the duplication of packets. OR uses multiple paths to deliver the packets without increasing the transmission cost. A node forwards only those packets which haven't been received by any other high priority node. After transmission, all nodes have to wait for the forwarding of the nodes with higher priority in order. ETX (Expected Transmission Count) is not an optimal metric to choose the forwarder list in opportunistic routing, as it only considers one link with the lowest cost.

Fair opportunistic routing scheme also builds a candidate forwarder set such that all the nodes in it are fair without any priority. The set includes some closer nodes to the destination than the source. MORE (MAC independent Opportunistic Routing and Encoding) is a typical fair opportunistic routing scheme which supports spatial reuse and multi – cast with ETX as the metric to choose the candidate set. The challenge is to achieve lower number of duplicate transmissions between source and destination with higher throughput.

2.5 Szymon Chachulski [6] presents MORE, a MAC independent Opportunistic routing protocol. MORE randomly mixes packets before forwarding them. This ensures that routers that hear the same transmission do not forward the same packet. It doesn't need any special scheduler to coordinate routers and can run directly on top of 802.11. It also proposes EOTX routing metric which minimizes the number of opportunistic transmissions to deliver a packet to the destination. Although the optimal number of transmissions is given by EOTX, both MORE and EXOR use ETX to determine the priority ordering of forwarders because both pre-date the new metric.

2.6 Douglas S. J. De Coutoet al [2] Proposes Expected Transmission Count (ETX) metric, which finds high throughput paths on multi hop wireless networks. It minimizes the expected number of packet transmissions including retransmissions required to successfully deliver a packet to the ultimate destination.

The ETX metric incorporates the effects of link loss ratios, asymmetry in the loss ratios between the two directions of each link, and interference among the successive links of a path. In contrast, the minimum hop-count metric chooses arbitrarily among the different paths of the same minimum length, regardless of the often large differences in throughput among those paths, and ignoring the possibility that a longer path might offer higher throughput.

The metric must account for the following issues:

- Wide range of link loss ratios.
- The existence of links with asymmetric loss ratios.
- The interference between successive hops of multi-hop paths.

The ETX Metric

The ETX of a route is a sum of the ETX for each link in the route. The ETX of the link is calculated using the forward (d_f) and reverse (d_r) delivery ratios of the link. 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 forwarding delivery ratio d_f of the ETX metric.

ETX has several important characteristics:

- ETX is based on delivery ratios, which directly affects throughput.
- ETX detects and appropriately handles asymmetry by incorporating loss ratios in each direction.
- ETX can use precise link loss ratio measurements to make fine-grained decisions between routes.
- ETX penalizes routes with more hops, which have lower throughput due to interference between different hops of the same path.
- ETX tends to minimize spectrum use, which should maximize overall system capacity.
- ETX decreases the energy consumed per packet, as each transmission or retransmission may increase a node's energy consumption.

The delivery ratios d_f and d_r are measured using dedicated link probe packets. Each node broadcasts link probes of a fixed size, at an average period τ (one second in the implementation). To avoid accidental synchronization, τ is jittered by up to $\pm 0.1\ \tau$ per probe. Because the probes are broadcast, 802.11b does not acknowledge or retransmit them. Every node remembers the probes it receives during the last w seconds. The delivery ratio from the sender at any time t is:

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

Count (t-w, t) is the number of probes received during the window w, and w/τ is the number of probes that should have been received. In the case of the link X→Y, this technique allows X to measure d_r, and Y to measure d_f. Because Y knows it should receive a probe from X every τ seconds, Y can correctly calculate the current loss ratio even if no probes arrive from X.

Calculation of a link's ETX requires both d_f and d_r. Each probe sent by a node X contains the number of probe packets received by X from each of its neighbours during the last w seconds. This allows each neighbour to calculate the d_f to X whenever it receives probe from X.

STR is the successful transmission rate between a node and destination. Each node calculates its STR and selects some into the forwarder set.

STRs are calculated from a node closer to the destination, to the node farther away from the destination.

FORLC, like in MORE scheme, divides the data into batches of K packets called native packets and are un coded. Every node maintains a forwarder list before and forwarding it updates the packet's forwarder list. A node after receiving a packet checks whether it's in the forwarders list and if so, checks whether packet is linearly independent and stores the innovative packet into its cache. When destination receives K independent packets, it sends ACKs back to source along the best route.

ADVANTAGES:

- FORLC improves network performances, in terms of throughput and the packet transmission cost.
- STR based FORLC can reduce the packet transmission cost.

2.7 Yuan Sun et al [11] analyses the requirements for deployment of Hybrid Wireless Networks in different applications, to combat the limitations of infra structured wireless networks and provides internet connectivity to ad hoc networks.

The limitation of the ad hoc networks is that there is no connectivity between the fixed network and the nodes due to lack of preexisting infrastructure. To overcome this limitation, hybrid wireless networks can be built to broaden usage of wireless networks. Traffic in hybrid networks can be both within 'ad hoc – infra structure less' and 'Wireless – infra structure based' network. Two routing schemes were designed for different traffic patterns in hybrid networks to achieve optimal performance. Both the schemes use Mobile IP protocol and Ad hoc On-Demand Distance Vector Protocol.

Routing Scheme 1: It is used when there is a large amount of traffic passing through the wired/wireless network gateway and applications are short web oriented sessions. It is desirable for mobile nodes to always have a default route to the gateway which will significantly reduce the route acquisition response time there by reducing the data transmission latency. In this scheme each node is required to register with the foreign agent or default gateway. Each node maintains the gateway as its default router and when it has data, it sends to gateway node. Gateway node then sends it to the intended destination.

Routing Scheme 2: It is used when large amount of traffic is within the ad hoc network and internet applications are not sensitive to latency. Nodes register to the foreign agent only if they have data to transmit to the wired network. This scheme uses AODV protocol where nodes generate Route Request (RREQ) message for the destination. Using RREQ, foreign agent and Route Reply (RREP) message, data is transmitted to the destination.

Simulation results [11] show that with a large percentage of short web-based traffic sessions, using a gateway as a default router results in better performance with lower latency, fewer routing table entries, and manageable control overhead. When traffic locality is high and Internet traffic is only an occasional occurrence, the reactive routing scheme results in better performance with low control over-head and higher throughput.

2.8 Yong Pei et al [9] analyses the capacity of ad hoc networks, which is constrained by the multi hop relay traffic. In order to localize ad hoc network, hybrid wireless networks are used. This paper proposes a different traffic partitioning strategy between the ad hoc and base station traffic based on normal node centric partitioning instead of base station centric partitioning and also proposes an L-maximum hop routing strategy in order to obtain improved spectrum efficiency. The throughput capacity of hybrid wireless networks is analyzed.

The major objective of the use of base station in hybrid wireless network is to localize the ad hoc traffic, which is to avoid overcoming burden of relaying packets between source and destination in pure multi hop ad hoc networks which limits the scale of the networks.

Two types of transmission modes in hybrid wireless networks are ad hoc mode and infra-structure mode. Instead of using cell based approach (Base station Centric) to organize ad hoc traffic, normal node base strategy in which data is forwarded in ad hoc mode to the destination is with maximum of L-hops from the source. If L=1, it is in ad hoc mode and the traffic is local traffic. If L>1, data is forwarded in the infra-structure mode. This routing strategy is called as L-maximum routing strategy, which avoids the problem raised by using K-nearest-cell routing strategy.

The overall bandwidth, W bits/sec is divided into W1 for ad hoc mode and W2 and W3 for downlink and uplink for infra-structured mode respectively. Since we assume the same amount of uplink and downlink traffic, W2=W3. Therefore,
W= W1+2 W2.

Capacity of hybrid wireless networks using l-maximum-hop routing strategy.

For L=1

In Infra-structured Mode, $T_i = \alpha W_2$. ---- (i)

In Ad Hoc Mode, $T_a = \beta W_1$. ---- (ii)

Where, T_i, T_a are Throughputs for Infra-structured and ad hoc mode and $\beta = \frac{1}{1+C1}$ ---- (iii)

The aggregate throughput capacity of the whole network is

$T = nT_a + mT_i = n\beta W_1 + m\alpha W_2$ ---- (iv)

The ratio between the local and global traffic is given by

$R = nT_a mT_i = n\beta W1 m\alpha W2$ ---- (v)

It is seen that the aggregate throughput capacity of the whole network increases as the number of nodes ‘n’ increases. This is because the global traffic is localized by using the available infrastructure. The amount of global traffic is now limited by the number of base stations available. To support increasing global traffic more base stations has to be deployed.

For L>1

$n\zeta = n\beta W_1 = nW1/_{1+c1}$

$T_a = n\zeta n\hat{L}$ Where $\hat{L} = 23$ L, $T_i = \alpha W_2$.

$T = nT_a + mT_i$.

$R = nT_a mT_i = (n_1+c_1)\ (W1/\frac{2}{3}L)\ m\alpha W2$.

Effective throughput for a hybrid wireless network employing L-maximum-hop routing strategy is constrained by L.

3. CONCLUSION

After analyzing various routing techniques and metrics supported for wired and ad hoc networks, it is proposed that EXOR routing technique with ETX metric would provide better throughput and performance in hybrid environment.

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