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OPPORTUNISTIC ROUTING WITH PARTIAL DIVERSITY IN MOBILE AD HOC NETWORKS

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Abstract: Adaptive routing algorithms that opportunistically route the packets in the absence of reliable knowledge about channel statistics and the network model. In this paper, design adaptive routing algorithms, Distributed Opportunistic Routing (d-AdaptOR), which minimizes the expected number of transmissions and thus improving the throughput. The remainder of the dissertation concerns with the design routing algorithms to avoid congestion in the network. Describe a Distributed Opportunistic Routing algorithm with Congestion Diversity (ORCD) which employs receiver diversity and minimizes end-end delay.

Keywords: Mobile Ad Hoc Networks, Opportunistic Routing, Diversity Protocols

I.INTRODUCTION

Dynamic routing that is used in fixed networks will not work well in the highly mobile environment of the battlefield, because network convergence speed is too slow to support real-time communication requirements. Without any fixed networking infrastructure, a MANET has to be created "on the- fly". A MANET is a self-configuring, infrastructure-less network of mobile devices connected by wireless links. Each device in a MANET is free to move independently in any direction and therefore will change its links to other devices frequently. Each node must be willing to participate in forwarding traffic even though the packet is not of its interest. The fact that these networks are self-forming and self-healing facilitates the deployment process and minimizes the need for manual configuration and intervention. MANETs support multi-hop networking to extend coverage and provide redundant paths for increased resilience.

The emergence of low-cost portable devices such as smart phones has led to an increasing research interest in MANETs, where every person, vehicle, or user is able to communicate with neighbors via short-distance wireless radio transceivers. Such a communication paradigm offers multiple advantages: low starting costs, rapid development, resilience to disruption, and high bandwidth. Although general purpose MANETs may not yet be widespread, specialized networks are already a reality. In the following, brief descriptions of some typical networks, which are based on the concept of MANETs, are presented. These networks are concrete instances of MANETs in certain specific application domains. Therefore, they have different features and also have different application requirements.

- **Delay Tolerant Networks (DTNs):** DTNs [1] have been proposed and used to provide connectivity in areas where a fully connected network is not always available. Examples of such networks are those operating in mobile or extreme terrestrial environments.
- **Vehicular Ad-hoc Networks (VANETs):** VANETs [2] are used for onboard safety systems, virtual traffic signs, real-time congestion and traffic information, and commercial applications, which require vehicle-to-vehicle or vehicle-to-roadside communication. Vehicle ad-hoc networks have some distinct features compared to other mobile ad-hoc networks such as large computational and infinite power resources. The mobility of the nodes may be quite high, but with mobility patterns constrained to roadways. VANETs applications usually have more strict requirements on packet transmission delay, since a late alarm message is not acceptable for safety.
- **Wireless Sensor Networks (WSNs): WSNs** [3] have been proposed to rapidly deploy low-cost, low-power wireless motes in a target area. In practice, WSNs have been used in many industrial applications, such as industrial monitoring, environmental monitoring, or animal monitoring. The data collected and often already partially processed by the sensors is transmitted to the destination node, which is controlled by a gateway node or monitoring center. Wireless sensor networks have very strict limitations on battery level, communication and computation capacities, and memory spaces. Due to the fact that sensors are battery powered, power consumption is the major concern in a wireless sensor network application.
- **Wireless Multimedia Sensor Networks (WMSNs):** WMSNs [4] are new types of sensor networks gaining research interest due to the availability of low-cost and mature technologies in camera sensors and scalar sensors. As an extension of traditional scalar wireless sensor

networks, WMSNs are composed of wirelessly interconnected sensor nodes equipped with multimedia devices, such as cameras and microphones, and are capable to retrieve video and audio streams, still images, as well as scalar sensor data. WMSNs can visually observe the physical behaviors of the objects in the targeted areas, which significantly enrich the application ranges of wireless sensor networks. The support of multimedia transmission in WMSNs provides additional information to evaluate the network performance from the perspectives of the end users.

- **Personal Area Networks (PANs):** PANs [5] are short-range, localized networks where nodes are usually associated with a given person. These nodes could be attached to someone's pulse watch, belt, and so on. In these scenarios, mobility is only a major consideration when interaction among several PANs is necessary, illustrating the case where, for instance, people meet in real life.
- **Unmanned Aerial Vehicular Networks:** In case of disasters of emergent conditions, existing communication infrastructures may be broken and become unavailable. To facilitate the necessary operation in this kind of scenarios, it is important to deploy quickly a temporary communication network to assist the rescue operation. An unmanned aerial vehicular network can be set up and deployed into the dangerous area to form unmanned aerial vehicular networks (UAVNet) [6] or Flying Ad-hoc Network (FANET) [1] to perform rescue tasks.

II. OPPORTUNISTIC ROUTING

Low quality of wireless links leads to perpetual transmission failures. To mitigate this problem, opportunistic routing has been proposed to overcome the deficiencies of conventional MANET routing. Unlike traditional MANET routing, which finds end-to-end paths to send unicast packets, opportunistic routing exploits the broadcast nature of wireless medium to postpone the selection of packet forwarders to the receiver side. Opportunistic routing lets multiple receivers of a transmission coordinate with each other and decide which one will actually forward the packet. Traditional MANET routing selects one of the multiple intermediate nodes as the packet forwarder prior to data transmissions. The data is then unicast to the selected node, and other nodes will drop the packet even though they opportunistically overhear the transmission. If the unicast transmission is failed, the source node has to retransmit the same packet or even has to find a new path. However, in opportunistic routing, the source node sends the packet without knowing who will be the forwarder. It preselects a set of nodes, called relay candidates, as possible forwarders and broadcasts the packet. The broadcast transmission might be overheard by multiple nodes. As far as one of the candidates receives the transmission, it further forwards the packet. The source node retransmits the same packet only when all the intermediate nodes simultaneously miss the previous transmission, which is of much lower probability than the case of traditional routing. The performance of opportunistic routing depends on several factors, among which candidate selection and forwarder election are the most important.

As an example, a directed graph in Figure 1 represents a wireless network in which a link (x,y) has a delivery probability P(x,y). Traditional routing mechanisms achieve only 20%end-to-end delivery probability for any possible routing path (via A, B, C, D, or E) from source to destination. However, an opportunistic routing could achieve a delivery probability of $(1 - (1 - 20\%)^5) = 67\%$ if all five neighbors of source are selected as relay candidates. As another example, Figure 2 illustrates how opportunistic routing can affect an entire routing path. For clarity, the delivery probabilities for some links are not shown in the figure. It should be clear that each of links (src, B), (B, D), (D, dst) has a 60% delivery probability, and each of links (src, C), (C, dst) has a 40% delivery probability. A packet from a source may follow different paths to reach the destination. Traditional MANET routing would always choose the most reliable link to forward the packet, which results in a path of src→A→B→C→D→E→dst. This fixed end-to-end path has the success packet delivery probability of $((80\%)^5) = 26\%$. With opportunistic routing, if restrict a node to route packets via paths with at most three hops, there are four paths meeting this requirement: src→C→dst, src → C→D → dst, src→B→C→dst, and src→B→D→dst. The first two paths have a successful delivery probability of P(src,C) X (1-(1-P(C,dst) X (1-P(C,D) X P(D,dst))) = 40% X (1-(1-40%) X (1-80% X 60%)) ≈ 27.5%. Similarly, the last two paths have a successful delivery probability of 60% X (1-(1-60% X 60%) X (1-80% X 40%) ≈ 33.9 %. The overall successful delivery probability by the above four paths is therefore 1-(1-27.5%) X (1-33.9%) ≈ 52.1%, which doubles the value of traditional approaches. Most of the existing opportunistic routing protocols choose the next-hop forwarder based on a predefined candidate list. A source node, before the data transmission, injects a certain amount of beacon messages into the network to learn network link qualities. Then, it infers and obtains a ranking of nodes as forwarding candidates, according to the estimated quality of each link.

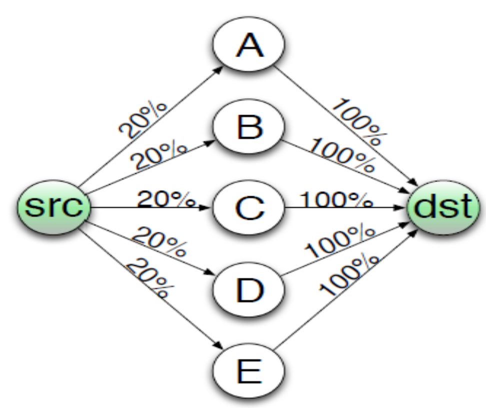


Figure 1: An illustration of single-hop multiple candidate-based opportunistic routing.

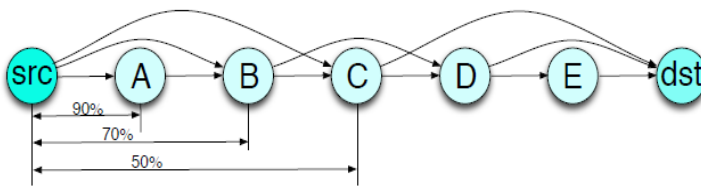


Figure 2: An illustration of multihop opportunistic routing.

This list is then embedded within the data packet and used as a reference to select a forwarder at each hop. As can see, the candidate list is calculated prior to data transmission according to certain network metric. However in reality, wireless links are extremely unstable, as they often experience quality fluctuation and distortion due to interference. Therefore, the link quality-based candidate list that is generated before data transmission may not be valid anymore when the data is being transmitted. Moreover, when mobility is introduced, nodes will move according to certain mobility patterns. The network topology will change and thus the estimated candidate list will be invalid. Therefore, the list-based feature of the existing opportunistic routing protocols restricts the freedom of opportunism, and thus, it is not appropriate for the dynamic feature of MANETs. An opportunistic routing protocol without a candidate list is more promising for packet transmissions in dynamic environments, such as MANETs or WSNs.

Challenges of Opportunistic Routing Design

The major challenge in opportunistic routing design is to maximize the routing progress of each data transmission towards the destination without producing duplicate transmissions or incurring significant coordination overheads. In order to achieve the potential benefits of opportunistic routing and avoid the abovementioned problems, an effective protocol should implement the following tasks in a distributed fashion:

- **Candidate selection:** All nodes in the network must run an algorithm for selecting and sorting the set of neighboring nodes (candidate list) that can better help in the forwarding process to a given destination. Refer to this algorithm as candidate selection. The aim of the candidate selection algorithm is to guarantee that only the qualified nodes become the candidates and to build the candidate list. In order to accurately build the candidate list, OR protocols require certain metrics to evaluate the network and rank network nodes.
- **Forwarder selection through candidate coordination:** Forwarder selection provides a scheme to select, among all the candidates that have successfully received the packet, only one node that really forwards the packet. Because there is no central controlling node, the forwarder selection process is done through the coordination of multiple candidates. Coordination requires signaling among candidates, and imperfect coordination may cause duplicate packet transmissions.
- **Forwarding responsibility transfer:** This function allows the nodes involved in the forwarding process - the actual forwarder plus the candidates - to become aware of the winner of the selection. The responsibility transfer is the distinguishing feature that differentiates opportunistic routing from flooding. In fact, in both opportunistic routing and flooding, multiple nodes will receive the broadcast transmission from a packet sender. However, unlike in the flooding algorithm, opportunistic routing allows only one node at a time to be in charge of packet forwarding.
- **Duplicate transmission avoidance:** This process is required only in case of imperfect responsibility transfer. If the forwarding responsibility is correctly transferred to the winning forwarder, there is only one node in charge of packet forwarding at any time. In contrast, several packet transmissions occur but only one is innovative, i.e., the one made by the winning forwarder. More effective the duplicate avoidance mechanism is, less network resources will be wasted.

III. LITERATURE REVIEW

- **Omer, *et al.* [7]** proposed the flow of congestion control which is a part of the general network of wireless mesh network nowadays. Resciults are taken by using the real time scenarios in simulator on which more bandwidth is received by the flow of one hop whereas the flow of two hops starves. It means the congestion control flows are starved after measuring the environment of wireless mesh network. The policy which is implemented by IEEE 802 is the proposed solution involved by a contention window's policy and it defined standard mechanism. Though it is a simple and the behavior of network is powerfully affected by the policy. The points of queuing the network creates the problem of behavior of transportation and Mac and ensure that for specific location the bandwidth of gateway is not constant and fair shared way taken by TCP flows they have.
- **Yang, *et al.* [8]** proposed a stable and fair algorithm of scheduling on heterogeneous Multi-Channel Multi-Radio Wireless Mesh Network (MCMR WMN) which balances the objectives of the network through put. Algorithm coloring multiple and matching maximum make the basic of scheduling algorithm here the interference and channels of wireless links corresponds to the nodes set in the graph of bipartite. For achieving a minimum period of scheduling multi channel and interface would be effectively colored. When the flow of data is congested Max-Min fairness could decrease the output of heterogeneous network. The fairness and the throughout would be degraded by the stable scheduling however, as the channel would possibly fail so the maximum throughput part maintained. Optimized network throughput can be effectively achieved by algorithm. The high throughput is improved by building a more stable scheduling algorithm.
- **Nivedita Gaur, *et al.* [9]** proposed a Load-aware Non-Persistent small-world long- link Routing (LNPR) algorithm for small-world wireless mesh networks to

reach lower average transmission path length for data transfer sessions among some source-node and destination- node pairs in the network. LNPR uses load balancing strategy to raised distribute the network traffic on the list of normal-links and the non-persistent long-links in the small-world wireless mesh networks for efficient use of long-links which are precious data transmission paths in the network. LNPR provides 58% to 95% improvement in call blocking probability and 23% to 70% in maximum load reduction with increment which range from only 0.7% to 9% increase in average transmission path length. Small-world wireless mesh networks find numerous applications in rural and community networks for cost-effective communication.

- **Govindaraj. E, *et al.* [10]** have proposed a QoS aware robust multipath routing algorithm for wireless mesh networks. The goal of the protocol is to offer a QoS constrained route from source to the destination. So a multiple disjoint paths for a source destination pair. Hence for initial time interval, probe packets are sent along all paths simultaneously from the origin to the destination. On receiving the probe packets, cumulative transmission energy, average delay and bandwidth are estimated for every path and a feedback report is provided for the destination. Therefore from the multiple paths, the robust best path is selected on the basis of the feedback report from the destination. Additionally it detects the changes in the path quality that hinders QoS requirements of the flows and reroutes the flow through alternative robust routes.

IV.OPPORTUNISTIC ROUTING WITH PARTIAL DIVERSITY

The three-way handshake procedure achieve receiver diversity gain in an opportunistic scheme is achieved at the cost of an increase in the control overhead. In particular, it is easy to see that this overhead cost, which is the total number of ACKs sent per data packet transmission, increases linearly with the size of the set of potential forwarders. Thus, consider a modification of D-ORCD in the form of opportunistically routing with partial diversity (P-ORCD). This class of routing policies is parameterized by a parameter M denoting the maximum number of forwarder nodes. This is equivalent to a constraint on the maximum number of nodes allowed to send an acknowledgment per data packet transmission. Such a constraint will sacrifice the diversity gain, and hence the performance of any opportunistic routing policy, for lower communication overhead. In order to implement opportunistic routing policies with partial diversity, before the transmission stage occurs, find the set of "best neighbors" for each node i at anytime t, denoted by B^*_i (t), where B^*_i (t), ≤ M. After transmission of a packet from node i at time t, the routing decision is made as follows: 1) among the nodes in B^*_i (t), \Si(t),select a node with the lowest congestion measure as the next forwarder; or 2) retain the packet if none of the nodes in the set B^*_i (t), has received the packet. Next present a mathematical formulation for modification of D-ORCD with partial diversity. Let B be the collection of all subsets of size less than or equal to M. In the D-ORCD protocol with partial diversity, (PD-ORCD), the corresponding quantities V^d_i (t) are updated as

$$\bar{V}_i^d(t) = \min_{B\in\mathcal{B}} \left\{ L_i^d(t) + \sum_{k:k\in\mathcal{B}} P_{succ-k}^{(i,d)}(t)\tilde{\bar{V}}_k^{(i,d)}(t) \right\},$$

- While the next hop is selected as

$$K_{PD-ORCD}^{(i,d)}(t) = \underset{k\in\{S_i(t)\cap B\}\cup i}{\arg\min} \ \tilde{\bar{V}}_k^{(i,d)}(T(t)).$$

V.THE SIMULATION RESULTS

Our simulations are performed in Qual Net. consider two set of topologies in our experimental study:

1. Canonical Example: In this example, study the canonical example in Figure 3. motivate the performance improvement for D-ORCD by a scenario which exemplifies the need to avoid congestion in the network by highlighting the shortcomings of the existing routing paradigms: shortest path and backpressure. Consider the network shown in Figure 3 which is parameterized by N. Nodes 12; 13; : : : ; 12 + (N -1) form a "hole" in the network whose size is controlled by the parameter N. Now discuss the delay gains under D-ORCD as parameters N and 1 (the incoming traffic rate at node 1) are varied and verify them in this section. Note that the source node 1 can route packets either through node 2 or node 3. Since only node 1 has a routing choice, focus on the delay experienced by packets originating in node 1. Figure 4 provides plots of the average end-to-end packet delay and the buffer overflow ratios for all the routing algorithms as the arrival rate 1 is varied. observe that D-ORCD has better delay performance than the other algorithms over the range of incoming traffic rates considered. Figure 5 plots the highest priority next hop for node 1 under the candidate protocols throughout the duration of the experiments.

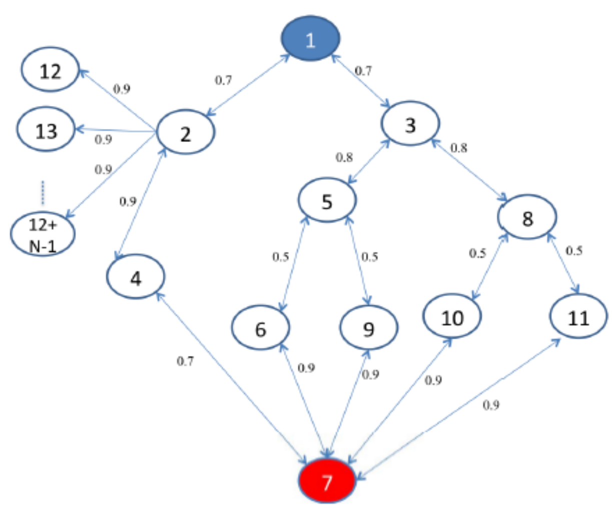
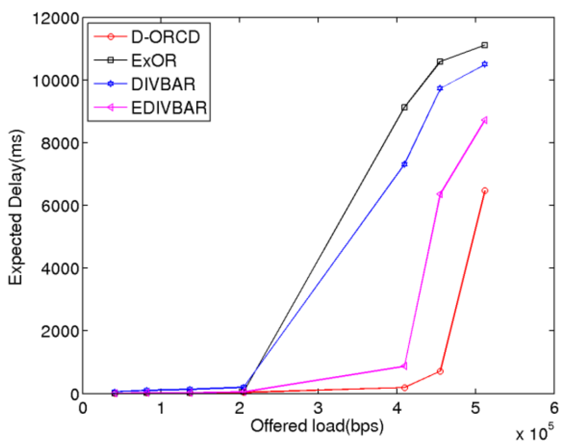
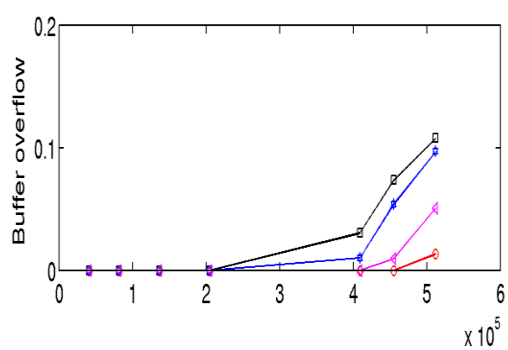


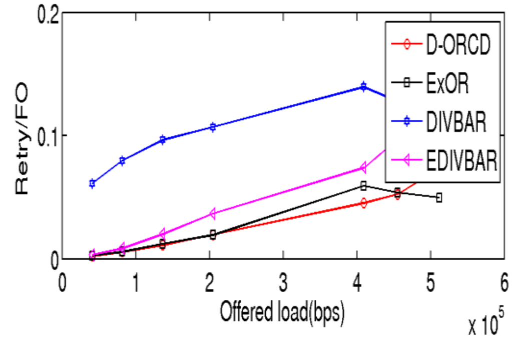
Figure 3: Structure of the canonical network from

ExOR gives higher priority to node 2 than node 3 independent of the congestion at intermediate nodes ($ETX(2,7) = 2.53$ and $ETX(3,7) = 4.36$). ExOR can thus suffer from poor delay performance as the arrival rate at node 2 approaches capacity. ExOR has the worst delay performance among all the algorithms as seen in Figure 5 particularly when the traffic load on the network is high. In observe that DIVBAR and E-DIVBAR forward significant number of packets into 12,13 and 14 increasing the interference and packet drops as well as delay. Next, study the impact of the size of the "hole"; i.e. N on the expected per packet delay. Under DIVBAR the packets that arrive at node 2 from source 1 are likely to be forwarded and wander between nodes 12, 13 . . . ,12 + (N − 1) before eventually forwarding to 4. In contrast, increasing N has no effect on the performance of ORCD. This is because $V(t) < V_{12+i}(t)$, $i = 0, 2, . . . ,N − 1$, for all time slots t, in effect, preventing the packets to enter the "hole". It provides the expected delay encountered by the source packets under various routing policies, as the size of the "hole", N, increases and the arrival rate is set to low value of 1 = 200 kbps. The figure shows that the average delay under D-ORCD is significantly lower than other candidate protocols as N increases from 1 to 5.



(a) Delay





(b) Fraction of packet loss

Figure 4: Performance for Canonical Example for N=2

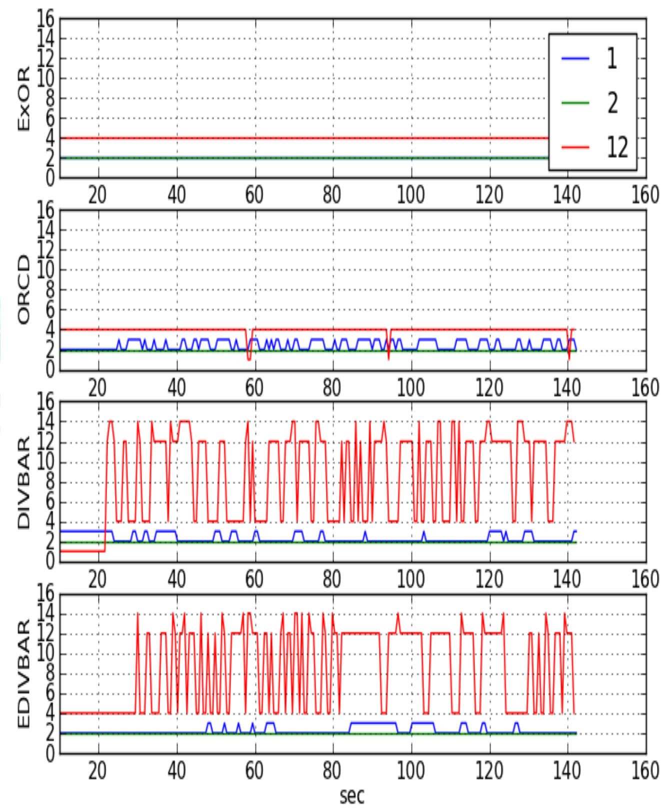


Figure 5: Highest priority nodes for Canonical Example.

VI.CONCLUSION

In this paper studied various routing algorithms for wireless mesh networks. The main objectives were classified into two categories i) determine a routing algorithm when the topology information is unavailable ii) finding routes to avoid congested paths. For the first objective, routing algorithms AdaptOR and provided a distributed opportunistic routing policy with congestion diversity (D-ORCD) combining the important aspects of shortest path routing with those of backpressure routing.

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