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A Dynamic Resource-Aware Routing Protocol in Resource-Constrained Opportunistic Networks

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Abstract: Recently, Opportunistic Networks (OppNets) are considered to be one of the most attractive developments of Mobile Ad Hoc Networks that have arisen thanks to the development of intelligent devices. OppNets are characterized by a rough and dynamic topology as well as unpredictable contacts and contact times. Data is forwarded and stored in intermediate nodes until the next opportunity occurs. Therefore, achieving a high delivery ratio in OppNets is a challenging issue. It is imperative that any routing protocol use network resources, as far as they are available, in order to achieve higher network performance. In this article, we introduce the Resource-Aware Routing (ReAR) protocol which dynamically controls the buffer usage with the aim of balancing the load in resource-constrained, stateless and non-social OppNets. The ReAR protocol invokes our recently introduced mutual information-based weighting approach to estimate the impact of the buffer size on the network performance and ultimately to regulate the buffer consumption in real time. The proposed routing protocol is proofed conceptually and simulated using the Opportunistic Network Environment simulator. Experiments show that the ReAR protocol outperforms a set of well-known routing protocols such as EBR, Epidemic MaxProp, energy-aware Spray and Wait and energy-aware PRoPHET in terms of message delivery ratio and overhead ratio.

Keywords: Opportunistic networks; mobile ad hoc networks; routing protocols; resource-constrained networks; load balancing; buffer management

1 Introduction

In opportunistic networks (OppNets) [1], contacts are unscheduled and unpredictable, so the topology is unstable and connections among them are interrupted continuously. The only information available to a node is the information it can collect from the other nodes it encounters while roaming on the network. Hence, the gathered information is of great importance as it reflects the opportunities of meeting among nodes. In contrast to stateful OppNets, stateless OppNets does not require a central entity to save and manage status for communications among devices that are appointed to the network. Therefore, any node must rely on itself to forward data packets through the network. In addition, and in contrast to social OppNets, no information about node affiliation is available in non-social OppNets. This information, if available, helps the nodes route messages to their destinations and choose the best route.

In OppNets, mobile nodes are not supposed to acquire any knowledge of the network topology. Routes from the sender to the destination of a message are created dynamically, and any possible node can opportunistically be used as the next hop. For these reasons, routing data in OppNets is a crucial challenge. Most routing protocols take advantage of contact history information to make message forwarding decisions like in Chen et al. [2]. However, due to the dynamics of OppNets, routing protocols, that depend only on contact history information, face challenges. The main challenge in OppNets is to achieve a high delivery ratio with low overhead. The basic methodology to address this issue is to flood the network with message copies, like in flooding-based routing protocols [3]. A node will have to buffer data until it gets an opportunity to forward this data. So data must be stored, sometimes for a considerable interval of time. Hence, the networking performance is guaranteed only if resources are assumed to be unlimited, which is unfortunately non realistic in OppNets because of their limited and constrained resources [4–6]. Therefore, a buffer management scheme must be implemented to handle stored data.

To conserve the network's resources, utility-based routing protocols send the message only to the intermediate nodes that are more likely to reach the destination. These nodes are considered to be the most active nodes on the network. Since the activity of the node is related to its resources, most routing policies rely on these resources when formulating message routing decisions, as in [7–9]. As a result, a small group of nodes will bear the brunt of delivering messages to their destinations as discussed in [10,11]. In Pujol et al. [12], it was shown that if the traffic is mainly concentrated on the most active nodes, the resources of these nodes are exhausted, which leads to their interruption. Due to the reduction in the number of nodes in the network, the connectivity in the network is decreased and the network performance decreases as stated in Roy et al. [13]. This problem is known as load unbalancing, which leads to congestion that has a negative impact on the network performance and ultimately incurs a bottleneck [11,14]. On the other hand, Mtibaa et al. [15] show that absolute fairness in the load distribution among nodes adversely affects performance. This is because the absolute fairness among nodes leaves active nodes, which play a key role in raising performance, underutilized.

Many researches seek to maximize the probability of message delivery by means of invoking node's attributes in the expression of the forwarding decision metric. Node's attributes describe the characteristics or reflect the state of a node, such as available buffer space, mobility speed (MobSp), bandwidth (BW), information about node's community. The impact of a node's attribute is quantified by a specific weight. In Lenando et al. [16], we proposed the mutual information-based weighting scheme (MIWS). The basic idea behind the MIWS approach is to assign each attribute a weight corresponding to the amount of mutual information between nodes' effectiveness and the attribute. In other words it quantifies the correlative relationships between the