

Chapter 20

DEAR-2: An Energy-Aware Routing Protocol with Guaranteed Delivery in Wireless Ad-hoc Networks



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Abstract Nodes can connect with each other to form a self-organizing, infrastructure-less, wireless ad-hoc network, in which every node performs the actions of both host and router. The demand for wireless ad-hoc networks is growing because of their simple and quick installation. However, the limited power of nodes and continuously changing topologies of wireless networks adversely affect the performance of wireless ad-hoc networks. A major problem is maximizing the lifetime of wireless networks while ensuring that packets are delivered to their destinations. Much research has been published on the routing protocols of wireless ad-hoc networks, but most of the algorithms focus on a single performance metric of wireless networks. In this chapter, we propose a routing protocol referred to as DEAR-2 for a heterogeneous wireless ad-hoc network. We have embedded the energy and device type awareness features of the Device and Energy Aware Routing (DEAR) routing algorithm in the face routing algorithm, which focuses only on guaranteed delivery.

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20.1 Introduction

An ad-hoc wireless network is collection of self-organizing and infrastructure-less nodes, connected with each other to form a network for transferring data within the network. These networks can be deployed anywhere without any special infrastructure such as a base station, which makes these networks extremely useful in emergencies (e.g., in disaster areas where no infrastructure is available). Two nodes can transfer data easily when they are in the range of each other. When a wireless network consists of more than two nodes but the sender and receiver are not in range of each other, then intermediate nodes can act as routers and forward the data packets to the next node toward the destination [1]. A common example of an ad-hoc network is a network of devices connected via Bluetooth without any central infrastructure. Ad-hoc wireless networks may be used because of their low cost and ease of installation; in addition, a problem with one device does not affect the whole network. However, these networks also have some issues, including the continuously changing topologies of networks and limited power [2]. In these networks, structures change so frequently that it may not be possible for hosts to know the topology of the network.

Much research has been done to design routing algorithms for the efficient transmission of data within ad-hoc wireless networks. However, most routing algorithms focus on a single performance metric, such as guaranteed delivery, energy conservation, or quality of service. In this chapter, we propose a new algorithm called DEAR-2 that focuses on two metrics: energy conservation and guaranteed delivery in ad-hoc wireless networks. The main objective for the algorithm is the confirmed delivery of data packets within the network while maximizing the lifespan of the network. In the proposed routing algorithm DEAR-2, we use device type and multiple paths for transmission from the Device and Energy Aware Routing (DEAR) algorithm [1] along with the path-finding techniques of the FACE routing algorithm [3], which provides the guaranteed delivery of packets to a destination in a planar graph to improve the performance of wireless ad-hoc networks. The FACE routing technique uses a planar graph of a wireless network, draws a line from sender to receiver, and sends data packets along this line. Whenever an edge intersects the line, it takes the current node and the starting node, then continues to traverse the graph until it reaches the destination. However, the FACE technique has one limitation when finding a route: it assumes that the network topology does not change during the transmission of the data packets. In our proposed protocol, we use a planar graph to find routing paths, but we use the paths that have more nodes powered by a constant power supply. The remainder of this chapter is organized as follows: Sect. 20.2 discusses related work, DEAR-2 is presented in Sect. 20.3, and the conclusion is presented in Sect. 20.4.

20.2 Related Work

Previously published research has aimed to improve the routing protocols of wireless ad-hoc networks. Major problems to solve for wireless ad-hoc networks include increasing the lifetime of the networks and ensuring reliable packet delivery to the destination [4].

20.2.1 *Energy-Aware Routing Protocols*

Power-Aware Routing in Ad-Hoc Networks Singh et al. [5] argued that other metrics—including the total energy consumption of a network, cost per packet delivered to the destination, and reductions to the difference in power levels among all nodes within a network—should also be considered to improve routing protocol performance, rather than just focusing on the shortness of paths in the network.

Device and Energy Aware Routing The Device and Energy Aware Routing (DEAR) protocol [1] was proposed for heterogeneous ad-hoc wireless networks. DEAR distinguishes nodes on the basis of power supply, depending on whether they are powered by a continuous supply or batteries. The main function of this protocol is to send packets through nodes with a continuous supply of power to maximize the lifespan of a network.

CLUSTERPOW and MINPOW The CLUSTERPOW protocol [6] creates clusters of nodes in the network according to their energy levels and sends packets through the routes while maintaining a maximum transmit power level for each node. The MINPOW protocol considers the total power consumption in a network rather than maintaining the power levels of individual nodes in the network.

Minimum Energy Hierarchical Dynamic Source Routing The Minimum Energy Hierarchical Dynamic Source Routing (MEHDSR) protocol is an improved version of the Dynamic Source Routing protocol. MEHDSR finds the most efficient paths for packet delivery using a flooding method. However, due to differences in the power levels of nodes and high overhead, its network lifetime is reduced [7].

20.2.2 *Guaranteed Delivery Routing Protocols*

Because wireless ad-hoc network topologies are continuously changing, guaranteed packet delivery to a destination is a major problem. Much research has been conducted to design a location-based protocol that ensures packet delivery. Location-based protocols are of three different types: restricted directional flooding, face routing, and greedy routing. We will be focusing on face routing. Some important face routing-based protocols include the FACE [3] first location-based

protocol, which ensures guaranteed delivery without flooding. This protocol uses a planar graph of a network to find routes for packet delivery. A line is drawn from the sender to the receiver, and the packet is delivered along the boundaries of faces.

The Greedy Perimeter Stateless Routing (GPSR) [8] protocol was designed using a combination of greedy routing and face routing. In this protocol, a node sends a packet to the closest node with respect to the destination, if the neighbor is closer to the destination than the sender node.

However, little work has been done to design a protocol that is efficient with respect to power consumption and packet delivery in the network. Therefore, we combined a newer version of the FACE routing technique with the power-aware routing features of the DEAR algorithm to obtain better performance in heterogeneous wireless networks.

20.3 Device and Energy Aware Routing Protocols

The DEAR protocol was designed with an aim to maximize the lifetime of a heterogeneous wireless ad-hoc network. In a heterogeneous wireless ad-hoc network, the nodes are of two types: internally powered by batteries and externally powered. In routing table entries, a binary attribute is the addition of device type, where 0 means that the device is battery powered and 1 means that the device is externally powered. In DEAR, the cost of passing the packet through an externally powered node is considered to be zero. DEAR works to pass the maximum traffic through externally powered nodes to increase the lifetime of a wireless ad-hoc network [9–16].

20.3.1 Network Lifetime Performance

In DEAR, most of the traffic is passed through externally powered nodes. Therefore, nodes powered by batteries maintain their energy levels and the lifetime of the heterogeneous wireless ad-hoc network is increased significantly.

20.3.2 Delivery Rate

As previously stated, the DEAR protocol attempts to send most packets through externally powered nodes. If two nodes communicate frequently, then the path with the maximum-powered nodes will be chosen every time. This will eventually drain the power of battery-powered nodes, thus causing a low delivery rate.

20.4 FACE Routing Protocol

The FACE routing protocol guarantees packet delivery in a planar graph. Guaranteed conveyance ensures the capacity to effectively send a message from a source to a destination. In a relative neighborhood and with Gabriel graphs, recovery from a failure in directing is possible without changing between any adjoining faces [17]. Most of the time, wireless ad-hoc networks use an uncontrolled path, changes in topology occur, and hosts may not know the topology of the entire framework. In this chapter, we attempt to coordinate a wireless ad-hoc network for which nothing is known about the framework, besides the range and the zones of the hosts to which the network can confer direction. Specifically, we consider a case in which all hosts have a comparatively wide conveyance [18].

FACE routing is based on location. A routing table is maintained; it contains information about the topology of the network and a planar graph of the indicating nodes of the network. FACE routing guarantees packet delivery to the destination in a fixed planar graph. As the topology of the wireless network changes, the routing table is also updated.

20.4.1 FACE Routing Constraints

FACE routing [3] requires a separately constructed subplanar graph of a wireless ad-hoc network and assumes that the subplanar graph of the network is static during the routing process.

20.4.2 Network Lifetime Performance

FACE routing does not focus on energy metrics. FACE tries to deliver packets to the destination through any possible way, without considering the energy levels of the nodes of the wireless network. Therefore, the performance of FACE is not good when considering energy or network lifetime metrics. Passing packets through the same path will decrease the lifetime of a wireless ad-hoc network.

20.4.3 Delivery Rate

The FACE routing protocol is specifically designed to ensure the delivery of packets from the source to the destination in a wireless ad-hoc network. In FACE, the main idea is to divide the network graph into planes in a localized manner, then to forward a message along one face or a sequence of adjacent faces that are progressing toward the destination node [19, 20].

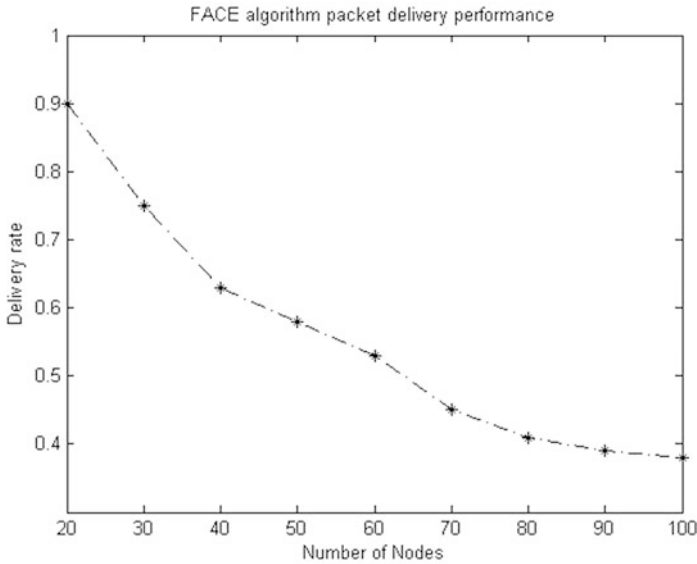


Fig. 20.1 Percentage change in the delivery rate as the number of nodes increases by a degree of 4 using the FACE routing protocol

With an increase in the degree of nodes, the delivery rate also increases (Fig. 20.1). In FACE, a packet travels through the edges that intersect the line between the source and the destination. When the packet reaches an edge intersecting with a face, then it is forwarded to the next edge. The delivery rate is high when compared with other protocols.

20.5 DEAR-2 Protocol

20.5.1 Motivation

Most routing protocols are focused on single performance metric. For example, the FACE protocol was designed with the aim to increase the delivery rate, whereas the DEAR protocol was designed to increase the lifespan of a wireless ad-hoc network. Very few protocols focus on more than one metric to improve the routing algorithm in a network, such as to maximize the lifetime of a network and increase the delivery rate at the same time. Consider a wireless ad-hoc network for soldiers to communicate with each other; here, the maximum lifetime of the network and the maximum delivery rate are both equally important. However, no protocol has been developed yet for a wireless ad-hoc network where both metrics of energy and delivery rate are important. Here, we propose the DEAR-2 protocol, which aims to provide good performance according to both metrics.

20.5.2 Design and Operation of DEAR-2

The DEAR-2 protocol uses rules from both DEAR and FACE. All devices in the wireless network are divided into two types: battery-powered nodes and externally-powered nodes. A line is drawn from the source node to the destination node. The packets traverse through edges that intersecting lines connecting the source and destination nodes. An associated planar diagram (G) segments the plane into faces, which are limited by polygonals made up of the edges of G . Steering from the source to the destination uses these faces.

Algorithm for Packet Forwarding

```

/*Address for next node through FACE */

fAddress=FACEnext ();
each entry  $d$  in routing table(RT) and redirect table(RD), do{

/* if distance from next to destination is bigger or equal
   to nearest powered node */
if (RT[d].costToDestination >=ShortestCostToPoweredNode)
RD[d].redirectToAddr = redirectPowereNode;
else
/* powered node is much distance from destination */
RD[d].redirectToAddr = fAddress;
}

```

Given a vertex v on a face f , the boundary off can be crossed in a counterclockwise course (or clockwise if f is the external face) using the notable right-hand decision [21, 22], by which it is conceivable to visit each divider in a maze by keeping your correct hand on the divider while strolling forward. A packet being forwarded from a node is calculated to find next node; it will also find the nearest powered nodes if the distance from the powered node is less than or equal to the distance of the next node selected for packet forwarding, then forward the packet to the powered node. The same method is again used to traverse through the graph to reach the destination.

20.5.3 Performance

DEAR-2 possesses the capability to increase the lifetime of a network because power is critical in a wireless ad-hoc network. This protocol also provides an increased delivery rate in wireless networks. By using externally-powered nodes to traverse through the network from the source to the destination, the lifetime of battery-powered nodes increases significantly.

Figure 20.2 indicates that the performance of the DEAR-2 protocol is similar to the performance of the FACE protocol, but provides a better delivery rate in the wireless network.

Figure 20.3 clearly shows that the lifespan of a wireless ad-hoc network increases with the use of the DEAR-2 routing protocol. This significant increase in lifespan is achieved with little overhead in calculating the distance of a powered node from the destination.

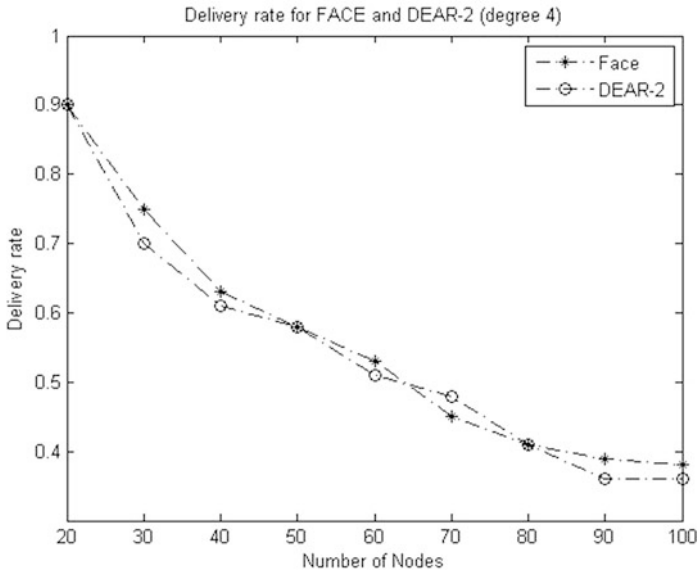


Fig. 20.2 Comparison of the delivery rates of the DEAR-2 and FACE protocols

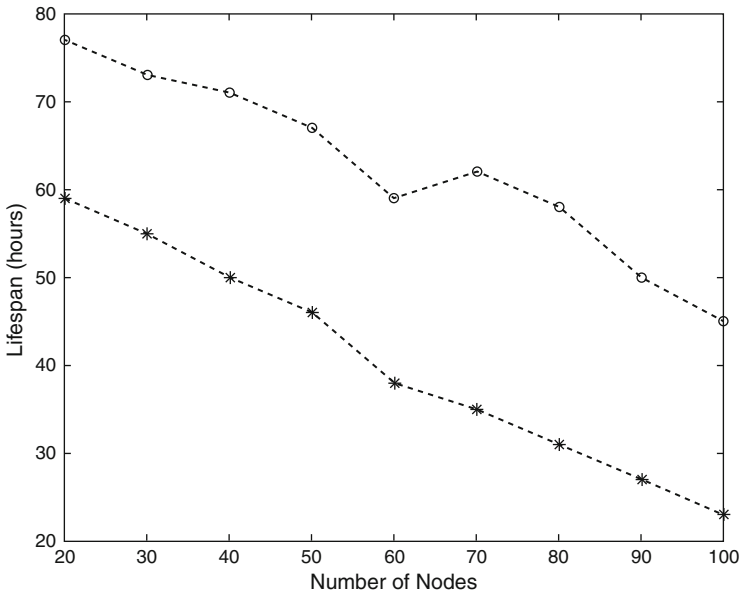


Fig. 20.3 Comparison of the network lifespans of the DEAR-2 and FACE protocols

20.6 Conclusion

In this chapter, we described the FACE routing protocol, which was designed to guarantee delivery, and the DEAR protocol, which aims to increase the lifespan of a wireless ad-hoc network. To meet the need for a protocol that focused on both the metrics of energy and delivery rate, we proposed the DEAR-2 protocol to increase the network lifetime and delivery rate. The DEAR-2 protocol was designed by adding a few steps to the FACE algorithm to use powered nodes for routing from the source to the destination.

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