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Efficient Beaconless Geographic Cross-Layer Routing Protocol: CoopGeo for Optimal Relay Selection in Wireless Ad Hoc Networks

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Abstract

Ad hoc wireless network is an autonomous self organizing system of mobile nodes connected by wireless links where nodes not in direct range communicate via cooperation of intermediate nodes. To achieve efficient communication benefits from cooperation, more interactions at higher protocol layers, particularly the MAC (Medium Access Control) and network layers, are vitally required. For this purpose, MAC facilitates a routing protocol at network layer especially Beacon-less geographic routing (BLGR), based on position location of nodes. This paper propose a cross layer framework involving two levels of joint design--a MAC network cross-layer design for forwarder selection (or termed routing) and a MAC-PHY for relay selection-over symbol-wise varying channels. Based on location knowledge and contention processes, the proposed cross-layer protocol, CoopGeo; aims at providing an efficient, distributed approach to select next hops and optimal relays to form a communication path. Simulation results demonstrate the best Relay selection and the comparative of direct mode with the cooperative networks. In addition it include security scheme in the Ad Hoc network, Asymmetric encrypting of Data packets to protect from malicious node attacks.

Index Terms: Ad hoc networks, cross-layer design, Beaconless geographic routing, cooperative networks, relay selection, forwarding and recovery phase.

Introduction

Ad Hoc wireless network which means that the users or nodes that want to communicate with each other form a self organising temporary network without any centralized administrator. Ad hoc -- a Latin phrase which means "for this [purpose]" and it also means -- no advance planning. An autonomous system of mobile hosts connected by wireless links, called *Mobile Ad hoc NETworks* (MANETs). To achieve efficient communication benefits from cooperation, more interactions at higher protocol layers, particularly the MAC (Medium Access Control) and network layers, are vitally required. For this purpose, MAC facilitates a routing protocol at network layer especially Beacon-less geographic routing (BLGR), based on position location of nodes.

Concept of BLGR:

BLGR is one of the most efficient and scalable routing solutions for wireless ad hoc and sensor networks. The key advantage of BLGR is that it needs neither the prior knowledge of network topology for making a route decision nor the periodic exchange of control messages (i.e., beacons) for acquiring neighbors' geographic locations. A current node can make its own routing decisions by using local information. In general, a BLGR protocol comprises two operating phases: forwarding phase and recovery phase. A forwarding node executes the greedy mechanism in the forwarding phase, and, if failing, switches to recovery mode to perform a face routing algorithm, finding another path to the destination.

MAC in multihop Ad hoc networks

Ad Hoc networks consist of small, inexpensive, resource constrained nodes/host/router that communicate wirelessly in a multihop network. Each node collaborates with other devices in the network to perform some operation for the end user, such as environmental monitoring or target tracking. End users typically desire to deploy nodes randomly throughout the target area in large numbers—hundreds to thousands of nodes; however, some special cases may require the precise deployment of a smaller network.

Nodes communicate by forming a multihop network to forward messages to the destination, which may collect data for later retrieval by the end user or transfer the data over a dedicated communications link. Nodes avoid direct communication with a distant destination due to the high transmission power requirements for reliably sending messages across the deployment area, which may cover a large geographical area. Despite using multihop communication to reduce energy requirements for communication, the wireless transceiver often consumes the largest amount of energy—per time period of use—within a node and, thus, provides the greatest potential for energy savings. Beyond improving the radio design, an efficient medium access control (MAC) protocol possesses the greatest capability to decrease the energy consumption of the transceiver since it directly controls transceiver operation.

The rest of the paper is organized as follows. Section 2 summarizes related work. In Section 3, we present the proposed CoopGeo with the cross-layer design for cooperative networks along with the problem statement. Section 4 gives the network model using BLGR, in which beaconless geographic routing and relay selection, along with the protocol description, are included. In Section 5, we discuss the simulation results for CoopGeo and evaluate its performance by comparing with an existing protocol. Finally, we conclude this paper in Section 6 with future outlook.

Related Work

Ad-hoc networks are infrastructure-less networks, auto configured with limited power Bandwidth. Each node participating in the network acts as both host and a router to forward packets for other nodes. Two nodes that are within transmission range of each other are called one hop neighbours. Multihop ad-hoc networks [1] [3] are ones in which the source node route the packets to destination node more than one hop away via intermediate nodes. Disaster management operations and battalion of soldiers are the example of applications of such cooperative ad-hoc wireless networks. The Cooperative ad-hoc networks [1] [8] are formed by several homogeneous wireless nodes. All the nodes cooperate with each other, (i.e.), the traffic for the nodes that are more than one hop away is routed by the intermediate nodes. The intermediate nodes are called relaying nodes or helper nodes. Cooperative relaying has been proposed as a promising transmission technique that effectively creates spatial diversity through cooperation among spatially distributed nodes. For this purpose, we propose a routing protocol CoopGeo [1] [4], based on position location of nodes obtained using GPS technology [7].

To achieve efficient communications while gaining full benefits from cooperation, more interactions at higher protocol layers, particularly the MAC (Medium Access Control) and network layers [2], are vitally required. For this purpose, MAC facilitates a routing protocol at network layer especially Beacon-less geographic routing (BLGR) [3], it is certainly a very promising research area. Geographic routing has emerged as one of the most efficient and scalable routing solutions for wireless networks. In traditional geographic routing protocols, each node exchanges periodic one-hop "Beacons" to determine the position of its neighbours [2] [4]. Since these beacons can create severe problems in real deployments due to the highly dynamic and error-prone nature of wireless links, we use Beacon-less geographic routing protocol (BLGR) [3]. It mainly focus only on physical (PHY)-layer relaying techniques. This paper, propose a novel cross layer framework involving two levels of joint design—a MAC network cross-layer [8] design for *forwarder selection* (or termed routing) and a MAC-PHY [3] [8] for *relay selection* —over symbol-wise varying channels. Based on location knowledge and contention based selection processes, the proposed cross-layer protocol, CoopGeo [1] [11], aims at providing an efficient, distributed approach to select next hops and optimal operates properly with varying densities of nodes.

A geographic relay selection scheme [4] based on the knowledge of location information of nodes. By jointly combining the source-relay and relay-destination distances, the optimal relay offering the best cooperative link can be efficiently determined. However, the selection process proposed by requires a central controller to decide which relay [6] is most helpful, leading to more overhead and power consumption. One goal of this paper is to present a distributed relay selection protocol based on, with MAC-physical cross-layer design. The Beaconless Forwarder

Planarization (BFP) scheme [6] finds correct edges of a local planar subgraph at the forwarder node without hearing from all neighbors.

To perform position-based unicast forwarding without the help of beacons, our contention-based forwarding scheme (CBF) [11] the next hop is selected through a distributed contention process based on the actual positions of all current neighbors. For the contention process, CBF makes use of biased timers. To avoid packet duplication, the first node that is selected suppresses the selection of further nodes. The BLGF mechanism [6] is carried out using the timer's settings [11], applying an area-based assignment function. In addition, a solution to detect malicious nodes [13] normally operate during determination of a route over but modifies or drop data during data transmission or report wrong information regarding a normal node, using a report message and a report table that list reporter nodes and suspect nodes.

Existing cross-layered BLGR protocol called BOSS [7] protocol, using a three-way (DATA/RESPONSE/SELECTION) handshake and an area-based timer-assignment function to reduce collisions among responses during the forwarder selection phase. BOSS, the Beacon-less On Demand Strategy for Geographic Routing in Wireless Sensor Networks. Geographic Routing (GR) algorithms require nodes to periodically transmit HELLO messages to allow neighbours know their positions (beaconing mechanism). To reduce the control overhead due to these messages, beacon-less routing algorithms have recently been proposed. However, existing beacon-less algorithms have not considered realistic physical layers.

Proposed Cooperative Cross-Layer Protocol

To avoid the drawback of existing protocol, we present a fully beaconless protocol without requiring beacons in both the greedy forwarding and recovery modes. We introduce the roles of interactions between the MAC and physical layers and between the network and MAC layers in a cooperative scenario as in fig.1.

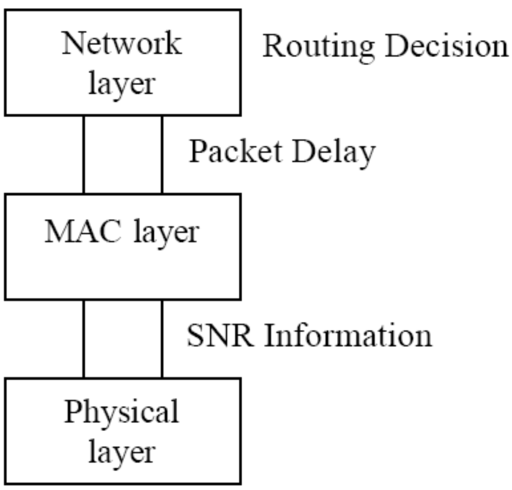

Figure 1: Cross layer protocol

The proposed cross-layer framework, called CoopGeo, consists of two joint cross-layer designs:

- A joint network-MAC design for next hop selection and
- A joint MAC-physical design for relay selection.

Issues over existing COOPMAC design with Relay solution

Two issues, routing and relay selection, are the two chief considerations. We assume that channels changes quickly enough as symbol wise varying channels.

1. When to cooperate?
2. Whom to cooperate with and how to do selection?

For the first question, intuitively cooperation may not be a requisite for reliable transmission if the direct link is of high quality. In addition, the use of cooperation inevitably introduces somewhat inefficiency due to extra protocol overhead and limited payload length. Therefore a cooperative MAC protocol should be carefully designed to prevent unnecessary cooperation [2]. A cooperation metric related to the instantaneous source-relay and relay-destination channel measurements was proposed in [5] to decide if cooperation is needed.

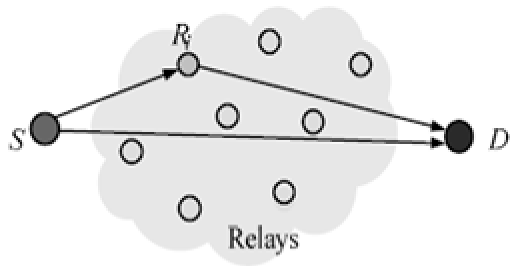

Figure 2: Wireless adhoc network with relay selection.

The second question is about cooperative MAC design addresses the typical relay selection problem. There may exist a group of available relays around the source; however, some are beneficial and some not. How to find the optimal one(s) efficiently and effectively is of vital importance to a practical MAC protocol. In particular, both the routing and relay selection solutions in CoopGeo are beaconless geographic protocols using contention-based selection processes, providing a strongly practical multi-layer integration for cooperative networks.

Hidden and Exposed node problems

The transmission range of stations in wireless network is limited by the transmission Power; therefore, all the station in a LAN cannot listen to each other. This means that normal carrier sense mechanism which assumes that all stations can listen to each other, fails. In particular, this gives rise to hidden node and exposed node problem as shown in Fig.3.

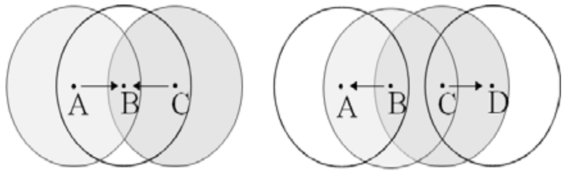

Figure 3: Hidden and Exposed node problem

A simple and elegant solution to the hidden node problem [Fig.4.] is to use small packets called RTS (Request to Send) and CTS (Clear to Send) for handshaking before transmission of data packet.

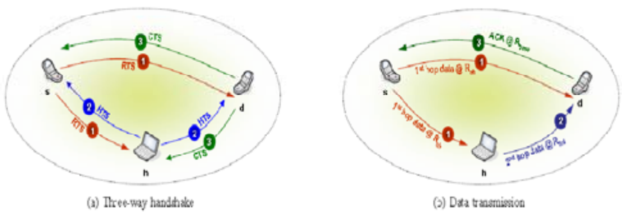

Figure 4: Solution to hidden node problem

CoopGeo: Geographic routing protocol

The routing process works in two phases, i.e. BLGF and BLRF. Both phases share equally a time interval $Tmax$ within which the forwarder selection is executed. The first half of the $Tmax$ period is allocated to the BLGF phase and the second half to the BLRF phase. In the BLGF phase, a next hop that provides maximum progress toward the destination is selected through a timerbased contention process. As failing to find a next hop in the BLGF phase, the routing process enters transparently to the BLRF phase and applies face routing by using graph planarization along with a select-and-protest principle.

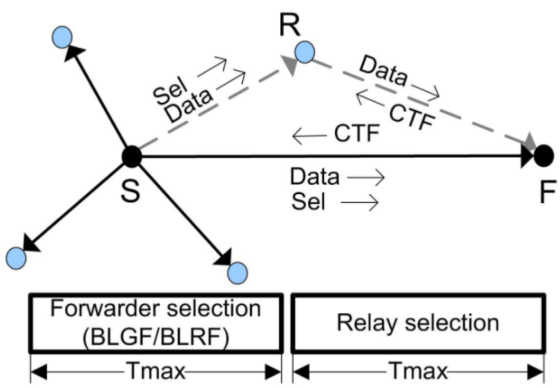

Figure 4: CoopGeo phases.

Cooperative relaying is required after the routing task whenever the selected next hop decodes the data packet erroneously. In this case, CoopGeo starts out to execute the relay selection task within another time interval , selecting an optimal relay that offers the best cooperative link between the current source and next hop. Fig.4. gives an example for both the routing and relay selections in CoopGeo.

Network Model using BLGR

Consider a wireless ad hoc network of nodes randomly deployed in an area, expressed as a dynamic graph (,), where = { 1, 2, . . . , } is a finite set of nodes and = { 1, 2, . . . , } is a finite set of links between nodes. We denote a subset ( ) ⊂, = 1, . . . , , as the neighbourhood of the node , i.e., those nodes within the radio range of . In this paper, we consider there is a single session in the network, where data delivery may cross over multiple hops. Fig 3.6 (a) depicts the wireless ad hoc network model, in which the source sends its data to the destination in a multihop manner. In this figure the dashed circle centered at illustrates the radio range of , and so on. At the beginning of every data transmission, broadcasts the data to its neighbours ( ).

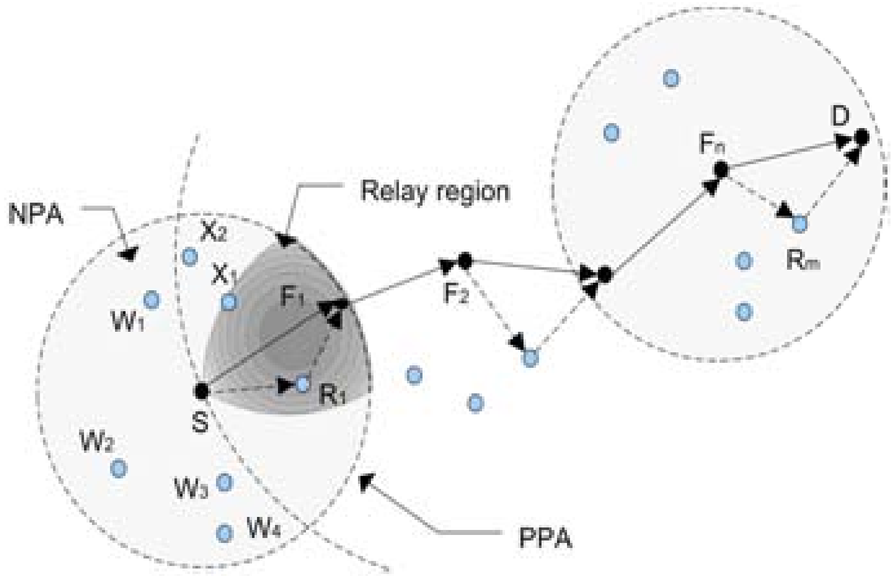

Figure 5: Network model using BLGR.

SER performance metric

The Selection metric, indicates the SER performance at the destination.

$$m_i = A^2 d^p_{S,Ri} + B d^p_{Ri,D};\ i=1,2, .., N \text{ ---} \tag{1}$$

where m_i - selection metric,

$d^p_{i,j}$ - *distance-dependent parameters* in case of M-QAM modulation,

$$A = M-1/2M+ (1-1/\sqrt{M})^2 / \text{, and}$$

$$B = 3(M-1)/8M + (1-1/ \sqrt{M})^2 /\pi$$

*Smaller the metrics, better the resulting SER performance.

Simulation and Result Analysis

First consider a single-hop cooperative relay network with n = 5 available relays, deployed in R. Denote (x, y) as the coordinates of nodes. We locate the source and the destination at (0, 0) and (1, 0) respectively, and randomly place, with uniform distribution, the relays in a square field following $\{(x, y) \mid 0 \leq x \leq 1, |y| \leq 0.5\}$. We assume that the channel variances between any two nodes follow $\sigma^2{}_{i,} \propto d^{-p}{}_{i,}$, where the path loss exponent is taken to be $p = 2$ in our simulations.

Table 1: Simulation Settings

Input	Value
No. of Neighbors Channel model Path Loss Exp. Modulation Type Constellation Size	1-15 Rayleigh 2 QAM 4-128

Result Analysis

The resulting figure depicts the SER versus SNR performance, where SNR is defined as $P/N0$ and P is the total transmit power fixed. Fig.6.1 shows that the selected best relay contributes to the minimum SER at the destination as compared to other relays.

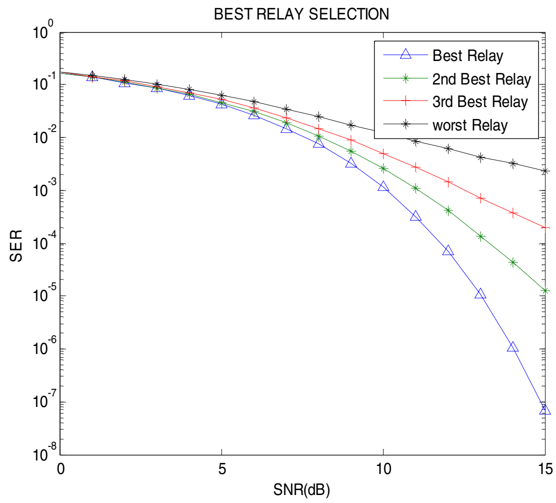

Figure 6.1: Best Relay Selection

In addition, it also reveals that worst relays corresponds to larger selection metrics, that is, the smaller the selection metrics, the better the resulting SER performances. This is because each relay has the same opportunities to be selected such that the performance will be averaged over all the distributed relays.

In the Fig 6.2, the performance of direct transmission from the source to the destination is provided as a benchmark for a non-cooperation scheme is compared with the Cooperative relay selection scheme, which results in High Performance with the Cooperative scheme.

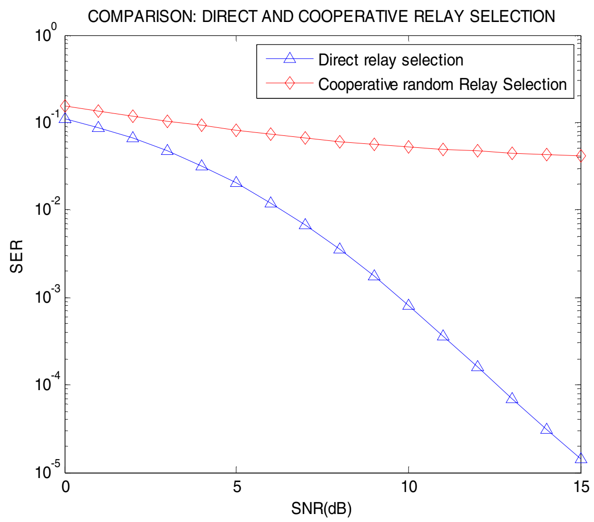

Figure 6.2: Cooperative mode Vs Direct mode

Conclusion

The advantage of position-based geographic routing over other ad hoc routing protocols is the fact that nodes require only knowledge about the local neighborhood and the destination's location instead of global route topology. Therefore, position-based routing is better suited for networks with a certain degree of mobility. Thus we have proposed a cross-layer protocol CoopGeo based on geographic information to effectively integrate the network, MAC, and PHY layers for cooperative wireless ad hoc networks. The CoopGeo provides a MAC-network cross-layer protocol for forwarder selection as well as a MAC-PHY cross-layer protocol for relay selection. Simulation demonstrates that the selected best relay contributes to the minimum SER at the destination as compared to other relays. In addition, it also reveals that worse relays corresponds to larger selection metrics, that is, the smaller the selection metrics, the better the resulting SER performances. It also demonstrates that by using the geographical information, nodes in cooperative networks can efficiently perform relay selection than the direct relay to improve the SER performance at the destination.

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