

Survey of MARS: Spatial Link Quality and Node Positioning in Wireless Relay Network

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Abstract—Multihop wireless relays can extend the area of network connectivity instantly and efficiently. However, due to the spatial dependence of wireless link-quality, the deployment of relay nodes requires extensive, expensive measurement, and management efforts. This paper presents a mobile autonomous router system, (MARS) through which a relay router autonomously seeks and adjusts the best “reception” position for itself and cooperatively forms a string-type relay network with other neighboring routers. Specifically, MARS 1) accurately characterizes spatial link-quality through a new measurement technique, 2) effectively probes/optimizes node positioning via a spatial probing algorithm, and 3) maintains error-tolerant position information via an inexpensive positioning algorithm. MARS has been prototyped with both a commodity mobile robot and a wireless router with IEEE 802.11 cards. Our experimental evaluation of both the MARS prototype and ns-2-based simulation show that MARS achieves an average of 95 percent accuracy in link-quality measurements, and reduces the measurement effort necessary for the optimization of a node’s location by two-thirds, compared to exhaustive spatial probing.

Index Terms—Wireless relay networks, robot-based wireless router, wireless link-quality measurement, IEEE 802.11

I INTRODUCTION

OVER the last decade or so, wireless relay networks have attracted considerable attention due to their potential for instantly and inexpensively extending network coverage [1], [2]. For example, relay nodes can be deployed in a string or a tree topology to existing wireless backhaul networks for emergency response or outdoor events. However, channel fading and shadowing often degrade the quality of wireless links and require time-consuming and expensive network deployment and management efforts, especially for manual adjustment of nodes’ placement and configuration [3]. Significant efforts have been made to improve quality-of-service (QoS) and reduce management costs of wireless relay networks. For example, measurement-driven deployment of relay nodes determines their placement positions that meet the required network QoS [4]. Rate-adaptation and transmission-power-control algorithms allow for dynamic selection of modulation schemes and transmit-power levels at fixed positions [5], [6]. Multiple-input-multiple-output (MIMO) or multiple interfaces enable a node

to exploit spatial diversity by adaptively choosing the best antenna or antenna element [7], [8]. In spite of these efforts, wireless relay networks still suffer from several fundamental limitations as follows: First, changes in the physical environment of a wireless relay network (e.g., due to dynamic obstacles and interferences) often calls for manual link-quality measurement and node relocation over a large coverage area which are tedious, time consuming and costly. Second, even if relay nodes can make simple movements to improve link bandwidth, these adjustments determined by geographic distance or node density are not guaranteed to meet the overall QoS requirement of networks [9], [10]. Third, relay nodes may be able to relocate themselves “optimally” (in some sense) by using simple signal-to-noise ratio (SNR) or traffic volume information. However, accurate characterization of spatial wireless link-quality along with efficient node relocation is key to the efficient (re-)formation of relay networks [11]. In this paper, we study the feasibility of using a commodity mobile robot for addressing some of the limitations mentioned above. Specifically, we propose a mobile autonomous router system (MARS) that enables a wireless relay node to 1) characterize wireless link conditions over the physical space and 2) seek and relocate to, the best reception position to form string-type relay networks. Specifically, MARS is

equipped with a measurement protocol that defines and characterizes spatial wireless link-quality. This measurement protocol controls each MARS node, mounted on a mobile robot, to move and measure wireless link-quality over the deployment area. Furthermore, based on the raw measurement results, the protocol extracts unique correlations of link-quality with environmental factors, such as distance, obstacles, or interference sources, which are useful in reducing the measurement space (see Section 5.3). Here, MARS focuses on the string-type relay network that allows for the easy

II SURVEY RESULTS

MARS ARCHITECTURE

MARS is designed and operates as follows: Initially, a MARS node receives the bandwidth requirement of link to AP or a neighboring node and then checks if the node's current position meets the requirement, labeled as satisfiability check in the figure. If the current position does not meet the requirement, MARS then decides which direction it has to move-and-measure based on previous link-quality information. Next, if further measurements are necessary, MARS moves to a different location and measures the linkquality at the new location (Measurement). Based on the measured link-quality, MARS again checks the bandwidth satisfiability. This procedure is repeated until MARS finds the position that satisfies the bandwidth requirements. Finally, for each movement, MARS maintains the node's position information (Position) using the distance information periodically measured by sonar sensors.

MEASUREMENT PROTOCOL

MARS is equipped with a measurement protocol that defines and characterizes spatial wireless link-quality. This measurement protocol controls each MARS node, mounted on a mobile robot, to move and measure wireless link-quality over the deployment area. Furthermore, based on the raw measurement results, the protocol extracts unique correlations of link-quality with environmental factors, such as distance, obstacles, or interference sources, which are useful in reducing the measurement space. MARS focuses on the string-type relay network that allows for the easy

deployment of extended backhaul links between remote endpoints.

SPATIAL PROBING ALGORITHM

MARS includes a spatial probing algorithm by which the node can efficiently find its optimal position that satisfies the bandwidth demand on its link. This probing algorithm guides the robot to identify a space to probe. This space is then explored at progressively finer resolutions until a locally optimal position is found. Moreover, the algorithm enables a set of MARS nodes to cooperatively form and adjust wireless relay networks in case link conditions or QoS demands change. MARS focuses on QoS demands of backhaul links, excluding client-to-access node links. Access node (i.e.,MARS) can aggregate QoS demands from multiple clients that are associated with it and then use the aggregate demands to form relay links.

POSITIONING SYSTEM

The final component of MARS, a positioning system, that provides the location information of a node. The function of a positioning system is to continuously maintain the accurate location information of a node for both derivation of spatial link-quality and relocation to previous measurement areas. MARS uses an infrastructureless hybrid positioning system, especially for indoor environments. The system is designed for using DR combined with landmark-based positioning. To build the landmark information, the positioning system includes a semiautomated landmark collection procedure.

III PROPOSED METHODS

The feasibility of using a commodity mobile robot for addressing some of the limitations mentioned above. Specifically, a mobile autonomous router system (MARS) that enables a wireless relay node to characterize wireless link conditions over the physical space and seek and relocate to, the best reception position to form

string-type relay networks. Specifically, MARS is equipped with a measurement protocol that defines and characterizes spatial wireless link-quality. This measurement protocol controls each MARS node, mounted on a mobile robot, to move and measure wireless link-quality over the deployment area. Furthermore, based on the raw measurement results, the protocol extracts unique correlations of link-quality with environmental factors, such as distance, obstacles, or interference sources, which are useful in reducing the measurement space. Here, MARS focuses on the string-type relay network that allows for the easy.

IV. CONCLUSIONS

MARS—a mobile wireless router that is aware of spatial diversity in wireless link quality. MARS autonomously measures spatial wireless link-condition and reforms a wireless relay network with neighboring nodes. Built MARS' prototype using commodity robots and IEEE-based wireless routers. The MARS's positioning system keeps the average location errorless than 7.3 cm, MARS probing algorithm saves energy by up to 54 percent (for the grid size of 0.25 m). In addition, as the grid size decreases, the energy savings comes from the reduced navigation distance (i.e., Hier-Dist) as well as the reduced number of measurements (Hier-Measure) achieved by the MARS's hierarchical probing algorithm. Using extensive experimental evaluation, demonstrated the feasibility and practicality of MARS for dynamic (re)formation of a multihop relay network.

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