Demo Abstract: A Cooja-based Tool for Maintaining Sensor Network Coverage Requirements in a Building

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ABSTRACT

Contiki's Cooja is a very popular Wireless Sensor Network (WSN) simulator, but it lacks support for modelling sensing coverage. We introduce WSN-Maintain, a Cooja-based tool for maintaining coverage requirements in an in-building WSN. To analyse the coverage of a building, WSN-Maintain takes as input the floorplan of the building, the coverage requirement of each region and the locations of sensor nodes. We take account of the heterogeneity of device specifications in terms of communication capability and sensing coverage. WSN-Maintain is run in parallel with the collect-view tool of Contiki, which was integrated into the Cooja simulator. We show that WSN-Maintain is able to automatically turn on redundant nodes to maintain the coverage requirement when active nodes fail and report failures that require physical maintenance. This tool allows us to evaluate different approaches to maintain coverage, including deferring physical maintenance to reduce operational costs.

Categories and Subject Descriptors

[**Networks**]: Sensor networks

General Terms

Design, Reliability, Performance

Keywords

Sensor Networks, Post-Deployment, Coverage Maintenance

1. INTRODUCTION

Maintaining coverage in an in-building Wireless Sensor Network (WSN) poses several challenges. Firstly, a building itself may evolve. Physical obstacles such as walls and doors, that limit sensing coverage, are often removed or added when a refurbishment is carried out. Secondly, coverage requirements may change. Rooms that are later dedicated for server or electrical purposes may require a higher degree of sensing coverage compared to office spaces. When the building and the requirements change and nodes fail, the network must evolve. In this case, redundant nodes need to be turned on to maintain coverage. Contiki's Cooja [1] is a very popular WSN simulator, but it lacks support for modelling sensing coverage. We propose WSN-Maintain, a Cooja-based tool that takes the floorplan of the building, the coverage requirement of each region and the locations of sensor nodes for analysis. In the demonstration, WSN-Maintain is run in parallel with the collect-view tool of Contiki, which was integrated into the Cooja simulator. When a user simulates node failures by killing nodes in WSN-Maintain, it can either automatically turn on redundant nodes to maintain coverage or report failures that require physical maintenance.

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2. WSN-MAINTAIN: BASIC DESIGN

WSN-Maintain is designed to allow users to evaluate different techniques to turn on redundant nodes to maintain coverage. Users can import the floorplan of a building from an XML file or manually draw one by clicking and dragging walls and doors on its canvas. While we use walls and doors as indoor obstacles that can limit communication and sensing capabilities, for simplicity, we currently do not consider the types of construction materials used. In addition to the floorplan, users can click on the canvas to place sensor nodes or load their locations from a file. We currently use the Tmote Sky hardware [2] and consider the heterogeneity of device specifications by allowing users to select different power levels and sensing ranges for each node.

WSN-Maintain exports a topology file in XML format that can be loaded by Cooja. When using the Unit Disk Graph Model (UDGM), the file contains node locations, transmission range, interference range, transmission success ratio and receive success ratio. As we follow the specified format of XML files from Cooja, we can only create a network with homogeneous communication capabilities using UDGM. That is, all sensor nodes have the same range and receive success ratio. To create a heterogeneous network, users may opt for Directed Graph Radio Medium (DGRM). With DGRM, WSN-Maintain automatically calculates Received Signal Strength (RSS) and receive success ratio for every pair of sensor nodes using the formula specified in [6, 5]. The parameters used in the calculation for both Line-of-Sight (LOS) and Non-Line-of-Sight (NLOS) conditions are based on real experiments using Tmote Sky reported in [3].

We use the binary detection model and Elfes's model described in [4] to create a coverage map of the building. With the binary model, the probability that a sensor node senses

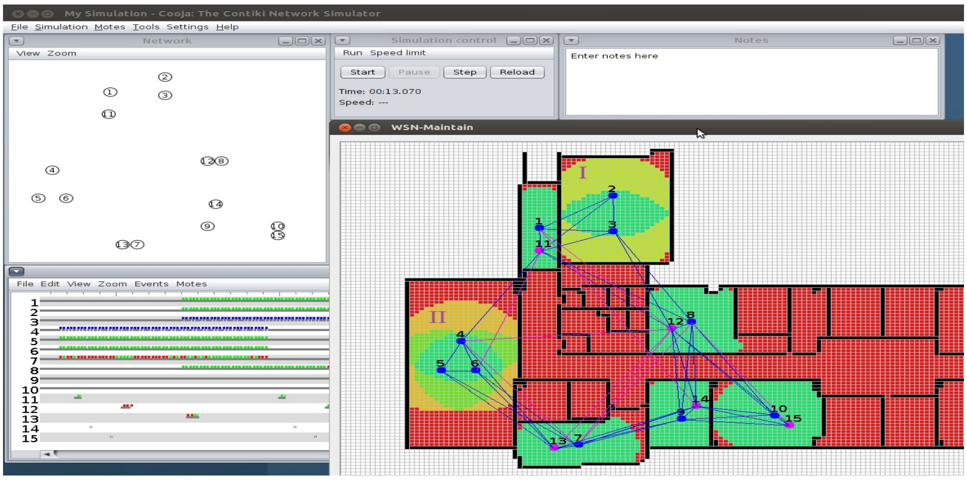

Figure 1: WSN-Maintain runs in parallel with Cooja

a point in a floorplan is 1 if the distance between them is less than or equal to the node's sensing range. Elfes's model introduces a grey area between $r - r_e$ and $r + r_e$, where r is the sensing range and r_e ($r_e < r$) is a measure of uncertainty in sensor detection. We currently approximate $r_e = 0.25 \times r$ and set the probability threshold to 0.9, i.e. a point cannot be sensed if its probability is less than this threshold. In this work, we assume that sensor nodes cannot sense through walls and doors. We also assume that users may require different coverage degrees for special rooms, such as a server room and an electrical room. WSN-Maintain allows users to do this by clicking a point inside a room and specifying the coverage requirement. The total coverage percentage is calculated as the ratio of the total area satisfying the coverage requirements to the total interior area of the building.

We demonstrate WSN-Maintain by running it in parallel with the collect-view tool of Contiki, which was integrated into the Cooja simulator. There is a two-way interaction between WSN-Maintain and Cooja. WSN-Maintain can read the log file generated by collect-view to get nodes' remaining energy and to identify node failures. When a node dies, the coverage percentage decreases. If the coverage percentage is below a threshold, WSN-Maintain will either automatically find and turn on non-overlapping redundant nodes to maintain the coverage requirement or report failures that require physical maintenance. WSN-Maintain communicates with Cooja regarding the on/off status of nodes through a binary file, which is created by WSN-Maintain and read by Cooja. During the demo session, users are invited to interactively use WSN-Maintain to simulate node failures by killing nodes and to see the results of WSN restoration.

3. PRELIMINARY EVALUATION

Figure 1 shows a snapshot of the prototype implementation of WSN-Maintain and Cooja that simulates a data gathering application. The floorplan shown is the first floor of a building on our campus. 15 sensor nodes are placed arbitrarily in 7 rooms, where nodes number 11 to 15 are redundant nodes. All rooms have a coverage requirement equal to one, except rooms I and II have requirements equal to two and three, respectively. WSN-Maintain visualises the coverage map with colours ranging from red to green. Red area (darker colour if the figure is in grayscale) means the coverage requirement is not satisfied at all, while green (lighter colour in grayscale) means the requirement is satisfied. For example, when a user turns node 8 off, WSN-Maintain will turn on redundant node 12 to maintain the coverage. These changes will be informed to Cooja through a binary file that contains the on/off status of all nodes. Cooja will act accordingly by turning off node 8 and turning on node 12.

4. SUMMARY AND FUTURE WORK

We present WSN-Maintain, a Cooja-based tool to maintain coverage requirement in an in-building WSN. While in the demo session we only turn on non-overlapping redundant nodes to improve coverage, our future work will include techniques to schedule, predict and defer the physical maintenance. WSN-Maintain allows us to evaluate different algorithms for these purposes.

5. ACKNOWLEDGMENTS

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