A Robotic-aided IoT System for Automatic Deployment of 6TiSCH Networks

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***Abstract*—The automated deployment of Internet of Things (IoT) systems in industrial environments is an open challenge at the edge of networking and robotics domains. In this work, latest research by the authors in the development of a robotic-aided deployment system is presented. To this end, a design methodology has been conceived to attain the set up of a fully connected IoT network in a target area, based on the measured Received Signal Strength Indication (RSSI) of wireless links, required spatial sensing resolution, and number of available IoT nodes. To demonstrate the effectiveness of the proposed methodology, an experimental testbed has been set up, consisting of an Unmanned Ground Vehicle (UGV) that automatically deploys an IoT network both in a laboratory and outdoor environment. Experimental results clearly show that the UGV is able to deploy a fully connected 6TiSCH network that matches spatial resolution requirements, highlighting how the proposed policy affects the position of IoT nodes release points.**

***Index Terms*—robotic-aided IoT, automatic deployment, industrial internet of things**

I. Introduction

Nowadays, IoT technologies are considered as the angular stone of the Industry 4.0 digital innovation process. In this context, one of the key challenges to face is the automated deployment of industrial IoT networks, especially in harsh and/or large scale environments [1]. Robots can effectively face this challenge thanks to their inherent capability to execute tedious and repetitive tasks [2], such as the placement/maintenance/replacement/configuration of multiple IoT nodes (known as motes) also in wide environments. When wireless technologies are used, the optimal placement of a finite number of motes within a target area entails several competing requirements that should be properly traded off. From one hand, based on the monitoring application, a minimum number of motes per surface unit should be deployed to pursue the desired spatial sampling resolution of the phenomena of interest [3]. On the other hand, the placement of the different motes should consider the radio signal strength, which is very hard to predict in industrial environments, in order to result in a fully connected IoT network [4]. In addition, upon deployment, each mote should be fully configured in order to make it able to exchange data with the rest of the network. The configuration involves all layers of the protocol stack. Therefore, the robots in an automated deployment system should be able to: self locate themselves within the area of interest, sense the radio signal strength, and physically release the motes according to ad hoc decision rules. The robotic-aided IoT deployment systems proposed so far [3]-[5] implicitly or explicitly assume that radio communications between motes are omni-directional and symmetric in all directions. This assumption is very far from reality since shadowing, scattering, and multipath propagation completely break the circular symmetry of any real communication process, especially in industrial environments, as very well known from basic digital communication theory and practice [6]. To bridge this gap, a robotic-aided IoT deployment system is proposed hereby, which uses an unmanned vehicle for the automated deployment of a 6TiSCH network, based on actual measurements of radio signal strength. The 6TiSCH technology has been considered as a representative example of industrial IoT stack, but the methodology proposed hereby can be adapted, with appropriate customizations, to any IoT protocol architecture. In this scenario, recent and current research by the authors is aimed at studying and developing a robotic-aided IoT deployment systems in harsh and/or large scale environments [7]– [9].

II. Contribution

The main contribution of this work is to instruct an unmanned vehicle to: (i) dynamically map the environment in terms of radio signal propagation, (ii) verify the most convenient release points for each IoT device, and (iii) deploy and configure these network entities. The envisioned solution is able to constantly monitor the environment searching for the optimal position to release the IoT device while keeping trace of the number of release events. After each release event, IoT devices are able to autonomously execute synchronization tasks, while creating and maintaining stable links. In this way, an automated deployment, based on the actual connectivity parameters, becomes possible. An experimental campaign has been carried out both in a laboratory and in outdoor environment, focusing on the release policy of the IoT nodes affected by the RSSI value during the area patrolling. The obtained results showed that the adoption of a release policy sensibly affected the actual deployment, thus granting network connectivity.

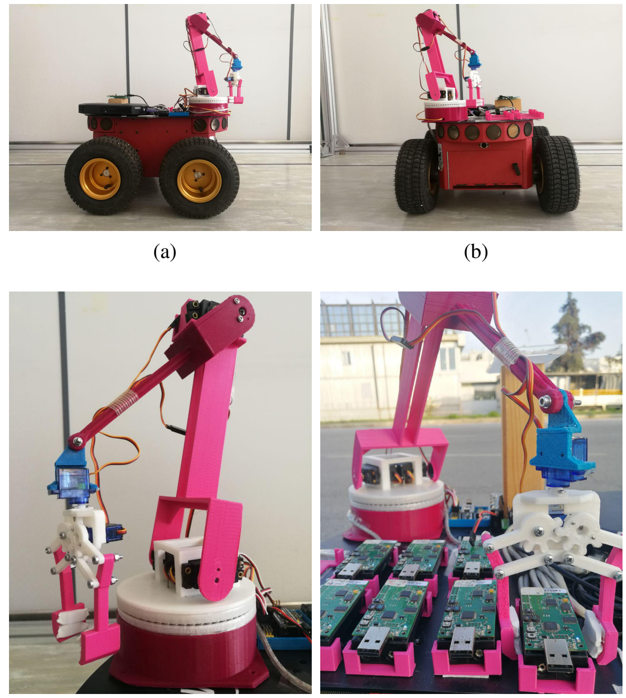
III. Proposed approach

The proposed approach can be briefly illustrated through the following points (more details can be found in [9]):

- an UGV moves along a pre-defined trajectory and spans a given area of interest to automatically deploy IoT devices;
- the starting point of the path is located in close proximity with a network coordinator, which operates as a local base station for the network to be deployed, hereinafter referred to as ground network;
- the UGV carries an onboard patrolling network made of an on-board coordinator and a set of nodes to deploy. Moreover, the UGV is equipped with a probing node, connected to the ground network, that senses the surrounding area in search of radio activity;
- the UGV releases IoT nodes while it moves along its trajectory, based on the actual RSSI of wireless links, target coverage area, required spatial sensing resolution, and number of available IoT nodes;
- once released, the IoT device is added to the ground network and becomes able to monitor environmental parameters.

IV. Experimental Setup

The envisioned setup, illustrated in Fig. 1, is composed of a robotic unit and IoT devices. The former is a Pioneer3-AT, an four-wheel drive UGV equipped with a manipulator devoted to the physical deployment of the network nodes. The IoT devices involved in the experimental setup are the Telos rev B, also known by the name of TelosB, a well known hardware platform that has been used in both academic research activities and industrial deployments over the latest ten years [7] [10]. Then, the deployment algorithm has been functionally evaluated together with the release procedures considering different strategies. More details can be found in [9].



(a) (b) (c) (d)

Fig. 1: Experimental setup: the Unmanned Ground Vehicle, side (a) and rear (b) view, the robotic manipulator (c), and the IoT motes to be deployed (d).

V. Conclusions

Innovative results in the context of robotic-aided IoT have been illustrated. The activities concerned in particular the development of a robotic-aided approach for automated IoT network deployment in environmental monitoring applications. As for future research, an extended multi-robot experimental evaluation for the deployment problem is highly recommended. Moreover, the presence of obstacles could not only lead to a trajectory change for the UGV.

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