A Mobile Platform for Measurements in Dynamic Topology Wireless Networks

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1 Introduction and Motivation

In the last years, cooperative wireless networks have quickly gained the interest of many researchers in the scientific community. Several studies have shown how performance of a wireless network can be improved by using principles of cooperation [2, 7]. A novel architecture, namely cellular controlled peer-to-peer (CCP2P), has been introduced in [3]. According to it, cellular devices can create cooperative clusters with neighboring devices in their proximity using a short range technology. Each terminal is then contributing to the cooperative cluster by sharing its cellular link. The grouped members acting in a cooperative manner can achieve better performance than a stand-alone device, in different scenarios. Performance can be improved in terms of data rate, as described in [9], where authors show the improvements achieved for mobile web browsing applications. In other cases, performance can be improved in terms of energy consumption, as shown in [6, 8]. In these papers, authors show that by using the CCP2P architecture for streaming and file downloading, the energy consumption can be reduced and the quality of the service can even be increased. For other examples of performance improvements, we refer the interested reader to [4].

Authors in [10] have carried out some energy and throughput measurements on state-of-the-art mobile phones, which cooperate over IEEE 802.11b/g short-range links. During the measurement phase, the mobile phones were in a fixed position. This is in contrast with what usually happens in a real world scenario, where the topology of the network is rapidly changing due to the user mobility. Therefore, with such kind of measurements, it is not possible to quantify the effect that the changes in the topology would cause. To overcome this problem, some software can be used

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to simulate cooperative wireless networks, namely Netlogo [1]. However, simulations usually give only an approximation of real world scenarios. Another approach could be to make experimental measurements in a real environment. However, this is not trivial to implement, especially if limited resources are available.

To trade off the need of a realistic performance evaluation and the costs of on-the-field measurements in this chapter, we design and test a simple and cheap platform, which can be used to perform measurements in mobility. Recently, the term *Internet of Things* has gained popularity in the scientific community. It refers to a number of technologies and research disciplines that enable the Internet to reach physical objects. This is another research area where it could be important to have a tool like the one we designed, which helps to make experimental measurements of a dynamic environment.

This chapter is organized as follows. In Sect. 2, a detailed overview of the designed platform is given. Sections 3 and 4 introduce the possible communication architectures for the platform and some examples of applications, respectively. Finally, Sect. 5 presents our conclusions.

2 The Proposed Mobile Platform

In this chapter, we introduce a mobile platform designed to optimize measurements for mobile wireless networks with dynamic topology. The platform, in the following referred as the *robot*, is shown in Fig. 1. The robot consists of two main blocks, namely the *mechanical block* (used for the motion) and the *controller block* (used for controlling the engines for motion).

The *mechanical block*, shown in Fig. 2, is composed of two engines, two wheels, a battery pack, and a metal platform to host a mobile phone.

The core of the *controller block* is the *Opensensor* (see Fig. 3), a circuitry board developed by Mobile Devices Group at Aalborg University in Denmark [5]. It is a highly integrated device that supports different kinds of data communication interfaces such as Bluetooth, RS232 (or USB), and an nRF905 antenna. By using these different interfaces, the *Opensensor* can receive commands for the motion and transmit them to the engines. This makes it possible for the robot to be remotely controlled by:

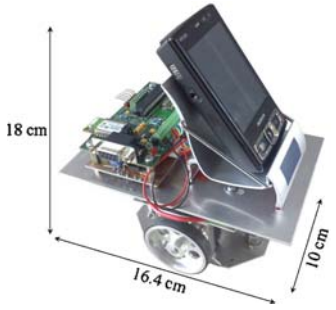
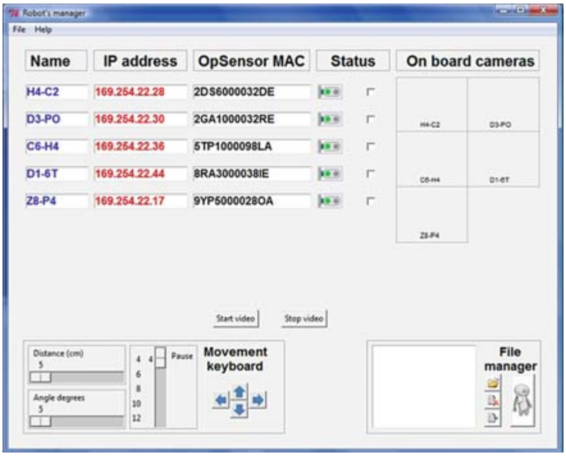


Fig. 1 Picture of the *robot*, the mobile platform designed for carrying out measurements for mobile wireless networks with dynamic topology

Fig. 2 Mechanical block: it is composed out of two engines, two wheels, a battery pack and a metal platform to host the mobile phone

Fig. 3 Opensensor, the core of the controller block



Name	IP address	OpSensor MAC	Status	
H4-C2	169.254.22.28	2DS6000032DE	●	☐
D3-PO	169.254.22.30	2GA1000032RE	●	☐
C6-H4	169.254.22.36	5TP1000098LA	●	☐
D1-6T	169.254.22.44	8RA3000038IE	●	☐
Z8-P4	169.254.22.17	9YP5000028OA	●	☐

On board cameras

Fig. 4 Graphical user interface of the application developed for controlling the robot using a PC

- PCs (using either Bluetooth or a cable)
- Bluetooth-enabled devices (including mobile phones or Opensensor)
- Opensensors (using the nRF905 antenna)

To easily control multiple robots during measurements, an application for PCs has been developed. A daemon program is running in the background and waiting for robots to connect. Upon a successful connection, the information regarding the connected robot pops up on the screen. By using the Graphical User Interface, shown in Fig. 4, it is possible to select one or more robots to control. Each of them can receive a single movement command or a script with a list of movement commands for automatizing measurements.

All the information for building, programming, and using the robot are available for the scientific community on the project webpage [11].

3 Communication Architectures

As mentioned in the previous section, the high flexibility of the platform allows the robots to be remotely controlled by using several technologies. In this chapter, we give a short description of four possible communication architectures for controlling the robot. Each of them is characterized by different communication links and devices involved, as shown in Fig. 5.

Architecture 1. In this architecture, a Bluetooth connection is established between the Opensensor board and the phone sitting on the robot. Another phone can be used to remotely control the robot by establishing a Wi-Fi ad-hoc connection with the phone (that will forward the commands back to the Opensensor). Finally, the Opensensor sends the right pulses to the engines for the motion. If many robots need to be controlled, the messages are broadcasted to all the phones sitting on the robots.

Architecture 2. This architecture is very similar to the previous one, but a PC is used as a controller instead of a phone. The Graphical User Interface on the PC makes it very easy to control one or more robots at the same time.

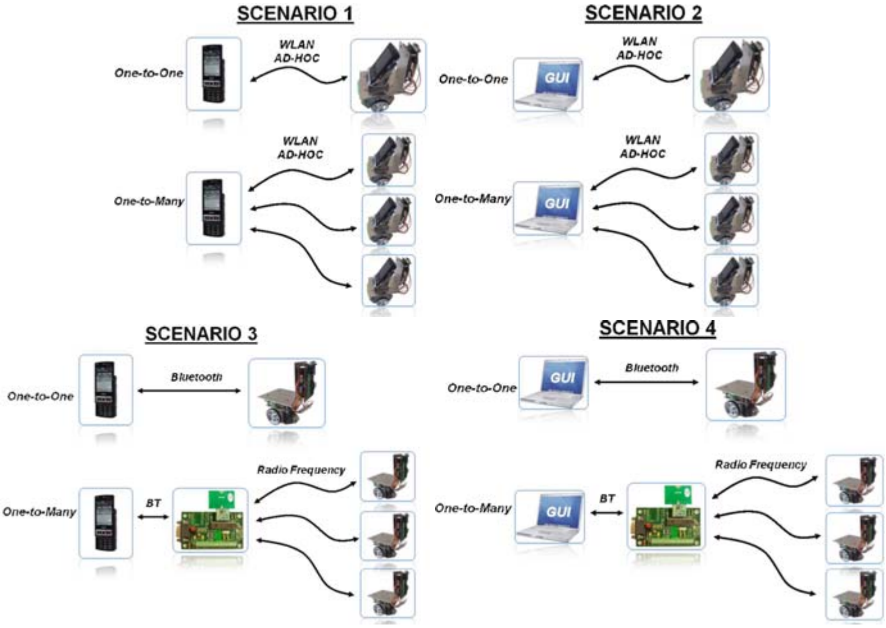


Fig. 5 Architectures overview

Architecture 3. For this architecture, in the one-to-one topology, the mobile phone controlling the robot is connected directly to the Opensensor using Bluetooth. The main limitations of this architecture are two. Firstly, the number of devices in a piconet is limited to 8 by the Bluetooth standard. Secondly, the communication range is limited to 15–20 m. For these reasons, to implement the one-to-many topology, an extra Opensensor is connected to the phone and the commands are sent to the robot using the nRF905 antenna, as shown in Fig. 5.

Architecture 4. This architecture is very similar to the previous one, with the difference that a PC is used instead of a mobile phone to act as the controller.

4 Examples of Applications

In this section, we present some usage examples of the robot. There are two main categories of usage depending on the scenario:

Passive transport. In this scenario, the robot carries a phone around as a passenger, meaning that no communication link is established between the motion part of the robot and the phone. The phone is free to take measurements in the environment with its internal sensors. The robot is controlled using a second phone, as in the communication architectures 3 and 4 described in Sect. 3. An example for this scenario is to use the mobile phone carried on the robot for making energy or throughput measurements over the IEEE802.11b/g connection with other mobile phones. In this case, it is very important that the phone does not have any other open connection to avoid interference with the measurements. The movement commands can be preset in a script file sent to the robot before starting the measurements.

Active transport. In this scenario, the phone sitting on the robot has a connection open with it. This allows the phone to control directly the robot and therefore being in charge of the mobility. This can be done using the communication architectures 1 and 2 described in Sect. 3. This could be useful in scenarios where the robot has to track and to chase moving objects or if the phone collects data using its internal sensors (GPS, light sensor, microphone, camera), and it has to move accordingly to some occurring events.

4.1 Passive Transport Scenario

In order to test the robot in a *passive transport scenario*, we have made some throughput measurements of the IEEE802.11b/g connection between the controlling phone and the transported one. It is important to note that the main goal of this chapter is to present this new tool for measurements in wireless networks, rather than give accurate measurements results.

4.1.1 Example 1: Direct Transmission

The location for this measurement is a corridor, approximately 30-m long. To carry out this measurement campaign two Nokia N95 8GB mobile phones have been used, one as the sender and the other one as the receiver. The sender is standing at one end of the corridor, whereas the receiver is placed on the robot. The robot is moving in a straight line from the sender to the opposite end of the corridor with low speed (see Fig. 6). The sender is continuously sending UDP packets of 1 KB to the receiver over a Wi-FI connection. The receiver sitting on the robot measures the throughput. In Fig. 7, the throughput of the transmission is shown and, as expected, the throughput decreases along with the distance between sender and receiver.

4.1.2 Example 2: Transmission Relay

In the second example, the sender and the receiver are not in the transmission range. They are located one at the beginning and one at the end of a 30 m L-shaped corridor. The setup of the experiment is shown in Fig. 8. In this setup, the direct transmission is not possible because the sender and the receiver are not in the range of connection. Therefore, a relay becomes strictly necessary to assure a transmission from the sender to the receiver. We use two phones as sender and receiver, and a third one, sitting on a robot, as relay. After setting up a Wi-Fi ad-hoc network among the three phones, the sender starts the transmission. The relay receives the packets, computes the throughput, and forwards them to the receiver, which computes the

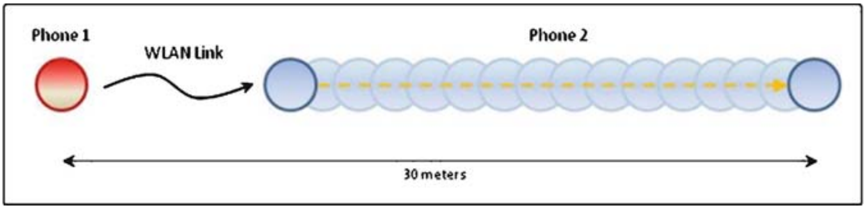


Fig. 6 Sketch of the measurements setup for the direct transmission

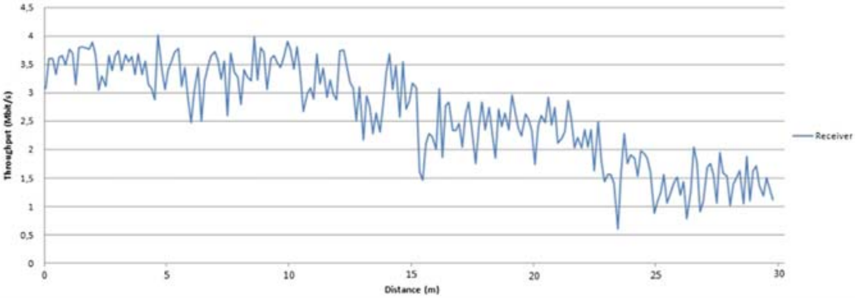


Fig. 7 Throughput measured on the receiver side

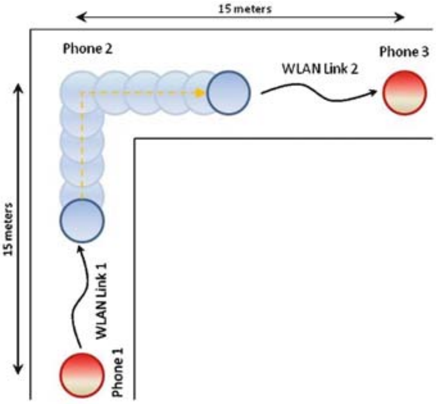


Fig. 8 Setup for the measurements in the transmission relay scenario

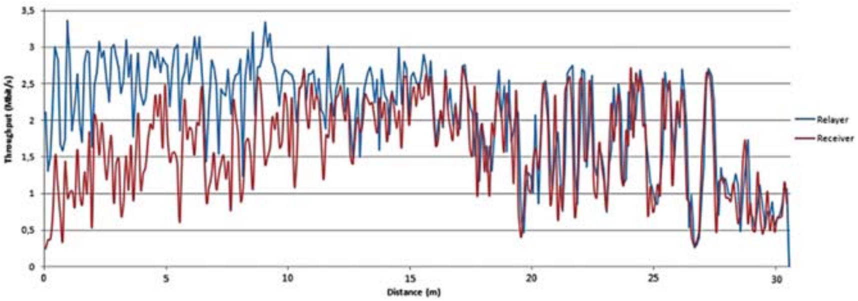


Fig. 9 Throughput at the relay and the receiver side for the relay transmission setup

throughput as well. While the transmission is taking place, the robot is moving with low speed from the sender toward the receiver. As we can notice from the plot in Fig. 9, the throughput of the receiver has a parabolic trajectory. The maximum value of the throughput is around 2.6 Mbit/s and is given at 15 m, when the relay reaches the corner of the corridor.

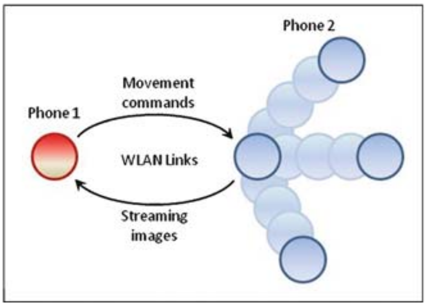
4.2 *Active Transport Scenario*

In the following, we present an application developed to give a simple example for the *active transport scenario*. The goal of this application is to remotely control a robot used as a video stream server. The phone placed on the robot is streaming the video from its camera and broadcasting it by using IEEE802.11b/g.

4.2.1 Remote Camera Application

The purpose of this application is to show how the robot can be be used according to the architecture 1 described in Sect. 3. In this example, the phone sitting on the

Fig. 10 Setup description for the remote camera application



robot uses the camera to collect images and streams them to another phone using a Wi-Fi connection. As shown in Fig. 10, the *Phone 2* is connected to the robot and streaming the images, whereas the *Phone 1* is receiving the images and it is able to send movement commands to the *Phone 2* that will forward them to the robot. A possible applicative scenario where this application can be used is an advanced video surveillance. For example, if a user wants to monitor some areas, he/she can control the robot over the Internet (with the help of an Access Point) by sending movement commands to the *Phone 2*, which will stream back the images.

5 Conclusions

In this chapter, we have presented a mobile platform designed to optimize measurements for mobile wireless networks, especially those with dynamic topology. This platform has wheels to allow movements and can be controlled by several kinds of devices (e.g., mobile phones, PC, Opensensors) using different wireless technologies (Bluetooth, Wi-Fi, RF antennas). The main purpose of this work is to offer to the scientific community a new interesting, very flexible and freely available framework for performance evaluation of wireless networks and devices. Therefore, all the information for the hardware and the software can be found on the webpage of the project [11].

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