Mobile terminal as opportunistic sensor network device for research on cognitive radio networks

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Abstract. The cognitive radio (CR) concept is promising to relax the pressure on the available radio resources and increase the efficiency of their use by dynamic spectrum allocation and spectrum sharing. Research focus related to CR networks is recently moving from simulation-based investigations to actual testbeds, many of them based on Wireless Sensor Networks (WSN), which support some CR research scenarios. Advanced mobile terminals can extend WSN features with mobility, sensing and measurements collection. This paper presents the concept of using a mobile terminal as an opportunistic sensor network device, capable of cooperation with dedicated sensor nodes to build Radio Environment Map to support the operation of CR networks.

Keywords: Mobile terminals, sensor nodes, Wireless Sensor Networks opportunistic, spectrum sensing, cognitive radio, hidden node.

1 Introduction

There are various wireless devices around us, which share the same frequency spectrum. In this respect, national and regional regulators recommend, set, and enforce output power and energy radiation rules for spectrum frequencies divided to the licenced and non-licenced bands. Due to such regulation, frequency bands are not fully exploited neither in time nor space. To solve this issue, the cognitive radio (CR) concept was introduced [1]. Its main advantage in comparison to traditional radios used today is a cognition cycle, which includes radio environment observation, learning from previous experiences and planning its own operation. While majority of initial CR related research relied on computer simulations, more recent studies started to investigate spectrum sensing, opportunistic spectrum
access and spectrum sharing procedures in real testbeds, many of them based on Wireless Sensor Networks (WSN). Practical experimentations in this field can be performed in ISM (Industrial Scientific Medical) frequency bands, in which expensive professional measurement equipment (e.g. spectrum analysers), medium-cost devices (e.g. USRPs) as well as low-cost devices, such as WSN nodes, can be used for testing. However, real sensing scenarios' goal is to have a maximum number of measuring devices available in order to acquire the most accurate results in the specific field of interest. To achieve this, sensor nodes seem a suitable choice, since they offer a good compromise between the price, the number of devices, and their computing, communication and sensing capabilities. As presented in [2], there are already several WSN testbeds, which use dedicated WSN gateway(s) to transfer the sensor measurements to the remote server locations for further analysis and processing. However, static deployment of dedicated sensor nodes and gateways is not always an optimal solution, resulting in many initiatives to use advanced mobile terminals equipped with different embedded sensors and communication interfaces as opportunistic sensors nodes and/or gateways [3]. In this respect, the aim of this paper is to present the mobile terminals’ sensing capability and opportunistic sensor network role in CR research scenario. In the following, Section 2 presents mobile terminals’ sensing and communication features. Section 3 presents difficulties and solutions of accessing sensors on the mobile terminals. Section 4 depicts our considered spectrum sensing scenario and in parallel presents a possible solution for the issues from Section 3. Finally, Section 5 concludes the paper.

2 Sensing and communication features of mobile terminals

Mobile terminals can be treated as a specific type of sensor nodes, however, their embedded higher processing, storing and communicating capabilities reflect in larger energy consumption, mostly due to the high resolution displays and relatively fast communication interfaces. It can be noticed that also low-power WSN adopted radios, in addition to Bluetooth technology, are slowly gaining the attention of the mobile terminals developers, whereas they already integrate many different types of sensors.
Table 1 Android most common supported embedded and virtual sensors

<table>
<thead>
<tr>
<th>Microphone</th>
<th>Magnetic field sensor</th>
<th>Pressure sensor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Camera</td>
<td>Gravity sensor</td>
<td>Proximity sensor</td>
</tr>
<tr>
<td>Touch screen display</td>
<td>Gyroscope sensor</td>
<td>Relative humidity sensor</td>
</tr>
<tr>
<td>Buttons</td>
<td>Light sensor</td>
<td>Rotation vector sensor</td>
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<tr>
<td>Global Positioning Sensor (GPS)</td>
<td>Ambient temperature sensor</td>
<td>Linear accelerometer sensor</td>
</tr>
<tr>
<td>Orientation sensor</td>
<td>Radio interfaces sensors for GSM, CDMA (logical level)</td>
<td>Radio interfaces sensors for Wi-Fi, Bluetooth (logical level)</td>
</tr>
</tbody>
</table>

Several most common embedded and virtual sensors, supported by increasingly popular Android-based mobile terminals, are listed in Table 1, however, none of them is actually appropriate for spectrum sensing on the physical level. A solution could be implemented through the usage of additional external sensors. Wired connections with sensors can be established over the serial connectors, USB connectors or even SD and uSD card sockets, while wireless connections are mostly available over high-power consuming Wi-Fi, medium-power Bluetooth or low-power WSN communication interfaces, if available.

3 Challenges related to mobile terminals used as sensor nodes

To efficiently access and retrieve sensor measurements from dedicated sensor nodes and opportunistic sensor network devices (e.g. mobile terminals) in the public networks, both device types must communicate and cooperate. However, access to mobile terminals through the internet over the mobile network cannot be done in a straightforward manner. In principle, mobile terminals can only post sensor measurements over self-created data session called Packet Data Protocol (PDP) context in GSM/UMTS and EPS bearer in LTE to the servers in the public networks, as depicted in Figure 1. Namely, all measurement retrieval requests coming in the opposite direction, as depicted by the red line in Figure 1, are not possible, since the mobile operators normally block all communication session initiation attempts coming from the public networks.
4 Spectrum sensing scenario with opportunistic sensor devices

Our considered sensing scenario for practical demonstration of Radio Environment Map (REM) [4] creation is depicted in the left side in Figure 2. It consists of the fixed sensor nodes (F) forming WSN and mobile opportunistic sensor network device(s) (M). This enables spectrum sensing over the specific area of interest to build an efficient REM needed for detection of the hidden node or primary user transmitter (H), as presented on the right side in Figure 2. Such scenario can be realized with majority of the mobile terminals available despite the issues presented in Section 3. On the mobile network side a private access point name (APN) for a connection with its own security policy has to be prepared to allow the access to measurements from the external networks, as depicted in Figure 1 with the green line. To prove the concept for the mobile terminal, we took Android-based Samsung I9100 mobile terminal, which lacks WSN compatible radios and sensors being capable of spectrum sensing. We selected VESNA sensor node [5] capable of spectrum sensing to which we connected Roving Networks XBT RN-41 Bluetooth module. Thus, we enabled communication among mobile terminal and VESNA node together presenting an
opportunistic sensor network device. A test software for managing such a virtual sensor network device was written as a code in C programming language on the side of VESNA node and as Java-based Android application communicating with data frames, presented in [6].

5 Conclusion and future work

In this paper we outlined mobile terminals’ sensing capabilities and their prospects to become opportunistic sensor network devices capable of cooperating with WSNs in spectrum sensing scenarios if complemented by appropriate sensors. Their sensor measurements can be accessed over the mobile network over private APNs. Our further work includes testing of opportunistic sensor network devices in real outdoor scenarios with the aim to support development of algorithms for hidden node detection.

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References

For wider interest

Wireless Sensor Networks (WSN):
- are wireless networks build of spatially distributed small and low-power autonomous devices called sensor nodes, equipped with heterogeneous sensors to measure various physical phenomena over specific area of interest.

Opportunistic sensor network devices:
- are devices which can be used as sensor nodes,
- can be mobile terminals which can opportunistically cooperate with WSNs in various scenarios.

Cognitive radio principles:
- include methods for more efficient spectrum usage,
- enable multiple users sharing the same frequency spectrum in a cooperative or competitive way,
- enable non-licensed secondary users to communicate on the same frequencies as licensed primary users if and only if they do not cause any harmful interference.

Hidden node problem:
- is a problem in cognitive networks where secondary users in some situations are not aware of the primary user’s presence in the vicinity.

Our work:
- outlining mobile terminals’ features which enable them becoming opportunistic sensor network devices,
- pointing out mobile network issues related to sensor measurements access on mobile terminals and their lack of WSN compatible communication interfaces,
- presenting solutions for these issues.

Future work:
- to test mobile terminals as opportunistic sensor network devices in real testbeds meant for spectrum sensing and efficient Radio Environment Maps building to support multiple issues in cognitive networks.