Demo Abstract: A Proof of Concept Implementation for Cognitive Wireless Sensor Network on a Large-scale Wireless Testbed

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***Abstract*—Cognitive Radio (CR) is a promising technology in the wireless communication field. CR is able to adapt its channel according to the local spectrum condition. Recently CR technology is also applied in the field of wireless sensor network (WSN).**

Receiver Directed Transmission (RDT) is a cognitive solution for wireless sensor network developed under the FP7 CONSERN project[2]. In RDT, the sender selects the optimum channel according to the location of the receiver, assuming sensors are distributed spatially and there is sufficient diversity in spectrum across the entire network.

In this demo we focus on an implementation of RDT-based WSN on a large-scale wireless testbed. The channel selection of RDT relies on distributed and heterogeneous sensing. We compare the performance of the cognitive WSN against regular WSN. We further explore how the energy detection threshold can influence the performance of the RDT solution. The experiment is conducted via a set of benchmarking tools, developed in the scope of the European project CREW[1].

I. Introduction

With the growth of wireless technology, radio spectrum becomes increasingly crowded. Optimization of spectrum allocation is needed in order to achieve better performance. Cognitive radio (CR) allows radios to switch channels at runtime and hence provides capacity for dynamic spectrum allocation. In the Receiver Directed Transmission (RDT), the channel used for transmission is determined by the interference measured at the receiver. For a large-scale network where sensors are covered under complex interference conditions, finding one single channel that is suitable for all sensors is very difficult. Instead of selecting a singa large scale wireless testbed —le channel for the whole sensor network, each sensor node select its own optimum receive channel individually. This is the motivation of RDT.

The demo scenario is about a wireless sensor network (WSN) deployed in an office environment. Typical applications of sensor networks are wireless building automation or alarm detection. Reliability is critical for such kind of applications. The challenge is how to realize a reliable sensor network operating in the already crowded ISM bands. We consider two types of sensor networks: one is the cognitive sensor network based on RDT solution; the other is a regular sensor network with static channel configuration.

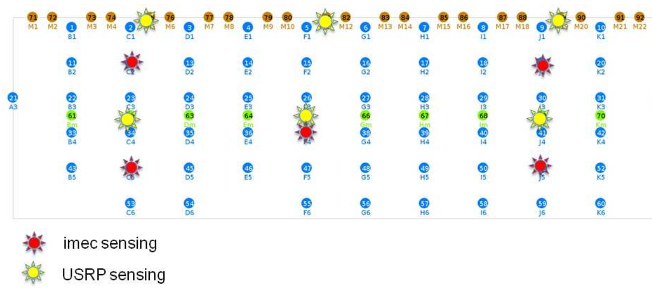

Fig. 1. Sensing engines in w-iLab.t Zwijnaarde

We implement our demo on the w-iLab.t Zwijnaarde testbed[3]. For RDT based sensor network, we use the distributed and heterogeneous sensing facility in w-iLab.t Zwijnaarde as input for distributed energy detection. Based on this input, we further use the CREW benchmarking tools to explore the performance of RDT based WSN under various conditions. In the remainder of the introduction part, we briefly introduce the w-iLab.t Zwijnaarde testbed and the CREW benchmarking tools. Part II describes the demo scenario in more details and finally we give a preview of experiment results and some conclusions in Part III.

a) w-iLab.t Zwijnaarde testbed: The w-iLab.t Zwijnaarde testbed is a generic and heterogeneous wireless testbed. It is located at a utility room where no human activity is present. A regular node in w-iLab.t Zwijnaarde consists an embedded PC with two Wi-Fi interfaces, one Zigbee sensor and one Bluetooth dongle. A subset of the Zigbee sensors form the WSN of the demo. The floor plan of the testbed is shown in Figure 1. In addition, there are 6 USRP and 5 imec sensing engines deployed. USRP is a popular software-defined radio platform[4]. We combine customized software application and USRP hardware for spectrum analysis. This is referred as the USRP sensing engine. The imec sensing engine is a powerful customize designed sensing engine[5]. It uses an advanced front-end and dedicated chips for spectrum analysis. In our demo, the sensing engines are configured to monitor the energy level on all Zigbee channels in 2.4GHz ISM band. The output of sensing engines are stored in a predefined database.

b) CREW Benchmarking Tool: The CREW benchmarking tool is a web-based generic tool, explained further below. It has three parts, experiment configuration, experiment execution and benchmarking. Users can easily configure, schedule experiments and benchmark the results. Benchmarking is the act of measuring and evaluating a solution under reference conditions relative to a reference evaluation. To this end different solutions are compared based on a general score, a value between 0 and 10, that is derived from measurements. The benchmarking framework also provides advance features for automatic parameter optimization.

II. Implementation

We first emulate an office environment by setting up 4 Wi-Fi networks and 2 Bluetooth pairs. The Wi-Fi networks are present on Ch.1, Ch.5, Ch.9 and Ch.13 respectively. The interference sources are spread over different parts of the testbed to ensure sufficient diversity in frequency domain. The scenario is illustrated in Figure 2. A sensor network is superimposed on top of the office environment. Sensor nodes are highlighted in Figure 2. We consider the collecting tree protocol(CTP) scenario[6], where the sensor at the right end is selected as the sink node, the rest of the sensors transmit towards the sink node following the tree topology, as indicated with arrows in Figure 2. The packet reception rate(PRR) is measured on each link individually. We use the averaged end-to-end PRR as the performance metric. This metric is scaled by a factor of ten. The scaled metric is the score used in the benchmarking framework.

Apart from the background environment, the RDT solution also requires channel assessment. Here we use the distributed and heterogeneous spectrum sensing. The 6 USRP and 5 imec sensing engines are configured to scan over all 16 Zigbee channels in the 2.4 GHz band. At higher level, an energy threshold is specified. When the measured energy is above this threshold the channel is considered busy. Next the percentage of the channel being busy over a certain interval is calculated. The result is referred as channel occupancy. We rank the Zigbee channels based on the channel occupancy for all sensing engines individually. Each sensor node is associated with one sensing engine based on distance. For a specific receiver, the most nearby sensing engine is selected. Before transmission, each sensor node queries the sensing engine associated with the targeted receiver for the best local channel.

III. Conclusion

For the RDT solution, we vary the energy threshold in certain range and observe the benchmarking score. The result of an example experiment is shown in Figure 4, where the energy threshold is varied from -85 to -55 in step of 5 dBm. We can see that the score shows a reverse "U" shape, best performance appears around -70 dBm, which is slightly above the noise floor of the testbed. For comparison, we use static channel configuration on the same sensor network, the channel index is varied from 12 to 24 in step of 2. The score seems to increase with channel index. This is because nearby the sink node, Wi-Fi interference is located on the lower part of the 2.4GHz ISM band. Links nearby sink node have more impact on the end-to-end PRR, hence the overall score is dominant by the PRR on links nearby the sink. The best score of RDT solution is 10, meaning all packets on the network are successfully received. We hence have demonstrated that the RDT solution performs better than the single channel solution, certainly when considering that the interference conditions may be very dynamic and RDT will always dynamically select the most optimal channel.

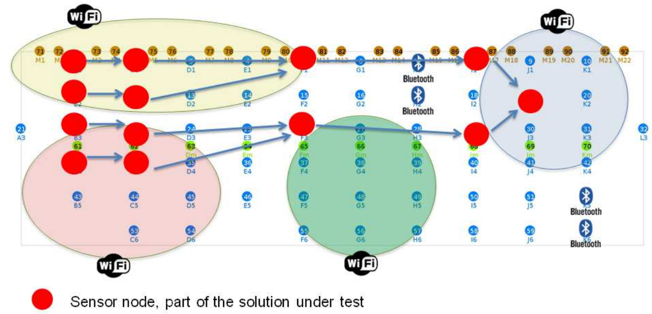

Fig. 2. Sensor Network and Office Environment

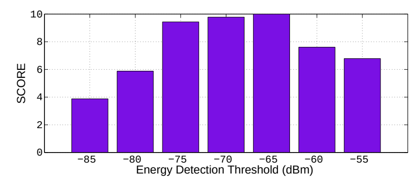

Fig. 3. Score of RDT solution vs energy threshold

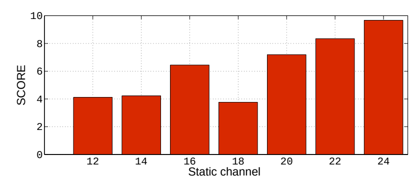

Fig. 4. Score of static solution vs channel index

Acknowledgment

The research leading to these results has received funding from the European Union's Seventh Framework Programme FP7/2007-2013 under grant agreements n 257542 (CONSERN project) and n 258301 (CREW project).

References

[1] http://www.crew-project.eu/
[2] http://kandalf.di.uoa.gr/consern/
[3] S. Bouckaert et al. "Federating wired and wireless test facilities through Emulab and OMF: the iLab.t use case" in the proceedings of TridentCom 2012
[4] Ettus Research. http://www.ettus.com/.
[5] S.Pollin, "An integrated reconfigurable engine for multi-purpose sensing up to 6 GHz", in Dyspan, 3-6 May 2011
[6] G.Omprakash, F.Rodrigo et al. "Collection tree protocol" in SenSys: 114, 2009