Radio Spectrum Maps for Emerging IoT and 5G Networks: Applications to Smart Buildings

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***Abstract*— The high demand for wireless Internet including emerging Internet of Things (IoT) applications is putting extreme pressure on better utilisation of the available radio spectrum. The expected spectrum "crunch" requires highly efficient radio resource management schemes with low complexity and high responsiveness to the changing network conditions. Spectrum sharing is regarded as an essential approach to regaining access to otherwise unused spectrum and it is considered an essential component in the development of IoT and 5G networks. Spectrum sharing can be conducted at different time scales. As the time scale of the operation of spectrum sharing decreases, the possibility for utilising more available spectrum holes increases. However, the shorter time scale brings with it challenges. Efficient decisions regarding the use of spectrum sharing require accurate knowledge of the spatial and temporal spectrum use in a geographical area of interest. This knowledge can be represented in Radio Spectrum Maps which need to be generated efficiently and accurately. In this paper we give an overview of the spectrum sharing concept for IoT and 5G networks. We also present our research on spectrum sharing to enable Smart Building IoT applications.**

Keywords—Radio Environment Maps; 5G; IoT; spectrum sharing

I. Introduction

The future 5G networks aspire to provide an enhanced experience to the mobile users through extremely high data rates, ability to support massive number of subscriptions, and enabling ultra low latency communications. Enabling these services requires access to more spectrum resources. Although there are large blocks of unused spectrum resources available in high frequency bands, due to challenging propagation characteristics 5G networks require more spectrum in cellular bands below 6 GHz. In this regard, spectrum refarming has traditionally been the solution of choice, however the regulatory bodies are now promoting spectrum sharing schemes as a solution [1-3].

There are two prominent spectrum sharing schemes being developed – Licensed Shared Access (LSA) [1] and Spectrum Access System (SAS) [2, 3]. LSA was developed by the ETSI Reconfigurable Radio Systems group for the 2.3-2.4 GHz band in Europe [1]. SAS is currently being developed by the FCC for 3.55-3.7 GHz band in the US. SAS system model is shown in Fig. 1. Spectrum sensing is a key enabler of SAS. The conventional spectrum sensing techniques that focus on time and frequency domains only provide local information. Such local information is not sufficient when managing interference to/from a large cellular network spread over a wide area.

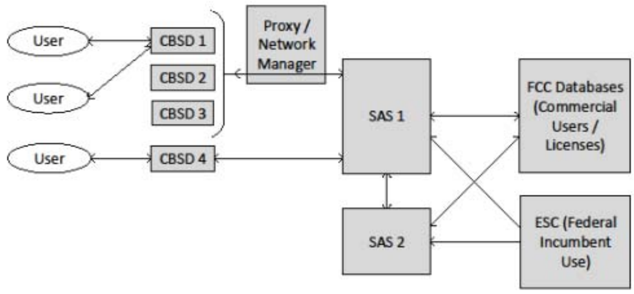

Fig. 1. Spectrum Access System (SAS) architecture

Instead spectrum sharing should be focused on time, frequency and space domains. This can be achieved by building a Radio Environment Maps (REMs) dynamically [4, 5]. REM can be viewed as a framework that collect and store data that characterizes the RF environment. In a spectrum sensing scenario, the sensing nodes can be used to gather geolocation-tagged RF measurements such as the Received Signal Strength (RSS), matched filtering, and cell synchronization signal detection. A dynamic REM shows such measurements in real-time on a map of the area. Therefore, REM is expected to be a tool that facilitates interference monitoring and policy enforcement in spectrum sharing.

REMs can be constructed using geo-statistical models. Literature proposes using techniques such as Kriging Interpolation which is widely used in commercial planning techniques [6]. A-priori knowledge of the propagation characteristics can be exploited with compressive sensing based REM construction techniques [7]. Application of such techniques go through learning and operational stages.

In section II, we present the REM construction platform architecture. How this platform can be used for smart buildings is discussed, with some use cases, in section III.

II. Dynamic Radio Environment Map Construction

We propose to construct REM with multiple distributed sensing nodes. We assume the sensing area is divided into N×N grid and each sensing node is located at one grid point. All sensing nodes will collect the RSS measurements at the same time in the same band with the geolocation tags. The RRS measurements will then be aggregated in the central processing node and used to plot REM.

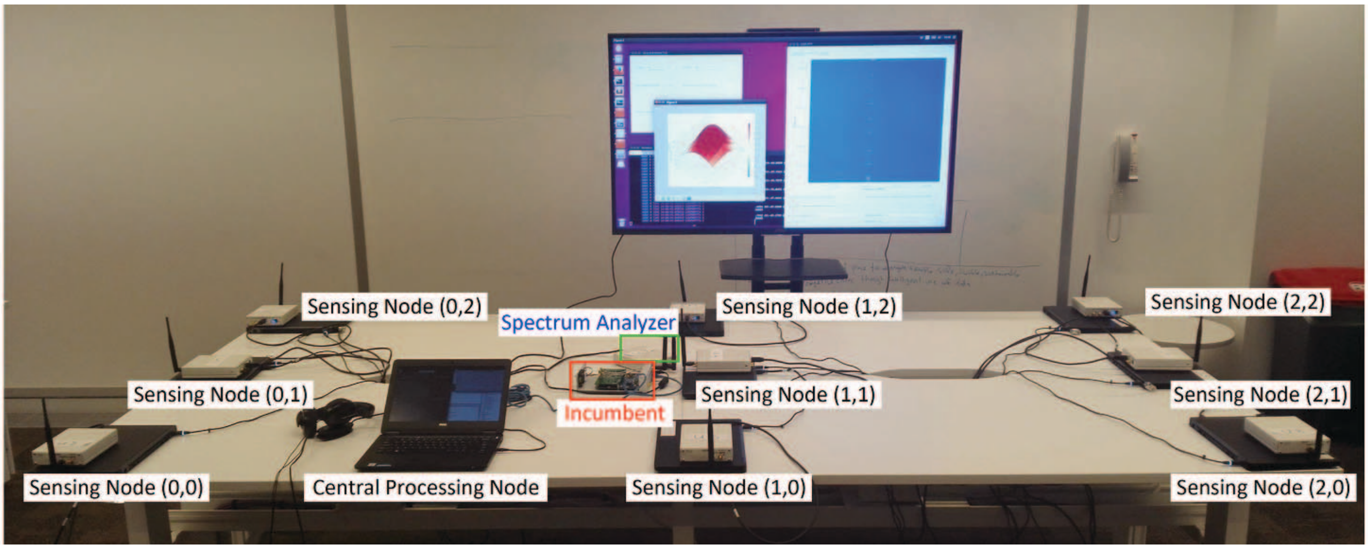

Fig. 2. Dynamic Radio Environment Map (REM) construction platform

The sensing nodes are comprised of one PC running GNURadio and one USRP device. The central processing node is implemented with a powerful PC or a workstation. The communication link between the sensing nodes and the central processing node is WiFi or Ethernet.

The central processing node will send the sensing requests to the sensing nodes with the configuration of the physical receiving parameters, such as, receiving frequency, bandwidth and sample rate. The sensing node will start to receive time domain signals and convert the time domain signals into frequency domain using FFT. Moreover, the sensing node will further process the frequency domain obtain more precise data or adding pilot to the data for later processing. The frequency domain samples will be stored in the RAM of the PC in the sensing node and also sent to the network shared memory of the central processing node.

To make sure the measurements in the same REM are received at the same time. The sensing nodes need to be highly synchronised. The central processing node can achieve the synchronisation by two levels. We implement the coarse level with the Network Time Protocol (NTP). In the receiving request sent from the central processing unit to sensing nodes, the sensing nodes are configured to adjust their clocks to follow the central processing node's clock.

The accuracy of NTP could possible vary between 5-100 ms. This depends on the accuracy of the central processing node and the quality of the network connection between the sensing and the processing nodes. In our setup the worst case synchronization error was in the order of 20 ms. Furthermore, the central processing node can use fine synchronisation by detecting characteristic symbols, such as preambles or reference signals. The detection can also be distributed into multiple sensing.

The aligned RSS data from each sensing node with different geolocation tag will be used to generate REM. The data will also be used to analyse the dynamic interference level, identify irregular physical layer activities and optimise the wireless spectrum resource usage and allocation.

In our testbed show in Fig. 2, we divided the sensing area into 3×3 grid. On each grid point, we used USRP B200 for one sensing node. A dummy OFDM transmitter that is modelling the incumbent or co-channel interference source is set up with USRP2 and a PC. Moreover, a spectrum analyser with USRP B200 is placed next to the transmitter to monitor the incumbent signal.

We measured 5.23 GHz unlicensed band, with 5MHz bandwidth. The overall processing delay from the sensing node to the generation of the REM is around 180 ms.

III. Application to Smart Buildings

Spectrum sharing in commercial indoor environments is quite challenging. For an example the RF environment in a shopping mall varies due to reconfigurations of floor plans, popup stalls, posted signs, and the change of number of people within a shopping mall. Spectrum sensing should ideally detect the variations caused by the external factors and determine how they affect the interference conditions. This can be done by a deployed IoT network of sensors that are collecting RF measurements to construct a REM in real-time.

This IoT infrastructure can also be used to locate external sources of interference. Due to the presence of many electronic equipment in indoor environments, this will reduce the network troubleshoot time. Therefore REM architecture will enable smart buildings that are capable of providing guaranteed indoor coverage and enforcing spectrum sharing regulations.

IV. Conclusion

Paper presented the REM construction testbed architecture. We discussed how it can be applied to 5G spectrum sharing. Particularly REM can be constructed through an IoT infrastructure in indoor smart building applications.

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