Abstract. The smart grid (SG) system is expected to involve huge amount of data with different levels of priorities to different applications or users. The traditional grid which tend to deploy propriety networks with limited coverage and bandwidth, is not sufficient to support large scale SG network. Cognitive radio (CR) is a promising communication platform for SG network by utilizing potentially all available spectrum resources, subject to interference constraint. In order to develop a reliable communication framework for CR based SG network, thorough investigations on the current radio spectrum are required. This paper presents the spectrum utilization in Malaysia, specifically in the UHF/VHF bands, cellular (GSM 900, GSM 1800 and 3G), WiMAX, ISM and LTE band. The goal is to determine the potential spectrum that can be exploit by the CR users in the SG network. Measurements was conducted for 24 hours to quantify the average spectrum usage and the amount of available bandwidth. The findings in this paper are important to provide insight of actual spectrum utilization prior to developing a reliable communication platform for CR based SG network.

1. Introduction
In Malaysia, the electricity demand is expected to increase up to 3.5% annually for the next 10 years [1]. However, the local natural gas resources are depleting and there is serious concern on CO$_2$ emission. As national agenda, Malaysia aims to revolutionalized the existing grid to become a smart grid. Smart grid is a term referring to modernization of generation, transmission and distribution of a power grid system with the integration of advanced ICT infrastructure. The smart grid is envisioned to comprise major features such as advanced metering infrastructure (AMI), demand-side management (DSM), fault-tolerance and self healing system [2]. The concept of SG can be visualized as shown in figure 1.

The key determining factor in establishing these features is timely access to information via a reliable communications infrastructure. According to [3], among the five identified key technology areas in smart grid is the implementation of integrated communications. Currently, utilities company operate extensive private internal communications to support the safe, efficient and reliable delivery of essential services to the public at large [5]. However, the current communication systems are not suited to support the large scale of SG network, which need to support many interconnected components and
huge amount of data to be transmitted, managed and analyzed. Most systems either lack of bandwidth, limited coverage area, latency or security. Therefore, a revolutionary communication system is urgently demanded, such as cognitive radio.

Cognitive radio enables dynamic spectrum access, which allows the SG to exploit the underutilized frequencies in opportunistic manner. By leveraging CR technology, the radio agility allows the SG devices to sense all potentially unused (idle) spectrum opportunities in the surroundings and utilized them subject to interference constraints. The motivations behind why CR network is a promising communication platform for SG are summarized as follows [3, 5]:

(a) The existing smart grid devices for Home Area Network (HAN) is usually operate in the ISM band (i.e: Zigbee, Bluetooth and WiFi). Thus, there exist significant coexistence interference among the devices. Therefore, the spectrum in HAN is becoming overcrowded and contaminated that will endanger reliable SG communications. In view of this, it is beneficial to adopt CR based radio technology in HAN, which will intelligently coordinate the power and schedule the transmission.

(b) The volume of SG data is expected to increase tremendously in the near future. CR network is a workable approach to increase communication capacity by utilizing the idle spectrum efficiently.

(c) SG covers a large geographical area, and therefore different spectrum regulations can exist. CR can enables heterogeneous network through hardware reconfigurability and context awareness.

In view of this, deep and thorough investigations on the current frequency spectrum are required for a successful implementation of CR for reliable SG communications. By doing so, it enables us to understand the dynamic characteristics of spectrum in order to meet the QoS of SG.

The rest of this paper is organized as follows. Section 2 presents the measurement setup, which was conducted in UNITEN and MIMOS. Section 3 discusses the measurement results to determine the potential spectrum for CR based SG network. Finally, conclusions and future recommendations are drawn in Section 4.

2. Measurement Setup
An outdoor spectrum measurement has been carried out at MIMOS located in Technology Park Malaysia, Kuala Lumpur and UNITEN Putrajaya Campus, Selangor (as shown in figure 2). The AOR DA3200 discone antenna which covers the frequency range of 25 MHz to 3 GHz or a tri-band dipole (XPO2V-880-2175/1355) antenna is connected to the ADVANTEST U3741 spectrum analyzer.
through a low loss coaxial cable. The frequency range of the spectrum analyzer is 9 kHz to 3 GHz. The spectrum analyzer is then connected to a computer with LABVIEW installed, which is used to configure the required parameters for the measurement and to automatically capture the data. The spectrum survey was conducted for a period of 8 weekdays covering frequency range of two TV broadcasting bands (VHF and UHF TV), three cellular bands (GSM 900, GSM 1800 and 3G), two broadband wireless access bands (WiMAX and LTE) and ISM 2.4 GHz band. The discone antenna is used to measure the TV broadcasting band, while the tri-band dipole is used for the other measured bands.

![Measurement setup at UNITEN: (a) Discone antenna (b) Tri-band dipole antenna (c) ADVANTEST U3741 spectrum analyzer and computer installed with LABVIEW.]

Decision threshold is a very important parameter to determine whether the spectrum is idle or busy. If the received signal power is above a certain threshold value, the frequency channel is considered as occupied. However, if the received signal is lower than the threshold value, the frequency channel is classified as idle. Selecting very high decision threshold value will cause the frequency channel to be classified as unoccupied even though the licensed signal is present. Selecting very low received power threshold value will result in the frequency channel to be classified as occupied when noise is mistakenly accounted for licensed signal. In this study, the decision threshold value is determined by adding certain dB above the average noise level as recommended by ITU [6]. Table 2 tabulates the frequency bands and their decision threshold selected above the noise level for all eight bands.

### Table 2. Received power decision threshold selected for each band.

| Service        | Frequency Range (MHz) | dB Above Noise Level | Received Power Decision Threshold (dBm) |
|----------------|-----------------------|----------------------|----------------------------------------|
| VHF TV         | 174 - 230             | 10                   | -85.7                                  |
| UHF TV         | 470 - 798             | 10                   | -85.8                                  |
| GSM 900        | 880 - 960             | 3                    | -92.8                                  |
| GSM 1800       | 1710 - 1880           | 3                    | -90.7                                  |
| 3G (IMT-2000)  | 1885 - 2200           | 3                    | -89.2                                  |
| WiMAX          | 2300 - 2390           | 10                   | -81.4                                  |
| ISM 2.4 GHz    | 2400 - 2500           | 10                   | -81.4                                  |
| LTE            | 2500 - 2700           | 8                    | -81.9                                  |

3. Results & Analysis

This section discusses measurement results and analysis for all 8 bands mentioned earlier. The average duty cycle for both locations is presented in table 3. Generally, the spectrum utilization at MIMOS is slightly higher compared to at UNITEN. It is noted that the spectrum utilization is low for TV bands and medium for cellular bands at both locations. However, the spectrum utilization for broadband wireless access bands and ISM 2.4 GHz are very low at both locations. This is due to the measurement equipment which may not be sensitive enough to capture the broadband wireless access signals. The
LTE service is just recently launched and this explains why the utilization is very low at present. Based on the findings, UHF/VHF TV broadcasting band is recommended as a very potential candidate for the CR based SG communication network in Malaysia, due to low spectrum utilization and high unused bandwidth. Furthermore, the characteristic of TV signal which covers wide area range, longer propagation waves and penetration of buildings is suitable for smart grid application such as connecting the grid to the rural area or backhaul communication platform (ie: WAN) which requires larger bandwidth. Due to medium spectrum utilization in the cellular band, it can be opportunistically used for neighborhood area network (NAN) of SG network. The NAN is basically collecting data from several HANs to be transmitted to the WAN.

Table 3. Summary of average duty cycle

| Service       | Frequency Range (MHz) | Bandwidth (MHz) | Average Duty Cycle (%) |
|---------------|-----------------------|-----------------|------------------------|
|               |                       |                 | UNITEN                |
| VHF TV        | 174 – 230             | 56              | 4.03                  |
| UHF TV        | 470 – 798             | 328             | 3.02                  |
| GSM 900       | 880 – 960             | 80              | 35.31                 |
| GSM 1800      | 1710 – 1880           | 170             | (UL = 13.31, DL = 63.47) |
| IMT-2000 (3G) | 1885 – 2200           | 315             | 26.08                 |
| WiMAX         | 2300 – 2390           | 10              | 0.13                  |
| ISM 2.4 GHz   | 2400 – 2500           | 100             | 0.096                 |
| LTE           | 2500 – 2700           | 200             | 0.12                  |

|               |                       |                 | MIMOS                  |
|---------------|-----------------------|-----------------|------------------------|
|               |                       |                 |                        |
|               |                       |                 | (UL = 23.23, DL = 53.41) |
|               |                       |                 | (UL = 0, DL = 18.30)   |
|               |                       |                 | (FDD UL = 11.52, FDD DL = 74.54, TDD = 26.29) |
|               |                       |                 | (FDD UL = 22.07, FDD DL = 51.54, TDD = 39.96) |
|               |                       |                 |                        |

4. Recommendations and Conclusions
This paper presented an investigation of idle spectrum that can be exploited for CR based SG network. The findings shows that the spectrum utilization is low for TV band and thus recommended for CR based SG network supporting the WAN. On the hand, the cellular band is a potential spectrum supporting the NAN of CR based SG network. This can provide useful information for the energy utilities and the spectrum regulators to consider opportunistic access of the underutilized spectrum for smart grid network.

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