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Feasibility Study of Using IEEE 802.22 Wireless Regional Area Network (WRAN) in Malaysia

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***Abstract*—Abstract— This paper introduces the implementation of IEEE 802.22 Wireless Regional Area Network (WRAN) for broadband internet access in rural areas. It highlights the advantage of implementing such technology and feasibility to co-exist with Digital Video Broadcasting – Terrestrial (DVB-T) in Malaysia. It adopts a model to determine the maximum number of WRAN base stations (BSs) by analyzing its co-channel interference between the BSs. The analysis shown that maximum WRAN BSs that could co-exist are 8 to 19 BSs outside the protection contour of the DVB-T BS. Coverage areas of 30 – 100 km will be also feasible to co-exist. By implementing the IEEE 802.22 WRAN, the digital divide can be narrowed and broadband penetration would be increased.**

***Index Terms*—IEEE 802.22 Wireless Regional Area Network (WRAN), co-channel interference, rural broadband connectivity.**

I. Introduction

The United Nations (UN) [1] reports that there will be more than three billion people living in rural areas as in 2005. The largest numbers of rural residents are reported in India, China and Indonesia. India and China will also remain as having the largest number of rural residents in 2030 as projected by United Nations. As in Malaysia, UN projected that there are 7.7 million people currently living in rural areas in 2030. For these communities, it is believed that providing communications services are an important step to facilitate development and social equity [2].

There is always a mismatch between costs and demand for rural communications where most of the places are low in population density. The demand for the services is much lower as compared to the urban areas. In Malaysia, most of the rural communities are elderly people and living in a simple life. The deployment and maintenance of wired communications in rural areas is costly since it covers large areas and hard to reach by land due to its difficult terrain. Hence, wireless technologies are favorable for the rural connectivity.

In Malaysia, most of its Community Broadband Centres (CBCs) are connected by either broadband wired connection or very small aperture terminal (VSAT). The wired broadband connection is provided by Telekom Malaysia (TM) through its broadband service based on telephone line service. The service can offer up to 1 Mbps per household. The VSAT is offered by Jaring Communications Sdn Bhd which can reach up to 4 Mbps. There are also various approaches being implemented throughout the world for rural communications such as RuralNet [2] in India, WiFi for rural in Japan [3] and DakNet [4].

One of the current technology under consideration and heavy development is IEEE 802.22. It is a standard for enabling Wireless Regional Area Network (WRAN) using white spaces in the TV bands. The standard is aimed at using the cognitive radio techniques to allow sharing of unused spectrum allocated to the Television Broadcasting Services. This initiative is on the non-interfering basis to enable the broadband Internet access to the rural areas which is hard-to-reach or low population density areas. Although the initiative is targeted to the rural environments, it has potentials for a wider applicability to other areas as well.

In the next section we look into the spectrum utilization in Malaysia by presenting the result of spectrum occupancies test done in four locations and highlight the existence of spectrum holes that can be utilized. In section III, we outline the IEEE 802.22 WRAN overview and properties. Section IV describes the usage of DVB-T bands by analysing the co-channel communication setting for rural broadband. Section V describes the simulation settings. Section VI discusses results of the analyses. Finally, in section VII we conclude the paper and outline future directions.

II. Spectrum Utilization

In recent years, there has been a significant increase of wireless applications being deployed, and along with traditional services, these hace placed significant amount of pressures on sharing the available spectrum especially in Very High Frequency (VHF) and Ultra High Frequency (UHF) bands. This is due to the fact that these bands are considered as 'sweet spot' for their advantages in propagating signals and hardware costs.

In addition to this the occupancy level of the spectrum that has already been allocated is relatively low. For example in Malaysia, not all TV channels are in use as it is necessary to allow guard bands between active high power transmitters to prevent mutual interference. Also not all TV stations are active all of the time. A routine scan by Malaysian Communication and Multimedia Communications (MCMC) also confirms this situation (see Figure 1). The figure shown spectrum occupancy scans for four places in Malaysia which is in Johor Bahru, Kuala Lumpur Penang and Alor Setar for frequency range of 54 – 862 MHz.

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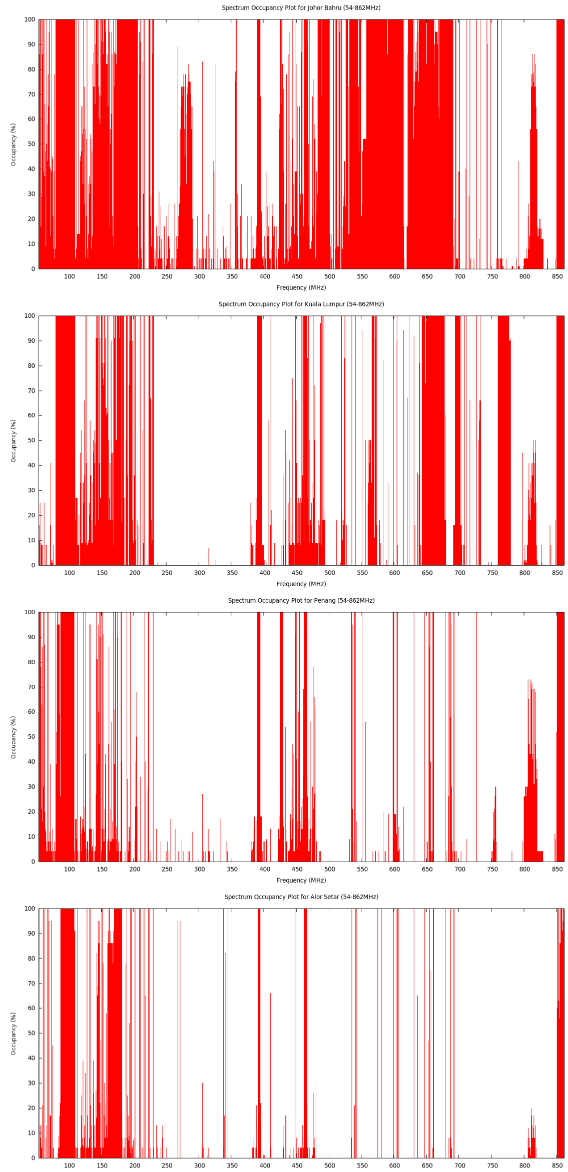

Figure 1. Spectrum Occupancy for Johor Bahru and Kuala Lumpur, Penang and Alor Setar.

Therefore by organizing other services around these constraints it is possible to gain greater spectrum utilization without causing interference to other users.

One particular technology that may bring better spectrum utilization is cognitive radios technology as it can sense its environment and adapt accordingly. The use of cognitive radio technology is therefore the key to the new IEEE 802.22 WRAN standard.

III. IEEE 802.22 Wireless Regional Area Network (WRAN)

In May 2004, US Federal Communication Commission (FCC) has issued a Notice of Proposed Rulemaking (NPRM) to allow unlicensed radio transmitter to operate in broadcast television spectrum at locations where that spectrum is not being used [5]. In response to the NPRM, the IEEE 802.22 working group on Wireless Regional Area Networks was formed in October 2004. Its main objective is to develop a WRAN system that would deliver broadband connectivity particularly to rural areas by sharing the television spectrum.

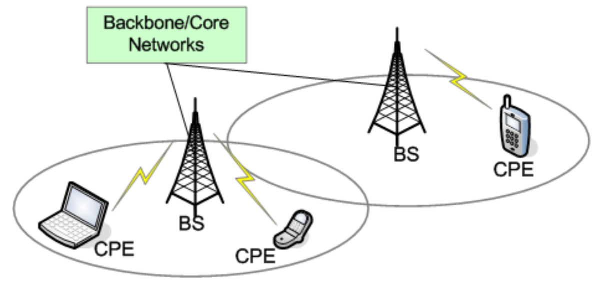

Figure 2. IEEE 802.22 System architecture

By May 2006 draft v1.1 [6] of the IEEE 802.22 standard was available, although much work was still required. Discussions need to be done with broadcasters whose spectrums are being shared as they are fearful of interference and reduced revenues from advertising. The standard is expected to complete by the first quarter of 2010 where some of the first networks could then be deployed.

There are several elements that were set for the IEEE 802.22 standard. These element can be classified into system architecture, coverage area and system capability. Each of those element is highlighted as follows:

A. System Architecture

The system is similar to current 3G, UMTS and WiMAX technologies which has a base station (BS) with a number of users or Customer Premises Equipments (CPEs) located within a cell. A BS is linked to the main network and transmits data on the downlink or downstream (DS) to the users or receivers. The data transmitted from users or CPEs is on the uplink or upstream (US). It is also control the medium access and perform traditional roles as in the conventional systems. Besides that it also manages the cognitive radio aspects of the system. The BS uses the CPEs to perform distributed measurement of the signal levels of other signals on various channels at their current position. These measurements are reported to the BS and decide which frequency, channel or transmission power to be used. The architecture of the IEEE 802.22 is depicted in Figure 2.

B. Coverage Area

The coverage area for the IEEE 802.22 is much greater than other IEEE 802 LAN/MAN standards. Figure 3 shows the comparison of the IEEE 802.22 standard with the other IEEE 802 LAN/MAN family. IEEE 802.22 standard specified that the range for a CPE is 33 km and in some instances base station coverage might extend to 100 km. Then, to achieve the 33 km distance, the power of the CPE should be 4 Watts EIRP (effective radiated power relative to an isotropic source).

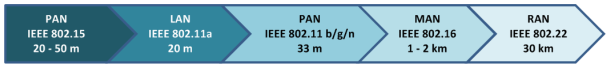

Figure 3. IEEE 802.22 standard comparison

C. System Capability

The system has been defined to enable users to achieve performance similar to DSL services. This eventually gives the download speed of about 1.5 Mbps at the cell edge and an uplink speed of 348 kbps. The figures were assumed based on 12 concurrent users. Hence the overall system capacity must be 18 Mbps in the downlink connection.

Therefore, in order to meet these requirements using a 6 MHz television channel spectral efficiency, 3 bits / sec / Hz are required to give the required physical layer raw data transfer rate. Table I summarizes the characteristics of the IEEE 802.22 WRAN standard.

Table I
IEEE 802.22 STANDARD CHARACTERISTICS

Parameter	Specification
Range	30-100 km
Methodology	Spectrum Sensing to identify free channels
Channel bandwidth (MHz)	6 or 7 or 8
Modulation	OFDMA
Channel capacity	18 Mbps
User capacity	Downlink: 1.5Mbps Uplink: 384 kbps

IV. DIGITAL TV AND DATA SERVICES FOR RURAL

As for end of 2009, 10 countries had completed the process of turning off analogue terrestrial broadcasting or digital switchover (DSO). Other countries had plans to do the same and in the process of consultation with the industry players. Malaysia has published its Standard Radio System Plan (MCMC SRSP-521 DTT) in September 2007 for Digital Terrestrial Television (DTT) [7]. It is expected that the current analogue TV service will continue to operate until 2015. In 2016, all analogues TV broadcasting will be discontinued.

Majority of Malaysian broadcasters including government owned Radio Televisyen Malaysia (RTM) will adopt Digital Video Broadcasting – Terrestrial (DVB-T) before 2016. Furthermore the DVB-T is using the Orthogonal Frequency Division Multiplexing (OFDM) which is also used in the IEEE 802.22 WRAN for modulation. The OFDM works by splitting the digital data stream into a large number of slower digital streams with each carrier frequency digitally modulated a set of closely spaced adjacent carrier frequencies. This will eventually ease the detection of incumbent for the cognitive radio part of the standard.

A. Maximum Number of IEEE 802.22 WRAN Cells

In determining the maximum number of IEEE 802.22 WRAN cells, we adapt the model developed by Liu et al. [8] for co-channel setting. It is assumed that both DVB-T and IEEE 802.22 WRAN cells are in circular shape. This setting is depicted in figure 4 and the challenge is to determine how many IEEE 802.22 WRAN cells can fit in the circumference of the DVB-T protected contour and its margin. In order to determine the number of IEEE 802.22 WRAN cell, the angle between both cells as shown in the figure have to be calculated.

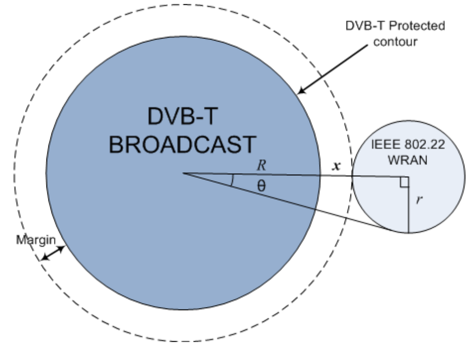

Figure 4. Determine maximum number of WRAN cells

Therefore the formulas for determining the maximum number of IEEE 802.22 WRAN cells are:

$$\theta = \sin^{-1}\left(\frac{r}{R+x+r}\right) \tag{1}$$

$$N_{MAX} = \frac{2\pi}{2 \times \theta} \tag{2}$$

B. Interference from WRAN to DVB-T Receiver

The interference from each IEEE 802.22 WRAN BS towards the DVB-T BS station is given by:

$$I_i = P_s - PL\left(d\right) + G_r \tag{3}$$

where P_s is the trasmitted EIRP from IEEE 802.22 WRAN BS, $PL\left(\right)$ is the free-space path loss in dB and d is the distance of the IEEE 802.22 WRAN BS from the DVB-T receiver. Based on figure 4, $d = R + x + r$. G_r is the DVB-T receiver gain.

Aggregate interference from all IEEE 802.22 WRAN BSs is the sum of all interference affecting the DVB-T BS.

$$I_{total} = 10\log\left(\sum_{i=1}^{N_{MAX}} 10^{\frac{I_i}{10}}\right) \tag{4}$$

C. Signal Estimation

The power received from a transmitter at a distance d directly impacts the signal-to-noise ratio (SNR), which the desired signal level is represented in received power P_r and is derived by

$$P_r = \frac{P_t G_t G_r}{PL\left(d\right) L}\ [\text{Valid if } d \gg 2D^2/\lambda], \tag{5}$$

where P_t is the transmitted power in miliwatt (mW), G_t and G_r are the transmitter and receiver gains, $PL\left(d\right)$ is the path loss (PL) with distance d, L is the system loss factor ($L \geq 1$, transmission line etc., nothing to do with propagation), D is the maximum dimension of transmitting antenna, and λ is the wavelength of the propagating signal [9].

In the free space propagation model, the propagation condition is assumed idle and there is only one clear line-of-sight (LOS) path between the transmitter and receiver. On unobstructed LOS path between transmitter and receiver, the PL can be evaluated as

$$PL(d) = \frac{(4\pi d)^2}{\lambda^2} \tag{6}$$

or when powers are measured in dBm

$$PL(d) = 92.4 + 20\log(f) + 20\log(d) \tag{7}$$

From Eq. 6 the desired threshold or transmitter-receiver separation distance in meters can be determined. Hence,

$$d = \frac{\lambda}{4\pi}\sqrt{PL(d)} = \frac{c}{4\pi f}\sqrt{PL(d)} \tag{8}$$

V. Simulation Settings

In simulating and calculating the model, we refer to Standard Radio System Plan (MCMC SRSP-521 DTT) [7], [10] and [8]. We use Matlab for simulating the model. The system parameters are as follows:

A. WRAN BS

- UHF TV channel: 43
- Frequency: 650 MHz
- Channel bandwidth: 7 MHz
- Tx antenna gain: 12 dBi
- Filter and cable loss: 3 dB
- Antenna height, HAAT: 75m

B. DTV Receiver

- Transmitted power: 1 MW
- DVB-T protected contour (Diameter): 134.2 km
- Protection ratio: 21 dB
- Rx antenna gain: 12 dBi
- Channel frequency: 650 MHz
- Distance limitation to protected Contour: 16.1 km

VI. Results

In realizing the connectivity of the rural communities with broadband internet access, we need to determine how many BSs can accommodate the rural areas. This would give a rough idea on the implementation and matching the cost and demand for the rural areas. WRAN also cannot affect the primary services, in this case the DVB-T.

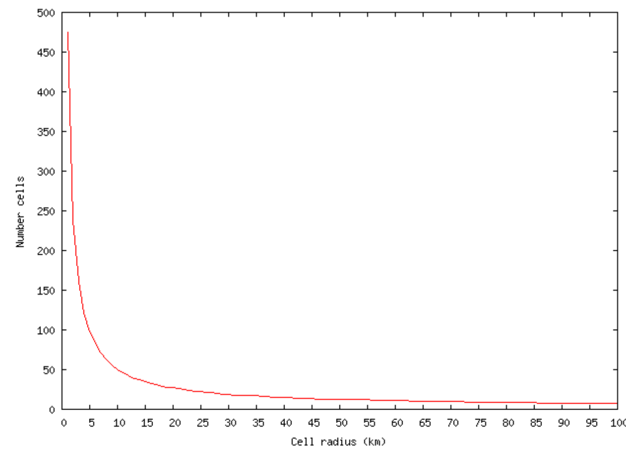

Figure 5. Maximum number of WRAN cells with respect to cell radius

A. Maximum Number of WRAN Cells

After running the simulation model, maximum number of IEEE 802.22 WRAN BSs at the protection contour plus the keep-out region, was determined. The results can be viewed in figure 5.

The IEEE 802.22 are supposed to serve an area from 30 – 100 km. From the plotted graph, the number of maximum WRAN cell can be varied from 19 to 8 cells at the edge of the DVB-T coverage cell. Hence this would benefit the rural communities in having the broadband services outside the coverage areas of DVB-T.

B. Cumulative Interference to the DVB-T

DVB-T BS is affected by the existence of WRAN cells. In figure 6, it is shown that cumulative interference decreases as the cell radius increases. This is due to the fact that, as the cell radius getting larger, the WRAN cell numbers will decrease and hence reduce the cumulative interference towards the DVB-T BS. The cumulative interference for WRAN cells of 30 to 100 km is between –59.0 dBm to –65.6 dBm. Since the rejection threshold of DTV is –84 dBm, the desired over undesired (D/U) signal ratio is 1.42 dB and 1.28 dB. The D/U is much lower compared to 23 dB of co-channel protection at threshold of visibility (TOV).

C. Signal Estimation

Different modulation schemes such as quadrature phase shift keying (QPSK), 16 quadrature amplitude modulation (16-QAM) or 64 quadrature amplitude modulation (64-QAM) will result in different PL values [9]. These values are 125 dB for QPSK, 120 for 16-QAM and 115 for 64-QAM and will significantly give impacts to the calculation of distance. In the case of WRAN in Malaysia, the frequency bands for DTV are from 174 - 230 MHz and 470 - 742 MHz. For the overall view, we draw the relation of frequency and the distance between two isotropic antennas with different modulation schemes as depicted in figure 7.

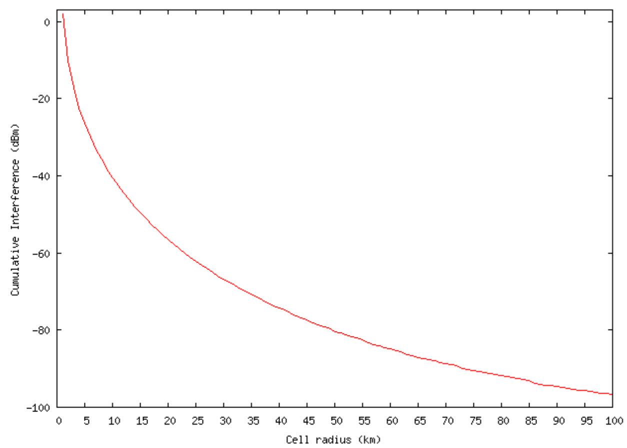

Figure 6. Maximum interference with respect to number of WRAN cells

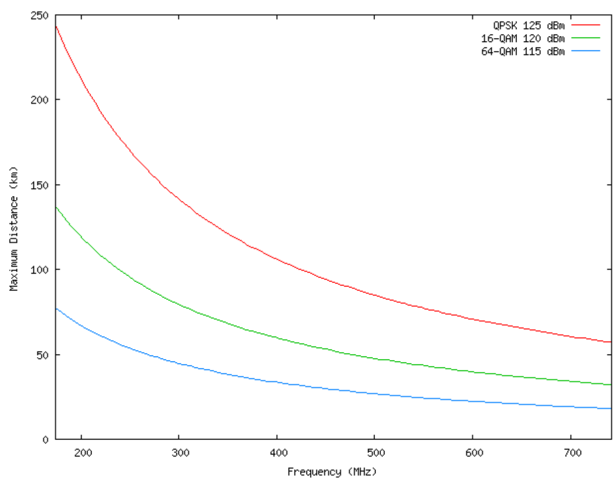

Figure 7. Maximum transmission distance versus frequency from 174 to 742 MHz in OFDM with different modulation schemes

According to the IEEE 802.22 Draft v1.1 [6], "a typical application can be the coverage of rural area around a village within a radius of 17 km to 30 km depending on the EIRP of the base station using adaptive modulation although the MAC should be able to accommodate user terminals located as far as 100 km when RF signal propagation condition prevail". The implementation of the modulation schemes depends on the distance of user terminals from the IEEE 802.22 base station. It indicates that 64-QAM is used for <= 20 km, 16-QAM is used for 20 – 23 km and QPSK is used for 23 – 30 km.

VII. Conclusion and Future Works

In order to really implements the IEEE 802.22 WRAN for rural in Malaysia, further analysis need to be considered. All angle need to be addressed for example the cost benefit analysis; number of users per base station; protection ratio between DVB-T and IEEE 802.22 WRAN; and coexistence of the service within the DVB-T coverage areas. Full cognitive radio function will also need to be investigated since the IEEE 802.22 WRAN is the first standard that comes with it.

This paper has highlighted the possibility of implementation the IEEE 802.22 Wireless Regional Area Network for rural areas in Malaysia. This will pave way for minimizing in the digital divide among urban and rural communities in Malaysia. Infrastructure is always been the highest priority in order to narrow the digital divide in Malaysia. The idea of introducing the broadband to the rural will eventually increase the penetration rate in Malaysia which is quite low compared to other countries in Asia.

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