Sub 1GHz M2M Communications Standardization: The Advancement in White Space Utilization for Enhancing the Energy Efficiency

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Abstract—**Energy efficiency of machine to machine (M2M) communications terminals is one of the major design goals of M2M networks, resulting from anticipated over 50 billion M2M communications devices to be deployed into the networks by 2020 [1]. The stakeholders in the M2M communications have observed that it will be environmental and economic catastrophic to deploy M2M communications devices without solving the energy inefficiencies associated with wireless devices that are expected to be used for M2M communications. In view of the aforementioned energy challenge, sub 1GHz spectra have provided enormous opportunities that can be energy efficient, cost effective and coverage efficiency which can be utilized for M2M communications. This work will evaluate the energy efficiency benefits of optimized Sub 1GHz spectra for M2M communications.**

Keywords— Energy Efficiency, IEEE 802.11ah / 802.11af / 802.22 / 802.15.4 Standards, M2M Communications, Sub 1GHz Communications, Weightless Standard.

I. INTRODUCTION

White space M2M communications is recently receiving huge interest in academia and industries, because of the inherent features of conserving resources and increasing efficiency [2]. As a result, the Weightless Special Interest Group has developed M2M communications specification for Sub-1GHz spectrum in White space. The communications spectra specified are from 470MHz to 790MHz, with communications range of up to 10Km. The core objectives of the specification include energy efficiency – up to 10 years battery lifespan and cost effective – approximately $2 per chip [3]. This specification is expected to be very efficient for over 50 billion M2M devices because of the core specification objectives and the amount of available spectra in the White space.

Weightless specification and other sub 1GHz standards like ZigBee, DASH7 Alliance, 6LoWPAN, RPL, IEEE 802.11ah, IEEE802.22 and proposed IEEE 802.11af are arguably the future of energy efficient and cost effective M2M communications [4][5][6][7][8]. This is because the signals range of these sub 1GHz standards and specifications are greater than their counterpart in the over 1GHz frequency bands at any given transmission power. To that effect, fewer base stations or access points will be required for a given coverage, compared with the over 1GHz frequency specifications and standards like WiFi, LTE, CDMA, UMTS, DCS etc. This will also facilitate networks coverage of the rural communities which could not be covered by the current wireless networks, as a result of low cost advantages of such locations especially in the developing world. It is on these bases that the sub 1GHz spectra are becoming more popular for M2M communications than over 1GHz frequency spectra. In addition, the over 1GHz spectra are congested with different wireless applications, in which Antonio M. et al observed that wireless devices are experiencing spectrum congestion and yet a spectrum campaign shows the underutilization of the sub 1GHz spectra especially the White space; in which the conversion of analogue television to digital television which will create a great amount of spectra that can be efficiently utilized by the application of cognitive radio was advocated [4].

Currently, the environments are flooded with wireless devices that operate at over 1GHz spectra; around 2GHz - 2.5GHz and 5GHz which are supposedly being proposed to be used for M2M communications. One of the arguments of the supporters of these proposals is that the technology is readily available and hence can be adapted for M2M applications, but the inherent characteristics of M2M communications which differ significantly from human to human (H2H) communications paradigm undermines this idea. The data rates of most of the M2M applications are small; hence interfaces of the existing wireless medium will not be optimal for such applications [5]. Apart from the energy efficiency, cost, and range attributes of sub 1GHz communications, it will also aid to decongest the congested 2.4GHz ISM bands where most of these applications are using for their communications. Coupled with that most of the proposed sub 1GHz spectra can be accessed free of exorbitant license fee – the 900MHz ISM bands and White space.

This work will evaluate the energy efficiency and cost advantages of using the sub 1GHz spectra for M2M communications. This will be done by firstly reviewing the related sub 1 GHz standards that could be used for M2M communications; followed by a review of the components parts of Weightless network architecture, the energy efficiency benefits of sub 1GHz communications and conclusion.

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II. RELATED SUB 1GHz STANDARDS

A. Sub 1GHz WLAN (IEEE 802.11ah)

IEEE802.11ah task group was established in 2007 to adjust the interfaces of IEEE802.11 Wi-Fi family to operate in the unlicensed sub 1GHz bands to enhance the energy efficiency and coverage up to 1km. The lack of sufficient standards that operate at 900MHz ISM bands despite its global availability necessitates IEEE802.11ah [6]. This standard can support a data rate of more than 100 kbps which is suitable for M2M communications [7] [5]. The design of this standard can accommodate about 8191 per access point (AP) for short-data transmissions through hierarchical ID structure and one-hop network topology mechanism which could be used for outdoor M2M devices [8]. The features of this standard are very important for M2M communications paradigm. The academic and industrial experts are advocating for the applications of this standard in M2M communications, especially because of the energy efficiency of the standard which can guarantee longer battery lifespan of the M2M devices. The energy efficiency of this standard is achieved by deactivating the RF modules of the nodes during the non-traffic period, while periodically listen to beacons for update by the page segmentation. These energy efficient techniques in collaboration with long sleeping time (the nodes are only active for 160µs) by the nodes can elongate the battery lifespan of the nodes to over 10 years [8].

B. IEEE 802.11af

This is another standard that is gaining momentum in its application for M2M communications. The standard is the enhancement of the IEEE 802.11 physical layers and medium access sub-layers to support operation in the TV unused channel called White space [9]. This standard will operate in a Wi-Fi like structure called White – Wi-Fi and will implement the mechanism of cognitive radio (CR) in its operation. The CR functions are aided by channel power management (CPM) and the technique of dynamic station enablement (DSE) that will control the channel dependent stations (STAs) [10]. The standard has an indoor range of less than 100m and outdoor range of less than 5Km.

C. IEEE 802.22

This is the first White space IEEE and world's standards that are based on cognitive radio communications, the standard is based on frequency range of 54MHz to 862MHz [11]. This standardization group was formed in 2004 by IEEE whose objective is to optimize the physical layer and medium access control of the wireless communications mediums for long distance signal propagations with very high frequency selective fading and provides compensation for long round trip delays - 100KM respectively [12].

D. IEEE 802.15.4

This standard was formed in 2003 to adapt the medium access control (MAC) and physical layer (PHY) specification of wireless devices for low-rate wireless personal area networks (LR-WPANs) [13]. This standard is being used widely on some of the M2M/IoT applications because of the features of low power consumption, low data rate, and low cost wireless devices [14]. They also established a task group for the amendment of IEEE 802.15.4 standard support the PHY for active RFID system bi-directional and location determination applications in 2006 using 433 ISM bands with their first specification in 2011 [15].

Sub 1GHz Standard /Properties	**Weightless**	**IEEE 802.22**	**IEEE 802.11af**	**IEEE 802.11ah**	**IEEE 802.15.4**
Frequency (MHz)	470 – 790	54 – 862	470 - 790	755 - 928	868, 915
Modulations	16-QAM, QPSK, BPSK, DPSK, FH	OFDM	OFDM, 16-QAM, 64-QAM	OFDM,256QAM, 64QAM,16QAM, QPSK, BPSK	CSMA-CA, BPSK, OQPSK
Maximum Range (KM)	10	30		1	0.075
Maximum Downlink Throughput (MHz)	16	18	18.1	6	0.04
Uplink Throughput (MHz)	0.5	0.384	-	0.14	-
Structure	Cellular	Cellular	White -Wi-Fi	Wi-Fi - like	Star, Mesh
Bandwidths (MHz)	6, 7, 8	6, 7, 8	-	1 - 8	2
Proposed Application	M2M Communications / internet of things	Wireless broadband in rural and remote areas	-	Wireless sensor network	Wireless Sensor Network
Applications of Cognitive Radio (CR)	No but uses frequency hopping	Yes	Yes	No	No

Table 1: Sub 1GHz Properties

III. COMPONENTS OF WEIGHTLESS SPECIFICATION

Weightless specification availed a low-cost bidirectional wireless data transfer from M2M devices in wide area. The network which has a cellular structure will use the unlicensed TV channel for communication by occasionally adapting to the changes in the Whitespace channels availability. In this section, the component parts that made up of the weightless network shown in fig1 will be briefly discussed.

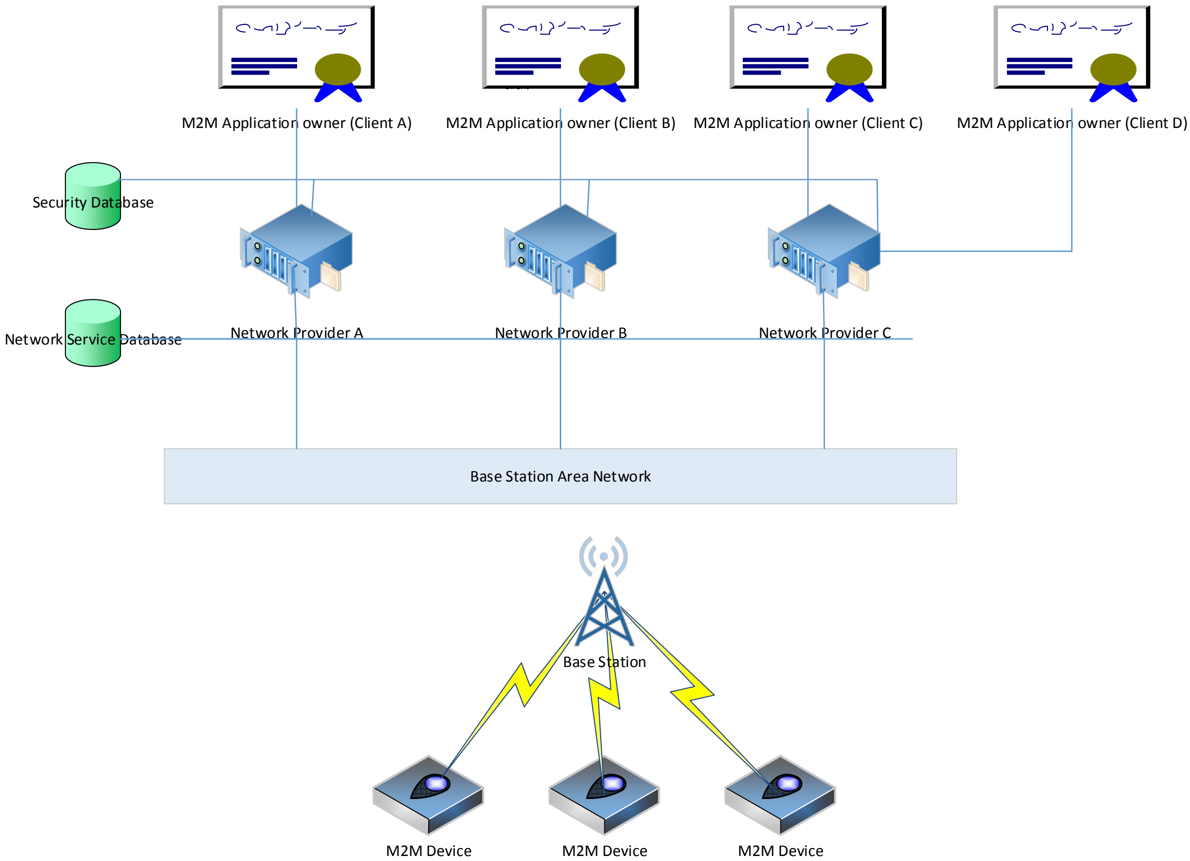

Fig 1: The Weightless Network Architecture

A. M2M Devices

These are the electronics devices that will be deployed to the environment for monitoring and controlling purposes, for instance, the sensor nodes that are deployed to the power grid for monitoring the generation, transmission and distribution (example SCADA). These devices are numerous [1] and will be much more in future, hence the need to have a reliable network resource that will accommodate them all. To be able to accommodate all these devices, Weightless is based on White Space in which the unused spectra are greater than the entire 3G network [16]. White Space M2M Communications could be the only optimized solution for the predicted number of M2M devices.

B. Base Station

Weightless operates cellular based M2M structure. This structure could be the optimum solution for variety of applications associated with M2M communications. The cellular based M2M communications structure is very necessary especially as results of the negative remote environmental characteristics of some M2M applications, like static M2M devices in basement, tunnels, etc. need an elevated signal transmission with high signal penetrating power to achieve the required coverage [17].

C. Base Stations Area Network

This is a network that connects all the base stations in a given geographical area together. In the GSM network architecture, it is akin to a cluster network that being controlled by a backbone base station. While in 3G, it is akin to radio network controller (RNC).

D. Network Provider

This is a weightless Network services provider. They are akin to the common cellular networks providers that exist today. They are the platforms through which the M2M applications companies can assess the Weightless services.

E. M2M Application Owners

They are the companies that use the Weightless network to connect to their devices, like the power companies that connect their sensor nodes in the grid to their server through the weightless network. The connection is through the network services providers.

F. Network Services Database

This is a database that contains all the Weightless Network providers. This is akin to home location register (HLR) in the current cellular architecture, and it is used to by the base stations to find the M2M devices network provider.

G. Security Database

This is database that contains all the security data of M2M devices.

IV. THE ENERGY EFFICIENCY BENEFITS OF SUB 1GHZ M2M COMMUNICATIONS

From Friis's transmission formula [18], the power of a received signal P_R transmitted by an antenna with a signal power P_T in inversely proportional to the square of the transmitted frequency f,

$$P_R = \frac{P_T G_T G_R C^2}{(4\pi R f)^2} \qquad (i)$$

Solving for R in (i) will result to (ii)

$$R = \frac{10^{\frac{P_T + G_T + G_R - P_R}{20}}}{41.88 \times f} \qquad (ii)$$

Where R = signal transmission distance in KM, f = frequency **(MHZ), P_T and P_R are transmit and received power in dBm** respectively, G_T and G_R are transmitter and receiver gains in dBi respectively. Using the variables as shown in Fig 2, the relationship between the ranges of signal propagation, the transmitters' transmission power and the communications frequencies are established.

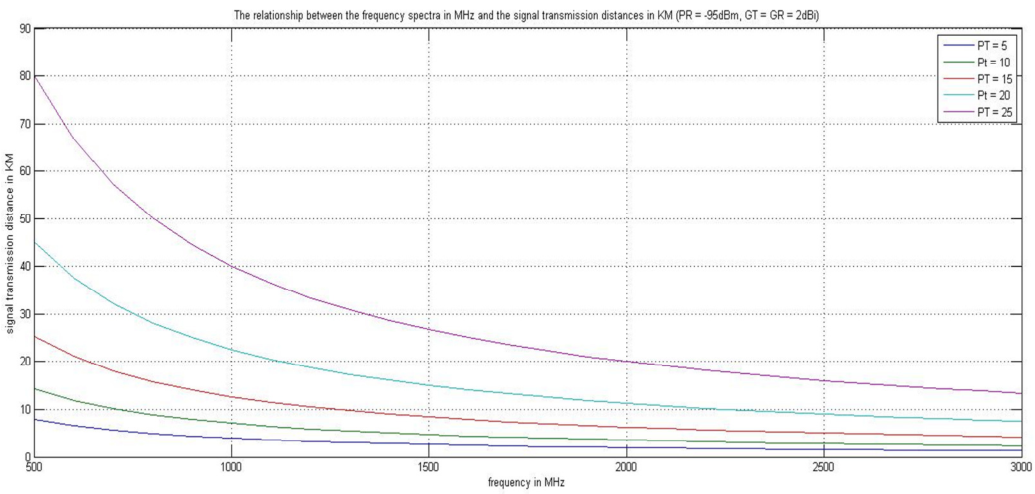

Fig 2: The relationship between the Frequency and Signal Coverage

The graph in fig 2 above shows the relationship between the communications frequency spectra and the signal coverage from the BS. It can be seen that in the sub 1GHz spectra, the signals coverage is well longer from a single BS compared to the spectra above 1GHz. This implies that less number of BS will be deployed for M2M communications when compare to the spectra above 1GHz. In addition, there is less power requirement by M2M devices to send their packets to the BS which will enhance the battery longevity of M2M devices.

IV. WHITE SPACE BASED CELLULAR M2M COMMUNICATIONS STRUCTURE

The popularity of the cellular based M2M structure is necessitated by the ubiquitous coverage, plug – and – play support and mobility support that can achieved in the cellular based M2M communications structure. Also, the energy efficiency benefit associated with cellular base M2M communications structure by lowering the transmission power needed by M2M device cannot be over emphasized couple with the qualities of the BS to deal with traffic scheduling and interference locally. The cellular based M2M communications solution will provide better coverage and lower the cost of network deployment [20]. Furthermore, over 2Mbps can be achieve using White space spectrum in over 10KM from the base station and is about 23Mbps close to the base stations [21]. This range of throughput shows that White space and indeed other sub 1GHz spectra can conveniently accommodate all the anticipated applications of M2M communications. The spectrum available in White space is about 150MHz in most part of the world [16]. And these spectra have available 64 channels with bandwidth of 6MHz that the M2M devices can transmit and receive their data; this shows that there are sufficient spectra that can accommodate the numerous anticipated devices of M2M communications.

To this end, the optimization of the sub – 1GHz specifications is imminent. This can be done by enabling dual interface in the M2M devices, so that they can operate in both in the sub 1 GHz Wi-Fi like networks – IEEE802.11ah and IEEE802.11af. While the M2M applications that require high throughput use the IEEE802.11ah because of the higher bandwidth when compared to later, the applications that require low throughput will use IEEE802.11af. The sub 1GHz cellular network structure will be very efficient for the M2M applications that are mobile like telemetry, vehicle – to – vehicle (V2V) communications, monitoring the engine performance of the electro – mechanical devices - cars, lorries etc. Also, the M2M cellular structure will provide the needed ubiquity needed for M2M to thrive. The marriage of the sub 1GHz cellular and Wi-Fi structure is needed to be able to accommodate the anticipated applications and give rooms for the development of new applications.

V. CONCLUSION

The Sub 1GHz spectra provide sufficient access, cheap, and energy efficient communications medium that can be harness for M2M communications. There are existing IEEE standards that are being optimized for M2M communications, but the Weightless standard is primarily being designed for M2M communications in White space could be the ideal standard for M2M communications. This is as a result of the available bandwidth in the White space (150MHz); the White space is license free; couple with over a decade life span for the M2M communications devices that being designed into the specification. The IEEE 802.22 which is also a cellular White space based standard is also an alternative, but while IEEE 802.22 standard is primarily for internet connections in rural and remote locations, weightless standard is primarily for M2M communications.

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