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Survey and Comparative Study of Wireless Technologies for Enhanced MANET

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Abstract

Wireless communication technologies are playing a significant role in the design and implementation of Mobile Ad hoc Network (MANET). The characterization of MANET such as dynamism in topology, limited bandwidth and power consumption increases the unlicensed communication technologies and complexities in existing protocols. This paper surveys and compares the current and near future Wireless communication Technologies in the 2.4 GHz band. Also, this paper considers the highlights and limitations of those technologies and finally concludes with the necessity for the development of suitable unified protocol for existing and future wireless technologies.It is believed that the survey and comparison presented in this paper would benefit researchers and application engineers in selecting an appropriate technology for MANET services.

Keywords— Wireless Communication Technologies, MANET, UWB, Wi-Fi, Li-Fi and Giga IR.

1. INTRODUCTION

The role of 2.4 GHz Industrial, Scientific, and Medical (ISM) band and other frequency band in communication is growing day by day. This growth is supported by two emerging wireless technologies: Wireless Personal Area Network in short WPAN and Wireless Local Area Network called WLAN.

According to techopedia “A wireless local area network (WLAN) is a wireless distribution method for two or more devices that use high-frequency radio waves and often include an access point to the Internet. A WLAN allows users to move around the coverage area, often a home or small office, while maintaining a network connection.” As defined by webopedia, “A wireless personal area network (WPAN) is a personal, short distance area wireless network for interconnecting devices centered on an individual person's workspace. WPANs address wireless networking and mobile computing devices such as PCs, PDAs, peripherals, cell phones, pagers and consumer electronics. WPANs are also called short wireless distance networks.” Table 1, shows the Comparison of WPAN and LAN. Fig.1 shows technologies involved in WPAN and WLAN. Wireless technology networks are simple to create and deploy.The cost of creation and deployment of wireless network in some cases are less than wired Local Area Networks. The wireless approaches have many merits and demerits when compared to the conventional wired networks. Mobility offered by the wireless communication is one of the major advantages. Dynamism provided to the users in joining or leaving the network is the major advantage lies in this kind of network. This dynamism allows users to create a network in an Ad hoc manner. It also supports users to join or leave the network without any hurdle.

TABLE I COMPARISON OF WPAN & WLAN

Characteristics	WPAN	WLAN
Coverage	Within a reach of a person	Within a campus or building
Performance	Moderate	High
Standards	IEEE 802.15	IEEE 802.11
Applications	Cable replacement for peripherals	Extension of wired network

Fig.1 shows technologies involved in WPAN and WLAN. The advantages of Mobility and ad hoc connectivity in wireless networks create a Mobile Ad Hoc Network. A Mobile Ad hoc Network (MANETs) [1] refers to collection of various heterogeneous mobile nodes that are dynamically forming a network. MANET does not need any centralized administration or pre-existing network infrastructure. Mobile nodes in MANET are arbitrarily located and are free to move freely at any given time. This mobility in MANET makes interconnections between nodes unpredictable and network topology to change rapidly.Formation of MANET cannot be confined to a particular wireless technology, because each technology has its own highlights and limitations. Due to the day-by-day increase in number of devices and utilization of 2.4 GHz frequency band by the new systems,mitigating interference among these existing and new systems becomes complex in nature[2] [3].According to the Glossary of Telecommunication Terms - Federal Standard 1037C, “interference is defined as a coherent emission having a relatively narrow spectral content”.

To have a general review about the existing and future communication technologies, this paper presents a survey and comparison of various wireless communication standards authored by the Institute of Electrical and Electronics Engineers (IEEE) [4] for the benefit of researchers in the emerging domain of Mobile Adhoc Network (MANET).

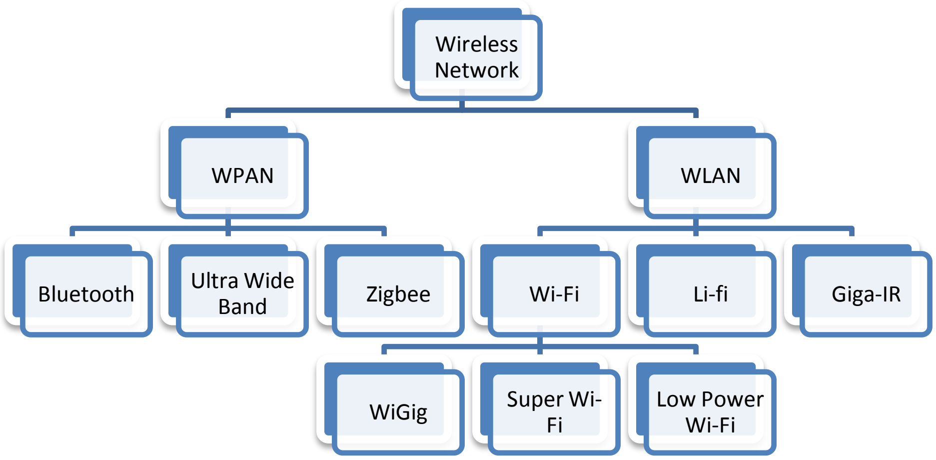

Fig. 1 – Technologies in WPAN and WLAN

The remaining part of this paper is organized as follows. Section II gives the overview of the various wireless communication technologies that are currently available for MANET and a brief evaluation of them is discussed in Section III. In Section IV, technology complexity is compared based on the IEEE standards. A conclusion for this survey and comparative study is specified in Section V.

2. WIRELESS COMMUNICATION TECHNOLOGIES

This section introduces various wireless communication technologies for MANET. In MANET, there is no standard licensed band for each communication technologies for its operation. This allows companies to develop their own specifications covering the Mobile Ad hoc network, security issues and application profile layers.

1.1. Bluetooth

Bluetooth networking transmits data in low-power radio waves.Bluetooth devices communicate on the widely accepted and agreed frequency band of ISM. Bluetooth devices deploys Time Division Multiplexing (TDD) technique for communication. This Bluetooth communication equally splits the channel into slots with a 1mbps symbol rate.The capacity of a slot is 625 bits. Transmission occurs in packets.Different hop frequencies are used for each packet. The maximum frequency hopping rate for transmission is 1600 hops/s. Bluetooth devices are divided into three classes of category based on power consumption and communication range as follows:

Category	Maximum Power	Range
Class 1	100 mW	40m-100m
Class 2	2.5 mW	15m-30m
Class 3	1 mW	5m-10m

1.2. UWB
Ultra wide band is a radio technology used for high data rate communication over short distances. Its unique feature is that its bandwidth is up-to 480Mbps which is suitable for audio and video delivery in home environment. UWB uses DS-UWB (direct sequence ultra wide band) and MB-OFDM (multiband orthogonal frequency division multiplexing)spread spectrum method to transmit information at regular specificTime intervals. It occupys large bandwidth whereas conventional radio transmits information systems transmit information by varying power level and frequency [5]. UWB has some characteristics which makes it more attractive such as: Low complexity and low cost, Resistant to severe multipath and jamming, having a noise-like signal spectrum, having a very good time domain resolution for location and tracking applications.

1.3. ZigBee
Based on IEEE 802.15.4 specified MAC and PHY layers, the ZigBee transceivers are operated on un-licensed industrial, scientific and medical (ISM) radio spectrums; 2.4 GHz globally, 868 MHz and 915 MHz in Europe and inUSA respectively. At 2.4 GHz, a total of 16 channels, each supporting data rate of 250 kbps, are allocated. The typical communication range of ZigBee transceivers is up to 100 meters and the network size of the ZigBee controller can grow up to 65,536 nodes. In order to secure the communication, the 128-AES algorithm is supported.

1.4. Wi-Fi
Wi-Fi networks are mostly utilized in office buildings, homes, and even outdoors in urban areas. It is specified by the IEEE 802.11 standard. The IEEE 802.11specification offered 1 or 2 Mbps data transmission rates are operated at 2.4 GHz and this standard evolved through new modulation to produce 802.11b. It is operated at 2.4 GHz and provided data transmission rates up to 11 Mbps. Simultaneously 802.11a systems was also developed that provides data transmission rates up to 54 Mbps at the 5.7 GHz frequency band. To support backward compatibility and to provide high-speed data transmission for the 802.11bsystems and 802.11 systems, 802.11g system was designed.This System offers 54 Mbps data transmission with 2.4 Ghz frequency range.Hence,Wi-Fi comes in many different variations like IEEE 802.11a/b/g/n.It utilizes2.4 GHz and 5 GHz frequency of ISM band along with 802.15.4, 802.11 transmissions, then it can blocked with positioning of 802.15.4 networks. In a nutshell the key differences of Wi-Fi include , type of wireless access ,frequency band and maximum data transmission rates. The application of WLAN is growing hugely and it is part of consumer gadgets. The gadgets used by consumers' uses anyone of the above said 802.11 variations.IEEE 802.11 gained huge popularity because of the cost effectiveness and easy deployment. It is used in broadly arranged wireless network technologies in the world.

1.5. Wi-Gig
WiGig (802.11ad), otherwise known as Microwave WiFi, operates in a diverse and much higher frequency band i.e. unlicensed 60GHz. It is recognized that WiGig

provides low power and very high performance technology. The data transfer rate is seven gigabits per second. The 60 GHz signal cannot typically penetrate hard obstacles such as walls and blocks. It can easily propagate off reflections from ceilings, walls, objects and floors using the technique called beam forming. While roaming away from the one location to another location, the technology supports switching from lower band to higher band or vice-versa but at a much lower rate.

1.6. SuperWi-Fi

Super Wi-Fi, it is also called as White-Fi or 802.11af. This White-fi technology uses frequencies range between 54MHz and 790MHz. This technology covers over very long distance when compared with Wi-Fi.This technology also offersa reasonable throughput with a transmission rate at 24Mb/s. The applications of this SuperWi-fi is similar to that of 802.11ah.

1.7. Low Power Wi-Fi

IEEE 802.11 aka Wi-Fi is used in everywhere nowadays.Wi-fi is not suitable for the Internet of Things (IoT) because the basic characteristics of Low-power Wi-Fi is to offer higher data transmission to a limited number of stations in an indoor or short range communication. To carry out IoT requirements, a committee has been formed by IEEE and the committee is named as LMSC (LAN/MAN Standards Committee). The committee has formed a Task Group (TG-ah) called IEEE 802.11ah to extend the applicability area of 802.11 networks with very low energy. This energy efficient protocol aims to allow thousands of outdoor and indoor devices to work at the same area. The IEEE technical name for Low Power Wi-Fi, is 802.11ah. It provides bandwidth for sensors, monitors in gadgets, and in various home appliances.

1.8. Li-Fi

Light-emitting diodes (LEDs) plays a significant role in the design of Li-Fi. LEDs technology is gaining popularity instead of standard light bulbs.It has been nearly four decades since optical wireless (OW) system was suggested as an alternative tool for data transmission in wireless technologies [6]. Li-Fi has many advantages, it is able to be used in areas that are electromagnetically sensitive. Some of the application areas are hospitals, aircraft cabins, nuclear energy projects and were Wi-Fi fails completely [7]. Optical characteristics of Li-Fi workseven under the water bed or sea bed, which offers a great data transmission in navy and military operations.Organised LED transmitters in a building could provide much consistent internet with more localized connectivity.

1.9. Giga-IR

Gigabit Infrared (Giga-IR) process and works at minimum link speeds of 512 Mb/s and to the maximum of 1.024 Gb/s. The characteristic of Giga-IR allows it to integrate easily into the portable products and consumer devices.DC-balanced line encoding scheme is the coding method for Giga-IR. The information are encoded on a 10-bit character, is to facilitate clock recovery at the terminal end. The GigaIR optical transmitter can be either a LD or LED. A two level ASK modulation format is used in the LD transmitter. If LED is used as the transmitter then a four-level ASKS modulation format is used.

3. Comparative Study

The comparison is based on the standards specified by IEEE. Table 2 summarizes the main differences among the existing and near future wireless communication technologies. Following are the definitions for the comparison,

1. *IEEE Specification :* Standard specified by the IEEE
2. *Network Size / Nodes:* Refers to the maximum number of mobile devices in a particular network
3. *Security/ Data Protection:* Encryption and decryption methods for data secured transmission.
4. *Coexistence Mechanism:* coexistence are defined to mitigate mutual interference among the existing devices.
5. *Frequency Band:* Refers to the specific range of frequencies in Radio Frequency system

Table 2– Comparison of existing and near future wireless communication technologies

Communication Standard	***Bluetooth***	***UWB***	***ZigBee***	***Wi-Fi***	***Wi-Gig***	***Super Wi-fi***	***Low Power Wi-Fi***	***Li-Fi***	***Giga-IR***
IEEE spec..	802.15.1	802.15.3a	802.15.4	802.11 a/b/g	802.11ad	802.11af	802.11ah	802.15.7 (802.11 with VLC)	802.xx
Frequency band	2.4GHz	3.1-10.6 GHz	2.4 Ghz	2.4 GHz; 5 Ghz	2.4, 5 and 60 GHz bands	2.4GHz	2.4GHz	Not Regulated	5, 10, 40 Gb/s
Signal rate	1 Mb/s	110Mb/s	1 Mbps	54 Mb/s	7 Gbit/s	54 Mbps	12 Mbps	10 Gbps	512 Mb/s and 1 Gb/s
Coexistence Mechanism	Adaptive freq.hopping	Adaptive freq. hopping	Dynamic freq. selection	Dynamic freq. selection transmit power control (802.11)	Dynamic freq. selection transmit power control	Self	Self	Self	Self

Spreading	FHSS	DS-UWB, MB-OFDM	DSSS	DSSS,OFDM	OFDM	OFDM	OFDM	OFDM	Two and Four Level ASK
Basic cell	Piconet	Piconet	Star	BSS	ESS	BSS	BSS	Scatternet	ESS
Nominal range	10 m	10 m	<100m	100m	Beyond 10 m	Indoor: up to few 100 m	Indoor: up to few 100 m	Based on Light Intensity	1cm - 10m
Nominal TX Power	0 - 10 dBm	-41.3 dBm/ MHz	0 dBm	15-20dBm	15-20dBm	40dBm	10dBm	Low	Low
Number of RF Channels	79	(1-15)	1/10/16	14 (2.4 Ghz)	1-40	14 (2.4 Ghz)	7 (2.4 Ghz)	-	1-60
Channel Bandwidth	1MHZ	500MHz 7.5GHz	2 MHz	22 MHz	60GHz Microwave spectrum	54MHz and 790MHz	54MHz and 790MHz	Spectrum Free	Eye-safe Infra-Red spectrum
Modulation type	GFSK	BPSK, QPSK	O-QPSK	BPSK, QPSK, COFDM, CCK, MQAM	QPSK, COFDM	BPSK, QPSK, 16-QAM, 64-QAM	BPSK, QPSK, 16-QAM, 64-QAM	On off Keying (OOK) and (Variable PPM) VPPM	TOSA module, chipset
Extension of the basic cell	Scatternet	Peer-peer	Mesh	ESS	ESS	ESS	ESS	BSS	Scatter net
Max number of cell nodes	8	8	65536	>2000	>5000	>5000	<1000	Not specified	>10
Data protection / Security	16-bit CRC	32-bit CRC	128 AES	32-bit CRC,WPA	CBC-MAC	WPA, WEP	Conv. Code	Less secured	AES,

(Acronyms: AES (advanced encryption standard), ASK (amplitude shift keying), BPSK/QPSK (binary/quardrature phase SK),BSS/ESS (basic/extended service set), CBC (cipher block chaining) , CCK (complementary code keying), COFDM (coded OFDM), CRC (cyclic redundancy check), DSSS (direct sequence spread spectrum), FHSS (frequency hopping spread spectrum), GFSK (Gaussian frequency SK), MAC (message authentication code), MBOFDM (multi-band OFDM), OFDM (orthogonal frequency division multiplexing),M-QAM (M-ary quadrature amplitude modulation), O-QPSK (offset-QPSK),TOSA (Transmit Optical Sub-Assemblies), VLC (Visible Light Communication), WPA (Wi-Fi protected access), WEP (wired equivalent privacy))

6. *Transmission Time:* It depends on the distance between two nodes , message size and the data rate.
7. *Spread Spectrum:* When a narrowband signal is elaborated into a large or wide band spectrum, then the wide band spectrum is termed as spread spectrum
8. *Signal Rate :*Rate in which signal transmits in a medium
9. *Modulation:* The method of changing the properties of signal from one form to another .
10. *Channel Bandwidth:* difference between the upper and lower frequency cutoff.
11. *Nominal Range :* Maximum distance of a signal transmission
12. *Nominal Tx Power :* Minimum energy required for the device operation
13. *Basic Cell :* Structure of the network.
14. *Number of RF channels:* Maximum number of RF devices that can be operated simulatenously

4. TECHNOLOGY COMPLEXITY AND DISCUSSION

The new era of wireless communication technology is very challenging due to its divergent characteristics and availability for various standards for particular domain of communication. This section discusses the features with complexity in existing communication technologies.

The unlicensed ISM band, which is the 2.4 GHZ frequency, is shared by major wireless standards [8] and [9] in communication arena WPAN and WLAN are considered the broadest classifications in the 2.4 GHz band.

The specified non-proprietary features of the 2.4 GHz license free band suffers from the data sharing, resource sharing or bandwidth allocation. This study identifies that the Wi-Fi and Bluetooth are considered to be the most frequently and broadest systems in the ISM band with 2.4 GHz. Bluetooth, UWB ,Zigbee and Wi-Fi are the existing communication technologies for MANET. Li-Fi, Low Power Wi-fi , White-Fi, and Wi-Gig, and are the most promising near future wireless communication technologies for MANET

From the survey and comparison, it can be noted that Bluetooth and Ultra Wide Band (UWB), are mainly used communication technology in the WPAN. Wi-Fi, Low Power Wi-Fi and Super Wi-fi are designed for WLAN (about 100m). Li-Fi can be used as remote control devices where radio wave doesn’t work.

The Bluetooth technology offers wireless communication in an environment. This technology eliminates the need for cables and connectors, so the expenses are reduced, which provides a huge cost benefit to the organization. Wi-Fi is focused towards the effective communication among the computers. Wi-Fi is an extension of LAN and Wi-Fi can be made as an substitution for cabled LANs[1]. As per the standard specifications of IEEE 802.11n, the speed given by Wi-Fi to its user ranges from 100-150mbps but Gfeller and Bapst [6] identifies that it is still insufficient to accommodate number of desired users. The emergence of Low Power Wi-Fi supports the Internet of Things. Obviously, Wi-Fi and Ultra Wide Band (UWB) provides a very higher data rate, than the Bluetooth communication devices. Li-Fi can produce data rates faster than normal broadband connection. The data rate normally ranges from 10 mbps to 15 mbps. Li-Fi offers many features than the Wi-fi but Li-Fi is a complementary technology to the Wi-Fi. In Li-Fi, Interference occurs in the path of transmission from external light sources and opaque materials which will cause interruption among the communication. 2.4 ISM frequency band is for Bluetooth, most of the Wi-Fi, Wi-Gig communications and 54 MHz-790 MHz for Low Power Wi-fi and Super Wi-Fi. Co-existence of these devices in a particular location leads to interference in the data transmission due to the utilization of same frequency band. These divergent characteristics of each communication technologies make a complexity in the design for unified protocols for communication.

From the survey and comparison, it can be noted that the there are various advance technological and conventional challenges involved in MANET. Some of the challenges are higher power consumption, data transmission rate, frequency usage and data security threats. Data security threat is the inbuilt property in any communication technology. This challenges leads to design of various communication technologies for MANET. Nevertheless, it can also be noted that the main challenge of WLAN and WPAN wireless communication is interference [10], [11], [12], [13], [14]. Now-a-days, Cognitive radio technology is used to analyze the spectrum of WPAN and WLAN and it is also used for the detection of interference among WPAN and WLAN technologies under various dynamic conditions. The interference caused by 802.11 networks cannot be predicted. Interference occurs in this MANET sustains from several minutes to several hours. This interference will cause a huge packet loss in the Mobile ad-hoc network. The interference could make threats to functionality and security of the MANET. Unfortunately, research in this area is so young that researchers have to investigate different ideas regarding the identification of a universal measure to mitigate network interference in the aforesaid ISM bands. From this study, it is found that usage of common spectrum suffers from interference and effective interference mitigation mechanism is needed for the co-existence of WPAN and WLAN [15],[16], [17].

5. Conclusion

MANET is likely to be used in many practical applications, which includes home area networking, personal area networks, military environments, and so on. MANET cannot be confined to a particular wireless communication technology, because each technology has its own highlights and limitations. This paper aims to provide researchers a brief survey about various wireless communication technologies such as Bluetooth, UWB, Wi-Fi, Li-Fi, Wi-Gig, Giga IR, Low Power Wi-Fi and Super Wi-Fi used in MANET. This work also presentsa comparative study and quantitative evaluation in terms of technology complexity of various communication technologies of MANET also concludes that, Due to the increasing number of devices and systems that operate in the 2.4 GHz band, interference among these systems becomes unavoidable and complex in nature. Despite with different efforts to minimize and mitigate the effect of interference, simultaneous coexistence of WLAN and WPAN in MANET exerts serious research challenges in the environment. It includes decrease in throughput, performance degradation, and finally malfunctioning of the whole Adhoc network in a given time and location.Understanding the effect of interference and modeling a interference-free in wireless communication is essential, especially among WPAN and WLAN technologies in the 2.4 GHz unlicensed band.

To meet the various challenges of existing communication technologies of MANET with primary operational requirements, a new adaptive communications systems need to be designed,which facilitates to structure MANET and to transfer data through any form of wireless communication technology either it may use radio waves or light waves with wide range of frequencies and different bandwidths.

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