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Industrial Automation using Zigbee Communication Protocol

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Abstract: ***If we compare wireless communication over wired communication, wireless communication offer more advantages when compared to wired communication such as lower cost, fast deployment, higher flexibility & scalability and mobile nature of system communicated wirelessly. In Industrial automation, industrial communication has very challenging requirements like packet deadline, low transmission jitter, etc. In some places wired communication is only accepted and it cannot be replaced by wireless communication. Industrial applications also run more flexible requirements applications such as email, Video content or any other application. Those services are known as Best Effort (BE) services. In order to do both the industrial application and BE services we have proposed Zigbee communication together with the IEEE 802.11 standard in this article along with comparison between the two standards using physical layer solutions. This Zigbee communication is performed using a industrial automation design and it leads to less power consumption. Result and analysis in terms of real time services is left as a future work in this paper. It is proposed that through Zigbee solution it is possible to obtain better result in certain cases than those achieved using IEEE 802.11 standards.***

Keywords: ***Zigbee communication, IEEE 802, Industrial automation, low power, Best Effort.***

I. INTRODUCTION

The fourth industrial revolution is the current revolution which is taking place integrating Internet of Things (IOT), robotics, virtual reality and artificial intelligence.

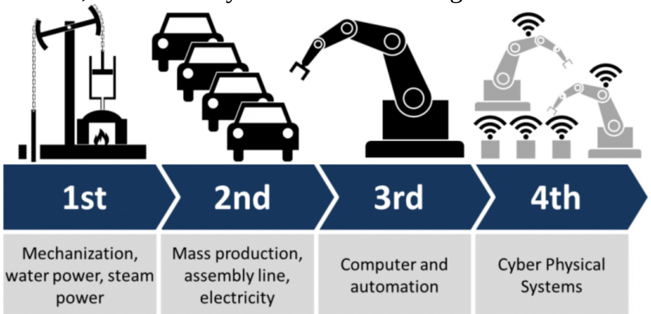

Figure 1: Industrial Automation

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The main aim in fourth industrial revolution is to wirelessly connect and computerized the old industrial environments and to improve the integration between processes and industry [1]. Even with the increasing use of wireless technology, the major industries are wired. The main reason for wired over wireless technology is the strict requirements imposed by the industrial applications.

An industrial wireless sensor network is shown in Figure 2.

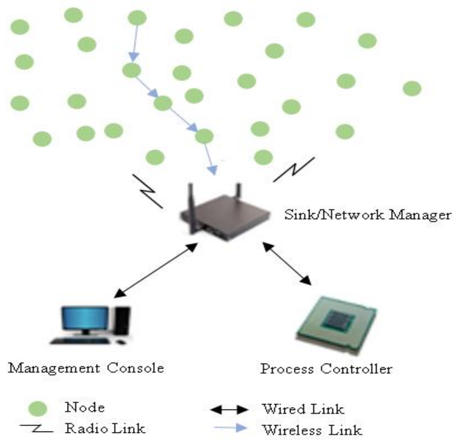

Figure 2 Typical Industrial Environments

It consists of sensors (nodes), a sink, management console and the process controller. A sensor sends the information to the sink and later processed by network manager and process controller. Same frequency is used to communicate with different sensors and sink. There are two type of requirements (i) Best Effort and (ii) Real-Time. Best Effort traffic requirements are less strict and loss delay tolerant whereas the Real-Time are with strict time requirements and loss intolerant. Because of the asymmetrical nature Non-orthogonal multiplexing access (NOMA) techniques are used more efficiently than the TDM/FDM schemes [2].

The 802.11 wireless standards were not designed keeping in view of industrial communication. Even though 802.11 communication standards are used in the industries. One of the main advantage of using 802.11 standard is that it is compatible with the Ethernet and this ensure that Ethernet/WLAN operate well with each other. It has its own disadvantages such as the medium access mechanism which uses CSMA/CA. The CSMA/CA does not guarantee real-time services. It is not deterministic behavior.

Medium access technology plays one of the important roles in the success of industrial communication. In [3], a soft real-time control system is presented using CSMA. In [4], a novel approach based on contention-based and schedule-based protocol is proposed.

This paper proposes the use of Zigbee communication in collaboration with IEEE 802.11 standard along with comparison between Zigbee communication and IEEE 802.11 standard communication. In this paper we will try to fulfilled the requirements of next generation industrial 4/0 application.

II. CHARACTERISTICS AND REQUIREMENTS OF INDUSTRIAL COMMUNICATION.

IEEE 802.11

The IEEE 802.11 communication standard is also known as Wireless Fidelity (Wi-Fi) for wireless local area network (WLAN). Wi-Fi connect to wired network and computers to each other i,e. computer network also.

According to Federal Communications Commission (FCC), the 802.11 standard uses 2.4 GHz or 5.2 GHz ISM band (Industrial, Scientific and Medical Band) to enable wireless local area networking [5]. The frequency band falls under unlicensed frequency band i.e. it can be used by anyone without license. Under IEEE 802.11 we have 802.11a, 802.11b and 802.11g.

802.11 Family

- Comparison of 802.11 standards

IEEE Standard	Speed (Mbps)	Frequency Band (GHz)	PHY?	Notes
802.11	1 & 2	2.4	DS & FH	1st standard (1997), featured both DS and FH modulation...
802.11b (Wireless Fidelity = Wi-Fi)	5.5 & 11	2.4	DS	Standard (1999), and Products released in 1999.
802.11a (Wi-Fi5 ...5GHz)	Upto 54	5	OFDM	Standard (1999), and Products not released until late 2000.
802.11g	Upto 54	2.4	OFDM	Not standardized yet. (estimated final approval: May 2003)

PHY = Physical Layer, DS = Direct Sequence, FH = Frequencey Hopping, OFDM = Orthogonal Frequency Division Multiplexing

Table I Comparison of 802.11 Family

Different standards have different methods and IEEE 802.11 standard has its own security method to prevent unauthorized access or security threat. The security that is used in IEEE 802.11 is wireless equivalent privacy (WEP) and Wi-Fi protected Access (WPA). WPA replaced WEP as WEP is least secured method. Latest method is WPA2 which is more advance when compared to WPA.

Wi-Fi and Bluetooth use frequencies in the close proximity as shown in figure 3.

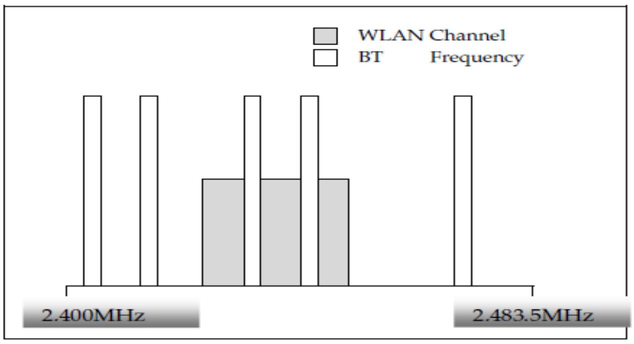

Figure 3. Bluetooth/Wi-Fi Interference

Both Wi-Fi and Bluetooth occupy 2.4 GHz ISM band that is 83 MHz wide and hence interfere with each other. Because of interference, data packet gets corrupted and is send again and again. When interference occurs, data need to be resend when transmitting data as Asynchronous Connection Less (ACL) link. It will affect the data throughput as more packet need to be send again and again. In transmitting information using synchronous connection oriented (SCO) links to transmit time-sensitive data such as voice, packet can also be lost.

Bluetooth uses frequency hopping spread spectrum (FHSS). It hop between 79 different channels of 1 MHz width bandwidth at a rate of 1600 hops/seconds. Wi-Fi uses Direct Sequence Spread Spectrum (DSSS) and has 11 channels of 83 MHz wide band into 22 MHz wide each band.

Zigbee:

Zigbee is a high level communication protocol which uses low power digital radios for personal area network using IEEE 802 standard. Zigbee uses mesh network to transmit data over longer distances. It transmit data through intermediate devices to reach more distant ones.

Zigbee is used in applications where a low data rate, long battery life and secure networking is required. Zigbee has a data rate of 250 Kbits/sec used for periodic or intermittent data or a single signal transmission from sensor to the sink. It works with consumer and industrial equipment such as switches, electrical meters, traffic management system, etc. that work with short range wireless transfer of data at relatively low data rates transfer.

Zigbee uses mesh network standard for low cost, low poer applications. Because of its lo9w cost it is widely deployed in wireless control and monitoring applications. Because of its low power sensors work for longer time when compared to industrial communication. Mesh networking has high reliability and more range. Zigbee chips comes with integrated radios and microcontrollers between 60 KB and 256 KB memory.

Zigbee is a IEEE 802.15.4, 2003 specification standard of physical and MAC layers. The protocol stack has its own network & applications layer. Zigbee comes in three rages (i) Zigbee Coordinator (ZC) (ii) Zigbee Router (ZR) and Zigbee End Device (ZED).

Zigbee alliance has over 300 companies such as Texas instruments, Philips, Epson, Atmel, etc. which develop and promote this technology. This alliance is publishing and maintaining the Zigbee specification. The manufacturers provide software, hardware and reference design to anyone who uses Zigbee technology.

Non-Orthogonal Multiplexing Access (NOMA):

NOMA consists of several layers. Each layer taking a portion of the total power delivered by the transmitter. Each layer consist of decoding threshold, robustness level, etc. depending on power distribution, modulation and coding the multi-layer power distribution as shown in figure 4.

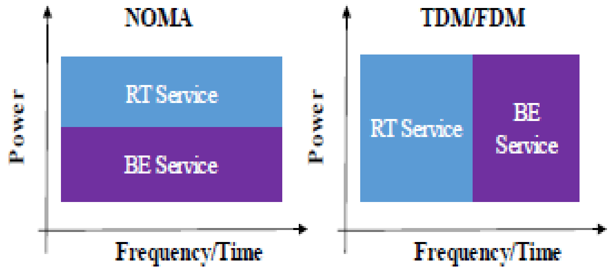

Figure 4: NOMA

The general frequency signal consist of

$$x_{NOMA}(k) = x_{RT}(k) + G\, x_{BE}(k)$$

where x_{RT} and x_{BE} are Real-Time and Best Effort data streams. x_{NOMA} is the combined data stream, k is the sub-channel index. The g parameter is the linear power allocation ratio between layers.

The multiple signal in the same channel with unequal error was given by [6]. It was possible only now. One of the main reason for the technique to become possible is because of development in error coding and advances in low density parity check (LDPC) codes [7]. The second reason for it to become practical is the newly implemented signal cancellation structure implemented in [8]

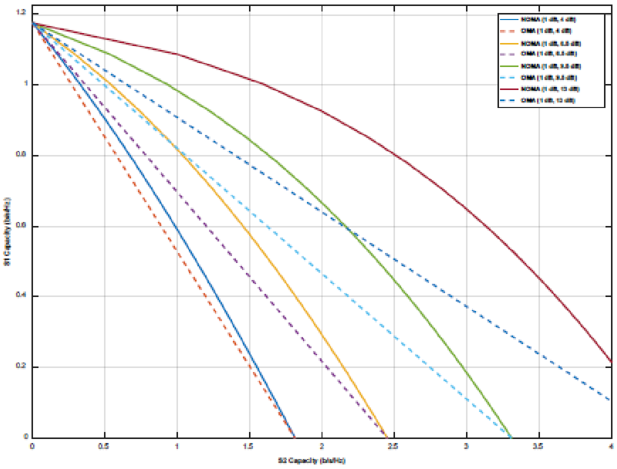

Figure 5: NOMA and OMA Comparison

In figure 5, there is comparison of NOMA and TDM/FDM for spectral efficiency scheme when services are deployed in the same time and frequency [9]. NOMA based solutions was depicted by solid lines in terms of bps/Hz. TDM/FDM services are represented by dashed lines. Each curve gives the maximum achievable capacity for different SNR threshold for each service. NOMA performance is better compared to TDM/FDM.

TDM/FDM:

Multiplexing combines multiple signals like analog into one signal. It is defined as a way of transmitting different signals over a single line.

FDM: In FDM various frequency signals are united into a one signal.

TDM: In this signals are transmitted in time slots. Single slot is used for one particular message signal.

The proposed system for industrial automation is as shown in figure 6.

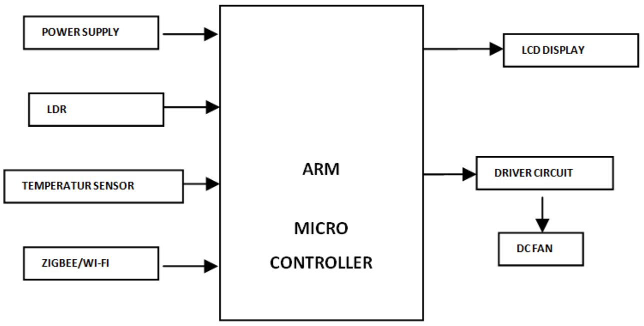

Figure 6: The proposed system.

LPC 2148 ARM Microcontroller can be used in this proposed model. The pin configuration of LPC 2148 is shown in following figure [10].

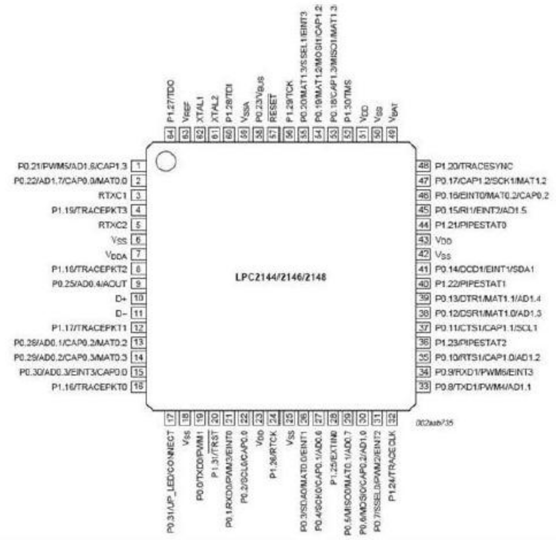

Figure 7: Pin configuration of LPC 2148 ARM Microcontroller

LDR is a light dependent resistor which depends on the light intensity for the resistance value. If light intensity varies, the resistance value of LDR will also vary.

Temperature sensor senses the temperature and is converted into a electrical signal.

III. RESULTS

Since we are using the Zigbee communication protocol for industrial automation, it uses low power as we have studied its characteristics when compared to IEEE 802.11 standard. The proposed system is implemented and as we have studied the proposed system utilize low power as Zigbee communication standard is used. Because of the low usage of the power the battery life of the sensors has increased tremendously.

IV. CONCLUSION

The lifetime of the battery of the sensors is increase tremendously as we have used low power Zigbee communication standard. Also, due to the NOMA usage the Best Effort services can be used without jitters. NOMA is found to be superior when compared to the TDM/FDM for Best Effort services.

FUTURE WORK

In the proposed scenario one of the important characteristics is the reliability of the Real-Time Services. We have to study the NOMA based simulation losses in terms of packet error rate (PER) where TDMA does not give any constant behavior.

The concept of robustness is much more important in Real-Time services when compared to the Best Effort services. An error in RT package can have error in other packets also there by disrupting the factory production.

REFERENCES

1. A. Varghese y D. Tandur, «Wireless requirements and challenges in Industry 4.0,» de International Conference on Contemporary Computing and Informatics (IC3I), Mysore, India, 2014.
2. S. M. R. Islam, N. Avazov, O. A. Dobre and K. Kwak, "Power-Domain Non-Orthogonal Multiple Access (NOMA) in 5G Systems: Potentials and Challenges," in *IEEE Communications Surveys & Tutorials*, vol. 19, no. 2, pp. 721-742, Secondquarter 2017.
3. Tavassoli, B., Jabehdar-Maralani, P., & Rezaee, N. (2009). Tuning of control systems over CSMA networks. IEEE Transactions on Industrial Electronics, 56(4), 1282-1291.
4. Le, H., van Eck, J., & Takizawa, M. (2013). An efficient hybrid medium access control technique for digital ecosystems. IEEE Transactions on Industrial Electronics, 60(3), 1070-1076.
5. Neeraj Chhabra," Comparative Analysis of Different Wireless Technologies", IJSRNSC, Volume-1, Issue-5, Dec- 2013
6. P. Bergmans and T. Cover, "Cooperative broadcasting," in *IEEE Transactions on Information Theory*, vol. 20, no. 3, pp. 317-324, May 1974.
7. D. J. C. MacKay and R. M. Neal, "Near Shannon limit performance of low density parity check codes," in *Electronics Letters*, vol. 32, no. 18, pp. 1645-, 29 Aug. 1996.
8. L. Zhang, W. Li, Y. Wu, X. Wang, S.-I. Park, H. M. Kim, J.-Y. Lee, P. Angueira y J. Montalbán, «Layered-Division-Multiplexing: Theory and Practice,» IEEE Transactions on Broadcasting, vol. 62, nº 1, pp. 216-232, 2016.
9. L. Zhang, W. Li, Y. Wu, X. Wang, S.-I. Park, H. M. Kim, J.-Y. Lee, P. Angueira y J. Montalbán, «Layered-Division-Multiplexing: Theory and Practice,» IEEE Transactions on Broadcasting, vol. 62, nº 1, pp. 216-232, 2016.
10. Raghu Vidap, Guruling Shahane, "DEVELOPMENT AND IMPLEMENTATION OF ARM MICROCONTROLLER BASED CO GAS MONITORING SYSTEM", International Journal of Advances in Engineering & Technology, Oct., 2015.