IoT Performance Improving for Indoor and Outdoor Environments

Morteza Shafiee Neyestanak
Faculty of Electrical and Computer
Malek Ashtar University of Technology
Tehran, Iran
Mshafiee@Mut.ac.ir

Ehsan Azizi
Faculty of Electrical and Computer
Malek Ashtar University of Technology
Tehran, Iran
Ehsanazizi423@Gmail.com

Elham Salarpour
Faculty of Electrical and Computer
Malek Ashtar University of Technology
Tehran, Iran
Salarpoorelham@Gmail.com

Abstract— **Internet of Things is a term used to describe a world, in which all disparate objects and devices have ability to address, control, and share information. The technology brings a lot of convenience to human life and consequently introduce a new level of threats, which can simultaneously attack a wide range of facilities and stop providing services. Therefore, investigating, analyzing and securing the types of channels in this growing technology and improving their communication efficiency is of particular importance. In this paper, while categorizing the types of important channels in IoT technology, we provide a solution to improve communication efficiency of each of them. Then, we simulate and analyze the effects of our suggestions for indoor and outdoor applications of IoT.**

Keywords: Internet of Things (IoT), Outdoor, Indoor, Hostile, Communication Performance, Fading Channel.

I. INTRODUCTION

Internet of Things (IoT) is a term for describing a world in which all objects interact each other and share information or communicate with humans via Internet network [1]. This technology offers new levels of capabilities, applications, services and therefore, new levels of needs for safety and security. All objects and devices in IoT may be addressed and controlled by others such as another thing or human and also may share information with others [2]. The technology utilizes recent advances in software, hardware, cost efficiency as well as modern human living standards for its definition and development. Some important tools, which help the Internet of Things to achieve these goals are artificial intelligence, modular design methods, scalability in network and communications, various sensor matching, heterogeneous node supporting and so on [3].

Nowadays, IoT is widely going to enter all areas of life such as business, house and process monitoring, agriculture, social life facilitation, life standard improvement, automation, machine-to-machine and machine-to-human interactions etc. [4, 5]. Therefore, the technology must provide a wide range of services in variety of conditions for small and large resource levels and in different environments i.e. indoor, outdoor, humored and hostile. In another word, IoT nodes will be faced various channels which affect their communication performance in some different manners. So, we need some simple, practicable and low-cost techniques to cover high performance communication for IoT nodes in various environmental conditions.

In this paper, we attend to categorize IoT channels, propose suitable techniques for high performance communication in the channels and investigate the proposed solutions. According to the simulations, spread spectrum and/or diversity techniques may properly improve Bit Error Rate (BER) curves as our performance criteria. We simulate and investigate our proposed techniques for Indoor and outdoor conditions and also, discuss about hostile environments as a future work.

Some researches in this field review in second section of paper. Then, the problem briefly studied in section III and our proposed techniques for solving the problem are presented in fourth section. Section V, shows simulation results and their analysis and finally, section VI summarizes and concludes the paper and suggests further works.

II. RELATED WORKS

Nowadays, many researches on all aspects of IoT have been followed by researchers. Reference [6] discusses effects of frequency hopping on Positioning Reference Signals (PRS) for narrowband IoT applications. Reference [7] introduces a Narrowband Physical Random-Access Channel (NPRACH) based on a single tone frequency hopping to optimize power consumption and coverage in IoT. Since the hopping pattern is predetermined, the paper shows that the Time of Arrival (ToA) can be estimated by phase differences. In reference [8], a random-access method for IoT was proposed, simulated and its performance was studied. Reference [9] also, has studied the PHysical (PHY) layer and Media Access Control (MAC) sub layer for Narrow Band Internet of Things (NB-IoT). Due to lack of available spectral resources, reference [10] discussed about spectral sharing as a desirable solution for IoT.

III. PROBLEM DISCRIPTION

Due to entrance of Internet of Things in various environments such as smart city and home, building, industry, business,

intelligent transportation, health and so on, many types of indoor and outdoor applications were propounded, in which the IoT faces various models of channel. So, we must categorize the applications of IoT in some partible environmental class to introduce appropriate channel for the classes and propose solutions for performance improving in any channel type i.e. in any application.

According to custom types of channel in communication theory, we may divide all applications of IoT into three types of environments based on their communication conditions. In another word, communication conditions lead us to three channel types of:

A. Fading Channel for IoT applications and nodes in indoor environments such as buildings, greenhouses etc.

B. Additive White Gaussian Noise (AWGN) Channel for IoT applications and devices in outdoor environments such as farm, roadway etc.

C. Jamming Channel for IoT applications and services in hostile environments, where the nodes are faced various types of attacks, jamming, interceptions etc.

Fig.1 shows our proposed environmental divisions for improving communication performance in IoT applications. The next section also, presents our solutions to improve communication performance in these indoor, outdoor and hostile environments.

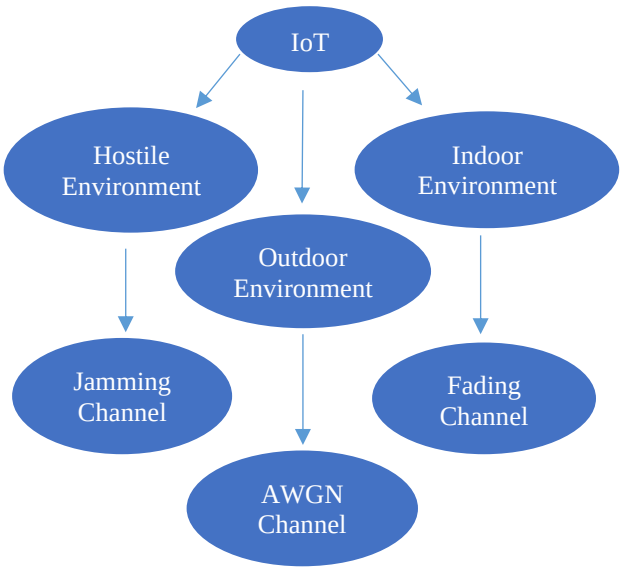

Figure 1. Proposed Channel Types for IoT Applications

IV. Our Proposed Solutions

According to Fig.1, we must propose appropriate solutions, which can properly improve communication performance for IoT applications. Our suggestions in three main types of proposed channels are as mentioned in the following:

A. Indoor Environment:

As we know based on wireless communication theory, indoor applications are severely faced signal variation and dropping due to multi-path phenomena. So as mentioned, multipath fading will be the most suitable channel model for indoor IoT applications. Therefore, based on properties and features of communication techniques, we can propose Frequency Diversity (FD) technique as well as Direct Sequence Spread Spectrum (DSSS) to improve communication performance in this fading channel i.e. indoor applications of IoT. Although, one of the techniques may be sufficient. But we choose both of them due to cost efficiency, better power (and perhaps bandwidth) consumption and more rational system parameters.

B. Outdoor Environment:

Outdoor environments such as farm, plain, roadway and so on include any multipath phenomena, unexpected interference or any hostile attacks. So as mentioned, Additive White Gaussian Noise (AWGN) channel will be the best model for the channel i.e. for IoT outdoor applications. Therefore, we can propose one of Frequency Diversity (FD) or Direct Sequence Spread Spectrum (DSSS) techniques to improve communication performance for outdoor applications of IoT. Although, both the techniques may be jointly used for outdoor applications, but considering the light conditions of outdoor environment and functional properties of the techniques, we may hope one of these methods will be sufficient.

C. Hostile Environment:

Clearly in future years, IoT infrastructures will be an important target for hostile behavior, which can affect all aspects of social life in world countries. Generally, a hostile environment may include various harsh behavior such as jamming, interference, interception, denial of service attacks etc. So, in future researches, we must investigate each of these harsh behaviors and propose solutions to completely cover them. Primarily, we may propose Frequency Diversity (FD) as well as DS spread spectrum techniques, especially with long length codes for improving communication performance in a hostile environment. But as mentioned, we leave the solution for future studies.

Fig.2 summarizes our proposed solutions for improving communication performance in various IoT environments and applications.

V. Simulation Results

In this section we are going to simulate and analyze our proposed solution for performance improving in indoor and outdoor IoT applications. The evaluation criterion is Bit Error Rate (BER) and we utilize custom modulations of QPSK and BPSK for data transferring. Also, simulations are performed in Matlab@R2019b on Intel 2.4GHz CPU and simulation parameters are presented in Table 1, where E_b and N_0 are bits energy and noise Power Spectral Density (PSD), respectively. Spread spectrum type is Direct Sequence (DS) and Pseudo

Noise (PN) code are Maximally length Sequences (M-Sequences). Also, we suppose Rayleigh Probability Distribution Function (PDF) for simulating the multipath fading channel [11].

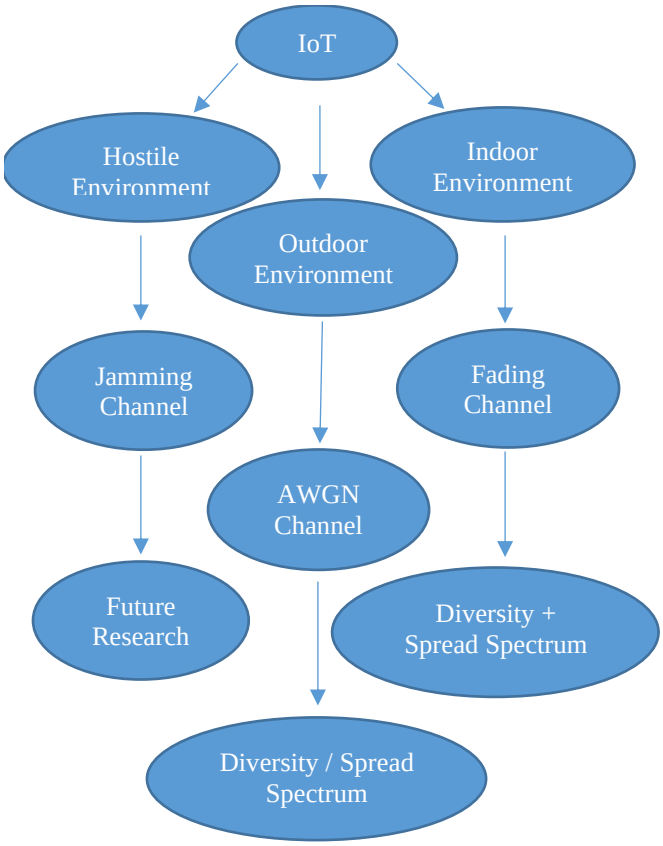

Figure 2. Our Proposed Solutions

Table 1. Simulation Parameters

Ranges of E_b / N_0	-10 : 10
Modulation Types	BPSK, QPSK
# of Simulation Bits	10^6 bits

A. Solution Analisis – Indoor Environment:

As mentioned, due to hard communication conditions for indoor environment, we proposed Frequency Diversity (FD) as well as Direct Sequence (DS) spread spectrum techniques for improving communication performance in a cost-effective manner. Fig. 3 shows effects of only Frequency Diversity (FD) for performance improving in fading channel i.e. indoor conditions. As seen in Fig. 3, we minimally need L = 8 branches (diversity orders) for achieving BER < 10^{-4} at E_b/N_0 = 0 dB, where this is very expensive and wastes more resources (i.e. power, memory, CPU capacity, cost etc.) of IoT nodes.

But, Fig. 4 shows effects of jointly Frequency Diversity (FD) with L = 2 branches as well as low cost DS spread spectrum techniques. According to Fig. 4, we may achieve BER < 10^{-4} (exactly BER = 10^{-5}) at E_b/N_0 = 0 dB, utilizing a PN code length of N = 8. In the better word based on figures of Fig. 3 and Fig. 4, by only inserting a simple worthless shift register or performing DS spread spectrum in software part of system, we can improve the communication performance and severely decrease the implementation cost, as well.

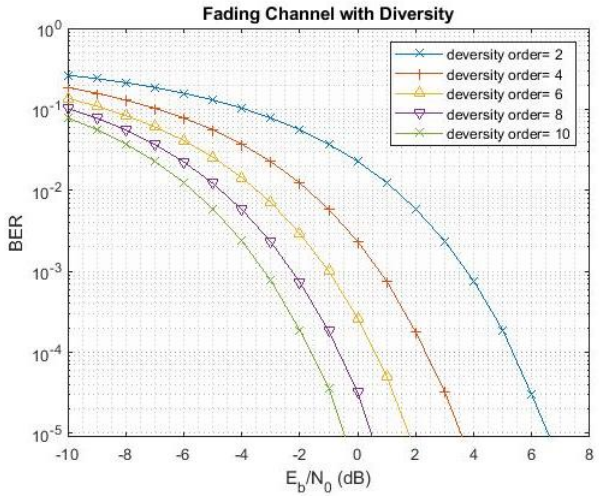

Figure 3. Effect of Diversity Technique for Indoor Environments

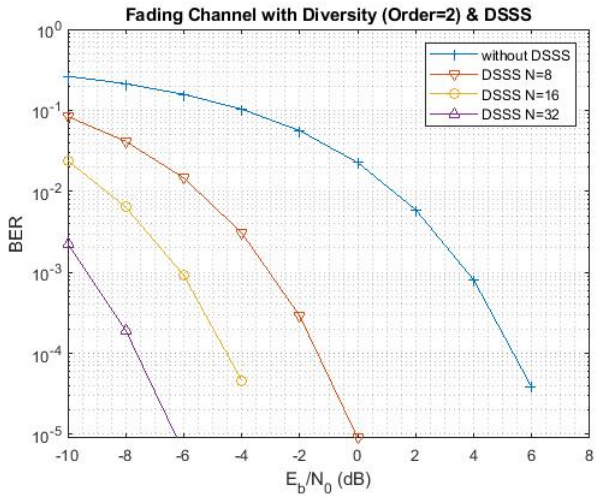

Figure 4. Effect of Diversity and DS-SS Techniques for Indoor Environments

B. Solution Analisis – Outdoor Environment:

According to previous section, outdoor environment leads us to AWGN channel, where we proposed one of FD or DS techniques to improve communication performance. Fig. 5 and Fig. 6 show the effect of Frequency Diversity (FD) and Direct Sequence spread spectrum techniques in outdoor IoT applications, respectively. For example, as seen in Fig. 5, we are minimally need L = 10 branches for achieving BER < 10^{-5} at E_b/N_0 = 0 dB.

On the other hand, according to Fig. 6 this situation can be achieved by DS spread spectrum technique only with N = 16 chips of code length. Therefore, since diversity technique imposes more heavy cost to system hardware and resources, DS

spread spectrum will be better choice than FD technique for improving communication performance in outdoor applications of IoT.

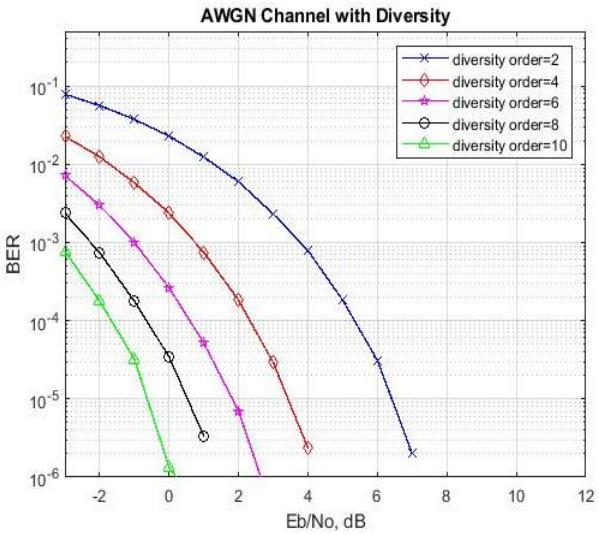

Figure 5. Effect of Diversity Technique for Outdoor Environments

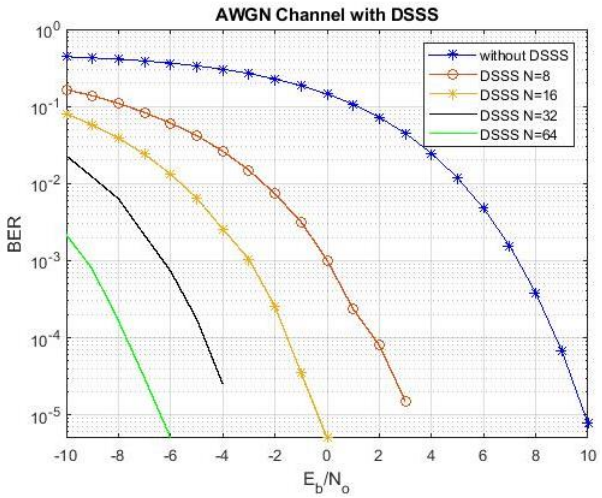

Figure 6. Effect of DS-SS Technique for outdoor Environments

VI. CONCLUSION

Nowadays, all aspects of life are going to equip with data collection and transferring ability, artificial intelligence algorithms and networking. This progressive phenomenon is referred Internet of Things (IoT). Due to entrance of Internet of Things in our all-around environments, its performance and security are very important and critical. In this paper, we introduced the problem, categorized the applications of IoT into three group of Indoor, Outdoor and Hostile environments, proposed appropriate channel models for any group as well as proper solutions for the channel models and finally simulated and analyzed the solutions for indoor and outdoor applications. Based on the study, we may utilize Frequency Diversity (FD) as well as Direct Sequence (DS) spread spectrum to cost effectively improve communication performance of IoT in indoor applications, whereas for outdoor applications only DS techniques may be sufficient.

In future works, we will attend to study, simulate and analyze communication performance of IoT in hostile environments.

References

[1] Alok K.G., Rahul J. (2019), “IoT Based Electrical Device Surveillance and Control System”.

[2] Hittu G., Mayank D. (2019), “Securing IoT Devices and Securely Connecting the Dots Using REST API and Middleware”.

[3] Miguel A.L., Isabel M.F. (2019), “SAT-IoT: An Architectural Model for a High-Performance Fog/Edge/Cloud IoT Platform”.

[4] Aaron G.M., Raquel P.L., García A., Alfonso F.D. (2018), “NB-IoT Random Access Procedure: System Simulation and Performance”.

[5] Sakshi P., Rakesh K. (2019), “A Survey on Energy Efficient Narrow Band Internet of Things (NB-IoT): Architecture, Application and Challenges”.

[6] Jose A., Rosado L., Salcedo, Gonzalo S. (2017), ”Impact of Frequency-Hopping NB-IoT Positioning in 4G and Future 5G Networks”.

[7] Wha S.J., Seung B.S., Dong G.J. (2018), “Effective Frequency Hopping Pattern for ToA Estimation in NB-IoT Random Access”.

[8] Aaron G.M., Raquel P.L., Ana G.A., Alfonso F. D., “NB-IoT Random Access Procedure: System Simulation and Performance”.

[9] Collins B., Malik h., Mahtab A., Yannick L.M., Sven P. et al. (2019), “Narrow Band Internet of Things (NB-IoT) From Physical (PHY) and Media Access Control (MAC) Layers Perspectives”.

[10] Lin Z., Ying L., Ming X. (2018), “Spectrum Sharing for Internet of Things: A Survey”.

[11] Run-Fa L., Hong W., Jinsong W., Huanhuan S., Fei P. and Lian D. (2018), “The Rayleigh Fading Channel Prediction via Deep Learning”.