

# **Performance and Implementation of IOT using Transmit Diversity**



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# DECLARATION

We hereby declare that we carried out the work reported in this thesis in the Department of Electronics and Communications Engineering, East West University, under the supervision of **Dr. Mohamed Ruhul Amin and Mustafa Mahmud Hossain**. We solemnly declare that to the best of our knowledge, no part of this report has been submitted elsewhere for award of a degree. All sources of knowledge used have been duly acknowledged.

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# Abstract

The Internet of Things (IoT) refers to the ever-growing network of physical objects that feature an IP address for internet connectivity, and the communication that occurs between these objects and other Internet-enabled devices and systems. The Internet of Things extends internet connectivity beyond traditional devices like desktop and laptop computers, smartphones and tablets to a diverse range of devices and everyday things that utilize embedded technology to communicate and interact with the external environment, all via the Internet.

There are four things form basic building blocks of IoT system –Sensors or Device, Network, Service Support, Applications. Each of these nodes has to have their own characteristics in order to form an useful IoT system. Here we will discuss about Network Layer, which includes GSM/UMTS,LTE, LTE-A, WiFi, Ethernet etc. Wireless Internet and multimedia services have given a limited Spectrum the only way to support high data rates is to develop new spectrally efficient radio communication techniques. It was shown recently that multiple input multiple output (MIMO) system have a potential to significantly increase spectral efficiency in the wireless communications. Space Time codes are practical techniques used to approach the theoretical MIMO spectral efficiencies

Unfortunately uplink transmit diversity is not directly applicable to the cellular due to the small size of the mobile station and electromagnetic interaction of antenna elements on the small platform. Furthermore the channels corresponding to different antennas are correlated because of the miniature size of the mobile phone.

We survey and simulate the basic designs and diversity results of Network Layer, and summarize its performance. Finally a new idea is suggested for practical implementation using Alamouti Codes & Transmit diversity.

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# Chapter 1

## Introduction

## INTRODUCTION

Modulation is one of the very important techniques of telecommunication. To send the transmitted message to its destination without losing any of its components whether it is near or far modulation is needed. And if the desired destination is far then modulation is a must process to be done. Without modulation, even a message reached at the destination, which has been transmitted from far away may lose some of its components or the message may be changed.

In telecommunications, a diversity scheme refers to a method for improving the reliability of a message signal by using two or more communication channels with different characteristics. Diversity is another important scheme for telecommunication. After transmission, a message may be diverse into many copies of the original message and may propagate through different paths. But all messages will reach to the desired destination at different times and this may create inter-symbol interference (ISI). As more than one message will arrive the destination so if any portion of the message is missing then this missing part may be recovered by mitigating the ISI by some well established methods.

With transmit diversity; multiple antennas transmit delayed versions of a signal, creating frequency-selective fading, which is equalized at the receiver to provide diversity gain.

Antenna diversity is especially effective at mitigating multipath situations. This is because multiple antennas offer a receiver several observations of the same signal. Each antenna will experience a different interference environment. Thus, if one antenna is experiencing a deep fade, it is likely that another has a sufficient signal. Collectively such a system can provide a robust link. While this is primarily seen in receiving systems (diversity reception), the analog has also proven valuable for transmitting systems (transmit diversity) as well.

In radio, multiple-input and multiple-output or MIMO is a method for multiplying the capacity of a radio link using multiple transmit and receive antennas to exploit multipath propagation. MIMO has become an essential element of wireless communication standards.

The Internet of Things is a network of connected devices which communicate over the Internet, and they do so autonomously, machine to machine, without the need for human intervention.

The first reference to the IoT was in 1982, when researchers at Carnegie Mellon University developed the world's first IoT-enabled Coke Machine. Mark Weiser developed the concept further in the early 90s; and Kevin Ashton coined the term 'Internet of Things' around 1999<sup>[1]</sup>.

Since then, many visionaries have seized on the phrase "Internet of Things" to refer to the general idea of things, especially everyday objects, that are readable, recognizable, locatable, addressable, and/or controllable via the Internet, irrespective of the communication means (whether via RFID, wireless LAN, wide- area networks, or other means). Everyday objects include not only the electronic devices we encounter or the products of higher technological development such as vehicles and equipment but things that we do not ordinarily think of as electronic at all - such as food and clothing. Examples of "things" include:

- a) People;
- b) Location (of objects);
- c) Time Information (of objects);
- d) Condition (of objects).

So IoT data undergoes a long and fascinating journey. There is a data up-stream from the sensors in the field, via the wireless connectivity, into the IoT platforms. Then, there are data mash-up opportunities within the platforms allowing us to leverage Big Data opportunities. Finally, there is a data down-stream from the platforms back to the actuators in the field or some beautiful frontends on your computer screen or smart phone.

# **Chapter 2**

# **Modulation**



## **2.1 Modulation**

In electronics and telecommunication modulation is the process of varying one or more properties of a periodic waveform, called the carrier signal, with a modulating signal that typically contains information to be transmitted.

In telecommunications, modulation is the process of conveying a message signal, for example a digital bit stream or an analog audio signal, inside another signal that can be physically transmitted. Modulation of a sine waveform transforms a baseband message signal into a passband signal.

## **2.2 Use of modulation in communication system**

Modulation allows us to send a signal over a bandpass frequency range. If every signal gets its own frequency range, then we can transmit multiple signals simultaneously over a single channel, all using different frequency ranges. Another reason to modulate a signal is to allow the use of a smaller antenna.

## **2.3 Types of modulation**

Basically we use 3 types of modulation .These are have their importance in communication systems.These 3 Modulation types are

- Amplitude modulation
- Frequency modulation and
- Phase modulation.

### **Amplitude modulation (AM )**

As it is cleared from its name that this type of modulated is used when amplitude of the carrier signal is modulated (changed) in proportion to the message signal .Here the phase and frequency and phase are kept constant.

Amplitude modulation (AM) is a method of impressing data onto an alternating-current (AC) carrier waveform. The highest frequency of the modulating data is normally less than 10 percent of the carrier frequency. The instantaneous amplitude (overall signal power) varies depending on the instantaneous amplitude of the modulating data.

In AM, the carrier itself does not fluctuate in amplitude. Instead, the modulating data appears in the form of signal components at frequencies slightly higher and lower than that of the carrier. These components are called sidebands. The lower sideband (LSB) appears at frequencies below the carrier frequency; the upper sideband (USB) appears at frequencies above the carrier frequency. The LSB and USB are essentially "mirror images" of each other in a graph of signal amplitude versus frequency, as shown in the illustration. The sideband power accounts for the variations in the overall amplitude of the signal.

## **Phase modulation**

In this type of modulation, phase of carrier signal is changed according to low-frequency of the message signal .

Phase modulation is a form of modulation that can be used for radio signals used for a variety of radio communications applications. As will be seen later, phase modulation, and frequency modulation are closely linked together and it is often used in many transmitters and receivers used for a variety of radio communications applications from two way radio communications links, mobile radio communications and even maritime mobile radio communications.

Phase modulation is also the basis for many forms of digital modulation based around phase shift keying, PSK which is a form of phase modulation. As various forms of phase shift keying are the favored form of modulation for digital or data transmissions, this makes phase modulation particularly important.

## **Frequency modulation (FM)**

Here, we use to modulate the frequency of the carrier signal is modulated in accordance with message signal keeping both phase and amplitude constant.

Frequency modulation is similar in practice to phase modulation (PM). When the instantaneous frequency of a carrier is varied, the instantaneous phase changes as well. The converse also holds: When the instantaneous phase is varied, the instantaneous frequency changes. But FM and PM are not exactly equivalent, especially in analog applications. When an FM receiver is used to demodulate a PM signal, or when an FM signal is intercepted by a receiver designed for PM, the audio is distorted. This is because the relationship between frequency and phase variations is not linear; that is, frequency and phase do not vary in direct proportion.

# Chapter 3

## DIVERSITY

### 3.1 Diversity

In telecommunications, a diversity scheme refers to a method for improving the reliability of a message signal by using two or more communication channels with different characteristics. Diversity is mainly used in radio communication and is a common technique for combating fading and co-channel interference and avoiding error bursts. It is based on the fact that individual channels experience different levels of fading and interference. Multiple versions of the same signal may be transmitted and/or received and combined in the receiver. Alternatively, a redundant forward error correction code may be added and different parts of the message transmitted over different channels. Diversity techniques may exploit the multipath propagation, resulting in a diversity gain, often measured in decibels.

### 3.2 Classes of Diversity

The following classes of diversity schemes can be identified:

- **Time diversity**: Multiple versions of the same signal are transmitted at different time instants. Alternatively, a redundant forward error correction code is added and the message is spread in time by means of bit-interleaving before it is transmitted. Thus, error bursts are avoided, which simplifies the error correction.
- **Frequency diversity**: The signal is transmitted using several frequency channels or spread over a wide spectrum that is affected by frequency-selective fading. Middle-late 20th century microwave radio relay lines often used several regular wideband radio channels, and one protection channel for automatic use by any faded channel. Later examples include:
  - OFDM modulation in combination with subcarrier interleaving and forward error correction
  - Spread spectrum, for example frequency hopping or DS-SS.
- **Space diversity**: The signal is transmitted over several different propagation paths. In the case of wired transmission, this can be achieved by transmitting via multiple wires. In the case of wireless transmission, it can be achieved by antenna diversity using multiple transmitter antennas (transmit diversity) and/or multiple receiving antennas (reception

diversity). In the latter case, a diversity combining technique is applied before further signal processing takes place. If the antennas are far apart, for example at different cellular base station sites or WLAN access points, this is called macrodiversity or site diversity. If the antennas are at a distance in the order of one wavelength, this is called micro diversity. A special case is phased antenna arrays, which also can be used for beam forming, MIMO channels and space–time coding (STC).

- **Polarization diversity**: Multiple versions of a signal are transmitted and received via antennas with different polarization. A diversity combining technique is applied on the receiver side.
- **Multiuser diversity**: Multiuser diversity is obtained by opportunistic user scheduling at either the transmitter or the receiver. Opportunistic user scheduling is as follows: at any given time, the transmitter selects the best user among candidate receivers according to the qualities of each channel between the transmitter and each receiver. A receiver must feed back the channel quality information to the transmitter using limited levels of resolution, in order for the transmitter to implement Multiuser diversity.
- **Cooperative diversity**: Achieves antenna diversity gain by using the cooperation of distributed antennas belonging to each node.

### 3.3 Transmit diversity

Transmit diversity is radio communication using signals that originate from two or more independent sources that have been modulated with identical information-bearing signals and that may vary in their transmission characteristics at any given instant.

It can help overcome the effects of fading, outages, and circuit failures. When using diversity transmission and reception, the amount of received signal improvement depends on the independence of the fading characteristics of the signal as well as circuit outages and failures. Considering antenna diversity, in many systems additional antennas may be expensive or impractical at the remote or even at the base station. In these cases, transmit diversity can be used to provide diversity benefit at a receiver with multiple transmit antennas only. With transmit diversity, multiple antennas transmit delayed versions of a signal, creating frequency selective fading, which is equalized at the receiver to provide diversity gain<sup>[2]</sup>.

# **Chapter 4**

## **Space-Time Block Codes and Alamouti Theory**

## 4.1 Space-Time Block Codes

Space-time block codes were introduced to obtain coded diversity for a multiple-antenna communication system, in this work, we cast space-time codes in an optimal signal-to-noise ratio (SNR) framework and show that they achieve the maximum SNR and, in fact, they correspond to a generalized maximal ratio combiner. The maximum SNR framework also helps in calculating the distribution of the SNR and in deriving explicit expressions for bit error rates. We bring out the connection between the theory of amicable orthogonal designs and space-time codes. Based on this, we give a much simpler proof to one of the main theorems on space-time codes for complex symbols. We present a rate  $1/2$  code for complex symbols which has a smaller delay than the code already known. We also present another rate  $3/4$  code which is simpler than the one already known, in the sense it does not involve additions or multiplications. We also point out the connection between generalized real designs and generalized orthogonal designs<sup>[3]</sup>.

STBCs as originally introduced, and as usually studied, are orthogonal. This means that the STBC is designed such that the vectors representing any pair of columns taken from the coding matrix is orthogonal. The result of this is simple, linear, optimal decoding at the receiver. Its most serious disadvantage is that all but one of the codes that satisfy this criterion must sacrifice some proportion of their data rate.

Moreover, there exist quasi-orthogonal STBCs that achieve higher data rates at the cost of inter-symbol interference (ISI). Thus, their error-rate performance is lower bounded by the one of orthogonal rate 1 STBCs, that provide ISI free transmissions due to orthogonality.

## 4.2 Alamouti Theory

In 1998, Alamouti proposed a simple transmit diversity scheme which improves the signal quality at the receiver on one side of the link by simple processing across two transmit antennas at the opposite end<sup>[4]</sup>.



## Two Antenna Transmit Diversity Scheme

For scattering environment the antenna diversity is a practical, effective and widely applied technique for mitigating the effect of multipath fading. To combat the effect of fading is usage of multiple antennas at the receiver side and perform combining or selection in order to improve the quality of the received signal. The major problem with using the receive diversity approach is the cost, size and power of the remote units. Moreover the use of multiple antennas and radio frequency (RF) chains makes the remote units larger and more expensive<sup>[5]</sup>.

As a result, diversity techniques are deployed at the transmitter side i.e. is at the base station to improve the reception quality. Since a base station serves thousands of units, it is more economical to add equipments to base station rather than remote units. So Alamouti proposed a simple diversity technique which improves the signal quality on the receiver side by processing two transmit antennas at the opposite ends.

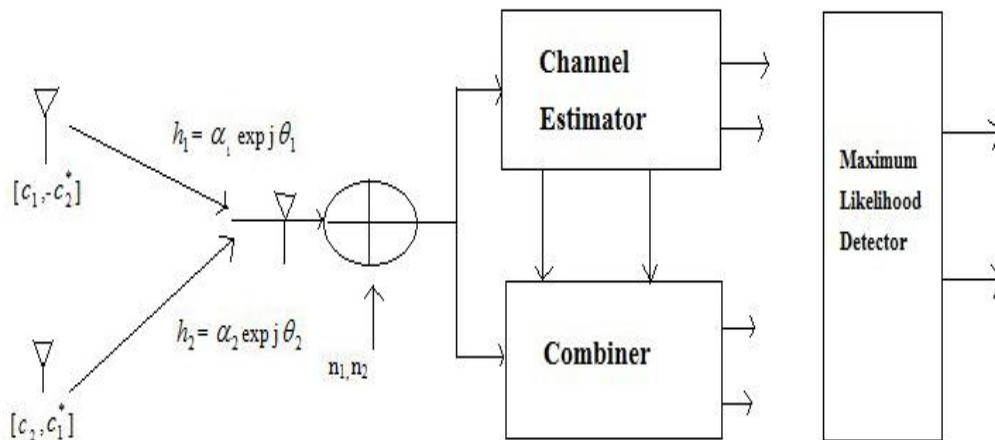


Figure 4.1: Block diagram for the proposed scheme

At a given symbol period, two signals are simultaneously transmitted from the two antennas namely  $c_1$  from the first antenna, and  $c_2$  from the second antenna  $Tx_2$ . In the second symbol period, signal  $(-c_2^*)$  is transmitted from  $Tx_1$  and signal  $c_1^*$  is transmitted from  $Tx_2$ , where  $*$  denotes complex conjugation.

Let  $h_1(t)$  denote the path gain from  $Tx_1$  to receiver; similarly let  $h_2(t)$  be that from  $Tx_2$  to receiver. Assuming that fading is constant across two consecutive symbols, we can write the following: -

$$h_1(t) = h_1(t+T) = h_1 = \alpha_1 \exp^{j\theta_1}, \quad (1)$$

$$h_2(t) = h_2(t+T) = h_2 = \alpha_2 \exp^{j\theta_2}, (2)$$

Where  $T$  is the symbol period. The received signals are,

$$r_1 = r(t) = h_1 c_1 + h_2 c_2 + n_1, \quad (3)$$

$$r_2 = r(t+T) = -h_1 c_2^* + h_2 c_1^* + n_2, (4)$$

Where  $r_1$  and  $r_2$  are the received signals at time  $t$  and  $t+T$  respectively.

The combiner combines the received signals as follows:

$$\tilde{c}_1 = h_1^* r_1 + h_2 r_2^* = (\alpha_1^2 + \alpha_2^2) c_1 + h_1^* n_1 + h_2 n_2^*, \quad (5)$$

$$\tilde{c}_2 = h_2^* r_1^* - h_1 r_2^* = (\alpha_1^2 + \alpha_2^2) c_2 + h_1 n_2^* + h_2^* n_1, (6)$$

Sends them to maximum likelihood detector, which minimizes the following decision metric:

$$\left| r_1 - h_1 c_1 - h_2 c_2 \right|^2 + \left| r_2 + h_1 c_2^* - h_2 c_1^* \right|^2, (7)$$

Over all possible values of  $c_1$  and  $c_2$ . Expanding this and deleting terms that are independent of the code words, the above minimization reduces to separately minimizing the following terms for detecting  $c_1$  and  $c_2$  respectively.

$$\left| r_1 h_1^* + r_2^* h_2 - c_1 \right|^2 + (\alpha_1^2 + \alpha_2^2 - 1) |c_1|^2, (8)$$

$$\left| r_1 h_2^* - r_2^* h_1 - c_2 \right|^2 + (\alpha_1^2 + \alpha_2^2 - 1) |c_2|^2, (9)$$

for decoding  $c_2$ . Equivalently, using the notation  $d^2(x-y) = (x-y)(x^*-y^*) = |x-y|^2$ , the decision rule for each combined signal  $\tilde{c}_j$ ,  $j = 1;2$  becomes: Pick  $c_i$  if and only if,

$$(\alpha_1^2 + \alpha_2^2 - 1) |c_i|^2 + d^2(\tilde{c}_j - c_i) \leq (\alpha_1^2 + \alpha_2^2 - 1) |c_k|^2 + d^2(\tilde{c}_j - c_k), \forall i \neq k, (10)$$

For PSK signals (equal energy constellations), this simplifies to,

$$d^2(\tilde{c}_j - c_i) \leq d^2(\tilde{c}_j - c_k), \forall i \neq k, (11)$$

### Maximal Ratio Combination

In the case of maximum ratio combining (see Fig (3)), the resulting received signals are,

$$r_1 = h_1 c_0 + n_1, (12)$$

$$r_2 = -h_2 c_0 + n_2, (13)$$

and the combined signal is,

$$\tilde{c}_0 = h_1^* r_1 + h_2^* r_2 = (\alpha_1^2 + \alpha_2^2) c_0 + h_1^* n_1 + h_2^* n_2, (14)$$

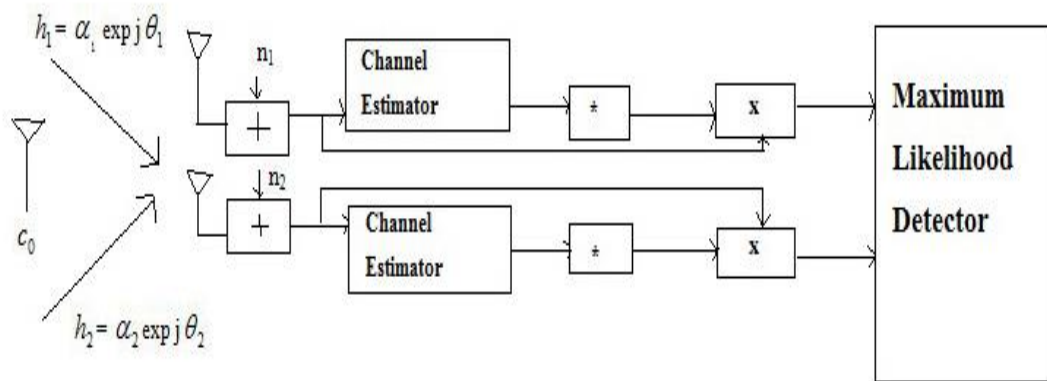


Figure 4.2: Block Diagram of Combined Signal

The maximum likelihood detector decides signal  $c_i$  using exactly the same decision rule in (10), or in (11) for PSK signals. Note that the MRC signal  $\tilde{c}_0$  in (14) is equivalent to the resulting combined signals of the transmit diversity scheme in (10), except for a phase difference in the noise components which do not affect the effective SNR. This shows that the diversity order from Alamouti's two-antenna transmit diversity scheme is the same as that of the two-branch MRC.

# **Chapter 5**

## **Internet of Things (IoT)**

## 5.1 What is IoT

The Internet of Things (IoT) refers to the ever-growing network of physical objects that feature an IP address for internet connectivity, and the communication that occurs between these objects and other Internet-enabled devices and systems. The Internet of Things extends internet connectivity beyond traditional devices like desktop and laptop computers, smartphones and tablets to a diverse range of devices and everyday things that utilize embedded technology to communicate and interact with the external environment, all via the Internet. There are four things form basic building blocks of IoT system –Sensors or Device, Network, Service Support, Applications. Each of these nodes has to have their own characteristics in order to form an useful IoT system. Here we will discuss about Network Layer, which includes GSM/UMTS, LTE, LTE-A, WiFi, Ethernet etc. Wireless Internet and multimedia services have given a limited Spectrum the only way to support high data rates is to develop new spectrally efficient radio communication techniques. It was shown recently that multiple input multiple output (MIMO) system have a potential to significantly increase spectral efficiency in the wireless communications. Space Time codes are practical techniques used to approach the theoretical MIMO spectral efficiencies.

Unfortunately uplink transmit diversity is not directly applicable to the cellular due to the small size of the mobile station and electromagnetic interaction of antenna elements on the small platform. Furthermore the channels corresponding to different antennas are correlated because of the miniature size of the mobile phone.

We survey and simulate the basic designs and diversity results of Network Layer, and summarize its performance. Finally a new idea is suggested for practical implementation using Alamouti Codes & Transmit diversity.

A growing number of physical objects are being connected to the Internet at an unprecedented rate realizing the idea of the Internet of Things (IoT). A basic example of such objects includes thermostats and HVAC (Heating, Ventilation, and Air Conditioning) monitoring and control systems that enable smart homes. There are also other domains and environments in which the IoT

can play a remarkable role and improve the quality of our lives. These applications include transportation, healthcare, industrial automation, and emergency response.

The IoT offers a great market opportunity for equipment manufacturers, Internet service providers and application developers. The IoT smart objects are expected to reach 212 billion entities deployed globally by the end of 2020. By 2022, M2M traffic flows are expected to constitute up to 45% of the whole Internet traffic. Beyond these predictions, McKinsey Global Institute reported that the number of connected machines (units) has grown 300% over the last 5 years. Traffic monitoring of a cellular network in the U.S. also showed an increase of 250% for M2M traffic volume in 2011. Economic growth of IoT-based services is also considerable for businesses. Healthcare and manufacturing applications are projected to form the biggest economic impact. Healthcare applications and related IoT-based services such as mobile health (m-Health) and telecare that enable medical wellness, prevention, diagnosis, treatment and monitoring services to be delivered efficiently through electronic media are expected to create about \$1.1–\$2.5 trillion in growth annually by the global economy by 2025. The whole annual economic impact caused by the IoT is estimated to be in range of \$2.7 trillion to \$6.2 trillion by 2025 [11]. Figure 2 shows the projected market share of dominant IoT applications.

On the other hand, Wikibon predicts that the value created from the industrial Internet to be about \$1279 billion in 2020 with Return on Investment (ROI) growing to 149% compared to 13% in 2012. Moreover, Navigant recently reported that the Building Automation Systems (BAS) market is expected to rise from \$58.1 billion in 2013 to reach \$100.8 billion by 2021; a 60% increase. All these statistics, however, point to a potentially significant and fast-paced growth of the IoT in the near future, related industries and services. This progression provides a unique opportunity for traditional equipment and appliance manufacturers to transform their products into “smart things.” Spreading the IoT and related services globally requires Internet Service Providers (ISPs) to provision their networks to provide QoS for a mix of M2M, person-to-machine (P2M) and person-to-person (P2P) traffic flows.

## 5.2 Layers of IoT

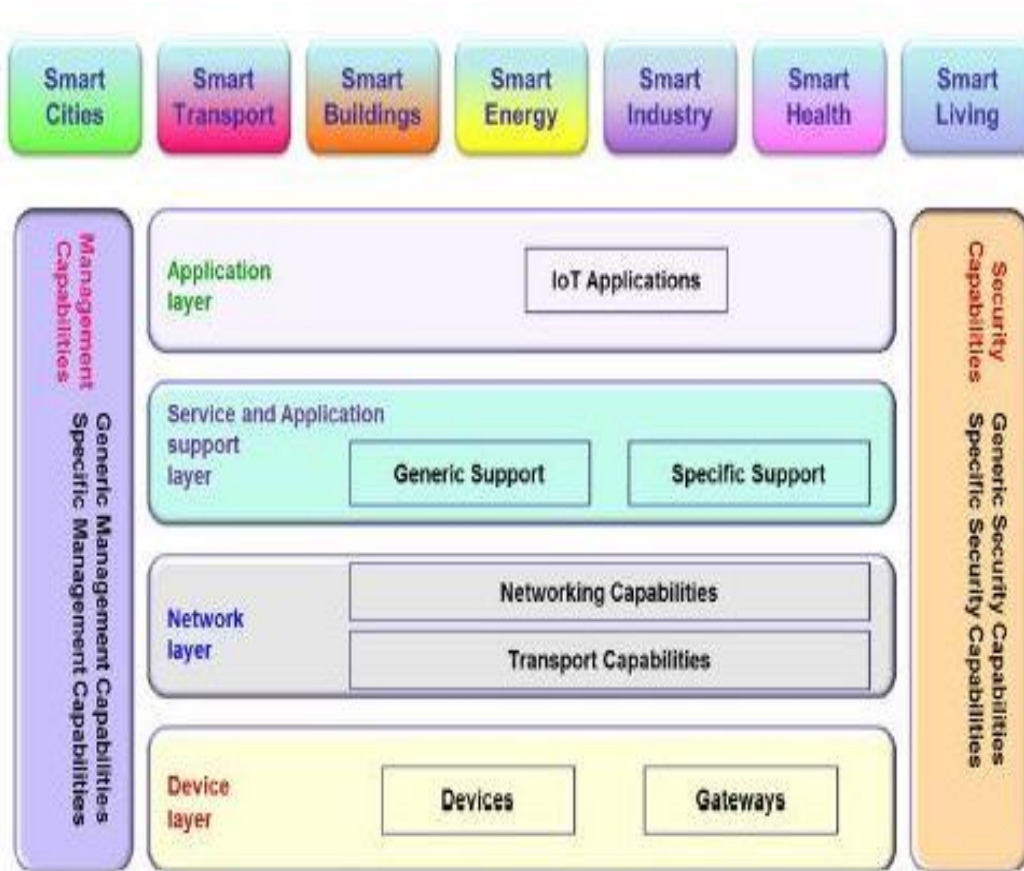


Figure. 1 IoT Layered Architecture <sup>[6]</sup>.

### A. Objects Layer

The first layer, the Objects (devices) or perception layer, represents the physical sensors of the IoT that aim to collect and process information. This layer includes sensors and actuators to perform different functionalities such as querying location, temperature, weight, motion, vibration, acceleration, humidity, etc. Standardized plug-and-play mechanisms need to be used by the perception layer to configure heterogeneous objects. The perception layer digitizes and transfers data to the Object Abstraction layer through secure channels. The big data created by the IoT are initiated at this layer.

## **B. Object Abstraction Layer**

Object Abstraction transfers data produced by the Objects layer to the ServiceManagement layer through secure channels. Data can be transferred through various technologies such as RFID, 3G,GSM,UMTS,WiFi,Bluetooth LowEnergy, infrared, ZigBee, etc. Furthermore, other functions like cloud computing and data management processes are handled at this layer.

## **C. Service Management Layer**

Service Management or Middleware (pairing) layer pairs a service with its requester based on addresses and names. This layer enables the IoT application programmers to work with heterogeneous objects without consideration to a specific hardware platform. Also, this layer processes received data, makes decisions, and delivers the required services over the network Wire protocol.

## **D. Application Layer**

The application layer provides the services requested by customers. For instance, the application layer can provide temperature and air humidity measurements to the customer who asks for that data. The importance of this layer for the IoT is that it has the ability to provide high-quality smart services to meet customers' needs. The application layer covers numerous vertical markets such as smart home, smart building, transportation, industrial automation and smart healthcare.

## **E. Business Layer**

The business (management) layer manages the overall IoTsystem activities and services. The responsibilities of this layer are to build a business model, graphs, flowcharts, etc. based onthe received data from the Application layer. It is also supposed to design, analyze, implement,evaluate, monitor, and developIoT system related elements. The Business Layer makes it possible to support decision-making processes based on Big Data analysis. In addition, monitoring and management of the underlying four layers is achieved at this layer. Moreover, this layer compares the output of each layer with the expected output to enhance services and maintain users' privacy.



## **5.3 Applications of IoT now a days**

### **Smart home**

Smart Home clearly stands out, ranking as highest Internet of Things application on all measured channels. More than 60,000 people currently search for the term “Smart Home” each month. This is not a surprise. The IoT Analytics company database for Smart Home includes 256 companies and startups. More companies are active in smart home than any other application in the field of IoT.

### **Wearables**

Wearables remains a hot topic too. As consumers await the release of Apple’s new smart watch in April 2015, there are plenty of other wearable innovations to be excited about: like the Sony Smart B Trainer, the Myo gesture control, or LookSee bracelet. Of all the IoT startups, wearables maker Jawbone is probably the one with the biggest funding to date. It stands at more than half a billion dollars!

### **Smart City**

Smart city spans a wide variety of use cases, from traffic management to water distribution, to waste management, urban security and environmental monitoring. Its popularity is fueled by the fact that many Smart City solutions promise to alleviate real pains of people living in cities these days. IoT solutions in the area of Smart City solve traffic congestion problems, reduce noise and pollution and help make cities safer.

### **Smart grids**

Smart grids is a special one. A future smart grid promises to use information about the behaviors of electricity suppliers and consumers in an automated fashion to improve the efficiency, reliability, and economics of electricity. 41,000 monthly Google searches highlights the concept’s popularity. However, the lack of tweets (Just 100 per month) shows that people don’t have much to say about it.

## **Industrial internet**

The industrial internet is also one of the special Internet of Things applications. While many market researches such as Gartner or Cisco see the industrial internet as the IoT concept with the highest overall potential, its popularity currently doesn't reach the masses like smart home or wearables do. The industrial internet however has a lot going for it.

## **Connected car**

The connected car is coming up slowly. Owing to the fact that the development cycles in the automotive industry typically take 2-4 years, we haven't seen much buzz around the connected car yet. But it seems we are getting there. Most large auto makers as well as some brave startups are working on connected car solutions. And if the BMWs and Fords of this world don't present the next generation internet connected car soon, other well-known giants will: Google, Microsoft, and Apple have all announced connected car platforms.

## **Connected Health**

Connected health remains the sleeping giant of the Internet of Things applications. The concept of a connected health care system and smart medical devices bears enormous potential (see our analysis of market segments), not just for companies also for the well-being of people in general. Yet, Connected Health has not reached the masses yet. Prominent use cases and large-scale startup successes are still to be seen. Might 2015 bring the breakthrough?

## **Smart retail**

Proximity-based advertising as a subset of smart retail is starting to take off. But the popularity ranking shows that it is still a niche segment. One LinkedIn post per month is nothing compared to 430 for smart home.

## **Smart supply chain**

Supply chains have been getting smarter for some years already. Solutions for tracking goods while they are on the road, or getting suppliers to exchange inventory information have been on the market for years. So while it is perfectly logic that the topic will get a new push with the Internet of Things, it seems that so far its popularity remains limited.

## **Smart farming**

Smart farming is an often overlooked business-case for the internet of Things because it does not really fit into the well-known categories such as health, mobility, or industrial. However, due to the remoteness of farming operations and the large number of livestock that could be monitored the Internet of Things could revolutionize the way farmers work. But this idea has not yet reached large-scale attention. Nevertheless, one of the Internet of Things applications that should not be underestimated. Smart farming will become the important application field in the predominantly agricultural-product exporting countries.

# **Chapter 6**

## **Results and Discussions**

### Simulation

Here we have taken number of transmitted symbol is 10000, MPSK order 2 and initial, final and increment values of SNR are 0dB, 20 dB and 1dB respectively.

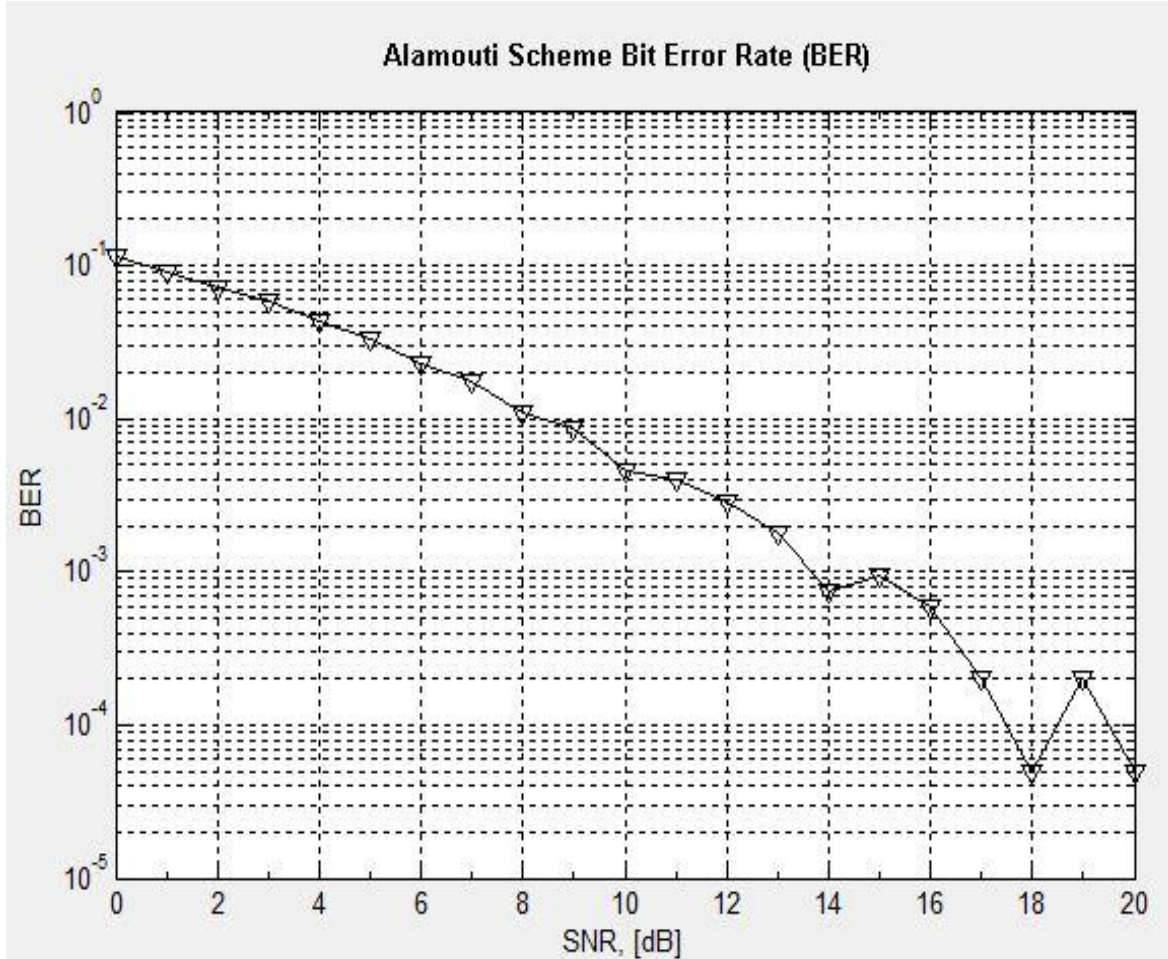


Figure 1: SNR vs BER with Number of Transmitter 2 & Number of Receiver 1

Figure 1 shows The variation of Signal to Noise Ratio (SNR)with respect to Bit Error Rate (BER). For Two Transmitter and one receiver for BER, the SNR goes to 20 dB.For this configuration the value of SNR is not desired. Our target is to get the minimal SNR. So we are going to our next configuration.

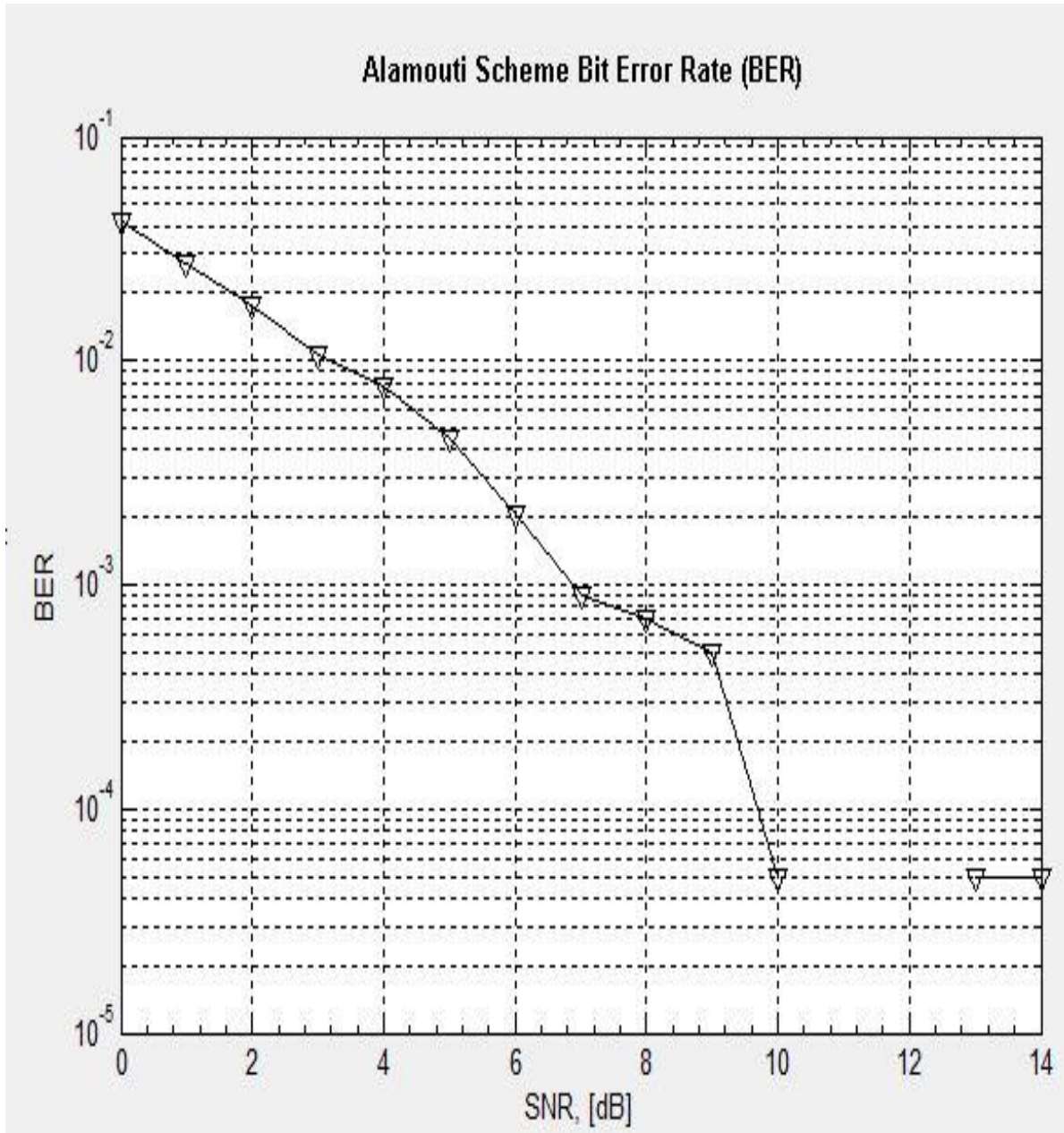


Figure 2: SNR vs BER with Number of Transmitter 2 & Number of Receiver 2

Figure 2 shows The variation of Signal to Noise Ratio (SNR)with respect to Bit Error Rate (BER). For Two Transmitter and two receiver for BER, the SNR goes to 10dB.For this configuration the value of SNR is half of the first one, that is also not desired. We can reduce the SNR by increasing the number of receiver as shown in the following figure.

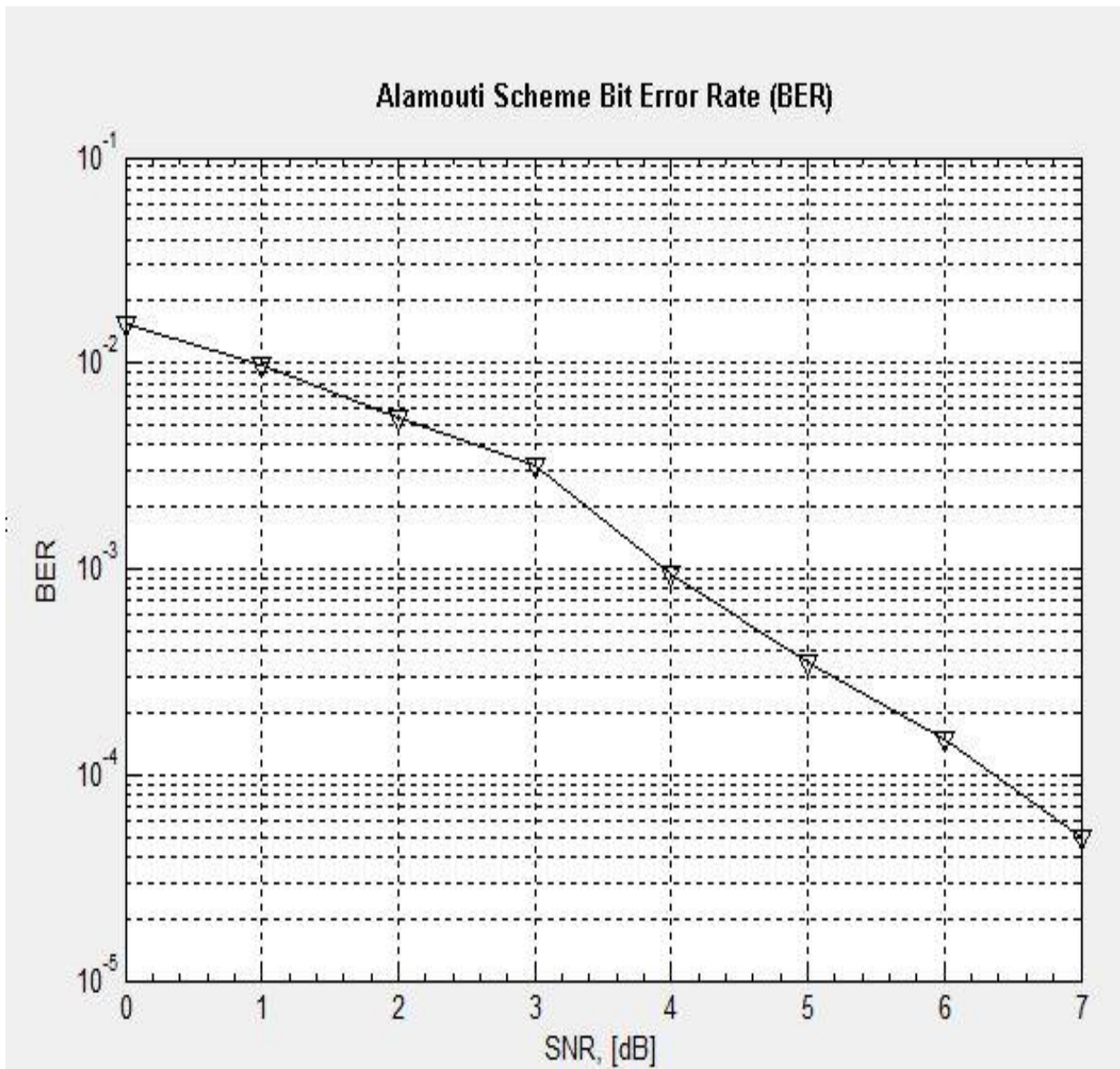


Figure 3: SNR vs BER with Number of Transmitter 2 & Number of Receiver 3

Figure 3 shows The variation of Signal to Noise Ratio (SNR)with respect to Bit Error Rate (BER). For Two Transmitter and three receiver for BER, the SNR goes to 7dB, which is better than previous two configurations. For this configuration the value of SNR is much better that we expected.

In the first figure (transmitter 2 & receiver 1) the SNR goes to 20 dB whereas in the second (transmitter 2 & receiver 2)& third (transmitter 2 & receiver 3) figure the SNR goes to 10dB and 7dB respectively. As the number of receiver increased, the SNR also decreased. So if the SNR margin decrease the download speed will increase which is very essential for IoT applications.



# Chapter 7

## CONCLUSION

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## CONCLUSION

In this Paper STBC Code along with Virtual antenna is observed for the improvement of the Network layer of Internet of Things (IoT).The IoT promotes a heightened level of awareness about our world, and a platform from which to monitor the reactions to the changing conditions that said awareness exposes us to. And, like the advent of the Internet itself, the IoT enables a myriad of applications ranging from the micro to the macro, and from the trivial to the critical. As power is one of the major issues in IoT structure, we believe,our virtual antenna model can be a smart solution in this regard. An approach was presented that successfully combines transmit diversity and relaying technology. It was suggested to encode the original signal stream at the BS utilizing STBC, where the original stream is received by the target mobile terminal and the helper/relaying mobile terminal. Eventually, the helper mobile retransmits the original information to the target mobile. Therefore,Alamouti scheme is effectively emulated.

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