MAXIMIZING COMMUNICATION RELIABILTY IN WSN BY INTRODUCING MIMO TECHNOLOGY

Dissertation submitted in partial fulfillment of the requirement for the degree of

MASTER OF TECHNOLOGY

IN

ELECTRONICS AND COMMUNICATION ENGINEERING

B y

Nidhi Chauhan

Enrolment No:-132010

Under the Supervision of

Mr. Sunil Vidya Bhooshan

JAYPEE UNIVERSITY OF INFORMATION AND TECHNOLOGY
WAKANAGHAT, SOLAN – 173234, HIMACHAL PRADESH

JAYPEE UNIVERSITY OF INFORMATION TECHNOLOGY

(Established under Act 14 of Legislative Assembly of Himachal Pradesh)

Waknaghat, P.O. Domehar Bani, The. Kandaghat, Distt. Solan-173234 (H.P.)

Phone: 01792-245367, 245368, 245369

Fax: 01792-245362

DECLARATION

I hereby declare that the work reported in the M. Tech thesis entitled "**Maximizing Communication Reliability in WSN by Introducing MIMO Technology**" submitted by "Ms. **Nidhi Chauhan**" at Jaypee University of Information technology, Waknaghat, Solan , India under the guidance of "**Mr. S.V Bhooshan**".I have not submitted this work elsewhere for any other degree.

NIDHI CHAUHAN

Department of Electronics and Communication Engineering

Jaypee University of Information Technology (JUIT)

Waknaghat, Solan-173234, India

JAYPEE UNIVERSITY OF INFORMATION TECHNOLOGY

(Established under Act 14 of Legislative Assembly of Himachal Pradesh)

Waknaghat, P.O. Domehar Bani, The. Kandaghat, Distt. Solan-173234 (H.P.)

Phone: 01792-245367, 245368, 245369

Fax: 01792-245362

CERTIFICATE

This is to certify that work entitled "**Maximizing Communication Reliability in WSN by Introducing MIMO Technology**" submitted by "**Nidhi Chauhan"** in partial fulfillment for the award of degree of Master of Technology in Electronics & Communication Engineering to Jaypee University of Information Technology, Waknaghat, has been carried out under my guidance. This work has not been submitted partially or fully to any other University or Institute for the award of this or any other degree or diploma.

Dr. S.V Bhooshan
Head of the Department
Jaypee University of Information Technology
Waknaghat, solan-173234, India

ACKNOWLEDGEMENT

I would like to express my gratitude to my guide **"Dr. S.V Bhooshan,"** head of the department for final year project, for providing excellent guidance, encouragement and inspiration throughout the project work. Without his invaluable guidance, this work would never have been a successful one.

Last but not least a special thanks to my parents, supporting professor, and friends for their caring and encouragement.

Signature of the student

Name of Student : NIDHI CHAUHAN

Date

ABSTRACT

Wireless sensor networks (WSN) is a very important and exciting new technology with great potential for several current applications in medication, transportation, agriculture, industrial process control, and also the military as well as creating new revolutionary systems in areas like global-scale environmental monitoring, precision agriculture, home and assisted living medical care, smart buildings and cities, and numerous future military applications. In fact, it is difficult to consider any major application area that cannot benefit from WSN technology. Typically, WSN are composed of enormous numbers of minimal capacity sensing, computing, and communicating devices and various sort of actuators. To date, analysis and real-world implementations have made several wonderful low level mechanisms and protocols to gather, transport, perform sensor fusion of this data and react with control actions. In the harsh working environments, channel fading, interference, and radio irregularity further pose challenges on the design of such scheme. Our focus is on reliable data transmission WSNs. As multiple-input–multiple-output (MIMO) technology has the potential to dramatically increase the reliability or reduce transmission energy consumption in fading channels, So for reliable communication in WSN MIMO technology is a possible option. But applying multiple antenna techniques directly to sensor network is impractical because of the limited size of a sensor node usually supports a single antenna. So the MIMO transmission in wireless sensor networks must be operated in a cooperative way, which means multiple sensor nodes with single-antenna in each of them, form MIMO link.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF ABBREVIATIONS

WSN	**Wireless Sensor Network**
MIMO	**Multi Input Multi Output**
MISO	**Multi Input Single Output**
SIMO	**Single Input Multi Output**
SISO	**Single Input Single Output**
CO-MIMO	**Cooperative Multi Input Multi Output**
OSI	**Open System Interconnection**
MAC	**Medium Access Control**
LOS	**Line of Sight**
SNR	**Signal to Noise Ratio**
STBC	**Space Time Block Code**
SM	**Spatial Multiplexing**
MMSE	**Minimum Mean Square Error**
CSI	**Channel State Information**
STTC	**Space Time Trellis Code**
AF	**Amplify and Forward**
DF	**Decode and Forward**
CF	**Compress and Forward**
ADC	**Analog to Digital Converter**

Chapter 1
Introduction

1.1 Background

Since the primary remote broadcast was developed by Guglielmo Marconi in 1901, remote analogy addition has created for over one century and was the foremost dynamic zone in interchanges and systems administration. From the end-to-end message transmission to media, substantial volumes of data stream and there is huge connection between systems in the current society. Large of remote items, for example, cell cellular telephone system, satellite TV administrations, remote web, and so forth, are rolling out large enhancement to our day by day life. Remote ways moreover, their applications in numerous form of systems, which might bolster higher data rate, higher correspondence unwavering quality, the key fascinating problems in these days' analysis all over the world. The exploration focus of this postulation is remote sensor system (WSN). WSN sensor network (WSNs) have emerged as one of the dominant technology trends of this decade [3]. Massachusetts institute of technology (MIT) Enterprise Technology Review [4] predicted that wireless sensor would be one out of ten emerging technologies that will change the world and affect the way we live and work.

It’s a self-sorted out system created out of thickly sent sensing element. It has been from the beginning projected by the examination bunch in Carnegie Mellon University in 1978 for military utilization. As of late, its application has been grownup into common utilization. There are numerous analysis compassed concerning wireless sensor systems since nineties, for instance, SIM (sensor information modernization), WINS (remote consolidated system sensors), Smart Dust, AMPS (smaller scale versatile multi-area power-mindful sensors), Sea Web, and so on.Not quite the constant as totally different remote corresponding organizes, the foremost essential basis in configuration of wireless sensor networks is vitality proficiency in lightweight of the very fact that sensor nodes are usually deployed in an exceedingly immense territory and work utilizing non-rechargeable battery.

1.2 Motivation

Wireless sensor network (WSN) comprises of hundreds to thousands of small nodes employed in a wide range of data gathering applications such as military, environmental monitoring and other fields [1][2]. Due to limited energy and difficulty in recharging a large number of sensor nodes, energy efficiency and maximizing network lifetime have been the most important design goals for the network. However, channel fading and radio interference pose a big challenge in design of energy efficient communication protocols for WSN. In harsh environments, sensor nodes must be provided with reliable communication links. As we know MIMO technology can increase the channel capacity because of spatial multiplexing and communication reliability because of the spatial diversity so Multi-input Multi-output (MIMO) schemes when incorporated in wireless senor network (WSN) can significantly improve the communication performance. But applying multiple antenna techniques directly to sensor network is impractical because of the limited size of a sensor node usually supports a single antenna. So the MIMO transmission in wireless sensor networks must be operated in a cooperative way, which means multiple sensor nodes with single-antenna in each of them, form MIMO link. In this way we can achieve the diversity gain in WSN.

1.3 Dissertation Overview

This dissertation examines the use and performance of cooperative MIMO communication mechanism in WSNs with reliability as the main focus. Chapter2 examine existing traditional MIMO communication system. Chapter 3 studies existing fundamental Intelligent WSN. Chapter .4 studies basics of cooperative diversity. Chapter 5 includes simulation results. Chapter 6 concludes the dissertation.

Chapter 2

MIMO Technology

In this chapter, some basic ideas for wireless attenuation channels square measure introduced initial. Then the background of MIMO communication and wireless device network introduced., accentuation the benefits of MIMO over the normal technologies and also the specialties of WSNs. Supported this, the need and feasibleness of mixing such two analysis fields are often clear, that collectively explains the inventory of this subject and also the aim of this thesis. The literature review of recent cooperative MIMO technique in WSNs is additionally explicit to clarify the contributions of the work.

2.1 **wireless fading channels**

The wireless environment is very unstable and fading is cause due to multipath propagation. Multipath propagation results in fast inconstancy of the phase and amplitude of the signal. The presence of obstructions in the wireless environment ambient a transmitter and receiver create multiple paths that a transmitted signal can pass through. As a result, the base station receives the multiple copies of the transmitted signal, each pass through a different path and suffers different fading. Each signal copy can suffers deviation in attenuation, delay and phase shift when transmitted from the transmitter to the receiver. This can end in either constructive or destructive interference, at the receiver signal gets amplifying or attenuate. There are three basic mechanisms that impact signal propagation in a mobile communication system. They are reflection, diffraction, and scattering [11].

Reflection: occurs when a propagating electromagnetic wave impinges on a smooth surface with very large dimensions compared to the RF signal wavelength (λ).

Diffraction: occurs when the radio path between the transmitter and receiver is obstructed by a dense body with large dimensions compared to λ, causing secondary waves to be formed behind the obstructing body. Diffraction is a phenomenon that accounts for RF energy traveling from transmitter to receiver without a line-of-sight path between the two. It is often termed shadowing because the diffracted field can reach the receiver even when shadowed by an impenetrable obstruction.

Scattering: Scattering occurs when a radio wave impinges on either a large rough surface or any surface whose dimensions are on the order of λ or less, causing the reflected energy to spread out (scatter) in all directions. In an urban environment, typical signal obstructions that yield scattering are lampposts, street signs, and foliage.

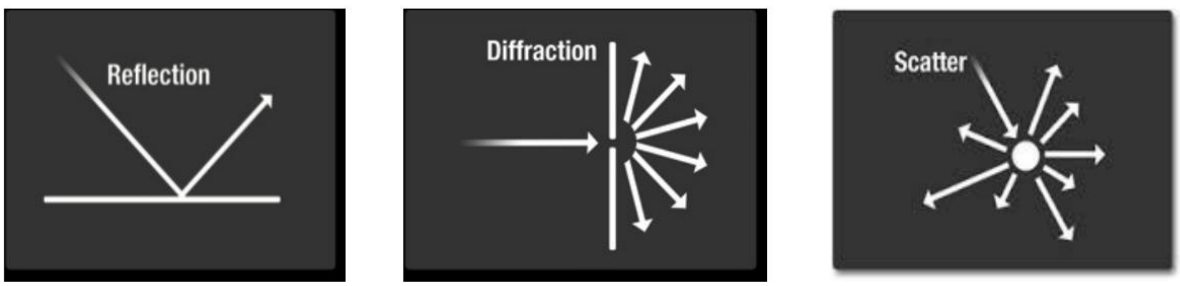


Figure 2.1 Reflection, Diffraction, Scattering

Fading can be further categories as large scale fading or small scale fading [13]. Supported multipath time delay spread small scale fading is classified as flat fading and frequency selective fading. If information measure of the signal is smaller than bandwidth of the channel and delay spread is smaller than relative symbol period then flat fading occurs whereas if bandwidth of the signal is greater than bandwidth of the channel and delay spread is greater than relative symbol period then frequency selective fading happens. Based on Doppler spread small scale fading may be fast fading or slow fading. Slow fading occurs when the coherence time of the channel is relatively large to the delay constraint of the channel. The amplitude and phase change obligatory by the channel may be considered roughly constant over the period of use. Slow fading may be caused by events like shadowing, wherever a large obstruction like a hill or massive building comes within the main signal path between the transmitter and the receiver.

Fast fading is occurs due the coherence time of the channel is relatively less to the delay constraint of the channel. The amplitude and phase change obligatory by the channel varies significantly over the period of use. In a fast fading, the user can take advantage of the variations in the channel conditions using time diversity to assists increase robustness of the communication. Multipath propagation phenomenon is shown as in figure 2.2

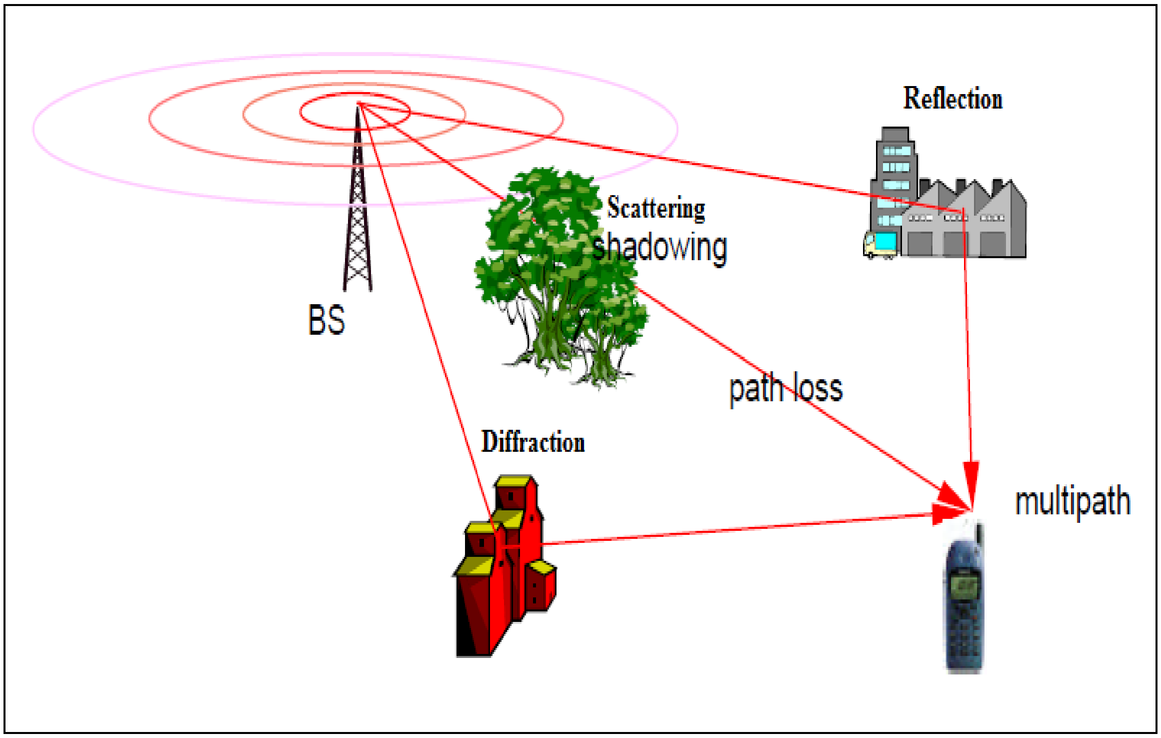


Figure2.2 Multipath Propagation Mechanism: *Ref* (49)

The signal which is directly received at the receiver is called line-of-sight (LOS) path. Other Multiple copies can also reach to the receiver because of multipath propagation mainly caused by reflection, diffraction, and scattering. Then at the receiver side (Rx), amplification or attenuation of the signal power is seen because of superposition. The worst situation is so called deep fading which means a temporary failure of communication between Transmitter and Receiver due to a severe drop of signal-to-noise ratio (SNR).

2.1.1 Small-Scale Fading

Electromagnetic waves that radiate from a transmitting antenna strike obstacles during their propagation toward the receiving antenna[10]. Depending on the nature of those obstructions, the waves experience reflection, diffraction, or scattering, and finally, multiple waves which propagate via different paths (multipath propagation) impinge on the receiver. Those scattering, reflected waves superimpose constructively or destructively depending on their phase shifts and time delay. If consider the scenario where mobile users present or uncertainty in the environment, results in different multi-paths and thus reduced the received signal to-noise ratios (SNRs). Indeed, deep fades, i.e., locations where the received signals are below the noise level and assume as of error free receptions are only separated by some fraction of the wavelength of the carrier frequency. Communicating nodes also suffer from fading effects even when they do not move, which reveals the time variance of the channel caused by changes in the environment. Small-scale fading is also called Rayleigh fading because if the multiple reflective paths are large in number and there is no line-of-sight signal component, the envelope of the received signal is statistically described by a Rayleigh PDF. When there is a dominant non fading signal component present, such as a line-of-sight propagation path, the small scale fading envelope is described by a Rician PDF.. A mobile radio roaming over a large area must process signals that experience both types of fading: small-scale fading superimposed on large-scale fading

2.1.2 Large Scale Fading

This phenomenon is affected by prominent terrain contours (hills, cliffs, forests, billboards, clumps of buildings, etc.) between the source and destination. The receiver is generally represented as being “shadowed” by such eminence. The details of large-scale fading provide a way of computing an estimate of path loss as a function of distance. This is described in terms of a path loss (nth-power law) and a log-normally distributed variation about the mean.

2.1.3 Rayleigh Fading

For a wireless channel, the envelope of the channel response is modeled to have a Rayleigh distribution. Rayleigh Fading is a reasonable model when there are many objects in the environment that scatter the radio signal before it reaches the destination. The delays related with different signal paths in a multipath fading channel change in an unpredictable manner and can only be characterized statistically. When there are a large number of channel paths, the central limit theorem can be applicable to model the time-variant impulse response or channel response of the channel as a complex-valued Gaussian random process. When the impulse response is formed as a zero mean complex-valued Gaussian process, the channel is said to be a Rayleigh fading channel.

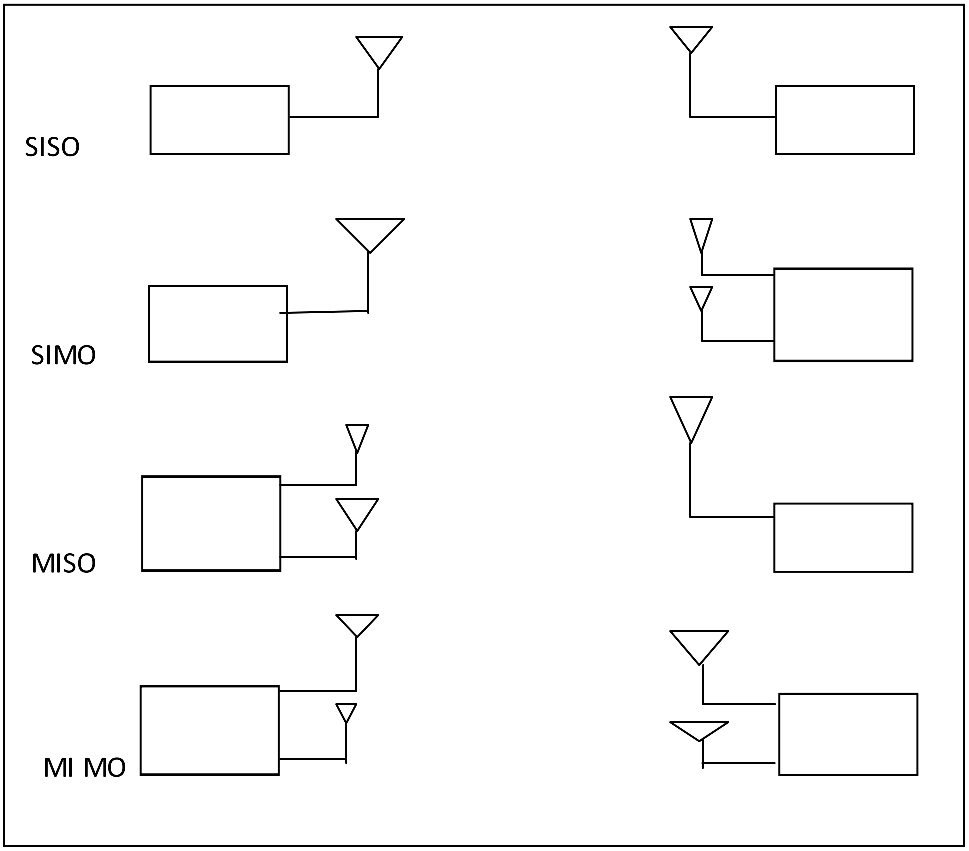
2.2 Introduction to MIMO

MIMO (Multiple-Input Multiple-Output) technology is a significant development in wireless communication and intelligent antenna research. The earliest ideas in this field can be traced back to the begin work during 1970s and 1980s by A.R. Kaye, D.A. George, W.van Etten, and Jack Winters, etc [23]. MIMO technology first explored from the antenna array used for military purposes. It aimed to provide enhanced diversity gain by employing more space dimensions and to overcome co-channel interference and noise in fading channels. Recently, some effort has also made to introduce MIMO technology into emerging communication standards, including the high data rate downlink packet access (HSDPA) mode of third generation cellular networks, IEEE 802.11n for next-generation wireless local-area networks (WLAN), and IEEE 802.16 for outdoor fixed/nomadic wireless wide-area networks (WWAN) [17]. Its application has increases to our daily life, such as 3G mobile phones, and internet wireless accessing for our laptops, and promises to play an important role in the future.

2.2.1 Design of MIMO System

Different from the common single-transmitter single-receiver system, so-called SISO (single-input single-output), in MIMO [24] technology multiple antennas at both the transmitter and the receiver side are deployed to improve transmission communication performance.

There are some other class which are derived from MIMO, known as SIMO, MISO. Diagrams depict SISO, SIMO, MISO and MIMO [23-25]are shown in Figure2-3



2.3 Figure of SISO, SIMO, MISO, MIMO system

2.2.2 Subcategories of MIMO System

There are different sub-categories for MIMO[23] system depending on the formation of number of antennas and number of users, such as single-user MIMO, multi-user MIMO (MU-MIMO), and cooperative MIMO (CO-MIMO).

Single user MIMO

A transmitter which consists of more than one antenna at transmitter side and communicate only with one receiver that has multiple antennas, shown as figure 2.3(a)

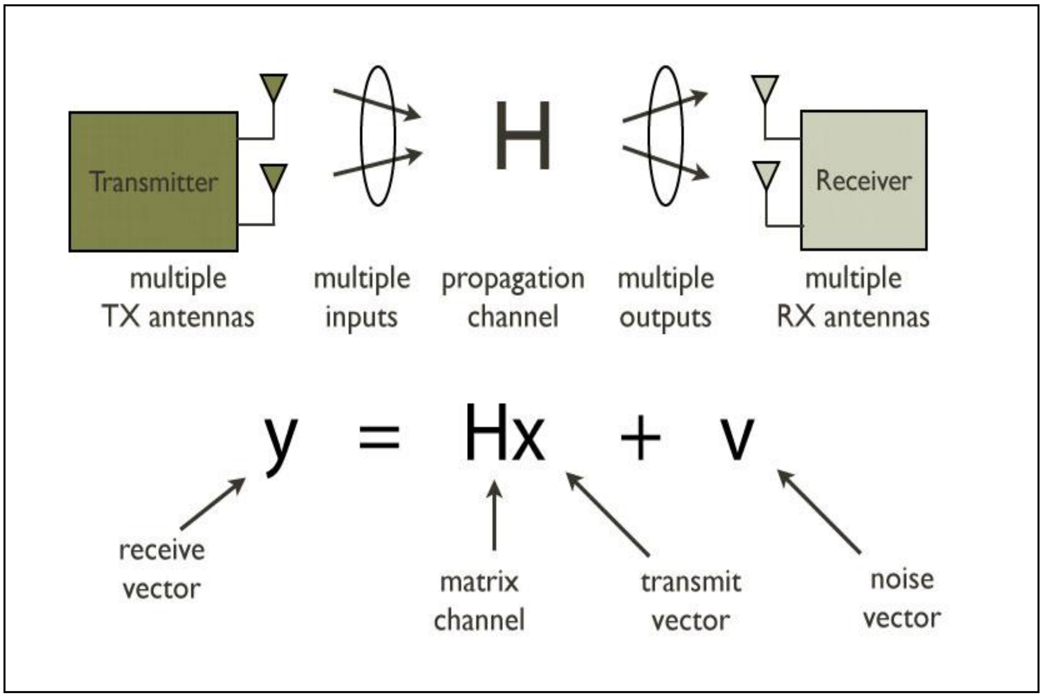


Figure 2.3(a) Single User MIMO*: Ref[46]*

Multi-user MIMO

A transmitter having more than one antenna communicating with multiple antennas at the receiver side (figure 2-3(b))

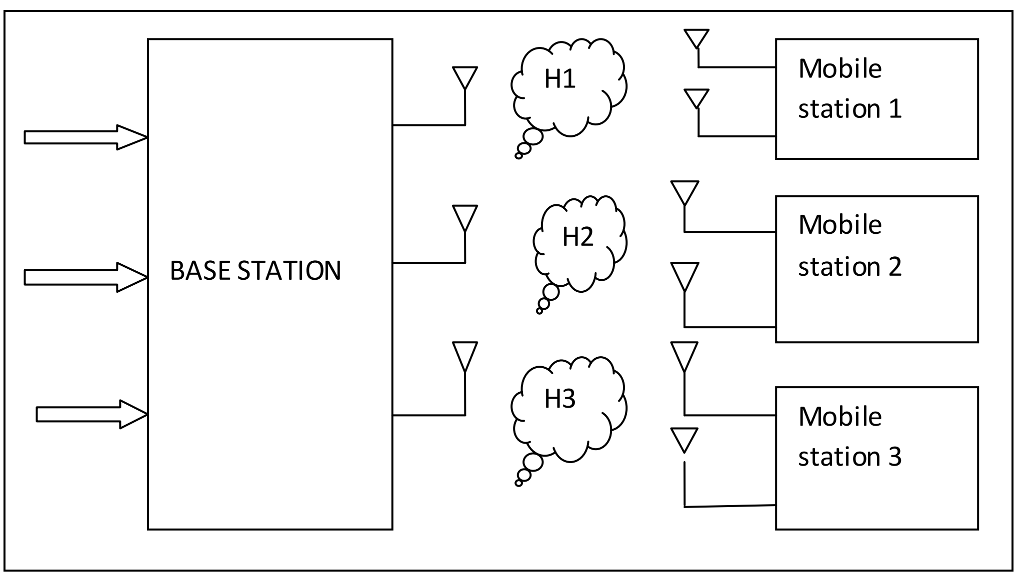


Figure 2.3(b) Multi User MIMO System

Cooperative MIMO

Different users are used as a individual antennas and form a virtual MIMO link at both transmit and receiving sides.

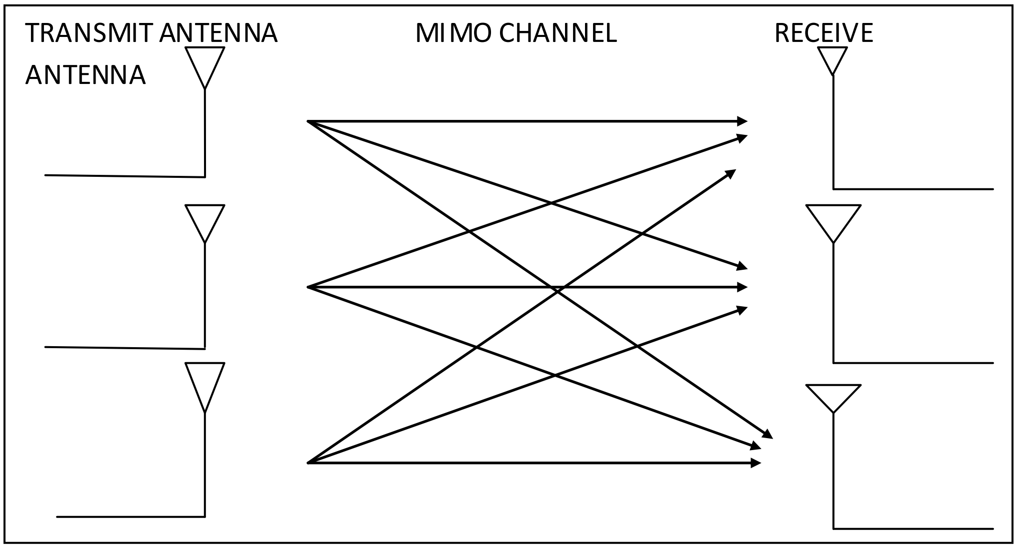


Figure 2.3(c) cooperative MIMO system

2.3 Spatial Diversity

Spatial diversity is achieved by the use of multiple antennas or nodes at either end or at each ends of the MIMO communication link. The separation in-between the antennas should be quite more than half a wavelength through a regular scattering environment. Spatial diversity gains increase data rate that's lead to higher information throughputs and vital improvement in information transmission reliability. These advantages are achieved without any enlargement of bandwidth or higher transmit power that this methodology terribly applicable to be enforced in energy constrained WSNs. Diversity techniques will be combined to realize greater enhancement in reliability and possible transmission rates. Perhaps the foremost popular combination technique is between space diversity and time diversity by exploitation channel coding. The combination yields the space-time coding (STC) scheme. The variants of the STC scheme rely on the channel coding being used. For example, space-time block coding (STBC) [27] schemes are based on block coding and space-time trellis coding scheme (STTC) schemes are based on trellis coded modulation. Multiple antennas or nodes are going to be exploited in many ways in which at every ends of the MIMO communication link.

2.4 Spatial Multiplexing

Spatially multiplexed MIMO (SM-MIMO)[14] systems will transmit information at a far better speed than MIMO systems exploitation antenna diversity techniques. Spatial multiplexing splits a high rate signal into multiple independent lower rate streams and each is emitted from a transmit antenna within the same frequency channel. In associate $Nt \times Nr$ system, where N_T and N_R represent the number of transmit and receive antennas severally, the utmost spatial multiplexing order (capacity gain) is $N_S = \min(N_T, N_R)$.

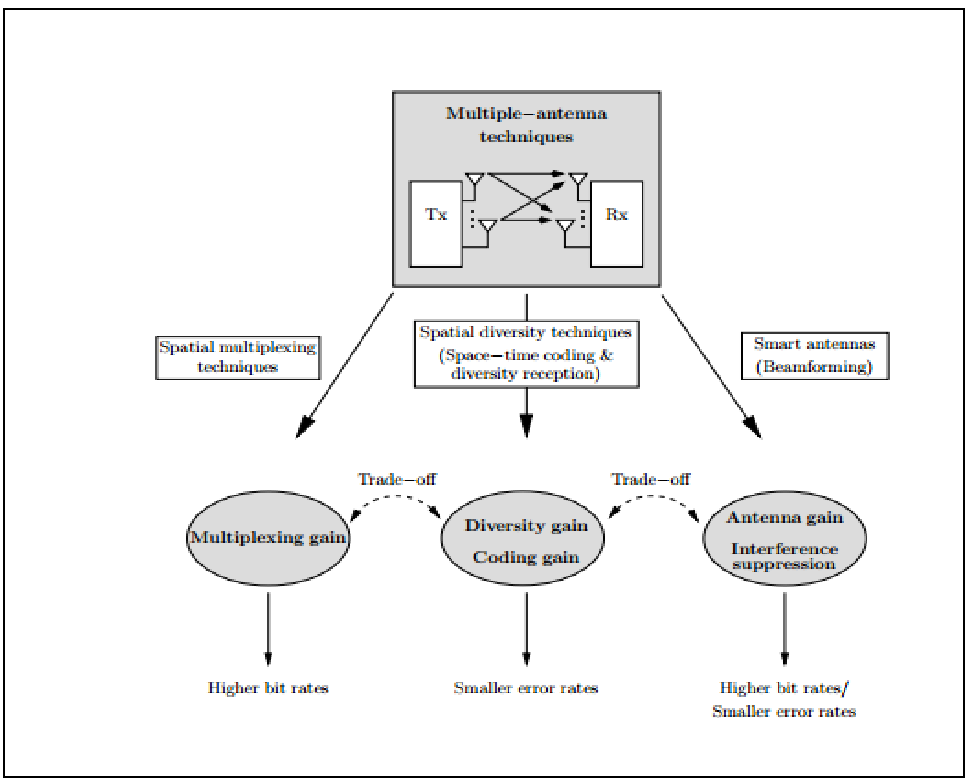


Figure 2.4 Multiple Antenna Technique: *Ref* [47]

2.5 Beamforming

Beamforming may be a signal processing technique used to control the directionality of the transmission and reception of radio signals. The fore most effective variety of beamforming is dynamic digital beamforming this kind of beamforming uses a complicated on chip digital signal process rule to achieve complete management over Wi-Fi signals. By forming many several independent paths to optimally focus radio energy to and from client server on a per packet, performance is dramatically enhanced. With in the case of two stream configuration, this makes it doable to steer the energy of the antenna array within the independent spatial directions associated with both data streams, whereas at the same time avoiding interference.

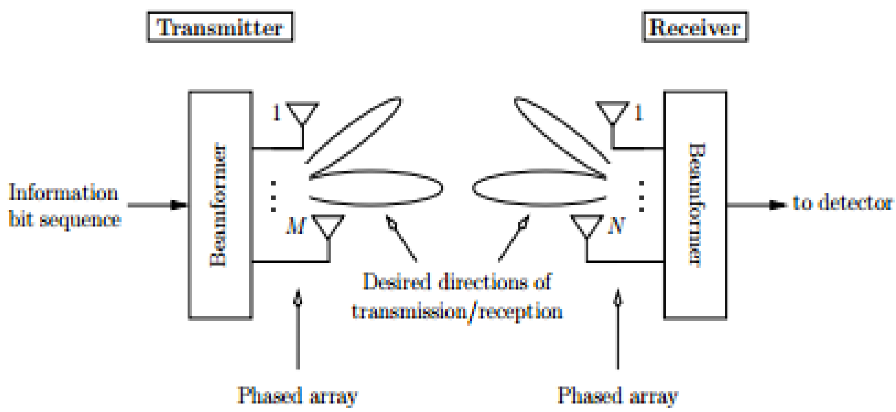


Figure *2.5* Beamforming: *Ref* [47]

2.6 Pre-coding

Pre-coding can be considered to be any spatial processing operations at the transmitter side. Throughout a single-layer system (MISO), beam-forming is used to send the recurrent signal from every antenna with applicable weight such the signal power is maximized at the receiver input. Once there are more than one antennas at the receiver aspect, that could be a MIMO system, pre-coding of multi-layer beam-forming at the identical time maximize the magnitude in any respect of the receive antennas [18]. Some examples of pre-coding method are singular value decomposition (SVD) [19] for single-user MIMO, linear pre-coding of minimum mean square error (MMSE), zero-forcing (ZF) and therefore the nonlinear precoding of dirty paper coding (DPC) for multi-user MIMO systems [20]. All these method need information of channel state information (CSI), full or restricted, at the transmitter.

2.7 Alamouti code

Alamouti[15][17] offers a simple method for achieving spatial diversity with two transmit antennas.

we take into account, that we have a transmission sequence, for example(x1 and x2).

- Two Transmit antenna – 1 Receive antenna

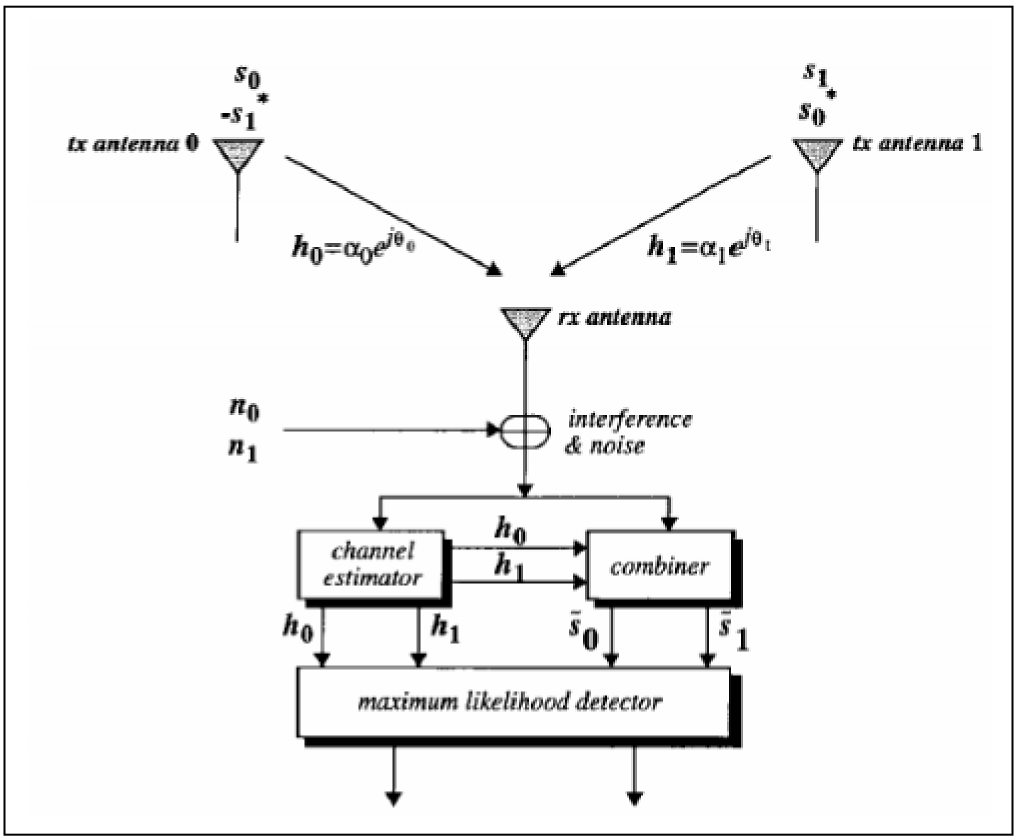


Figure 2.6 Alamouti Scheme: *Ref* [48]

In traditional transmission, we will be sending x1 within the first time slot, x2 in the second time slot. However, Alamouti advised that we tend to group the symbols into groups of two. In the first time interval, send x1 and x2 from the primary and second antenna. In the second time interval sends -x2* and x1* from the primary and second antenna. Notice that although we tend

to grouping two symbols, we tend to still need two time slots to send two symbols. Hence, there is no amendment within the rate.

An STBC [29] will be described as a matrix, with every row representing a time interval and every column representing one antenna's transmission over time [34]. A block codeword with *T* time slots is called *T* length coding. If associate STBC block encodes k symbols of a signal, then the code rate can be expressed as [29].

$$R = \frac{K}{T}$$

It is used to measure how many symbols this coding transmits per time slot on average. Then the system data rate is the product of symbol rate multiplying by the code rate.

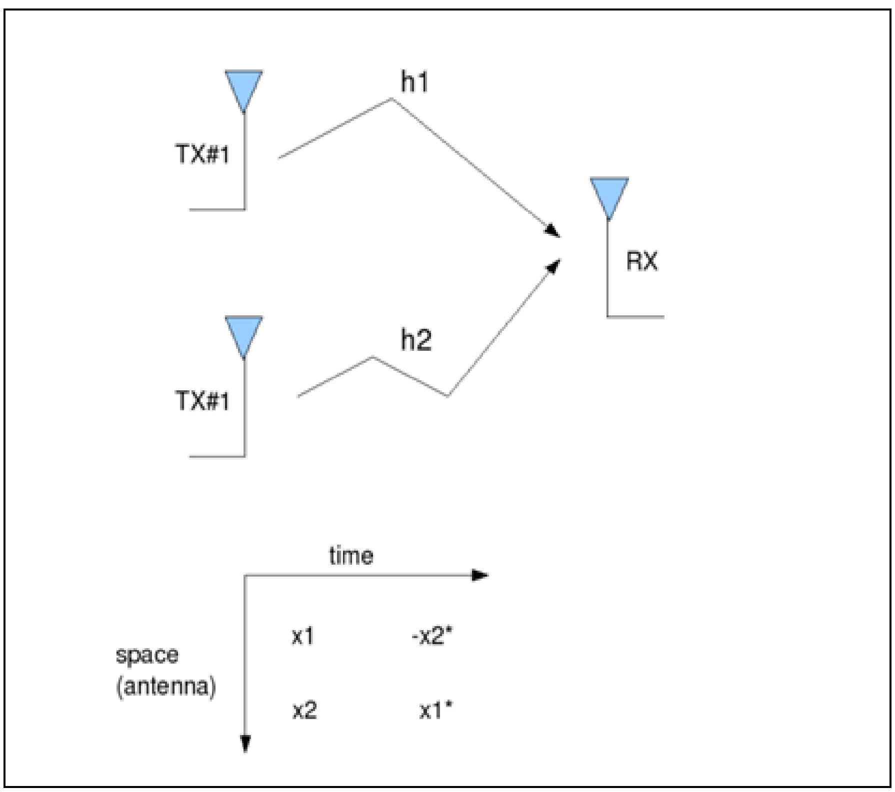


Figure 2.7 Alamouti Transmission

In the first time slot, the received signal is,

$$y_1 = h_1x_1 + h_2x_2 + n_1 = [h_1h_2]\begin{bmatrix}x_1\\x_2\end{bmatrix} + n_1 \tag{1}$$

In the second time slot, the received signal is,

$$y_2 = -h_1x_2^* + h_2x_1^* + n_2 = [h_1h_2]\begin{bmatrix}x_2^*\\x_1^*\end{bmatrix} + n_2 \tag{2}$$

Where,

- Y_1 and Y_2 is the received symbol on the first and second time slot respectively.
- h_1 is the channel from first transmit antenna to receive antenna.
- h_2 is the channel from 2nd transmit antenna to receive antenna.
- X_1 and X_2 are the transmitted symbol and n_1 and n_2 is the noise on time slots.

$$y_2^* = [h_2^* - h_1^*]\begin{bmatrix}x_1\\x_2\end{bmatrix} + n_2^* \tag{3}$$

By combining 2 received signal we get,

$$\begin{bmatrix}y_1\\y_2^*\end{bmatrix} = \begin{bmatrix}h_1 & h_2\\h_2^* & -h_1^*\end{bmatrix}\begin{bmatrix}x_1\\x_2\end{bmatrix} + \begin{bmatrix}n_1\\n_2^*\end{bmatrix} \tag{4}$$

W_1 and W_2 are the weighting coefficient multiply with the received signal at the receiver to detect X_1 and X_2.

Where W_1 and W_2 are given as,

$$w_1 = \frac{c_1}{\|c\|} \quad , \; w_2 = \frac{c_2}{\|c\|} \tag{5}$$

In matrix form we can write the weighting coefficient as:

$$w_1 = \begin{bmatrix}\frac{h_1}{\|h\|}\\\frac{h_2^*}{\|h\|}\end{bmatrix}, \quad w_2 = \begin{bmatrix}\frac{h_2}{\|h\|}\\\frac{-h_1^*}{\|h\|}\end{bmatrix} \tag{6}$$

$$w_1^H y_1 = \begin{bmatrix} \frac{h_1^*}{\|h\|} \frac{h_2}{\|h\|} \end{bmatrix} \begin{bmatrix} h_1 & h_2 \\ h_2^* & -h_1^* \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + n_1^* \quad (7)$$

$$w_1^H y_1 = \|h\| x_1 + n_1^* \quad (8)$$

Similarly we can obtain symbol X_2 by multiplying W_2 with the received vector Y_2.

$$w_2^H y_2 = \|h\| x_2 + n_2^* \quad (9)$$

2.8 Properties of Alamouti codes

Unitary: The product of channel matrix with its Hermitian transpose is equal to the 2×2 identity matrix.

Linearity: transmitted symbol in Alamouti code is linear.

Full rate complex code: is the only complex space time block code with unity code rate.

Optimality of capacity: for two transmit antennas and a single receive antenna, the alamouti code is the only optimal space time block code in terms of capacity.

Chapter 3
Fundamentals of Intelligent Wireless Sensor Networks

In recent years, together with the event of computing, telecommunication, automation, artificial intelligence, and micro-electro-mechanism system (MEMS), a brand new reasonably observation network, wireless sensor network (WSN), has been paid more and additional attention and becomes one in all the recent topics in IT research field [34]. Completely Different from other computer and wireless communication networks, WSN has some specific options and its own criterion for style. In the section, we will provide a fundamental introduction of its structure and a few vital techniques for its operation.

3.1 Basic structure for wireless sensor networks

A wireless sensor network is consists of a large number of sensor nodes that are densely and randomly deployed in specific terrains, like battlefields or inaccessible environments, for observation [34]. The position of sensor nodes need not be designed or preset and even throughout its period, the topology of the network still keeps on dynamical. Communication takes place in WSN in two modes 1) node to node communication and other one is cluster to cluster communication. The sketch of a sensor network and its basic operating mode are shown in Figure 3.1

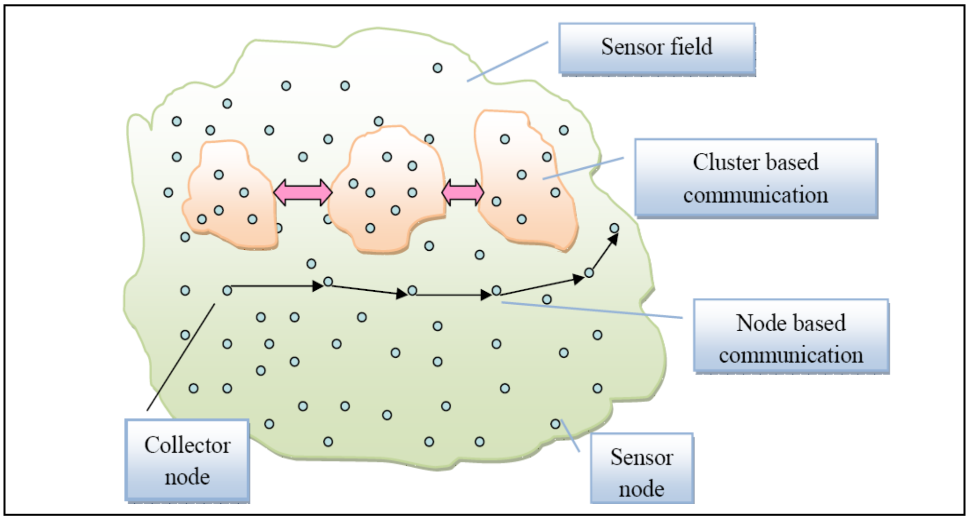


Figure 3.1 A Wireless Sensor Network: *ref*[43]

3.2 Sensor Node Architecture

Sensor Node Architecture mainly consists of 4 unit components and some additional application specification components are:

- Sensing Unit
- Processing Unit
- Transceiver Unit
- Power Unit
- Location finding system
- Power Generator
- Mobilizer

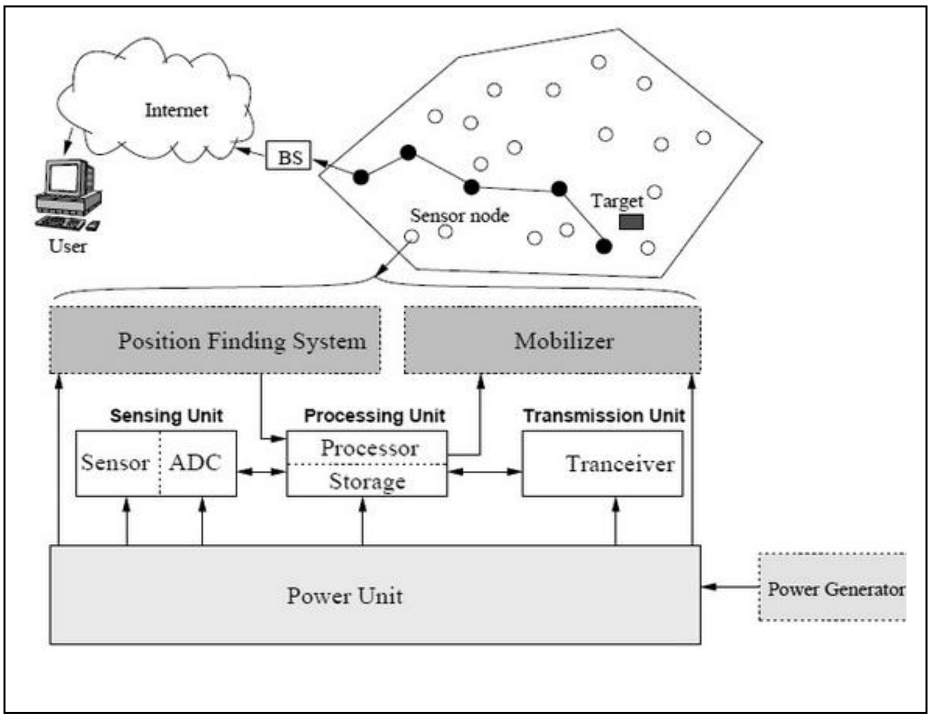


Figure3.2 Hardware Architecture of a Sensor Node: *Ref [45]*

Sensing unit

Sensing units are generally composed of two subunits : sensors analog to digital converters (ADCs). The analogue signals created by the sensors are converted to digital signals by the ADC so fed into processing unit.

Processing unit

The processing unit is generally related to a small storage unit and it will manage the procedures that create the sensor node collaborate with the other nodes to carry out the allotted sensing tasks. The signal received from the ADC is further processed using the processor unit. All the signal processing tasks are run by this unit. It also takes care of algorithms and communication protocols related to the actual application. Every sensor node needs memory to store the information concerning to a specific task, such as process values, data or packets. The processor unit works in co-ordination with the memory unit to achieve the required response.

Transceiver Unit

This unit helps the sensor nodes to communicate with one other or with the BS. The communication often established in any range of frequencies i.e. either in infrared or optical or in radio frequency (RF) range. Just in case of RF transmission the bit stream is converted into a RF waves and is then transmitted, which are then recovered back at the other end.

Power Unit

Power unit is one amongst the important components of the sensor node. It provides the power needed to run every component in the sensor node, typically battery is employed as a power source. As the power is limited, therefore it is needed to use it in an efficient manner to enhance the lifetime of a node. An ideal power source must have features like high capacity, low cost, small size, light weight etc.

Location Finding System

This is one amongst the extra units mounted on the sensor node counting on the need of the application or task. As some applications or tasks need the knowledge of physical location of a sensor so as to route data or to sense a specific event in a region, therefore sensor nodes needs a location finding system to seek out its position within the physical environment. GPS are often utilized in location finding system, however it may increase the dimension and cost related to the sensor node. However, location finding algorithms also can be used to find the location of a specific sensor.

Power Generator

As the whole operation of the sensor node is carried out using a battery, so it becomes necessary to use it in an efficient manner to prolong the network lifetime. Sometimes the sensor nodes which are deployed in external environments can use solar cells to generate power for the functioning**.**

Mobilizer

The sensor nodes in a network are typically static in nature, however sometimes movement of sensor nodes is important so as to meet the tasks related to the actual application. So, a mobilizer is needed to move the sensor nodes within the network.

3.3 Communication Model

3.3.1 Node to Node communication

The simplest and most ancient transmission mode in WSNs is point-to-point. Data gathered from the source node is transmitted to the sink node or BS directly without any relay. Solely the combine of communication ends are activated whereas the other nodes within the network keep on sleeping to avoid waste energy. The fundamental structure of a single-hop SISO system in a WSN is shown in fig, 3.3

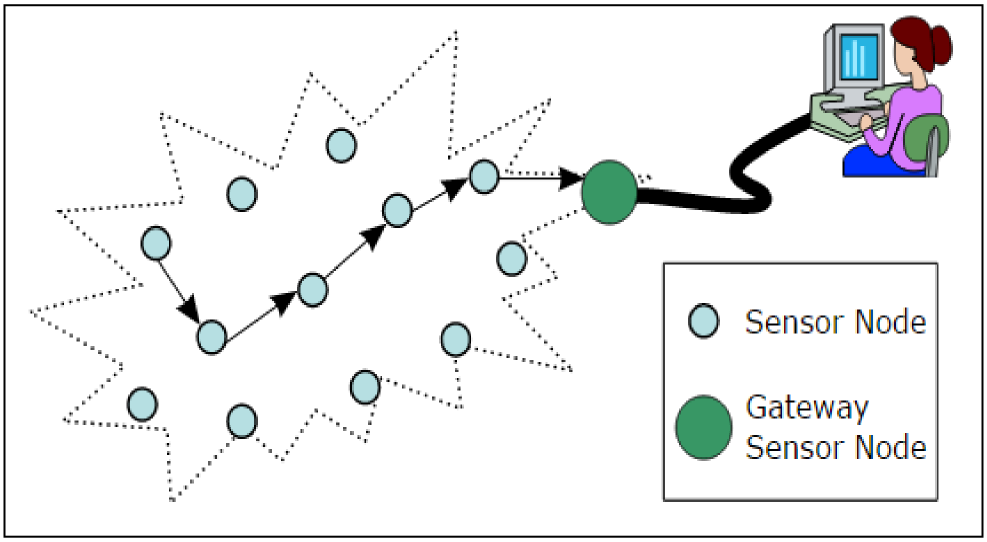


Figure *3.3* Node to Node Communication :*Ref* [50]

3.3.2 Cluster based communication

When a wireless sensor network is composed of clusters, the transmission mode is cluster-based [89]. All the sensor nodes within the network are classified into clusters and there might or might not be a cluster-head for every of them, counting on the cluster forming algorithm or routing protocol. The node-based sleep scheduling strategy then turns to cluster-based one. Clusters not concerned in the communication stay in sleep mode [90]. A typical one-hop cluster-based cooperative transmission mode is displayed within in the following figure 2.9

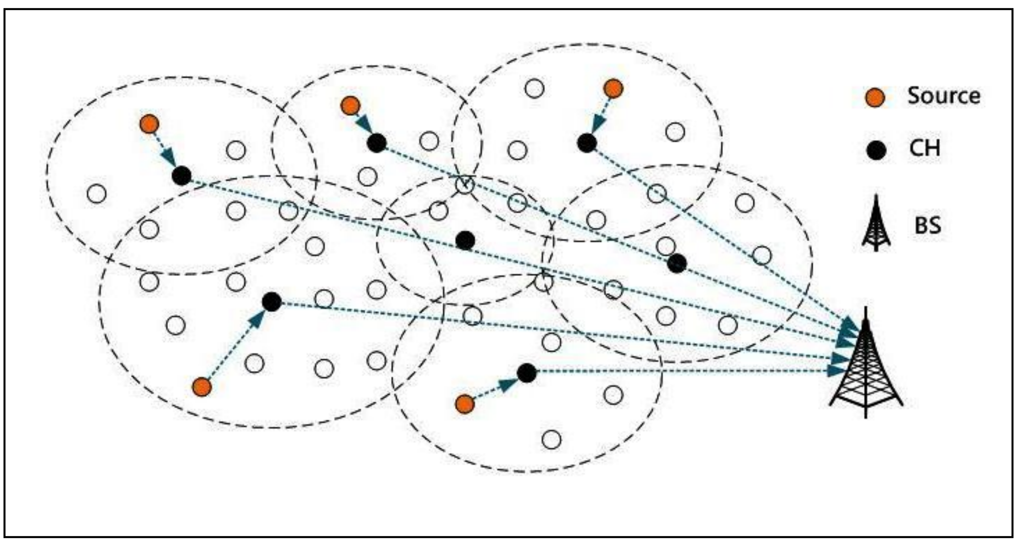


Figure 3.4 Cluster to Cluster Communication: *Ref* [51]

3.4 Factors influencing sensor network design

In order to design a wireless sensor network one requires a great knowledge in the fields of software, digital signal processing, embedded systems, networking and wireless communication. There are many factors which influence the design of any typical wireless sensor network e.g. scalability, hardware constraints, fault tolerance, production cost, sensor network topology, transmission media and power consumption [30]

Fault Tolerance

The sensor nodes in a network may die due to lack of power or can get damaged during their deployment in harsh environments. The failure of sensor nodes within the network should not affect the coverage and connectivity of the entire network. The protocols and algorithms should be designed in accordance with the application or with the environment in which they are deployed. Some applications such as household can work fine with low fault tolerance protocols but for the applications such as military the fault tolerance of the protocols designed should be high as the sensor nodes are more prone to failures as they can get damaged due to the hostile actions.

Scalability

The sensor nodes deployed over a particular task can be large in number. In order to monitor a physical phenomenon the node density may vary from few hundreds to thousands [16, 17]. The new protocols designed should be able to deal with such high density of nodes in an efficient manner. In particular, node density depends on the task or event which had to be monitored by sensor nodes.

Hardware Constraints

A typical sensor node constitutes of four basic units viz. sensing unit, processing unit, transceiver and power unit. All these units must be of small size so that they can be fitted inside a module not larger than a size of a matchbox. Along with that it must consume very low power for its operation, should have low production cost, must be able to operate in harsh environments or if left unattended for a long period of time [21, 22, 23].

Production Cost

As the wireless sensor network consists of high density nodes, so the cost of one node should be kept low in order to minimize the cost of entire network. Typically a sensor node consists of different subunits and also requires some additional units depending on the application, so it is a tedious task to keep the cost of a sensor node less than a dollar [24].

3.5 Wireless Sensor Network OSI Layers

The sensor are usually scattered in a sensor field. Each of these scattered sensor nodes has the capabilities to collect data and route data back to the sink and the end user[13]s. Data are routed back to the end user by a multi- hop infrastructure less architecture through the sink. The sink may communication with the task via internet or satellite.

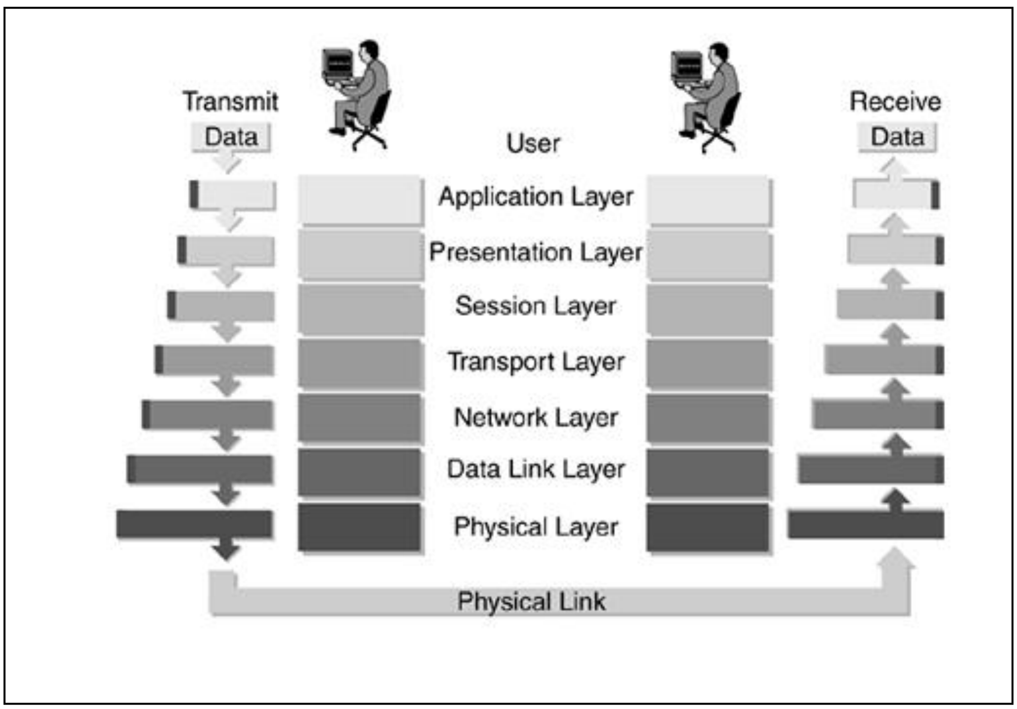


Figure 3.5 OSI Layer Model: *Ref(44)*

I. Physical layer

Physical Layer can offer an interface to transmit a stream of bits over physical medium. This layer is responsible for frequency selection, carrier frequency generation, signal detection, Modulation and encoding.

II. Data link layer

Responsible for multiplexing information streams, data frame detection, MAC, and error management, guarantee reliability of point–point or point– multipoint. Errors or unreliability comes from:

• Co- channel interference at the MAC layer and this problem is resolved by MAC protocols. Multipath fading and shadowing at the physical layer and this drawback is solved by forward error correction (FEC) and automatic repeat request (ARQ).

ARQ: not widespread in WSN because of extra re-transmission cost and overhead. ARQ is not economical to frame error detection therefore all the frame has to retransmitted if there is a single bit error.

FEC: decreases the number of retransmission by adding redundant information on every information packet therefore the receiver will detect and correct errors. By that we will avoid re-transmission and wait for ACK.

III. Network layer

The major responsibility of this layer is routing. This layer encompasses a ton of challenges counting on the application however apparently, the main challenges related with power saving, restricted memory and buffers, sensor doesn't have a world ID and need to be compelled to be self organized. The fundamental idea of the routing protocol is to stipulate a reliable path and redundant paths according to a precise scale referred to as metric, which differs from protocol to protocol. There's plenty of routing protocols available for this layer, they will be categories as; flat routing (for example, direct diffusion) and hierarchal routing (for example, LEACH) or is divided into time driven, question driven and event driven. In continuous time driven protocol, the data is distributed sporadically and time driven for applications that needed a periodic observation. Data aggregation and data fusion: so as to produce a complete coverage for a particular area, even after we have a failure, we have to deploy redundant sensors.

IV. Transport layer

The responsibility of this layer is to provide reliability improvement and congestion avoidance. Providing a reliable hop by hop is lot of energy efficient than end to end and which is one of the reason why TCP is not preferred for WSN. Some-times the link from base station to node is taken into account as downstream link for multicast transmission and UDP traffic owing to the restricted memory and overhead avoiding. In general, Transport protocols can be classified as:

a) Packet driven: in this protocol all packets sent by source should reach destination.

b) Event driven: in the event protocol, protocol should be detected, however it is enough that one notification message reaches the base station.

V. Application layer

Responsible for traffic management and provide software for different applications that translate the information in an understandable form or send queries to get bound information. Sensor networks deployed in numerous applications in numerous fields, for example; military, medical, environment, agriculture fields.

Chapter 4

Introduction to Cooperative Diversity

4.1 Cooperative diversity

Cooperative diversity [28-29] is a promising technique that addresses the disadvantage of exploitation multiple antennas. The main idea is that neighboring nodes collaborate by sharing their antennas to realize spatial diversity. A single node does not require multiple antennas nor sophisticated receiver hardware to find out from diversity effects. The increasing node density ensures the existence of multiple neighbors which might nearly share their antennas among each other.

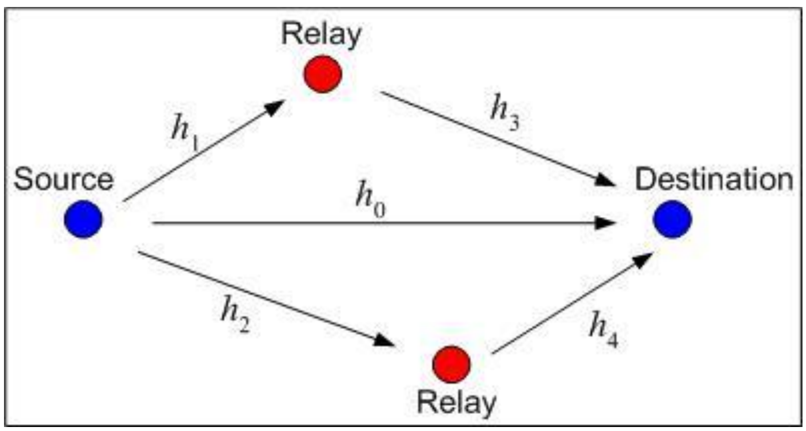


Figure: 4.1 Cooperative Relaying

Basic idea

The basic plan of cooperative diversity is shown in figure 2.10. Source node S tries to transmit a information to destination node D. Due to the broadcast nature of the wireless medium, all nodes

in transmission range of S can basically overhear this data exchange. This comes with none further except the energy consumed for receiving the information. Due to presence of obstacles in the channel, node D may not receive or may not correctly decode the packet from S. In such situations, a retransmission from Source S could make depending on the coherence time of the channel. Thus, it might be beneficial to exploit a common neighbor.

In the simplest form of cooperative diversity, a single node or relay in the depicted example denoted by R overhears the transmission from S and retransmit it to D afterwards. Hence, this node is called relay. We observe that a communication achieve using cooperative diversity has at least two phases. In the first phase or time slot, the direct transmission from S to D takes place. During this slot, R also overhears this data transmission. We refer to this phase from now on as direct transmission phase. In the second phase, R forward/retransmit the packet to D. We denote this phase cooperative transmission phase. Since the packet from S reaches D via two independent paths, diversity is achieved by combining two received signal by using MRC technique. Furthermore, we observe that cooperative diversity exploits both spatial and time diversity.

4.1.1 Characteristics of Nodes

Source node

Source information transmits to the destination either directly or by using relay. The source node needs to be known about that its transmission is retransmitted by a relaying node. Since the relaying happens only after the transmission from the source, the destination may not acknowledge the packet transmission from the source until the information reception from the relay.

Relay node

Relays can basically operate in three ways which are called Amplify and Forward (AF), Decode and Forward (DF), and Compress and Forward (CF). Relays working in AF mode act as regenerative repeater. They do not demodulate and interpret received packets. Instead, they receive noisy information and amplify it and forward received signals. Since the relay regenerates the received signal without decoding, it also amplifies the received noise. AF provides the destination with all the information the relay was able to observe leaving the decision to the destination. Nevertheless, if the SNR of the overheard signal is too low, no useful data can be forwarded and the time as well as the energy spent for the cooperative transmission is wasted.

In Decode and Forward, relays decode the overheard information which receive from source node before forwarding it to the intended destination. Cooperation fails whenever the relaying node is not able to accurately decode the packet from the source. In this context, AF performs better, since for the destination it is better to have additional information that is up to a certain level unreliable than having no additional information at all. The great advantage of DF is that having decoded information enables the relay to further increase the reliability of the communication by applying special channel coding.

In schemes applying Compress and Forward relay only forward a compressed version of the signal they have received from the source. The original data cannot be reconstructed solely based on the compressed information. However, given that the destination collects information about the compressed data it can fully reconstruct the original information source coding. The destination has to collect the necessary information from the source transmission and/or transmissions of other relays.

Destination node

Basically, the destination can try to decode the packet after the reception from the source or also wait until it has received the data from source and relay. In the former case, the destination could inform the source and the relay whether a cooperative transmission is necessary after the reception from the source (incremental relaying). In case of a successful direct transmission, the time and energy needed for the cooperative transmission is spared. In case of cooperative transmission, the destination has to combine the received signals from source and relay. Obviously, this combination also depends on the operation mode of the relay. If no special coding is used at the relay, the destination could apply the same methods as used in traditional diversity techniques to combine the signals received via different paths on the physical layer.

4.2 Cooperative MIMO In WSN

The concept of cooperative MIMO [27] was introduced in WSNs by utilizing the collaborative nature of dense sensor nodes with the broadcast wireless medium to provide reliable communication links in order to reduce the total energy consumption for each sensor node.

Therefore, instead of using multiple antennas attached to one node or device such in the traditional MIMO concept,

cooperative MIMO presents the concept of multiple sensor nodes cooperating to transmit and/or receive signals. Multiple sensor nodes are physically grouped together to cooperatively transmit and/or receive. Within a group, sensor nodes can communicate with relatively low power as compared to inter-group communication. Furthermore, by using this cooperative MIMO concept, we can provide the advantages of traditional MIMO systems to WSNs, particularly in terms of energy efficient operation.

The MIMO term originally describes the use of the multiple antennas concept or exploitation of spatial diversity techniques. In early research work, the MIMO [28] concept was proposed to fulfill the demand for providing reliable high-speed wireless communication links in harsh environments. Subsequently, MIMO technology has been proposed to be used in wireless local area networks and cellular networks (Proakis, 2001), particularly at the base station and access point sides to tackle the challenges of low transmission rates and low reliability with no constraints on energy efficiency. In contrast, WSNs have to deal with energy constraints due to the fact that each sensor node depends on its battery for its operation. In harsh environments, sensor nodes must be provided with reliable communication links. However, current WSN design requirements do not require high transmission rates.

Spatial diversity is achieved by the use of multiple antennas or nodes at either end or at both ends of the MIMO communication link. The separation between the antennas or nodes has to be more than half a wavelength in a uniform scattering environment. Systems with multiple antennas are also referred to as MIMO systems. Therefore we can refer to systems with multiple nodes as cooperative MIMO systems. Spatial diversity gains increase channel capacity which leads to higher data throughputs and significant improvement in data transmission reliability. These advantages are achieved without any expansion of bandwidth or higher transmit power which makes this technique very suitable to be implemented in energy constrained WSNs.

4.3 Different MIMO Scheme in Wireless Sensor Networks

Three major MIMO [29] schemes in both synchronous and asynchronous scenarios and their practicality in WSNs. Synchronous operation assumes perfect synchronization between cooperating transmitting nodes and asynchronous operation refers to scenarios where imperfect synchronization occurs. The three MIMO schemes are:

4.3.1 SIMO System

Perhaps the first technique in diversity particularly related to spatial utilization is the receive diversity (SIMO) technique. At the receiver side, more than one antenna or node must be used to gain spatial diversity which leads to higher reliability by increasing the average signal-to-noise ratio (SNR) and lowering the bit error rate (BER).

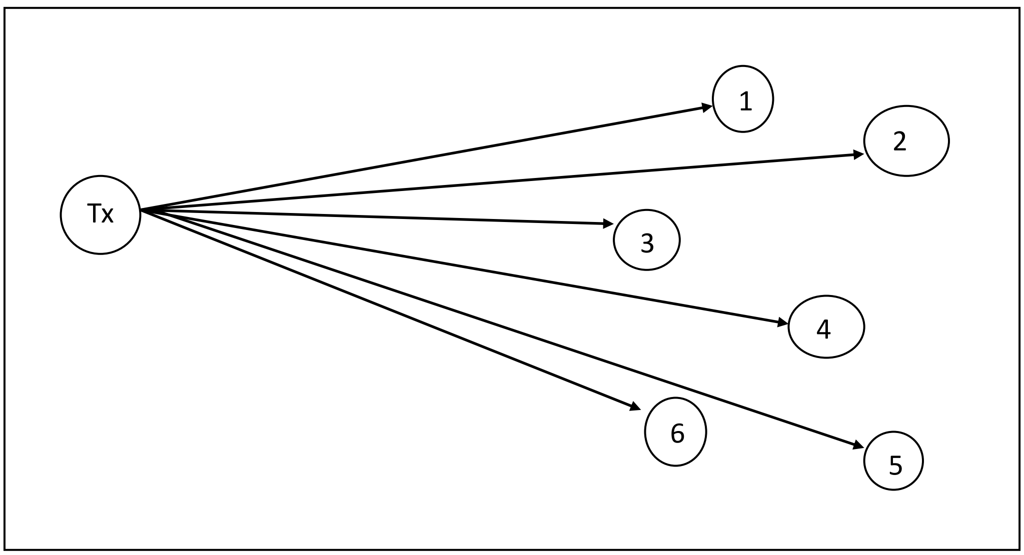


Figure 4.2 SIMO System in WSN

4.3.2 MISO system

The main motivation for using of multiple antennas at the transmitter is to reduce the required processing power and complexity at the receiver which leads to lower power consumption, lower size and lower cost. However, the MISO concept is not easy to exploit and to implement (Naquib and Calder bank, 2000). Additional signal processing is required at both the transmitters and receiver in order to correctly decode the received signals another challenge is that the transmitter does not know the channel conditions unless channel information is fed back by the receiver to the transmitter.

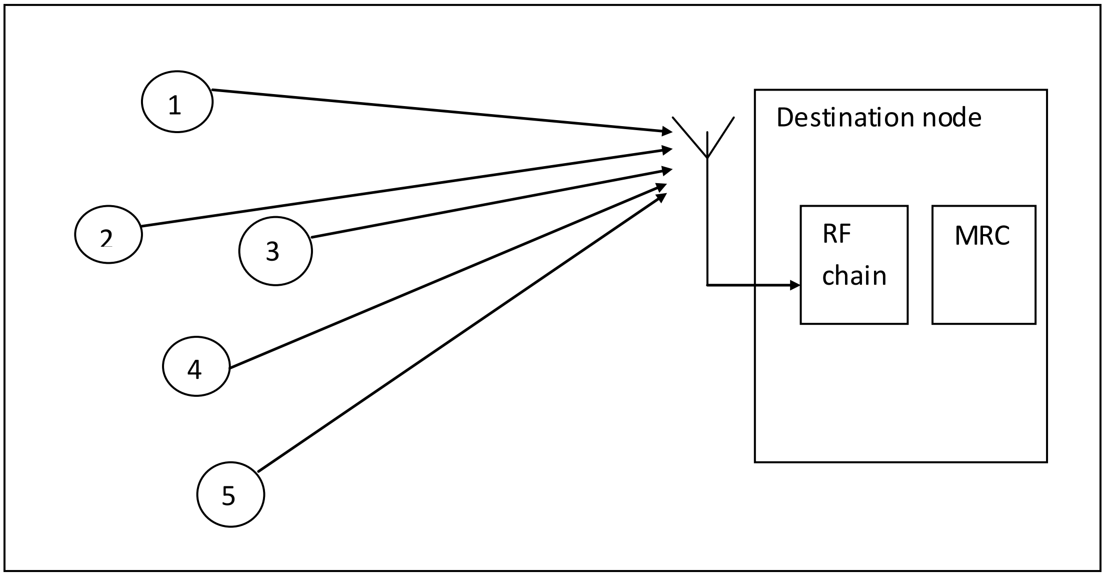


Figure 4.3 MISO System in WSN

4.3.3 MIMO system

By using a transmission method, where the number of receive antennas must be equal or greater than the number of transmit antennas ($N \geq M$) in order to separate and detect the M transmitted signals. The separation process involves a combination of interference suppression and cancellation.

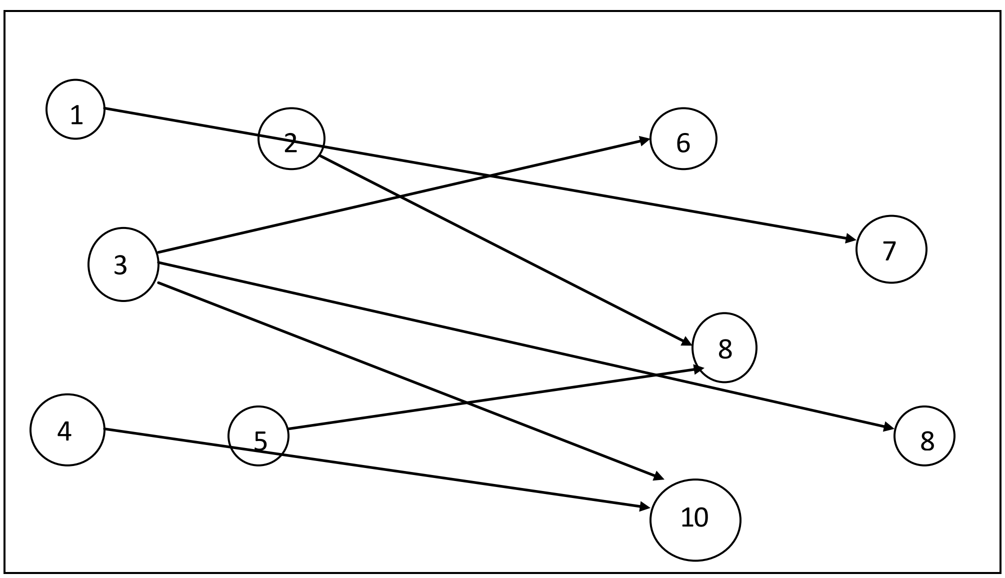


Figure 4.4 MIMO System in WSN

4.4 Optimum Position of the Relay

The position of a fixed relaying node has obviously great impact on the performance of cooperative diversity destination. The best performance is achieved when the relay is closer to the destination. However, multi-hop routing outperforms cooperative diversity when the intermediate hop has equal distances to source and destination. For D&F with fixed relaying, the relay needs to be closer to the destination. Only when the relay can decode the packet from the source without error the transmission to the destination is successful.

4.5 Related work

To reduce energy consumption in WSNs, many techniques and protocols have been explore using different approaches, such as reducing transmit power or compact data for transmission or the combination of the two. By creating spatial diversity using the multi-input–multi-output (MIMO) technique in a wireless network, small transmit power is required than that in a single-input–single-output (SISO) system under the same bit-error-rate and throughput performance requirements [37]. A sensible wireless sensor network is realized, however, important challenges should be overcome. Multiple input, multiple output (MIMO) communication guarantees performance enhancements over standard single input, single output (SISO) technology for an equivalent radiated power. If leveraged in a sensor network, MIMO could also be ready to offer significant network performance enhancement in power consumption, latency, and network robustness. MIMO provides improvement to wireless sensor networks, significantly those that have low to midrange node densities [41]. A cluster-based cooperative multiple-input-multiple-output (MIMO) scheme is proposed to reduce the fading, interference impacts caused by radio irregularity in multi-hop wireless sensor networks. This scheme enhanced the LEACH protocol to exploit the multi-hop transmissions between clusters by incorporating a cooperative MIMO scheme into hop-by-hop transmissions. Through the adaptive selection of cooperative nodes and the coordination between multi-hop routing and cooperative MIMO transmissions, the scheme can achieve effective performance improvement in terms of efficient communication performance. Based on the energy consumption model developed, the optimal parameters such as the number of clusters and the number of cooperative nodes to minimize the overall energy consumption are found [27].

A comparison study of 3 schemes, cooperative MIMO, beam forming (BF), STBC and spatial multiplexing (SM) where only transmission energy and circuit energies are considered. Wireless sensor network operating in quasi- static Rayleigh fading channels with M cooperating transmit nodes and N cooperative receive nodes. The single in single output (SISO) scheme is more energy efficient and has lower packet latency at higher regions of transmission power. While the three schemes are more energy – efficient and cooperative MIMO outperform than the SISO scheme at the lower regions. Maximize the network life span, a virtual MIMO transmission scheme coupled with multi-hop transmission. In our cross-layer style, the transmission rate, the number of clusters and therefore the number of virtual antenna nodes are jointly optimized. In contrast to the existing work that is mostly based on Alamouti scheme, the proposed transmission scheme does not need transmitter-side cooperation (joint STBC encoding/decoding), making it additional appropriate for application in real wireless sensor networks. Energy efficient cooperative diversity protocol which combats attenuation introducing in WSN by multipath propagation. The underlying techniques build upon the classical relay channel and related work and exploit space diversity offered at distributed antennas through coordinated transmission and process by cooperating radios. Energy antennas through coordinated transmission and process by cooperating nodes transmit to each other and may be help by an Amplify and Forward relay node. It is not necessary that relaying is always more energy efficient than direct transmission. Cooperative-diversity networks use the relay nodes to help the source by sending the source information to the destination for achieving spatial diversity. Regular cooperative-diversity networks build an inadequate use of the channels as a result of relays always forward the source signal to the destination regardless of the channel conditions. Incremental-relaying cooperative-diversity has been proposed to save the channels by restricting the relaying method to the poor channel conditions solely. Incremental-relaying cooperative-diversity networks exploit restricted feedback from the destination terminal, for example, a single bit indicating the success or failure of the direct transmission. If the destination provides a negative acknowledgment via feedback, during this case only, the relay will retransmits the source signal in an attempt to exploit spatial diversity by combining the signals received at the destination from the source and also the relay [40].

Chapter 5
Proposed work

This dissertation mainly focuses on increasing the reliability in WSN. . The project aims to exploit advantage of MIMO technology in WSN.STBC coding technique is used to transmit multiple copies of data across the number of sensor nodes and exploit the various received data at the base station to improve reliability.

5.1 Comparison between cooperative and non-cooperative communication

Compare the performance of direct transmission (non-cooperative) and normal relaying networks.

System model

Consider a cooperative communication dual hop network where information is transmitted from source user S to destination D with the help of relay user R as shown if Figure1.We assumed that all signals are transmit using time division multiplexing (TDM).

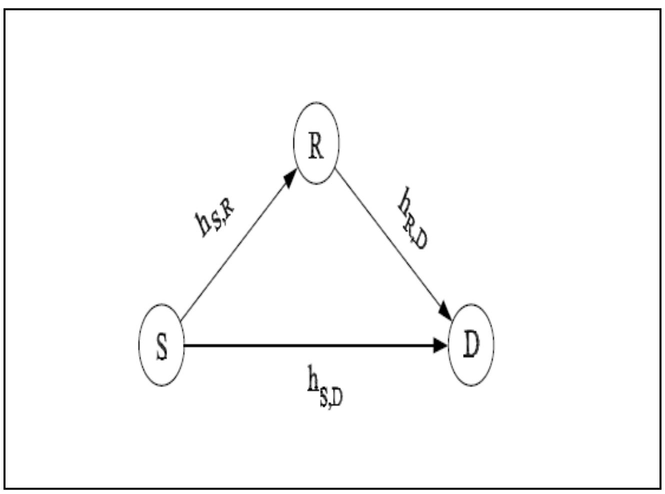


Figure 5.1 cooperative communication

The information source(S) and destination (D) communicate over a channel with Rayleigh fading coefficient ($hs,$). A relay terminal participates by providing the destination with a second copy

Of original signal through two hop-link with Rayleigh fading coefficient (hS,) and (hR,).All channel coefficient are independent of each other. Assuming TDM so in the first time slot, the source sends its signal. Both relay and destination receive faded noisy version of the original signal. In the second time slot relay send the signal which it received from the source. Then Combine the received signal which comes from the relay and directly from the source. The signal which are received from source at the destination and at the receiver it can be written as

$$y_{S,D}(t) = h_{S,D}\sqrt{E_a}a(t) + n_{S,D}(t) \tag{4.1}$$

$$y_{S,R}(t) = h_{S,R}\sqrt{E_a}a(t) + n_{S,D}(t) \tag{4.2}$$

Where, Ea = transmitted signal energy

a(t)= transmitted signal

nS, (t), nS,(t)= noise terms

The received signal at the destination from the relay is given by

$$y_{R,D}(t) = h_{R,D}\sqrt{E_a}a_r(t) + n_{R,D}(t) \tag{4.3}$$

Where, $a_r(t)$ is the transmitted signal from the relay with unit energy. Or signal received from relay to destination also be written as in terms of amplification gain given by

$$y_{R,D} = h_{R,D}A\sqrt{E_a}y_{S,R} + n_{R,D}(t) \tag{4.4}$$

Where A is the amplification gain and can be given as

$$A = \frac{1}{\sqrt{E_S h_S + N_0}} \tag{4.5}$$

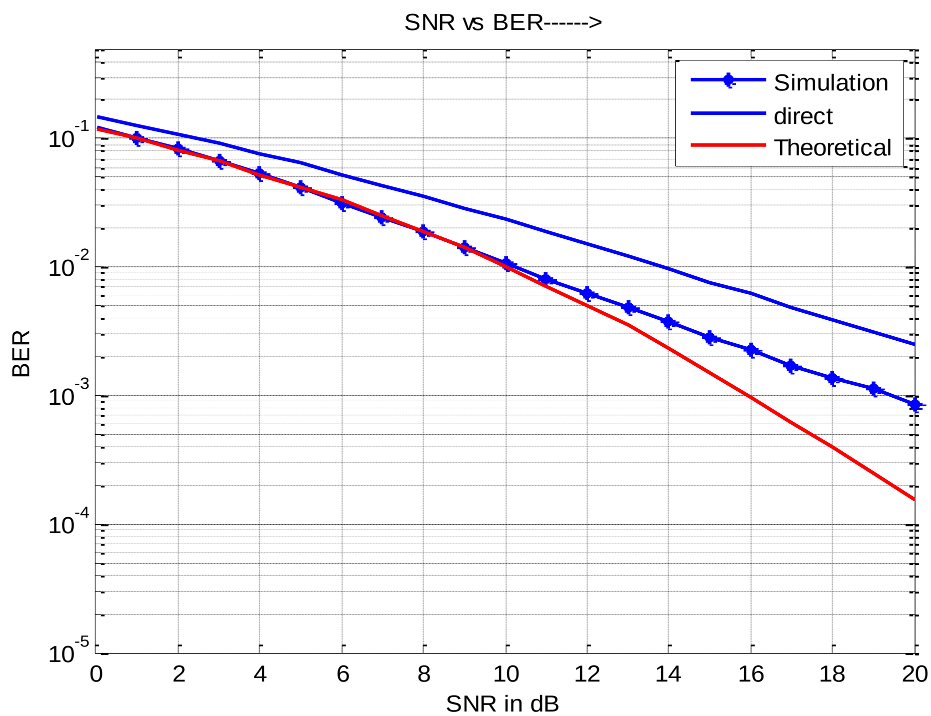
Where, (t) is the transmitted signal from the relay with unit energy. By using combining technique (MRC) [8] combined receive signal can be written as,

$$y_{combined} = \frac{h_{S,D}^{*}Y_{S,D}(t)}{h_{S,D}^{*}\, h_{S,D}} + \frac{h_{R,D}^{*}y_{R,D}(t)}{h_{R,D}^{*}h_{R,D}} \tag{4.6}$$

By comparing equation (1) and (6) we compare the cooperative and non-cooperative communication. Equation (1) shows that direct received signal where equation (6) shows the Cooperative signal which is coming from both relay and destination.

5.2 Simulation

In our simulation result shows that when we use cooperation reduction in BER can be achieve . In case of cooperative communication at SNR 12 dB BER is around 1.9*10^-4 where in case of direct transmission BER is around 2.9*10^-3.



5.2 .1 MISO Link Formation

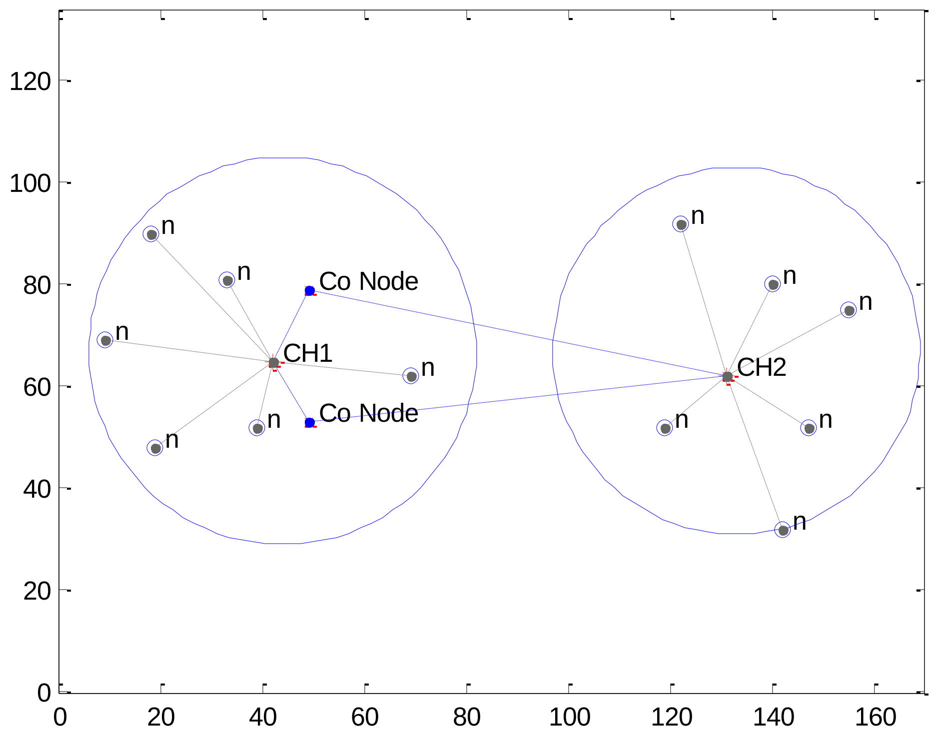


Figure 5.2 MISO Link Formation in WSN

Firstly the whole sensor network is organized in the cluster form by using LEACH clustering algorithm. All the sensor nodes inside a cluster sense the data and transmit collected data to the cluster head CH1 associated with that cluster. Then cluster head CH1 aggregate the received data which comes from all the sensor nodes and distribute aggregated data to the cooperative nodes. Then cooperative nodes forward the data to the other cluster.

5.2.3 MIMO Link Formation Between

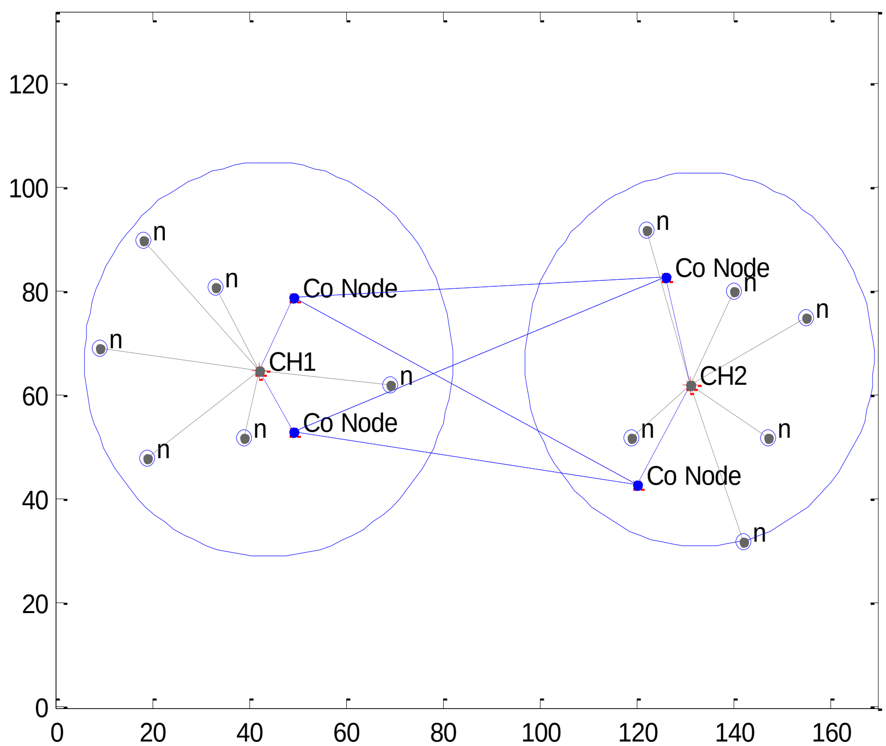


Figure 5.3 MIMO Link Formation in WSN

In MIMO link formation all sensor nodes sense the data and transmit it to the cluster head associated with that cluster. Then cluster head aggregate the received data and transmit it to the cooperative nodes. These cooperative nodes take part in data transmission between two clusters.

5.3 Reliability Analysis Using STBC Codes in WSN

The cluster based cooperative MIMO transmission scheme can only be achieved maximum throughput when uses STBC with code rate 1. So firstly Alamouti scheme is investigated in MISO system (2 transmit antenna and 1 receive antenna) between 2 cluster using Rayleigh fading channel. For simplicity we assume no code modulation is perform in intra-cluster communication in all the simulation. Figure 4.4, 4.5 shows the relationship between SNR and BER using Alamouti scheme. The y-axis represents the bit error rate and x-axis represents the signal to noise ratio. In figure 4.5 Alamouti scheme is investigated with two transmit antenna and two receive antenna (MIMO system) in Rayleigh fading channel.

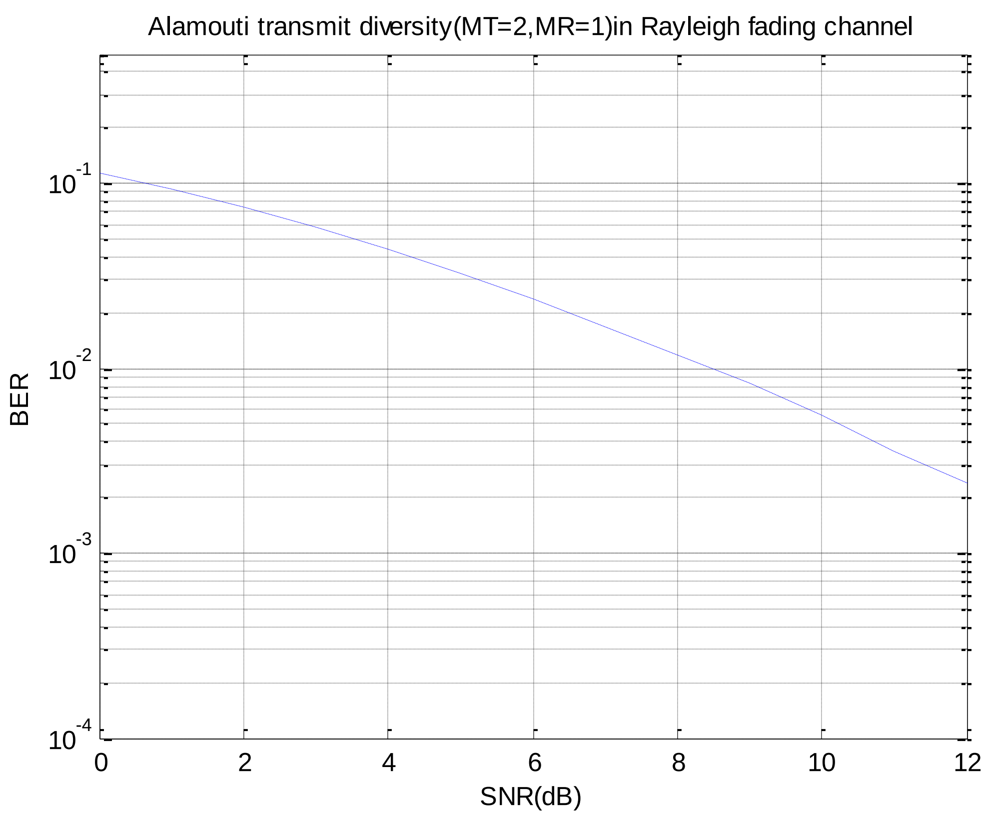


Figure 5.5 SNR versus BER

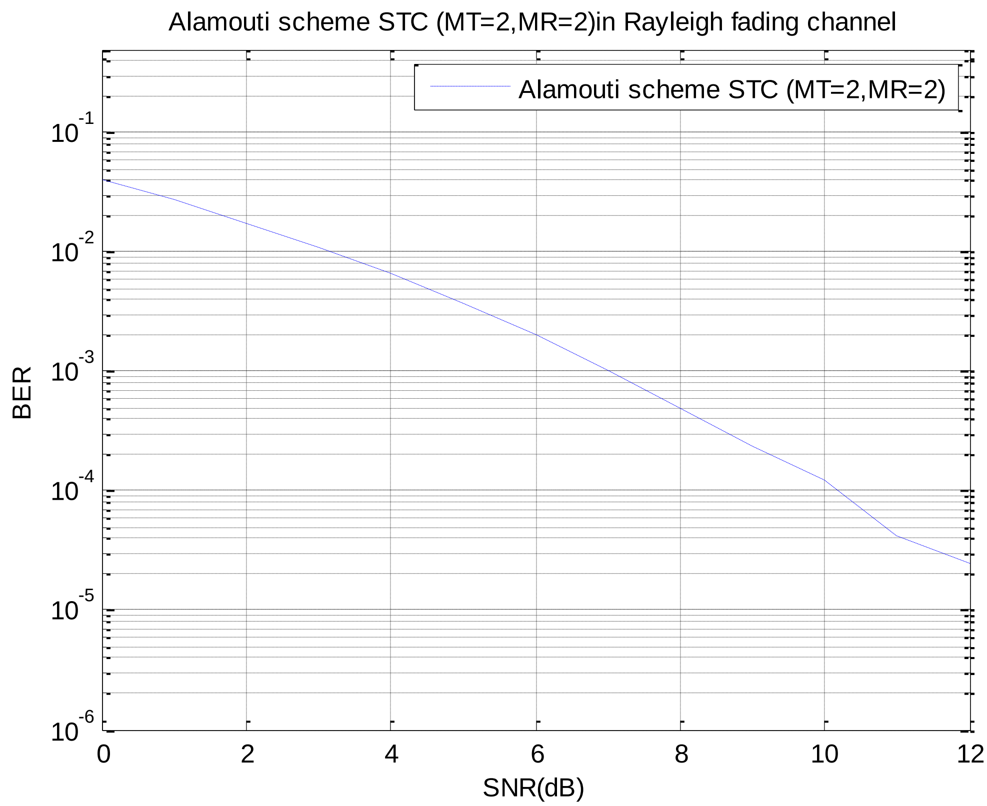


Figure 5.6 SNR versus BER

With the help of simulation we can conclude the when using cooperative scheme in WSN we can achieve reliable communication. Cooperative MIMO link perform much better than the cooperative MISO link in WSN. At SNR 12 db MISO system reduce the BER around 2.9*10^-3 while in case of MIMO system at the same SNR it reduces the BER approximately 3*10^-5.

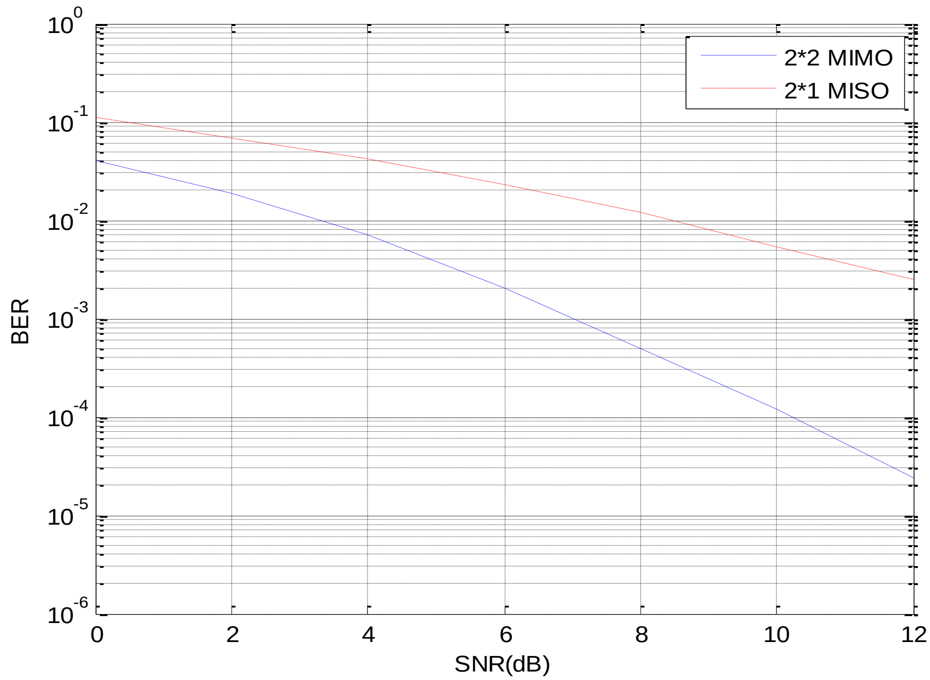


Figure 5.7 Comparison between 2*2 MIMO and 2*1 MISO

Chapter 6
Conclusion

Ensuring energy efficiency and reliable transmission of information in resource constrained WSN is one of the primary concern to achieve high degree of efficiency monitoring. Retransmission technique is used in WSN to achieve reliability but retransmission scheme might be results in additional transmission overhead that not only increase the energy consumption but also make the network congested that in turns affects the reliable transmission of data.

Cooperative MIMO in WSN is one of the hot topics in research. Cooperative MIMO approach seems better than the traditional SISO technique. This dissertation investigated two transmission modes in WSN and produces a intense understanding of cooperative MIMO technology compared with cooperative MISO in respect of reliable communication.

Results in chapter 4 shows that cooperative MIMO system provides reliability in WSN and as well as reduce energy consumption. Cooperative MIMO system is more energy efficient when transmission distances is large and perform better than cooperative MISO system.

Future work

The cooperative transmission mode considered in the mode switching framework is mainly 2×1 and 2×2 transmit and receive antennas. When considering more antennas at both transmitter/ receiver sides more problems will be take forward, such as:

1) The selection of more corporative nodes in transmitting cluster.
2) The information exchange phase in the relaying cluster and its cluster-head selection mechanism.
3) The differences of energy consumption of relaying nodes working in AF and DF ways need to be investigated.
4) Uses Space time trellis codes.

References

[1] David Tse, Pramod Viswanath, "Fundamentals of Wireless Communication", Cambridge University Press, 2005, pp. 10-25.

[2] I. F. Akyildiz, Weilian Su, Y. Sankarasubramaniam, E. Cayirci, "A Survey on Sensor Networks", Communications Magazine, IEEE, Aug. 2002, vol. 40, no. 8, pp. 102 – 114.

[3] M.Ali, U.Saif, A.Dunkels, T. Voit, K. Romer, K. Langendoen, J. Polastre, and Z.A. Uzmi, "Medium Acess Control Issues in Sensor Networks," ACM SIGCOMM Computer Communication Review, VOL.36,pp.33-36,2006.

[4] T.Review, "10 Emerging Technologies That Will Change the World: Wireless Sensor Networks," in Electronics MIT Technology Review at http://www.technologies.com/infotech/13060/page2/, February 2003.

[5] T. S. Rappaport, "Wireless Communications: Principles and Practice", Second Edition, Prentice Hall, 2002, pp. 23-40.

[6] J. Burdin, J. Dunyak, "Enhancing the Performance of Wireless Sensor Network with MIMO Communications", IEEE Military Communications Conference 2005, vol. 4, pp. 2321-2326.

[7] E. H. Gallaway, "Wireless Sensor Network: Architecture and Protocols", CRC Press LLC, 2004, pp. 41-62.

[8] A. J. Coulson, G. Williamson, R. G. Vaughan, "A statistical basis for lognormal shadowing effects in multipath fading channels". IEEE Transactions on Communications, 1998, vol. 46, pp. 494-502.

[10] Bernard Sklar, "Rayleigh Fading Channels in Mobile Digital Communication Systems Part I: Characterization". IEEE Communications Magazine, July 1997, vol. 35, no. 7, pp. 90–100.

[11] A.Del Coso, U. Spagnolini, C. Ibars, "Cooperative Distributed MIMO Channels in Wireless Sensor Networks", Selected Areas in Communications, IEEE Journal on, February 2007, vol. 25, no. 2, pp. 402 – 414.

[12] Yijia Fan, "MIMO Communications Over Relay Channels". PhD thesis of the University of Edinburgh, December, 2006, pp. 10-15.

[13] Gerard J. Foschini. "Layered Space-time Architecture for Wireless Communications in a Fading Environment When Using Multi-element Antennas". Bell Labs Technical Journal, Autumn 1996, pp. 41–59.

[14] L. Zheng and D. Tse . "Diversity and Multiplexing: A Fundamental Tradeoff in Multiple-Antenna Channels". IEEE Transaction on Inf. Th. May 2003, vol. 49, no. 5, pp. 1073–1096.

[15] Vahid Tarokh, Nambi Seshadri, A. R. Calderbank, "Space–time Codes for High Data Rate Wireless Communication: Performance Analysis and Code Construction", IEEE Transactions on Information Theory, March 1998, vol. 44, no. 2, pp. 744–765.

[16] S. M. Alamouti. "A Simple Transmit Diversity Technique for Wireless Communications", IEEE Journal on Selected Areas in Communications, October 1998, vol. 16, no. 8, pp. 1451 1458.

[17] Vahid Tarokh, Hamid Jafarkhani, and A. R. Calderbank, "Space–time Block Codes from Orthogonal Designs", IEEE Transactions on Information Theory, July 1999, vol. 45, no. 5, pp. 744–765.

[18] S. M. Alamouti, "A simple diversity technique for wireless communications," *IEEE Jour. on Selected Areas in Communications,* vol. 16, no. 8, pp. 1451–1458, 1998.

[19] Haibin Yu, Peng Zeng, Wei Liang. "Intelligent Wireless Sensor Networks". Science Publication in Beijing, 2006, pp. 6-9.

[20] M. J. Handy, M. Haase, D. Timmermann, “Low Energy Adaptive Clustering Hierarchy with Deterministic Cluster-head Selection”, 4th International Workshop on Mobile and Wireless Communications Network, 2002, pp. 368- 372.

[21] Qiangfeng Jiang; D. Manivannan, “Routing Protocols for Sensor Networks,” IEEE Consumer Communications and Networking Conference, Jan. 2004, pp. 93- 98, 5-8.

[22] W. Heizelman, A. Chandrakasan, H. Balakrishnan, “Energy-efficient Communication Protocols for Wireless Sensor Networks”, IEEE Proceedings of the Hawaii International Conference System Sciences, 2000, pp. 3005-3014.

[23] Bravos. G. N. and Efthymoglou. G., (2007) “MIMO-based and SISO multihop sensor network: Energy efficiency evaluation”, *Proceedings of IEEE International Conference on Wireless and Mobile Computing, Networking and Communications,* pp13-18.

[24] Cui. S., Goldsmith. A. J. and Bahai. A., (2004) “Energy-efficiency of MIMO and cooperative MIMO techniques in sensor networks”, *IEEE Journal on Selected Areas in Communications*, Vol. 22, No. 6, pp1089-1098.

[25] L. X. H. Dai and Q. Zhou, “Energy efficiency of mimo transmission strategies in wireless sensor networks,” in *International Conference on Computing, Communications and Control Technologies (CCCT),* Austin, TX, USA, August 2004.

[26] Yuan.Y, He. Z. and Chen. M., (2006) “Virtual MIMO- based cross-layer design for wireless sensor networks”, *IEEE Transactions on Vehicular Technology*, Vol.55, No.3, pp856-864.

[27] Yuan. Y., Chen. M. and Kwon. T., (2006) “A novel cluster-based cooperative MIMO scheme for multi-hop wireless sensor networks”, *EURASIP Journal on Wireless Communication and Networking*, Article ID 72493, pp1-9.

[28] Shuguang Cui, Andrea J. Goldsmith, Ahmad Bahai, "Energy-efficiency of MIMO and Cooperative MIMO Techniques in Sensor Networks", IEEE Journal on Selected Areas in Communication, August 2004, Vol. 22, No. 6, pp.1089-L

[29] Pillutla and V. Krishnamurthy, "Energy Efficiency of Cluster Based Cooperative MIMO Techniques in Sensor Networks," IEEE Transactions on Signal Processing, 2005, pp. 34-40.

[30] J. Boyer, D. Falconer, and H. Yaniko meroglu, "Multi-hop Diversity in Wireless Relaying Channels," IEEE Transactions on Communications, October 2004, vol. 52, no. 10, pp. 1820–1830.

[31]J. N. Laneman, D. N. C. Tse, and G. W. Wornell, "Cooperative diversity in wireless networks efficient protocols and outage behaviour*,"* IEEE Trans. Inform. Theory, vol. *50,* no. 12, Dec. 2004.

[32] A. Nosratinia, T. E. Hunter, and A. Hedayat, "Cooperative Communication in Wireless Networks," IEEE Commun. Mag., vol. 42, no. 10, Oct. 2004, pp. 68–73.

[33] M. Janani et al., "Coded Cooperation in Wireless Communications: Space-Time Transmission and Iterative Decoding," IEEE Trans. Sig. Proc., vol. 52, no. 2, Feb. 2004, pp. 362–71.

[34] A. Stefanov and E. Erkip, "On the Performance Analysis of Cooperative Space-Time Systems," Proc. IEEE WCNC, March 2003, pp. 729–34.

[35] B. Zhao and M. Valenti, "Some New Adaptive Protocols for the Wireless Relay Channel," Proc. Allerton Conf. Commun., Control, and Comp., Monticello, IL, Oct. 2003.

[36] P. Larsson, "Selection Diversity Forwarding in a Multihop Packet Radio Network with Fading Channel and Capture," Mobile Comp. Commun. Rev., vol. 5, no. 4, Oct. 2001, pp. 47–54. BIOGRAPH.

[37] A. Paulraj, R. Nabar, and D. Gore, Introduction to Space-Time Wireless Communications, Cambridge, U.K.: Cambridge Univ. Press, 2003.

[38] Ahmad, M.R.; Dutkiewicz, E.; Xiaojing, "Performance analysis of MAC protocol for cooperative MIMO transmissions in WSN," Personal, Indoor and Mobile Radio Communications, 2008. *PIMRC 2008. IEEE 19th International Symposium on* , vol., no., pp.1,6, 15-18 Sept. 2008.

[39] Can Sun; Chenyang Yang, "Energy efficiency comparison among direct, one-way and two-way relay transmission," Communications (ICC), 2012 IEEE International Conference on , vol., no., pp.4288,4293, 10-15 June 2012Overview of cooperative diversity network.

[40] Ikki, S.S.; Ahmed, M.H., "Performance analysis of incremental-relaying cooperative-diversity networks over Rayleigh fading channels," Communications, IET , vol.5, no.3, pp.337,349, Feb. 11 2011 doi: 10.1049/iet-com.2010.0157.

[41] J. Burdin, J. Dunyak, "Enhancing the Performance of Wireless Sensor Networks with MIMO Communications", IEEE Military Communications Conference,2005, vol. 4, pp. 2321-2326.

[42] Kanru Xu; Wei Yuan; Wenqing Cheng; Yi Ding; Zongkai Yang, "An Energy-Efficient V-BLAST Based Cooperative MIMO Transmission Scheme for Wireless Sensor Networks," *Wireless* Communications and Networking Conference, 2008. WCNC 2008. IEEE , vol., no., pp.688,693, March 31 2008-April 3 2008.

[43] Xiaojun Wen, "Distributed MIMO for Wireless Sensor Network". PhD thesis of the University of Edinburgh, February, 2011, pp. 10-15.

[44] "PPT on Transport Layer of OSI Model" September 20, 2010.

[45] M.A Matin and M.M Islam"Overview of a Wireless Sensor Network" Institut Teknologi Brunei, , Brunei Darussalam North South University, , Dhaka, Bangladesh.

[46] Robert W. Heath Jr, "Single User MIMO" University of Texas at Austin.

[47] Jan Mietzner " multiple antenna system" janm@ece.ubc.ca, Room: Kaiser 4110.

[48] Abdelkader Youssefi, Nawal Bounouader, Zouhair Guennoun, Jamal El Abbadi " Adaptive Switching between Space-Time and Space-Frequency Block Coded OFDM Systems in Rayleigh Fading Channel" Vol. 6 No. 6 (2013).

[49] Farhad E. Mahmood "Mobile Radio Propagation prediction" DOI: 10.5772/46469.

[50] "Wireless sensor network" from Wikipedia.

[51] Cheng-Lung Yang[1], Wernhuar Tarng[1], Kuen-Rong Hsieh[2] and Mingteh Chen[3] "A Security Mechanism for Clustered Wireless Sensor Networks Based on Elliptic Curve Cryptography" National Hsinchu University of Education, Hsinchu, Taiwan, Ralink Technologies, Hsinchu, Taiwan, Micrel Semiconductor Inc., San Jose, California, U.S.A.