COOPERATIVE SPATIAL MULTIPLEXING
IN WIRELESS SENSOR NETWORKS

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ABSTRACT

Wireless sensor networks are an enabling technology for many future surveillance-oriented applications. Before a practical wireless sensor network is realized, however, significant challenges must be overcome. Chief among the obstacles to netted sensors is providing low power, robust communications between sensor nodes. Multiple Inputs, Multiple Output (MIMO) communication promises performance enhancements over conventional Single Input and Single Output (SISO) technology for the same radiated power

MIMO is the use of multiple antennas at both the transmitter and receiver to improve communication performance. Wireless networking is now commonly associated with MIMO because it offers significant increases in data throughput and link range without additional bandwidth or transmit power.

Spatial multiplexing is a transmission technique in MIMO wireless communication to transmit independent and separately encoded data signals from each of the multiple transmits antennas. Therefore, the space dimension is reused, or multiplexed, more than one time. The wireless networking is modeled by simulation run by Matlab software.

This project aims to study the performance of this technique on certain parameter and compared to other transmission technique in wireless network for example SISO technique. The parameters to be examined are delay, bit error rate (BER) and energy consumption.

ABSTRAK

Rangkaian sistem pengesan tanpa wayar digunakan dengan meluasnya pada hari ini bagi tujuan pengawasan. Bagi menyediakan sistem tanpa wayar yang berkualiti tinggi satu halangan utama perlu diatasi iaitu sistem yang disediakan perlulah stabil (mempunyai kebaragkalian bit error yang rendah) dan beroperasi dengan sumber kuasa yang rendah. Multiple Input and Multiple Output (MIMO) digunakan untuk menyediakan system ini.

MIMO adalah sistem dimana terdapat beberapa antena penghantar dan penerima berbanding sistem Single Input and Single Output (SISO) yang hanya mempunyai satu antena penghantar dan penerima. MIMO menyediakan rangkaian pengesan tanpa wayar yang lebih pantas tetapi pada masa yang sama masih beroperasi dengan penggunaan tenaga yang sama dengan SISO.

Teknik Spatial Multiplexing adalah salah satu teknik modulasi yang digunakan dalam MIMO. Secaara amnya teknik ini menghantar data dari antena-antena secara serentak pada satu masa. Data-data yang dihantar ini juga berbeza antara satu sama lain. Justeru itu ia dapat meningkatkan kelajuan operasi sistem dan mengurangkan kebarangkalian bit eror. Simulasi system ini dilakukan didalam perisian Matlab.

Projek ini akan mengaji 3 aspek sistem penghantaran MIMO dan membandingkannya dengan SISO. Aspek- aspek yang diuji adalah tempoh masa penghantaran, kebarangkalian berlaku bit eror dan tahap penggunaan tenaga.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLE

ABBREVIATION

ACK	-	Acknowledgment
ADC	-	Analogue-to-Digital Converter
BER	-	Bit Error Rate
BF	-	Beamforming
BLAST	-	Bell Labs Layered Space-Time
BPSK	-	Binary Phase Shift Keying
DAC	-	Digital-to-Analogue Converter
DATA	-	Data Packet
DBLAST	-	Diagonal Bell Labs Layered Space-Time
HBLAST	-	Horizontal Bell Labs Layered Space-Time
IEEE	-	Institute of Electrical and Electronics Engineers
IFA	-	Intermediate Frequency Amplifier
LNA	-	Low Noise Amplifier
MIMO	-	Multiple-Input Multiple-Output
ML	-	Maximum Likelihood
MMSE	-	Minimum Mean Square Error
PDF	-	Probability Density Function
PER	-	Packet Error Rate
PSD	-	Power Spectral Density
QoS	-	Quality of Service
RX	-	Receiver
SISO	-	Single-Input Single-Output
SM	-	Spatial Multiplexing
SNR	-	Signal-to-Noise Ratio
STBC	-	Space-Time Block Coding
TX	-	Transmitter

VBLAST	-	Vertical Bell Labs Layered Space-Time
WLAN	-	Wireless Local Area Network
WSN	-	Wireless Sensor Network
ZF	-	Zero Forcing

CHAPTER 1

INTRODUCTION

1.1 Projects Background

Over the past decade or so an unprecedented growth in the demand for providing reliable, high-speed wireless communication in order to support a wide range of application is exponentially increased [1]. Providing such reliable links is challenging due to the fact that in wireless environment, unlike many other channels, transmitted signals are received through multiple paths which usually add destructively resulting in serious performance degradation. Furthermore, the medium is normally shared by many different users/applications, thus there is the possibility of interference.

MIMO based communication architectures have recently been proposed as a means for improving energy efficiency of energy-constraint, distributed wireless sensor networks. There are many different schemes that can be applied to the MIMO system. MIMO systems demand powerful signal processing procedures to recovers the signal transmitted by the antenna arrays, thus the potential advantages of the MIMO system can be guaranteed and the MIMO system will work in the best possible way.

Among the different signal processing algorithms that exist for the MIMO system, the V-BLAST algorithm from the spatial multiplexing technique has become a potential alternative due to its excellent complexity-performance tradeoff.

The main challenge for Wireless Sensor Network (WSN) is to produce powerful yet low cost and tiny sensor nodes. It is important to acknowledge that all the processing of a node is normally depends solely on the battery. The sensor node lifetime can be estimated from the ratio of the battery capacity to the energy usage per second by the sensor node. Thus in order to elongate the sensor node lifetime, the usage of energy consumed by the nodes must be minimized.

However there is a trade-off between minimizing the energy with the performance of the WSN. Should ever the energy consumed is set too low there will be degrading on the algorithm. Thus causing the information to be sent to have significant delay or in worst case scenario the information is totally loss [2].

This project aims to study the fundamental of MIMO Multiplexing technique in particular the Spatial Multiplexing (SM) technique and compares the results with conventional SISO technique in terms of delay and energy consumption.

There are several objectives that need to be considered in this project such that:

- To design and simulate SM algorithm using Matlab simulator.
- To evaluate the performance of SM technique in terms of delay and energy consumption.
- To compare SM performance with Single Input and Single Output (SISO) system.

1.2 Scope of Works

In this project, the Spatial Multiplexing Technique is designed by Matlab software. The simulation is carried out until the result obtained meets the required specifications. Finally, the comparison between the simulation result and existing system is investigated.

1.3.1 Problems Statement

Common radio devices use a single-input, single-output (SISO) configuration with one transmitter and one receiver and information sent over a single data channel. However, a move is under way from single-carrier technologies that transmit one digital symbol at a time to new methods that can potentially transmit hundreds of symbols simultaneously. One such method is multiple-input multiple-output (MIMO).

The main challenge of WSN is to produce powerful yet low cost and tiny sensor nodes. This means less energy consumption due to the fact that the sensor operates solely on the tiny battery which it is installed. Another aspect to be considered is the fact that the design network should have minimum time delay to achieved better data throughput.

Multipath effects can degrade a SISO transmission. For example, a Bluetooth signal with a symbol rate of 1M symbols per second must receive a symbol within a window of one microsecond. If multipath effect delays the signal by more than this, a significant symbol error will occur. MIMO systems, on the other hand, require multiple paths. If two signals are transmitted with known characteristics, for instance a header, at the receiver end, one can assume what the signal should look like and create a model of the channel effects. When the unknown signal comes, i.e. the data, subtracting the channel effects can solve for the transmitted symbols. [3]

The relationship between symbol error probabilities to the data rate is crucial. As the invention of MIMO is indeed to provide more stable and less error link it is in need of low error rates. This is unachievable by SISO as there is only one channel path used. As mention above, the WSN should operate in relatively low power. This comes to another relationship between error rate and energy consumption. Whenever error is beyond repair at demodulator, the request for retransmission is entered. Retransmission requires more energy usage and eventually added the usage of power for WSN.

From the discussed theory above, MIMO transmission is proposed to build low power consumption with fast and reliable link. The SM technique is one of the techniques used in MIMO transmission. The performance of SM is investigated and the comparison is done with respect to SISO.

1.4 Significant of the Project

The project proposed the SM technique in MIMO transmission environment. The proposed way is expected to provide fast and reliable wireless link with relatively low power consumption. The technique is more powerful than SISO in terms of BER and Delay time, with the same or slight increased in power consumption. Thus the intention of providing stable and low consumption network is achieved.

1.5 Orientation of the Thesis

The thesis is organized into 5 main chapters focusing on the SM technique in WSN environment. Chapter two gives the introduction to WSN, comparison between wired and wireless network, followed by fading channels and diversity techniques. Also, the sensor network is explained with conjunction of network topology. The fading channel considered in this thesis is quasi-static fading. The diversity techniques is discussed based on energy saving and less delay attributes. Two common diversity associated with SM performance analysis are diversity gain and multiplexing gain. Then the thesis follows on the aspects of MIMO communication theory. This includes error probability, channel modeling, the comparison between traditional and cooperative MIMO and the employment of SM in MIMO.

Chapter 3 yields methodology of the project. This includes the flow chart, Matlab environment, and script of the actual simulation code. All discussion focuses on running the project smoothly. The Matlab discussion includes the history, usage, and examples on syntax exploitation to be used on the real coding script. Move on then, the script is discussed thoroughly to yields all the connections and relationship to the parameters examined.

Chapter 4 produces the result of simulations depending on the parameter reviewed. The output graphs are discussed and relates to their respective theories. Discussion is made afterward comparing all graph to three major concern; delay, BER and energy consumption. The last chapter concludes all with a summary of the major results obtained and identifies open research issues for future work.

CHAPTER 2

SPATIAL MULTIPLEXING THEORY

2.1 Introduction of Wireless Sensor Network

Wireless Sensor Networks consist of small nodes with sensing, computation and wireless communication capabilities. Various architectures and node deployment strategies have been developed for wireless sensor network, depending upon the requirement of application. Sensor networks are used in different applications e.g. environmental monitoring, habitat monitoring, home automation, military application etc [3].

2.1.1 Wired Networking

In a wired networking, coaxial cable or special grades of twisted pair wires and network adapters connect the devices. Back in the dawn of computing, two computers were directly wired to each other using a crossover cable. In order to accommodate the demands of a network and connect more computers, central devices like hubs, switches, or routers have evolved [3].

2.1.2 Wireless Networking

Wireless networking send and receive data through the air and use radio and infrared waves to transmit information without a physical connection. The access point receives, buffers and transmits data between the wireless and the wired network infrastructure. A single access point can support a small group of users and can function within a range of less than one hundred to several hundred feet [3].

2.1.3 WLAN and Wired LAN Comparison

In a wired network, the cables that connect each computer can be inconvenient because they need to be hidden in walls or discreetly laid out in the open so they don't become a hazard or an annoyance. On the other hand, cables, hubs and switches are very inexpensive while wireless equipment may cost three or four times as much.

For Local Area Network, wired LANs offer bandwidth up to 100 Mbps. Wireless LANs using 802.11b support a maximum bandwidth of 11 Mbps, while 802.11a and 802.11g WLANs support only 54 Mbps. On the other hand, the greater mobility of wireless networks can compensate for the performance disadvantage. In addition, the same Wi-Fi adapter that connects laptop to WLAN will connect to the hotspots that becoming more ubiquitous every day [9].

Technically, wired networking is more secure than wireless network. Since wireless signals are transmitted through the air, devices outside of the network can capture them. However, the majority of wireless network today protect their data with the Wired Equivalent Privacy (WEP) encryption standard, which makes wireless communications almost as safe as wired ones [9].

To sums up the comparison, Wired Network has been around for a long time and wireless network is a way to modernize the network. It allows a simple matter to relocate a communicating device, and no additional cost of rewiring and excessive downtime is associated with such a move. It is also a simple matter to add in a communication device to the system or remove one from the system without any disruption to the remainder of the system. Other than the initial outlay on setting up the cell sites, the cost of running and maintaining a radio based communications solution is minimal.

2.2 Sensor Network

The sensor network serves in the challenges ofdetecting the relevant quantities, monitoring and collecting the data, assessing and evaluating the information, formulating meaningful user displays, and performing decision-making and alarm functions are enormous. The usage of wireless technology is commonly associated to sensor network due to the fact that today's environment is increasingly open to more studies and wireless capability makes it easier for researchers to gathered useful data without actually are there. Wireless enable for example fireman to know there is a fire in the jungle without has to spend hours to locate the estimated area burn [2].

2.3 Network Topology

The basic issue in communication networks is the transmission of messages to achieve a prescribed message throughput (Quantity of Service) and Quality of Service (QoS) [10]. QoS can be specified in terms of message delay, message due dates, bit error rates, packet loss, and economic cost of transmission or transmission power. Networking topologies can be:

i. Star
ii. Ring
iii. Bus
iv. Tree
v. Mesh
vi. Fully Connected

Mesh networks are regularly distributed networks that generally allow transmission only to a node's nearest neighbors. The nodes in these networks are generally identical, so that mesh nets are also referred to as peer-to-peer (see below) nets. Mesh nets can be good models for large-scale networks of wireless sensors that are distributed over a geographic region, e.g. personnel or vehicle security surveillance systems. Note that the regular structure reflects the communications topology; the actual geographic distribution of the nodes need not be a regular mesh. Since there are generally multiple routing paths between nodes, these nets are robust to failure of individual nodes or links. An advantage of mesh nets is that, although all nodes may be identical and have the same computing and transmission capabilities, certain nodes can be designated as 'group leaders' that take on additional functions. If a group leader is disabled, another node can then take over these duties [11].

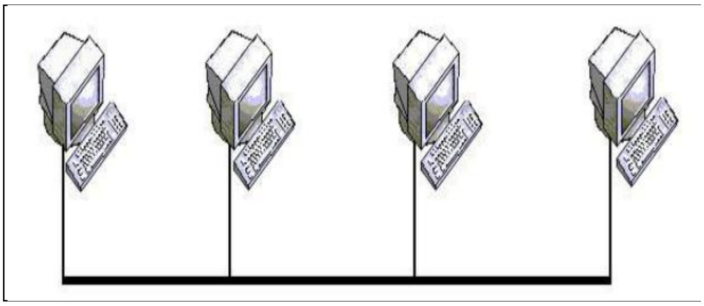

Figure 2.1: Bus Topology [11]

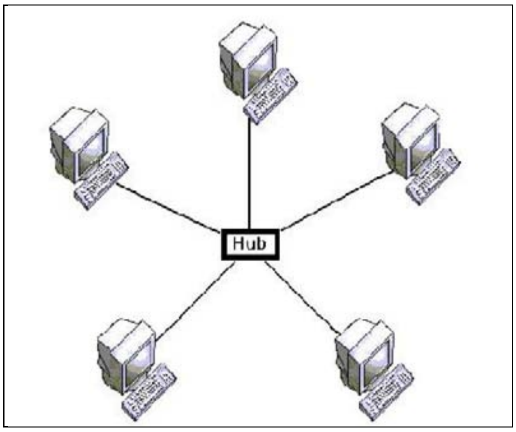

Figure 2.2: Star Topology [11]