Building to Building Communication using Zigbee(IEEE802.15.4) Standard

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Declaration

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Abstract

The present technologies Bluetooth and Wifi are basically used for local short range voice communication. Bluetooth technology can be used to communicate between the two android end devices without any hops but it limits the communication range in orders of meters. Wifi can overcome the above problem but it is power hungry as the android devices discharge power very fast. To address the above problems, we proposed an optimum solution using the zigbee (IEEE 802.15.4) technology. In our approach we design and build a self-powered wireless chipset which is interfaced to the android mobile using serial port and the network is established with the chipsets as relays.

We can use android mobile with integrated chip set as a handset for both cellular calls and building to building communication and it may also be used for village networks. The design of hardware for handset is not required this comprise one of the main advantage of our approach. we can use any android mobile for integration of chip-set. In this thesis, we discuss about gateway node(USRP or Raspberry-PI) to support real time voice traffic and problems of routing voice calls through the wireless mesh network. The solution to this problem is to increase packet generation between the end users with time diversity MIMO technique.

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Chapter 1

Introduction

In recent years, there has been tremendous increase in short range communication among the cellular subscribers and the range is in the order of few kilometers. For instance, in colleges, companies, hospitals and government departments the voice traffic flows among the cellular subscribers within a very short range. However, we dont require high teledensity and high speed data services in these areas. The goal of this thesis is to propose solution for the current infrastructure without using any celluar base stations. To acheive our goal we present the design, deployment and implementation of a communication network for subscribers within a short range. In this chapter, we describe in brief about the telephony services in the developing world . Our thesis can be used for the village networks i.e., voice traffic flows among the villages without any cellular network.

1.1 Cellular Network

In india, there are a large number of villages which are not covered by cellular networks. This cellular coverage is very low in rural areas compare to urban. Cellular network providers are not interested in covering these areas because of the low teledenisty. The main reason for this is, it requires high infrastucture cost for setting up a cellular base station,takes high capital expenditure and maintainance cost of base station and also it require power generators in case of power failures . The solution for these problems is to avoid setting up a cellular base stations for the low teledensity traffic and an alternative technique is being choosen for covering rural areas at low cost and best converage. Subsequently, we describe our approach to solve the problem in the following section

1.2 Building to building communication

The use of wireless technologies in building to building (B2B) communication offers significant benefits [12]. A key benefit of going wireless is vastly enhanced node mobility. If nodes are mobile, links change, and the physical network topology is modified. An interesting property is that a wireless node can establish communication between two nodes which are not within transmission range of each other with just a single radio. Thus, every device can act as a router without additional hardware. Such a peer to peer routing scheme is especially interesting. For this system, there are restrictions on the power consumption and data rates. It

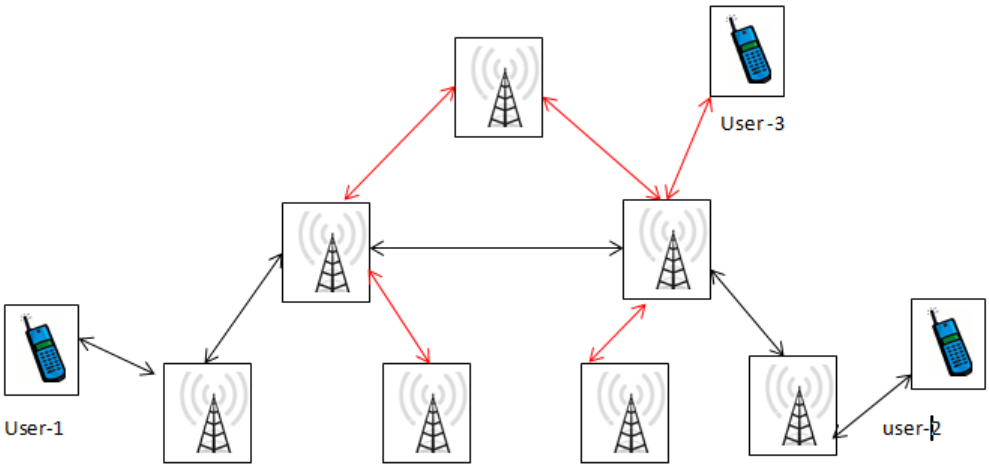

Figure 1.1: B2B Communication System

can be implemented using unicast or broadcast services. These services delivers message to single or multiple recipients in the network.

This B2B communication provides solution for the village networks that are not covered by cellular base stations. It significantly helps the villagers to exchange messages over a range of 3 to 4 square kilometers. The infrastructure cost for the B2B network is low compared to cost of setting a base station and also it can run uninterruptedly without any external power supply for few months. It provides services of voice, text communication with in the system.we use zigbee protocol for this network unlike in wifi and bluetooth.

As we noted above, B2B chooses 802.15.4 as the underlying radio technology to enable voice applications in developing regions. 802.15.4 technology has low cost since 802.15.4 platforms have limited on-board resources (CPU, memory, etc.). For instance, the TelosB [20] platform costs less than USD 60. Also, 802.15.4 radio operates in 2.4GHz unlicensed ISM band. While 802.15.4 can also operate in 900MHz band, we choose to use 2.4GHz since 900MHz is not universally unlicensed, e.g., in India it is licensed. Further, 802.15.4 platforms consume very low power (TelosB platform requires only 100mW, in comparison to 2-10W for WiFi platforms or several KW for cellular base stations), and they can run for several days without power off-the-grid. Thus, B2B can meet the economics of low cost and stringent power budget necessary for sustainable deployment in developing regions.

1.2.1 Zigbee communication

ZigBee is a low-cost, low-power, wireless mesh network standard [18]. The low cost allows it for wide deployment in wireless control and monitoring applications. Low power usage allows longer life with smaller batteries. Mesh networking provides high reliability and more extensive range. It operates in the industrial, scientific and medical (ISM) radio band (2.4 GHz) with data transmission rates of 250 kbps. The wireless communication among sensor motes will be according to the IEEE 802.15.4 standards.

1.3 Contributions of the thesis

To implement the low power, low cost network with the available android mobile as the handset. In this thesis following contributions are being made.

1.3.1 Networking and file transfer Between B2B enduser to gate way node

The text message is transmitted using a custom android app in the mobile. Communication between android mobile and zigbee mote happens through universal asynchronous receiver and transmitter (UART) communication. In this an android app is developed as an interface for the serial communication between the andriod mobile and the IITH mote. We can use this application for file transfer and chatting with the gateway node like USRP or Raspberry-PI.

To ensure the good connectivity and reliablity, end to end delay is minimized. This is achieved by decreasing delay between packet to packet which results in increase in data rate. By using Multiple Input and Multiple Output(MIMO) of time diversity scheme packet generation rate is increased.

Chapter 2

Related work

In this section, we will see the previous work done in the Building to Building (B2B) system. We will also see some related work for short range communication.

2.1 GNU Radio and USRP

The USRP [2] has coverage area about 1.5 square kilometers with a single antenna. We can use this radios as base stations or femto cells and they are capable of handling high data rates in order of Mbps. These Radios can be used as modem for connecting B2B system which is covering rural areas and with the cellular base station which is few kilometers far away from the villages. It can also acts as base station between two B2B system for exchange of messages.

- USRP acts as the hardware interface for the GNU Radio [3]. USRP is a radio system consisting of a signal processing motherboard and supports two transmit and two receive daughterboards. A USRP motherboard consists of an ADC/DAC module and a user programmable FPGA. A USB interface is available for programming the USRP motherboard. A recent version of the USRP, the USRP2 contains a more powerful FPGA and a faster programming interface via an Ethernet connection.
- We will implement software-defined radio using GNU Radio, an open-source signal processing toolkit. Applications for the GNU Radio are written by creating graphs using the python scripting language. The graphs contain an interconnection of different signal processing blocks implemented in C++. The diverse range of signal processing blocks provided by GNU Radio makes it a powerful tool for development of complex digital signal processing applications on a desktop computer when connected to radio peripherals. A large number of applications have been implemented in the GNU Radio [3]. Some of them include the transmitter and receiver structures, different modulators and demodulators and concurrent multichannel receivers.

In the following section briefly explains how exchange of messages happens between them.

2.2 Zibee Communication with USRP and IITH Mote

IEEE 802.15.4 standard specifies the Physical layer(PHY) [18] and Media Access Control(MAC) for low-rate wireless personal area networks (LR-WPANs). MAC layer deals with the packet formatting and PHY

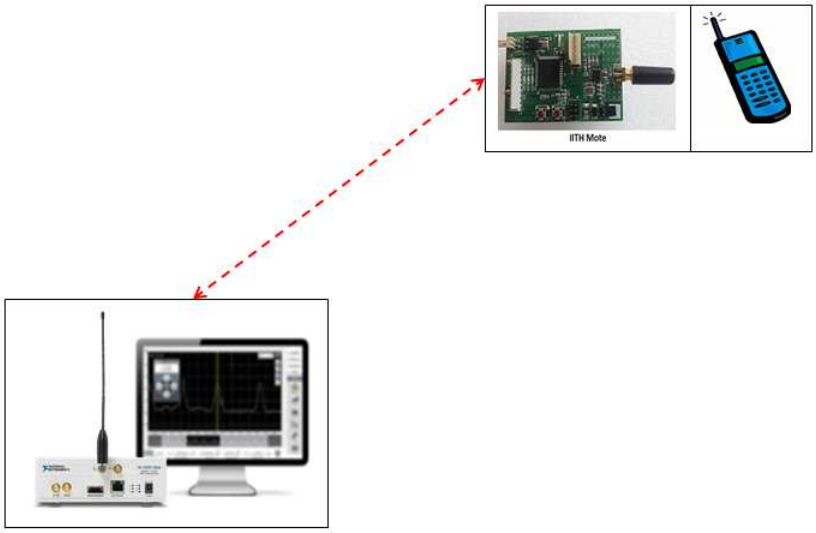

Figure 2.1: Communication link between USRP and Mobile with IITH Mote

layer deals with modulation as well as pulse shaping. It uses Direct Sequence Spread Spectrum. In DSSS, the information to be transmitted is divided into small pieces and each of which is allocated to a frequency channel across the spectrum. DSSS uses a spreading sequence of each PN sequence having 32 bits. It [2] uses OQPSK modulation followed by half sine pulse shaping. For 2.4GHz PHY, there are 16 channels numbering from 11 to 26 with each channel having 5MHz bandwidth.

2.2.1 Transmission at IITH Mote and Reception at USRP

- In this the data received from the mobile has to be transmitted by the mote through radio.The transmission of the data can be unicast or broadcast, it depends on the type of the application using. Finally we have to programme the mote such that it will sends the serial data in the form of packets through the radio.
- This IITH mote follows a particular standards for the transrecieve purpose. The transmitted data will be allocated a fixed channel of frequency,the transmitted data will be received by the Usrp which is connected to the computer. The data can be received by the usrp and can be displayed in the computer with the help Gnu radio software with the approipate flow graph
- The range of communication can be 10-15m which can be improved using relays.

2.2.2 Transmission at USRP and Reception at IITH Mote

- At the USRP [15] we have to transmit the data, by designing the flow graph of communication modules of the network. The frequency of channel transmission is flexible and the antenna of USSP tramit the data along with its header. The transmited data of the usrp will consists of source address and data as an payload.

- IITH mote will receive the broadcast packet of usrp with an extra header. So we have to remove that extra header and retrive the original data. By this we can succesfully receive the data. But the buffer of tinyos [1] is limited to 28bytes. So the mote can receive data only to an certain extent. Inorder to extend the limit of receiving data, we have to transmit data as different packets.

2.3 WIFI Networks

Wifi is an emerged technology for high rate generation, it enables voice, video and data applications and it has good coverage [19]. A user can be connected to wifi through phone and it covers a range of about 600m with a high rate of order of mbps. For the voice services, kbps speed is sufficient. In comparison to the B2B, there is downslide for the wifi technolgy which is power. The power consumption of B2B network is very less than Wifi network. It is robust for the power failures and it can run for few months without battery recharge. Although, our chipset is self powered by the renewable energy sources like solar panels, frictional motions. For instance, it is independent on the battery recharge and renewable energy sources, it run for several days.

First distinction about B2B network is that the node is operated on AA batteries and consumes very less power compared to WiFi. Secondly, the overall cost of the B2B network is comparetively much less than a WiFi network

2.4 Bluetooth

Bluetooth (802.15.1) is a low cost, low power technology for voice communication, and it offers high data rates in order of Mbps. It does not have support for multi-hop networks and single hop coverage is considerable low in order of few meters. In comparison, B2B uses 802.15.4 platform as a node which offers considerable amount of data rate and support multi-hop networks. This multi-hop network will increases the coverage range.

Chapter 3

Components of B2B System and Handset design

To enable the voice communication among villages which are uncovered by cellular networks. We argued that communication technology carefully chosen to minimize the cost and power requirements. This design choice of B2B are important to enable real-time voice streaming [4] in the network because there is limited capacity of 802.15.4 radio

3.1 Communication Modules and Sytem Tools

As shown in fig 1.2, there are two types of nodes in B2B system
(1) infrastructure nodes acting as relay nodes for voice communication,
(2) handset nodes acting as data originators or terminators.
The figure shows a multi-hop local voice call in progress between two B2B handsets using 802.15.4 mesh network.

3.1.1 IITH Mote

- The IITH-mote is a 2.4 GHz Mote used for enabling low-power wireless sensor networks. It works on 8 MHz atmega microcontrollers with 8 kb RAM. AVR programmer is used to program IITH-mote.It has a 6 male pins for serial communication. The mobile is connected to this interface via FTDI RS232 chip which converts the data format from USB to UART.
- It has the wireless protocol available standards include 2.4 GHz radios based on IEEE 802.15.4. A sensor node, also known as a mote in a wireless sensor network that is capable of performing some processing, gathering sensory information and communicating with other connected nodes in the network.

3.1.2 Packet structure

- Destination Address(2 Bytes)
- Link Source Address(2 Bytes)

dest addr	link source addr	msg len	groupID	handlerID	source addr	counter
ff ff	00 00	04	22	06	00 02	00 0B

- Message Length(1 Byte)
- Group Id(1 Byte)
- Active Message handler type(1 byte)
- Payload(up to 110 bytes)

3.1.3 TinyOs

- IITH mote is programmed with the tinyos. TinyOS [1] is especially useful for microcontroller based devices that have sensors. Its been designed for very resource-constrained devices, such as microcontrollers with a few kB of RAM and a few tens of kB of code space. Its also been designed for devices that need to be very low power.
- Tinyos supports multiple microcontroller families and radio chips. It has especially strong support for low-power operation, including wireless networking. TinyOS link layers support low-power operation, and TinyOS multihop protocols use these features.
- It supports low duty cycle operation through low-power link layers. Rather than keep the radio always on, it turns the radio on periodically (every few ms) to check if there is a packet to receive. This enables the network to appear always on yet support sub-1 % duty cycles: the basic tradeoff is that communication has higher latency.

3.1.4 Android App

- Android is a mobile operating system (OS) based on the Linux kernel. With a user interface based on direct manipulation, android is designed primarily for touchscreen mobile devices such as smartphones and tablet computers. Android devices are usually battery-powered, android is designed to manage memory (RAM) to keep power consumption at a minimum.
- In this project an android app is developed for serial communication purposes. In the android mobiles there is no MIG(message interface generator) tool for forming the packet structure, for visualizing the sensor data or sending the data to mote we need to develop an app. This app will visualize the sensor data through serial port and display the data in mobile.

3.2 Handset Design

As mentioned eariler, for handset we use any android mobile and also we argued that our B2B system should be chosen such that it minimize the cost and power requirements of the system. In this section, we will describe the design of hardware and software of handset. B2B handset comprises of android mobile, Telsob

platform [20] has 8Mhz Micro controller unit with 8KB of RAM and IEEE 802.15.4 compliant CC2420 radio and it can be programmed using TinyOS, an open source operating system for embedded wireless platforms Finally, we made transfeering the voice through handset

3.2.1 Hardware interfacing of android mobile

The following block diagram explains hardware interfacing of android mobile with telosb mote. The Mobile is interfaced to telosb with Universal Asynchronous Receiver and Transmitter (UART). To establish voice communication, we need to translate the voice samples into serial data and this serial data is transferred to the telosb mote with UART. Telosb mote forms the data packet of serial data and packet is kept for transmission. We do not require any hardware for signal processing, entire operations will happen in the android mobile, it is main advantage by using it. Telsob mote [20] forms the packet and send to radio for transmission. We are using Aakash tablet as a android mobile which is low cost device that is readily available in the market. Instead of aakash tablet we can use other android devices which is comfortable to the user-end.

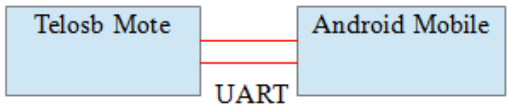

Figure 3.1: Telosb interfaced to android mobile

3.2.2 Software for voice transmission

For the voice transmission, we developed an android application which is B2B app, it will perform following functions.

- It will record the voice of the user and send to the Telosb mote which is interfaced serially. This is for transmission of the real-time voice.
- For reception of voice, the packet which is received by the telosb radio, Mote will decodes the packet and payload is sent serially to the android. The received data is played as voice with application developed .

For establishing the voice calls, B2B application at the end users will be in open mode and they starts exchanging the messages with this app. Packet transmission, reception functions are performed by the mote interfaced to the mobile. Call forwarding operations will be headed by the B2B network. Signal processing happens in the android mobile, and voice samples are encoded by using the Speex codec with data rate of 16Kbps for the unidirectional flow. We sample the voice at 8Khz as 16 bit samples. Speex codec operates on these samples and generate 16Kbps datarate. Telsob mote takes 38 Bytes of serial data, it forms packet and sends to radio for transmission. The processing delay for formation of packet and sending to radio is 60ms. Baud rate for intake of serial data is 115.2 Kbps. The serial data delay cannot be decreased because of fixed baud rate. We can decrease the processing delay of the packet by decreasing the packet size which is

not preferred. We can minimize processing delay by time diversity technique of MIMO Communication [8]. This technique is briefly described in MIMO Communication chapter.

Chapter 4

Network Placement

The long distance communication in the Wireless Sensor Network is costly [9], since energy consumption is directly proportional to the distance between the sensor nodes. The radio signal power in the sensor networks drops off with r^4 where r is the distance between the sensor nodes. To increase the network lifetime while preserving the network connectivity is to deploy a many number of relay nodes whose task is communicate with the other relay nodes and the user end sensor nodes [10]. We focus on topology control by minimizing the maximum transmit power or minimizing the total power with preserved network connectivity. We focus on the mesh network which we are using in our system.

4.1 Single Hop

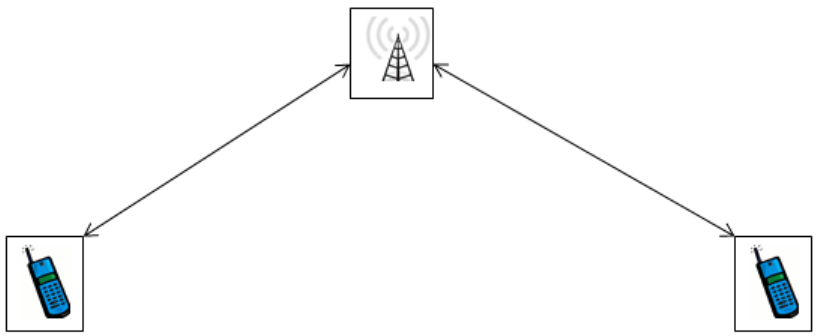

Figure 4.1: Single-Hop

In this communication model the transmit node communication range is r, to increase the communication range between the source and the destination nodes [7], we have to deploy the relay node. With the deployment the effective communication range increased to R where $R > r$ [6] . This node will receive the data packets from the transmission node and it forwards to the receiving end node. This model is the static

topology where the relay node is fixed and routing schemes are not required. The end-users has a mobility with in the communication range of the relay node.

The job of single hop is to receive and forward, it act as an inter-mediator between the two user-ends. The role of single hop is to receive the packet from the source, perform the signal processing operations and form the packet for sending to radio. The radio sends to destination node of the user.

4.2 Multihop

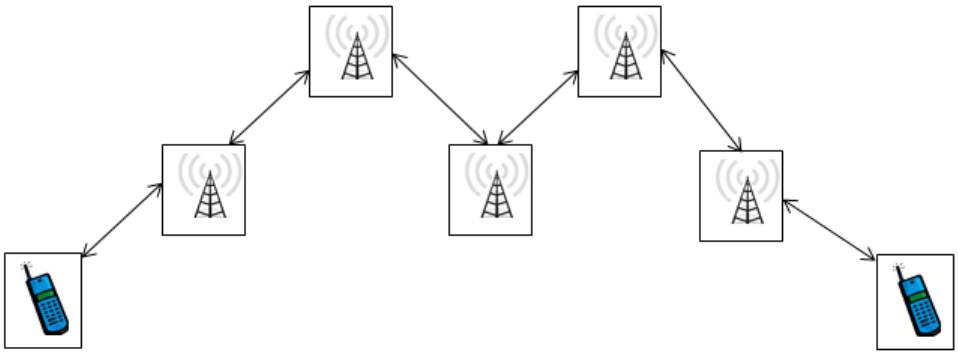

Figure 4.2: Multi-Hop

This model consumes less energy compare to the single hop for long distances [5]. We focus on the network topology design to achieve the different requirements. Requirements include throughput maximization, delay constraints, security and reliability. Connectivity between the nodes is determined based on the distance considerations. Energy efficiency is considered by having a minimum energy path between each pair of nodes in a wireless multihop network. Topology is controlled by varying the transmission power at each node, and the transmission power at the each antenna is considered as the criterion for the energy efficiency [11].

In this section, we model network as static where the mobility of users is not provided. We established simple local network for exchange of messages. Every user is allocated the fixed base station which means that if he wants to exchange message, it goes through particular base station node and next it uses the lookup table for forwarding the message. The user has mobility in the coverage region of allocated base-station only. In this scenario, every user and relay nodes are provided node ids. When the user wants to start conversation with other end-user, it keeps the destination address of the enduser in the first byte of payload of packet and sends to allocated base station. The base station will maintain the lookup table for forwarding the next node according to the destination address. Every relay node maintains the lookup table and when it receives the packet, it checks the destination address which is present in first byte of payload with the lookup table and forwards the packet according to routing algorithm provided in the table. This process of checking in lookup table happens in every relay when it receives packet. Finally, it reaches the destination end user.

When a new user wants to join in the network, it is provided with the node-id and lookup table in the every relay node is modified. In this model, when the new user wants join in the network at every time we have to

change the lookup table in every node manually by programming every node and also when users wants to exchange the messages network will be in congestion because of increase in traffic by the new nodes. This is cumbersome process when the new nodes join in the network. The solution for above problem is network should be centralized TDMA Structure. The Network structure is briefly explained in the following Mac Chapter.

Sensors having data to transmit should relay to single sources using multihop. Nodes that do not have data to transmit or that are not relaying the data of other nodes can put to sleep state. Energy efficiency [5] can be achieved is achieved by reducing the number of active nodes

4.3 Energy Model

Low power hardware design is the key to save energy in wireless sensor network system, the energy consumption characteristics of chip is a key research object. In general, the supply voltage of nodes are essentially constants, the current of nodes are key factors in power consumption study. Therefore, considering energy saving and compatibility, the design of nodes is put forward based on MSP430 and CC2420 [20].

As mentioned earlier power consumption is critical for sensor networks. Sensor nodes consume battery energy to transmit the data from node to another. The amount of the power consumption depends on the distance between the transmitter and the receiver nodes, and the amount of data transmitted. There are two modes of operations for sensor nodes: Fixed and adaptive energy levels.

The source node can send the data to the destination node using one or more relay nodes, rather than directly, to reduce the power consumption. Each relay node acts as a router that forwards the received packets from one neighbor to another. The relay node consumes three kinds on energy when forwarding the packet; energy to receive the data, energy to amplify the data signals and energy to transmit the data. This can be expressed using following expressions.

we assume the simple model for the energy dissipation for transmitting one packet. Energy consumed by the transmitter when sending a packet E_{tx} and the energy consumption for receiving a packet E_{rx}. In general energy consumed by a transmitter has a two components. The first is energy dissipation due to RF signal generation and this is mostly depends on the modulation techniques we are used. The second component is the energy consumed the electronic components necessary for frequency synthesis, frequency filters. The energy consumed by the receiver is depends on receiver electronics

Thus to transmit an l-bit message a distance r, the radio expends energy

$$E_{tx}(l,d) = (lE_{elec} + lE_{fs}d^2) \tag{4.1}$$

$$E_{rx}(l) = lE_{elec} \tag{4.2}$$

Here the equation 4.1 models the energy consumption of the transmitter and the equation 4.2 models the energy consumption of the receiver.
Here the amplified energy is increased in the square of the distance. Thus, reducing the power consumption by introducing more relays will have a great effect to reduce the power consumption to amplify signals since the sum of the square distance of segments are much less that the square distance of the total distance. In other words, if $d = d_1 + d_2 + ...d_h$ then $d^2 >> d_1^2 + d_2^2 + ...d_h^2$. However, at each relay, there is extra energy needed

to receive and retransmit the data. Thus, it is a tradeoff to balance between these two types of reduction and increment in power consumption to achieve optimal total value.

4.4 Cost and Power Consumption

The final cost of the B2B system depends on the various components. The following table given below gives the cost of various components and total cost of the system.

Component	**Quantity**	**Cost**
Aakash Tablet	3	3*3000=9000
Telosb Mote	6	6*3000=18000
Avr Programmer	1	1*3000=3000
Connectors		2000
Total cost		**32000**

Table 4.1: Power Cost of various Components

The power consumption of the system is power consumed by all of its components. The following table shows power consumption of all components

Component	**Power Consumption**	**Power Consumption in Sleep mode**
Aakash Tablet	200mW	$< 1mW$
Telsob Mote	20 mW	$< 1mW$
Total Power Consumption	0.22W	1mW

Table 4.2: Power consumption of various Components

4.5 TDMA MAC

In a CSMA MAC protocol, a node senses the channel to see if there are any ongoing transmissions in the network. If it senses the channel to be busy, then it waits for the channel to be free. Once it detects a free channel, it transmits a packet to the intended recipient. A CSMA MAC protocol often implements a link layer reliability mechanism to notify the transmitter about the delivery of its packet to the receiver. Thus, once a node transmits a packet to a receiver, it waits for the receiver to send an acknowledgement (or ACK) of the reception. If the transmitter receives an ACK, it proceeds to transmission of next packets. Otherwise, the transmitter backs off suspecting a collision of its transmission with other transmitters which are out of its sensing range. The back-off mechanism is often referred to as Collision Avoidance (CA) since the transmitters involved in collision independently wait for a set of random periods before attempting to transmit again to

resolve the contention. These back-offs during contention resolution give rise to a large delay and jitter which can degrade the performance of real-time applications.

In the context of supporting real-time applications such as voice which often require constant bit rate traffic flow. With the CSMA-based multihop MAC operation does not maintain the required quality of service. It is also results to high delay and jitter when the traffic is high, which is unfavorable for real time applications. The problems that are faced by lookup table are solved by using centralized TDMA MAC [17].
A TDMA network can eliminate transmission collisions in the network. Further, through a careful scheduling, the time slots can be assigned to each node on a routing path such that the end-to-end delay of the flow can be guaranteed. Additionally, since a TDMA MAC [17] protocol can keep track of the assignment of available time slots and channels, it can also allow an admission control in the network. Furthermore, a TDMA MAC can provide good support for duty-cycling and thus power savings in network nodes. Through such duty cycling, only a relevant set of nodes which are on the path between the two communicating nodes need to be fully awake; the other nodes can sleep to conserve the power. In sleep state the computation and communication units turn themselves to a low power state.

In this section we briefly look over the centralized, TDMA-based protocol to support real-time voice applications by considering mesh network. The challenges involved in this mac are described below.

- Time synchronization must be built into the MAC.
- It should support dynamic routing.
- it should support dynamic flow setup and tear-down

For this operations, we have time-slotted system. In this context ,root node has central control over the other nodes and decides , who transmits in which slot and to whom. We have three kinds of slots control, contention and data slots.
Control slot: We consider the root node is central node to broadcast scheduling information in control slots. The control slots are used by the root node along with the infrastructure nodes to disseminate the scheduling information. Control slots are assigned by the root, for control packets to flow down the tree. The control packets originate at the root node and are further transmitted by the infrastructure nodes, as per the control slot assignment. The information contained in this slot about time-synchronization, information about tree structure, so that every node is aware of its relationship and information about the data scheduling.
Contention slot: These slots are for control packets to flow up to the central node. The packets are forwarded from leave to parent so that finally, it should reach the root. The functions involved in contention slot are

- New node join requests
- flow requests.

We dont prefer carrier sense or back-off mechanisms because we can accommodate within limited slot. If we include these mechanisms, delay increases which is not suitable for real time applications. So every node transmits it information within contention slot which is provided.
Data slot: These are used for the actual data flow from the source to destination. Once the path is scheduled the actual data flows. This data flow happens after completion of two stages which is described in the above. It is concern about the data exchange between the the user ends.

Chapter 5

MIMO Communication

The motivation for the Multiple Input and Multiple Output(MIMO) communication is to decrease the processing delay in formation of packet and to increase the data rates of the network. The concept of MIMO 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 [6].
In sensor networks and depending on the type of motes used, the power consumed in receiving and processing may constitute a significant portion of the total consumed power. Time diversity can provide gains in terms of increasing the data rates

5.1 Channel Model

Radio channel plays an important role in the performance of wireless systems, particularly dealing with the system power. When a signal propagates, the signal strength decays as the distance from the source and destination increases. In this context we model both free space model(direct path) and multipath fading model(reflection model), depending on the distance between transmitter and receiver. If the distance between the transmitter and receiver is below the threshold known as the cross-over distance, then the Friis free space model is used, and the distance is greater than the cross-over distance, then the two-ray ground propagation model is used.
The cross-over distance is defined as

$$d_{xover} = \frac{4\pi h_r h_t}{\lambda} \tag{5.1}$$

If the distance between transmitter and receiver is less than d_{xover}, that is $d < d_{xover}$ then the received signal power at receiver is modeled using Friis free space model

$$P_r(d) = \frac{P_t G_t G_r \lambda^2}{4\pi^2 d^2 L} \tag{5.2}$$

If the distance between transmitter and receiver is greater than d_{xover}, that is $d > d_{xover}$ then the received

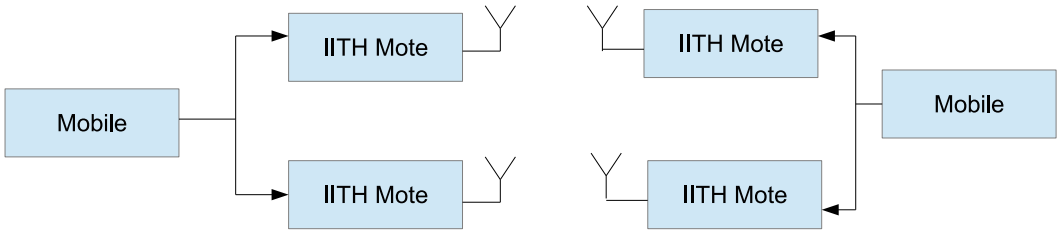

Figure 5.1: 2X2 MIMO Communication

signal power at the receiver is modeled using

$$P_r(d) = \frac{P_t G_t G_r {h_t}^2 {h_r}^2}{d^4 L} \tag{5.3}$$

where $P_r(d)$ is the received power for a transmitter-receiver separation of d, $L >= 1$ is the sysytem loss factor, h_t and h_r are the heights of the transmitter and receiver antennas above the ground respectively, G_t and G_r are the antenna gains, and λ is the wavelength of the carrier signal.
The receiver can receive a packet with acceptable error rate only if the received signal power is greater than receiver sensitivity threshold and the signal to noise ratio (SNR) is above a threshold.

5.2 MIMO Technique

For sensor networks, maximizing the network lifetime, decreasing delay is the main concern [8]. Decreasing processing delay increases throughput and it can be useful for real time applications [17]. Since sensor networks are mainly designed to cooperate on some joint task where per-node fairness is not emphasized, the design intention is to minimize the total energy consumption in the network instead of minimizing energy consumption of individual nodes. In this section, we propose a strategy to minimize the total energy consumption of multiple nodes from a network perspective. As we discussed in the last section, MIMO includes 2x2 or 3x3 can provide energy savings in fading channels. Thus, if we allow cooperative transmission [8] among multiple nodes, we can treat them as multiple antennas to the destination node. By using this MIMO

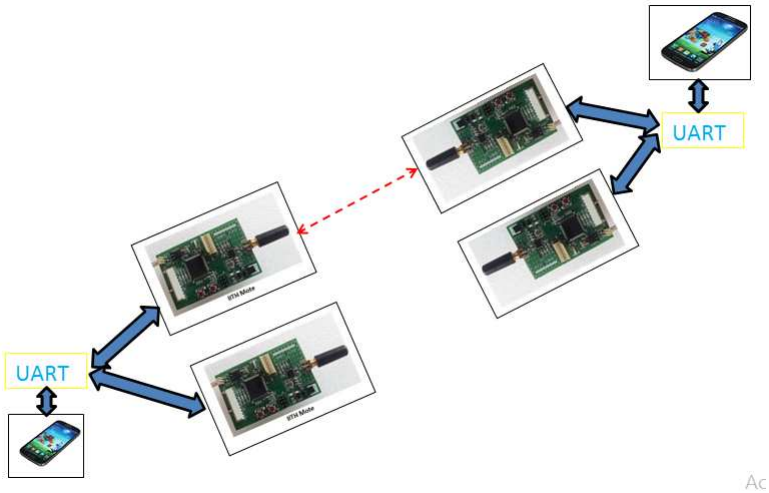

Figure 5.2: Packet transmission from mote 1

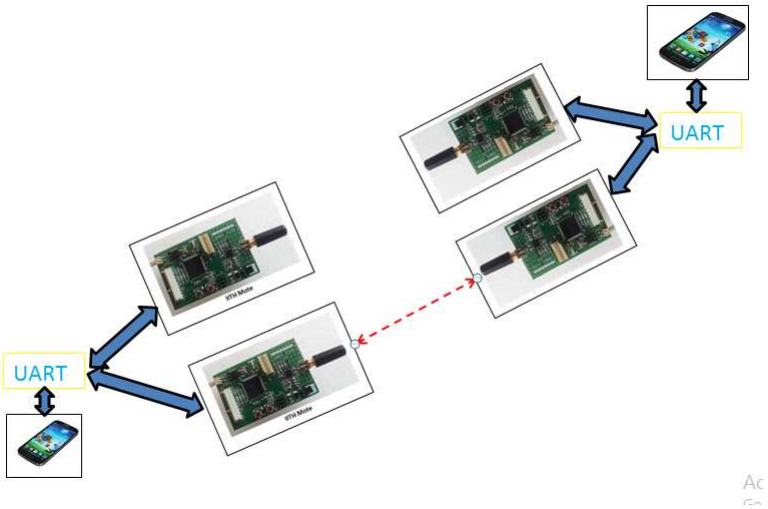

Figure 5.3: Packet transmission from mote2

system, the requirement on transmission energy for the long-haul transmission can be reduced.

In the above fig 5.1 shows the 2x2 mimo model where two motes are interfaced to the one android mobile at the transmitting and receiving side. These sensor nodes are interfaced using the serial cables and both sensor motes always in the listening mode. For instance, if one mote transmitted the packet and after few milli seconds other mote starts transmitting the packet. This cycle repeats continuously, in this situation first packet is send by first mote ,second packet is send by another mote and for the third packet first mote get a chance to transmit and it repeats. Thus time diversity is achieved by the sensor motes with different data instead of sending the same data.

Let t_d is time delay of the UART is the time taken for transmitting serial data from mobile user to sensor note and it is inversely proportional to baud rate of the particular sensor mote. For TelsoB baud rate is 115200 Bytes, Iris mote 57600 Bytes. t_p is the time taken by the mote for packetesizing the serial data and transmitting the packet in air. The mote will be in lock state for t_p seconds once it receives 38 bytes serial

data which is equal to packet length. It will receives serial data again after $t_p$seconds which increases the delay. Finally, the overall time delay increases which effectively decreases data rate.

The total delay is t= $t_d + 2t_p$

The solution for the above problem is interface the other mote instead of waiting for t_p seconds of time and also energy consumption per node decreases which effectively increase the life time of the sensor network. The concept of mimo technique is using two or more antennas for exchanging the messages instead of one antenna for delay between packet to packet. For sending the data we use two antennas one after the another in a time diversity method.

The total delay by using mimo technique t=$t_d + t_p$.

Chapter 6

conclusion

B2B system is very practical and very useful for developed and developing regions. This gives great advantage to the villagers who can call among villages which are near using B2B network. We described the design and implementation of building a low cost and low power wireless mesh network. The novelty of our work lies in its use of IEEE 802.15.4 wireless radio to provide telephony services in rural regions by using available android mobiles. 802.15.4 was originally designed for a completely different application space of non-real-time, low data rate embedded wireless sensing. However, we used it to design and prototype a telephony system for real-time voice applications, which we term as B2B . B2B primarily provides local voice within the wireless mesh network with the available cellular mobile as a handset. Thus the cellular handset can be used for both B2B system and cellular network with interfacing B2B chipset to the mobile.

For future work we can implement the full-fledged network by using TDMA MAC as extension to current network. And apart from real-time voice calling it may possible to stream data over B2B system. In particular, we have to use raspberry-pi as a gateway node that can enhance relay data as well in addition to voice. Thus B2B system can be extended to provide cellular data acces to B2B end-users.

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