

Reliable Wireless Data Transfer in a High EMI Environment

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DECLARATION

I, Abdul Ghaffar Barakzai, identity number _____, and student number _____, hereby declare that this research project which has been submitted to the Central University of Technology Free State, for the degree MASTER OF ENGINEERING IN ELECTRICAL ENGINEERING, is my own independent work and complies with the Code of Academic Integrity, as well as other relevant policies, procedures, rules and regulations of the Central University of Technology, Free State, and has not been submitted before by any person in fulfilment (or partial fulfilment) of the requirements for the attainment of any qualification.

.....

Signature of student

.....

Date

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ABSTRACT

Industrial wireless communication has had many recent developments in improving transmission to overcome Electromagnetic Interference (EMI) in the industrial environment. Many industrial monitoring systems available on the market work on real-time communication, with nodes and data logging, which has limitations as to number of nodes that can be supported depending on the system's processor capabilities.

This research focuses on a different approach to design and implements a wireless industrial monitoring system using LabVIEW™, a system which is not limited by a certain number of nodes with real-time data logging at nodes and data transmission taking the EMI environment into consideration. In addition, the study looks at creating a wireless monitoring system where delays in system updates are acceptable until real-time log data can be received.

Wireless monitoring devices have many advantages over cable or wired industrial monitoring; including fast deployment, intelligent processing capability and flexibility. In this dissertation, design principles are described in terms of hardware and software development. The aim is to use the existing wireless communication network "IEEE 802.11b/g/n 2.4 GHz" at an industrial plant for communication using techniques to avoid or lower the amount of data which is lost. Moreover, this research looks at processing and logging data at nodes to allow the receiver/server to communicate with unlimited nodes in a timely manner. The research was performed, developed and tested at Route Management-South African Truck Bodies manufacturing plant.

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LIST OF ABBREVIATION

AC: Alternating Current

BER: bit error rate

BEMI: Broadband Electromagnetic Interference

CCTV: Closed Circuit Television

CSV: Comma Separated Values

CNC: Computer Numerical Control

CT: Current Transformer

DHCP: Dynamic Host Configuration Protocol

EEPROM: Electrically Erasable Programmable Read-Only Memory

EMI: Electromagnetic Interference

FEC: Forward Error Control

IWSN: Industrial wireless Sensor Network

IEEE: Institute of Electrical and Electronics Engineers

IOT: Internet of Things

LabVIEWTM: Laboratory Virtual Instrument Engineering Workbench

mA: milliamps

PING: Packet InterNet Groper

PCB: Polychlorinated Biphenyl

RFI: Radio Frequency Interference

RTC: Real-Time Clock

SD: Secure Digital

SRAM: Static Random Access Memory

UPS: Uninterruptible Power Supply

HART: Highway Addressable Remote Transducer

WIMS: Wireless Industrial Monitoring System

WLAN: Wireless Local Area Network

WSN: Wireless Sensor Network

ZIGBEE: Zonal Intercommunication Global-standard

Chapter 1

Introduction

This chapter describes an overview of the research problem, aim, methodology, and hypothesis regarding the design of a communication technique which will be able to transmit data in a high electromagnetic interference environment.

1.1 Preface

Recently, new technologies have emerged to address data transmission in high electromagnetic interference (EMI) industrial environments, but in many cases these wireless data transmission devices are limited and provide only partial solutions. Typically, the device options are not well drafted and the manufacturers' application support is lacking. At the end, clients want reliable data and feature-rich solutions that they can configure and apply to meet their unique needs like accommodating existing wireless networks as well as new installations. The system requires flexibility, compatibility and configurability. End-users want a system that incorporates as many features as possible to keep capital and maintenance costs to a minimum.

1.2 Motivation and objective of dissertation

With recent advances in wireless sensor networks, the realisation of low-cost embedded industrial automation systems has become feasible. In these systems, tiny wireless sensor nodes are installed on industrial equipment which examine the parameters critical to each piece of equipment's efficiency, based on a combination of measurements such as vibration, temperature, pressure and power quality. This data is then transmitted wirelessly to a sink node that analyses the data from each sensor. Personnel at the plant are notified of any potential problems via an advanced warning system.

This enables plant personnel to repair or replace equipment, before their efficiency drops or they fail entirely. In this way, catastrophic equipment failures and the associated repair and replacement costs can be prevented, while complying with strict environmental regulations.

1.3 Hypothesis

A wireless industrial monitoring system (WIMS) can be utilised to monitor power consumption of a factory's machines, such as a welder machine, which in turn can assist in optimising the factory's production and reducing wasteful energy practices. The reason for deploying wireless monitoring in industrial systems is to log status (discrete) and measurement/control (analogue) information at one place and transfer it to the server. The link should be able to carry information in both directions and to be used for both monitoring and control.

1.4 Methodology of research

In designing a WIMS, the following were identified as essential elements:

1.4.1 Transmitter

The transmission of data from node to server plays a vital role, especially in a high EMI environment. The node must be able to communicate with the server to verify data transmitted, and if data verification fails, then be able to perform necessary error correction steps. My goal is to design a node which is able to create communication with its surroundings to detect EMI presence and transmit with EMI considerations.

1.4.2 Receiver

Laboratory Virtual Instrument Engineering Workbench (LabVIEW™) designed software which is responsible for communication with nodes and which performs necessary error correction techniques on data received. LabVIEW™ - designed software stores data from different devices using LabVIEW™ techniques like data queue, data socket, loops, data handler, and so on, which help with data handling and collection of data in sequence-based methods.

1.5 Outline of dissertation

The flowchart in Figure 1-1 shows the basic outline of the dissertation. The theory is utilised in the overall research design and the development of a wireless industrial monitoring system. The results are then noted, evaluated and discussed with a conclusion on the study and the results which were obtained.

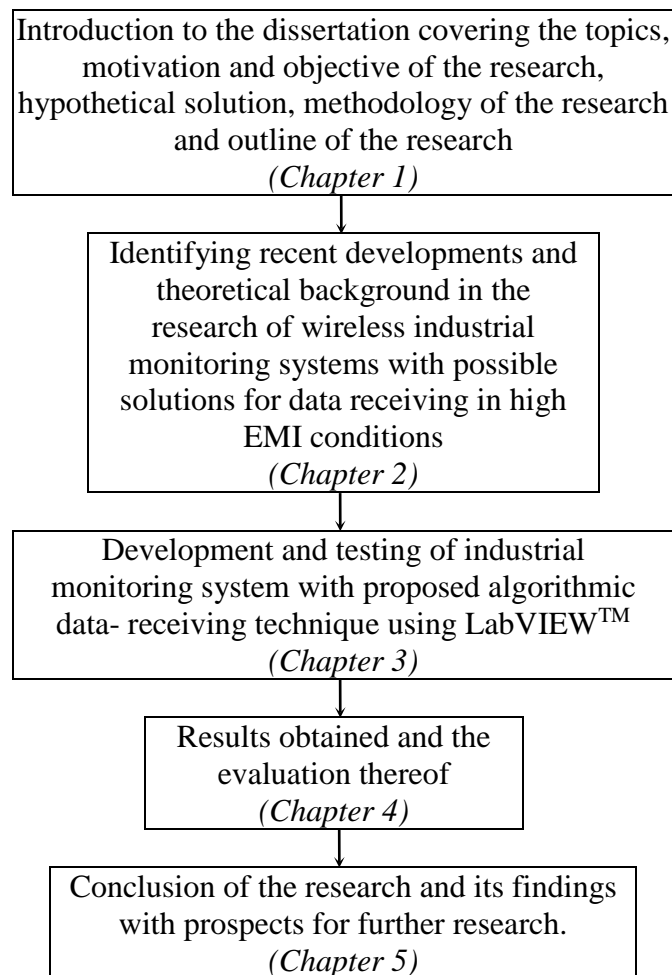


Figure 1-1: Outline of the dissertation including research phase

Chapter 2

Wireless industrial communication system: technical background

This chapter gives an overview of the proposed system design within the existing developments to improve industrial wireless communication. Only the theories relevant and seemingly important for this study are discussed.

2.1 Introduction

In this chapter, wireless industrial monitoring systems' latest developments, technical challenges and design principles are introduced in terms of hardware and software developments and system architecture and protocol design. Specifically, radio technologies, energy-harvesting techniques and cross-layer design for WIMS are discussed.

In an era increasingly characterised by many industrial systems and dynamic industrial manufacturing factories, intelligent and low-cost wireless industrial monitoring automation systems are required to improve productivity and efficiency. The nature of WIMS brings several advantages over traditional wired industrial monitoring and control systems, including self-organisation, rapid deployment, flexibility, and inherent intelligent-processing capability. In this regard, an industrial wireless sensor network (IWSN) plays a vital role in creating a highly reliable and self-healing industrial system that rapidly responds to real-time events with appropriate solutions.

2.2 Related work in WIMS

Previous innovations in industrial wireless communication came about with the introduction of wireless sensor networks (WSNs). There are many WSNs which are used in wireless industrial monitoring systems on the market with a similar basic concept as displayed in Figure 2-1. Multiple wireless nodes/sensors are placed across the factory floor, which transmit the data from the sensors to a gateway. The gateway sends the raw data to a central server which executes all the processing and monitoring functions [1].

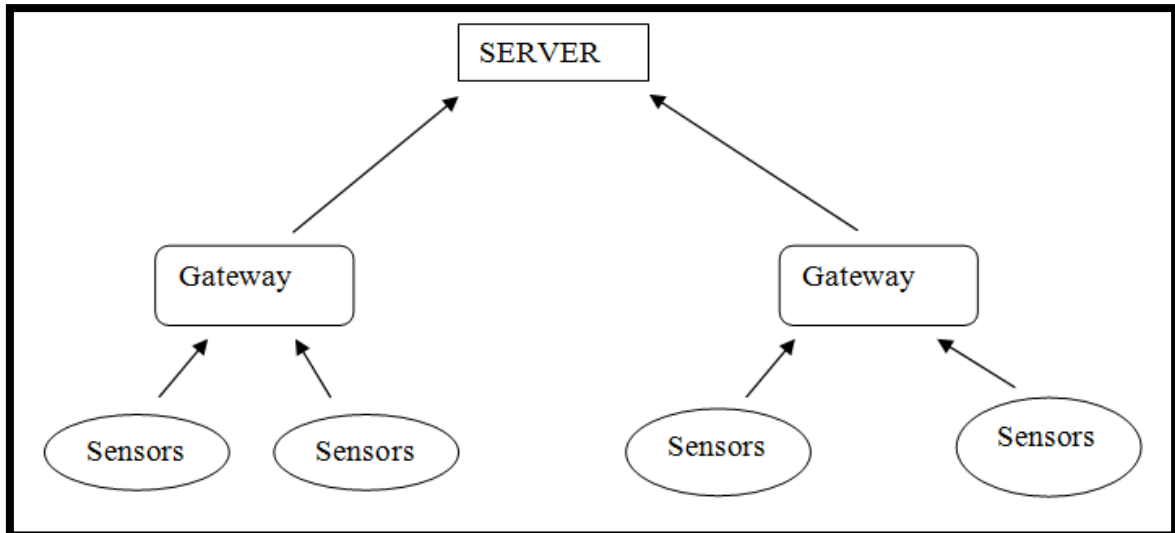


Figure 2-1: Basic concept of wireless sensor networks

This research is based on key principles discussed below in the design of WIMS. Research and development has been performed on previously proposed solutions to improve the key models mentioned in the section below [2].

- EMI sources in an industrial environment
- Wireless network protocols
- Network configuration used to communicate with the wireless nodes
- Node failure detection methods
- Data error correction
- Scalability

2.2.1 Electromagnetic interference sources

EMI or radio frequency interference (RFI) occurs from many sources. Some of the major sources are found in an industrial environment, such as power lines and welding machines, which generate undesirable noise on the radio [3]. It affects the transmission channel or systems. In the case of a data path these effects can range from an increase in error rate to a total loss of the data. There are many types of EMI noise, however broadband EMI usually affects wireless communication.

2.2.1.1 Broadband EMI (BEMI)

Discrete frequencies occupy a relatively large part of the electromagnetic spectrum. These are caused by welding machine arcing or corona and cause most of the EMI problems in digital data equipment. An example of BEMI is an electric power transmission line.

2.2.2 Network Protocols

Industrial wireless sensor protocols have undergone many developments since their initial inception. The introduction of a wireless highway addressable remote transducer (HART) in September 2007 [4] and ZIGBEE [5] have brought numerous improvements in wireless industrial automation and WSNs.

Wireless local area network (WLAN) or WiFi still remains the most commonly available communication protocol across different platforms, and for this research WLAN standard protocol has been used.

2.2.2.1 HART wireless

HART is a digital protocol for two-way communication between a host application and smart field instruments, providing access to diagnostics, configuration and data processing [3].

Wireless HART is an extension of the HART protocol and is specifically designed for monitoring and control. The technology employs IEEE 802.15.4-based radio, frequency hopping, redundant data paths and also retries mechanisms. Wireless HART networks utilise mesh networking, in which each device is able to transmit its own data as well as relay information from other devices in the network (Figure 2.2). The phoenix contact [6] provides an industrial rated solution for an industrial wireless system which makes use of Wireless HART.

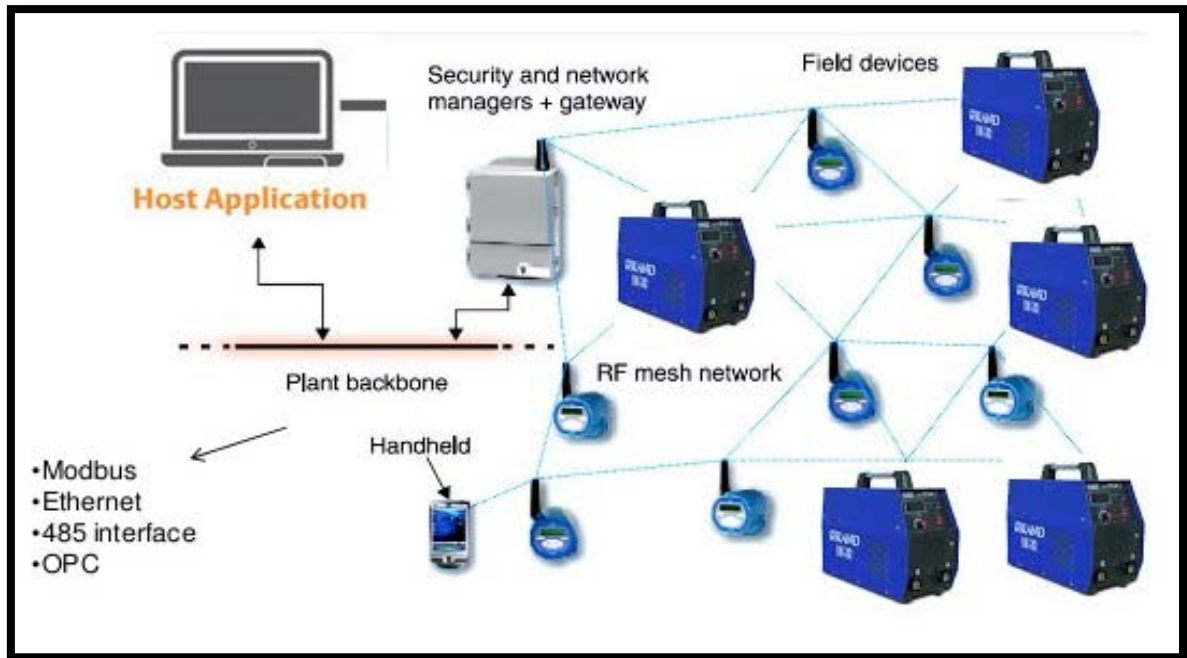


Figure 2-2: Wireless HART network infrastructure

2.2.2.2 ZIGBEE

The 802.15.4 specification upon which the ZIGBEE stack operates, gained ratification by the Institute of Electrical and Electronics Engineers (IEEE) in 2003. The specification is a packet-based radio protocol intended for low-cost, battery-operated devices. The protocol allows devices to communicate in a variety of network topologies, namely ZIGBEE Network topologies [4]. The ZIGBEE network layer supports star, tree and mesh topologies.

Star topology implies that the network is controlled by one single device, called the ZIGBEE coordinator which is responsible for initiating and maintaining the devices on the network. All other devices, known as end-devices, communicate with the ZIGBEE coordinator directly.

2.2.2.3 WLAN

A WLAN is a local area network using wireless connectivity. WLAN protocols originated from the IEEE 802.11 standard protocol developed by the IEEE. WLAN specifies an over-the-air interface between a wireless client and a base station or between two wireless

clients. WLAN also supports a higher rate of data transfer compared to ZIGBEE which has a maximum of 250 kbps. A lower transmission rate requires a longer transmission time cycle.

2.2.3 Wireless sensor network configuration

Network configuration refers mainly to the way WSN communicates with the Wireless nodes. The main components of a sensor node are a microcontroller, transceiver, external memory, power source and one or more sensors. The communication with node can either be real-time or with delayed intervals. Usually, with real-time transmission, raw data is sent to the server which then processes the data. However, with interval transmission, some data processing typically takes place at the node. Both transmission methods' usage depends on the application requirements.

2.2.3.1 Real-time

The real-time data transmission method is mentioned in [7]. The proposed system shown in Figure 2.3 uses ZIGBEE as the medium of communication to log energy consumption. The logging-in is performed in real-time to a cloud-based server for storage. The proposed system consists of a power slave node, a master node, a gateway, a database cloud server and a web server (NodeJS). The master node gathers energy consumption statistics from all the power slave nodes. The gateway receives data from the master node and writes data into the cloud database. The web server gets the required data from the cloud database for visualisation. This system is ideal in a home environment as designed by the author. However, in an industrial environment where wireless connection losses are normal, this might not work as no error correction mechanism is used to detect connection loss.

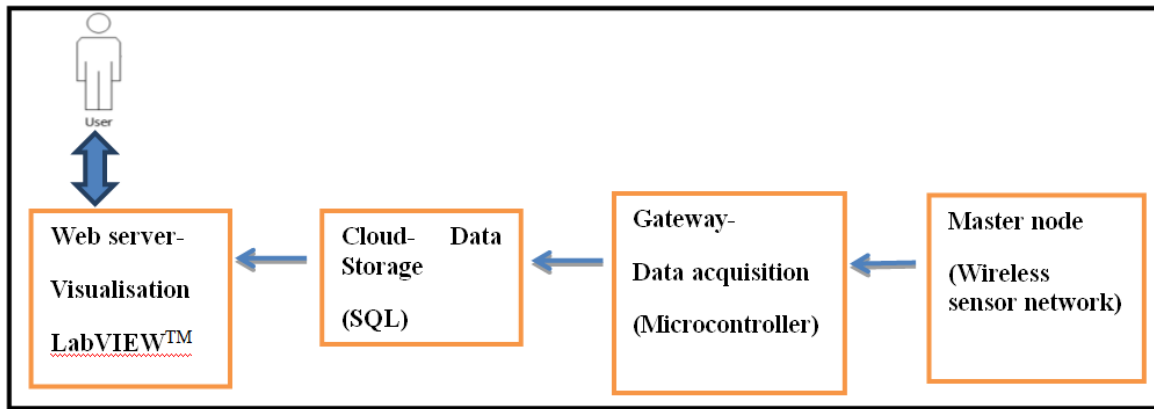


Figure 2-3: Real-Time network in WSN

2.2.3.2 Interval logging

The system proposed in [8] is a simpler concept to the one mentioned before; however, in this system the nodes only start logging after a certain condition is met. As some processing is performed on the node/transmitter side, it results in a reduction of the data size and transmission bandwidth used.

Thus, the drawback is that the storage occurs on the cloud server, which means that if the network connection is lost, the system will not work for that period. A node failure detection method is needed to improve these systems.

2.2.4 Node failure detection

In [9], the research uses Packet InterNet Groper (PING) in a ZIGBEE-based node setup to detect node failure. 'Pinging' is performed by sending a special network packet to the target device which then responds with a response packet. The time which elapses between sending the packet and receiving the response is the 'ping time', and is usually measured in milliseconds.

The result has validated that a dual-hop multicast ping method can be used in a ZIGBEE loop network for accurate node failure detection. The simulation shows that the implementation of this method increases the average end-to-end delay from 0.06 seconds to 0.08 seconds for 40 nodes, as a trade-off to network performance [7].

2.2.5 Scalability

The other drawback of the real-time wireless communication system is the limit on the number of wireless nodes that can be installed on a given system, as the processor capabilities are affected by the number of nodes. The Power Tag solution from Schneider Electric is a wireless real-time energy monitoring system. The wireless communication devices, such as shown in Figure 2.4, provide compact and high density metering solutions with rich and accurate data for building systems that can send energy, power, current, voltage and temperature and power factor information to an Acti9 Power Tag Link concentrator (Figure 2.5). This system is limited to around 20 nodes per gateway [10].



Figure 2-4: Power tag



Figure 2-5: Power Tag Active link

Current industrial graded wireless communication systems like the radio line wireless system from Phoenix Contact [11] and Siemens [12] make use of the latest wireless communication protocols for transmission of data in real-time. Most of these are used where real-time data transmission is needed, for example, in industrial control systems and medical warning systems. The downside of these current systems, since the transmission is real-time, is that as the number of nodes increases, a processor with higher performance will be required to process the data on the server side. This procedure provides an optimal solution if real-time monitoring is required.

2.3 Data lost Recovery

The average bit error rate (BER) of wireless channels fluctuates widely. To recover error packets, there are two basic methods: Automatic Repeat Request and Forward Error Control (FEC). Automatic Repeat Request works as follows: a receiver will acknowledge a message from a sender, and the sender will retransmit the message if it is not acknowledged within a certain time. Forward Error Control uses redundant information along with the data bits to recover the damaged packets. As no acknowledgements are sent to the original sender, the packet will be lost when the error cannot be corrected. Seeing as though in WSNs, packets are commonly broadcast over shared channels and forwarded over multiple hops, using FEC is preferable because it can reduce the need to retransmit data packets, thereby reducing the power consumed in the process [13]. Although there are various encoding schemes, such as Reed-Solomon codes [14] and convolutional codes [15], none of them are directly applicable to the WSNs. A typical wireless sensor node currently has low processing power and a small memory.

2.4 Data Transmission Mathematical Model

In wireless data transmissions processes, data loss is an important factor that reduces the robustness of WSNs. In many practical engineering applications, data loss compensation algorithms are then required to maintain the robustness and where a large memory of microcontroller is needed. This research presents an improved algorithm, based on a random demodulator, to overcome the difficulty of microcontroller-dependence in the traditional data loss algorithms. The newly developed LabVIEW™ algorithm demonstrates the following advantages: 1) low space complexity, 2) low floating-point

calculations and 3) low time complexity. Therefore, it is more suitable to be embedded into ordinary nodes as compared to the traditional algorithm [16].

As the severity of wireless networks increases, it requires better way of describing some of transmission delays. In many WIMS applications delay is a key performance metric. The transmission of a sensor data from transmitter to the receiver Figure 2.6 is activated at time (T_{start}) and this data is received by the receiver at time (T_{stop}). T_{EMI} is the delay cause by EMI and sometimes with the correct transmission of a data is not persistent as it has been depended on the number (n) of retransmissions [17]. The difference between these two:

$$T_{total} = (T_{start} - T_{stop}) - \{T(EMI)n\} \quad [17]$$

T_{total} is the total time required for the transmission. This shows that EMI can a major impact on transmission time.

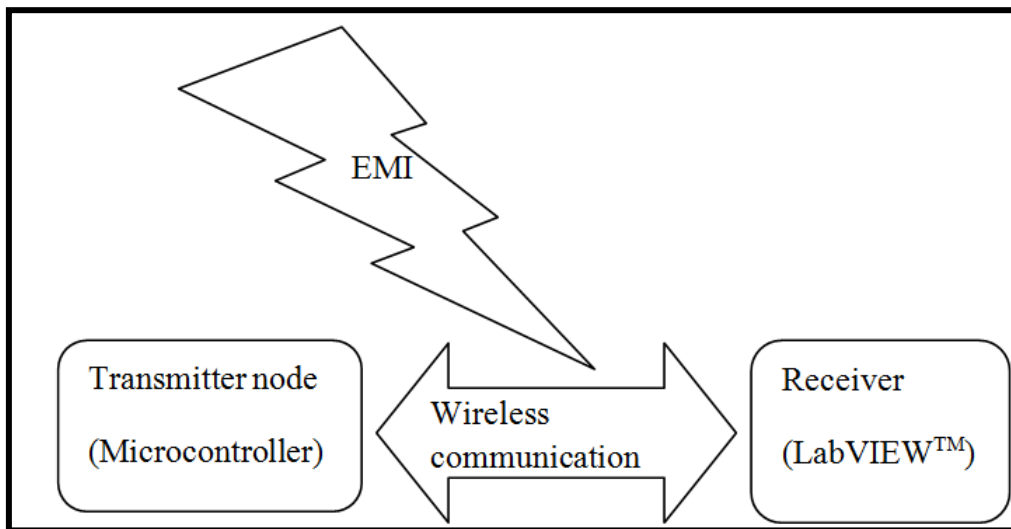


Figure 2-6: Data Transmission Model

2.5 Energy monitoring

Most WIMS' aim is to receive the power usage data from the factory floor. This data can be used to perform necessary performance calculations. Sensors are required to measure the power of the machine. A current transformer (CT) produces an alternating current in its secondary winding, which is proportional to the current being measured in its primary. Current transformers reduce high voltage currents to a much lower value, such as

milliamps (mA) and provide a convenient way of safely monitoring the actual electrical current flowing in an alternating current (AC) transmission Figure 2.7.

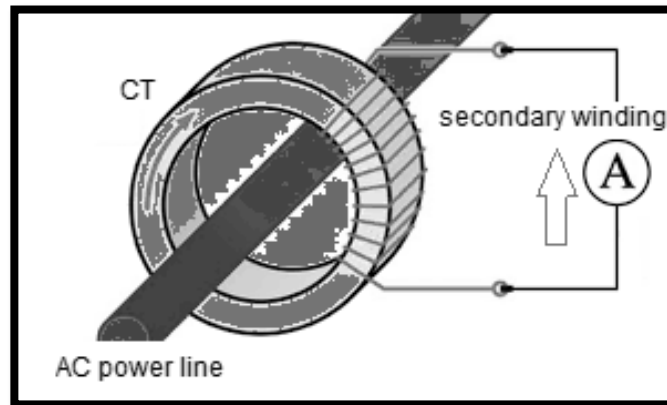


Figure 2-7: Current transformer's basic concept

2.6 Summary

This chapter covered the relevant literature on WIMS with a focus on data transmission. Most of the current systems require a better transmission protocol with error detection techniques, especially in an industrial environment. This section was followed by the key components of energy monitoring, and the chapter concluded with EMI effects on wireless communication. In the next chapter the design of WIMS is covered, to overcome the current drawbacks which were described in this chapter.

Chapter 3

Development of a WIMS for monitoring purposes for an industrial plant

Based on the related work, which was performed on WSNs for the design of WIMS as mentioned in chapter 2, this chapter begins by determining the key areas of focus. The design of WIMS is discussed in detail, including the design of different transmission protocols both on hardware and software level.

3.1 Introduction

As mentioned in the related literature in chapter 2, the aim in the design of the WIMS is to improve upon the current drawbacks associated with WSNs. The key design concepts are mentioned in section 3.2.

3.2 Proposed design concept

To test different transmission methods and to verify which works the best using the literature already provided, Section 3.2.1 and 3.2.2 describe some of the key points that will be looked at in order to create a better transmitter medium. The hardware design of wireless nodes will be kept constant during the tests; however, the microcontroller programming and receiver software will vary as per transmission protocol requirements. The receiver is responsible for communicating with different nodes for data acquisition. Section 3.2.2 mentions the key point to be considered in the design of receiver software. Both transmitter and receiver must be able to communicate in order to successfully transmit data. The research will focus on the key elements mentioned below.

3.2.1 Transmitter

The most important characteristics of transmitter nodes:

- Better transmission method to reduce bandwidth required
- Verification of connection status for receiver
- Lost data recovery algorithm
- Data file verification

3.2.2 Receiver

The receiver or server where the data is received from different nodes should be able to:

- Identify node connection status
- Allow for fast and easy scalability of the system
- Verify received data from node
- Represent data from node

The node is to be installed in different factory machines to measure and record energy consumption data. The data is then transmitted to the server or receiver. The design of the system is divided into two main sections, namely Wireless node “transmitter” and Receiver. Wireless node hardware design, mentioned in Section 3.2.2, is responsible for the transmission and storage of data. Under Section 3.3, node transmission protocols using various transmission methods are discussed. The receiver design, which is the other main section in the system design of WIMS, is referred to in Section 3.4. The results of this design and testing receiver’s software “implemented in LabVIEW™ are addressed in Chapter 4.

3.2.3 Hardware required for different transmission protocols

The design of the node combines a processor or microcontroller and a few add-ons, which are discussed in detail in this section. Figure 3.1 shows the block diagram of the wireless node.

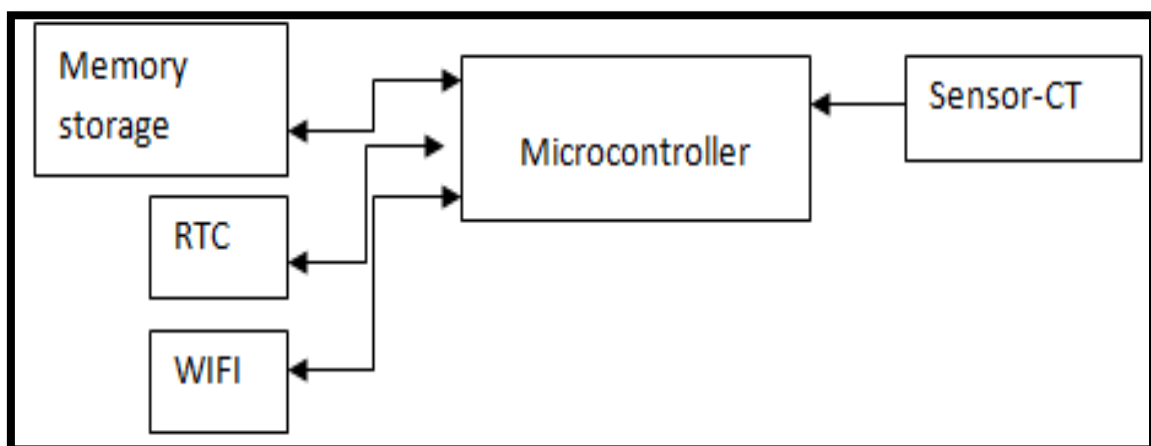


Figure 3-1: Node design block diagram

3.2.3.1 Microcontroller or processor

The design of the node requires a microcontroller with analogue and digital inputs and outputs. Using the analogue capabilities, a CT sensor can be connected and the information can be used for processing. For the design of this node, an ATmega328 microcontroller can be used.

ATmega328P is a high-performance microchip Pico power 8-bit AVR RISC-based microcontroller combined with 32 KB ISP flash memory with read-and-write capabilities, 1024B electrically erasable programmable read-only memory (EEPROM), 2 KB static random access memory (SRAM), and 23 general purpose I/O lines [18].

3.2.3.2 Wi-Fi transmitter

Another aspect of the hardware is a Wi-Fi transmitter, which is used to connect to the local network for the transmission of data. Arduino Wi-Fi shield with built-in SD support was used for the transmission of data.

3.2.3.2 Real-time clock

The DS1307 serial real-time clock (RTC) is a low power, full binary coded decimal (BCD) clock/calendar plus 56 bytes of NV SRAM. The address and data are transferred serially through an I2C, bidirectional bus. The clock and calendar provides detailed information in terms of seconds, minutes, hours, day, date, month and year [19].

3.2.3.3 Storage

Logged data from the sensor is stored in a memory storage secure digital (SD) card and sent to the server. The use of an SD card also helps in recovering data at a later stage if the node hardware failed due to a power failure, and provides backup for the data.

3.2.3.4 Sensor

An analogue signal produced by the sensor based on the measurement detected is converted into a digital value using analogue to digital converters for the microcontroller to process further. The machine's power usage can be monitored by means of a CT placed on the power lines. This helped to determine when the machine was in an operational state. Figure 3.2 below shows the 100A CT placed across AC power lines for monitoring purposes.



Figure 3-2: Current transformer on alternating current power lines

3.2.3.5 Node hardware

The node hardware is made from three-layer polychlorinated biphenyl (PCB) as shown in Figure 3.4 in order to save space, and includes an Arduino Uno microcontroller, Wi-Fi shield with SD card support and a third custom-designed PCB for RTC and a sensor connector as shown in Figures 3.3 and 3.4.

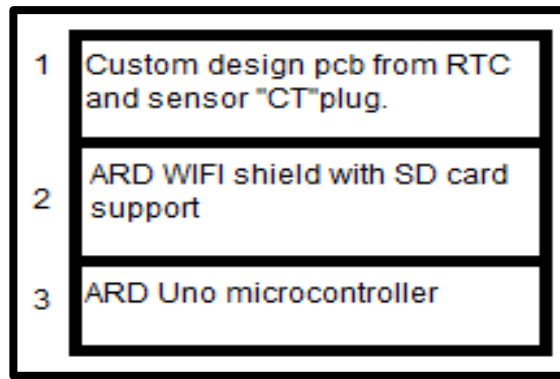


Figure 3-3: Node 3 design block diagram

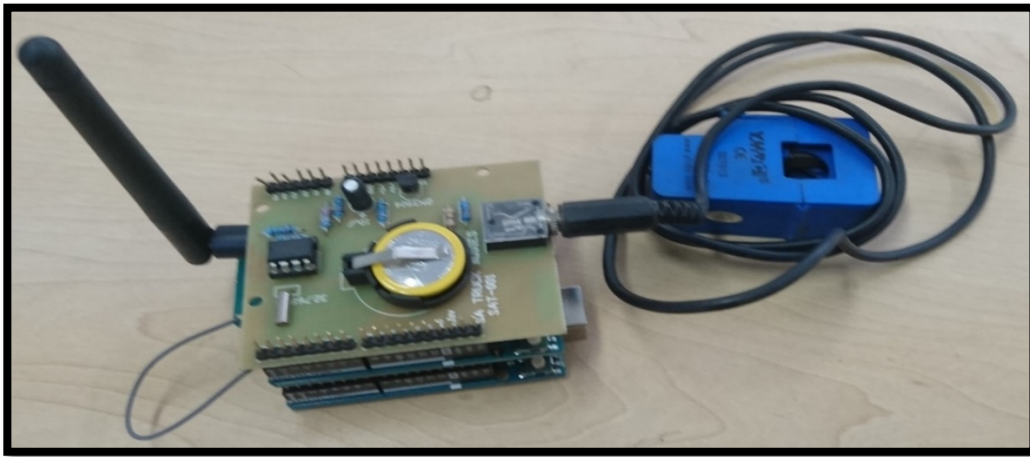


Figure 3-4: Node hardware design

3.3 Node transmission protocol

The node is responsible for sensing power consumption using CT, logging sensor data and transmission of data. These three responsibilities will be discussed in this section.

3.3.1.1 Power measurement

The microcontroller controls the data logging operation of the node. It can be used for instance, if a welding machine is monitored in order to calculate its efficiency during a specific period. The total time during which the welding machine is in operation is important in order to calculate power consumption efficiency. The operating state can be determined by monitoring the power consumption using a CT placed on the power line of the welder. The microcontroller monitors the output from the CT sensor. This concept is discussed in detail under section 3.4.1.

3.3.1.2 Data storing and transmission method

Transmission plays a vital role as any error in this will directly affect the final output. The two main transmission protocols, Real-time transmission and the Algorithmic transmission method (the proposed method) are discussed as follows.

3.3.1.2.1 Real-time transmission

The real-time transmission protocol requires the wireless node to transmit sensor readings (e.g. current reading for CT) in real-time and requires the server to log and represent the data. For the test, LabVIEW™ can assist in the design. Software is designed as listed below to display the wireless node transmitter's current value. Key indicators are as follows and shown in Figures 3.5 and 3.6.

1. Machine operation active state
2. Machine idling state
3. Connection lost state
4. Wireless node IP address
5. Current reading for the sensor
6. Graph to display output

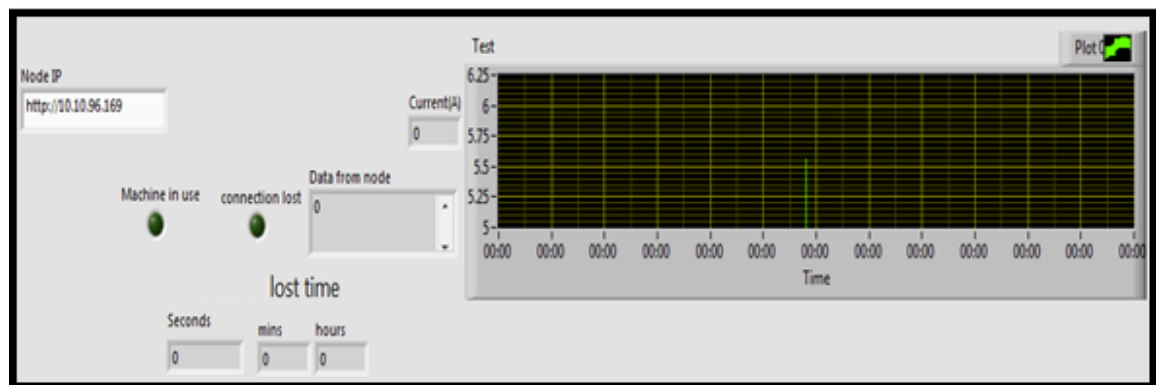


Figure 3-5: Front panel real-time transmission

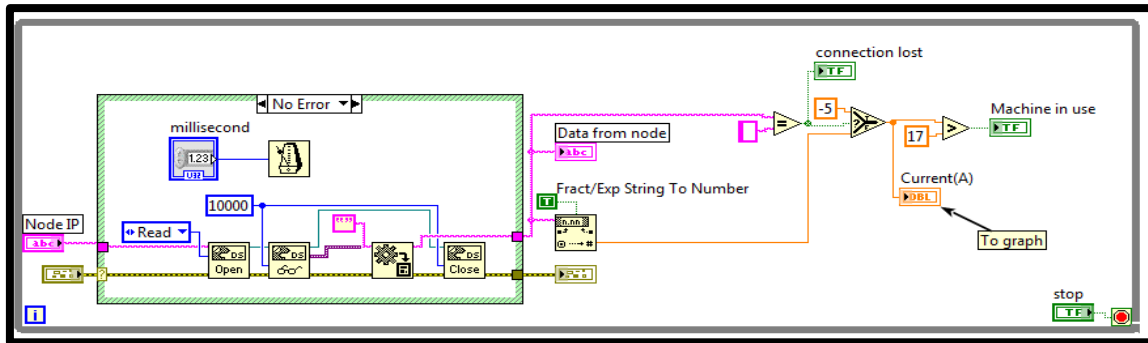


Figure 3-6: Block diagram real-time transmission

The block diagram in Figure 3.6 can assist in determining the real-time transmission protocol performance. The graph can give a good indication of the current value received and can display connection lost status. Results and outcomes of this process are mentioned in chapter 4.

3.3.1.2.2 Algorithmic transmission method (proposed method)

For energy or power consumption monitoring, the user typically requires the data at the end of the day or during the day at different intervals. The user or manager normally requires a summarised report at the end of each day for efficiency calculations. This means that real-time data logging is required; however, a delay in the transmission of data is feasible in such a system. A wireless node can log the energy consumption data continuously and only transmit it when requested by the server. This will require some updates and modifications on the node programming, as discussed in the next section. The server also should be able to determine the best time interval to receive the logged data.

3.3.2 Algorithmic transmission operation

The node must be able to store the logged sensor data in the SD card and only transmit it when requested by the server. The size of the transmitted file affects the duration of the network connection required for transmission; to shorten the duration of the network connection needed, data must be processed at the node.

To summarise the two main changes at the node side:

- Data processing at node

- Data transmission on request

3.3.3 Data processing and storage at node

In order to reduce data file size for transmission, the data logging from the sensor must be processed simultaneously. One way this can be achieved is by only logging the events when the machine is in a working state, and not when it is in an idle state. This method can reduce the data file size significantly. For example, if a welding machine is monitored to calculate efficiency, the main concern is the working state of the machine. The working state can be determined using a CT sensor placed on the supply of the machine. Figure 3.7 below shows the node sample code; in this case, the working state power consumption was determined to be 6 amps and data logging function “logToSD” is only called if the amps determined from the CT sensor were greater than 6 amps.

```
const int numReadings = 30;
float readings[numReadings]; // the readings from the analog input
int index = 0; // the index of the current reading
float total = 0; // the running total
float average = 0; // the average

float currentValue = 0;
total= total - readings[index];
readings[index] = analogRead(0); //Raw data reading from sensor pin
readings[index] = (readings[index]-510)*5/1024/0.04-0.04;
//Data processing:510-raw data from analogRead when the input is 0;
//5-5v; the first 0.04-0.04V/A(sensitivity); the second 0.04-offset val;
total= total + readings[index];
index = index + 1;
if (index >= numReadings)
    index = 0;
average = total/numReadings; //Smoothing algorithm
currentValue= average;

if(currentValue>=6)
{
    LogToSD();
}
    delay(30);
}
```

Figure 3-7: Node microcontroller code

Figure 3.8 and Table 3.1 summarise the concept of processed data transmission versus unprocessed data transmission. The end result of both transmissions is similar; however, processed data transmission can only be performed by the algorithmic transmission method as in real-time transmission, the node s transmits to the server continuously. Each transmission method depends on the application required. For example, raw data transmission will be required in applications where a quick response is needed, like a medical apparatus monitoring heartbeat. On the other hand, applications such as power efficiency monitors and attendance clocking systems, where the data is not required in real time, can use a different transmission method.

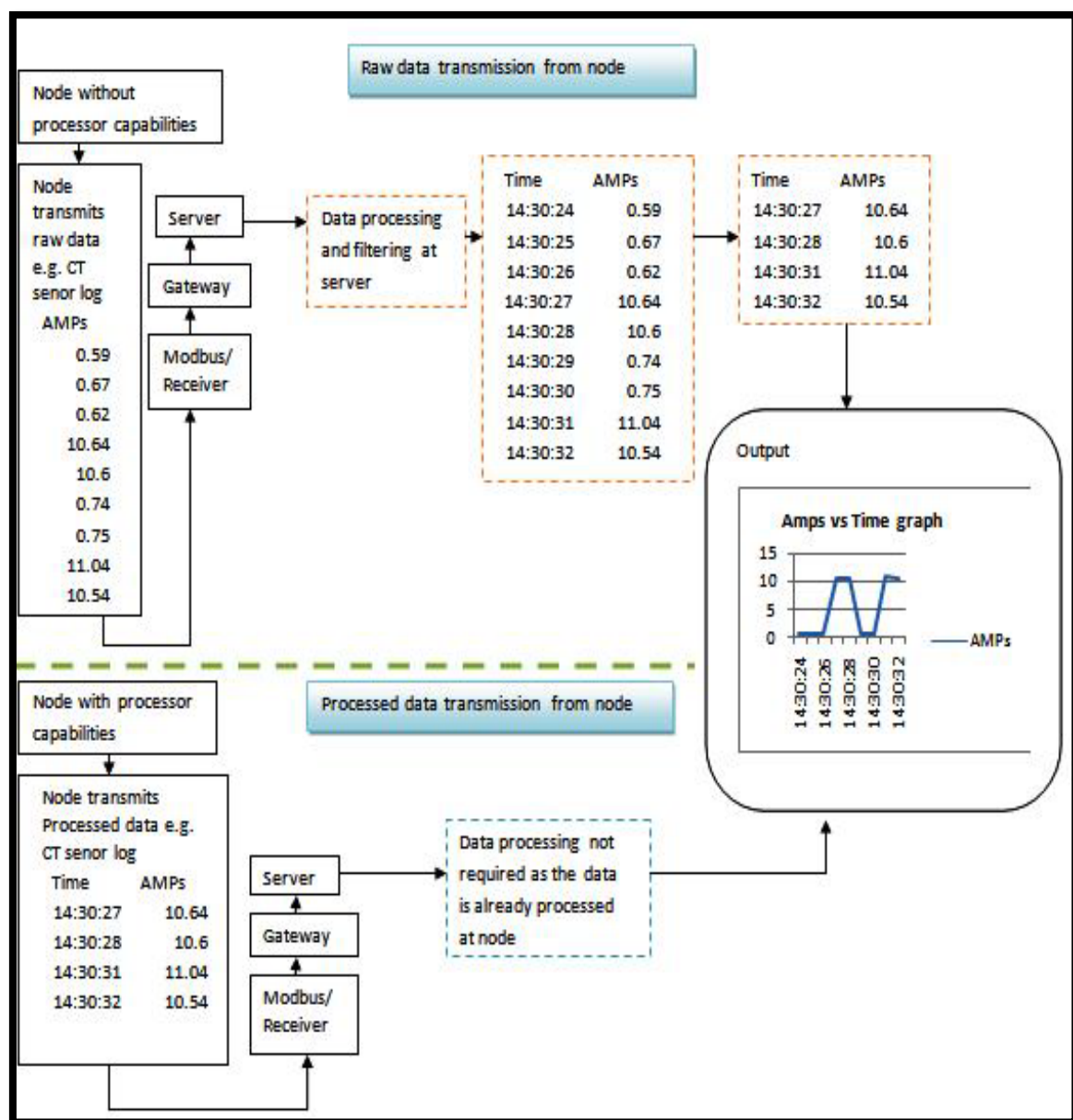


Figure 3-8: Data transmission techniques

Table 3-1: Data transmission methods

Unprocessed data transmission from node	Processed data transmission from node
Real-time system update, as data is processed in real time as received from all the nodes at server.	Delay in systems update as the data is received from the nodes at different intervals
As the number of nodes increases, higher server processing is required	Not affected by the number of nodes
Uses higher network bandwidth as unprocessed data received from nodes	Less network bandwidth used as only the processed data is transmitted; less data processing required at server
If connection drops data is lost	Not affected if connection drops as processed data is stored at node

3.3.4 Data transmission on request

The processed data in the storage SD card needs to be transmitted to the server. Figure 3.9 explains the node operation required to perform the task. It operates under two protocols, transmission mode “green” and normal mode “orange”. When the transmission request is received from the server, the node starts the transmission process. The transmitting node first communicates the size of the data file to the server and then sends the actual data file. Once the transmission file is sent it waits for the positive feedback from the server before cleaning the storage (Figure 3.9). The server must be able to compare the sent file size with the actual received file size before sending the positive feedback to the node. The server software design will be discussed in the following sections. During the normal mode process, the node continuously checks the sensor reading to determine the working state and when the reading is higher than the set value (amps), it stores the time events in the SD file.

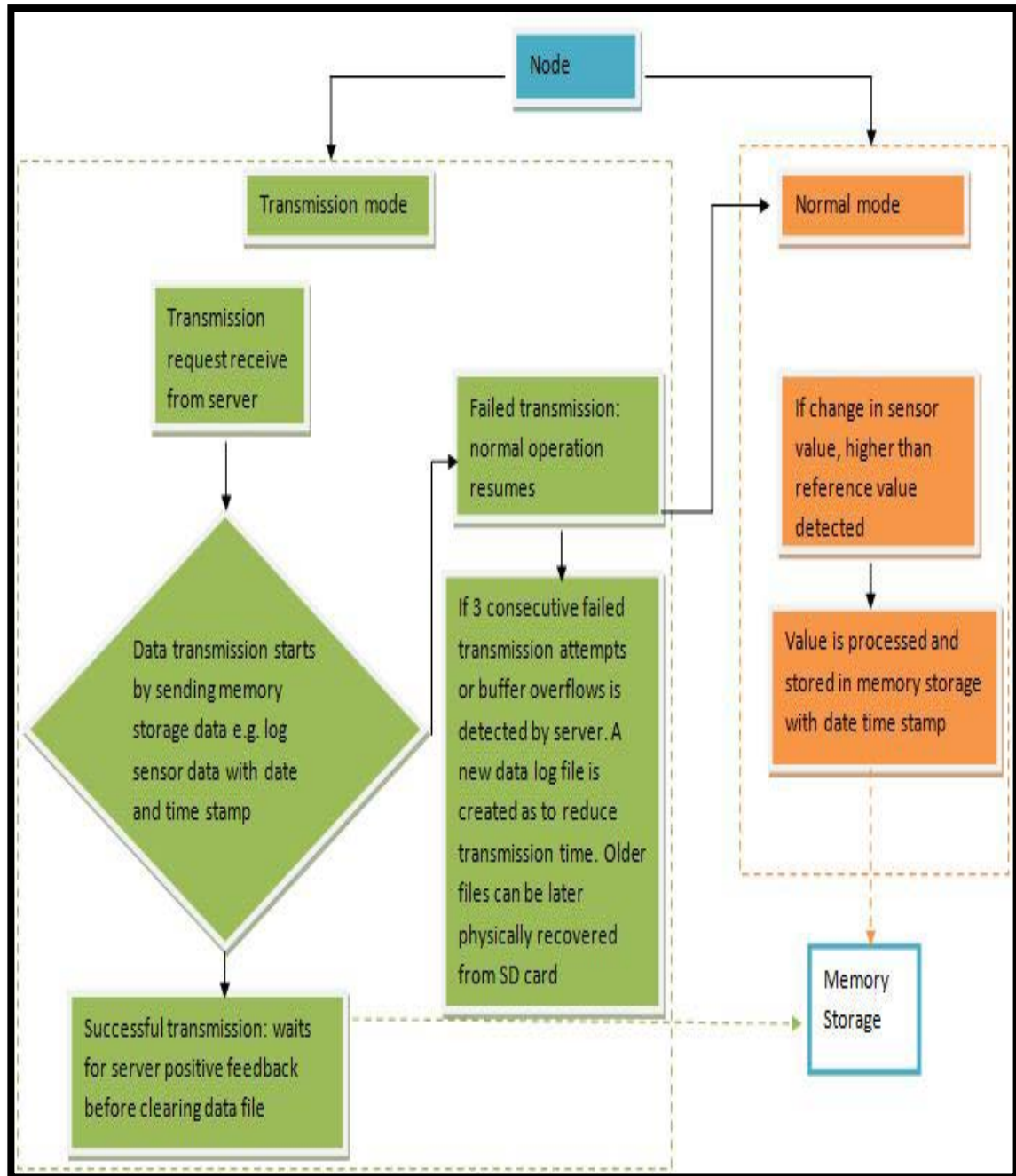


Figure 3-9: Data processing at node

3.4 Receiver's design techniques and technical approach

LabVIEW™ can be used in the design of receiver/server software where the nodes' data is received. In Section 3.2.2 the following key points mentioned as critical to the design of the receiver's software.

- **Identify node connection status:** As was discovered in [9], ping can assist in determining the connection status of the node. Whether or not this information can be used to predict if successful data transmission can occur is to be tested.
- **Verification of data from node:** The software should be able to communicate with wireless nodes to verify successful transmission feedback.
- **To allow for fast and easy scalability of the system:** The software should be able to communicate to wireless nodes in a multiplex method to allow for better scalability of the system.

The design is divided into three sections as indicated by the block diagram below, with each section performing a specific task (Figure 3.10). Data receiving and verification sections consist of the key points mentioned above and the rest of the software section depends on the data collected from there.



Figure 3-10: WIMS software data flow block diagram

3.4.1 Data receiving loop

Each wireless node receives a unique IP address from the Dynamic Host Configuration Protocol (DHCP) server, which can be used to ping the wireless node and determine connection status and strength. Figure 3.11 below shows a section of the design of LabVIEW™ software using the ping functional block with the key point explained as follows.

1. Number of times wireless node to be pinged (e.g. 6).
2. Set the ping timeout/ response time
3. Ping function with wireless node IP address as the input
4. Calculates the number of times wireless node pinged
5. Displays the pinged status for the user
6. Displays the number of unsuccessful pings
7. Successful pings required before data receiving can occur from a wireless node; e.g. If a wireless node is pinged six times, the software must only receive the data if a minimum of four of the pings were successful.

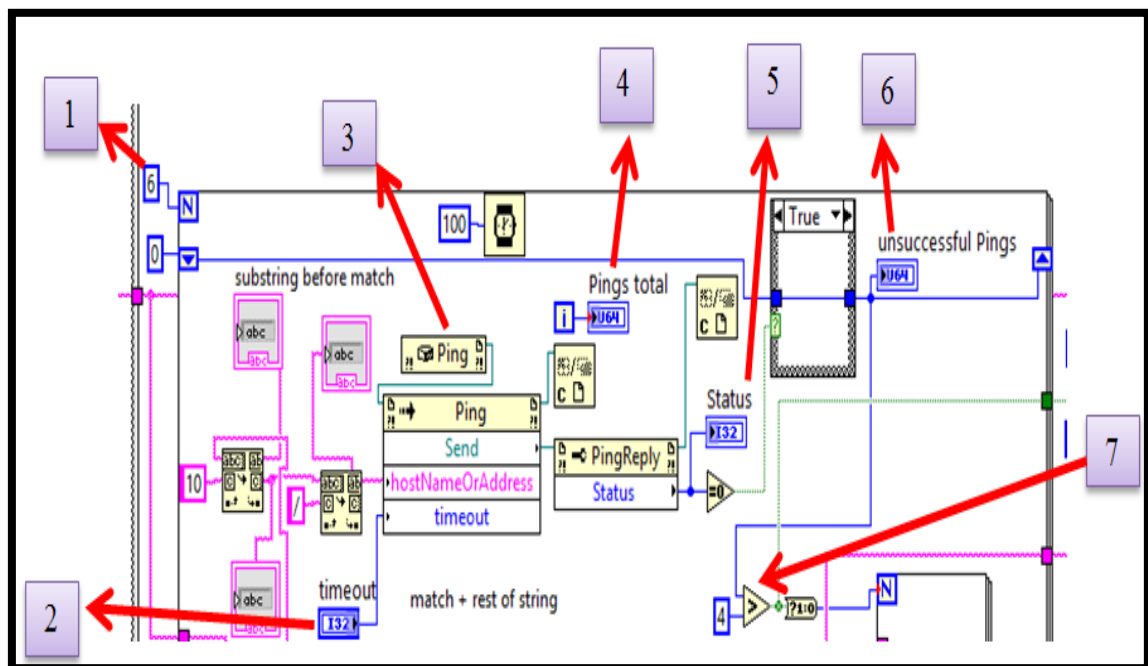


Figure 3-11: LabVIEW™ ping loop

The next step of a positive ping status is data transmission. The wireless node can transmit data file size initially, which can be used to verify data size after transmission is finished. The data received is stored as a Comma Separated Values (CSV) file, which will be discussed in the next section regarding the software responsible for the sorting and representation of data. Figure 3.12 indicates the sequence of events that can occur during the data receiving and verification loop.

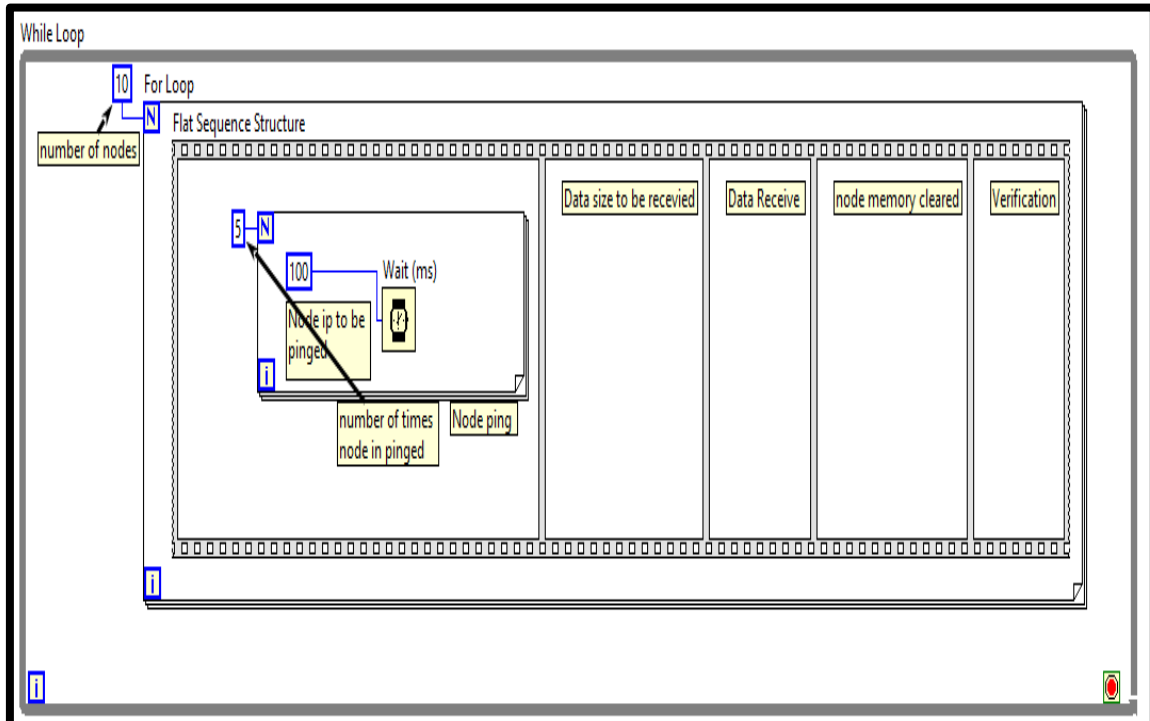


Figure 3-12: Data receiving loop

3.4.2 Data sorting loop

The main purpose of this section of software was to scan every data entry stored in the CSV file of each wireless node. Wireless nodes store each data entry with a current data time stamp which is used to check the data for errors. This can range from receiving the previous day's data due to a power outage at the node side to data received only on the current day. Below is the overview block diagram for the section of software with an explanation of key parts as follows (Figure 3.13):

1. File pathway for the node CSV file
2. Each data entry forwarded to scan for errors

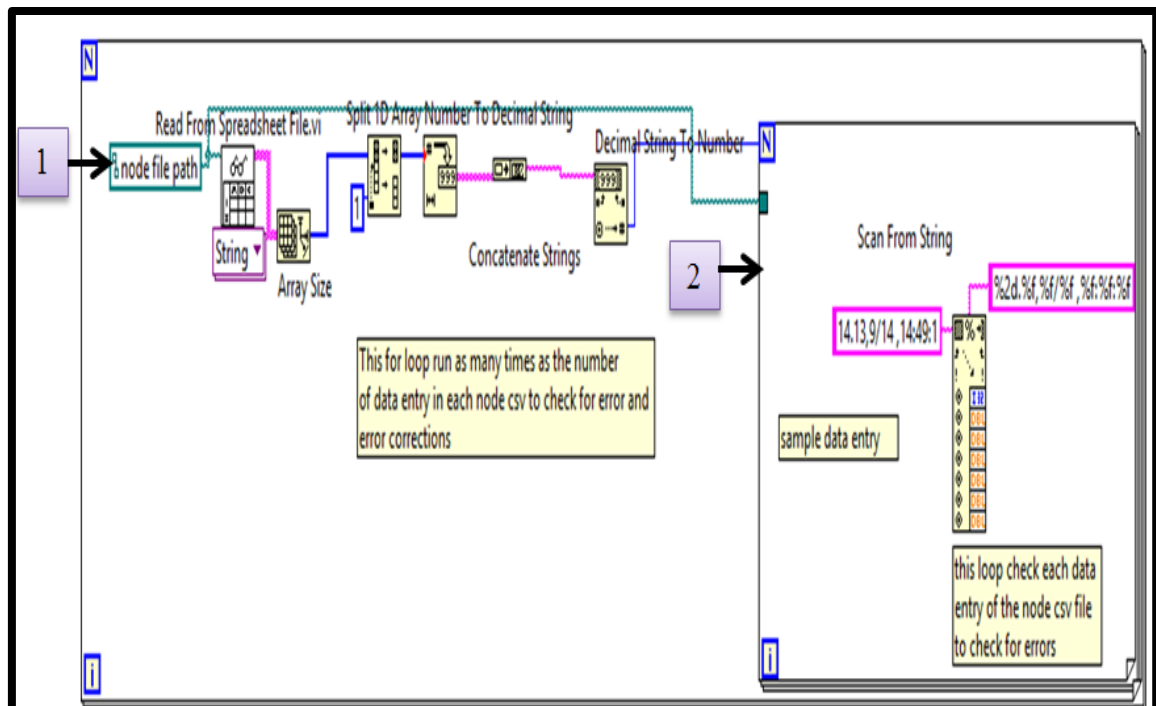


Figure 3-13: Data sorting

3.4.3 Data representation loop

Once the data is sorted and checked for errors, as discussed in the previous section, it can then be used for representations and to perform the necessary calculations required. Each node data entry is added in the loop, which then separates it in terms of current value, date and time stamp. This information will then be used to plot the graph. Figure 3.14 shows when each data entry of the node can be separated to be used later (in Figure 3.15) for plotting the graph and performing the necessary calculations.

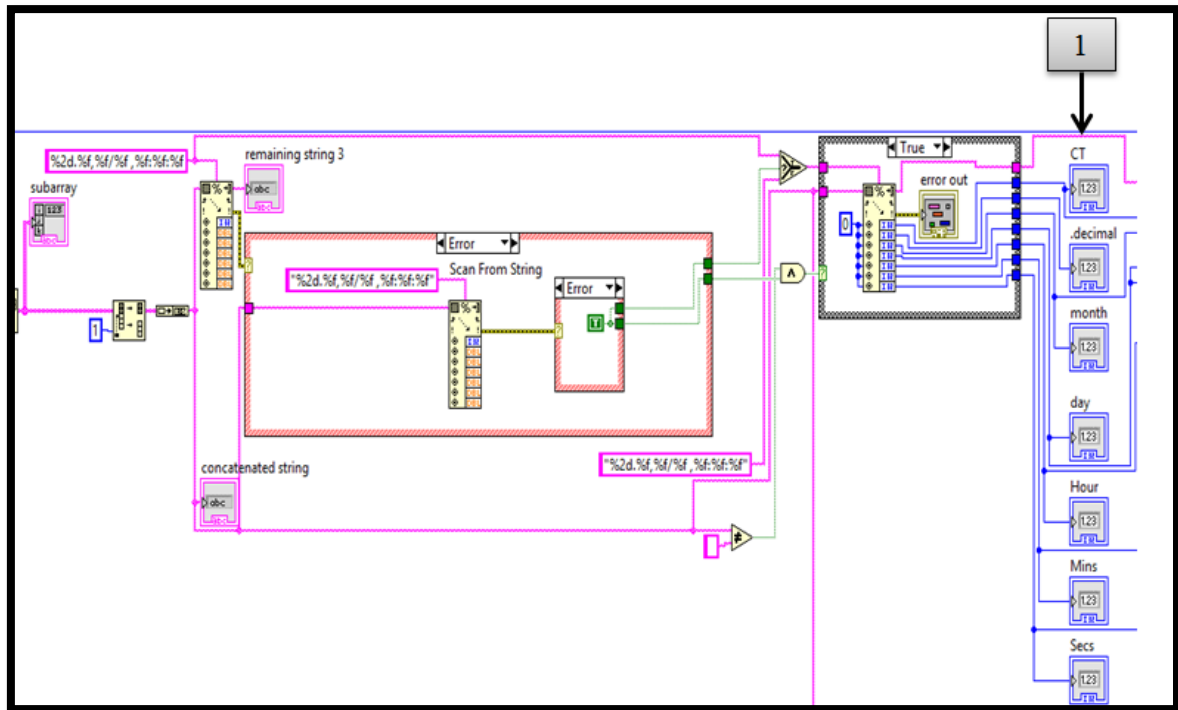


Figure 3-14: Data representation

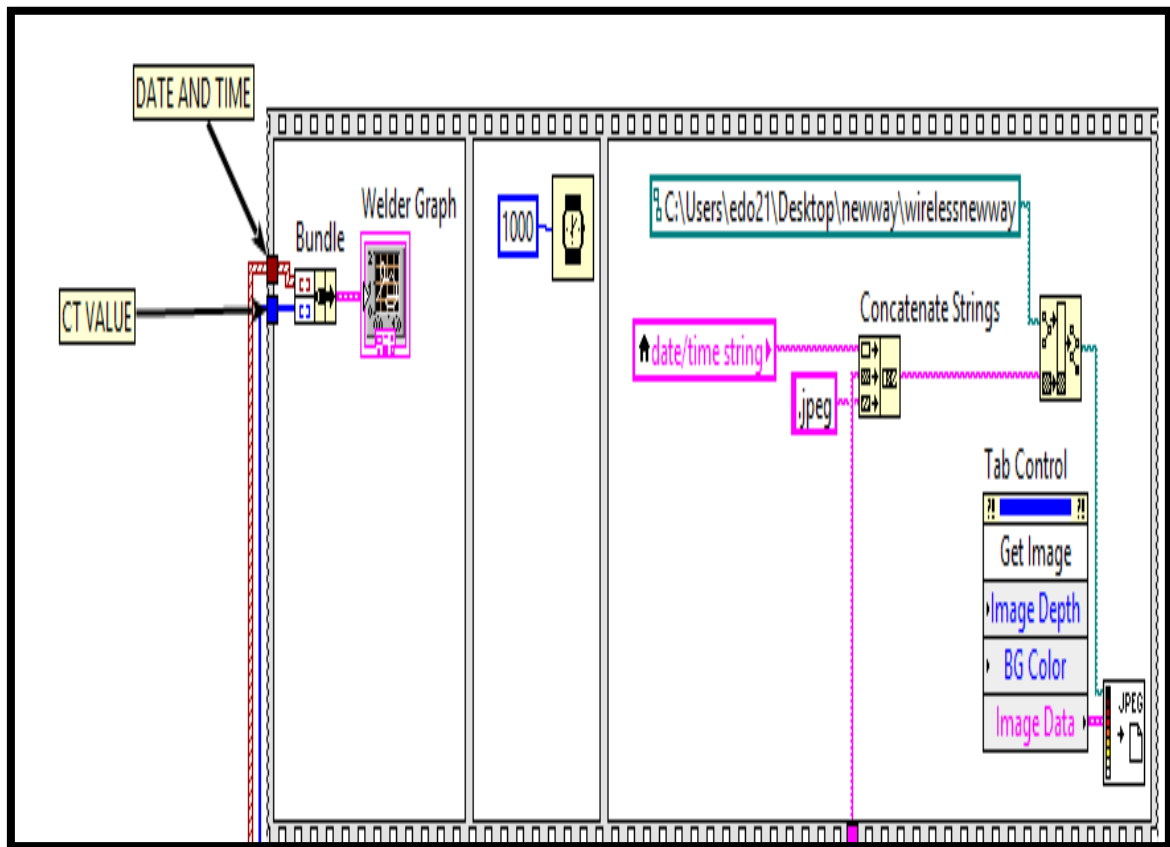


Figure 3-15: Data plotting

3.5 Conclusion

This chapter provided a detailed explanation of the design of a WIMS. The system results and the testing thereof are discussed in the following Chapter 4.

Chapter 4

Testing WIMS Results

This chapter starts by describing EMF noise within the 2.4 GHz Wi-Fi spectrum in a factory environment during production time, the WIMS testing wireless node connection using the pings function, and finally, the representation and testing of LabVIEW™ designed software to display data from wireless nodes.

4.1 Introduction

In the previous section, the design of WIMS was discussed based on different transmission protocols using LabVIEW™ for the software design of the server or receiver and microcontroller-based device used in the transmitter node. Before testing different transmission protocols, the performance presence of EMI noise must be detected.

In this chapter, the following order was followed:

- Testing EMI in the factory
- Testing real-time transmission method (results)
- Testing processed method (results)
 - Data sent
 - Data sorting
 - Data representation
- Final results

4.2 Results of industrial EMI

It is however important to be able to check and measure the presence of EMI in the factory. The spectrum analyser is used to perform a test and to detect noise. Average noise during production hours (welding processes) such as displayed in Figure 4.1 and Figure 4.2 was compared with that during non-production hours as shown in Figure 4.3 and Figure 4.4. Multiple new peak signals are formed during production especially where

welding is taking place. This EMI can significantly affect data transmission or disrupt the data carrier signal.



Figure 4-1: Spectrum analyser industrial environment test

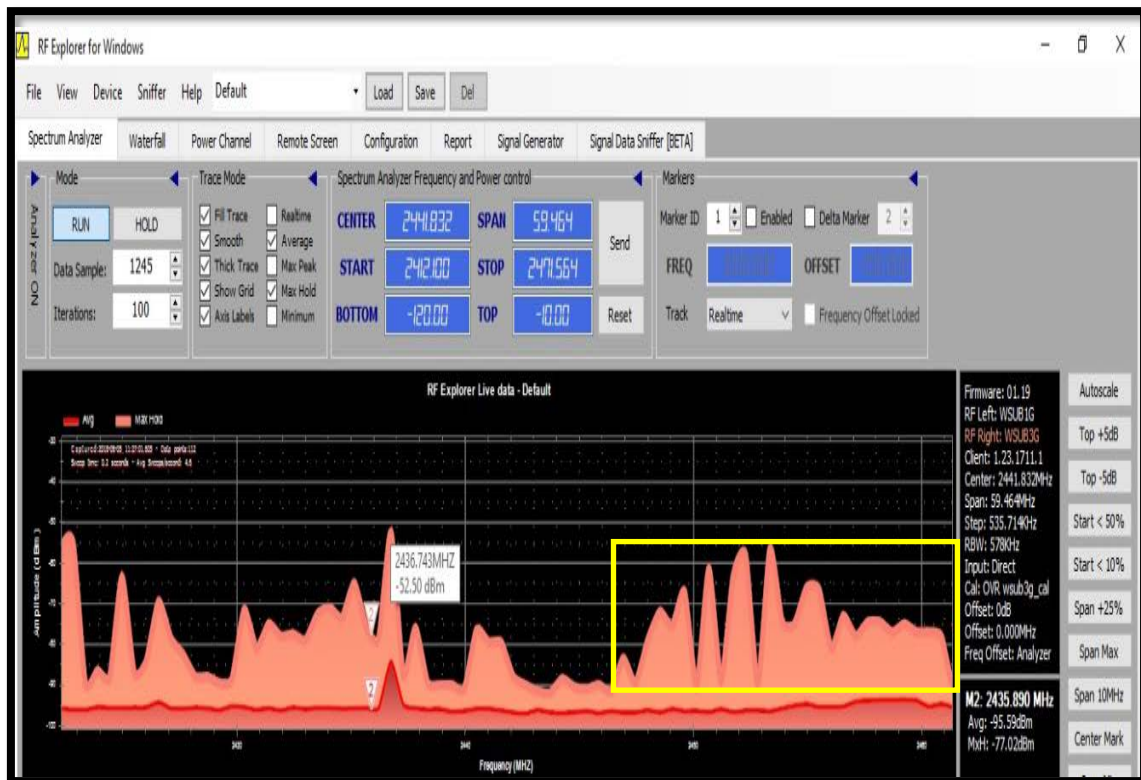


Figure 4-2: Average noise during welding process



Figure 4-3: Spectrum analyser indoor environment test



Figure 4-4: Average noise during non-welding process

4.2.1 Data effected EMI

Data noise plays a vital role as it affects the quality of the data received. By pinging the wireless node before receiving the data, it was discovered that the nodes which had a higher rate of successful pings had better data quality and got full data recovery from the wireless node.

Figure 4.5 on the left hand shows a wireless node with a unique IP address which was requested for data transmission even after unsuccessful pings. Noise can be seen in the recovered data and only 38% of the data was received. Figure 4.5 on the right hand shows the same node pinged; however, this time it had a successful pinged output, and it can be seen that the data was recovered without noise and the full data file size was received.

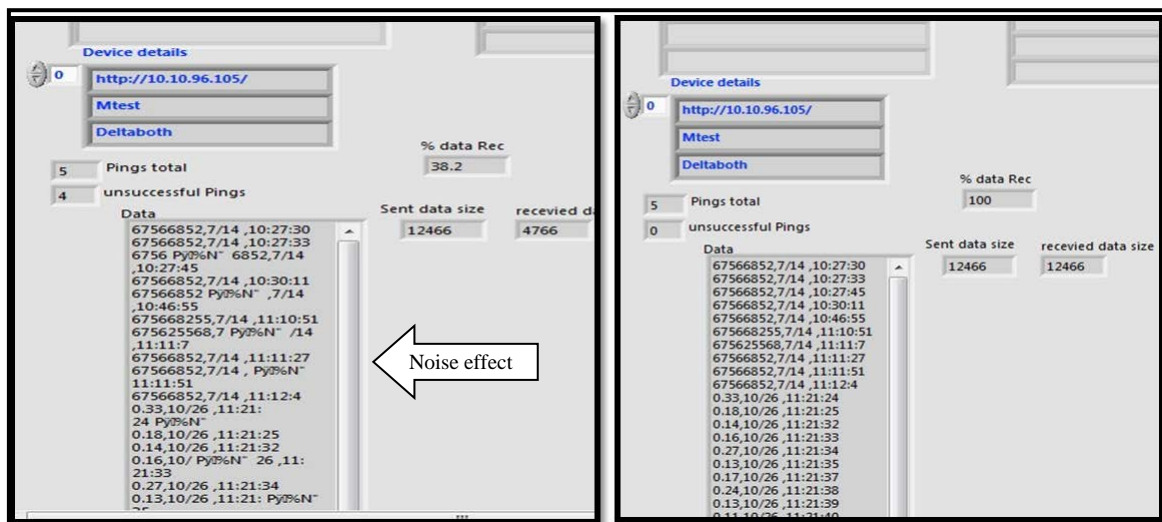


Figure 4-5: Data with received with noise vs. Data received without noise

4.3 Results

The industrial wireless monitoring system is being tested at SA Truck Bodies branches across South Africa, including in Bloemfontein and Cape Town. Following are the results from testing WIMS:

4.3.1 Node status monitor

Figure 4.6 shows a virtual designed layout using the Mikrotik “The Dude Network Monitor” free software [9]. Each block indicates a node in green and red colour. Nodes are pinged at certain intervals and depending on the feedback from the node, the block turns green for positive feedback and red for negative.

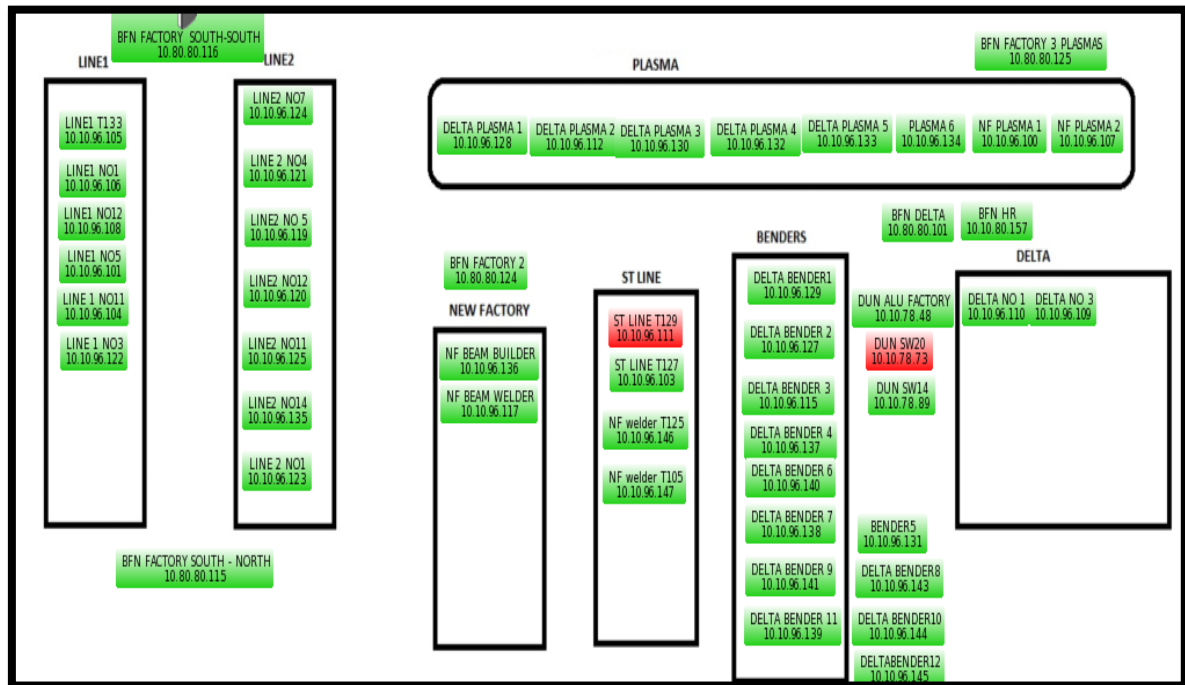


Figure 4-6: Node status monitor

4.3.2 Real-time transmission test

To test real-time transmission with the designed software and hardware as discussed in Chapter 3 to test the real-time transmission to check data lost occurrences, and to calculate connection lost time under different conditions, the following tests were performed:

- Low EMI test indoor
- High EMI test production plant (welding)
- Ping test

4.3.2.1 Indoor low EMI

Figure 4.7 show the wireless node hardware as discussed in Chapter 3 which was installed across an uninterruptible power supply (UPS) supply line indoors with low EMI. The test was performed for around one hour with a connection lost time of 17 seconds. The graph was plotted indicating current vs. time, with below zero readings indicating connection lost (Figure 4.8).



Figure 4-7: Node for real-time monitoring with CT on Live wire

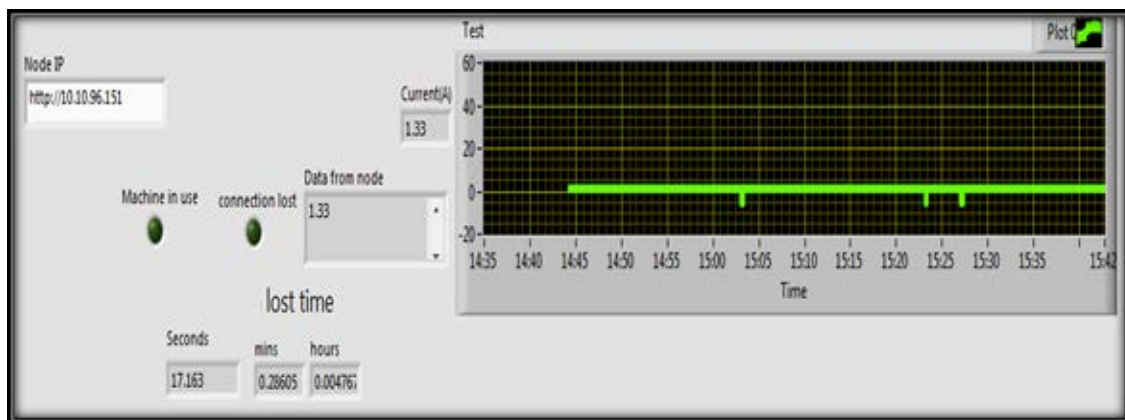


Figure 4-8: Graph for low EMI wireless node performance

4.3.2.2 Outdoor low EMI

A wireless node with similar hardware as shown in Figure 4.7 was installed in a computer numerical control (CNC) plasma machine to log power usage at a production plant, as it was discovered that during production hours there is a high presence of EMI, as indicated in Section 4.2. The connection lost time for around one hour was 231 seconds (3.8 minutes). This is 92% higher than in an indoor environment with low EMI (Figure 4.9).

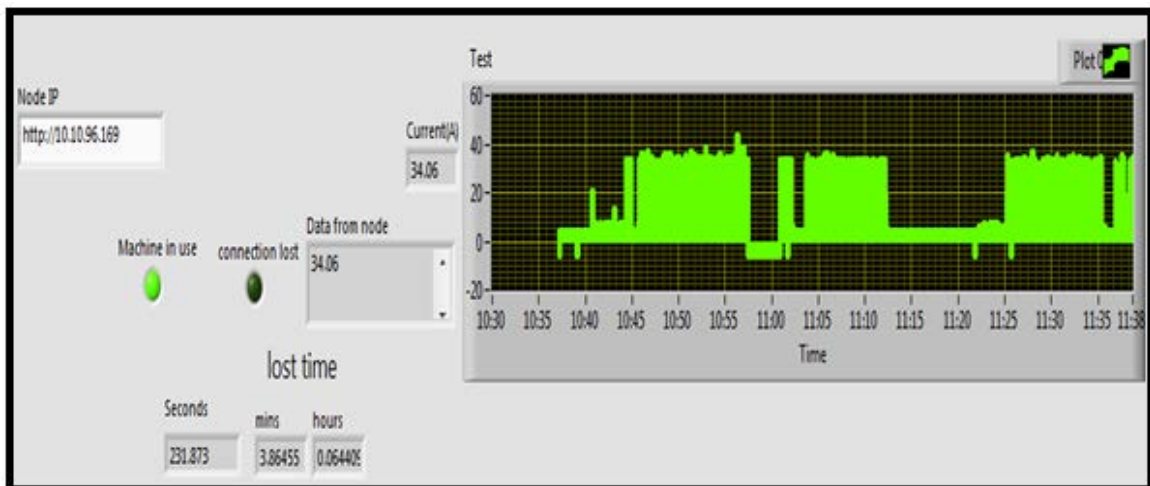


Figure 4-9: Graph for high EMI wireless node performance

4.3.2.3 Real-time ping test

To perform the test, a few wireless nodes are placed in the factory while connected to the wireless network. The node connection status is tested at regular intervals using ping function to determine the device's average response time and connection status using Windows' built-in standard command prompt. The test was performed at SA Truck Bodies' production facility (Table 4.1).

Table 4-1: Real-time transmission test

Time(24h)	Ping response time (average) milliseconds (ms)	No. of time ping lost
Shift 1 (07:00 – 9:20)	1521 ms	15
Tea break (09:20 – 09:40)	5 ms	1
Shift 2 (09:40 – 13:00)	1978 ms	21

Lunch (13:00 – 13:30)	6 ms	0
Shift 3 (13:30 – 16:30)	1607 ms	18

The results pointed out a few factors. There is a connection between ping response time and EMI noise generation during production time vs. non-production time. The results also showed that if the node communicated in real-time in the current scenario, data loss will occur, especially during production time due to the higher number of pings lost.

The solution can be obtained by improving hardware both on the transmission and on the receiver's side. However, it is difficult to change the entire industrial communication hardware just to support the system's need. An alternative solution is required which does not affect the current network setup and which ensures that the least amount of data is lost. As it was discovered that real-time communication would not be possible in a high EMI environment using the standard Wi-Fi medium, an alternative solution was needed to overcome or reduce data lost.

4.3.3 Algorithmic transmission method test

The algorithmic transmission test was performed with similar hardware to that used in real-time, only with an updated microcontroller code and server software as discussed in Chapter 3. The system was tested in the following order:

- Testing processed data transmission
- Data receiving and sorting loop
- Data representation

4.3.3.1 Processed data transmission

To test the proposed algorithmic transmission test, a closed circuit television (CCTV) camera was installed. The node with updated code was installed in a welder to be monitored. The main purpose of this was to check and compare that only the working state events are logged on to the SD card. The data is stored in terms of time events; each event contains sensor readings (amps) and date time stamps e.g. (amps, month/day, hours, minutes and seconds). Figure 4.10 shows a time event logged at 9:51:16 and the next one

was logged at 9:51:29. The time in between was not logged as the machine was in an idle state.



Figure 4-10: Testing node data processing concept

4.3.3.2 Receiving and sorting data

Data receiving with the ping test to assist in its success was done using the LabVIEW™ designed software discussed in Chapter 3. The test was performed 15 times to check if there was a relationship between data received vs. ping success rate as shown in Table 4.2, Figures 4.11 and 4.12. The relationship between data received and the ping success rate was found.

Table 4-2: Algorithmic transmission test

Test	pings (6)	Ping successful %	% data Received
1	5	83.33333333	99
2	6	100	100
3	5	83.33333333	98
4	6	100	99
5	6	100	97
6	6	100	98

7	2	33.33333333	10
8	5	83.33333333	97
9	5	83.33333333	99
10	6	100	99
11	5	83.33333333	96
12	4	66.66666667	70
13	1	16.66666667	30
14	6	100	98
15	5	83.33333333	100

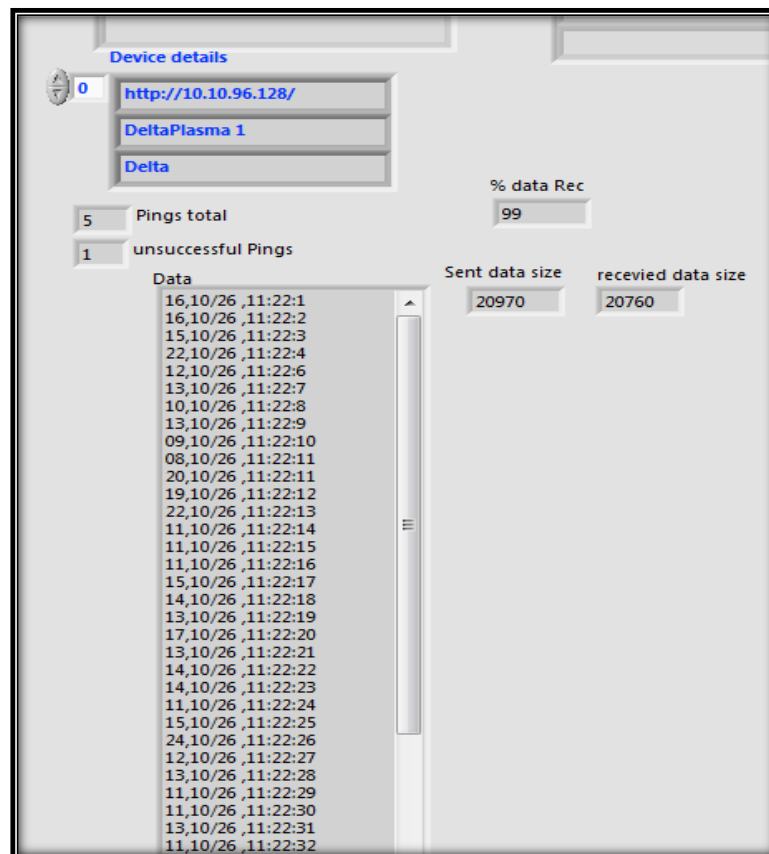


Figure 4-11: Algorithmic transmission LabVIEW™ front panel

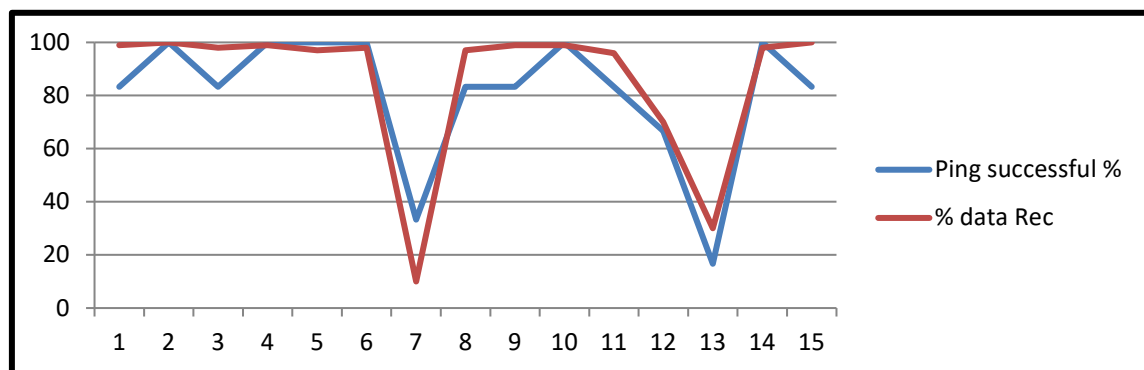


Figure 4-12: Ping success vs. % data received

4.3.3.3 Data representation using LabVIEW™

LabVIEW™ was used to perform the efficiency calculations and generate a real-time graphic view. Figure 4.13 shows the operation durations during each shift, and start and stop times for the beam welder machine used, based on different shifts and a real-time graph. The colour green indicates the different intervals at which the machine was operated. Figure 4.14 shows a summarised efficiency report of the nodes using the *write to spreadsheet* function in LabVIEW™ to meet the company’s specifications in terms of minutes, using a welding machine operation during a shift, specifically in the period from 7:00 am until 9:20 am.

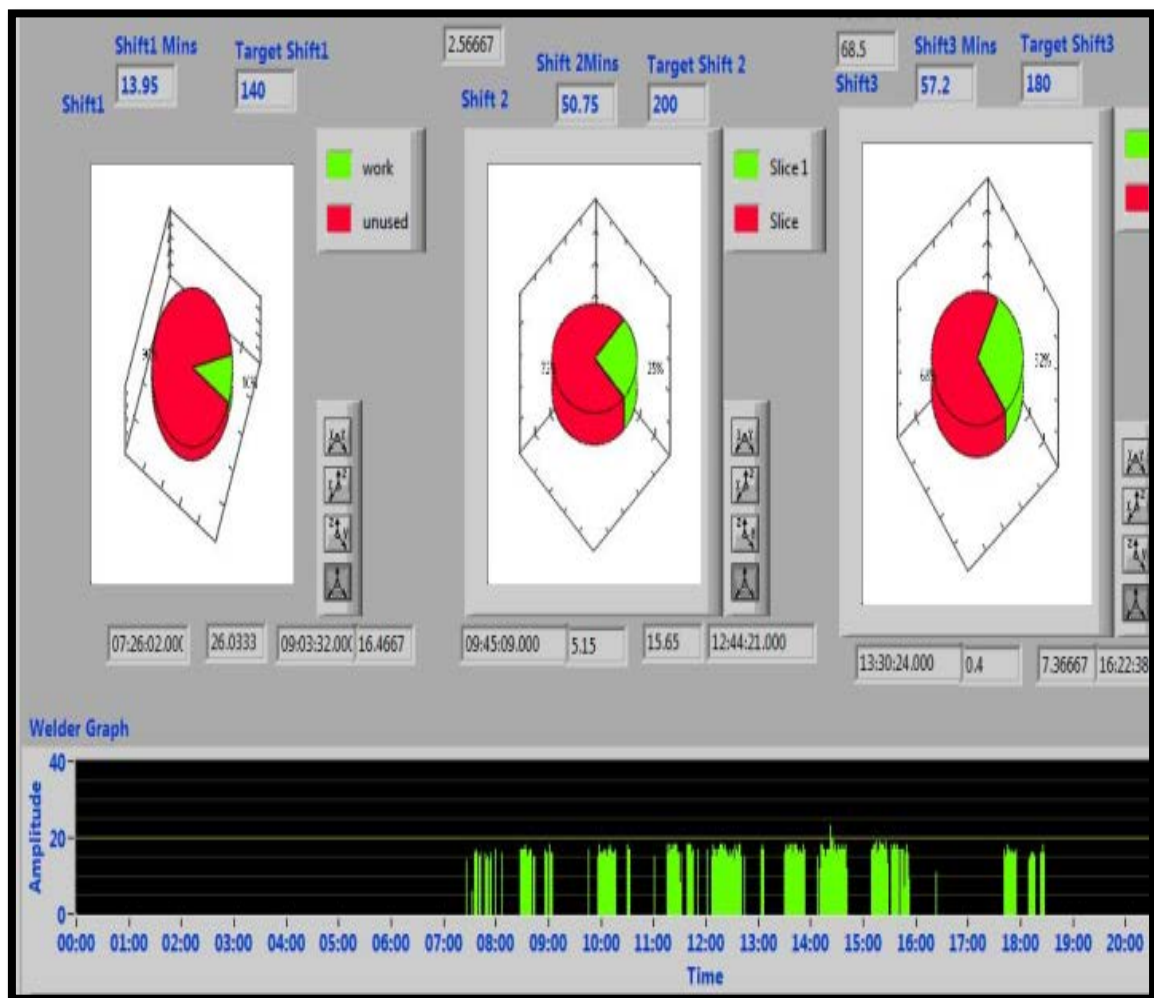


Figure 4-13: Summarised report in LabVIEW™

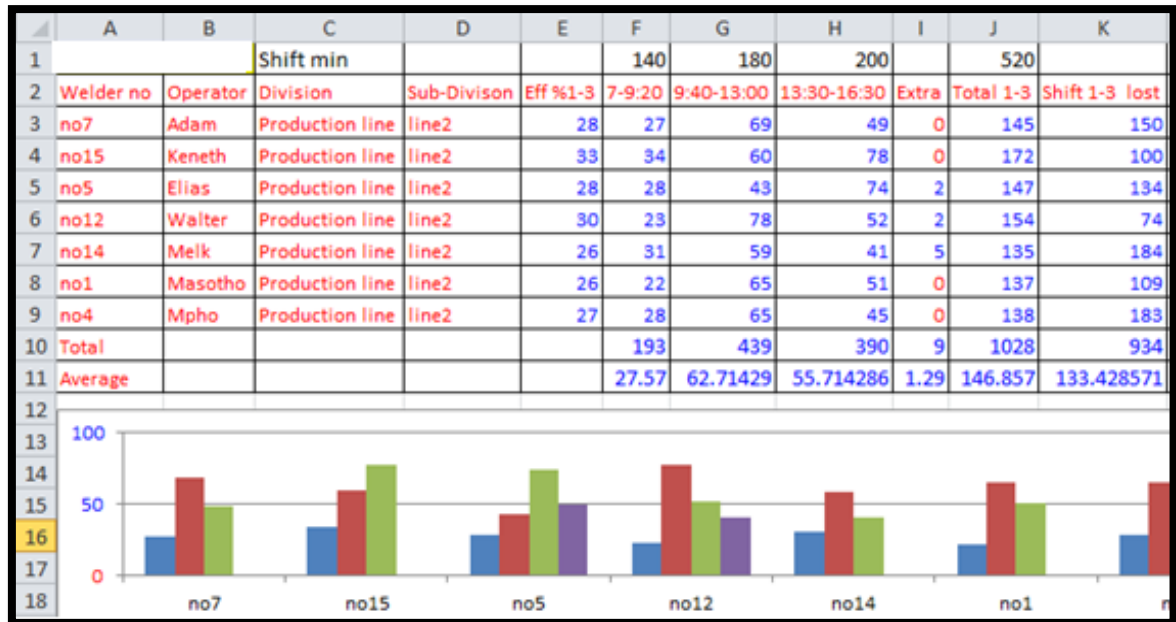


Figure 4-14: Summary report of a welding station

4.4 Energy saving

The wireless nodes were installed at different locations in different types of machine. With one wireless node installed at a bending machine, energy usage was monitored and showed a constant working state during the night shift (Figure 4.15). There was an error as a bending machine only pulls high current (10-15Amps) during the bending process, which is for a few seconds and low current (2-3Amps) can be measured when the machine is in an idle state. The investigation revealed that the foot pedal switch, which is pressed during the bending process, had a malfunction. This caused the bending machine to be in a working state continuously and to waste energy. With the assistance of the system, this issue and many other related issues were discovered.

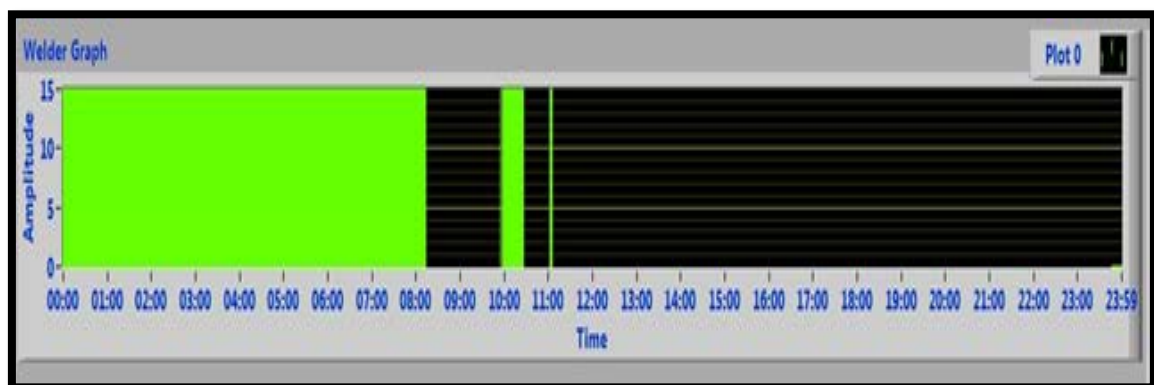


Figure 4-15: Energy saving

4.5 Conclusion

In this chapter, WIMS testing and its results were discussed. The tests were performed considering EMI in a factory during production versus an indoor environment using a spectrum analyser. A high presence of EMI was found during production hours and affected real-time data transmission. It demonstrated that transmission delay is affected by EMI as discussed in Section 2.4 with ping response time (average) longer during high EMI periods Table 4.1. The processed algorithmic transmission method proved to be a capable alternative solution in successfully receiving data in a high EMI environment.

Chapter 5

Conclusion

This chapter summarises the contributions of this dissertation and possible directions for future research.

5.1 Summary

This research focused on a different approach to designing a wireless industrial monitoring system using the standard wireless communication protocols for applications where real-time transmission is not required.

The research also focused on giving processor abilities to the nodes, which in turn provides nodes with the ability to process raw data before transmitting it to the server in a multiplexing structure using LabVIEW™. By receiving data in a multiplex medium, the server can communicate with many nodes without any real deficiency. As the number of nodes increases, the delay in the system update period will increase. This type of solution is suitable for an application where real-time data presentation is not required, for example power usage data from CT sensors incorporated at individual nodes. These nodes can communicate information at a specific time of day for time management and regarding electricity usage for efficiency calculations.

The server processor productivity proposed is high enough to allow simulation of a real-world setup under real-world conditions in a reasonable time and using reasonable computational resources.

The aim of the research was to design and implement a wireless industrial monitoring system that can overcome the communication challenges in an industrial environment, using existing Wi-Fi technology. Considering the node-response time using the ping method before receiving data in LabVIEW™ proved to be an efficient solution. The system designed can communicate with an unlimited number of nodes using a multiplexing method. This was done by giving processor and storage capabilities to the

nodes, assisting in sending processed data to the server, and thus reducing transmission time and processor usage on the server side. This could be implemented in industrial applications that require wirelessly logged real-time data from sensors and where a minor delay in data update is acceptable. The system proved to be ideal for applications such as attendance and clocking systems. This system worked efficiently for SA Truck Bodies which monitors different machine efficiencies using the power usage data from nodes and only requires an efficiency report at the end of each day.

5.2 Future research

The aim of this research would be testing data transfer techniques used in WIMS on different applications like attendance clocking systems to reduce data lost under high EMI. This system can be implemented using different hardware and software solutions. The exciting WIMS can be developed further with an interface to a cloud server or Internet of Things (IOT), allowing for remote access worldwide.

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Appendix

Reliable Wireless Data Transfer in High EMI Environments Using LabVIEW

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Abstract—Recently, industrial wireless communication had many developments in upgrading transmission to conquer Electromagnetic interference “EMI” in an industrial environment. Many industrial monitoring systems available in the market work on real-time communication by nodes for data logging that has restrictions on the number of nodes that it can support depends on system’s processor potential. This research focuses on a distinct approach to design a wireless industrial monitoring system using LabVIEW, which is not limited to the number of nodes, with real-time data logging at nodes and data transmission with environment EMI consideration. In addition, a wireless monitoring system where delay in system update is acceptable until real-time logged data is been archived.

Keywords— EMI; monitoring; LabVIEW; nodes;

I. INTRODUCTION

Many wireless industrial monitoring systems are available in the market with a similar concept as displayed in Fig 1. Multiple wireless nodes are placed across the factory floor, which transmits the data from the sensors to a gateway that then send the raw data to a central server which execute all the processing and monitoring functions [1].

The downside of these current systems is that as the number of nodes increases, a processor with higher performance will be required to process data on the server side. This procedure provides an optimal solution if real-time monitoring is needed.

This research focuses on giving processor abilities to the nodes that in turn provides nodes to process raw data before transmitting to the server in a multiplexing structure using LabVIEW. By receiving data in a multiplex medium, the server can communicate with many nodes without real deficiency. As the number of nodes multiply, the delay in the system update period will increase. This type of solution is suitable for an application where real-time data presentation is not needed, for example power usage data from current transformer (CT) sensors incorporated at individual nodes communicating at a specific time of day for time management and electricity usage for efficiency calculation.

The server processor productivity proposed is high enough to allow simulation of real-world setup under real-world conditions in a reasonable time and using reasonable computational resources [2].

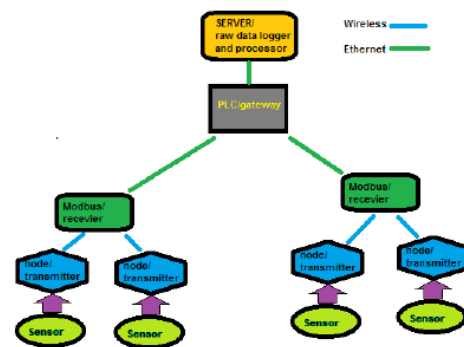


Fig. 1. System concept layout from sensor communication to server

II. SYSTEM DESIGN QUALIFIERS

Some of the major factors the research focused on are as follows:

A. Physical Design of nodes

The implementation of a wireless monitoring node has a limit on the physical size and requires a robust design because of its location with in equipment. Constrained by the physical size, their memory size is limited and has restricted micro controller capabilities [3].

B. Signal reflection

Wireless data packets have a high penetration rate through drywall, office cubicles, wood and other materials found in our homes or offices. However, Wi-Fi signals reflect off larger objects, metals, and concrete. This reflection can redirect the data signal and return it to the original transmitter, causing an “echo” or “multi-path”.

C. EMI

High power generated from industrial application does generate EMI [4]. Using a spectrum analyzer to monitor a broadcasting radio station generated the frequency spectrum shown in Fig.2, with peaks created during the welding process as a cause of EMI in the range of $\pm 10\text{kHz}$.

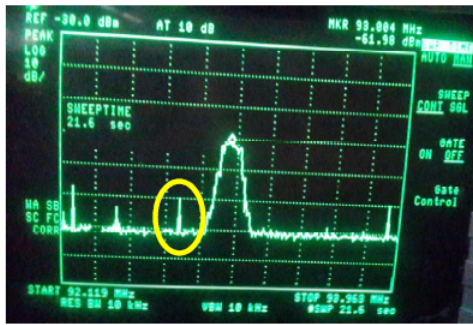


Fig. 2 EMI created during welding process at SA Truck bodies

D. Environmental factor

Sensors can be subject to radio frequency (RF) interference or corrosive environments, high humidity levels, vibrations, dust and dirt, or other conditions that challenge communication performance [5].

E. Large-scale implementation

The system might be installed at different company locations all over South Africa. Moreover, the lack of predetermined network infrastructure necessitates the nodes to establish connections and maintain network connectivity.

III. DESIGN TECHNIQUES AND TECHNICAL APPROACHES

The design of wireless industrial monitoring system consists of the three major parts.

1) *Transmitter Node Design*: The design indicated in Fig. 3 and explained as follows.

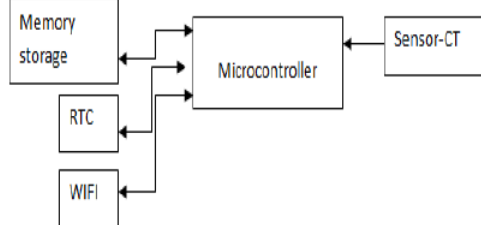


Fig. 3. Node design block diagram to be implemented

a) *Processor/microcontroller*: The design of the node requires a microcontroller with analogue and digital inputs and outputs. Using the analogue capabilities, a CT sensor can be connected and the information used for processing.

b) *Wi-Fi transmitter*: Wi-Fi transmitter used which connects to the local network for transmission of data.

c) *RTC- Real Time Clock*: DS1302, a real-time clock used to combine the data with date time stamp.

d) *Storage*: Logged data from the sensor is stored in memory storage and send to the server.

e) *Sensor*: Analogue signal produced by the sensor based on the measurement detected was converted to a digital value using analogue to digital converters, for the microcontroller to process further. The machine power usage can be monitored by means of a CT placed on the power lines. This helped to determine when the machine was in an operational state. Fig. 4 below shows the 100A CT placing across AC power lines for monitoring purposes.

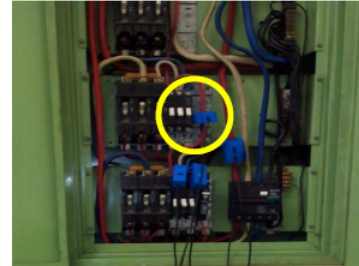


Fig.4. 100A CT placing on power line

2) *Transmitter node operation*: The operation of the transmitter node is defined as follows.

a) *Data logging sequence*: The microcontroller controls the data logging operation of the node. For instance, if a welding machine is monitored in order to calculate its efficiency during a specific period. The total time of which the welding machine is in operation is important to calculate power consumption efficiency. The operating state can be determined by monitoring the power consumption using a CT placed on the power line of the welder. The microcontroller monitors the output from the CT sensor. Measurement of six to twenty amps was determined using CT sensor and verified using a multimeter to confirm actual current consumed by welding machine during operation. Fig 5 shows the sample code where the current measured value was used. In efficiency calculation, the main concern was the on-times of the machine, moreover only logging data if the value is higher than the reference value as shown in Fig. 5. The data is stored with a date-time stamp and as the server receives the data from the node. The data is already organized and ready to conduct the representation process.

Fig. 6 shows the two data transmission structures from node to the server. The processed data from the node broadcast processed data to the server that reduced the transmission bandwidth used across different channels. For example, the node only sends the sensor value higher than six amps as defined in Fig. 5 and incorporates it with date and time stamp. However, the raw data transmission from the node in Fig. 6 shows the node broadcast raw data to the server that increases bandwidth used across different channels and demands the server additional processing of data before the representation process.

```

const int numReadings = 30;
float readings[numReadings]; // the readings from the analog input
int index = 0; // the index of the current reading
float total = 0; // the running total
float average = 0; // the average

float currentValue = 0;
total = total - readings[index];
readings[index] = analogRead(0); //Raw data reading from sensor pin
readings[index] = (readings[index]-510)*5/1024/0.04-0.04;
//Data processing:510-raw data from analogRead when the input is 0;
//S-Sv; the first 0.04-0.04V/A(sensitivity); the second 0.04-offset val;
total = total + readings[index];
index = index + 1;
if (index >= numReadings)
    index = 0;
average = total/numReadings; //Smoothing algorithm
currentValue = average;

if (currentValue >= 5)
{
    logToSD();
}
delay(30);
}

```

Fig.5. Reference value define in microcontroller code

To summarise,

Table 1 Data transmission methods	
Data Transmission Method	
Unprocessed data transmission from node	Processed data transmission from node
Real-time system update, as data is processed real-time as received from all the nodes at server.	Delay in systems update as the data is received from the nodes at different intervals.
As the number of nodes increases higher server processing required	Not affected by the number of nodes
Uses higher network bandwidth as unprocessed data received from nodes	Less network bandwidth used as only the processed data transmitted, less data processing required at server
If connection drops data is lost	Not affected if connection drops as processed data storage at node

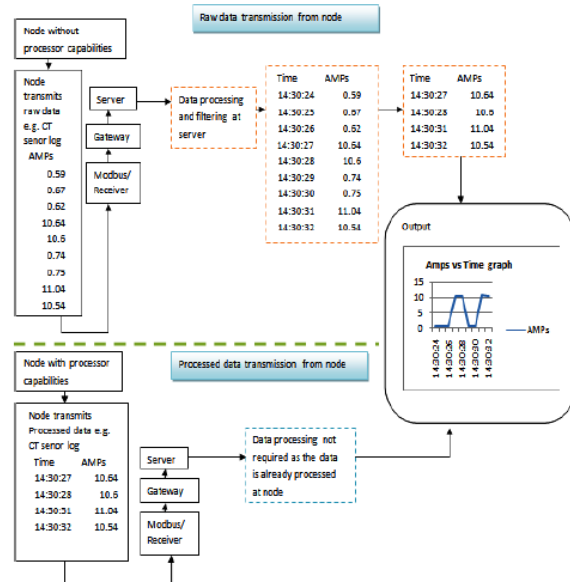


Fig.6. Raw data from node vs. processed data from node transmission option

b) *Data transmission operation:* The transmission operation illustrated in flowchart form is shown in Fig. 7. The starting point is where the server requests the nodes to launch logged data from the storage. The node keeps sending all logged information. It then waits for the server for an affirmative feedback before clearing storage. If the transmission failed, the storage is not cleared until successful transmission. Data is sent during the next transmission cycle. The node automatically detects connection lost during transmission and resumes normal operation.

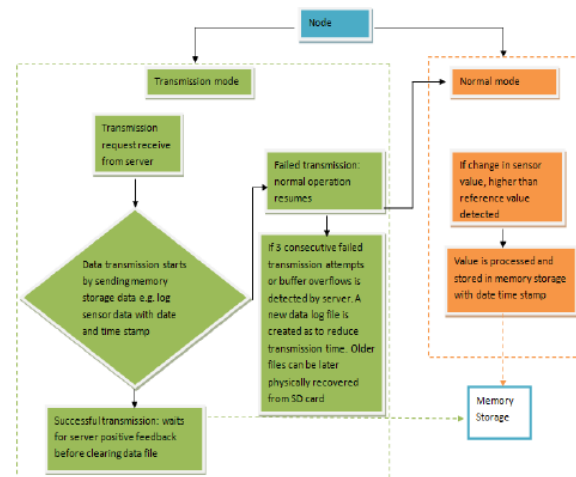


Fig.7. Data transmission procedure flow chart

3) Receiver operation

The server behavior is defined in the flowchart depicted in Fig 10. Communication starts with each node using a unique IP address. A node is pinged few times at 100ms intervals and if the device response within the interval a positive communication link is considered and data receiving initiate. Using this technique the link is tested. If the EMI noise to signal ratio is excessive the server moves to the next node [6][7].

Fig. 8 shows node number 70's communication using the LabVIEW designed software. The node was pinged six times with five successes and one failed ping. The data was successfully collected from the node using LabVIEW's data socket server [8]. Fig. 8 also shows the size of the data sent from a node and actual received data size in bytes. This is used to calculate the actual percentage of data successfully received. Fig. 9 shows EMI effects on the data logged caused by noise influencing the RTC circuit of the node. This occurs by forcing the node to broadcast data in excessive EMI conditions with a high number of failed pings. Data can be corrected by Forward error correction techniques (FEC) by comparing the time before and after noise period.

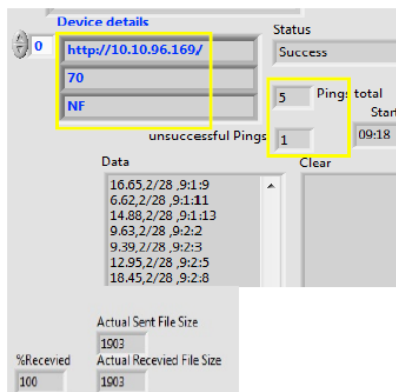


Fig.8. Communication with node 70 using LabVIEW

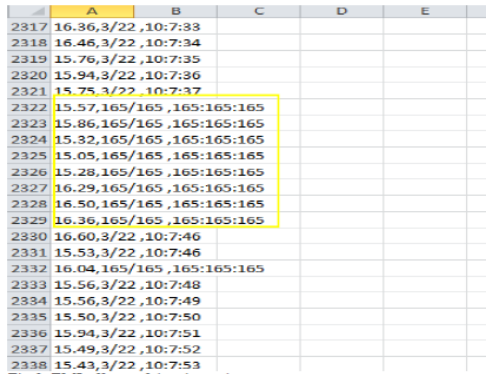


Fig.9. EMI effects of data logged

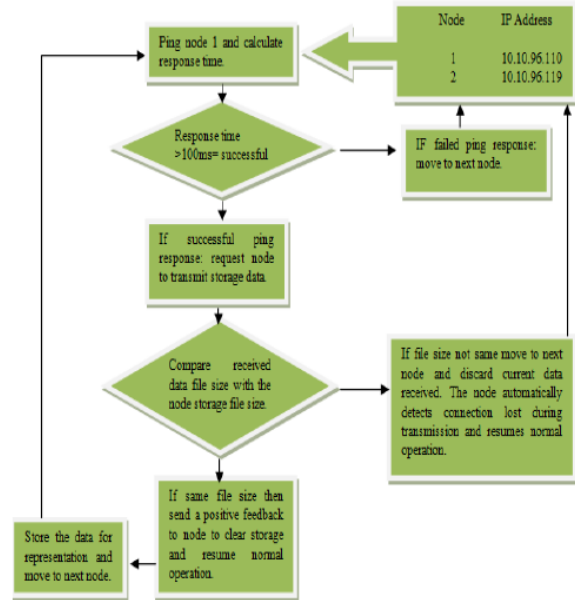


Fig.10. Receiver's operation flow chart

IV. RESULTS

The Industrial wireless monitoring system is being tested at SA Truck Bodies' branches across South Africa that includes Bloemfontein and Cape Town.

A. System evaluated

Fig.11 represents a virtual designed layout using the Mikrotik "The Dude Network Monitor" free software [9]. Each block indicates a node in green and red color. Nodes are pinged at certain intervals and depending on the feedback from the node, the block turns green for positive feedback and red for negative.

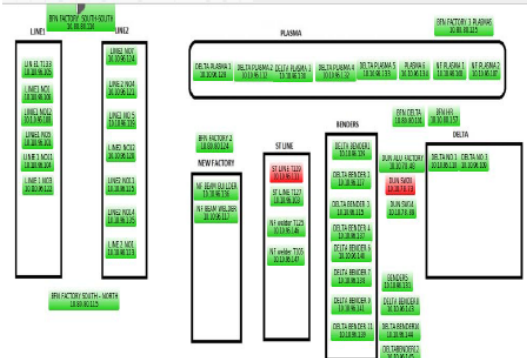


Fig.11. Pinging nodes for connection status using Mikrotik

B. Data representation

LabVIEW was used to perform the efficiency calculations and generate real-time graphic view. Fig. 12 shows the operating durations during each shift, start and stop times for the beam welder machine used based on different shifts and a real-time graph with green indicating the intervals machine was operated. Fig. 13 shows efficiency summarized report of the nodes using *write to spreadsheet* function in LabVIEW to meet the company's specifications in terms of minutes a welding machine operation during a shift, highlighted a period from 7am until 9:20am.

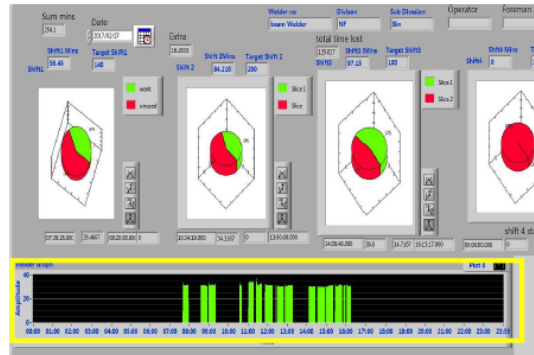


Fig. 12. Detail view of a node data representation

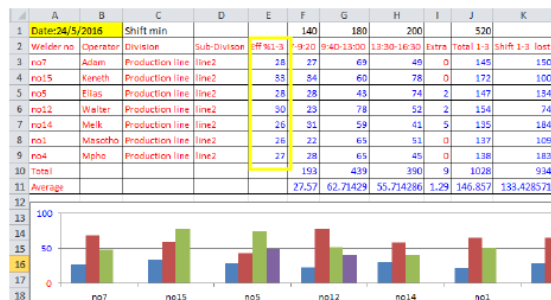


Fig. 1. Summary sample report of a welding Station

V. CONCLUSION

The Aim of the research was to design and implement a wireless industrial monitoring system that can overcome the communication challenges in industrial environment using existing Wi-Fi technology. Considering the node-response time using a ping method before receiving data from a node in LabVIEW proofed an efficient solution. The designed system can communicate with an unlimited number of nodes using a multiplexing method. Giving processor and storage capabilities to the nodes, assisted in sending processed data to the server. Thus reducing transmission time and processor usage on the server side. This could be implemented at industries that require wirelessly logged real-time data from sensors, where a minor delay in data update is acceptable. The

system proved to be ideal for applications such as attendance and clocking systems. This system worked to expectation for SA Truck Bodies that monitor different machine efficiencies using the power usage data from nodes and only require an efficiency report at the end of each day.

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