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Development of a Propeller P8X 32A Based Wireless Biosensor System for Cattle Health Monitoring and Disease Detection

Kazi Naziba Tahsin[1*]

[1]School of Engineering, University of Guelph, Guelph, Ontario, Canada.

Author's contribution

The sole author designed, analyzed and interpreted and prepared the manuscript.

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ABSTRACT

Aims: In order to meet the increased global bovine meat demand, reduce losses due to diseases and improvise current cattle husbandry techniques, it is necessary to develop a wearable sensor node which measures parameters such as the temperature of the animal and monitors its activity. To map health issues and disease symptoms with respective sensors. To effectively transfer the data wirelessly to the receiving end and the design should be sensitive and reliable. The sensor's performance should be tested on similar objects as an unhealthy cow and faulty nodes. Cost of sensors must economic in terms of the Canadian cattle sensor markets and power saving strategies for health monitor's future performance should be evaluated.
Study Design: This paper projects the design of a health monitor which wirelessly transmitted the mean activity and skin temperature of the animal to the herd administrator. The activity and behavior was determined by a dual axis accelerometer, temperature using a digital temperature sensor which was controlled by the propeller P8X32A micro controller board using SPIN programming.
Place and Duration of Study: Design and experiments at Bio signals Research Lab, University of Guelph from January 2014 to December 2015.
Methodology: Simulated experiments were carried out using the designed sensor at a sample rate of 30 minutes intervals continuously for 72 hours in the lab. Experiments were first carried out using

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**Corresponding author: E-mail: ktahsin@uoguelph.ca;*

sensor simulations on standard temperature and normal activity levels then trials of controlled experiments were carried out with variants deviating from the standard value, with reference to the symptoms as derived before.

Results: Simulated results show that the designed system was sensitive to the experiments and the designed sensor be used monitor cattle health and detect symptoms of common diseases. Large scale market analysis was compared with Canadian cattle sensor markets and power saving methods was discussed

Conclusion: The designed system could be an effective, efficient, reliable and economic detection method to trace any health issues or diseases in cattle for the livestock and dairy industry.

Keywords: Cattle diseases; wearable wireless sensor; Canadian cattle sensor market.

1. INTRODUCTION

The livestock industry plays a vital role in the world economy and animal protein accounts for a huge portion of human diet [1]. It is estimated by the US department of Agriculture, on average a North-American eats 67 pounds of beef per year [2]. Along with the increase in population every year, the need for dairy and cattle farming to move towards more production intensive (larger herd and animal sized) and profit-driven enterprises [3]. There have a collapse in production rates when the industry had suffered significant economic losses due to cattle undergoing isolated incidents of several diseases and poor farming methods [4,1]. Learning from past mistakes, farmers today, give special attention to cattle feeding systems, cattle health and offspring productions.

Historically, farmers would own small farm businesses, and the farmer alone would take care of a fewer cattle having direct contact with the animals themselves. Now with the increase in farm size and having fewer people to monitor the cattle, there is a greater need to monitor the animal's health status and transfer the information to the farmer. In the fields of robotics, many sensor systems are used for monitoring and controlling. However the introduction of sensor systems for animals has been slow and thus has shifted the interest of many researchers in this direction. Bio terrorist attacks have harmed the livestock industry in many countries, so in order to keep livestock safe and avoid damage to the human food chain, an integrated control and surveillance is necessary on farms.

1.1 The Problem

Beef sent to the market must be safe for consumption so it must be ensured that the beef was originated from a healthy cow. Pathogenic diseases such as anthrax, cryptosporidiosis, Q Fever, Ringworm, bluetongue, foot and mouth disease are transmissible to humans by close or direct contact with infected cows. So methods of farming must be developed which involved a reduction in frequency of animal – worker close contacts, in order to maintain the safety of its workers, if the animals on the farm were to be infected with any contagious diseases. In many mixed farming industries, not only is there a risk for the entire cattle population to be infected with these plaques, transmission amongst the other animals on the farm is possible. Thus an monitoring system is needed on farms which will monitor the health status of the herds, regularly and sense any abnormalities therefore notify the appropriate personal- in- charge.

Vaccination programs are successful, only when integrated with an automated health monitoring technique. Avoidance of surveillance and concentrating on vaccination alone, is not an effective solution for prevention of diseases in cattle. Due to the changing nature of several diseases, the cases in [5,6] have proved that when cattle were vaccinated against pathogenic vaccines, 10 % of the cattle population was infected when exposed to spores of that disease. Vaccination alone, are not complete solutions for protecting livestock.

For dairy cows, efficient milk production is the result of healthy cows and high reproduction rates [7]. Inability to detect estrus cycles or illness can degrade the quality of milk and can lead to lower fertility rates [7]. Many animal husbandry techniques such as artificial breeding, use sensor aided measuring techniques [7,8] to detect heat. Dairy cows are also prone to certain diseases, which have negative impact on the health, welfare, productivity and milk yield of the cow. Mostly occurring of these diseases include mastitis, ketosis and lameness, can be easily detected by several sensors [3].

1.2 Background

It is necessary to understand the health events of cow in order to design the monitoring system effectively. At first the normal conditions of a healthy cow need to be measured or noted. Table 1 shows the conditions of a healthy cow at normal conditions.

It is necessary to understand the health events of cow in order to design the monitoring system effectively. Table 2 describes the diseases and health complicacies that are common in cattle. Most of the discussed diseases are listed as Federally Reportable Diseases by the Canadian Food Inspection Agency as they may spread rapidly and widely. Table 1 lists several severe diseases in cattle, their symptoms and clinical signs which are usually measured. After critical analysis, relevant sensors which could be used to identify the symptoms were mapped to those diseases.

Dairy cattle undergo several health problems many of which are negatively impacting the welfare of the animal itself. Identifying these issues as whole will not only benefit the animal, but also increase farmer profitability due to calving to conception timings and milk yields. Table 3 show the health issue and their mapped sensors.

Table 1. The health pattern of a healthy cow

State of Health	Conditions	Sensor for detection
Skin temperature	Temperature of 103°F for hot and humid countries (40℃) [6]. Temperature of Cow may vary from 100℉ to 104°F (37.8℃ to 40℃) [9].	Temperature Sensor
Activity levels	An active cow. No aggressiveness. Activity levels tend to decrease at night. No signs of laziness and lameness.	Accelerometer Pedometer Motion sensor
Behaviour patterns	No excessive mooing, no sign of coughs or sneezing. Healthy food intakes.	Microphone
Heart rate / Respiration rate	The heart rate of an healthy cow is between 65~90 bpm. [10]	Pulse meter Pulse oximeter

Table 2. Common cattle diseases and their sensor detectors

Disease	Symptoms	Sensor for detecting symptoms
Foot and mouth disease (BFMD)	Salivation and erosion in the mouth. Lameness. Extreme fever lasting for 2 to 3 days. Weight loss.	Wet sensor Accelerometer Temperature sensor Force Sensor
Bovine spongiform encephalopathy (BSE), Mad cow	Severe behavioural issues: nervousness or violence. Incoordination in walking, getting up. Reduced Milk production. Weight loss	Accelerometer Accelerometer, pedometer In line sensor. Force sensor.
Anthrax	Swelling and high temperature over high temperatures over 107°F. Sometimes close to 109°F [5,6]. Dullness, dropping head and ears.	Temperature sensor Accelerometer
Bovine viral diarrhea	Dehydration Weakness Thinning Loss of Appetite	Activity sensor Weight sensor Invasive sensor
Bovine tuberculosis	Cough	Microphone

Table 3. Health and welfare problems in dairy cows [3]

Parameter of animal health	Behavioural symptoms	Sensor
Lameness	Lesser movement, standing mostly or sitting. Less Grazing	Accelerometer, Pedometers Torque Sensors
Oestrus	Hormone Level (E.G. Progesterone) Increases in walking and lying behaviour [9,10] Increases in heat of animal.	Chemical Sensors Accelerometer/ Pedometer Temperature sensor
Mastitis	Inflammation of udder causes an increase in body temperature Reduced mobility due to swollen udder [9,10,11]	Temperature sensor Accelerometer/ Pedometer
Ketosis	Monitoring grazing during pregnancy Breathing ketones	Accelerometer/ Pedometer Gas Sensor
Milk fever (Hypocalcaemia)	Excitement and movement disorders	Accelerometer/ Pedometer

It was also noticed in Table 3, that here again, the most commonly appearing sensors in most health monitoring are the temperature sensor and the accelerometer/ pedometer. It was shown in [3] that the symptoms of a dairy cow and their related sensors could be appropriate to design with an activity and a temperature sensor. Our review in Table 2 showed that it could be also possible to detect many common cattle diseases by a health monitor designed with an accelerometer and a temperature sensor.

1.3 Related Work

A biosensor is a transducer that converts a biological stimulus, e.g skin temperature, into an electrical signal, e.g - voltage. Today's automated farming systems consist of two types of sensing devices: Mobile sensors and fixed/immobile sensors. Many farms such as described in [12] choose to use both the system to get accurate more accurate results. The health monitoring technology hierarchy starts with fixed sensors, which determine behaviour, weight and food intake for beef cattle. The most common fixed monitors, are usually surveillance cameras, which acquire data using image analysis algorithms [12]. In line sensors are placed at milking machines to detect milk conductivity and temperature. Such sensing techniques are common in mastitis detection, oestrus counts and other dairy cattle diseases [13]. Ketosis detection is sometimes done by electronic noses consists of sensors and a computer-based pattern recognition system. An array to detect the amount of ketones in the breath of animals is a difficult process [12]. The core body temperature, electrical conductivity and pH of internal tissues for dairy cattle are sometimes measured by invasive technology such as the ingestible pill in [14] or the bolus form as in [4] or the acidic bolus telemeter in [15] inserted at the rectum. ALT pedometers in [9,10] and are used to detect the oestrus levels, mastitis, lameness and other illness by considering the number of steps taken will decrease or increase according to the detected health event. It typically consists of heat detectors, a position sensor for the lying positions and a piezoelectric sensor for measuring the step activity. Animal activity is said to increase during oestrus periods than non-oestrus periods in cattle [16]. The RFID technology used in [17] uses the base station (master node) to write a unique network ID to every sensor node (slave node) in the network. The system used this unique ID to identify dairy cattle amongst the herd. The RFID technology usually consists of sensors and ID tags and the transceiver sending the data. The sensors collect data, the sensor unit authorises the RF reader to attach the sensor ID data into the tag. For power efficiency the smart node works in two modes such as the sleep mode and active mode [18].

1.3.1 Previous work on sensors for animals

Earlier work done on the design of wireless sensor was for poultry farms in [8,19] included temperature sensors, activity sensors along with a micro control unit (MCU), transceiver IC, and a battery, which had been dramatically improved in performance and functions due to micro-electromechanical systems (MEMS) technology. The main advantage of using MEMs was to achieve size reduction and cost reduction as the microstructure could be programmed without a microprocessor which eventually reduced power consumption and reduced physical space. The sensor node in [20] proved that it was possible to detect outbreaks in farms if the sensor nodes are attached to about 5 % of chicken population in farms, we could detect the avian influenza by the sensor network 2 days earlier than by the present patrol. Others could detect the infection, in the livestock, several hours before the death of chickens, simply by the activity ratio, without false signals [21]. These methods could be used for cattle as well, by attaching nodes to some population of the herd, such as herd leaders or the more active cow of the herds. This technique could be an effective method for cost reduction and providing a simpler networking technology. These are the techniques used for both size and power reduction because when considering the chicken as the host, very weightless and small sensors must be designed. But when designing for cattle size and weight reduction maybe an advantage but it is not a requirement.

1.3.2 Previous work on farm telemetry

The Bovine Mobile Observation Operation (BMOO) described in [22] used a GPS (Global Positioning System) unit and sensors for measuring pulse, temperature, respiration. Sensor data was stored on an external memory when the animal was far from base station. Usually in such systems there are multiple base stations on the farm and while the animal is within range of a receiving sensor data, it must be transferred at a fast rate. The GPS is used for animal tracking systems which gives cattle location and motion data but in the cost of huge amount of power consumption. The GPS is also considered to be an expensive for small farm businesses. Farms are usually located in remote areas far away from the cities and these are areas where the GPS is prone to failure. It is much feasible to use wireless sensor ID tags for identifying each individual cattle monitoring. The Radio-Frequency Identification (RFID) is a technology used for identification of an individual in a population through tags. The effective networks have emerged both the RFID tracking system with the wireless sensor networks for status monitoring, along with identifying the individuals being monitored [23]. Of the commonly used ones, are the simple mixture of RFID tags and sensor nodes, Here, the base node receives information from both and sends it to host PC . The other is the smart node, consisting of the sensor and RFID tags and the transceiver sending the data. The sensors collect data and through the controller, the sensor unit authorises the RF reader to write the host data into the tag. For power efficiency the smart node works in two modes such as the sleep mode and active mode [24]. When the smart node is active it collects health monitoring data of its host and write it in its own tag. The RFID technology used in [18] uses the base station (master node) to write a unique network ID to every sensor node (slave node) in the network. The system used this unique ID to identify dairy cattle amongst the herd. A rough comparison of using technology such as Zigbee, Bluetooth and Wifi have been analyzed in [25] and this table could be useful for the system design in Section 2.2 as they have chosen Zigbee for its range, topology flexibility and high numbered nodal connectivity.

Due to limitations in the cost and availability of data storage and communication, the use of WSNs is gaining popularity. WSN in farming and the livestock industry allows feasibility in monitoring and capturing measurements of the health and welfare states of individual animals or processes in detail that otherwise would have been impossible. Cattle stay in groups. The herd system reduces stress levels and ensures safety for each animal. However herds are not uniformly distributed and some members of the herd may not stay collectively. As a result, herds may be scattered and their members may also be spread non uniformly in a farm location. These parameters are needed to be considered when designing WSN implementations. How to change network topologies when herd size tend to increase? What are chances of nodes (cows) moving out of range of other nodes and away from the base stations [26]? These all are considered when choosing the right topology. The multiple nodal system used in [25] can be referred for experiments on temperature health monitoring with multiple aged patients and conducted on different days for verification of results.

1.4 Objective of Research

The main goal of the developing a cattle health and disease monitor was that it had to work for both, the beef cattle and dairy industry and to overcome the flaws in many previous sensors. The contributions of this paper involved a design and implementation of a non-invasive sensor system which detects vital parameters such as ambient skin temperature and activity levels of the animal. Effective transfer of data wirelessly to the receiving end and sensor's performance was discussed in the paper as well. This research focused on the Canadian sensor and livestock market, so plays a vital role in showing large scale cost effectiveness, analysis and power saving strategies for health monitor's future performance.

2. DESIGN METHODOLOGY

2.1 Sensor Design

The Cattle Health Monitor and Disease Detector (CHMDD) should be able to monitor a cow's health remotely, so the design must be made per cattle unit which collected biomedical data from the host and sent it to the base station for analysis. The system was designed to communicate with the temperature and activity sensor using WSN to relay these data to a farmer, a rancher, a veterinarian, or management system. The brain of the CHMDD unit was the microcontroller which controls the sensors, averaging the sensor data then storing it in a package until the animal is near a base station, and then transmitting the data to the base station. Fig. 1 shows the overall working principal of the CHMDD unit.

2.1.1 Temperature sensing

The moderate temperature of a healthy cow is within the range of 38℃ to 40℃. The temperature of an unhealthy cow may deviate away from 40℃. Cows in estrus may also have

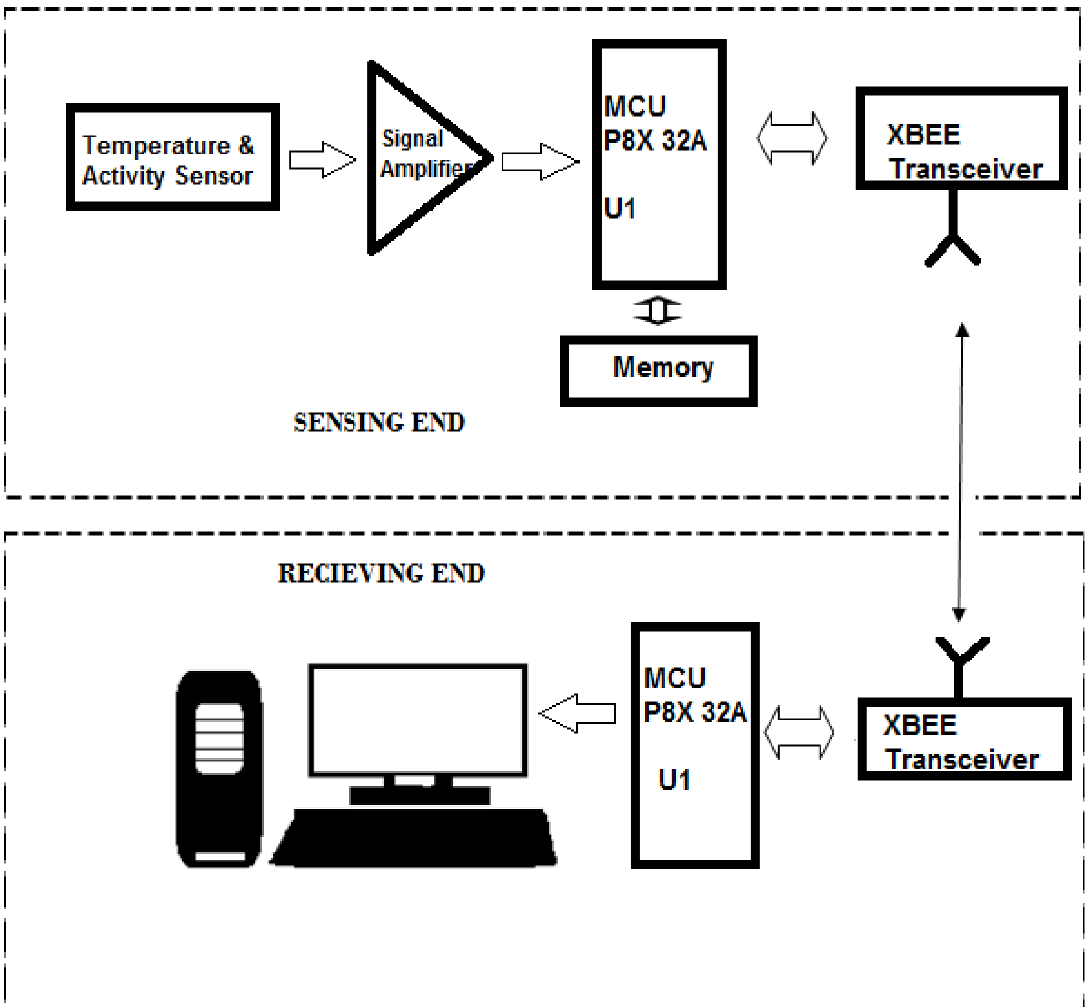


Fig. 1. Block diagram of the cattle health monitor and disease detection

heat indicators. Using Table 1, it could be concluded that the most diseases could be detected by the accelerometer and temperature sensor. Comparing the temperature sensors the DS1620 Digital Thermometer and Thermostat was used as it had high sensitivity in both Fahrenheit and Celsius and gave a digital output to the controller as shown in Fig. 2. It provided a 9–bit temperature readings with three temperature alarm outputs. DS1620 acted as a thermostat if THIGH was driven high when DS1620's temperature was greater than or equal to 41° F which was the usual temperature of the cow. TLOW could be driven high if the DS1620's temperature was less than or equal to 37° F – which showed faulty measurements. TCOM could be used as alarm which turned on the LED/ siren, as it was driven high when the temperature would exceed TH and stayed high until the temperature fell below that of TL [27].

2.1.2 Activity measurements

Monitoring the activity patterns in cows was necessary so both, the lateral and horizontal movements, was recorded by Memsic 2125, the cost effective thermal accelerometer, then transferred to the propeller. It was capable of measuring tilts which may be necessary during low activity periods such nights, collision with other cows, static and dynamic acceleration along with high sensitivity and low power consuming [28]. Faulty activity was reduced by taking into account of the Spatial Average Vector (SAM) in all directions in Eq.1, where a_x and a_y are the accelerations in 2 axis directions [21].

SAM (acceleration) =

$$\sqrt[2]{(\sum_{n=1}^{20}|axn - axn - 1\,|)^2 + \;(\sum_{n=1}^{20}|ayn - ayn - 1\,|)^2} \qquad (1)$$

2.1.3 The controller unit

For the controller unit, the Propeller microcontroller, U1, an 8-core, super-fast interface using up to 20 MIPS per core, was chosen. The controller when given multi tasks, partitioned each task into separate cores, allowing it to load many programs and features and distributing resources on the fly, without the overloading of an operating system. Applications which require dedicated hardware could be defined in language and ran in parallel. This saved a lot of power even when it ran at a total of 160 MIPS, the power consumption is much less than 80 mA [19]. This application is necessary when storing the number of data readings and is advantageous if it can process faster with parallel task processors. The Propeller Quick-Start is chosen because of being a simple and an accessible development platform for the design of our sensor nodes. The Parallax Propeller was controlled by using Propeller Spin, a multi-tasking, high-level programming language.

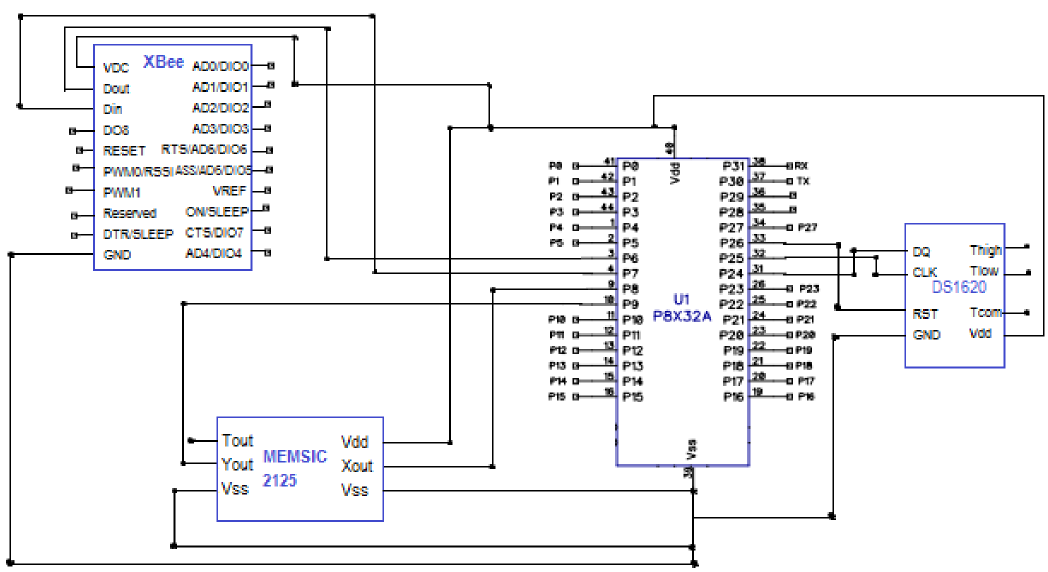


Fig. 2. Schematic diagram of sensor node

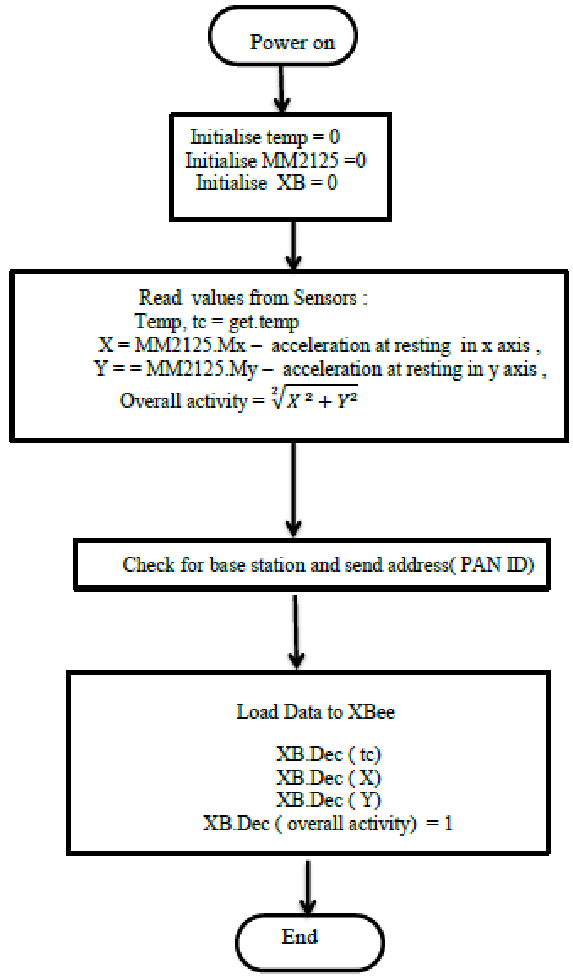


Fig. 3. Flow diagram of the sensor node/ end module

Variables were loaded into the 32KB RAM of the Propeller when the software debugged the code. It is optionally booted in to the I²C EEPROM. After debugging, the variable are copied from the EEPROM into the 2KB RAM of an initial COG register memory. Then the COG started writing the variables into the 32KB SRAM. Many objects can be debugged simultaneously in parallel COGS so Spin advantages its threads to be processed in parallel. In a Spin code program, the assembly programming allows inline running of individual COGs on their own. The Propeller Tool version 1.3.2 is the environment for multi-threaded SPIN as it reads its codes in bytes. Reading of each code per byte, from user defined, edited, compiled, and finally saved onto the Propeller the software specific IDE. The IDE is marketed by Parallax named "The Propeller tool" is intended for use under the Windows operating system. The Spin code when written on the Propeller Tool develops like a GUI-oriented software development platform.

For simplicity the communication protocol used by the XBee Series 1 in the design implementation was ATP mode (Transparent Mode). Since we focused more on the sensor not the transmitting medium, the sensor data was sent by the transmitter and received by the USB adapter acting as the base station. Better transmission and reception, assured correct destination reception and error checking bytes could be implemented in API mode.

The sensor design involved one nodal communication with the base station. The work flow diagram of the implementation is shown in Fig. 3. The work operation of the sensor node was simple and started when the power is on. At first Initialisation of the previous bytes: temp, MM2125, XB values are cleared. Then the microcontroller gets values from each sensor. These values are then loaded into the XB (XBee). After a base station becomes available, the XB data would be sent to the base station with the address of the XB (PAN ID).

2.1.4 Circuit layout

The complete circuit that includes all the sensors and the controller unit described in section 2.1 is shown in Fig. 2. The schematic layout of the CMDD sensor node consists of a Controller unit, temperature and activity monitor, along with an XBee transceiver for wireless communication as described in the above sections.

2.2 System Design

The base station and its communication to nodes used the API mode consisting of packages of data with destination address, category of message, and acknowledgements were sent. Base station received the data with nodal address (PAN ID), signal strength and acknowledgements with a greater intense programming requirement. Since it was not necessary that both the base station and end nodes need to share the same modes. Data could be sent in AT Mode and received in API Mode. The communication flow of the base station started with sequentially selecting an ID in the list and sending the request for data transmission to the sensor node of respective ID. If there was no acknowledgement from the selected ID node, then node/cow was too far from base station, so going to the next node in sequence. Otherwise if the respective sensor node acknowledged that request and transimtted its data packet to the base station, the base station would then store the data received by that node in an array for calculating at an 30 minute

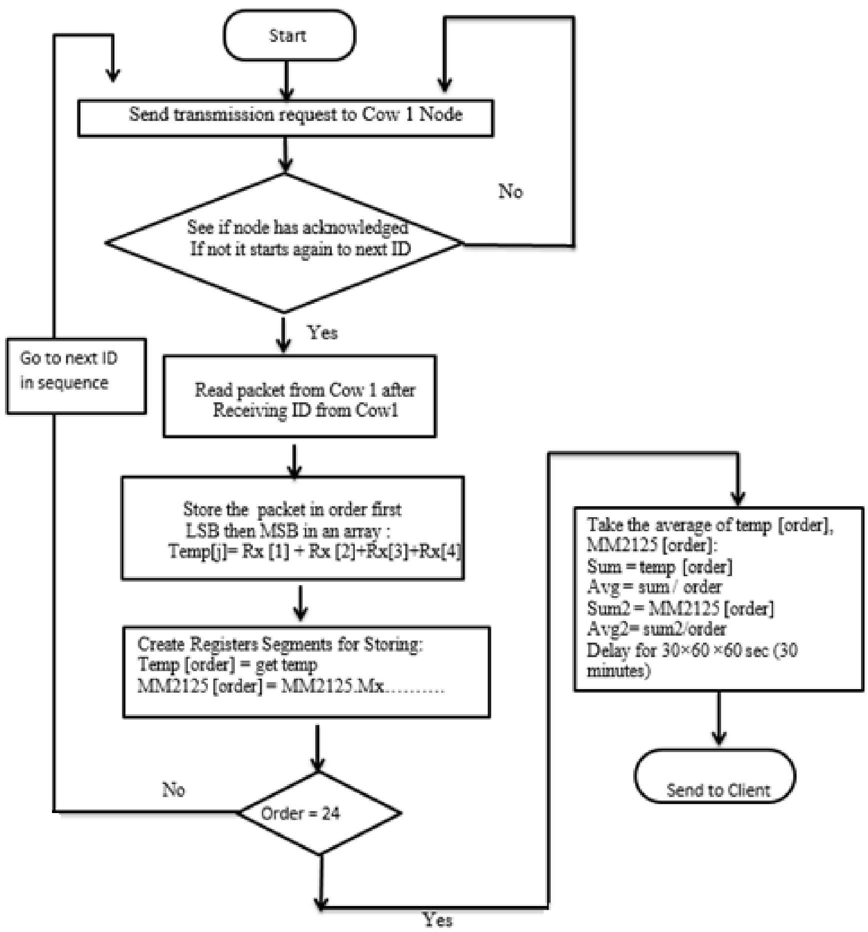


Fig. 4. Flow diagram of the base station

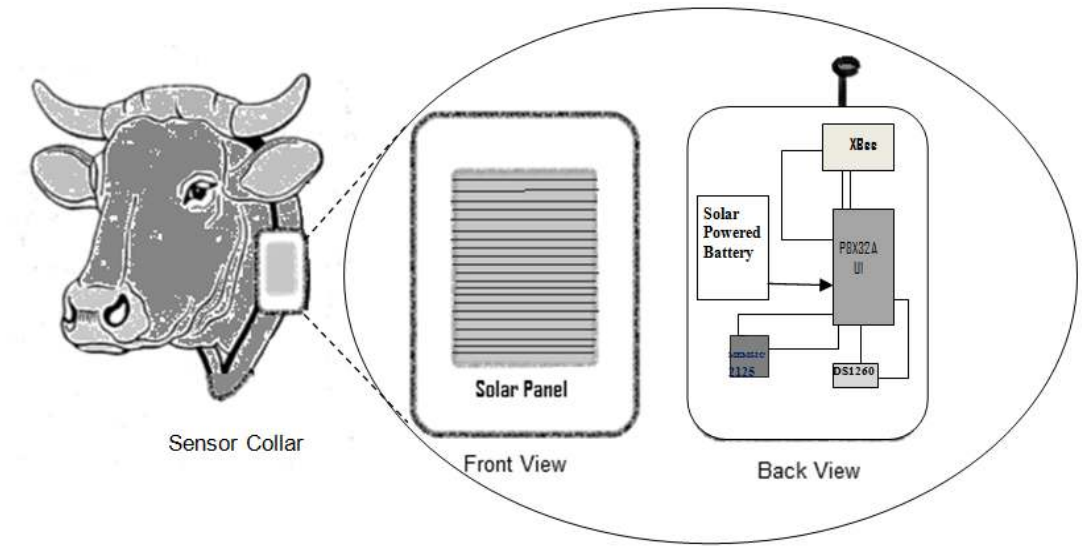


Fig. 5. Alternative source of power for the sensor node

intervals. The average of the stored data at the end of 12 hours (at least 24 arrays stored) was sent to the client server. The client would then notice the data of the cow for each day.This was repeated for all nodes near the base station. The workflow was shown in Fig. 4.

2.3 Power Saving Modes and Alternate Power Source

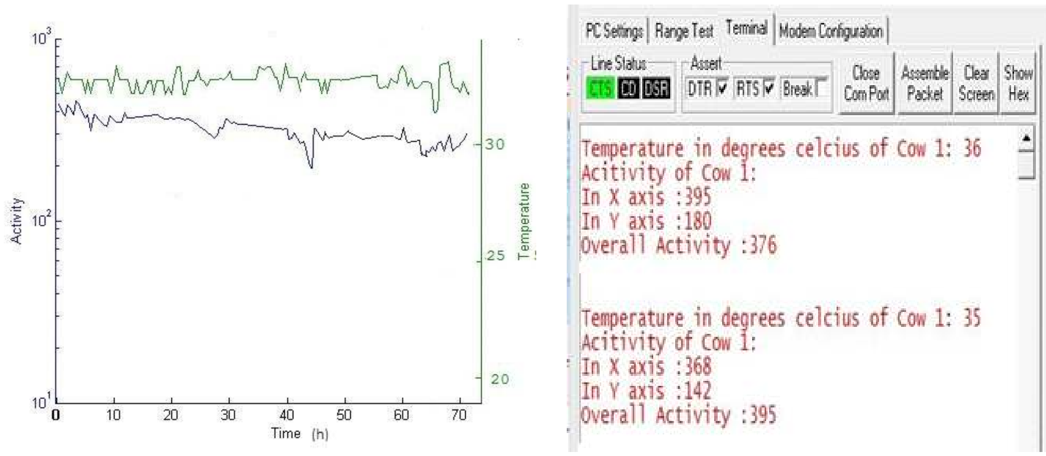
There are many strategies for minimal power consumption. The strategies must have been placed such that it did not harm the effectiveness and reliability of the system. Firstly increasing the efficiency of transmitting data. Minimising the frequency of the data transmission could be implemented. Instead of receiving every 30 minutes it could be increased to 1 hour. Message quantity could be minimised as less as possible. The data sent could be shortened to only the values of overall activity and temperature. The power for transmission is the major element for energy consumption in any node and this was proportional to the quantity of message sent and received. The node could stay OFF or in Sleep mode for most of the time and would turn on only when the base station sent a request for transmission. After the transmission was done it would go back to sleep mode again.

The lifetime of a battery was one of the key aspects of research today for sensor systems. As described above in Fig. 5, the collar of the cow could be composed of a battery source which was rechargeable by solar energy when the animal was outside during daylight. Increasing the area of the solar panel would be preferable. This was helpful in saving the lifetime of the battery.

3. RESULTS AND ANALYSIS

3.1 Simulated Results of Healthy Cow

As mentioned in Table 1, the normal temperature of a cow is around 37℃. This temperature was simulated by using hot water of exactly 40℃ and placed on the node. An extra digital thermometer was used to verify this temperature. In order to measure the activity, a toy animal was placed below the sensor for testing if the sensor was able to measure activities while in motion. These parameters all reflected the behavior of a normal cow. Fig. 6 shows the simulated data sent by the sensor node for 72 hours (3 days), particularly reflecting a healthy cow. As shown, the average temperature sent to the base station every 30 minutes, was nearly 37℃ and the activity is moderate of 300 (0.03 g), moving in all directions. This also shows the ID of the cow being “Cow 1”. Figs. 6(b) and 7(b) shows an example of the data being received from a particular node (Cow 1) by the base station which is the XBee adapter. The results are viewed using XCTU (Digi International, Minnetonka MN) and Quick start Board (Parallax INC, Rocklin, Ca).



(A) **(B)**

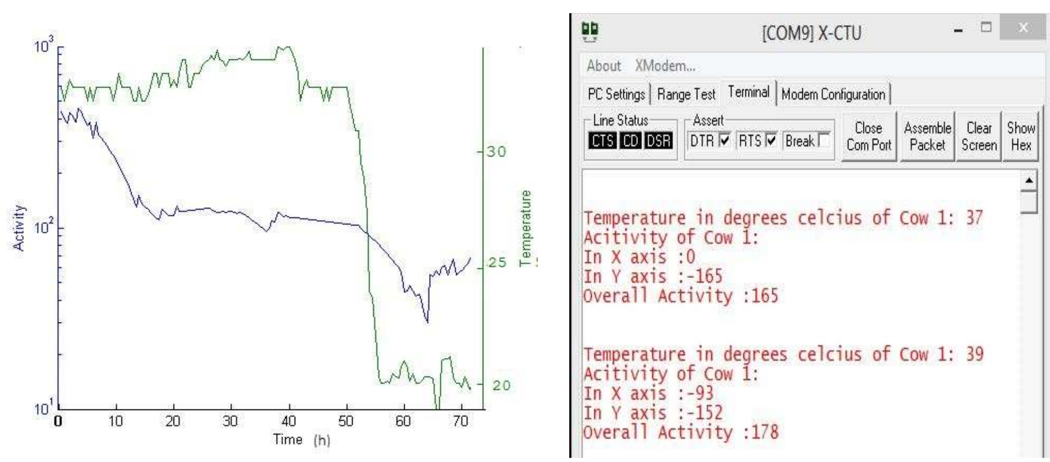
Fig. 6a. Graphical representation of sensor node data showing activity (blue) and temperature (green). b) Sensor node showing data sent from cow to end receptor

3.2 Simulated Results of a Sick Cow

Many diseases listed in Table 2 included symptoms of high fever and lameness, extreme fever and weakness, severe fever and depressions such BVD, anthrax, BFMD, etc. mastitis and lameness. These symptoms were interpreted and mimicked by simulating of high fevers (42℃) on the node and little movements of the node. Finally on the 3rd day, the node measured room temperature with no movement. The node was able to detect such changes and gave data that was similar to a unhealthy or a negative welfare impacted cow. Fig. 7 demonstrated the data transmitted to the base station by the node.

3.3 Large Scale Analysis

Many markets have exploited the production of cattle monitors due to simply the fact that whether lower costs of the such systems are possible or not. To give a comprehensive cost analysis of the Cattle health monitor and disease detector for roughly 100 cattle per herd size was taken into account. The estimated herd size profit margins per year were included. There are estimated about 86500 beef farms in Canada with a total of more than 15 million cattle and calves [29].



(A) **(B)**

Fig. 7a. Graphical representation of sensor node data. b) Sensor node data sent to base station sensitive to temperature and activity decrease against time

Table 4. Large scale cost of the cattle health monitoring and disease detector system

Device	Cost per 10	Cost per 100
Temperature sensor	$ 1. 35 * 10 = $13.5	$ 1.2 * 100 = $ 120
Activity sensor	$ 4.3*10 = $43.00	$ 4.3 *100 = $430
Propeller P8X32A-D40 chip	$ 7.99* 10 = $ 79.9	$ 7.19 * 100 = $ 719
128 Kb (16 KB) EPROM	$ 1.35* 10 = $13.50	$ 1.20 * 100 = $ 120
5 MHz 20 pF crystal	$ 0.99 * 10 = $ 9.9	$ 0.88* 100 = $ 88
2 XBee modules	2 * 10* 14.45 =$ 289.9	2 * 100* 14.45 =$ 2559
Battery lithium 3V coin 20 mm	$ 0.366 * 10 = $ 3.6	$ 0.325 * 100 = $ 32.5
Total	$452.4	$4068.00

Profits of Beef Cattle = price margin + feed margin

Price margin = $1.80/kg purchase price of 300 kg bull is $ 540 and sold for $ 2 per kg is $600 = $ 600 - $540

Feed Margin = $1.90/kg for the feed of 200 kg on the calf which is $ 380 and the 500 kg adult bull sold for $2.00/kg which is $ 1000, the farmer has had a gain of $ 620

So Profit Margin = $ 60 + $ 620 = $ 680 per cow

Profit margin for 100 cow herd = $ 68,000

As published by [30] Ontario Ministry of Agriculture, Food and Rural Affairs, and [29], the initial cost on investment in a pedometer or activity monitoring system that is readily available in the market could be between $13,000 and $30,000 for herd sizes of 100 cattle. So per cattle it is said to be $ 150 to $ 300. This was only half the profit margin of a farmer.

So the target for our system was to design a system for 100 cows which could cost well below $ 13,000. The cost estimates are given below in Table 4.

It could be shown from the above Table 4, that the cost per head of 100 herd system for the designed system would be $ 40.68. However the profit for the system developer could be 3 times the material cost which is $ 122. 04. This meant the developer would make a profit of $ 81. 36.

As we have calculated the cost of our design even with the profit is much less than $ 130 of the existing farm monitoring systems. If sold with a profit of twice the inventory cost, it was only 11 % of the farmers profit margin. This showed that our Cattle Health Monitoring and Disease detection system was large scale as well as small scale cost effective.

4. CONCLUSION

This paper aimed to describe the development of a wireless sensor system to monitor cattle health and ensure the well being state of cattle amongst the widespread pandemics occurring in today's times both naturally and externally. Due to the high demand in beef, beef products, milk and dairy products, the meat and dairy industries are under constant pressure for increasing yields, high meat quality and healthy calves. This leaded to the demand for healthy cows and so intensive surveillance and monitoring programs are chosen. This paper mapped the basic and common health and diseased characteristics to specific sensors. These sensors were then used to design a measurement node to monitor and detect some common diseases. A sensor node to base station was implemented and the data were verified to actually sense symptoms. The communication system workflow of multi- nodal analysis was developed and discussed.

Strategies for power reduction included infrequent and reduced sized messages. Other sources of power such as the solar batter were mentioned for the implemented design. Size reduction was not considered as the host was of 200 kg and was able to bear the weight of the sensor. The system was analyzed for large scale cost effectiveness. The cost of one sensor was only 11 % of the farmer's profit margin and was 31 % of the price of the lowest available cattle sensors available in the market when considering development cost twice that of the capital cost.

Improvements to the system could be done by further developing a more complex and reliable multi-nodal wireless sensor systems with the RFID. This must be feasible for herd capacity of 100 cattle. Using a higher ranged RF could be done. This project could be extended to the use of Zigbee and Bluetooth for connecting to the internet as an app. The client server could be developed for an app in a mobile phone. A more accurate, energy saving sensor could be consisting of MEMS technology. Size reduction of the sensor nodes could be done in the wafer level. This could be no bigger than a coin. Further implementation on cattle for detecting infectious diseases. Sensitivity of sensor on detecting diseases could be evaluated.

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COMPETING INTERESTS

Author has declared that no competing interests exist.

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