An IoT Solution for Cattle Health Monitoring

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Abstract. Animal husbandry is an increasingly popular business where cattle are nurtured for food and other products. The productivity of cattle farms is largely affected by the health conditions of the cattle. Cattle with a communicable disease can drastically bring down the productivity of the whole farm. So it is highly recommended to identify unhealthy cattle. In this context IoT can contribute a lot in terms of developing an autonomous system for health monitoring of cattle. A system is developed in this work consisting of data gathering, mobile nodes and IoT cloud platform. The data gathering node is provided with various sensors to sense the health parameters of the cattle and these data gets transmitted to the mobile node with the TDMA scheme in order to prevent data collision. The mobile node acts as a gateway to the IoT cloud platform where data analytics on the sensor data is carried out to identify unhealthy cattle and the owner of the farm and the vet gets notified.

1. Introduction
Agriculture plays an important role in improving the economic status of a country. The Agricultural sector in India itself accounts for about 18% of its Gross Domestic Product. Also, 50% of India’s workforce is employed from Agriculture [1]. Agricultural growth of India has been impressive over the last few years. Agriculture also provides a significant contribution to the international trade market and the export is now expected to be $95.7 billion which is clearly a 10.3% increase from the previous year [3] [2]. Agriculture and animal husbandry both go hand in hand. Animal husbandry is a practice in which animals are nurtured for food and non-food products. Food products include milk and milk supplements, eggs and meat. Non-food products include wool, bone products, pharmaceuticals etc. It requires extensive caring of the animals in a day-to-day manner. As a branch of agriculture, a part of its productivity comes from animal husbandry. In India, about 20.5 million people depend on livestock for their living, that is two-thirds of the rural community gets their livelihood from livestock [3]. From farm animals we can get a variety of food and non-food products.

The health of cattle is an important factor for increased production and maintaining the quality of these products. Cattle diseases can have an adverse effect on productivity in terms of quality and quantity. Major cattle diseases include milk fever, ketosis, stress, lameness, fever etc. In large farms where thousands of cattle are raised together, these diseases can spread quickly and can cause a huge drop in income. Cattle health conditions must be monitored regularly to prevent the spreading of communicable diseases. In earlier days, cattle health monitoring was a labour intensive work with individual cattle being assessed for its health. The cattle will be periodically observed for any symptoms that mark a disease. These symptoms such as a change in mooing sound, change in rumination and feeding patterns, change in grazing patterns or any other behavioural changes are identified and taken to the vet. So in order to simplify the effort of laborers a system has to be developed which will automatically monitor the health conditions of the cattle periodically and analyze the data for any possible sickness of the cattle with minimal human intervention.
2.1. Literature Survey
Domestication of cattle can be dated back to around 4000 BC. For a progressing country like India, agriculture plays a crucial part in the economy and welfare of the people and cattle farming acts as a backbone for agriculture. Farm animals including goats and cows are nurtured and protected in order to help the farmers in agriculture and for the production of milk. The health of the animals is a major concern in terms of production quantity as well as quality. As the size of the farm increases the attributes of farm management becomes extensively complex, which is a good niche for farm automation.

2.1. Sensors and disease mapping
An efficient cattle farming system depends on how accurately the diseases in the cattle can be identified by the system. For such a system, sensing of various parameters is of utmost priority. Recent developments in MEMS, and wireless sensor networks paves way for automatically recording fluctuating data into a microcontroller.

Wireless Sensor Networks (WSN) can be used for monitoring as well as recording physical conditions and organizing the data gathered at some central location [4]. Swetha [4] compared temperature, heart rate and fall frequency of the cattle against normalized values for variations to determine the health conditions of the cattle. Using the Wi-Fi module, these data are sent to a centralized location and a health graph is sent to the vet's mobile. Several works have been done on this type of systems and the sensors required for it. Invasive and non–invasive are two methods of sensor implementation for the system. The invasive method comprises of sensors attached to the body. Attached sensors can be on-cow and in-cow sensors. On-cow sensors are sensors that are attached to the body of the cow and in-cow sensors are sensors that are implanted inside the skin. Non-attached are off–cow sensors. In this case, sensors are attached to a wearable device that is placed on the cow or positioned in an area where cows are more likely to be present [5]. Sensors provide simple and efficient techniques for measurements of numerous health metrics. They continuously observe the body signals of the cattle and deliver output in the form of electrical signals.

Also various diseases that can affect the cattle and its symptoms are studied in [5] and [6]. These diseases can cause changes in the body parameters of the cattle which are identified and sensors that can effectively sense these changes are selected for the purpose. Table 1 shows how the diseases, sensors and body parameters are mapped. The sensors are to be integrated with a microcontroller. It should be efficient in all aspects and also should be able to provide low power operation. A CSMA/CA solution for communication in systems that consists of transmitter and receiver is proposed in [7]. Low power consumption is implemented such that the transmitter gets supplied from a battery and it works in a loop: running the program, sending the data and then sleep. A system is implemented in [8] which employs Time Division Multiple Access (TDMA) based algorithm in a WSN test bed that consists of over 150 sensors for reducing power consumption.

| Parameters to be measured | Temperature | Fall detection | Heart rate | Humidity |
|--------------------------|-------------|----------------|------------|----------|
| Sensors for measuring the parameters | NTC Thermistor | Accelerometer | Pulse sensor | DHT11 |
| Diseases mapped to the change in the body parameter | Fever | Ovarian Cyst | Milk Fever | Stress Anxiety | Stress level |

2.2. Existing Systems
In [9] a system was developed which uses Arduino UNO to measure the body parameters of cattle and LabVIEW to view the graphical representations of the signals in real time. The system has two blocks, the transmission block and the receiver block. The transmitter has an Arduino UNO for
integrating the sensors and a ZigBee module. The receiver block has an Arduino for interfacing with the PC and ZigBee transceiver for receiving the data sent by the transmission block which is fed to a LabVIEW for analysis. In [10], a health monitoring system using an AMD 186 processor on a Tern microcontroller board is developed. It is equipped with various sensors such as head motion sensor, temperature and humidity sensor and a GPS module. Each animal in the farm will be given a health monitoring device and a unique identification number. Download stations that are ZigBee compatible will be present in areas where there is more animal traffic. The data is observed in an Apache web server run java web start based program. In [11] a Cloud Based Mobile Gateway Operation System is proposed. A lightweight framework for cloud based mobile device is developed. A system which observes the biological parameters like wound indication, temperature and pH value using a network of body sensors has been developed in [12]. Temperature sensor acts as a wake-up device such that it wakes up other sensors whenever there is a change in temperature. ARM 7 is used for integrating these sensors and LCD where the sensed parameters are displayed. The assigned unique ID of the cow helps in identifying the cow if any abnormal condition occurs. An IoT based hazard monitoring system is implemented in [13]. Raspberry Pi is used as the gateway node to collect data from different other nodes. MySQL database is used to store the sensor data using MQTT message protocol.

A prototype of a monitoring system that monitors physiological parameters such as surrounding humidity, body temperature, rumination and heart rate has been discussed in [14]. A ZigBee device, PIC16F4550 microcontroller and various sensors are used in the development of a sensor node. The sensors integrated with microcontroller collects the data. Zigbee sends the data in every 4 seconds to the sink module. LabVIEW 9.0 is used for a graphical user interface. In [15] and [16] a survey on efficient communication technology is presented including ZigBee, Wi-Fi, Bluetooth, Z-wave, Wireless HART, 6LoWPAN etc. ZigBee stack is light weighted than Wi-Fi and Bluetooth. They also have a battery life of 5 years, while Wi-Fi has a battery life of 8 – 12 hours and Bluetooth devices for several hours. Zigbee devices have many advantages compared to other techniques such as high data rate, high power profile, long range of operation and the stack size of ZigBee protocol is much less compared to other communication technologies [17].

The existing systems lack proper sensor node management, scheme for addressing scalability of the system. As the number of nodes increases the probability of collision of data from nodes also increases. An efficient channel access method has to be implemented to overcome this challenge. A novel system is proposed that takes care of the shortcomings of existing cattle health monitoring systems.

3. Proposed System
From the literature survey, various parameters to map diseases are identified as temperature, humidity, heart rate and fall frequency. The system has two sets of nodes as given in Fig 1, data gathering node and the mobile node. All the sensors that are used for obtaining the body parameters are interfaced to the data gathering node. The data collected will be communicated to the mobile node via communication technology. A communication modem will be interfaced with the data gathering node for transferring of the data. The data collected by it will be stored in the node using a file management system in an external memory connected to the node. This data is stored until it is sent to the mobile node after which it is deleted from the memory.

Mobile node moves in a predefined path to acquire data from all the data gathering nodes via the communication device attached to it. The mobile node initiates communication by sending a signal. Upon receiving the signal, the node sends its data. The received data is stored in the mobile node by creating a local database. After collecting data, it is uploaded to a cloud platform where it can be viewed and analyzed in a front end application for conclusive inference on cattle health. The methodology can be explained briefly in three steps.

3.1. Development of data gathering node and the mobile node
The data gathering node has three parts as shown in Figure1.: sensors, microcontroller and the
communication modem. The data gathering node will be implanted on the skin of each cattle. Another feature of the data gathering node is its low power operation mode. Sleep mode in software is implemented in the data gathering node so as to reduce consumption of battery when not in operation. The sensors that are used for collecting the body parameters of the cattle are interfaced with the data gathering node. Each node will be having a unique identification number corresponding to a cattle. The data sensed from the sensors are stored in an external memory using a file system implementation. To address the issue of data collision between multiple data gathering nodes, TDMA is implemented in the data gathering node. The mobile node is developed such that it moves in a predefined path so as to cover all the possible cattle positions. This should be able to communicate with the data gathering node using a particular handshake mechanism. The handshake mechanism is the TDMA method implemented to prevent the collision. In this process, the mobile node when it comes in the vicinity of the data gathering node will send an initiation signal to the data gathering node. Upon receiving the signal, the data gathering node will wait for a precise amount of time which is determined by its unique ID and then send the data. The data received by the mobile node is stored in it using a database management system. This data is then uploaded to the cloud using an efficient IoT protocol.

![Figure 1. Proposed System Overview](image)

3.2. WSN of data gathering node and mobile node
Communication between the two nodes is instigated using a sequence communication protocol. The mobile node when it comes in the vicinity of the data gathering nodes will initiate a handshake signal. Upon receiving the signal, the data gathering node will send the sensor data to the mobile node using the TDMA scheme. The TDMA is implemented to avoid the clash of data during communication. After communication records of data in the data gathering node are erased.

3.3. IoT data analysis
The data collected by the mobile node is sent to an IoT cloud platform. The data is stored and viewed in the front end application and conclusive analytics of the data is obtained. The received parameters are analysed by comparing with the normal health parameters of the cattle. Variations in the measured parameters are used to identify unhealthy cattle.
4. Implementation and Result
As mentioned in section 3.1, the primary hardware setup for the system has the data gathering node, which consists of all the nodes that are implanted on the cattle, and the mobile node. The hardware implementation of the system as a whole is shown in Figure 2. Data gathering node is Arduino Mega 2560 based MCU which is interfaced with NTC thermistor, pulse sensor, DHT11 and accelerometer. Apart from the sensors it also has an RTC module for keeping track of time for the implementation of Time Division Multiple Access and a micro SD card adapter for connecting SD card to the microcontroller. The sensors are interfaced with Arduino Mega 2560 to automatically collect data every three seconds. The data is then stored in external memory. The ZigBee trans-receiver connected to the Arduino communicates and transfers the data collected to the mobile node using the TDMA channel access method. The data communication functionalities of the mobile node are implemented using a Raspberry Pi and ZigBee trans-receiver.

![Figure 2. Hardware Setup](image)

The data from the sensors are stored in the micro SD card using the FAT filesystem. A new file is created daily with the date as the file name, so as to have a distinction between sensor data of various days. The format in which the data is stored in the file is given in Fig. 3. RTC module keeps track of time and date in order to stamp the time at which the data is acquired and also to name the CSV file after the date at which the data is collected. Fig. 4 shows the data as it is stored in the CSV file according to the format in Figure 3.

| Time Stamp | Node ID | Body Temperature | Humidity | Heart Rate | Accelerometer X | Y | Z |
|------------|---------|------------------|----------|------------|-----------------|---|---|
| 11:01:20   | 1       | 30               | 99       | 72         | 1098            | 728| 578|
| 11:01:23   | 1       | 30               | 99       | 73         | 1000            | 650| 480|
| 11:01:26   | 1       | 30               | 99       | 72         | 1018            | 690| 560|
| 11:01:29   | 1       | 30               | 99       | 75         | 991             | 728| 553|
| 11:01:32   | 1       | 30               | 99       | 74         | 870             | 620| 636|
| 11:01:35   | 1       | 30               | 99       | 73         | 1000            | 650| 570|
| 11:01:38   | 1       | 30               | 99       | 76         | 980             | 700| 523|
| 11:01:41   | 1       | 30               | 99       | 78         | 820             | 1020| 500|
| 11:01:44   | 1       | 30               | 99       | 72         | 973             | 783| 626|
| 11:01:47   | 1       | 30               | 99       | 76         | 960             | 885| 589|

![Figure 3. Format for CSV file](image)

The mobile node sends an initiation signal in order to start a TDMA frame. Nodes nearest to the mobile nodes will receive the signal and send their data to the mobile node according to the
designated time slots. The data to be sent is read from the SD card and is erased after the mobile node receives it.

The communication technology between the mobile node and the data gathering node is ZigBee. This data is stored in SQLite until it is sent to the Ubidots cloud platform for visualization and analysis.

![SQLite format 3E. Table elements CREATE TABLE elements (id TEMP PULSE X Y Z, HUMIDITY date CURRDATE )](image)

**Figure 5. Data sent from data gathering node, received by the mobile node and stored in the SQLite database**

Figure 5 shows the data as it is received in the mobile node and is stored in the SQLite database. When the data gathering node receives the signal handshake signal, it will send all the data including the current data to the mobile node. After it receives data from all the nodes it will aggregate the received data and send to the Ubidots cloud platform.

![Figure 6. Data Received in Ubidots](image)

Figure 6 shows the data received by Ubidots for storing and analysis. The parameters are compared with normal values and changes are noted to find unhealthy cattle. A message, as shown in Figure 7, is sent to the owner's mail ID if any abnormality in the parameters are identified. This system drastically reduces the time and labor devoted to the health management of cattle in large farms.

![Figure 7. Mail received by the owner for a change in body parameter.](image)
5. Conclusion
The proposed automatic cattle health monitoring system is incredibly helpful in monitoring and identifying cattle diseases. The need for continuous monitoring is eliminated as an alert message will be sent to the owner if there is any change in the parameters from the normal value. The system architecture supports scalability of the data gathering nodes which is an essential requirement in terms of real world deployment.

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