Materials Today: Proceedings xxx (xxxx) xxx

Contents lists available at ScienceDirect

Materials Today: Proceedings

journal homepage: www.elsevier.com/locate/matpr

Smart cattle health monitoring system using IoT sensors

G. Suseendran [a,*], D. Balaganesh [b]

[a] Department of Computer Science, Lincoln University College, Malaysia
[b] Dean Faculty of Computer Science and Multimedia, Lincoln University College, Malaysia

ARTICLE INFO

Article history:
Received 8 January 2021
Received in revised form 8 January 2021
Accepted 27 January 2021
Available online xxxx

Keywords:
Cattle Monitoring
Health condition
Sensors
Reliable communications
Gateway
Fuzzy decision model

ABSTRACT

For Smart Cattle Monitoring using IoT sensors, it is required to accurately predict the illness of cattle, well in advance and take the necessary actions. It is also necessary to ensure failure-free, stable and energy-efficient communications. Hence in this paper, a SmartCattle Health Monitoring System with reliable communications using IoT sensors is designed.To accurately predict the illness of cattle well in advance,a fuzzy based health monitoring module is proposed.To ensure reliable data transmission module between the gateway and collar attached on the cattle, an antenna diversity scheme and Reliable Intra and Inter Gateway Routing Protocol (RIIGRP) are designed. The proposed architecture is simulated usingNS2 and implemented in Arduino sensor environment. From the experimental results, it is shown that the proposed system achieves 4% higher packet delivery ratio, 14% lesser delay and 12% higher residual energy than the existing systems.

1. Introduction

The cattle industry is themain component of the world market since animals like cow, buffalo, sheep, goat etc are vital for rural life. Fig. 1 shows the cattle form for cows or dairy forms. To increase the performance of dairy cows, the process of supplying the essential food and maintaining their welfare is required. However, the performance of the cattle industry is affected due to many reasons such as various diseases, lower insemination and reproductive health issues [1]. These problems of cattle results in lesser milk production, early exclusion of prospective cows and reduces calves [2]. The cattleis being affected by various kinds of diseases like Foot and Mouth Disease (FMD), Anthrax, Black-quarter (Black-leg), contagious bovine abortion and Bovine mastitis [2]. In animal health care systems, the utilization of body sensors and wearable techniques are gaining more importance. Wireless sensor network (WSN) comprises of many small-sized cheap devices which forms an ad hoc system. Sensors can monitor the activities of cattle periodically, to measure and collect various parameters related to nutrition, reproduction, health etc [3]. Due to the recent advances in the area of Internet of Things (IoT), precision dairy-monitoring technologies (PDMT) are now utilized to avoid the drawbacks of traditional WSN [3]. The conventional way of cattle monitoring involves manual supervision which requires huge skilled manpower and time. Hence PDMTs are expected to minimize labour costs and time. It is difficult for the farmers to locate the cattle if it goes out of the farm. Hence it will be better to automate the monitoring process of cattle cost-effectively so that lifetime of cattle may be extended [4].

Due to the increase in the size of the dairy farms, conventional milking is being transformed into automatic milking systems (AMS), the regular human-cattle interaction has almost vanished. Hence, other methods of observing the behavioural changes have become highly necessary for the well-being of the herd such as advanced sensing and intelligent processing [6].

1.1. Novelty of the work

The main objectives of the proposed work are to accurately predict the illness of cattle, well in advance and take the necessary actions and to ensure failure-free, stable and energy-efficient communications. To meet these objectives, the Smart Cattle Monitoring System using IoT sensors is designed.

Though a lot of works have been done on monitoring the health conditions of cattle, they have considered an only limited set of attributes and failed to do an accurate prediction of the illness in advance. Moreover, those techniques are restricted to specific

* Corresponding authors.
E-mail address: suseendar_1234@yahoo.co.in (G. Suseendran).

https://doi.org/10.1016/j.matpr.2021.01.873
2214-7853/

Please cite this article as: G. Suseendran and D. Balaganesh, Smart cattle health monitoring system using IoT sensors, Materials Today: Proceedings, https://doi.org/10.1016/j.matpr.2021.01.873

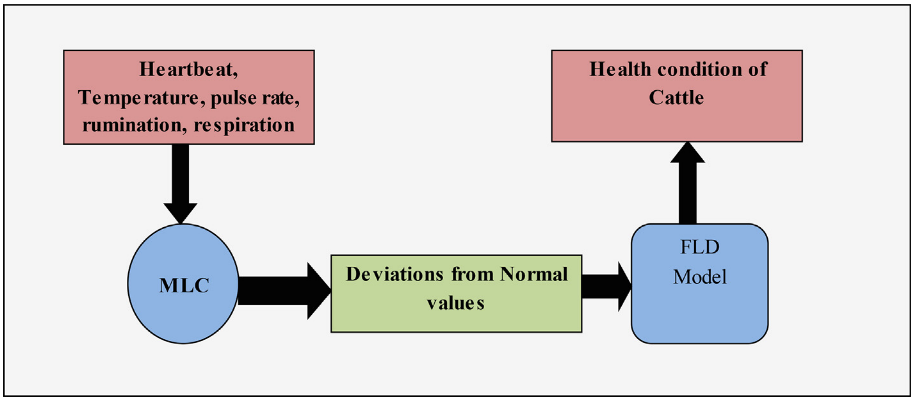

Fig. 1. Block diagram of smart cattle monitoring architecture.

range limitations. This work considers all the main attributes such as heartbeat, body temperature, pulse rate, rumination and respiration information required for monitoring the health of cattle. In cattle health monitoring applications, cattle are generally located in a large herd which will seriously affect the radio performance of sensors. When sensor nodes are deployed over the cattle, their locations change frequently during cattle movement. This affects the reliability of communications between the sensors and the base station. Hence the network topology and routing path should be dynamic in responding to frequent movement of the cattle [7]. Reliable data transmission module of the smart Cattle monitoring system provides reliable communications between the gateway and collar attached on the cattle. The link disconnections due to mobility are resdolved through desigining an Intra and Inter Gateway Routing Protocol (RIIGRP).

1.2. Main contributions of the work

The main contributions of this work are as follows:

I. The Health monitoring module contains health sensors for measuring various health factors which are deployed on the body of the cows. The collected information is examined at the medical research server (MRC) and compared against the range of values from the reference table.
II. The deviations between the observed and the normal values are considered as input to the Fuzzy logic decision (FLD) model to determine the health condition of the cattle.
III. If the health condition is CRITICAL, then a warning message will be sent as SMS to the respective doctor's mobile using the ESP8266 WiFI module.
IV. To optimize the collar radio coverage and to guarantee higher received signal strength (RSS), an antenna diversity scheme is applied with two antennas.
V. RIIGRP ensures energy-efficient and stable communication.

The organization of the paper is as follows. Section 2 contains the related works. The section contains the design and methodology of the architecture. Section 4 contains the results and discussion and section 5 concludes the paper with future work.

2. Related works

In this section, the comparison of existing cow health monitoring systems is presented in Table 1 with their research gaps.

3. Proposed methodology

Fig. 1 presents the block diagram of the smart cattle monitoring system and Fig. 2 shows the components involved in the architecture and contains two modules:

I. **In Health monitoring module,** various health sensors collect the required parameters from various body parts of the cattle. The collected information is transmitted to the MLC via the RMG. At MLC, the normal range of values for various factors such as body temperature, heartbeat, pulse rate etc will be stored in a reference table for each type of cattle, based on the previously observed data. The collected health information over some timeis aggregated and compared against the range of values in the reference table. The deviations between the observed and the normal values are considered as input to the Fuzzy logic decision (FLD) model to determine the health condition of the cattle. If the condition is CRITICAL, then a warning message will be sent as SMS to the respective doctor's mobile using the ESP8266 WiFI module.
II. **Reliable data transmission module,** reliable communications between the gateway and collar attached on the cattle, is established and maintained. To optimize the collar radio coverage and to guarantee higher received signal strength (RSS), an antenna diversity scheme isapplied in which two antennae can be used. To minimize the link disconnections due to mobility, a Reliable Intra and Inter Gateway Routing Protocol (RIIGRP) is designed. Intra gateway routing indicates the communication between the sensors and the WLG and inter gateway routing indicates the communications between the WLG to RMG. RIIGRP ensures energy-efficient and stable communication.

The system model of the proposed architecture is presented in the next subsection.

3.1. System model

The system model of the proposed methodology is shown in Fig. 3. It consists of a variety of sensors deployed on different body parts of the cattle. A wireless local gateway (WLG) resides in the local premises of the cattle. Each sensor observes and collects its corresponding data and transmits it to the WLG through other routers sensors. The WLG gathers all these data and then communicate with a remote medical gateway (RMG) through wireless access. The RMG transmits the gathered data to the medical

Table 1
Existing Approaches and Research Gaps.

Author	Title	Technology Used	Health Parameters	Research gaps
Alberto L. Barriuso et al [3]	Combination of multi-agent systems and wireless sensor networks for the monitoring of cattle	Multi agent systems and sensors	Heat, calving time and levels of feed	Involves huge computational and communication cost
Myeong-Chul Park et al [4]	Development of effective cattle health monitoring system based on biosensors	Zigbee and Biosensors	Heartbeat, breath rate and momentum	Less accuracy as there is no decision making module
Meenakshi et al [5]	Cattle health monitoring system using Arduino for early detection of diseases	Arduino and IoT	Body temperature, Respiration, Humidity, Heat beat and Rumination	Less accuracy as there is no decision making module
Lenka S.K et al [6]	A Novel approach of cattle health monitoring for early detection of disease	Biosensors	Body temperature.	It considers only body temperature for predicting illness
AteevAgarwal et al [7]	WPAN Based Cattle Health Monitoring With Labview as A Data Logger	IEEE1451.1, 1451.2, and 802.15.4 standards.	Body temperature, sweating, heartbeat, and rumination	Less accuracy as there is no decision making module
OlgierdUnold et al[8]	IoT-Based Cow Health Monitoring System	IoT sensors	Body temperature, heartbeat, and rumination	Involve high storage overhead and no decision making module
Anuj Kumar et al [9]	A Zigbee-Based Animal Health Monitoring System	IEEE1451.1 and Zigbee	Rumination, heart rate, temperature and humidity	Less accuracy as there is no decision making module
AmrutaAwasthi et al [10]	Non-Invasive Sensor Technology for the Development of a Dairy Cattle Health Monitoring System	Ontology matching	temperature and accelerometer	Heart beat and ECG are not considered.
Myeong-Chul Park et al [11]	Design of cattle health monitoring system using wireless bio-sensor networks	Zigbeesensors	ECG, breath rate Heartbeat and momentum	Less accuracy as there is no decision making module
Akhila Suresh et al [12]	An IoT Solution for Cattle Health Monitoring	IoT and TDMA	Body temperature, heartbeat and humidity	The use of TDMA increases the end-to-end delay

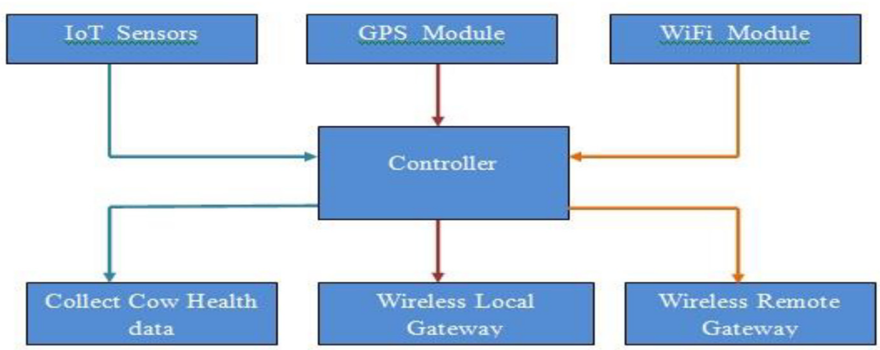

Fig. 2. Components involved and Architecture.

research server (MRS) where the condition of the cattle is determined.

3.2. Health condition details of cattle

The health sensors collect the heartbeat, body temperature, pulse rate, rumination and respiration information from various body parts of the cattle. In this subsection, the normal range of these parameters and the details of corresponding sensors are presented.

I. Heartbeat
II. The normal heartbeatof an aged cow is in the range of 48 to 84 beats per minute. The heartbeat sensor used in the experiments is a stethoscope. It is placed behind cow's elbow to observe the left portion of the cow's chest. The elevation of the heartbeat can result in an indication of pain. Fig. 4 shows the Heartbeat sensor and its output.
III. Body temperature
IV. The usual body temperature of the cow is in the range of 38.5–39.5 °C. When the body temperature becomes lower than the normal range, it results in various diseases like milk fever, poisoning, indigestion etc. When the temperature becomes higher than 41 °C,it results in diseases like anthrax, influenza and foot & mouth disease. Fig. 5 shows the body temperature sensor. Table 2 shows the range of normal body temperature values of various animals.
V. Rumination
VI. It is a valuable part of the process by which cattle digests the food. Rumination period is mainly determined by the amount of food consumed together with the ration composition mainly fibre substance and particle size. A reduction in rumination is a clear sign of health problem which will affect milk production. The cattle normally Ruminates is around 450–500 times per day.

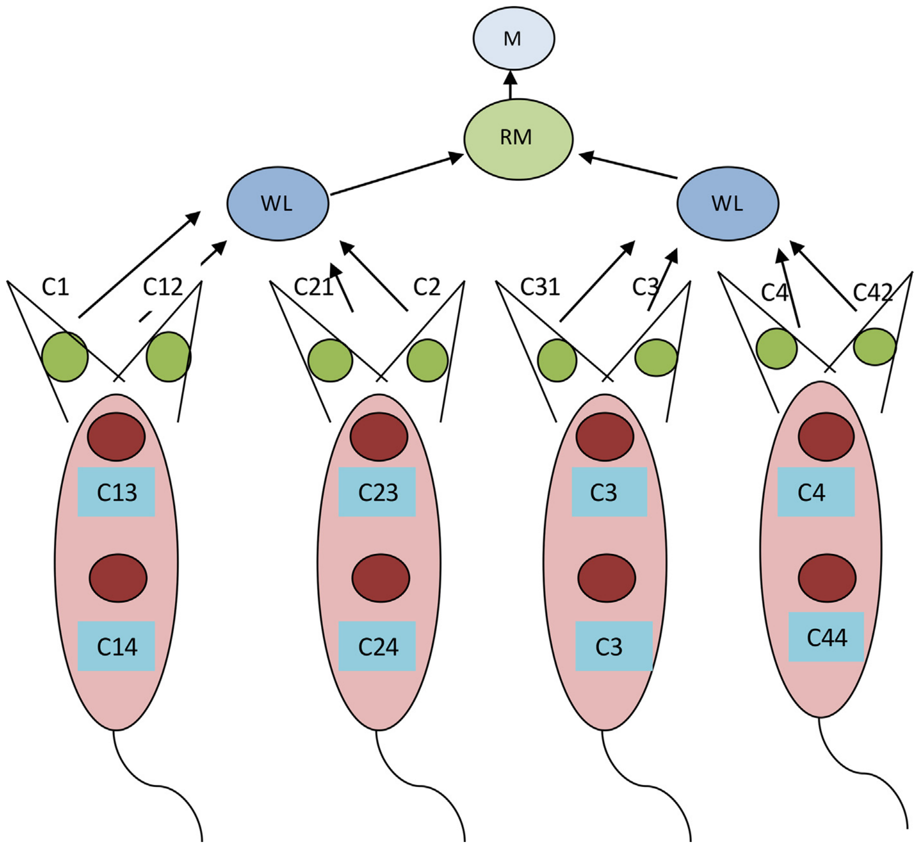

Fig. 3. System Model.

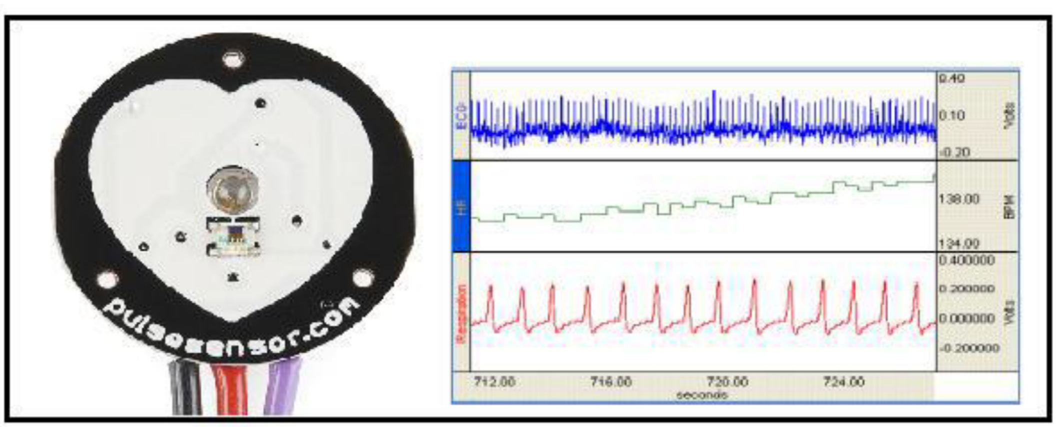

Fig. 4. Heartbeat Sensor &its output.

VII. Respiration

VIII. Respiration rate of cattle is 26 and 50 breaths per minute. When the respiration rate of cattle increases it represent stress or pain or weakness or maybe a sign of respiratory disease. If cattle get too hot, they may increase heat loss through evaporation. Cattle panting at above 100 breaths per minute are under severe heat stress Fig. 6.

3.3. Health monitoring module

The health sensors collect the heartbeat, body temperature, pulse rate, rumination and respiration information from various body parts of the cattle. The collected health information over some timeis aggregated and compared against the range of values in the reference table.

Let $Havg(t_j)$ be the average heartbeat of a cattle over the time period t_j.

Let $Tavg(t_j)$ be the average body temperature of a cattle over the time period t_j.

Let $Pavg(t_j)$ be the average pulse rate of a cattle over the time period t_j.

Let $RUavg(t_j)$ be the average rumination value of a cattle over the time period t_j.

Let $REavg(t_j)$ be the average respiration value of a cattle over the time period t_j.

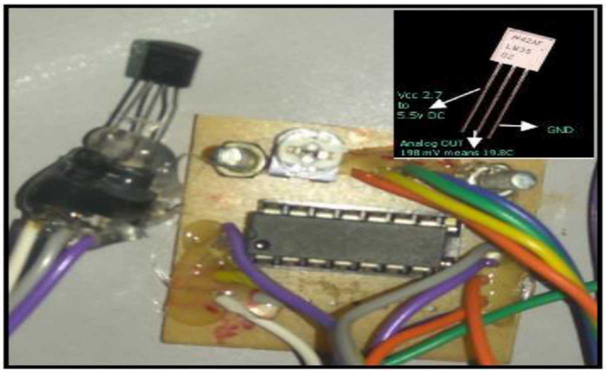

Fig. 5. Body Temperature Sensor.

Table 2
Usual body temperatures.

Animal	Usual Temperature °C
Cattle	38.5
Buffalo	38.2
Sheep	39
Llama	38
Donkey	38.2
Chicken	42
Calf	39.5
Goat	39.5
Camel	34.5–41.0
Horse	38
Pig	39
Piglet	39.8

Let D(H), D(T), D(P), D(RU) and D(RE) be the deviations between the aggregated values and the normal values stored in the reference table, given by

$$D(H)+ = abs(NH - H_{avg}(t_j)) \quad (1)$$

$$D(T) = abs(NT - T_{avg}(t_j)) \quad (2)$$

$$D(P) = abs(NP - P_{avg}(t_j)) \quad (3)$$

$$D(RU) = abs(NRU - RU_{avg}(t_j)) \quad (4)$$

$$D(RE) = abs(NRE - RE_{avg}(t_j)) \quad (5)$$

Where *NH, NT, NP, NRU* and NRE are the normal range of values corresponding to the heartbeat, body temperature, pulse rate, rumination and respiration, respectively.

absare the absolute value of the difference between the normal and the observed values.

Fuzzy logic decision (FLD) model is applied by considering these deviations as input variables. Each of the values given by Eq. (1) to (4) arecategorized as MINIMUM, MODERATE and HIGH, depending on their values.

The fuzzy decision model is shownin Fig. 7.

Fuzzification: In this phase, theinput variables D(H), D(T), D(P), D(RU) and D(RE) are given a degree to appropriate fuzzy sets. These input variables are categorized as MINIMUM, MODERATE and HIGH, depending on their values. The health condition (HC) of the cattle will be returned as the output as NORMAL, MODERATE and CRITICAL.

Fig. 8 shows the input membership function for the deviation of heartbeat D(H) with Minimum, moderate and High range of values.

Fig. 9 shows the input membership function for the deviation of temperature D(T) with Minimum, moderate and High range of values.

Fig. 10 shows the input membership function for the deviation of pulse rateD(P) with minimum, moderate and High range of values.

Fig. 11 shows the input membership function for the deviation of Rumination D(RU) with Minimum, moderate and High range of values.

Fig. 12 shows the input membership function for the deviation of respiration D(RE) with Minimum, moderate and High range of values.

Fig. 13 shows the output membership function for a health condition (HC) with Normal, moderate and critical range of values.

Fuzzy Rule Aggregation: In this phase, fuzzy rules are formed for the input membership functionswith various combinations along with the corresponding output. Table 3 presents the fuzzy rules corresponding to the input membership functions along with the output.

Defuzzification: In this method, a crisp value is returned from the output fuzzy set. Here, the centroid of the area scheme is considered.

Eq. (6) gives a crisp value using the defuzzifier method.

Crisp value = $[\sum_{allrules} f_i{}^{*} \alpha(f_i)] / [\sum_{allrules} \alpha(f_i)]$ (6)

Where f_i is all rules and variable and $\alpha\ (f_i)$ is their membership function.

Critical Warning Notification

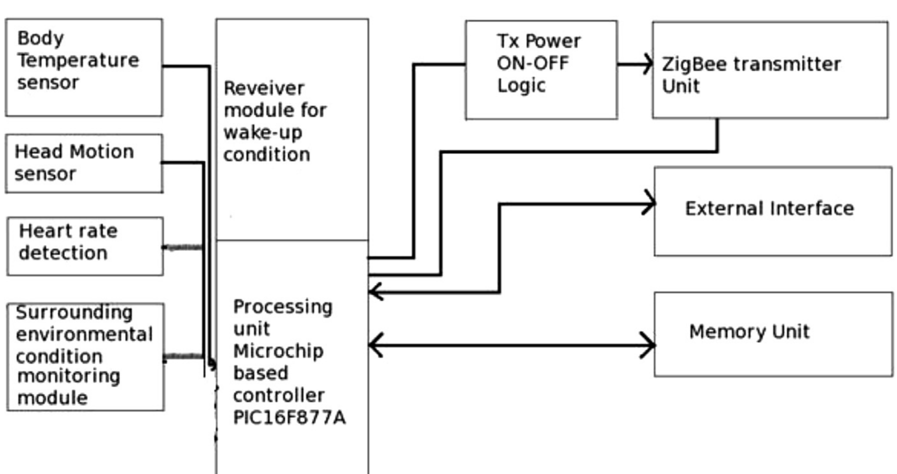

Fig. 6. Architecture of a single sensor mote.

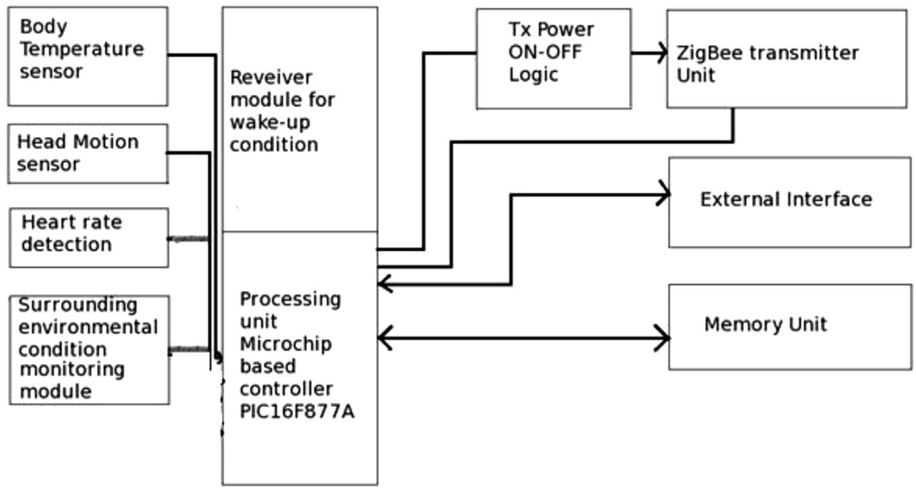

Fig. 7. Fuzzy Decision Model.

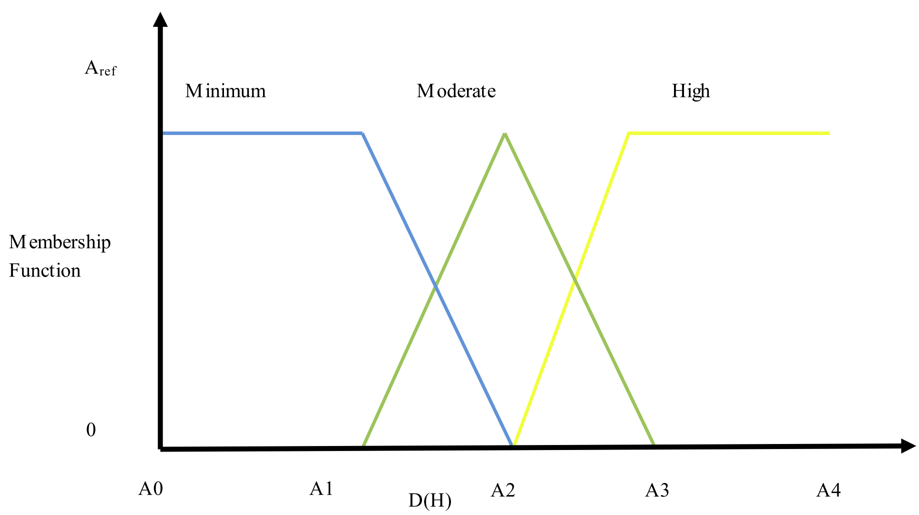

Fig. 8. Membership Function for D(H).

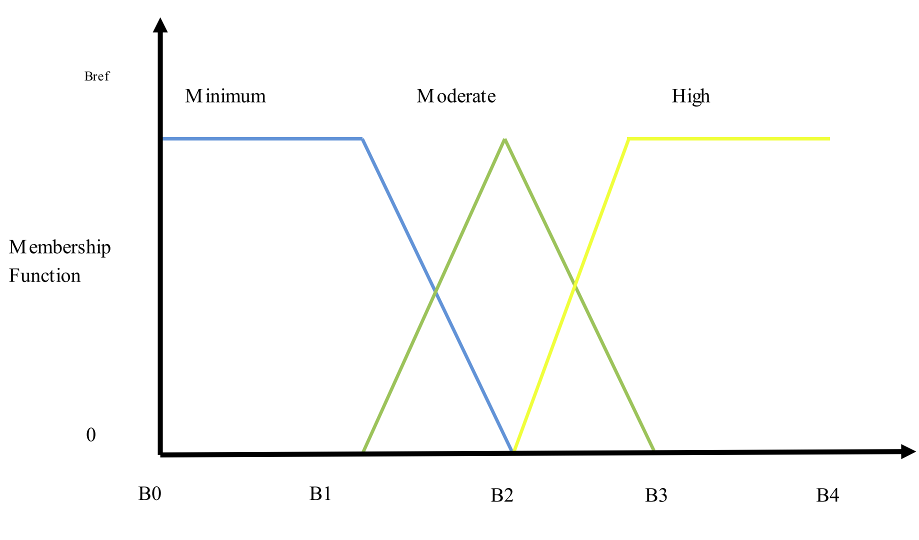

Fig. 9. Membership Function for D(T).

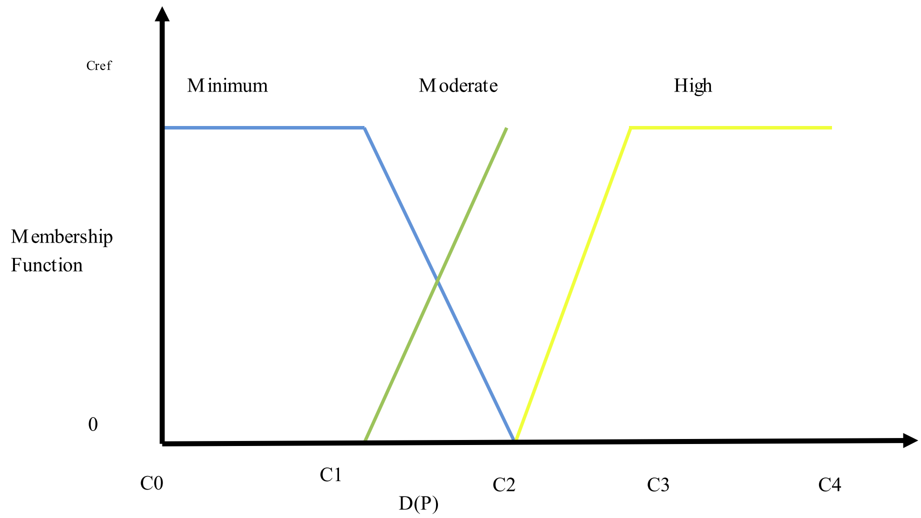

Fig. 10. Membership Function for D(P).

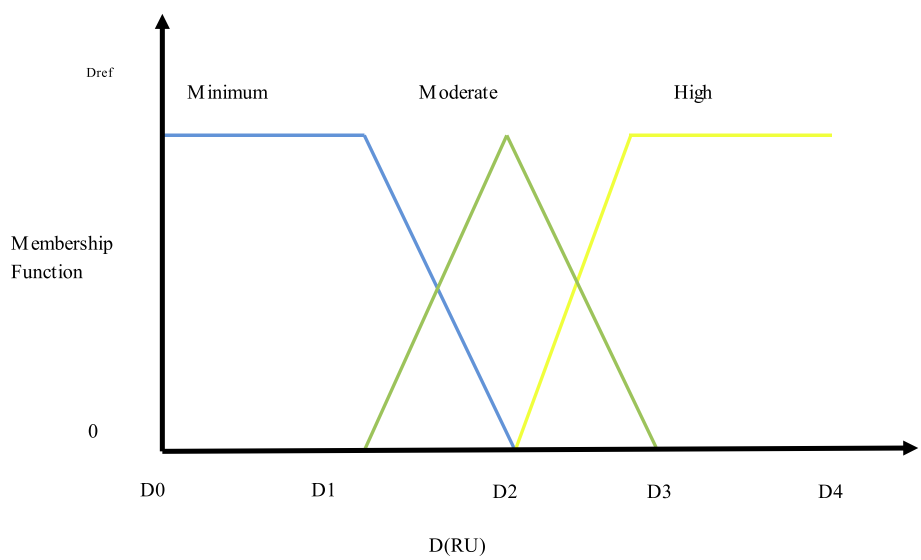

Fig. 11. Membership Function for D(RU).

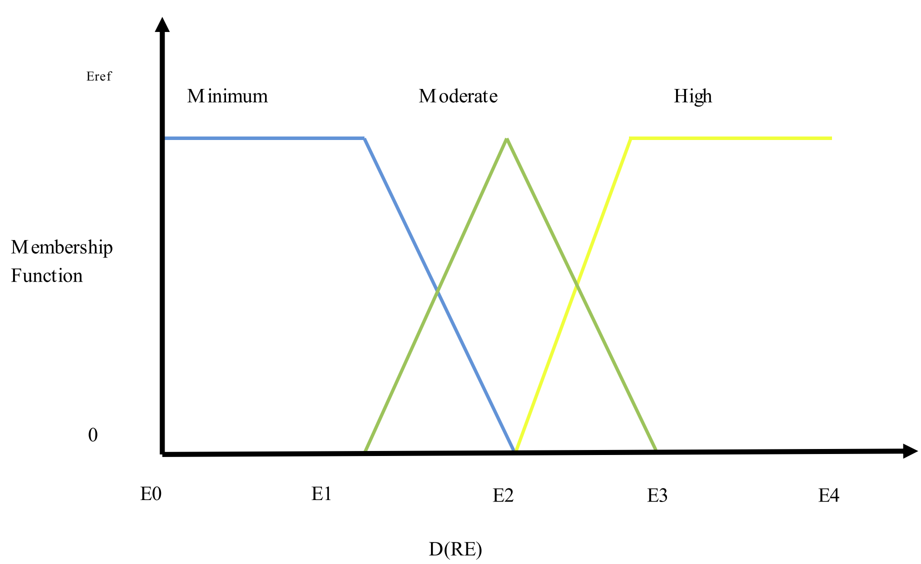

Fig. 12. Membership Function for D(RE).

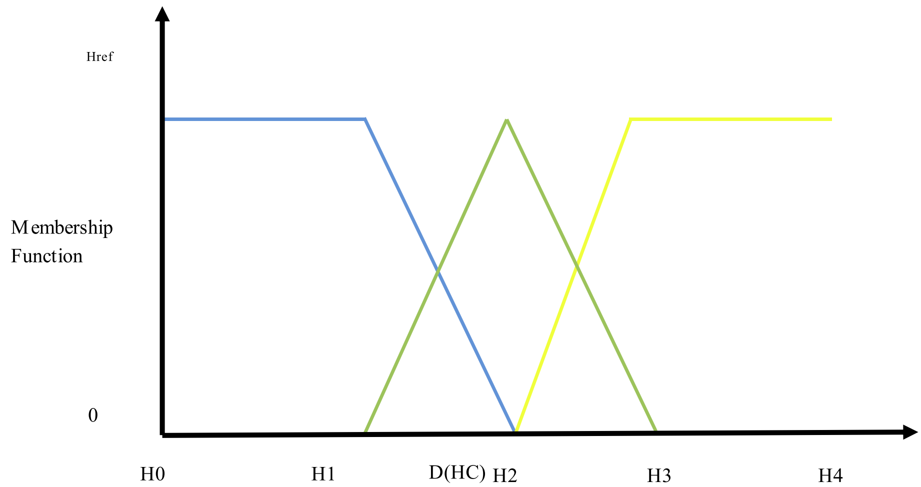

Fig. 13. Membership Function for HC.

Table 3
Fuzzy Rules Table.

S.No	D(H)	D(T)	D(P)	D(RU)	D(RE)	HC
1	Minimum	High/Moderate/Minimum	Minimum	Minimum	Minimum	Critical
2	Minimum	High/Moderate/Minimum	Minimum	Minimum	Moderate	Critical
3	Minimum	High/Moderate/Minimum	Minimum	Minimum	High	Critical
4	Minimum	High	Minimum	Moderate	Minimum	Critical
5	Minimum	Minimum /Moderate	Minimum	High	Minimum	Critical
6	Minimum	High	Moderate	Minimum	Minimum	Critical
7	Minimum	High	High	Minimum	Minimum	Critical
8	Minimum	Moderate	Moderate	Moderate	Moderate	Moderate
9	Minimum	Minimum /Moderate	High	High	High	Normal
10	Moderate	High/Moderate/Minimum	Moderate	Moderate	Minimum	Moderate
11	Moderate	High/Moderate/Minimum	Moderate	Moderate	High	Moderate
12	Moderate	Minimum /Moderate	Moderate	High	High	Moderate
13	Moderate	Minimum /Moderate	High	High	High	Normal
14	High	High/Moderate/Minimum	High	High	High	Normal
15	High	Minimum /Moderate	Moderate	High	High	Normal
16	High	Minimum /Moderate	High	Moderate	High	Normal
17	High	Moderate	Moderate	Moderate	Moderate	Moderate
18	High	High	High	High	Minimum	Normal
19	High	Minimum /Moderate	High	Minimum	High	Normal
20	High	Minimum /Moderate	Minimum	High	High	Moderate
21	High	High	Minimum	Minimum	Minimum	Critical
22	High	Minimum /Moderate	Minimum	Minimum	High	Moderate
23	High	Minimum /Moderate	Minimum	High	Minimum	Moderate

If the health condition of the cattle is returned as CRITICAL, then a warning message will be sent as SMS to the respective doctor's mobile using ESP8266 WiFI module. This WiFI module transmits signals by means ofIoT technology. Thus, this module provides early and accurate detection of cattle's health condition.

The following algorithm is executed at MRC.

Algorithm-1: Health Monitoring and Critical Warning Algorithm
INPUT: Aggregated values over time tj: Havg(tj), Tavg(tj), Pavg (tj) , RUavg(tj), REavg(tj)
OUTPUT: Health condition (HC) of Cattle
BEGIN
For each(time period tj)
Find deviations D(H), D(T),D(P),D(RU),D(RE)
Form input membership function and Fuzzy set for each deviation
Form output membership function and Fuzzy set for HC
Apply Fuzzy rules as per table 2 table 3 table 4
Crisp value(HC) → Defuzzfication (Output Fuzzy set)
If Crisp value(HC) == Critical then
Send warning SMS to Doctor mobile
End if
End For
END

3.4. Reliable data transmission module

To minimize the link disconnections due to mobility, a Reliable Intra and Inter Gateway Routing Protocol (RIIGRP) is designed. Intra gateway routing indicates the communication between the sensors and the WLG and inter gateway routing indicates the communications between the WLG to RMG. RIIGRP ensures energy-efficient and stable communication.

Reliable Intra and Inter Gateway Routing Protocol (RIIGRP)

The steps involved in RIIGRP are as follows:

Intra-Gateway Routing

1) Each sensor$N_i$analyzes the other nodes$N_j$based on its received signal strength. When it identifies a suitable sensor with maximum RSSI, N_i sends a request message (RO_REQ) to N_j.

$N_i \xrightarrow{RO\_REQ} N_j$

2) $N_j$upon receiving the request verifies its node cache which results in the following two solutions.

a) If N_j contains the route to WLG in its cache, then it forwards RO_REQ to the WLG. Then it acknowledges N_i by sending a reply message (RO_REP)

$N_j \xrightarrow{RO\_REQ} WLG$

$N_j \xleftarrow{RO\_REP} N_i$

b) If N_j does not contain relevant route to WLG in its cache, then it forwards the request to another node. This process continues until WLG receives RO_REQ

$N_j \xrightarrow{HO\_REQ} N_{j+1}$

Inter Gateway Routing

1) When WLG want to send data to RMG, it broadcast a remote route request message (RMO_REQ) to RMG.

In order to prevent WLG from unnecessary broadcasts, WLG following the reception of RMO_REQ message wait until an update is received from CH for time t. Then it re-broadcasts the message after time expiry.

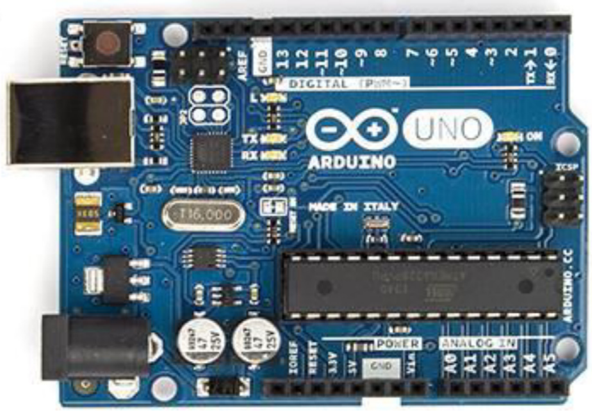

Fig. 14. Graph of body temperature.

2) It allows any WLG in different clients control also to detect request message.

3) RMG upon receiving the request responds with the remote route reply message (RMO_REP) to WLG.

Algorithm-2: RIIGRP Algorithm
INPUT: Collected readings
N_i – sender N_j- Neighbours
OUTPUT: ACK from the RMG
BEGIN
For each sensor N_i
If (RSSI(N_j) ==Maximum) **then**
N_i sends RO_REQ to N_j
End if
If ($N_j$contains route to WLG) **then**
N_j forwards RO_REQ to WLG
Else
N_j forwards RO_REQ to N_{j+1}
End if
If (WLG receives RO_REQ) **then**
WLG sends RO_REP towards N_i
End if
End For
WLG broadcasts RMO_REQ to RMG
If (RMG receives RMO_REQ) **then**
RMG sends RMO_REP to WLG
End if
END

---

4. Experimental results

This section presents the experimental settings and results associated with the proposed system.

4.1. Observed results

The results obtained from the temperature and heart beat sensors are shown in Fig. 14 and Fig. 15, respectively.

4.2. Simulation experiments

The simulation of Smart Cattle Monitoring Architecture for Reliable Communications (SCMA) is conducted in NS2 and it is com-

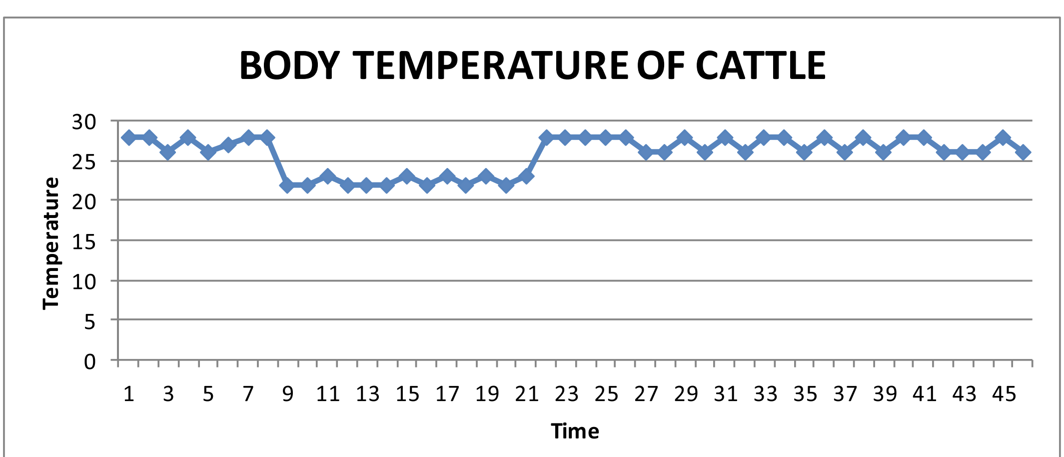

Fig. 15. -Graph of heartbeat.

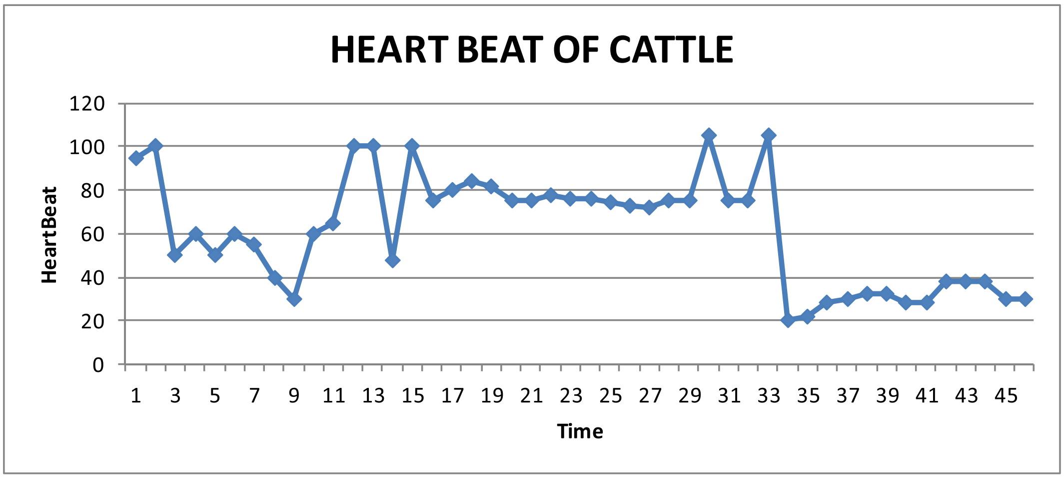

Fig. 16. Simulation Topology.

Table 4
Simulation Parameters.

Parameter	Value
Number of Nodes	20
Size of the topology	50 X 50 *m*
Propagation type	Two Ray Ground
Transmission Range	12 *m*
Antenna Type	Omni Direction
MAC protocol	IEEE 802.15.4
Simulation Time	200 s
Traffic Source	Constant Bit Rate
Data Rate	10 to 50 Kb/s

pared with the Multi-Agent System (MAS) based monitoring [5]. The performance is evaluated concerning Packet Delivery Ratio (PDR), Delay, Packet Drop, Residual energy and Overhead.

4.2.1. Simulation setup

Fig. 16 shows the simulation topology used in the experiments. Table 4 shows the simulation settings used in the experiment.

Packet Delivery Ratio (PDR): Itis computed as the ratio of packets sent to the number of packets received.

PDR = (packets received/packetssent) (7)

Packet Drop: It is the number of packets sent by the source, but not received by the destination node.

$$DRP = \sum_{i=1}^{n}(N_t^s - N_t^r) - \sum_{t=1}^{n} N_i^s \qquad (8)$$

End-to-End Delay: It is calculated as the difference between the packet receiving time and packet sending time.

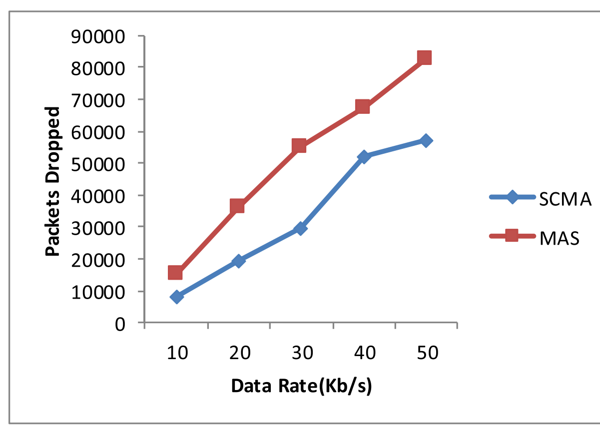

Fig. 18. PDR for varying Nodes.

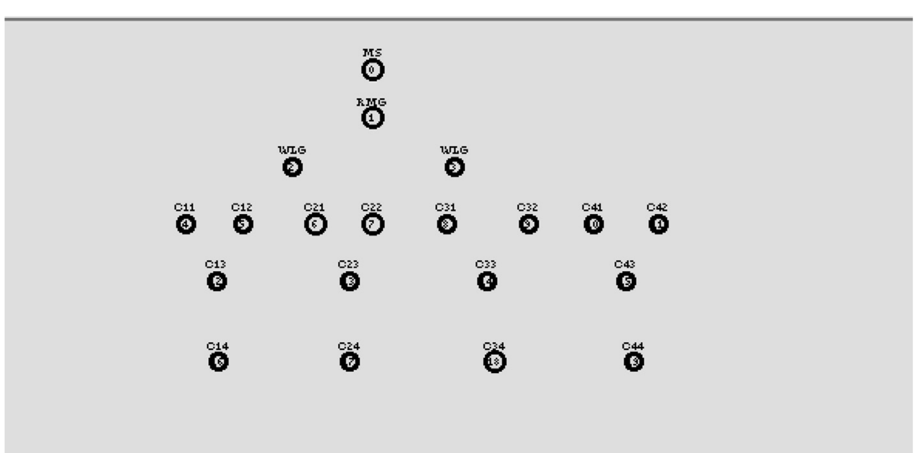

Fig. 17. Packet Drop for varying Rate.

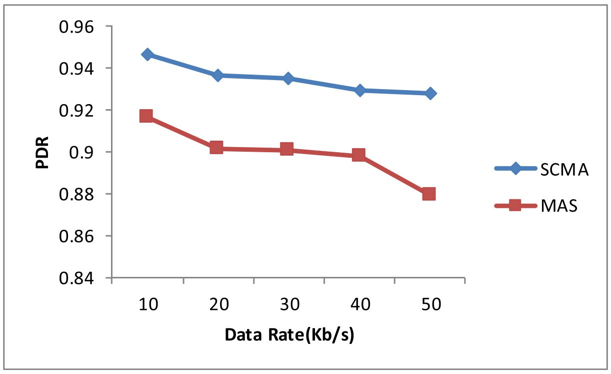

Fig. 19. Residual Energy for varying Nodes.

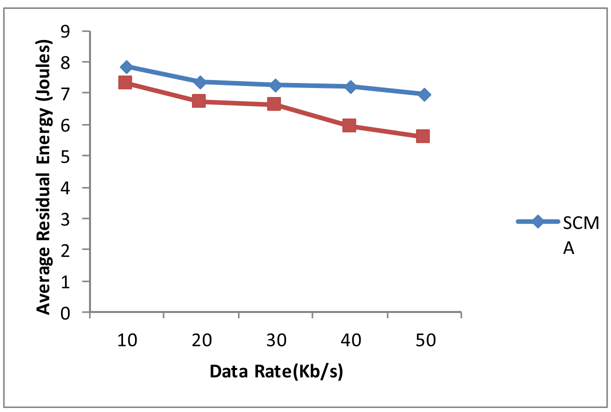

Fig. 20. Delay for varying Nodes.

$$\Delta = \frac{\sum_{i=1}^{nrcd} \Delta_i}{N_{rcd}} \quad (9)$$

4.2.2. Simulation results and analysis

This section presents the simulation results and their analysis

Fig. 17 shows the result of packets dropped for the two schemes. It depicts that the packet drop of SCMA is 38% lesserthanMAS.

Fig. 18 shows the result of PDR for the two schemes. The figure depicts that the PDR of SCMA is 3.85% higher when compared to MAS.

Fig. 19 shows the result of average residual energy for the two schemes. The figure depicts that the SCMA has 12.35% higher residual energy when compared to MAS.

Fig. 20 shows the result of the end-to-end delay for the two schemes. It depicts that the SCMA has 13.8% lesser delay than MAS.

5. Conclusion

In this paper, we have proposed a smart Cattle Monitoring Architecture for reliable communications using IoT sensors. To accurately predict the illness of cattle well in advance, the fuzzy-based health monitoring module is proposed. To ensure reliable data transmission module between the gateway and collar attached on the cattle, an antenna diversity scheme and Reliable Intra and Inter Gateway Routing Protocol (RIIGRP) are designed. The proposed architecture is simulated in NS2 and implemented in Arduino sensor environment. From the experimental results, it is shown that the proposed system achieves 4% higher packet delivery ratio, 14% lesser delay and 12% higher residual energy s than the existing systems.

6. Future work

Future work focuses on handling the mobility issues and designing a location monitoring module for estimating whether a cow has been located within its geographical boundary. Collars with integrated GPS are deployed to track the movement of the cattle. The current location and movement speed are collected from these collars from which the regular movement pattern of the cattle is estimated. Then the probability that the cattle will move outside its boundary, is determined.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

[1] Vannieuwenborg, F., Verbrugge, S., &Colle, D. (2017, November). Designing and evaluating a smart cow monitoring system from a techno-economic perspective. In2017 Internet of Things Business Models, Users, and Networks (pp. 1-8). Ieee.
[2] D. Aswini, S. Santhya, T.S. Nandheni, N. Sukirthini, Cattle health and environment monitoring system, IRJET 4 (2017).
[3] B. Sharma, D. Koundal, Cattle health monitoring system using wireless sensor network: a survey from innovation perspective, IET Wireless Sens. Syst. 8 (4) (2018) 143–151.
[4] A.L. Barriuso, G. Villarrubia González, J.F. De Paz, Á. Lozano, J. Bajo, Combination of multi-agent systems and wireless sensor networks for the monitoring of cattle, Sensors 18 (1) (2018) 108.
[5] M.C. Park, O.K. Ha, Development of effective cattle health monitoring system based on biosensors, Adv. Sci. Tech 117 (2015) 180–185.
[6] K.B. Swain, S. Mahato, M. Patro, S.K. Pattnayak, in: May). Cattle health monitoring system using Arduino and LabVIEW for early detection of diseases, IEEE, 2017, pp. 79–82.
[7] S.K. Lenka, A.G. Mohapatra, A novel approach of cattle health monitoring system based on wireless sensor network for early detection of disease, J. Grid Distribut. Comput. 2 (1) (2012).
[8] Ateev Agarwal, Eesh Mehandiratta, Rohit Sanket, Rohit Samkaria, Ambujaksh Shah, Rajesh Singh, Anita Gehlot, WPAN based cattle health monitoring with labview as a data logger, Int. J. Future Gener. Commun. Netw. 9 (6) (2016) 275–284.
[9] O. Unold, M. Nikodem, M. Piasecki, K. Szyc, H. Maciejewski, M. Bawiec, M. Zdunek, in: IoT-Based Cow Health Monitoring System, Springer, Cham, 2020, pp. 344–356.
[10] Anuj Kumar, Gerhard P. Hancke, A zigbee-based animal health monitoring system, IEEE Sens. J. 15 (1) (2015) 610–617.
[11] A. Awasthi, A. Awasthi, D. Riordan, J. Walsh, Non-invasive sensor technology for the development of a dairy cattle health monitoring system, Computers 5 (4) (2016) 23.
[12] Suresh, A., &Sarath, T. V. (2019, October). An IoT Solution for Cattle Health Monitoring. InIOP Conference Series: Materials Science and Engineering (Vol. 561, No. 1, p. 012106). IOP Publishing.

Further Reading

[1] S. Neethirajan, Recent advances in wearable sensors for animal health management, Sens. Bio-Sens. Res. 12 (2017) 15–29.
[2] P.K.M. Nkwari, S. Rimer, B.S. Paul, in: Cattle monitoring system using wireless sensor network in order to prevent cattle rustling, IEEE, 2014, pp. 1–10.
[3] K.H. Kwong, T.T. Wu, H.G. Goh, B. Stephen, M. Gilroy, C. Michie, I. Andonovic, Wireless sensor networks in agriculture: Cattle monitoring for farming industries, Piers Online 5 (1) (2009) 31–35.
[4] S.K. Lenka, A.G. Mohapatra, A novel approach of cattle health monitoring system based on wireless sensor network for early detection of disease, J. Grid Distribut. Comput. 2 (1) (2012) 15.
[5] T.A. Shinde, J.R. Prasad, IoT based animal health monitoring with naive Bayes classification, IJETT 1 (2) (2017).
[6] AmrutaTaral SwetaJha, VaishnaviShinde KomalSalgaonkar, ShraddhaSalgaonkar, E-Cattle health monitoring system using IoT, J. Netw. Commun. Emerg. Technol. 7 (2017) 8.