Cloud IOT based novel livestock monitoring and identification system using UID

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Abstract

Purpose – We propose cloud IoT based LMS (Livestock Management System) with three features. i) Animal healthcare monitoring and recording using IoT sensors via wearable collar, ii) Animal livestock identification using UID for animals (smart tag) and owners (smart card), iii) QR code reading, processing and display of the details in mobile via wireless technologies.

Design/methodology/approach – The developed animal monitoring device is used to detect animal physiological parameters such as body temperature; physical gestures like sitting, standing, eating and heartbeat, environmental parameters such as air temperature and relative humidity. Also, e-animal husbandry information network management system is the comprehensive web-based animal husbandry software designed for better interaction between veterinary hospital, veterinary doctor, owner, farmer and animal husbandry management.

Findings – Animal monitoring device mounted on the neck sense the values and predict the health status of the animal by using cloud IoT analytics platform. The accuracy of the system is 90 per cent and it can be well placed in the livestock environment.

Research limitations/implications – This research is carried out in livestock cows located in Tirunelveli district. The practical difficulty was in placing sensors on the animal. The digital feed from the farmers and the veterinary hospital is input in the animal husbandry management software.

Practical implications – The developed system can be implemented for monitoring the health status of the animal from anywhere using mobile applications. Also, the digitized animal information helps the government to take the right decisions on policies and fund allocation.

Social implications – The implemented system can be easily scaled up to large environments by using wireless communication and animal husbandry data will be available immediately. UID scheme for animals can uniquely identify the animal and its details.

Originality/value – The proposed work implements novel livestock monitoring and analytics system along with Aadhar (Unique ID) for animal. The proposed UID scheme is innovative and unique.

Keywords RFID, Sensor networks, Biometrics, Food industry, Wireless sensor networks, Body sensors, Animal Husbandry, E-animal Health

Paper type Research paper

1. Introduction

Animal husbandry is the one of the core branches of agriculture sciences which deals with care, breeding and management of the animal. Animal husbandry sector plays a crucial role in supplementing the income of small, marginal farmers and landless laborers and in generating gainful employment opportunities especially self-employment to a substantial amount of the rural and urban population. Animal husbandry provides veterinary health care and improves the genetic production potentialities of livestock and poultry reared in the state. Animal disease surveillance is an integral part of animal husbandry and veterinary services through which veterinarians can diagnose, monitor, control and eradicate existing and emerging diseases in livestock that causes economic losses to the farmer and on the whole to the nation and protect public health by preventing zoonotic disease (Agritech portal for Animal Husbandry, 2017).

The animal husbandry management system (Agritech portal for Animal Husbandry, 2017) includes livestock (domesticated animals such as cattle, buffalo, goat, sheep, goat, pig and rabbit); poultry (domesticated fowl like hen, turkey, duck and quail); integrated farming (deals with combination of fish cum poultry, fish cum dairy, fish cum pig, fish cum duck); machineries and equipment (milking machine, incubator, chaff cutting machine); Post-harvest technology (value-added products such as milk, egg, chicken, ice-cream); services such as veterinary hospitals in Tamil Nadu, milk cooperative societies, slaughter houses, animal welfare organization, and marketing (milk/egg marketing and broiler marketing). Figure 1 shows the list of livestock domesticated animals.

Cloud offers on-demand services to the pooled users and devices. All these services are hosted in the cloud provider's servers and instances are launched in the client devices when they are in need of those services (Saravanan and Rajaram, 2015). Cloud IoT is the term evolved because of the convergence of cloud computing with Internet of Things (IoT).

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Figure 1 Lists of livestock domesticated animals

Both of them complement each other by leveraging its services. The number of devices used in day-to-day life of the human as well as industries is growing rapidly because many services are automated. Animal livestock can leverage the power of cloud IoT services.

In this paper, we propose cloud IoT-based LMS (Livestock Management System) with three features: i) animal healthcare monitoring and recording using IoT sensors via wearable collar, ii) animal livestock identification using UID for animals (smart tag) and owners (smart card), iii) QR code reading, processing and display of the details in mobile via wireless technologies. This paper is organized as follows. Section 1 gives introduction about the livestock system. Section 2 deals with related study followed by Section 3 that presents the architecture of the proposed animal livestock management. Then, Section 4 gives the experimentation setup and Section 5 analyzes the performance of the system. Finally, Section 6 concludes our work.

2. Related work

Kumar and Hancke (2015) designed animal health monitoring system to detect health conditions of animals by detecting parameters such as temperature, rumination, heartbeat, environmental humidity and air temperature. Ting *et al.* (2007) designed RFID-based mobile monitoring system (RFID-MMS) to manage the animals in dynamic information retrieving, location tracking and behavior analyzing over a wireless network. Tedín *et al.* (2013) describe a computational intelligence based automatic body conditioning system for cattle called automatic body condition assessment (ABiCA) which uses pictures captured from the camera. A rear end shape of animal is segmented through active shape model using an evolutionary algorithm. Hayashi *et al.* (2015) explained that the product concept of RF enlightens the pass way to smart IoT and minimizes the power consumption of the IoT devices. Ariff and Ismail (2013) designed the hardware and software for livestock information system using android smart phone. It uses android operating system equipped with Bluetooth technology and wearable device which consists of the sensors to communicate and display the results in statistical format in mobile. Huang and Hsieh (2013) explained the gateway with an embedded system which uses the gateway as a data collector. Saranya et al proposed (Diwakaran *et al.*, 2014) the increase of energy efficiency to minimize energy consumption and gives long life for the sensor nodes using energy-balancing algorithm (Diwakaran *et al.*, 2014). Here, the leader is selected on the basis of the energy calculated by the neighboring node energy.

Patil *et al.* (2015) designed an animal monitoring device which is used to detect the diseases of the animal earlier. This system is based on the Zigbee wireless communication and also used the Arduino microcontroller. The results are displayed on the web using the graphical user interface. Turner *et al.* (2000) explained the behavior of the cow using the global positioning system (GPS). Animal graze pattern is obtained by exporting the data into a geographic information system. Kim *et al.* (2010) describes the real time intelligent animal tracking services using the sensor, RFID and GPS which provide information such as location, body temperature and image of the animal. Handcock *et al.* (2009) demonstrated the animal and environment monitoring using GPS collar and satellite image in wireless sensor networks. Gutierrez *et al.* (2013) demonstrated localization of herds using wireless sensor networks which consist of primary and secondary nodes. The secondary node collects the information with the position and time and sends this information to the base station. By using the node concept, the battery count is reduced and there is easy tracking of the herds. Volk *et al.* (2015) designed a low cost telemetry system using radio frequency identification which is used to measure the electrocardiogram, arterial blood pressure and body temperature of the animal. With reduced cost, it monitors the animal and refines the procedure in preclinical test.

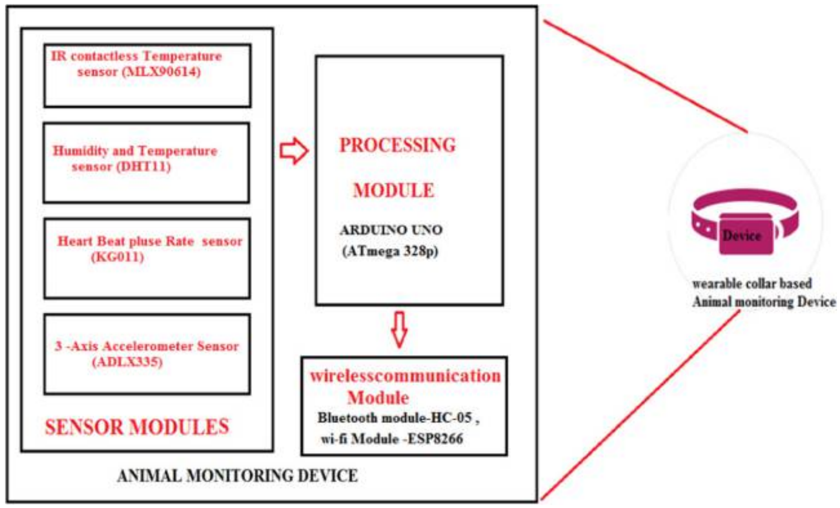
Höflinger *et al.* (2015) designed the active and passive sensor to monitor motor dysfunction of laboratory animals. The active sensor is used to detect the body temperature and heart rate of the animal. The passive sensor is used to monitor the cage and area around the animal such as its drinking dish and sleeping box. Valero-Sarmiento *et al.* (2014) explained the capsule-based bio-photonic sensor system for continuous monitoring of the hemodynamic parameters in animals. Anu *et al.* (2015) describes animal identification and management of animal database using the radio frequency technology. Floyd (2015) explained the RFID tag to track animals from different countries. Beng *et al.* (2016) proposed wireless sensor network based livestock monitoring system using the near field technology for transfer of power using wireless. Memon *et al.* (2016) describes the smart animal farm which is used to monitor the entire farm with the help of internet and intranet connectivity using the device. Mersini *et al.* (2013) proposed the QR code-based medical data using a smart phone which improves interoperability cases.

3. Methodology of the livestock management system

3.1 Animal monitoring system

Figure 2 shows the block diagram of the animal monitoring device, developed according to the standards of IEEE 802.11 & 802.15. The developed animal monitoring device is used to detect animal physiological parameters such as body temperature, physical gesture like sitting, standing, eating, heartbeat and environmental parameters such as air temperature and relative humidity. The surrounding temperature and relative humidity provide the real-time calculation of Temperature Humidity Index (THI). The output signal of the developed sensor module is sent to a processing module for processing the sensed signal. The analog output of sensor is fed to an inbuilt ADC of microcontroller in processing module. The output data of the developed device are sent to the user terminal through the wireless communication module. The value of body temperature, surrounding humidity, surrounding temperature, heartbeat and physical gesture activities can be displayed on the smart phones and cloud-based IoT platform. The design of the animal monitoring device is

Figure 2 Diagram of animal monitoring with collar device



autonomous so that the other monitoring parameter can be easily added in the sensor modules, when required.

Figure 3 depicts that the animal monitoring system with a wearable collar device to monitor the animal condition. The animal monitoring device monitors the body temperature, heartbeat, surrounding temperature and surrounding humidity, physical gesture activities like standing, sitting and eating. This device sent the data to a cloud-based gateway and then the data were transferred into the cloud-based IoT analytics platform server. All the sensed data can be visualized using Bluetooth-enabled smart phones. The advantage of this cloud IoT-based animal monitoring system is to analyze and view the animal's health from anywhere, anytime. The animal owner, health worker and veterinary hospital can see the animal's health via mobile interface. As the animal is being monitored on continuous basis, in case of any issues in the animal's health, it can be easily identified in real time.

3.2 E-animal husbandry information network database management system

Figure 4 shows the architecture of the e-animal husbandry information network management system database. It is a comprehensive web-based animal husbandry management software designed for better interaction between veterinary hospital, veterinary doctor, owner, farmer and animal husbandry management. This software handles all the requirements such as security, highest reliability, data loss, availability, multiuser access over web in the animal husbandry system. The web-based software can be accessed from anywhere in the world, which enables the stakeholders of the veterinary system to be in touch with each other at all times. The animal management system collects the information of the owner and the animal by web form filling at the animal husbandry hospital and uploads the data to the cloud database. They can verify their animal details such as tag ID, age, breed,

Figure 3 Architecture of cloud IoT-based LMS (livestock monitoring system)

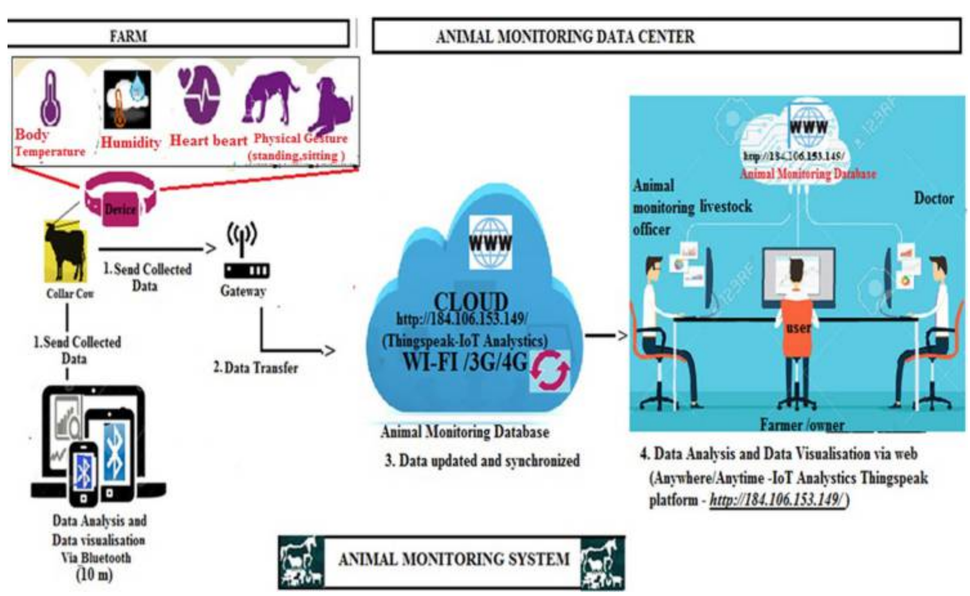
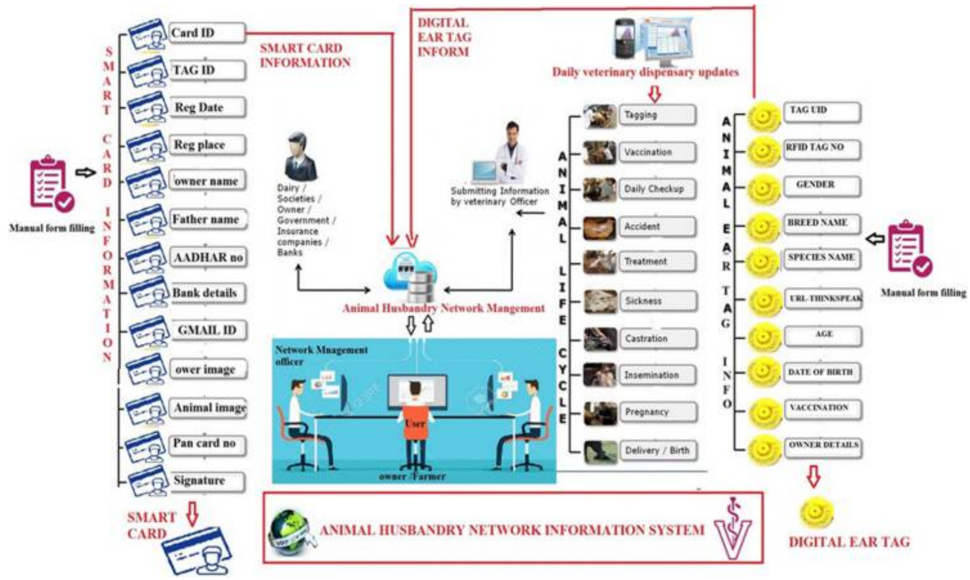


Figure 4 Architecture of e-animal husbandry information network database management system



species, Thinkspeak ID and owner details such as owner name, animals he/she owns, card ID etc. The veterinary hospital updates the daily activities such as tagging, vaccination, daily check-up, treatment, certification, insemination, pregnancy, delivery/birth, decease and death report into the animal husbandry management database. It also has a built-in forum which develops an online farmer and doctor community over the internet, sharing each other's ideas.

3.3 UID numbering scheme

A unique Identification is a string assigned to identify the animal uniquely. It can be used to assign a unique ID to every animal in the country and it ensures that each individual animal is assigned one and only UID. The process of generating a new UID in this numbering scheme would ensure that duplicate UIDs are not issued. Using this proposed numbering, 80 billion UIDs could be generated. Table I shows each string in the UID code and its function. The format of 12-digit number is discussed as follows:

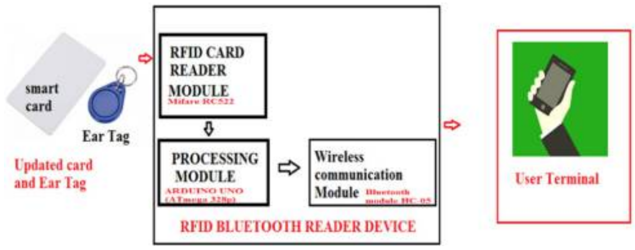
Table I Summary of the code and its function

Code	Function
A1	Version Number
A2	Gender
A3	Species Code
A4	Breed Code
A5	State Code
A6	Pin Code 4th digit number
A7	Pin Code 5th digit number
A8	Pin Code 6th digit number
A9	Implicit number
A10	Implicit number
A11	Implicit number
A12	Implicit number

1. Version Number: Some digits may be reserved for specific applications (Aadhar Numbering Scheme, 2017). This is an implicit form of a version number embedded into the numbering scheme. The following reservations:
   - numbers (A1 = 0) could be used as an "escape" for future extensions to the length of the number.
   - numbers (A1 = 1) could be reserved for entities rather than individuals.
   - 2-9 numbers (A1 = 2, 3 . . . 9) right away to assign UIDs. That is, 80 billion numbers – plenty of space.
2. Gender code: Contains the information of gender such as Male (M) or Female (F).
3. Species Code: contains the information of the species such as cow (C), goat (G).
4. Breed code: contains the information of the breed code such as Gir (1), jersey (2).
5. Pin code: It describes the pin code of the place.
6. State code: contains the information of the state.
7. Implicit Number: It refers to the random number generated using a randomized process at the time one requests a new ID.

Radio frequency enables an automatic identification process for transmitting data from an RFID tag/card to RFID reader with the help of radio-frequency electromagnetic fields. Figure 5 represents the RFID Bluetooth-based card reader which consists of RFID reader module, microcontroller processing module and wireless communication module. The RFID reader has the RFID reader and antenna. It is small in size and integrates with any sort of hardware design and used to read the data stored in the RFID tags/card. Data are transferred from RFID tag/cards to RFID reader and then to microcontroller processing unit and transfer the data to smart phone through the wireless communication module. The data stored in this tag are referred to as "smart card" for owner card and digital ear tag for animal. Once the card/tag is placed in front of the RFID reader, it reads the data and compares the data stored in the

Figure 5 Block diagram of RFID Bluetooth-based card reader



microcontroller which is programmed by using embedded C language. If the data matches, then it displays the information on the smart phone. This RFID smart and digital ear tag system also makes use of the status button for retrieving the status of owner/animal details, which is interfaced to the microcontroller. By using this, time can be saved as all the owner/animal information is directly stored in the database.

4. Experimental setup and results

We have demonstrated and tested the animal monitoring system in the animal livestock located in Tirunelveli district, which is located on the interstate border (Tamilnadu and Kerala in India). Hence, extra surveillance and control of animal disease and preventive vaccination is required. The total number of veterinary dispensaries in Tirunelveli district is 101. The livestock population of different animals in Tirunelveli district (Animal Livestock population, 2011) is mentioned in Table II.

4.1 Implementation for animal monitoring device

The proposed animal monitoring device is implemented with hardware and sensors such as IR temperature sensor, three-axis accelerometer sensor, pulse rate heart beat sensor and humidity sensor, ATmega 328 microcontroller, ESP2866 Wi-Fi module, HC-05 Bluetooth module and power supply unit. When the animal is attached with the wearable collar monitoring device and the power is turned on, the sensors are activated. Then the sensor gathers and transmits the data to the smart phones through Wi-Fi/Bluetooth communication module. Figure 6 shows the hardware setup and Figure 7 shows the result of animal monitoring device sensors value in smart phone

Figure 8 depicts the result of animal monitoring device in ThingSpeak IoT analytics platform (Maureira *et al.*, 2014), which can be used to aggregate, visualize and analyze live sensor data. By collecting data into a channel from an animal

Table II Livestock population in Tirunelveli district

S. no.	Name of the species	Total nos
1	Cattle	5,04,332
2	Buffalo	1,14,758
3	Sheep	12,22,310
4	Goat	4,61,300
5	Horses and Ponies	19
6	Dog	59,911
7	Pig	43,998
	Total	**24,06,628**

Figure 6 Hardware setup of device in neck of a) cattle b) dog

(a) (b)

monitoring device, this platform analyzes, stores and visualizes the data. Channels store all the data such as animal body temperature, surrounding humidity and temperature, physical behavior and location of the animal.

4.1.1 Animal health monitoring

Disease symptom identification and prevention is the main function of the animal health monitoring (Meenakshi and Kharde, 2016). The average body temperature of the cow is 38.5 °C-39.5 °C and the average body temperature of the dog is 38.3°C-39.2°C. When the body temperature of the animal is above the average temperature mentioned above, it indicates that the animal is not healthy. In Table III, we represent the body temperature and the corresponding symptoms for diseases of cow.

4.1.2 Right time for artificial insemination

Detecting estrus is normally difficult. Animal monitoring device works by constantly monitoring the body temperature of the cow to detect if it is in heat. Figure 9 shows the increase in the body temperature to 40 °C between 5.00 p.m. and 7.00 a.m. If farmer does the insemination for their cows in between 7 a.m. and 9 a.m., it is probable they will have a female calf.

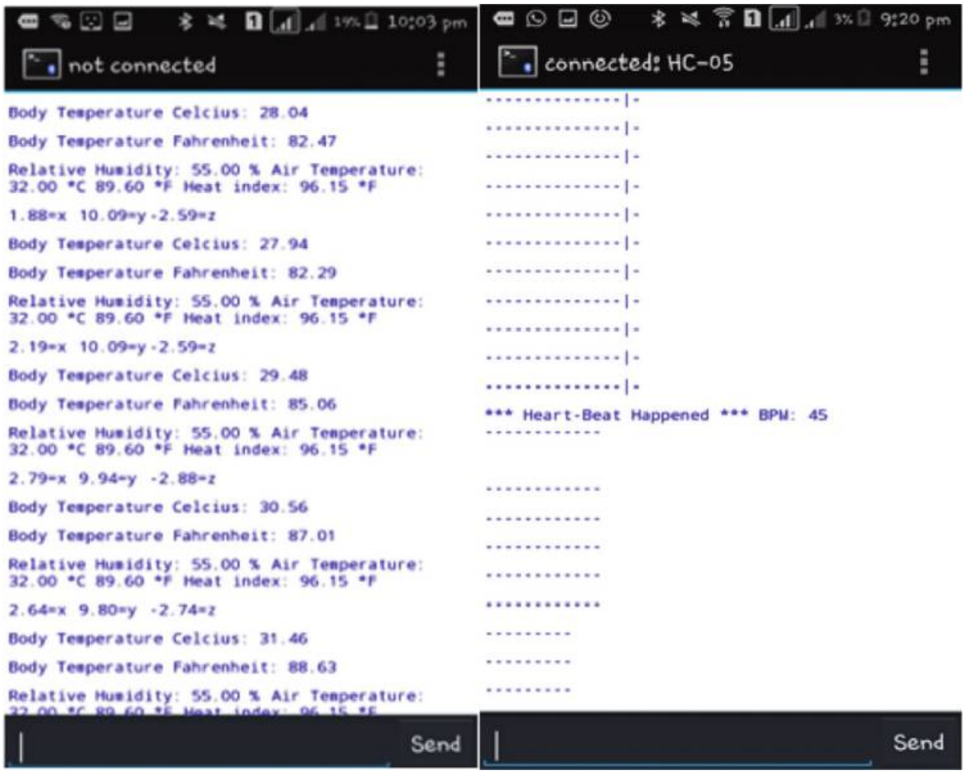
4.1.3 Heat stress level

Heat stress (HS) causes the cow to produce less milk with the same nutritional input, which increases the farmer's production cost. Table IV shows the Thermal Humidity Index (THI) chart (Illapakrti and Vuppalapati, 2015) by using stress level can be classified (Kumar and Hancke, 2015). The stress level of the animal proportionally increases the respiration rate and body temperature of the animal. Because of low moisture content in summer season, it leads to increase in stress level of the animal; the animal can even die. Table V shows the THI versus rectal temperature versus stress level.

4.1.4 Physical gesture recognition

By using the accelerometer sensor output (X, Y and Z axis) from the animal monitoring device, gesture analysis can be made. In typical cattle, animal behavior is classified into stationary and traveling. Stationary activities are sitting, standing and sleeping whereas traveling activities are running, walking and grazing (Vazquez Diosdado *et al.*, 2015). Figure 10 depicts the animal behavior in a 25-min window observation. In this graph, X axis represents the time and Y axis represents the accelerometer sensor value of animal monitoring device. Figure 11(a) shows the experimental setup of three-axial accelerometer sensor module.

Figure 7 Animal monitoring sensor values displayed on smart phone



4.1.5 Rumination

To detect the rumination in the cow, animal monitoring device is mounted in the nose. Rumination deals with how the animal digests food (Kumar and Hancke, 2015). Usually, the cow spends about one-third of a day (9-10 hours) in ruminating. Rumination monitoring provides a very accurate indication of the animal's health. Figure 11(b) shows the experiment setup of rumination monitoring in nose. Figure 12 shows the graph of unhealthy and healthy rumination pattern of cow. Here, X axis represents the time and Y axis represents the accelerometer sensor value of the animal monitoring device.

4.1.6 Pulse and estrus detection

The average heartbeat of the adult cow is 43-84 bpm and the average heartbeat of the calf is 100-140 bpm (Kumar and Hancke, 2015). By using the animal monitoring device, heart rate can be constantly taken. Cow does not change its state often. The amount of motion can be evaluated by placing the animal monitoring device in the leg of the cow. Figure 11(c) shows the experimental setup of the animal monitoring device to detect the estrus condition of the cattle. When the cow is in estrus condition, it will mount on other cows and become restless. Figure 13 shows the unestrus versus estrus pattern value from the accelerometer sensor. Here, X axis represents the time and Y axis represents the accelerometer sensor value of animal monitoring device.

4.1.7 Calving prediction

The device is placed in the tail of preparturient cow before and after rupture of membrane. Figure 14 shows the monitoring values of normal and calving cow from the tail movement pattern. In the graph, X axis represents the time and Y axis represents the accelerometer sensor value of animal monitoring device.

4.2 E-animal husbandry information management system

E-animal husbandry information management system is a comprehensive web-based animal husbandry software, which is designed for better interaction between veterinary hospital, veterinary doctor, owner, farmer and animal husbandry management. This system collects the information of the owner and animal by manual form filling through the animal husbandry hospital. The information is uploaded in database for further references. Figure 15 shows data entry web form with the required fields for collecting the information from owner. Login credentials are given to enter the data and see the report. By creating a data entry form, it can directly fetch the data fed into the animal husbandry form by easily mapping the fields in the animal husbandry form with the corresponding column in animal husbandry reports. Animal husbandry network officer, veterinary hospitals, veterinary doctor, user, farmer and owner can view and update their profiles, so that most current information are available in animal husbandry database and also can print the report in PDF format for further reference.

4.2.1 UID numbering for digital ear tag and smart card

A digital ear tag is tagged in ear of the animal. The purpose of using the ear tag is to give a unique ID for individual animal. We used both bar code and QR code scheme to embed the UID in the ear tag. Figure 16 shows the 12-digit UID number ear tag

Figure 8 Screenshot of animal monitoring device in ThingSpeak webpage

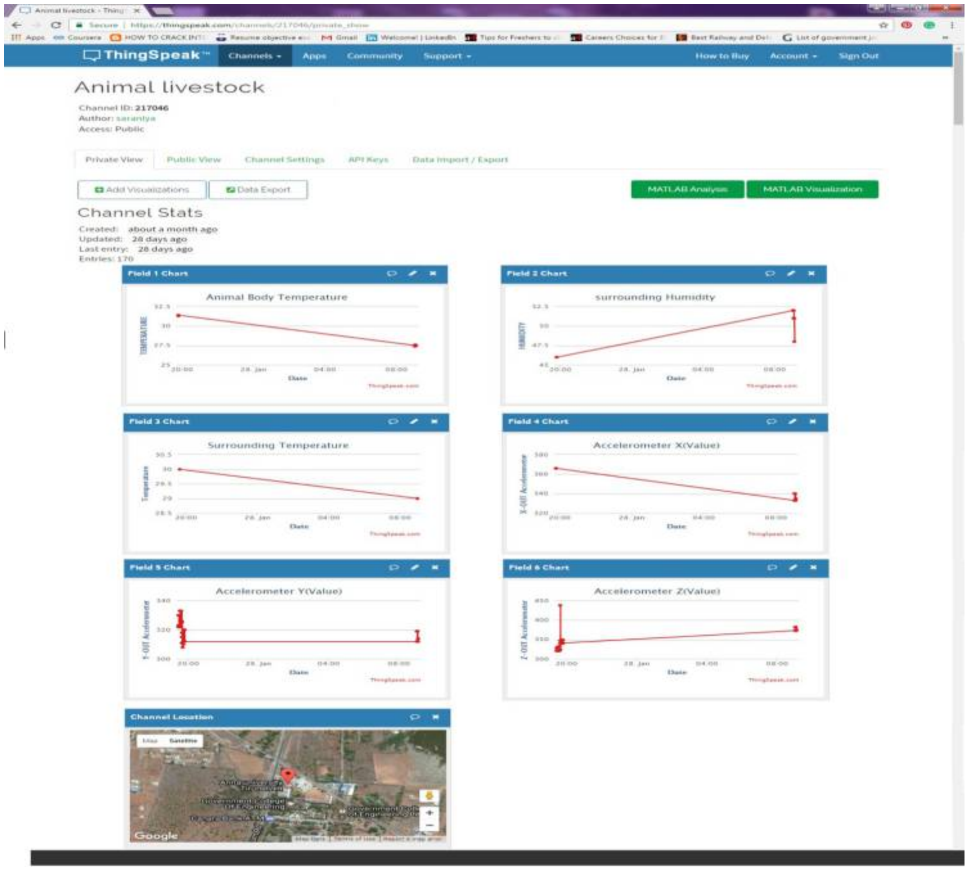
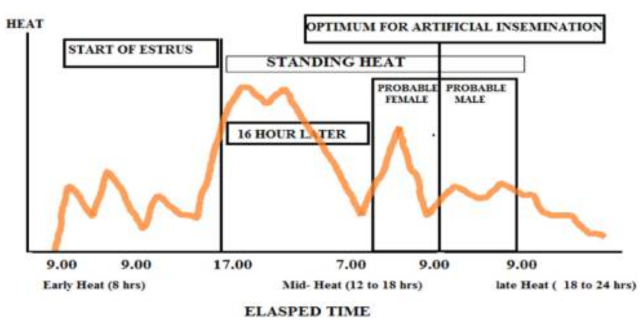


Table III Body temperature versus diseases

Body temperature	Diseases
Below 38.5 °C	Indigestion, milk infections
Above 41 °C	Influenza, Anthrax

Figure 9 Chart showing how system is able to accurately tell when a cow is in heat



with QR/bar code based digital ear tag. The UID numbering system divided into 12 sections from left to right represent gender, breed, species, state, district pin code so that each animal can be allocated to a unique identification code. For example, if there is a female jersey cow in Tirunelveli district,

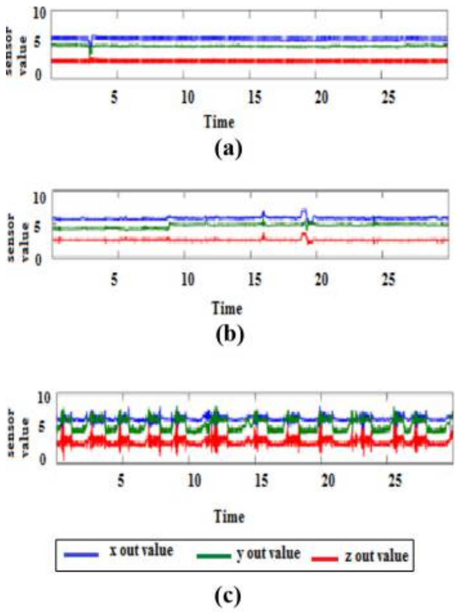
Table IV Thermal humidity index (THI)

Relative humidity (%)	Air temperature (Degrees F) 70	75	80	85	90	95	100	105	110	115	120
0	64	69	73	78	83	87	91	95	99	103	107
10	65	70	75	80	85	90	95	100	105	111	116
20	66	72	77	82	87	93	99	105	112	120	130
30	67	73	78	84	90	96	104	113	123	135	148
40	68	74	79	86	93	101	110	123	137	151	
50	69	75	81	88	96	107	120	135	150		
60	70	76	82	90	100	114	132	149			
70	70	77	85	93	106	124	144				
80	71	78	86	97	113	136	157				
90	71	79	88	102	122	150	170				
100	72	80	91	108	133	166					

Table V THI versus rectal temperature versus stress level

THI	Rectal temperature	Stress level
70-79	38.5°C	Mild
80-89	39°C	Moderate
90-98	40°C	Severe
>98	41°C	Danger

Figure 10 Different types of animal behavior observations



Notes: (a) Lying; (b) Standing; (c) Feeding

Figure 11 Experimental setup of a three-axial accelerometer sensor module on (a) neck (b) nose (c) leg (d) tail

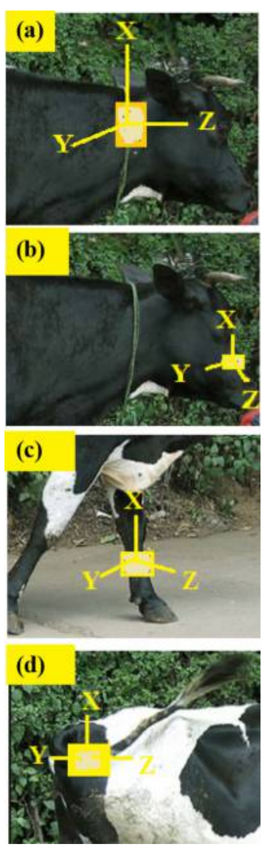


Figure 12 Graph of rumination pattern (a) unhealthy and (b) healthy cow

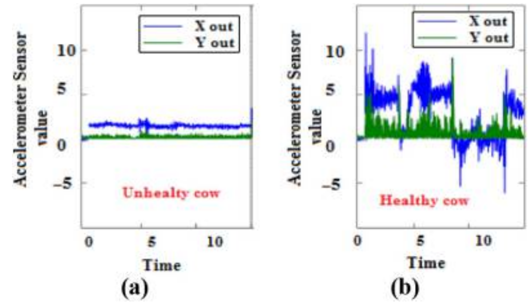


Figure 13 Graph of estrus detection pattern (a) unestrus condition (b) estrus condition

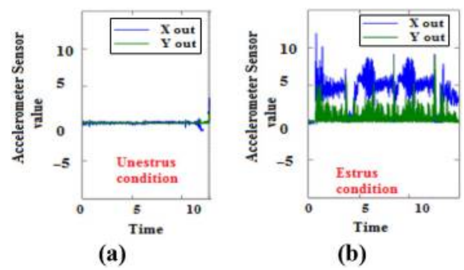
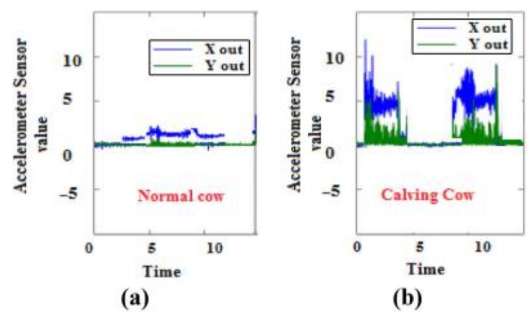


Figure 14 Graph of tail movement pattern (a) normal cow (b) calving cow



Tamilnadu state, India, UID Number will be AFC210070001 (F-Female; C-Cattle; 2-Jersey; 1-State; 007-District; 0001-ID Number). By scanning the QR/Bar code from the ear tag, we could to collect the information of the animal.

A smart card designed for the owner/farmer is shown in Figure 17. A smart card is a kind of plastic card that contains an embedded computer chip comprising a microprocessor with memory to store and query the data. This smart card data can be read using Bluetooth card reader. These smart cards improve the security and privacy of the animal information, provide a secure carrier for portable medical records, reduce health care fraudulence, support new process for portable medical records and provide secure access to emergency medical information. This smart card contains the complete details of the owner such as name, date of birth, contact number, unique ID, animal details, etc. UID scheme for

Figure 15 Screenshot of entering data in data entry form

Figure 16 Design of digital ear tag for animal with QR/Bar codes

Figure 17 Design of smart card for owner

animals can uniquely identify the animal and its details (Aadhar for Animal).

4.3 RFID bluetooth card reader

RFID Bluetooth card reader is used to read the data from the smart cards and ear tag. Only the authorized owner is provided with the smart card and digital tag for animals which is used to maintain the record of the owner and animals' details. The smart cards and digital ear tag can be placed in front of the RFID Bluetooth-based card reader to read and display the information on smart phone. Figure 18 shows the experimental setup of the RFID Bluetooth-based card reader. Figure 19 shows the result of scanned smart card and digital ear tag in smart phone via Bluetooth technology.

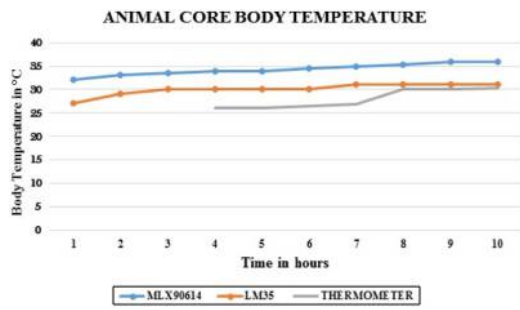
5. Performance analysis

Figure 20 shows that the measurement of animal core body temperature graph by using different kinds of temperature measuring elements such as MLX90614, LM35 and thermometer. In this graph, the X axis represents the time in minutes and Y axis represent the body temperature in °C. Animal body temperature is observed in a 10-h interval at the neck of the animal. In this project, MLX90614 is used

Figure 18 Experimental set up of the RFID bluetooth-based card/tag reader

Figure 19 Result of scanned digital tag and smart card using card reader in smartphone via bluetooth

Figure 20 Animal core body temperature measurement



because it is an infrared non-contact sensor, which can sense the temperature of the animal up to 2 cm body depth. Thermometer is the traditional method and widely used for measuring body temperature of the animal. But it is very slow in reacting to the temperature changes. LM35 is the temperature and contact sensor. By using the MLX90614 temperature sensor, we can measure the body temperature of animal by penetrating through the fur which gives a fast reaction to temperature changes, even in small decimal changes. Also, it can sense within seconds and is 99 per cent accurate and sensitive.

Figure 21 shows the comparison of the proposed animal monitoring system with the existing system (Kumar and Hancke, 2015). Here, we compared the physiological parameters such as body temperature, air temperature, environment humidity and heart rate. In the existing animal monitoring systems, thermometer, psychrometer and ECG is used. In the proposed system, we used sensors and wireless module. From the results, it is evident that proposed system has the less response time when compared to the existing system.

Figure 22 shows the recorded behavioral activities on each individual cow in the cattle by using a wearable sensor collar. In a mean time of observation of the cow completed for 1 h, we found that 15 min were spent lying, 30 min in standing, 5 min in running and 10 min in feeding. Similarly, manual observation was also done and all these behavior observations were entered into a spreadsheet with the start and end time of every activity and identification of the corresponding cow. Observer and sensor values matched accurately. These values synchronized at the start of the observation period so that observation data could be accurately aligned with the tri-axial accelerometer data retrieved from the sensor in a single database.

Figure 21 Comparison between proposed and existing method of animal monitoring system

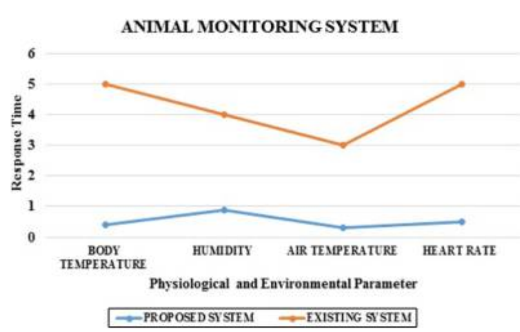
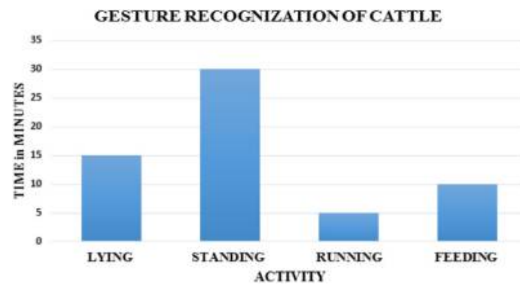


Figure 22 Gesture recognition of the cattle

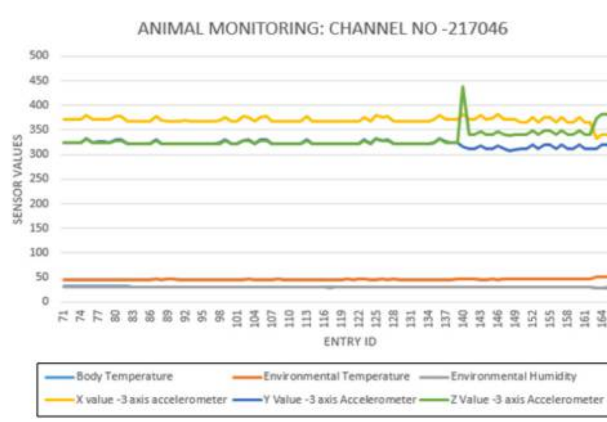


The performance of animal monitoring system is evaluated by running the system continuously for about 7 h. A total of 100 events are collected from the wearable collar-based animal monitoring device over a period. Figure 23 shows the animal monitoring graphs for the channel no 217046 in ThingSpeak IoT platform. Here, X axis represents the entry ID in different periods; Y axis represents the sensor values of different sensors. The animal monitoring device mounted on the neck senses the values and predicts the health status of the animal by using cloud IoT analytics platform. The accuracy of the system is 90 per cent and it can be well placed in the livestock environment.

6. Conclusion

In this paper, we proposed cloud IoT-based novel animal monitoring system to detect the animal's physical parameters such as body temperature, stress level, gesture recognition and pulse rate of heartbeat as well as environmental parameters such as air temperature and relative humidity. These parameters taken from respective sensors are stored in ThingSpeak-IoT analytics platform on cloud. Also, we implemented unique numbering and identification for the cattle animals and their owners. Animal ear tag with UID and smart card for owners are developed as part of e-animal husbandry information

Figure 23 Data analysis of animal monitoring using channel



system. By using this system effectively, we saw improved insemination, less pregnancy deaths, short calving interval, reduced insemination cost and increased milk yield.

References

Aadhar Numbering Scheme (2017), available at: https://uidai.gov.in/UID_PDF/Working_Papers/A_UID_Numbering_Scheme.pdf

Agritech portal for Animal Husbandry (2017), available at: http://agritech.tnau.ac.in/animal_husbandry/animhus_index.html.

Animal Livestock population (2011), available at: http://agritech.tnau.ac.in/animal_husbandry/animalhusbandry2011.pdf

Anu, V.M., Deepika, M.I. and Gladance, L.M. (2015), "Animal identification and data management using RFID technology", 2015 International Conference on Innovation Information in Computing Technologies (ICIICT), *IEEE*, *Chennai*, pp. 1-6.

Ariff, M.H. and Ismail, I. (2013), "Livestock information system using android smartphone", 2013 IEEE Conference on Systems, Process & Control (ICSPC), *IEEE*, *Kuala Lumpur*, pp. 154-158.

Beng, L.T., Kiat, P.B., Meng, L.N. and Cheng, P.N. (2016), "Field testing of IoT devices for livestock monitoring using Wireless Sensor Network, near field communication and Wireless Power Transfer", 2016 IEEE Conference on Technologies for Sustainability (SusTech), *IEEE*, *Phoenix, AZ*, pp. 169-173.

Diwakaran, S.M.E., Muthulakshmi, M., Pratheesha, M. and Saraniya, S. (2014), "Selection of leader to achieve energy efficiency for wireless sensor networks", *International Journal of Engineering, Science and Mathematics*, Vol. 3 No. 4, p. 168.

Floyd, R.E. (2015), "RFID in animal tracking applications", *IEEE Potentials*, Vol. 34 No. 5, pp. 32-33.

Gutierrez, A., Dopico, N.I., Gonzalez, C., Zazo, S., Jimenez-Leub, J. and Raos, I. (2013), "Cattle-Powered node experience in a heterogeneous network for localization of herds", *IEEE Transaction on Industrial Electronics*, IEEE, Vol 60 No. 8, pp. 3176-3184.

Handcock, R.N., Swain, D.L., Bishop-Hurley, G.J., Patison, K.P., Wark, T., Valencia, P., Corke, P. and O'Neill, C.J. (2009), "Monitoring animal behaviour and environmental interactions using wireless sensor networks, GPS collars and satellite remote sensing", *Sensors*, Vol. 9 No. 5, pp. 3586-3603.

Hayashi, Y., Yahagi, K., Sato, H., Sato, K. and Muratani, M. (2015), "Easy-to-use" RF-solutions for IoT applications", *2015 IEEE International Symposium on Radio-Frequency Integration Technology (RFIT)*, IEEE, Sendai, pp. 13-15.

Höflinger, F., Zhang, R., Volk, T., Garea-Rodríguez, E., Yousaf, A., Schlumbohm, C. and Reindl, L.M. (2015), "Motion capture sensor to monitor movement patterns in animal models of disease", *2015 IEEE 6th Latin American Symposium on Circuits & Systems (LASCAS)*, IEEE, Montevideo, pp. 1-4.

Huang, J.D. and Hsieh, H.C. (2013), "Design of gateway for monitoring system in IoT networks", Green Computing and Communications (GreenCom), 2013 IEEE and Internet of Things (IThings/CPSCom), IEEE International Conference on and IEEE Cyber, Physical and Social Computing, *IEEE*, *Beijing*, pp. 1876-1880.

Illapakrti, A. and Vuppalapati, C. (2015), "Building an IoT framework for connected dairy", IEEE First International Conference on Big Data Computing Service and Application, *IEEE Computer Society*, *Redwood City, CA*, pp. 275-285.

Kim, S.H., Kim, D.H. and Park, H.D. (2010), "Animal situation tracking service using RFID, GPS, and sensors", 2010 Second International Conference on Computer and Network Technology (ICCNT), *IEEE*, *Bangkok*, pp. 153-156.

Kumar, A. and Hancke, G.P. (2015), "A zigbee-based animal health monitoring system", *IEEE sensors Journal*, Vol. 15 No. 1, pp. 610-617.

Maureira, M.A.G., Oldenhof, D. and Teernstra, L. (2014), *ThingSpeak–an API and Web Service for the Internet of Things*, World WideWeb, Geneva.

Meenakshi, M. and Kharde, S.S. (2016), "Advance cattle health monitoring system using Arduino and IoT", *International Journal of Advance Research in Electrical, Electronics and Instrumentation Engineering*, Vol. 5 No. 4, pp. 3365-3370.

Memon, M.H., Kumar, W., Memon, A., Chowdhry, B.S., Aamir, M. and Kumar, P. (2016), "Internet of Things (IoT) enabled smart animal farm", 2016 3rd International Conference on Computing for Sustainable Global Development (INDIACom), *IEEE*, *New Delhi*, pp. 2067-2072.

Mersini, P., Sakkopoulos, E. and Tsakalidis, A. (2013), "APPification of hospital healthcare and data management using QRcodes", 2013 Fourth International Conference on Information, Intelligence, Systems and Applications (IISA), *IEEE*, *Piraeus*, pp. 1-6.

Patil, A., Pawar, C., Patil, N. and Tambe, R. (2015), "Smart health monitoring system for animals", 2015 International Conference on Green Computing and Internet of Things (ICGCIoT), *IEEE*, *Noida*, pp. 1560-1564.

Saravanan, K. and Rajaram, M. (2015), "An exploratory study of cloud service level agreements-state of the art review", *KSII Transactions on Internet & Information Systems*, Vol. 9 No. 3.

Tedín, R., Becerra, J.A., Duro, R.J. and Peña, F.L. (2013), "Computational intelligence based construction of a body condition assessment system for cattle", 2013 IEEE International Conference on Computational Intelligence and Virtual Environments for Measurement Systems and Applications (CIVEMSA), *IEEE*, *Milan*, pp. 185-190.

Ting, J.S., Kwok, S.K., Lee, W.B., Tsang, A.H. and Cheung, B.C. (2007), "A dynamic RFID-based mobile monitoring system in animal care management over a wireless network", International Conference on Wireless Communications, Networking and Mobile Computing, 2007, WiCom 2007, *IEEE*, *Shanghai*, pp. 2085-2088.

Turner, L.W., Udal, M.C., Larson, B.T. and Shearer, S.A. (2000), "Monitoring cattle behavior and pasture use with GPS and GIS", *Canadian Journal of Animal Science*, Vol. 80 No. 3, pp. 405-413.

Valero-Sarmiento, J.M., Bhattacharya, S., Krystal, A. and Bozkurt, A. (2014), "Towards injectable biophotonic sensors for physiological monitoring of animals", *SENSORS, 2014 IEEE*, IEEE, Valencia, pp. 503-506.

Vazquez Diosdado, J.A., Barker, Z.E., Hodges, H.R., Amory, J. R., Croft, D.P., Bell, N.J. and Codling, E.A. (2015), "Classification of behaviour in housed dairy cows using an accelerometer based activity monitoring system", *Animal Biotelemetry*, Vol. 3, pp. 1-14.

Volk, T., Gorbey, S., Bhattacharyya, M., Gruenwald, W., Lemmer, B., Reindl, L.M. and Jansen, D. (2015), "RFID technology for continuous monitoring of physiological signals in small animals", *IEEE Transactions on Biomedical Engineering*, Vol. 62 No. 2, pp. 618-626.

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