Implementation of Smart Infrastructure and Non-Invasive Wearable for Real Time Tracking and Early Identification of Diseases in Cattle Farming using IoT

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***Abstract*— The major objective of this system is to make infrastructure of cattle farming smarter and to implement a non-invasive wearable to track physiological and biological activities of cattle using Internet of Things alias IoT. Each cattle is tagged with a wearable device. The wearable device and sink node is designed based on architecture of device to cloud. The wearable device is for early detection of illness, abnormalities detection, emergency handling, location tracking, calving time intimation and determine disease before visual signs. The sink node is responsible for smart lighting, smart ventilation, smart watering and smoke detection along with sprinkler actuation to make infrastructure smarter and safer. All sensor readings will be forwarded to thingspeak cloud to enable remote access. Through thingspeak cloud real time health characteristics of individual cattle, smoke level in farm, daily water and electricity usage will be displayed in line graph. All data along with time and date can be extracted as an excel sheet for further analysis. As a result overall cattle health and milk production will be improved by reducing cattle health inspection costs ensuring small size, low cost, high consistency and reliability.**

Keywords*— IoT, wearable, nodes, early detection, location, abnormalities, emergency, calving time, smart lighting, smart ventilation, smart watering, smoke, cloud, visualization, storage, analytics

I. Introduction

In India nearly 66.67% of rural people rely completely on livelihoods like cows, buffaloes, sheep, goat, donkey, horses, and camels. The livelihood population in India is 2.4% camels, 12.5% cattle, 56.7% buffaloes, 20.4% small ruminants, 1.5% pigs, 3.1% poultry and 1.4% equine compared to world total livelihood population [1]. Economic survey for year 2015 to 2016 reported India ranked first for milk production. Milk production of India is 18.5% of world milk production [2]. The major problems in cattle farming are unable to detect illness at early state. If the initial illness (fever) not treated properly then it will develop as a disease like pneumonia, lung congestion, laminitis etc. When the severity of disease reaches high then it will easily spread to all other cattle which leads to entire cattle death and capital loss. Cattle farm infrastructure during various seasons and environmental conditions plays a vital role in cattle health.

Some case studies of cattle death because of various diseases and environment conditions are stated as follows. 500 cows died in Jaipur cattle farm within 10 days because of illness, injuries and irregular feeding. Report stated that nearly fifty cows died in last one week. [3]. 26 cattle died because of foot and mouth disease at Agra. Report said all 26 cattle has shown same symptoms like excessive salvia, swelling in mouth and sore mouth before dying. As a result farmer lost buffaloes of worth 4.80 lakh. [4]. As stated in 19th livestock census in India, livestock population has reduced by 3.33%. Wistfully indigenous cattle population depreciated by 8.94% [5]. Not only India other countries also affected by cattle death. Nearly 300 animals including cattle died because of hoof and mouth disease in Banteay Meanchey [6]. Dozen number of cattle died because of unfamiliar disease in Tonj North [7].

Case studies for cattle death due to fire accident are as follows. 30 cattle and 500 milking goats died in fire at Delaware, London. The estimated damage at goat farm which is situated near Delaware is 2 million dollars [8]. 20 calves and 50 cows died in fire at Brockton, Ontario. 500000 dollars is the estimated damage of this incident [9]. 6 cattle died because of fire accident at Shillong [10].

II. Literature Review

The various existing methodologies which are related to determine cattle diseases and to make infrastructure smarter are described as follows. Biological sensors like respiration sensor and heart beat sensor can also be used along with temperature sensor and rumination sensor. The increase and decrease of those values indicates stress or illness severity will be calculated [11]. Once sensors tied with cattle body and deployed in cattle farm environment read data then it will be stored in centralize data storage via connected local storage using batch processing. Local storage is to get immediate response corresponding to user’s query. Whereas centralized storage is for nearby veterinary hospital for real time monitoring to determine illness, death ratio etc. [12]. Sensor details regarding cattle health can be forwarded to server via Bluetooth communication standard for illness detection [13].

Labview can be used for cattle health monitoring to notify farmer when sensor readings like core body temperature, rumination period, sweat and heartbeat rate goes abrupt [14]. Global positioning system and 3 axis accelerometer sensor can be used to monitor distance walked and daily activities of individual cattle. Depends on these cattle behavior convenient steps can be done to improve cattle health additionally estrus period can be determined [15]. Pregnancy of cattle can be confirmed by cattle core body temperature rise during day 5 to day 12 after insemination [16]. To eliminate human intervention and to save electricity IR transmitter and receiver can be used in autonomous street lighting. When there is a vehicle detection in a darkness time street lights will be actuated accordingly [17].

Water contact sensors can be used to detect water levels in tank systems either empty or full. Centrifugal pump will be actuated accordingly based on present water level thereby eliminates human intervention and to achieve effective distribution of water [18]. Smoke sensor along with temperature sensor can be used to detect smoke level and potential of fire. Once detected fire or smoke fire extinguisher vehicle will soon locate fire region and start extinguishing fire. This can be done by pre-determined path, remote control based locating and image processing based fire areas detection using web cam, obstacle detection method and temperature sensing method [19]. From ADXL345 accelerometer sensor readings physical abnormalities and heat stress of cattle can be accurately determined by using binary tree support vector behavior classification algorithm [20].

III. PROPOSED SYSTEM

Both wearable device and end node are designed based on device to cloud architecture and it is shown in figure1. The flow diagram for early detection of illness by wearable device is shown in figure 2.

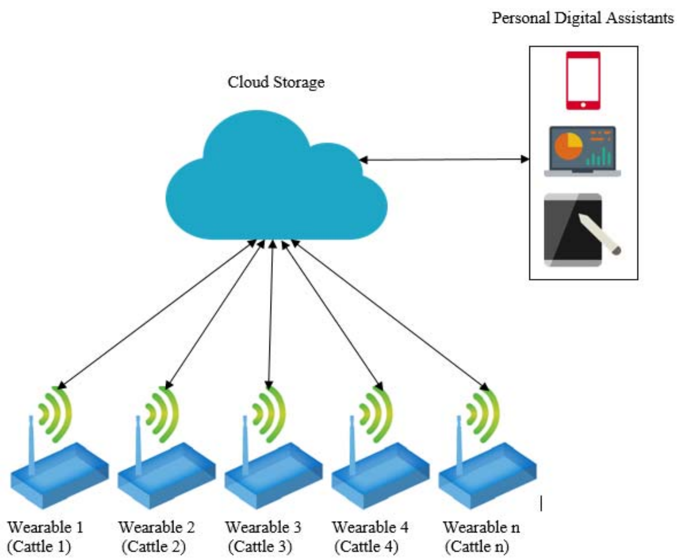

Fig. 1. Block diagram of proposed system

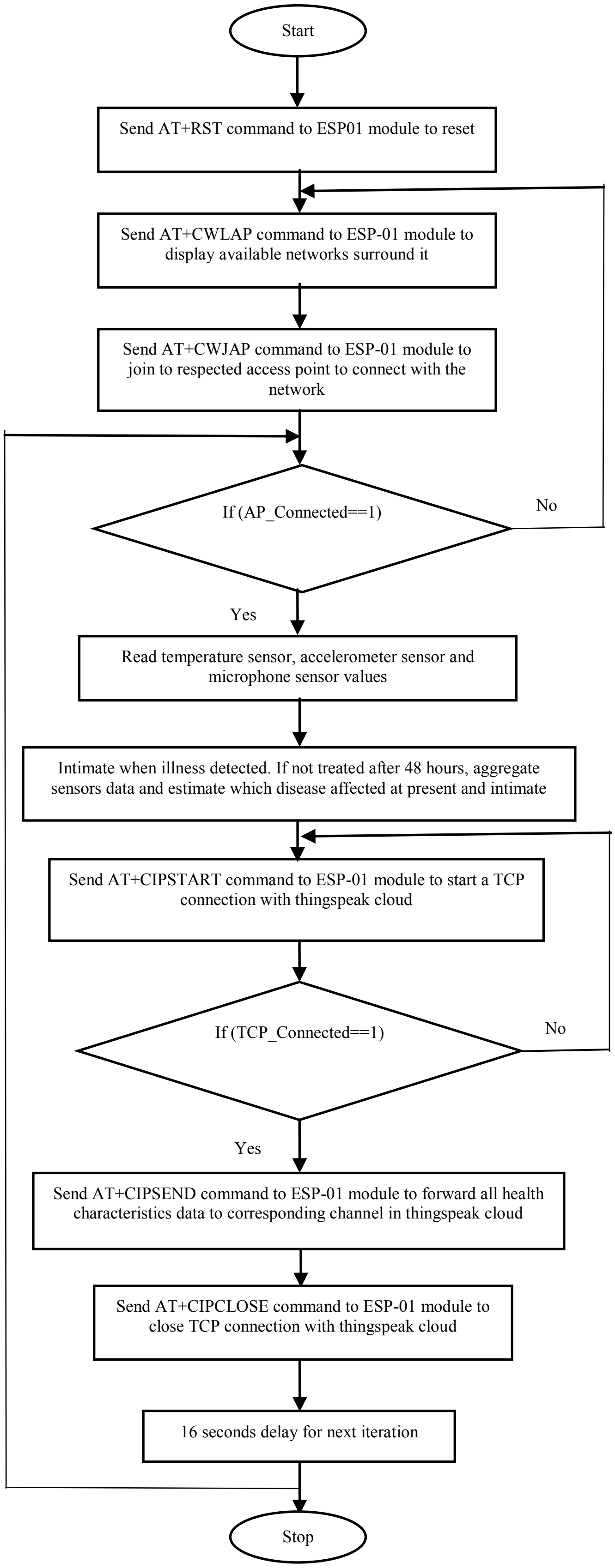

Fig. 2. Flow diagram for early detection of illness

A. *Wearable device*

The wearable device is a small wireless sensor node with IP enabled using ESP01 8266 Wi-Fi module. The basic components of wearable device are sensing unit, processing unit, communication unit and power unit.

1) Sensing unit: The sensing unit is for measuring parameters like temperature, light intensity etc. Wearable device contains sensors namely LM35 sensor, accelerometer sensor and micro phone sensor.

a) LM35 sensor: This sensor will be kept near tympanic membrane of cattle to measure core body temperature for illness detection. It's operating voltage and current consumption is -0.2V to +35V DC and 60µA. Its measures temperature range from -55 ºC to +150 ºC. Its output voltage increases by 10mW for every degree rise in temperature and vice versa.

b) Accelerometer sensor: Two number of ADXL335 accelerometer sensors are used in this wearable device for lambness detection and alerting during pregnancy. One will be tied under jaw of cattle to calculate rumination period whereas another one will be tied with cattle collar to calculate standing time, lying time, distance walked and estrus period. It's operating voltage and current consumption is 3.3V to +5.0V DC and 350µA. Its operating temperature is -40 ºC to +85 ºC. Its measures vibration in 3 different directions namely X, Y and Z.

c) KG181 Microphone sensor: This sensor is used for measuring the sound intensity from the cattle for illness and emergency detection. Its operating voltage is 5V DC and its current consumption is greater than or equal to 15mA.

2) Processing unit: This unit is responsible for processing the sensor readings to detect illnesses. Arduino Nano is used as a processing unit in this wearable because of its small size and low power consumption. Its operating voltage is 5V DC and 16MHz is its operating frequency. It has dedicated serial peripheral interface, 8 analog to digital converter and 14 GPIO out of that 6 pins can be used as pulse width modulation.

3) Communication unit: This unit is used for sending data from one sensor node to another or to cloud. The communication unit of wearable device is ESP01-8266 Wi-Fi module. Its operating voltage is 3.3V DC.

4) Power unit: This unit is power supply provider to all the components. 5V rechargeable battery is used in this wearable device as a power unit.

B. *Sink node*

The processing unit, communication unit and power unit of sink node is as same as wearable device. Only the sensing unit for various module changes. The various modules in sink node are smart lighting module, smart ventilation module, smart watering module and smoke detection and intimation module.

1) LDR sensor: This sensor is used for monitor real time light intensity in cattle farm environment for smart lighting purpose. It's operating voltage and current consumption is 5V DC and 75mA. Its operating temperature range is -60 ºC to +75 ºC. Its power dissipation is 250mW at 30 ºC. Its output resistance is indirectly proportional to incident light.

2) Infra-Red sensor: This sensor is used for count the occupancy level of cattle in farm for smart lighting and smart ventilation purpose. It's operating voltage and current consumption is 3.3V to 5.5V DC and <10mA. Its detection range lies from 2 to 80 centimeters. Its output voltage is directly proportional to detection of obstacle. By tuning potentiometer, it sensitivity can be extended based on requirements.

3) LM35 sensor: This sensor is used for monitor real time temperature in cattle farm environment for smart ventilation purpose. Its operating voltage and current consumption is -0.2V to +35V DC and 60µA. Its measures temperature range from -55 ºC to +150 ºC. Its output voltage increases by 10mW for every degree rise in temperature and vice versa.

4) DHT11 Humidity sensor: This sensor is used for monitor real time humidity in cattle farm environment for smart ventilation purpose. It's operating voltage and current consumption is 3.5V to +5.5V DC and 0.3mA. Its operating temperature is 0 ºC to +60 ºC. Its output voltage is directly proportional to humidity.

5) MQ-02 smoke sensor: This sensor is used for detection of smoke level in cattle farm environment. Its operating voltage is 5V DC. Its heating consumption is less than or equal to 900mW. Its heating resistance is 31Ω±3Ω. Its output voltage is directly proportional to smoke level.

C. *Functionalities of wearable*

1) Early detection of illness: The phenomenon of rise of temperature is called as fever. Fever is first and foremost indication for cattle before particular disease goes to severe level. Common diseases to cattle namely anthrax, pneumonia, back leg, lungs congestion, laminitis, joint ill and novel ill. Nearly 48 hours will be required to get into these common diseases from fever. Visual appearance of cattle disease can be only possible after 24 hours from particular disease in affected stage. So early detection of illness mainly rely on cattle core body temperature. Best places to measure core body temperature is rectum and tympanic membrane which is located at middle ear. This wearable device measures core body temperature from tympanic membrane by keeping temperature sensor into cattle ear safely.

From core body temperature readings rise of temperature can be calculated from microcontroller side. Rise of temperature can be calculated by subtracting maximum temperature recorded to minimum temperature recorded for a day. For every 1 hours core body temperature will be read and stored in an array. After that rise of temperature will be calculated. Based on that severity of illness will be notified to farmer. This module will responsible for detection of illness before 36 hours from visual signs of illness detection. As a result getting into particular disease stage and spreading of diseases can be prevented. The relationship between rise of cattle core body temperature and severity of illness are presented in table 1 [21].

TABLE I. Rise of cattle core body temperature vs. severity of illness

Rise of Temperature (°C)	**Severity of illness**
1	Normal condition
2	Fairly normal
More than 3	Sick
Linear order increment	Risk

2) Early detection of other abnormalities which may develop as a disease: The average walking speed of cattle is 2.7 kilometers per hour [22]. The recommended lying time to any cattle for high milk production is 12 hours a day which improves diffusion of blood nearly 5 liters per minute though udder. Increase of standing time and decrease of lying time and walking speed proportionally increases severity of lambness [23]. Lambness is not a disease initially but if it is not treated at initial stage which may develop as viral infection and finally as a disease. Once X, Y and Z axis angles value are read from accelerometer 1 standing time, lying time and distance walked will be calculated from microcontroller end to detect severity of lambness. From accelerometer 2 Once Y axis angle value are read rumination count will be calculated from microcontroller end to check daily whether cattle take enough food or not. This module effectively prevent cattle to get into particular disease from lambness.

3) Detection of emergency condition: Cattle used to generate sound called as mooing to indicate emergency conditions [24]. Possible emergency conditions are listed below.

- Cattle might separate from its group
- Cattle might see any terrible things like snake etc.
- Cattle might have taken insufficient food
- Cattle might lost its calf while grazing
- When disease in severe level

This module will keep on detecting mooing sound using microphone sensor. Once mooing detected notifications about emergency condition will be sent to farmer. This module not only handling emergency condition but also prevents missing of cattle while grazing.

4) Detection of location: Each wearable device has GPS module to read real time location coordinates of individual cattle. When cattle or calf missed during grazing, this module will be helpful to track its location to get back.

5) Early intimation of calving time: The pregnancy period of cattle lies form 279 to 287 days [25]. The average time for calving is 283 days [26]. The best indication of calving is behavior of walking very slowly especially before 24 hours to give birth to calf [27]. This module has a dedicated button for farmer to start count of days once confirmed pregnancy of particular cattle. Pregnancy of cattle can be confirmed if there is rise of core body temperature from day 5 to day 12 after insemination. Intimation of calving time before 24 hours is done by satisfying below 2 conditions. Once these 2 conditions matched intimation will be sent to farmer.

- Day count should be 283 that can be determined by counter
- When walking rate reaches below minimum rate for the particular time of 283rd day that can be determined from accelerometer 1 readings.

6) Estimating particular disease once treatment has not been given to cattle after identification of illness: If treatment has not provided to illness cattle after 48 hours, then that illness will turned into particular disease. This module is helpful to determine and notify about what type of disease suffered by individual cattle before 24 hours from visual signs of disease detection. The relationship between cattle core body temperature, lying time, standing time and distance walked for detecting particular disease is presented in table 2 [28].

TABLE II. The particulars of core body temperature and physiological activities to determine disease

Core body temperature (°F)	**Observations**	**Disease**
105 to 106	Cough	Pneumonia
104 to 108	More lying time, reduced walking time	Back leg
105 to 106	More standing time	Lungs congestion
104 to 106	More lying time	laminitis
105 to 108	Walks slowly and stiffly, less distance walked	Joint ill and novel ill

7) Oestrus period detection: Oestrus period can be detected efficiently from y axis readings of accelerometer 1 which tied in cattle collar [29].

D. Functionalities of end node

1) Smart lighting module: To achieve effective utilization of electricity this module actuate the lighting systems based on 2 conditions.

- Based on light intensity
- Based on occupancy level

Let a cow farm of 600 cows which allocates 10 cows in each rows. Each row has dedicated lighting system. 2 Infra-red sensors are deployed at entrance of cow farm. One is used to count how many cows are entering and another one is used to count how many cows are leaving. Parallel this module monitors the light intensity level. Lighting systems will be active only when light intensity reaches below minimum threshold. Lighting systems in rows where cows are occupied only will get actuated. All remaining lighting systems will be in off state to save usage of electricity and cost. It will also compute power utilization of lighting system in term of watts-hours in every hour.

2) Smart ventilation module: The core body temperature of healthy cow lies from 38.0 ºC to 39.3 ºC. Average core body temperature of healthy cow will be 38.6 ºC. Cattle does not have sweat glands. Environment is said to be comfort for cattle when air temperature lies from 10 ºC to 20 ºC and relative humidity lies from 40% to 80 % [30]. When environment temperature reaches cow core body temperature it will create heat stress to cattle. When environment temperature reaches below zero or negative it will create cold stress to cattle. Cattle has to spend lot of its energy to be comfort with heat stress or cold stress time. This will reduce cattle health and milk production. Fortunately in India maximum recorded temperature is 34 ºC and minimum recorded temperature is 7 ºC [31]. So cattle will undergo negligible cold stress. That can be easily overcome by changing feeding system, keeping cattle place clean and dry [32].

Temperature Humidity Index (THI) is a value which tells severity of heat stress in cattle. This proposed system uses Kibler Method (1964) to determine THI efficiently. The mathematical relation to compute THI from ambient temperature and relative humidity is expressed in (1) [33]. The relationship between THI and intensity of heat stress to cattle is presented in table 3. The proportion of milk production based on cattle farm environment temperature and relative humidity is presented in table 4 [34].

$$TH_{index} = \left(1.8T_{ambient} - \left(\left(1 - R_{humidity}\right) * \left(T_{ambient} - 14.3\right)\right) + 32\right) \quad (1)$$

Where

TH_{index} - Temperature Humidity Index

$T_{ambient}$ - Ambient temperature (ºC)

$R_{humidity}$ - Relative humidity (%)

TABLE III. THI vs. intensity of heat stress

THI Range	Intensity of heat stress
100 – 104	Cattle may die
80 – 99	Severe
72 – 78	Moderate
66 – 71	No

TABLE IV. Impact of temperature and relative humidity in milk production

Temperature (ºC)	Relative Humidity (%)	Milk Production (%)
22	40	100
29	40	97
29	90	67

The smart ventilation module keep on monitoring air temperature and relative humidity. When severity of heat stress reaches moderate level and above, ventilation systems will be activated in the rows where cattle occupies to save electricity and cost. Parallel sprinkler system will be activated to spray water of 3.5 liters per cow for a duration of 3 minutes. To do this desired time for sprinkler operation will be done in coding end. After that no spraying of water for next 12 minutes to corresponding cattle. This remedy operation reduces cattle core body temperature by 1.7 ºC during heat stress and it also increases milk production per cattle by 0.79 kg/day [34]. It will also compute power utilization of ventilation system in term of watts-hours in every hour.

3) Smart watering module: This module assisted with strip based water level indicator for real time monitoring of water level. Once water level reaches minimum level (level 1) valve will automatically opened until water fills completely (level 4). The designed strip based water level indicator contains simple circuit made of transistors and resistors which are connected in active region configuration. This module has 4 different levels namely level 1, level 2, level 3 and level 4 ranges from lower level to higher. This module work on basic principle of conductivity.

The status of each level is connected as GPIO to controller namely GPIO2 for level 1, GPIO3 for level 2, GPIO4 for level 3 and GPIO5 for level 4. When water level reaches from level 4 to level 3, only GPIO 5 changes from state 1 to state 0 because current will not flowing from collector to emitter since absence of base to emitter voltage in that particular transistor. Based on this principle, microcontroller understands current water level and actuate valve accordingly. It will also compute water utilization for cattle feeding purpose in term of liters in a day. This module ensures availability of water to cattle at any time.

4) Smoke detection and intimation module: This module keep on monitoring smoke level in cattle farm. When intensity of smoke reaches above minimum threshold (10%) siren and sprinkler will be actuated accordingly. Automatic notification to fire engine department also possible in cloud end when smoke level reading reaches minimum threshold and above.

All health characteristics data of individual cattle will be sent to corresponding channel of thingspeak cloud from wearable device side. Real time status of lighting and ventilation system, hourly power utilization of lighting and ventilation system, daily water utilization and real time smoke intensity will be sent to corresponding channel of thingspeak cloud from sink node side. The hardware implementations of standalone wearable device and sink node along with laptop are shown in figure 3 and figure 4 respectively.

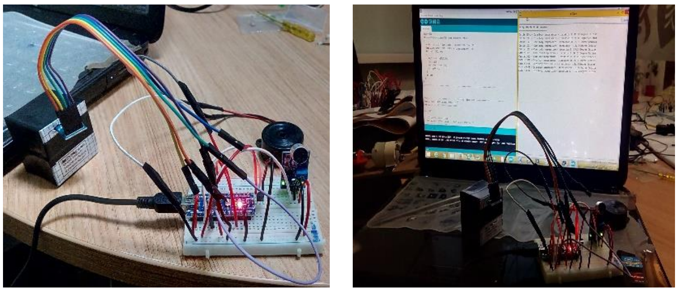

Fig. 3. Hardware implementation of wearable device

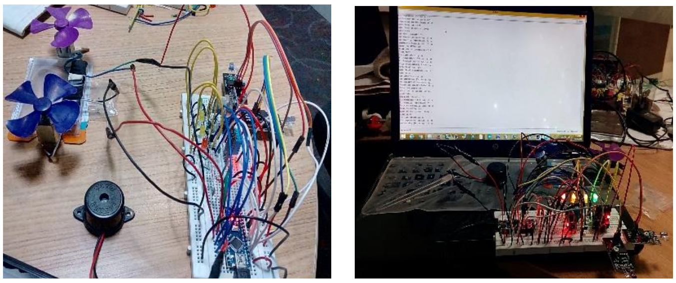

Fig. 4. Hardware implementation of sink node

IV. EXPERIMENTAL RESULTS

A. Wearable device real time readings

The real time readings of cattle core body temperature, standing time, lying time, distance walked and intensity of mooing sound that has read each and every hour from 7AM to 6PM on 26-10-2016 is presented in table 5 and graphically shown in figure 5.

Table V. The particulars of cattle core body temperature, standing time, lying time, distance walked and intensity of mooing sound on 26-10-2016

Core body temperature (ºC)	Standing time (min)	Lying time (min)	Distance walked (KM)	Mooing sound (db)
38.2	20	40	0.020	121
38.2	15	45	0.025	145
38.2	18	42	0.040	246
38.3	5	55	0.010	101
38.3	12	48	0.030	189
38.3	6	54	0.020	156
38.3	12	48	0.033	185
38.3	17	43	0.035	194
38.2	50	10	2.609	122
38.2	48	12	2.632	149
38.2	45	15	2.671	188
38.2	47	13	2.685	126

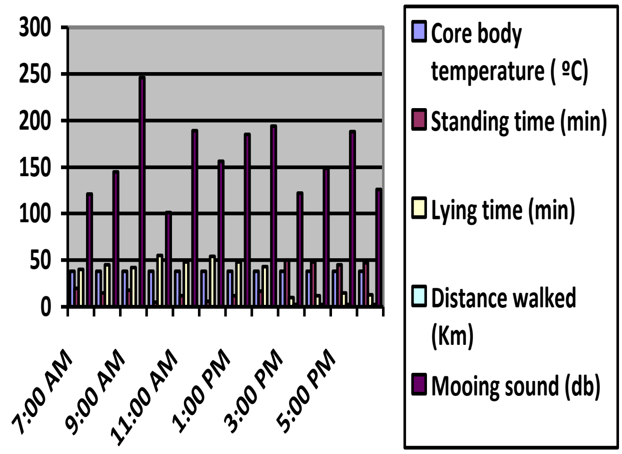

Fig. 5. Real time readings of cattle core body temperature, standing time, lying time, distance walked and intensity of mooing sound on 26-10-2016

B. Sink node real time readings

The real time readings of electricity consumption by lighting systems, electricity consumption by ventilation systems and water utilization by watering system in each and every day on month of October is presented in table 6 and graphically shown in figure 6.

Table VI. The particulars of electricity consumption by lighting systems, electricity consumption by ventilation systems and water utilized by watering system on month of October

Day	Smart lighting	Smart ventilation	Smart watering
	Electricity consumption (Watts Hours)	Electricity consumption (Watts Hours)	Water utilization (liters)
16	130	600	230
17	128	589	234
18	133	593	237
19	126	599	239
20	124	603	233
21	136	607	231
22	138	612	236
23	129	611	239
24	122	602	238
25	137	594	239
26	125	591	234

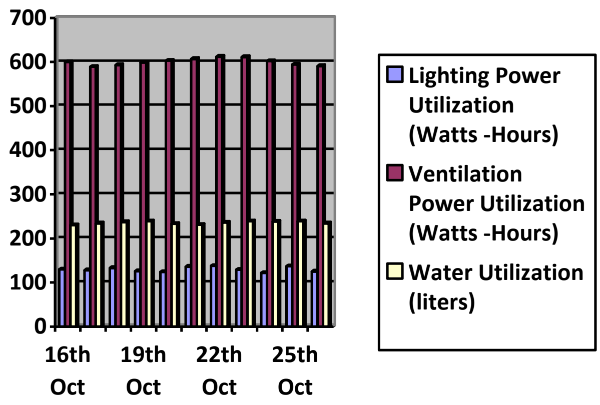

Fig. 6. Real time readings of electricity consumption by lighting systems, electricity consumption by ventilation systems and water utilized by watering system on month of October.

V. CONCLUSION

The main focus of this proposed system is on making the infrastructure of cattle farm smarter and to detect, notify and handle illnesses at earlier stage, abnormalities, emergency conditions, calving time and diseases using Internet of Things. GPS assisted wearable improves location tracking of all cattle. Because of the deployment of various sensors in wearable like temperature sensor, microphone sensor and accelerometer sensor improves consistency, resolution and reliability of output. Arduino Nano and ESP-01 8266 Wi-Fi module in wearable and sink node greatly reduces size as well as cost of product without affecting performance. Smart ventilation system improves cattle health by preventing environment to reach critical. Smoke detection and intimation system improves safety to cattle and cattle farm from fire accident. Smart watering ensures water availability to all cattle at any time. Smart ventilation and smart lighting saves consumption of electricity which leads to save lot of money. As a result this system saves time and maintenance costs for the farmer ensuring improved cattle health and high yield.

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