International Journal of Engineering and Advanced Technology (IJEAT)
ISSN: 2249 – 8958 (Online), Volume-9 Issue-4, April, 2020

Development of Wildlife Conservation System using Energy-Efficient Real-Time Sensor Networking

Subhajit Mukherjee, Subhrajit Nandy, Abhishek Dey

***Abstract**: Wireless Sensor Networks (WSNs) can be used to protect the wild animals from being accidents on roads or railway tracks in the vicinity of reserve forest areas due to its smart sensing and distributed networking architecture. This paper proposes a novel strategy that reduces the probability of accidents of wild animals by the car, railway, or any civil infrastructure surrounded by a forest area. Our WSN based system is made up of a two-tier architecture which can enhance the battery life and reduce the end to end delay by decreasing the number of hops between source and the sink node. The proposed system is capable of the generic target (animal) tracking in the surrounding area of wildlife passages, i.e., national highways or railway tracks, which built in the vicinity of reserve forest to establish safe ways for animals to cross transportation infrastructures. Besides, it allows target identification through the use of motion & image sensors connected to the nodes deployed strategically. The communication between the sensor nodes is established using the Zigbee wireless protocol (IEEE 802.15.4), and the connection between the cluster node and the remote server has been established using the WiFi protocol (IEEE802.11). The alert message from the sensor node is 1st received by the cluster node, which is used for controlling the traffic management system. Furthermore, the alert message is sent to the remote server where it is stored in the database for behavioral studies of animals.*

***Keywords**: Embedded System, Energy Efficient Sensor Networking, Microwave Motion Sensor, Zigbee Pro transceiver, Real-time transmission.*

I. INTRODUCTION

Today the whole world is facing a significant challenge to conserve the wildlife species from natural disasters, poaching activities, or human-animal conflict due to natural habitat loss to protect Biodiversity. The ever increasing population and thereby civilization is a significant threatening for the conservation of wildlife species, specifically those who are enlisted as rare endangered and critically endangered categories according to the International Union for Conservation of Nature (IUCN) list. In India, the human-animal conflict is of more concern due to the presence of agricultural lands in the vicinity of reserve forests and the national highways and railways tracks that pass through the animal corridors of the reserve forests, which causes the loss of wild animals due to accidental events. The government has taken initiatives to reduce this conflict by increasing the compensation for the destruction of crops or lives due to wild animals [1]. But from the last few years, a loss of wildlife species due to roads or railway accidents increased significantly, as reported by the Ministry of Environment, Forest and Climate Change, Govt. of India (MoEF) [2]. These are mainly caused by the unplanned traffic controlling system at roads, or railway tracks passes through the animal corridors in the reserve forest areas. A lot of research papers have been published on the conservation of wildlife species in their natural habitats. In [3], the authors proposed a system for detecting poaching activities in protected forest zone by employing over 2000 no of Zigbee based wireless sensor nodes around 500 sq Km area using the concept of Mobile Sensor Networks. The authors in [4] proposed a CMOS wireless infrared image sensor network to obtain visual information about the target and also uses a GPS based location finding system. A Virtual Sensor Cloud (VSN) based two-tier WSN system is proposed in [5], where they used mobile agents for handling more significant areas to trace wildlife species and their activities. The issues in wildlife habitat monitoring are addressed in [6], where the authors proposed a novel method of surveying the wildlife species using the concept of Delay Tolerant Network (DTN) with the least number of sensor nodes to cover the larger area for habitat monitoring. The authors in [7] proposed a real-time target tracking system for the application field of Battlefield, Border Security, or Wildlife Monitoring using large scale sensor networks where the target can be detected and classified in a timely and energy-efficient manner. A cluster-based and position-based routing protocol for multi-hop WSN is reported in [8], where the primary motivation of the paper was to avoid the direct long communication between cluster head and sink node to preserve the node battery lifetime. The issues of global warming, deforestation, poaching activities, and forest fire are addressed in [9], and they proposed a system with a PIR sensor, Temperature sensor, Pressure sensor, Water level sensor, and a web camera as a possible solution. In [10], the authors proposed an energy-efficient sensor networking system for environmental monitoring using buffer

Revised Manuscript Received on April 25, 2020.
* Correspondence Author
Subhajit Mukherjee*, Electronics & Telecommunication Engineering Department, Technique Polytechnic Institute, Hooghly, West Bengal, India. Email: mukherjee.subhajit91@gmail.com

management protocol based on the queue threshold technique. The issues related to accidental events of wild animals caused by overrun of railways that passed through the animal corridors in a reserve forest are addressed in [11], and the authors proposed a system having infrasonic sound-emitting device mounted with the sensor nodes to deter the wild animals from railway track.

The issues in developing sensor networking based wildlife conservation systems are mainly concerned about coverage area, connectivity among nodes, deployment strategy, overall development cost, detection accuracy, delay in message transmission, and energy consumption of each node during sensing, computing, reception & communication of information. If we want to cover the whole reserve forest using sensor nodes, then a more significant number of sensor nodes need to be deployed in a deterministic manner to ensure the coverage of the entire area and proper connectivity among individual nodes. These may be a significant issue since overall development cost is in direct proportion with the number of sensor nodes. Also, if the monitoring areas have higher density, then the deterministic deployment is again a challenging task that insists on the connectivity issue among nodes, and it will require a sophisticated routing algorithm to deliver the message at the sink node. So, in practice, it will be more convenient to develop wildlife conservation system both from economic and technology perspective if we deploy the sensor nodes on those areas only which are more prone to human-animal conflict like agricultural lands in the vicinity of reserve forest, and roads & railway tracks that are passes through the animal corridors in protected areas inside the reserve forest.

In this paper, we propose a wildlife conservation system using two-tier sensor networking architecture, which ensures the least power consumption and fully connected network using deterministic deployment on the monitoring area under the interest. We use a Microwave motion sensor and a CMOS image sensor that further increases the detection accuracy by classifying the wildlife species. Also, we use the real-time traffic control mechanism based on the detection of wild animals on two-tier locations around railway tracks or roads in the forest areas. Tier 1 location is selected by considering a zone having a 40-50 meter radius around the railway track or route. In contrast, Tier 2 location is chosen by considering a region having not more than a 100-meter range around the railway track or road. Sensor nodes are placed in Tier 1 and Tier 2 locations to provide the different alert messages to the cluster node based on the detection activity, and the traffic management system can be controlled accordingly.

II. PROPOSED SYSTEM

A. Architecture

The primary motivation of our work is to minimize the human-animal conflict to reduce the loss of wild animals due to roads or railway accidents in the surrounding forest areas. In this project, our idea is to monitor the activities of wild animals on the streets or railway tracks surrounding the forest areas and generate an alert message for the vehicles or trains passing through that area to minimize the probability of collision with the wild animals. For the practical implementation of our idea, we formed a prototype model having two monitoring regions (named as Tier-1 and Tier-2) around the roads or railway track. The architecture of the proposed system is shown in Fig. 1. In both the regions, sensor nodes are deployed in such a manner so that a connecting network can be formed. The sensor nodes are composed of a Microwave motion sensor, a CMOS image sensor, a Zigbee transceiver module, and a microcontroller board. Apart from these sensor nodes in Tier-1 and Tier-2 region, there is another node that can be termed as cluster node is placed along the road or railway track, and this node is mounted with the controlling of the traffic management system. The cluster nodes are separated from each other, with approximately 200 meters of distances. Each cluster node is composed of a Zigbee transceiver module, a WiFi transceiver module, and a microcontroller board. This cluster node is used to control the traffic management system in real-time according to the alert message from sensor nodes and send the alert message to the remote server where it stored in the database for analysis of wildlife activities. The alert message from the Tier-2 region will slow down the traffic, whereas the alert message in the Tier-1 area will stop the vehicle immediately.

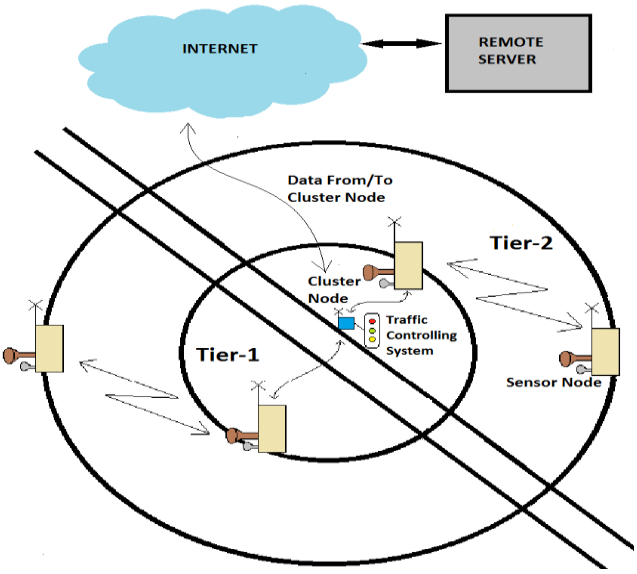

Fig. 1. Architecture of the proposed system

B. Details Operating Procedure of the System

The proposed system is developed based on energy efficiency, cost-effectiveness, and reliability. The underlying MAC protocol used CSMA-CA with a non-beacon-based enabled communication scheme to ensure the reliability in data delivery to the cluster node [12]. When a sensor node is in the sleep state, the transmitter module is disabled, and the receiver & sensor module is only in the active state to save the amount of energy exhausted from the battery. If the motion sensor detects the motional activity, then the microcontroller module activates the image sensor that captures the image of the moving object, and the transceiver module will also send an alert message to the cluster node. If detection occurred in

Retrieval Number: D8039049420/2020©BEIESP
DOI: 10.35940/ijeat.D8039.049420
Journal Website: www.ijeat.org

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

the Tier-2 region, then alert message will be sent to the cluster node via a network associated with Tier-1 nodes, and if detection occurs in the Tier-1 area, then alert message will be transmitted directly to the cluster node. In this mechanism, the number of hop travels by the alert message to reach the cluster node is reduced, which further reduces the complexity in routing and computational power of each node. The cluster node doesn't have stringent power requirements since it is considered to have abandoned power supply. The cluster node finally sends the alert message to the remote server with the help of WiFi Networks, and also the cluster node will take immediate action through the controlling of the traffic management system. If motional activity detected in the Tier-1 region, which is near the road or railway track of interest, then traffic signals will go to RED. If motional activity detected in the Tier-2 area, then traffic signals will go to YELLOW.

C. Flow Diagram of different nodes in the System

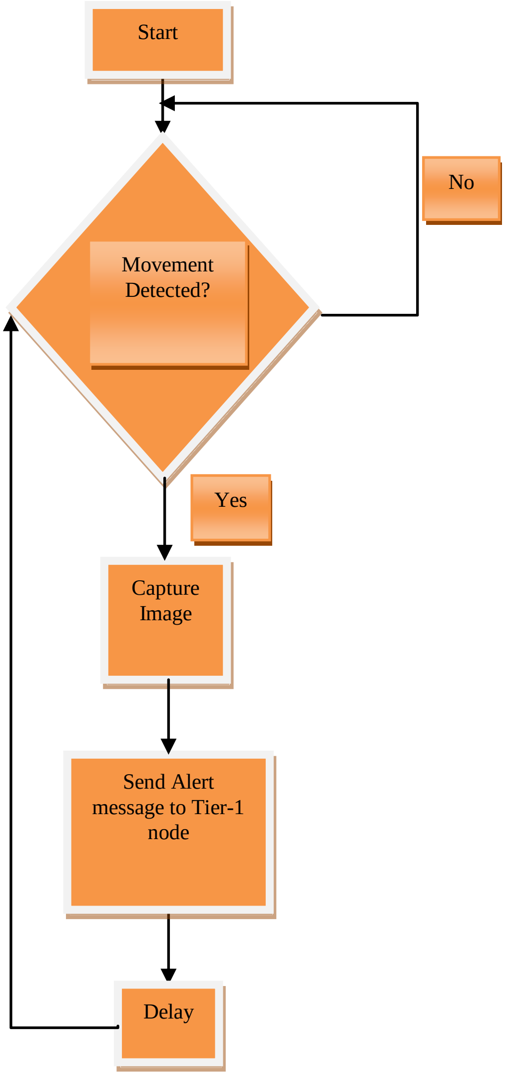

Fig. 2.Flow diagram of Tier-2 node

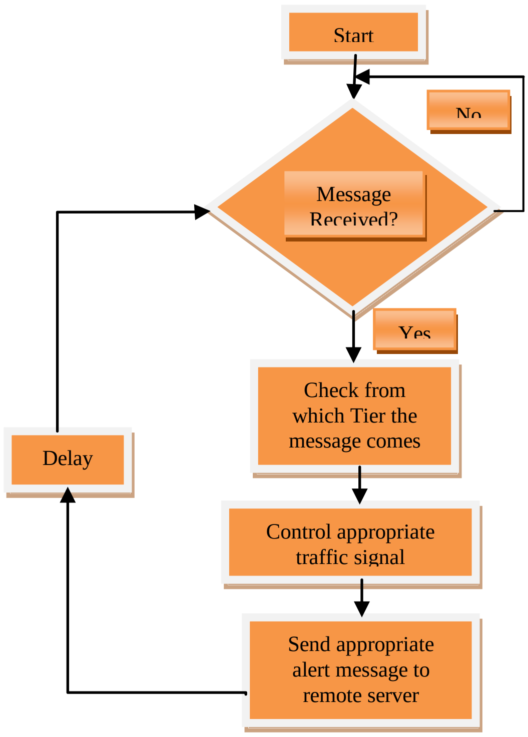

Fig. 3.Flow diagram of Cluster node

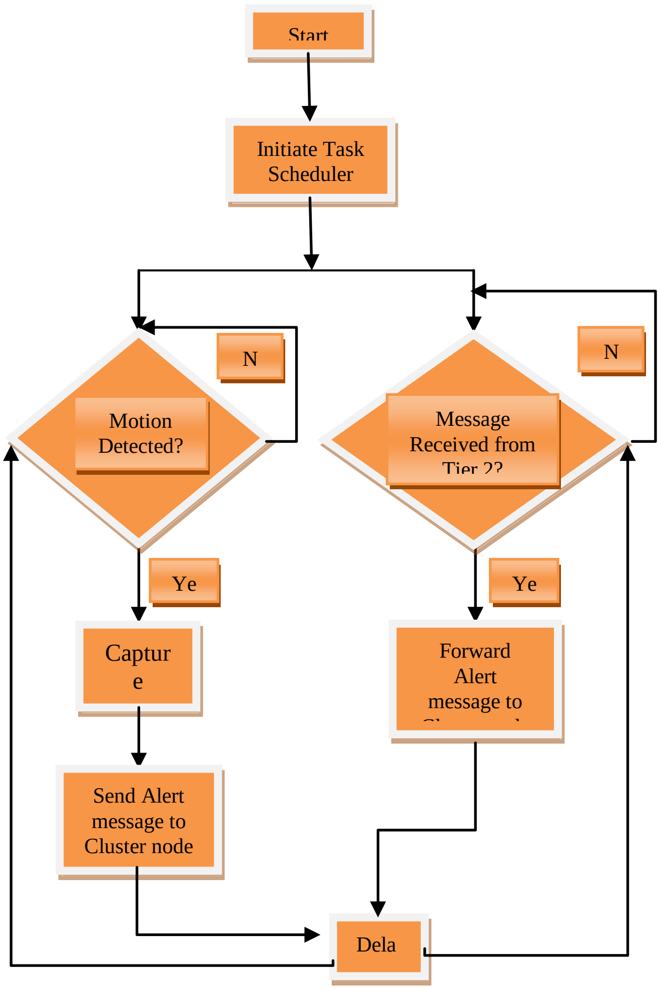

Fig. 4.Flow diagram of Tier-1 node

III. ARCHITECTURE OF DIFFERENT MODULES

A. Arduino uno Microcontroller board

Arduino Uno is a microcontroller board with an ATMEGA328P microcontroller module. It operates on 16 MHz clock frequency with 32 KB of flash memory. The board consists of 6 Analog I/O pins and 14 digital I/O pins, out of which six digital pins can be used as PWM output. The operating voltage of the board is 5V, and the maximum output voltage is from 6V to 20V.

Fig. 5.Arduino Uno R3 [20]

B. Microwave Motion Sensor

Microwave motion sensor has a distinct advantage over PIR (Passive Infrared based) motion sensor in outdoor environment is that the performance of microwave sensor doesn't get affected by the external light source which is a major drawback in PIR sensor. In our proposed sensor networks we have used HB 100 microwave motion sensor which works in X band frequency (10.525 GHz) and also independent from temperature and humidity variations. It can cover a maximum range of about 20 meters for detection of target using the principle of Doppler frequency shift.

Fig. 6.HB 100 X band Microwave Motion Sensor [21]

C. CMOS Image Sensor

The camera module we used in our project is a CMOS image sensor that composed of a Video Graphics Array (VGA) camera and an image processor in a small footprint package. It produces an 8-bit image, and the image array is capable of operating at a maximum rate of 30 frames per second.

Fig. 7.OV7670 CMOS camera module [22]

D. Zigbee Module

Zigbee wireless module is used to establish a communication network between sensor nodes in the 2.4 GHz unlicensed spectrum with an average data rate of 250 kbps. The module can cover a range of about 10 to 60 meters in NLOS, but with an increase in transmission power, the module can capable of transmitting at a range of about 90 m in NLOS and about 3 km in LOS. In our proposed sensor networks (Fig. 1) both the Tier-1 and Tier-2 nodes are consists of Xbee Pro module as shown in Fig. 8 which can operate at a transmission power of 63 mW and can cover a maximum range of 90 meters in NLOS and a maximum range of 3 km in LOS. In our project, we used star topology and master-slave configuration of Zigbee modules to form the sensor network. Also, the Zigbee modules operate on beacon mode to save the battery power of sensor nodes.

Fig. 8.Xbee Pro Module (IEEE 802.15.4) with 63mW Tx Power [23]

E. Microcontroller module with WiFi SoC

The cluster node in our project work is choosing to be a microcontroller module with WiFi System on Chip (SoC). We used NodeMCU firmware for this purpose. It has 4 MB flash memory, 64 KB SRAM, 1 analog pin, and 16 digital pins. For communication with peripheral devices it consists of 1 UART and SPI interface each. The operating voltage of the module is 3.3V and system clock speed is about 80 MHz.

Fig. 9.NodeMCU module [24]

IV. ESTIMATION OF BATTERY LIFE TIME OF SENSOR NODES

The battery lifetime of a node depends on the amount of current consumes by the individual components associated with the node. Nodes in both the region are consist of Microcontroller module (Arduino UNO R3), Sensor module (HB 100 motion sensor), Camera module (OV7670), and Transceiver module (Xbee Pro).

Retrieval Number: D8039049420/2020©BEIESP
DOI: 10.35940/ijeat.D8039.049420
Journal Website: www.ijeat.org

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

Since most of the battery power is consumed for sensing, image capturing, and transmission; therefore, we have mainly considered these tasks for estimation of battery lifetime. In this section, we estimated the battery life as a function of the mean drain current of sensor, camera, and transceiver module. The battery lifetime of Tier-1 node can be stated as,

$$L_{Tier\_1}(in\_days) = \frac{C/24}{I_{drain}^{Tier\_1}(M)} \quad (1)$$

Where, C= Battery Capacity in mAH,

$I_{drain}^{Tier\_1}(M) = I_{drain}^{Task\_1}(M) + I_{drain}^{Task\_2}(M)$ = Mean battery drain current of each Tier-1 node,

$I_{drain}^{Task\_1}(M) = I_{drain}^{Sensor}(M) + I_{drain}^{Camera}(M) + I_{drain}^{Tx}(M)$

= Mean battery drain current for Task 1 of Tier-1 node,

$I_{drain}^{Sensor}(M)$ = Mean battery drain current of sensor module,

$I_{drain}^{Camera}(M)$ = Mean battery drain current of camera module,

$I_{drain}^{Tx}(M)$ = Mean battery drain current for transmission of transceiver module,

$I_{drain}^{Task\_2}(M) = I_{drain}^{Rx}(M) + I_{drain}^{Tx}(M)$

= Mean battery drain current for Task 2 of Tier-1 node,

$I_{drain}^{Rx}(M)$ = Mean battery drain current for reception of transceiver module,

$I_{drain}^{Tx}(M)$ = Mean battery drain current for transmission of transceiver module.

Similarly, Battery life time of Tier-2 node can be stated as,

$$L_{Tier\_2}(in\_days) = \frac{C/24}{I_{drain}^{Tier\_2}(M)} \quad (2)$$

Where,

$I_{drain}^{Tier\_2}(M) = I_{drain}^{Sensor}(M) + I_{drain}^{Camera}(M) + I_{drain}^{Tx}(M)$

= Mean Battery drain current of each Tier-2 node.

A. Battery drain current of Sensor module (HB 100)

The current consumption of the sensor module is due to sensing of motion, which takes time approximately 0.5 ms (Pulse repetition period) with a duty cycle of 4% as listed in Table-I. During this period of the active state, the sensor consumes a maximum of 4 mA current, and during off period, the current consumption is of the order of µA.

Table- I: Characteristic parameters of Motion Sensor [13]

Parameter	Description	Value	Unit
I_S	Active State Current	1.2 - 4	mA
I_Q	Quiescent Current	10	µA
f_p	Pulse Repetition Frequency	2	kHz
τ_P	Pulse Repetition period	0.5	ms
D	Duty Cycle	4	%

The mean battery drain current due to sensor module can be obtained from equation (3) as

$$I_{drain}^{Sensor}(M) = \frac{I_S \times T_{ON} + I_Q \times T_{OFF}}{T_P} \quad (3)$$

Where, $T_{ON} = \frac{D}{100} \times T_P$ =on time,

And, $T_{OFF} = T_P - T_{ON}$ =off time.

B. Battery drain current of Camera module

The camera module is responsible for the consumption of energy mostly during the capturing of the image with VGA frame format and during the Serial Camera Control Bus (SCCB) operation. The characteristic parameter for the estimation of the current consumption of the camera module is listed in Table-II.

Table- II: Characteristic parameters of Camera module [14]

Parameter	Description	Value	Unit
I_A	Active Current	18	mA
I_S	Standby Current (Power Down Sleep Mode)	10	µA
I_{SCCB}	Standby Current (Serial Camera Control Bus Operation)	01	mA
t_{VGA}	VGA Frame Time (Described in Section V) (for YUV format)	22.39	Ms
t_{HD_STA}	Start Condition Hold Time	600	Ns
t_{SU_STA}	Start Condition Setup Time	600	Ns
t_{SU_DAT}	Data in Setup Time	100	Ns
t_{DH}	Data out Hold time	50	Ns
$t_{R/F}$	SCCB Rise/Fall Time	300	Ns
t_{SU_STO}	Stop condition Setup Time	600	Ns

The battery drain current for capturing of an image after each detection of motion can be estimated as,

$$I_{drain}^{Cam}(D) = \frac{(I_A \times t_{VGA}) + (I_{SCCB} \times t_{SCCB})}{T_{act\_cam}} \quad (4)$$

Where,

$t_{SCCB} = t_{HD\_STA} + t_{SU\_STA} + t_{SU\_DAT} + t_{DH} + 3 \times t_{R/F} + t_{SU\_STO}$

(One complete SCCB interval requires 3 no's of clock pulses)

$T_{act\_cam} = t_{VGA} + t_{SCCB}$ =Activity Period

Now considering an average of N no's of detections per hour, the mean drain current over a complete hour for the camera module can be computed from equation (4) as,

$$I_{drain}^{Cam}(M) = \frac{(I_{drain}^{Cam}(D) \times T_{act\_cam} \times N) + [T_{Hour} - (N \times T_{act\_cam})] \times I_S}{T_{Hour}} \quad (5)$$

Where, N= Average number of detections per hour,

$T_{Hour} = (60 \times 60) = 3600\ seconds$

C. Battery drain current of transceiver (Zigbee) module (Transmission Mode)

Most of the energy consumption of the battery will take place due to the transceiver module of the sensor node. In our proposed network, we selected Xbee pro (consume 120 mA current for transmission) as the transceiver module for nodes in Tier-1 and Tier-2 region.

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

The description of the characteristic parameters of the Zigbee transceiver module is listed in Table-III, which will be used for computation of battery drain current due to the transmission of the alert message to the cluster node.

Table- III: Characteristic parameters of Zigbee transceiver module for Transmission mode [15, 16]

Parameter	Description	Value	Unit
t_{on_off}	Time to wake up and turn off the transceiver	13	ms
I_{on_off}	Current to wake up and turn off the transceiver	13	mA
$t_{listening}$	Time to access radio channel and receive ACK from coordinator	2.1	ms
$I_{listening}$	Current to access radio channel and receive ACK from coordinator	31	mA
I_{Tx}	Current for transmission of n bytes data	120	mA
P_{out}	Output Transmission Power	63	mW
		+18	dBm
I_{sleep}	Current in sleep mode	0.03	µA

The battery drain current for transmission of n bytes data after each detection of motion can be computed as,

$$I^{Tx}_{drain}(D)=\frac{(t_{on\_off}\times I_{on\_off})+(t_{listening}\times I_{listening})+(t_{Tx}(n)\times I_{Tx})}{T_{act}(n)} \quad (6)$$

The overall transmission time, $t_{Tx}(n)$ for n bytes of data payload with a consideration of no of retransmission as a function of bit error rate can be obtained from [16] as follows,

$$t_{Tx}(n)=\frac{8\times(O_{MAC}+n)}{r}\left[1+\sum_{i=0}^{aMaxF}\left(p_o^{mMaxb+1}\right)^{i+1}p_r^i\right] \quad (7)$$

Where, r= Data transmission rate = 250 kbps for 2.4 GHz ISM band with QPSK modulation,

O_{MAC} = MAC Overhead (Preamble, Start Frame Delimiter, MAC header, Cyclic Redundancy Check) = 31 bytes for IEEE 802.15.4,

aMaxF= Maximum number of times retransmission takes place (by default the value is 3),

p_o= probability that the channel is occupied in CSMA/CA channel access mode. This can be computed as a function of number of active nodes, m, as described in [17],

mMaxb=Maximum number of times that CSMA algorithm is repeated (by default the value is 4).

The probability that a bit is in error within the data frame, *Pr* or bit error rate can be estimated by equation (8), which described the likelihood that the coordinator node does not receive an acknowledgment after transmission of a data frame. After receiving the data frame, the receiver of the Zigbee node performs the CRC operation to check whether the frame is corrupted or not. If one or multiple bits in the data frame are in error, then the result of the CRC operation will not be the same as the CRC field in the received MAC frame; the ACK frame will not be sent to the coordinator node. As a result of this, the time out occurs at the coordinator node, and retransmission takes place. The bit error rate in equation (9) is estimated for an AWGN (Additive White Gaussian Noise) Rayleigh Fading channel with the QPSK modulation scheme.

$$p_r=BER_{avg}(N_o)=0.5\times\left(1-\sqrt{\frac{SNR}{2+SNR}}\right) \quad (8)$$

Where, SNR=P_{Rx}/N_o=Signal to Noise ratio for the Noise power of N_o,

$P_{Rx}=P_{Tx}$-A=Received Power,

P_{Tx}=Transmitted Power= 63 mW or +18 dBm for Xbee Pro,

A=Path loss which can be estimated using different path loss models described in [18, 19],

$z=8\times(O_{MAC}+n)$=Number of bits in a packet.

The total activity time for transmission operation can be stated as,

$$T_{act\_Tx}(n)=t_{on\_off}+t_{listening}+t_{Tx}(n)$$

Now, the mean drain current of transceiver module for an average of N no's of detections /hour can be estimated from equation (6) as,

$$I^{Tx}_{drain}(M)=\frac{(I^{Tx}_{drain}(D)\times T_{act\_Tx}(n)\times N)+[T_{Hour}-(N\times T_{act\_Tx}(n))]\times I_{sleep}}{T_{Hour}} \quad (9)$$

Where, N= Average number of detections per hour,

$T_{Hour}=(60\times 60)=3600\ seconds$

D. Battery drain current of transceiver (Zigbee) module (Reception Mode with Acknowledgement (ACK))

The data from Tier-2 node cannot be able to reach directly at the cluster node but through the Tier-1 node. Due to this Tier-1 node has to perform as a relay between the Tier-2 node and cluster node. The consumption of battery drain current in Tier-1 node for this purpose depends on the various characteristic parameters described in Table-IV, which are used for computation of reception current consumption of the transceiver module.

Table- IV: Characteristic parameters of Zigbee transceiver module for Reception mode with ACK [15, 16]

Parameter	Description	Value	Unit
T_{Rx_Tx}	Rx to Tx Turnaround Time	192	µS
T_{Tx_Rx}	Tx to Rx Turnaround Time	192	µS
I_{Turn}	Current during Turnaround	13	mA
I_{rcv}	Current for receiving n bytes of data	18.5	mA
I_{sleep}	Current in sleep mode	0.03	µA

The battery drain current of Tier-1 node for reception of n bytes data and sending acknowledgement to the transmitter node after each detection of motion at Tier-2 region can be computed as,

$$I^{Rx}_{drain}(D)=\frac{I_{rcv}\times t_{Rx}(n)+(T_{Rx\_Tx}+T_{Tx\_Rx})\times I_{Turn}+t_{listening}\times I_{listening}+t_{ACK}\times I_{Tx}}{T_{act\_Rx}} \quad (10)$$

Where,

$t_{Rx}(n)=\frac{8(O_{MAC}+n)}{r}$ =Reception time for n bytes of data payload [16],

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

$t_{ACK} = \frac{(8 \times 11)}{r}$ = Transmission time of ACK frame of 11 bytes (for IEEE802.15.4 MAC ACK Frame),

$T_{act\_Rx} = t_{Rx}(n) + T_{Rx\_Tx} + t_{listening} + t_{ACK} + T_{Tx\_Rx}$ =Activity Period.

The mean drain current of transceiver module of Tier-1 node due to reception from Tier-2 node for an average of N no's of detections /hour can be estimated from equation (10) as,

$$I^{Rx}_{drain}(M) = \frac{(I^{Rx}_{drain}(D) \times T_{act\_Rx} \times N) + [T_{Hour} - (N \times T_{act\_Rx})] \times I_{sleep}}{T_{Hour}} \quad (11)$$

Where, N= Number of detections per hour,

$T_{Hour} = (60 \times 60) = 3600\, seconds$

V. END TO END DELAY ESTIMATION FOR EACH NODE

The time required to reach the alert message from the sensor node to the cluster node after each successful detections of motion is known as end to end delay. These comprise sensing delay, delay due to capturing of the image, and transmission delay. The transmission delay depends on the no of hops required to reach the alert message to the cluster node. If detection found in the Tier-1 region, then only one hop requires for transmitting the alert message to the cluster node, whereas, if detection occurred in the Tier-2 area, then two hops are required to reach the alert message at cluster node.

The end to end delay for Tier-1 node can be computed as,

$$T^{End\_to\_End}_{Tier\_1} = \tau_P + T_{act\_cam} + T_{act\_Tx} \quad (12)$$

Where, τ_P= Pulse Repetition Period.

The end to end delay for Tier-2 node can be computed as,

$$T^{End\_to\_End}_{Tier\_2} = T^{Tier\_1}_{Tier\_2} + T^{Cluster}_{Tier\_1} \quad (13)$$

Where, $T^{Tier\_1}_{Tier\_2} = \tau_P + T_{act\_cam} + T_{act\_Tx}$ = Time to reach the alert message of n bytes at Tier-1 node from Tier-2 node

$T^{Cluster}_{Tier\_1} = T_{act\_Rx} + T_{act\_Tx}$ = Time to reach the alert message of n bytes at Cluster node from Tier-1 node.

VI. RESULT & DISCUSSION

The analysis of battery life is done by considering AA battery (2400 mAH) as the source of energy of sensor nodes. The alert message format that transmits by each node in Tier-1 and Tier-2 regions is "Region:Tier-1 Node ID:20" which is about 26 bytes of the string. Also, it has been assumed that the noise power is about -60 dBm for measuring battery lifetime. Battery lifetime is estimated as a function of a number of detections of motion in each hour for different path loss models (Fitted ITU-R model, Weissberger's Modified exponential model, & COST235 model [18, 19]) developed for forest environment as well as for different probability of channel access failure which is a function of a number of active nodes (m) during accessing of the channel [17]. An observation from Fig. 10 reveals that the battery life almost changes equally concerning the number of detections for different path loss models. In contrast, the battery lifetime degrades proportionately with the increase in the probability of channel access failure, as shown in Fig. 11.

Table- V: Battery Life Estimation for different path loss model
(P_o=0.8, d=60 meter for Tier-1 & d=80 meter for Tier-2)

N	Fitted ITU-R Model		Weissberger's Model		COST235 Model	
	Tier-1 node	Tier-2 node	Tier-1 node	Tier-2 node	Tier-1 node	Tier-2 node
10	535.21	545.76	535.12	545.71	535.18	545.74
20	523.33	538.03	523.16	537.94	523.28	538.00
30	511.96	530.52	511.73	530.39	511.89	530.48
40	501.08	523.22	500.78	523.04	500.99	523.17
50	490.66	516.12	490.29	515.90	490.54	516.05
60	480.65	509.20	480.23	508.95	480.52	509.13
70	471.05	502.47	470.58	502.19	470.90	502.39
80	461.82	495.92	461.30	495.60	461.66	495.82
90	452.95	489.53	452.39	489.18	452.78	489.43
100	444.41	483.31	443.81	482.93	444.23	483.20

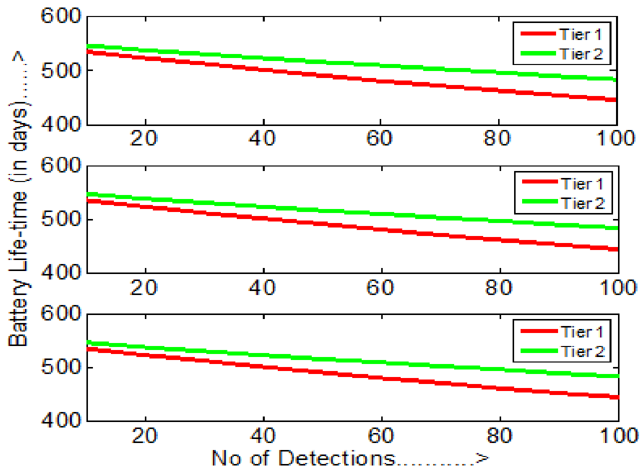

Fig. 10. Analysis of battery life-time as a function of Detection frequency for different path loss models in forest environment

Table- VI: Battery Life Estimation for different probability of channel access failure (Considering COST235 model)

N	P_o=0.5 (m=2)		P_o=0.8 (m=5)		P_o=0.9 (m=10)	
	Tier-1 node	Tier-2 node	Tier-1 node	Tier-2 node	Tier-1 node	Tier-2 node
10	536.60	546.48	535.18	545.74	533.08	544.64
20	526.00	539.44	523.28	538.00	519.27	535.86
30	515.80	532.58	511.89	530.48	506.16	527.37
40	506.00	525.89	500.99	523.17	493.70	519.14
50	496.56	519.37	490.54	516.05	481.83	511.16
60	487.46	513.01	480.52	509.13	470.52	503.42
70	478.70	506.80	470.90	502.39	459.73	495.92
80	470.24	500.74	461.66	495.82	449.43	488.63
90	462.08	494.82	452.78	489.43	439.57	481.56
100	454.19	489.04	444.23	483.20	430.14	474.68

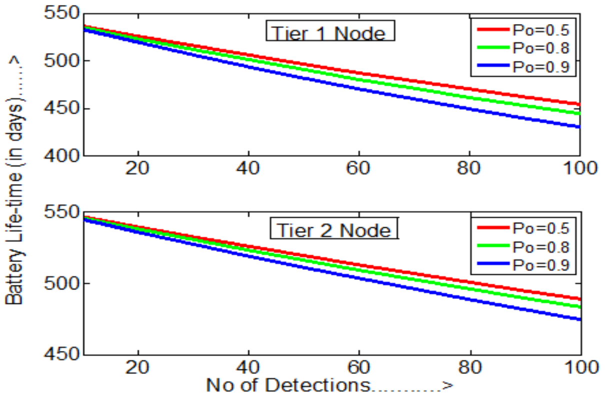

Fig. 11. Analysis of battery life-time as a function of Detection frequency for different probability of channel access failure

Table- VII: End to End Delay Estimation for different path loss models and for different probability of channel access failure

Node	Fitted ITU-R Model	Weissberger's Model	COST235 Model
Considering P_o=0.8 (m=5)			
Tier-2	32.77	32.86	32.79
Tier-1	28.34	28.39	28.35
Node	**P_o=0.5 (m=2)**	**P_o=0.8 (m=5)**	**P_o=0.9 (m=10)**
Considering COST235 Model			
Tier-2	31.32	32.79	35.00
Tier-1	27.61	28.35	29.47

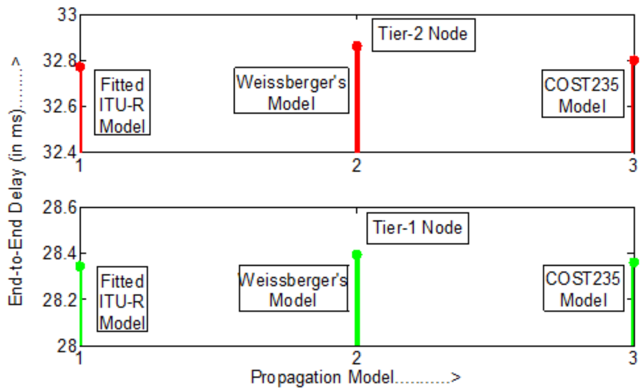

Fig. 12. Analysis of End-to-End delay for different path loss models in forest environment

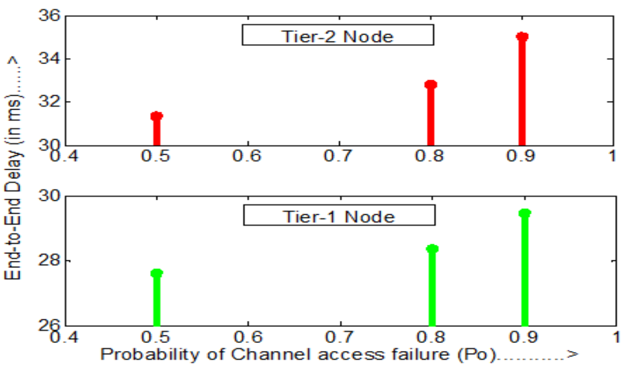

Fig. 13. Analysis of End-to-End delay for different probability of channel access failure

The End-to-End delay for Tier-1 and Tier-2 nodes are estimated for different path loss models (shown in Fig. 12) and for the distinct probability of channel access failure (shown in Fig. 13). It has been obtained from the above the analysis of End-to-End delay is that for worst-case scenario the Tier-1 node requires about 29 ms and Tier-2 node requires about 35 ms (considering COST235 model and *Po*=0.9 for ten no of active nodes [17]) to reach their data into the cluster node.

VII. CONCLUSION

Human-animal conflict is of today's primary concern for the protection of wildlife species in their natural habitat. Most of the conflict arises on the national highways or railway tracks that are passes through the animal corridors. So, it is of utmost importance to save those wild animals from being an accident in those conflict areas. In this paper, we proposed a wildlife conservation system through sensor networking that can reduce the chances of the accident of wild animals using the detection of wildlife activities in those conflict areas. The accident can be reduced by controlling the traffic management system, which depends on the received alert message from sensor nodes belonging to the different tier regions. One of the primary design constraints of sensor networking is energy efficiency, on which the battery life of sensor nodes is dependent. The energy consumption of a sensor node is primarily depends on the number of detections per unit time and the transmission of alert message to the sink node. We have shown that our proposed two tiers based sensor networking architecture can increase the battery life of the sensor nodes, which is more than one year, even if in the worse condition i.e., higher frequency of detections over extreme path loss scenario and a higher probability of channel access failure. So the rate of network maintenance can be reduced significantly. Also, with this proposed networking hierarchy, it has been shown that in the worst-case scenario, the transmission of an alert message can reach the cluster node in real-time for controlling the traffic management system.

REFERENCES

1. "Annual Report", Ministry of Environment, Forest & Climate Change, Govt. of India, 2018-19, pp: 46. Available:http://moef.gov.in/wp-content/uploads/2019/08/Annual-Report-2018-19-English.pdf
2. "Death of Wild Animals in Rail and Road Accidents", Starred Question No. *267, RAJYA SABHA , Ministry of Environment, Forest & Climate Change, Govt. of India, 7th January, 2019, pp: 4-6. Available:http://www.indiaenvironmentportal.org.in/files/file/Death%20of%20wild%20animals%20in%20rail%20and%20road%20accidents.pdf
3. A. Badescu, L. Cotofana, "A wireless sensor network to monitor and protect tigers in the wild," Ecological Indicators, May 12, 2015, pp. 447–451.
4. J. Zhang, et.al., "A Wildlife Monitoring System Based on Wireless Image Sensor Networks," Sensors & Transducers, Vol. 180, Issue 10, October 2014, pp. 104-109.
5. S. K. Tetarave, A. K. Srivastava, "FOREST GUARD: A complete safety for Wildlife using Mobile Agents and Sensor Clouds in WSN," International Journal of Computer Science Issues, Vol. 9, Issue 6, No 3, November 2012.
6. A. Tovar, T. Friesen, K. Ferens, B. McLeod, "A DTN Wireless Sensor Network For Wildlife Habitat Monitoring," IEEE 23rd Canadian Conference on Electrical and Computer Engineering, Edmonton, AB, Canada, May 2010.

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

7. T. He et al. "Achieving Real-Time Target Tracking Using Wireless Sensor Networks," Real-Time and Embedded Technology and Applications Symposium, IEEE, San Jose, California , United States, May 2006
8. W. Wibisono, T. Ahmad, R. Anggoro, "Position-Based Scheme for Multi-Hop Routing Protocol in Cluster-Based Wireless Sensor Networks," IEEE 4th International Conference on Wireless and Telematics (ICWT), Nusa Dua, Indonesia, July 2018.
9. C.A Varuna , A. Babu, "A Wireless Sensor Network Based Habitat Monitoring for Protection of Endangered Species," IJIRSET, Vol. 6, Issue 6, June 2017
10. P. Maheswar et al., "Energy Efficient Real Time Environmental Monitoring System Using Buffer Management Protocol," IEEE 9th International Conference on Computing, Communication and Networking Technologies (ICCCNT), Bangalore, India, October 2018.
11. P. Mathur, H. R. Nielsen, N. R. Prasad, R. Prasad, "Wildlife Conservation and Rail Track Monitoring using Wireless Sensor Networks," IEEE 4th International Conference on Wireless Communications, Vehicular Technology, Information Theory and Aerospace & Electronic Systems (VITAE), Aalborg, Denmark, May 2014.
12. Min Zhou, Zhang-long Nie, "Analysis and Design of ZigBee MAC Layers Protocol," IEEE International Conference on Future Information Technology and Management Engineering, October 2010.
13. HB-100 Microwave Doppler Radar Motion Detector Datasheet, Available: https://www.rhydolabz.com/documents/H100_H200A.pdf
14. OV7670 Image Sensor Datasheet, Available:http://web.mit.edu/6.111/www/f2016/tools/OV7670_2006.pdf
15. 2.4 GHz IEEE 802.15.4 Zigbee Pro Transceiver Datasheet, Available: http://www.ti.com/lit/ds/symlink/cc2520.pdf
16. Eduardo Casilari , Jose M. Cano-García, and Gonzalo Campos-Garrido, "Modeling of Current Consumption in 802.15.4/ZigBee Sensor Motes", Sensors, Volume:10, pp: 5443-5468, June 2010.
17. M. Goyal et.al. "A stochastic model for beaconless IEEE 802.15.4 MAC operation", Computer Communications, Volume: 34, pp: 1460–1474, December 2010.
18. Dora Cama-Pinto et.al. "Path Loss Determination Using Linear and Cubic Regression Inside a Classic Tomato Greenhouse", International Journal of Environmental research and Public Health, Volume: 16, pp:1-15, May 2019.
19. Y. S. Meng, Y. H. Lee, and B. C. Ng, "Study of Propagation Loss Prediction in Forest Environment", Progress In Electromagnetics Research B, Volume:17, pp: 117-133, 2009.
20. Arduino UNO R3 Microcontroller Board image, Available: https://robokits.co.in/arduino/boards/
21. HB 100 X band Microwave Motion Sensor image, Available:https://robokits.co.in/sensors/motion-detector/microwave-doppler-radar-motion-sensor-module-hb100?
22. OV7670 Camera Module image, Available: https://thinkrobotics.in/products/ov7670-camera-module?
23. Xbee Pro Transceiver Module image, Available: http://schemobotics.com/product/zigbee-xbee-pro-s2c/
24. NodeMCU module image, Available: https://robu.in/product/nodemcu-cp2102-board/

AUTHORS PROFILE

Subhajit Mukherjee (mukherjee.subhajit91@gmail.com) was born in West Bengal, India on 25th December 1991. The author received his B.Tech degree under WBUT in Electronics & Communication Engineering in 2014 and M.Tech degree from Jadavpur University on the specialization of Distributed and Mobile Computing in 2016. He was awarded for AICTE GATE fellowship from MHRD, Govt. of India, during the tenure of his M.Tech course. He received the JRF award under the DST PURSE-II program, Govt. of India, in 2016. He has more than three years of teaching experience in the field of Electronics & Telecommunication Engineering for diploma and undergraduate students. Currently, he is associated with the Department of Electronics & Telecommunication Engineering, Technique Polytechnic Institute, Hooghly, W.B, India, where he is now a lecturer. He has eight numbers of publications in International Journal and Conferences. His research interest includes Wireless Communications, Internet of Things, Real-time Communications, & Sensor Networking. He is a life member of the Indian Society of Technical Education (ISTE- LM 119681).

Subhrajit Nandy (iamthor.1993@gmail.com) was born in West Bengal, India on 15th December 1993. The author is currently pursuing his diploma course in Electronics & Telecommunication Engineering from Technique Polytechnic Institute, Hooghly, W.B, India. He completed IT smart from APLL with an appreciation grade. He has expertise in C programming in various Embedded System platform, interfacing of different peripheral devices with Arduino, component testing & circuit making on Vero board, PCB and PCB design through different software platforms. He also completed a workshop regarding the hands-on practice with Arduino and NodeMCU from SKUBOTICS. He is currently working on the development of the IoT platform for various Sensor Networking Applications.

Abhishek Dey (abhishek.dey.ece@gamil.com) was born in West Bengal, India on 3rd January 1986. The author received his B.Tech degree under WBUT in Electronics & Communication Engineering in 2008 and M.Tech degree from WBUT on the specialization of Mobile Communication and Network Technology in 2010. He received district level 2nd position at Science Seminar from Govt. of West Bengal in 1999. He has more than six years of teaching experience and one year of industry experience in the field of Electronics & Telecommunication Engineering. Currently, he is associated with the Department of Electronics & Telecommunication Engineering, Technique Polytechnic Institute, Hooghly, W.B, India, where he is now a lecturer. He has ten numbers of publications in International Journal and Conferences. His research interest includes Semiconductor Devices, Networking & Internet of Things, VLSI and Digital Signal Processing. He is a life member of the Indian Society of Technical Education (ISTE- LM 119679).