Project wildSENSE

Track and monitor wildlife

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***Abstract*—This project demonstrates the application of Wireless Sensor Networks to track and monitor wildlife using Zolertia RE-Mote hardware units. The wild animals can be tracked if they enter surrounding human villages and target animals can be monitored for their health conditions as well. Tiger-human conflict in Sunderbans National Park has been taken as the target case in this project. Mobile Zolertia RE-Motes are assumed to be attached to the tigers and they broadcast their localization and health data continuously. Static motes forming the network gather and forward this data to a central entity, the Gateway. Data collected at the gateway is used to display the health conditions of the tigers and also helps in locating them. The implementation has been realized with Contiki, an open source event driven operating system for the internet of things, that finds its use in networking models having low power and memory constraints.**

***Index Terms*—Zolertia RE-Mote, Tiger Mote, Neighbours, Gateway**

I. Motivation and Introduction

With the ever-increasing population of humans, the demand of land increases which leads to humans encroaching into forest areas and thus human-wildlife conflicts. Habitat destruction and lack of food causes the wild animals to come out of forests and enter human habitats which often end in loss of animal or human life. The Sunderbans, stretched across the border of India and Bangladesh is the largest mangrove forest in the world and home to the Royal Bengal Tiger. It has frequent cases of animal-human conflicts and statistics depict that 49 tigers and 232 people have been killed between 2001 and 2014 as a result of tiger-human conflicts in the Sunderbans. Apart from tigers, elephants also stray into the human villages that causes tremendous damage to human property and crops. This project can provide an insight regarding the solution of this scenario. Motes can be attached to the animals that transmit broadcast packets to the static network nodes which forward the packets by unicast to their neighbours and ultimately to the gateway. Forest officials can visualize the whereabouts of the tigers (or elephants) in the GUI connected to the Gateway mote. When the animals stray into the village, no broadcast packets would be received by the network nodes from the animal nodes and this would be an alarm for the forest officials to launch search operations before the tigers have strayed too much into the village and caused loss of property or life. Direction of search can also be determined from the mote which had last received packets from the animal.

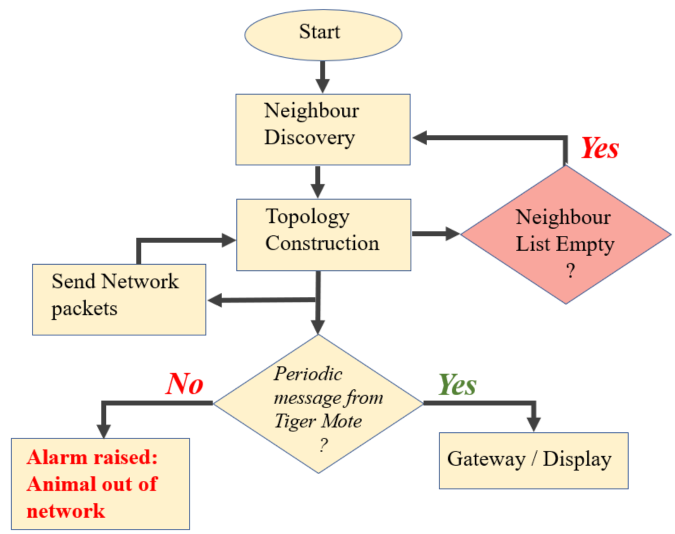

Fig. 1. Implementation Architecture

II. Architecture

Figure 1 gives an overview of the project flow. A *distance vector based distributed routing protocol* is implemented in this project. After switching on the motes, the network would be constructed by each of the motes filling up its own routing table with its neighbour motes and the gateway being the central entity. This would be done by broadcasting certain number of packets only by the network static nodes(not the gateway). After the network is formed, three processes would be going on: sending packets to maintain the network, checking if the neighbour list is empty and forwarding any packets received from the animal mote to the gateway. Each of the motes send packets to their neighbours at a fixed interval so that the whole network remains intact and if any mote is dead the information can be tracked. If a node is dead, i.e. packets are not received from it by it's neighbours it gets removed from the routing table of its neighbours. If at some point of time, the neighbour list of a mote is empty it again enters the neighbour discovery mode to find its path to the gateway. These two processes ensures the resilience and dynamic nature of the network so as to achieve the third final fundamental task of forwarding packets from the tiger mobile mote to the gateway mote. Information at the gateway mote is displayed on the GUI with the help of Qt. This project shows three sensor values (Battery, Temperature and Heartbeat) of the mobile animal mote on the GUI along with the routing path. These displayed temperature and heartbeat sensor values aid in monitoring the health of animals which is of great use when some animals are introduced in a new habitat after some injury or rehabilitation.

III. Network Formation And Maintenance

A. Neighbour Discovery

After switching on the motes, network topology is constructed by broadcast mechanism by the network motes except the gateway. Each of the motes broadcasts 10 packets and on receiving a broadcast packet above a threshold RSSI, the address from which the packet is received is added to the routing table of the receiving mote with cost to gateway as '*infinite*' and a certain Time to Live (TTL). The reason for having 'Infinity' is that the cost to gateway is still unknown. The significance of TTL is explained in the section Network maintenance post topology formation.

B. Gateway Discovery

The gateway does not send any broadcast packet, however on receiving a broadcast packet, it adds the sender to its neighbour table and sends a unicast packet to the sender to inform that the gateway can be reached with zero cost (since it is the gateway). The neighbours of the gateway now adds gateway to their routing table with cost equal to one and also inform their neighbours by unicast that the gateway can be reached through them with cost one. On receiving the unicast packets with the cost to gateway information, the other motes accordingly update the cost of their neighbours as the received cost plus one. This continues till all the motes have updated their routing table with a finite value of cost to gateway. This method is known as *'backward learning'* and at this point the complete network is constructed which is ready to receive packets from the tiger mote and forward them to the gateway.

C. Network Maintenance Post Topology Formation

With the help of TTL, network maintenance is carried out. All the network motes share their routing table to each of their neighbours within the TTL - the specified interval. This helps to maintain the network topology.

D. Inclusion Of A New Network Node

If a new network node is added to the network, as per the configuration, it broadcast 10 packets. The motes nearest to the newly added mote on receiving the packets would add the new mote to their routing table with cost infinity. When the route table share routine starts, the neighbours of the new mote would send it unicast packets with the routing information. The new mote on receiving the unicast packets would update its routing table with the addresses of the senders and corresponding cost to gateway and thus the network is reconstructed including the new mote.

E. Network Re-establishment On Link-breakdowns

There can be a situation when a mote does not receive routing information from a neighbour within the TTL assigned to it. The probable reason for such incident can be due to exhausted battery of a mote which means that it is not a part of the network anymore and has to be taken out from the topology since if packets are sent to this mote by its neighbours they would not be delivered to the gateway. This would severely impact the functioning of the network. To avoid such a scenario, TTL is used. If a mote (including the gateway) does not receive the routing information from a neighbour within the assigned TTL, the particular neighbour address is removed from the routing table of the mote. So the network topology is updated with the exclusion of the dead mote and thereby restoring end-to-end functionality of the network again.

IV. Functionality Of Each Network Node

A. The Gateway Mote

The processes that run in the gateway mote is shown by the flowchart in Figure 2. The gateway mote is configured to react to the reception of broadcast and unicast packets. Broadcast packets are received during the initial construction of the network or, if post network formation, any new node is added in its vicinity (in terms of received threshold RSSI). On receiving a broadcast packet it adds the address of the sender to its neighbour table and informs that particular address that the gateway can be reached with zero cost if routed through it. Gateway mote can also receive broadcast packets from the animal motes directly if they are in the vicinity of the Gateway mote.

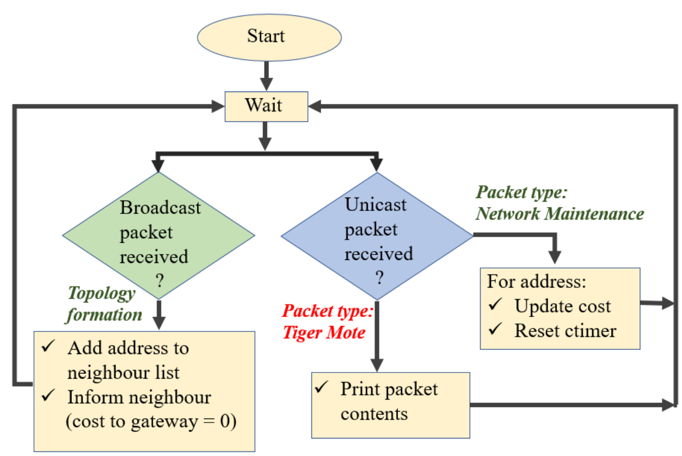

Fig. 2. Process Flow In Gateway Node

Unicast packets received can be of two types: route information packet or a tiger mote packet. If the packet is a route information packet then the gateway updates its routing table as a part of network maintenance process. If the packet is an animal mote packet that was forwarded through the network, then it prints the packet as its serial output.

B. *The Static Forwarding Motes*

Figure 3 depicts the processes that go on in a static node of the network. The static motes can send and receive both broadcast and unicast packets. During the initial neighbour discovery phase of the network, they broadcast 10 packets and on receiving broadcast packets from the motes in the vicinity, the address of the sender is added to the routing table with cost equal to infinity since the gateway has not been discovered yet. Post gateway discovery, on receiving unicast packets from the neighbours of the gateway the cost of the sender is updated to *'previous cost plus one'*.

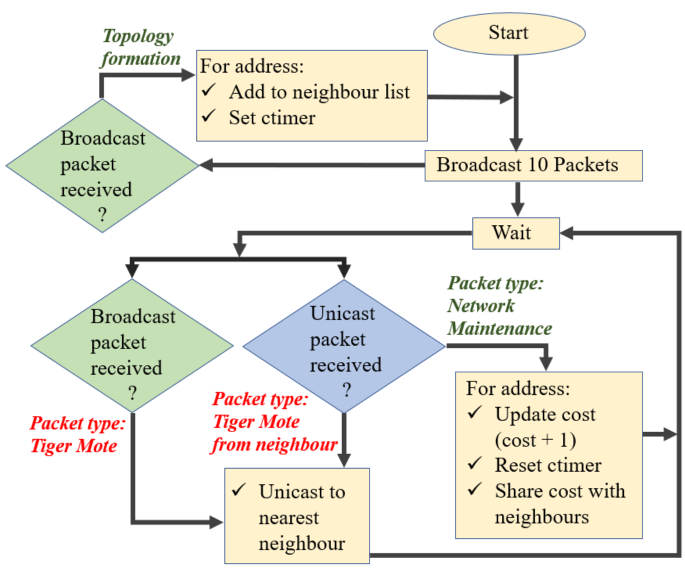

Fig. 3. Process Flow In Static Network Nodes

The motes are required to send routing table information using unicast packets to their neighbours at fixed time intervals as a part of network maintenance. On receiving such unicast packets the routing table of the receiver is checked if the address is already present. If the address is present then the table is updated with new costs, if any, and the timer for the sender is re-initialized. If the address of the sender is not found in the routing table, which probably might have been caused since the receiver did not send any packet within its specified TTL, the address of the sender is added again to the routing table with cost as *'received cost plus one.'*

The other type of broadcast packets that can be received by a network node are tiger mote packets. On receiving such packets the motes unicast the packets to the neighbour having minimum cost to the gateway. This process continues until the tiger mote packet reaches the gateway and the details are displayed in the GUI.

V. Tiger Motes and Sensors

A. *Configuration*

The motes attached to the tigers are configured to transmit broadcast packets continuously. The network motes that are nearest to the tiger motes collect the packets and forward them to the gateway.

B. *Sensors*

In this project three sensors have been used: *External Heart Beat Sensor*, *Internal Temperature and Battery Sensor*. Temperature and Heart Beat sensors are used to monitor the health conditions of the animals continuously while battery sensor indicates at what point the battery needs to be replaced so that the mote can function as required. Sensor data of the animal is transmitted in the broadcast packet that is sent by the animal motes. After the animal mote packet reaches the gateway, along with the routing path, the sensor data is also displayed on the GUI. Abnormalities in the health conditions, as deduced from the sensor data, can help the forest officials to act promptly and provide necessary medical support.

VI. Qt - Graphical User Interface

A. *Network Layout*

Qt Creator has been used to create the graphical user interface in this project where the user can monitor localization and the sensor data of the animals in a compact form. In the GUI, the network is shown approximately as the static nodes are laid out. This gives a rough idea of localization of the tigers. When the tiger mobile mote is out of the network range, an alarm is raised which is seen in the GUI. This helps the forest officials to launch search operations for the animals in and around the network node which received packets from the animal mote for the one last time.

B. *Dynamic Routing*

The GUI has been configured to dynamically show the routing path of the packet that is forwarded from the animal mote to the gateway through intermediate static motes. When the animal moves from one location to another, i.e.- it moves across the neighbourhood of each static mote, the routing path changes in real time thus tracking the tiger mobile mote all along its way in the forest.

C. *Sensor Data*

Along with the routing path of each mobile mote, sensor data values are also displayed on the GUI. Battery of the two tiger motes are shown in *percentage* along with their temperature in *Celsius* and heart beat in *Beats per minute (BPM)*.

VII. Conclusion

A *distance vector based distributed routing protocol* is implemented in this project. This can be further optimized by using the battery values to deploy an energy-efficient routing technique. This project provides an economic and simple solution to the problem of human-animal conflicts in areas adjacent to forests.

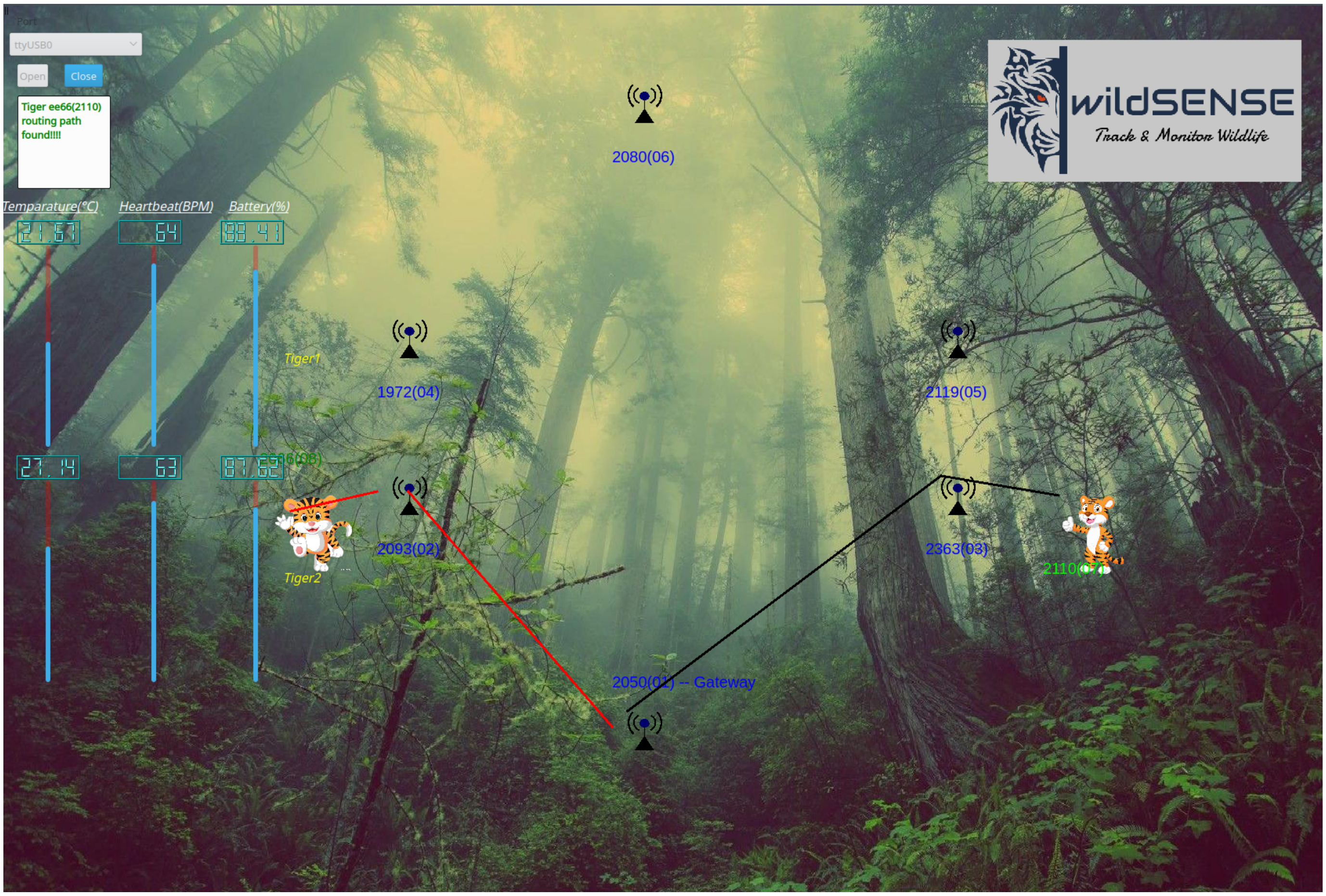

Fig. 4. wildSENSE GUI displaying network topology, routing path with sensor data

Acknowledgment

This project has been done as a part of Wireless Sensor Networks Laboratory offered by the chair of Lehrstuhl für Kommunikationsnetze. We are glad to get an opportunity to work on such a novel project where we have gained the hands-on experience of a real-time wireless sensor network. We would like to sincerely thank Mr. Samuele Zoppi, Mr. Onur Ayan, Ms. Hansini Vijayaraghavan, Mr. Jörg v. Mankowski and Mr. Besar Lami whose invaluable advice and guidance finally helped us realize the project. Finally, we express our deepest thanks and regards to Prof. Wolfgang Kellerer for offering this well-designed innovative laboratory course.

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