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HYBRID WIRELESS SENSORS NETWORKS FOR TRACKING ANIMALS

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Abstract

Wildlife protection has become more and more important preparation, because of the harmful effects of human behaviour on the environment. The great evolution of advanced wireless sensor networks has played a role in protecting wildlife. Recently wireless sensor networks are used to track animals in their habitat to follow the behaviour and lives of some endangered animals, but monitoring still difficult issues because may reason inside WSN: energy and deployment. Problems will appear another side the nature of wildlife: the size of animals will limit the technology that will use. When studying the types of networks the WSN will be the best solution to this case. In this paper WSN used to track the small type of birds calls "partridge" to protect birds and monitoring its behaviours. The proposed algorithm in this paper provide a new way to track and control a group of birds in their natural dwellings by using a hybrid wireless sensor network consist of set of predefined reference nodes, where sensitive information is sent to the base station through these beacon nodes, then resolve it and use it to the sacrificial location of the animals. This method is evaluated using Network Simulator (NS2). This method was inexpensive, easy, accurate, low energy consumption, and acceptance when compared with the modern method of wildlife tracking.

Keywords: GPS, Localization algorithms, Positioning algorithms, Wildlife tracking, WSNs.

1. Introduction

Wireless sensor networks have unique characteristics that make them suitable for many applications. Recently, it has been interesting growth in applications based on these networks. The small size and low cost of these sensors allow for large quantities to be deployed. Environments, especially those that are hard to reach [1]. The most important thing in these networks is the knowledge of nodes in the network after deployment. Positioning the sensor nodes in the network helps us in the routing process, in addition to optimizing the limited network resources [2]. The most important positioning applications in the wireless sensor networks are tracking target which is known to pursue a target (person - animal - machine) within the network coverage area.

One of the most important tracking applications in recent times is tracking the life of animals in their nature reserves and habitats, so how do animals live in their homes? Where is it going? These questions about the nature of animals' lives in their natural reserves have recently increased, but monitoring the activity of animals in the forests is a very difficult task, especially if the animals are very small, the harsh and dangerous nature of forests that prevent the human ability to connect and thus the use of wireless sensor networks in such a task is the most appropriate solution [3], some research has followed the traditional methods of animal control.

There are tracking systems based on GPS these devices are placed on the animal's body to be located. Some other methods have used a chip placed on the body of the animal chip RFID. This chip is marked when the animal passing in the range of the RFID reader [4]. A new way is provided to track and control a group of birds in their natural dwellings by using a hybrid wireless sensor network consist of set of predefined reference nodes, where sensitive information is sent to the base station through these beacon nodes, then resolve it and use it to the sacrificial location of the animals. This method is evaluated using Network Simulator (NS2).

2. Types of Positioning in Wireless Sensor Networks

When publishing the sensor nodes randomly from an aircraft. For example, this random deployment causes many problems, the most important of which are localization problems, which are the estimation of the coordinates of an unknown node in the network. The data provided by the sensors lose their importance if they are free of location information. This is also a misinterpretation of the data. Global Positioning System (GPS) may be a good option [5]. It provides acceptable accuracy. In some applications, however, the use of GPS receivers is inefficient both in terms of their high energy consumption and weight. , Because of the obstacles, landscapes, and dense forests, this system does not work in the internal environments. it requires a line of sight between the transmitter and receiver so it was necessary to use positioning algorithms. Most of the positioning algorithms share three basic stages:

A. Distance estimation

The relative distance between nodes is estimated using a combination of techniques.

B. Position calculation

The location of the node is evaluated here relative to the other known node of the site.

C. Localization algorithms

At this stage, the distance and location information are bound to determine.

a.1. Distance estimation techniques

Distance estimation techniques can be classified into two main categories:

a.1.1. Range-free technologies

The basic principle of its operation depends on the fact that two modes of communication have been able to be smaller than their limited maximum transmission distance R, whose accuracy depends on contract density. The number of reference nodes known on the site and the network architecture. This method is characterized by simplicity and low cost, Location accuracy is not critical [6].

a.1.2. Range based technologies

- **Time of Arrival (TOA):**

The transmission time, propagation speed, and latency (for signal) are used to calculate distance according to the following relationship: Distance = speed × time. Disadvantages: You need to synchronize the transmission and reception.

- **Received Signal Strength Indicator (RSSI):**

The power of the radio signal is inversely proportional to the distance, so using a radio propagation model; the signal strength can be converted to distance. Disadvantage: It suffers from a problem of accuracy due to the change in signal intensity due to changes in the surrounding environment.

- **Time Difference of Arrival (TDOA):**

This method uses two different signals in the transmission and reception. There are two different speeds in the transmission and reception, the difference between the arrival time and distance calculation is calculated.

- **Angle of Arrival (AOA):**

Depends on the matrix antennas to determine the angle of the reception signal. Both parties must be able to determine the angle of the reception signal. If the target knows its direction, then it is needed to contact it with two senses. When the target does not know the target, the target must be in contact with three sensors [7].

b. Position computation techniques

b.1. Pointing technology:

In this method, the site of the node is calculated through three known reference nodes location adjacent to its Trilateration, when used with three-dimensional space, four nodes Multi-late ratio are needed. The node location is determined by the intersection of three circles these centers are three nodes adjacent to the well-known location, the radius is the distance from these nodes to the desired node to locate. It is disadvantageous because the distance information may be wrong. So circles cannot intersect [8]. Figure 1 shows this technology.

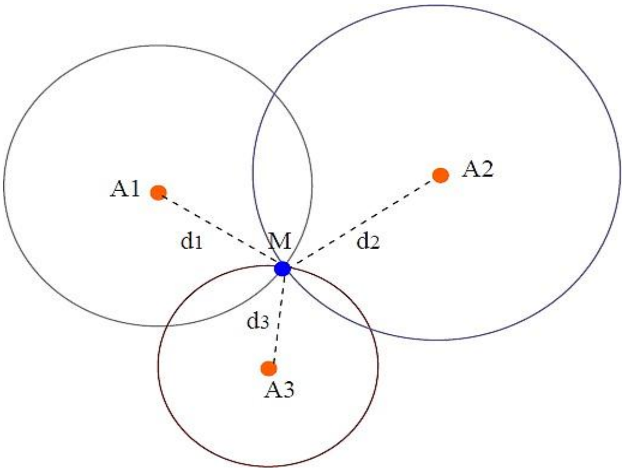


Fig. 1. Trilateration technology.

b.2. Triangulation:

Here, a minimum of three reference nodes is used. The node location is calculated through the angles for the complex. A reference that forms a triangle is based on triangulation as in Fig. 2.

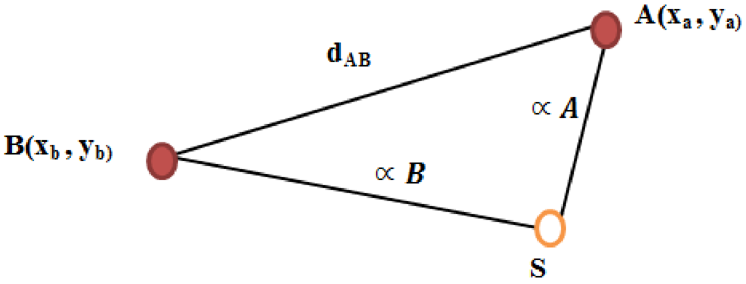


Fig. 2. Trilateration technology.

Pattern Matching Localization:

It is also called the **Fingerprint Algorithm** and includes two phases:

- **The first phase offline**:

Record the signal parameters coming from the nodes in a database called the radio map.

- **The second phase online**:

Sensors are used in which the map is calculated. The location of the node is estimated by comparing the captured signal specification with the pre-recorded values. In the map the technique is of atmospheric fluctuations because it has recorded the signal parameters in the first phase. So it needs to be re-implemented phase First again in the new atmosphere.

b.3. Localization algorithms

From these algorithms:

(i). Range-Free Anchor-Free Methods (MDS)

In this algorithm each node (sensitive) forms a protected map for the distribution of the nodes (sensors) located on two leaps of them depending on the main communication processes that take place between them. After that all the sensors in the network connection. To collect these local maps and eventually form the final shape of the general position for the network, this algorithm suffers from the difficulty of forming the final map, in addition to inaccuracy in the precise location of the sensors. They use the algorithms of DV (Distance, hop to form the distance matrix [9].

(ii). The Local Position Discovery Algorithm (LPD)

This algorithm aims to build a local scheme of places to place the sensors (local map) within each cluster from the gate node in each cluster

(iii). Positioning Algorithm with Bacon Mobile Localization (LMB):

Localization with mobile beacon all nodes in the network are determined by a single moving node, equipped with a GPS receiver that broadcasts messages in the network containing their coordinates. When the anonymous node receives three messages from the moving node [10].

3. Animal Tracking Systems:

One of the most important positioning applications used is the applications of tracking animals in their natural habitat. The information that is needed to is the location of these animals, the location of the animal over time. This process is called radio-tracking. There is also animal physiological information, (Temperature, heart rate, activity information, ambient temperature, weather humidity). This process of obtaining this physiological information is called telemetry. Animal tracking systems have varied and varied. Since the 1960s and until today, it has been difficult to trace a biological object in a large area, so the device is integrated into the body of the animal, but there are still restrictions. The rules to connect devices on the body of the animal, in general, must not exceed the weight of the device 5% of the weight of the animal to avoid adverse effects on its behaviours, the weight of the animal to be monitored if a major role in determining the technology to be used in the devices deployed on animals, the relationship between the weight of the device and age because of the weight that contributes to the battery of the device [11].

4. Related works

There are many studies on animal tracking. This process started by Cochran and Lord [12] where the very high-frequency system was used where radio signals are sent by an animal transmitter, but this method is limited in coverage. The future of the data must be within the range [13]. The ARGOS satellites are used to monitor types of birds. This system features universal coverage but suffers from high cost and low accuracy compared with other systems, in addition to the restriction on transmitters they operate on the same frequency (to avoid interference).

In many types of research, GPS has been used to place receptors on the animal's body that receive signals from the satellite. This system provides global coverage but, like its predecessor, is expensive and a large consumer of energy [14]. RFID cards have their identification number placed on the animal's body and its identification number is sent to the neighbourhood. This method is the most cost-effective but very limited. This requires a large number of RFID readers.

It is useful only to show if the animal is in the area or not exists, in other research, cameras have been used to be placed on roads of animal in strategic places and take pictures but if this is the way fit only animals that crown specific paths (tigers and lions) [15].

It is noted that all the above methods provide only animal location information. It provides no further information about the state of health. Therefore, the use of wireless sensor networks for such a task was noted [16]. The Automated Radio Telemetry System (ARTS) was used in a tropical forest on BarroCarolado, using towers deployed in the forest, reception units connected to antennas receiving signals from sensors located on animals are located.

The location of the animal is determined if it falls within the range of three or more towers. This system was used to monitor more than 38 types of animals. It is reached the limits to 50 meters, but if compared to the GPS, it has reduced the cost by about ten times.The application of sensor networks Zebranet used by Hongyim [17], the sensors were placed on animals, each of which is limited to the GPS receiver to provide location information is collected from animals by a mobile sink, but this method is expensive.

If each animal is provided with a GPS device to locate it, another project is to monitor a group of birds, Great Duck Island GDI, where static sensors are deployed in the nests to monitor them. Via a transit gate with a satellite control station [18], the results show that energy consumption increases with the number of hops. This system is suitable for monitoring static sensors in limited geographical areas.

A system that depends on Bluetooth Low Energy (BLE) to tracking social behavior of chimpanzee; specifically, the dyadic levels rather than measuring absolute locations [19]. Another system that uses the receiving signal strength and depends on the technique of matching patterns in guessing the location of the animal [20]. The energy in the science of the formation of the radio map is strongly influenced by the factors of the atmosphere. Because the measurements of the strength of the signal in the first phase of the risk to return this phase in the new atmosphere but gave an error acceptable positioning ranges from 1.2 to 3.5 meters, comparing between the two systems rely on the signal strength of the receiver, the first depends on the strength of the reference signal [20].

The second depends on the strength of the signal-dependent on the weight. Note that the positioning error decreased from 1.7-10 m in I to 2-6 in the second, but overall all previous methods that used signal strength measurements suffer from the low accuracy because of their vulnerability to atmospheric factors, obstacles, and terrain, especially in an internal environment such as forests. Table (1) summarizes the different technologies available for wildlife tracking.

Table 1. Different technologies available for wildlife tracking.

Technology	Range	advantage	disadvantage
ARGOS satellite system	850 km	Signal is available wide on the globe, ability to study rare rapid migration movements that were frequently missed with VHF studies and increased mechanistic insights into climate movement /habitat.	Lack of information about behaviour, High cost and low accuracy comparing to other systems and The limitation on transmitters because they operate on the same frequency (to prevent interference)
GPS	Dependent on service provider maybe 20,000 above earth	Signal is available anywhere on the globe, There is no charge to utilize the GPS service, The GPS system gets calibrated by its own and hence it is easy to be used by anyone and it provides user with location based information.	GPS chip drains battery in 8 to 12 hours. This requires either battery replacement or recharge, GPS signal does not pierce through the solid walls, under water or in dense tree regions or in underground, GPS accuracy depends on sufficient received signal quality. This leads to error of about 5 to 10 and it is in the hand of US to allow or deny the GPS service at any time.
RFID	1.5-3 m	High speed, Multipurpose and many format, High accuracy, Multiple reading, Can handle exposure to sun & rain and Complex duplication	Interference, High cost, Some materials may create signal problem , Implementation can be difficult & time consuming and Overhead reading (fail to read)
Wireless sensor network	Depended of the type of WSN Technology that used	Network setups can be done without fixed infrastructure, Flexible if there is ad hoc situation when additional workstation is required, Ideal for the non-reachable places such as across the sea, mountains, rural areas or deep forests and Implementation cost is cheap.	Lower speed compared to a wired network, The low accuracy of these measurements due to their susceptibility to weather, obstacles, and topography, especially in an indoor environment such as forests

5. Proposed Algorithm for Tracking Animal

In this study, a group of partridge birds in a nature reserve was tracked by using (NS2) simulator and divide the trace area into a subset area and perform the simulation on one sub-region. This scenario is repeated when needed according to the area of the protected area. Figure 3 shows a model of the total area of the design and division of regions Sub-branch and how the nodes are distributed:

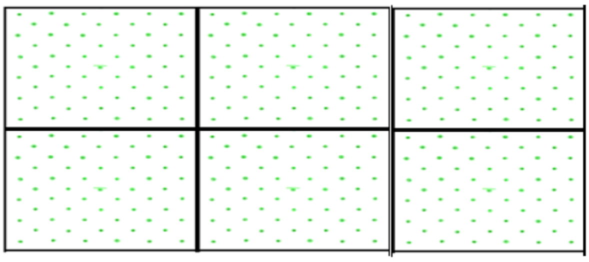


Fig. 3. Division of the trace area.

First step beacon nodes begin by sending periodic packets in the network to link with the mobile sensors within the range of transmission, any animal within the node transmission area will receive this packet and prepare to send its data. In this research, more than one case is considered.

- **First case 1**:

  Only one beacon node can be found around the animal, therefore; receive a signal from that node and send a packet to the central coordinator containing its address, health information through beacon node known as the location, using the DAAM addressing system The node's address can be identified by the central coordinator through the associated mobile sensor address. The network coordinator initially determines the maximum number of Cm children for any node that can possess, the maximum number of routers Rm (beacon node). The rest stations will be terminals ZEDs(animals), also performs determining the maximum depth of the network through the Lm parameter By default, the coordinator has a depth index equal to zero, while his first children have a depth index equal to / 1 /. Each node has a depth indicator equal to the number of jumps the packet must follow to reach the end of the central collector Each router in the network parameters R_m, Lm, Cm for the C_{skip} function which determines the size of the sub-headings can be assigned. If the depth of the router D, the child can calculate by the following relationship:

$$C_{skip}\ (d) = \begin{pmatrix} 1 + Cm * (Lm - d - 1 \quad if\ Rm = 1 \\ \frac{1+Cm-Rm^{lm-d-1}}{1-Rm}\ if\ Rm <> 1 \end{pmatrix} \ldots\ldots\ldots\ldots \quad \ldots(1)$$

Suppose the parent router (beacon node) is in depth *D* and has the title a parent, and the address of the son handler (a child) which you rank *n* as follows:

$$A_{child} = A_{parent} + (n-1) * C_{skip}(d) + 1 \quad \ldots\ldots\ldots\ldots \quad \ldots\ldots(2)$$

$$A_{child} = A_{parent} + (n-1) * C_{skip}(d) \quad \ldots\ldots\ldots\ldots \quad \ldots\ldots(3)$$

$$when\ n = 1$$

where *n* represents the order of the child node.

The following steps are the summarization of the case (1) :

Step 1: the Beacon nodes send configuration packet to the mobile sensor nodes in range of beacon to connect.
The first case: if there is one Beacon node around the birds: the **Mobile node (animal)** do the following

1. Update the Time table (no. of neighbor nodes).
2. update Packet header (add the neighbor nodes address to the packet)
3. if T=KT then go to step 2 else go to step 1

Step 2: Received packet from mobile sensor.
Step 3: send the packet to the PAN Coordinator
Step 4: the PAN Coordinator determine (C_m ,R_m ,L_m).
Step 5: Received packet from Beacon node.
Step 6: Extract the sender address, depth, and order then compute parent address by using equations 1, 2 and 3.
Step 7: Locate the child node by using parent node.
Step 8: send information to the base station.

Figure A-1. (*Appendix A*) shows the flowchart of the algorithm.

• Second Case 2:

The animal can be located at a given moment within the transmission area for more than a beacon node, assuming that the coordinates of the beacon nodes adjacent to the animal receiving a signal are as follows:

$$idB1(x_1,y_1).\,idB2(x_2,y_2).\,idB3(x_3,y_3)\ldots\ldots\ldots\,idBn(x_n,y_n))\ldots\ldots\ \ldots\ldots\ldots(4)$$

Thus, the animal will receive a signal from this node and prepare a package containing the title and addresses of the beacon node, which received a sign signal, and then directs this packet to one of the neighbouring beacons to if it is sent to the central complex. The central coordinator calculates the approximate location of the animal by loading the packets received from the mobile sensor and using the known locations of the beacon contact addresses listed in the package. If the real animal location is the id (*x*, *y*), the approximate location of the animal (id) (*x*', *y*') can be detrmined, where *x*' is the average of the total coordinates of the beacon contract on the horizontal axis *y*' is the average of the total coordinates of the beacon contract on the vertical axis as follows:

$$x' = \frac{x_1+x_2+x_3+\cdots x_n}{n}\ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(5)$$

$$y' = \frac{y_1+y_2+y_3+\cdots y_n}{n}\ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(6)$$

where n represents the total number of beacon nodes

The following steps are the summarization of Case 2:

Step 1: the Beacon nodes send configuration packet to the mobile sensor nodes in range of beacon to connect.

If there is one Beacon node around the birds: the **Mobile node (animal)** do the following

i. Update the Time table (no. of neighbour nodes).
ii. update Packet header (add the neighbour nodes address to the packet)
iii. if T=KT then go to step 2 else go to step 1

Step 2: Received packet from mobile sensor .
Step 3: Send the packet to the PAN Coordinator
Step 4: The PAN Coordinator Determine (C_m ,R_m ,L_m).
Step 5: Received packet from Beacon node.
Step 6: Extract mobile and beacon nodes address by using equation 4
Step 7: Extract beacon nodes address included in the packet.
Step 8: Calculate location of the nodes (animal) by using equation 5 and 6.
Step 9: Send information to the base station.

Figure A-2. (*Appendix A*) shows the flowchart of the algorithm.

6.Simulation Scenario:

In this study, a network of 60 fixed beacon nodes, 6 sensors (animals) moving within the region (120×120 m^2), one PAN coordinator in the middle of an area with random movement, is simulated. The movement model was chosen so that the sensors moved rapidly (0.5 m/s) The AODV (Ad Hoc On-Demand Distance Vector Guidance Protocol) is selected because it is the most widely used in these networks it is suitable for this size of networks. Table 2 shows the simulation parameters adopted. The interest here is to locate it in the case of walking, which is a suitable speed. The work area (120×120 m^2) was considered as a template *M* replicated to the rest of the protected areas according to their area.

Table 2. Configuration of the network parameters.

Parameter	Value
Size of the environment	120×120
No. mobile nodes	6
No. fixed nodes	60
animal speed	0.5 m/s
Packet size	100 byte
Packet type	CBR
MAC protocol	IEEE.802.15.4
Transmit range	20 m
Routing protocol	AODV
Visual tool	NAM

The following scenario has been adopted to evaluate algorithm performance:

A network consists of 60 nodes and 6 mobile sensors (1, 2, 3, 4, 5, 6). Table (3) shows the path of each of the coordinates (x1, y1). To coordinates (x2, y2)

Table 3. The path of coordinates (x1, y1) and coordinates (x2, y2).

No. of sensor	x1	y1	x2	y2
1	6	18	110	118
2	77	6	118	47
3	7	68	118	68
4	111	115	1	118
5	118	7	60	118
6	60	118	1	1

When performed the simulation and then calculated the location of the estimator according to the proposed algorithm for each sensor for several random packets received from the animal at certain moments.

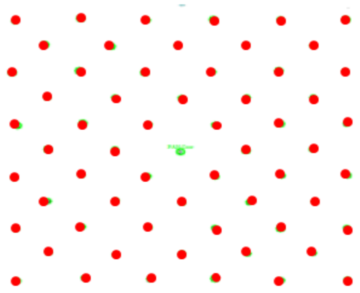
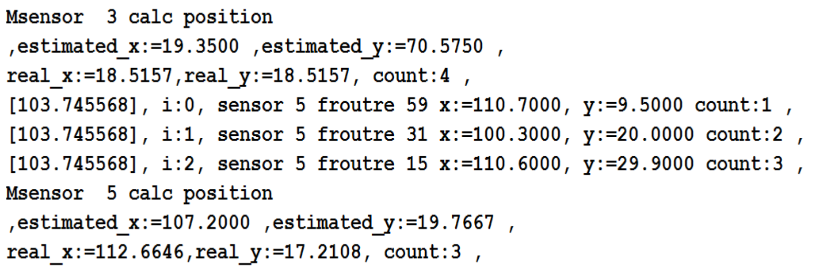


Fig. 6. Network scenario.

7. Results and Discussion

The position calculation is a result for the moving sensor (5) when a packet is received to the central coordinator is shown Fig (7) method of calculating the position according to the proposed algorithm:

Positioning error rate of sensor1 show in Fig (8) the positioning error for each packet received from the moving sensor1.



```
Msensor  3 calc position
,estimated_x:=19.3500 ,estimated_y:=70.5750 ,
real_x:=18.5157,real_y:=18.5157, count:4 ,
[103.745568], i:0, sensor 5 froutre 59 x:=110.7000, y:=9.5000 count:1 ,
[103.745568], i:1, sensor 5 froutre 31 x:=100.3000, y:=20.0000 count:2 ,
[103.745568], i:2, sensor 5 froutre 15 x:=110.6000, y:=29.9000 count:3 ,
Msensor  5 calc position
,estimated_x:=107.2000 ,estimated_y:=19.7667 ,
real_x:=112.6646,real_y:=17.2108, count:3 ,
```

Fig. 7. Screen shot to the calculation error in NS2.

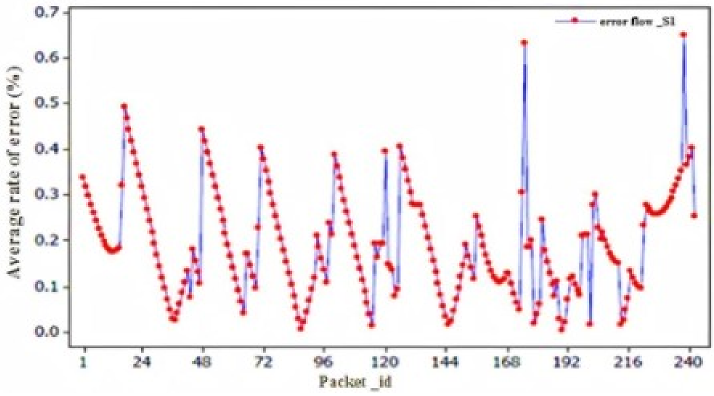


Fig. 8. Positioning error for Sensor1.

Through the implementation of the proposed algorithm, when calculated the location of the mobile sensor for several received packets from sensor1 it is looks as shown in Fig (8).The positioning error is calculated for each point in Figs (8), then calculate the mean error for the site is (0.192621) which is a percentage of the transmitting field was 20 m. It is a good accuracy. Note: the positioning error is calculated as a percentage of the transmission field with the following relationship:

$$Erorr = \frac{(x'-x)^2 + (y'-y)^2}{R} \tag{7}$$

So the positioning error for each sensor will be:

Localization error (m) for sensor1 = 0.192621 * 20 = 3.85242 ~ 4 m
Localization error (m) for sensor2 = 0.471007 * 20 = 9.422014 ~ 9 m
Localization error (m) for sensor3 = 0. 285908 * 20 = 5.7816 ~ 6 m
Localization error (m) for sensor4 = 0. 502741 * 20 = 10.05482 ~ 10m
Localization error (m) for sensor5 = 0. 260654 * 20 = 5.21308 ~ 5 m
Localization error (m) for sensor6 = 0. 229193* 20 = 4.58386 ~ 5 m

Then the mean error for all sensors will be:

Localization error (m) for all sensors = (0.192621+0.471007+0.285908+0.502741+0.260654+0.229193)/6=0.323709.

Overall average rate as a percentage of the transmission field: is

Localization error (m) = 0.323709 * 20 = 6.4~7 m

The figures from (9) to (13) show the rest error of sensors and the table (3) shows the summarization of average positioning error of all sensors.

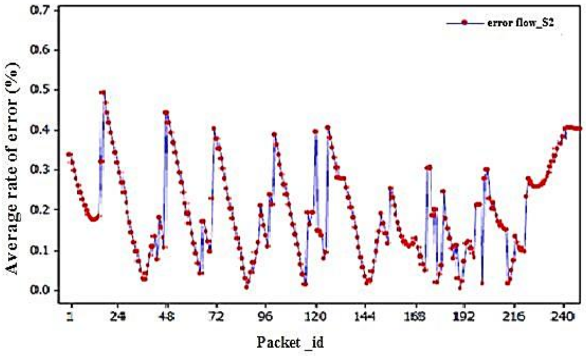


Fig. 9. Positioning error for Sensor2.

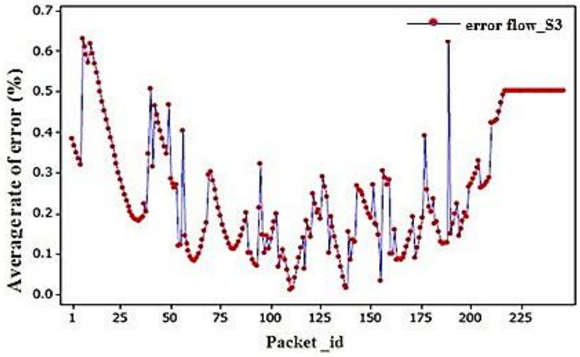


Fig. 10. Positioning error for Sensor3.

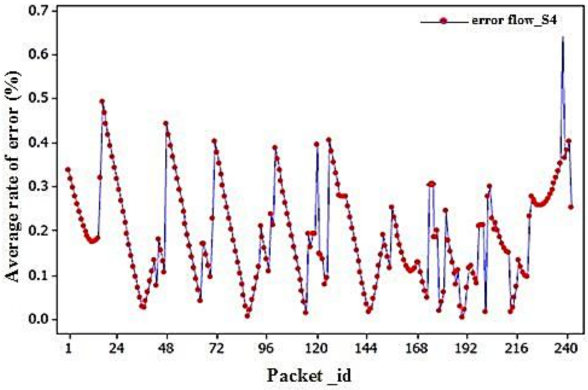


Fig. 11. Positioning error for Sensor4.

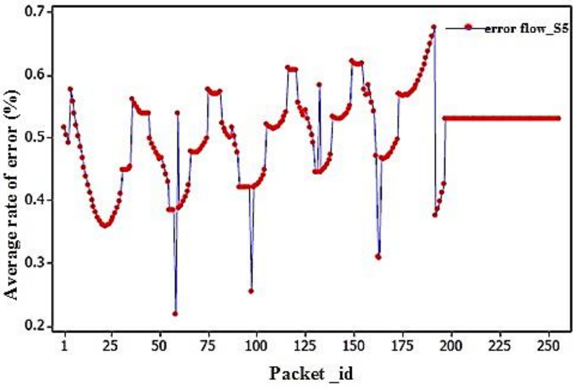


Fig. 12. Positioning error for Sensor5.

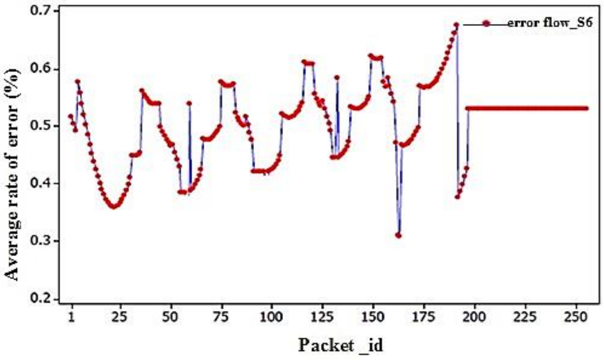


Fig. 13. Positioning error for Sensor6.

Table 3. Summarization of average positioning error of all sensors.

Sensor	Average of error
1	0.192521
2	0.471007
3	0.285908

4	0.502741
5	0.260654
6	0.229193

8. Conclusion and future works:

The proposed algorithm provided an easy and simple way to calculate the position since it only needs to list the nodes of the beacon nodes adjacent to the moving sensor. If there is more than one node, it is sufficient for the central assembler to obtain these addresses simply and quickly to calculate the location of the sensor. A good accuracy with an error of 7 meters is achieved. It is observed from the results that the accuracy increases when the moving sensor approaches the intermediate point between the beacon contract the abnormal values arise when the sensor loses one of the lighthouse nodes that contributed to improving its accuracy (yet the accuracy obtained is worse). Cases for track T. mobile sensors were acceptable (while the fixed values of the error arise when it stops sensitive).

This method also provided us with the ability to locate. Without any additional energy expenditure if compared to other research because no additional positioning packages used or sent (It was relied only on data packets delineated by default), therefore; no additional power outages in the location. The first two studies Zebranet, GDI, where a lot of energy exchange because of the use of GPS devices as well as reference studies that rely on the strength of the signal RSSI requires the measurement of signal strength values from a large number of reference points in the region to form RSSI maps. Thus, also spend a lot of energy adopted in the current research to control the effective period in the sensitive life cycle, Duty cycle so that the period of rest of the delicate work of equal period BO = 6, SO = 6 can be by increasing the value of the BO reduction of this period and saving energy.

In this proposed method, it was able to locate in a very low-cost way compared to other research that used GPS devices such as Zebranet and GDI. Besides, the weight of the sensitive node that can be added by the GPS device was reduced, which may hinder the movement of animals, small size. As future work, it is proposed to increase the number of beacon nodes and topical planning so that they give greater accuracy.

Abbreviations

AOA	Angle of Arrival
GPS	Global Positioning System
LMB	Positioning Algorithm with Bacon Mobile Localization
LPD	The Local Position Discovery Algorithm
MDS	Range-Free Anchor-Free Methods
RSSI	Received Signal Strength Indicator
TDOA	Time Difference of Arrival
TOA	Time of Arrival

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Appendix A

Figures of Design Charts

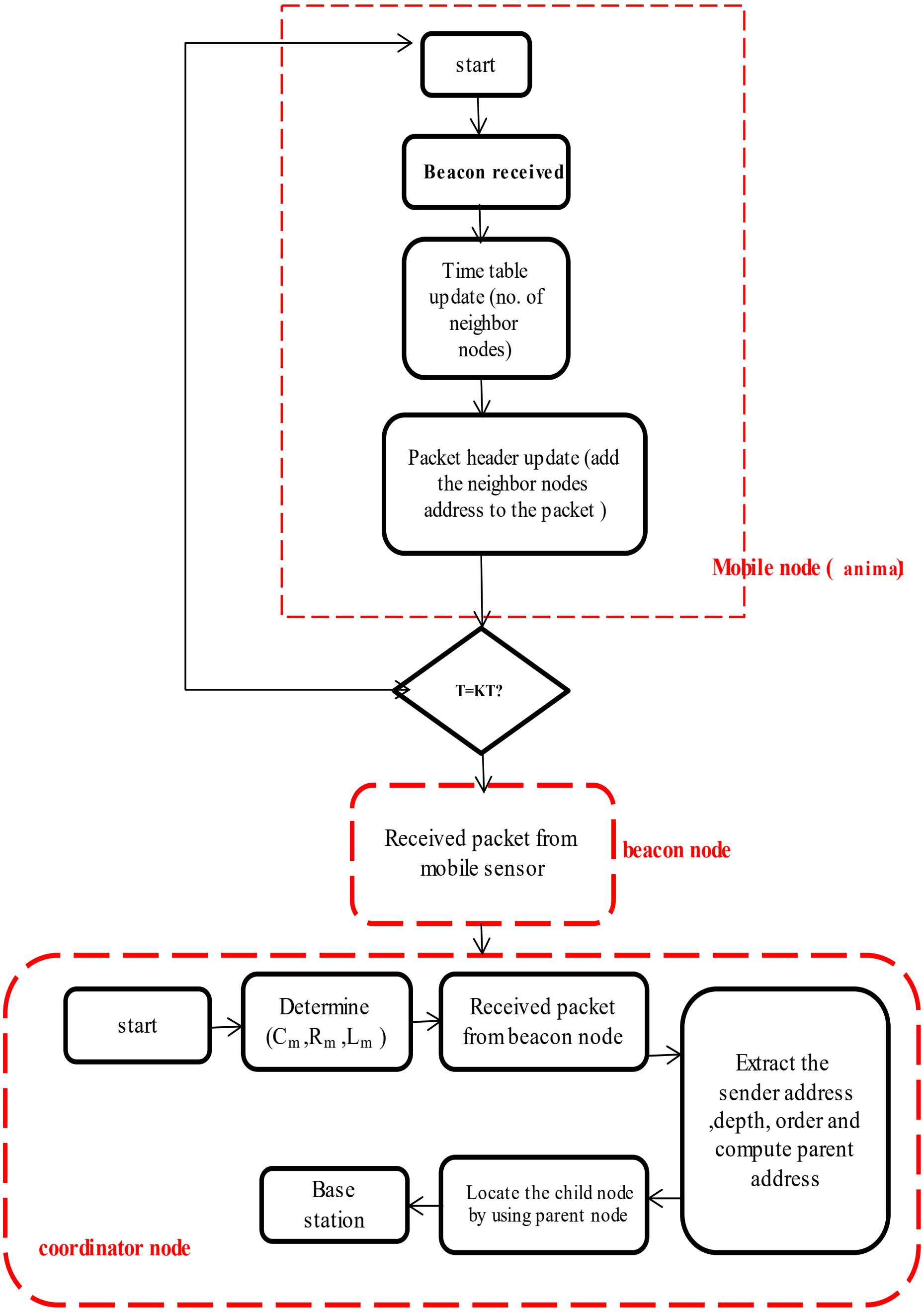

Fig. A-1. Scheme of the algorithm (Case1).

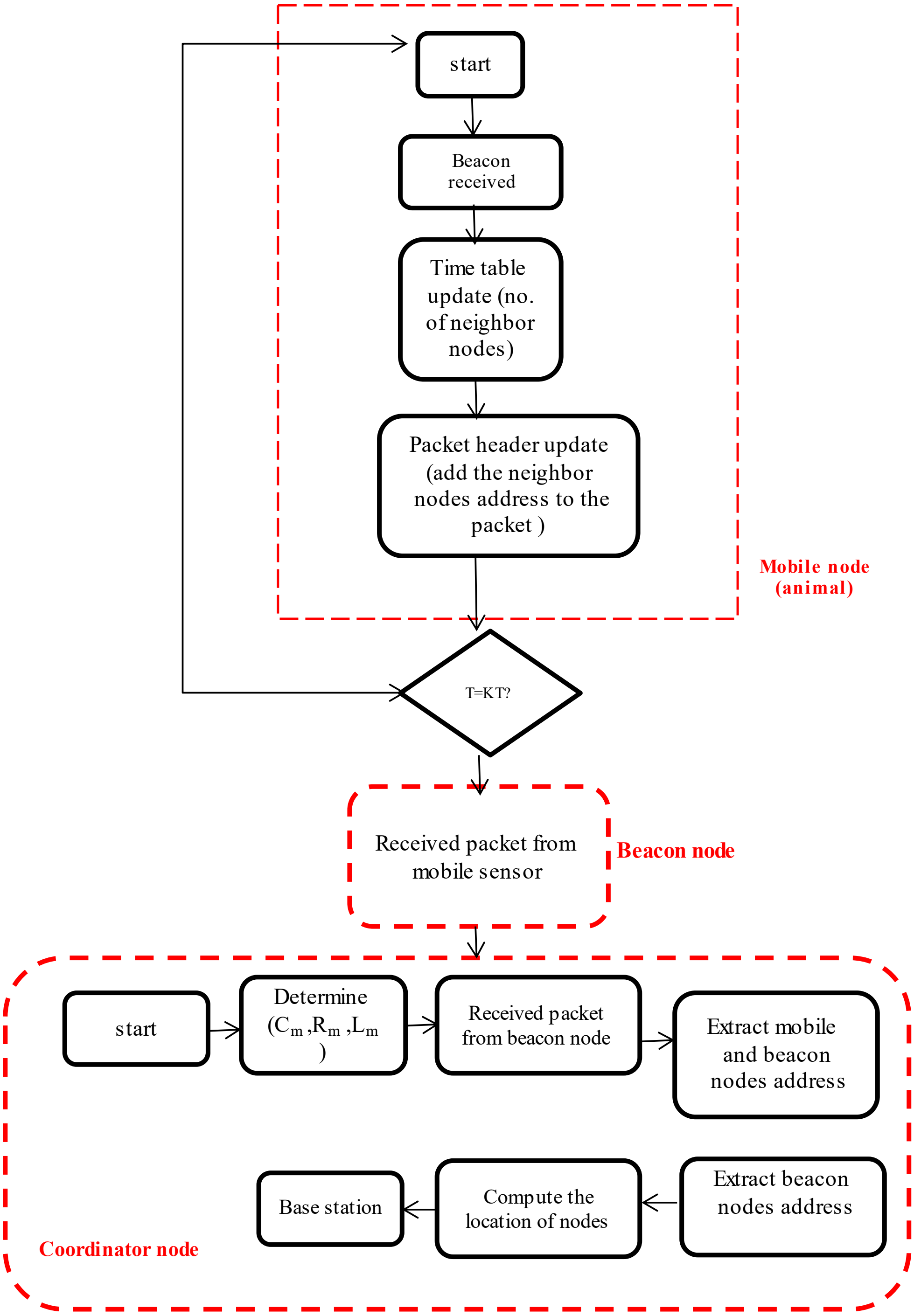

Fig. A-2. Scheme of the algorithm (Case2).