Localization and Classification of Species in a Habitat in WSN: A Species Perspective

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ABSTRACT
In past few years Wireless Sensor Networks have got large engrossment from the researchers as well as the scientific society. With their extensive application in almost every field, the hunt for measures to take advantage of the sensors in the most beneficiary way has begun. In this review paper we shall discuss about the relevance of wireless sensor networks in the area of localisation. A wide variety of sensors have been deployed in the spectrum of wireless sensor networks to scale various types of habitats in the challenging scenarios. The rush to look out for cost-efficient, energy-efficient and accurate sensors and sensor algorithms is keeping the researchers on their toes. In this paper we shall go through a brief study of the various existing algorithms and hence draw a comparison analysis amongst them based on the parameters which hold importance to researchers.

Keywords
Wireless; sensor; networks; localization; habitat; monitoring; algorithms; RSSI; TDOA; AOA; TOA; GPS; VGN; MSPA; NIRAA

1. INTRODUCTION
Recent advances in wireless communication, digital electronics and analogue devices have enabled sensor nodes that are low cost, low power and communicate untethered in short distances and collaborate as a group [1]. A wireless sensor network (WSN) comprises of spatially distributed autonomous sensors which invigilate physical or environmental conditions such as temperature, sound, pressure etc. and then collectively collect , manipulate and send their data through the network to the destination. Aggrandizing heavy and power-hungry data collection impedimenta with lighter and smaller wireless sensor network nodes leads to faster and larger deployments. Arrays constituting of dozens of wireless sensor nodes are now possible, allowing scientific studies that aren't achievable with trivial instrumentation [2]. The WSN is made up of nodes which may number up to hundreds or thousands. These nodes are connected to sensors which typically have components such as: radio transceiver, a micro controller and a battery as shown in Figure 1.

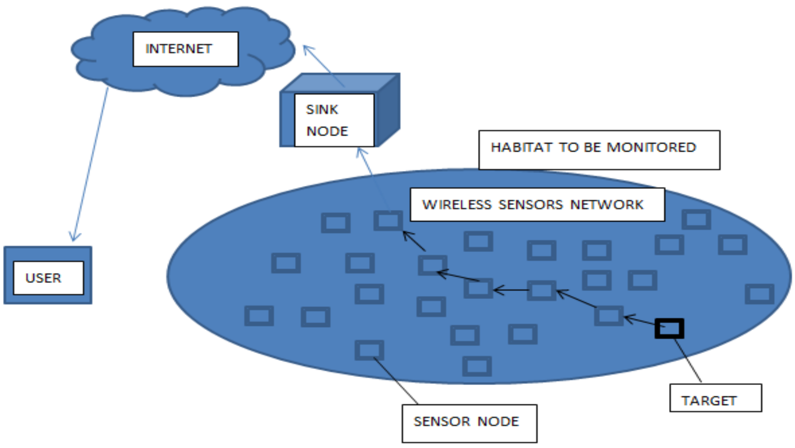

Figure 1. Wireless Sensor Networks basic architecture

Wireless Sensor Networks can be used to sense the environment and for initial stages of processing hierarchy normally referred to as in-site processing [3]. Wireless Sensor Networks have aample range of applications attributing to their ability to adapt in different environments. They can be used to fetch data from the areas where otherwise it would have been very difficult if not impossible for humans to get the data and process it.

One of the most prevalent applications of wireless sensor networks is localization. Localization refers to detecting a target in the vicinity of the wireless sensors. It is one of the most important subjects because the location information is typically useful for coverage, routing, location service, target tracking, and rescue. It becomes indispensable when there is an uncertainty in the exact location of some fixed or mobile devices. In this review by localization we shall mean to monitor a habitat and try and identify the different species in that particular habitat. This is of great significance to the scientific society and the society as a whole. The reason behind the same being it enables us to know about the counter species we share our planet with. The usage of wireless sensor networks has eased this task further because it has enabled to get an access to the areas which otherwise were not possible for the mankind to scale manually. Localization is still a latest and impressive field, with new algorithms, hardware, and applications being developed at a febrile pace; it is hard to say what techniques and hardware will be prevalent in the end [4]. A variety of different algorithms are available which can be used to monitor all types of natural environments. But still no algorithm is a clear favourite across the spectrum. The reason for the same being the certain parameters and trade-offs associated with all the algorithms. Every algorithm comes with its own pros and cons. While some algorithms guarantee high accuracy others guarantee high energy efficiency with a little compromise on the former parameter. Whereas there are some algorithms which attract the researchers on account of their easiness to apply and implement or may be with their easiness to scale over time. Still there are some algorithms which provide us robustness and fault tolerance which again is of utmost importance as repeated deployment and implementation of algorithms due to failures can be both challenging and financially exhausting. Hence to find an appropriate algorithm while settling with beneficiary and intelligent trade-offs is the need of the hour in the technology of wireless sensor networks.

Some other applications of wireless sensor networks apart from Habitat and ecosystem monitoring are Civil structural health monitoring- the nodes deployed in the structures are used to check periodically the health, tension, stress and various other characteristics to determine and make sure that the building is safe and secure for the presiders , Seismic monitoring- the deployed nodes measure the seismic parameters after the calamities , Logistics and telematics- they find an application in tracking, Precision Agriculture- the deployment of the nodes tells us precisely in which part of the land the fertilisers are actually needed thus helping us to cut on the fertiliser costs, Industrial process monitoring- wireless sensor nodes can be used for various industrial process monitoring right from the evaluation of the raw material to the production to the delivery process, Machines efficiency and fault monitoring- deployment of nodes helps to ensure that various parts of the machines are working efficiently and in case of any fault they help us to find out the area of defect, Perimeter security and surveillance- nodes can be deployed for the surveillance of buildings, army etc. to detect any intruders or accidents etc. and their integration with their devices can help us to raise alarms, Automated building- the fanning out of sensor nodes in buildings can be used to automate the buildings in terms of temperature control, turning off the lights, shutting of doors and windows etc. Apart from these wireless sensor nodes are extremely being used in all the smart objects. Their miniaturized sizes allow them to be deployed almost everywhere.

2. LITERATURE SURVEY

Being the trending topic of research amongst the masses, clearly there exists a large amount of literature on the wireless sensor networks. A short review about the various algorithms discussed in this literature is given hence forth. Generally in such monitoring applications the network scans the physical environment and tries to detect any changes in it for the purpose of target tracking. For this purpose the information about the location of both the phenomenon and the sensing nodes [5]. We have a large number of algorithms for the same.

These algorithms can be differentiated into two categories: Range based algorithms, where the point-to-point distance or angle information is required and on the other hand the Range free algorithms, where no distance or angle measurement between nodes is required. A simple flowchart depicting the categorization of various algorithms is shown in Figure 2.

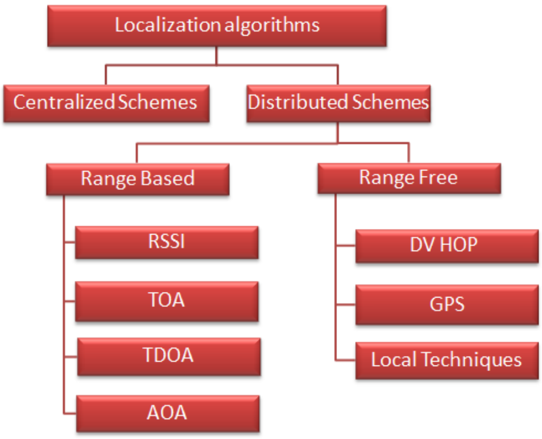

Figure 2. Flowchart to depict the categorization of various algorithms

The research paper [5] depicts how Received Signal Strength Indicator can be used for localization. RSSI can be used to evaluate the distance between two nodes on the basis of the strength of the signal received in comparison with the strength of the signal sent. More is the distance the signal has to travel, more is the energy dissipated a\hence lesser is the received strength of the signal. Mathematically this received strength of the signal is inversely proportional to the square of the distance travelled. But the drawback of this method is that in the real time scenario, the strength of the received signal is effected not just by the distances it has travelled but also by other factors such as the noise in the channel, obstacles etc. This leads to inaccuracies in the result unless these factors are also included in the mathematical modelling. Further the experiments carried out in the research paper [6] conclude that RSSI is not very efficient in estimating distances especially when the wireless sensor nodes are deployed inside a building. The reasons behind the same being extensive scattering along with the hindrances mentioned above.

With the advancement in technology the demand and expectation of efficiency and accuracy from the algorithms implemented in wireless sensor networks is pretty obvious. This has led to the advent of many more algorithms each struggling to fit into the spectrum completely.

[7] suggests that we can identify the location of the source on the basis of the Time of Arrival(TOA), Time Difference of Arrival(TDOA) or by using the combination of the both. There are typically to ways to calculate TDOA. One of them being we calculate the difference between the arrival times (TOA) of two signals at the same node. The other one is the cross-correlation technique, in which the signal received at one node is related mutually with the signal received at another node. Regarding Angle of Arrival (AOA) [8] suggests that this is not really a favourite among the wireless sensor users due to the requirement of large sized directional antennas associated with this technique. As a result there is the need of further investigation in context of the system configurations so that they can be incorporated in the light weight wireless devices. Further [9] explains how the ad hoc nature and the lack of a proper infrastructure in the wireless sensor networks lead to the rise in the positioning problem. This problem comprises of the calculation of the position of the non-anchor nodes which is complicated by the fact that sometimes all nodes are treated equal.

Also [10] mentions an issue related with TDOA which involves calculations related to the intersection of the hyperbolae as there are

$$\binom{K}{2} = \binom{\binom{n}{2}}{2}$$

pairs of hyperbolic functions. The position to be found out is the weighted average of these points. It is further complicated by the fact that each pair may have zero, one or more than one intersections which results in difficulty in finding the correct one.

[11] tells us about Neighbour Informed Rate Adaptation Algorithm a mechanism which is a totally distributed algorithm and uses message exchange between neighbours in order to eliminate the need for exact location information of the event and the nodes along with monitoring the moving objects also ensures that the energy usage is done in as efficient way as possible. It basically focuses on exploiting the different modes of the sensor nodes such as sleep and awake during the course of monitoring a moving object. It assigns relative importance values to each node in the system by following a message exchange mechanism. [11] However the probability of detection by the node is considerably affected by the velocity of the object. Reason behind the same being that in this case the object will traverse the area to be sensed very quickly.

[12] comes with another technique of pattern matching which follows on the lines of decentralization. This algorithm namely the Graph Neuron Algorithm is based on the concept of distributed cooperative problem solving [12]. This is a very light weighted algorithm which does in-pattern recognition by developing a graph like structure which interconnects the sensor nodes. This graph is called the GN array. This algorithm provides a very efficient way for depicting the spatio-temporal information in form of a pattern. It also enables parallelism through a virtual structure in the sensor network. Execution of the Graph Neuron algorithm within a small-world network [13] solves the problem of searching for a matching pattern in a large pattern domain.

Even though Graph Neuron Algorithm promises us good accuracy and scaling properties yet there are pretty much chances of its accuracy being getting hindered due to the incorrect input patterns. In such a case there may be interference in the patterns which may ultimately lead to incorrect results.[14] Further the Graph Neuron algorithm pays considerations only to neighbourhood communications, hence there is no obvious way to attain a global decision.

To overcome the flaws of GN the Voting Graph Neuron Algorithm [15] or VGN approach is proposed. The VGN approach recognizes events by adopting a novel energy-efficient template-matching approach. In essence, the VGN approach uses graph neuron (GN) concepts. The VGN approach is deals with how to intuit exhaustive global information from the local information of sensor nodes. Patterns are matched by means of votes, in contrast with the GN algorithm, which uses a simple binary decision. Additionally, techniques such as node collaboration along with distributed in-network processing as well as distributed storage, and life-cycle management are employed to enable rational, pragmatic and energy-efficient pattern-recognition using resource-constrained sensor nodes.

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Another technique is given in [16] is GPS based localization. Most of GPS-based localizations inhere to absolute localization. These systems help the nodes to localise their position in the global coordinates by using comparatively lesser number of beacon nodes. Even though GPS based localization techniques help us to pan an area of few squared metres and determine the locations of the noes lying within this area, but still the cost associated with the GPS devices combined with the phenomenon of canopying that is unavailability of the GPS signals in confined areas intercepts their wide scale implementation in wireless sensor networks.

[17]provides us a WSN localization scheme which is a GPS-free method called the Matrix transform-based Self Positioning Algorithm (MSPA). It tries to find out the coordinates of the static nodes in 2D as well as 3D space by using the distance between the nodes. This method basically relies on the matrix transform technology and follows a completely distributed network structure. However since in SPA every node individually participates in the process of building and merging the clusters that is the local coordination systems this turns out to be a disadvantage since now the communication costs and the convergence time grow exponentially with the increase in the number of the nodes.

[18] suggests the use of DV-Hop algorithm. It mentions the well-known fact that every location must be scrutinised critically. But due to practical reasons such as cost associated and power consumption etc., it is not feasible to pan the entire area with GPS enabled nodes. In actual practise only few of the nodes have the accurate positioning capability. Therefore, DV-Hop algorithm helps us to estimate position using lesser number of anchor nodes by maintaining the count of the number of hops it takes to reach the unknown node from the beacon node.

However, [19] presents an even more improvised version of DV-Hop algorithm. Simulation and comparison results show that it provides increased accuracy than DV-Hopalgorithm without any increase in the hardware cost of the sensor node.

3. COMAPARATIVE ANALYSIS

Even though all the algorithms come with their own pros and cons but still we need to look out for the best one and settle with the most pertinent trade off which guarantees maximum benefit. A comparison of the above discussed algorithms on the basis of certain parameters such as cost, accuracy, energy efficiency and hardware size is given henceforth. In terms of cost the GPS based technique, Angle of Arrival and Time of arrival based algorithms are the costliest ones. All the other techniques that is TDOA, RSSI, DV hop and GPS free are much more appropriate to be implemented whenever the cost is in question attributing to their much lower costs.

In terms of accuracy the GPS based algorithms and TDOA provides maximum accuracy followed by GPS free, RSSI, TOA and DV Hop. RSSI, TDOA and DV Hop also turn out to be the most energy efficient algorithms. As far as Hardware size is concerned, TDOA requires the least complex hardware whereas in order to implement GPS based algorithms we need complex hardware. The comparison in tabular form is as follows:

Table1. Comparative analysis of various algorithms

Technique	Cost	Accuracy	Energy Efficiency	Hardware
GPS	High	High	Low	Large
GPS free	Low	Medium	Medium	Small
RSSI	Low	Medium	High	Small
TOA	High	Medium	Low	Large
TDOA	Low	High	High	Less Complex
AOA	High	Low	Medium	Large
DV Hop	Low	Medium	High	Small

4. CONCLUSION

In the end we see learn about the growing implementation of wireless sensor nodes. We also came to know the reason behind their excessive deployment which is the ease in their deployment and their cost and energy efficiency. We realised their vivid applications in almost every fields. Followed by this we learned about the various algorithms available from which can choose appropriately for our purpose of habitat monitoring. We also realised about the different parameters associated with these algorithms and ultimately we drew a comparative analysis among the variety of algorithms available. Out of which we can choose as per our requirements, after dealing with a few trade-offs of course.

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