A SURVEY ON RANGE BASED LOCALIZATION IN WIRELESS SENSOR NETWORKS

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Abstract: The advent of ubiquitous computing and the proliferation of portable computing devices have raised the importance of mobile and wireless networking. Wireless Sensor Networks is emerging technology which has created significant research interest. Research is been carried on Power Management, energy aware routing protocol ,localization, data aggregation, coverage of events , maintainability and security in wireless sensor networks. Localization is an important aspect in WSN's. Localization basically are of two category , range based and range free. In this paper we survey and discuss, different methods used in range based localization. We also compare the advantages and disadvantages of these methods.

Keywords: Localization, RSS, TOA, TDOA, AOA

I. Introduction

1.1. Wireless sensor networks

A wireless Sensor network has attracted many researchers in different aspects. A Wireless Sensor Network (WSN) is a network of many small sensing and communicating devices called sensor nodes (or motes). [1] Tiny, cheap and low power sensor nodes called MOTES form this network wirelessly. These nodes must consume extremely low power, operate in high volumetric densities, have low production cost and be dispensable, be autonomous and operate unattended, be adaptive to the environment. This system is called a wireless sensor networks. These motes can be deployed in an urban, rural or in any remote destination. There are different key challenges when these wireless sensor networks are used for application like forest surveillance, habitat monitoring, industry monitoring, environmental monitoring, office security and many more.[8]-[13]. For all these application it is very important to know the position/localization in which the actual physical parameter has been send.

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Manually localizing is not feasible for a large scale network.

Localization plays a major role, without knowing the position the network is useless.[14] Fig 1. Shows the simple wireless sensor network and a mote. Sensor Network localization algorithm estimate the location of sensors with initially unknown location information by using the knowledge of few sensors and inter-sensor measurement such as distance measurement and bearing measurement. Sensors with known location are called anchors or beacons.

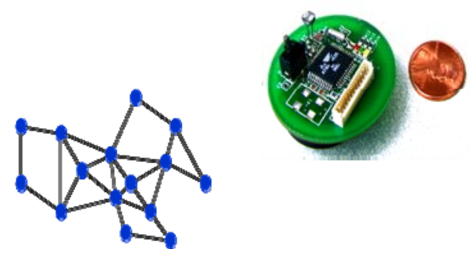

Fig.1 Wireless Sensor Networks.

Anchor nodes location can be preprogrammed or a GPS can be used with the sensor nodes. For GPS enabled motes, we require an additional hardware. So additional cost for the motes. But GPS will not work fine in indoors, where GPS signals are weak(Since buildings can block satellite signals). So GPS will not be a solution for Localization. Fig.2 Show the various components of the sensor nodes.

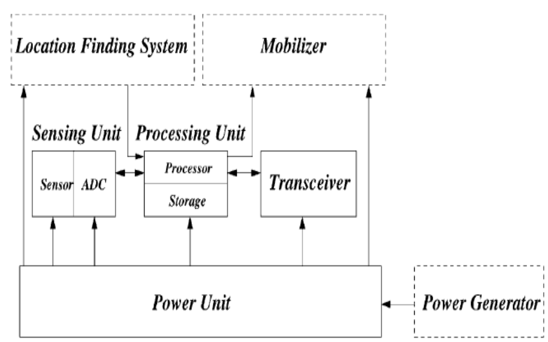

Fig 2. Components of the Sensor Node (MOTE)

Each mote may have a sensor for sensing the physical parameter, the sensed signal is send for processing to embedded processor having an ADC. There may be a location finding system, like GPS or others. A Transceiver which can be used for transmitting the computed data from the processing unit. These motes have to operate on the power unit attached. Typically alkaline battery can be used. These sensor nodes are expected to work for a long period with this power unit. Lot of research going on in energy harvesting techniques. So there may be a power generator unit required.

In section II, III, IV, V, VI and VII we discuss about the various measurement techniques used for range based methods. In conclusion, we give the comparison of these range based methods.

II. Range Based Localization

The range based localization uses the signal propagation for the distance measurement. There are various techniques used for range based localization. The different methods are Angle of Arrival, Time difference of Arrival, Time of Arrival, Received Signal Strength Indication and Mapping Method. There are generally two phases involved in localization. First is the distance measurement, using the signal propagation and the second phase is the calculation of the position. For the second phase it uses triangulation or trilateration and sometimes multilateration. In the next section we will discuss on these methods. The advantage of Range based localization is that they are more accurate than the range free localization.

III. Angle of Arrival

Angle of Arrival method depends on the angle at which the signal is arrived. AOA measurements are widely known as *beamforming* and it is based on the anisotropy in the reception pattern of an antenna. [17].The size of the measurement unit can be comparatively small with regards to the wavelength of the signals.

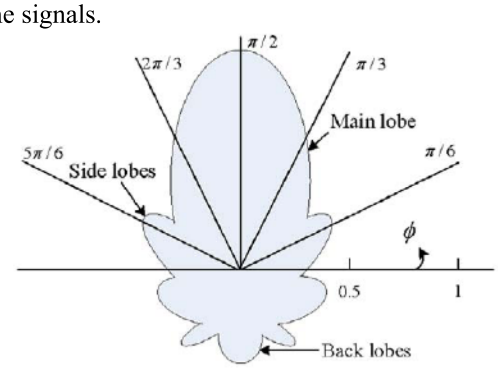

Fig 3. The Horizontal Antenna Pattern of typical anisotropic antenna in polar co-ordinates.

Figure 3 shows the beam pattern of a typical anisotropic antenna.

The accuracy of the measurements is determined by the sensitivity of the receiver and the beam width. Using a rotating beam has the potential problem that the receiver cannot differentiate the signal strength variation caused by the varying amplitude of the transmitted signal and the signal strength variation caused by the anisotropy in the reception pattern. This problem can be dealt with by using a second non-rotating and omnidirectional antenna at the receiver. The accuracy of AOA measurements is limited by the directivity of the antenna and the measurements are further complicated by the presence of *shadowing* and *multipath* in the measurement environment. Multipath problems in AOA measurements have been usually addressed using *maximum likelihood (ML)* algorithms. There are other well known algorithms presented based on AOA are MUSIC (*multiple signal classification)*,ESPRIT(*(estimation of signal parameters by rotational invariance techniques).*

IV. Time of Arrival methods

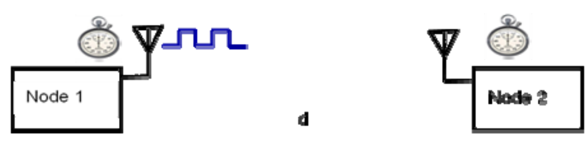

Fig 4 . Time of Arrival

The time of arrival method determines its position using the signal arrival time. A typical example is GPS, where a GPS Satellite transmits the signal to the receiver with all the details of time. Based on the time at which it arrives at the receiver end, the distance can be calculated. Then it uses mulilateration for the calculation of the position. The disadvantage of ToA method is that it suffers from multipath. The ends, transceiver and receiver the time should be synchronized.

V. Time Difference of Arrival

On each transmission, a transmitter sends an RF signal and an ultrasonic pulse at the same time. The RF signal will arrive at the receiver earlier than the ultrasonic pulse. When the receiver receives the RF signal, it turns on its ultrasonic receiver and listens for the ultrasonic pulse. The time difference between the receipt of the RF signal and the receipt of the ultrasonic signal is used as an estimate of the one-way acoustic propagation time. This method gives fairly accurate distance estimate at the cost of additional hardware and complexity of the system because ultrasonic reception suffers from severe multipath effects caused by reflections from walls and other objects. This method is referred to as *time-difference-of-arrival (TDOA)* measurement, i.e., measurement of the difference between the arrival times of RF signal and ultrasonic signal, in some *Time-difference-of-arrival (TDOA)* measurements measure the difference between the arrival times of a transmitter signal at two receivers respectively. The accuracy of TDOA measurements is affected by the synchronization error between receivers and multipath. The accuracy and temporal resolution capabilities of TDOA measurements will improve when the separation between receivers increases because this increases differences between times of Arrival. *Roundtrip propagation time measurements* measure the difference between the time when a signal is sent by a sensor and the time when the signal returned by a second sensor comes back to the original sensor. Since the same local clock is used to compute the roundtrip propagation time, there is no synchronization problem. The major error source in roundtrip propagation time measurements is the delay required for handling the signal in the second sensor. This internal delay is either known via *a priori* calibration, or measured and sent to the first sensor to be subtracted. the synchronization error, the accuracy of both one-way and roundtrip propagation time measurements is affected by noise, signal bandwidth, non-line-of-sight (NLOS) and multipath.

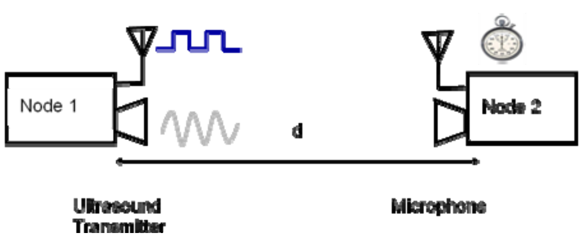

Fig 5. Time Difference of Arrival Method.

Recently, ultra-wide band (UWB) signals have started to be used for accurate propagation time measurements. A UWB signal is a signal whose bandwidth to centre frequency ratio is larger than 0.2 or a signal with a total bandwidth of more than 500 *MHz*. In principle, UWB can achieve higher accuracy because its bandwidth is very large and therefore its pulse has a very short duration. This feature makes fine time resolution of UWB signals and easy separation of multipath signals possible.

VI. Received Signal Strength Method

Received signal strength (RSS) measurements estimate the distances between neighboring sensors from the received signal strength measurements between the two sensors (Bergamo & Mazzini, 2002;Elnahrawy, Li, & Martin, 2004; Madigan et al., 2005; Niculescu & Nath, 2003; Patwari et al., 2005).Most wireless devices have the capability of measuring the received signal strength. The wireless signal strength received by a sensor from another sensor is a monotonically decreasing function of their distance.

Fig 6. RSS – Received Signal Strength

This relationship between the received signal strength and distance is popularly modeled by the following log-normal model:

$$P_r(d)[dBm]=P_0(d_0)[dBm]-10m_p\log10(d/d_0)+X_\sigma \quad (1)$$

where P_o d_o $[dBm]$ is a reference power in dB milliwatts at a reference distance $d0$ from the transmitter,*np* is the path loss exponent that measures the rate at which the received signal strength decreases with distance, and X σ is a zero mean Gaussian distributed random variable with standard deviation σ and it accounts for the random effect caused by shadowing. Both *np* and s are environment dependent. The path loss exponent *np* is typically assumed to be a constant however some measurement studies suggest the parameter is more accurately modeled by a Gaussian random variable or different path loss exponent should be used for a receiver in the far-field region of the transmitter or in the near-field region of the transmitter. Given the model and model parameters, which are obtained via *a priori* measurements, the inter-sensor distances can be estimated from the RSS measurements. Localization algorithms can then be applied to these distance measurements to obtain estimated locations of sensors.

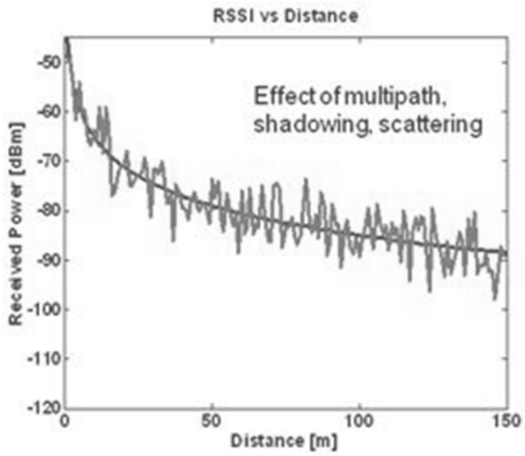

Fig 7. RSS Vs Distance Measurements

VII. Mapping Method

Fingerprinting or mapping techniques are also widely studied for their robustness in terms of performance. The fingerprinting methods employ a two step approach. The first step involves the construction of the signal map for a desired environment (also called the offline phase), the second step is the actual positioning step (online phase). inherently capture all environment related propagation effects like multipath, shadowing, scattering etc and hence might be used for applications where geometric methods fall short of expectations. However due to extensive measurement and mapping involved in this approach, it might not be preferred for large areas where it may not be feasible. Additionally the structural changes in the environment might necessitate remapping for the affected regions of the database [19-21]. The two most commonly used mapping methods are the RSS mapping and CIR mapping. In RSS mapping, a receiver terminal is taken to almost every feasible part of an area that is intended to be mapped and signal power from multiple anchors are recorded into the database. Once mapping is done, actual positioning is obtained by comparing the RSS in online phase to one of the mapped points. The algorithms employed for this purpose are mostly k-NN algorithms[23-25]. Another application is the mapping of CIR for desired locations. The unique characteristics of the CIR, such as rms delay spread, average power… etc might then be used for comparison [20][25]. The same paper also discusses the use of neural networks for position estimation.

VIII. CONCLUSION

In this paper we have discussed about the various range based localization techniques. The localization techniques using range based methods give greater accuracy compared to range free methods, but at the cost of additional hardware. So, the selection of localization algorithms are based on the trade off of power, communication overhead also, how many times to localize. A brief comparison chart is provided for the methods discussed above. Still localization is open issue even though extensive research has been done.

Methods	Advantages	Disadvantages
RSS	• Simple to implement (most wireless devices report power) • Not sensitive to timing and RF bandwidth.	• Not accurate • Requires models specific to application case and Environment
AOA	• Only requires 2 anchors for localization.	• DP blockage and multipath affects accuracy • Requires use of antenna arrays/smart antennas • Accuracy is dependent on RF bandwidth
TOA/TDOA	• Accurate ranging/localization can be obtained. • Can be scaled to a multitude of applications.	• Accuracy is dependent on RF bandwidth • DP blockage might cause large error.
Mapping Method	• Capture all channel related parameters hence resilient to DP blockage.	• Requires extensive database construction/training

Table 1 . Comparison of Range Based Methods

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