Methods of Coordinates Determination in Wireless Sensor Networks

Zlatan Ganev

Abstract – **In this article methods of coordinates determination of nodes in wireless sensor networks are described. More special attention is paid to the triangle method by measuring distances and measuring angles. In the article are presented as well the methods of: registered presence, environment analysis and number of steps for packet transmission.**

Keywords –**coordinates, network, sensor, wireless, ICEST 2013**

I. INTRODUCTION

Nodes coordinates are necessary for precise picture of physical quantities being measured as well as for efficient communication inside the network. Coordinates determination is accomplished in two stages. Firstly, methods, that allow nodes to determine their own geographical location, are used. During second stage algorithms are implemented by which nodes receive the coordinates of other nodes chosen by them.

The most common methods of coordinates determination are: *the triangle method*, *environment method* and *the registered presence method.*

II. TRIANGLE METHOD

This method uses triangle geometry for nodes coordinates determination. The method is applied in two varieties:

- ***Distances measurement***
- ***Angle measurement***

1. Triangle method with distances measurement.

In the first variation of the triangle method with distances measurement nodes coordinates are determined by measuring the distances to *reference points*. These reference points are nodes whose coordinates are known.

A method called **trilateration** is used [1,2]. In it geometry of circles for determining of objects position is used. The position of two or more reference points and the distance from the object to each one of them is necessary to be known. For the precise determination of the position of a point in the plane at least three reference points are necessary.

Fig.1 shows determination of the position of the node N4 in two dimensional space. Reference points are nodes N1, N2 and N3.

The referent position of node N4 towards nodes N1, N2 and N3 is determined by measuring distance r1, r2 and r3. Distance r1 determines position as a point of a circle of radius r1 and center. R2 reduces possibilities for the position to be one of the intersections A or B. The third measurement r3 determines the precise coordinates of the point. More than tree measurements could be made for the fault to be found.

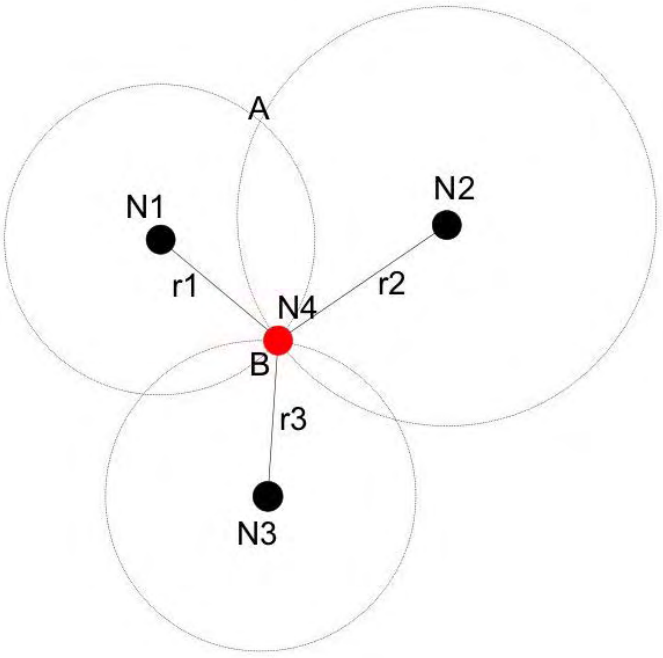

Fig.1 Coordinates determination

For the precise determination of the position of a point in the plane are necessary at least three reference points, which shouldn't be situated on one straight line.

For coordinates determination in three dimension space four reference points, which are not situated on one plane, are needed.

In practice three approaches of measuring the distance are used: *direct measurement*; measurement of time of single distribution between two points-*Time of Arrival* (ToA) and measurement the strength of the received signal-*Received Signal Strength* (RSS).

1.1 Direct measurement.

This method implies physical action, which is difficult to be automated. One option is robots to be used [1].

Zlatan Ganev is with the Faculty of KTT at Technical University of Varna, Bulgaria, E-mail: zganev@gmail.com

1.2 Measuring time of signal distribution between two points - *Time of Arrival* (ToA).

This is the most popular method of distances measurement. It consists in measurement of time for distribution of a wave with known speed [1,4]. Knowing that the speed of sound waves is 344 m/s at 21°C, then 8.7 ms time for distribution of ultrasonic signal will correspond to distance of 3 m.

Timing of radio signal distribution is possible too. For the same distance of 3 m time of radio signal distribution is 10 ns.

Mistakes are possible when there is a poor synchronization at time measurement, deviations in the speed of the wave from the nominal and possibly multiple cutoffs of the beam during its journey.

The principle of operation in GPS is based on measurement of distance from the place, whose coordinates we are trying to find out, to a group of satellites, whose coordinates are fixed and known [5]. The method of *trilateration* is used, by which the position of one point is determined as intersection of several circles (or spheres) with a known radius and coordinates of the center. In the context of GPS each satellite could be determined as a centre of a sphere with coordinates-satellite position and radius- the distance from the satellite to the receiver.

Distance is calculated on the basis of the time of radio signal distribution from the satellite to the user (ToA).

In GPS receiver is not synchronized with transmitter in the satellite and is not able to calculate accurately the time for flying of the signal from space to earth. However satellites have precisely synchronized clocks and include their time in the signal. This allows the receiver to calculate the difference in signal distribution time. The time itself is calculated by the difference in the phase of transmitted and reflected wave signal.

Despite the considerable improvements during last years, use of GPS receivers could lead to unacceptable increase in price, consumed power and sizes of sensor nodes. Furthermore there are many cases when either visibility to satellites is missing or the obtain precision is not enough. One compromise solution is only part of the nodes to be equipped with GPS receiver. The rest of the nodes determine their coordinates by measuring distances to nodes with known coordinates.

1.3 Measuring difference in delay of two simultaneously transmitted signals - TDoA (Time Difference of Arrival).

In sensor networks a greater distribution has received the method, in which the difference of delay of two simultaneously sent signals, is measured (TDoA). Here a synchronization of the receiver only is necessary. The object with unfamiliar position receives radio signals emitted by distant sensor nodes. The decision does not require synchronization of the receiver and energy for active sensors is not wasted, since it is only paid attention to coming signals. This makes this method perhaps the best for absolute localization with static antennas.

Usually it is combined together with the radio signal an ultrasound or acoustic signal. Increase in punctuality of this method is at the expense of additional hardware [1]. It is successfully applied as well only for small distances between nodes.

This method is named *hyperbolic* positioning. Much before the GPS satellite network appearance, there were systems based on hyperbolic positioning.

1.4 Received Signal Strength Measuring - RSSI (Received Signal Strength Indicator).

This approach uses strength of received signal RSS for distance determination [1]. Signal attenuation is proportional to the distance of degree 2, 3 or 4. Receiver measures the strength of received signal and calculates distance. This method does not allow high punctuality, since the received signal strength does not depend only on the distance between transmitter and receiver but also on superposing of reflections on the main signal. It should be noted as well that, height of nodes above the ground, orientation of receiver towards transmitter and communication frequency, change the received signal strength.

There are cases when *time of arrival* (ToA) is too small for sufficiently accurate data to be received. Then for measuring the journey an account is given of how much of its power the signal has lost (RRSI). This is the method utilized, for instance, for GSM telephones localization. The main problem here is that signal scattering depends on many factors undeterminable in advance. Therefore precision of such a system is lower. In case of multiple cutoffs of wave, we will have different results when using at the same time RSSI and ToA. Thus, by combining them in a joint system such mistakes could be more easily avoided.

2. Triangle method by angles measuring.

Here a method from trigonometry and elementary geometry, called **triangulation,** is used [1,3]. In triangulation method the distance from given point is calculated by measuring the distance between two referent points and the angles between the object and the straight line formed by these points. In other wards this is a triangle method in which *two angles* and *one distance* are used.

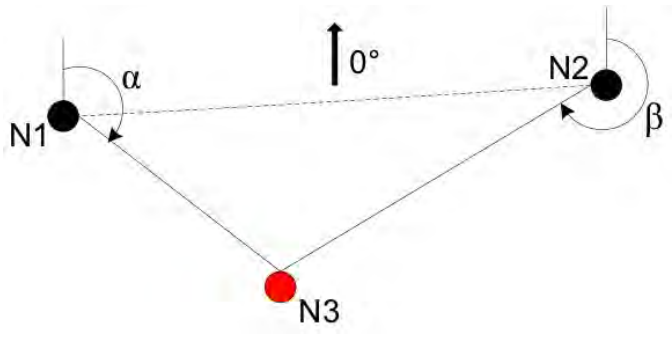

Fig.2 Triangle method by angles measuring

Fig.2 shows an example of coordinates determination by this method. Node N3 location is determined on the basis of distances between this node and the nodes with known coordinates N1 and N2. Angles α and β are necessary as well. The two angles are measured towards reference vector, for which direction north is usually chosen. Directed antennas utilization restricts this method application for sensor networks, but it is widely used in aviation – VHF Omni directional Ranging (VOR).

III. Registered presence method.

This method is used for determining if the object is near to a point with known coordinates. This could be implemented by physical contact registering. Technologies for physical contact acceptance include pressure sensors, touch sensors and capacitive detectors.

The presence of an object in the range of one or more points for wireless network access could approximately determine location. Fig.3 displays an example of nodes presence in the range of two networks with radio communication and one network with infrared beams. Infrared beams absorption by walls leads to rectangular form of the area [1].

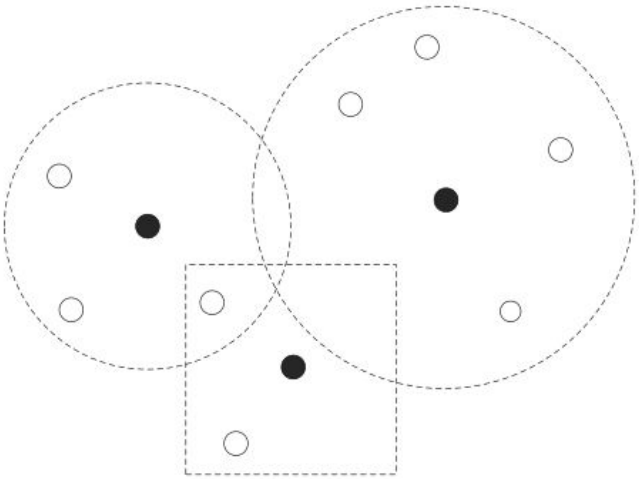

Fig.3 Presence registration

IV. Environment analysis.

This method uses observation of the object, which should be localized.

Cameras are usually used. The resulting picture is adjusted to obtain characteristic parameters. A data base is used to obtain an agreement between snapshot and object coordinates. An advantage of the method is that it does not use geometric properties, which is connected with additional signals transmition and consequently with increased energy expenditure [1].

V. Method using steps number for packet transition.

In cases when applications do not require real coordinates, distances between nodes could be substituted with steps number for packet transmition (virtual coordinates). Thus for the distance between two nodes can be judged by the number of intermediate nodes [1].

II. Conclusion

In the present article methods for nodes coordinate determination in wireless sensor networks were treated. Some characteristic peculiarities were described in the frequently used methods: *triangle method, registered presence method, environment analysis*, and *steps number for packet transmition*. Advantages and disadvantages of some of these methods were analyzed and it was pointed out when it is appropriate for them to be used.

It should be noted that, when the results are not good and accurate enough, we resort to different techniques combination. Herewith the improvement of sensor nodes positioning is intended, which in turn makes the network more reliable and efficient.

References

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