3D Routing and Localization for IoT Enable Medical Sensor Network

Vakhatng Mosidze
TTU, Department of Informational Technology
Tallinn, Estonia
mosidze@gmail.com

Abstract— **IoT in general terms, enables network connectivity, between smart devices at all times, everywhere, and about everything. In this context, Wireless Sensor Networks (WSNs) play an important role in increasing the ubiquity of networks with smart devices that are low-cost and easy to deploy. However, sensor nodes are restricted in terms of energy, processing and memory. Additionally, low-power radios are very sensitive to noise, interference and multipath distortions. In this context, this article proposes a routing protocol, based on 3D localization and addressing.**

Keywords – Mesh Network; 3D routing; Geographic routing; sensor network, special relativity theory,IoT routing;IQRF.

I. Introduction

Energy efficiency and communication algorithm in IoT/WSN networks needs a major shift toward to more scalable and more affordable solutions. For example, in case of applications for healthcare, patients can carry medical sensors to monitor key parameters, such as body temperature, blood pressure, ECG (electrocardiogram) and so on. Furthermore, medical centers are able to perform advanced remote monitoring to access a patient's condition. However, in this particular case, we need to use some gateway device, to allow long-range communication. This completely negates all advantages of a sensor network and leads us to use regular mobile or radio communication, as a middleware between end node and some monitoring center.

According to above, we have low powered, radio-emitting, effective devices, which are not able to provide any data in the emergency.

Problem is, that is for now, all of available IoT solution's are more internet oriented, and the is no backup connectivity in case of ER-situations.

For instance, in case of earthquake, IoT devices, can provide data stream, which can be used by researcher's to predict future disease, and also can help to emergency services to find and save trapped under the rubble people
It's also important to consider that's IoT able to monitor not only medical data or be a part of smart homes, they can provide data acquisition for an air quality, detect hazardous gas pollution and, according to [17] can be used in environment, particular landslide monitoring. However, due to a desire of simplify, and due to limitations in memory, processor and so on, IoT devices are often connected to existing infrastructures like smart phones or a Wi-Fi network.
If we will take in account that's IoT solution in most cases are originated from Sensor Networks, [7] we can to resume, that's they also have same nature and behavior, at least in radio communication domain e.q they can be interconnected (or just connected) by using 3 available topologies

- Point to Point or a bus connection
- Pont to multipoint - as a star topology
- MESH topology

The last one is the best from the perspective of creating a self-organized network and implement full fault-tolerance network coverage.

Moreover, the mesh network, is most energy effective, since only in Radio transmitting mesh, we can adaptively adjust power consumption by choosing next hope neighborhood according to Received Signal Strength Indicator (RSSI) or Link Quality Indicator (LQI) [13],[14],[15]. As an IoT is a part of Software Defined Radio (SDR), and in some cases and additional changes in hardware can represent the model of future Cognitive Radio System

Considering the many different options for routing algorithm, we can see one regularity- all the basic models are built completely true and accurate, except for the fact that they were all originally built for two-dimensional basis [3] and are adapting protocols for wired, stationary networks
For nowadays, there is no dedicated algorithm that takes into account two features: -three dimensionality and dynamic sensor network as a mobile radio system. Before moving to the question of basic model of three-dimensional network, we must to understand the existing models and identify some features of radio, which has been omitted, such as radio wave propagation [11] and wave-particle duality. During propagation, digital radio (mesh network also belong to this class) just as well will be influenced by the environment as

well as analog radio. To begin with, it should be understood that the space routing requires some coordinates of nodes. This is one of the important issues when planning the network, getting the device coordinates related primarily to its localization, and building a coordinate system.

II. STATE OF ART

As an integral part of Sensor network, IoT nodes are not aware from challenges, which are common for WSN, e.q [6]

A. Node Deployment

Unlike conventional networks where network topologies are determined in the beginning of network construction Node, deployment in WSN's is randomized. In such randomized deployment, sensor nodes are randomly scattered creating an unknown and unstable network topology. Data routing in this type of node deployment inherently possesses no prior knowledge of network topology and thus requires processing more routing data. [11]

B. Energy consumption :

Routing protocols are required to maximize the energy-conserving form of communications and computations to prolong the battery lifetime. However, these types of communications and computations still provide needed accuracy of routing protocols. The second aspect of energy concern in WSNs is to maintain the accuracy of routing protocols in a presence of low power sensor nodes.

C. Network dynamic:

Most of WSNs consist of non-stationary sensor nodes. Routing messages in this type of dynamic networks are more challenging due to quickly changing routing path. In a dynamic network, strategy for routing protocols is to simply generate routing path on demand. Due to the unsuitability of the network, pre-calculating of routing path is almost impossible.

Routing protocols for IoT can be classified in many ways, depending on different criteria.

Flat routing protocols are mainly used for networks with flat structure with a large amount of sensor nodes. Each sensor node plays equal role in the network and neighboring nodes can collaborate to gather information or perform sensing task. The large number of IoT nodes results in the impossibility of assigning global unique identifier for each node. This has led to data centric routing mechanism where the receiver node sends queries to a certain group of sensor nodes and waits for reply from the intended sensors. An example of flat routing protocols is SPIN (Sensor Protocols for Information via Negotiation) where each node considers every other nodes as potential receivers. The protocol utilizes the similar data in the neighboring nodes to avoid sending redundant data throughout the network.

Hierarchical routing protocols are designed for networks with a hierarchical structure like Internet. The idea is to divide the network into clusters and select from each cluster a cluster head. Usually, the higher energy nodes are used to process information, send data while the lower energy nodes used to sense in the proximity of the target. This type of routing protocols offers the advantages of scalability and efficient communication at the expense of the overhead of cluster formation and cluster head selection in the beginning.

Location-based routing protocols are protocols that take into consideration the specific location of sensor nodes. The location [3] can be addressed by the signal strength if nodes are close to each other. In the case of distant nodes, a relative coordinate of nodes can be extracted through information exchanged between neighboring nodes.

Currently, there are several solutions of location-based routing in three-dimensional space- the most practically and usable are:

Robotic Routing Protocol (RRP) is a Grid based recovery technique. Network is logically partitioned into cells / grids with edge length dGdR / p2 where dR is the transmission radius. In other words, all nodes in a cell are one-hop neighbors and can communicate directly. Each node in the network maintains the routing information about its neighbor cells as well as its one-hop neighbor nodes. Simple Right hand rule is performed between the cells to walk around the obstacle / empty cell. [10]

Greedy Distributed Spanning Tree (GDSTR) uses minimal path spanning trees called hull trees for void handling. Beacon-based solutions select some nodes in the network as landmark node switch help in routing around the void. [10]

Beacon Vector Routing (BVR). BVR assigns a set of randomly chosen nodes as beacon nodes. Every node in the network, learns its distance in terms of hop count to all the beacon nodes and forms a vector of these distances called the beacon vector. [10]

As we can see from above, this systems are working pseudo 3D space, by using only 2 real, depended on radio propagation service. Mostly they not were dealing with localization of each node, as they are using a principle of simple, hop count routing- respectively to algorithm, and are concentrated on void handling, which, is mandatory.

However, as clearly seen, all these technologies or engaged in reference to the coordinates of the Earth's surface (Geo-

Logical Routing (GLR) or use an algorithm to find the shortest path on a sphere with a pseudo coordinate (GDSTR). We, for our part in this work, will provide the way of creating virtual coordinates for networks and show the ability to use the key mechanisms of radio signal propagation to build an independent, networks-oriented coordinate system.
However, as this task is not easy, we need to split it into two parts, and only part one will be discussed in this paper.

- *Localization of nodes*
- *Use radio propagation values for creation of coordinate system*

III. CURRNT LOCALISATION TECHNICS

They are not so much localization methods for the moment [4]:

RSSI, ToA (Time of Arrive) and AoA (Angle of Arrive).They are related directly to the transceiver, and all change their characteristics dynamically, depending on the position in space and time. All existing localization and routing system currently uses these three parameters (as standalone or as combination of) to determine the distance and shortest path

IV. TOA OR TIME OF ARRIVAL

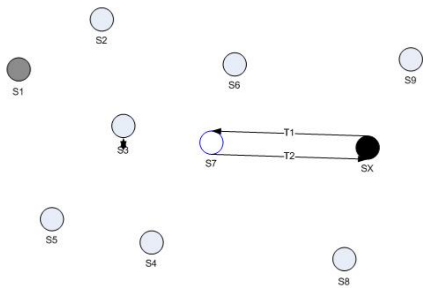

Figure 1

The very first thing that the easiest way to use- the time required to get the return signal. S_x transmitter sends a test signal, note the time and waits for the response. As soon as it receives it, according to the formula

$$D_s = c\,(T_2 - T_1) \qquad (1)$$

Where D- distance, c = speed of propagation of the radio signal coincides with the speed of light, T2 and T1 time sensor 1 and 2, respectively. Thus, it is possible up to a certain point, which depends on the accuracy of real-time clock to figure out the distance from S_7 to S_x in our case.

However, if we are dealing with the real world, after checking and calculating the distance from each point to other - we get an picture.

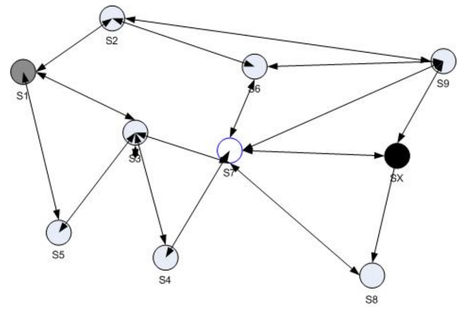

Figure 2

Table 1

	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8	S_9	Sx
S_1	0,0	1,1	2,2	3,3	4,4	5,5	6,6	7,7	8,8	9,9
S_2	1,1	0,0								8,8
S_3	2,2		0,0							7,7
S_4	3,3			0,0						6,6
S_5	4,4				0,0					5,5
S_6	5,5					0,0				4,4
S_7	6,6						0,0			3,3
S_8	7,7							0,0		2,2
S_9	8,8								0,0	1,1
Sx	9,9									0,0

That is, as a result of signal propagation, we have a huge amount of data (Table 1), which gives us time periods, and the distance between nodes (figure 2). It would seem that this is enough, however, to construct a route with two coordinates trivial task, since the distance to the sensor- good, time to return the signal- also good, the question in the direction of the source and destination remains open. Because we have no estimation to send and from were expected signal-, we have no information about a direction of a signal. After all, the closest and strongest signal does not mean the right direction to send data. Nevertheless, there is a simple way to get direction- trilateration.

Generally, in the field of positioning with a minimum of data, there are more than capable multilateration, which is used by all GPS system, but for a more or less accurate data requires, at least, four satellites in the existing coordinate system, fixed emitters, with very precise synchronization of time. In the future, we will look at these issues in more detail.

V. RECEIVER SIGNAL STRENGTH

The second most important characteristics and signal - is RSSI *In* IEEE 802.11 system, RSSI is the relative received signal strength in a wireless environment, in arbitrary units. RSSI is an indication of the power level being received by the antenna.

Therefore, the higher RSSI number, then stronger the signal. Means that the stronger is the signal, the closer the location of the receiver to the transmitter. Respective to the inverse-square law:

$$P = \frac{1}{R^2} \tag{2}$$

Where P-power and distance R. Multiple authors [4], [5] claim that they have achieved acceptable results in the determination of the location of node. However, in accordance with the principle of Huygens, we have a Fresnel zone, according to which each point of the medium to which comes disturbance itself becomes a source of secondary waves and the radiation field will be considered as superposition of all the secondary waves. Based on this principle can be shown that objects lying within concentric circles held around the line of sight of two transceivers, can affect the quality, both positively and negatively. All the obstacles that get inside the first circle, the first Fresnel zone, have the most negative impact.

Consider a point located on the direct path between the transmitter and the receiver, wherein the distance from the transmitter is equal to S, and the distance from the receiver equal to D, that the distance between the transmitter and the receiver S + D.-figure 3

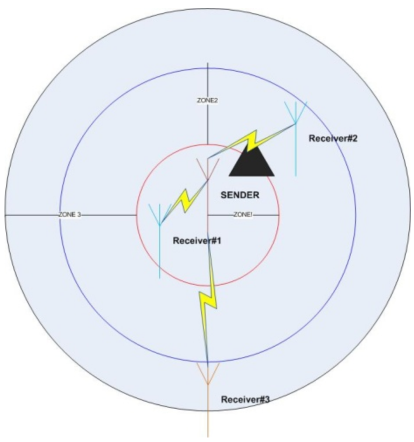

Figure 3

$$R_m = 17.3 \left(\frac{\sqrt{1}}{f_{GHz}} \frac{S_{km} D_{km}}{S_{km} + D_{km}}\right) \tag{3}$$

Where R_m is the distance to the first Fresnel zone.
In addition, in telecommunications, a formula explains the transmission power depending on the radius a.k.a Friis formula.

$$\frac{P_r}{P_t} = G_t G_r \left(\frac{\lambda}{4\pi R}\right)^2$$

Where:
Gt - The gain of the transmitting antenna
Gr - The gain of the receiving antenna
Pt - power of the transmitting antenna (W) (without loss)
Pr - power received by the antenna (W) (without loss)
R - Distance between antennas in meters
λ - wavelength in meters corresponding to the transmission frequency
With take into account the fact that we have identical transceivers, we can calculate the radius of the transmission as:

$$R = 4\sqrt{\frac{g_2 P_1}{\pi^2 g_1 P_2 f^2}} \tag{4}$$

Knowing the radius, we can in the future, based on the coordinate data, calculate the maximum effective transmission range of each transmitter, depend to power, frequency, attitude and distance that in the future will give us the opportunity in the calculation of the optimal path. Thus, demonstrable that the method for obtaining data RSSI is the correct, nevertheless, to obtain the exact distance is impossible. However, since this characteristic allows obtaining data- it should be considered in further developments

VI. ANGE OF ARRIVAL

Angle-of-Arrival (AoA): AoA estimates the angle at which signals are received, and use simple geometric relationships to calculate node positions. Generally, AoA techniques provide more accurate localization result than RSSI based techniques but the cost of hardware of very high.

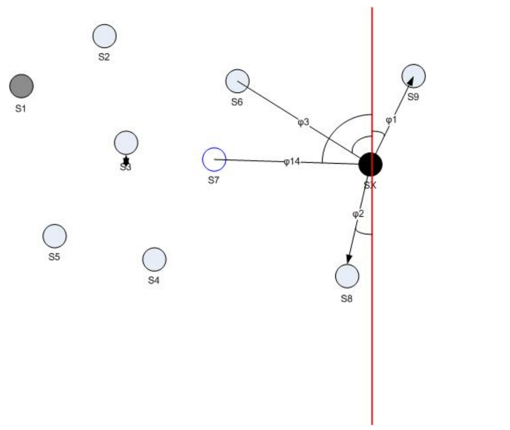

Figure 4

These method- one of the best in terms of positioning, but this method requires a fixed coordinates and sect oral antenna array, which is expensive firstly, and secondly poorly suited for a sensor network, according to the power consumption and portability.

Figure 4 demonstrates AoA work principle, as more mowers we have at directional antenna then is more probability of correct direction, and combining this with RSSI data gives us away to calculate correct location. However, without using a some coordinate basement, is useable, but using with combination with RSSI can build own coordinate structure. In real world application is often used for Radio triangulation schemes

Summarizing all of the above, we getting the following results

- *RSSI- measures stronger signal, possibility to estimate position by triangulation and directional antenna.*
- *TODA- measures distance to sensor, with trilateration and beacons can detect position of sensor node, with 3 beacons at least.*
- *AoA- measures angle and direction. Calculation to signal is possible with directional antennas, need to be bounded to some coordinates greed*

VII. BUILD ON INDEPENDED COORDINATE SYSTEM

In the construction of any route in space, you need to know at least 4variables - source point, destination point, the distance between them and direction. Itself a mathematical model of finding a particular point coordinates known since the mid-10th century, as well as the of mapping. However, in our system, several problems do not allow us to use real geographic coordinates- for example power efficiency

Taking in to account above description, received values from all existing techniques and, if we take as a basis a Cartesian coordinate system, we can represent the following characteristics for axes as:

RSSI values as =Z;
ToA values as =Y;
And
Distance (Calculated byToA) as =X

Respectively, we can build the following representative model. For now, we have a model of sensors network placed in 3-dimension space. However, if RSSI gives us values in raw mode, ToA and distance need to be calculated. Also, as we have virtual Cartesian coordinates, we have to prove that's this coordinates are not based on some material base-only in this case we can continue to build routing path in future. Because, building network for some particular scenario is not good approach. By taking a look to this network from the point of view of the postulates of the Special Theory of Relativity, namely

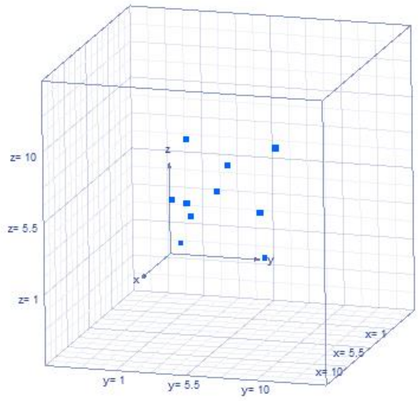

Figure 5

Reference system is a material body, chosen as the origin of this system, a method for determining the position of objects with respect to the reference system and method for measuring time. Usually distinguish between reference systems and coordinate systems. Adding measurement procedure time to the coordinate system "converts" it into a the frame of reference.

Reference systems (RS) - is a system where the object is not subject to external influences, moving uniformly in a straight line. It is postulated that there are RS and any frame of reference moving with respect to the inertial system of uniform and rectilinear, is also belong to RS.

In STR postulated the possibility of defining a single time in the framework of the inertial reference system. For this, the procedure of synchronizing two clocks at different points in IRS. Suppose the first hours from the time **t1** to the second time signal is sent (not necessarily light) at a constant speed **u**. Immediately after reaching the second clock (in their readings at time T) signal is sent back to the same constant velocity u and reaches the first clock at the time **t2**. Watches are considered *synchronized if the relation*

$$T = \frac{(t_1 + t_2)}{2} \quad (5)$$

Time synchronization is high demand for our system, as we are going to calculate the distance between two nodes by sending and receiving signal, deviation in nanosecond is impossible, because speed of radio propagation, which is almost equal to speed of light 1 ns, means 1 m of distance.
Based on SRT time synchronization principle we can offer a different approach to building networks are as follows:

We draw attention to the basic problems of localization-accuracy; we can say that they cannot achieve acceptable performance, as it cannot accurately position a node in space. It should be noted that the system requires precise positioning of time, even in such as modern GPS system atomic clocks provide insufficient accuracy. However, in our system we do not plan to rely on the route survey points, the question arises why do we then bind your system to the standard time intervals?

Consider in more detail our system- we have the coordinates of each of the sensors, and can put them on the axes in a certain space. From the point of view of laws of geometry, physics and mathematics, we get completely coordinate system, the axes of which will be set aside, in this case, such as the magnitude and distance RSSI, ToA and distance in same way and we have a frame of reference.

As we have established a system of coordinates, and since it is not based on any geographical coordinates, we can introduce a so-called zero time calculated from as start of an initiating sensor with coordinates 0.0.0. In other words, we have to adjust to the time interval for private system, which already allows us to calculate the time intervals comfortable for us, in such manner we getting the invariant coordinate system. Let us prove that the system satisfies the postulates of SRT

1) The initiating object is at the origin.
2) All the calculated values of the distance and relative to initiator by time reference.
3) The initiator provides the starting point of time and in space..
4) Moving initiator in space does not occur changes of his coordinates and does not affect to cell units.
5) Any node, leaving the limits of the cell, and once in the range of another will be programmed in accordance with the initiator of the cell, as he is a slave and not being able to create a cell around him, if it was not provided with the topology.

Chosen the coordinates are correct and the corresponding inertial system because:

RSSI, is logarithmic value expressing strength of the received signal, thus, when moving the source around, we have values changing over time, and, given that the measurement can be carried out in a conventional timing system, and in the interior, it is possible to assume that this parameter is independent of any coordinate system, or from time to time, the value is only the distance and the measured signal in a given time interval. Thus, the coordinate is the right choice

ToA - time pinpoint from starting the transmission and to receive feedback. Does not depend on the coordinates, using only time period, which pinpoints the beginning of the transmission. Obtained that a system can operate with a timer, as well as with ordinary clock but, however, is more independent timer in our analysis. Mathematical, distance has been associated with the speed of light and ToA (1), that is a valid value in this context,

Thus, we can consider these coordinates as satisfying the conditions for the creation of an inertial IRS

Based on these data, we can create a table of coordinates of each sensor in our network

S_0=0; 0; 100
S1=0, 5; 2; 50
S3=1; 3, 3; 10

Where:

X=distance=c (t2-t1), (cm)
Y=ToA=t=t2-t1 (ns)
Z=RSSI dB (%)

By using formulas (3) and (4), and substitute values we can find that's

$$R = 4\sqrt{\left(7 * \frac{0.1}{pi^2 * 7 * (0.1) * (0.18)^2}\right)} = 7{,}95\text{m}$$

It turns out that our system is effective at a distance 7.9 m in this condition

Since we are dealing with three-dimensional model, the calculation of the distance between two points is not problematic

$$|a| = \sqrt{X^2 + Y^2 + Z^2} \quad (6)$$

If we want to calculate, the distance between two points is

$$|ab| = \sqrt{(X_2^2 - X_1^2) + (Y_2^2 - Y_2^2) + (Z_2^2 - Z_2^2)} \quad (7)$$

That is, we getting an a scalar value, which give us a possibility to calculate shortest path by using simple geometry

VIII. Future Work

Thus, the problem of finding the shortest path reduced to finding the shortest distance between two points located in the same space. Knowing all three coordinates, consider finding direction is trivial solutions of the triangle, and this work will not be considered

However, this method is optimal in the presence of only a few sensors - in the case of calculating a route in a network consisting of more than 10 sensors, the problem becomes more difficult.

Introduction to the theory of relativity in our work allows us to use the entire mathematical formalism used in this theory, and although the use of Hamiltonian systems and entropy we produce is not required at this stage, however, the use of tensor mathematics and probability theory in ISO gives us a theoretical possibility to calculate the optimal route without resorting to energy-intensive operations

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