Localization Methods for Internet of Things: Current and Future Trends

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***Abstract* - Internet of things (IoT) is a network which consists of billions of small sensors which communicate with each other to obtain solutions for environmental problems. The location information is very important to know where the data come from. This paper introduces and analyzes different categories of localization in IoT from different views. The advantages and disadvantages of each technique and which application it is suitable for will be demonstrated.**

***Index Terms* –Wireless Sensor Network (WSN), Internet of Things (IoT), Localization Techniques.**

I. INTRODUCTION

Internet of things is a huge model that consists of devices called 'things'. The 'things' of IoT consists of sensors which collect data from surroundings and actuators which take the reaction depending on sensor's data. IoT connected all these devices to the Internet. IoT has many applications [1], such as home automation [2], military applications [3] and circumstances monitoring [4]. All these applications needs to know the positions of the nodes to benefit from the data coming from sensors. Global positioning system (GPS) is used to find positions of nodes. However, it comes at a high cost, consumes a lot of power and not suitable for many applications. So, there are a lot of researches proposed to handle localization in IoT.

Localization in wireless sensor network is a wide study issue in literature. It is the operation of determining the positions of some nodes in the network; unknown nodes using the known of positions of other nodes. The approaches used to determine the position are usually based on structural calculations such as triangulation (by measuring angles related to fixed points with known positions called anchor nodes) and trilateration (by measuring distances among nodes). In order to measure the distance between two nodes, several [16] methods can be used, Such as natural aspects of the carrying wave, synchronization and received signal strength. In this paper, we will introduce a survey that shows different divisions of localization techniques in IoT.

II. LOCALIZATION ISSUE IN IOT

A. LOCALIZATION ISSUE IN IOT

IoT is a very big network containing a huge number of networks called Wireless Sensor Networks (WSNs) [5][6][7][8][9]. Because of the huge number of devices connected to the IoT, we need to construct the data that comes from IoT devices. The position information has a very important role in IoT; the data collected from devices are ordered depending on information of the position. The traditional way to get the location of devices is GPS, however, it cannot be useful in many cases and not suitable for all environments. So, there are a lot of techniques developed to overcome problems of the surrounding area.

There are many criteria of classification in localization such as the characteristics of the surrounding for range based and range free techniques [10]. Range based techniques that depend on the characteristics of the surroundings are Received Signal Strength (RSSI)[11][12][13], Time Of Arrival (TOA)[14][15][16], Angle Of Arrival (AOA)[17][18], Time Difference Of Arrival (TDOA)[19][20]. Range based techniques are suitable for applications which are in open areas or places where there are no obstacles in the surroundings. On the other hand, Range free techniques depend on the connectivity information not on the characteristics of the signal [21]. There are a lot of range free techniques such as DV-HOP [22], APIT [23], and MDS [24]. Also, another classification depends on the movement of data between nodes as Centralized and Distributed algorithms [25]. In centralized localization, the data of the nodes are collected by a central processor which computes the position of each node [26]. In distributed localization, nodes know their positions by exchanging data between nodes. Distributed algorithms are scalable and suitable for large networks [27][28]. There is also a classification that depends on mobility; it classifies the IoT networks into mobile sensors of IoT and static sensors [29][30]. Many localization approaches on IoT have been presented; authors in [4] introduce a survey of localization techniques in IoT. In [31] the enhancements in localization techniques in IoT fields are introduced and several applications of localization in IoT are presented. Authors in [29] present a categorization of localization techniques and display factors that influence the operation. While in [31] authors present a categorization of localization techniques into range based and range free techniques.

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B.METHODOLOGIES

In the last decades, researchers have been thoroughly investigating to find the most suitable localization algorithm for each application. Calculating the position of a sensor node passes by two steps; the first step, calculates the distance between the unknown node and the anchor nodes. The second step calculates the position of the unknown node using calculated data. Measuring the distance between the anchor node and the unknown node can be achieved using two methods; the first method, using the hardware options like calculating the received signal strength. The second method, using the neighboring nodes information. There are many applications in IoT that need localization techniques. Each application needs a relevant and suitable technique. So, this section gives a summary for the current techniques used in localization in IoT. It divides these techniques and makes a scope at each category.

The first category of localization is based on the characteristics of the surrounding: Range based and Rang free techniques. Where range based depends on the characteristics of the surroundings like Received Signal Strength (RSSI), Time of Arrival (TOA), Angle Of Arrival (AOA), Time Difference Of Arrival (TDOA).

A. Time of Arrival

This technique is used to find the distance between two nodes via time of signal propagation and the velocity of the signal. There are different schemes of this technique. One-way time of arrival, Two-way time of arrival as shown in Fig. 1. In one-way time of arrival scheme, the propagation time is the difference between the receiving time and the sending time. The distance in the case of one–way time of arrival can be calculated using eq (1)[34].

distance $_{1,2}$ = (receiving time(t_2) – transmitting time(t_1)) * signal velocity(v) (1)

In two-way time of arrival scheme, the propagation time is calculated at the sender node after round trip of the signal. The distance in the case of two–way time of arrival can be calculated using eq (2) [31].

distance $_{1,2}$ = (receiving time of returning signal(t_4) – transmitting signal(t_1)) – (transmitting signal of returning signal(t_3) – receiving time of signal(t_2)) /2 * signal velocity(v) (2)

These two schemes need the clocks between sender and receiver to be synchronized [34], so, it is very costly and not suitable for many applications.

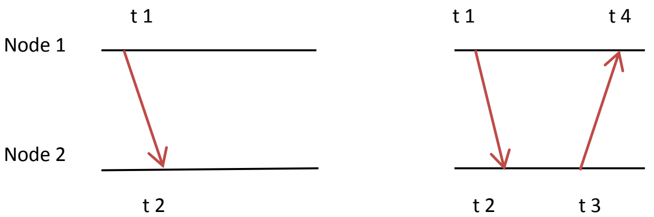

Fig.1 Time of arrival schemes (a. one- way time of arrival, b. two-way time of arrival).

B. Angle Of Arrival

The angle of arrival (AOA) is the phase between the signal propagation and known reference. Angle of arrival technique used to measure the distance between the sender node and receiver node. To implement this technique, we need a good antenna to determine the angle of signal propagation. This technique is very costly and not suitable to huge networks [35].

C. Received Signal Strength

This technique is used to find the distance between two nodes via the strength of the received signal. It does not need extra hardware [33]. The distance calculated in case of RSSI can be calculated using eq (3).

$$d = d_0 * 10^{\frac{p0(d0)-pr(d)}{10*np}} \quad (3)$$

Where p_0 (d)[dB_m] is the power in db mille watts at a reference distance from the sender, np is pass loss exponent and its value reflects the surrounding noise.

Range based techniques are suitable for applications which are in open area and there are no obstacles in the surroundings. While range free techniques depend on the connectivity information not on the characteristics of the signal. There are a lot of range free techniques such as DV-HOP, APIT, MDS.

A. Approximate Point In Triangulation (APIT)

This technique depends on the existence of certain anchor nodes which know their positions via any method such as GPS. Any consolidation among three anchor nodes forms a triangular area. Each unknown node finds the triangular areas which it locates. Then it computes its location by computing the point of crossing of all triangle regions which it locates as shown in Fig. 2 [23].

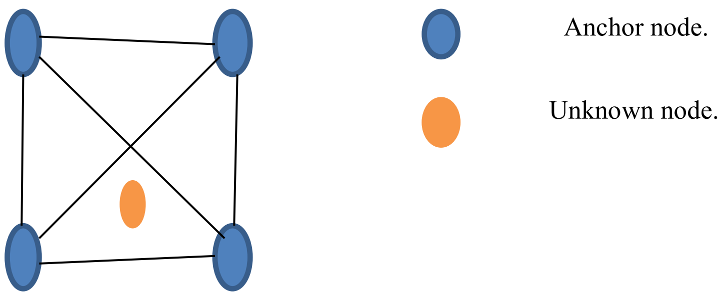

Fig.2 position determination depends on the crossing of anchor triangle regions.

B. Multidimensional Scaling (MDS)

Multidimensional Scaling (MDS) is a range free technique which is a set of mathematical equations used to analyze the data. This algorithm uses the relationships between nodes. i.e. the shortest paths between any pairs of nodes in the network to reconstruct map containing the positions of all nodes in the network. In MDS, the network implemented as a graph of anchor nodes i and unknown nodes j, where i<j. the connectivity information between nodes is implemented with edges [24].

C. DV-Hop

In This technique, the distances between unknown nodes and anchor nodes are determined using hop counts. Each anchor node estimates its hop size using eq (4).

$$hopsize_n = \frac{\sum_{n\neq m} \sqrt{(R_{xn}-R_{xm})^{\wedge}2-(R_{yn}-R_{ym})^{\wedge}2}}{\sum_{n\neq m} hops_{n,m}} \quad (4)$$

The unknown node must have at least three anchor nodes positions and the measured distances from these anchor nodes to the unknown node. Then any mathematical technique. Such as, trilateration method used to calculate its position. See Fig.3 [22].

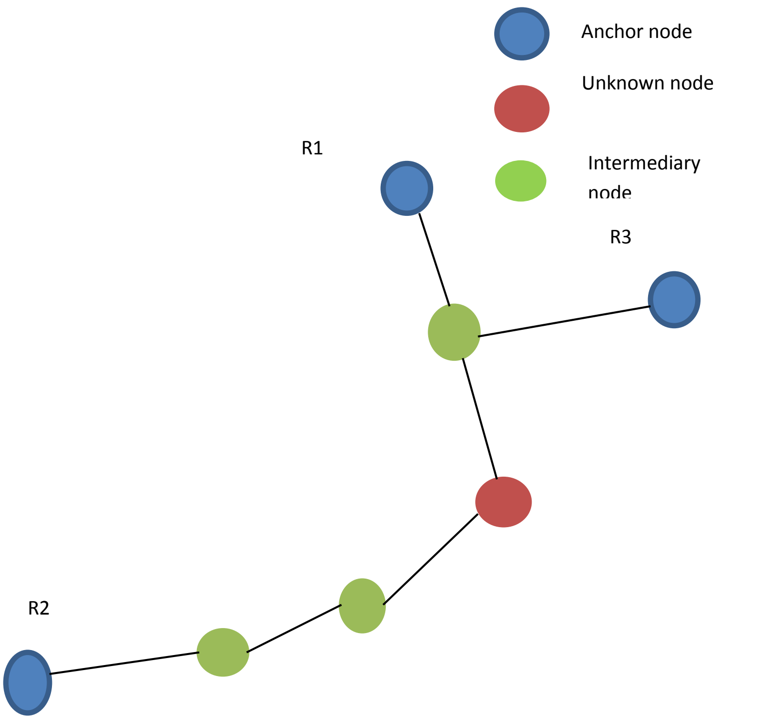

Fig.3 Example of DV-Hop algorithm.

Also, another classification depends on the movement of data between nodes: Centralized and Distributed algorithms. In centralized localization, the beacon nodes send data to a central processor, that accumulates it and makes its calculations to find the positions of unknown nodes by using the data of anchors and the relationships between anchor nodes and unknown nodes. In distributed localization, nodes know their positions by exchanging data between nodes. Distributed algorithms are scalable and suitable for large networks. Another classification depends on the mobility of anchor nodes: Mobile-anchor based and static based. We usually use mobile anchors in the network when there are no many fixed anchors in the network. The mobile anchors move in paths and there are types of paths according to the movement if it is random or not. If the motion is not random, the movement path is either static or dynamic. The main difference between static and dynamic is the mobility and the direction choice made through the movement [44]. This paper will also discuss mobility in localization to address all different applications of IoT.

III. Techniques of Localization in IoT

A. *Ranging techniques in IoT*

There are a lot of ranging techniques which depend on the characteristics of the surrounding. It is suitable for applications which are in open areas where there are no obstacles or noise. Also, some ranging techniques need extra hardware like time of arrival and angel of arrival. The authors in [35] proposed new algorithm which depends on time of arrival technique (TOA) to find the position of an unknown node. This system consists of two types of nodes, anchor nodes and mobile nodes. The anchor nodes are fixed while the mobile nodes are movable. The sender can be the anchor nodes or mobile nodes, corresponding to the signal received from the anchor nodes or mobile nodes. In this paper, the mobile node is the receiver node and the anchor node is the sender. The anchor node transmits an ultrasonic signal while the mobile node receives the signal and calculate its location. Then it sends its location to the control node using Wi-Fi signal as shown in Fig. 4.

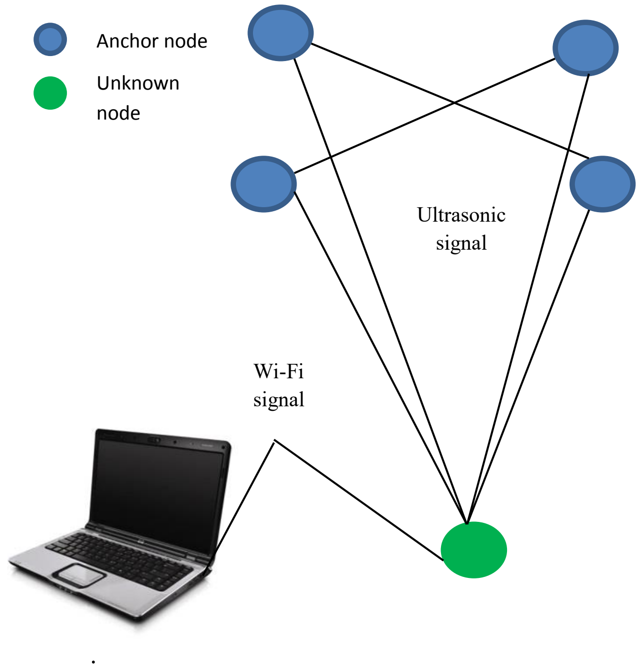

Fig.4 Diagram of location system

The authors in [36] proposed an improved localization algorithm using indoor environments depending on RSSI. The improved model uses intel Galileo (Gen 2) board as an access point. The improvement method solves the problem of obstacles impact indoors by enhancing received signal strength evaluation. In this paper, the authors have proposed a model as follows:

1- The positions of access points and their mac addresses are stored in a data base.
2- They choose the positions of reference points at known points, measure the distances between access points and reference points and save them in the data base.
3- The data which includes (access points positions + mac addresses + distances form access points to reference points + positions of reference points) are sent to the server.
4- The server uses all the distances from the access points to the device and the positions of the access points to

get the coordinate of the unknown location device using trilateration method.

5- The server again uses the data coming from the data base which including distances from access points to reference points and the positions of reference points to compare and match the calculated distance to the device with the distance to reference point using matching method. Then, the equalizing reference point position and unknown device position are averaged to get enhancement position.

6- The enhancement position is sent to the unknown device.

B. Range free techniques in IoT

Range free techniques are used in the applications which do not need accuracy positions of the nodes. There a lot of techniques such as; DV-Hop, MDS, APIT. Authors in [37] proposed weighted centroid algorithm based on IoT. The algorithm consists of many steps:

1- The anchor node broadcasts a message containing the ID and position to all nodes (including anchor nodes and unknown nodes) in the network.
2- All the nodes save information of the anchor node.
3- All anchor nodes compute the distance to unknown nodes using received signal strength.
4- Positions of unknown nodes is estimated using weighted centroid equation, using eqs. (5) and (6):

$$X=\frac{\sum_{j=1}^{r} wc_j x_j}{\sum_{j=1}^{r} wc_j}=\frac{wc_1\, x_1+ wc_2\ x_2\ +\cdots+ wc_r\ x_r}{wc_1+wc_2\ +\cdots\ wc_r} \quad (5)$$

$$Y=\frac{\sum_{j=1}^{r} wc_j\ y_j}{\sum_{j=1}^{r} wc_j} = \frac{wc_1\, y_1+wc_2 y_2+\cdots+ wc_r y_r}{wc_1+wc_2+\cdots+wc_r} \quad (6)$$

(x ,y) = calculated positions of unknown node.
r= number of anchor nodes.
w_{cj} = the weighted centroid factor.
(x_j ,y_j)= positions of anchor node.

The authors in [38] proposed a new algorithm called location estimation- kernel partial least squares (LE- KPLS). This algorithm solves the issue from the number of hop counts between unknown nodes and an anchor node, this doesn't reflect the real measured distance between them as presented in Fig. 5. The distance between anchor node 1 and anchor node 2 is 50m and the distance between anchor node 1 and anchor node 3 is 110m. However, the hop size of anchor node 1= sum of distances between other nodes/total number of hop counts between anchor node 1 and others. This equals 50+110/8=20m. So, by calculations the distance between anchor 1 and 2 equals number of hop count*hop size=40m, which does not reflect the real distance and the calculation distance between node 1 and 3 which equals 6*20=120m which also does not reflect the real distance. The algorithm depends on building a model depending on Gaussian kernel function which converts the data of hop counts between unknown nodes and anchor nodes to physical values representing the measured distances. These physical values are used by unknown nodes to estimate their locations.

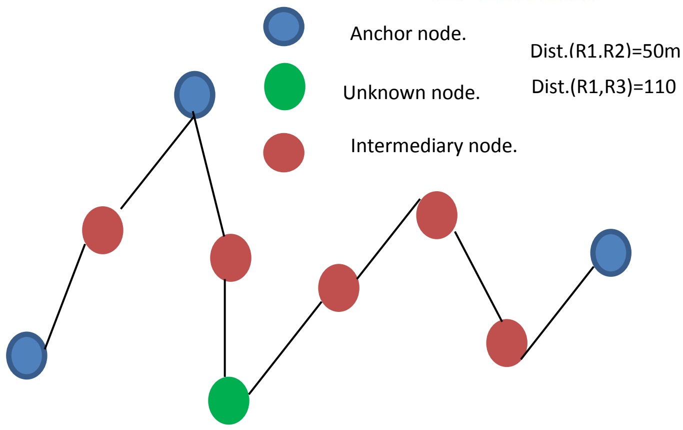

Fig.5 Example of calculated distance does not real distance

C. Distributed localization algorithm in IOT

- The distributed localization is an algorithm that depends that each unknown node knows its position by itself without the need of central processing to get data and calculate the positions of all unknown nodes. The unknown nodes know their position using the information from neighbouring anchor nodes. All the nodes have the same order. The authors in [39] proposed localization technique utilizing sparse anchors (LASA algorithm). LASA algorithm is a distributed algorithm. Each unknown node determines its position from communicates with neighboring anchor nodes.
- LASA algorithm depends that each unknown node acts as if a considerable portion is attached to its neighbor using a spring. The real length of the spring is the calculated distance in the related space. The rest of the spring length is the measured distance.
- The spring makes effort to make the real length equivalent to the rest of the length.
- So, if the calculated distance is less than the measured distance, the spring forces the two considerable portions connected and attracted to it. On the adverse, if the real length is very long, it pulls the 2 considerable portions and decreases its real length. Each unknown node calculates its position and sends this position periodically to all neighbors. So, each node has a look up table containing its position and the positions of its neighbors. The authors in [40] proposed GOSSIPY algorithm which depends on using a crew of composite mobile RFID anchors. The algorithm depends on collaboration of mobile RFID readers to share information in certain time intervals to allocate mobile unknown nodes. This algorithm consists of 3 steps: (1) gathers labels which contain the location information and floods this information across the RFID neighboring readers, (2) determines the labels information and saves it, (3) broadcasts the information of the labels to the neighboring nodes. In [41] authors proposed a distributed localization method which improves the trilateration method that depends on received signal strength. The received signal strength is a very

efficient localization technique. However, it has many drawbacks; such as, it's not suitable for many environments and it is affected by some surrounding factors such as the proportion of the length to width and the size of the surrounding. So, the distributed technique which is called a Dynamic-Circle-Expanding mechanism (DCE) overcomes the problems of trilateration algorithm. It calculates the positions of nodes via estimating the relationship among unknown nodes and anchor nodes to find the positions of unknown nodes. This algorithm is energy efficient because it finds the distance between the anchor node and unknown node via Received Signal Strength (RSS). So, there is no need for multi hops between nodes.

The Algorithm contains the following steps:

1- The unknown nodes broadcast beacon messages.
2- They receive the replay packets of anchor nodes which contains ID of each node and save the RSSI and ID of the node.
3- They wait for a period and check the number of anchor nodes. If it more than three, an error message is sent to the gateway that it hasn't enough number of anchor nodes to determine its position.
4- Convert RSSI into distance with the help of RSSI- distance model.
5- Use the DCE technique to calculate the location.
6- Send the calculated position to the gateway.

D. *Centralized localization algorithms in IOT*

In The centralized localization algorithm, it achieves the position calculations with good accuracy. However, it causes communication traffic. So, it's good for small networks. The authors in [42] proposed a method which depends on accumulating the data of beacons which comes from sensor nodes and sends it to a central server. The server combines the data transferred into the database then the data implemented on the indicator board as shown in Fig. 6.

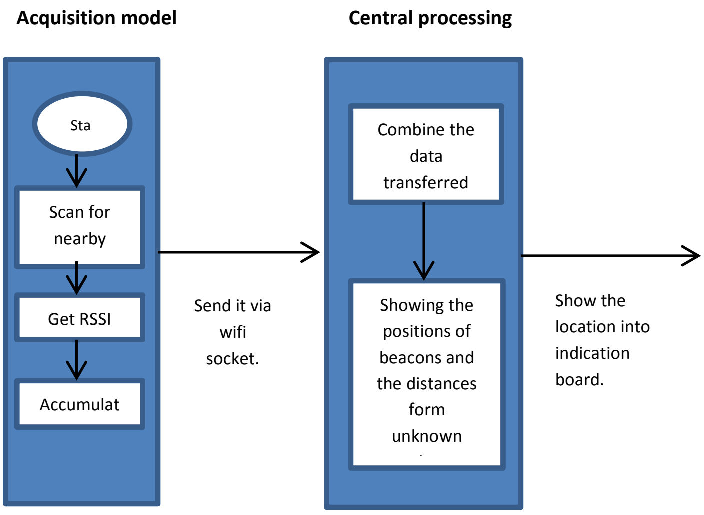

Fig.6 The proposed model in[42]

E. *Fixed anchors localization techniques in IOT*

The Fixed anchors techniques depend that all anchor nodes in the network are fixed nodes, the unknown nodes and anchor nodes. The authors in [7] proposed two algorithms which are Equal sub area based DV-hop and Equal sub area based DV-hop with RSSI. The two algorithms are derived from DV-hop algorithm. They depend on separating the whole area into small and equal sub areas, putting equal nodes in each sub-area. Then the hop size for each anchor node is calculated from anchors in the same sub-area. In the first algorithm, the position of unknown nodes is calculated from the number of hop counts (which reflect the measured distances) between them and anchor nodes in the same sub area. In the second algorithm, the positions of unknown nodes is calculated from the RSSI of the neighbor anchor nodes and from the hop count number between them and anchor nodes in the same sub-area, if they are not neighbors.

F. *Mobile anchors localization techniques in IOT*

The mobile anchors techniques depend on the mobility of anchors and its movement path. It is suitable for applications which do not use many anchor nodes. So, using one mobile anchor instead of many fixed nodes is suitable for these applications. The authors in [43] proposed recently research issues and many applications in the IoT-robotics assistance. This paper provides us with the following: (1) it presents the fundamental issues relevant with wireless communication networks, IoT-robotics assistance, computer network security, applications of robotics in scattered surrounding. (2) It presents the most hot-topics in this field. (3) It introduces the scientific tools which have been used todays. The authors in [44] proposed a new stationary path model. For localization based mobile anchor. The proposed model is called H-Curves, because it consists of individual H-Curves paths in its design as shown in Fig. 7. This model pledges that all nodes are connected to each other and able to send and receive the information. Also, this model solves the problem of collinearity. It optimizes the energy consumptions of the mobile anchor and the length of the mobile path.

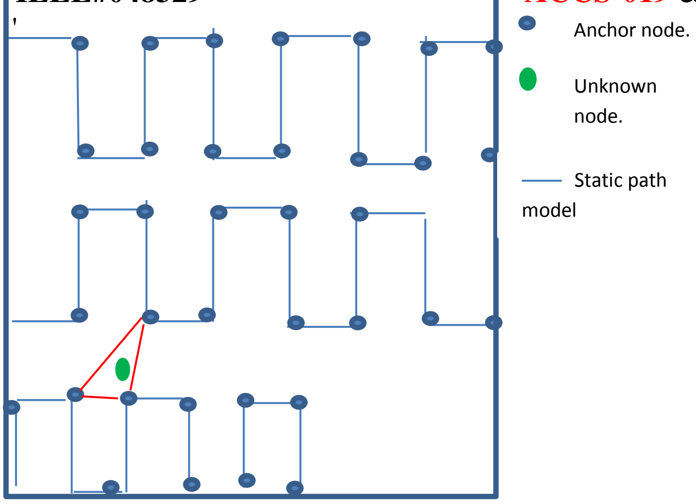

Fig.7 The proposed path mode

IV. CONCLUSION

This paper introduces the comprehensive description of different categories of localization in IoT (Range based localization, Range free localization, fixed anchors, mobile anchors, distributes localization and centralized localization) from different views. It also presented the strong points and weak points of each technique.

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