New Geometric Geolocalization Method for Tracking Patients in Medical Environments

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***Abstract*— The geolocalization is a technique which assures the determination of the geographical positions of individuals through their mobile equipments or elements equipped with a specific device. It has received research interest due to the success of the emerging wireless sensor network technology. To achieve some applications, such as environmental monitoring, military surveillance and disaster relief, node localization is fundamental and essential. Moreover, the availability of location information can enable a myriad of applications such as, intrusion detection, inventory management, road traffic monitoring, reconnaissance, health monitoring and surveillance, in order to insure an intervention in the suitable time and place. There are different methods of geolocalization able of resolving this problem. All these approaches are characterized by their own disadvantages and advantages, making them adapted to various applications. So, we always try to improve them by proposing a new approach with the aim of having a better precision and a more accurate positioning. This paper presents a new geometric method which can improve the poor locating performance of the typical Distance Vector-Hop (DV-Hop) algorithm, without increasing the hardware cost for sensors. We propose this approach to ensure the monitoring and the positioning of patients in medical environments for indoor use and to achieve a good compromise between positioning accuracy, computation complexity and energy cost. The influences of anchors on the algorithm and simulation results are also explored in this paper.**

Keywords-Geolocalization; wireless sensor network; precision; Distance Vector–Hop; medical environments.

I. INTRODUCTION

Wireless Sensor Networks (WSN) represent a very interesting domain of development that has become a new research focus in communication and computer fields [1]. They are tremendously being used in different environments, in a random way, to perform various monitoring tasks such as rescue, search, target tracking, disaster relief and a number of tasks in smart environments [2]. A wireless network is composed of plenty of nodes that are deployed in the monitoring field, and that have perception, processing and communication ability [3]. Each node is capable of sensing the environment and then communicating the measured data to its neighbours, and eventually to the external users. Many applications require geographical information to work effectively. Indeed, we cannot make decisions without knowing the locations of some persons or certain objects because there are information that depends on the positions of the users like the forecasts, the meteorological observations and also the road traffic [4]. Localization capability is necessary in most WSN applications, particularly for tracking patients in medical environments. In fact, the determination of a person location means placing it in a defined environment or finding its place in a space with Cartesian coordinates. So, one of the basic challenges in the WSN is node geolocalization, which is a particular case of localization [2][5]. It is the positioning of a person or an object using geographic locations. Thus, we can distinguish between so many approaches to assure the implementation of this process. These approaches commonly aim at positioning target nodes as accurately as possible. A localization method is a set of technologies implemented and used to perform the positioning task [4]. Its performance depends on some factors, such as the system accuracy, the costs of communication and the density of nodes.

The purpose of this paper is to explain the principle and the interest of the specific localization case through geographic coordinates. The rest of the paper will be organized as follows: In the second section, we will present an overview of the geolocalization problem. A presentation of the problem in medical environments will be also cited in Section 3. Section 4 describes the basic DV-Hop algorithm. In the next section, we discuss a new geometric positioning approach based on DV-Hop algorithm. Section 6 presents the simulation results and analysis. Finally, we will conclude the paper in Section 7.

II. WIRELESS SENSOR NETWORK GEOLOCALIZATION

Many applications use a random deployment of a large number of sensors. So, the localization phase is required to realize network operation and also to exploit collected information. We must then locate all the nodes with the best possible accuracy. Just like management issues of energy consumption, the problem of localization and specifically of geolocalization seems challenging and research works should focus on the development of effective positioning methods. In fact, the geolocalization in the WSN is considered as a typical case of localization. It presents a process that ensures the positioning of an object (information, a person, etc.) on a map or a plan through its

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geographic coordinates. It is also used in order to position mobile nodes. The realization of this operation is done using a terminal capable of being located by using a Global Positioning System (GPS) receiver or through other techniques and ensuring the publication of its geographical coordinates in a differed way or in real time [5]. Saved locations can be stored inside the terminal and extracted later, or transmitted in real time towards a software platform that provides the geolocalization. Sending in real time requires a terminal equipped with a telecommunication tool which its type can be radio or satellite, allowing it to transmit the positions during regular intervals. Thus, the terminal location can be visualized in a map by a geolocation platform which is often accessible via Internet.

Geolocalization is needed today for the development. It is applicable in several levels. It allows tracking vehicles carrying people and goods and ensures their localization in real time and also the detection of problems. In fact, these are sensors with varied forms, making it possible to provide information according to geographical positions of the users. The geolocalization offers many services in different fields. For example, security services can find reinforcement in some positioning techniques. Thus, everyone is currently agreed on its important value.

Before its establishment, the WSN deployment requires a simulation phase of the used protocol to ensure a good performance. There are so many solutions for WSN positioning that can be classified according to various criteria. These methods include Amorphous [6][7], Centroid [8], DV-Hop [9] and Approximate Point In Triangulation (APIT) [10]. These techniques are simple because they respect the material and energy constraints of sensor nodes and they also provide a low cost. However, their fundamental problem is the low accuracy. Thus, the main objective of this paper is to propose a geolocalization technique for tracking patients in health care settings, ensuring high accuracy without increasing the operational cost of the network.

III. GEOLOCALIZATION IN MEDICAL ENVIRONMENTS

In the sociomedical institutions, clinics and hospitals, ensuring the security and the protection of patients, as well as safeguarding mobile equipments, has become an increasing priority. Currently, monitoring and supervision of patients is done manually in hospital by medical staff and in a regular way [11]. This process of collecting information can be problematic. In fact, the collection is not done in real time (so many times per day) and hence the staff mobilization becomes necessary during a considerable interval of time. Thus, one often tries to solve these problems while benefiting from technological advances that provide advantageous techniques of care and assistance for the patients. The WSN is used in the medical field as it allows patient monitoring at a distance and the control of human physiological data, such as heart rate and glucose level [12]. Indeed, we can attach to the patient small sensor nodes able to carry out specific tasks, such as detecting heartbeats and the control of blood pressure. In addition, video micro-sensors can be implanted under the skin in order to receive images of a body part in real time without surgery. Therefore, it will be possible to supervise the recovery of muscles or the progression of diseases. Several medical problems, such as cancer, can be then controlled. Wireless sensors permit also the detection of older people behavior, so one can intervene quickly in case of need [13]. Staff can be informed of the transmitter location and also the patient name, and as soon as a disorientated patient or a sick person suffering from senile dementia or psychic disorders leaves a protected area, staff will be warned using alert messages that can be sent via a wireless telephone, an alarm system, a pager or the call nursing system.

The sensors are used not only for the wireless monitoring of the patients, but also for the monitoring and the control of the doctors within the hospital. In addition, they can be attached to drugs and medicines to be administered, in order to decrease the probability of giving bad treatments to patients and minimizing the possibilities of side effects caused by the use of inappropriate drugs. The sensor network is effective in the medical field, as the micro-sensors provide a movement ease for the controlled and monitored subjects and also a faster identification of some symptoms to doctors. We propose through this paper to perform a collection of information in real time and in an automated manner via a WSN. Our proposal consists of presenting a global method for tracking and positioning patients in health care settings, grouping several technologies, for an indoor employment.

In the field of WSN geolocalization, we always try to guarantee a better precision with a low energy consumption and lower cost. We try then to benefit from the advantages of the various existed localization methods and we propose a new algorithm which solves the problems of the constraints satisfaction. This problem can be resolved by employing an algorithm which consists in making the combination of different techniques. Indeed, it exploits the good properties of the various methods by applying them to the problems that can be solved efficiently [14][15]. As a typical range-free algorithm [4], DV-Hop algorithm has the advantage to localize normal nodes that have less than three neighbour anchors. Many works in the literature propose schemes and improved DV-Hop methods for many purposes. Since each was developed to fulfill a different goal, they vary widely in many parameters including accuracy, cost, configurability, security, and reliability [3].

IV. DV-HOP POSITIONING ALGORITHM

Niculescu and Nath [16] have proposed the DV-Hop algorithm, which is one of the typical representatives of range-free localization algorithm. Its basic idea is that the distance between the unknown nodes and the reference nodes is expressed [17]. The algorithm implementation is comprised of three steps. First, it employs a classical distance vector exchange, so that all nodes in the network get distances, in hops, to the landmarks. Then, it estimates an average size for one hop, which is deployed as a correction to the entire network. Finally, unknown nodes compute their location by trilateration [18]. The complexity of this algorithm is higher than that of some approaches, such as Centroid [19] and Convex Position Estimation (CPE) [20], designed for normal nodes which have at least three neighbour anchors. The Centroid algorithm has a low computation cost, and does not increase the network traffic. It can also get relatively good accuracy, when the distribution of anchors is regular. However, when the distribution of anchors is not even, the estimated position derived from the Centroid algorithm will be inaccurate [21]. CPE has slightly higher localization accuracy than Centroid [3].

DV-Hop is a suitable solution for normal nodes having less than three neighbour anchors. In the first implementation step, each anchor node broadcasts an anchor to be flooded throughout the network containing the anchors location with a hop count value initialized to one. Each receiving sensor maintains the minimum hop count value. Anchors with higher hop count values are defined as the useless and ignored information. Then, the rest of anchors are flooded outward with hop count values incremented at every intermediate hop. Through this process, all nodes in the network get the minimal hop count to every anchor node. In the second step, once an anchor gets hop count value to other anchors, it estimates an average size of one hop, which is then flooded to the entire network. After receiving the hop size, the unknown nodes multiply the hop size by the hop count value to derive the estimated physical distance from the anchor. Each anchor node broadcasts its hop size to the network using controlled flooding. Unknown nodes receive the hop size information and save the first one. Meanwhile, they transmit the hop size to their neighbour nodes. This scheme ensures that most nodes receive the hop size from the anchor that has the least hops between them. In the last step, when unknown nodes get three or more distance information from anchors, the trilateral measuring method or the maximum likelihood estimation approach is used to calculate their locations [3]. The average hop size is estimated by the anchor node i using the following formula [22]:

$$HopSize_i = \frac{\sum_{j \neq i} \sqrt{(x_i - x_j)^2 + (y_i - y_j)^2}}{\sum_{j \neq i} h_{ij}} \tag{1}$$

where (x_i, y_i) and (x_j, y_j) are coordinates of anchors i and j, respectively, and h_{ij} is the hop count between the anchor nodes i and j. It is assumed that (x_u, y_u) are the location of the unknown node u, (x_i, y_i) are the known location of the ith anchor node and d_{ui} is the distance between them. Then, the coordinates of u are computed by the following formula [17]:

$$F = (C^T C)^{-1} C^T D \tag{2}$$

where $$F = \begin{bmatrix} x_u \\ y_u \end{bmatrix} \tag{3}$$

$$C = -2 \times \begin{bmatrix} x_1 - x_n & y_1 - y_n \\ \vdots & \vdots \\ x_{n-1} - x_n & y_{n-1} - y_n \end{bmatrix} \tag{4}$$

and $$D = \begin{bmatrix} d_{u1}^2 - d_{un}^2 - x_1^2 + x_n^2 - y_1^2 + y_n^2 \\ d_{u2}^2 - d_{un}^2 - x_2^2 + x_n^2 - y_2^2 + y_n^2 \\ \vdots \\ d_{u(n-1)}^2 - d_{un}^2 - x_{n-1}^2 + x_n^2 - y_{n-1}^2 + y_n^2 \end{bmatrix} \tag{5}$$

Finally, the refinement process of locations is carried out. In fact, after estimating their positions, the sensors ensure their dissemination to their neighbors. Thus, based on this information and according to the different neighborhood relations, these sensors determine again their positions which are close to their actual locations. The sensors fix then their estimated positions after a definite number of iterations. The precision of the DV-Hop algorithm is low because the average distance of one hop represents an approximate estimation and it is difficult to know the exact values of the distances separating the nodes [23]. Indeed, this algorithm exactitude varies according to the precision of these distances. The second weakness is related to the type of nodes distribution; because the more regular it is, the more results are accurate, i.e., it is not applicable for the random distributions. However, the advantage of this method is that it doesn't require additional hardware for the distances estimate and the determination of the unknown locations. This significantly reduces the economic and energetic localization cost and also it avoids the constraint imposed by Centroid and CPE (the requirement of a minimum of three neighbour anchors). Moreover, it employs a very simple algorithm that does not require too many computing and radio communication and processing operations, i.e., not much energy consumption.

V. IMPROVED DV-HOP GEOLOCALIZATION SCHEME

We propose through this paper to perform a collection of information in real time and in an automated manner via a WSN. Our proposal consists of presenting a global method for tracking and positioning patients in health care settings, grouping several technologies, for an indoor employment. In fact, one or several fixed nodes will form a backbone which is responsible for relaying the data collected by sensors that are placed on mobile patients. Fixed sensors must be organized in an efficient and robust virtual structure, whereas the other mobile nodes require being able to be adaptable to various displacements in order to broadcast the information in a proper manner. It is essential to use mobile anchors that will communicate with the other nodes to simplify the coordinates attribution to the sensors attached to patients. Generally, the existence of several reference nodes is compulsory to have a good accuracy and certainty in the determination of the positions but practically this is difficult because of the rising cost of these anchors. In the wireless sensors network, anchors are necessary for the localization of nodes in a global coordinates system. These are ordinary nodes that know their coordinates a priori. These anchors, which play a very important role, can be affixed or carried by people working at the hospital (doctors, nurses, etc.) and they also can be inserted in medical equipments. Figure 1 shows this principle.

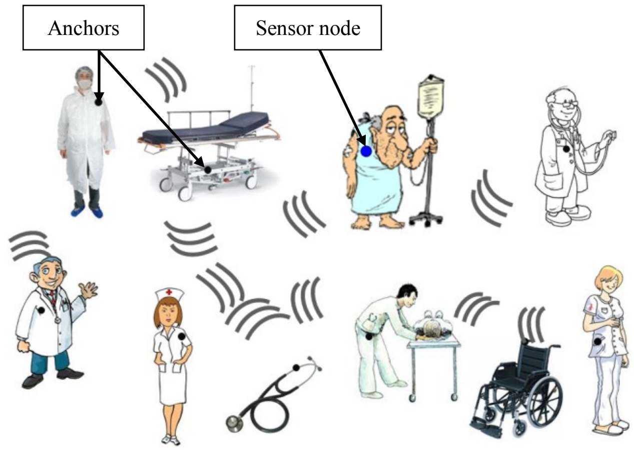

Figure 1. Positioning method in medical environments

Since their positions change over time, it is necessary to update them. To do this, we propose to employ Radio Frequency Identification (RFID) technology. In fact, it is based on remote research, extraction and storage of data, which requires the presence of an RFID reader, a tag and a database. It designates the recognition of objects and even people by radiofrequency transmission [24]. An RFID system includes a reader (interrogator) that transmits a signal to a radio tag or more placed in its reading field depending on a given frequency. This is a transceiver which provides the communication with the corresponding tag by electromagnetic waves. This latter is designed to receive a radio signal and then to return immediately another response signal containing relevant information. To perform data exchange, a dialogue is established between these two components using a communication protocol. Tags are small objects that can be incorporated into products or implanted in living beings like animals or the human body. They include an antenna linked to an electronic chip and this antenna allows them responding to requests sent from the reader. RFID system is illustrated in Figure 2.

Figure 2. RFID system (reader+tag)

Indeed, a set of RFID readers that are equipped with several types of antennas are placed in order to cover the entire desired area. This zone is then subdivided into cells with varied surfaces according to the power of the deployed readers and their number. If a person equipped with RFID tag is located in these zones, it will be possible that the system calculates its position based on the number of readers detecting the tag, and it will be able to deduce the approximate location of the individual on the basis of the established cutting diagram [25]. However, this technique remains very approximate in real time and its exactitude will only specify the hallway or the part where the person exists. This geolocalization technique is especially employed in hospitals as RFID readers can be positioned in the building doors in order to indicate if a person, equipped with a tag, is going through them. Then, we will choose to use powerful readers and passive tags, because they are characterized by a low cost and a small size and their functional lifetime is important. Each tag will be associated with an anchor and each time it will be awake by a reader, a dialogue will be established and data will be exchanged. An update of this anchor position will be made and we will be able to use it in order to geolocate the patients. Figure 3 shows this principle.

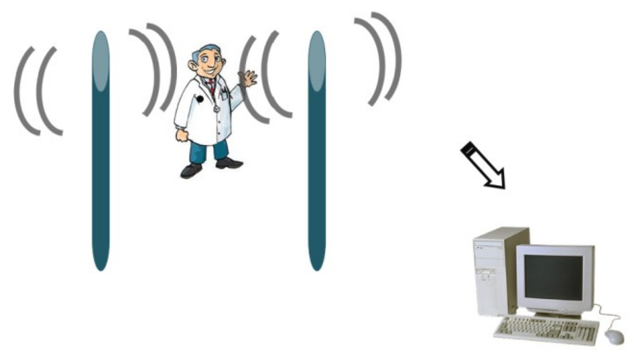

Figure 3. Data transmission procedure

In the field of WSN geolocalization, we always try to guarantee a better precision with a low energy consumption and lower cost. We try then to benefit from the advantages of the various existed positioning methods and we propose a new algorithm which solves the problems of the constraints satisfaction. This algorithm must find the most economical path and ensure a prolongation of the nodes lifetime [26]. Our approach consists in proposing an algorithm based on DV-Hop which is considered as a typical example of the category of methods that are at once distributed, anchor-based and range-free [4]. Indeed, the DV-Hop method is not precise enough [22]. Thus, the localization accuracy must be further improved. Then, we seek to guarantee the reduction of our algorithm cost and to ensure assessment of the network load caused by the protocol which is associated with this algorithm. Consequently, we propose a new algorithm in order to realize a satisfactory compromise between location accuracy and computation complexity. Our improved DV-Hop (Intersect DV-Hop) consists of four steps. The first two steps are the same as the DV-Hop method, while others are specific to our proposal.

In step one, all nodes in the network get the minimal hop number to every anchor. In step two, after obtaining the hop-size, anchor node broadcasts its hop-size to network as a correction. In fact, at this point, each normal node N_x knows its $hop_{i,Nx}$, which represents the minimal hop number from N_x to A_i. Each anchor A_i has also obtained $hop_{i,k}$, which is the minimal hop number to any other anchor A_k. So, A_i can calculate its average distance per hop dhp_i, and then broadcasts dhp_i through the network. After receiving dhp_i, the normal node N_x can use (6) to get $d_{i,Nx}$, which is the approximate distance between each anchor A_i and N_x.

$$d_{i,Nx} = hop_{i,Nx} \times dhp_i, \; i = 1,2....m \qquad (6)$$

Our aim in the third step is to determine the closest three anchors to the normal node N_x by comparing the approximate distances obtained at the end of the previous step. The node is then located in the coverage area of cells of these anchors. Let $A_1(x, y)$, A_2 (x_1, y_1) and $A_3(x_2, y_2)$ be these three beacons, knowing that $d_{1,Nx} < d_{2,Nx} < d_{3,Nx}$.

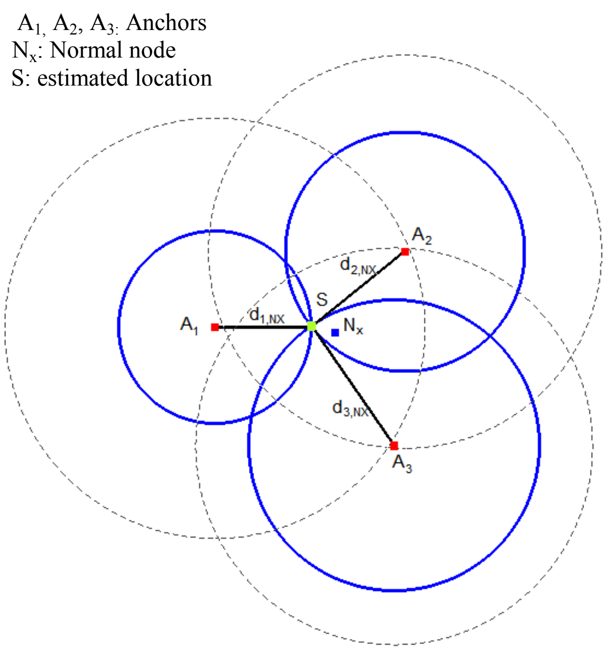

Figure 4. Principle of Intersect DV-Hop

We assume that the communication ranges of anchors are all the same as displayed by the circles of Figure 4. The normal node N_x locates in the overlapping communication region of A_1 A_2 A_3. We determine then at the last step the intersection of the three circles of Figure 4 that their centers are respectively A_1, A_2 and A_3 and their radius are respectively $d_{1,Nx}$,$d_{2,Nx}$ and $d_{3,Nx}$. Finally we calculate S, which is the final estimated position of N_x. If the coordinates of three anchors A_1 A_2 A_3 are (x, y), (x_1, y_1), and (x_2, y_2) and in the case where A_1 is considered as the origin of the coordinates system, the cross point S of the three circles can then be calculated as displayed by (7). Finally, S becomes N_x's estimated position which is the result of our proposed method.

$$\begin{cases} x_S = \dfrac{x_1^2 + d_{1,Nx}^2 - d_{2,Nx}^2}{2x_1} \\ y_S = \dfrac{x_2^2 + y_2^2 + d_{1,Nx}^2 - d_{3,Nx}^2 - 2x_S x_2}{2y_2} \end{cases} \qquad (7)$$

VI. Simulation Results and Analysis

In this section, simulation results are presented and analyzed. The obtained results during the evaluation of the DV-Hop algorithm and the suggested improvement will be presented. To achieve our simulations and to study our approach performance, we have developed the Matlab software. The sensor network that we have simulated comprises 100 sensors (ordinary nodes and anchors) which are dispersed in a zone with the fixed size of 100 X 100 m^2 (Figure 5). They are deployed according to a random distribution in order to test the performances of the proposed algorithm under conditions more similar to those real. The random placement of the anchors allows measuring our approach exactitude in a more realistic context.

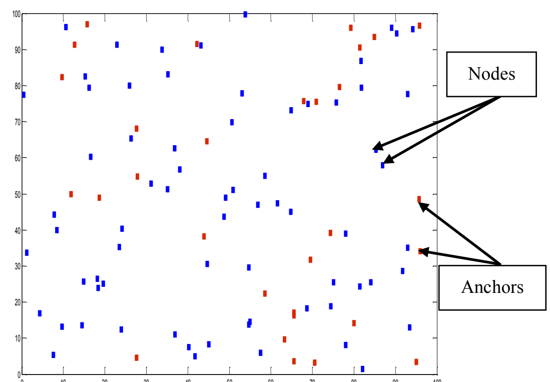

Figure 5. Random distribution of the sensors

The two most important parameters in our work are the error and the precision of localization. According to the various research studies already realized concerning the anchors influence on positioning, it was noted that the exactitude increases with the increase of anchors number. Therefore, we are interested in evaluating the variation of the precision and the error according to the number of employed anchors. The radio range of the sensors (R) indicates the communication range of nodes, which generally varies between 10 and 100 meters. Assuming the absence of the obstacles and the multiple paths, the antennas are considered to be ideal and the nodes keep the same radio range modulated by a circle that surrounds each sensor.

In our work, R is set to 50 meters. To quantify the accuracy of a geolocalization method, we consider the localization error it makes. Even for the best techniques, an inevitable error is associated with each one of them. In our simulations, it is regarded as the distance separating the real node position and that calculated using the geolocalization technique. The more this distance is considerable, the less the system is accurate. So, we consider the metric geolocation error (expressed in radio range percentage) for evaluating the performance of geolocalization accuracy. Geolocation error is defined as distance (estimated location, true location)/NB×100%. Here, distance (estimated location, true location) is the distance between a node's estimated position and its true position and NB is the number of sensors.

An anchor ratio is defined as the ratio of the number of anchors on the total number of nodes which is set to 100. In other words, it is the ratio of anchors among the network nodes. These ratios vary from 3% to 60%. We have simulated four algorithms: our Intersect DV-Hop algorithm and three existing algorithms, which are DV-Hop, Checkout DV-Hop [8] and Mid-Perpendicular algorithm [3].

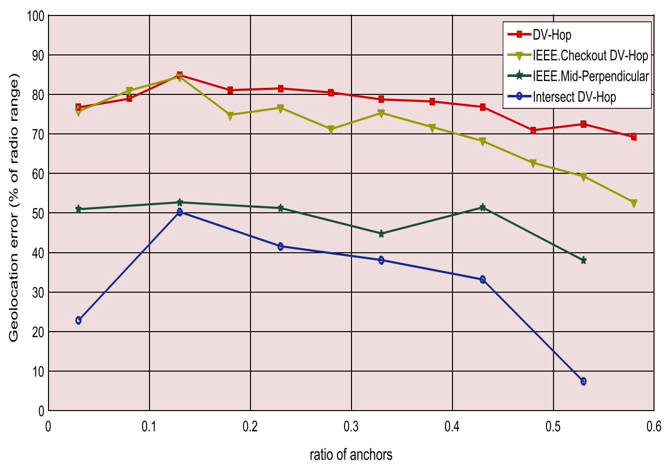

Figure 6. Geolocation error

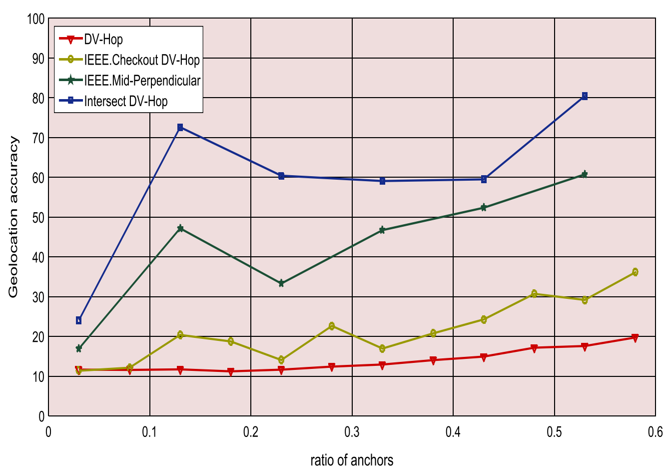

Figure 7. Geolocation accuracy

Through Figure 6, we can see that the average error of our algorithm is lower than that of other techniques. Then, we can conclude that the new method achieve better performance than Mid-Perpendicular, Checkout DV-Hop and DV-Hop. This idea is confirmed and also shown in Figure 7, which presents the positioning accuracy depending on ratio of anchor nodes for the four algorithms. We can notice that increasing the number of anchors guarantee the reduction of the localization error. For the same ratio of anchor nodes, position error is smaller when our improved method is applied in the same WSN environment than the DV-Hop algorithm and the two others. For example, with 10 anchor nodes (10%), Intersect DV-Hop has an average error of about 42% R, while the others are more than 51% R. When the number of used anchors increases to 50, the error decreases and becomes 17%. In this case, the geolocalization errors of the other algorithms are approximately more than 42%. It is clear from our simulations that the improvement provided by this new method is effective and that our algorithm is more accurate than the others, already mentioned. The Intersect DV-Hop performance exceeds the original DV-Hop location algorithm performance from our simulations results.

VII. CONCLUSION AND FUTURE WORKS

In this paper, we proposed a new geolocalization algorithm for wireless sensor networks based on the DV-Hop algorithm. It was shown from the simulation results that our proposed algorithm can improve location accuracy than the original DV-Hop, Checkout DV-Hop and Mid-Perpendicular. The proposed method adopts the distance reliability information to improve the convergence rate and the location accuracy using a geometric approach and adaptive iterative process. We have to find a solution to fulfill this paper objective, which consists in proposing a method of tracking and monitoring patients in order to determine their geographic locations inside a medical environment. Our suggested approach is mainly based on the improvement of the DV-Hop performance with the use of RFID technique that seems very beneficial in this case. It was shown that our contribution is interesting and that it guarantees a good improvement in the geolocalization accuracy. To accomplish our work, we aim to test our solution on the practical level. In fact, this test will put it under more real conditions and consequently we can refine the searched locations. Finally, we also aim to propose a strategy that guarantees the obtaining of solutions in real time once the problem is disturbed by the failures of some nodes.

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