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A Genetic–based Localization Algorithm for Elderly People in Smart Cities

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ABSTRACT
In the context of aging populations, maintaining persons at home represents one of the solutions seriously considered. In France, one person among three will be over 60 years in 2050, against one among five in 2005. Many works have investigated the monitoring of elderly peoples inside the institutions or homes (i.e. smart homes) but less in the outside. In this work, we investigate the outdoor monitoring for elderly in the context of smart cities. For this purpose, we focus our research on the problem of localizing the persons when they are outside. We propose an efficient algorithm in terms of rapidity, energy-saving, accuracy and cost. We improve the DV-Hop algorithm by using a genetic algorithm in the anchor selection step to efficiently recognize the location of the person and decrease the error rate.

Keywords
Localization; Elderly; Monitoring; Smart Cities; DV-Hop; Genetic algorithms; Prediction.

1. INTRODUCTION
Compared to the monitoring of persons in smart homes, in smart cities, the scope of the citizens' activities is large and not limited the set of basic activities of daily living (known as BADL or ADL). Intelligent cities should respond to the needs of the aging population in terms of healthcare, social participation, community support services, leisure and culture in order to guarantee a more friendly and secure environment for this vulnerable category.

In the aim of making the best effort for an independent live style outside the home, the objective is to enable the city to provide an outside persons' monitoring while preserving the ability to perform leisure activities such as sport, shopping, communication with others, etc. Hence, older people and disabled persons can rely on personalized and reliable services that permit a life of quasi-independency with the feeling of being safe thanks to the assistance of appropriate infrastructures that, for instance, can potentially trigger a call for an automatic or human assistance.

In this work, we investigate one of the main issues in supervision and assistance systems for elderly, which is the outside location. Estimating the location outside represents a complex task. Our objective is to ensure a localization service for elderly which should be provided in time and when it's necessary.

Recent research used several protocols and algorithms in order to detect the location of persons, objects, etc. Used approaches can be classified into two categories: range-based and range-free algorithms. Range-based algorithms, such as *Received Signal Strength Indicator* (RSSI) [18], *Time of Arrival* (TOA) [16] and *Time Difference of Arrival* (TDOA) [17], require additional hardware and important cost. On the one hand, range-free algorithms, such as *Centroid*, *Distance Vector-Hop* algorithm (DV-Hop) [14] and APIT [19], are more economical and cost effective. They do not require information of unknown nodes, however, their results are always less accurate than range-bases. In this paper, we focus on the range-free category and aim to improve its accuracy.

We consider the DV-Hop and genetic algorithms, in a smart cities context, in order to consider the mobility of elderly and provide them a continuous monitoring and assistance. DV-Hop is a location algorithm that enables nodes to learn their location without the need of range estimation. Furthermore, it is suitable for sensor positioning due to its cost effectiveness.

DV-Hop algorithm is based on the estimation of the unknown node's location based on the anchor location. Hence, we focus on the improvement of the most important step which is the choice of the anchor node. To do so, propose to investigate the selection of anchors using genetic algorithms to improve the quality of estimation and increase the accuracy of our algorithm.

The particle swarm optimization and fuzzy logic have been recently used with success to evaluate genetic algorithms [15].

The paper is organized as follows. In section II, we present the related works. In section III, services of smart cities are described. Section IV is devoted to the wireless body area sensor in the context of a smart city. In section V, we discuss the localization algorithm and focus on the DV-Hop one. We describe our proposed algorithm and improvements used to predict the mobility of the elderly outside. Simulations and results, that illustrate the provided model, are described in Section VII.

2. RELATED WORK

Many recent researches have been conducted in smart environments and spaces seen the widespread integration of connected objects (or things) that can sense, share information and provide a wide range of services in many areas. In this section, we explore related researches concerned smart cities, elderly needs and algorithms of localization. Skouby *et al.* [10] highlighted the needs of creating new services in cities in order to tackle the aging population challenges. New cities should be aware about the urban demographics especially with the increasing number of aging people in the future: from 2012, the number of elderly increased to almost 810 millions and it is expected that this number will be exceed the double in 2050. Consequently, it is necessity that the smart environments offer a better life for this population. In this context, monitoring the elderly in a smart city involves many challenges such as wellbeing, mobility, healthcare and safety. Chen *et al.* [2], combine wireless sensor networks (WSN) and computer networks to create a multilayer architecture for the smart city based on semantic Web technology. The work considers the heterogeneity of data detected from the city and proposes the *Dempster Shafer* theory. The proposition is used to achieve a reasoning and recognition of data in a multilevel smart city architecture. Jin *et al.* [6], present a framework information to develop a smart city through the Internet of Thing (IoT). The authors provide the different building blocks of a smart city infrastructure based on various domains such as cloud-centric and data-centric IoT and show the benefits of using IoT to handle a wide variety of information.

In [4], a people-centric platform is proposed to consider the challenges of aged persons in the city such as chronic disease, user's limitation of mobility and hearing or visual impairments. For this purpose, the authors propose a health and emergency care framework to monitor the health state of the disable and aging people. For the analysis of data collected by sensors, the fuzzy logic theory was applied in order to efficiently recognize the health condition of the person. Chunping proposes in [11] a new localization algorithm based on DV-Hop in the context of the wireless sensor networks. The work investigates the crucial problem of localizing unknown nodes in the wireless sensor network and proposes a new distance vector mass-spring model localization algorithm (DV-MSO). The work concludes that the DV-Hop algorithm, with a modification of the hop count, achieves a best accuracy in the localization results. Hence the new algorithm of DV-Hop, based on DV-MSO, restraints the localization error of DV-Hop and improves the localization of unknown node with high accuracy.

3. SMART CITIES

In order to ensure an efficient supervision in the smart city, we propose to link all the components forming the surrounding environment of the supervised person. Such component can be a smart home, smart theater, smart library, smart garden, etc. The objective is to take benefits from the available technologies to fulfill the person's needs and offer him an independent living and increases his self-confidence. The diversity and the variety of data collected from the smart city using IoT technologies focuses on all the aspects of collecting, processing and interpreting data.

3.1 Advantages of the Internet of Things

IoT can collect many types of data related to mobility, health service, energy usage and safety while being in the city. The data are used to ensure a connection between the city and the monitoring center to provide the necessary interventions in emergency cases. IoT is used to guarantee the collection of heterogeneous data and the conversion of it to a common format to ensure the interoperability. Data processing, such as extraction, analysis and fusion of collected data is ensured by using an a set of smart and efficient methods. IoT provides data interpretation based on the representation, reasoning and integration of data for the monitoring center. It is an important step that enables the prediction and recognition of abnormal events regarding the supervised person.

3.2 Protocols of the Internet of Things

IoT concept dominates the technologies used in smart environments and involves handling heterogeneous data. Existing protocols used in IoT involve various services and devices that make them suitable for a large number of applications. In a smart environment, data can be stored and processed in the cloud, because cloud computing simplifies uses by allowing to overcome the constraints of traditional computer tools (installation and updating of software, storage, data portability ...). Cloud computing also offers more elasticity and agility because it allows faster access to IT resources (server, storage or bandwidth) via a simple web portal and thus without investing in additional hardware equipment. Cloud storage, data routing (using wireless and wired means) and security are required. A wide variety of protocols are used in this area such as: Bluetooth Low Energy (BLE), ZigBee with different profiles, Z-Wave, and 6LowPAN. ZigBee is based on the IEEE 802.15.4 protocol while Z-Wave is a low-power RF communications technology that is primarily designed for home automation for products such as lamp controllers and sensors. 6LowPAN (IPv6 Low-power wireless Personal Area Network) is a key IP based technology. Finally, SNMP (Simple Network Management Protocol) is mainly used for supervising and managing the collections of sensor nodes.

4. WIRELESS BODY AREA NETWORKS IN SMART CITIES

To monitor correctly and dynamically the state of health of our patient outside it's necessary to talk the wireless body area networks (WBAN), in the aim to offer them an independent life.

So in this paper we propose to use a wireless body area network. WBAN[7] technology used for the health monitoring enable us to place a sensor in the body of the person in order to follow the health state like heart rate, level of glucose, temperature of the body, etc.

This type of wireless allows our elderly to move independently outside with a great health security. In the recent years, there are several protocols to aggregate data from the body to the sink and subsequently to the health surveillance center.

4.1 The use of WBAN

It is a smart wireless consists of limited number of nodes deployed in the body of the person. Each sensor concerned a specific disease such as: ECG sensor, glucose sensor, diabetes and cardiovascular sensor more that a sink node responsible to collect all this health data. Thereafter the transmission to the monitoring center is required from the sink.

This type of the wireless help us to monitor the state of health of elderly also helps the person to move with liberty in the city (outside the home) and always stay controlled by their doctor and nurse.

4.2 WBAN Protocol

WBAN used to monitor the health care of the people for this purpose in a recent proposition, and authors focus on this protocol. Latre *et al.* [7] propose a secure low delay protocol, [9] propose a self–organization protocol for BAN, in addition Nadeem *et al.* [8] propose a new protocol called Stable Increased-Throughput Multi-hop Protocol for Link Efficiency in Wireless Body Area Networks. These previous protocols are a routing protocol used to detect dynamically the evolution of the state of health of the elderly [increasing, decreasing or stable] in order to intervene when the situation of the person require it.

5. LOCALIZATION OF THE PEOPLE

To achieve the complete freedom of the elderly and to practice all outside daily activities such as shopping, sport, walking, etc. In this paper, we focus on the crucial challenge to monitor the move and the localization of the person dynamically and in the real time. In this context, we propose an efficient algorithm to detect the localization of the person based on many criteria linked to the health state such as Forgetting the path/ trajectory, Medication time, fall, Vertigo. All this criteria require an immediate intervention therefore the necessity of a precise identification of person location at time.

The current known location systems are GPS (Global Positioning System) and GSM (Global System for Mobile communications). However, these solutions do not meet the needs of maintaining older people in particular positional accuracy (about 10 meters offset). Today's challenge is to provide a locating system such as "outside" with more accuracy. In other words, the new system in question does not depend on GPS or GSM. In addition, the economic requirement is another important factor to design the kind of system. Therefore, it is expected an embedded system with a minimum cost.

Facing with various constraints such as real-time location, price optimization and energy, computing resource management (storage, processor, etc.), the bandwidth of the communication, management mobility, conflict management, there's no efficient algorithm. However, to solve these problems, research has produced solutions more optimized and efficient.

Two categories of localization algorithms have been defined: centralized and distributed.

For centralized techniques, all nodes in the network refer to a base station where all the computation is required. The multidimensional scaling (MDS-Map) and Semi-definite programming (SDP) are two types of treatment usually used in such cases.

To ensure the independence of nodes and avoid these centralized calculations, distributed algorithms have been proposed. Generally, the location is performed by measuring the strength of Received Signal Indicator (RSSI) of the anchors located at known positions.

But this method may be inaccurate in some circumstances (mobility, moving, etc.).

Thus, some works use of other mechanisms such as Arrival Time Difference (TDoA) based on ultrasound or audible frequency; these systems have proven accurate location sight but require additional constraints to correct wrong data received. Another device is the Angle Of Arrival (AoA) allowing the angular positioning of the sensors.

These methods are called "Range-based", they can attain an excellent resolution. But more of their dependencies to some unrealistic assumptions about the spread of the signal (if the environment changes), they still require special and expensive equipment. Consequently, localization algorithms called "Range-free" have been set up as an alternative. First, these algorithms based tags are a distributed algorithm they locate the nodes in the coordinate system of tags. They use different methodologies such as distribution, limiting the edge, the gradient and APIT. These algorithms are based on the number of hops (for example the DV-Hop, DV-distance, etc.).

Despite the best feature found in the Range-free algorithm such as rapidity, low cost of implementation and not require any special equipment, it is still limited view point the accuracy and certainty about the detection of the location. For this purpose, we think to improve the precision of the elderly location by using the genetic algorithm in the anchors selection phase in order to increase the performance of the DV-Hop algorithm (accuracy of the localization).

5.1 DV-Hop Algorithm

Is a location algorithm range-free type the highlight is the ability to calculate the position from simple deductions? One of the advantages of this family does not need complex tools to process information.

The method of DV-Hop localization is inspired by distance vector routing protocols to provide an estimate of the mobile position based on the number of hops [14].

Each anchor here is responsible for transmitting a frame containing its position and a field dedicated to count jumps. On receipt of this message, all nodes decide to retransmit or not by comparing the number of hops to the anchor contained in the frame to information stored in memory. If hop-Count is less than the memory contents, the data is updated, the field of the frame is incremented and the retransmitted frame.

Once all the tags have retrieved the position and the number of hops separating them from their homologous, they calculate an average distance of each anchor node (hop-size) with the following formula:

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

Where (x_i, y_i), (x_j, y_j) are the coordinates of the anchor i and the anchor j, h_{ij} is the hop count between anchor i and anchor j.

Then, each node broadcasts the information with its hop-size to the network through the use of controlled flooding.

The unknown nodes receive information hop-size and keep the first. Simultaneously, they transmit the hop-size their neighboring nodes. After all unknown nodes have received the hop-size of anchor nodes that have the least breaks them, they calculate the distance d_i to the anchor nodes based on two factors the hop-size and the minimum number of hop.The formula is as follows:

$$d_i = h_{id} \times HopSize_i \quad (2)$$

In the third step, the unknown nodes calculated their position according to the distance from each anchor node which is obtained in the second step. The representation of anchor i coordinates are (xi, yi) and (x, y) are the unknown node coordinates, the following formula shows the distance of each node relative to the anchor node:

$$\begin{cases} (x - x_1)^2 + (y - y_1)^2 = d_1^2 \\ (x - x_2)^2 + (y - y_2)^2 = d_2^2 \\ \dots\dots\dots\dots\dots\dots \\ \dots\dots\dots\dots\dots\dots \\ (x - x_n)^2 + (y - y_n)^2 = d_n^2 \end{cases} \quad (3)$$

The above formula can be presented as linear equation AX = B, where

$$X = \begin{pmatrix} x \\ y \end{pmatrix}, \quad A = 2\begin{bmatrix} x_n - x_1 & y_n - y_1 \\ x_n - x_2 & y_n - y_2 \\ . & . \\ . & . \\ x_n - x_{n-1} & y_n - y_{n-1} \end{bmatrix} \quad (4)$$

$$B = \begin{bmatrix} d_1^2 - d_n^2 + x_n^2 - x_1^2 + y_n^2 - y_1^2 \\ d_2^2 - d_n^2 + x_n^2 - x_2^2 + y_n^2 - y_2^2 \\ \dots\dots\dots\dots\dots\dots \\ \dots\dots\dots\dots\dots\dots \\ d_{n-1}^2 - d_n^2 + x_n^2 - x_{n-1}^2 + y_n^2 - y_{n-1}^2 \end{bmatrix} \quad (5)$$

The position of the unknown node is obtained using the least squares method, which may be expressed as follows:

$$X = (A^T A)^{-1} A^T B \quad (6)$$

5.2 DV-Hop based on Genetic Algorithm

Genetic algorithms (GA) are stochastic search methods inspired from the natural biological evolution. GA operate on a population of potential solutions by applying the principle of *survival of the fittest* to determine progressively a better approximations to a given objective [5].

Genetic algorithm models operate like natural processes such as selection, recombination and mutation. Figure 1 shows the structure of a simple genetic algorithm.

In each new generation, the GA performs the following process. A new set of approximations is created after a selection of individuals based on their level of fitness to the problem domain. Individuals are then reproduced together using operators inspired from natural genetics. The resulting population of individuals is better suited to the environment than the initial individuals that they were created from, which is similar to a natural adaptation.

Genetic algorithms work on populations of individuals instead of individual. At the beginning of the computation a number of individuals (the population) are randomly initialized.

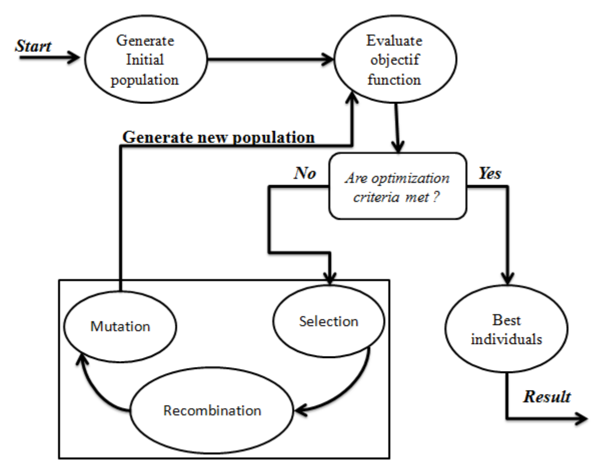

Figure 1. The Principle of the genetic algorithm.

The objective function is then evaluated for these individuals. The first/initial generation is produced. If the optimization criterion is not satisfied, the creation of a new generation starts. Individuals are selected according to their fitness for the production of offspring. Parents are recombined to produce offspring. All offspring will be transferred with a certain probability (mutation probability) this operator allows to introduce the novelty of the population.

The fitness of the offspring is then computed. The offspring are inserted into the population replacing the parents and producing a new generation. This cycle is then performed until the optimization criterion is achieved. Such a single population genetic algorithm is powerful and performs well on a wide variety of problems.

Suppose that there are $n + k$ nodes in a sensor network, which includes n anchor nodes, whose locations are known, and k unknown nodes whose locations are unknown. The coordinates of anchor node is (x_i,y_i), (i=1,2….n) and the coordinate of unknown node is(x,y) According to the second phase of DV-Hop According to Eq. (3), we get the distance di between an unknown node and the anchor nodes i, (i=1,2…..n).

Because the distance is an estimated value, so there must be an error. Therefore, we proposed an improved DV-Hop based on GA to minimize the error of localization problem in WSN, and the localization problem can be formulated as:

The objective function:

$$F(x,y) = Min\left(\sum_{i=1,\ldots,n}\left|(x-x_i)^2+(y-y_i)^2-d_i^2\right|\right) \quad (7)$$

The fitness function as follows:

$$fitness(x,y) = \frac{\delta}{F(x,y)} \qquad (8)$$

Where δ is a positive real coefficient.

The general steps of our proposed algorithm DV-Hop based on GA are summarized as follows:

Table 1. Pseudo-code of the DV-Hop based on GA.

Step1	Calculate the minimum hop-count value from each node to each anchor node;
Step2	According to Eq. (1) estimate the average size for one hop of each anchor node.
Step3	According to Eq. (2) each unknown node estimates the distance to the anchor node using the minimum hop-count value and the average size for one hop.
Step 4	Determine the population feasible region of Each unknown node and generate an initial population in the feasible region;
Step 5	Evaluate the fitness of each individual.
Step6	Three genetic operations (crossover, mutation, and selection) are performed to generate the next generation.
This algorithm is repeated till some stopping criterion is met.	

6. SIMULATION AND RESULTS

In order to evaluate the location performance of DV-Hop based on AG, we conducted a set of experimental simulations using the MATLAB environment.
Each node in the network represents one person (elderly) who evolves in the city. We propose that each anchor node can presented bya power pole or a nurse. We can also classify people according to their autonomy in the sense that people with more independency (more autonomous in their life) can take the role of an anchor node.

The experiment region is a city presented with a square area with the fixed size of 1000 m * 1000 m in all the experiments. The structure of our proposed city is composed of a Theater, Library, Cafeteria, Pharmacy, Garden, Gym, Restaurant, Shopping mall and a department consisting of k smart home (H_1,. ., H_k). Our smart city is also staffed by k number of elderly equipped by WBANs and n number of anchor nodes.
The blue nodes represent the elderly residents of the city whose locations are unknown and the red node represent the anchor node whose locations are known (Figure 2).

To evaluate the performance of the DV-Hop based on AG we first initialize the number of nodes and the number of anchors.

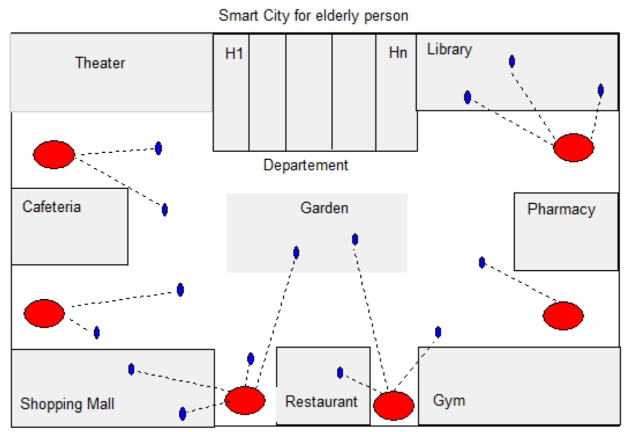

Figure 2. Architecture of our smart city.

We perform the results of the localization using 30 anchor nodes and 10 people (unknown node). Each node is linked to the closest anchor as shown in Figure 2 and dynamically updated when the location of the unknown node has changed and subsequently the choice of the new closer anchors should be carried.

Firstly, we study the error accuracy of the localization of each unknown node.

In this context, many emergency situations require an accurate prediction of the location such as follows.
-A decrease of the health state.
-An elderly who loose his way/path/ trajectory.
-A medication intake on time.
-A risky or unexpected event like falling, vertigo, etc.

Therefore, in order to evaluate the performance of our localization algorithm we evaluate the error of the location using the following formula.

$$Error = \sqrt{(x_p - x_i)^2 + (y_p + y_i)^2} \qquad (9)$$

Where x_p and y_p are the predicted coordinates of the unknown node and x_i; y_i are the actual coordinates of the unknown node i.
We evaluate the error rate compared to the number of generations of GA. Figure 3 shows that the error rate decreases rapidly from 0.1 to 0.03 errors. Thereafter, it decreases to 0.01 in nearly the 2000th generation.

The simulations of our proposed DV-Hop algorithm based on AG reveals a high accuracy with an error of 0.0185.

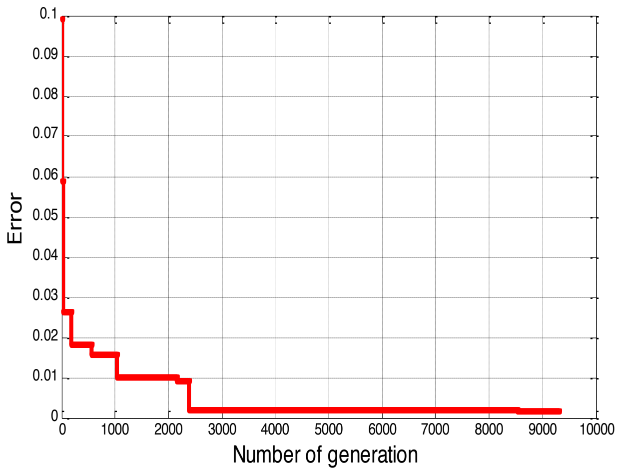

Figure 3. Regression of the error according to the number of generations.

In order to assess the performance of our location algorithm we compare the error localization of our DV-Hop based on AG and the classic DV-Hop algorithm. Table 2 presents the results of this comparison.

Table 2. Comparison of the prediction error of the localization between the classic DV-Hop and the DV-Hop based on GA.

Algorithm	Classic DV-Hop	DV-Hop based on GA
Error	1.1974	0.0185

The result shows clearly the improvement of the performance and the accuracy of the DV-Hop based on AG. The location error of the classic DV-Hop is 1.1974 against 0.0185 for the DV-Hop based on AG as mentioned before.

It is worth noting that the number of anchors has an effect on the accuracy of the localization as shown in Figure 4. Indeed, we can observe that when the number of anchor nodes increase, the error of prediction significantly decreases.

Hence, to offer an accurate location it is necessary to implement an important number of anchor nodes with a careful attention in selecting the number of anchors to meet the targeted performance and improve the accuracy.

7. CONCLUSION

Seen the growing number of aging population, it becomes necessary appropriate to propose a smart environment that provide required needs for this vulnerable category of persons either inside a home or in the outside. Elderly and dependent persons require more attention and interest especially in monitoring their activities and actions outside the home where the risk can increase.

In this paper, we were interested to a crucial problem in smart environments that is the outside monitoring with the ability of localizing persons when it is required, for instance in emergency cases. We took advantage of the Internet of Thing (IoT) paradigm for collecting the heterogeneous data that are broadcasted in the city and considered the Wireless Body Area Networks (WBAN) to monitor the health state of the person. To consider the monitoring of the person's mobility, we improved the DV-Hop algorithm using the genetic algorithm in the selection of the anchors.

The results confirm that our proposed model provides a better result when compared to the classic DV-Hop. We showed that the prediction of the DV-Hop based on GA is very significant (provide a negligible rate of error) . Consequently, the proposed model becomes suitable for health professionals to efficiently monitor the elderly outside and can provide assistance, with a great confidence, in emergency situations.

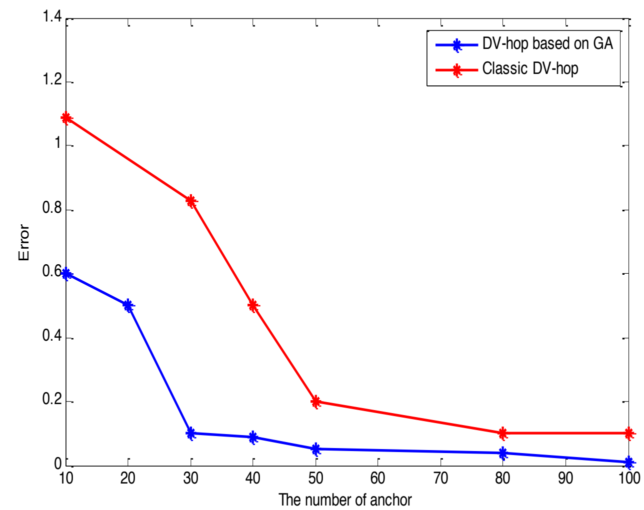

Figure 4. Error rate based on the number of anchors between classic DV-Hop and DV-Hop based on GA.

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