# Distance Based Energy Optimization through Improved Fitness Function of Genetic Algorithm in Wireless Sensor Network

**Muhammad Aamir PANHWAR[1]*, ZhongLiang DENG[1], Sijjad Ali KHUHRO[2], Dil Nawaz HAKRO[3]**

[1] School of Electronic Engineering, Beijing University of Posts and Telecommunications, Beijing, 100876, China
maamirpanhwar@gmail.com[1] (**Corresponding author*), dengzhl@bupt.edu.cn[2]

[2] University of Science and Technology of China, Anhui, Hefei, 230026, China
Sijjadali786@mail.ustc.edu.cn

[3] IICT, University of Sindh, Jamshoro, 76080, Pakistan
dil.nawaz@gmail.com

**Abstract:** For the last few decades, Wireless Sensor Networks (WSNs) has been drawing important considerations due to having application-specific characteristics. These WSNs are usually deployed in one of the following two manners: deterministic or random (ad hoc). In the ad hoc manner, the deployment is mostly subjected to a significant number of limitations such as limited bandwidth, routing failure, storage and computational constraints. The overall performance of the WSNs is determined by a robust routing scheme. Nevertheless, WSNs include prominent application parameters for routing such as energy usage and network longevity. Therefore, the routing scheme is the key element for the longevity and usability of WSNs. In the conventional WSNs, the routing design can be opted for the network longevity optimization, while, assuming all the other objectives to be the limitations are imposed on the optimization problem Genetic Algorithm (GA) performs the small-scale computation and large-scale computation as well. Performance of GA is robust in both small scale and large scale computations. The original GA is assumed with some modifications. In this paper, a GA based optimization in the stationary WSNs with the deployment of multiple sinks is proposed. It is assumed that the sensor nodes route the data towards the nearest sink through the multiple hops communication strategy. In our simulations results: routing is following the multiple hops to the sink by the optimized routing. Moreover, we've enhanced the Network lifespan. The proposed technique saved both the route distance through optimization and energy by routing the data through optimized neighbor sensor nodes.

**Keywords:** WSNs, Optimization, GA, Route lifetime, Energy.

## 1. Introduction

The sensor network is a combination of small sensor nodes. The sensor nodes operate via a radio link. Naturally, these sensor nodes are low cost and constraint in bandwidth and computational capabilities. The operational capabilities of a sensor node depend upon its battery. Thus the battery power must be used efficiently for the sake of the node`s lifetime. (Akkaya &Younis, 2005)

Additionally, these batteries are extremely rare due to a large number of sensors and difficult to get in the environment. Due to the small size of the sensor nodes, main controls, for instance, the partial amount of bandwidth, trivial operational abilities and small-sized battery are imposed on the sensors. Therefore, the development of the sensor node is as old as the history of MEMS (Micro-Electro-Mechanical-Systems) and in other words the technology of MEMS-enabled the development of sensor nodes. As the sensor nodes are small in size, so they have small battery size (Solangi et al., 2017). The deployment method of sensor nodes can be distinguished into two types such as ad hoc manner and deterministic manner.

The ad hoc manner of deployment includes the random placement of the sensor nodes, while the deterministic deployment comprises the orderly placement of the sensor nodes.

The deployment of sensor nodes varies as the environment and application scenario differs. Mostly, the dense deployment of sensor nodes occurs in most harsh and inaccessible environments.

Applications of sensor nodes and sensor technology are numerous, but a few of them are environmental monitoring, habitat monitoring, animal monitoring, enemy tracking, vehicle tracking (Solangi et al., 2017).

A Wireless Sensor Network (WSN) is mainly composed of a sink, various sensor nodes and a user. The sensor nodes generate the data and transmit it to the sink via wireless connection and the user or database administrator manages the received data. All processes of communication involve the efforts of the sensor nodes and their battery power. Therefore, it is clear from this fact

https://doi.org/10.24846/v27i4y201810 

that the overall lifetime of the sensor nodes depends upon the battery of the sensor node (Zhao et al., 2017). The sensor nodes are capable to generate the data from their vicinity or surroundings. The sensed or generated data demands the battery power transmit the data (Baranidharan & Santhi, 2015). So, it inevitably transmits the data through the possible and easiest route towards/ from the sink. The node`s energy depletes when the transmission path is not determined because the transmission of data consumes maximum energy than sensing and processing.

In WSNs, two methods for communication establishment are used. One method is the direct communication method as shown in Figure 1, where all sensor nodes send data directly to the sink. The second method for communication establishment in WSNs is multiple-hop communication scheme as illustrated in Figure 2. The multiple hop communication scheme allows every node sensor to transmit data with the help of neighbor sensor nodes. The previous scheme is very useful for the nodes which are nearer and are in the surrounding of the sink, whereas the second method is useful for the nearer nodes and farther nodes as well. The energy of the sensor node is consumed primarily by the farther nodes using direct communication scheme. Therefore, a significant amount of energy can be saved by using the multiple-hop communication method (Naik et al., 2015) (Latiff et al., 2015). Therefore, the optimum route selection is necessary, and the routing towards the most optimal node or sink is inevitable, where the transmission and routing consume minimum energy. (Singh, & Nagarathna, 2012).

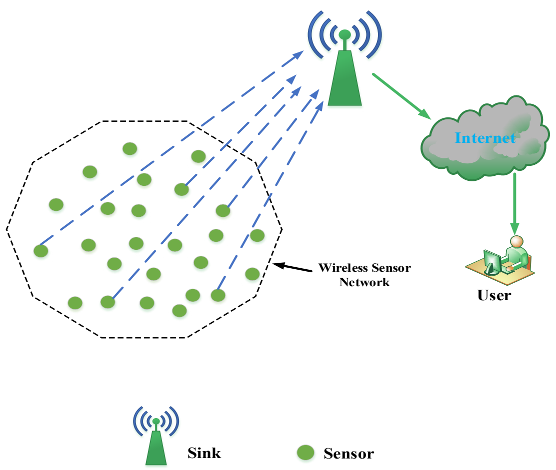


**Figure 1.** Direct Communication Scheme

The various research studies have been suggested for the minimum energy consumption in WSNs. The majority has been done using optimization for the sake of minimum energy consumption (Memon et al., 2015). Hence, the optimization is an efficient method for optimizing both the route and energy of the sensor node and WSNs.

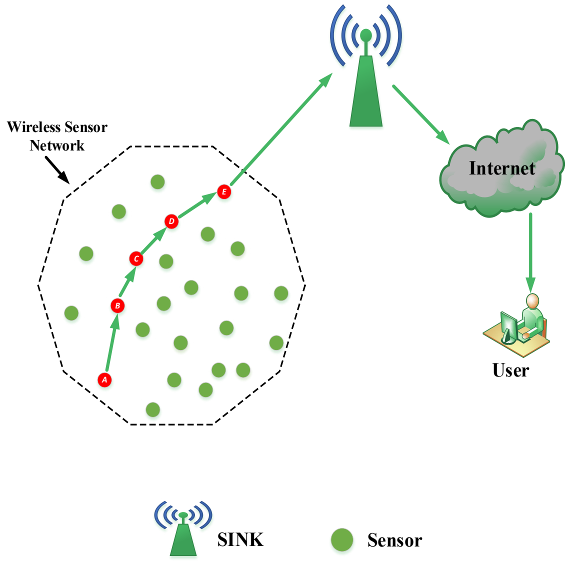


**Figure 2.** Multi-hop Communication paradigm

Optimization provides the optimal solution and helps reduction of the distance as well. In this paper, optimization with the help of a Genetic Algorithm (GA) improves the working efficiency of the network for the maximum amount of time. Also maintains the distance reduction by selecting an optimal neighbor/relay sensor node so the data is transmitted to the nearest sink. By the proposed technique, the paper provides contribution using distance-based optimization which can help to reduce energy consumption. The energy consumption will be provided by data transmitting/relaying to the nearest neighbor nodes so as a determined path can be established. Also, the optimum path will result in less energy expenditure than the long/undetermined path. The structure of the paper is as follows; in section 2, we gave the description of the Genetic algorithm in 3, background in 4, simulation results in 5, discussion of the research, in 6, conclusion of the paper and in 7, the future directions.

## 1.1 Related Material

(Mugheri et al., 2018) presented a study about security analysis in the WSN. The security analysis based on providing knowledge about resources limitation before proceeding to implement and use sensor nodes in the WSN. The security goals have been termed as distributed database security which encompasses the authentication of the user and genuine data. In other words, the authentic data only be accessible to the trustworthy user. Therefore, the security can be provisioned as inside security and outside security. The outside security is considered by security for distributed databases while the inside security depends upon the confidentiality, scalability, authenticity and resilient. The security about the attacks on WSNs includes Sybil attack, eavesdropping and traffic analysis based attacks.

In contrast, the research proposed by (Gaber et al., 2018) focused on clustering of the WSNs and based on trust and intelligent system of transportation using BOA (Bat Optimization Algorithm). The working of BOA is based upon selecting a Cluster Head (CH). Every CH selected on the basis of the residual energy, the number of neighbor nodes and trust value. The selection of CH among the malicious nodes under the diverse percentage of 30% and 50%. The authors claimed promising results in terms of minimum energy consumption by comparing the work with other standard schemes such as LEACH, SEP and DEEC algorithms. The study of (Vashisht et al., 2018) presents a technique of malicious node detection and its isolation in a WSN with the help of LEACH protocol. The whole mechanism of detection of malicious sensor node depends on the Denial of Sleep (DoS) node attack. The research of (Alshinina & Elleithy, 2018) advocates about the security cause in a WSN by studying accurate deep learning and middleware. The middleware is nothing but an intermediate layer between the user and WSN, which acts as protection provider from malicious nodes to make middleware robust and protect it from unknown and malicious attack the Secure Wireless Sensor Network Middleware (SWSNM) protocol is suggested. The results are simulated and implemented in the NS2 platform. The authors claimed promising results of the study.

## 2. Genetic Algorithm

Genetic Algorithm (GA) is an evolutionary and meta-heuristic algorithm (Goldberg, 1989). The GA is used widely in WSNs for optimization. It is known for its mimicking process of natural selection (Sasi et al., 2015). For doing this job, the GA uses its operators to find the most optimum solution from the provided solutions (Norouzi & Zaim, 2014), (Jameii et al., 2015).

The idea of the GA algorithm was suggested by Professor John Holland, University of Michigan, in 1975 (Khan et al., 2012). The process of selecting the best solution from all possible solutions through its operators is illustrated in Figure 3. In this study, these operators of GA have been selected with some moderate modifications (Gupta, 2015). The prime focus has been paid on the fitness function, which defines the fitness level of each individual (Memon et al., 2015), where each individual is considered as one population in GA (Gaoqi & Xie, 2009). All operators of GA work for population generation (Gharaei et al., 2018) selection of fit individual and select fit individuals among the population (Hameed & Mian, 2016). The operators of GA are discussed with some operational requirements as follows:

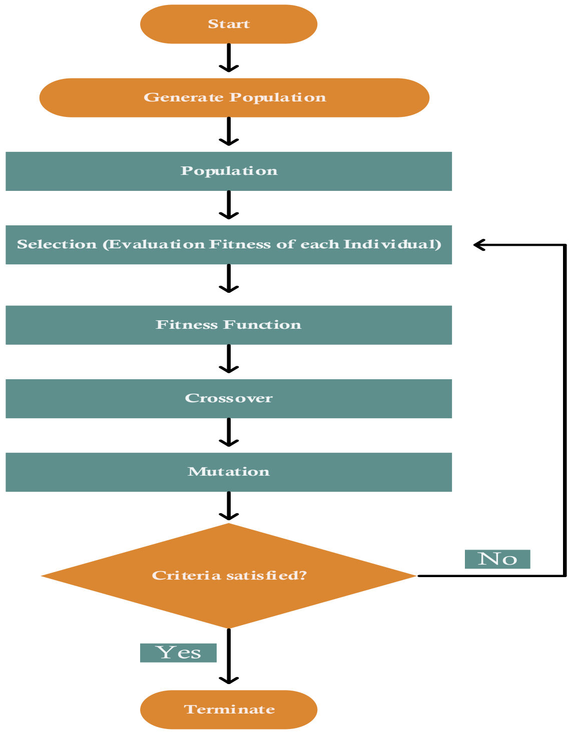


**Figure 3.** Genetic Algorithm operators

### 2.1 Chromosomes

The population is constituted by considering all the individuals as one. All individuals are assumed to be the possible solutions with equal numbers and lengths in the form of strings. Furthermore, every solution or node is called genes in the GA terminology (Yuan et al., 2017), (Hemalatha & Srinivasan, 2018), (Akram et al., 2018).

### 2.2 Selection

This operator opted for the selection of all strong individuals corresponding on the basis of fitness values (Memon et al., 2015). All population have a certain value of fitness level. Here, all fit and strong individuals have greater chances for qualifying for the next level.

### 2.3 Crossover

In this method, the whole population is supposed to go through the process of selecting fit individuals which are the result of the endurance as illustrated in Figure 4 (Akkaya &Younis, 2005). Two fit individuals are selected for having offspring and they are given the name as parents.

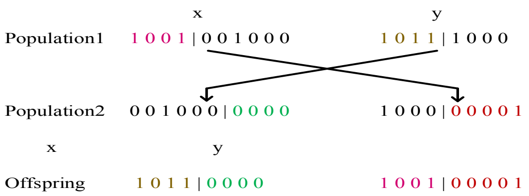


**Figure 4.** Crossover of individuals

These parents' individuals interchange their respective position randomly for the fit offspring.

### 2.4 Mutation

The mutation is applied for the selection of fit individuals from the pool of fit individuals by random selection of fit individuals as shown in Figure 5. In this study, we opted 0.7 probability as mutation probability.

.. 10001000…

↓ mutation ↓

..00010001…

**Figure 5.** Mutation

### 2.5 Fitness function

It is the main function of its kind for the selection of fit individual on the basis of energy level and which can have the ability to produce more offspring. The term Fitness Function (FF) is used here to denote that the fit individual from the available population (Khan et al., 2012).

$$F(x) = \frac{FF\ for\ randomly\ selected\ individuals}{FF\ of\ all\ population} \tag{1}$$

By applying the above criteria, the fit gene is obtained if the value is 1 and further that a gene is assumed to undergo the crossover function.

## 3. Background

The optimization in WSNs has been utilized for the sake of determining the optimum energy level. For energy optimization in WSNs, a significant number of research scholars has endeavored. The optimization with GA is (Kaswan et al., 2018), usually, is taken into consideration of the scholars of the day. Therefore, various research studies have been found about suggesting the methods for resolution of the minimum energy consumption (Wang et al., 2017). The minimum energy usage proves the extension of the lifetime of WSNs (Bhulania et al., 2016). Thus, the energy expenditure can be minimized with the optimization. The studies proposed a multi-dimensional technique in (Khan et al., 2012) (Kalayci & Uğur, 2011) using Particle Swarm Optimization (PSO), whereas (Chen et al., 2015) proposed a GPS system for the energy saving and the deployment of non-stationary sink (Banka & Jana, 2016) at a 1-hop distance from the sensor nodes. GPS system helped in finding the location of the sink (Jourdan et al., 2004). Another technique of area and location-wise deployment of sensor nodes using GA is suggested by (Norouzi, & Zaim, 2014). The study of (Gupta et al., 2015) utilized multiple sinks and GA for optimization.

The sensor nodes placement in a fully connected WSNs and the sinks placement have been addressed in (Manjeshwar & Agrawal, 2001) for Local Area Network (LAN) traffic. Similarly, the work of (Wang et al., 2015) and (Poe & Schmitt, 2008) suggested the lifetime longevity scheme using GA.

## 4. Simulation results

The simulation results have been conducted using MATLAB R2017a where the simulation comprised an environment of 100 ×100 m^2 area for the large-scale deployment of 100 sensor nodes and a sink at (0, 0) coordinates as depicted in Figure 6. First, we simulate and estimate the distance of the sensor nodes directly towards the sink using the Euclidean distance formula. The distance among multiple hops of each sensor node to the sink has been evaluated, and all distances are measured altogether as illustrated in Figure 7.

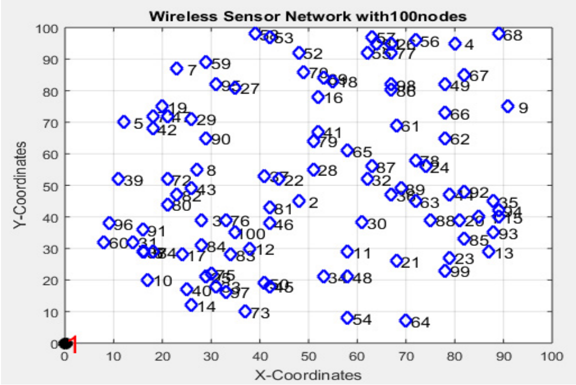


**Figure 6.** Deployment of sensor nodes and sink

The distance of each sensor node to/from the sink has been calculated with the help of Euclidean distance formula, which is implemented to select the route to the sink, where any sensor node is given a performance distance to/from the sink.

$$S_{i,j} = \sqrt{(x_i - x_j)^2 + (y_i - y_j)^2} \quad (2)$$

After the evaluation, the GA is applied to re-evaluate the distance with the help of its fitness function. With the better fitness function of GA, an efficient routing strategy is presented with multiple hops scheme through optimization. The multi-hop strategy helps to reduce the distance with the help of neighbor nodes. The optimization with GA plays a pivotal role in diminishing the distance between the neighbor nodes and nearest sink.

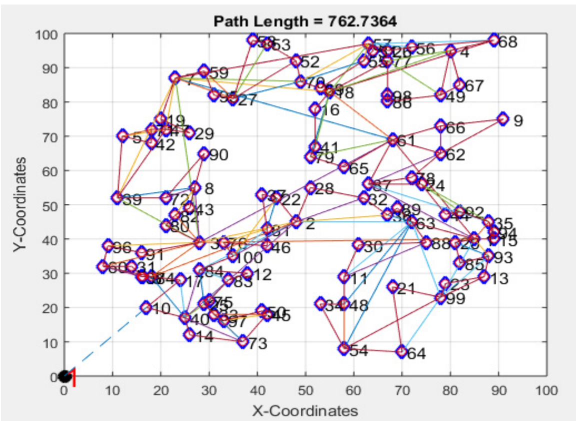


**Figure 7.** Multiple hops to/from the sink

## 4.1 Simulation parameters

The parameters for the simulation for both techniques, i.e. standard TEEN scheme and proposed scheme are considered the same as illustrated in Table 1. The prime consideration has been paid to the energy usage over the number of rounds and distance among the sensor nodes.

The distance between nodes is nicely optimized by the GA, which maintains and keeps the most optimum route information for the sake of routing towards the sink.

**Table 1.** Simulation Parameters

| Size of Network | |
|---|---|
| Number of Nodes | 100 |
| Initial energy of each node | 0.7 J |
| Number of generations (rounds) | 4000 |
| Energy dissipation | 50 nJ/bit |
| Energy Amplification $d_i < d_j$ | 10 pJ/bit/m |
| Energy Amplification $d_i > d_j$ | 0.0013 pJ/bit/m |

The simulations results of the proposed technique are compared with TEEN (Threshold sensitive Energy Efficient sensor Network protocol) standard algorithm (Manjeshwar & Agrawal, 2001). It is assumed that every node route data towards the nearest neighbor nodes and then nearest sink. The main purpose of comparison of the proposed scheme with is:

- To analyze and compare the energy usage for both the proposed scheme and the standard TEEN algorithm.
- To compare and study the multiple hops techniques over clustering scheme.
- To compare the distance among the sensor nodes with respect to the energy dissipation towards/from the sink.

It has been observed by comparing the performance of the proposed scheme with the (Manjeshwar & Agrawal, 2001) that when the multiple hops communication paradigm is applied, it reduces the efforts of selecting the cluster heads and sends data to the cluster heads. With the multiple hops, every sensor node is able to communicate with/to all sensor nodes and transmits the data only to the optimum route. The route information has been determined with the help of GA.

The performance of the proposed scheme overcomes (Manjeshwar & Agrawal, 2001) in terms of quality of service through maximum number of packets received at the sink end as shown in Figure 8, while, the number of alive nodes compared of both proposed the scheme and (Manjeshwar & Agrawal, 2001) has been studied. The result of alive nodes of the former scheme is better than the latter as illustrated in Figure 9.

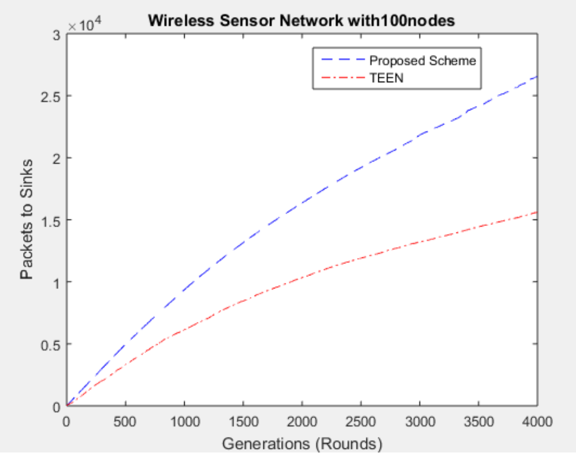


**Figure 8.** Packets to Sink

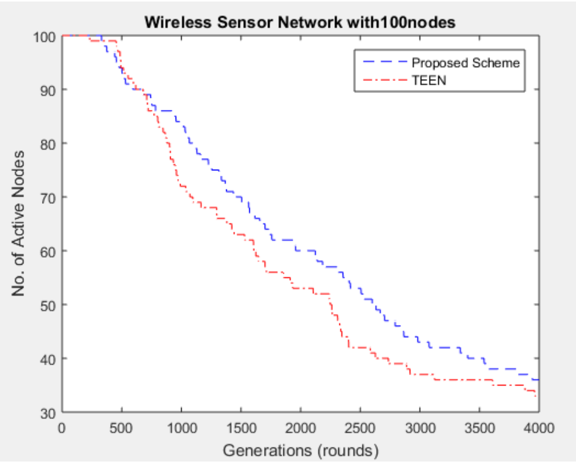


**Figure 9.** Number of alive sensor nodes

## 5. Discussion

This section provides a brief discussion of the proposed research. The deployment strategy is ad-hoc placement of the sensor nodes and simulations are performed accordingly. A large sized WSN is assumed by deploying 100 sensor nodes. The complexity of the WSN in terms of routing towards the specific and determined route has been overcome by GA and performing optimization.

The simulation comprising 100 sensor nodes has been evaluated by calculating distance in multiple hops paradigm is 762.7364 meters depending on the Euclidean distance matrix in order to know the distance all (any) nodes towards all (any) nodes. The performance is further compared with the standard TEEN algorithm (Manjeshwar & Agrawal, 2001) as shown in Figure 8 and Figure 9. The results shown in Figure 8 shows the better performance of the proposed scheme than the standard TEEN algorithm (Manjeshwar & Agrawal, 2001) while the simulations results illustrated in Figure 9 show the number of alive nodes. Therefore, the numbers of alive sensor nodes are better than the standard TEEN scheme TEEN algorithm (Manjeshwar & Agrawal, 2001).

## 6. Conclusion

Wireless Sensor Networks (WSN) have remained a most demanding field due to its application-specific characteristics. These WSNs are usually deployed in one of the two manners namely deterministic manner and random (ad hoc). Mostly, in ad hoc manner, the deployment suffers a significant number of limitations such as limited bandwidth, routing failure, storage and computational constraints. The overall performance of the WSNs determined by a robust routing scheme. Nevertheless, there are various applications for WSN, and some well-known application parameters are energy consumption and life-span longevity of routing. Therefore, the routing scheme is the key element for the longevity and usability of WSNs. In the conventional WSNs, the routing design can be opted for the network longevity optimization, while, considering all other objectives assumed to be the limitations are imposed on the certain problem. Genetic Algorithm (GA) is a robust optimization technique and possesses the large-scale computational applications. The GA is utilized in the proposed approacwith some modification in fitness function and mutation function as well. For this, the sensor nodes deployed randomly in a WSNs area with a sink. When an optimized path is determined by the GA then that path information is saved for routing all data until the drain of the sensor`s energy. All sensor nodes transmit/relay the data through all neighbor nodes. These neighbor nodes do not perform any execution of any operation but relay the data towards the next hop or sink as well. The simulation results show that the routing through the multiple hops to the sink by the optimized route enhances the network lifespan. Additionally, our proposed scheme saved both the route distance through optimization and energy by routing through optimized neighbor sensor nodes.

## 7. Future directions

The research areas and the scopes of maximizing the lifespan of WSNs have been developed by using the multiple hop communications methods. But there still remain some challenging aspects. A protocol which relies on an application beyond its specific constraints namely the disaster, medical, military and wildfire ones will be researched in a future work.

**Acknowledgements**

This research work has been carried out in the State Key Laboratory Intelligent Communication, Navigation and Micro-Nano System, Beijing University of Posts and Communications. The research reported in this paper has been financially supported by the National High Technology 863 Program of China (No.2015AA124103) and by the National Key R&D Program no 2016YFB05502001.The authors are thankful for the financial support and guidance and assistance provided by the State Key Laboratory Intelligent Communication, Navigation and Micro- Nano System, BUPT.

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