IMHRP: Improved Multi-Hop Routing Protocol for Wireless Sensor Networks

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Abstract. Wireless sensor network (WSN) is a self-organizing system formed by a large number of low-cost sensor nodes through wireless communication. Sensor nodes collect environmental information and transmit it to the base station (BS). Sensor nodes usually have very limited battery energy. The batteries cannot be charged or replaced. Therefore, it is necessary to design an energy efficient routing protocol to maximize the network lifetime. This paper presents an improved multi-hop routing protocol (IMHRP) for homogeneous networks. In the IMHRP protocol, based on the distances to the BS, the CH nodes are divided into internal CH nodes and external CH nodes. The set-up phase of the protocol is based on the LEACH protocol and the minimum distance between CH nodes are limited to a special constant distance, so a more uniform distribution of CH nodes is achieved. In the steady-state phase, the routes of different CH nodes are created on the basis of the distances between the CH nodes. The energy efficiency of communication can be maximized. The simulation results show that the proposed algorithm can more effectively reduce the energy consumption of each round and prolong the network lifetime compared with LEACH protocol and MHT protocol.

1. Introduction
Wireless Sensor Network (WSN) is a distributed sensing network which is composed of many sensor nodes. The sensor nodes cooperate with each other in self-organization [1] and take charge of monitoring the environmental information (such as temperature, vibration, pressure or contaminants) in the WSN [2]. Sensor nodes are typically powered by microcells. Therefore, their computing, storage and communication capacity are limited. It is the first consideration for designing routing algorithm to efficiently make use of node energy to maximize the network lifetime [3]. The routing protocol of the WSN is mainly divided into flat routing protocol and hierarchical routing protocol [4]. The flat routing protocol needs to keep a routing table in each node, which is not suitable for large-scale sensor networks. The hierarchical routing protocol divides the network into clusters. Each cluster has a cluster head (CH) node and the rest are non-cluster head nodes [5]. Each non-cluster head node transmits the data to the CH node. Then the CH node aggregates and transmits the data to the base station (BS) [6]. This approach can meet the scalability of the sensor networks, effectively balance the energy consumption of the sensor nodes and thereby prolong the network lifetime. LEACH [7] is the first proposed energy-efficient clustering routing protocol. The network topology of LEACH is shown in Figure. 1. The LEACH protocol divides the network lifetime into a series of rounds. Each round is divided into two phases: the set-up phase and the steady-state phase. In the set-up phase, each node in the network randomly creates a number between 0 to 1. If the random number of the node is less than
the threshold $T(n)$, the node is selected as the CH node. The threshold is calculated by the following equation.

$$T(n) = \begin{cases} \frac{p}{1 - \frac{p}{r} \mod \frac{1}{v}} & \text{if } n \notin G \\ 0 & \text{otherwise} \end{cases}$$

Where $p$ is the optimal percentage of cluster heads in the network, $r$ is the current round, and $G$ is the set of nodes in the last $t/p$ round that are not selected as cluster heads.

![LEACH protocol topology](image)

Figure 1 LEACH protocol topology

A large number of clustering routing protocols have been proposed after the LEACH protocol. In recent years, although the hierarchical routing protocol has made great progress, there is still much room for improvement. In this paper, an improved Multi-Hop Routing Protocol (IMHRP) is proposed. The protocol improves the clustering process and routing process. Compared with LEACH and MHT, the lifetime of IMHRP is obviously prolonged, and the energy consumption of nodes is more balanced. The rest of the paper is organized as follows: section 2 presents some of the improvement protocols based on the LEACH protocol as related work. The IMHRP routing model is presented in section 3. The IMHRP protocol is described in detail in section 4. The simulation results are given in section 5 and section 6 is the conclusion.

2. Related Work

In recent years, researchers have proposed a variety of hierarchical routing protocols to balance the energy consumption of WSN to prolong the network lifetime.

MHT [8] is a LEACH based protocol which discusses routing by dividing the network into two layers according to the distances between nodes and BS. However, for large-scale network environment, MHT cannot do a good job. Bhaskar Prince et al. proposed the EEUGCR [9] for large-scale networks. Dividing the network into fixed rectangular clusters in different sizes, EEUGCR selects the nodes with the highest residual energy and the closest distance to the cluster center as the CH nodes. However, the CH nodes can only transfer data to the direct upper layer, instead of based on the energy consumption to choose the next hop. In literature [10], two improved LEACH-based protocols, energy-LEACH and multihop-LEACH, are proposed. energy-LEACH improves LEACH's CH nodes election algorithm. Multihop-LEACH changes single-hop transmission of LEACH to multi-hop transmission. Energy-LEACH chooses the node with the highest residual energy as the CH node, but it cannot guarantee the evenly distributed of the CH nodes. The multihop-LEACH is superior to LEACH only when it is applied in a small-scale network. The EEM-LEACH [11] protocol chooses CH nodes based on the residual energy and the average energy consumption of nodes, which ensures that a CH node transmits the data to the next hop with minimum energy consumption, but it does not guarantee the minimal energy consumption of the total route and network energy consumption is uneven since the uneven
distribution of CH nodes. Different from other routing algorithm, DAIC [12] adds gateway CH nodes in the network. In the DAIC, BS compares the distance $d_i$ between the BS to the node and the average distance $d_{avg}$ among between the whole network nodes and the BS. If $d_i < d_{avg}$, the nodes are called sub-layer nodes. Conversely, if $d_i \geq d_{avg}$, the nodes are called main-layer nodes. The DAIC uses the gateway nodes to relay the sub-layer CH nodes and the main-layer CH nodes in order to reduce the energy consumption of the CH nodes, but the $d_{avg}$ in the DAIC is uncertain and the $d_{avg}$ directly affects the energy consumption of nodes. Wendi B. Heinzelman et al. proposed LEACH-C [13] which improves the set-up phase of the LEACH protocol and uses a centralized control algorithm to select the CH nodes. Although LEACH-C can select the optimal number of CH nodes which have the highest residual energy, the uniform distribution of CH nodes cannot be guaranteed. On the basis of EEBCDA, Manoj Pant et al. proposed a multi-hop routing protocol [14]. The protocol makes a more balanced energy consumption of CH nodes which are far away from BS and prolongs the network lifetime, but the load problem of sensor nodes is not taken into account. Xueting Zhang et al. [15] used dynamic weights to classify nodes, but since the distance between nodes with different weights is still likely to be longer, the energy consumed would be more.

3. IMHRP Routing Model
Most of the existing routing protocols mainly improved electing methods of CH nodes to extend the network lifetime. In addition to the improvement for electing CH nodes during the set-up phase, IMHRP mainly improves the routing algorithm during steady-state phase

3.1 IMHRP Network Model
In this paper, the network model assumes that there are $N$ sensor nodes randomly distributed in the square area of $M* M$. The assumptions of the network environment are as follows:
- All sensor nodes are homogeneous.
- The location of the BS is fixed and positioned outside the square network area.
- After the network is deployed, all sensor nodes are fixed and energy constrained.
- All sensor nodes are able to adjust their own energy consumptions based on the distance to the receiver.

3.2 IMHRP Energy Consumption Model
The energy consumption model of this paper is the same as that in the literature [16] [17] [18], as shown in Figure. 2.

![Energy consumption model](image)

**Figure 2** Energy consumption model

The energy consumption of the transmitted data depends on the distance between the sending node and the receiving node. The energy consumed to transmit $k$-bit data between two nodes with distance $d$ can be calculated as follows:
In Eq. (2), $E_{\text{elec}}$ is the energy that the sensor node consumes to transmits or receives 1-bit data. The threshold distance $d_0$ is calculated by the following equation:

$$d_0 = \sqrt{\frac{\epsilon_f}{\epsilon_{mp}}}.$$

Where $\epsilon_f$ and $\epsilon_{mp}$ are two parameters of the amplifier. When $d<d_0$, the energy consumption of the sensor nodes uses the Free-space model, and the amplifier parameter is $\epsilon_f$. When $d\geq d_0$, the energy consumption of the sensor nodes uses Multi-path fading model, the amplifier parameter is $\epsilon_{mp}$.

4. IMHRP protocol
At the beginning of the IMHRP algorithm, there is a network initialization phase. The purpose is to initialize the sensor nodes in the network and the relevant parameters of the base station (BS). After initializing the entire network environment, the IMHRP protocol divides the lifetime into a series of rounds and each round is divided into a set-up phase and a steady-state phase.

4.1 Initialization phase
In the initialization phase, the BS broadcasts its own position to the sensor nodes of the whole network. Each sensor node calculates the distance to the BS. The distance between the $i$-th sensor node and the BS is $d_i$. If $d_i<d_0$, the $i$-th sensor node is an internal node which transmits the data directly to the BS. If $d_i\geq d_0$, the sensor node is an external node which transmits the data to its cluster head. If the external sensor node is the cluster head node, the node transmits the data to the BS according to the routing algorithm mentioned below. The initialized wireless sensor network is shown in Figure 3.

4.2 Set-up phase
In the set-up phase, like other clustering protocols, IMHRP divides the network lifetime into rounds. Each node chooses a random number between 0 and 1 in each round. If the random number of a node is less than the threshold $T(n)$, the node would be selected as the CH node. The threshold is calculated by the Eq. (1). In this paper, after selecting a CH node, the nodes with the distance less than $d_i$ to the CH node will not be selected as a CH node. $d_i$ is a constant distance in this paper.

After the CH nodes are selected, all CH nodes broadcast the ADV message to the non-cluster head nodes in the current round. The non-cluster head nodes select a cluster to join according to the signal.
strength of the received ADV message. Since the greater the signal strength is, the closer the non-cluster head node is to the CH node that issued the message. After selecting a cluster, each non-cluster head node sends an added message to the CH node of the cluster which it belongs to. Finally, the CH node creates a TDMA table for nodes to transmits data and sends it to non-cluster head nodes in the cluster.

4.3 Routing algorithm
According to the distance between the nodes in the network, nodes are divided into internal nodes and external nodes. The multi-hop routing is discussed on the basis of the distance relationships among CH nodes. There are six cases discussed as follows.

In Figure 4, the tiny black dots represent internal non-cluster head nodes. In Figure 4-Figure 9, the small hollow dots represent CH nodes in the network. Node A is the source CH node. Node B is the internal CH node which is closest to node A and node B1 is the external CH node which is closest to node A. \(d_{BSA}\) is the distance between the BS and node A, \(d_{BSB1}\) is the distance between the BS and node B1, \(d_{B1A}\) is the distance between node B and node A, \(d_{B1A}\) is the distance between node B1 and node A. The algorithm selects B1 as the next hop on the premise that \(d_{BSA} > d_{BSB1}\).

1) When \(d_{BSA} < d_{0}\), that is, the source node A is an internal node, then the energy consumption of node A to transmit data to the BS is proportional to the square of distance. The multi-hop mechanism cannot save more energy than node A directly connected to the BS. Therefore, node A uses a single-hop communication directly to transmit data to the BS and the internal non-cluster head nodes also directly transmit data to the BS. The internal CH nodes only act as relays for external CH nodes. Routing is shown in Figure 4.

In Case 2)-Case 6), source node A is an external node, that is \(d_{BSA} > d_{0}\). According to the energy consumption Eq. (2), the energy consumption for node A to transmit data to the BS is proportional to the biquadrate of the distance. There is no way to directly transmit data from source node A to node B and the energy consumed by source node A to transmit data to node B and the energy consumed by node B to transmit data to the BS both are proportional to the square of the distance. The energy consumed by source node A to transmit data to the BS both are proportional to the square of the distance. The distance from source node A to node B is an internal node, the energy consumed by node B to transmit data to the BS is proportional to the biquadrate of the distance. Also the energy consumed by node B1 to transmit data to the BS is proportional to the biquadrate of the distance. The consumed energy of the data transmission between source node A and node B is proportional to the biquadrate of the distance. Since node B is an internal node, the energy that it consumes to transmit data to the BS is in proportion to the distance from node B to the BS. Therefore, source node A sends the data to the BS via node B, as shown in Figure 5.

3) When \(d_{BSA} < d_{0}\), \(d_{B1A} < d_{0}\), the energy consumed by source node A to transmit data to node B1 is proportional to the square of the distance. The energy consumed by node B1 to transmit data to the BS is proportional to the biquadrate of the distance. The energy consumed by source node A to transmit data to node B is proportional to the biquadrate of the distance between the two nodes. Since the node B is an internal node, the energy consumed by node B to transmit data to the BS is proportional to the square of the distance from node B to the BS. There is no way to directly determine which node to be selected as the next hop. Hence, it is necessary to determine the transmission path of node A by calculation. The routing is shown in Figure 6.

4) When \(d_{BSA} < d_{0}\), \(d_{B1A} < d_{0}\), the distance between source node A and node B1 and the distance between source node A and node B both are greater than the distance between source node A to the BS, so source node A uses a single-hop communication directly to transmit data to the BS. The routing is shown in Figure 7.

5) When \(d_{BSA} < d_{0}\), \(d_{B1A} < d_{0}\), the energy consumed by source node A to transmit data to node B1 is proportional to the square of the distance. The energy consumed by node B1 to transmit data to the BS is proportional to the biquadrate of the distance. The distance from source node A to node B is greater than the distance from source node A to the BS. Therefore, source node A chooses node B1 as a relay for forwarding data to the BS. The routing is shown in Figure 8.

6) When \(d_{BSA} < d_{0}\), the energy consumed by source node A to transmit data to node B and the energy consumed by node B to transmit data to the BS both are proportional to the square of the distance.
distance. At this point, node B₁ is not considered as a relay for source node A, so the data of source node A is transmitted to BS via node B. The routing is shown in Figure 9.

Figure 4 case 1: d_{BS-A} < d₀

Figure 5 case 2: d_{BS-A} ≥ d₀, d_{BA} ≥ d₀, d_{BS-A} > d_{BA}, d_{B₁A} ≥ d₀

Figure 6 case 3: d_{BS-A} ≥ d₀, d_{BA} ≥ d₀, d_{BS-A} > d_{BA}, d_{B₁A} < d₀

Figure 7 case 4: d_{BS-A} ≥ d₀, d_{BA} ≥ d₀, d_{BS-A} < d_{BA}, d_{B₁A} ≥ d₀

Figure 8 case 5: d_{BS-A} ≥ d₀, d_{BA} ≥ d₀, d_{BS-A} < d_{BA}, d_{B₁A} < d₀

Figure 9 case 6: d_{BS-A} ≥ d₀, d_{BA} < d₀

The routing of CH nodes in the above discussion is based on the distance between CH nodes. The distances from any internal nodes to the BS are less than d₀, so the internal nodes all directly transmit data to the BS. The internal CH node only acts as a relay and does not need to consume energy to aggregate the data collected from non-cluster head nodes. From the CH nodes which are closer to the BS, the source external CH node chooses the next hop node by comparing the energy consumed in
transmitting to the nearest external CH node and the energy consumed in transmitting to the nearest internal CH node, thereby achieving a minimum energy consumption of multi-hop transmission routing and extension of the entire network lifetime. The flow chart of the routing algorithm is shown in Figure 10. According to the routing algorithm we can get the routing process diagram which is shown in Figure 11.

![Routing algorithm flow chart](image1)

**Figure 10** Routing algorithm flow chart

![Routing process diagram](image2)

**Figure 11** Routing process diagram

### 4.4 Steady-state Phase

During this phase, if the internal CH node in the network acts as a relay for external CH nodes, the internal CH node aggregates the data of external CH nodes and the data obtained from the environment
and transmits the data to the BS directly. If the internal CH node does not act as the relay of external CH nodes, the internal CH node transmits its own environmental data directly to the BS. The internal CH node does not receive the data from the internal non-cluster head nodes. All the internal non-cluster head nodes directly transmit data to the BS. Each external CH node will have an TDMA table for the data sent by the member nodes in the cluster. The external CH nodes use TDMA to allocate the time slots for the cluster members to transmit data. The external CH node fuses the data sent by their member nodes in the same cluster and transfers the data to the BS through the above-mentioned routing protocol. In order to reduce the signal interference between clusters, each cluster of IMHRP has different CDMA spreading codes. All nodes in the same cluster use this code to transmit data to the CH node of the cluster. When the nodes in the cluster receives signals, they would filter out the signals of other clusters.

5. Simulation and Results

We use MATLAB for simulation. In order to simplify the entire simulation process, the paper assumed that the network has an ideal MAC layer. Data link communication is reliable and BS’s energy is not restricted. Only the energy of the sensor nodes is considered during the experiment. The parameters of the network area are preprocessed before the algorithm starts. The simulation parameters of sensor nodes are shown in table 1.

Table 1 Sensor node simulation parameters

| NO | Parameter | Value |
|----|-----------|-------|
| 1  | $E_T/(nJ/bit)$ | 50    |
| 2  | $E_{fs}/(pJ/bit^1.m^2)$ | 10    |
| 3  | $E_{mp}/(pJ/bit^1.m^4)$ | 0.0013 |
| 4  | $E_{DA}/(nJ/bit)$ | 5     |

The simulation parameters of the network area are shown in table 2.

Table 2 Network area simulation parameters

| NO | Parameter | Value |
|----|-----------|-------|
| 1  | Number of Nodes(N) | 200   |
| 2  | Deployment Area($\Omega$)/m² | 300*300 |
| 3  | Co-ordinate of Sink($x_0,y_0$)/m | (150,380) |
| 4  | Initial energy of SN/J | 0.5   |
| 5  | $d_x$/m | 80    |

d$x$ is obtained after many times of experimentation. The experiment results shown in table 3.

Table 3 The average rounds of IMHRP in the experiments

| $d_x$/m | 30 | 40 | 50 | 60 | 70 | 80 | 90 |
|---------|----|----|----|----|----|----|----|
| Average rounds | 595 | 591 | 602 | 590 | 605 | 619 | 606 |

The above experiment results indicate that $d_x=80m$ is more appropriate in the 300m*300m network environment.

The death states of the nodes of LEACH, MHT and IMHRP in the 300m*300m network environment are shown in table 4.

Where FND indicates the round in which the first dead node occurs. LND indicates the round in which the last dead node occurs and the number of rounds of these protocols.
Table 4 The node death status of the network area

|       | LEACH |      | MHT |      | IMHRP |      |
|-------|-------|------|-----|------|-------|------|
|       | FND   | LND  | FND | LND  | FND   | LND  |
| Average rounds | 31    | 383  | 33  | 432  | 75    | 543  |

![Figure 12 The number of alive nodes](image1)

![Figure 13 The number of packets received by the BS](image2)

![Figure 14 Energy consumption of node at coordinates (150,50)](image3)

![Figure 15 Energy consumption of node at coordinates (150,150)](image4)

Simulation experiments were carried out on LEACH, MHT and IMHRP in the corresponding network environment. Figure 12 shows the changes in the number of alive nodes of the three routing protocols. Figure 13 shows the number of packets received by the BS in the networks of the three routing protocols. According to table 4, IMHRP protocol can more effectively reduce the energy consumption of node transmission data when considering the distance relationship between CH nodes. In the 300m*300m network environment, the number of rounds of IMHRP is about 41.8% higher than that of LEACH, which is about 26.0% higher than that of MHT, and the round in which first dead node of IMHRP occurs has also delayed significantly, which means that the energy consumption of the whole network of IMHRP is more uniform and the network lifetime is more prolonged.

At the same time, this experiment compares three fixed nodes’ energy consumption of LEACH, MHT, IMHRP in the network environment. The results are shown in Figure 14, 15 and 16.

The three fixed nodes are respectively positioned in (150, 50), (150,150) and (150,300) in the 300m*300m network environment. Comparing IMHRP with LEACH and MHT, it can be concluded that the rate of the energy consumption of each node of IMHRP is slower than the other two protocols which also means that the energy consumption of overall network is more balanced than the other two protocols and the network lifetime...
is efficiently prolonged.

**Figure 16** Energy consumption of node at coordinates (150,300)

6. Conclusion

Based on the analysis of various hierarchical routing protocols, an energy efficient hierarchical routing protocol (IMHRP) was proposed. We concentrated on the energy consumption problems like clustering and routing. The IMHRP protocol divides the sensor nodes in the network into internal nodes and external nodes according to the distance from the nodes to the BS and the threshold distance. In the set-up phase, the distance constraints are added so that the distribution of CH nodes would be more uniform. In the steady-state phase, the internal nodes directly transmit data to the BS. The external CH nodes determine their own routes according to the distance relationships with other CH nodes. Each external non-cluster head node transmits data to the CH node in its own cluster. IMHRP achieves multi-hop transmission without fixed hops. In essence, the routing of IMHRP is based on the amount of energy consumed rather than the distance. Simulation experiments showed that compared with MHT and LEACH, the first dead node of IMHRP appears later than the other two protocols. The number of alive nodes in the network reduces at a slower rate and the network lifetime of IMHRP is significantly prolonged. Among the three protocols, the energy consumption of each node of IMHRP is slower than that of the other two protocols. The energy consumption of IMHRP is more balanced than that of the other two protocols.

In future, we will have a more in-depth improvement of the set-up phase to achieve a more even distribution of CH nodes, more balanced energy consumption and more prolonged the network lifetime.

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8. References

[1] I. F. Akyildiz, W. Su, Y. Sankarasubramaniam, E. Cayirci, “A survey on sensor networks,” IEEE Communications Magazine, pp. 102-114, 2002.

[2] Padmavati, T. C. Aseri. “Comparison of routing protocols in wireless sensor network using mobile sink-A survey,” Engineering and Computational Sciences (RAECS), 2014: pp. 1-4.

[3] Alotaibi E; Mukherjee B. “A survey on routing algorithms for wireless ad-hoc and mesh Networks,” Computers networks,2012,56(2): 940-965.

[4] He LY, Li YM, Wang QD. “Clustering routing for wireless sensor network,” Journal of Chongqing University, 2007, 30(1): 50-53
[5] Arumugam G S, Ponnuchamy T. “EE-LEACH: development of energy-efficient LEACH Protocol for data gathering in WSN,” Eurasip Journal on Wireless Communications & Networking, 2015, 2015(1):1-9.
[6] Younis, O., Fahmy, S. “HEED: A hybrid, energy-efficient, distributed clustering approach for ad hoc sensor networks,” IEEE Trans. Mob. Comput. 2004, 3, 366-379.
[7] Heinzelman W R, Chandrakasan A, Balakrishnan H. “Energy-Efficient Communication Protocol for Wireless Microsensor Networks,” Hawaii International Conference on System Sciences. IEEE, 2000:8020.
[8] EmadAlnawafa, Ion Marghescu. “MHT: Multi-hop technique for the improvement of leach protocol,” 2016 15th RoEduNet Conference: Networking in Education and Research, 2016, pp. 1-5.
[9] Bhaskar Prince, Prabhat Kumar. “An Energy Efficient Uneven Grid Clustering based Routing Protocol for Wireless Sensor Networks,” In Proceedings of the 2016 IEEE international conference on wireless communications, signal processing and networking (wisnnet), Chennai India, 2016, pp.1580-1584.
[10] F. Xiangning, S. Yulin. “Improvement on LEACH Protocolof Wireless Sensor Network,” in International Conference on Sensor Technologies and Applications, 2007. SensorComm2007, 2007, pp. 260–264.
[11] A. Antoo, R. Mohammed. “EEM-LEACH: Energy Efficient Multihop LEACH Routing Protocol for Clustered WSNs,” IEEE International Conference on Control Instrumentation Communication and Computational Technologies (ICCICCT), pp. 812-818, 2014.
[12] NavinGautam, Jae-Young Pyun. “Distance aware intelligent clustering protocol for wireless sensor networks,” Journal of Communications and Networks, 2010, 2010(4):122-129.
[13] W. Heinzelman, A. Chandrakasan, H. Balakrishnan. “An application-specific protocol architecture for wireless microsensor networks,” IEEE Trans. Wireless Commun., vol. 1, pp. 660-670, Oct. 2002
[14] Manoj Pant, BiswanathDey, Sukumar Nandi. “A multi-hop routing protocol for wireless sensor network based on grid clustering,” Applications and Innovations in Mobile Computing (AIMoC), 2015, pp.137-140.
[15] Xuetong Zhang, Yingwu Chen, Jiang Jiang, Bingfeng Ge, Qi Wang. “A routing algorithm based on dynamic weight of the wireless sensor network,” 2015 6th IEEE International Conference on Software Engineering and Service Science (ICSESS), 569-572, 2015.
[16] Manjeshwar A, Agrawal D P. “TEEN: a routing protocol for enhanced efficiency in wireless sensor networks,” In: Proceedings of 15th Parallel and Distributed Processing Symposium Workshops, San Francisco, USA: IEEE, 2001, 2009-2015.
[17] Ye, Mao, Chengfa Li, Guihai Chen, Jie Wu. “EECS: an energy efficient clustering scheme in wireless sensor networks.” In Performance, Computing, and Communications Conference, 2005. IPCCC 2005. 24th IEEE International, pp. 535-540. IEEE, 2005.
[18] Zhijun Gao, Hongyu Wang, Chunyan Xue, Zhonghua Han, “An Energy Efficient Hop-Number-Constrained Multi-hop Routing Algorithm for Heterogeneous Wireless Sensor Networks,” In Proceedings of 2012 International Conference on Modelling, Identification and Control, Wuhan, China, June 24-26, 2012.