

# Data-Centric Routing Mechanism Using Hash-Value in Wireless Sensor Network

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## Abstract

Traditional routing protocols as TCP/IP can not be directly used in WSN, so special data-centric routing protocols must be established. The raised data-centric routing protocols can not identify the sensor nodes, because many nodes work under a monitoring task, and the source of data is not so important some times. The sensor node in the network can not judge weather data is come from the some sink node. What's more, the traditional method use IP to identify sensors in Internet is not suitable for WSN. In this paper, we propose a new naming scheme to identify sensor nodes, which based on a description of sensor node, the description of a sensor node is hashed to a hash value to identify this sensor. The different description generates different identifier. Different from IP schema, this identifier is something about the information of the sensor node. In the above naming scheme, we propose a new data-centric routing mechanism. Finally, the simulation of the routing mechanism is carried out on MATLAB. The result shows our routing mechanism's predominate increase when network size increase.

**Keywords:** Wireless Sensor Network, Routing, Hash Value, Sensor Identifier

## 1. Introduction

Wireless sensor network has become a research focus of computer technology; it is a complex system which combines the sensing, embedded computing, distributed processing, wireless communications, and many other technologies. Since the concept of sensor network was proposed, a growing number of research institutions began to join into the field. The WSN could collect information from physical world directly, then it links with the logic world through the network [1], it greatly extends the traditional network ability and the ability of human being to control the physical world.

## 2. Recent Research

Wireless Sensor Network is a large scale network of hundreds or thousands of sensor nodes. These sensor nodes are networking by self-organization. WSN with many features: sensor nodes are random spread in sensor field, so it is infrastructure-less; the sensor node is energy restricted, so node can not support long communication range, and they communicate with other nodes by

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multihop. What's more, WSN is scalability, easy deployment, low cost, application-related and so on.

For those features, WSN can not direct use traditional networking technologies. And researchers have begun to study its exclusive technology. Wireless sensor networks have many key technologies, such as routing protocols, MAC protocols, location, time synchronization, etc., in these key technologies, the routing protocols is a research hotspot.

The routing protocols of traditional networks focus on the availability of a high quality of service and the equitable and efficient of network bandwidth. In the wireless sensor network, the node energy is limited and nonrenewable, the node can not support the large distance of information transmission, so the data packets pass through network to reach the destination node by multi-hop way. So the routing protocols need to use energy efficiently. At the same time, the number of nodes is very large in WSN, the node can only get the nearby network topology information, and every node should find its routing path according this partly information. These problems are not encountered in traditional networks, which determine the routing algorithm of traditional networks can not apply to wireless sensor net-

works. One important goal of the routing protocol of sensor network is to maintain a longer network lifetime. Currently, researchers have classified the proposed routing protocols in WSN into four categories [3-5]. The first category is hierarchical routing protocol, such as LEACH; the second type is geographical routing, such as GAF, GEAR. The third category is a reliable route routing protocol, such as SPEED. The fourth category is data-centric routing protocols, such as SPIN, Rumor, DD and so on.

For wireless sensor networks is a network which closely related to application, and it is data-centric, more researchers focus on data-centric routing protocols and got many achievements.

SPIN [6] is a kind of data-centric routing protocols; it sends messages through network by negotiation. When a node A want to send a message, it first send a ADV, ADV is used to broadcast meta-data which is a description of the data that ready to send; another node B who receive the ADV and it is willing to receive the data send REQ back to A to request data; at last, the node A send the data to B.

Directed diffusion [7] is a data-centric routing mechanism. "Interests" in particular sensing information are disseminated over the sensor network starting from the sink. "Gradients" back towards the sink are constructed in the meanwhile. This essentially uses flooding to subscribe to interested events. Once a sensor detects the interested events, an energy-efficient routing path between this sensor and the sink will be reinforced. To maintain robust paths for information flows, the sinks need to periodically cast their "interests" to the sensor network. Directed diffusion also supports in-network processing. Every sensor is equipped with local memory to cache sensor data for identical data aggregation or suppression. Rumor routing [8]: when a sensor node in sensor field sensing an event, it generates a proxy message (agent), agent messages randomly select a neighbor node to forward, at the same time the query sent by sink node is also spread in the network randomly. When the two of them meet, the path from source node to sink node formed. Rumor overcomes the defect of energy consuming DD in broadcast interest in network, but it is so randomness that the delay of data is obviously.

### 3. Main Title

The nodes in SPIN, Rumor, and directed diffusion routing mechanism algorithms are not have an identifier. Because there are too many nodes in a WSN, to maintain an identifier will consuming lots unnecessary energy, what's more, WSN is a network of data-centric, care little about where the data come from but the detail of the data; so identifier in WSN is seems not so important as in

traditional network. But this no identifier also bring many problems, we can not know where the data is exactly come from. Take DD for example, a node in network can not judge the different interest come from which specific node, in **Figure 1**, several sink nodes all broadcast a interest, and they reach node A, in this moment A can not distinguish the source of the interest, and do not know how to deal with it. And in **Figure 2**, an interest reach node A from one sink node in different path. The node can throw all interest but the first one or it can establish gradient for each interest. But what about the situation in **Figure 3**.

In this paper we propose a new naming schema to give an identifier to each node in WSN. Considering the feature WSN have, the identifier is not just numbered like IP address, but something about data-centric. Base on this naming schema, we propose a new routing mechanism. At the last of paper, we have simulate to verification the effectivity of the routing mechanism.

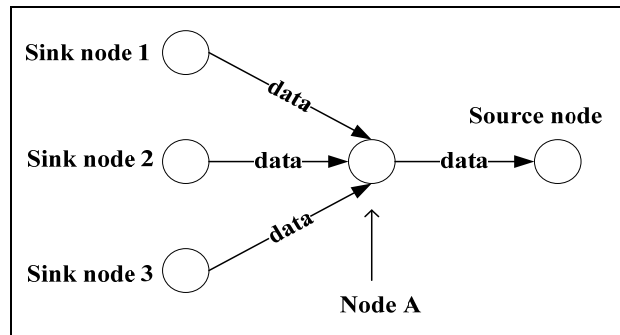


Figure 1. Interests from different sink nodes.

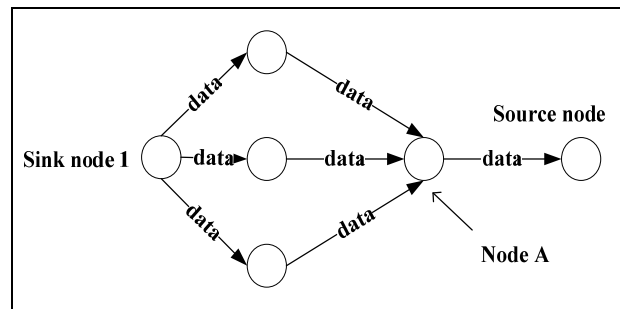


Figure 2. Interests from one sink node.

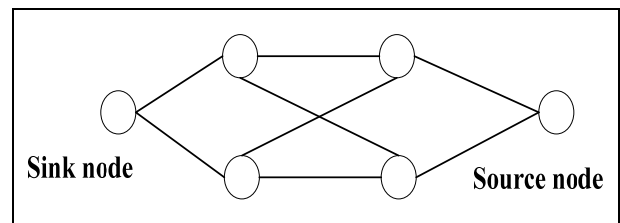


Figure 3. The complex topology from source node to sink node

#### 4. Naming Scheme Based on Hash Value

Paper [9,10] proposed a data-centric storage scheme, use data itself to describe its storage location, that is the name of the data represent a keyword, you can use this keyword to find the data. And queries can be routed to the data directly by the name of the corresponding node. In this paper, we propose a new naming scheme according to data-centric scheme above. We first describe the data by attribute pairs, for example: there is a sensor node in the room 621 of library to monitor the temperature, and then it has a description below:

```

ATtribution{
    Service = temperature
    Room = R621
    Building = library
}
    
```

(1)

If the node has more than one sensor model, performs several monitor task, for example the sensor node in room 621 not only monitor the temperature but also object monitor, then it can also describe like this:

```

ATtribution{
    Service = Object Monitor
    Room = R621
    Building = library
}
    
```

(2)

One node could have several descriptions, but one description can only describe one node.

Meanwhile, we use the same naming scheme to name the query, such as a query to check the room 621's temperature, and then the description of this query is:

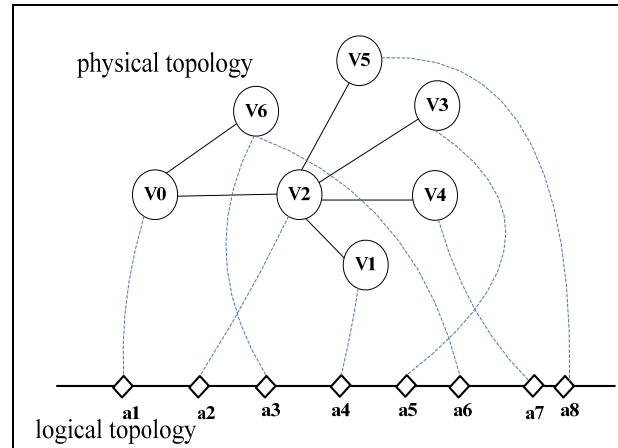
```

ATtribution{
    Service = temperature
    Room = R621
    Building = library
}
    
```

(3)

After each node and query has its description, we use a certain hash algorithm to generate a hash value, and use this hash value to identify the node or query. For the above description (1) and (3), (1) describes the detail of node in room 621 and (3) describes the query whose destination is node in room621. We can find that the description of (1) and (3) is identical; by the same hash function the query will generate the same hash value with its destination node. So it can be routed directly and correctly. Thus each node in network will have a unique identifier.

According to this naming scheme, we can map the complex physical topology of a network to one-dimensional logical topology. As shown in **Figure 4**. One node could have several ID to identify itself, for example v6 mapped to a3 and a6, but one ID can unique identify a node.



**Figure 4.** Mapping from physical topology to logical topology.

This naming scheme based on hash value is aiming to solve the problems in raised data-centric routing mechanism which has no uniform identification. And this naming scheme is different from the traditional network which base on IP address, the ID of node is not just a number, but a keyword of data, it is data-centric.

#### 5. Routing Mechanism

Base on the above naming schema, each node maintains a routing table, a logical neighbor table and a physical neighbor table, and according to those routing information, messages can be delivered to destination efficiently.

##### 5.1. Tables of Routing Information

###### 5.1.1. Routing Table

Routing table is used to help messages to deliver to destination, it maintains three parameters. The first parameter is leader node, leader nodes are those identifying hash-value that closest to  $R/2^n$  away from the hash value of local sensor, while R as the range of the hash domain, and n is the routing scope. The second parameter is path, it record the path to the leader and the third parameter is cost it spends from local node to leader. **Figure 5** is the structure of the routing table.

For one node, there are several scopes about leader. The first scope is the node whose ID is closest to  $R/2$ , and the second scope is the node whose ID is closest to  $R/4$ , and third scope  $R/8\dots$ , we select leader by the formula below:

$$U_n = v + \frac{R}{2^n}$$

“n” is the scope of leader. So, node v0's namespace can be segmented as in **Figure 6**.

Leader	Path	Cost
--------	------	------

Figure 5. Routing table.

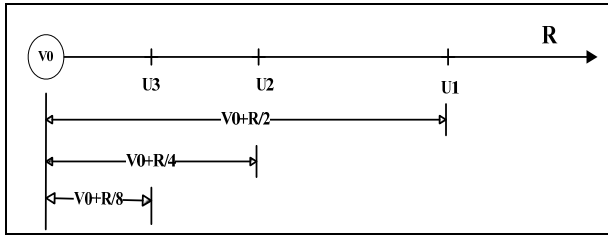


Figure 6. Name space of node v0.

With the segmentation of the name space and the select of leader, routing table records the path to the nodes whose identifying hash values are exponentially changed, and it makes message to reach the destination quickly.

5.1.2. Logical Neighbor Table

Each node also maintains a logical neighbor table; the logical neighbor records the node whose hash value is closest to local node. It provides a shortcut to reach the destination.

Logical neighbor: the node whose hash value is closest to local node. Path: the path from local node to logical neighbor. Cost: the spending from local node to logical neighbor. Figure 7 shows the logical neighbor table.

5.1.3. Physical Neighbor Table

Each node also maintains a physical neighbor table, it record the physical neighbor which is one hop away from local node.

The parameters maintain by physical table is similar with logical neighbor table.

Physical neighbor: the node which is one hop away from local node. Path: the path from local node to physical neighbor. Cost: the spending from local node to physical neighbor. Figure 8 shows the physical neighbor table.

5.2. Routing Process

Wireless sensor network has many restrictions in various

Logic neighbor	Path	Cost
----------------	------	------

Figure 7. The logic neighbor table.

Physical neighbor	Path	Cost
-------------------	------	------

Figure 8. The physical neighbor table

resources, so the process of routing should be simple and efficient. When the networking begins, nodes in network broadcast “hello” packet to other nodes. And node constructs its routing tables by received packet. The step is below: (local node with hash value V0 receive a message send by node whose hash value is V1)

- 1) Node V0 receives a hello packet which contains its destination V1.
- 2) Node V0 judges whether the packet is sent from its physical neighbor who is only a hop away, if yes, records the node to its physical neighbor table, and continue.
- 3) Node V0 judges whether it is the first packet received, If yes, records V1 to its logical neighbor table, else compare with the item which is already in logical table, if it is closer to local node’s hash value, replace the original item with new V1.
- 4) Node V0 should determine whether the V1 is a leader, a simple calculation of distance between the hash value can be drawn. If yes, records it in routing table and records the path to it, else forward it.
- 5) Wireless sensor networks based on specific size and the number of nodes to define the hello packet time to live. Before the routing mechanism works, we should design a reasonable life time for “hello” packet to save energy consumption of network. Figure 9 is the flow chart.

The judge in dashed box is to construct node’s routing table, Figure 10 shows the detail flow chart.

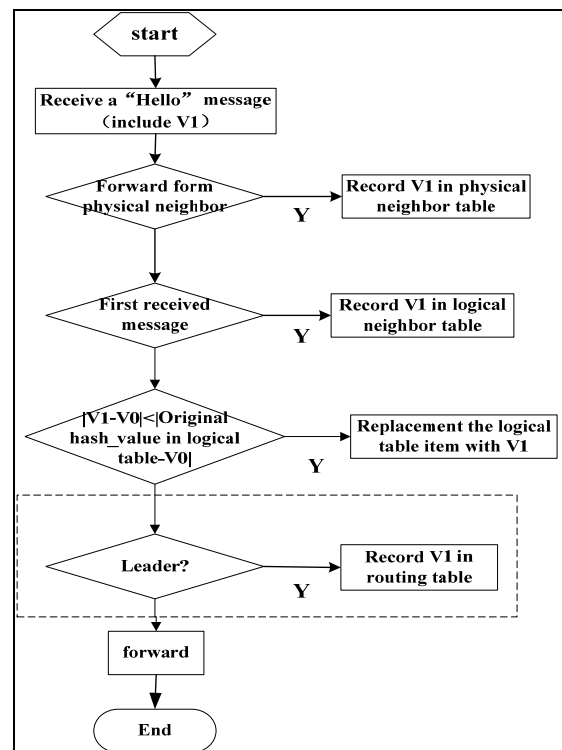


Figure 9. Flow chart of routing tables establish.

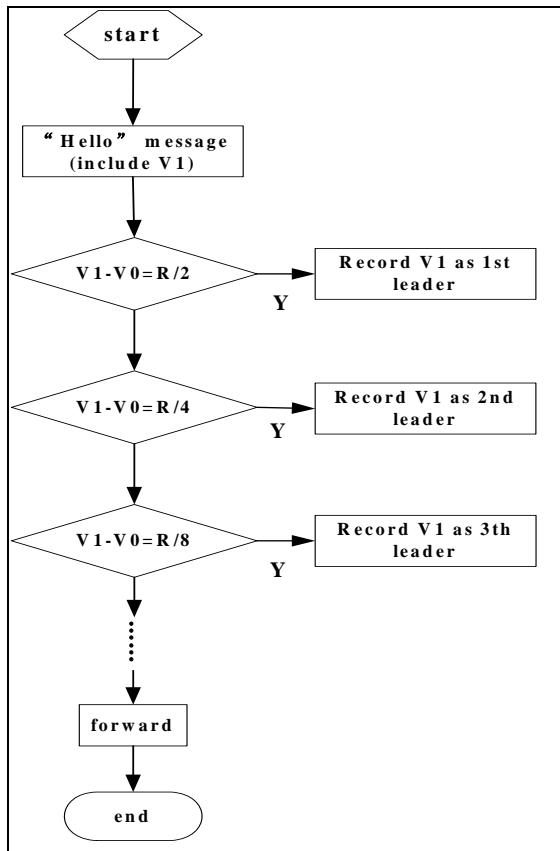


Figure 10. Flow chart of leader definite.

With the three tables of routing information, the node can forward every packet wherever its destination is. The routing mechanism as:

1) When a node receives a packet from other node, it first checks its physical neighbor table and logical neighbor table to determine whether there is a path to the destination node, if yes, send the packet to node record by either table.

2) Otherwise, the node calculate its own hash value and the packet hash value to determine which scope of leader the node need to help to forward the packet. For example: If the packet's hash value is closer to the 1st leader, then it forwards the packet to its 1st leader.

3) Repeat step one, step two, until the packet accurately reach its destination.

### 5.3. Route Maintenance

By the networking is complete, we need maintenance the routing information regular to ensure the correctness. The simplest method is to periodically broadcast the node's hash value contains in a "hello" packet, to declare its own survival. If one node hasn't broadcast a hello packet for a long time, then other node will think it is for

some reasons departed from network, and the path contains this node will failure.

When invalid nodes leave or new nodes join the network, the routing table and neighbor table need to be updated.

#### 5.3.1. New Nodes Join the Network

When a new node needs to join a network, its routing information should be constructed first.

1) To join a sensor network, a new sensor first contacts one of its "physical" neighbors randomly to construct physical neighbor table. A sensor's physical neighbors are those sensors geographically close.

2) Then this sensor generates  $\lceil \log R - 1 \rceil$  joining requests with a key  $R/2^n$  plus its identifying hash value. Conceptually, these joining requests will be forwarded to the sensors that are numerically closest to each key. The Sensors visited by a joining request will be recorded in this request to track the routing path. When those requests reach the destination, the destination node records the new node and reply. After collecting all the replies, the new sensor can construct its own routing table.

3) This sensor generates a joining request with a key of its own identifying hash value. This joining request is used to construct the neighbor table. When the numerically closest sensor to that hash value receives the joining request, it returns its logical neighbors and the paths to the neighbors to the new sensor and meanwhile updates its neighbor table with that hash value and the routing path recorded in the request. The reply of this reply provides the information of node's logical neighbor.

#### 5.3.2. Nodes Withdraw from the Network

Wireless sensor network is a kind of dynamic, adaptive network, if a node's energy is exhaust, or for other reasons lost its contact with the network. So the routing information is not correctness, to support robustness of the sensor network, the sensors need to update the routing tables periodically.

#### 5.3.3. Support for Mobile Node

Although most of the nodes in wireless sensor network are fixed, there is a part of node need mobility, and those nodes always play an important role. How to support mobile nodes properly is a new challenge in wireless sensor network. Figure 11 shows the WSN with mobile node A.

By the naming schema raised in paper, each nodes use a hash value to identify themselves, so we can map the complex physical topology into a 1-D logical topology, as Figure 1 describe. In this case, as shown in Figure 7, a mobile node S5, it moved from T0, T1, T2 moment, but the hash value of S5 is changeless, so whenever the

physical topology of the network changes, the logical topology is changeless, shows in **Figure 12**, because the identifier of the mobile node is abiding.

In this paper, we support mobile nodes by the routing information that each nodes maintains. Firstly, we request node add an attribute to describe the node's mobility. And then we add constraints to routing tables:

- 1) Each node maintain a routing table, all the nodes maintained in this table must be immovable.
- 2) An immovable node will maintain two different logical neighbors, an immovable logic neighbor table and a mobile logical neighbor table. However, the movable sensor needn't maintain a mobile logical neighbor table.

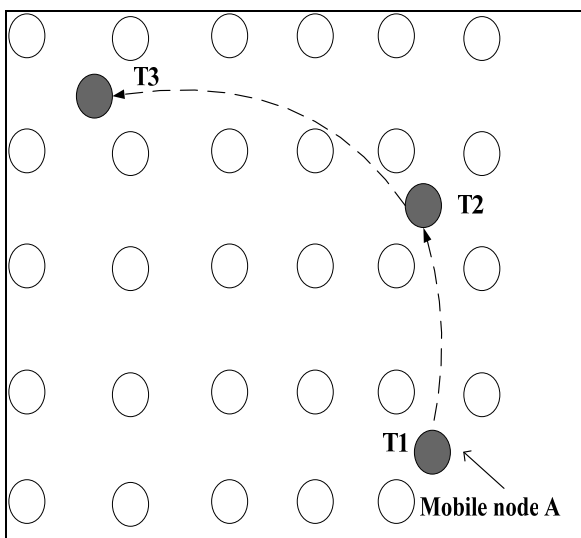


Figure 11. Mobile nodes in WSN.

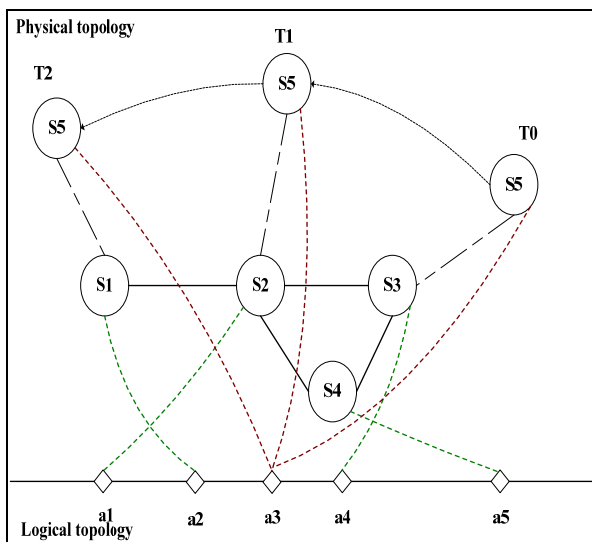


Figure 12. Mapping from physical topology to logical topology with a mobile node.

3) Movable sensors also maintain an immovable logic neighbor table and a mobile logical neighbor table. Different from tables immovable node maintain, it didn't maintain the path to neighbor node for those path is variable.

By the constraints written above, When a mobile node willing to send a packet to the immovable node, it can just forward packet to its nearest immovable physical neighbor, and then the packet will be forwarded according to routing mechanism. If a node has a packet to send to the mobile node, there is no direct path to the mobile node, the sending node will just sent it to the mobile node's logical neighbors. Mobile node sends regular send hello messages back to its neighbor to get the packet. In this way, data flow from mobile node to immovable node is established.

Here follows the concrete steps:

- 1) The mobile node broadcast a hello packet to other node when reach the new place to get its physical neighbor information.
- 2) When a mobile node to send a packet, it send the packet to its physical neighbors.
- 3) When an immovable node has to communicate with mobile node, either node sends packet to it or replies. It sends the packet to mobile node's logical neighbor.
- 4) The mobile node periodically sends hello packets to its logical neighbors to get the packet.

### 6. Simulation

We compare proposed routing mechanism to Directed Diffusion, Rumor, and Flooding. **Figure 9** is describes 100 nodes random distribution in the 100 meter multiply 100 meter space. **Figure 13** depict node A's logical neighbor and leader. We can see from **Figure 14** that the logical neighbor and leader are well-proportioned in the region. In **Figure 14**, red arrows point to node A's leader, and blue arrows point to its logical neighbor.

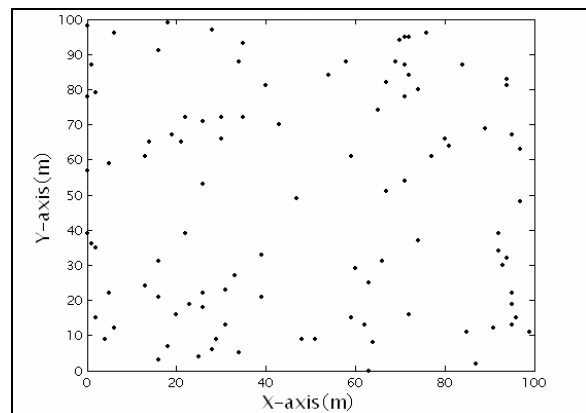
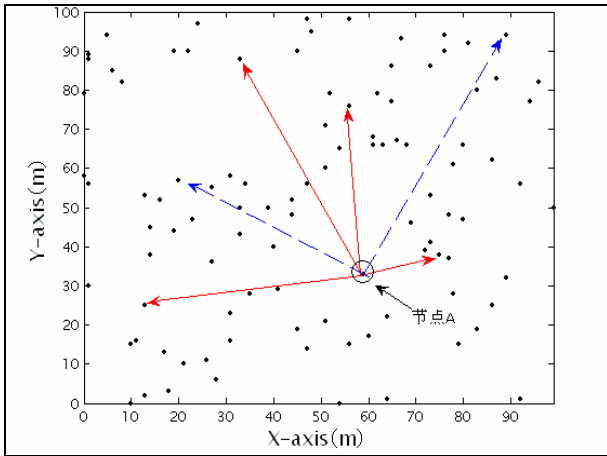
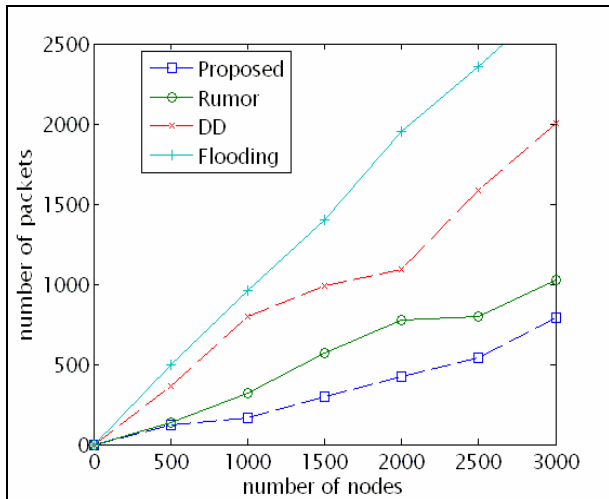


Figure 13. 100 nodes in 100m\*100m.

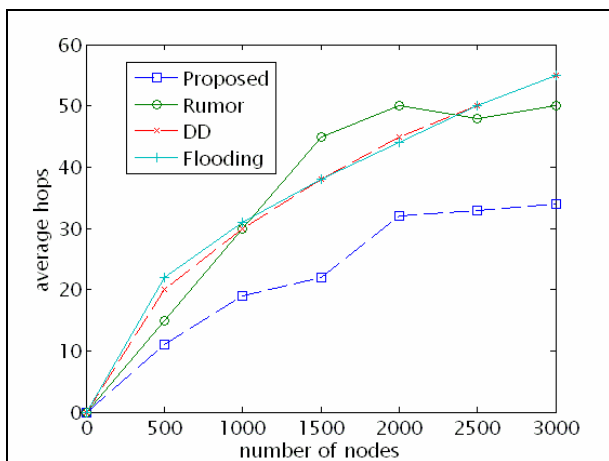
The **Figure 15** shows the packet number required for a success query



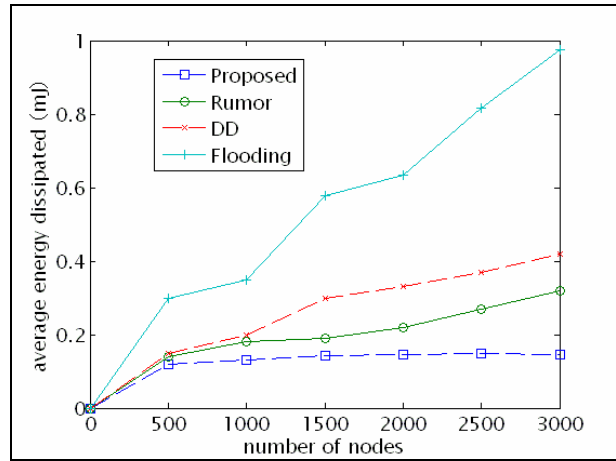
**Figure 14. Logical neighbor and leader of node A.**



**Figure 15. Packet number of a query.**



**Figure16. Average hops of a query.**



**Figure17. Average energy dissipated of a query.**

The **Figure 16** shows the average hops a packet cost to destination node. From which we can see that proposed routing mechanism is advantageous when the network scale increased.

The **Figure 17** is the average energy dissipated for a discovered routing path.

### 7. Conclusions

The proposed routing mechanism is superior to other data-centric routing, especially when nodes in a WSN increased.

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