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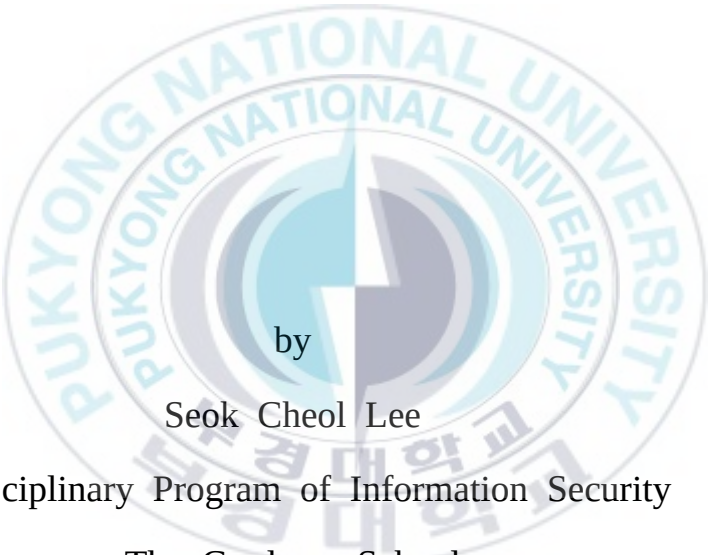
Thesis for the Degree of Master of Engineering

Design and Implementation of Improving Flat-based Routing Protocol in WSN



by

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The Graduate School

Pukyong National University

February 2008

Design and Implementation of Improving Flat-based Routing Protocol in WSN
무선 센서 네트워크의 개선된 평면 기반 라우팅 프로토콜의 설계 및 구현

Advisor: Prof. Chang Soo Kim

by
Seok Cheol Lee

A thesis submitted in partial fulfillment of the requirements
for the degree of
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February 2008

Design and Implementation of Advanced Flat-based Routing Protocol in WSN using TinyOS

A Dissertation

by

Seok Cheol Lee

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February 26, 2008

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무선 센서 네트워크의 개선된 평면 기반 라우팅 프로토콜의 설계 및 구현

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요 약

현재 무선 센서 네트워크 관련 기술은 WPAN(Wireless Personal Area Network) 기술을 근간으로 한 유비쿼터스 컴퓨팅 실현에 있어서 중요한 기술로 평가 받고 있다. 특히, 인프라 구축이 어려운 상황에서의 상황 인식 기반 정보 획득, 물리적 공간에서의 환경정보 습득과 자동 제어 기술에의 응용은 보이지 않는 컴퓨팅을 실현하는 중요한 기술로 인지되고 있다. 그러나 무선 센서 네트워크는 제한된 전력, 무선 전송 칩셋의 전파 도달 한계 등의 제약을 안고 있으며, 특히 무선 전송의 한계를 극복하기 위해서 멀티 홉 통신이라는 ad-hoc 기반의 네트워크 기술이 중요하다. 이러한 멀티 홉 통신을 지원하기 위해서는 기존의 무선 네트워크와는 차별된 독특한 라우팅 기술의 개발이 선행되어야 하는데, 이는 센서 네트워크가 가진 데이터 중심적 속성과 부합한다.

본 논문은 무선 센서 네트워크에서의 Gossiping으로 대표되는 ad-hoc 평면 기반 라우팅에서의 효율적인 전송 경로 설정을 위한 라우팅 기술을 다루고 있다. 기존 평면 기반 라우팅의 경우 전송 시에 발생하는 병목현상과 중복 수신의 문제점을 안고 있다. Gossiping의 경우 지정된 전송 경로를 탐색하여 유니캐스트(unicast) 형태로 데이터를 전송함으로써, 오버헤드를 획기적으로 줄인 프로토콜이다. 그러나 이웃 노드 판별에 있어서 임의적인 선택으로 인하여 Data Delivery의 문제와 최악의 경우 전송이 이루어지지 않을 수 있는 Worst Case 문제가 발생하게 된다. 본 논문에서는 이러한 Data Delivery의 문제점과 Worst Case 문제를 해결하고자 RSSI(Received Signal Strength Indicator)에 의한 이웃 노드의 후보 우선순위 판별과 이웃 노드와의 연결 개수를 고려한 노드 선택 방법에 의한 향상된 Gossiping 기반 평면 라우팅 프로토콜을 설계 및 구현하였다. 구현된 라우팅 프로토콜은 TinyOS 기반으로 실제 디바이스에 이식(porting)이 가능하며, 개발된 프로토콜의 성능분석 및 평가는 TinyOS에서 제공하는 TOSSIM에 의한 시뮬레이션 평가와 실제 디바이스에 이식하여 동작을 확인하였다. 본 논문에서 설계 및 구현한 기법을 기존 Gossiping과 비교하였을 때[3][4], Source 노드로부터 Sink 노드까지의 Data Delay Time과 Power Usage 부분에서 우수한 성능을 나타내었다.

Chapter Ⅰ. Introduction

1.1 Background

Wireless Sensor Network(WSN) is composed of many wireless sensors for accurate sensing to environmental sources. The existing ways of WSN platforms have generally micro-controller and Radio Frequency Chipset for computing and wireless communication. Thus, the most important strategies of constructing the embedded system like WSN technology are to raise the efficiency of routing and durability of the network lifetime. Wireless Sensor Network started the parts of the IEEE802.15 Working Group[12][18] in Wireless Personal Area Networks but it is required a number of sensors for the constructing the huge sensor field like remote-observation system or military service and social infrastructure. Suppose the area of WSN is extended on a large scale, there are some problems had to solve them. They are how to make the network topology, how to raise the efficiency of network and how to extend the life-time. WSN system is needed to self-configuration that applies the variation of environmental effect and fusion and so many researchers have focused on the energy-efficient routing protocols.

Routing technique for WSN is based on the sensing, processing, and communication[2]. Especially, communication area is most important

because the ratio of the consuming energy in communication is high. According to the reference, the consuming energy in communication is found over 60% [1][2][6][9][12].

In this point of view, the way of minimum costs of communication in wireless sensor network and development of routing technique for energy-efficient network are required for extending life-time that depend on uniform energy-distribution of whole nodes and improvement of performance in all over WSNs.

Routing protocols applicable to wireless sensor network are different from the ad-hoc network algorithm called ADOV[14] that is applied wireless LAN (IEEE802.11). The features of ADOV is searching the minimum costs path for guarantee its speed and setting up the detour path for supporting QoS(Quality of Service). On the contrary, routing protocols that is applicable to wireless sensor network focuses on the context-aware service and environmental effects through sensors in specific unit of area and it is required that the technology of operating networks.

Low power profile or energy-efficient routing techniques for wireless sensor network are distinguish from the data centric routing based on the flat-based routing like flooding and gossiping and hierarchical routing based on the network clustering represented LEACH[2] and PEGASIS[2][7]. These two protocols have different merits and demerits. Flat-based routing use the ad-hoc sensor network that is difficult to construct infrastructure without any access point. To construct the large

scale or have plan of some access point that is connectable any other sensor nodes mainly use the hierarchical network based on the clustering. Sometimes, two protocols are properly collaborated. In this case, it is depend on the measurement range, number of node, and installation area. Consequently, it is difficult to decide what protocol is more excellent.

Flooding-based protocol representative flat-based routing is the basic technique of routing which is used the wireless ad-hoc network[2][4][11].

The principle of this protocol is that sensor nodes send the message packet to the rest nodes and they are relaying the received packet to any other nodes. Existed flooding protocol is a technique that all node in one sensor field joins the network and communicates each other without any specific routing path. In this case, there are many overheads for finding the other nodes and costs of communication increase before setting up the proper routing paths. Moreover, sensor network that allows the fault tolerance use the flooding protocol finding new node when the power of specific sensor node is dried up.

Gossiping protocol[2][3][4][5] is the solution of the overhead problem having the flooding protocol. Gossiping protocol periodically transmits the advertise packet called the "hello packet" for recognizing the neighborhood nodes. Periodic advertise packets are broadcasted its own ID by period. It is only sent in one hop range. Others that are received doesn't resend the data to the other nodes.

The process of finding neighbor nodes is randomly selecting node which is searched by MAC information of gossiping and set up the routing path. Consequently, real communication is performed by unicast form and the data is transmitted to selected nodes by routing path.

Gossiping protocol is able to decrease the node that takes part in communication but the serious problem of gossiping protocol is that its performance has best case and worst case. In this case, if the source node always selects the most efficient case of neighbor node. Its performance is very best. However its delay time is maximum and data delivery becomes minimum. In most worst case, transmission data from source node to sink node that is last node and connect with the gateway is not sent because of disconnection of routing path. This problem is called 'Worst Case Problem in Gossiping'[1][3][4].

1.2 Main Contributions and Organization of the Thesis

My approach in this paper is basically focused on the way of selecting the neighborhood based on gossiping protocol. In exploring the questions of the each transmission case, this paper will be limited to consideration of selecting the node that is used the combination of RSSI value and the number of connection link.

The existing research of Routing protocol based on the gossiping used the way of periodical broadcast message and selected the random neighbor node for setting up the path. The next processing are the transmission of reinforcement and transmits the data by unicast form.

However, when you suppose the limitation of the sensor nodes sensor nodes easily have exhausted because nodes have the limitation power like AA or AAA batteries. Besides, if you suppose the fault tolerance of sensor networks, source node must find new neighbor and set up new routing path for transmitting data. In this case, source node can't help transmitting the broadcasting message continuously and occur many packet overhead in the communication. It is required that routing protocol in WSN is able to decrease the overhead message and increase the efficiency of network. Moreover, it is required that design that can filter the message for accurate information and architecture of message for reducing the duplication of message.

This paper is organized in the following manner. In the next section, we described related works that is related to wireless sensor network

protocol for the design of proposed routing model. In the section 3, we designed the proposed routing algorithm for implementing and described the implementation method for examination by device-level and simulation. In proposed system, we described the way of set up restricted routing paths based on the signal strength of RF Chipset, backup paths and the method of filtering for data duplication. Last of chapter 3, we described the contents of implementation by TinyOS. In the section 4, we described the result of examination by simulation using TOSSIM in the package of TinyOS and experimentation result through the device level. In the section 5, we described the result of our proposed model versus existed Gossiping Protocols and analysis of experimental results. Last chapter, we summarize this research and describe the conclusion.

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Chapter Ⅱ. Related Works

2.1 Overview of Wireless Sensor Network

Wireless sensor network consists of a number of sensor-nodes for accuracy of collected data and extension of sensing area. In order to realize the sensor network, it is required the localization which is able to sense the information between sensor and others, synchronization, data aggregation which is able to prevent redundant data from other sensors and design of the energy efficient network protocols in MAC layer for increasing the entire network performance.

Table 2-1 shows the wireless sensor network layer in a point of view the OSI Protocol Layer[18].

<Table 2-1> Layer of Protocol in Wireless Sensor Network

Layer	Research Theme of each Layer
Application	Context Aware Middleware
Transfer	Querying, Data Tracking
Network	Data Centric, Data Aggregation, Self-Configuration
Data Link	CSMA/CA, TDMA, Synchronization
Physical	Sensing, Processing, Antenna

Physical layer in wireless sensor network is the part of radio communication. Many researchers have been studying about the low power profile and energy-efficient of modulation/demodulation. The purpose of research about data-link layer is synchronization between nodes with the other nodes, the way of sensing the location information and energy-efficient data transmission. In network layer, there are many research about setting up the routing path based on the multi-hop technology and the way of data aggregation. In recent years, many researchers have been studying about design of the energy efficient protocol in a sensor unit and efficient of the entire sensor fields or network for overcome the limitation of wireless devices and weakness of wireless access media. In addition, the research of transmission layer and application layer is relatively weak but many research groups in wireless sensor network try to develop the context-aware middleware and technique of query for inter-communication from user to each sensor.

In this background, the specification and issue of consideration for constructing wireless sensor network and efficient communication is following manner[2][6][11][17][18][19].

① Limitation of resource - Wireless sensor node is driving the limitation of computing and communication resources. For example, Most of the wireless sensor nodes have a mobile MCU like ATMega128 and is driving under 2.4Ghz bandwidth. So, it is

required that sensor nodes must overcome the limitation of resource through making up for high rate of failure and cooperation.

② Limitation of energy - Most of sensor node is driving under AA or AAA batteries. The exhaustion of the sensor node means the lost of its features. Therefore, it is required that sensor nodes must be designed for energy-efficient and low power profile.

③ Self-configuration - When the sensor node is arranged on the large scale, all sensor nodes must be able to set up the network automatically without the action by administrators. Therefore, it is required that all sensor nodes must have capability of making up the networks by itself.

④ Direction of data - Each sensor node always have original direction because the data which is relayed from source node transmits to the sink node that is terminal node connected with gateway or server.

⑤ The size of data packet in application based on the wireless sensor network is more smaller than existing access media or web information

⑥ Research about the security of wireless sensor network in transmission and recognition of local information is required.

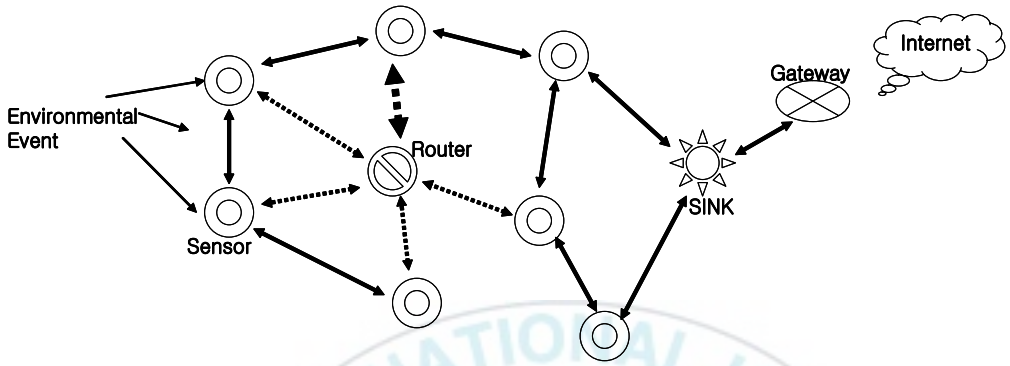

Figure 2.1 - Concept of Wireless Sensor Network

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2.2 Routing Protocol for Wireless Sensor Network

The protocol of wireless sensor network is divided the flat-based routing, location-based routing and hierarchical routing by network architecture.

Flat-based routing protocol is that all nodes can communicate with each other by coordinate level. So the communication of this protocol is performed without any access point or infrastructure.

Location-based routing protocol is that all nodes can communicate with each other based on its location information by GPS or other devices which is possible to recognize the location information.

Hierarchical routing[7][9][11] is divided the layer into node clustering. In this protocol, there are two types of node which performs the role of coordinator or collecting. Full Function Device (FFDs) is communicate with interconnection and is able to control the other sensor nodes. Reduced Function Device (RFDs) is only able to communicate with FFDs. Therefore, RFDs which performs the sensor node collects the data from environmental effects and transmits data to FFDs. FFDs can communicate with other FFDs or RFDs and transmits the data to sink or gateway. Table 2-1 shows the features of hierarchical and flat-based routing protocol.

<Table 2-2> Hierarchical vs. Flat Topologies Routing

Hierarchical Routing	Flat Routing
Reservation-based Scheduling	Contention-based Routing
Collisions Avoided	Collision Overhead Present
Reduced Duty Cycle due to periodic sleeping	Variable duty cycle by controlling sleep time of nodes
Data aggregation by cluster head	node on multihop path aggregates incoming data from neighbors
Simple but non-optimal routing	Routing can be made optimal but with an added complexity
Requires global and local sync.	Linked formed on the fly without sync
Overhead of cluster formation	Routes formed only in regions
Energy dissipation is uniform	Energy dissipation depends on traffic

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2.2.1 Technique of Flat-based Routing

Current flat-based routing protocols are the most of flooding based because the node in wireless sensor network is difficult to get the global IDentification. This protocol performs the routing based on the transmitted data rather than network address. So, this protocol pays attention to data centric routing models. All nodes is received from the specific nodes and relays the transmission data to neighbor nodes. In flat-based routing, routing information which is able to recognize the data is only premised on the neighbor nodes. Nodes in the network can decide the routing path using the meta-data or reinforcing the direction of transmission. These representative flat-based routing protocols are SAR, GBR, SPIN, Directed Diffusion, MECN, SMECN [1-3]. Flat-based protocol is able to apply the wireless communication widely and easy to implement it. However, its performance is very low and occurs the transmission overhead because of the data from one node is transmitted to all the other nodes.

2.2.2 Directed Diffusion[8]

This protocol is the most famous routing technique in wireless sensor network. The principal and interest of this architecture is following manner. First of all, collecting node we called source node transmits the query to the entire nodes. Nodes which are responsive the acknowledge to the source node. This protocol is called the data-centric routing protocol because of is set up the routing path based on named data by application and it is different from existing ad-hoc mechanism which is based on the network address. The steps of driving the Directed Diffusion are like this.

Phase1) Interest Propagation

First of all, source nodes transmit the query for getting the specific area, type of sensing information and etc to entire nodes.

Phase2) Initial Gradient Setup

A node which is received the query from source node memorize and store the source node information. When the request packet is received from the specific node which is related to the stored query, node transmits the data to request node. This process is called the Gradient Setup.

Phase3) Data Delivery Along Reinforced Path

Because the gradient which is set up the phase2 is driving the

various path, collection node is received the request data from multiple nodes. In phase 3, collection node transmits the query in order to gather more data and to increase the period of creation from sensor node. It is called reinforcement. It is purpose of simplification of routing path.

Figure 2-2 shows the steps of each phase.

Directed Diffusion is on-demand routing protocol that is set up the routing path based on the received information for the recognition of occurring some events in specific area.

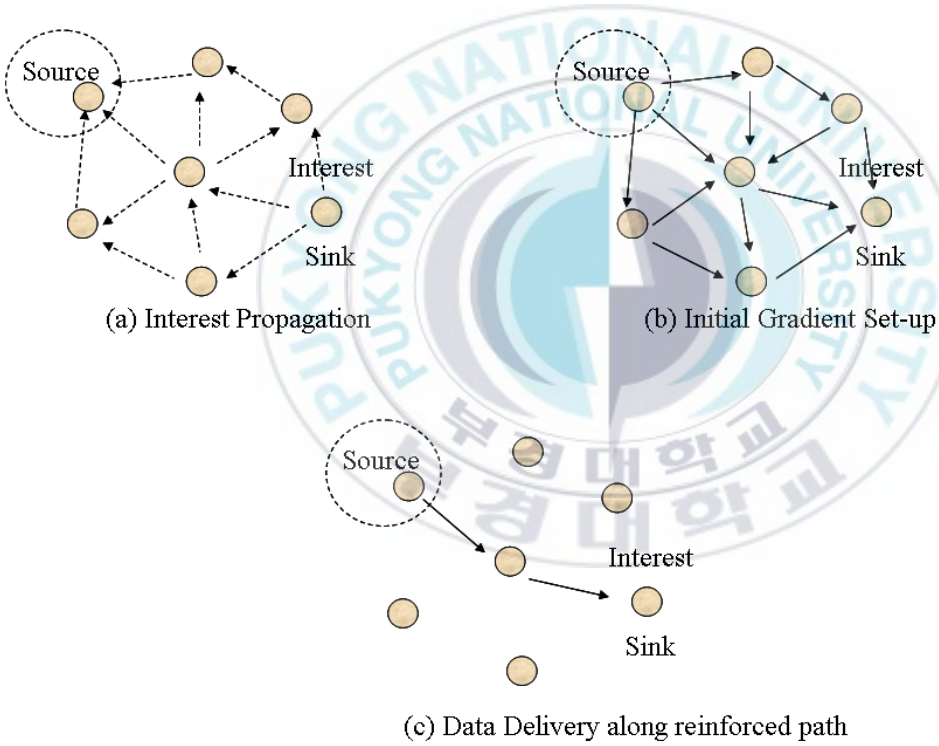


Figure 2-2 Phases of Directed Diffusion

2.2.3 Protocol based on the Flooding and its problems

Flooding protocol is currently simple routing protocol according to speak before. The technique of its mechanism is forwarding from a node to the others without specific routing path. Source node transmits the broadcast-packet to neighbor node and neighbor nodes which is received from source node also retransmit the packet to the other neighbors. However in case of transmitting the packet continuously, it occur the problem of data duplication. Thus, the unlimited loop is created and relay the same data packet continuously. It is called implosion[1].

So, the flooding protocol must design the preventing from replay of same packets through giving the specific sequence and set up the TTL that is the value of maximum number means the limitation of forwarding. If the TTL value is 20, it means that the packet is dead automatically after twenty times maximum of forwarding.

Problems of flooding protocol are like this and Figure 2-3 shows the representative problems of flooding.

① Implision: Bottleneck problem has occurred because the packets from several nodes are concentrated to the target node.

② Overlap: One node is able to receive the same packet over 2 times because the packet is sent by broadcast form.

③ Dependency: Performance of constructed network depends on its

RF Output strength.

④ Non-economical: Many nodes must join the data communication for transmitting one packet and can be forward the data by other node after the target node has been received the packet.

⑤ Collision: the rate of data collision very increases because of many nodes join the network for data transmitting.

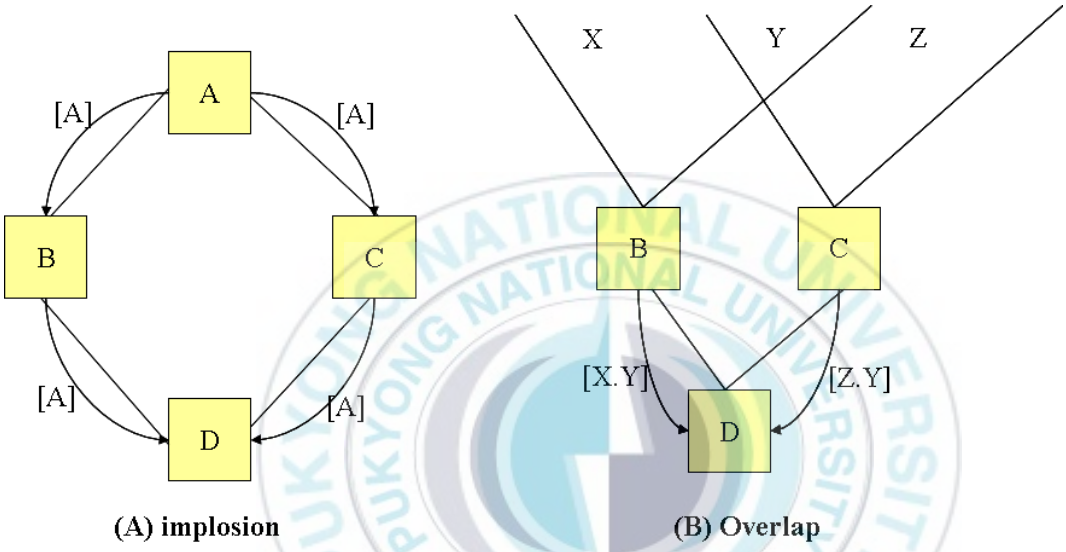


Figure 2-3. Representative problems of Flooding

2.2.4 Gossiping protocol for the solution of Flooding

Representative problem of Flooding is low efficiency of network because too many nodes join the process of packet forwarding.

Generally speaking, the basic concept of wireless sensor network is the transmission of small size packets accurately but there are many overheads in flooding protocol. For example, oversize of head section which is assigned for the routing table, hop information included the before and after links of nodes.

For the solution of these flooding problems, gossiping protocols [1-3] [26] is proposed. Gossiping protocol uses the ways of transmitting packet by probability function. Thus, this protocol transmits the periodic advertise message called 'hello packet' for finding the neighbor node in one hop count. Nodes which are received the hello packet shares with the information of neighbor nodes. These advertise packet is only transmitted in one hop count and is never forwarded by any other node [26].

In gossiping protocol, if one node is received the packet which have to forward it, relevant node must confirm the neighbor's information and select the neighbor node randomly [29]. Next, selected node is only received the packet by unicast form. Thus, gossiping protocol can widely reduce the numbers of joining the nodes. The number of reduced node means reduction of packet and it is more efficient than flooding aspect of decreasing overhead of network and energy of

transmission. Figure 2-4 shows the mechanism of gossiping protocol.

As you show the Figure 2-4, suppose the node 'A' has the data which is ready to transmit to node 'D'. Node 'A' randomly selected node 'B' in neighbor node 'B','H' and 'E'. If node 'B' selects the node 'C' it forward the packet to node 'C'. In this case, the routing path will set up 'A->B->C->D'.

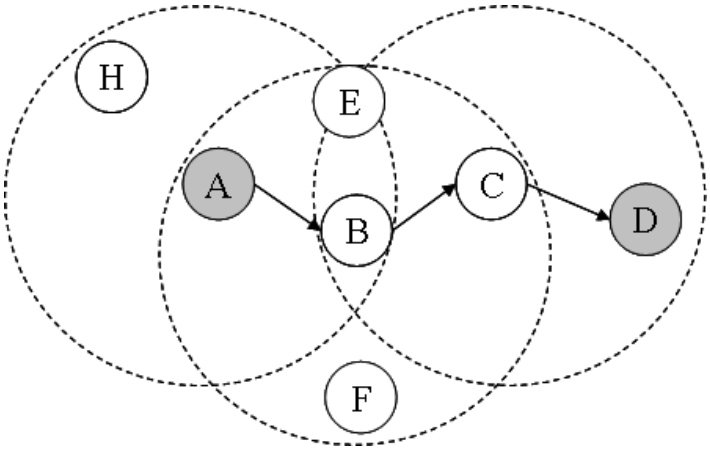
However, gossiping protocol in Figure 2-4 describes the best case of its mechanism. if you suppose the worst case in Figure 2-4, node 'B' selects the neighbor node 'F' and node 'F' can't transmit the packet any more because node 'F' is alone in the its hop range. In this case, there is no solution for this problem in the classic gossiping protocol.

Many researchers try to solve this problem and its solutions have been proposed by related research. Representative solutions for this problem use the way of selecting the multiple neighbor nodes and transmit the packet at the same time and the sorting algorithm based on probability function which is established on the carrier sensing.

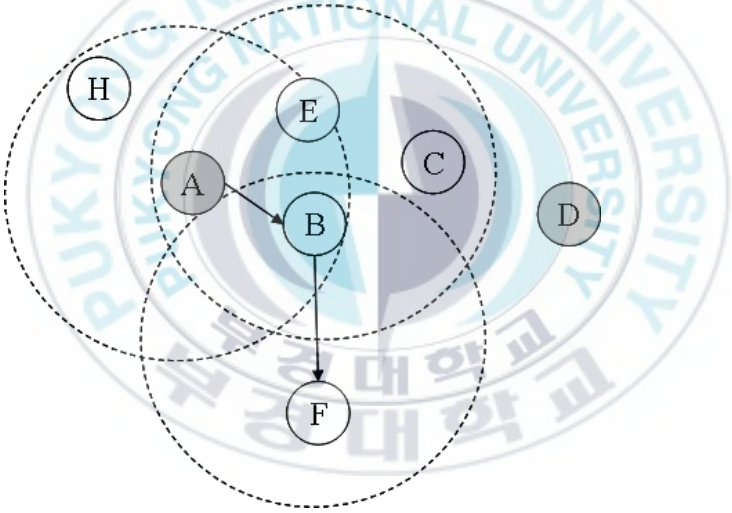
Although the data delivery of gossiping protocol is lower than flooding algorithm but it is more efficient than flooding aspects of consuming the energy and reducing the overhead of network. Finally, in order to apply the flat-based routing technique to real field, advanced protocol that is mixed the merits of each protocol as well as improvement of performances is required.

In this paper, we propose the way of improving the performance of flat-based routing based on the signal strength for selecting node and

transmitting the packet efficiently.



Gossiping - Best Case



Gossiping - Worst Case

Figure 2-4. Gossiping - Best Case vs. Worst Case

2.3 Construction of the Wireless Sensor Networks

2.3.1 Architecture of Wireless Sensor Networks

Hardware platform for wireless sensor network consists of three parts. First is MCU (Micro Control Unit) which drives the sensor, collects the data through the ADC circuits, and has the rights of control. Second is radio frequency chipset that performs the wireless communication and antenna. Last is the micro-sensor part gathers the environmental data from sensing area. Currently, most of the hardware platform for constructing wireless sensor network is based on the MOTE[23] series which is developed by U.C. Berkeley since 1999 and it has been developed various sensor hardware by other company.

Especially, MICAz[23] is installed CC2420[24] RF chipset that supports the Zigbee platform in IEEE802.15.4 - Low Rate Wireless Personal Area Network. Most of the hardware for sensor network are installed the MCU like ATMega128 by ATMel or TI-MSP430 by Texas Instrument and MCU is interlocked with CC2420.

CC2420 chipset uses the 2.4Ghz bandwith and its speed is maximum 250Kbps per 16 channels and also it is able to perform the secure communication using AES-128 cryptography algorithm. In recently years, integrated chipset has been developed owing to SoC(System on Chip) technology. For example, CC2431 has 8051 MCU Core and RF chipset in one chip. If the user designs the sensor hardware using this

chipset, the size of sensor node will be more smaller.

Figure 2-5 shows the hardware block diagram for wireless sensor network.

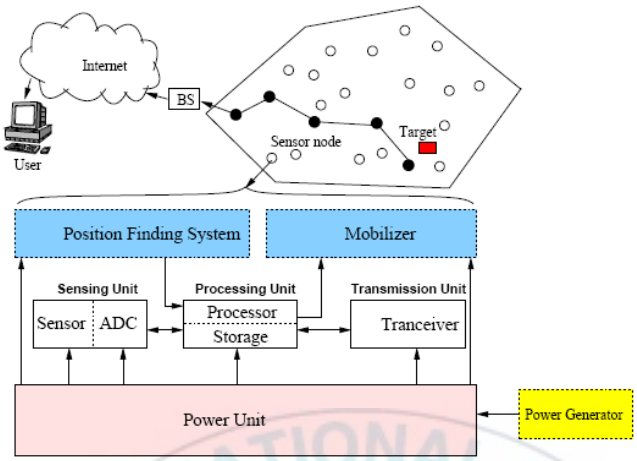


Figure 2-5. Hardware Block Diagram for Wireless Sensor Network[2]

In this paper, we used the sensor hardware called Telos-B (TIP710CM) which is used the TI-MSP430 MCU and CC2420 RF chipset. TIP710CM is clone product of Telos-B and compatible with it perfectly. Figure 2-6 shows the front and back of TIP710CM.

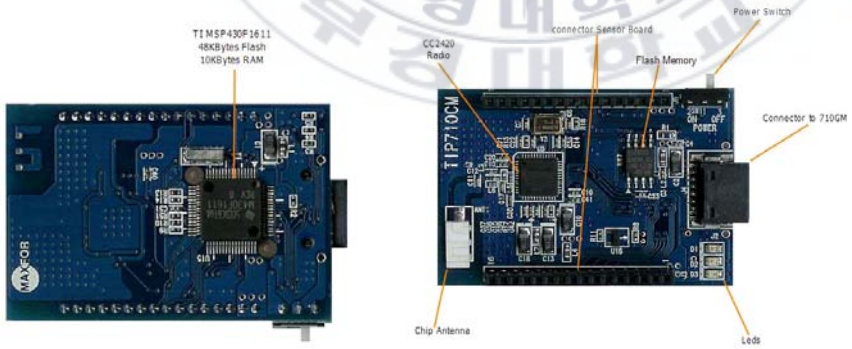


Figure 2-5. Wireless Sensor Hardware - TIP710CM[31]

2.3.2 TinyOS for Design the Routing Protocols

TinyOS[32] is the sensor network operating system for constructing the wireless sensor network based on event-driven model. The application of TinyOS consists of various small components. In other words, TinyOS has the various components like HAL (Hardware Abstract Layer), ADC for converting analog signal to digital, and RF chipset. So, it is possible that terms of development is reduced if you develop the wireless sensor network using the TinyOS.

The scheduler of TinyOS consists of simple scheduler that forms the FIFO(First In and First Out) and one task unit is performed independently. Interrupt processing in TinyOS can only be performed by event and event is processed by hardware interrupt like Timer, User Button and etc.

TinyOS supports the component named by 'CC2420RadioC' for using the radio communication and controlling the CC2420. Radio component in CC2420RadioC supports the sleep-awake algorithm for reduce the energy in duty cycle.

In this paper, we designed and implemented proposed routing protocol based on the component supported by TinyOS and verified it by TOSSIM the simulator in TinyOS. TOSSIM is the package of simulation of TinyOS Application. TinyViz is simulator supports the Graphic User Interface based on JAVA.

Chapter Ⅲ. Design of the Proposed Model

This section presents the basic routing architecture for design of proposed algorithm. In order to find the neighbor node, sensor node sends a broadcast message (hello packet), receives the acknowledgement message based on the RSSI information from neighbor node and selects the neighbor node by priority. In this thesis, our proposed model shows the difference of existing model aspects of finding the neighbors.

3.1 System Overview - Core Mechanism

The core mechanism of our protocol is the following manner. First of all, a source node transmits the broadcast message to other neighbor which is in a single hop count after a source node has initialized by operating system. When the sensor node transmits the broadcast message, there are some problems that are occurred the packet collision and hidden terminal. In this thesis, we have solved the problems using virtual carrier sensing that transmits the RTS/CTS packet at first.

For the first time, our proposed algorithm uses the neighbor's information. When all nodes is turned on the power, they are initialized the MCU and RF by OS scheduler and run the task for communication and routing. Each source node transmits the broadcast message (i.e. hello packet). 'Hello Packet' includes the ID that is the source node

information. Broadcast message is only transmitted in one hop count and can't be relayed by any neighbors. We don't consider the problem of getting out of hop counts. All nodes which is transmitted a broadcast message, except of source node send the acknowledge message to source node. Acknowledge message is included the own ID and signal strength until the destination of source node. Source nodes distinguish the target node which has highest RSSI signal strength and the others. Source node can decide the priority by this information.

According to the reference, RSSI information is in proportion to the link quality. RSSI is a measurement of the power present in a received radio signal. If the node of RSSI value is higher than the other nodes it means that a source node and target node is closer. Figure 3-1 shows the entire phases of proposed routing algorithm.

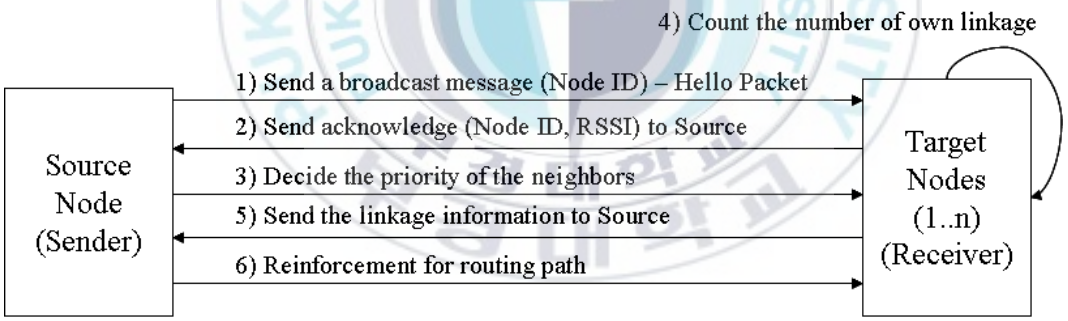


Figure 3-1 Entire Phases of Proposed Routing Algorithm

3.2 Routing Architecture

3.2.1 Entire Phases of routing architecture

First of all, suppose the entire nodes are in the single hop count and state of the each node is idle or sleep. Following steps is like this.

① If the power is turned on, each node performs the Initialized task. Initialized task is included the MCU, RF, OS initial component.

② Source Nodes which have to join the network transmit the broadcast message that is included own ID for find own neighbor nodes.

③ Nodes received data from source node measure the RSSI signal strength and transmit the acknowledge packet to source nodes.

④ Source nodes received the acknowledge message from neighbor nodes.

⑤ Source nodes select the priority of neighbor and store it to the network stack.

⑥ After the Phase 1~5 steps, all nodes have the linkage from sources to neighbors and each node transmits the packet included the number of linkage to the previous node.

⑦ If the linkage number of neighbor is below two or the node is deleted in routing table because it occurs the worst case problem.

Finally process of phase 1~7 in following steps, All nodes are able to transmit the data through one direction and set up the routing path.

If any node is in communication or no carrier state, source nodes try to retransmit the packet. This mechanism is supported by CSMA/CA algorithm in CC2420 chipset [24] and if any specific node doesn't request message any more, source node can transmit the packet the next priority. Therefore, we suggest that the problem of worst case in gossiping protocol is solved by this mechanism.

Figure 3-2 shows the mechanism of this protocol.

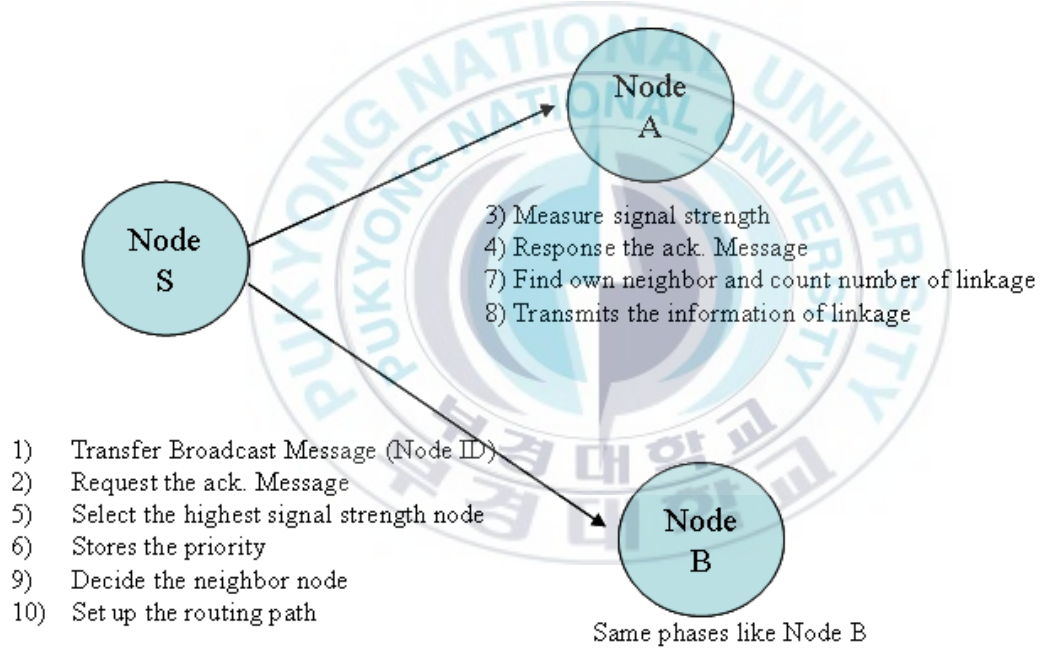


Figure 3-2. Mechanism of this protocol.

3.2.2 Joining the New Sensor Node in Existing Network

The node which is extension of network or recovery work after replacement of batteries must join the network. In this section, we described the process of joining new nodes.

The process of new node joint is same process of described before 3.2.1. New source node transmits the data and requests the neighbor's information. Existing node responses the request information of RSSI strength and number of linkage. In this case, the phase is simpler than the initialize phases because existing network is set up the routing path and transmit the packet normally.

Figure 3-3 shows the process of new node joining

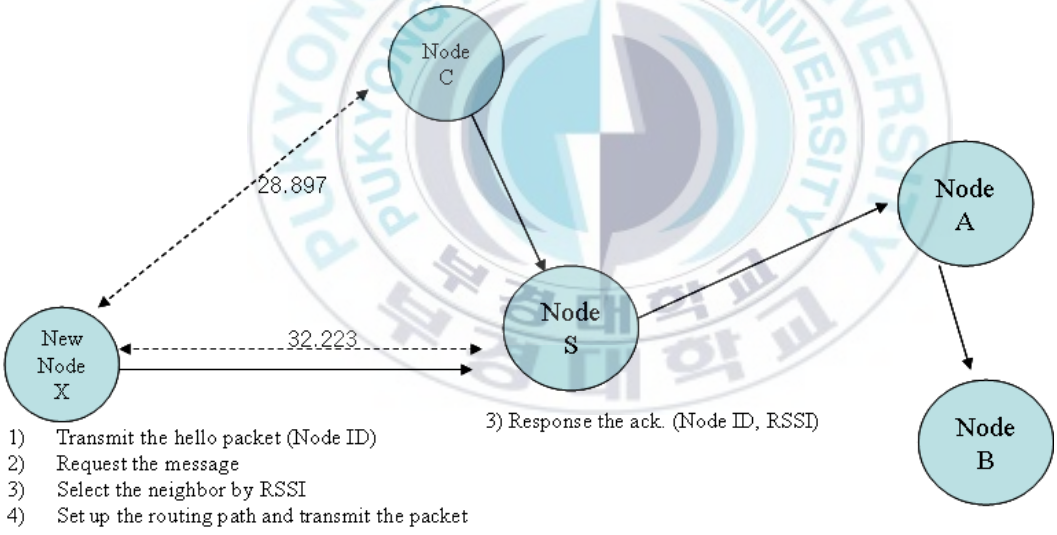


Figure 3-3 Process of new node joining

3.2.3 Delete the New Sensor Node in Existing Network

Wireless sensor node is the embedded system based on the micro-controller which is used the limitation of power and communication. So it is very important the management of resource in sensor network. Gossiping protocol is a single linkage from source to neighbor and if any sensor node is dried up and the linkage of node is disconnected. In order to prevent from this problem, the node which is anxious about the shortage must connect the other node from previous node to their new neighbor. It is important problem that finding a point of time in sensor's shortage. To find way of a point in time is the way of monitoring the node's internal voltage and computing the duty-cycle of each circuit like micro-processor, RF chipset and batteries. In case of CC2420, the minimum power is required upper 1.5V for normal wireless communication and the minimum operation voltage of TI-MSP430 is upper 1.2V. Therefore, the required voltage is minimum upper 1.5V and if the internal voltage is below 1.5V and sensor node must stop the operation by itself. In case of the node must delete owing to the problem like power limitation, node must inform the delete-request-message to the neighbor and previous node. Only so the previous node can find the new neighbor and reset up the new routing paths. Figure 3-4 shows the process of deleting the node which is worrying deadline.

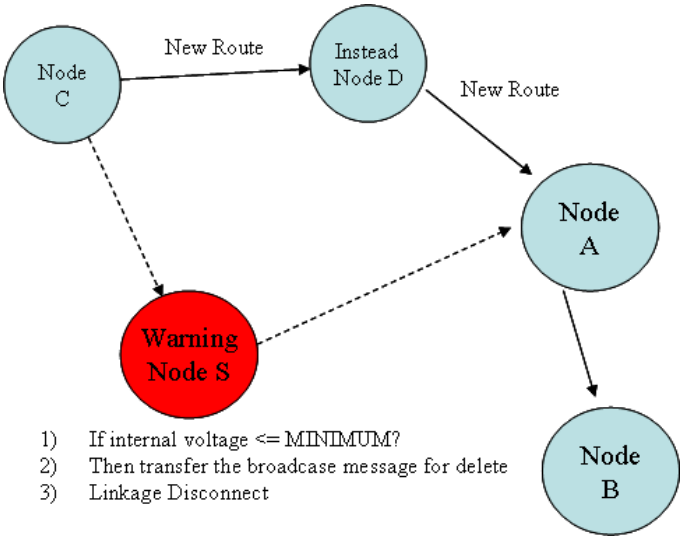


Figure 3-4 Process of delete worrying about the power shortage

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3.3 Implementation of the TinyOS Components

We implemented this routing protocol based on the proposed algorithm by TinyOS platform. TinyOS supports the example application called Surge[32] and there is a basic router component in Surge application. In this section, we replaced our protocol with the basic ad-hoc component.

Figure 3-5 shows the entire component diagram of proposed routing protocol.

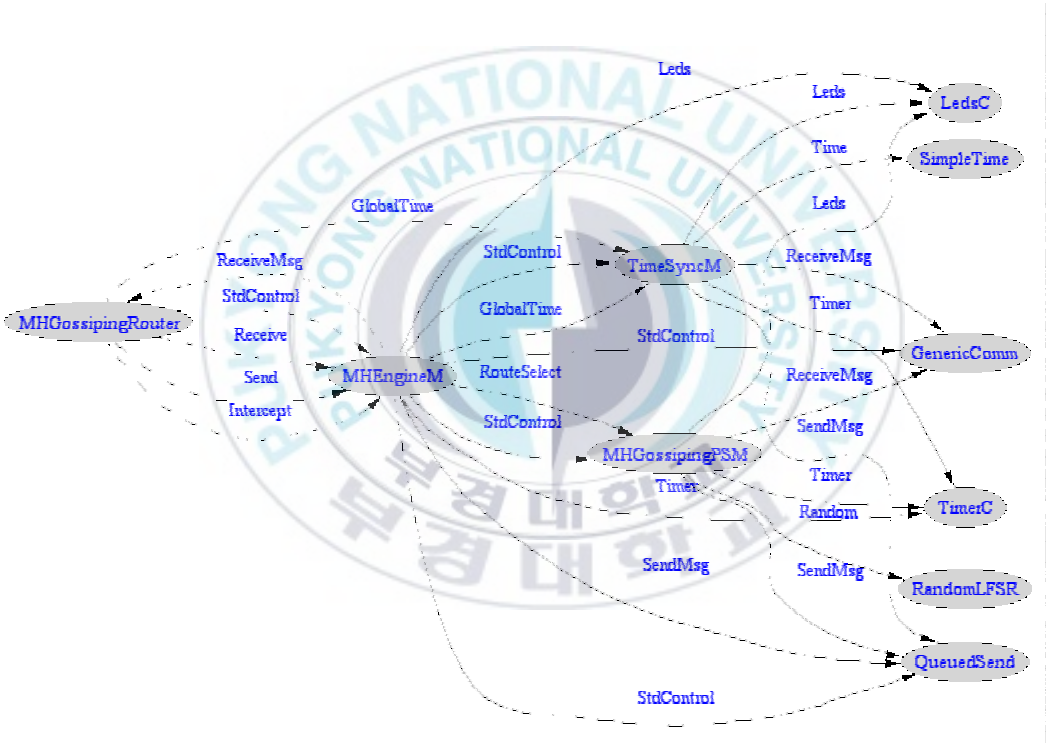

Figure 3-5. Component Diagram of proposed routing protocol.

Our development component named the NewGossiping includes the basic component called MultiHopEngine and MHGossipingPSM.

NewGossiping consists of the three main functions called 'selectRoute' and 'advertise'.

selectRoute function performs the decision of the transmission of packet by priority in routing table and advertise function is performed by timer and its features are transmitting the broadcast message for finding neighbor node.

Main features of these components are following

① Features of selectRoute includes the routing table and stores the information of strength in neighbors, priority and update function that is decision by periodic advertise message.

② selectRoute function is consist of the method called 'Relay' that performs the relay the packet from previous to target node and the function related forwarding.

③ Advertise function which is used for updating the routing table is occurred by posted event which is called 'timer fired()' and is updated by 'updateTable' function. This 'updateTable' function consists of two main mechanisms. First of all, updateTable function performs the decision by filtering the neighbor node using RSSI value and check the neighbor's linkage number. If the linkage number is under two that is called 1:1 connection updateTable function doesn't connect with relevant node because

the worst case problem is occurred by data delivery. So we designed the proposed model for preventing it from worst case problems.

Figure 3-5 describes the simple source codes of proposed model.

```
module MHGossipingPSM
{ ..... //TinyOS Basic component Wiring}
implementation
{
  typedef struct NeighbourTable
  {
    uint16_t nodeID; // Node ID
    uint16_t receivedCount; // Number of messages received
    uint16_t timerTicks; // Timer ticks since last packet
    bool nodeAlive; // Node status
    uint16_t strength; // Strength of link
  }
  task void updateTable()
  {
     ..............
  }

  task void advertise()
  {
          ........................
   if (call SendMsg.send(TOS_BCAST_ADDR, length, &routeMsg) == SUCCESS)
    {
      dbg(DBG_TEMP, "MHGossipingPSM - Advertising presence\n");
    }
  }
  command result_t StdControl.init()
  {     .................
  }
```

```
  command result_t StdControl.start()
  {     return call Timer.start(TIMER_REPEAT, ROUTE_UPDATE_RATE);
}

  command result_t StdControl.stop()
  {    return call Timer.stop();  }

  command bool RouteSelect.isActive()
  {
     if (neighbourTable[i].nodeAlive == TRUE)
     {       alive = TRUE;       break;     }
  }

  command   result_t   RouteSelect.selectRoute(TOS_MsgPtr   msg,
uint8_t id)
  {
    MHMessage *pMHMsg = (MHMessage *) &msg->data[0];
    // If the packet has arrived from another node
    if (pMHMsg->sendingNode != TOS_LOCAL_ADDRESS)
    {     pMHMsg->sendingNode = TOS_LOCAL_ADDRESS;
      pMHMsg->hopCount++;    }
    // If the current node is the base station address to the UART
    if (TOS_LOCAL_ADDRESS == BASE_STATION_ADDRESS)
    {
      msg->addr = TOS_UART_ADDR;
    }
    else if (entries > 0) // Else pick a random entry
    {
      uint16_t num = call HighRSSI.select();
      int i;
        if (neighbourTable[num].nodeAlive == TRUE)
        {  msg->addr = neighbourTable[num].nodeID;        break; }

     if (i == entries)  //if there are no more nodes to neighbors
```

```
 {
     dbg(DBG_TEMP, "MHGossipingPSM - Failed to select route\n");
     return FAIL;     }
  else
  {
    dbg(DBG_TEMP, "MHGossipingPSM - Failed to select route\n");
    return FAIL;
  }
event result_t Timer.fired()
{
  post updateTable();
  post advertise();
  return SUCCESS;
}
```

Figure 3-5. simple source codes of proposed model

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3.4 Tests by TOSSIM

TOSSIM[32] is the simulator supported by TinyOS and is compiled by 'make pc' which is command based on PC from TinyOS source codes. TOSSIM is able to experiment on the operation until 1000 units virtually.

TOSSIM supports the output for debug operation, GUI based on the JAVA, Packet Traffic Monitoring and analysis of UART packet.

Figure 3-6 shows the TinyViz supports the GUI based on JAVA

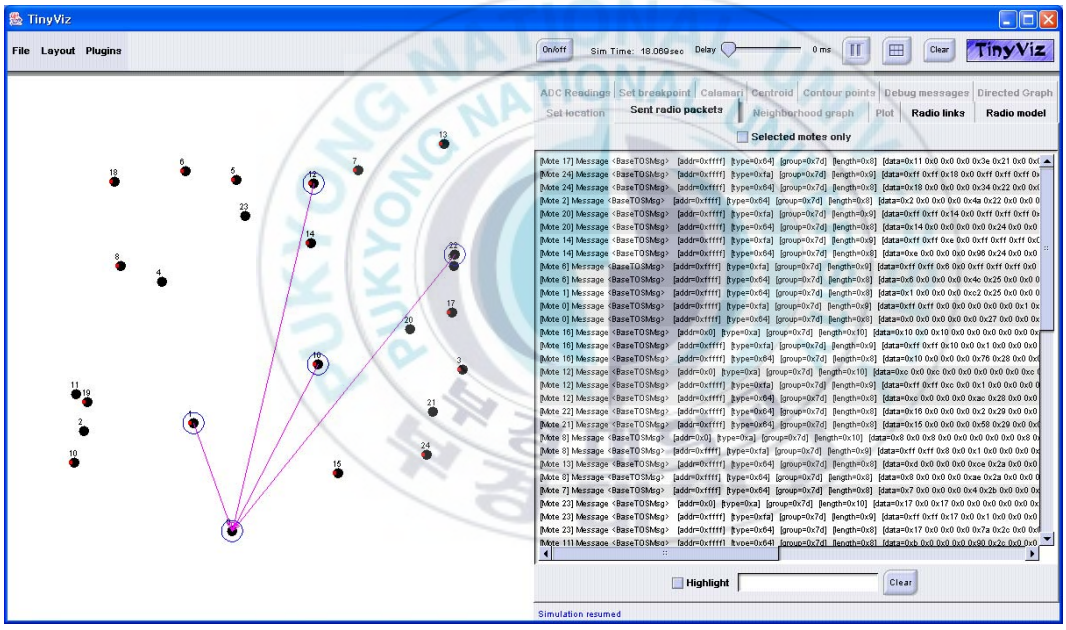


Figure 3-6 the TinyViz supports the GUI based on JAVA

3.4.1 Simulation Configuration

We tested the proposed model based on the PC platform in order to measure the performance by simulation. In this section, we will be limited to consideration of routing performance before porting the real MOTE. This simulation has no bearing the platform like PC or MOTE and we pay attention to consider the routing path, detection of signal strength. In this paper, we use the Windows OS and Cygwin that is linux emulator.

How to operate the TinyViz[32] are following steps.

① Component compile by command called 'make pc'

② After the build work, run the TinyViz through below command.

- '/opt/tinyos-1.x/tools/java/net/tinyos/sim/tinyviz -run ./build/pc/main.exe 15(Total Node Number)'

In this step, the number 15 is the number of nodes to simulate and user can test it until 10000.

③ Select the ’Sent Radio Packets', 'Radio Link', 'Radio Model' in ‘Plugin' menu. This function is to transmit packet, determine the wireless communication and topology.

④ If the user presses the play button the TinyViz simulates the TinyOS application.

3.4.2 Experiments by TOSSIM

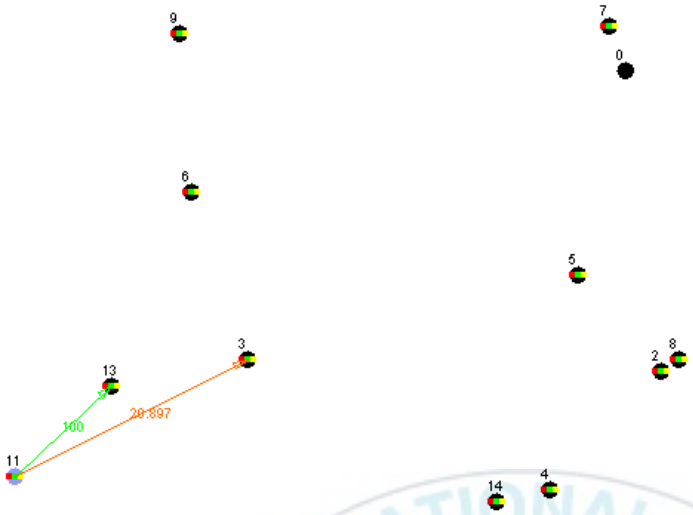


Figure 3-7. Example of decision the neighbor (Phase 1)

As the Figure 3-7 is shown, total node number is 15 and these nodes are distributed by random. Suppose the source node is 11, source node sends the broadcast message (i.e. hello packet) and node number 13 and 3 response their node number and signal strength (Figure 3-7)

In this case, node 13 is higher than node 3 and source node is set up the 1st priority node 13. The 2nd neighbor node is set up the node

11. As you shown Figure 3-8, the neighbor node(13) of source node 11 has 2 linkages and node 3 has 5 linkages. Therefore, the priority of neighbors information is decided the node 13 and is reinforced the routing path by UpdateTable function.

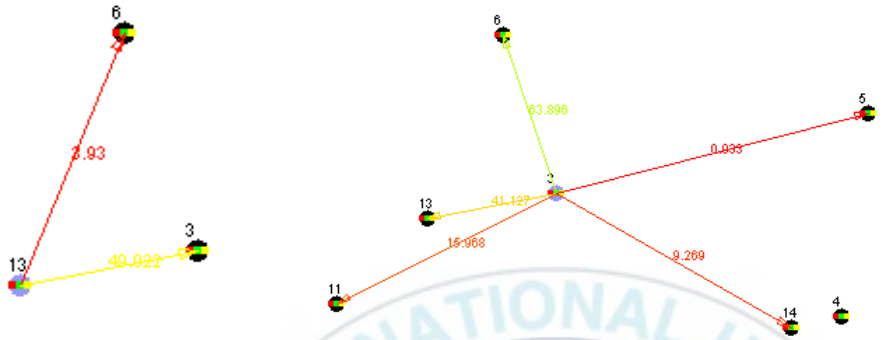


Figure 3-8 Count the linkage number (Phase 2)

The rest node decides the neighbor nodes and setting up the routing path by this technique. In reinforce the routing path, if the destination node is sink node which is end-terminal and connects the gateway the source node is able to ignore the priority and transmit the packet to sink directly.

3.5 Real Device Porting

We use 10 Telos-B[23] motes to install this application. Sample program measures the temperature during 5 second. It transmits the data to node number 0(sink node) as the forming the routing path.

How to install the proposed model is following steps.

① Compile the TinyOS application by make command.

② After the build work, reinstallation of each node.

③ Connect the Sink node (Node ID-0) to USB port and confirm the port number (USB-to-Serial).

④ Turn on the rest node (0~9) power.

Figure 3-9 Real Mote Test by telos-b

We experiment with Surge application that is applicable to real-time status monitoring of sensor nodes. Surge-application is able to show the statistics of information in each node and support the graphical interface and linkage information.

Figure 3.10 shows the experimental result by measuring the 'Surge-application'.

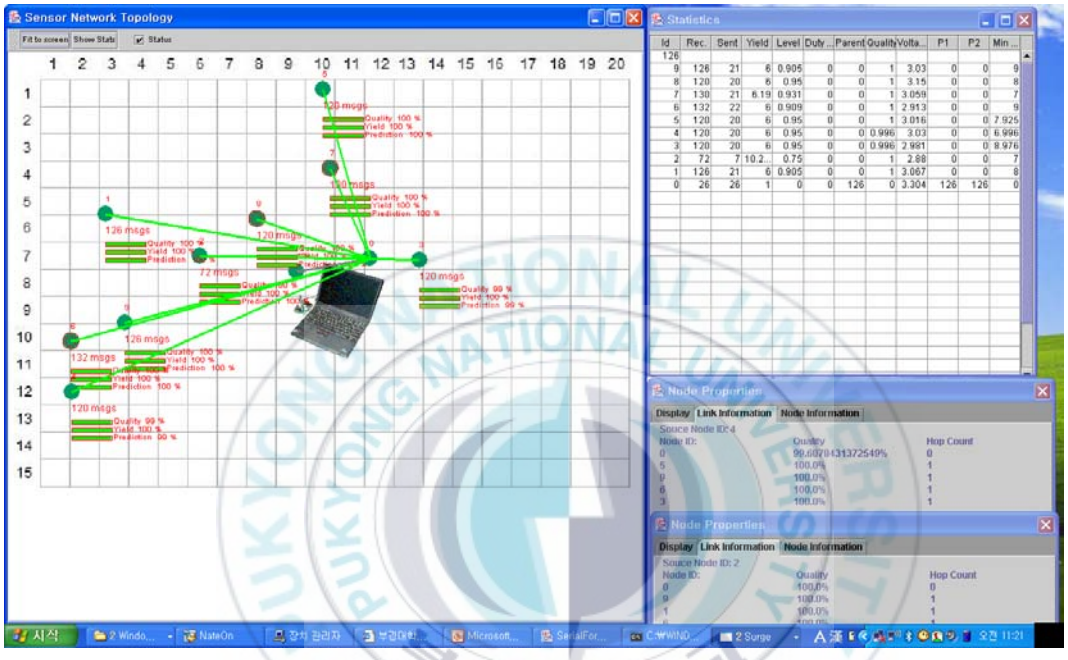


Figure 3.10 Experimental result by measuring the 'Surge-application'

Chapter Ⅳ. Experimental Result & Analysis

4.1 Experimental Configuration

In this section, we tested following configuration of transmission. The considerations of configuration have mainly three factors.

① Experiment the transfer rate by the number of node.

② Experiment the Best-Hop transmission by the number of node.

③ Experiment the Worst-case transmission by the number of node.

Table 4-1 describes the configuration of test-bed

<Table 4-1> Configuration of Test-bed

Variable	Specification	Etc.
Machine	Core2Duo CPU, 1GB RAM Windows XP SP2	SONY Notebooks
TinyOS Ver.	1.1.15Dec2005	Updated 2005.12
Network Topology	Pure Ad-hoc Network Mode	No infrastructure one sink nodes
Use Plugin in TinyViz	Sent Radio Packet Radio Links Radio Model - Empirical	Graphic View in TOSSIM
Delay Time	200ms	for Receiveing the Debug Message

4.2 Analysis of the Routing Performance

In this experiment, we distributed the node by grid form because reduce the standard deviation. Node distribution by random is higher than grid form or other form. Figure 4-1 shows the distribution of grid form in TinyViz.

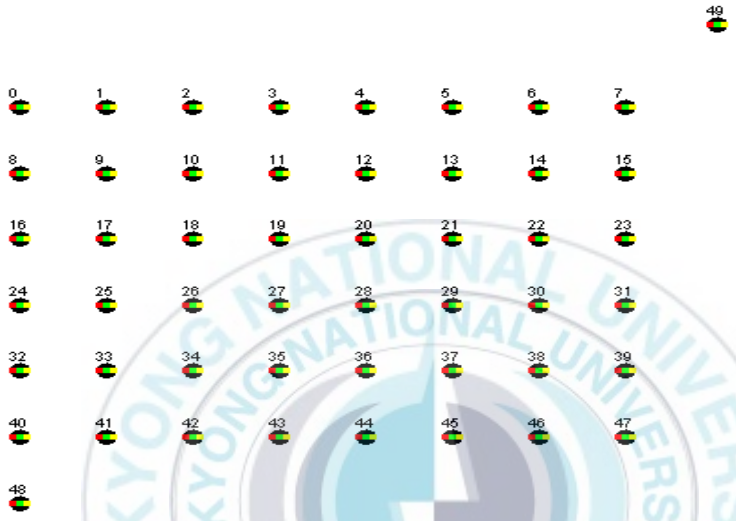


Figure 4-1. Node Distribution

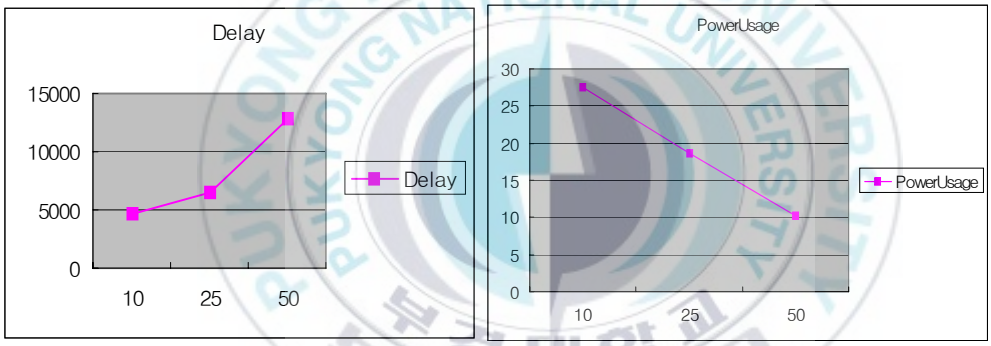
At first, we decide the source node to gather the information of temperature sensor. Source nodes are in the first column that is 0,8,16,24,32,40, and 48. Sink node is the last number 49. Source nodes gather the data by temperature sensor and perform the self-configuration using proposed algorithm. After the first test was performed we tested the many times on changing the source nodes number. Table 4-2 describes the results of the experiment.

<Table 4-2> Protocol Simulation Results by TOSSIM

Number of Nodes	Delay	PowerUsage	Loss of Data	Connectivity
10	4733.36	27.46	54.22%	99.54%
25	6438.58	18.66	12.63%	99.50%
50	12821.50	10.22	2.39%	99.51%

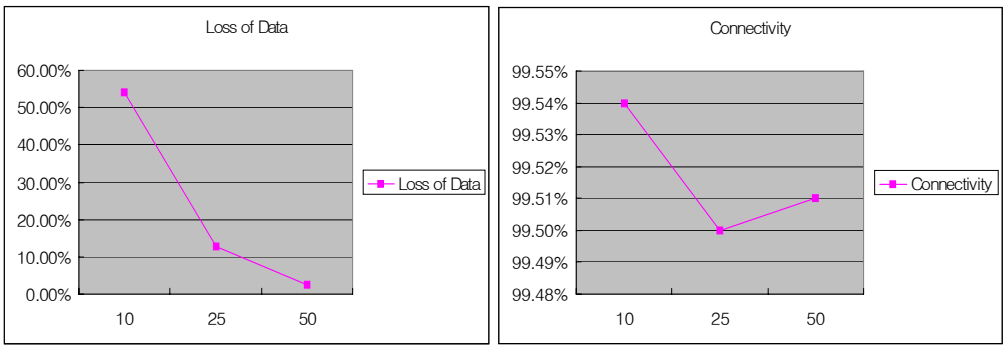
As the shown the Table 4-2, the delay time is increasing in proportion to the number of nodes but the usage of power and loss of data is decreasing in a single node case, although a unit of network relatively have many hop-counts. Moreover, connectivity of node is about the same proportion although the number of node is increasing.

Figure 4-2 and Figure 4-3 present the result of experiment by graph.



(a) Delay of transmission (b) Power usage of transmission

Figure 4-2 Experimental Result



(a) Loss of Data (b) Connectivity

Figure 4-3 Experimental Result

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4.3 Comparing with Gossiping Protocols

We tried to compare our proposed protocol with existed gossiping protocol. The main differences of our protocol are that the neighbor node is selected by information of signal strength and counting the edge node number against random selection.

We compared the classic gossiping protocol with the proposed protocol and used the classic gossiping implemented by TinyOS 1.1.11 version. Figure 4-4 shows the comparison by delay time. Delay time is relatively increasing as the numbers of node increase in proposed model. The main reason of increasing the delay time is in proportion to the number of nodes. On the contrary, when the node number is 25 delay time is decreasing in classic gossiping protocol. This phenomenon is given an explanation of using random technique of selecting neighbor node and classic gossiping model doesn't consider the error rate and standard deviation. Figure 4-4 shows the comparison of two techniques.

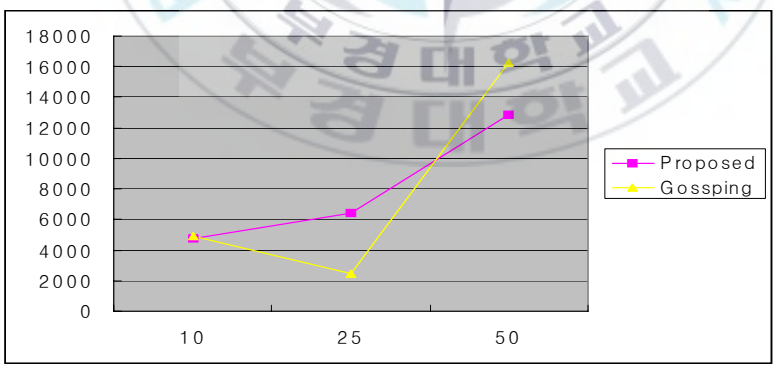

Figure 4-4. Proposed Model vs. Gossiping in Delay Time

Figure 4-5 shows about the power usage by graph. Proposed model is a little more efficient than classic model. The reason is that proposed model use the way of selecting node before speaking the section 3.2. It is efficient that selecting node by signal strength is better than by random. After all, if the location of source node is far from the neighbor the signal strength is relatively weak and transmission power is an inverse proportion.

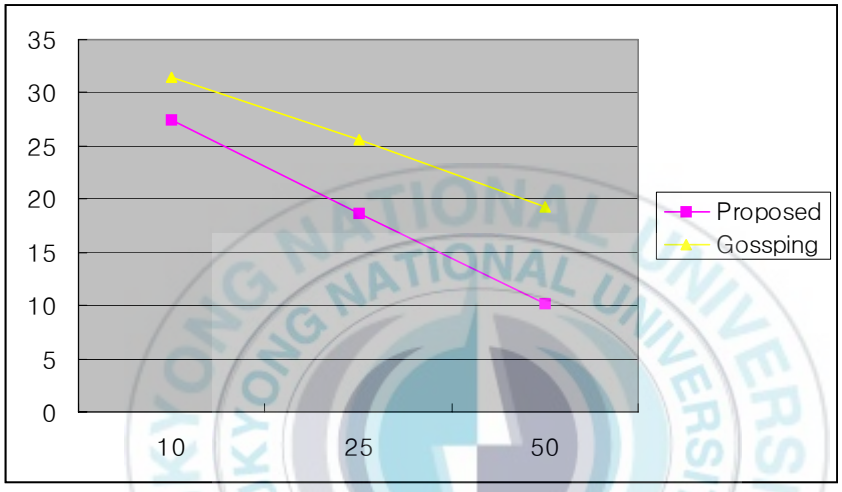

Figure 4-5 Proposed Model vs. Gossiping in Power Usage

Figure 4-6 shows the proportion of loss data in proposed model vs. classic model. In proportion of data loss is no more difference between proposed model and classic model. However, the rate of data loss is over 50% in case of constructing small number of node. The reason is that there are no more way of solution between proposed model and classic model. However, if the number of node is guaranteed the proportion of data loss is rapidly decreased.

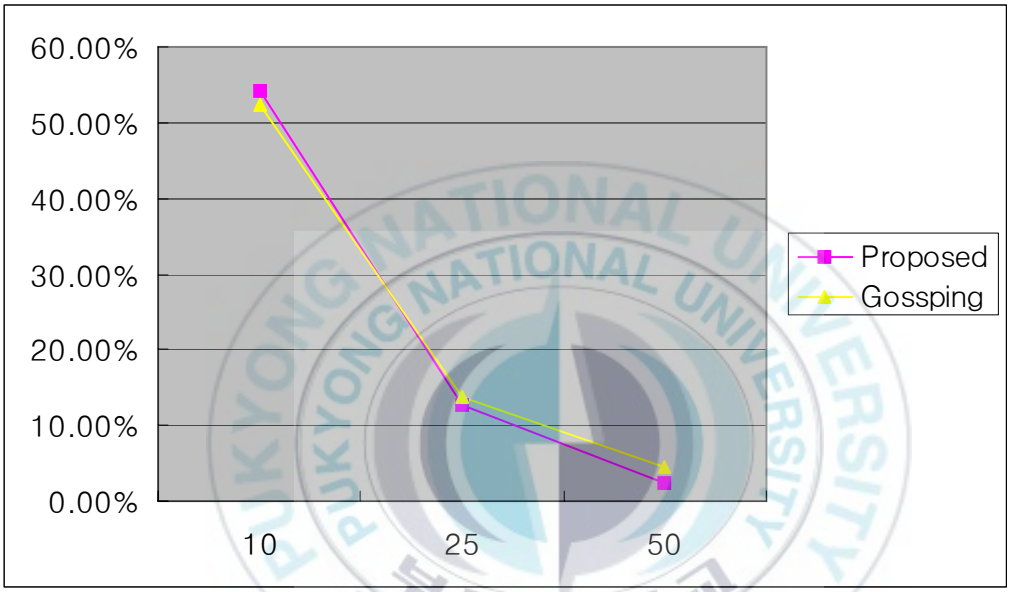

Figure 4-6 Proposed Model vs. Gossiping in Loss of Data

Lastly, Figure 4-7 shows the connectivity of proposed model vs. classic model in a single hop count. As you see the figure most of nodes guarantee the state of stability. However, the comparisons of proposed model with the classic mode is that proposed model doesn't transfer the packet if the signal strength is not guaranteed. The classic model is the way of random selection of neighbor node and it occurs to drop the reliability of transmission. On the contrary, there is no problem in proposed model because its mechanism is based on the priority level. Moreover, suppose the specification of wireless media like SNR ratio and white noise each protocol is shown the perfect connectivity.

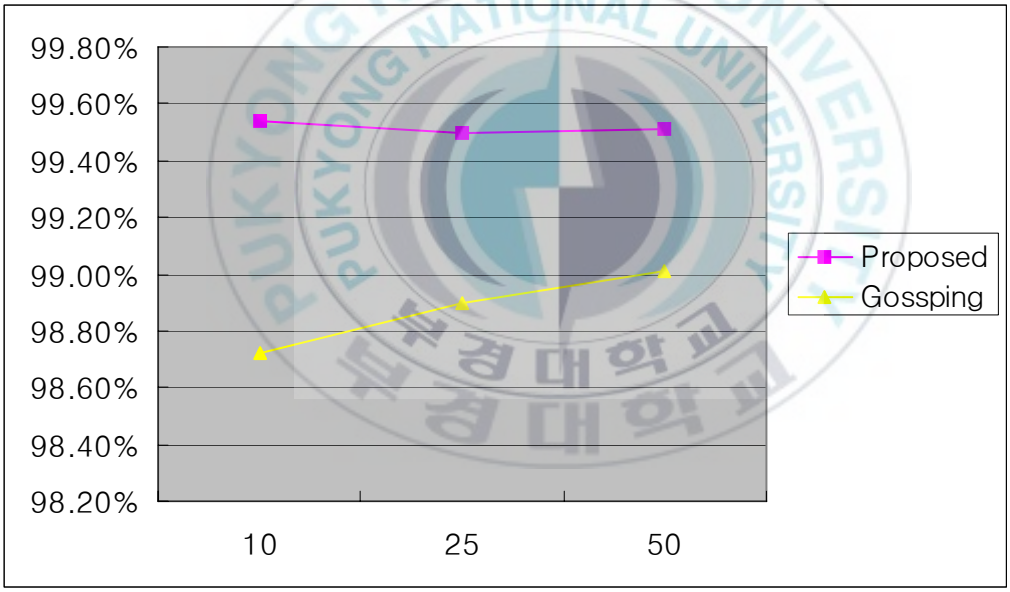

Figure 4-7 Proposed Model vs. Gossiping in Connectivity

Chapter V. Conclusion

Wireless Sensor Networks are a subset of wireless networking applications focused on enabling connectivity without specific infrastructure and the use of wires to sensors in general. The purposes of WSNs are gathering the information from environmental effect, communicating each other and construct its own network at any time and anywhere. So the self-configuration for constructing network and accurate routing technique are required.

The routing technique of Wireless Sensor Network is mainly classified the Flat-based and hierarchical-based technique. The former is used the network without any other infrastructure and the latter is used the large scale network or with access points.

In this thesis, we performed the research of the routing technique based on gossiping and try to raise the performance as we solve the problem having gossiping protocols. We designed the way of selecting neighbor node replaced the technique of reinforcement by RSSI with improving the random selection and tried to minimize the worst case problems using the linkage number. Using the way of this mechanism is more efficient than classic model aspects of delay time and power usage.

However, we can't help avoid facing the case of a node connects to the neighbor with only one linkage and if the nodes is relatively

crowded, delay time is increasing. We can't solve this problem perfectly. I think that this problem is the limitation of flat-based routing.

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