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# 무선 메쉬 네트워크에서의 응용 서비스 인지 라우팅 프로토콜 선택 기법

# ( Application-aware Routing Protocol Selection Scheme in Wireless Mesh Network )

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요 약

본 논문은 무선 메쉬 네트워크에서의 응용의 특징에 따른 라우팅 프로토콜 선택 방법에 대해서 제안한다. 각 응용들은 생성되는 평균 패킷 크기와 같은 서로 구분되는 특징을 가지고 있다. 예를 들자면, 텍스트 메신저는 작은 크기의 패킷을 주로 발생시키며, 파일 전송 응용의 경우는 큰 크기의 패킷을 주로 발생시킨다. 또한, 라우팅 프로토콜도 각기 다른 특징을 가진 경로를 설정한다. 최단 거리의 홉을 설정하는 라우팅 프로토콜과 홉 수는 보다 증가하더라도 높은 bandwidth를 가지는 링크로 경로를 구성하는 라우팅 프로토콜 등 각각의 특징을 가진 라우팅 프로토콜이 존재한다. 제안하는 방안은 서로 다른 응용의 특성을 제일 잘 반영시킬 수 있는 경로를 설정할 수 있도록 라우팅 프로토콜을 선택하는 방법론을 제시한다. 본 논문은 제안하는 방법이 반영되어 검증 및 구현된 메쉬 네트워크 시스템과 이에 대한 실험 결과를 보인다.

Abstract

We propose a novel routing protocol selection scheme based on the application feature in wireless mesh network. Each application has its own feature such as its packet size. For example, text messenger generates short size packets and file transfer application generates long size packets. Routing protocols in wireless mesh network discover the route with different features. Some find shortest hop routes; others find the routes consisting of high bandwidth though they have more hops. The proposed scheme selects the routing protocol by matching the feature of routing protocol and that of application. This paper shows the system that we have developed for supporting mesh routing as well as the proposed scheme and experimental results.

**Keywords :** Wireless Mesh Network, Routing, Wireless LAN, Cross-layer, Application-aware

## I. 서 론

Wireless mesh networks have been deployed in many places in the world to provide the internet connection. Some deployment is progressed to resolve the digital divide phenomenon, which is usually called digital inclusion. This kind of activity is possible because the wireless mesh network can provide the network infrastructure with low cost. No need of high cost deployment of wired line and cheap device such as Wi-Fi AP(Access Point) makes the low cost possible.

Wireless connection among APs makes the routing discovery more important and more difficult than other kind of network because of more combination of the route and the interference among the wireless connection. There are many routing protocols

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proposed and implemented. Each routing protocol has its own purpose and the feature. This paper proposes the selection scheme of routing protocol to maximize the feature of each routing protocol. The philosophy of the proposed scheme is matching the feature of routing protocol and that of the application that uses the established route.

Jain et al.[1] proposed the algorithm that selects the routing protocol between the reactive routing protocol where the routing control messages are generated on demand and the proactive routing protocol where those are generated periodically. This algorithm calculates the cost such as the power that is needed for transmitting the routing control messages and updating routing table. It selects the routing protocol based on this cost.

Rangnekar et al.[2] proposed the scheme in which the network unifies the routing protocol among the different routing protocols of different part of the network. One node collects the information of routing protocol of near nodes, and finds the most commonly used routing protocol and broadcasts this information to other nodes in the network.

Chander et al.[3] proposed the selection method that chooses one of the routes that more than two routing protocols established. From the same source to the same destination, more than two routing protocols work to establish the route and then the best route is selected. More than two routing protocols works at the same time cause the burden to the network.

Previous works select the routing protocol based on the cost, unify the routing protocol among the network, or select the route among the already established routes by more than two routing protocols. In this paper, we propose the scheme of selecting the routing protocol in terms of the application. With the feature of the application and that of the routing protocol, it selects the routing protocol based on the application. To distinguish the application, we use the port number of transport layer. Therefore, the applications are FTP, TELNET, HTTP and so on.

Similar work exists on the point of using the port number. Kola et al.[4] proposed the scheme of allocation of resource to the network based on the measured traffic characteristics of each port number. It is different from our proposed scheme because the proposed scheme uses port number itself not to allocate the resource but to select the routing protocol.

The remainder of this paper is organized as follows. In section II, the proposed scheme is shown. In section III, experimental system that we developed and the test result are described. Finally, Section IV concludes this paper.

## II. 응용 서비스 인지 라우팅 선택 기법

Since this paper uses Ad hoc On demand Distance Vector (AODV) and Fastest Transmission Time Selection (FTTS) routing protocol as the examples of routing protocols, we describe the operation of the AODV and FTTS and then we present the proposed scheme.

### 1. AODV v.s. FTTS

The AODV routing protocol proposed by Perkins et. al.[5] is one of the most common routing protocols for the ad hoc networks. Routes are established only when the packet needs to be transmitted. It does not require periodic routing information exchange. When a source node needs to send data packets but does not have any routing information available, it broadcasts the RREQ packet. The RREQ packet is uniquely identified by the source address and the RREQ ID. If a node receives a non-duplicate RREQ packet, it records the address of the node from which the RREQ packet is arriving and the source address for reverse routing. And then the RREQ packet is broadcasted to its neighbors. If it receives duplicate RREQ packets, they are discarded.

When either the destination node or an intermediate node having fresh enough routing

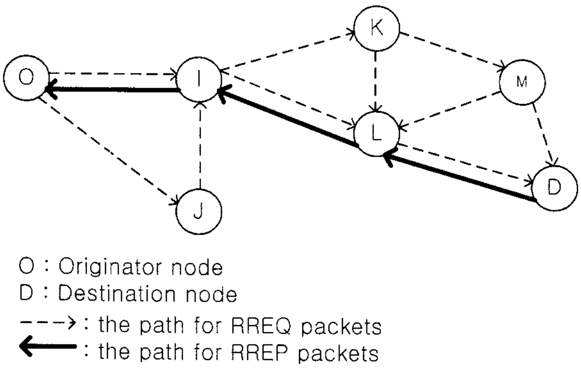


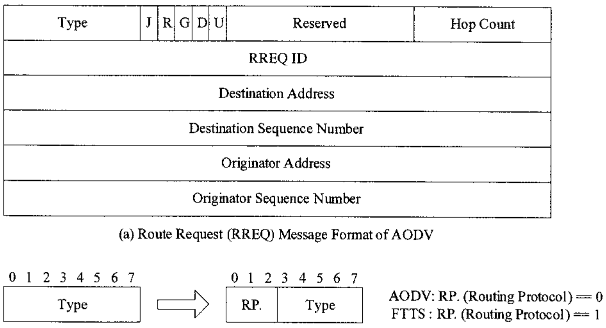

그림 1. AODV 동작 예
Fig. 1. Operation of AODV.

information towards the destination node receives the non-duplicate RREQ packet, it generates the route reply (RREP) packet and sends back to the source using the reverse route. As the RREP packet traverses along the reverse route, the forward route table entry for the corresponding destination node is created or updated to be used to forward data packets to the destination. It is shown in Figure 1.

A sequence number maintained by each node is used to determine the freshness of the information. In AODV, the sequence number increases monotonically. A node's routing information is called fresh enough if the destination sequence number in the node's route table entry for the destination node is greater than or equal to the destination sequence number of the received RREQ packet.

Fastest Transmission Time Selection (FTTS) is newly designed on-demand (reactive) routing protocol. It is based on AODV and it is like radio-metric AODV in IEEE 802.11s[6]. It selects the route having the smallest transmission time, while AODV selects the route having the shortest hops.

FTTS is different from the AODV on two points. The routing metric of FTTS is changed from that of AODV. Transmission Time (TT) = 1 bit / bandwidth + minimum processing time of the node. The Routing metric function, f is the sum of TT over the link over the route. A Route is composed of links. We assume that the node N can know the actual transmission (or maximum bandwidth) bandwidth of




| Type | message |
|---|---|
| 1 | RREQ |
| 2 | RREP |
| 3 | RERR |
| 4 | RREP-ACK |

| Type | message |
|---|---|
| 1 | RREQ of AODV |
| 2 | RREP of AODV |
| 3 | RERR of AODV |
| 4 | RREP-ACK of AODV |
| 33 | RREQ of FTTS |
| 34 | RREP of FTTS |
| 35 | RERR of FTTS |
| 36 | RREP-ACK of FTTS |

(b) Change of the Type field

그림 2. FTTS와 AODV 예제
Fig. 2. Example of FTTS and AODV.

the link with the node M that sends routing control message to node N. When the node receives the packet it can know Received Signal Strength Indication (RSSI) of the received packet. Based on this value, the node guesses the transmission rate. Therefore, the node N can calculate TT.

FTTS selects the route having the smallest sum of TT of each link over the route. Dealing the duplicate RREQ is different from that of AODV. While AODV discards duplicate RREQ always, when FTTS receives duplicate RREQ having better routing metric than that of the existing routing table entry it will update the routing table entry with new routing metric value and re-broadcast RREQ.

Because FTTS is designed based on AODV, routing control messages can be distinguished from those of AODV using different type value of RREQ. The example is shown in Figure 2.

## 2. 제안 기법

In brief, Figure 3 shows the concept of the proposed scheme. We assume that some kinds of routing protocols (in our example, FTTS and AODV) exist in the system. The Routing Protocol Selector activates one of them with the application information. In Figure 4, the wireless mesh network

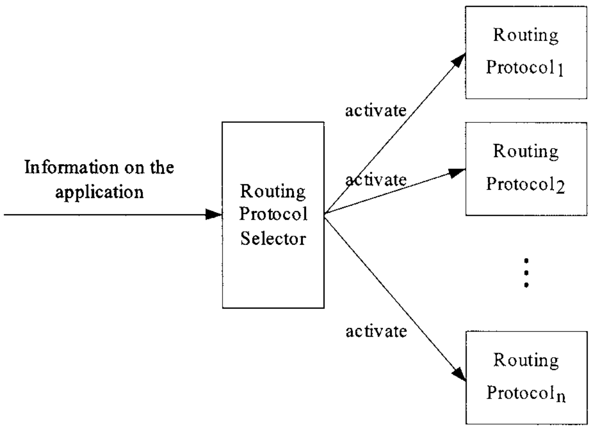



그림 3. 라우팅 프로토콜 선택의 개요
Fig. 3. Abstract of routing protocol selection.

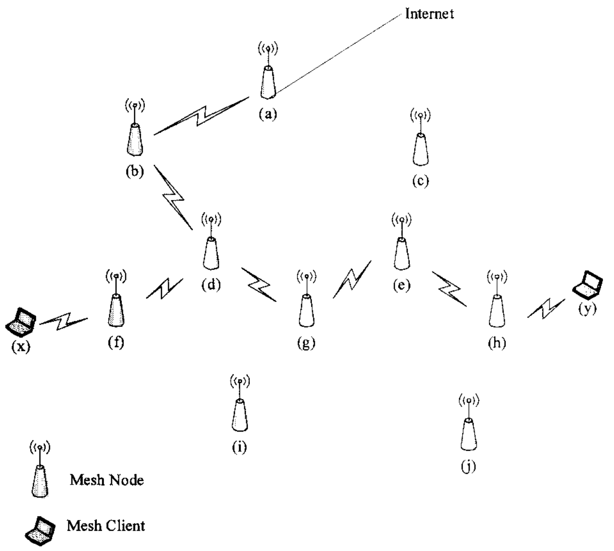



그림 4. 무선 메쉬 네트워크 구조
Fig. 4. Wireless mesh network.

is composed of mesh nodes that connect to themselves by wireless connection. Mesh client connects to mesh node to access the network. This figure shows the example of the connection between mesh client (x) and (y). It shows also the route between mesh node (f) and (h). We call node (f) as the source node and mesh node (h) as the destination node. The intermediate nodes such as node (d), (g), (e) and (h), and the wireless links represent the route. Depending on which routing protocol is selected, the route can be changed. In other words, the combination of the intermediate nodes can be changed.

When the source node receives the request of route

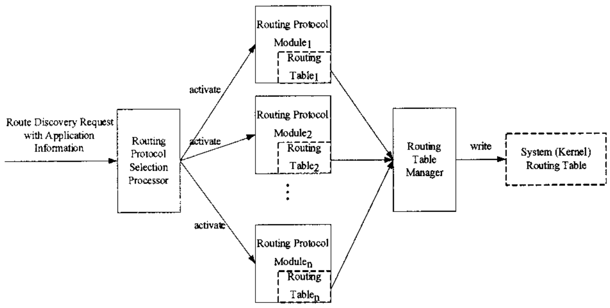



그림 5. 소스 노드에서 라우팅 프로토콜 선택 구조
Fig. 5. Routing protocol selector in the source node.

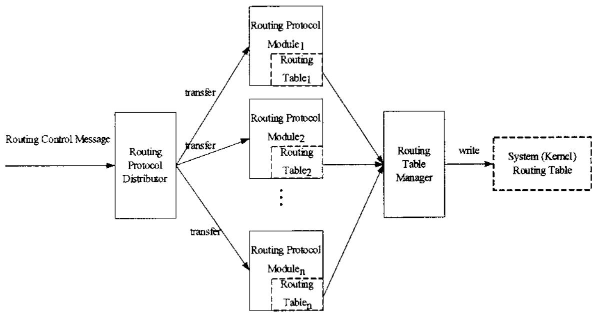



그림 6. 중간 노드에서의 메시지 분배
Fig. 6. Message distributor in the intermediate nodes.

establishment from the mesh client, it selects the routing protocol with the application information and activates the selected routing protocol. If the routing table is updated, routing table manager detects it and updates the system routing table. This process is drawn in Figure 5. Figure 6 shows transferring of routing control messages to the corresponding selected routing protocol when it receives the routing control messages. The system routing table is also updated if the internal routing table is updated.

The decision rule of the selection is defined as the routing protocol selection table. The example of this table is shown in Figure 7. The application feature is defined as the destination port number. Figure 8 shows how the application information is extracted from usual TCP/IP packet. The destination port number represents the application such as FTP, TELNET, HTTP, etc. With the destination address and the application information, the node selects the routing protocol based on routing protocol selection table.

| | Port | Protocol | AODV | FTTS |
|---|---|---|---|---|
| | 20 | FTP, Data | Not Use | Primary |
| | 21 | FTP, Control | Not Use | Primary |
| | 23 | TELNET | Primary | Not Use |
| TCP | 25 | SMTP | Primary | Reusable |
| | 80 | HTTP | Reusable | Primary |
| | 53 | DNS | Primary | Reusable |
| | 111 | RPC | Primary | Reusable |
| UDP | 69 | TFTP | Not Use | Primary |
| | 123 | NTP | Primary | Reusable |
| | 161 | SNMP | Primary | Reusable |
| | others | Others | Reusable | Primary |

그림 7. 라우팅 프로토콜 선택 테이블 예제
Fig. 7. Example of routing protocol selection table.

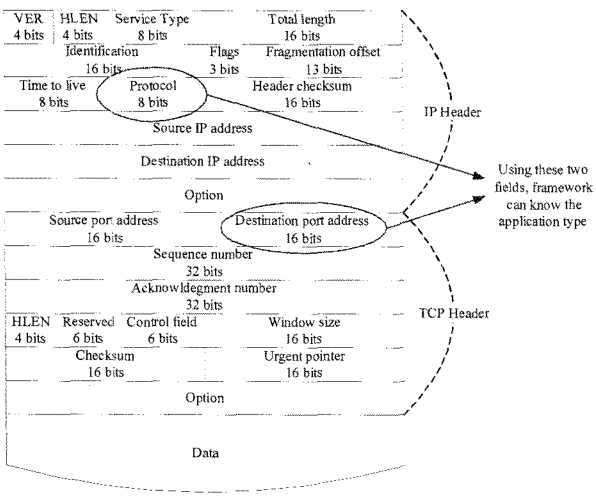



그림 8. TCP/IP 패킷의 응용 서비스 정보
Fig. 8. Application information in TCP/IP packet.

In the entry of one destination port, the routing protocol having "Primary" is selected. If the same destination address and the same routing information exist already in the system routing table, the existing route information is used without any further operations. System routing table is different from usual routing table, that has the entry identification with the destination address because it has the entry identification with the destination address as well as the routing protocol. Figure 9 shows the example of the system routing table. To provide the different route to each application, the routing table needs this kind of identification.

| Dest. | Routing | Seq. | Metric | NextHop | NextLink | Time | LifeTime | IsGW | Etc. |
|---|---|---|---|---|---|---|---|---|---|
| Node9 | FTTS | 2 | 0.22 | Node3 | . | . | . | No | . |
| Node9 | AODV | 3 | 0.5 | Node5 | . | . | . | No | . |
| ⋮ | | | | | | | | | |
| Node20 | . | . | . | . | . | . | . | Yes | . |

Dest.: Destination
Routing: Routing Protocol
Seq.: Sequence number
Metric: Routing Metric
Time: Timestamp
IsGW: Is it Gateway?

그림 9. 라우팅 테이블 엔트리의 예제
Fig. 9. Example of the routing table entry.

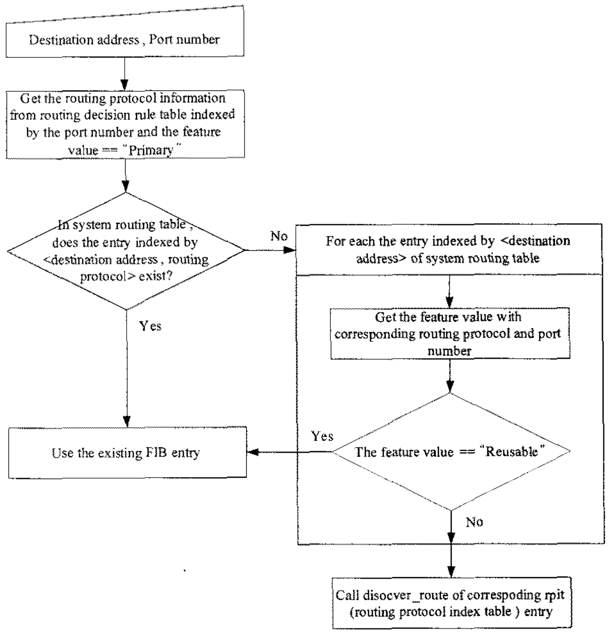



그림 10. 라우팅 프로토콜 선택의 흐름도
Fig. 10. Flowchart of routing protocol selection.

Though the same destination address exists in the routing table entry if the different routing information exists, the operation depends on the value of the existing routing protocol column. The value can be "Reusable" or "Not use." If the value is "Reusable," the node uses the already established route with the routing table entry information. However, if the value is "Not use," the node activates the selected routing protocol. Therefore, it is possible to have several routes between the same source node and the same destination node because more than one routing protocol can be activated. This selection process is drawn in Figure 10.

The proposed scheme selects the routing protocol with the application feature. It identifies the routing table entry with the destination address and routing protocol. Even if there is an existing route, if the different routing protocol is used to establish the route, a new route can be established by other routing protocol. This decision is performed based on the routing protocol selection table. If the application feature can be matched to more than two routing protocols, these two routing protocols can reuse the route without newly establishing the route. If not matched, a new route establishment is needed.

Here is the example of routing protocol selection. When the route is established and the system routing table entry is created previously, the reuse of the system routing table is decided by the decision table. For example, when the route of FTP was made by FTTS previously, the following cases are possible. I) If TFTP connection is needed, the same routing protocol (FTTS) is marked as the "Primary," it can reuse the route. II) If the SMTP connection is needed, though AODV is marked as "Primary", it can reuse the route, because prior routing protocol (FTTS) is marked as "Reusable." III) If the telnet connection is needed, AODV is marked as "Primary" and prior routing protocol (FTTS) is marked as "Not Use." This case needs invocation of AODV routing protocol. To reuse the route efficiently, making the decision rule table is very important.

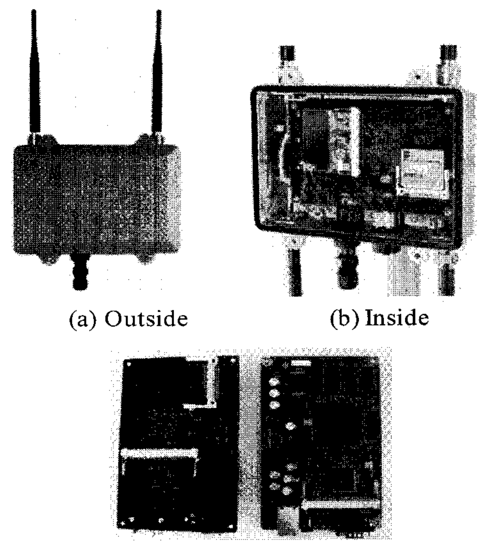
The routing protocol selection table must be designed carefully. However, many cases are decided intuitively. For example, TELNET has the feature generating short length packet in irregular and FTP has the feature generating long length periodically. They do not have sharable feature. However, SMTP generates short length packet or long length packet depending on the length of E-mail. Therefore, it can share the feature of TELNET or FTP.

## III. 구현 및 결과

The proposed scheme is verified through the implementation by the real system. Actually, the system and simulator have some features other than routing. However, in this paper, we will introduce them in the view of routing.

We implemented the real system using the meshbox shown in Figure 11. It has the dual wireless LAN interfaces. One is IEEE 802.11b/g for mesh client access and another is IEEE 802.11a for mesh node routing. Based on embedded Linux (linux-2.4.25-imedia), we developed routing protocols and other modules. The overall architecture and modules are illustrated in Figure 12. We named it as MAC-Independent Mesh Networking System (MMNS). The GLL (Generic Link Layer) provides generic MAC interface supporting a few kinds of Wi-Fi MAC. The Self-Organization Block (SOB) is composed of Neighbor Discovery (ND) and authentication, etc. Forwarding Information Base (FIB) keeps system routing table. When there is a data packet to forward, GLL refers FIB rather than the routing table of each routing protocol. Forwarding Table Manager (FTM) activates the proper routing protocol and updates FIB with the result of the routing protocol. For data packet forwarding, routing table is not used, but FIB is used.

The Routing protocol is invoked by the message from FTM. FTM sends the message when it receives



(a) Outside (b) Inside

(c) Frond and rear of board

그림 11. 구현 결과물(메쉬 박스 형상-메쉬노드)
Fig. 11. Shape of Meshbox (MeshNode).

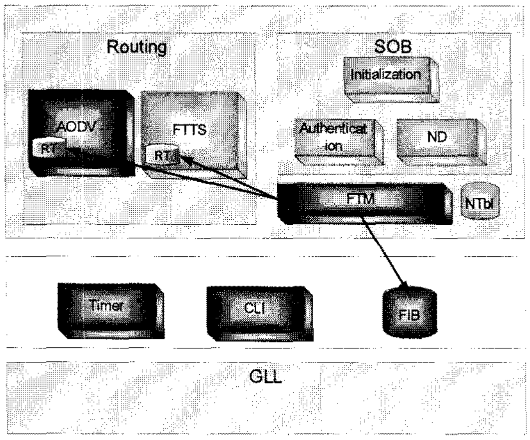



그림 12. 제안 시스템 MMNS의 전체 구조
Fig. 12. Overall Architecture of system (MMNS).

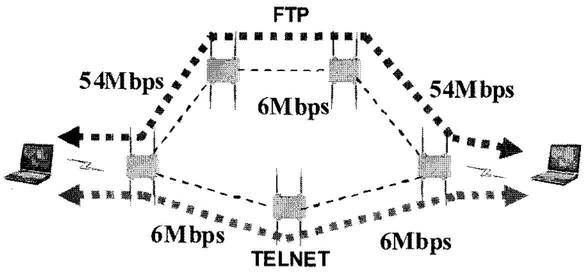



그림 13. 실험 결과
Fig. 13. Result of the experiment.

the messages from GLL. FTM does not bypass the messages but decides the destination of the message. In other words, FTM selects the routing protocol according to the message from GLL. The main point of proposed scheme is implemented in FTM.

When the packet arrives from the client node to mesh node, GLL forwards the packet to other mesh node based on FIB. If there is no information in FIB on received data, GLL invokes FTM to establish the route. Then FTM selects the routing protocol using the routing protocol selection table. For the selection of routing protocol, the specific information of the client packet is needed. GLL extracts the information and provides it to FTM when it invokes FTM. After the selection of routing protocol, FTM invokes the corresponding routing protocol. After the route establishment, routing protocol updates routing table and requests FIB to update FTM. GLL header of the packet must have <destination node address, routing protocol identifier> information supporting the fast forwarding.

With the developed system, we have done the test. Five mesh nodes and two clients are located like Figure 13. When this network operates, there are different routes corresponding to FTP and TELNET by inspecting FIB of each mesh node. In Figure 13, the route of FTP is composed of two 54 Mbps links and one 6 Mbps link. The route of TELNET is composed of two 6 Mbps links. For TELNET, AODV is selected and the shortest hop route is established and for FTP, FTTS is selected and the route composed of fast speed links is established. In the case of long size file transmission with FTP, we observed that file transfer is finished earlier comparing with the case that we designates the routing protocol as AODV with artificial manipulation. In the case of TELNET, we observed that lagging phenomenon is less comparing with the case that we designate the routing protocol as FTTS.

## Ⅳ. 결 론

We proposed a routing protocol selection scheme based on the application feature in wireless mesh network. Each application has its own feature such as its packet size. The proposed scheme selects the routing protocol by matching the features of routing protocol and that of application. This paper described the proposed scheme with two routing protocols and developed system supporting the mesh routing and proposed scheme. Besides, this paper showed the result of experiment. To get the performance of the proposed scheme in the network of many nodes, we developed the simulator. In near future, we will evaluate the performance result of simulator through various experiments. And we will study more on the design of the routing protocol selection table and the features of the mesh routing protocols.

## 참 고 문 헌

[1] M.-S. Jain, T.-Y. Chou, and C. Lee, “An

Adaptive Routing Protocol Selection Algorithm Corresponding to Dynamic Wireless Network Environment," ICACT2006, Feb. 2006.
[2] Rangnekar et al., Routing Protocol Selection For An AD HOC Network, Pub. No.: US 2003/0123419 A1, Pub. Date: Jul. 3, 2003.
[3] Chander et al., Method and System For Enabling A Route And Flow Table Update in A Distributed Routing Platform, Patent No.: US 6,850,492 B2, Date of Patent: Feb. 1, 2005.
[4] Kola et al., Port Number Based Radio Resource Management of Packet Data, Pub. No.: US 2004/0213165 A1, Pub. Date: Oct. 28, 2004.
[5] Charles E. Perkins and Elizabeth M. Royer. "Ad hoc On-Demand Distance Vector Routing," Proceedings of the 2nd IEEE Workshop on Mobile Computing Systems and Applications, New Orleans, LA, pp. 90-100, February 1999.
[6] IEEE P802.11 Task Group S, IEEE 802.11s
[7] I. F. Akyildiz and X. Wang, "A Survey on Wireless Mesh Network," IEEE Radio Communications, pp. S23-S30, Sep. 2005.

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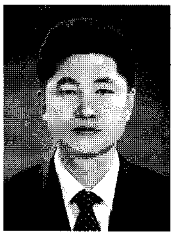

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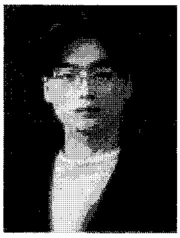

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