A Multiple-Metric Routing Scheme for QoS in WMNs Using a System of Active Networks

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Abstract. Wireless mesh networking is emerging as an important architecture for the future generation of wireless communications systems. The challenging issue in WMNs is providing Quality of Service (QoS). So, this paper proposes a multiple-metric routing scheme for QoS in WMNs using a system of active networks. The Active Network paradigm offers the attractive capability of being able to carry executable payloads that can change the characteristics of a given platform. In other words, network nodes not only forward packets, but also perform customized computation on the packets flowing through them. It provides a programmable interface to the user.

Keywords: wireless mesh networks, active networks, AODV.

1 Introduction

Wireless mesh networks (WMNs) will play an increasingly important role in future-generation wireless mobile networks. A WMN normally consists of mesh routers and clients, and can be independently implemented or integrated with other communications systems such as conventional cellular networks [1]. WMNs are characterized by their dynamic self-organization, self-configuration, and self-healing to enable quick deployment, easy maintenance, low cost, great scalability, and reliable services, as well as enhanced network capacity, connectivity, and resilience[2].

A method of providing QoS is the key technology for traffic management in WMNs. There have been various researches conducted on how to provide QoS in WMNs. A previous research for providing QoS has been studied with routing metrics such as hop count, Expected Transmission Rate (ETX) and Expected Transmission Time (ETT). The hop count is the base metric and is a simple measure of the number of hops between the source and destination of a path [3]. The ETX is a measure of link and path quality and the ETT is the Expected Transmission Time of a data transmission in a direct link [3][4][5]. Although there have been many studies on how to provide QoS, it is not suitable to offer QoS in a dynamic environment.

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T.-h. Kim et al. (Eds.): FGCN 2011, Part II, CCIS 266, pp. 346–353, 2011.

In this paper, an active network architecture is used to provide QoS in WMNs. Active Networking is primarily a DARPA funded project focusing on mechanisms, applications, and operating systems research to develop a reconfigurable network infrastructure. The active network paradigm offers the attractive capability of carrying executable payloads that can change the characteristics of a given platform. The key point of an active network architecture is the active node construction because the Active packets are operating on the active nodes. The active nodes architecture, which was put forward by DARPA, depicted the data processing flow. The logical constructions of active nodes involve three parts: Node OS, Execution Environment and Active Application.

The Node OS is similar to the general operating kernel which through a fixed interface to provide resources and render services for the execution environment. The Execution Environment is a transparent, programmable space and is unrelated to the platform. It operates in each active node and user terminal node; a multi-execution environment could operate on the same active node at the same time. The execution environment provides various network application interfaces for higher level applications. The Active Application is a series of user-defined procedures. By executing the network API provided by the executive environment, the necessary resources can be obtained when running a program. Finally, a customized function can be realized. The active node (routers, etc.) in Active Networks are not only data forward packets, but also perform customized computation on the packet flowing through them. The active node operating codes are initially contained in the active node. This code can also be dynamically inserted into the forwarding packet to configure them according to the needs of the applications in execution. This way, packets have the capacity of carrying not only data but also the code to be executed in remote nodes. Therefore, the user has the possibility of "programming" the network, providing that the programs to be used by the routers and switches to execute their computations are available. In an active network, the difference between network internal nodes (routers, switches, etc.) and user nodes is tenuous, since both are able to perform the same computations. Hence, the user can view the network as a part of his/her application and can adapt the network to obtain the best performance of his/her application [6].

2 Proposed Scheme

It has already been mentioned that, many performance metrics, such as ETX and ETT so on have been considered for QoS in WMNs. Since each individual routing metric considers some features, it is difficult to satisfy all the requirements of WMNs by using a single metric. Therefore, it is proposed that a multiple-metric routing scheme be used.

An active networking technique for QoS was grafted onto an existing routing protocol. The basic routing protocol of the proposed scheme is the Ad hoc On-demand Distance Vector (AODV). In this paper, this protocol is referred to as the

Active AODV. A routing table and a route discovery process make the difference between these two protocols. The modification performed is the addition of a QoS Type field to the routing table. It determines what type of QoS to use such as reliability, delay, interference and so on. And RREP, RREQ and RERR packets are also modified. A QoS field is added to reserve the fields of these three packets, since they have reserved fields. The QoS field also determines what type of QoS is required for the application. Nodes fill the QoS field when sending the route discovery message.

Nodes compare just the destination ID field when the process route discovery is in pure AODV. However, nodes compare not only the destination ID but also the QoS field of the discovery message. Therefore, each routing metric is used individually to select the demanded path in the Active AODV. In other words, the Active AODV determines where the suitable path is. For example, it determines the best path for the highest success rate for a packet, which will result in providing successful service. Further, it determines the fastest path for the delay demanded packet.

There are many QoS types for applications. Nevertheless, this paper considers only five metrics: HOP, ETX, ETT, AB and EI. AB and EI mean Available Bandwidth and Expected Interference, respectively. The AB of the link is defined as following equation 1.

$$AB_l = B_l - UB_l \tag{1}$$

B_l and UB_l denote link bandwidth and using bandwidth of link, respectively. Also, The EI of the link is defined as following equation 2.

$$EI_l = ETT_l \times N_l \tag{2}$$

N_l denotes the neighbor number of the link.

On the active protocol level, several solutions for active networks have been proposed so far. The base protocol of this scheme is the Active Network Encapsulation Protocol (ANEP). Further, payloads are encapsulated within ANEP packets and ANEP packets are encapsulated within an IP packet as shown in Fig. 1.

<table>
<tr><td></td><td>0</td><td>8</td><td>16</td><td>24 31</td></tr>
<tr><td>IP Header</td><td colspan="4">IP Header
Router Alter Option</td></tr>
<tr><td rowspan="3">ANEP Header</td><td>Version</td><td>Flag</td><td colspan="2">Type ID</td></tr>
<tr><td colspan="2">ANEP Header Length</td><td colspan="2">ANEP Packet Length</td></tr>
<tr><td colspan="4">Option</td></tr>
<tr><td colspan="5">AODV Packet(RREQ, RREP, RERR)</td></tr>
</table>

Fig. 1. Structure of encapsulated packet

All active packets are demultiplexed by ANEP. The Type ID field of the ANEP header indicates the evaluation environment of the packet. The active node should evaluate the packet in the proper environment. Yet, traditional nodes cannot demultiplex active packets, so it just forwards the packet. This means this scheme can operate on both networks

Fig. 2 shows the active node structure. When the node receives a packet, node OS it dispatched to a suitable EE. An active packet is dispatched to ANEP, but a normal packet is dispatched to IPv4 of IPv6. After that, an active packet is demultiplexed by the ANEP and the AODV packet is processed on the Active AODV

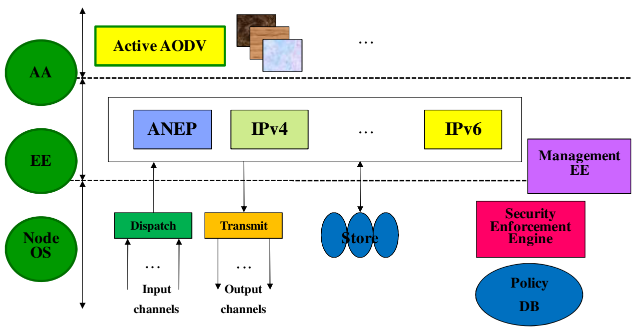
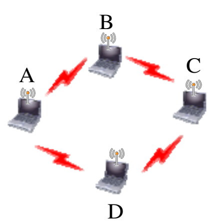


Fig. 2. Structure of active node

Fig. 3 shows an example of the proposed multiple-metric routing.



Routing Table of node C

Destination	Next hop		Metric	QoS Type
A	D	…	4	2
A	B		5	3
		. . .		

Fig. 3. An example of a routing table

This is the routing table of node C. There are two entries to node A. Hence, node C forwards a packet to node D for the packet success rate. On the other hand, node C forwards a packet to node B for a delay required packet. It means every node has many entries to the same destination. The QoS Type field makes it possible.

3 Evaluation

A simulation was conducted based on ns-2 to evaluate the Active AODV, which uses multiple metrics (HOP, ETT, ETX, AB, EI). In addition, a pure AODV and an Active AODV was used as a routing protocol. The simulations tried two ways of measuring the performance of the Active AODV according to the bandwidth in the networks. The first simulation used set nodes with varied bandwidths (1~4 Mbps) and the second simulation had a fixed bandwidth (1.5 Mbps).

The topology is a 4 x 4 Grid, the number of nodes with regular deployment is 16 and an IEEE 802.11 which is a MAC protocol, was used in the simulation. Table 1 shows the detailed parameters in the simulations.

Table 1. Parameters used for simulation

Parameters	*Values*
Topology	4 x 4 Grid
The number of node	16
The distance between nodes	90m
Radio rage	100m
MAC Protocol	IEEE 802.11
Packet size	512 Byte
Bandwidth	1~4 Mbps
Time of total simulation	200s

In the first simulation, the routings used in each HOP, ETX, ETT, AB and EI were compared according to nodes with increasing bandwidths from 1 to 4 Mbps.

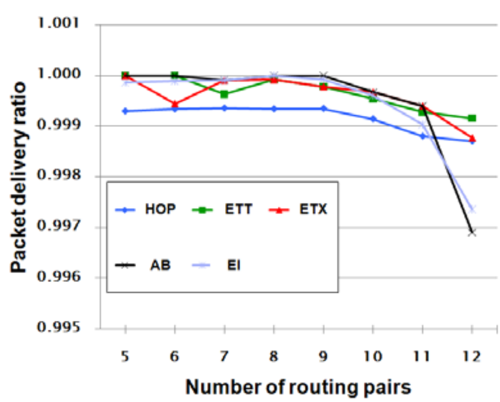


Fig. 4. Packet delivery ratio (1~4 Mbps)

Fig. 4 and Fig. 5 present the result ratio and the delay of packet delivery. It shows that the experimental result of routing with ETX, ETT, AB and EI is better than HOP when pairs of routing nodes were increased in Fig. 4. However, AB and EI obviously decrease when there are 11 pairs of routing nodes. It can be observed that AB and EI are worse than other metrics at high loads.

Fig. 5 illustrates that the performance of routing with ETT is greatly enhanced and the packet delivery delay is significantly reduced. It can be seen that routing with ETT provides an efficient path because it considers the packet delivery delay of a packet.

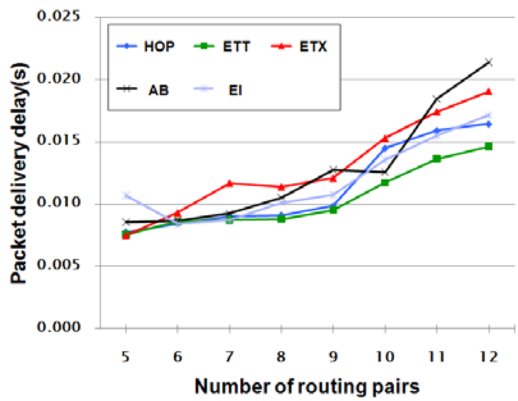


Fig. 5. Packet delivery delay (1~4 Mbps)

In the second simulation, the performance of routing with nodes with fixed 1.5 Mbps was tested according to the pairs of routing nodes in Fig. 6 and Fig. 7.

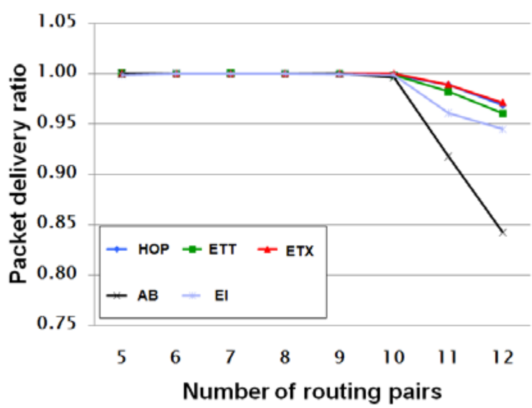


Fig. 6. Packet delivery ratio (1.5 Mbps)

Fig. 6 represents similar results in the performance when pairs of nodes are 10 but routing using AB and EI sharply declined. Fig. 7 shows that delay of all routing rose according to increasing loads. Also, routing using ETX and ETT showed improved performance when pairs of routing node are 8. It was observed, through this simulation, that routing is influenced by metrics. There is a noticeable difference in the routing performance when it is measured in metrics. It has been proven that efficient routing is possible when a property metric is used according to the QoS of data since there is a varied bandwidth in WMNs. Therefore, a path can be selected by considering the success rate when the data delivery ratio is important or a path can be selected by considering delay when data delivery delay is important.

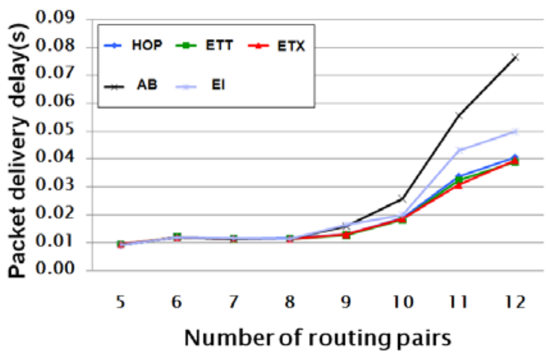


Fig. 7. Packet delivery delay (1.5 Mbps)

4 Conclusion

In this paper, the multiple-metric routing scheme for QoS in WMNs has been proposed by using a system of active networks. An active networking technique was grafted for QoS onto the existing AODV routing protocol. Moreover, the routing table and the routing discovery process of the AODV were modified. This makes the Active AODV determine where a suitable path is for the required QoS application. Plus, the simulation result proved this. The proposed scheme is especially useful in multiple-metric required environments in WMNs.

Acknowledgments

* This work was supported by the second phase of the Brain Korea 21 Program in 2011.
* This work was supported by National Research Foundation of Korea Grant funded by the Korean Government.

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