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Description	

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信学技報
IEICE Technical Report

無線および有線ネットワークのためのパスメトリック設計に関する検討

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あらまし　本来、パスメトリックは、ルーティングプロトコルによってルートの有用性を決めるための定量評価値として設定されるものであるが、対象が無線ネットワークであれ、有線ネットワークであれ、提案されているパスメトリックは非常に多種多様である。本論文では，無線および有線ネットワークのためのパスメトリックをいかにして設計するかの検討を中心に述べる。提案するパスメトリックの設計における要点および制約について説明し、また、コンピュータシミュレーションにより、提案するパスメトリックの遅延時間に関して行った性能評価結果を示す。

キーワード　無線メッシュネットワーク，有線ネットワーク，エアタイムコストメトリック，パスメトリック

Study of Designing Path Metrics for Wireless and Wired Networks

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Abstract　Path metrics are essentially specified to routes by routing protocols to provide measurable values, which are used to decide how useful a route will be. However, a large variety of path metrics has been proposed for either wireless or wired networks. In this paper, we are focused on studying how to design a path metric for both wireless and wired networks. We present the design considerations and constraints of our proposed path metric. Through computer simulation, we also investigate the performance of our proposed path metric in terms of average delay.

Keyword　wireless mesh networks, wired networks, airtime cost metric, path metric

1. INTRODUCTION

A comprehensive wireless mesh network (WMN) architecture that builds within the MAC layer of IEEE802.11 devices is specified in the IEEE802.11s standard [1]. This specified WMN standard has frequently emerged in our society and been discussed as an excellent one of the next generation wireless technology. WMN is a multi-hop IEEE802.11 wireless local area network which provides low-cost and convenient deployments to the users and possesses self-organization and self-configuration features. In IEEE802.11s standard, several aspects of the basic specification are introduced. For example, (i) it specifies new frame formats and information elements; (ii) it presents the path selection and forwarding procedures; (iii) it supports non-mesh stations by means of proxy operations; (iv) it adopts a new security framework to the mesh architecture; and (v) it states the peer node discovery and the management of the established link.

Among all these aspects, one of the most important feature is the path selection procedure, which is basd on the Hybrid Wireless Mesh Protocol (HWMP). HWMP forms multihop paths that connect the mesh stations. This operation is accomplished by means of the airtime cost metric (ACM), a newly specified metric that tries to capture the quality of the links as a function of the estimated frame loss probability. Because of these considerations, it is lead us to investigate the implementation and efficiency of the HWMP and the ACM. One main reason is because when a WMN connects to a wired network, the metric of path selection becomes difficult to cater both WMN and wired networks. Moreover, the default routing metric uses ACM, which is radio interface metric that cannot be applied in the wired network. To address this problem, we propose a feasible link metric for both WMN and wired networks that minimize the delay when the default routing protocol is used to find a path for any mesh station in the network of WMN.

At first, we set up a simulator to analyze the efficiency of the HWMP implementation and also the performance of the default routing metric, which is handled by the routing protocol. Through this investigation, we propose some simple enhancements that improve the performance of the routing protocol. Therefore, our purpose of this paper is to study and propose a feasible path metric for WMN to be incorporable with the wired networks.

The remainder of this paper is organized as follows. The research background of WMN, airtime cost metric, and HWMP routing protocol are given in Section 2. The operation and the proposed improvement of the airtime cost metric are described in Section 3. The simulation studies are presented in Section 4. Finally, some conclusive comments are drawn in Section 5.

2. RESEARCH BACKGROUND

2.1 WMN Architecture

Before introducing the network architecture of WMN, we first explain the original IEEE802.11 architecture. The basic service set (BSS) is the basic block of an IEEE802.11 WLAN. Each of BSS has some wireless stations (STAs) as members. The most basic type of IEEE802.11 WLAN is the independent BSS (IBSS). In IBSS, STAs directly communicate with each other without connecting to access point. This type of network is often referred to as an ad hoc network. An infrastructure BSS also forms a component of IEEE802.11 WLAN. When a STA acts as an access point, it enables access to the distribution system (DS) which handles address to destination mapping and seamless integration of multiple BSSs. The DS and infrastructure BSSs allows IEEE802.11 to create a wireless network of arbitrary size, which is called an extended service set (ESS) networks. An ESS is the union of the infrastructure BSSs connected by a DS.

To address the need of wireless mesh in WLANs, a mesh STA is not a member of an IBSS or an infrastructure BSS. Consequently, mesh STAs do not communicate with non-mesh STAs. However instead of existing independently, a mesh BSS (MBSS) also accesses the DS as showed in Fig. 1. The MBSS interconnects with other BSSs through the DS. Then, mesh STAs can communicate with non-mesh STAs. A mesh gate works as a router for different wireless networks. A portal is a connecter for transmitting frames between 802.11 and non-802.11 LAN. It is possible for one device to offer any combination of the functions of an AP, a portal, and a mesh gate. An example device combining the functions of an AP and a mesh gate is shown in Fig. 2. The implementation of such collocated entities is beyond the scope of this standard. The configuration of a mesh gate that is collocated with an access point allows the utilization of the mesh BSS as a distribution system medium. In this case, two different entities (mesh STA and access point) exist in the collocated device and the mesh BSS is hidden to STAs that associate to the access point.

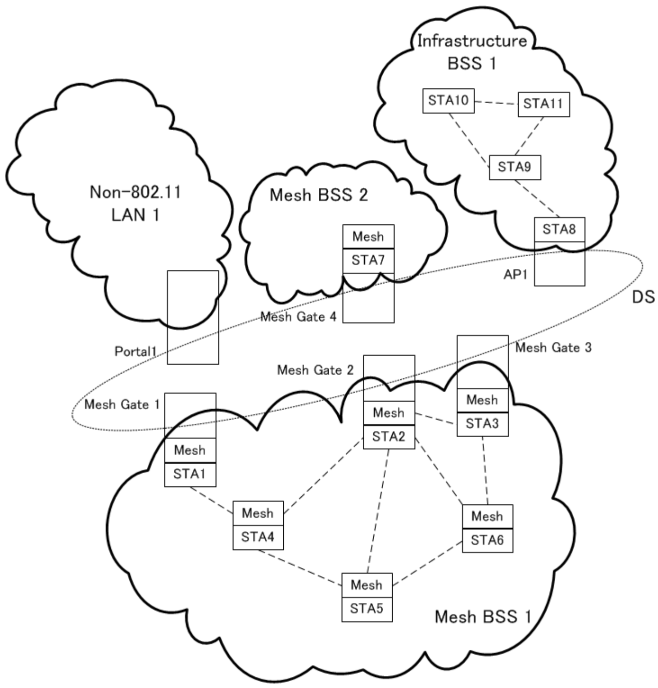

Fig.1 Example MBSS containing mesh STAs, mesh gates, APs, and portals

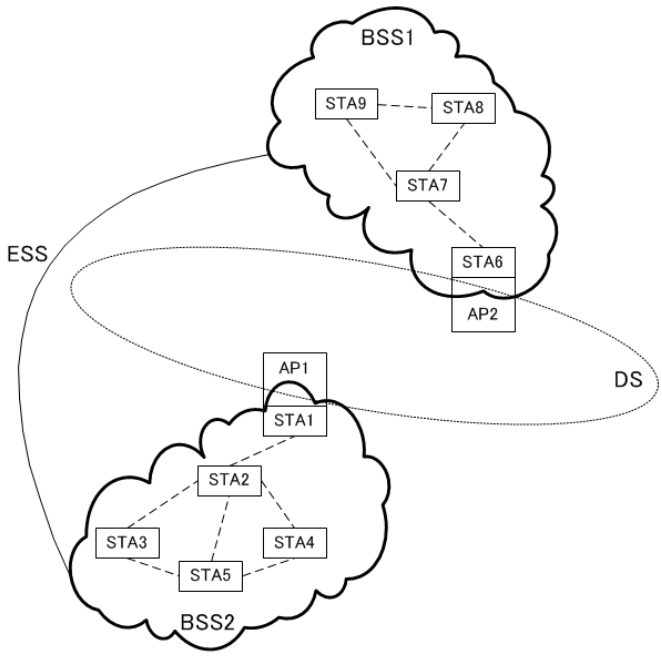

Fig.2 Example device consisting of mesh STA and AP STA to connect an MBSS and an infrastructure BSS

2.2 Airtime Cost Metric

Routing metric is a popular research topic in WMN during recent years. A link metric is a measured unit to a link and a path metric is a value which is assigned to a path, combining by all the link metrics in the path, used by the routing algorithm to select the optimized routes for a specified objective. The optimization objectives can be minimizing delay, minimizing energy consumption, maximizing throughput, etc. The path metric is the combination of the link metrics in the whole path and the method for combining the link metric and the path matric can be defined in varies ways which are depended by the actual situations. The usual functions are summation, multiplication and statistical measures (minimum, maximum, average).

Airtime cost metric (ACM) is a default link metric for path selection routing protocol in the IEEE802.11s Mesh Networking. The extensibility framework allows this metric to be overridden by any path metric as specified in the mesh profile. Airtime reflects the amount of channel resources consumed by transmitting the frame over a particular link. This measure is approximate and designed for ease of implementation and interoperability. The airtime for each link is calculated as follows.

$$C_a = [O + \frac{B_t}{r}]\frac{1}{1-e_f} \qquad (1)$$

where O and B_t are constants, O can be calculated as equation O is equal to the PLCP preamble length plus the PLCP header length plus the MAC header plus DIFS and CW_{min}. The input parameters r and e_f are the data rate in bit/seconds and the frame error rate for the test frame size B_t, respectively. The rate r represents the data rate at which the mesh STA would transmit a frame of standard size B_t based on current conditions and its estimation is dependent on local implementation of rate adaptation. The frame error rate e_f is the probability that when a frame of standard size B_t is transmitted at the current transmission bit rate r, the frame is corrupted due to transmission error.

2.3 Hybrid Wireless Mesh Protocol

HWMP is specified in IEEE802.11s Mesh Networking. In HWMP, on-demand routing protocol is adopted for mesh nodes that experience a changing environment, while proactive tree-based routing protocol is an efficient choice for mesh nodes in a fixed network topology. The on-demand routing protocol is specified based on radio-metric ad hoc on-demand distance vector (AODV) routing. The basic features of AODV are adopted, but extensions are made for IEEE802.11s. The proactive tree-based routing is applied when a root node is configured in the mesh network. With this root, a distance vector tree can be built and maintained for other nodes, which can avoid unnecessary routing overhead for routing path discovery and recovery. It should be noted that the on-demand routing and tree-based routing can run simultaneously.

Four information elements are specified for HWMP: root announcement (RANN), path request (PREQ), path reply (PREP), and path error (PERR). Except for PERR, all other information elements of HWMP contain three important fields: destination sequence number (DSN), time-to-live (TTL), and metric.

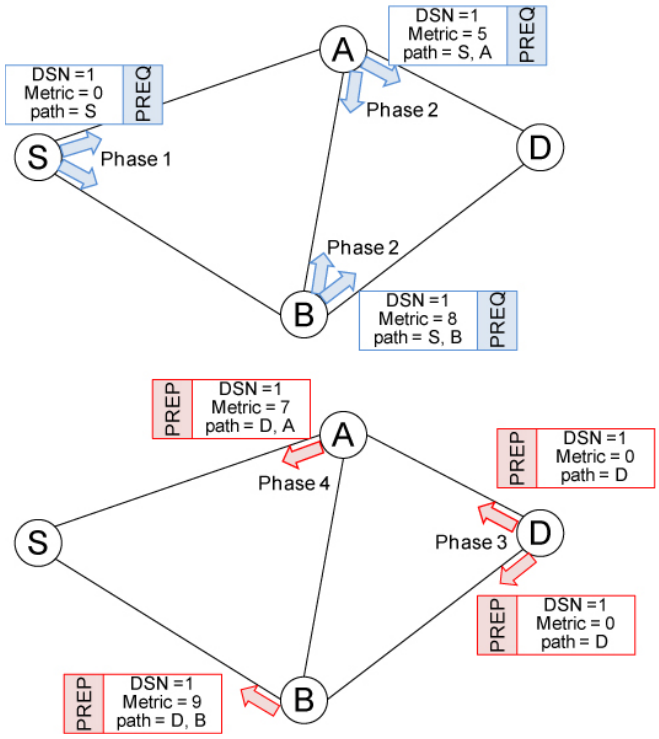

Fig.3 Example of the path discovery procedure

In the HWMP on-demand path selection algorithm (see Fig. 3), a source S wanting to send data to a destination D broadcasts a PREQ frame indicating the MAC address of D. All mesh stations receiving the PREQ create or update their path to S, but only if the PREQ contains a sequence number (denoted as DSN) greater than the current path or the same DSN and a better metric. Every mesh station, before re-broadcasting the PREQ, must update the metric field to reflect the cumulative metric of the path to S. Once D receives the PREQ, it sends S a unicast PREP. If D receives further PREQs with a better metric (and the same or greater sequence number), it sends a new PREP along the updated path. Intermediate mesh stations shall then forward the PREP(s) to S along the best path (stored during the PREQ flooding phase), and, when the PREP reaches S, the path is set up and can be used for a bi-directional exchange of data. If more than one PREP is received, the PREPs following the first are processed only if their information is not stale and announces a better metric (the same rules of PREQ apply). Note that the metric values carried by PREQ and PREP frames refer to two different paths: PREQs measure the reverse path, i.e. from D to S, whereas PREPs measure the forward (S→D) path. This is because the value inserted by each node refers to the metric it measures towards the node from which it received the PREQ/PREP. Hence, depending on the metric computation strategy, it may occur that the forward and reverse paths do not coincide.

3. PROPOSED ROUTING METRIC

Most of the cases, WMN is not used independently. WMN is designed to access to other types of wired networks. For such purpose, the function of portal that acts as root node is very essential. In this paper, we focused on proposing a feasible path metric for WMN to be incorporable with the wired networks. Since the ACM that specified in IEEE802.11s reflects the amount of channel resources consumed by transmitting the frame over a particular link. This measure should be transform in a generic path metric, i.e., packet latency. The packet latency is a measure of the time delay experienced by a packet from a transmitter to a receiver. This packet latency is taking over the ACM in order to find the best metric from a mesh station to a station that connected to a wired network.

4. SIMULATION STUDIES

In this section, we study the performance of the proposed path metric over the TBR protocol in the WMN environment. We use C++ console application to construct and simulate the WMN environment. This program is event-driven application. All the events are defined in the configuration file. In the program, we simulate each mesh station as a independent object. Each mesh station has its own properties. In the startup, the application first reads the configuration file to initialize the parameters and generate all the events. When an event meets its time, it will be forwarded to the specified node to process event.

In our simulation, all the mesh stations that included two roots are confined to a 100 m×100 m area. One root is located at (50, 0) and another one is located at (0, 50) whereas other mesh stations are placed randomly and distributed. Other parameters are summarized in Table 1. We model our traffic based on constant bit rate (CBR). All source mesh stations are chosen to send their data to the root. The CBR traffic consists of 1000-byte frame size, which sends at the constant data sending interval.

Table 1 Parameters and settings for the simulation

Hardware Specification	IEEE 802.11a
Network protocol	Tree-based routing
PLCP preamble length	20 μs
PLCP header length	4 μs
MAC header	69.33 μs
DIFS	34 μs
CW_{min}	135 μs
B_t	8192 bits
r	54 Mbps
Transmit power	100 mW
Energy model	Two-ray
RANN size	28 bytes
RANN interval	10 s
Network size	100 m×100 m
Transmission range	20 m
Traffic pattern	Constant bit rate
Data size	1000 bytes

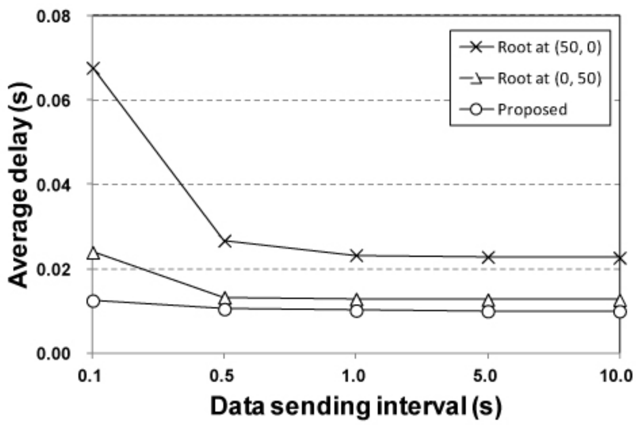

Fig.4 Average delay as a function of data sending interval

4.1 Simulation Results

Average end-to-end delay is the average elapsed time to deliver a packet from the source to the destination, and it includes all possible delays before data packets arrive at their destinations. Fig. 4 shows how average delay varies with the data sending interval. As the data sending interval increase, the maximum average delay of the proposed path metric can achieve about double times smaller than the root at (50, 0). This is because the proposed path metric yields smaller delays in routing the data messages with the best-metric route that shared with other root, resulting in an decrement packet contention and number of transmissions, which leads to low end-to-end delay. On the other hand, Fig. 5 shows how average delay varies with number of nodes. As number of nodes increase, the superiority of the proposed path metric becomes very obvious. This is shown that traffics around the root of the tree-topology becomes significantly less when the proposed path metric is forced to share the traffic load with other root. This leads to the fact that the number of packet drops due to packet collision and buffer overflow reduces largely as well as a decrement of packet processing and forwarding at the root.

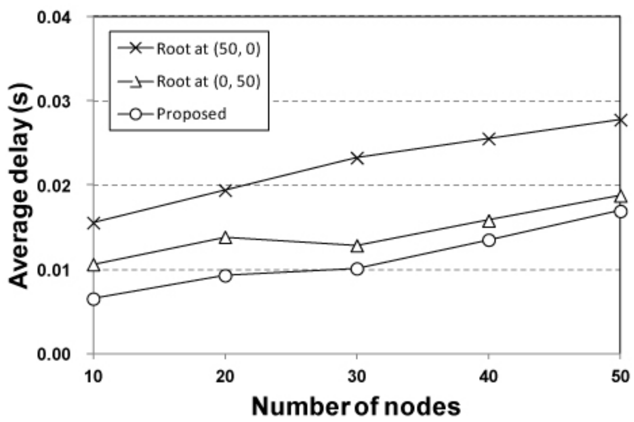

Fig.5 Average delay as a function of number of nodes

5. CONCLUDING REMARKS

In this paper, we have studied the ACM, which is a default path metric that is specified in IEEE802.11s standard. We proposed path metric that use packet latency to minimize the transmission delay in the wireless environment by sharing the traffic load in between two roots. Through computer simulation, we also examined the performance of our proposed path metric in terms of average delay. Our simulation results are very encouraging and we currently focus on examining the performance of proposed path metric when the traffic generation of each source mesh station is unbalanced.

References

[1] Amendment 10: Mesh Networking, IEEE802.11s, 10 September 2011.

[2] A.O. Lim, X. Wang, Y. Kado, and B. Zhang, "A hybrid centralized routing protocol for 802.11s WMNs," *Special Issue on SI Adv. Wireless Mesh Networks, Mobile Networks and Applications (MONET)*, vol. 13, no. 1-2, pp. 117–131, 2008.

[3] X. Wang and A.O. Lim, "IEEE 802.11s wireless mesh networks: Framework and challenges," *Ad Hoc Networks, Elsevier*, vol. 6, no. 6, pp. 970–984, 2008.

[4] R.G. Garroppo, S. Giordano, and T. Tavanti, "A joint experimental and simulation study of IEEE802.11s HWMP protocol and airtime link metric," *Int. J. of Commun. Syst*, vol. 25, pp. 92–110, 2012.

[5] J. Guerin, M. Portmann, A. Pirzada, "Routing metrics for multi-radio wireless mesh networks," *Australasian Telecomm. Networks and Applications Conf. (ATNAC)*, pp. 343–348, 2007.

[6] C. Koksal, H. Balakrishnan, "Quality-aware routing metrics for time-varying wireless mesh networks," *IEEE J. on Selected Areas in Commun.*, vol. 24, no. 11, pp. 1984–1994, 2006.