



- (51) **International Patent Classification:**
H04L 12/56 (2006.01) H04W 40/00 (2009.01)
- (21) **International Application Number:**
PCT/MY20 12/000 150
- (22) **International Filing Date:**
28 June 2012 (28.06.2012)
- (25) **Filing Language:** English
- (26) **Publication Language:** English
- (30) **Priority Data:**
PI201 170021 1 30 December 201 1 (30.12.201 1) MY
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(81) **Designated States (unless otherwise indicated, for every kind of national protection available):** AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SC, SD,

[Continued on nextpage]

(54) **Title:** A METHOD FOR ESTABLISHING AN END-TO-END ROUTE FOR TRAVERSING DATA

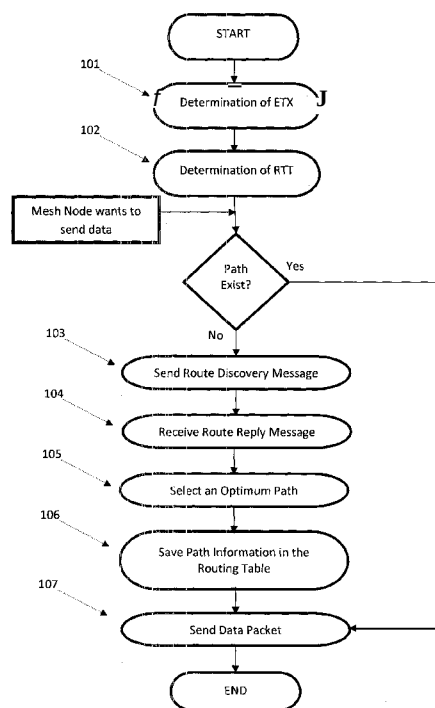


Figure 1

(57) **Abstract:** A method for establishing an end-to-end route for traversing data from source to destination through wireless mesh networks, characterized in that, the method is a method of incorporating multiple performance metrics into a shortest routing protocol in wireless mesh networks is provided, the method includes the steps of determining Expected Transmission Count (ETX) of neighboring mesh nodes, determining Round Trip Time (RTT) of neighboring mesh nodes, sending a route discovery message in a wireless mesh network, receiving the route discovery message, calculating Incorporated Multiple Metrics Value (IMMV) for the route, selecting an optimum path based on the IMMV, saving information of the optimum path in a routing table and sending data packets based on the routing table.

A METHOD FOR ESTABLISHING AN END-TO-END ROUTE FOR TRAVERSING DATA

5 FIELD OF INVENTION

The present invention relates to method for establishing an end-to-end route for traversing data from source to destination through wireless mesh networks. More particularly, the method is a method of incorporating multiple performance metrics into a
10 shortest routing protocol in wireless mesh networks.

BACKGROUND OF INVENTION

Wireless mesh networks (WMNs) are dynamically self organizing, self configuring and
15 self healing with nodes in the networks automatically establishing an ad hoc network and preserving mesh connectivity. Wireless mesh is functionally similar to standard IEEE 802.11 infrastructure network with respect to Basic Service Set (BSS) and Extended Service Set (ESS). Wireless Distribution Systems (WDS) use an extension of IEEE 802.11 MAC/PHY to provide a protocol for auto configuring paths between Mesh Points
20 (MPs) in a multi-hop topology, supporting broadcast, multicast and unicast traffic.

WMNs are emerging rapidly as the WMNs support several applications such as Broadband Home Networking, Community and Neighbourhood Networking, Enterprise Networking, Metropolitan area networks, Disaster Recovery and Security Surveillance.
25 Intel, Microsoft and Motorola have realized the potential of this technology and offering wireless mesh networking products. A few test beds are already established in university research labs. Existing solutions in mobile ad hoc and sensor networks cannot be directly

applied to WMNs due to the differences in traffic patterns, mobility scenarios, gateway functionalities and bandwidth requirements.

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WO 2008/097221 describes a method of calculating a link cost for each end to end route. However, this prior art describes a solution for multi channel, multi radio environments with single metric routes.

10 US 20001 16393 describes yet another solution for cost based route calculation. However, this solution targets Mobile Ad-hoc Network (MANET) especially. The multi metric approach used here uses data rate and reliability information for data links.

However, there are still a range of issues that need to be solved such as scalability,
15 Quality of Service (QoS) assurance, better performance metrics, throughput improvement and considerable research efforts are needed.

SUMMARY OF INVENTION

Accordingly, there is provided a method for establishing an end-to-end route for traversing data from source to destination through wireless mesh networks, characterized
5 in that, the method is a method of incorporating multiple performance metrics into a shortest routing protocol in wireless mesh networks, the method includes the steps of determining Expected Transmission Count (ETX) of neighboring mesh nodes, determining Round Trip Time (RTT) of neighboring mesh nodes, sending a route discovery message in a wireless mesh network, receiving the route discovery message,
10 calculating Incorporated Multiple Metrics Value (IMMV) for the route, selecting an optimum path based on the IMMV, saving information of the optimum path in a routing table and sending data packets based on the routing table.

The present invention consists of several novel features and a combination of parts
15 hereinafter fully described and illustrated in the accompanying description and drawings, it being understood that various changes in the details may be made without departing from the scope of the invention or sacrificing any of the advantages of the present invention.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will be fully understood from the detailed description given herein below and the accompanying drawings which are given by way of illustration only, and
5 thus are not limitative of the present invention, wherein:

Figure 1 is a illustrates a flow chart showing a method for establishing an end-to-end route for traversing data from source to destination through wireless mesh networks, wherein the method is a method of incorporating multiple performance metrics into a shortest routing protocol in wireless mesh networks in the preferred embodiment of the
10 invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

The present invention relates to a method for establishing an end-to-end route for traversing data from source to destination through wireless mesh networks. More particularly, the method is a method of incorporating multiple performance metrics into a shortest routing protocol in wireless mesh networks. Hereinafter, this specification will describe the present invention according to the preferred embodiment of the present invention. However, it is to be understood that limiting the description to the preferred embodiment of the invention is merely to facilitate discussion of the present invention and it is envisioned that those skilled in the art may devise various modifications and equivalents without departing from the scope of the appended claims.

The following detailed description of the preferred embodiment will now be described in accordance with the attached drawings, either individually or in combination.

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Figure 1 illustrates a flow chart showing a method for establishing an end-to-end route for traversing data from source to destination through wireless mesh networks, wherein the method is a method of incorporating multiple performance metrics into a shortest routing protocol in wireless mesh networks. The method includes the steps of determining Expected Transmission Count (ETX) of neighboring mesh nodes, determining Round Trip Time (RTT) of neighboring mesh nodes, sending a route discovery message in a wireless mesh network, receiving the route discovery message, calculating Incorporated Multiple Metrics Value (IMMV) for the route, selecting an optimum path based on the IMMV, saving information of the optimum path in a routing table and sending data packets based on the routing table.

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The step of determining ETX further includes the steps of sending a beacon message to the neighboring mesh nodes, receiving the beacon message from at least one

neighboring mesh nodes, determining the ETX of the at least one neighboring mesh nodes using the received beacon message and saving the ETX of the at least one neighboring mesh nodes in a table.

- 5 The step of determining RTT further includes the steps of sending a beacon message to the at least one neighboring mesh nodes, receiving a response from the at least one neighboring mesh nodes, receiving the beacon message from the at least one neighboring mesh nodes, determining RTT of the at least one neighboring mesh nodes and saving the RTT of the at least one neighboring mesh nodes in a table.

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For selecting the optimum path using the method, determination of ETX and RTT of neighboring mesh nodes are necessary. If a mesh node is required to send data to another mesh node, the routing table is checked to determine existence of any available path. If at least one path exists, the mesh node sends data through the available path.

- 15 However, if no path is found to be in existence, a path must be discovered. A mesh node generates a route discovery message and sends the route discovery message throughout the wireless network. Other mesh nodes that do not have capability to reply to the route discovery message receive the route discovery message and forward the route discovery message. Further, mesh nodes that have the capability of responding proceed to
- 20 generate a reply message and unicast a data packet to the source. A mesh node receives the reply message for the request message that was sent out. If only one path exists between the source node and the destination node, then the same path is a default choice. In the event that multiple paths exist, it now becomes necessary to calculate Incorporating Multiple Metrics Value (IMMV) to select an optimum path. Information
- 25 related to the selected path is saved in the routing table. A mesh node is now able to send data to another mesh node through the selected path.

As each individual routing metric consider some minimum related features, it was difficult to satisfy comprehensive requirements of wireless mesh networks (WMNs) by using a single metric. Multiple performance metrics are used in this method which includes, but not restricted to, a combination of ETX, RTT and traditional Hop Count, which guarantees a minimum hop count with loop free routing and avoiding highly loaded and lossy links. ETX is used to avoid lossy links and RTT is used to avoid highly loaded links.

Since Hop Count (HPC) metric implementation is default with most protocols, therefore implementation of ETX and RTT are described herein. A modified version of ETX is implemented, wherein only loss probability in reverse direction p_r is considered to simplify calculation and to keep routing overhead analogous to implemented protocol. Therefore, probability that packet transmission of a link is not successful can be defined from (1):

$$p = 1 - (1 - p_r) \quad (1)$$

where p denotes a probability that the packet transmission from x to y is not successful. Finally, an expected number of transmissions required to successfully deliver a packet from x to y is denoted by ETX:

$$ETX = \frac{1}{1-p} = \frac{1}{(1-p_r)} \quad (2)$$

The ETX path metric is a sum of the ETX values for each link in that path.

In calculating RTT, a node unicast one probe packet after a specific period, carrying a random timestamp to each of the node's neighbors. Upon receiving the probe packet, each neighbor immediately responds to the probe packet with an acknowledgement probe, echoing that of the timestamp. This enables a sending node to calculate a round

trip time to each of the node's neighbors. Subsequently, the RTT value at a specific time, t for a neighbor, is calculated using (3):

$$\begin{aligned} RTT_t &= (RTT_{t-1} + RTT_{new}) / 2 \quad \text{when } RTT_{t-1} \neq 0 \\ RTT_t &= RTT_{new} \quad \text{when } RTT_{t-1} = 0 \end{aligned} \quad (3)$$

Where RTT_{t-1} is an average round trip time for the neighboring node at time $t-1$ and RTT_t is a newly calculated round trip time to the neighboring node. ETX and RTT values are determined using layer 3 beacon messages exchanged among neighboring nodes.

When only one path exists between source and destination, that path is the default choice for the source that initiated route discovery. However, if there are two or more paths, the

IMMV is calculated to select a best path among them. The IMMV for a route can be calculated using (4):

$$\begin{aligned} IMMV_i &= \frac{ETX_i}{ETX_t} + \frac{RTT_i}{RTT_t} + \frac{HPC_i}{HPC_t} \\ IMMV_j &= \frac{U.K_j}{U.K_t} + \frac{KIT_j}{KIT_t} + \frac{HPC_j}{HPC_t} \end{aligned} \quad (4)$$

Where, $IMMV_i$ and $IMMV_j$ are calculated for route i and j . Among these two paths, the path with the lower IMMV is selected. The route between the source node and destination node is established based on on-demand routing.

Several features had to be considered in designing an efficient routing protocol suitable for wireless mesh networks. Using improved performance metrics, a reliable path is established between source and destination. Minimum hop-count is the metric most commonly used by existing routing protocols. As this approach implicitly assumes that links either work well or do not work at all, this is often true in wired networks. Unfortunately, this is not a reasonable approximation in WMNs, since many wireless links have intermediate loss ratios, interference problems and low throughput. Existing

performance metrics were designed but were insufficient to deal with the issues. Since each individual routing metrics consider minimum and related features and is difficult to satisfy comprehensive requirements of WMNs, it is necessary to incorporate multiple
5 performance metrics into a routing protocol to attain optimal performance.

This invention is adapted for use with permanent and non-permanent wireless mesh networks. The disclosed invention is suitable, but not restricted to, for use in performance optimizing of routing and forwarding mechanisms in wireless mesh networks.

CLAIMS

1. A method for establishing an end-to-end route for traversing data from source to destination through wireless mesh networks, characterized in that, the method is a method of incorporating multiple performance metrics into a shortest routing protocol in wireless mesh networks, the method includes the steps of:
 - i. determining Expected Transmission Count (ETX) of neighboring mesh nodes;
 - ii. determining Round Trip Time (RTT) of neighboring mesh nodes;
 - 10 iii. sending a route discovery message in a wireless mesh network;
 - iv. receiving the route discovery message;
 - v. calculating Incorporated Multiple Metrics Value (IMMV) for the route;
 - vi. selecting an optimum path based on the IMMV;
 - vii. saving information of the optimum path in a routing table; and
 - 15 viii. sending data packets based on the routing table.
2. The method as claimed in claim 1, wherein determining ETX further includes the steps of:
 - i. sending a beacon message to the neighboring mesh nodes;
 - 20 ii. receiving the beacon message from at least one neighboring mesh nodes;
 - iii. determining the ETX of the at least one neighboring mesh nodes using the received beacon message; and
 - iv. saving the ETX of the at least one neighboring mesh nodes in a table.
- 25 3. The method as claimed in claim 1 and 2, wherein determining RTT further includes the steps of:
 - i. sending a beacon message to the at least one neighboring mesh nodes;
 - ii. receiving a response from the at least one neighboring mesh nodes;

- iii. receiving the beacon message from the at least one neighboring mesh nodes;
- iv. determining RTT of the at least one neighboring mesh nodes; and
- v. saving the RTT of the at least one neighboring mesh nodes in a table.

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- 4. The method as claimed in claim 1, wherein the step of calculating IMMV for a route is only performed when multiple routes are found between the source node and destination node.

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- 5. The method as claimed in claim 1, wherein the route between the source node and destination node is established based on on-demand routing.

- 6. The method as claimed in claim 1, wherein ETX, RTT and Hop Count are used to determine IMMV for a route.

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- 7. The method as claimed in claim 1, wherein ETX and RTT values are determined using layer 3 beacon messages exchanged among neighboring nodes.

- 8. The method as claimed in claim 1, wherein the wireless mesh network is a permanent network.

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- 9. The method as claimed in claim 1, wherein the wireless mesh network is a semi-permanent network.

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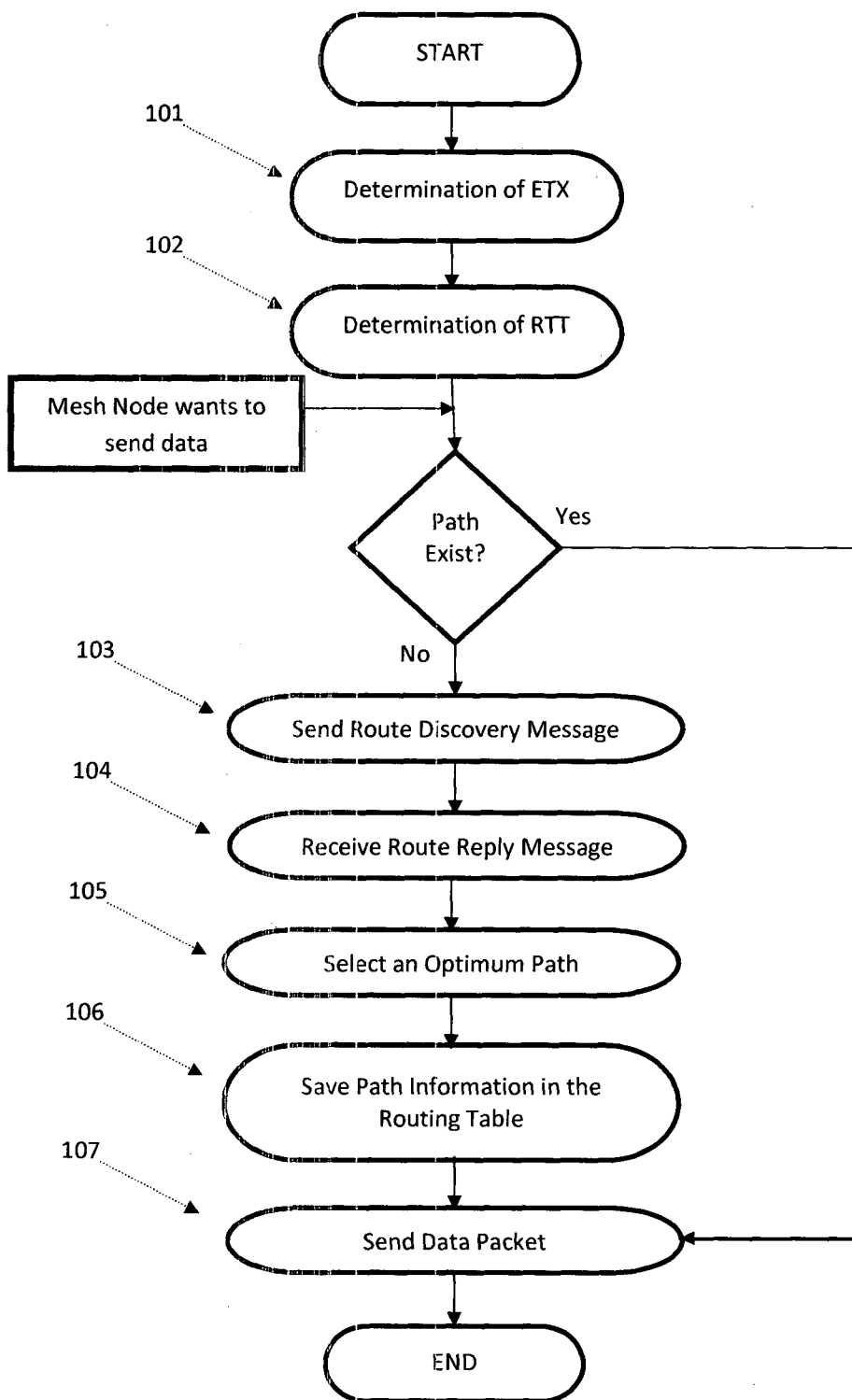


Figure 1

INTERNATIONAL SEARCH REPORT

International application No

PCT/MY2012/000150

A. CLASSIFICATION OF SUBJECT MATTER
 INV. H04L12/56 H04W40/00
 ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

H04L H04W

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal , WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2005/185632 AI (DRAVES RICHARD P JR [US] ET AL DRAVES JR RICHARD POWELL [US] ET AL) 25 August 2005 (2005-08-25) paragraphs [0036] - [0038] ; figure 1 paragraph [0044] ; figure 5 paragraphs [0058] - [0067] ; figures 6,7 ,9A,9B paragraphs [0072] - [0075] ; figures 11A. 11B ----- -/--	1-9



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

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"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

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"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

19 September 2012

Date of mailing of the international search report

26/09/2012

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INTERNATIONAL SEARCH REPORT

International application No

PCT/MY2012/000150

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	MD ARAFATUR RAHMAN ET AL: "Intergati ng Multiple Metri cs to Improve the Performance of a Routi ng Protocol over Wi rel ess Mesh Networks" , 2009 INTERNATIONAL CONFERENCE ON SIGNAL PROCESSING SYSTEMS, IEEE, PISCATAWAY, NJ , USA, 15 May 2009 (2009-05-15) , pages 784-787 , XP031491312 , ISBN: 978-0-7695-3654-5 Chapters I - 111 -----	1-9
Y	BIJIL RAJ M B ET AL: "Wei ghted Integrated Metri cs (WIM) : A Generi c Algori thm for Rel iabl e Routi ng in Wi rel ess Mesh Networks" , WI RELESS COMMUNICATIONS, NETWORKING AND MOBI LE COMPUTING (WICOM) , 2011 7TH INTERNATIONAL CONFERENCE ON, IEEE, 23 September 2011 (2011-09-23) , pages 1-6 , XP032059663 , DOI : 10. 1109/WICOM. 2011 .6040293 ISBN: 978-1-4244-6250-6 Chapters I - 111 -----	1-9
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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/MY2012/000150

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