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A Comprehensive Survey on Routing Protocols in IEEE 802.16 Wimax Standard

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Abstract— IEEE 802.16 or Worldwide Interoperability for Microwave Access is a technology aimed at bridging the communication gap between mobile and fixed terminal users. The demand for such services is increasingly rapidly since they are relatively cheaper and allow freedom of movement. The earliest version of WiMax was IEEE 802.16. The latest version is IEEE 802.16e which has extended functionality. However, the major installations of WiMax still use IEEE 802.16. The rising need has led researchers to find more optimized routing algorithms for 802.16 to increase throughout and decrease end to end delay. This paper presents a comprehensive survey on the work that has been done pertaining to routing algorithms and their performance in IEEE 802.16 networks.

Keywords— WiMax, IEEE 802.16

I. INTRODUCTION

WiMax or Worldwide Interoperability for Microwave Access is a communication standard created to provide constant bit rate of around 30-40 megabyte-per-second rates which has now been pushed to 1 Gb-per-second post the 2011 update. WiMax was adapted from the IEEE 802.16 standard for the WiMax Forum. WiMax can provide Broadband Wireless Access (BWA) upto 30 miles for fixed stations and 3-10 miles for mobile stations. The WiMax technology was practically implemented in 2006 when Korean Telecom launched the first mobile based WiMax network called WiBro which operates in the 2.3 GHz band [1].Wimax standards are given in Table 1 .

The rest of the paper is arranged as follows:

- Section 2 discusses the Ad Hoc On-Demand Distance Vector Routing protocol.
- Section 3 discusses about the Dynamic Source Routing Protocol.
- Section 4 discusses the DSDV Routing protocol.
- Section 5 compares the performance of the protocols.
- Section 6 presents the conclusion of this paper.

TABLE I : WIMAX STANDARDS

Factors	IEEE 802.16	IEEE 802.16 Revs'	IEEE 802.16 e
Completed	December 2001	May 2004	Est. Mid. 2005
Spectrum	10-66 GHz	2-11 GHz	2-6 GHz
Application	Backhaul	Wireless DSL and Backhaul	Mobile Internet
Channel Condition	Line of sight only	None line of sight	None line of sight
Bit Rate	32-134 Mbps	Up to 75 Mbps	Up to 15 Mbps
Modulation	QPSK, 16 QAM, 64 QAM	OFDM 256, OFDMA 2048,16 QAM,64 QAM	Same as 02.16 d
Channel Bandwidth	20,25,28 MHz	Bandwidth between 1.5 & 20 MHz	Same as 02.16 d

II. AD HOC ON-DEMAND DISTANCE VECTOR ROUTING

A. *Introduction*

Ad Hoc On-Demand Distance Vector Routing Protocol is a reactive routing protocol that uses bi-directional links for the delivery of data from the source to the destination. It's on demand nature means that it only searches for a path when needed. However, AODV is not a classical reactive routing protocol. It is a mixture of table driven as well as pure reactive protocols. AODV looks up a table each time a need arises for data to be transferred from one node to the other [2].

The AODV protocol has 2 major steps.

- *Route Discovery*

- *RREQ Broadcast*
- *RREP Unicast*

- Route Maintenance as shown in figure 1 and figure 2.

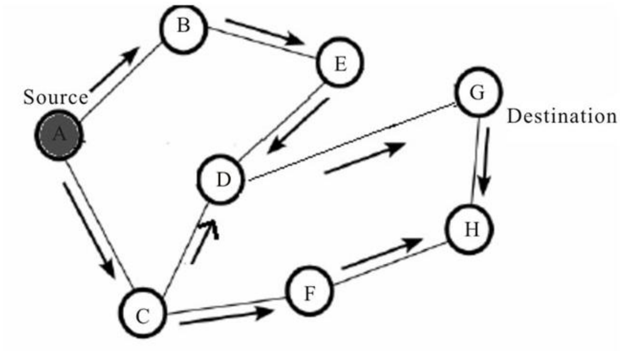

Figure 1. RREQ broadcast message in AODV

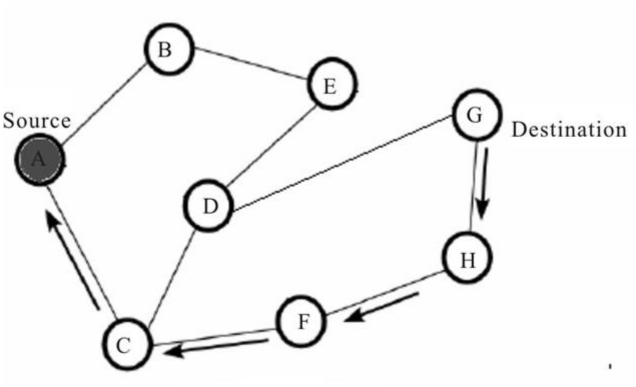

Figure 2 .RREP unicast in the discovered path.

Route Discovery: Nodes that can directly communicate with each other are called neighbours. A node constantly listens for HELLO messages to register a neighbour. The list of neighbours is maintained in the node's local routing table. When a node wishes to communicate with a node that it cannot find in its routing neighbours table, it sends a Route Request or RREQ broadcast message. This message packet contains a lot of information but most importantly: the source, destination, lifespan and a sequence number that serves as a unique ID for the RREQ message packet. When the message is broadcasted it is only captured and read by the router whose destination matches the one given in the RREQ packet.

Now the source can only send the packet to its neighbours, each neighbour checks its own routing table to see whether they have the destination as a number. If not, then the RREQ packet is broadcasted further. However, in the circumstance that a node finds the destination in its neighbour table then that node unicasts an RREP or Route Reply to the source indicating the destination. Each time a node rebroadcasts an RREQ message it appends its own address onto the packet. Thus an RREP message is unicasted since an exact path is available. Sequence numbers act as a lifetime of the message packet. It allows the other nodes to compare the recency of their information on other nodes. Every time a node sends out information it increases its own sequence number. A higher sequence number signifies a fresher route. This makes it a rudimentary task for other nodes to analyze which of the other nodes have more accurate information. Sequence numbers are also used to avoid looping in the network. Even though AODV can find multiple routes during the discovery process, it stores only one path since there is a lot of processing involved in storing more than one path to a singular location. However, if this path expires or breaks then the entire route discovery process has to be repeated.

B. Route Maintenance

AODV other than the RREQ and RREP messages also has a RERR or route error message used for reporting errors during any communication phase. Nodes monitor the link status [4] of next hops. When link breakage is detected in an active route, a RERR message is sent to the source indicating that the route is no longer usable. The message is sent back using the precursor list. The precursor list is a list that each node maintains and it contains the IP address of the node that preceding it.

Each time the route is used to forward a data packet it's the network increases its expiry time. The current time plus the ACTIVE_ROUTE_TIMEOUT (ART) [5] is assigned to the route. The ART is a value that maintains the feasibility of a new discovered route. It informs the nodes that how long a new route is usable after it has been discovered. After the ART has expired then the route is discarded.

III. DYNAMIC SOURCE ROUTING PROTOCOL

A. Introduction

Dynamic Source Routing is similar to AODV because it forms a route only when needed or on-demand, however, unlike AODV; DSR relies on source routing rather than table driven routing. Source routing collects the data of every node during route discovery and stores it in the source node. This learned information is used by nodes to create a cached path to the destination. This creates a redundancy wherein a large number of routing tables are created. This problem was eliminated in AODV. In DSR, the whole route is carried with the message as an overhead, whereas in AODV, the routing table is maintained hence it is not required to send the whole route with the message during the Route Discovery process.

DSR is composed of the two mechanisms of Route Discovery and Route Maintenance, which work together to allow nodes to discover and maintain source routes to arbitrary destinations in the network. Initially the every node before pushing a packet forward will check its cached table to find a route, if an unexpired route is found the packet is pushed through that route however, is no such route is found then a route discovery is carried out using RREQ and RREP messages as shown in figure 3. This results in updation of the cached routing tables of all the nodes propagates through the network. [2].

B. Route Discovery

```
    ^    "A"    ^   "A,B"   ^  "A,B,C"  ^ "A,B,C,D"
    |   id=2    |   id=2    |   id=2    |   id=2
+-----+     +-----+     +-----+     +-----+     +-----+
|  A  |---->|  B  |---->|  C  |---->|  D  |---->|  E  |
+-----+     +-----+     +-----+     +-----+     +-----+
    |           |           |           |
    v           v           v           v
```

Figure 3. RREQ broadcast message in AODV

When a new node wishes to send a packet, it attaches a new header called the ‘source route’ header to the packet which contains the hop count for which that packet is valid. Generally, the node will find the path to the destination by searching its own route cache table [6] but if no such entry is found then the route discovery process is started. We refer to the source as initiator and the destination as target.

To initiate a route discovery the initiator sends a local broadcast packet to all the nodes within wireless transmission range of the initiator. Each route request identifies the initiator and target and also contains a unique identification number determined by the initiator of the request. A copy of the listing is also recorded which contains the intermediate nodes that the request takes to reach a node. When a node receives the request and happens to be the target then that node returns a route reply indicating that the target has been found.

C.Route Maintenance

Each node in a network is responsible individually to check whether the path being used for communication is usable or not. Each node maintains a provision to receive and transmit acknowledgements [7] as shown in figure 4. These ACK messages can be transmitted at no extra cost. These messages are transferred as part of the MAC Layer architecture (the link layer acknowledgement as defined by IEEE 802.11) [8]. If an internal mechanism for transmission is not present then the node requests that DSR specific software acknowledgement. This ACK is transferred directly to the node.

IV. Destination-Sequenced Distance Vector Routing Protocol

A. Introduction

The DSDV protocol uses the distance director vector to find the route in a network that uses the DSDV protocol for wireless communication. The nodes in a DSDV protocol are responsible for passing the routing table information to the subsequent neighbours. This routing information is periodically updated throughout the network. At every transfer of packets in the network the node increments the distance vector. It does this to append its own value to the distance vector.

B. Route Advertisement

Every node is responsible for advertising its own routing information (table) to each of its neighbours. This information, however, can change randomly since the nodes are mobile and not stationary. Thus the nodes have to send the updated information every instance that the routing table entries change or a periodic timer whichever is earlier. The information that is passed to the neighbours includes the source address of the sender, the number of hops for which the packet will be valid and also the original sequence number which is assigned by the target destination.

```
+-----+     +-----+     +-----+     +-----+     +-----+
|  A  |---->|  B  |---->|  C  |-->? |  D  |     |  E  |
+-----+     +-----+     +-----+     +-----+     +-----+
```

Fig 4.Route maintenance in DSR

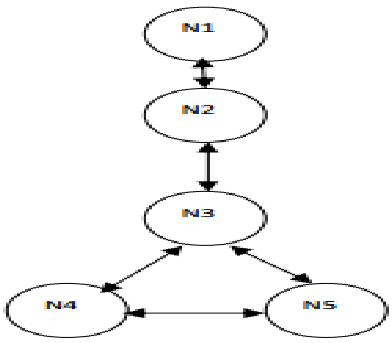

Fig 5. Route update in DSDV

C. Route Update

The update procedure begins after every node has advertised its own routing information as shown in Fig 5. The neighbours that receive this information store it in their routing tables. Initially the nodes only contain the information of their own neighbours and the distances to other nodes (not in the node’s neighbour list) have a distance of infinity. After this stage, the nodes advertise the information received from the previous steps to its neighbours. This creates a mutual exchange of information and updating of routing tables. The packets which have a higher sequence number appear fresher to the nodes and hence they replace their own information for that node. This creates an optimal path.

There are two kinds of packets [9] that are used in this process: full dump and incremental packets. Full dump packets carry all the available routing information and occupy the size of several Network Protocol Data Units (NPDU). Because of their large size they are infrequently transmitted in the network. Incremental packets only carry the changed information since the transmission of the last full dump packet. They occupy the size of one NPDU. Because they are lightweight they are transmitted frequently through the network.

V. PERFORMANCE OF THE ROUTING PROTOCOLS

A lot of sources were studied and the survey found that the DSDV protocol performs better than AODV and DSR in pertinence to throughput. However this changes sharply in the case of end to end delay. This difference in performance is because of the entirely table drive nature of DSDV which has to took up and update tables with each change of routing information but this also means that it doesn't need to create a fresh route on demand leading to better Packet Delivery Fractions than both AODV and DSR.

VI. Conclusion

This paper presented a true to life comparison between the three most used protocols for IEEE 802.16 in a wireless environment. Study of several simulation environment showed that AODV outperforms both DSR and DSDV [10] [11] [12] in terms of network viability. AODV outperforms because of its reactive routing format which allows it to maintain an active connection with the network and respond quickly leading to low end to end delay. The need for WiMax routing protocols is scalability and the ability to deployed quickly AODV successfully ticks off these criterion. Future work could entail a more encompassing comparison between more recent routing protocols like TORA (Temporally Ordered Routing Algorithm and GRP (Geographical Routing Protocol) [13].

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