Proceedings of the Med-Hoc Net 2003 Workshop
Mahdia, Tunisia 25-27 June, 2003

DYNAMIC VIRTUAL SUBNET ROUTING (DVSR) IN AD-HOC NETWORKS

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ABSTRACT

An ad hoc network is a dynamically re-configurable wireless network with no fixed infrastructure or central administration [8]. However, such a mobile wireless network environment is difficult to be managed. Furthermore, as it aims to be applied mainly for mobile devices, for example, laptops, PDA's and perhaps mobile phones, there are power consumption issues which need to be addressed. The aim of this paper is to describe the Dynamic Virtual Subnet Routing (DVSR) Protocol which would provide an effective connectivity in terms of reliability, adaptability, performance and power efficiency, even in critical environmental conditions. DVSR Protocol would be power aware and it would adopt dynamic virtual subnets in order to allow nodes to find the desired route efficiently across limited collision domains. Finally, once the DVSR Protocol design stage will be completed, a simulation will be required to test the protocol effectiveness.

1 INTRODUCTION

A wireless network, in Ad-Hoc mode, consists of mobile nodes in a network formed without any fixed infrastructure. In order to communicate, all nodes inside the network should co-operate with each other by individually transferring the packets towards the destination [14]. This process is power consuming; therefore it will completely absorb the mobile node's power along the time. Consequently, a routing protocol should be designed in such a way that the node spends less power while transferring packets and, at the same time, find the destination efficiently. Using the virtual subnet concept, which has been implemented in DVSR protocol, can mitigate these problems.

In a wired network, by using the subnet concept, bandwidth utilization is tremendously reduced and packets are efficiently routed. The same concept would be applied to Ad-Hoc networks by adopting Virtual Subnets. Effectively, they would divide the network into many virtual subnets (similar to collision domains) making use of power management to emulate IP subnets. This solution would enable the process of efficiently finding the destination node and obtain optimised power consumption.

Actually, Standard Wireless Networks (IEEE 802.11) spend constantly 1.4 W while transmitting packets at 2 Mbps [11]. Power management would be used in DVSR protocol to initially set the power to a minimum threshold level. This is justified by the fact that Ad-Hoc networks use shorter hops rather than standard wireless networks longer hops. In addition, power management is used to break down the network into many virtual subnets. This solution would allow even a wide network to be predictable in terms of size and topology.

The power management of the nodes is made even better by introducing different power modes like transmit, receive, idle and sleep mode [11]. Each mode consumes different power, while the node is in operation. These modes are activated according to the idle time of the node.

Usually, the source node selects a route which has the lowest power consumption [5]. Nevertheless, if the source node receives more than one route towards the destination node, then it will select the route which has the lowest power consumption. Additionally, in case more than one route with the same power consumption is detected, then the one which can be reached in less time is selected.

2 MAJOR FACTORS IN AD-HOC

While designing this routing protocol many issues were considered. They can be summarised as follow:

- How to find the route to the destination node without having routing table of other virtual subnets.
- Should the protocol send ACK packet when data packet is passed from one node to another node.
- How to avoid routing loops when passing packets between nodes and
- Should the protocol send regular "keep-alive" messages between nodes, so that the node know who is in its virtual subnet region.

The main criteria to be considered are

- Avoid wasting more power while transferring packet [9];
- Avoid overusing the bandwidth by sending unnecessary updates or messages [1];
- Should have efficient route discovery and maintenance algorithm.

These are the main hypothetical questions and criteria considered while designing this protocol, so that there will be power and bandwidth efficient routing of packets between the nodes.

3 POWER MANAGEMENT

In DVSR protocol, different power modes are used to reduce the power utilization in the node. These modes are activated according to the idle time of the node. Four types of power modes have been designed. They are transmit, receive, idle and sleep mode [2]. The power consumed for each mode is described in the following table.

Table 1: Power Modes Used

Mode	Power Consumed	Network Card Used	Mbps
Transmit (Tx)	1.4 W	Cabletron 802.11	2
Receive (Rx)	1.0 W	Cabletron 802.11	2
Idle	0.83 W	Cabletron 802.11	2
Sleep	0.13 W	Cabletron 802.11	2

In transmit mode, the power consumed is 1.4 W. This mode is activated depending to a specific situation. If the node wants to transfer packets, then this mode will be activated. Generally, transmit mode is activated when the node is switched ON.

In the receive mode, the power consumed is 1.0 W. This mode is activated when the node receives a packet from another node. Usually, even this mode is activated when the node is switched ON.

In the idle mode, the power consumed is 0.83 W. In this mode, the nodes neither transmit nor receive packet. This mode consumes power because the node has to listen to the wireless medium continuously in order to detect a packet that it should receive. So that the node can then switch into receive mode. This mode is activated when the node is idle for 60 seconds.

In the sleep mode, the power consumed is 0.13 W. This is the lowest power consumption mode. The network interface at a node in sleep mode can neither transmit nor receive packet, the network interface must be woken up to idle mode first by an explicit instruction from the node. This mode is activated if the node is idle for 90 seconds.

Whenever the node changes the power mode, the node will send a broadcast to everyone saying, “I have changed the power mode”. This is done, so that the surrounding nodes know when to send the packet to the node. These are the power modes used to reduce the unnecessary power consumption when the node is low of power resources.

4 DVSR APPROACH

4.1 Node Discovery Within Subnets

When a node is switched ON, the corresponding node forms a virtual subnet based on the threshold power level range, which is initialised by the protocol to 0.2 W - 0.3 W. The protocol uses 0.2 W – 0.3 W because the wireless card uses 1.0 W to power the electronic equipments (ADC, DAC, Modulator etc) present in the wireless card. After setting the threshold power level for all the packets, the source node sends a broadcast message saying, “This is my IP & MAC address” to all the nodes within its virtual subnet [10]. So that whichever node gets that message within that power level from the source node, it will update its routing table. After updating the routing table it will send an ACK for the packets received from the source node saying that “I am in your virtual subnet range and this is my IP and MAC address”. The source node will receive the ACK and then it updates its routing table. In this way, each and every node inside the virtual subnet exchanges packet and finally every node inside the virtual subnet will know who is inside or outside its range.

A node should be able to monitor all the nodes located inside its virtual subnet. For example, how can node A discover whether the nodes inside its virtual subnet moved out of the virtual subnet or not? Node A will trace the new nodes entering its virtual subnet, when it is receiving “keep-alive” messages from them, which doesn’t have an entry in node A’s routing table. Consequently, by perceiving that message, node A will send a broadcast again, saying, “I am in this virtual subnet range. Is everyone within my range?” Following this broadcast, node A will receive replies from many nodes within its virtual subnet range. Therefore, any new replying node will be added into the routing table whilst any node entries stored but not replying will be deleted.

4.2 Route Discovery

When a node enters a virtual subnet it will advertise to everyone its IP and MAC address and it also gets all other nodes address that is located within its virtual subnet. After getting them, the node will start electing its Border Nodes (BN) and then marks them in the routing table, as BN. BN nodes are the nodes that are located in the virtual subnet border range, which is 0.2 W to 0.3 W. The process of finding whether a node is located within the virtual subnet border range or not, is achieved by calculating the time it takes to send and receive the packets from a node. Also by seeing the power consumption of the packets after it is received by the node. The power consumed by a packet is compared with the threshold power level set by the protocol, so that the protocol will identify which packet is weaker and stronger in power and also whether it is a BN node or not

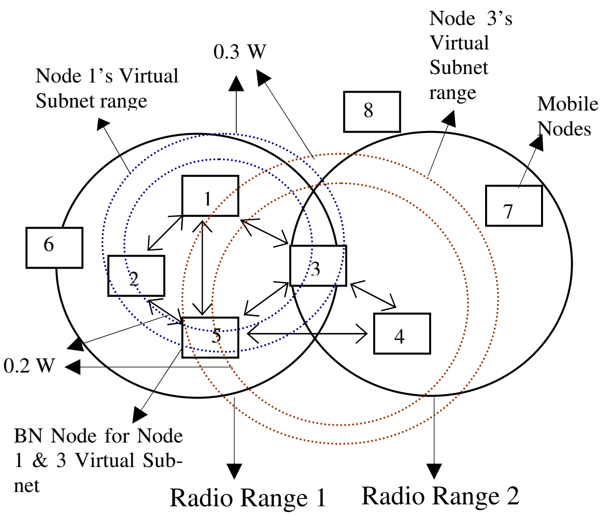

Figure 1: Ad-Hoc Network With Virtual Subnet

As you can see in the above diagram, if node 3 wants to send a packet to node 2, which is present in node 1's virtual subnet. Then node 3 will send a broadcast to all the border nodes, for example nodes 5 and 1 but not to Node 4 because it's inside the virtual subnet border. After sending the broadcast, the BN nodes will broadcast to its corresponding BN's and keep going until it reaches the maximum hop count or it finds the destination node.

Table 2: Node 1 Routing Table

Node	IP Address	MAC Address	Power Level (W)	BN	Power Mode
2	10.10.10.2	005004556F49	0.3	Yes	Tx / Rx
5	10.10.10.5	00A0CC23FE40	0.3	Yes	Idle
3	10.10.10.3	01005E000009	0.3	Yes	Tx / Rx

Table 3: Node 3 Routing Table

Node	IP Address	MAC Address	Power Level (W)	BN	Power Mode
1	10.10.11.1	00107B3A3F60	0.3	Yes	Idle
4	10.10.12.4	0010547E2CD3	0.1	No	Tx / Rx
5	10.10.10.5	00A0CC23FE40	0.3	Yes	Idle

As you can observe in the above routing table, Node 3 routing table has an entry for node 4, which is not in the boundary so it is marked as "No", which says that it is not the boundary node. The power level of node 4 is 0.1 W, which is below the threshold power value range (0.2 W to 0.3 W). So it is marked as "No" for BN node. But node 5 has power value as 0.3 W, which is between the threshold power value range, so it is marked as BN. When a node receives a packet, it always check the received packet power value with the threshold power value, so that the node can differentiate whether the node is BN or not. The power modes are marked as idle and Tx / Rx, because the node would be idle for 60 seconds or it is sending the packet at a constant time rate.

Coming back to the example, when node 3 sends broadcast to node 1 and 5, these nodes again will keep sending the broadcast till the maximum hop count is reached but node 1 will find the route to node 2 since this node has an entry in the node 1's routing table as BN node. So by following this approach, unnecessary broadcast of packet between the intermediate nodes is reduced and the communication will be between the BN's only, which will be less in number (e.g. In Hundred's) compared to the intermediate node communication (e.g. In thousand's). After the destination node receives the packet from source node, it back propagates through the same route saying, "This is the route you should follow to reach the destination node". Then the source node will view the packet received and follow that route and reach the destination node.

4.3 Management Of Node Movement

Till now everything looks to be fine, but if you examine the diagram below, node 4, which was in the border of node 1's virtual subnet at T minute, moved inside the node 1's virtual subnet at T+1 minute and became an intermediate node. Now how can node 1 differentiate whether node 4 is BN or not?

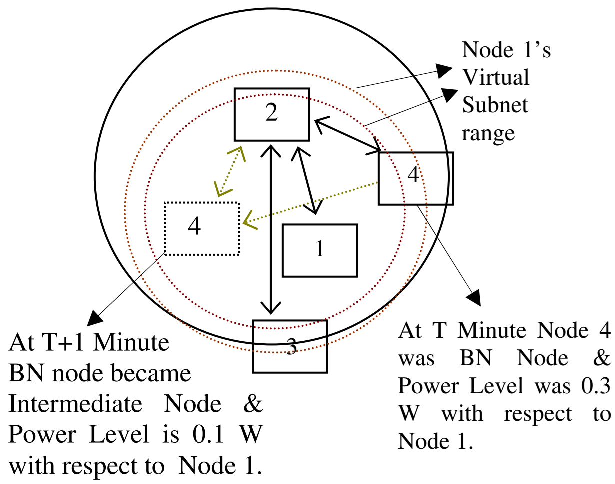

Figure 2: BN Node Movement In Node 1's Virtual Subnet

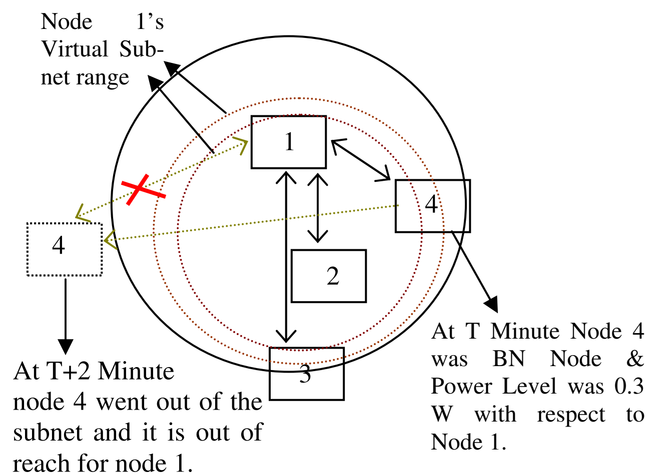

Figure 3: BN Node Movement In Node 1's Virtual Subnet

With the help of the power value in the packet, the node can differentiate the node type (BN or intermediate). Since the virtual subnet is formed with power range 0.2W to 0.3 W at the beginning. If a BN node is located at the border range and if it sends a packet, then the packet should consume at least 0.2W out of 0.3W, since its coming from the virtual subnet border.

Now, when node 1 receives the packet from node 4 at T minute, it checks with the threshold power value (0.3 W) and sees how much power it consumed, since it is coming from a BN node, the remaining power would be approximately 0.1 W to 0.15 W. After seeing the power value of the packet, node 1 will know that this packet was coming from a BN node and it will mark in the routing table as 0.3 W, which says that this node is under the BN node category. However, when node 1 receives a packet from node 4 at T+1 minute, the remaining power after calculating with the threshold power level would be greater than 0.2 W. After getting that power level of the packet, node 1 will know that the packet should be coming from an intermediate node and node 1 will be marked in the routing table as 0.1 W, which says that this node is under the intermediate node category. The threshold power level difference is set for the BN node in such a way that it will cover a particular range of distance in mile, so that the node doesn't fluctuate as intermediate or BN node.

In the above diagram you can see that, node 4 was a BN node with respect to node 1 at T minute. However, at T+2 minute, node 4 moved outside node 1's virtual subnet. Now node 1 will be unable to talk with node 4 without any intermediate node's help because it is outside its virtual subnet range.

4.4 Loop Avoidance

In this protocol sequence numbers are used. The sequence numbers are built in such a way that each sequence number will be unique compared to other sequence number [5]. So that if any two different source nodes send broadcasts at the same time asking to send to the same destination node, then the node which received this packet should be able to differentiate these two broadcast messages and send it to the destination. Even if a node receives a broadcast packet from the same source but through two different intermediate nodes then the node, which is receiving this packet should be able to know that it is coming from the same source but through different intermediate nodes. So to overcome this problem, this protocol will use a unique sequence number, which is created by using the machine part of the MAC address (last 24 bit). For example, if the node has a MAC address 00A0CC23FE40 then the sequence number for that node will be C23F40, which is the last 24 bit of the MAC address and it would be unique for every node.

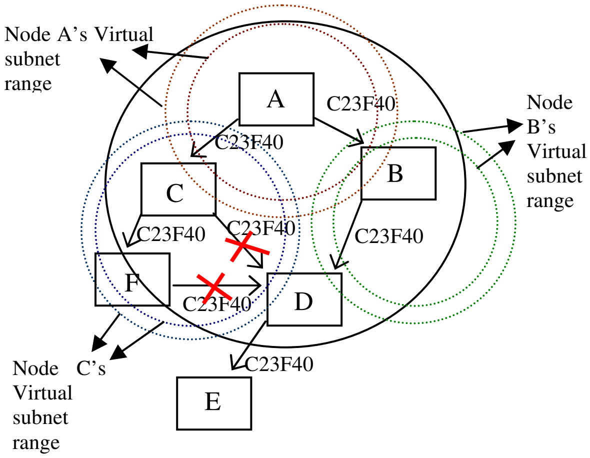

Figure 4: Avoiding Route Loops

In the above diagram, node A is the source node & node E is the destination node and nodes C, B, F & D are the intermediate nodes in the node A's and node B's virtual subnet. Consider for example, if node D receives three packets from three different intermediate nodes but from the same source node A, then node D will check whether it has send a broadcast for the same sequence number C23F40 before. If it did, then the node will discard the packet and won't send an ACK, but if it didn't send a packet for that sequence number C23F40 before, then node D will see the power consumed by all the packets received and choose the packet which has the lowest power. In this case, node D will receive packet from node C, node F and node B. Since packet from node F has come through three hops, the power consumed should be more compared to node C and node B. So due to that reason, the packet from node F is cancelled and sees which packet to choose now, whether from node B or node C? Since both the packets have two hops, the power consumed should be more or less the same. So to choose the packet between them, it can be done by checking the time taken to reach node D. Finally by using time as a factor, node C packet will be discarded because node C has to send two packets, one to node F and another to node D. The time for processing the packets and sending to two nodes F and D would take more time compared to node B, which would take less time since it should forward packet to node D only. After selecting the packet from node B, node D will forward that packet to node E, which is the destination node and also send an ACK to node B saying that "I have delivered your packet and I am in your virtual subnet range". The ACK is send for the packet and at the same time for the virtual subnet range also, so that the node can save power and bandwidth by not sending unnecessary packets, each time.

4.5 Routing Table Maintenance

In DVSR protocol, the routing tables are not transferred to other virtual subnets; instead it is used inside its own virtual subnet only. When a node is idle for a long time, for example more than 2 minutes, then the node should know where it is located because in an ad-hoc network, being idle for 2 minutes is too long. So, to overcome this problem, the node is allowed to send broadcast message saying "I am in this virtual subnet range and are you with me?" After sending this broadcast message, the source node (node which sent the broadcast) will receive many packets from its virtual subnet nodes. In that case, if any of the packets received are from unknown nodes, then the source node will include the entries of the new node in it's routing table, so that it will know who is inside its virtual subnet range. If the source node doesn't receive any reply from the nodes, which had an entry in its routing table, then the source node will delete the old node entries from its routing table.

This broadcast message will be sent every 110 seconds, if the node is idle for more than 2 minutes, otherwise the node will not send any broadcasts, to avoid unnecessary power and bandwidth consumption. The routing table will be updated whenever the node gets a packet from a new node that has entered the virtual subnet recently or if the node couldn't find an intermediate node, which was there before in its virtual subnet and had an entry in its routing table.

5 INETERNET CONNECTION USING DVSR

By using DVSR protocol, a mobile node can connect to the Internet. To connect to the Internet the node should have access to a nearby wired network which may be office network, home network or Internet Service Provider (ISP). If the mobile node is able to access any one of these network then the node should register with its IP and MAC address to any of these network, in order to get connected to the internet.

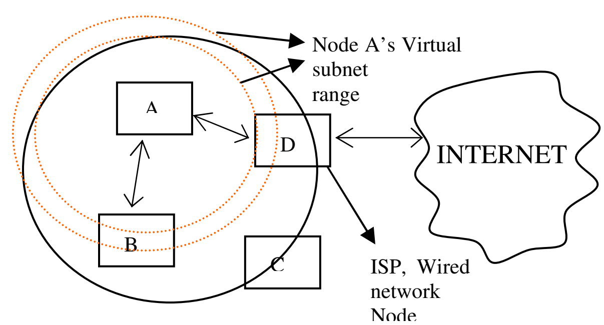

Figure 5: Mobile Node Connecting To Internet

From the above diagram, you can observe that node A can connect to the Internet through node D which is an ISP. Since node D is the BN for node A, node A could easily connect to the Internet in one hop. But in case the ISP is situated in another virtual subnet then node A should go through many hops to reach the ISP and then connect to the Internet.

6 DVSR PACKET FORMAT

When one node communicates to another node, the node sends its data in the form of packets. For every protocol there will be a particular packet format. By using these packet formats only the nodes talk to each other by sending data or any acknowledgements in the format shown below

Power Mode	Proto Used	Power Level	CRC	ACK	BN	Data

Figure 5: Packet Format For DVSR Protocol

The format is designed in such a way that it takes in all the necessary parameters into consideration like BN node, ACK, power mode, power level, data and the protocol type used. Depending on the situation, the corresponding bits will be set as one or zero. If the BN node is sending a data packet to an intermediate node then BN will be set as one, to declare that the BN node is sending the data and the power level of the packet also will be set as 0.3 W. The power mode of the node can also be set to transmit, receive, idle or sleep mode. Depending on the situation the corresponding bits will be set as one or zero and this packet format will be used for transmission of data between the nodes.

7 CONCLUSION AND FUTURE DEVELOPMENT

Although this protocol has been designed after considering many issues, a lot of points still need to be focused and may be changed using expert guidance. A simulation will be preformed in the near future. Such simulation should prove the protocol effectiveness and re-design could be successively required in order to apply corrections and improvements. After DVSR protocol is effectively working, the focus will be on subnetting similar to wired networks.

The main change that can be made in the DVSR protocol is the implementation of the variable power level virtual subnet. In this theory, the virtual subnet can be made further adaptive and variable, according to the number of nodes present inside the virtual subnet. In case the number of nodes inside the virtual subnet is less in number and if they are located in predictable distance then the virtual subnet can be formed with a lesser power compared to the constant threshold power level set by the protocol. By following this approach, unnecessary power consumption can be avoided and the virtual subnet can be made adaptive according to the node population.

The unnecessary broadcast of packets can be reduced by detecting the bandwidth utilization of the opposite end node. This concept is similar to CSMA/CD in wired network. By following this approach, the denial of service (DOS) attack can be avoided and the bandwidth utilization of the node can be reduced.

The author's contribution to the research work in this paper is the concept called Virtual Subnet and studying how the mobile nodes can interact with each other effectively using the Dynamic Virtual Subnet Routing protocol.

DVSR protocol will have a good scope, since it has an efficient routing mechanism and good power management of the nodes while routing packets.

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