Department of Electrical and Computer Systems Engineering

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An Experimental Study of Wireless Mesh Network under Mobility and Energy Consideration

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An Experimental Study of Wireless Mesh Network under Mobility and Energy Consideration

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1. Introduction

Wireless network has really become increasing in the market in the last couple of years due to the fall of deployment cost. They are going to replace wired communication network in the near future. For example, as Wimax technology arise, broadband delivery for devices will support high transmission rate so make roaming, portability, watching movies available on all devices implemented in more places. The paper presents some of preliminary experiment results that will be the base for the following experiments to improve routing on wireless mesh network. It first introduces about Ad Hoc On-demand Distance Vector Routing (AODV) protocol and some mobility models and assumptions about energy consumption. These models are implemented in AODV frame work simulation model written in Omnet++ software. The results examine the network performance under different mobility scenario. It also shows energy consumption distributions of clients on networks under different scenario.

2. AODV Operation

Many commercial companies are using AODV routing protocol. A source initiates a route discovery by flooding a RREQ packet when information about a destination is needed but not available. This node also put the RREQ time out in the waiting buffer. By the expired time, if the source does not receive the Route Reply (RREP) packet, and the RREQ_RETRIES is already reached then the RREQ and all data to the destination is removed from the buffer. Other wise, it attempts another trial.

Any intermediate node receive the RREQ, if it has a recent route to the destination, it will replies by unicasting a Route Reply (RREP) along the path formed by these reverse destination vectors. If the route to destination is old, it does nothing and if no route is available then it broadcast the RREQ again. Before sending RREP, the node put the RREP acknowledgement (RREP_ACK) into buffer so it remembers about the sending of the RREP. After the time out without receiving the RREP_ACK then it will find the neighbor that is expected to send it the RREP_ACK and put the neighbor in the list called BLACK_LIST. This means that the connection with the neighbor might be broken. This will help to avoid the situation when there are unidirectional links due to unequal power transmission range or links break due to node mobility.

The sequence number is used to ensure most up-to-date information. In the routing table, each node is associated with the highest known sequence number. When a node sends RREQ again, it updates the sequence number that it already knew about the destination. The destination will use the maximum of its current sequence number and the one in the RREQ to send the RREP back to the source. If any intermediate node got the sequence number associated with the destination is higher than the one in the RREQ then it sends the RREP back. Otherwise the information is already out of date.

Routes in the routing table are also inserted and updated by RREQ, RREP and Hello messages. When these messages arrive, node knows about a new route to the originator of message or the destination sending the RREP or the neighbor that send the Hello messages. The route time out is then reset to the original value ROUTE_TIME_OUT.

If there is no update by RREQ or RREP or Hello messages that is used to maintain the connectivity, each route will expire after time out and will be removed from the Routing table. However, before each route expires, it might be updated and the route time out is reset again as the new route.

After each route is removed from Routing table, a route error RERR message will be created and broadcasted over the network. Each node receive RERR will check its routing table again to remove invalid routes.

If any node put its neighbors into the BLACK_LIST then the RREQ that is sent by the neighbors will be ignored until the neighbors are removed from the BLACK_LIST.

3. Mobility models

To the best of our knowledge, there are five most common mobility models:

- **Random Walk mobility model**
- **Restricted Random Walk mobility model**
- **Random Waypoint mobility model**
- **Random Direction mobility model**
- **Normal Markovian mobility model**

In the random Walk model, speed is uniformly distributed between a determined min-speed and max-speed. The direction is also uniformly distributed between [0,2pi]. Each node assumes to move until a fixed distance. After that, they chose the random speed and direction again.

The restricted Random Walk is similar with the previous one. The only different is after a node finish a movement then it chose a speed uniformly between [s-k, s+k] where s is the last speed and the direction angle is between [α-π/4, α+ π/4].

The Random Waypoint model is one of the most common used one because it is quite realistic. The different with the first two is the host selects a random destination first. The node then stays stationary for a pause time. After that it moves to the destination with a speed between [v-min, v-max] and selects a random destination again. However, the model tends to produce high node density in the centre of the map which is some time not correct.

The Random Direction mobility model try to avoid high node density on the centre of map by combine Random Waypoint and Random Walk models. It chooses a speed and a direction distributed uniformly and goes on until it reaches a map border. After a pause time, the node chooses a new destination and speed.

The normal Walk model is derived from Markovian models and is often used for cellular networks.

Depending on the mobility model and its parameters then it produce different node density on the networks. As the topology of network changes then the data transmission on the network also changes and the energy consumption of each client on the network also vary. In the next sessions, we will present the data transmission and energy consumption of clients on the network under different scenario.

4. Energy models

The energy consumption of each wireless device varies depending on the specific products and specific technology. Some research groups took experiments on 2 Mbps 802.11 wireless network interface card. They showed that the difference between Transmit mode and idle mode is 484mW and between Receive mode and Idle mode is 123mW.

Modeling the power consumption of each wireless station is not an easy task and for the purposes of this study we have adopted a number of assumptions which we believe to be reasonable. We follow the experiments data above and assume that the data is measured when the wireless card is in full speed operation 2Mbps. Then the energy to transmit and receive a bit is $0.242e^{-6}$ W and $0.062e^{-6}$ W respectively.

This mean that the energy consumption on each node depends only on the number and the size of data packet and control packet it communicates during the time of measurement.

5. Simulation models

Mobility models and energy model are included into AODV routing protocol and all are developed using Omnet++, a discrete event based simulator. We use Omnet++ because it is a simulation platform of choice by others working in this area within CTIE. This permits us to draw upon the comprehensive libraries already developed.

An Omnet++ model consists of hierarchically nested modules. The depth of module nesting is not limited, which allows the user to reflect the logical structure of the actual system in the model structure. Modules communicate through message passing. Messages can contain arbitrarily complex data structures. Modules can send messages either directly to their destination or along a predefined path, through gates and connections. Each module can be treated as a layer in multilayer data communication.

In order to use the mobility pattern to model behaviors of networks, the mobility model will be defined in the sub module Mobility in each mobile host and they will communicate with Physic module each time a moving event occur to tell the physic module update wireless connection and the position with other mobile host.

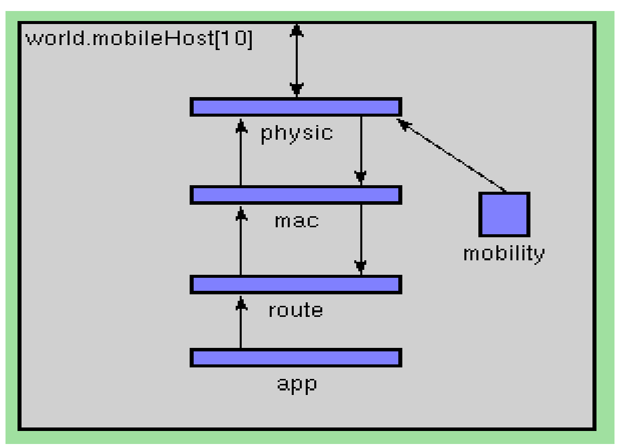

Fig 1: Sub modules communications

To model AODV routing protocol, there are ten types of messages used. Six of them are external messages that will travel from mobile hosts to mobile hosts: HELLO message, RREQ message, RREP message, RERR Route Error, DATA message, RREP_ACK (RREP acknowledgment message). The functions of these messages are discussed on the AODV operation above.

There are also internal or self message control the routing action of each mobile host.

DELETE: a self message scheduled to trigger a route expiration event. As AODV standard states, the first time a DELETE message is processed, it is scheduled to occur again in the future. In this way a "last chance" is given to this invalid route before deleting it;

FLUSH: this message handle the RREP time out. After occurring a fixed number of times all the messages stored in the data messages directed to the unknown destination are deleted from the output buffer.

SEND HELLO: a self message that triggers the host to send a new Hello message.

BLK LIST: a self message that triggers the exit of a neighbor node from the black list.

There are also settings for simulation test bed and parameters for other layers that communicate with AODV protocol during the simulation.

Map and hosts

Map size	550 *550 m
Number of hosts	40
Host enabled to transmit	40

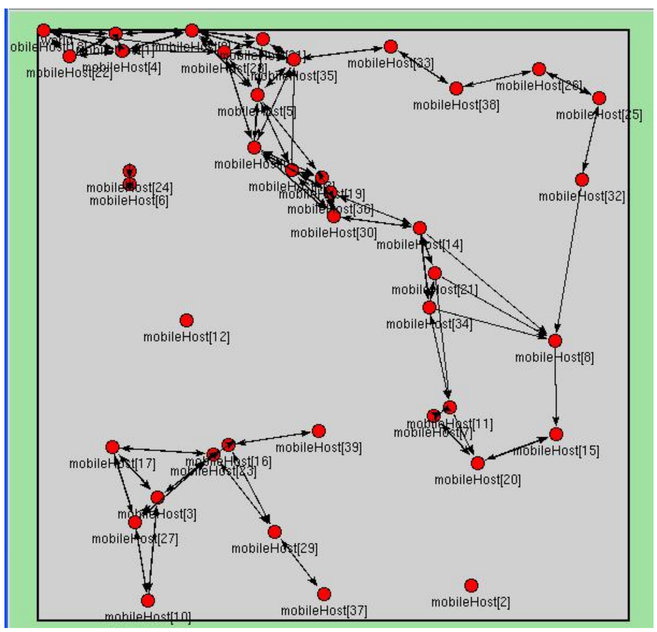

Fig 2: Simulation scenario

Physical layer

The layer controls the transmission and reception of packets between mobile hosts. It also communicates with mobility module to update the connection and interface between it and other neighbors inside its transmission range. The transmission range of each host is set at 100 m. The transmission rate is approximately equal 802.11 b which is 11 Mb/s. Channel propagation delay is 10 µsec.

Mac layer

The Mac layer is implemented in simple way in the simulation. It implements M/M/1 buffer queue for packet reception and another M/M/1 buffer queue for packet transmission. Each type of message has its all priority for example 1 for RREP and 3 for priority so RREP will be served on the M/M/1 queue first. The buffer capacity for both is 10Mbits. Further work might insert channel contention protocols such as CSMA/CA, MACA.

Routing layer

The routing layer is AODV with settings given in the table below.

Control message size	512 bits
Hello interval	0.5 sec
Route time out	3 sec
RREQ trials	3
RREP trials	2
TTL_START	1
TTL_THRESHOLD	7

Application layer

Application layer models each communication as Burst message. Each burst has 120 packets and the packet rate is 4 packets per second.

Data message size	12000 bits
Burst length	120 packets
Send packet rate	0.25 sec / packet
Burst interval	Exponential uniform with average 5 minutes

Mobility model

Restricted Random Walk: Each node will move to a random distance 100 m away from the Origin. It pauses randomly between 2 to 5 minutes and select another random destination 100 m away.

6. Simulation results

We first figure out the duration of simulation that make the data results become consistently converged.

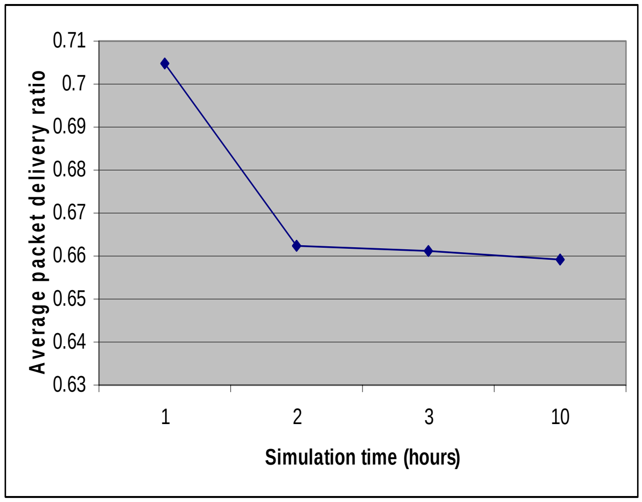

Fig 3: Simulation duration estimation

From Figure 3, it can be seen that after 2 hours simulation then the data result going to be stationary. Also, the longer simulation only gives a multiplication factor of data result after 2 hours simulation. As the results, we run each simulation for duration of 2 hours.

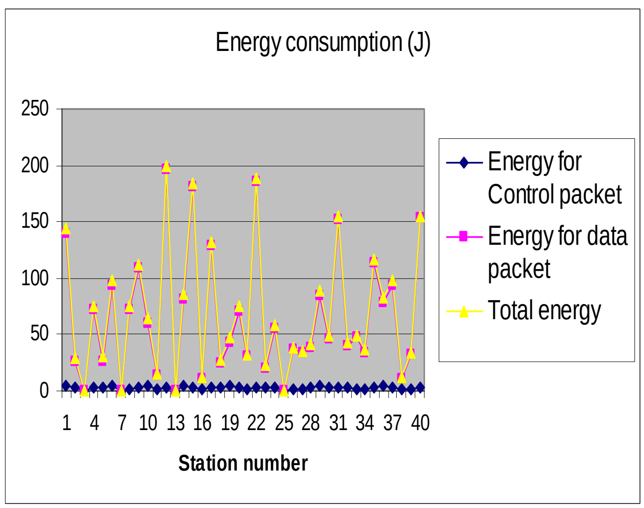

Fig 4: Energy consumption distribution on network

Figure 4 shows the energy consumption distribution of 40 stations after 3 hours simulation. Each node moves at 1 m/s velocity. It can be seen that the consumption variation is very big and the energy consumption for data is about 25 times bigger than for control packets.

The distribution variation versus node velocity is presented in the next figure. The variation is calculated by the ratio between the variance and the mean energy of all 40 nodes in different mobility velocity.

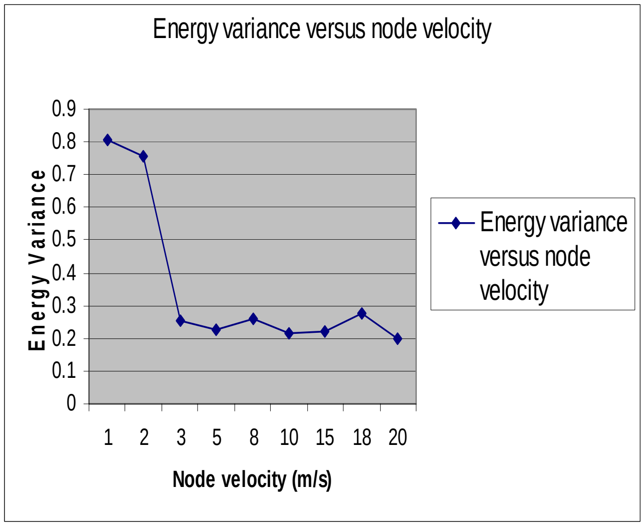

Fig 5: Energy variation on network versus node velocity

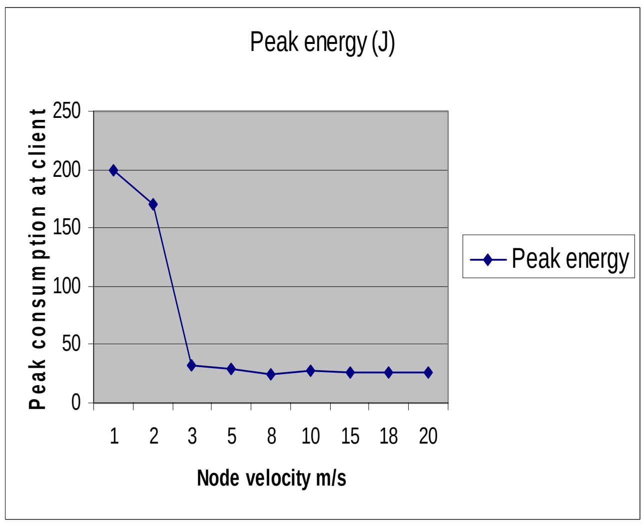

Fig 6: Peak energy consumption of network versus node velocity

It can be seen that the energy consumption is balanced when the node velocity increase and it is almost stable when velocity is from 3m/s to 20 m/s. Also, when the node moves faster then the peak energy consumption of network is much reduced. This is very important as it improve the network operation time because the energy resource is balanced on the networks. We also know when a particular client on the network runs out of energy.

Data transmit and the packet delivery ratios are also looked at when the velocity of nodes increases. They both show similar trend that is the amount of traffic and the delivery ratio fall sharply when the node velocity is higher than 3 m/s. However, they are quite stable when the node moves from 3 to 20 m/s.

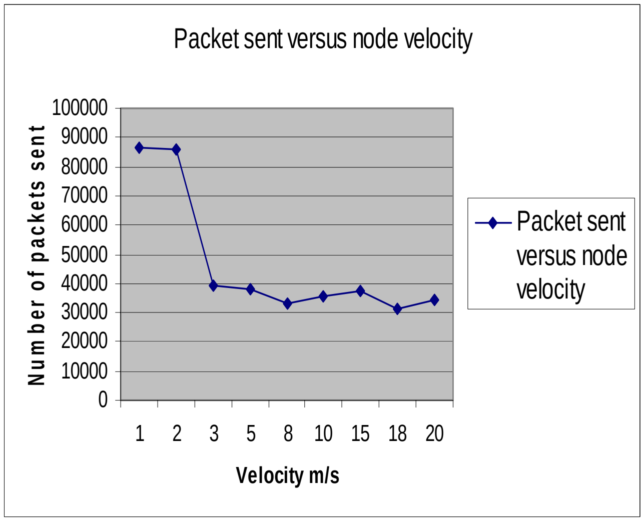

Fig 7: Number of packets sent versus node velocity

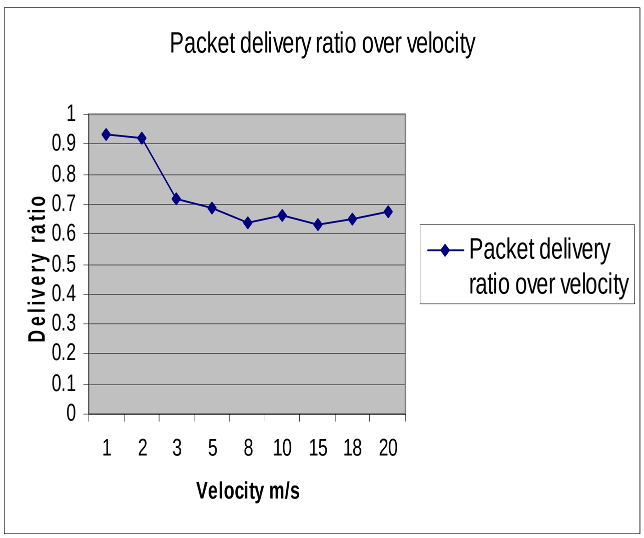

Fig 8: Packet delivery over node velocity

Fig 9 tells that the average energy for each station at normal movement (1 to 2 m/s) is about 65 J for 2 hours. If the movement is higher than 3 m/s then the data transmitted is reduced dramatically so as the average energy needed for the communication during 2 hours.

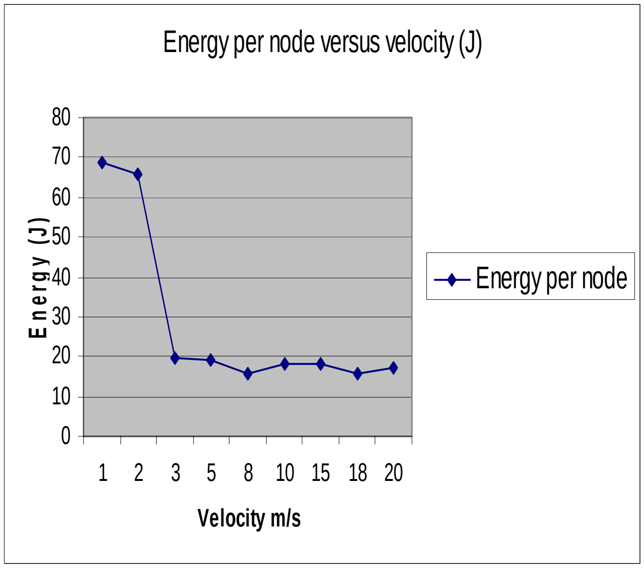

Fig 9: Average energy per node over node velocity

7. Conclusion

The results in this paper indicate that there is a significant scope for research in the area of energy based routing. This view is reinforced by the comparatively small amount of research in what is a rapidly area wireless communications.

The work and the results will be foundation for developing new routing techniques to improve the current performance of wireless mesh networks.

With power control, control messages can be used to optimize power consumption for network. On reactive protocol like DSR and AODV, RREQ messages are broadcasted over the network to find route. As the results, there are usually many possible paths to a destination. Then data might be transmitted over less hops but not energy efficient path. If RREQ messages are broadcast at the minimum power required to maintain network connectivity, leading to longer end-to-end paths at the network layer but with less distance per hop. This results in a significant reduction in the overall end-to-end energy consumption per delivered packet.

Control messages can also deliver energy metrics at nodes that they travel on their path. For examples, in DSR routing, each node inserts into RREQ packet power required to reach to next hop a long the path. Each node then caches the information then it can select the most energy efficient path from paths it receives from the RREP.

It is possible to expand the simulator in many ways. One can choose for example to add a new layer or to implement a new version of an existing one. In the first case a new layer can be added for example to simulate the transport layer. This will slow down the simulator speed but at the same time
produce more accurate results and better performance. To add a new layer one should edit the mobilehost.ned file that contains the connections between the host layers and insert here the new connection to the brand new layer.

Implementing a new version of an already existing layer means that a certain layer will keep the same connections specified in the mobilehost.ned file, but it will change its behavior. For example one can implement a new routing protocol or a better MAC protocol like 802.11.

8. Reference

[1] C. Perkins, E. Belding-Royer, and S. Das, “Ad hoc On-Demand Distance Vector (AODV) Routing”, RFC 3561, July 2003.

[2] A. Safwat, H. Hassanein, H. Mouftah, “Energy aware Routing in MANETs: Analysis and Enhancements”, MSWiM’02, September 28, 2002, Atlanta, Georgia, USA.

[3] www.omnetpp.org.

[4] T. Camp, J. Boleng, and V. Davies, “A Survey of Mobility Models for Ad Hoc Network Research”, Wireless Communication & Mobile Computing (WCMC): Special issue on Mobile Ad Hoc Networking: Research, Trends and Applications, vol. 2, no. 5, pp. 483-502, 2002.

[5] N.T. Tung, “Routing in wireless network: a literature survey for PhD”, Department of Electrical and Computer System Engineering, Monash University, Melbourne, Australia.

[6] V. Bhuvaneshwar, M. Krunz, A. Muqattash, “CONSET: a cross-layer power aware protocol for mobile ad hoc networks”, Communications, 2004 IEEE International Conference on Volume 7, 20-24 June 2004 Page(s):4067 - 4071 Vol.7.