DTN ROUTING BY AVOIDING BATTERY CRITICAL CONDITIONS AND DATA LOSS AT AN INTERMEDIATE NODE

Sreejith S Ambady*[1], R Ganesan#[2]
[1]Research Scholar, Department of ECE, NICHE, Kumaracoil, India, PIN- 629180
[2]Professor, NICHE and JIT-JIMMA UNIVERSITY, Jimma, Ethiopia.
[1]ambadihere@gmail.com, [2]dr.ganesh.jass@gmail.com

***Abstract*- Delay tolerant networks are used in the areas where the network connectivity is sparse as well as the delay is very high that is in communication challenged areas. The electronic devices used in such areas will be lacking continuous power supply and thereby mostly battery powered. So there may be circumstances where, the data transmitted to an intermediate node, and the node before forwarding the data may run out of battery life. Another circumstance that may arise is that the getting lost due to any physical damage to thee node. The paper addresses simple techniques to avoid data transfer to nodes with low battery and to share data with those nodes with sufficient battery power so as to prevent any data loss and to identify any bulk packet loss due to any above mentioned issues and to efficiently route the packets. The simulation is done in ONE simulator and results are being analysed in terms of throughput ratio for different buffer size, the results show a gradual increase in throughput by the method.**

***Index terms*-** delay tolerant networks, power management, routing protocol, software issues, and physical damage

I. INTRODUCTION

Delay tolerant networks are a solution for data exchange in areas where there are no fixed infrastructures for communication, where there are no base stations or any fixed repeater, instead of that the communication takes place by the mutual communication between nodes. The data moves in a store carry and forward method where data resides in a node and it is forwarded when an opportunity for connection arises. DTN comes to action in natural calamity occurred area where the conventional communication system is seized, in military fields, in inter planetary communication, etc. The conventional TCP/IP stack can't be used in such situations since TC/IP demands a continuous end to end connectivity and short round trip time. In such circumstances where there may never be an end to end path between source and destination, DTN routing comes into action.

DTN helps to exchange data even in circumstances with intermitted connectivity, high delay, highly vulnerable data rates and high bit error rates. The data carriers in these areas are generally mobile devices or generally battery operated devices due to the lack of a continuous power supply. The recent advances in technology have enabled mobile devices to carry a large amount data (range of Giga Bytes) because of the improved capacities in new portable storage devices. A simple concept is to carry large amount of data in a mobile device and on the go distributing it on need.

A scenario can be stated that, an intermediate node having data, die out of battery and thus the data not getting forwarded. In this case data from source is prevented from reaching the destination. In this paper, we propose a modified delivery predictability approach, such that messages depending upon their size are forwarded depending on the battery power of the nodes that come into contact. A new algorithm is proposed and evaluated with different buffer size.

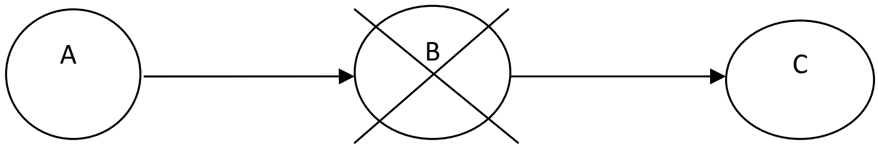

Fig. 1 Data forwarding blocked due to node die out of power

Fig. 1 shows three nodes A, B and C, where A is the source node and C is the destination node and these two nodes communicate through an intermediate node B. the situation is such that the intermediate node B getting die out of battery or the data in node B getting lost due to any physical damage to the intermediate node. All these cases may result in packet loss. The following sections explains the various approaches in delay tolerant network routing and the enhanced DTN routing technique used so as to overcome the above mentioned situation.

II. DELAY TOLERANT NETWORKS AND ITS ROUTING APPROACHES

There are two groups of routing protocols in DTN flooding families and forwarding families. The flooding family don't need any prior information of the network to forward a message and more than one copy of message will be within the networks. But in the case for forwarding family it requires a prior knowledge of the network so as to forward a data so as to reach destination. Flooding is more general approach in forwarding messages since it is simpler and doesn't need any sophisticated computing or need any external hardware to find network information. Epidemic routing, probabilistic routing (PRoPHET), spray and wait etc. are few among them.

A. Epidemic Routing

Epidemic routing is one among the first DTN routing methods. Here the data forwarding is such that, a node forwards data to another node if it is not having the data. It is flooding type protocol. All the nodes will be thereby having all the messages. Thus the message delivery to the destination is being guaranteed even with delay in delivery, still delivery ratio will be high and packet loss is low. The main drawback of the routing protocol is congestion in the network due to the heavy flow of data even to nodes that do not aids communication with destination. The over head is very high. The resources like bandwidth, spectrum etc. are used exploited in epidemic routing protocol.

B. Spray and Wait Routing

Spray and wait is an alternative to epidemic routing. It prevents the unwanted flooding of messages. Here a number L is associated with the messages which indicate the maximum number of copies of the message that is to be spread in the network. It has two phases, spray phase and the wait phase. First the source sprays L copies of the same message to L number of nodes. After receiving the message copy the L intermediate nodes will be in wait phase. The intermediate nodes wait until it gets a direct transmission with the destination. Here it ensures message delivery still with the usage of resources. Moreover certain nodes having no contact with the destination will be also having a copy of the message.

C. PRoPHET

Probabilistic routing protocol using the History of Encounters and Transitivity (PRoPHET) uses the non randomness of the real world. Here the source checks the encountered node for its history of contacts with the destination. Depending on these encounters a set of probabilities are developed and with this the next node to which message to be forwarded is determined. Every node maintains delivery predictabilities of the nodes which it had encountered. That is a node which is having frequent contact with the destination will be having higher predictability value, such that the data can easily reach destination if the data is forwarded to the node with high delivery predictability.

Calculation of this delivery predictability is as follows.

$P_A(B)$- Delivery predictability of node B stored in node A

$P_A(B)_{old}/P_A(B)_{new}$- Delivery predictability before/after encounter

Direct encounter- delivery predictability of encountered node increases with each encounter

- $P_A(B)_{new} = 0.5$ (on the first encounter , $P_A(B)=0$ initially)
- $P_A(B)_{new} = P_A(B)_{old} + (1 - P_A(B)_{old}) * P_{encounter}$ (for upcoming encounters)

Decay over time- all delivery predictabilities will be decreased if the nodes fail to meet for long time

- $P_A(B)_{new} = P_A(B)_{old} * \gamma^K$ (K is number of time units since last decay and γ is the aging constant)
  If $P_A(B)$ gets very small, set it to 0 and consider as the first encounter.

Transitive rule- If node A wants to send a message to node C, and B to C is a fair path, also A frequently meets B, then A can forward the message to C through B.

- $P_A(C)_{new} = \max [P_A(C)_{old}, P_B(C), * P_A(B)_{new} * \beta]$ (where β is a constant)

The following section explains how the data can be forwarded wisely by avoiding a node with battery critical situation and also forwarding data if there is damage to an intermediate node. Two scenarios are considered and different approaches are proposed to solve this

III. ENERGY AWARE ROUTING

In PRoPHET routing, the data is forwarded through hopes by calculating the delivery predictability as the criteria for forwarding and if an intermediate node dies out of battery then the data is lost. This problem is discussed in this section. The main idea is to classify data to two categories depending on the size and forward it if a particular percentage of battery remains in the intermediate node. This is done with an assumption that, smaller messages require lower power consumption while forwarding when compared to larger messages. So even if battery remaining in a node is low, the message can be forwarded if the message size is small. For this, depending on the battery percentage available to a node the delivery predictability calculation is modified.

Considerations done

- Message above 5mB (normally video files)
- Message below 5mB (normally photos, documents, programs, music etc.)

A. Messages above 5MB

For messages above 5mB the data will be forwarded only if the battery percentage of the encountered node is above 50%. Now to a node having battery percentage above 50 is not only a forwarding criterion. This is because there may be situations where these nodes have low delivery predictability (calculated by PRoPHET), i.e. these nodes will not be having a frequent contact with the destination. So we have to consider the delivery predictabilities of these nodes and formulate new delivery predictability such that from among the nodes encountered with the node, which is having high delivery predictability as well as having battery percentage above 50 is chosen and the data is forwarded only to this node.

The delivery predictability is formulated as follows

- First to check whether battery percentage above 50 of encountered node (here node A source and node B encountered node)

$P_A(B)$*Batt% of node B – $P_A(B)$ (1-Batt% of node B) > 0

(Here battery percentage implies, if 50% then 0.5 is taken)

If the above equation is true then battery percentage of node B will be greater than 50.

- Next is to relate delivery predictability and the remaining battery percentage.

$$\mathbf{P'_A(B)=P_A(B)+\lambda P_A(B)}$$

Where $P'_A(B)$ will be the new predictability value and λ is the constant added to include the battery remaining factor

- Now it is to formulate the value for λ

λ= [P(A,B)*Batt% - P(A,B)(1-Batt%)]/100

The above equations selects a node from a group of encountered nodes so as to forward the packets such that they will reach destination is, which satisfy the condition that the node will be having the highest delivery predictability- battery percentage remaining factor.

B. Messages below 5MB

Messages below 5mB are generally documents pictures etc. These files require short time connectivity for the data transfer. Therefore the power usage is lower in transferring while considering a file with bigger size. So a consideration is made that messages below 5mB will be forwarded even if the battery percentage is 30%. That is a node forwards these messages even if battery percentage remaining in the encountered node is above 30%.

The delivery predictabilities are formulated as follows

- First to find whether the encountered node has a battery percentage above 30

  $P_A(B)$*Batt% of node B – $P_A(B)$(1-Batt% of node B) > - 0.36

  The above equation finds out the nodes with battery percentage above 30%.

- Next is to relate delivery predictability and the remaining battery percentage.

  $$\mathbf{P'_A(B)=P_A(B)+\lambda P_A(B)}$$

  This is the equation as per PRoPHET routing. This is the basic equation that determines the delivery predictability of an encountered node that, whether it is being in frequent contact with the destination.

- Now it is to formulate λ

  λ= {[$P_A(B)$*Batt% of node B- $P_A(B)$(1-Batt% of node B)] + μ} /100

Here μ is a constant used to correct the predictability value μ=0.36. the above equation relates the delivery predictability along with the battery percentage factor. Node having the highest value for the above equation will be the one with maximum probability to deliver a message to destination before the battery getting died out.

IV. SIMULATION ENVIRONMENT

The simulation tool used here is Opportunistic network simulator (ONE). One is the basic simulation used to carry out routing is DTN environment.

TABLE 1. Simulation Conditions

Parameters	Dimensions
Total simulation time	12 Hrs
Simulation world size	450×340
Movement model	Random Way movement
Buffer size	Differing
Number of nodes	100
Interface transmit speed	Up to 2Mbps
Interface transmit range	10m
Interface used	Bluetooth interface
Initial battery conditions	1400

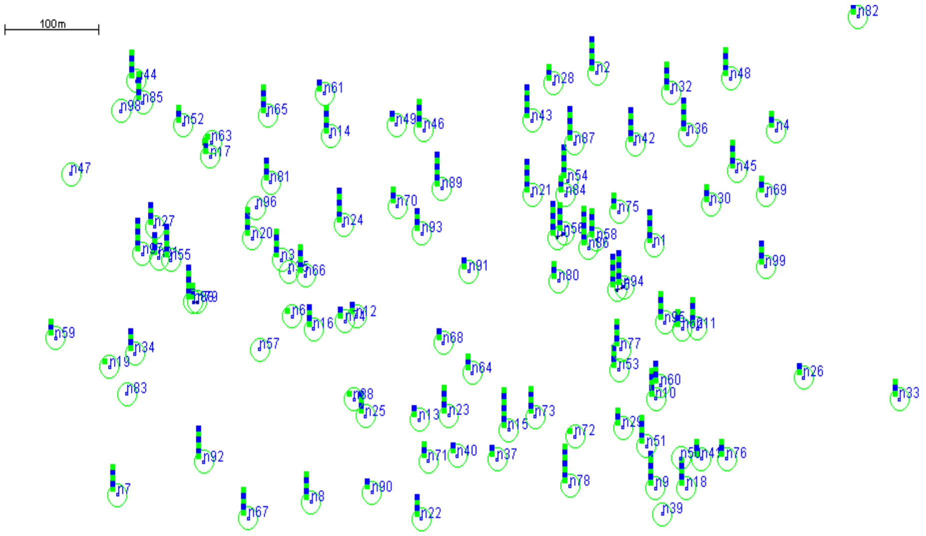

Fig. 2 ONE simulator simulation interface

Fig. 2 shows the simulation condition in ONE simulator with hundred nodes with all the nodes a possible destination. The results are analysed from the delivery ratio output obtained with respect to different buffer size applied in the simulation.

V. RESULTS

A. For Messages above 5MB

Here the data is forwarded to nodes with at least 50%battery remaining.

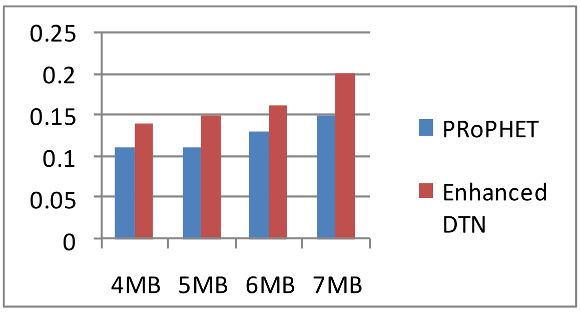

Fig. 3 Delivery predictability v/s Buffer size

From the graphs it is clear that enhanced DTN results a higher delivery predictability ratio while comparing with PRoPHET. The difference in the packet delivery ratio is appreciable such that the loss is kept to minimum. Not all the packets will be dropped, still some packets will be lost, but the packet drop due to the battery die out condition can be overcome to an extend by the technique.

B. For messages below 5mB

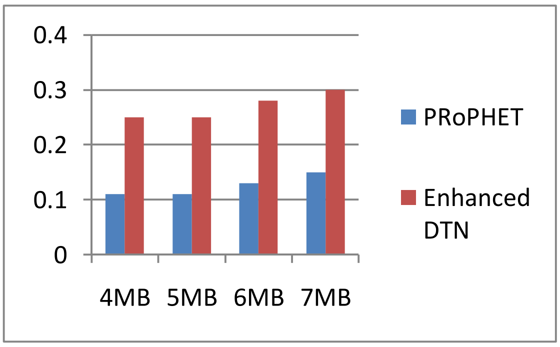

Fig. 4 Delivery ratio v/s Buffer size

Here also we can see the delivery predictability value is having considerable change with respect to PRoPHET.

In both the cases it is clear that the delivery predictability value will be determined along with battery percentage such that the remaining battery percentage will play the same role as the determining of the frequency in the nodes contact with destination in finding the new delivery predictability value. Here the data loss due to the nodes die out of power is encountered very efficiently due to the enhancements made in the PRoPHET routing protocol.

VI. EFFICIENT ROUTING BULK PACKET LOSS CONDITION DUE TO PHYSICAL DAMAGE TO THE INTERMEDIATE NODE

The issue mentioned in this section is the packet loss due to physical damage. Such a situation is handled by rerouting the message packets through another encountered node by the source. The work has two parts, first is to identify whether the messages are getting dropped and next is to reroute those messages.

A. TO FIND DEFECTIVE NODES BY CONSIDERING THE AGING FACTOR

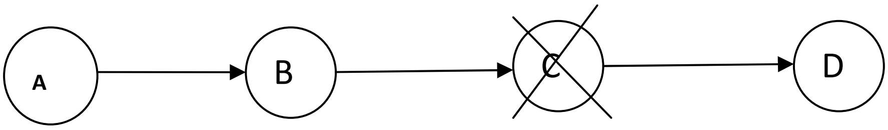

Fig. 5 Packet forwarding through two hopes

The section deals with the method of finding the defective node. Every node maintains a copy of message that is already forwarded within it. In fig 5 the ultimate intention is to transmit a message from source node A to destination node D. The scenario here described is such that message from node A traverse through node B from there to node C and from node C the packets reaches the destination D. Let the intermediate node C gets damaged or some fault occurred such that the packets within the node C gets dropped.

The primary intention is to find whether node is damaged. But Node A forwards the messages to node B and then it expects the message will reach the destination. The message received by node B will be forwarded to the node C. The next part is to determine the delivery predictability decay equation in PRoPHET routing. Here the node B checks for the delivery predictability decay with respect to node C.

- P_B (C)new = P_B(C)old * γK (K is number of time units since last decay and γ is the aging constant)

This new delivery predictability is used such that the value decreases implies the frequency of meeting between those nodes are getting low. If the nodes are not meeting for a long time then the delivery predictability decay will be getting decreased to zero.

- $P_B(C)_{new} = P_B(C)_{old} * \gamma^K ==> 0$

Node B checks this predictability value with respect to node C. If node C gets damaged then the node B checks the above equation to be true or not. If the above equation is true then the node B could confirm that node C got damaged. The selection of γ is of great importance. Since the consideration is done such that a node in between may get die, it is important to keep the value of γ as low as possible. By keeping the value of γ low, the aging factor results in a faster decay such that it may reaches zero quickly. So by checking regularly the predictability value and keeping γ value low the predictability value decreases and reaches 0 if the node C has got damaged.

But in general case the by name DTN means some delay is tolerable. This is the reason of keeping the value of γ near to 1. The main drawback is that the node B in Fig, 5 will come to know that node C got damaged only in a considerable amount of time. This increases the latency for the message to reach from source to destination. To overcome this, the work is extended. Some delay acceptable, but if using the γ value very low the latency of reaching the destination will very high since the acknowledgement from the destination to source will be also having latency. The destination expects for the message and keeps waiting and thereby the latency will be increased.

To overcome this, another technique is proposed. This works such that the damage to an intermediate node is determined with the help of another node which come into contact with source and also the node is having a frequent contact with the intermediate node which got damaged.

B. TO CHECK THE ENCOUTNTER WITH ANOTHER NODE

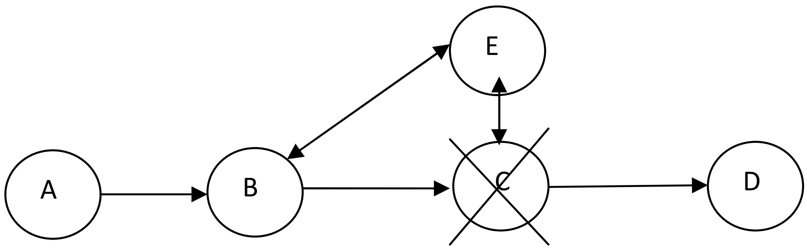

Fig. 6 checking encounter with another node

The source node A forwards a message and always expects it to reach the destination node D. Let the node C gets damaged and thereby the packets got dropped. In such a situatuation the idea mentioned is to check another node node E which may get into contact with node B and also having frequent contact with node C in the past. From the delivery predictability decay value this node E, determines whether the node C got damaged, and acknowledges node B.

The events that occur in fault detection are as follows:

- Node B after sending message to node C waits for the acknowledgement that the messages have reached the destination.
- Node B checks all the nodes arriving in its coverage are.
- Let node E arrives into the coverage area of node B after the damage of node C. (node B still unaware that node C got damaged)
- Node B then requests for the delivery predictability value of node E with node D

  $P_E(C)_{new} = P_E(C)_{old} + (1- P_E(C)_{old} * P_{encoutnter}$

  This delivery predictability value will be high if node E frequently encounters with node D
- Next is to check delivery predictability decay of node E with respect to node C

  $P_E(C)_{new} = P_E(C)_{old} * \gamma^K$

  This predictability value determines how long have these two nodes met. So if the delivery predictability value is 0 then it is sure that node E and node C haven't met for a long time. From this we can conclude that some fault occurred at the node C.
- Now node B is sure that node C have got some problem and the node B resend the message through another node which it have encountered.

VII. SIMULATION ENVIRONMENT

The simulation tool used here is Opportunistic network simulator (ONE). One is the basic simulation used to carry out routing is DTN environment. The conditions are all the same that is used in the previous simulation for the previous work.

TABLE 1. Simulation Conditions

Parameters	Dimensions
Total simulation time	12 hrs
Simulation world size	450×340
Movement model	RandomWay movement
Buffer size	Differing
Number of nodes	100
Interface transmit speed	Up to 2Mbps
Interface transmit range	10m
Interface used	Bluetooth interface
Initial battery conditions	1400

VIII. RESULTS

Considering both the techniques together and applied to the above mentioned simulation scenario the result will be as follows.

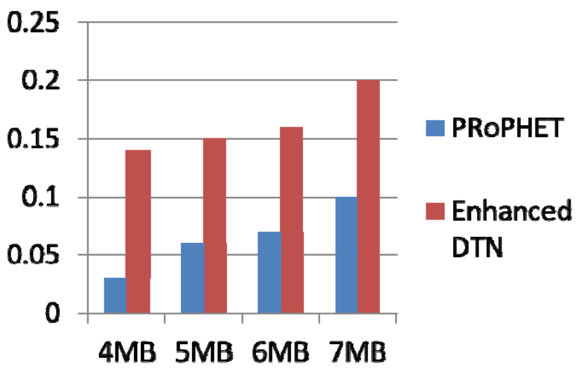

Fig. 7 delivery ratio v/s buffer size

From Fig. 7 it is clear that the packet delivery ratio of the new technique is high with respect to the PRoPHET routing technique. This is mainly because, the packets in an intermediate node, in PRoPHET routing technique, if got damaged will result in high packet loss. But in the enhanced routing technique the fault occurred node is determined and the messages to the destination are rerouted. A source can easily determine the fault with respect to an intermediate node and with the help of it the message can be rerouted.

IX. CONCLUSION

This enhanced DTN routing technique mainly addresses routing in battery critical condition avoidance in a dtn network and also a technique to avoid any loss of data due to any damage to an intermediate node carrying data packets. It prevents message being forwarded to a node which is in battery critical condition even if having high delivery predictability. It finds a node with high delivery predictability as well as having sufficient power to forward the message. The technique explained efficiently reroutes data packets in terms of any physical damage to an intermediate node. The simulation results clearly show that the packet loss in such conditions can be reduced. The future work is to reduce the delay since energy aware DTN routing imposes a higher delay while considering PRoPHET routing protocol.

ACKNOWLEDGEMENT

I would like to thank Dr. R Ganesan for helping me to simulate this work successfully and to prepare this paper.

REFERENCES:

[1] Sreejith S Ampady and R Ganesan, "DESIGN OF DELAY TOLERANT NETWORK FOR SMARTPHONES," International Journal of Applied Engineering Research, ISSN 0973-4562 Vol. 10 No.59, pp 243-250 (2015)

[2] Makoto Ikeda, Seiichiro Ishikawa, Taiki Honda and Leonard Barolli, "PerformanceEvaluation of Message SuppressionMethod for DTN Routing Protocols," Complex, Intelligent, and Software Intensive Systems 2015 Ninth International Conference on Complex, Intelligent, and Software Intensive Systems

[3] Razvan Beuran, Shinsuke Miwa, Yoichi Shinoda, "Network Emulation Testbed for DTN Applications and Protocols", 16th IEEE global symposium

[4] Jianling Hu, Ruhai Wang, Qinyu Zhang, Zhiguo Wei, and Jia Hou, "Aggregation of DTN Bundles for Space Internetworking Systems", IEEE SYSTEMS JOURNAL, VOL. 7, NO. 4, DECEMBER 2013

[5] Kang Chen,and Haiying Shen, "DTN-FLOW: Inter-Landmark Data Flow for High-ThroughputRoutingin DTNs",IEEE/ACMTRANSACTIONSONNETWORKING,VOL.23,NO.1,FEBRUARY2015
[6] Sergio M. Tornell, Carlos T. Calafate, Juan-Carlos Cano and Pietro Manzoni, "Assessing the Effectiveness of DTN Techniques Under Realistic Urban Environments", 38th Annual IEEE Conference on Local Computer Net
[7] Elizabeth M. Royer and Chai-Keong Toh, "A review of current routing protocols for ad hoc mobile wireless networks," IEEE Personal Communications Magazine, vol. 6, no. 2, pp. 46–55, Apr. 1999.
[8] Avri Doria, Maria Uden, and Durga Prasad Pandey, "Providing connectiv- ´ ity to the saami nomadic community," in Proceedings of the 2nd International Conference on Open Collaborative Design for Sustainable Innovation (dyd 02), Bangalore, India, Dec 2002.
[9] Glenn E. Prescott, Steven A. Smith, and Karen Moe, "Real-time information system technology challenges for NASA's earth science enterprise," in Proceedings of The 20th IEEE Real-Time Systems Symposium, Phoenix, Arizona, Dec 1999.
[10] George W. Boehlert, Daniel P. Costa, Daniel E. Crocker, Phaedra Green, Todd O'Brien, Syd Levitus, and Burney J. Le Boeuf, "Autonomous pinniped environmental samplers; using instrumented animals as oceanographic data collectors," Journal of Atmospheric and Oceanic Technology, vol. 18, no. 11, pp. 1882–1893, 2001, 18 (11).
[11] Tara Small and Zygmunt Haas, "The shared wireless infostation model - a new ad hoc networking paradigm (or where there is a whale, there is a way)," in Proceedings of The Fourth ACM International Symposium on Mobile Ad Hoc Networking and Computing (MobiHoc 2003), June 2003, pp. 233–244
[12] R. H. Kravets, "Cooperative solutions to the dynamic management of communication resources," in Ph.D. thesis, 1998.
[13] L. M. Feeney and M. Nilsson, "Investigating the energy consumption of a wireless network interface in an ad hoc network," in INFOCOM 2001.
[14] M. Stemm and R. H. Katz, "Measuring and reducing energy consumption of network interfaces in hand-held devices," IEICE Transactions on Communications, vol. E80-B(8), pp. 1125–1131, August 1997.
[15] W. Zhao and M. H. Ammar, "Message ferrying: Proactive routing in highly-partitioned wireless ad hoc networks," in FTDCS, 2003.
[16] S. M. Ross, Introduction to Probability Models. Academic Press, 2000.
[17] D. B. Johnson and D. A. Maltz, "Dynamic source routing in ad hoc wireless networks," in Mobile Computing, 1996.
[18] J. Yoon, M. Liu, and B. Noble, "Random waypoint considered harmful," in INFOCOM, 2003.
[19] F. Bai, N. Sadagopan, B. Krishnamachari, and A. Helmy, "Modeling path duration distributions in manets and their impact on reactive routing protocols," IEEE Journal on Selected Areas in Communications, vol. 22, no. 7, September 2004.