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A Survey of Factors Influencing Network Lifetime in Delay Tolerant Network

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Abstract

To what extend a wireless communication gadget can chip away at a single charge of a rechargeable battery obtains the importance. Capacity-wise, disposable batteries are superior to the rechargeable batteries. There are numerous ways utilized with which the battery life can be augmented. At the same time, identifying the cause of battery energy utilization boosts the researchers to design and develop protocols, methods and techniques to minimize the consumption of energy by which lifetime of the network could be extended. This paper investigates the sources and factors that lessen the network lifetime. The scope of this paper has been narrowed down to Delay Tolerant Network since this field of research has attracted a great deal of attention by the researchers mostly due to its challenging characteristic qualities. No promising connectivity, high mobility, indefinite node mobility patterns, energy and storage exhaustion comprise a few of the potential issues that one may confront in a DTN environment which in turn eat-off bandwidth and energy for the data delivery from the Source to the Destination.

Keywords: Ad Hoc Network, Delay Tolerant Network, Energy Efficiency, MAC Layer, Network Layer, Network Life Time

1. Introduction

Green networking[1-5] is a term leads to optimize and upgrade networking or make the communication more effective with any process that ultimately reduces energy consumption. The issue of green networking has numerous imperative applications, especially as energy gets to be more concern and people become more aware of the unconstructive impacts of energy consumption and so Green networking grabs the attention of the researchers now-a-days. This paper depicts the sources reducing the Network life-time in Delay Tolerant Network. Understanding the importance of the necessity of reduced energy consumption, we have put forward the study of the sources that consumes energy unfruitful.

Delay Tolerant Network (DTN)[6-10] is described as a network with frequent intermittent connections, disruptions and experience long delayed data delivery because of nodal mobility, sparsely deployed nodes, node failures, and so on. But, the nodal movement has been utilized for the data communication in such networks which is referred as Store-Carry and Forward[11-12]. Before the study of the factors of energy consumption, let us first consolidate the applications and the requirement for energy management schemes for such scenarios. Figure 1 shows one of the scenarios where Mobile Ad Hoc Network is used which experience the delay.

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2. DTN Applications

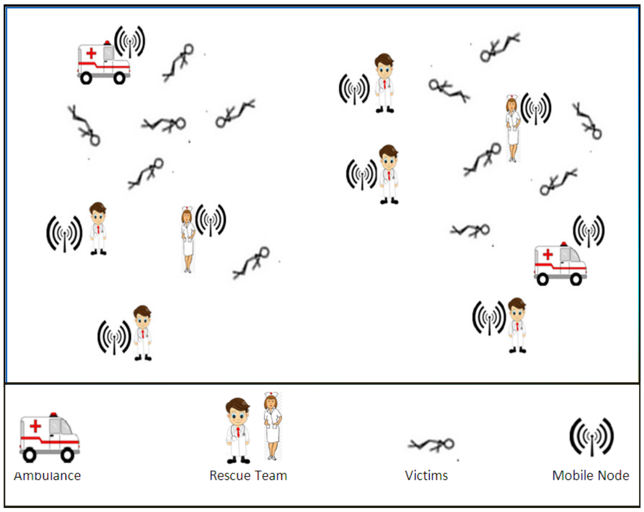

Figure 1. Delay/Disruption Tolerant Network-Emergency Rescue Scenario.

2.1 DTN for Maritime and Underwater Sensor Networks

Transmitting Wireless information through the ocean is one of the recent technologies for the development of future ocean-monitoring systems and sensor networks. Some of the applications of Underwater Sensor Networks (USN)[13-18] include sensing oil industry, aquaculture, prediction of natural disturbances, climatic condition recording, pollution control, undersea monitoring and exploration, disaster prevention and study of marine life. One of the major issues in the design and development of underwater communication protocols is the energy constraint since frequent change of batteries is complicated and costlier and so in need of energy management schemes which save superfluous energy consumption. To enhance the reliability in USN, multiple-path communications together with Forward Error Correction (FEC)[19] can be carried out. But reliability can be achieved at the cost of multiple paths, which in turn becomes a crucial factor for overall network energy consumption[20].

2.2 DTN in Space

DTN technology offers yet another way for profoundly focused on communications in space[21-25] environments, particularly those with frequent connection disruptions and long link delays in deep space missions. The protocols designed for DTN faces the communication issues and challenges like long link delay, very slow communication links, intermittent connections and availability of limited resources.

2.3 DTN in Emergency Response

Amid a disaster, situational awareness and responsiveness are a standout amongst the most important needs to minimize injury and death toll. Ad Hoc Networks helps in providing information during Emergency Scenarios[26-33]. DTN affords information to picture and to response the disaster site, the status of the disaster location and people, victim's medical information, need of the victims and to keep up communication with disaster rescue teams. The issues and challenges forced on the protocols developed for such network scenario are intermittent connectivity; congestion due to lot of repetitive data, limited network and device resources, device and link failures, and the sharing of individual gadgets makes security and protection threats. Information send from such scenarios ought to be reliable and comprehensive to make knowledgeable and prerequisite decisions.

2.4 DTN in Mines

Physical movement of people and equipment's inside a mine is largely predictable and periodic[34]. There are just about four thousand operating mines around the world and its existence relies upon the availability of the ore and may differ from a few years to several years. Inside the mines there exists tens to thousands of mining equipment's along with the workforce in the mines. Hence, exchange of data and information is required inside the mine for operations and monitoring which requires store-carry and forward of data with the help of intermediate nodes. The protocols designed for this application need to forward the data on-time with limited resources.

2.5 DTN in Forestry

Environmental monitoring in forestry[35] requires measurement of temperature, chemical contamination in the soil, intensity of natural lighting, fire hazards, radiation levels and air pressure. This information is collected by the wireless sensors randomly deployed in forestry. Sensor nodes in such environment experience long delay for encountering each other due to the nature of the location, natural harshness, heavy rainfall, fog and the movement of the wildlife. Sensing the information and forwarding the data are challenging in forestry. So the Sensor nodes and the protocols used are designed to withstand all the limitations in such applications.

Summarizing the above applications, extended Network Life-time is essential to facilitate resourceful data communication. In the following sections, we discuss the sources of energy consumption in DTN and the existing protocols.

3. Sources for Energy Consumption in DTN

3.1 Idle Listening

For an intermittently connected ad hoc network, time interval between the encounter of nodes are generally much larger than contact durations, which show that the nodes spend most part of their time in the idle listening mode rather than sending or receiving the information. In distributed network like Ad Hoc Network, centralized power saving strategies are also difficult. Experimental studies in[36] demonstrate that power consumption by an idle listening mode is more or less equal to the power consumed in a receiving mode. Analysis show that more than around 95 percent of the total energy is devoured by the idle listening mode in searching for neighbors. Energy is consumed not only in idle listening but also in several signaling activities[37].

3.2 Data Replication

In order to improve the data delivery probability, the majority of the routing protocols for DTN repeat transmitting the message duplicates[38-44]. The first algorithm which is developed for intermittent network is epidemic routing[45-47] in which packets that arrive at the intermediate nodes are forwarded to all encountering neighbors and this continues until the data reaches the destination or the time-to-live expires for the data. In spite of the fact that flooding-based scheme[48-49] can attain high delivery probability; it squanders much energy in the networks. Superfluous data transmission introduces flooding of messages that results in nodal buffer overflow which in turn creates congestion and affects the entire network. As a result, an energy-efficient forwarding algorithm which minimizes the number of data replication is recommended for DTN that influence the energy consumption as well as impact the overall network throughput also.

3.3 Packet Retransmission

Reliability is one of the main concerns in delay tolerant ad hoc network for the reason that of its characteristics like intermittency, long delay link, route failures etc. Reliable data transmission is achieved by packet retransmission[50,51] if it is concluded that the data is lost. It requires attention to the network and communication thereby reducing the number of retransmissions.

3.4 Fixed Transmit Power

Data transmitted from one node to the other with fixed transmit power consumes more energy. Since transmission power is directly proportional to the distance between the nodes, dynamic power control[52] is required to minimize the power consumption when the distance between the nodes is less.

4. Energy Efficient Routing Protocols for DTN

[53]The authors incorporate add-on techniques to improve the Epidemic Routing Protocol (ERP) in order to extend the lifetime of Delay Tolerant Mobile Sensor Network (DTMSN)[54-56]. After contemplating ERP with many variations to augment the network lifetime, three schemes viz., LT (Limiting the Time allowed for propagation) scheme, LC (Limiting the number of Copies) scheme and LE (Limiting the generation of the copies to the nodes with large residual Energy) scheme are presented. These schemes attempt to control the number of the duplicate copies forwarded. They extensively maximize the lifetime of DTMSN by shifting the control of creating the number of duplicate copies to the nodes with larger residual energy thereby diminishing the energy consumption for every node by controlling the packet flow. Boosting the network lifetime is not much equivalent to minimizing the number of the duplicate copies. When reliable data delivery is required, random minimization of the duplication of the packet copies is not recommended. In such cases, a node may transmit only to the nodes with the larger delivery priority towards the destination which is based on the destination node encounter history, mobility

pattern and other information regarding the network status and it is carried out by the control algorithms. In this paper, the authors concluded that ERP with LE scheme shows better performance in terms of extending network life time.

Authors[57], explains a new strategy in forwarding the multiple copies of data with the criteria of minimum energy consumption. If a node forwards data copies to all its encountered nodes, its batteries will be spent rapidly. An energy efficient n-epidemic routing protocol is proposed, keeping in mind the goal is to reach multiple intermediate nodes with less number of data transmissions. For this, it is better to transmit only when the number of neighbors inside the communication ranges reaching a certain threshold ‘n’. Choosing the threshold ‘n’ is significant and it is the key step in n-epidemic routing algorithm. Suppose if n is large and the likelihood of a node having such a large number of neighbors is low then chances of the packet sent out is minimum which in turn reduces the probability of receiving the packet by the destination. Conversely, nodes have lots of opportunities to forward a packet if ‘n’ is small and so the batteries energy will be drained rapidly.

The authors proposed an Energy-efficient Routing algorithm Based on Cross-layer design (ERBC)[58]. In DTN, same transmit power is consumed for exchanging data between mobile nodes which is an energy-consuming method and requires some power control mechanisms to make the routing effective. Low is the transmit power; more is the chance of missing the data delivery. Alternatively, high transmit power is wasteful of energy. As an alternative of utilizing fixed transmit power, ERBC predicts the distance between the mobile nodes based on the information acquired from RSSI technology[59-61] and using cross-layer design[62,63] selects the minimum transmission power level to exchange the data packets. In order to enhance the packet delivery ratio ERBC follows the method of broadcasting partial data packets. Simulation results show that ERBC can decrease 37 percent for per-bit energy consumption than the epidemic routing protocol. It predicts the distance between two nodes reasonably by the RSSI techniques then selects the minimal transmit power level to transmit the packets.

Authors[64] proposed a methodology named Distance and Energy-Aware Routing protocol (DER) to reduce the energy consumption cutting down the replicas based on the details of distance between the sensor nodes and the sink nodes in the network and the residual energies of each sensor nodes. Also DER calculates the data delivery probability between the nodes based on the frequency of encounters of sensor nodes with the sink node and its mobility direction.

In[65], the Authors proposed a Look-ahead probabilistic Energy Aware [LaHEA] routing strategy for DTN which chooses the forwarding node based on high delivery probability value that is higher than the predictability threshold. Also for Improvising energy efficient data forwarding, available energy of the receiver node ought to be known to the sending node and it is estimated by an energy estimation module. Forwarding to the node which lacks energy is superfluous since the battery drain out and fails in delivering the data to the destination thereby reduces network throughput and reliability.

5. Energy Efficient MAC protocols for DTN

Power saving mechanisms for Ad Hoc Networks[66,67] developed so for can be categorized into three types and are on-demand wakeup[68], scheduled wakeup, and asynchronous wakeup mechanisms[69]. The major sources of superfluous energy consumption considered are idle listening and the mechanisms proposed deal with minimizing the time duration of idle listening. One of the techniques for on-demand wake up mechanisms is the usage of additional secondary low power radio module to wake-up the mobile nodes radios when the data exchange is desired. For scheduled wakeup mechanisms, all the nodes in the network awaken at synchronized intervals in order to communicate with each other. As an initiative authors designed IEEE 802.11 PSM[70,71] a synchronous power saving protocol for single hop networks in which wireless devices in the network are maintained with synchronized clocks, periodically turn on and off their radio to minimize energy consumption. Concentration on Power Saving Mechanism in MAC Layer is said to be duty cycling[72-74] or a sleep scheduling[75]. But achieving synchronization is challenging in ad hoc networks since the nodes join or leave the network at any time. Cooperative coordination among the nodes minimizes the energy consumption. Asynchronous wakeup mechanisms do not necessitate global clock synchronization[76-78] and so duty cycling is predefined in every node so as to guarantee minimum of one overlapping wake up schedule among

Table 1. Comparison of Energy Efficient Protocols for DTN

Protocol	Network Type/Layer	Factors considered as sources of energy consuming	Approach	Parameters Analyzed	performance
ERP+ LE scheme	DTMSN/ Network Layer	Data Replication	1. Minimizing the number of copies. 2. Copies are generated by the nodes which has large residual energy	Delivery Probability, Normalized energy consumption	Life time of the network is maximized
EE n-epidemic	DTN/ Network Layer	Data Replication	Transmit the data only when the Number of neighbors reaching a certain threshold.	Delivery ratio, Average Delivery Performance	Increase the delivery performance of basic routing protocol by 434%
ERBC	DTN/ Network Layer	Fixed Transmit Power	Dynamically chooses the transmit power using both Cross Layer Design and RSSI Technology	Per-bit energy consumption, Network Lifetime, Success Rate	Reduce 37% for per bit energy consumption than basic routing protocol
DER	DTMSN/ Network Layer	Data Replication	Minimizes the number of replica based on the distance between the sensor node and the sink node and the Residual energy of the sensor node.	Delivery Rate, Delay, Network Lifetime	Performs better at the cost of lower traffic overhead and low energy consumption.
LaHEA	DTN/ Network Layer	Data Replication	Minimizes Data Replication based on Data Probability Value and the remaining energy of the current connected node.	End-to-End Delay, Energy Consumption, Delivery Probability	Reduces the number of retransmissions and Message drop and increases the delivery ratio.
EACDS/ MACDS	DTN/MAC Layer	Idle Listening	Adaptive Cyclic Difference Set System designed with multiple power saving levels	Delivery Ratio, Delivery Delay, Normalized Energy Consumption, Energy Consumption per Frame.	Reduces the energy consumption up to 35 percent- compared with power management protocols. Up to 90 percent – compared with without power management protocols.
EQ-MAC	DTMSN/ MAC Layer	Idle Listening	Uses Minimal Probe Frame, Dynamic Queue Management and a transfer mechanism initiated by the target receiver.	Throughput, Packet Drop Probability, Mean Packet Delay, Energy	Achieves 46% decrease in packet drop probability, 79% increase in system throughput, 25 % in mean packet delay

the nodes in the network where global synchronization is impractical to implement.

In[79] the authors focused on the power management schemes for DTN, and proposed asynchronous energy efficient clock-based sleep scheduling protocols. On the basis of hierarchical arrangements of Cyclic Difference Sets[80] and Rotational Closure Property, they have proposed two energy efficient adaptive asynchronous sleep scheduling protocols and discussed the implementation issues in maximizing energy efficiency in frame structure and neighbor discovery. First is the Exponential Adaptive Cyclic Difference Set (EACDS), a difference set called an initial set at power saving level 1(P1) is scaled by another difference set called an exponential set to create a hierarchical set with power saving level 2(P2). The hierarchical set can be scaled again with Exponential set to create yet a higher level hierarchical set P3 which provides higher energy efficiency than P2 at the cost of lower contact opportunities. Second is the Multiplicative Adaptive Cyclic Difference Set (MACDS) in which a multiplier set is used instead of an exponential set. Active Ratio and Neighbor Sensitivity are the parameters considered for the analysis of the proposed mechanisms.

In paper[81], the author proposes an energy-efficient MAC protocol for Delay Tolerant Mobile Sensor Network using dynamic queue management (EQ-MAC) for saving power consumption and data queue management. EQ-MAC protocol effectively minimizes the untargeted data transfer thereby increasing the successful data transmission in a timely manner. EQ-MAC protocol performs the best when compared with traditional MAC protocols in terms of energy consumption, mean packet delay, packet drop probability and throughput in Delay/Disruption Tolerant Network. Table 1 gives the comparison between the existing energy efficient protocols in DTN.

6. Open Research Issues

Maximizing Network Lifetime[82,83] and Minimizing Energy consumption are the important issues to be considered in Delay Tolerant ad hoc networks since such network experiences energy loss due to long delays and listening to the network. Energy of a node gets consumed during communication, computation and while sending beacon signals. Initiatives have to be taken in order to reduce energy consumption in all these aspects. Some of the research issues regarding the minimization of energy consumption are discussed in this section.

- Protocol design in Cross Layer approach reduces the power consumption considerably since it deals with multiple issues related to multiple layers.
- Analyzing the sources which consume energy while processing the data and finding the methods of reducing the superfluous consumption.
- Minimizing the beaconing signal without missing the encounter opportunity.
- Analyzing and avoiding unnecessary retransmission of data but without losing the reliability of the network.

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