JIMMA UNIVERSITY
JIMMA INSTITUTE OF TECHNOLOGY
FACULTY OF COMPUTING AND INFORMATICS

Proposing Energy Efficient Routing Strategy for Delay Tolerant Network

By:
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This thesis is submitted to Jimma University Jimma Institute of Technology Faculty of Computing and Informatics in Partial Fulfillment of the Requirements for the Degree of Master of Science in Computer Networking.

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This is to certify that the thesis prepared by Yimam Nurye, entitled as '**Proposing Energy Efficient Routing Strategy for Delay Tolerant Network'** and submitted in partial fulfillment of the requirements for the award Degree of Master of Science in Computer Networking submits with the regulations of the University and meets the accepted standards.

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Dedication

I have dedicated this thesis to my beloved parents (mother, brothers and friends) who never stop giving of themselves in uncountable way to help me in every aspect and their appreciation.

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LIST OF ABBREVIATIONS

MANET- Mobile Ad-hoc Network

DTN- Delay Tolerant Network

GUI-Graphical User Interface

ONE- Opportunistic Network Environment

SCF- Store-Carry and Forward

TTL- Time to Live

BP-Bundle Protocol

VANET- Vehicular Ad-Hoc Network

IPN -Interplanetary Network

CNN-current neighbour node

EERs – Energy Efficient Routing Strategy

ABSTRACT

Delay-tolerant (DTN) networks are the result of the evolution of mobile networks where there may be no end-to-end path. It enables communication between source and destination without the support of a fixed network infrastructure. The main principle of delay tolerant networks for message routing is the store-transport-forward approach, in which intermediate nodes store data for transmission until they find a suitable relay node to deliver messages on route to the target destination node. And DTN has many applications in the DTN network, such as wildlife monitoring, disaster management, assistance in detecting the movement of vehicles and traffic jams and military battlefields.

Several routing and forwarding strategies have been proposed in recent years. The main difference between the various DTN routing protocols is the amount of knowledge available to route messages. The store-carry and forwarding approach of DTN routing protocols generates many copies of a message on networks that consume node resources such as energy and buffer space.

The main challenge for delay tolerant networks is how to develop energy- efficient routing strategies and use fewer network resources. This study focuses on the proposed energy-efficient DTN routing strategy to tackle routing problems using node energy and distance to node information. Also investigate the performance of the DTN routing protocol with the metrics delivery ratio, overhead ratio and hopcount using the Opportunistic Network Environment (ONE) simulator.

The evaluation compares the proposed energy efficient routing strategy with the per hop routing strategy in terms of delivery ratio, overhead ratio, and hopcount. The results show that the energy efficient routing strategy outperforms on per hop routing with a higher message delivery ratio, less overhead and higher hop counts. At optimal message generation time intervals, delivery ratio of energy efficient routing strategy (EERs) is 91% for energy efficient routing strategy and while 88% per hop routing respectively. In terms of overhead ratio, energy efficient routing strategy is less than per hop routing strategy.

***Keywords*:** Routing strategies, Forwarding strategies, Delay tolerant networks, Opportunistic Network Environment, Energy Efficient Routing.

CHAPTER ONE

INTRODUCTION

1.1 Background

At present, with the rapid development of wireless communication technology and the widespread popularity of mobile smart devices such as smartphones and tablets, opportunistic networks based on mobile smart devices, especially opportunistic networks, have quickly become popular and used. Given the growing popularity of wireless technology, Mobile Ad Hoc Networks (MANET) has established itself in many areas such as tactical fields, sensor networks, disaster recovery and its ability to provide better communication in home networks. MANET, as defined, is a network of self-configuring mobile devices that communicate over wireless connections.

The MANET operation does not depend on any fixed infrastructure. However, even a MANET may not provide data transmission under extreme network conditions, where network density is sparse and network segmentation is quite frequent and long. As a result, end-to-end connections are not always practically available when nodes move from one place to another, or when node density is lacking over a large geographic area. Delay tolerant networks can be used to ensure data transmission even without end-to-end connections between communicating nodes, which is a basic requirement in MANET [1].

The idea of delay tolerant network (DTN) then came from the interplanetary networks (IPN), which began in the 1970s. IPN was invented to communicate between Earth and Mars. DTN is a wireless ad-hoc network which tolerates the intermittent connectivity. And DTN can also be defined as an intermittently connected wireless ad-hoc network that can tolerate the longer delays, intermittent connectivity, and avoid data loss using a store-carry-forward approach. This intermittent connection can be defined as the sudden change of state (up/down) of any communication link between nodes.

The terms “delay-tolerant networking” and “delay-tolerant network” were coined by Kevin Fall in 2002 and published the first time in his paper proposing a networking architecture for interplanetary Internet. This paper proposed a delay-tolerant networking architecture that interconnects normal networks that use TCP/IP with interplanetary network that with long signal propagation latencies and limited period of time for sending and receiving signals.

Therefore, to overcome the problem of intermittent connectivity, it is proposed to build delay tolerance networks (DTN). A node in a DTN basically stores a message and forwards a copy to another node when a connection is available [2].

The architecture of DTN cover different protocol layers and uses stored and forwarded messages called the bundle layer. This packet consists of header, control information and application data unit that provide services such as custody transfer, authentication, priority, announcement packet message forwarding.

The operation of DTN makes use of Bundle Protocol (BP), positioned above the TCP/IP protocol in the protocol architecture stack of DTN. The main functions a bundle protocol can provide are.

- Retransmission can be done any time as because the nodes hold the Custody of the message.
- Tolerate the intermittent connections
- Make use of different connectivity like scheduled, predicted, and opportunistic
- Supports late binding as it supports the heterogeneous environments.

Accordingly, a store-carry and-forward approach allows data to be stored on a node, moved during node movement, and delivered the data when a connection has been established. DTN provides asynchronous communication where data must be buffered and transmitted over a long period of time, which means that nodes need additional buffer space to store the message until the next node or a suitable destination not available for further forwarding. Because DTN relies on an underlying protocol called the Bundle Protocol to allow for delay during periodic communication between intermittently associated networks [3].

Furthermore, in delayed tolerant networks, routing approaches are categorized into two or more categories, which are flooding-based routing and forwarding -based routing approaches [4].

In this flood-based routing strategy, decisions can be made even when nodes are not knowledge of the nodes in the network. Then, flooding based routing can provide comparatively better results, but it consumes more network resources, because to deliver a single message, the entire network can contain so many copies of this message.

In the forwarding-based routing strategy, routing thus takes place when the nodes have relevant knowledge of the other nodes in the network. In a routing strategy of this type, no node will generate replicates of the messages. Thus, each node in the network searches for the most suitable relay node and forwards the message to them. This routing strategy reduces the consumption of additional resources as replication of messages is not allowed.

Therefore, this type of routing strategy is used when network resources are limited, such as buffer size of each node, node energy.

Now a day's smartphones are fast becoming the main computing and communication platform. They are equipped with communication capabilities (i.e Bluetooth and Wi-Fi) that enable messaging, especially in delay-resistant networks [5]. Thus, at present, the key method to solve the problem of information exchange in delay tolerant network is to efficiently select forwarding nodes, ensure the successful delivery of information to its destination in a short period of time and reduce resource overhead.

However, in the DTN routing, energy consumption is an important factor in the performance and implementation of modern computing and communications systems. The amount of energy a node has in this network is considered an important factor when sending and receiving messages. However, most modern smartphones are stored with limited energy and enough efforts have been made to increase the amount of energy that can extend battery life [6].

In most cases of delay-tolerant networks, hardware resources can be very constrained and it is important to consider the residual energy of a node when determining whether data should be exchanged during an encounter node [7]. And it is important to consider the availability of resources when designing the DTN routing protocol. The available buffer capacity then determines forwarding capabilities of the relay node, and the available energy supply determines the lifetime of the communication device. Some scenarios, such as battery-powered wireless networks, require you to consider the remaining energy of source and destination before starting the message transfer.

Therefore, in delay tolerant network routing is a major challenging issue since it must handle network partitioning, long delays and dynamic topology in such networks. Then to handle disruptions delay tolerant network routing strategies must take to a store-carry and forward approach, where data is incrementally moved and stored throughout the network in hopes that it will eventually reach its destination. And this common approach used to maximize the probability of a message being successfully transmitted is to replicate many copies of the message in hopes that one will succeed in reaching its destination [7] [41].

Thus, the issue of energy-efficient route strategy has not been widely studied, and it is this gap that will be filled in this work. So, since the previous work assumes the unlimited energy resources of the nodes, the typical delay-tolerant network algorithm adjusts its behavior very little based on the available energy of the node. The use of the DTN store-carry and forward approach [8] therefore overcomes problems associated with intermittent connection, long or variable delays, routing and high error rates. And the key idea is to facilitate opportunistic transport on a hop-by-hop basis rather than end-to-end streaming of data as in TCP/IP stack.

In principle, in a delay tolerant network (DTN), a node stores a received message in their buffer and waits for an opportunity or connection to retransmit it either directly to the final destination or to another relay to approach their destination node. This process is repeated until the message is delivered to its destination or expires.

Several DTN routing algorithms based on this mechanism have been proposed. The routing protocols are Epidemic [9], Spray and Wait, Spray and Focus [10], Prophet and MaxProp [11]. The objective of these protocols are improved delivery rate, reducing the overhead generated and minimizing the average delivery time without taking into account the energy level of the nodes and buffer space, which are essential elements for a good performance of DTN network to find out if those resources are sufficient for the nodes to participate in the transport of the messages. However, the majority of well-known DTN routing protocols do little consider energy constraints of mobile nodes in delay tolerant networks.

Many mobile nodes such as computers, PCs, smartphones, etc. have limited energy resources. They use a lot of energy to transmit and receive messages, and routing protocols take care of the energy consumption of mobile nodes, which is required for delay tolerant networks [12].

To perform any operations between different nodes, for example to send a packet, search a neighbor, store a packet, etc., energy is used. The node cannot forward the message if it does not have enough energy to perform the task in the network.

Therefore, energy is an important parameter of concern for delay tolerant networks in applications such as post-disaster scenarios where nodes are deployed primarily in locations that cannot be connected to a power source. In such a scenario, the available energy of the nodes should be taken into account in almost all networking activities, including the design of routing strategies.

Then, data delivery mechanisms must take this into account as well and must adapt to a wide range of scenarios. On the basis of message replication, routing protocols can be classified into two, which are single-copy, where one copy of each message is carried by a node in the network, and multiple-copy, where there are multiple copies of each message for delivery. And the DTN uses energy for transmission, store the message, receive and perform computations. For that reason, a routing strategy that sends fewer bytes and performs fewer computations is more energy efficient for forwarding messages.

Therefore, we analyze different DTN forwarding based routing strategies and select the per hop routing strategy to implement our study in delay tolerant network. In per hop routing strategy the source node forward the message hop by hop to its intermediate nodes using single copy message distribution on that communication range.

Generally, based on the above discussion, we propose an energy-efficient routing strategy for delay tolerant networks (DTNs) in this study, in which we take the energy value among nodes and the distance of nodes into consideration to improve routing performance.

1.2 Statement of the Problem

In delay tolerant network like networks, routing is challenging because the nodes are mobile and connectivity is rarely maintained.

Basically, in delay tolerant network existing routing strategies, a node broadcast the message, stores the message and when it encounters another node it forwards a copy of the message to the node which repeats the same process until the destination node is encountered. Therefore, DTN routing of the packets is implemented based on store-carry-and-forward approach. That is, when a node receives a message but if there is no path to the destination or even a connection to any other node, the message should be buffered in this current node and the upcoming opportunities to meet other nodes should be waited. Moreover, even a node meets with another node, it should carefully decide on whether to forward its message to that node.

Then routing is primary problem in existing DTN routing protocols to develop energy efficient routing strategy. And a number of routing strategies have been proposed for delay tolerant network to deal with a lack of persistent end-to-end connection between the source and the destination node. And in delay tolerant network routing algorithms nodes are resource constrained, i.e. they have less energy and have less memory to buffer messages, then at that time the relay nodes cannot deliver the message to the destination node effectively [6].

Hence, in delay tolerant network for forwarding message, efficient utilization of resources such as energy is important for best network performance. Thus a node's energy in DTN routing plays an important role in the success of delivering messages to the destination node.

In authors [13] have proposed an Energy Aware Epidemic (EA-Epidemic) routing protocol for DTNs. The original Epidemic routing protocol does not take consideration of energy consumption of nodes. A node transmits a copy of a message to every node it comes in contact and does not have the message.

As a result, a large number of transmission of messages occurs in the network. Furthermore, there are copies of the same message in many nodes.

Based on the Energy Aware Epidemic (EA-Epidemic) routing protocol, the routing works only a neighbor node which has higher remaining energy than the sender node and has enough available free buffer space for new messages will receive copies of messages because the node will live longer and will have higher chances of delivering the messages to destination nodes.

However, this routing protocol has implemented the epidemic routing protocol which is a node flooding a copy of message to that higher remaining energy and enough free buffer space, so it consumes the energy of node quickly and high overhead when storing and forwarding messages.

Therefore, in order to overcome the stated problems on the above base paper and to manage the use of network resources mainly energy of nodes, we have proposed an energy efficient routing strategy for DTNs that implements the forwarding based routing strategy which is per hop routing strategy for forwarding a single message occurs in the network. In this routing strategy the source node encounter with the intermediate node, they will update their status for the purpose of forwarding messages, then the node has high forwarding capability of message the routing decision is taken place.

Based on above discussion, we have proposed energy efficient routing strategy, in our study the relay node which has enough energy value and close distance for new message will receive from source node and the selected relay node among the nodes has the probability of forwarding the message to next or destination node.

1.2.1 Motivation

In DTNs architecture there are different data management activities such as data forwarding mechanisms and data dissemination. And in delay tolerant network different routing and forwarding strategies are proposed based on energy efficient. Still, most of the research efforts on data forwarding does little considered the available node energy within its distance information. Moreover, energy efficient strategies is a strategy that utilize the resource to optimize the packet delivery.

Those proposed routing and forwarding strategies that are less consider impact of the node energy on the performance of their forwarding process. This is an energy issue that motivate us to contribute an energy efficient routing strategy to tackle energy issues and distance information.

And this study focuses on strategy that take into consideration available energy resources of the nodes and uses the distance information to optimize routing decisions on the communication range.

The research will notice an energy efficient routing strategies with the goal of improved packet delivery rates and appropriate utilization of available energy.

1.2.2 Scope and Limitation of the Study

In this study the proposed energy efficient routing strategy is to deliver by using potential forwarder among nodes for data routing process for delay tolerant networks. And this energy efficient routing strategy has been implemented and tested by adopting traditional DTN routing protocols which is forward data without considering well energy resources. This means there is less investigation to design energy efficient routing strategy for this study. Thus we propose energy efficient routing strategy which improve data delivery rate in the routing process for better network performance for delay tolerant network.

Therefore, in this study only consider routing based on node available energy to deliver the data with optimal distance information for DTNs but not consider buffer space, security and bandwidth constraints.

1.3 Objectives

1.3.1 General objective

The main objective of this study is to propose an energy efficient routing strategy based on the relay node for data delivery probability for Delay Tolerant Networks.

1.3.2 Specific objectives

- Reviewing various existing delay tolerant networks routing strategies.
- Adopting the more related study on energy efficient routing strategies for delay tolerant networks (DTNs)
- Proposing an energy efficient routing strategy in delay tolerant network for our work
- Implementing and evaluating the proposed energy efficient routing strategy with the others study using different parameter metrics.

1.4 Research Methodology

1.4.1 Review Related Works

To propose our research methodology, we must first review different more related works to gain a better insight into DTN's energy efficient routing strategies, approaches and tools.

We then adopted the chosen routing strategy and proposed an energy-efficient routing strategy for DTN by applying per hop routing strategy to forward the message using node energy.

1.4.2. Identify the Statement of Problem

The previous routing strategies used in DTN scenarios investigated and developed the routing problem. Meanwhile, existing energy-efficient routing strategies place little emphasis on efficient message forwarding using node energy as well as distance, as the routing problem must be solved by developing an energy-efficient routing strategy.

1.4.3 Propose Routing Strategy

The problem with routing without delay tolerant network is that connections between routers are established so that packets can be transmitted from one node to another. If the link is not established, the packet will be dropped. But in a delay tolerant network, each node has the resources to store packets. The node now checks to see if there is a connection between the nodes or not. Otherwise, the node stores the packet and forwards it after the connection is established.

Therefore, in the literature review in Chapter two, there are flooding based routing, forwarding based routing and social based routing strategies that helps to propose an energy efficient routing strategy and distance information in that communication range.

Based on the literature review discussion, we identified that a forwarding-based routing strategy is an approach that requires knowledge of the network through a routing strategy and that nodes collect information about other nodes on the network to determine the best path to forward a message to the destination.

And also among forwarding based routing strategies, we have selected the per-hop routing strategy, in this routing strategy the forwarding decision is made by the intermediate node when a message arrives at the node. The node determines the next hop for the destination and places it in a queue for that contact. Then, this routing strategy follows the store-carry-forward approach that enables the nodes to take the message, store it in buffer and forward the same whenever new node comes in its communication range.

Thus, this our proposed energy efficient routing strategy follow this per hop routing protocol to deliver the data through the node available energy with its distance information.

1.4.4 System Model Design

In our proposed system model, we determined that the wireless nodes with a uniform communication range (Cr) were randomly distributed in a two-dimensional space. DTN nodes are mobile and heterogeneous (eg mobile phones, smartphones, tablets, laptops) in nature. And each node has limited energy and buffer space, and all messages on the network have the same transmission priority.

Hence, when a source wants to send the bundle message to the destination, then source node find the nodes which are high energy and nearer to the source node. The source node monitor the energy and calculates the distance amongst all the nodes which come under its maximum coverage area and the node which is high energy and most nearer to the source is selected for the message forwarding in the network.

1.4.5 Datasets

In different literatures real trace dataset which is most well-known and appropriate dataset for type of network such as delay tolerant networks that follows store-carry-forwarding approach is Helsinki-city dataset which is a default dataset integrated with ONE simulator. It was collected using group of people who carry smart phone device and share data through Bluetooth interfaces [2] [25] [34] [35] in CRAWDAD.

1.4.6 Evaluation Environment

Since opportunistic networks follows the store-carry-forward approach, we employed opportunistic network environment (ONE) simulator tool that was designed for evaluation of DTN routing protocol. As different researchers observed and used it for evaluation of their work, ONE is well designed tool for delay tolerant network routing and it allows creating scenarios upon different synthetic movement models and real-world traces [34][36][37][38].

1.4.7 Mobility Model

Mobility is also one of simulation parameter which provide communication among nodes in the network. Therefore, mobility of nodes in the network will help to bring them in contact. Otherwise they are disconnected world to each other.

There are different movement models available for different types of traces and different scenarios and explored by different researchers [37] [39] and their application. For instance, map-based mobility**,** is a map based movement models make the node movement to paths defined in map data in which nodes moves in the path defined in map. Even if these mobility models are simple to understand and efficient to use in simulations they do not generate intercontact time that match real-world traces, external dataset, especially when the number of nodes in the simulation is small.

The other mobility model, external movement model**,** uses external data of node location and reads timestamped node locations from a file and moves the nodes in the simulation accordingly.

On the other hand, the stationary movement model, use predefined connection traces from real traces dataset. So, the simulator should create connections among the nodes exactly as trace specifies. And other mobility models are random-based mobility models, the nodes move randomly without any restrictions. More specifically, the nodes choose their destination, speed, and direction randomly and independently of other nodes. For instance, random walk mobility model [35], it is a widely used model to represent purely random movements of the entities of a system. However, it cannot be considered as a suitable model to simulate wireless environments, since human movements do not present the continuous changes of direction that characterize this mobility model.

Another example of random based mobility model is the random waypoint mobility model. This can be considered as an extension of the random walk mobility model, with the addition of pauses between changes in direction or speed. When the simulation begins, each node randomly chooses a location in the field as the destination.

1.5 Application Area

The application area of the result of this study could be implement for different real world environments. For example, natural disaster recovery situations, military deployments, Village networks (Dacknet), in rural and surroundings by DTN limited non-existing infrastructure connects with digital connectivity. In these networks vehicles are used for the transportation system, which is used to give the communication of messages by gather/convey the message from/to different nodes. Wildlife monitoring (ZebraNet) and inter-vehicular and vehicle-infrastructure connectivity (Vehicular Communication).

Inter-Planet Satellite Communication Networks: In 1998 TCP was the first to promote transmission among satellites and emergence of DTN routing protocols. The main focus of this network task to complete the design and rules for exploration of the internet at the native country on globe along with the further casually placed on different globe or spacecraft. Intermittent internet is a network of IPN an advanced method is to be developed for internetworking of such surrounding.

1.6 Contribution of Study

The focus of this work is efficient routing using node available energy in resource constrained mobile nodes to deliver message packets and maximize the packet delivery rate. The main contributions of this thesis are as follows:

- Propose and contribute energy efficient routing strategy that have ability to deliver the packet by using node available energy with its distance information to improve delivery probability in energy constrained applications.
- Evaluate the relative performance metric of delay tolerant network algorithms with existing routing strategy in ONE simulator module.
- Moreover, the research will be used as an input for any other researcher to carry out advance studies on this area to develop energy efficient routing algorithm.

1.7 Thesis Organization

The reminder of the thesis is organized as follows: the second Chapter of the study is over view and literature review in details of delay tolerant networking (DTN), which describes about delay tolerant network architecture, store-carry and forward approach, delay tolerant network routing and forwarding strategies. And specifically it review related works in energy efficient routing strategies to identify a research gap in the area of energy efficient routing strategies for delay tolerant networks. Chapter three describes details of proposed algorithm, energy efficient routing strategy. The Chapter four presents implementation and experimental evaluation of proposed algorithm which is energy efficient routing strategy. Finally Chapter five present Conclusion and future works.

CHAPTER TWO

LITERATURE REVIEW

2.1 Overview of Delay Tolerant Network

MANETs are wireless networks that are formed by a network of hosts. The main assumption of MANET is that the connection of end-to-end for all nodes exists. Although in reality this connection is not always available due to the fact that nodes are constantly moving. Another problem occurs in large areas where the hosts' density is not sufficient to maintain connectivity. To overcome this intermittent connectivity problem, a delay tolerant network is used.

A node in DTN essentially stores a packet and forwards a duplicate of it to another node when they are in contact. This process is repeated until the goal of the message is achieved or the TTL of the message expires. A traditional routing algorithm for searching a path from a source to a destination cannot be used in DTNs. The reason for this is because such paths are not constantly available due to discontinuous connectivity caused by moving nodes. However, by using the store –carry-forward approach, DTNs can tolerate the longer delays and prevent the loss of data [24].

Therefore, the literature on DTN was reviewed, especially with a focus on the impact of constrained energy resources on packet routing in delayed tolerance networks. This review examines existing DTN routing protocols and identifies opportunities for improvement, if there is a suitable energy efficient routing strategy. For successful data transmission on a network with delay and interruption requires communication between nodes.

Recently, several routing strategies have been proposed for routing in delay tolerant networks (DTNs). In a delay tolerant network architecture, there are different data management activities such as routing and transfer mechanisms and energy efficient strategies for packet delivery operations [10].

The requirement of resource depends on types of application area. For example, in disaster response networks where resources/infrastructures are destroyed. It becomes challenging to establish communication in such scenario. In this network energy plays vital role in increasing the life time of the network. Hence, the energy needs to be used efficiently and for that an energy efficient routing strategies should be proposed for communication. Therefore, energy efficient routing strategies where system performance is not reduced are still an open issue in delay tolerant network (DTN) [11] [12].

As a result this literature review identifies the scope of existing work that addresses energy efficient routing with route information in delay tolerant network routing strategies.
And the delay tolerant network is suitable for various environments, such as disconnected and disrupted environments with long delivery delay. The DTNs have been studied in the wider field of wireless mobile ad hoc networks (MANETs) [15], DTNs have been widely used in monitoring wildlife. The most typical delay tolerant communication system is Zebranet [14], which is utilized to track the zebra by applying wireless peer-to-peer networking techniques. And have been applied in large scale wireless sensor networks using scheduled intermittent connectivity [16], satellite networks with moderate delays [17] or periodic connectivity and underwater acoustic networks [18] with frequent interruptions.
The internet connectivity for human oriented communications in remote areas includes many challenges, mostly concerning infrastructure availability and costs associated with installation and maintenance of the necessary equipment. The DakNet project is a DTN approach for providing network access to rural villages [19]. It was the first to introduce the concept of "data mule" i.e., an offline means, like a bus, a motorcycle, or even a bicycle, to move data between disconnected points.

2.2. Characteristics of DTNs

The DTN distinguishes itself from conventional networks by the following characteristics [20].

(1) Intermittent connectivity. The connectivity of DTNs is very poor. In most cases, it is impossible to have an end-to-end path. A node connects to other nodes only occasionally and the link is the scarcest resource in the network.

(2) Delay tolerable. The end-to-end transmission latency is dominated by the queuing delay. Messages have to be stored in the message queue until the node meets a neighbor node. Obviously, opportunistic connection will lead to long latency so that applications have to tolerate the large transmission delay.

(3) Sparse density. Node density is normally much lower in DTNs compared with the traditional densely deployed networks, which further deteriorates network connectivity.

(4) Node mobility. Since the nodes are attached to randomly moving objects, the network topology changes frequently. Besides, the buffer size of sensor nodes is usually limited. Since data messages may be stored in the buffer queue for quite a long time before being sent out, queue management is a challenge.

Clearly, a node only transmits its messages to the next hop when it meets other nodes and chooses an appropriate neighbor.

2.3 Delay Tolerant Network Architecture

The existing TCP/IP-based internet, while fabulously successful in many environments, does not suit all environments.

The ability of the TCP/IP suite to provide service depends on a number of important assumptions: (i) existence of end-to-end path between source and destination during communication session; (ii) (for reliable communication) that the maximum round-trip time over that path is not excessive and not highly variable from packet to packet; and (iii) that the end-to-end loss is relatively small.

Delay Tolerant Networks may not satisfy some of the assumptions due to their different characteristics such as long or variable delays, frequent partitioning, data rate asymmetry and interoperating among differently-challenged networks. The DTN architecture should provide the means for dissimilar networks to interoperate (Cerf et al., 2002).The network architecture used for the conventional networks may not be used as it is for DTNs.

The DTN architecture provides a common solution for interconnecting heterogeneous gateways or proxies that employ store-and-forward message routing to overcome communication disruptions (Cerf et al., 2007). At its inception, the concepts behind the DTN architecture were primarily targeted at tolerating long delays and predictably-interrupted communications over long distances (i.e., in deep space). At this point in time, the work was architecture for the Interplanetary Internet (IPN). By March 2003, when the first draft of the eventual RFC 4838 was published, one of the authors had coined the term delay tolerant networking suggesting the intention to extend the IPN concept to other types of networks, specifically including terrestrial wireless networks.

The DTN architecture creates a “network of Internets” by providing an end-to-end layer above the transport layer. DTN has one more layer known as the “bundle layer” which is an end-to-end message oriented overlay (Cerf et al., 2002).

The DTN architecture uses store-and-forward message switching technique by overlaying a new transmission protocol, called the bundle protocol on top of the lower-layer protocols such as internet protocols. The bundle protocol ties together the lower-layer protocols so that application programs can communicate across the same or different sets of lower-layer protocols under conditions that involve long network delays or disruptions. The bundle-protocol agent stores and forwards entire bundles (or bundle fragments) between nodes. A single bundle protocol is used throughout a delay tolerant network.

On the other hand, the lower-lower protocols below the bundle protocol are chosen depending on the characteristics of each communication environment [20][24].

2.3.1. Bundle layer

In DTNs, the studies define an end-to-end message-oriented overlay called the "bundle layer" that exists at a layer above the transport layer of the networks on which it is hosted and below application layer to the original five layers in the Internet Protocol stack. Devices implementing the bundle layer are called DTN nodes. The bundle layer forms an overlay that employs persistent storage to help combat network interruption. It includes a hop-by-hop transfer of reliable delivery responsibility and optional end-to-end acknowledgement. It also includes a number of diagnostic and management features.

2.3.2. Bundle Protocol (BP)

The bundle protocol is a single unit of combined information data, which is exchanged and forwarded in the DTN.

So for that the delay tolerant network can present an optional mechanism called custody transfer and messages called "bundles" are stored at intermediate nodes in local databases until the next hop is reached, after which they are delivered whenever connectivity is available. And bundles may be maintained in databases until receiver's acknowledgment.

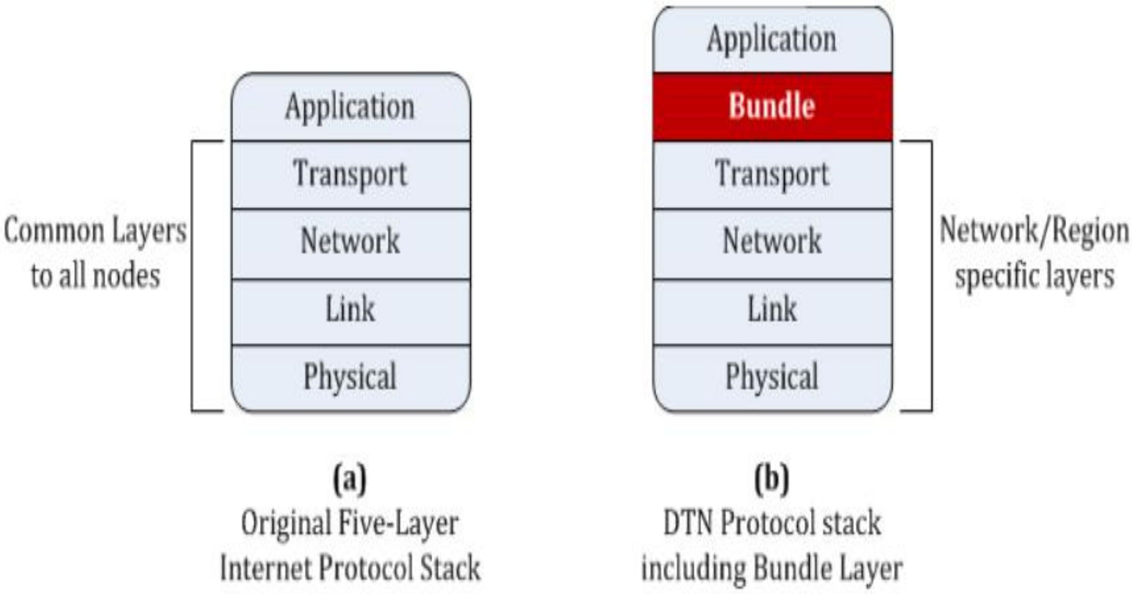

Figure 2.1 Original TCP/IP and Modified DTN Protocol Stack [24]

Routing protocols for conventional and MANET networks are insufficient to provide successful data transmission over delay tolerant networks due to the lack of continuous end-to-end connectivity. To overcome intermittent connectivity, various DTN routing protocols provide a common method called a store-carry-forward approach to control and manage issues such as high latency, long delay, limited resources, frequent disconnections and opportunistic or unpredictable connections. In this approach, messages can be transferred between source and destination over multiple hops. When the message is generated, it will be stored in the buffer of the source node and then forwarded to the encountered nodes. When the next node is not immediately available, the message will be buffered and moved while a suitable communication option is created.

2.3.3 Store- Carry and Forward Approach

Delay tolerant network (DTN) nodes use the store-carry and forward approach. The incoming messages in standard routing are kept in the present host buffer till the messages are sent to the following hop together with taking in account the decision of routing.

The concept of this store-carry and forward approach involves a DTN node carrying a bundle until connect to another DTN node and then transfers its messages when contacts another node. This process continues until the message reaches its final destination node [24]. Moreover, the buffer capacity is not large enough, as messages may not stay in the buffer for long period of time.

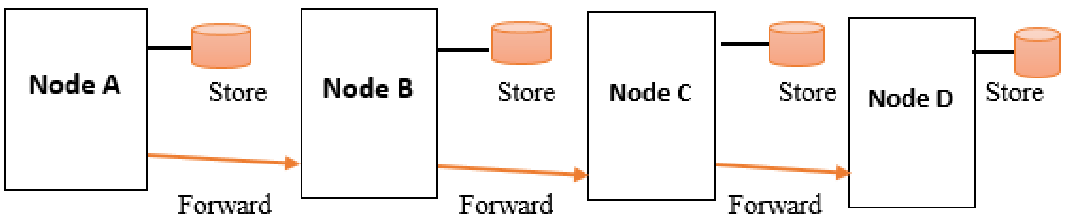

Figure 2.2: The store-carry and forward approach of DTN [24]

2.4 Delay Tolerant Network Routing Strategies

The DTN concept is similar to Mobile Ad-hoc Network (MANET), which is an infrastructure-less network of mobile devices that are connected wirelessly. DTN routing is different from MANET routing because end-to-end based routing algorithms designed for MANETs are not capable of routing the packets in DTNs due to the frequent disruption and the sparse contact topology of DTNs. MANET routing is based on transmitting the packets using end-to-end multi-hop routing because this connectivity is available. Due to intermittent connectivity in DTNs, routing is dependent on device mobility and contact opportunity for transmitting messages. The delay tolerant network (DTN) routing strategies can be classified in relation to the type of information collected by nodes to make the routing decisions. Based on finding the destination requires two different properties: replication and knowledge [25]. The replication strategy uses multiple copies of each message to increase the chance of delivery probability and reduce delivery latency. On the other hand, knowledge makes forwarding decisions based on information about the network. The DTN routing protocols are classified into three categories based on their properties [25] [26]

2.4.1 Flooding Based Routing Strategies

In the flooding routing strategy, each node spreads a number of copies of each message to other nodes without any information about the structure of the network. The nodes keep and store the copies of the messages in their buffer till they encounter the next nodes or the destination. The probability of message delivery is increased by using message replication because there is a good chance that at least one copy of message will reach the destination.

The study introduced Direct Delivery routing is a single-copy routing protocol where nodes only carry one copy of message for transmitting directly to the final destination without any relaying to additional nodes. This strategy does not require any information about the network and permits the messages to be transmitted through one hop only when the source nodes are in contact with the destination. This simple protocol has minimum overhead ratio, but has low delivery ratio. It is typically used as a comparison to other protocols [25].

Vahdat and Becker [28] proposed epidemic routing strategy, which is a flooding based forwarding strategy. The objectives of this routing are to maximize the delivery of the messages, and minimize the delivery latency in message delivery operation. In the epidemic protocol, nodes send copies of messages to all nodes that they encounter with no knowledge of the network. The encountered nodes save the messages in their buffer using the store-carry-forward method until meeting another node or destination.

The list of messages, which is stored in the node's buffer, is called the summary vector. Whenever two nodes encounter each other they exchange their summary vectors and compare them to identify new messages that should be downloaded from the encountered node. Although Epidemic routing has high delivery probability, flooding causes high overhead due to the number of copied messages in the network, which can congest the network. Also by spreading large numbers of messages in the network this type of algorithm will consume many resources such as power, bandwidth and buffer space.

Spyropoulos, et al. proposed in [29] the Spray and Wait algorithm is the advanced version of the epidemic routing. In this algorithm the nodes are not distributing the replicas to each and every node but an optimal number of nodes (say m) are selected to which the source node will relay the message. There are two phases in this approach: Spray & Wait. In Spray phase, the source node replicates the message to the m nodes and these m nodes will further relay the message to m relay nodes. If the destination is not found in spray phase then the relay nodes will store the message and performs direct transmission to the destination.

The other study [30] was introduced Probabilistic Routing Protocol using History of Encounters and Transitivity (PROPHET). The PROPHET uses the information which is derived from the past node encounters such as number of packet copies, mobility pattern, location, contact time and social behavior of nodes to optimize the packet delivery . In PROPHET when two nodes encounter each other, they exchange their summary vectors including the delivery predictabilities for all destinations known by every node and updating the interval delivery predictability. After updating the information, nodes decide which message should be exchanged based on forwarding strategy.

As indicated in [31] Burgess, et al. presented Maxprop, which uses knowledge of previous encountered nodes to decide which messages should be transmitted or dropped initially by maintaining an ordered queue based on the destination of each message. When two nodes encounter each other, they exchange their delivery likelihood vectors, which are estimations of a cost assigned to each destination. The likelihood vector allows them to calculate the shortest distance to reach the destination. And computing the shortest path to destination and ordering the nodes in a queue is based on the message hop counts and message delivery probability of previously encountered nodes.

The messages are ordered from the highest priority, which is the first message for transmitting to other hosts, to lowest priority, which is the first message for dropping from buffer when buffer is full.

To avoid the repeated propagation of data to the same node, it uses acknowledgements which delete the delivered the copies of the message from the buffer of other hosts.

The study proposed in [32] history-based routing protocol for opportunistic networks (HiBOp) is a fully context-based protocol. It uses two tables: the identity table (IT) that stores the local context of a node and the history table that stores the values from the IT seen by the node in the past. To decide on whether or not a node must transfer the message, HiBOp takes the following steps: (1) it sends a message to L nodes in the network, where L is calculated dynamically by taking into account the probability of delivering the message to the destination; (2) it determines whether there is a match between the context information of the node and the information associated with the message.

The other study suggested in [33], the history-based prediction of routing protocol (HBPR) is based on the predictions made about the next location of a node with the help of past history. This history is about a node's movement which describes the places it visits very frequently or the places it visits rarely. This information can be used to predict the geographical location of a node and its neighbours in the network that can be utilised to find out the closeness of a node to the destination. In HBPR, the movement of a node is assumed to be based on human mobility pattern.

According to the study presented [41] is two-hop relay approach, in this approach, the source node replicates the message to a large number of relay nodes. In this approach a message will be delivered to the destination within two hops only i.e. either the source node directly delivers the message to destination or the relay node. Relay nodes will not further replicate it to any other node except the destination node. Clearly, this method consumes more network resources, but it achieves better performance than direct transmission since it has better chance to communicate with the destination. And they proposed tree based flooding strategy [41] improves two-hop relay by distributing the task of making copies to other nodes. When a message copy is transferred to a relay node, it will tell the relay node the number of copies it will generate. Because the relay nodes form a tree rooted at the source, the method is called tree-based routing. There are many ways to decide the number of copies the relay node will make.

The Prioritized Epidemic Routing (PREP) is another improvement of Epidemic Routing proposed in [42]. The idea of PREP is to impose a partial priority on the messages for transmission and dropping. The priority calculation is based upon four inputs: the current cost to destination, current cost from source, expiry time and generation time. Each link's average availability is epidemically disseminated to all nodes.

As a result of this priority scheme, PREP maintains a gradient of replication density that roughly decreases with increasing distance from the destination.

The other study introduced Gossip [43] and it compared with flooding, Gossip tries to reduce network resources consumption by randomly choosing the relay node rather than delivering message to all nodes it meets. Clearly, the number of message copies is controlled and the resource consumptions decrease. However, randomly selected next hop might not be a suitable relay node and would make negative influence on the performance.

The Spray and Focus (SF) proposed in [44] improves spray and wait by substituting wait phase for focus phrase. The works of SF in the spray phase are the same as that of SW. In the focus phase, message carriers would select appropriate relay node based on predicted utility and then forward it. Spray and focus are established to achieve both good latency and low bandwidth overhead, thereby significantly reducing resource consumption in flooding routing.

2.4.2. Forwarding Based Routing Strategies

In flooding based routing strategies relay message blindly and consume huge network resources. And to forward messages efficiently, knowledge about the network could be used to optimize routing strategies and improve the performance. The knowledge about the network include link metric, history contact, mobility pattern, and network topology. According to the knowledge, a node can select the next hop which has the highest likelihood to communicate with the destination node.

In the link metric algorithms attempts on the most popular traditional networking routing protocols. They attempt to build a topology graph for the network, assign weights to each link and finally run a shortest path algorithm. This approach needs the maximum information of the network to implement the routing algorithm. The weights assigned to the links are based on some metrics: the highest bandwidth, lowest latency, highest contact schedule or highest delivery ratio. There are some other metrics which consider in minimizing buffer or power consumptions.

Jain [45] et al. proposed different metrics to implement the concept of forwarding strategies using certain network knowledge.

For instance, their first metric was presented to as minimum expected delay (MED) was based on the assumption of queuing time to be zero and that the average sum of transmission time, propagation delay and waiting time is specifically known. The sum depicts the average amount of time it takes for a message to move from one node to another. The MED needs little knowledge of the network as it determines the average value of the waiting time.

They proposed another metric called earliest delivery (ED) which was a variation of the first one as it assumed the queuing time to be zero and the propagation and transmission delays were assumed to be known accurately. This metric demands the information of the complete contact schedule. Thus ED can be considered as a more enhanced approach in comparison with MED but at the same time needs the complete contact history of the nodes in contact.

Jain et al. presented a metric called the minimum estimated expected delay (MEED), where the weights are based purely on the history contact record. And MEED estimates the transmission delay to the next hop and assumes that the future delay will be similar to the past. The delay metrics are distributed over the network by an epidemic protocol. The node computes the shortest path based on all received link states of the network. The MEED maintains a single message copy and selects the next hop with the shortest delay to the destination. But MEED introduces more network overheads when distributing the link states over the network, especially when the network topology changes frequently.

Jain et al. proposed another variant of ED called earliest delivery with local queuing (EDLQ) by considering buffer occupancy at each node so as to estimate the queuing delay to the ED metric. This metric not only demands the history of the contact schedule but also keeps information of the buffer space. Thus it is considered to be a revised version of ED with more knowledge of the network needed.

The other Jain et al proposed metric is the earliest delivery with all queues (EDAQ), it uses the Contacts and the Queuing oracles. In EDAQ, routes are not recomputed for messages in transit since the initial route predicts accurately all delays. EDAQ works only if capacity is reserved for each message along all contact edges. In practice, EDAQ is very difficult to implement in most delay tolerant network with low connectivity, as it requires global and accurate distribution of queuing state. Limited connectivity also severely limits practical implementations of edge capacity reservations.

Therefore, the abovementioned proposed metrics attempt to solve the issue of routing by seeking the accurate information about the complete contact schedule known in advance. This becomes impractical at times in DTN as the connectivity in the network is totally unpredictable and unreliable.

Tan et al. [46] presented a shortest expected path routing (SEPR) for DTN scenario. The forwarding probability of the link is calculated from the history of encounters. Based on this, the shortest expected path is calculated.

Burns et al [47] proposed by the Meet and Visit Routing (MV Routing), improves SEPR by using only the frequency of node contacts. It uses the frequency of the past contacts of nodes and also the visit to certain regions.

Xu et al. presented a novel data gathering method named relative distance-aware data delivery scheme (RDAD) in [48]. The RDAD introduces a simple non-GPS method with small overhead to gain the relative distance from a node to sink and then to calculate the node delivery probability which gives a guidance to message transmission. And RDAD also employs the message survival time and message maximal replication to decide message's transmission and dropping for minimizing transmission overhead.

Also, a distance-aware replica adaptive data gathering protocol (DRADG) is proposed in [49]. And the DRADG economizes network resource consumption through making use of a self-adapting algorithm to cut down the number of redundant replicas of messages and achieves a good network performance by leveraging the delivery probabilities of the mobile sensors as main routing metrics.

So far the routing strategies, they discussed do not consider the energy efficiency of the network. However, for some data-centric applications, they want to gather data from the network as much as possible.

Some other protocols use the context information to aid in data forwarding. According to Musolesi et al. proposed in [50] a context-aware adaptive routing (CAR), in which some context information such as the energy, moving speed, and communication probability are used to calculate utility. The node chooses the next hop that has the highest utility to transfer the messages.

And Based on CAR, other study by Mascolo et al. presented in [51] SCAR (sensor context-aware routing), a routing approach which uses the context of the sensor node (history neighbors, battery level, etc.) to foresee which of the neighbors are the best relay nodes for data forwarding. In addition, SCAR controls the number of message copies like spray and wait.

Leguay et al. proposed MobySpace [52], which utilizes the mobility pattern of nodes as context information. A MobySpace consists of Moby points. Each Moby point summarizes some characteristics of a node's mobility pattern. And Nodes with similar mobility patterns are close in MobySpace.

Position-based routing is a routing principle that relies on geographic position information, which is based on the idea that the source sends a message to the geographic location of the destination instead of using the network address.

The position-based routing requires that each node can determine its own location and that the source is aware of the location of the destination. With this information, a message can be routed to the destination without knowledge of the network topology or a prior route discovery.

Karp and Kung presented in [53] the Greedy perimeter stateless routing is a typical routing protocol for wireless ad hoc networks that uses the positions of routers and a packet's destination to make packet forwarding decisions. The GPSR makes greedy forwarding decisions using only information about a router's immediate neighbors in the network topology. When a packet reaches a region where greedy forwarding is impossible, the algorithm recovers by routing around the perimeter of the region.

The other study proposed in [54] the Geographic source routing (GSR) combines position-based routing with topological knowledge, as a promising routing strategy for vehicular ad hoc networks in city environments. And also presented in [55] the Greedy perimeter coordinator routing (GPCR) is a position-based routing protocol. The main idea of GPCR is to take advantage of the fact that streets and junctions form a natural planar graph, without using any global or external information such as a static street map. And the GPCR consists of two parts: a restricted greedy forwarding procedure and a repair strategy which is based on the topology of real-world streets and junctions and hence does not require a graph planarization algorithm.

And the other well-known forwarding based routing strategies proposed in delay tolerant network [56]. In this type of routing process no node will generate replicates of the messages. So each node will search for the best suitable relay nodes and forwards the message to them.

The NECTAR Routing Strategy: The concept of neighbourhood index table which is maintained at each of the node is given by the NECTAR strategy. The information about the meeting frequency of the node is stored in this table with every other node in the network. The higher index value is assigned to a node which is having a higher meeting frequency. When a node needs to forward the message to a particular destination, then it will choose one of the relay nodes that have highest index value for the respective destination.

In NECTAR routing strategy, the information maintenance is medium, high message delivery ratio, normal average delay and medium resource consumption.

Source Routing Strategy**:** The Source routing consist of two phases i.e. route discovery phase and route maintenance phase. Initially a route is discovered by sending control packets towards a destination node. Each of the intermediate nodes will append its address in the packet. Each node also maintains a cache for the routes that the node has learnt over time.

When the packet reaches at the destination the entire route is appended in the packet only. In route maintenance phase if a link failure is detected then a route error message is broadcasted by the source node.

In source routing strategy the information maintenance is normal, low message delivery ratio, high average delay and low resource consumption.

Per-Hop Routing Strategy: In Per-Hop routing, each intermediate node will decide the next node to which the packet is to be forwarded for a particular destination. This approach has better performance than source routing because the more updated information is used than source routing. The source node sends the message to all the connected nodes, and then these nodes search for the closeness of the destination node and the node have the destination node as closest will further broadcast it. This process goes on and thus the refinement of routes keeps going. In per hop routing strategy the information maintenance is medium, medium message delivery ratio, medium average delay and low resource consumption.

Per-Contact Routing Strategy: The most updated information is being used in per-contact routing strategy because when any intermediate node receives any message for a particular destination then it will update its routing table and will check the current up contacts and select the appropriate node for relaying the message and forward the message to the most appropriate node.

In per contact routing strategy the information maintenance is medium, high message delivery ratio, low average delay and medium resource consumption.

Hierarchical Forwarding and Cluster Control Routing (HFCR) Strategy: This strategy introduces the concept of clustering of nodes on the basis of link property and communication characteristics. After formation of clusters, a cluster head is selected depending upon some criteria. So, the cluster head node is selected based on the higher stability or the higher quality among all nodes within the cluster. The routing decisions are then taken by the selected cluster head in that communication range.

In hierarchical forwarding and cluster control routing the information maintenance is high, high message delivery ratio, normal average delay and high resource consumption.

2.4.3 Social Aware Based Routing Strategies

In the recent years, social structures have been used to help forwarding in intermittently connected networks. Social behavior analysis has been introduced to resolve the routing issues when the nodes are attached to the human and could achieve better performance by using social relationship or human behavior in real-life environment.

In society, there are inherent social relationships between people such as relatives, friends, colleagues, and schoolmates. The relationships usually remain stable in a long period of time. Based on the social relationships, message could be forwarded efficiently.

Hui and Crowcroft have proposed in [57] a routing strategy called LABEL which takes advantage of communities for routing messages. The LABEL partitions nodes into communities based on only affiliation information. Then ach node in the network has a label telling others about its affiliation. A node only chooses to forward messages to destinations, or to the next-hop nodes belonging to the same group as the destinations. And LABEL significantly improves forwarding efficiency over oblivious forwarding using their dataset, but it lacks a mechanism to move messages away from the source when the destinations are socially far away.

The other proposed routing strategy in [58], the BUBBLE combines knowledge of the community structure with knowledge of node centrality to make forwarding decisions.

People have different popularities in the real life so that the nodes have different centralities in the network. Moreover, people belong to small communities like in LABEL. When two nodes encounter, the node forwards the message up to the node with higher centrality (more popular node) in the community until it reaches the same level of centrality as the destination node. Then, the message can be forwarded to the destination community at the same ranking (centrality) level. The BUBBLE reduces the resource consumption compared to Epidemic and PRoPHET Protocol.

The study presented in [59] is SimBet, it makes routing decisions by centrality (betweenness) and similarity of nodes. The Centrality means popularity as in BUBBLE. More, the centrality value captures how often a node connects nodes that are themselves not directly connected. Similarity is calculated based on the number of common neighbors of each node. And SimBet routing exchanges the pre-estimated centrality and locally determined similarity of each node in order to make a forwarding decision. The forwarding decision is taken based on the similarity utility function (SimUtil) and betweenness utility unction (BetUtil). When the nodes contact with each other, the node selects the relay node with higher SimBet utility for a given destination.

Li and Wu proposed in [60] Local Com is a community based epidemic forwarding scheme in disruption tolerant network. LocalCom detects the community structure using limited local information and improves the forwarding efficiency based on the community structure. It defines similarity metrics according to nodes’ encounter history to depict the neighboring relationship between each pair of nodes. A distributed algorithm, which only utilizes local information, is then applied to detect communities and the formed communities have strong intracommunity connections.

The study proposed in [61] PeopleRank approach uses a tunable weighted social information to rank the nodes. PeopleRank is inspired by the PageRank algorithm employed by Google to rank web pages. Similar to the PageRank idea, PeopleRank gives higher weight to nodes if they are socially connected to other important nodes of the network.

With the emergence of Online Social Network platforms and applications such as Facebook, MySpace information about the social interaction of users has become readily available. Moreover, while opportunistic contact information is changing constantly, the links and nodes in a social network remain rather stable.

2.5. Routing Challenges in DTNs

One of the main design goals of DTNs is to exchange data between the nodes and employ the opportunistic links among the nodes for message transmission.

Clearly, the design of routing protocols in DTNs is influenced by many challenging factors. In the following, we summarize some of the routing challenges that affect routing and forwarding of message in DTNs [21].

2.5.1. Intermittent Connectivity. As mentioned before, intermittent connectivity is the essential property of DTNs. DTN is a partially connected network because of node mobility, sparse deployment, and poor communication quality. The network connectivity varies with time. Accordingly, it is hard to find an end-to-end connection between the source node and the destination node so that routing techniques in conventional network are not well suitable for DTNs. Intermittent connectivity means that the links between the nodes are opportunistic. How to get an opportunistic link and transmit a message is a challenging issue in DTNs.

2.5.2. High Latency. High latency is also a fundamental property of DTNs. In general, the transmission delay from a source node to a destination node is composed of four components: waiting time, queuing time, transmission delay, and propagation delay [31]. The waiting time is the interval that a message carried by node until it meets another node, depending on the contact time and the message arrival time.

The queuing time is the time it waits for the higher priority messages to be sent out. This depends on the data rate and the traffics in the network. The transmission delay is the time it takes for all the bits of the message to be transmitted, which is determined by data rate and the length of message. The propagation delay is the time a bit takes to propagate across the connection, which depends on the distance between two nodes. Obviously, messages have to be buffered in the queue of the nodes due to intermittent connectivity, incurring more waiting time and queuing time. Moreover, the low data rate of DTNs introduces more transmission delay. The design of routing protocols for DTNs should reduce the delivery latency as shorter as possible.

2.5.3 Heterogeneous Interconnection: The architecture of DTN is based on asynchronous message forward and operates as an overlay above the transport layer. DTN can run on different heterogeneous network protocol stacks and DTN gateway ensures the reliable transmission of interconnection message.

2.5.4 Limited Resources. The nodes in DTNs are often equipped with low-power RF module, limited buffer size, irreplaceable battery, and low computation capacity, that is to say, the resources of the nodes are limited. The scarce of resources degrades the performance of the routing protocols.

(1) Buffer Size. When a message is generated, the message is buffered in the message queue of the node. Once the node contacts other nodes, it chooses the next hop and delivers the messages in its queue. However, the node usually waits a long periods of time until it meets another node so that the messages have to be buffered in the queue. If the queue is full, some messages would be dropped off, which decreases the delivery ratio. Routing strategies might need to consider the limited buffer space when making routing decisions. In addition, there must be a scheme to manage buffer.

(2) Energy Efficiency. Nodes in DTNs are usually powered by the battery, which cannot be replaced easily. Lots of energy will be consumed for sending, receiving, and computing. While researchers have investigated general techniques for saving power in delay tolerant networks, none of the routing strategies has incorporated energy aware optimizations. In fact, most of the previous routing techniques do not consider the energy efficiency. In these works, the RF module of the nodes has to work all the time so as to find the possible links (opportunistic connectivity) to their potential neighbors. Then, the nodes will drain off their battery quickly and cannot contribute any more for routing, while degrading the performance of DTNs. Therefore, there is a tradeoff between the energy consumption and network connectivity. How to maintain an acceptable connectivity while keeping the energy consumption slowly is a challenging routing issue for DTNs.

(3) Process Capability. The nodes in DTNs may be very small and have small processing capability, in terms of CPU and memory. These nodes will not be capable of running complex routing protocols.

(4) Contact Schedules*:* Nodes in a DTN can communicate only when they are in radio range of each other. Since nodes are highly mobile, end to end path between pair of nodes may or may not exist at any given point of time. Two types of contact are scheduled and opportunistic. Scheduled contacts involve storing the information until the receiver receives it at sending rate. In opportunistic contacts, sender and receiver exchange information when they happen to be in range of each other.

2.5.5 Replication Management. Since the connectivity between mobile nodes is poor, it is difficult to form a well-connected network for data transmission. The nodes deliver the message to their neighbors opportunistically when they contact.

In order to achieve certain success delivery ratio in such an opportunistic network, data replication is necessary.

However, multiple copies of messages will increase transmission overhead, which is a substantial disadvantage for energy limited sensor networks. Replication management mechanism is necessary to control the number of message copies in order to reduce the overhead caused by redundant copies.

2.5.6 Network Topology. Due to nodal mobility or link quality, the network topology of DTMNs may change dynamically and randomly. It is impossible to maintain a stable end-to-end path in the networks, and routing in DTNs is often on demand. Routing strategies designed for delay tolerant networks must be adaptive to the frequent change of network topology.

2.6 Related Work

Different routing strategies with their own different characteristics and features have been proposed for DTNs. The existing delay tolerant networks routing strategies do little consider well the energy resources issue when making routing decisions to forwarding the packet. And few researchers have examined energy aware routing strategies.

They showed the impact of energy consumption on the performance of delay tolerant networks (DTNs) routing strategies and also evaluated the impact of the different forwarding strategies on the energy usage in the mobile node. Their work only measured energy consumption and did little use available energy with distance information for DTN routing decisions.

The authors in [62] [63] proposed a message-driven based energy-efficient add-on to the existing routing protocols such as the epidemic routing strategy and two-hop routing strategy, which uses a forwarding strategy based on the message lifetime and delivery probability requirements. They analysed the performance of epidemic routing (ER) and two-hop routing (2HR) by using analytical models such as an ODE model in heterogeneous DTN.

The author also proposed in [63] an ODE model was used to model the performance of these routing protocols with individual node selfishness.

These routing protocols may be suitable for this project but based on the fact that they have not evaluated the protocols in realistic applications, using their proposed protocols in the real world wildlife monitoring scenario needs further study.

F. De Rango, et al proposed in [64] an energy-aware epidemic routing protocol (EAER) is an extension of the n- Epidemic routing, which aims to achieve the good performance in terms of packet delivery ratio and energy consumption.

The n-parameter strategy is proposed for optimizing the possibility of transferring packets from a node to its neighbors when they are in the transmission range of each other. By using this technique a node will transmit its packet to the next node only when it is in range of at least n neighbors.

They also proposed an energy-aware heuristic called prevalence strategy (PS), which manages the value of n based on the current energy level (CEL) and current neighbour node (CNN). When the residual energy of a node is low, the n-parameter value will be increased so the probability of being within the range of many nodes is low and less transmission can be allowed, therefore the node can domain more energy.

Patel, et al. [65] proposed a new scheme for Spray and Wait routing called vibrant energy-aware spray and wait (VESW) to improve the energy efficiency of the Spray and Wait protocol. These energy-aware strategies were only applicable for Epidemic and Spray and Wait, and cannot be applied to other strategies.

Li, et al. [66] considered the issue of energy efficient opportunistic forwarding strategy for DTNs by introducing a Markov model and designed different types of forwarding. The performance of a number of routing protocols, including two-hop relaying, Epidemic routing and k-hop forwarding is evaluated by Li, et al. [67] with an energy constraint based on a continuous time Markov chain model. They derived expressions for the performance of message delivery delay and delivery energy cost analytically without using the ONE simulation. But their work did not propose any energy-aware routing strategy.

Sghaier, et al. [68] proposed EXLIOSE (extending network lifetime in opportunistic sensor networks), a routing protocol for mobile WSN based on a new metric called energy shortage cost (ESC). The aim of their approach is maximizing network lifetime by choosing the next hop based on ESC, which considers the energy consumption and residual energy of each sensor node. A decision for transferring the message to other nodes is based on calculation of the ESC in each node, and messages are forwarded to the neighbour with lower ESC.

Cabacas and Ra [69] proposed a novel context-metric queuing method (CEAMS) for delay tolerant network to achieve high delivery probability with high priority and utilize the node's energy efficiently in transmission.

They also introduced the new metric called node's delivery capability (NDC) to sort and queue a message in the buffer by using remaining energy of node, speed of node and estimated distance to the destination. To achieve effective utilization of a node's energy in transmission, an energy-aware transmission scheme is implemented to assign priority levels of messages for forwarding the messages to intermediate nodes.

The above both EXLIOSE and CEAMS proposed methods provide higher message delivery rate and performance over strategies that do not take energy into consideration. However, the energy consumption and residual energy of nodes are calculated based on radio scanning and transmitting energy without considering consumption energy for generating message.

In [70], Khuram Khalid et al. proposed HBPR protocol for OppNets is redesigned by incorporating some energy-related constraints, yielding the so called energy-efficient HBPR (AEHBPR). It uses a one hop acknowledgment mechanism, and for the design of the proposed AEHBPR, when a message has been delivered to its destination, there still many copies of it moving around in the OppNet. This unnecessary transmission consumes a lot of energy in the sending and receiving of messages by the nodes. These extra copies of the delivered messages occupy unnecessary spaces in the buffer of the nodes and may also cause congestion in the network, thus degrade the network performance since the overhead ratio may greatly increase.

In [71], Nimish Ukey and Lalit Kulkarni proposed an Energy Efficient Distance based Method (DEEF) for Improving the Network Performance and Reducing the Energy Consumption in Delay Tolerant Networks to improve the performance of network it is necessary to utilize the resources efficiently in delay tolerant network (DTN). And due to the mobility of node the energy is depleted. If the power resource is large, then the probability of delivering the bundle is also high. And if the power resource is less, then there is less chance to deliver the message to the destination. So, it is necessary to implement an efficient algorithm or a routing protocol to reduce the consumption of energy and also increase the performance of the network.

In [72] Mohamed Ababou, Mostafa Bellafkih and Rachid El kouch proposed an Energy Efficient Routing Scheme for Delay Tolerant Network Based on Fuzzy Logic and Ant Colony which is named EERPFAnt inspired by the ant colony intelligence and improved by the fuzzy logic technique to select the best relay by combining the energy of the nodes, as well as the information on the relay that have already received a copy of the message to estimate intelligently, the energy of the nodes at the time of encounter with the desired destination. And EERPFAnt is based on fuzzy logic and the ant colony optimization to propose a routing protocol for DTN network, which allows nodes to choose intelligently the relays that have the great chance to carry the message closer to its final destination.

In [73], Gao et al. proposed an energy-efficient routing protocol for opportunistic networks in which the node's speed and residual energy are used as routing criteria to determine the best forwarder to carry a message to its destination. These criteria are used in a utility function to ensure that low efficiency in data accumulation and uncontrolled spraying can be prevented.

In [74] Bhed Bahadur Bista and Danda B. Rawat have proposed a robust energy efficient epidemic routing protocol (REER) for delay tolerant networks. And their aim is to extend the life expectancy of a DTN by extending lives of nodes in DTN by reducing energy consumption and at the same time increase the delivery probability of messages. They have achieved this by considering nodes' remaining energy and available free buffer for receiving copies of messages. Note that even if a neighbor node doesn't have a copy of its message, it will not broadcast the message if its neighbor's remaining energy is less than its remaining energy or does not have enough free buffer to accommodate the message.

In [75] Fan Li , Hong Jiang, Hanshang Li, Yu Cheng *and* Yu Wang proposed Social Energy Based Routing for Mobile Social Delay Tolerant Networks (SEBAR) in mobile social delay tolerant networks . And inspired by general laws in particle physics, they introduce a novel social metric social energy to quantify the social ability of a node to forward messages to others. The social energy is generated via node encounters and shared by the communities of encountering nodes. An active node with many encounters will have a higher social energy, and a community with many encounters among its members or with members from other communities will have a higher social energy too.

In [76] Nelson Machado Junior and Carlos Alberto Vieira Campos presented a Social-based Energy-Efficient Forwarding Protocol for Opportunistic Networks (SOCLEER) that is a social-based opportunistic forwarding protocol which was proposed based on a remake of the established BUBBLE Rap protocol , in order to relieve the frequent repetition of nodes taken as preferred, by distributing its forwarded messages traffic load to other nodes with similar social features and thus decrease its energy consumption.

As indicated in [77] Cristian Chilipirea et al., presented a novel social-driven solution is an Energy-Aware Social-based Routing protocol in Opportunistic Networks (EASR) which includes energy as an important element in selecting the routing decision. If the energy consumption is considered, in social-driven opportunistic network routing popular nodes can be troubled and their resources drained.

Thus, previous works on energy-efficient routing strategies for DTN has mostly analysed the energy performance of routing protocols. And there has been little research done in energy efficient routing strategies for mobile nodes that include energy as well as buffer space by using different routing approaches.

As a result, to fill these existing routing gap based on energy, we proposed an Energy Efficient Routing Strategy (EER) for node energy and distance issues in delay tolerant networks which the propose routing is select the nodes based on their high energy level and minimum distance from intermediate node that adopt per hop routing (PHR) strategy.

Generally, the aim of this study is to propose an energy efficient routing strategy for delay tolerant network with the expectation for packet delivery in message transmissions.

Summary

In delay tolerant network routing algorithms discussed in this paper have techniques, advantages as well as drawbacks of different routing algorithms. Some of them will perform very well but consumes more network resources, while some of the algorithms give optimal solution with less resource consumption. The selection of routing algorithms is very important and it depends on the network scenario and the application where the network is deployed. Therefore in above studies, assured that still energy efficient routing is an open issue and a challenging that need to further study for tackling efficient routing based on energy and distance of nodes in network which naturally affect the overall network performance. Hence, we have made an attempt to compare the existing routing algorithms on the basis of different performance metrics.

Table 3.1 shows flooding based routing algorithms, **Table 3.2** shows forwarding based routing algorithms and **Table 3.3** shows social aware based routing algorithms.

Generally, even if forwarding based routing strategy is good algorithm to forward data through store- carry and forward approach and make good routing decision in data forwarding process in the delay tolerant network, but it is not as good as other strategies based on node energy issue and distance information on that communication range. Now we sumerized those different studies for delay tolerant network routing algorithms with different techniques as follows.

Algorithms	Techniques	Importance	Drawbacks
EAER [64]	▪ The n-parameter strategy and also proposed prevalence strategy (PS)	▪ for optimizing the possibility of transferring packets and ▪ **PS** manages the value of n based on the current energy level and current neighbour node.	▪ The residual energy of a node is low, the n-parameter value will be increased ▪ High resource consumption
VESW [65]	▪ Use Binary Spray and Wait (BSW) in Spray and Wait scheme	▪ To improve the energy efficiency	▪ High resource consumption and more delay
EXLIOSE [68]	▪ New metric energy shortage cost (ESC) and ▪ A decision for transferring the message to other nodes is based on calculation of the ESC in each node, and messages are forwarded to the neighbour with lower ESC.	▪ Maximizing network lifetime by choosing the next hop based on ESC Provide high performance	▪ Do not take energy into consideration ▪ Energy consumption and energy of nodes are calculated, but NOT considering for generating message.
CEAMS [69]	▪ A novel context-metric queuing method ▪ New metric Node's Delivery Capability to sort and queue a message in the buffer	▪ High delivery rate with high message priority. ▪ Utilize the node's energy efficiently in transmission ▪ Provides high perform	▪ The energy consumption and energy of nodes are NOT calculated when for generating message.
AEHBPR [70]	▪ Used a one-hop acknowledgment mechanism	▪ Removing copies of an already delivered message from the buffer of other nodes and ▪ Ensuring no extra copy of the same message is generated and transmitted	▪ No extra copy of message is generated when Ack is not reaches

DEEF [71]	▪ Use shortest node discovery approach	▪ To improve the performance of network and ▪ To utilize the resources efficiently	▪ And if the node resource is less, then there is no chance to deliver the message to the destination.
EERPFAnt [72]	▪ Fuzzy Logic and Ant Colony optimization approach	▪ To save energy due to the operation of transmission and reception of message ▪ To ensure delivery ratio	▪ It use multiple copies of each message in order to increase the delivery ratio. So it consumes more buffer space
REER [74]	▪ By considering: Nodes remaining energy and Free buffer space available	▪ Number of nodes does not affect the energy consumption of the node ▪ Network lifetime is extended & delivery ratio is also improved	▪ Size of buffer, size of message, varying mobility speed & data rate is not considered in simulation

Table 3.1 Flooding based routing algorithms

Algorithms	Techniques	Importance	Drawbacks
NECTAR Routing	▪ the occurrence of an opportunistic contact to compute Neighborhood Index	▪ Use high message delivery ratio and normal average delay	▪ Use medium resource consumption
Per –Hop Routing	▪ Use hop by hop mechanism for message transmission	▪ Use low resource consumption and medium message delivery ratio	▪ Use medium average delay
Per –Contact	▪ Use node contact exchange vector	▪ High message delivery ration and low average delay	▪ High resource consumption
Source Routing	▪ Route discovery phase and route maintenance	▪ Use normal information maintenance and low resource consumption	▪ Low message delivery ratio and high average delay
CRHC Routing	▪ Use Clustering (i.e. grouping) of node	▪ High message delivery ratio and high information maintenance	▪ High resource consumption

Table 3.2 Forwarding based routing algorithms [56]

Algorithms	**Techniques**	**Importance**	**Drawbacks**
SEBAR [75]	▪ Community detection method and a new social metric named social energy	▪ To minimize overhead ratio ▪ Considers social energy of encountering nodes	▪ Not considering remaining energy of node
SOCLEER [76]	▪ Social-based forwarding protocol	▪ Minimize message load distribution and reduce battery consumption	▪ By dissemination, messages are stored on the most popular nodes, may be popular nodes no more buffer space
EASR [77]	▪ Novel social relation based energy- aware	▪ Improve deliver performance	▪ Might be unwilling node to participate in the routing process

Table 3.3 Social aware based routing algorithms

CHAPTER THREE

PROPOSED SYSTEM

3.1 Routing Strategy in DTN

Routing issues in DTNs may occur as standard issues with routing to in mobile Ad Hoc networks (MANETs), but with extended connection failure times [78]. To support dynamic topologies in MANETs, an abundance of routing-layer protocols such as OLSR, AODV, LAR, STAR and many other routing layer protocols have been proposed. Some of these routing protocols use passive methods. Do not take the initiative to find a route to the destination until necessary.

However, all of these routing protocols implicitly assume that the network is connected and there is a simultaneous end-to-end path between any source or destination pair. In the standard dynamic routing problem, the structure is assumed to be considerably interconnected, and the objective of the routing algorithm is to find the best complete path currently available to transfer traffic from one end to the other.

The DTN routing problem can be viewed as an optimization problem where edges can be unavailable for long periods of time with storage constraints on each node. This makes DTN routing a completely different and more challenging problem.

Accordingly, important efforts have been made to develop new routing protocols and system architectures for DTNs. As mentioned above, there is no way for the source DTN node to indicate in advance whether an end-to-end path exists to the intended destination node. DTN routing has been described as a flexible set of forwarding decisions and is achieved by a store-carry and-forward approach by moving messages closer to their destination by one hop. As a result of such a situation, the knowledge of the mobility patterns of a group of nodes in a certain section of the DTN is of utmost importance in this regard.

Most of the routing work done in DTN falls into two broad categories: flooding routing protocols and forwarding routing protocols [79].

In the flooding routing protocol, each node spreads multiple copies of each message to other nodes without any information about the network structure. Nodes keep copies of messages and store them in their buffers until the next node or destination is completed. Message replication helps increase the probability of message delivery because more nodes are responsible for forwarding the message to the base station.

And in forwarding routing protocols is a knowledge-based approach without replication. In this strategy, knowledge about the network is required by the routing protocol and the nodes collect information about other nodes in the network to select the best path to forward the message to the destination.

In general, most of the previous work on DTN routing protocols focused on power consumption. In particular, forwarding decisions are made to be energy efficient, but these forwarding decisions little reflect the energy available on each node. In our work, forwarding decisions consider available energy of node and distance information. There is also very little research on energy-efficient DTN routing protocols for mobile nodes. Previous work has assumed energy is a decreasing resource. In the literature review shows that there is a research gap in the area of energy-efficient DTN routing strategy.

Hence, in this section, we propose an energy efficient routing strategy that takes into account the energy issues and the distance information to achieve the delivery rate.

In previous studies, to design energy aware routing strategies for delay-tolerant networks (DTNs), they should aim to minimize energy consumption, latency, and maximize delivery ratio [5]. As a result, we have proposed an energy efficient routing strategy for delay tolerant network and we use information about energy levels and distance to determine the ability to send node messages.

Firstly, in our propose energy efficient routing strategy for delay tolerant network we have an expectations that we have to discuss before going to modeling the system.

- If the nodes have enough available energy and the minimum distance, we consider in the source-neighbor-destination operation for energy efficient routing strategy in that communication range.
- If the node have medium energy level and has short distance for destination, it has high delivery capacity based on that energy or distance property.
- We have expected to propose energy efficient routing strategy and with nodes position to get the minimum distance information of neighbor and destination nodes.
- We assume that buffer space constraint of all nodes have enough storage to store-carry and forward approach until they exchange the forwarding message.

Generally, in delay tolerant network (DTN) the end to end route can never be achieved as traditional network so the hop by hop, in which the selection of next hop is done dynamically as per the application scenario as well as the algorithm used.

In general, when a node receives any bundle (or message) then as per the algorithm, that node will search the good relay node or potential forwarder to which it can forward the bundle to the next intermediate or destination node [24].

The transmission of message in delay tolerant network can either be done by flooding or replicating the message or forwarding it, that depends on the type of algorithm used.

Based on the forwarding based routing strategies, we have been selected the one suitable routing strategy and applied it on our propose energy efficient routing work. Hence, we have been applied ones forwarding based routing strategy which is per-hop routing (PHR) strategy. Therefore, in per hop routing strategy, when the source node involves to forward the messages to the relay or intermediate nodes in the communication range in delay tolerant network (DTN) uses the store-carry and forward approach. The concept of this store-carry and forward approach involves a delay tolerant network node carrying a bundle data until it is able to connect to another node and then transfers its messages which in turn carry it until it contacts another node. And this process continues until the message reaches its final destination.

Furthermore, in per-hop routing strategy, each relay or intermediate node will decide the next node to which the packet is to be forwarded for a particular destination node. Therefore, in per-hop routing strategy, the next-hop of a message is determined at each hop along its forwarding path. And it allows a message to utilize local information about available contacts and queues at each hop, which is typically unavailable at the source.

And this routing strategy has better performance because it is used the more updated information. Firstly in this routing strategy, the source node (**SN**) sends the message to all the connected nodes or relay nodes (**RN**), and then these nodes search for their energy or minimum closeness of the destination node and then node will forward the message to final destination node. Therefore, this process goes on and hence the improvement of message routes keeps going.

3.2 Proposed Energy Efficient Routing Strategy (EERs)

In our proposed system model, we consider that wireless nodes with uniform communication area (Cr) are randomly distributed in a two-dimensional space. (Figure 3.1) and forms a delay tolerance network (DTN). Nodes are mobile and heterogeneous in nature (for example, mobile phones, smartphones, tablets and laptops). And each node has finite energy and buffer space, and all messages in the network have the same priority for transmission.

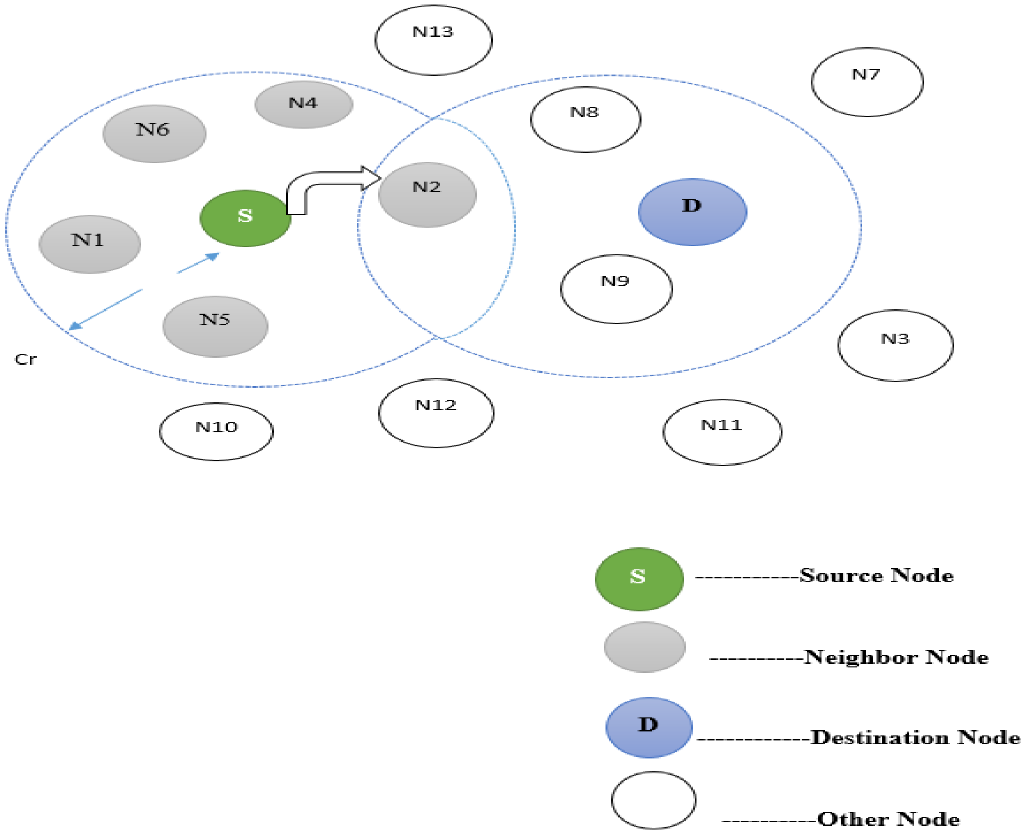

Figure 3.1 Proposed EER Strategy Model

This our proposed strategy model also takes into account the method of communication between unicast nodes through a process based on multi-hop forwarding. We also consider that each node knows its location (latitude and longitude), the location of its neighbors, and destination nodes. Thus, Figure 3.1 above shows the network system model for the case where **SN**, **RN** and **DN** are source, relay and destination nodes, respectively.

Based on the above information node **N1** to **N13** are a delay tolerant network nodes. Among them, **N1, N2, N4, N5, N6** are neighbor nodes (**NN**) of source node. The message stored in the communicating node at the same instance of time is also presented.

Therefore, in this section we describe our proposed energy efficient routing (EERs) strategy on the node energy level with distance information for delay tolerant network.

Whenever a source node **(SN)** proposes to send a message, it checks the available energy level of the relay nodes (**RN**) and if the relay node energy is found less than a predefined threshold value, it cannot forward the message to the destination node, so the source node checks again other candidate node for forwarding. And also the threshold value is set based on the energy consumption of the mobile nodes. We exploit the fact that normally, if a mobile node has available node energy less than minimum energy threshold it may not perform desired tasks or message forwarding capability efficiently on that communication scenario. Accordingly, the threshold value is set as minimum energy threshold of the initial energy value of the nodes. And for smaller communication range, source node gets less number of relay nodes resulting in reduction of its computation energy cost which implies increase in lifetime of the node. Then, source node checks whether there is a direct path to the destination node. If a direct path exists, source node transmits the message to destination node. On the other hand, if there is no direct path to destination node, the source node checks its neighbor-list to find the best next relay node based on node energy level or minimum distance information.

Thus during relay node selection, source node checks the energy level of relay nodes or distance information based on the utility value of node among the relay nodes list.

Therefore, with this process any node ***n*** whose utility value satisfies utility value (***uv***) is greater than or equal to the threshold value ***(thv)***, where ***uv*** is a utility value can be selected as a candidate node for message forwarding.

In this our proposed model **first** we have done in this proposed system is computation of available energy level of relay or intermediate nodes that helps to determine the best forwarding capability of nodes among the relay nodes of on that communication range.

Accordingly, this value determines the best forwarding capability of nodes for bundle messages and updating energy level value during scanning, transmitting, forwarding and receiving message to each other.

The **second** activity of energy efficient routing strategy is computation of distance value of nodes that helps to find the small distance path from the source to relays or destination node.

The **third** activity is computing of utility value of nodes in the network to determine the forwarding capacity of the relay nodes compare with their threshold value of each node in the communication network. And we have compute the utility value of nodes based on the multiply of energy value and distance value of nodes, then compare the utility value of any node whose utility value satisfies *Uv* is greater than or equal to the threshold value. Therefore, we proposed EER strategy based on the available energy level or minimum distance value of potential relay nodes for forwarding the bundle message to the target destination node. When the source node then wishes to forward the message to neighboring nodes, it knows the energy level or smaller distance value of the nodes on that network range.

First, the two nodes meet each other to exchange information about the nodes, such as message size, current energy value and buffer size.

And then the two nodes exchange their current utility value status with each other. If the source node's utility value is greater than the threshold then relay node can be selected as an optional node for the transfer of messages. At this point, based on the utility value of the relay node, the ability of each node to carry the message was decided based on the energy value or the short distance metric.

At that time, based on this relay node utility value, the message forwarding capability of each node is determined either by the energy value or by small distance.

On the other hand, the relay node with a high utility value will fulfil the selection criteria for forwarding messages to the destination node. For example in Figure 3.1, if the source node **SN** must forward messages to the destination node **DN** through relay node **N2** as the best message forwarding node.

3.2.1 Checking energy level of source and relay node (RN)

At present, most delay tolerant network routing algorithms are not well studied to take into account node energy factors. Especially in energy-constrained nodes such as smartphones used in people's daily networks. Energy consumption when the node is completed regardless of how often the node and destination node encounter messages, because there are not enough energy nodes that cannot be connected for the purpose of forwarding the message

Therefore, this study focuses on the routing to consider the impact of the node energy and we have proposed energy efficient routing strategy based on existing delay tolerant network routing algorithms. In this proposed energy efficient routing strategy in DTN, the routing algorithm works based on the node's energy level and the routing strategy is using store-carry and forward approach while available energy exchange, select node as the routing decisions and the optimal routing decisions to select the suitable relay nodes.

Therefore, in our energy-efficient routing strategy, the basic DTN routing module relies on the building node energy checking module to simulate the energy consumption of each node along the route. In the network module, nodes contain basic properties such as the node ID, buffer size, and node energy value.

At the beginning of the simulation each node will receive the initial energy value, and during the simulation the energy value will be different and will continue until the final energy consumption is turned off.

In the EER routing algorithm, the energy value of the node will be updated in real time by check and the energy value as a route to optimize routing decisions.

The utility value of a node indicates the appropriate level of the node as the message relay node. First taking into account the energy constrained DTN network scenario, the main factor affecting the route for the available energy is movement activity of nodes.

In EER strategy linked mainly with the degree of change in the node and the energy value of nodes are main attributes influencing factors as the energy utility value.

In our energy efficient routing, the routing decision not to select only the appropriate relay node, and then copy the message packet forwarded directly to the relay node.

In energy efficient routing strategy, based on the energy level routing decision-making process is as follows:

The neighbors of the source node **S** is the local node **S** is now assumed that the network communication shown in **Figure 3.1** and assuming the source node **S** neighbor node lists are **N1, N2, N4, N5** and **N6**. Accordingly, the encountered to the node **S** according to the order of the neighbor list followed by the node **N1, N2, N4, N5** and **N6** communication based on energy value or small distance.

In our energy efficient routing strategy the energy management checking module is actually implemented.

Firstly, before routing simulation begins as the network initial energy value of each node (initial energy) assignment, define the energy scan update cycle *ti*, energy consumption per scan and energy consumption per forwarding. And secondly, in the route every other time period *ti*, the node will update the energy value:

$$\textbf{Energy}_{new} = \textbf{Energy}_{old} - \textbf{Scan}\text{Energy} \qquad (3.1)$$

After each successfully forwarded a message packet, the node will update the energy value:

$$\textbf{Energy}_{new} = \textbf{Energy}_{old} - \textbf{Transfer}\text{Energy} \qquad (3.2)$$

And finally, when the node updates its energy value found $\boldsymbol{Energy}_{new} \leq$ minimum energy threshold value (meth) then the forwarder node is no longer have enough energy value to become a best relay node. When found $\boldsymbol{Energy}_{new} \leq$ minimum energy threshold, the node may not perform desired tasks or message forwarding capability efficiently on that communication scenario.

On the other hand, once the current node energy is less than the minimum energy threshold, it will not forward packets to other nodes or receive packets for forwarding.

Thus, a minimum energy threshold (600 Joules) is set so that whenever the energy level of an encountered relay node (which is not the destination node) is checked and found to be less than that threshold, the message will not be sent to that node. In this work, its threshold value has been set through simulation experiments [32].

In the previously mentioned energy-efficient transmission scheme, the messaging method used by flood-based routing protocols has several limitations, including inefficient and inefficient use of node's energy and other resources.

And in the energy efficient routing strategy, there is the forwarding criterion that determines whether an intermediate node can deliver messages based on its available energy value. And it also ensures that when a node's energy reaches a certain level, it will only send acceptable messages and prioritize the important ones.

Therefore, considering the energy level of nodes as routing parameter, this study proposes an energy-efficient routing strategy where the next best hop is selected based on the node's energy threshold value. Then, in energy efficient routing strategy, based on the energy threshold value of a node is making in the routing decision. If the neighbour of a node has insufficient energy level to support the message transfer, the probability for that node to be a successful carrier of the message will decrease. Then in other words in our implementation code, if current energy value is less than or equal to the minimum energy threshold value then nodes will neither forward nor accept the messages.

Algorithm 3.2.1 Pseudocode for checking energy level of relay node (RN)

1**: While** (connection is up)

2: Select the relay node **RN** current energy value

3**: For** all messages in the buffer

4**: If** Energy Level of RN < Minimum Energy Th and **RN** is not Destination Node (**DN**) **then**
Go to Step2

5: **Else If** calculate Energy Level of **RN** ≥ Minimum Energy Th

6: Forward message to next node or **DN**

7: **If** Relay Node is Destination Node then forward Message

8: **Else** Follow EER ALG to send message to **RN**

9**: End for**

10**: End while**

3.2.2 Computing the distance of nodes in the network

In our proposed work the distance information of relay and destination node is considered to get the potential forwarder node among the neighbour nodes. When a source node wants to send message to the destination, then source node find the nodes which are nearer to the source node. Consequently, the source node calculates the distance amongst all the nodes which come under its maximum coverage region and the node which is most nearer node to the source is selected as forwarder for the further communication purpose.

In our proposed routing strategy for neighbor discovery, we assume that all messages on the network have the same forwarding priority. Thus, the message at the top of the buffer is the first to receive the current node. And it is sent first as soon as the next node on the right is selected. First, every node in the network sends a HELLO packet from its hop to a possible neighbor using a low communication range that is half the maximum communication range. When a node receives a HELLO packet, it first checks that the source node is already on its neighbor list. If the source was its neighbor, drop the HELLO packet.

On the other hand, add the source node to its neighbor list and reply an ACK packet to the source node to inform that the neighbor relationship between them has been established. All nodes in the network can then list their one-hop neighbors. Therefore, due to the mobility of nodes in the network, it is necessary to periodically update the lists of neighbors. As a result, before the transmission of the message begins, the source node knows the distance information of the neighboring and destination nodes.

If the source node (SN) has a message to send to the destination node (DN), the next step is to select the next best relay node to forward packets to the destination.

First check the source node to see if there is a recent path to the destination node. If there is a new path, the source mode selects the recent path to take the message to the destination.

On the other hand, there is no new route to the destination, the source node checks its neighbor list to find the best next hop node.

Thus, under in our proposed energy efficient routing strategy process the minimum distance to forward to the best relay node. If node **2 or N2** is considered as potential relay node, then it may be possible that initially, that is other nodes in source network range. This may be more nearer to the source node rather than the current node.

The contact where the node will come into the range of source is called as the contact chance. If the relay node comes into the network area before the specified threshold time then the source node will wait for the node N2 to come into the network range.

In the proposed routing strategy the energy of the node has also been monitored and if this energy level has been reduced, then it gets recharged with a certain amount of energy that is provided in the setting to bring that node into the network. If some nodes has less energy level than the energy required for the transmission of the bundle then that node is not considered for further transmission purpose. Therefore, to allow that node for further participation in the network, the energy of that node and other nodes need to be updated in a frequent manner.

In our energy efficient routing strategy algorithm to compute the distance of relay node on our communication network model first, if there is any relay node existed within a maximum transmission range of the source node and its value is less than the threshold value, then the source node forwards the packet to that nearest relay node without copying the data. This routing algorithm is performed at the source node at every contact time.

In energy efficient routing algorithm, potential relay node with minimum distance is selected from the set of contacted neighbors.

In the scheme of the energy efficient routing strategy, using minimum distance next hop selection is based on the calculation of three parameters, namely **α, β and U.**

Initially, the energy efficient routing strategy dynamically generates encounter values of each node with every other node in the network. The encounter value of a node is the number of times that this node has encountered another node [27].

The *SumEncounter* value is defined as the sum of the encounters of all the neighboring nodes with the destination. And this value is dynamically calculated.

Also, the *SumDistance* value is defined as the sum of the distances of all the neighboring nodes with the destination. And this value is also dynamically calculated.

The source or any intermediate node that wishes to forward a message to its destination first identifies the neighbor nodes within its range.

We suppose there are **N** such neighbor nodes and to select the next suitable hop to carry the packet towards the destination, the so-called ***α*** and ***β*** parameter values are calculated for each of the **N** neighbor nodes as follows:

α = node encounter/SumEncounter ………………………..…….. (3.3)

β = node distance/SumDistance …………………………….……. (3.4)

Hence, in order to select the next suitable forwarders among the ***N*** neighbor nodes, the energy efficient routing strategy needs to maximize the number of encounters with the destination, and minimize the distance from the destination to a neighbor node for every message. With this in mind, the energy efficient routing strategy normalizes the mean of ***α*** and ***β*** values obtained for each neighbor node, and then calculates the forwarding parameter (utility value) **U** as follows:

U = α/β……………………………………………………..… (3.5)

A threshold value (***Thv)*** is calculated as the **average of the *U (utility value)* values** of the ***N*** neighbor nodes. And the message is then forwarded to all the neighbor nodes having a ***U*** value greater than or equal to the threshold value (***U value≥Thv)*** on that network range. Therefore, by considering an average threshold value of the forwarding parameter for every source-neighbor-destination pair, the energy efficient routing strategy selects an optimal set of nodes that will be the best next forwarders of the message to the destination node.

Algorithm 3.2.2 Pseudocode of Computing the distance of relay node

//getEnc (src, dest) returns the number of encounter values of the source node with respect to destination.

//getsumEnc () returns the sum of the encounter values of all the neighbouring nodes with respect to the destination.

//getDis (src, dest.) returns the sum of distances of all source nodes with respect to destination.

//getsumDis () returns the sum of the distance values of all the neighbouring nodes the destination.

1: **Begin**

2: **For** each message **do**

3: **For** each neighbor *n* of the source/interm. node **do**

4: α = getEnc (n, dest.) / GetsumEnc ()

5: β = getDis (n, dest.) / GetsumDis ()

6: U = α/β

7: **End for**

8: **End for**

9: **For** each neighbor **do**

10: If U value of neighbor node ≥ Thv **then**

11: Forward the packet copy to the nearest relay node

12: Else

13: Do not forward the packet copy

14: **End if**

15: **End for**

16: **End**

3.3.3 Computing utility value of nodes

In our proposed model to compute the utility value based on the distance value and energy value, first we have to set both value as below equation (3.6) and measure the distance of source from the neighboring and destination node, therefore to compute the utility value of the nodes, we have used both energy and distance metric to select those nodes that have available energy or at closer distance to the source node. In order to select the next best forwarder of the message, the proposed energy efficient strategy considers some parameters used as ***utility value***, namely **Zval**, which are calculated as follows:

Zval=(W1×(getCurrentEnergy(neighbour))/Energythreshold(node)+(W2× ηneighbour)/threshold ……………………………………………….. (3.6)

Where ***W1*** and ***W2*** are the weights assigned to node CurrentEnergy and Encounter and Distance based Routing protocol respectively, **ηneighbour** is the encounter to distance ratio of a neighbour node calculated value. Next, the proposed scheme selects the set of nodes from the neighbour of the source whose Zval is greater than or equal to Zparameter and stores these nodes in a Hashmap [27]. Based on this calculation, any node ***n*** which **Zval** is greater than or equal to threshold value satisfies **Zval ≥ *Thv***, where ***Thv*** is a set threshold can be selected as a candidate node for message forwarding.

If the next hop is the destination node, the message is forwarded directly to it without computing the utility value. Additionally, if the node n carrying message m does not encounter the destination node of message m currently and the current utility value Zval ≤ *Thv*, node n still carries message m until it meets the destination of message m. Note that, once the required utility value **Zval** ≤ *Thv* for a message m, the message m cannot be forwarded to other nodes.

And also we can know whether source node **S** decides to broadcast message m to other nodes or not at this time.

If source node **S** decides not to forward the message m to its current neighboring nodes, it will continue to carry message m until it encounters more appropriate forwarding opportunity or the destination node of message m. On the other hand, if node **S** decides to forward message m to its current neighboring nodes, it should select which node can forward message m to other nodes. Note that, as for a specific message m existing in the network, there may exist several replicas of the message m in different nodes.

When one of the source node **S's** neighbor node **N2** will send an acknowledgement message to node **S**, if it has successfully received message m. The sent acknowledgement message includes node N2's ID number, its available energy, message m's ID, and the distance that the node **S** will meet the destination within the TTL of message m.

Therefore, to update the utility values of source node SN and relay node RN when relay node RN forwards message for node SN. And the source node SN and relay node RN are exchange their utilities to determining the high forwarding capability node of for message transmissim. And then the among the relay nodes one highest forwarder RN determined to forward the message and also update the utility value of source node SN and relay node RN .

Algorithm 3.3.3 Pseudo code for computing and updating utility value

//Node **SN** and **RN** encounter and exchange utilities

If (**SN** checks **RN** is **DN** or not) **Then**

RN is **DN** the **SN** forward message **M** Then

//no update the utility value of **SN** and **RN** nodes

Utility value of relay node (**RNuv**) = **Uvrn** and

Utility value of source nod (**SNuv**) = **Uvsn**;

End if

Else if node **RN** of **Uvrn≥Thv** and (**RN** is selected forwarding **M** for node **DN**)

//Update utility value of both **RN** and **SN**

End if

End if

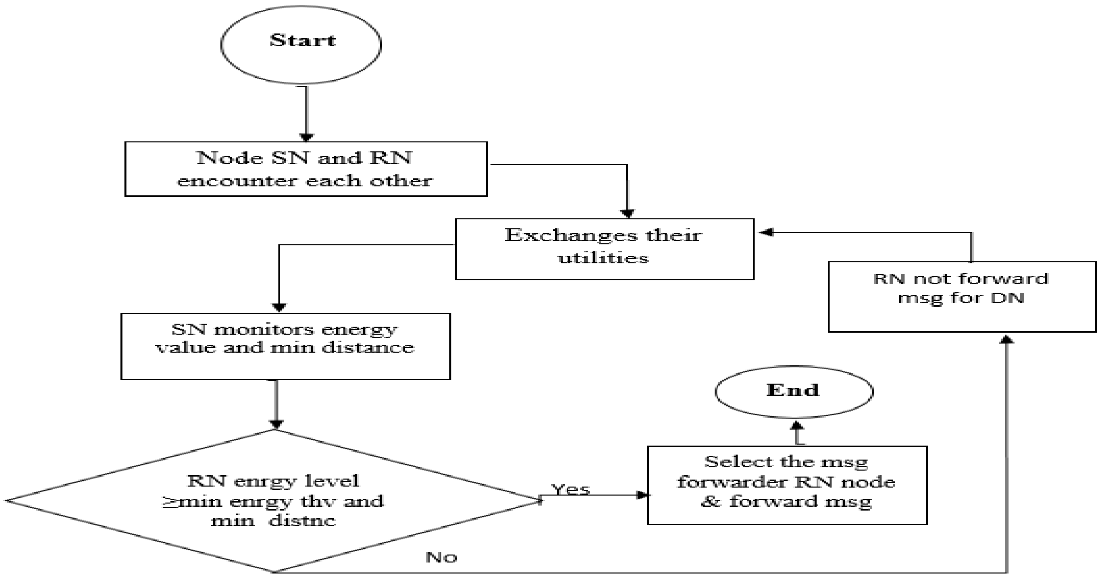

Figure 3.2 flowchart of proposed strategy between SN and RN nodes

In this **Figure 3.2**, **SN** as source node, **RN** as relay node, as utility value and **thv** as threshold value. Assume that node **SN** and **RN** are model in the above proposed system and node **SN** will be forward the message m for node **RN** which is relay node. When the two node encounter to each other they exchange their id, current utility value, energy level and message size as well as buffer size. Then node **SN** check the current status of the relay nodes if it fulfil the criteria that the scenario allow for it to provides forwarding message to destination node.

Therefore, node **SN** decide to forward the message based on the utility value of node **RN** whether it has greater than or equal to threshold value or not. If the utility value of the relay node is greater than or equal to the threshold value the relay node is deciding as high message forwarding capability from other relay nodes in the network.

CHAPTER 4

IMPLEMENTATION AND EXPERIMENTAL RESULT

In order to implement the proposed energy efficient routing strategy, a per-hop routing strategy is implemented using store-carry and-forward methods that provide high forwarding capacity of nodes based energy level or short distance to improve the delivery ratio. First, we assume that nodes are mapped to various scenario model activities using the navigation application. And it maintains the utility value of the source and the relay node with each communication area. This utility value shows the high ability to send nodes based on their energy level or distance value, as we have proposed an energy efficient routing strategy, and thus the relay node utility will be updated when the source node and relay node exchange information about the utility which has a high ability to send messages in the network.

In every node in the proposed flowchart records utility value for model network in a unit time interval. In the Figure 3.2 node SN and RN are in encounter and need to determine whether to forward message m or not between them by using the store-carry and forward approach. And in the proposed energy efficient routing strategy the source node SN check utility value of relay node RN and if it is enough value to get forwarding opportunity to destination node from node relay node RN.

But, in the case when node in the relay node have lower utility value which compared with threshold value which set in the configuration file is not forward message, but relay node utility value is greater than or equal to the threshold value for message forwarding interm s of energy level or distance value.

4.1 Implementation of Energy Efficient Routing Strategy

Hence, some of nodes represent the initial energy level of nodes and update energy value to accept and forward message to relay node and destination node. Thus, we model and select potential packet forwarder of node randomly from total number of nodes in real traces dataset which is default Helsinki-city map on ONE simulator.

So, we allocate all assign of nodes in the communication network and in this way we show that the source, relay or neighbour and destination node working scenario and then source node and relay nodes energy value or distance value from destination node for message forwarding.

First, we have assign initial energy of all nodes and update energy of nodes when the energy consumption per scanning, receiving, transmitting and forwarding messages in the network.

And show their impact on the performance of the network and evaluate the simulation to implement the energy efficient routing in energy module using ONE simulator.

Mostly to implement and evaluate our proposed routing strategy. After modeling, we have to compute the nodes energy level and distance value to determining the best hop selection based on the utility value is greater than or equal to that threshold value of nodes. And this energy and distance issue is the main study to indicate the impact of energy resource on the performances of the network in terms of performance evaluation metrics delivery ratio, overhead ratio. As a result, the study modeled and implemented the energy efficient routing strategy to tackle this energy based issue with the smallest distance information.

Accordingly, while utility value holds in message shows that it has value for forward message and then the relay node has high forwarding capability to forward message to target destination. This relay node also store and carry the received message until it encounters another node that is able to forwards to other node. In this routing strategy, each nodes have utility value with their id, energy value and distance value to select the potential message forwarder node from neighbours of source node.

However, if two nodes encounter to each other as source and relay node on that communication network, then the relay node and the source node exchange their previous history information about their encounter time, energy level and distance information. Therefore, if the relay node have high message forwarding capability, its utility value is greater than or equal to from the threshold value of other neighbor nodes in the network. Otherwise, the other relay node selection process is perform to get the best message forwarding opportunity. When message delivered successfully then the source, the relay and the destination node exchange their acknowledgment message

Therefore, the proposed energy efficient routing strategy (EERs) is implemented on routing module and compares with Per Hop Routing (PHR) algorithm.

We explored that the spread low energy level of nodes in the network decrease the performance of per hop routing algorithm which is not consider the require update information about the network energy resource and permits the messages to be transmitted through many hop when the source nodes are in contact with the destination.

And per hop routing algorithm has impact on the performance of network for delivery probability which has low delivery ratio.

4.2 Simulation Setup

In this work, we employed a dataset of real external traces for simulation setup. We used the Opportunistic Network Environment (ONE) simulation tool to evaluate the proposed system. It is developed to simulate and evaluate DTN routing protocols. Since its start, the ONE emulator has been very popular in the research community and is widely used. In addition to ensuring the implementation of some well-known routing protocols and mobility models. To evaluate the proposed scheme, our real trace dataset uses standard Helsinki city maps. Additionally, in this simulation setting, we set various parameters listed in Table 4.1 and evaluate the proposed schemes based on performance evaluation metrics such as delivery ratio, overhead ratio and hopcount.

4.3 Simulation Parameters

The parameters employed for these work and setup the simulation in the configuration will be here. In the configuration setting for our scenario shows the parameters that employed to evaluate and compare the result achieved in the evaluation of our proposed strategy. **Simulation End Time:** Determine that how many seconds need to simulate the simulation. For our work we set 12000 seconds as an optimal simulation duration.

Scenario Update Interval: This indicates that how many seconds are stepped on every update of routing. While increase this value simulation is faster, but then we will lose some precision result. Therefore, it should be 0.1 is good for simulation of our work.

Message Generation interval: When the message generated there is frequency interval time at which message should be generated. This means as the algorithm start to run with the given simulation end time (e.g. 12,000 seconds) there time at which message start to create (e.g. 200,400 interval). Therefore, this message creation time interval is assume that in the real scenario allowed to create message in the network instead of automatically generating which indicate us there is message generation time.

Communicate Interface It is interface type all nodes to have to communicate to each other. Since dataset we employed is external real trace dataset which gather using Bluetooth we employed Bluetooth for our simulation.

Transmit Range: The range at which nodes able to communicate to each other in meters since we employed Bluetooth we set it to 10M value.

Movement Model: This is the movement model that all hosts in the community should use. Since we used real trace dataset from CRAWDAD we employed shortest path map based movement model for all nodes.

Buffer Size: is size of the nodes' message buffer space at initially have with megabytes. We use 10M for our simulation.

Message TTL: is message time to live at which message expired time in simulated time of the messages created by the host.

This indicate that the TTL of each message check every time set and drop such messages if TTL expired and we set its value for our work 300 seconds optimal time.

Number of Nodes: is total number of nodes participate in the simulation. We employed **125** node from dataset integrated.

4.3.1 Simulation Scenario and Settings

For our simulation purpose, the node movement model we used shortest path map based movement under a simulation area of 4500 meters × 3400 meters. For this scenario we use Bluetooth features for interface types of nodes and TTL time to live in which determine the expiration time for messages generation, a TTL of 300 minutes is assigned to each nodes.

Field of number of host specifies the number of nodes that get from dataset which 125 hosts. Since we employed Bluetooth interface, node communicate at range of 10 metre apart.

The buffer size for out scenario is set to 10M that enable nodes to buffer message to each other. The other parameter is wait time which is the minimum and maximum wait times (in seconds) after reaching destination which set to 100,200 seconds respectively for our scenario as optimal wait time for our scheme. It defines how long nodes should stay in the same place after reaching the destination of the current path.

The time for which the scenario is to be simulated is simulation end time which is 12000 seconds according to our scenario in suggested strategy as optimal simulation end time. The message generation time interval is time frequency in which nodes create message in the network when the algorithm start to run which is [200,400] seconds in our proposed scheme scenario as optimal message generation frequency.

Simulation Parameters	Values
Simulation area	4500 m * 3400 m
Number of nodes	125
Communication Interface	Bluetooth
Buffer size	10M
Movement model	Shortest Path Map Based Movement
Message size	500K-1MB
Radio range	10metre
Transmission Speed (MB/s)	2
Scenario Update interval	0.1
Message generation interval	200-400sec
Simulation end time	12000 seconds
Message TTL	300 min
Dataset	Helsinki-city map

Table 4.1: Simulation Parameters.

And in our simulation scenario we have considered the energy parameters which are initial energy of all nodes 4800 Joules, scan energy: 0.092 Joules, transmit energy: 0.08 Joules, receive energy 0.08 Joules. Scan response energy: 0.1 Joules, base energy 0.07 Joules, and minimum energy threshold on energy level 600 Joules and threshold value is 0.6.

In the presented study AEHBPR (Energy-efficient HBPR) in [32] scenario, the number of nodes is fixed to 240. The above-mentioned threshold *T* on the utility function used in is varied from 0.2 to 0.7 with an increment of 0.1 each time, and the impact of this variation on the number of delivered messages and overhead ratio is studied when using the proposed AEHBPR protocol. The goal is to determine the best value of *T* for which the maximum possible number of messages delivered is achieved while maintaining the overhead ratio as low as possible. From the result it is observed that initially, the number of messages delivered decreases when the threshold is increased, but then, when the threshold value is greater than 0.3, it starts to increase progressively till the point 0.6, then recommence to decrease. On the other hand, in overhead ratio under varying threshold values using AEHBPR under the CMM Model. The result also observed that the overhead ratio increases initially up to point 0.3, then decreases progressively till the point 0.6, and then recommence to increase. From these observations, it can be concluded that a threshold of T = 0.6 yields a higher possible number of delivered messages while maintaining the overhead ratio as low as possible. For this reason, they will use T = 0.6 for all their simulation experiments.

Parameters	Values (Jules)
Initial Energy of all nodes	4800
Scan Energy	0.092
Transmit Energy	0.08
Receive Energy	0.08
Scan Response Energy	0.1
Base Energy	0.07
Minimum Energy Threshold	600
Threshold value	0.6

Table 4.2. Energy module parameters

In this scenario, all nodes have the same initial energy value. Where Initial Energy is the energy assigned to the hosts at the beginning**.** Scan Energy is the consumed energy during scanning. Transmit Energy is the consumed energy while transmitting. Receive Energy and Scan Response Energy is the consumed energy while scanning response, Base energy is the energy consumed while the node is idle i.e. not scanning, scan responding and transmitting.

4.3.2 Simulator Setup and Settings

4.3.2.1 ONE simulator

The Opportunistic Networking Environment (ONE) simulator is a Java program which makes complex DTN simulations more realistic [37] [38]. The ONE has been widely used for DTN and mobility research. This simulator is able to use various movement models from synthetic models to real movement traces to create a motion model of nodes, forwarding messages between nodes through different DTN routing protocols and visualizing the mobility motion of nodes and message transfer in its graphical user interface.

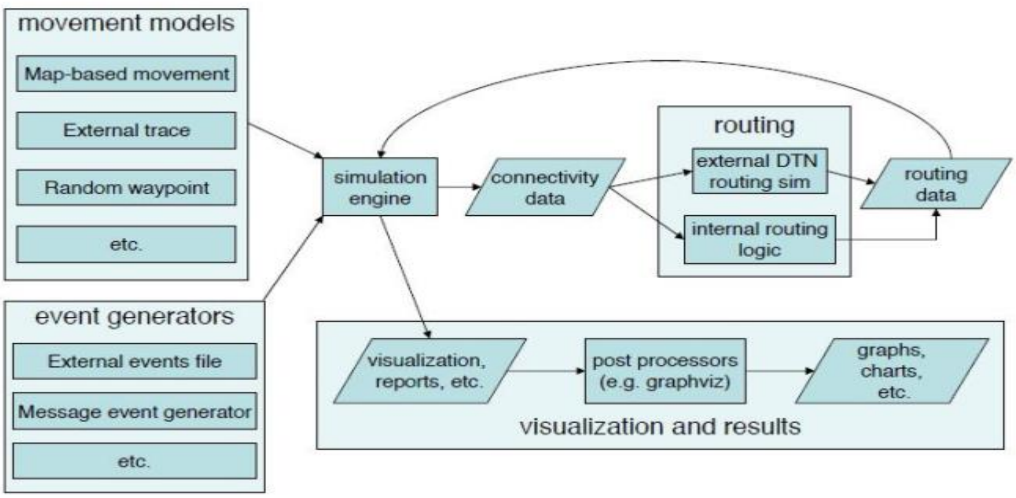

Figure 4.1 Overview of the ONE simulator [37] [38]

The movement model of nodes, inter-node contacts, routing and message handling are the main functions of the ONE simulator. Visualization, reports and post-processing tools are used for analysing and collecting the results. Figure 3.3 shows an overview of the ONE simulator, which has four modules, namely, movement models, routing, event generator and visualization, and results.

All movement models, report modules, routing algorithms and event generators are dynamically loaded into the simulator so extending and configuring the simulator with different type of plugins is made easy for users and developers: just creating a new class and defining its name in the configuration file is usually enough [79].

The routing module explains how the packets are forwarded between nodes. Different well-known routing protocols are implemented in the ONE: First Contact, Direct Delivery, Epidemic, Spray and Wait, Spray and Focus, Prophet, Maxprop. And external DTN routing protocols can also be implemented in the ONE simulator. When two nodes enter within their communication range, all protocols check if there is any new packet that the node does not already hold in its buffer then try to exchange the new packets. Some routing protocols take very simple forwarding decisions while some other algorithms have more complex decisions based on mobility patterns, number of copies of the messages, contact time and energy availability.

In addition to the energy module is applied on ONE simulator which as each node has an energy resource, which is consumed for node activities such as message forwarding, receiving, radio scanning and generating messages, the energy mechanism is implemented in the ONE simulator to examine the impact of energy consumption on the DTN routing protocols. This energy module is added within the existing routing module in the ONE.

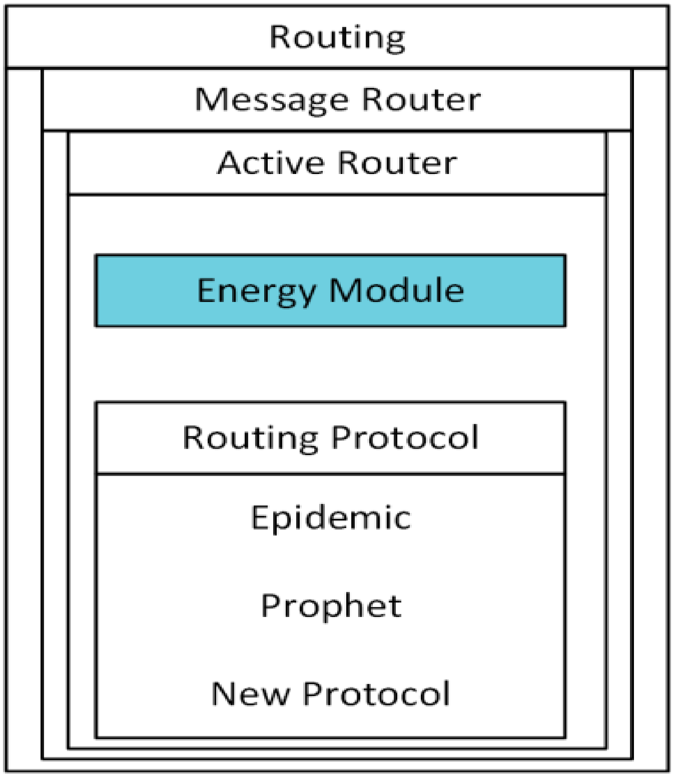

Figure 4.2. Energy module implementation in the ONE simulator [79]

This work also uses the open-source ONE simulator by allowing existing DTN routing protocols to make forwarding decisions based on the energy module to get available energy values. Most implementations of DTN routing protocols rely on shared functions that are used by all routing protocols. For example, the ActiveRouter java class implements the functionality associated with dropping packets due to the expired time-to-live field or full buffer. Then by extending the shared function components, energy-aware functionality can be enabled across all routing protocols in DTNs.

In this study, the proposed energy efficient routing strategy is combined to existing per hop routing strategy to deliver the message in a single copy forwarding approach. In per hop routing the messages transmitted in single copy to the nearest relay nodes of source. And in per hop routing the relay and source node exchange their update information to select their message forwarder node to deliver the packet to destination node.

Finally, per hop routing strategy uses less resource and has less overhead when forwarding message, because it not floods or replicates message in the network. Before, when two nodes encounter, the source node search the nearest relay node, select the potential message forwarder and then it deliver the message to the final destination node.

The output is produced by the visualization and results module. ONE is capable of visualizing results of simulation in two ways: via an interactive Graphical User Interface (GUI) and by generating images or graphs from the reports, which are created in the simulation. The ONE simulator can be run through two methods: GUI method and batch method. The GUI method is used for visualizing, testing and debugging whereas the batch mode is used for running multiple simulation scenarios with different parameters.

While the external events provide input for the simulation, the most important output is generated by the report modules. Report modules can register to connection, message, and/or movement related events. Whenever such an event happens in the simulation, the related method is called for all registered report modules and a reference to the relevant objects (e.g., nodes and messages) is given to the report module.

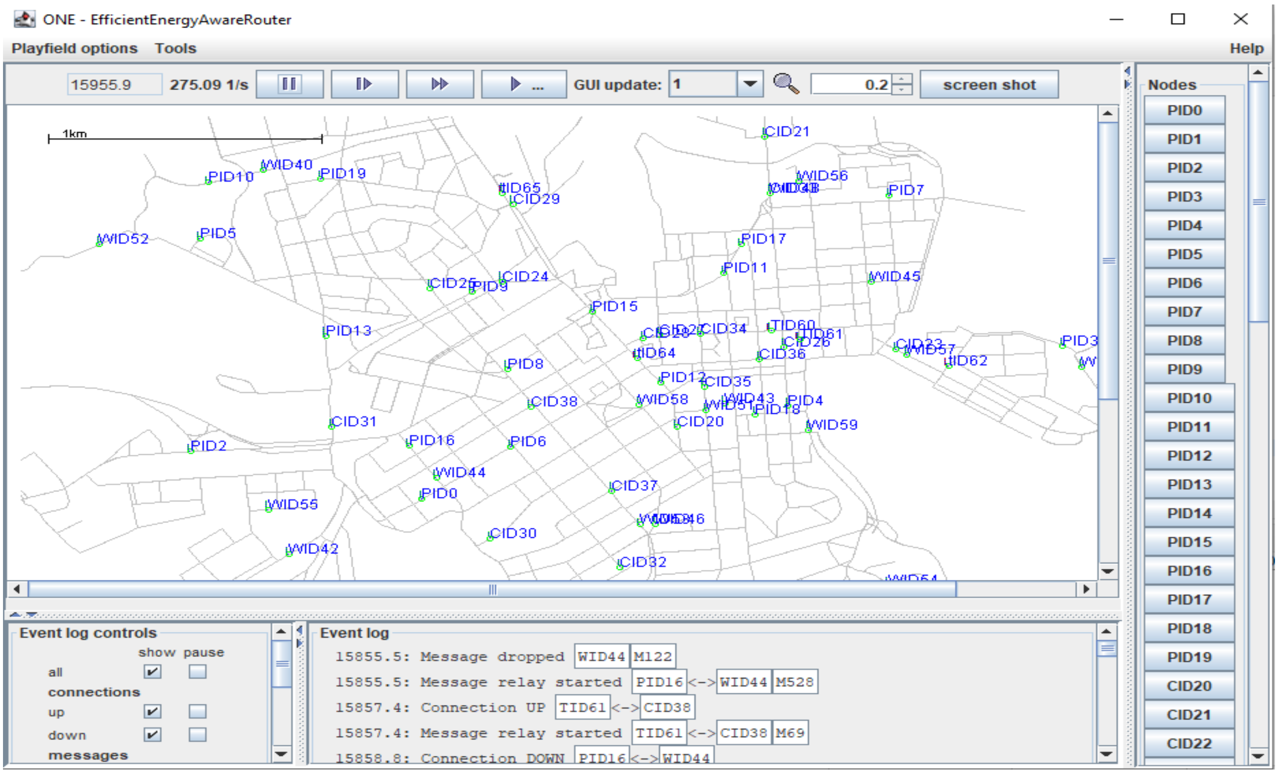

Figure 4.3. Screenshot of GUI in the ONE Simulator

As indicated in Figure 3.5, the GUI is presented in real time and shows locations of nodes indicated by blue points, movement of nodes during execution by red lines, radio range of each node by green circle, the number of messages that are carried by nodes and the map in the background. The GUI also has lists of nodes and event logs on the right hand side, which provide more information about nodes, messages, routing and connections between nodes.

4.4 Comparisions of Routing Strategy

In this work we consider forwarding based routing strategies with flooding based routing and at the beginning we evaluate the performance forwarding based routing. Thus our proposed energy efficient routing strategy is implemented and evaluated with one of forwarding based routing algorithm which is per hop routing strategy.

4.5 Comparison and Evaluation Metrics

4.5.1 Performance evaluation metrics

In this section, we provide performance metrics to evaluate the performance of DTN routing protocols as presented in [32]. We focus on just three of these metrics which are nodes delivery ratio, overhead ratio and hop count. The DTN routing protocols are evaluated and analyzed using the following performance evaluation metrics [24].

4.5.1.1 Delivery ratio

It is the ratio of the number of delivered messages to the total number of messages created by the source node in a given period.

Delivery ratio= DM/TCM ………………………………………. (4.1)

Where number of delivered msg (**DM**) is the total number of messages delivered in the network and total created msg (**TCM**) is the total number of messages created/generated in the network. If all messages that are created are delivered to the destination nodes, delivery ratio becomes one which is the best scenario of the network. This is one of the primary metrics used to evaluate the performance under a given scenario or using a particular protocol. Then we proposed to increase the performances of the network in terms of this metrics as well we use delivery ratio of message to evaluate energy efficient routing strategy.

4.5.1.2 Overhead Ratio

The ratio of the messages relayed and the messages delivered to the destination as follow. This has impact on the energy capacities of the nodes. Generally the overhead ratio is computed as

Overhead Ratio = (Mr (t) - Md (t)) / Md (t)…………………………….. (4.2)

Where **Mr (t)** is the total messages relayed by time t and **Md (t)** is the total messages delivered by time t respectively. So, it is a ratio of delivered messages to the total number of messages created in a given period. This metrics also didn't include the redundant messages [62].

4.5.1.3 Average Hop Count

The proportion of the total hops of each message copies to the total amount of generated messages. Therefore, the average hopcount information show us how challenging the evaluation scenarios was and how well routing scheme managed and used network resources.

$$\textbf{Average Hop Count} = \sum_{n=1}^{N} \textbf{Pnh} / \textbf{NC} \;\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \textbf{(4.3)}$$

Where **Pnh** is the number of hop count for every delivered message to reach its destination and **NC** is the total number of created messages. However, in delivery ratio of the messages, and overhead ratio are closely tied metrics. In practice, when one of them improves, another one fails to achieve what planned. For example, having large number of replicas of a message is helpful to improve its delivery chances. But, at the same time, it also suffers high overhead in the network.

4.6 Simulation Result and Discussion

In this section we discussed the simulation result and comparison with performances of the two routing strategies with each evaluation metrics. For instances, Table 4.3 below reveals that the simulation result with three metrics such as delivery ratio, overhead ratio and hopcount with 6 different simulation end times for the two routing strategies. The delivery ratio of EERs is better than Per Hop Routing strategy at different simulation end time. For example, at the 4000, 6000, 8000, 10000, 12000, 14000 and 16000 seconds the proposed strategy is achieved 70.81, 76.00%, 91.86%, 82.46%, 88%, 95 delivery ratio respectively with 200-400 message generation time interval.

Even if delivery ratio of proposed EERs decreases as increasing simulation end time its delivery ratio as explored in Table 4.3. At 8000s and 10000 simulation time the delivery ratio of EERs based on routing is better than per hop routing. The result show that the delivery ratio of EERs algorithm (91.86%) is better delivery probability that is from total number of generated messages, 91.86% of messages are delivered successfully. In addition to this, in terms of overhead ratio energy efficient routing strategy (EERs) is achieved better result as shown in the Table 4.3. In terms of overhead ratio EERs has high remarkable result as compared to per hop routing strategy.

For instance, in Figure 4.4 reveals the performance of proposed strategy with other schemes with performance evaluation metrics such as delivery ratio, overhead ratio and hopcount of message generated by each strategies with different simulation end time and different message generation time interval. The result discussed in this table, each strategies have evaluated with their own setting scenario in the configuration files.

As a result, we found that EERs have outperforms of the compared strategy with delivery ratio, overhead ratio and hopcount. Of course there is knotted of these metrics which means is difficult to achieve everything what intended because when we improve network performance in terms of one of these metrics the other may failed which is challenge in this type of networks.

Simulation Time(s)	Evaluation Metrics	**Two Routing Strategies/Algorithms**	
		Per Hop Routing Strategy (PHR)	Energy Efficient Routing Strategy (EERs)
4000	Delivery ratio	68.34	70.00
	Overhead ratio	71	66.83
	Hopcount	1.50	8
6000	Delivery ratio	67.66	76.81
	Overhead ratio	**80**	**77.64**
	Hopcount	1.25	8
8000	**Delivery ratio**	**85.73**	**90.86**
	Overhead ratio	81.31	76.54
	Hopcount	1.20	7
10000	**Delivery ratio**	**77.34**	**82.46**
	Overhead ratio	64.88	58.86
	Hopcount	1.17	7
12000	Delivery ratio	86	88
	Overhead ratio	**96.10**	**87.73**
	Hopcount	1.15	6
14000	Delivery ratio	93	95
	Overhead ratio	142	137.54
	Hopcount	1.64	6

Table 4.3 Simulation result for two routing strategies

4.6.1 Impact of Number of node

In this section to evaluate our work and get better result during simulation of the proposed strategy, we evaluate with different number of nodes in terms of different evaluation metrics. And In this scenario, the number of nodes is varied and the impact of this variation on the delivery ratio, overhead ratio of the studied strategy is investigated. We applied a set of number of node values as 30, 60, 90, and 120 to evaluate the impact of varying number of nodes on performance of delivery ratio, overhead ratio and hop count whereas other parameters are fixed as TTL is 300 hours (h), message size is 0.5 - 1 MB, message generation interval is 200- 400 seconds, different buffer size with the values as 3 MB and 9 MB.

The results are captured in Figure 4.5, and Figure 4.6 respectively. Also as shown in Figure 4.5, the impact of number of nodes on delivery ratio using different buffer size as 3MB, different message size and TTL is 300 h increasing along with increasing in number of nodes on both routing strategies. Moreover, in Energy Efficient Routing and Per Hop Routing, the delivery ratio increases while using 9MB of buffer size and the number of nodes increases.

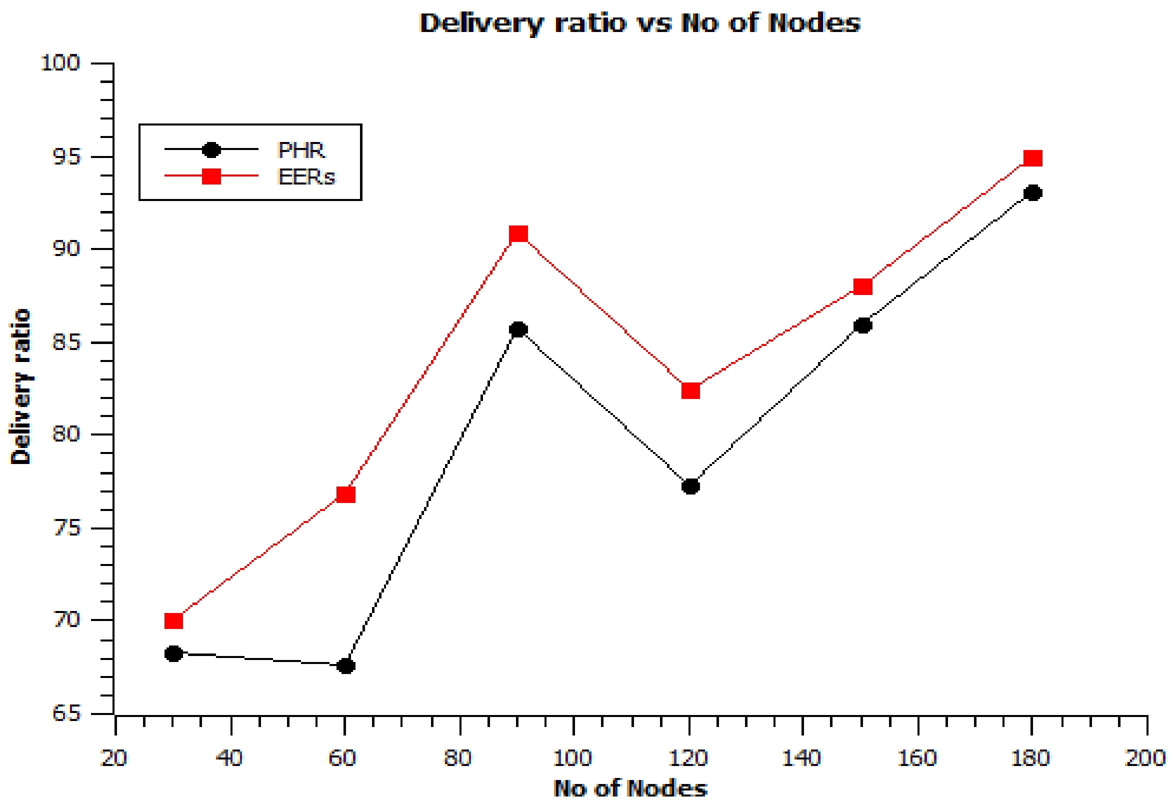

Figure 4.5: Impact of number of nodes on delivery ratio using buffer size as 3 MB

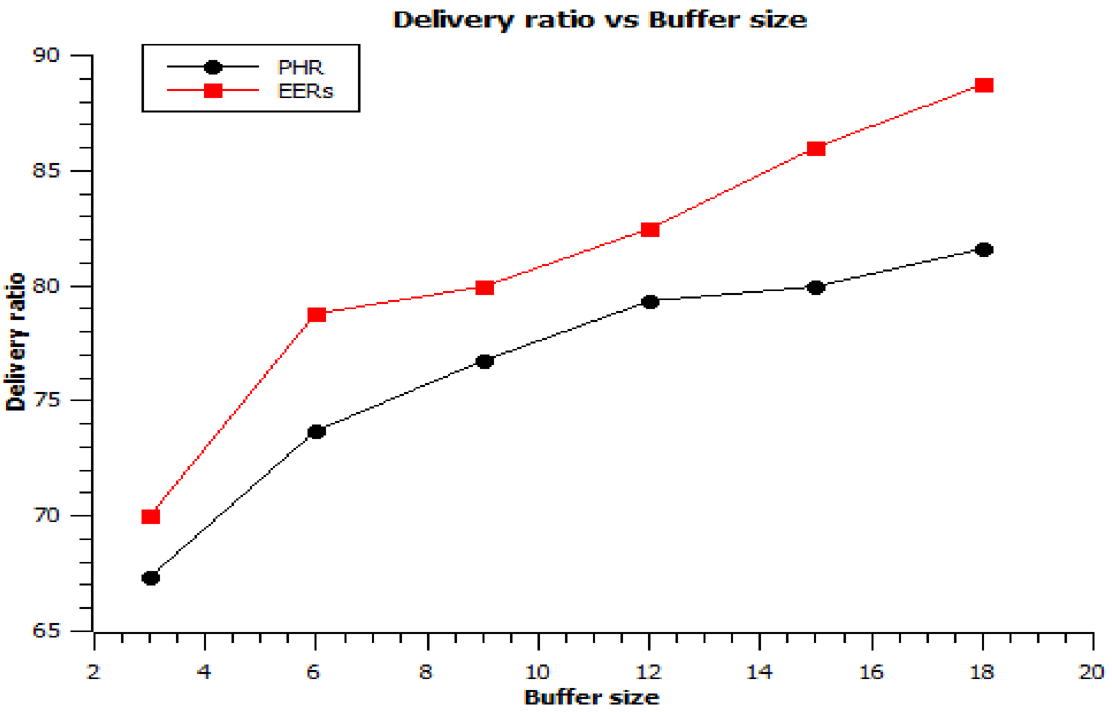

Figure 4.6: Impact of number of nodes on delivery ratio using buffer size as 9 MB.

In Figures 4.5 and 4.6, there are two different results since Per Hop routing and Energy efficient routing (EERs) go up by increasing the number of nodes due to their behavior as both protocols distribute forwarding and limited messages. For the same reason the overhead ratio go up which the number of nodes increase as shown in Figure 4.7.

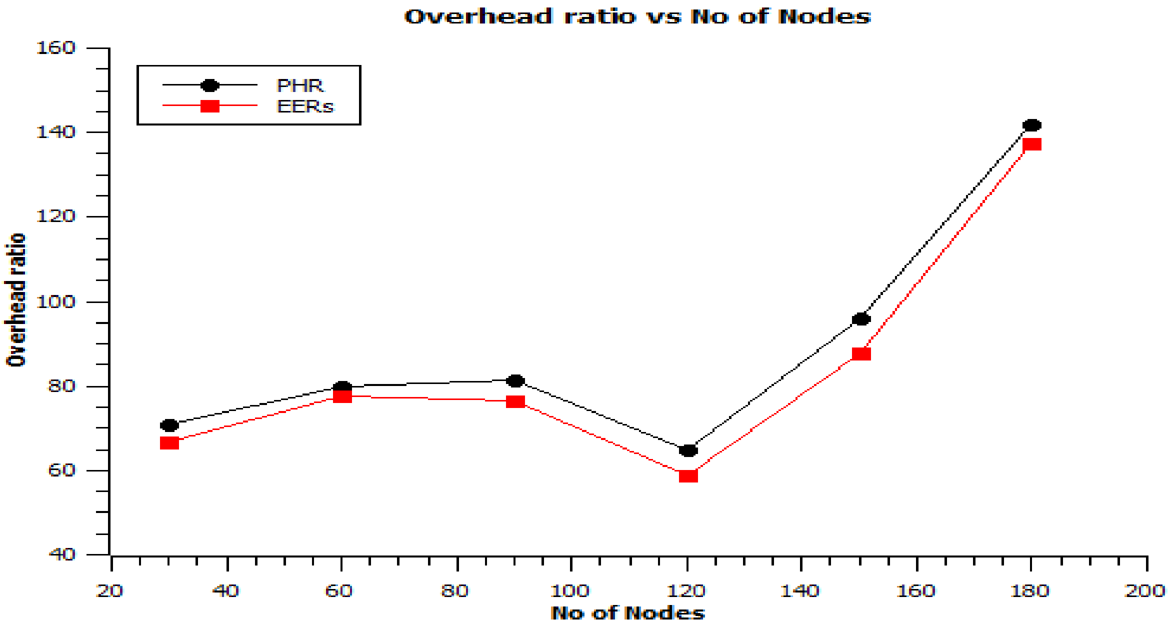

Figure 4.7: Impact of number of nodes on overhead ratio using buffer size as 3 MB

4.6.2 Impact of Message Size

In this experiment, we mainly explore the impact of message size on routing performance of different routing strategies and the value of message size in the network is set to 500, 600, 700, 1000, 1300, and 1600 KB respectively. Figure 4.8, 4.9 explain the change of the delivery ratio within a scenario where the number of nodes in the network is 30, 60, 90, and 120 respectively.

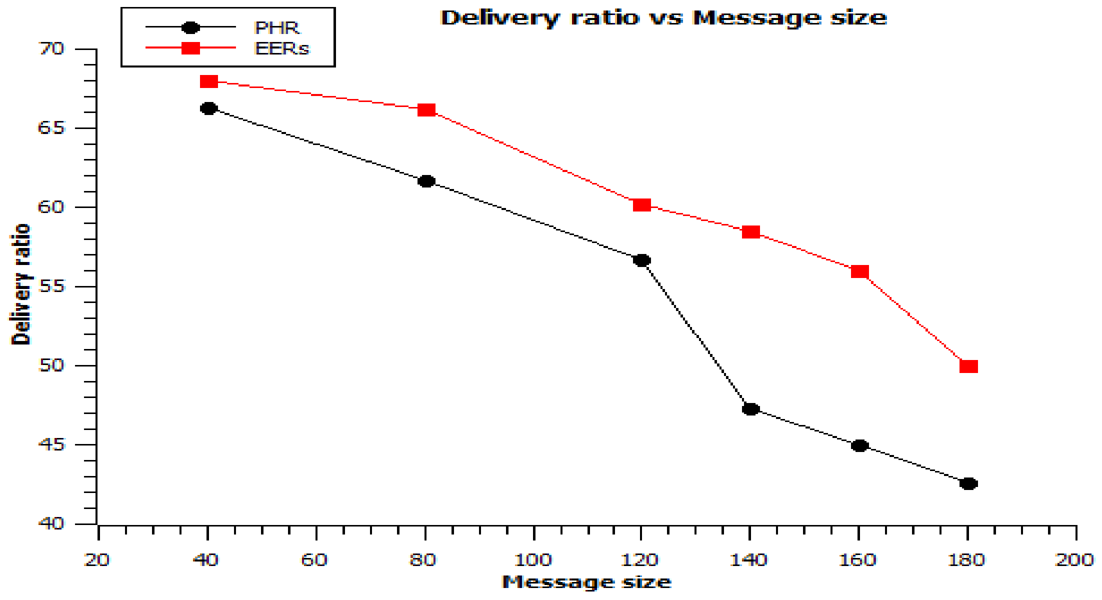

Figure 4.8 Impact of message size on delivery ratio using different buffer size.

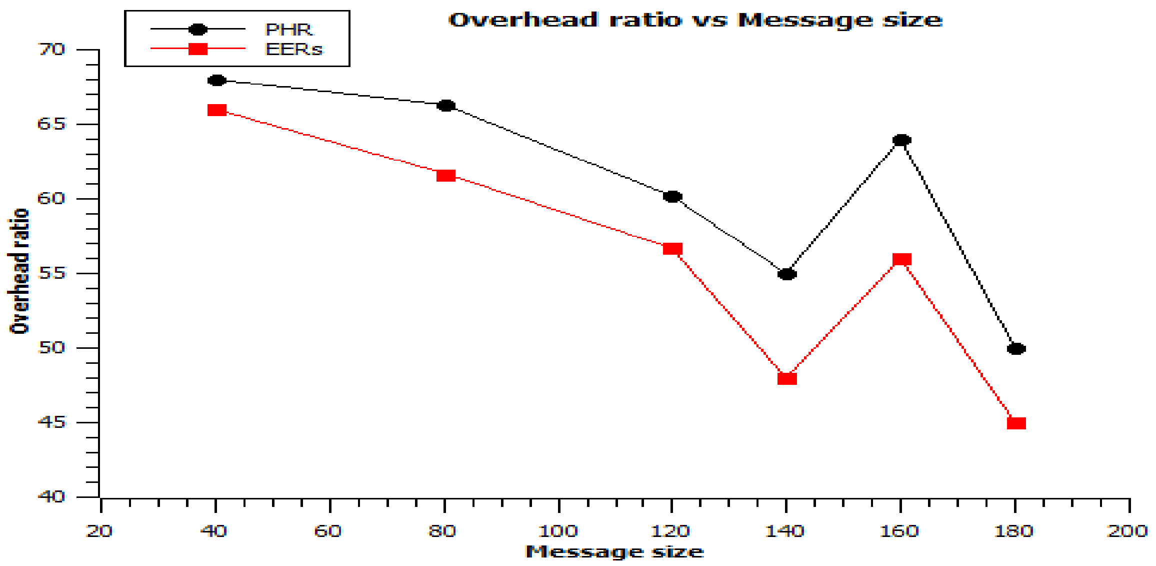

Figure 4.9 Impact of message size on overhead ratio using buffer size

In Figure 4.9 shows the change of the overhead ratio for different routing strategies with nodes in the network, as the message size increases. With the increase of message size, we can see clearly that the delivery ratio of different routing strategies shows a decreasing trend. The main reasons for this phenomenon are shown as follows:

Firstly, as the message size increases, the energy consumed to forward or receive a message would increase. Thus, nodes' energy would be consumed faster and these nodes would become useless soon when the residual energy of these nodes is drained. Similarly, the lifetime of the whole network would become shorter. Therefore, the messages stored in the nodes whose residual energy have been drained would lose the opportunity for being successfully delivered. In the whole network, the number of messages being successfully delivered to their destination nodes would decrease, and the delivery ratio slopes as well.

Secondly, as the message size increases, the number of messages that a node can store becomes less. Thus, a message would have less relay nodes to help deliver it to its destination.

Thirdly, as the message size increases, the time required to forward or receive a message would become longer. When the movement speed of nodes is constant, as the message size increases, any two encountered nodes in a pair are more likely to leave the communication range of each other in the process of forwarding or receiving a message, which may interrupt the message transmission and cause the transmission failure.

Therefore, as the message size increases, the number of messages that are successfully delivered to their destinations or successfully transmitted to other relay nodes will separately decrease. Hence, the delivery ratio of each routing algorithm decreases to different extent with the increase of the message size.

From Fig. 4.9, we can see that the overhead ratio of each routing algorithm is descending to different extent, as the message size increases. The main reason for this phenomenon is that the probability for successfully forwarding a message decreases with the increase of message size. Thus, both the number of messages being successfully transmitted to other relay nodes and the number of messages being successfully delivered to the destination decrease, as the message size increases. As a result, the overhead ratio of each routing algorithm decreases.

4.6.3 Impact of Message Generation Interval

To evaluate our work and get better result during simulation of the suggested energy efficient routing strategy (EERs), we evaluate with different message generation time in terms of different performance evaluation metrics.

In the configuration file we set different message generation interval in second that determine amount of message should create when the proposed strategy start to run. These message generation intervals such as 200-300, 200-400, 300-400 and 400-500 are created different amount of message in the network as reveals in Table 4.4. These message generation intervals show that as message generation time increase the amount of message created decrease in the network. Similarly, smaller message generation time will create more message in the network. For example, at the simulation time of 6000 second in the Table 4.4 below reveals different results of delivery ratio, overhead ratio, and hopcount with different simulation time in different message generation time.

In Table 4.4 we find that different delivery ratio for different message generation time intervals. For example, with 200-300 second message generation time interval resulted 56%, 50%, 66%, 77%, 80%, and 75% delivery ratio for 4000, 6000, 8000, 10000, 12000, and 14000 simulation end time respectively. Also the table shows different delivery ratio results from other different message generation time interval such as 200-300, 200-400, 300-400 and 400-500 with different simulation end time. For example at event interval of (200-400) delivery ratio for 4000, 6000, 8000, 10000, 12000, and 14000 are 75%, 81%, 92%, 94%, 85% and 84% respectively. From these result we concluded that message generation interval has its own impact on the evaluation of proposed EERs algorithm in message generation interval.

Then as the result in the show that 200,400 message generation frequency is better event interval to achieve better delivery probability. In addition to this from the results we also concluded that as message generation time increase the delivery ratio of messages decrease. Consequently at the (200-400) message generation interval the delivery ratio is better than other message creation time intervals for all simulation end time. As a result, at the (200-400) event interval EERs have capability of 90% delivery ratio at 10000 seconds simulation end time which means that 90% of messages delivered to respective destination from total message created during the simulation time . Here when we simulate with above and below 200-400 time interval, the delivery ratio decrease. At the same time we evaluate this work in terms of overhead ration with different message generation interval.

In the Table 4.4 also we show that evaluation result of EERs in terms of overhead ratio at different message generation time with different simulation time. Here the overhead ratio is less at (400-500) message generation time intervals. In this table we find better result in terms of overhead ratio at (400-500) event interval. However, at (200-400) interval time at 10000 simulation end time there is less overhead ratio than all intervals time and all simulation end time which is 62. So, from this result we concluded that EERs achieve better performance in terms of overhead ratio at (400-500) message generation interval.

Generally, the message generation interval has an impact on EERs in terms of overhead ratio. The indication of the impact of message generation interval is not limited with delivery ratio and overhead ratio but also continue to hopcount metric. Message generation interval also has an impact on the hopcount metric which is numerically show in the Table 4.4 below from different message creation interval and simulation of our scenario. As show in this table the hopcount of message until it reaches to respective destination is high at message creation time interval of (200-400) which is better event interval than other that computed in the table.

Thus, when compared hopcount of all message generation time interval with each other to show the impact of the average result of (200-400) interval is higher than other intervals. Hence, the message generation intervals have performance evaluation impact on the EERs in terms of hopcount because the increment of hopcount defines that there is high cooperation among nodes in the network in which message travers through a number of relay nodes to arrive at destination.

Simulation time	**Evaluation metrics**	**Message generation interval**			
		200-300	200-400	300-400	400-500
4000	Delivery ratio	56	75	62	70
	Overhead ratio	95	71	83	67
	Hopcount	3	8	6	8
6000	Delivery ratio	50	81	70	76
	Overhead ratio	105	80	77	72
	Hopcount	4	8	6	8
80000	Delivery ratio	66	92	76	81
	Overhead ratio	90	78	76	65
	Hopcount	4	7	5	7
10000	Delivery ratio	77	94	75	90
	Overhead ratio	93	62	79	73
	Hopcount	4	7	4	6
12000	Delivery ratio	80	85	80	81
	Overhead ratio	127	109	64	66
	Hopcount	4	6	4	6
14000	Delivery ratio	75	84	75	73

	Overhead ratio	160	189	123	72
	Hopcount	4	6	4	5

Table 4.4 Impact of message generation interval on the performance of EERs

In general, the performance of EERs also explored with graphs to show the overall difference among message generation intervals in terms of evaluation metrics.

In the Figure 4.11 the delivery ratio of EERs degrade as increasing the number of messages created in the network because of increasing message generation time interval. For examples, the delivery ratio of EERs is better at 200-400 interval with different simulation end time than 200-300,300-400 and 400-500 message generation frequencies. Also the overhead ratio of EERs increase as reducing message creation frequency as in Figure 4.12. For example, at 200-300 event interval time, is higher than 400-500. In Figure 4.13 also shows the impact of message generation interval on the performance of EERs in terms of hopcount. As a result, the performance of EERs also influenced by the message generation interval. In general, EERs achieved effectively at message generation interval of 200-400 seconds in terms of all evaluation metrics except overhead ratio which less at 400-500 intervals which is an optimal message generation interval for this work.

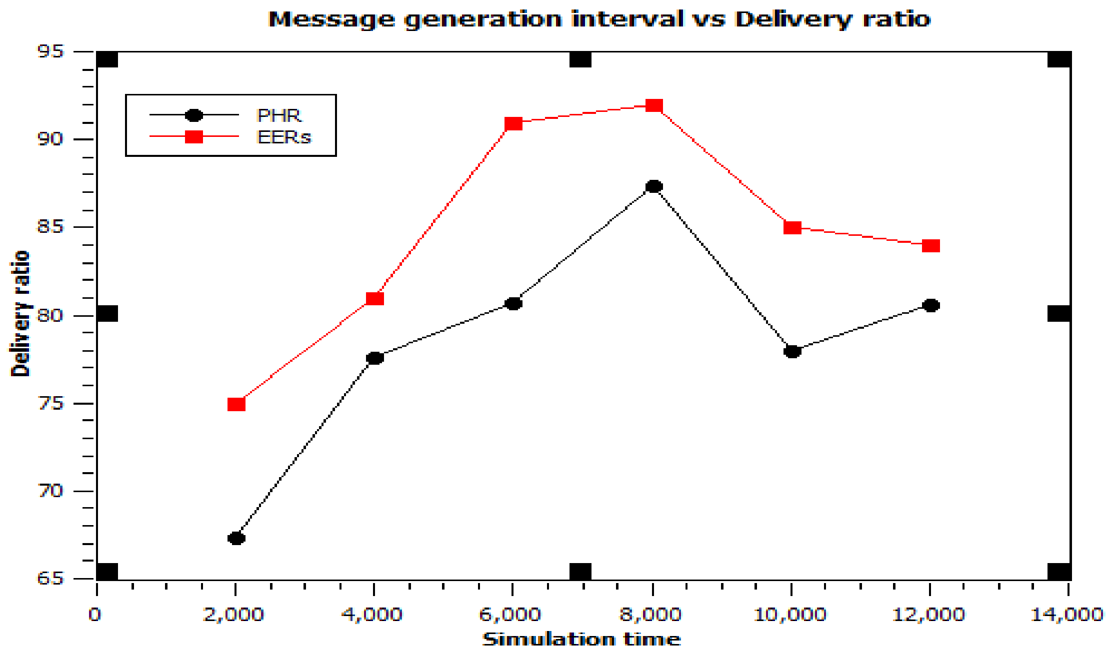

Figure 4.10 Impact of message generation interval on delivery ratio

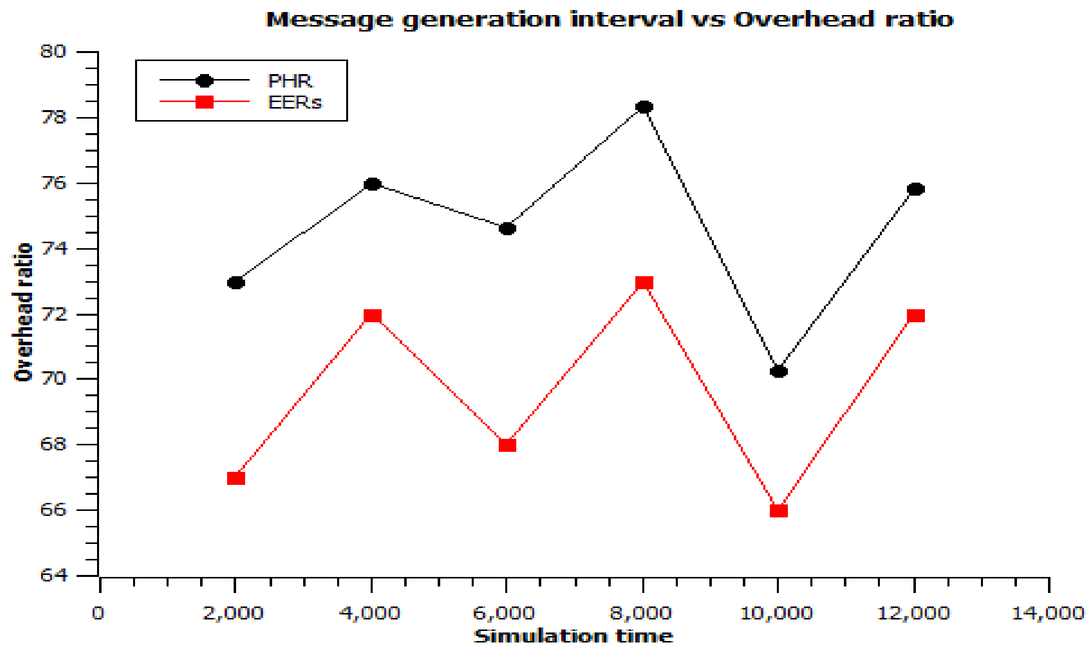

Figure 4.11 Impact of message generation interval on overhead ratio

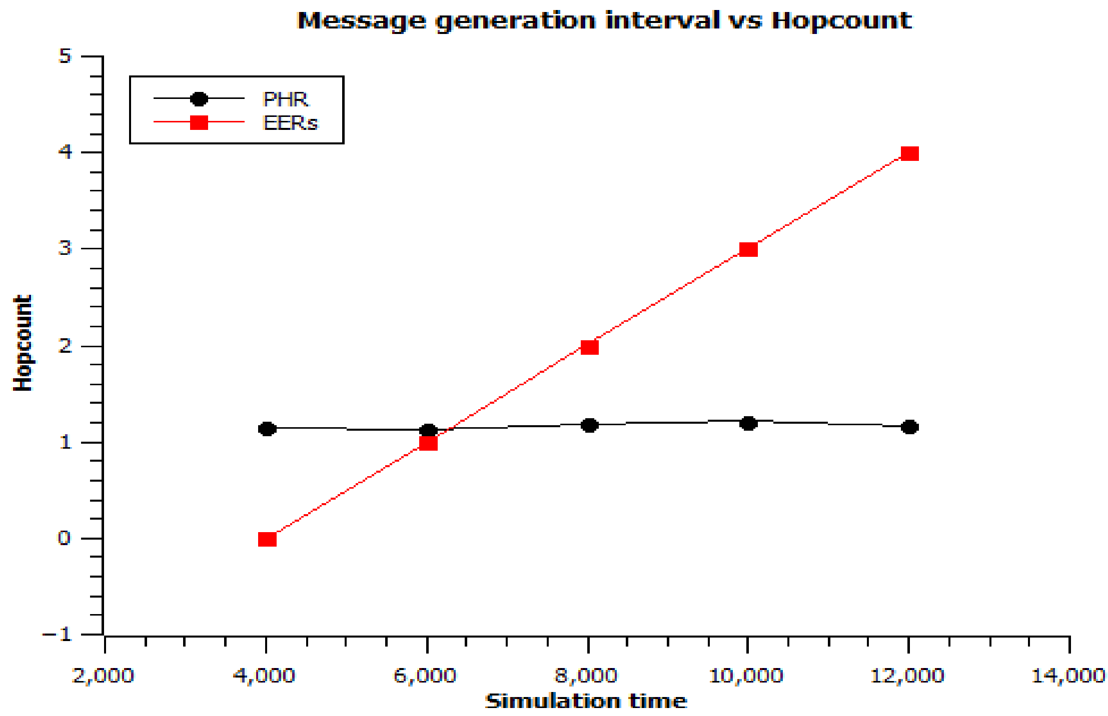

Figure 4.12 Impact of message generation interval on hopcount

CHAPTER 5

CONCLUSION AND FUTURE WORK

Delay tolerant networks are scatter host networks in which an end-to-end connection between source and its destination may not exist. The hosts in DTNs are required to transmit and hold on data bundles until it comes in contact with another host.

And in our study set out to examine the energy efficient routing strategy to challenge routing issue in DTNs for delivering message to the target node.

In this study we proposed the energy efficient routing strategy that employed per hop routing strategy for forwarding messages based on single message transmission for proper use of the node energy resource. And when the node forward the message based on its high forwarding capacity it provides forwarding messages to the next and destination node.

The simulation results demonstrate that energy efficient routing strategy stimulates node energy important to deliver message in routing process in the network and it improves the routing performance significantly in terms of performance evaluation metrics such data delivery ratio, overhead ratio and hop count.

Generally in this study, we discuss energy efficient routing strategy (EERs) scenario and concentrate on the routing of nodes based on their forwarding capacity criteria in terms of node energy and distance information. As the result, the evaluation reveals that EERs proposed routing strategy makes efficient routing and performs better network performance than compared routing strategy with higher delivery ratio, less overhead ratio.

And recommendations for future research and development studies regarding DTN must aim towards further investigation in developing new routing strategies especially intelligent energy efficient routing protocols which take into deliberation the rate of energy remaining in various nodes in the network. Also for this study for more full knowledge of routing strategy in the network topology we considered again is about energy and buffer space constraints.

Finally, in the future study the area is also desirable to make security issue for instance, by implementing a cryptography-based technique that protects the messages before their transmissions and checks the authenticity of the sender of the message.

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