JIMMA UNIVERSITY
JIMMA INSTITUTE OF TECHNOLOGY
FACULTY OF COMPUTING AND INFORMATICS

Enhancing the performance of Opportunistic Mobile Social Network using Social based Message dropping policy for simBet routing protocol

By

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

August 30, 2021

Jimma, Ethiopia

JIMMA UNIVERSITY

JIMMA INSTITUTE OF TECHNOLOGY

FACULTY OF COMPUTING AND INFORMATICS

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This is to certify that the thesis prepared by Girma Bula, entitled as '(**Enhancing the performance of Opportunistic Mobile Social Network using Social based message dropping policy for simBet routing protocol)**' and submitted in partial fulfillment of the requirements for the Degree of Master of Science in Computer Networking complies with the regulations of the University and meets the accepted standards with respect to originality and quality.

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ABSTRACT

Opportunistic network is network of wirelessly connected nodes in specific area and the topology of the network is changed due to the mobility of the nodes. Opportunistic networks use store-and-carry forward mechanism to deliver message from source to destination. This network is extension of wireless multi-hop mobile ad-hoc networks and a part of delay tolerant networks (DTN). Routing in opportunistic network usually utilizes multiple message copies in order to guarantee the data delivery. But, data delivery is affected by limited storage in the network due to storage congestion problem. To overcome this problem proper buffer management should be used on the selected routing protocol.

Authors in this area proposed different message dropping policies for buffer managment to drop the right message from the buffer when buffer is full in order to accept the incoming message. But the problem is which message should be dropped frist without affecting network performance is an important task. This research work proposed social based message dropping policy for SimBET routing protocol by combining message remaining time to live with node SimBET utility. Therefore Social based dropping policy drops a message having least Remaining time to live and node SimBET utility because they have lowest delivery probability.

The study uses the ONE network simulator tool to conduct experiment in order to evaluate the performance of proposed dropping policy with existing dropping policy. the simulation result shows the proposed SMDP dropping policy performs better interms of message delivery in the network by varying message time to live and buffer size of the nodes then the result report shows the Average delivery of message by varying TTL is 73.93% in number 5401 messages are delivered for SMDP and 73.79% or 5391 messages are delivered for TTL based dropping policy and by varying buffer size 75.85% in number 5541 messages are delivered for Social based Message Dropping Policy and 75.52% in number 5517 messages are delivered for TTL based dropping policy for simulation time 43200s or 12hr. Thus the result shows the proposed SMDP performs better than the existing dropping policy interms of Delivery ratio, Overhead ratio and Average hop Count using two scenarios TTL varying and Buffer size Varying.

Keywords: ***Oportunistic network, SimBET Routing Protocol, Social based Message Dropping policies, Storage Congestion, Delay Tolerant Network.***

ACKNOWLEDGMENT

First of all, I would like thanks to almighty God, for helping me throughout my study in every aspect of my life. Secondly, I would like to give my special gratitude to my Advisor Esmail Kedir [Phd Candidate] and Co-advisor Mr.Getahun Abera for their guidance and encouragement comments throughout the preparation of this thesis work completing it successfully.

At last, I would like to thanks all my friends who are constantly encouragement me during all my thesis work and others Jimma university staff members who have give me suggestion and comments.

Thank you All!!!

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ACRONYMS

AD	Average Delay
AHC	Average Hop Count
BS	Buffer Size
DF	Drop Front
DP	Dropping Policy
DR	Delivery Ration
DTN	Delay Tolerant Networks
LAN	Local Area Network
MANET	Mobile Ad-hoc networks
OMSN	Opportunistic Mobile Social Network
OR	Overhead Rario
RTTL	Remaining Time to Live
SMDP	Social based Message Dropping Policy
SESN	Spontaneous &Ephemeral Social Network
SimBET	Similarity and betweenness
TTL	Time to live
VANET	Vehicular ad-hoc Network

CHAPTER ONE

1. INTRODUCTION

1.1 Background of the study

To bring communication in the areas where no infrastructure exists and where the cellular network infrastructure has become inefficient due to too many requests new communication paradigm is used which is formed due to the rapid increasing of personal mobile devices with different wireless communication. This enables the development of novel applications and services where devices can exchange messages in an opportunistic ad hoc manner by relying on node mobility [1].

Personal mobile devices are one of the objects that have become pervasive and an inseparable part of our daily lives. These devices have evolved rapidly from simple phones and SMS capable devices to smartphones that we use to connect, interact and share information with our social circles. The smartphones are used for traditional two-way messaging such as voice, SMS, multimedia messages, instant messaging or email. Moreover, the current advances in the mobile application development frameworks and application stores have encouraged third party developers to create a huge number of mobile applications that allow users to interact and share information in many new ways. [2]

In rapid increasing of personal mobile devices with different wireless communication is enabling reason for the developments Opportunistic Network. In such types of network communication is through opportunistic contact and store–carry-forward paradigm the advantages of opportunistic communications include potentially high capacity, low cost, localized communications, fully decentralized operation and independence of any infrastructure. These benefits are directly related to the varying capabilities of the available networking technologies [3].

The Opportunistic networks are temporarily associated mobile ad-hoc networks. They are extension of wireless multi-hop mobile ad-hoc networks and a part of delay tolerant networks (DTN). In these networks, the probability of end-to-end path establishment is very low for message forwarding to take place that is establishing and maintaining end-to-end path is not feasible at all times because of mobility of nodes and entry/exit of nodes in the general area of interest. Mainly, the forwarding of messages takes place in a hop-by-hop manner. Each node is responsible for selection of next hop for forwarding the message [4]. Today's wireless devices, for example smart phones, have inherently variable performance characteristics in terms of bandwidth, radio range, reliability, battery usage etc. due to several network interfaces.

Authors in Opportunistic Network focus in a single research field in which all the challenging problems in the networking research community was concerned about designing different routing protocol [5] such as flooding, prediction and social based are mostly used routing strategies. They are able to decide whether to forward the data to the counterpart when two nodes encounter [6] [2]. In opportunistic network since nodes are mostly controlled by humans there are plenty of social relationships and properties which may be used to facilitate the data routing using Social based routing algorithms. These algorithms are particularly suitable for opportunistic networks because of the social-aware opportunistic routing solutions have shown great potential in information delivery. Due to the social information is much less volatile than human mobility and the rapid increasing of social network applications and mobile device users increases contact opportunity [7] [2].

However, in opportunistic network even if heuristic Social based Routing protocols are designed they only perform well in areas of unlimited resources [8]. But, when resource is limited the performance of the network or the routing protocols are affected [5]. In opportunistic network the design of routing protocol has to include different complimentary components and it has to be designed by including dropping policy [5], message forwarder [9] and Replication method [1] to give an integrative solution for different challenges. Where each of the components are designed for specific challenge such as dropping policy for limited storage, scheduling for limited bandwidth and replication in order to control message copies. But only an effective combination of the complementary components can improve the performance of routing protocol [1].

In particular when SimBET (Similarity and betweenness) routing protocol is used in opportunistic network area having limited storage and dynamic topology the performance is poor [1]. In order to improve the performance researchers design SimBET multi-copy routing protocol with replication method which performs better in sufficient resource but it will perform poor in areas where there is limited storage, Patel, Gondaliya et.al. have recommended designing buffer management for SimBET routing protocol [8]. Buffer management includes both scheduling and dropping policy together. Where dropping policy is needed since nodes in opportunistic network have limited buffer in order to cooperate or accept incoming message during full storage space, dropping policy drops the right message from the buffer without affecting network performance. Unless the performance of the routing protocol is affected by dropping policy they used [10].

Since, existing dropping techniques in the literatures may drop a message having a higher probability of being delivered to the destination than the messages in stored in buffer based on SimBET routing protocols information, which affects the performance of SimBET routing protocol. So this study has designed dropping policy that can improve the performance of SimBET routing protocol by including node SimBET utility in dropping policy with remaining time to live.

1.2 Statement of the Problem

In SimBET routing protocol that replicates message proportional to node SimBET utility in the area of opportunistic network where the storage of the nodes are not enough to support the overall traffic load, it results frequent message drop at the nodes which compromises the low delivery ratio and high delay and hop count. This is due to SimBET routing is theoretical design with the assumption of unlimited resource. So using SimBET routing in areas where nodes having a limited buffer size, it needs dropping policy that manages nodes storage congestion problem.

Nikhil Gondaliya et. al. [8] in the area used time to live (TTL) dropping policy with SimBET multi-copy routing scheme with SimBET routing protocol in order to control nodes storage congestion which drops message with expired TTL. But from literature review the study generalized this dropping policy is simple which perform poorly in opportunistic network [10]. This is TTL dropping policy for SimBET routing protocol will drop message only TTL expire message in the buffer but this message may cause the storage congestion problem [8]. Waiting until the message TTL expire may block the new incoming message which has high probability of being delivered to the destination than the messages which are stored in buffer. Even if SimBET routing protocol delivers a message based on SimBET utility, when buffer is full the TTL dropping policy doesn't consider node SimBET utility. This will affect the performance of SimBET routing protocol. If TTL is not set, routers use infinite as a default TTL value. and if we don’t set the Dropping policy for SimBET router it will use the default dropping policy which is called Default dropping policy which drops the oldest message when the buffer is full. [10] This message may have a probability to reach its destination thus it affects the delivery ratio of the network.

1.3 Research question

Literatures have recognized that storage congestion is the frequent problems in mobile social network. To eliminate this problem they have designed different message dropping policies for different routing protocols in opportunistic network. But their solution is not sufficient since it does not consider SimBET Utility. To address this problem, this thesis is looking to use SimBET Utility and RTTL (Remaining TTL) based dropping policy to maximize the delivery ratio and minimize overhead ratio, delay and average hop count for SimBET routing protocol in opportunistic mobile social network.

The specific research questions to be answered in this thesis are:

RQ1: How can the existing dropping policies are working and what’s makes them to score poor performance?

RQ2: What performance improvements are gained by the use of "SMDP" in terms of average Delivery Ratio, Overhead Ratio, Average Delay and Average Hop count?

RQ3: How does the performance of "SMDP" vary with algorithm parameters (such as TTL and buffer size), with movement model and traffic load?

1.4 Objectives

1.4.1 General Objective

The objective of this thesis is to enhance the performance of SimBET routing protocol using SimBET utility based message dropping policy in the area of limited storage space opportunistic mobile social network (OMSN).

1.4.2 Specific Objectives

- To preview opportunistic mobile social network
- To Design SimBET utility and RTTL based Message dropping policy for SimBET Routing protocol for opportunistic mobile social network .
- To evaluate the performance of the proposed Message Dropping policy over SimBET routing protocol.
- To compare the performance of the proposed Dropping policy with existing Dropping policies.

1.5 Significance of the study

In opportunistic mobile social network Storage and energy is scared resources as stated in Michael F. et.al.[11]. In this type of network storage congestion problem is a frequent problem due to nodes limited buffer size thus to eliminate this problem the proper message dropping policy is needed as clearly stated in literature review. Thus the proposed SMDP dropping policies have solution for opportunistic mobile social network by mitigating the storage congestion problem maximize the delivery of data or message in the network.

1.6 Scope and Limitations

The scope of this research work has developed dropping policy based on SimBET utility to drop the right message from the buffer during storage congestion occur with respect to achieving high delivery ratio, low Overhead ratio, low delay and low Average hop-cont when SimBET is use as routing protocol in opportunistic mobile social network. As limitation the research work doesn't include the effects of limited energy and limited bandwidth on performance of SimBET routing protocol.

1.7 Thesis Organization

This research work primarily focuses on the design of the SimBET Message dropping policy based on SimBET utility and RTTL, and the resultant achievable high delivery ratio and low overhead ratio in opportunistic mobile social networks. Organization of the thesis is as follows,

This research work composed of five chapters. The first chapter one describes about the introduction of the thesis. It introduces problems of statement, research work aim, Significance of the research work, research work scope and limitation of the research work.

In Chapter two, the research work reviews different papers and clarify what is DTN and OPPNET and different routing protocols in opportunistic networks.

In chapter three it describes different dropping policies available in opportunistic network then mentions the related work done in opportunistic and research gaps.

In chapter four the study design the SimBET message dropping policy (SMDP) by combining SimBET utility with Message remaining time to live. Here how the existing dropping policies and the proposed dropping policy are working is discussed. What algorithm is used for the proposed dropping policy is answered at this chapter.

Chapter five describes detail about the simulator used in this thesis with simulation set up and configuration, simulation tools and simulation parameter are presented in this chapter later discuss about the results of the simulation based on the simulator report generated. Here the simulation is compiled with two scenarios one is by varying the message time to live value over the limited buffer size and varying the buffer size over constant message time to live and evaluation is done in case of delivery ratio, overhead ratio, average delay and average hop counts. Based on the results gain from the simulator discuss about the results briefly included in this chapter.

In Chapter 6 the conclusion of the proposed scheme in the thesis are summarized and suggest some recommendations for future work.

CHAPTER TWO

2. LITERATURE REVIEW

2.1 Delay Tolerant Network

In recent years, there has been a remarkable increase in the number of mobile devices, and these devices have the capability to communicate with each other using peer-to-peer technologies such as Bluetooth and Wi-Fi hotspots these technologies enable us to communicate wirelessly. In field scenarios there may not be any centralized network like LAN to facilitate connection among these devices. Therefore it is necessary to pass on important information from the source device to the destination using wireless links. In such cases, the mobile devices can form their own wireless opportunistic network referred to as Delay Tolerant Networks (DTN) [12][13].

Delay or disruption tolerant networks (DTNs) have recently drawn much attention from networking researchers due to the wide applications of these networks in challenging environments, such as space communications, military operations, and mobile sensor networks DTN is formed by a collection of nodes and each node interacts with other nodes only when they are within a short distance. Unlike traditional end-to-end connections, DTN has intermittent connections only when two nodes are nearby each other. Instead of seeing the intermittent connection as a disadvantage, DTN utilizes it for sharing relevant information between the nodes to forward the message to the destination node. Thus, message transfer from a source node to the destination may pass on through various intermediary nodes resulting in delay and significant data loss [14].

2.1.1 Features of Delay Tolerant Network

i) Intermittent connectivity

Due to limitation of mobility and energy of nodes, DTN frequently disconnected, thus resulting in continue change in DTN topology. This means the network keeps the status of intermittent connectivity [15] and partial connection so that there is no guarantee to achieve end-to-end route.

ii) Limited resource

The nodes in DTNs are mobile and thus, they have limited resources. . For example, to forward packets to the next node, the data should be safely stored within the current node until the connectivity to the next node is available and establish. However, new data can be received and collected which occupy another part of the buffer space. Therefore the limited memory capability will restrict the data buffering.

iii) High delay, low data rate

End-to-end delay indicates that the sum of the total delay of each hop on the route. Each hop delay might be very high due to the fact that DTN intermittent connection keeps unreachable in a very long time and thus further leading to a lower data rate and showing the asymmetric features in up-down link data rate.

DTN applications areas can be classified in two categories.

- i) Deterministic routing protocol: Complete knowledge of node trajectories, encounter probability of nodes and node meeting times and period to make the forwarding decision.
- ii) Non-deterministic routing protocols: Zero knowledge of predetermined path between source and destination.

In Deterministic routing protocol it is based on the knowledge of the topology the node has in the network at given time. If the topology is deterministic and known, the required forwards can be scheduled ahead of time; examples of such types of network are Inter-planetary and satellite networks. In this network Data delivery is by using store and forward mechanisms used where there is no available line to the known next hop, therefore messages are stored in the node buffer and waiting for next contact event. On the other hand routing protocols relying on known contact schedules (Non-deterministic) or controlled node movement, scheduled type of contacts are more compliant to the DTN Architecture model. This type of architecture includes: end-to-end acknowledgments and integrates simple storage congestion notification mechanism based on identifying local storage congestions and notifying the involved peers [16].

2.2 Opportunistic Network

Opportunistic Network Topology is unpredictable and unknown. Generally opportunistic network shares the idea of DTN which uses store-carry and forward paradigm but are designed with the assumption of more unpredictable mobility [2]. Communication is achieved though node mobility combined with store-carry-and-forward mechanisms where nodes in such types of network store message in the buffer and carry to forward messages between disconnected areas. Such types of network are using in packet-switched networks or human network [14] and vehicular networks (VANET) [10].

DTN Architecture is working well in the area of scheduled type's topology but it has challenges in the opportunistic network, since opportunistic network has some characteristic that is distinct from scheduled type network. This is due to characteristic very large delays, intermittent and different network architectures [2].

Additionally nodes in such network are small form factor will always introduce resource limitations in storage space and energy [7] [15]. So it is not feasible to apply storage congestion control based on the aforementioned end-to-end manner rather, it is important to apply storage congestion control at node level [8].

2.2.1 Opportunistic Communication

Today mobile computing devices are equipped with multiple radio interfaces including cellular radio, 802.11 (Wi-Fi), Blue-tooth and Infrared. Blue-tooth and Wi-Fi are only used for opportunistic communications [6]. But no unique technology can be effectively used for opportunistic communication; every technology has its own limitations. So the authors address this difficulty by integrating all communication interfaces as shown in Figure 1 in SESNs (Spontaneous and Ephemeral Social Networks) framework [17].

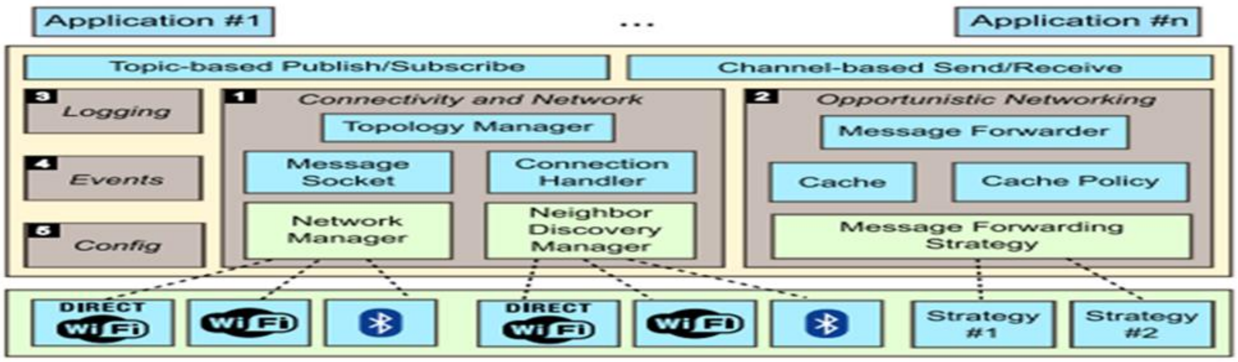

Figure 1 General Architecture of the SESNs Framework

2.2.2 Store – Carry and Forward

Store-carry-forward has become a key concept used in DTN technologies according to the litratures. Store-carry-forward is an asynchronous message passing paradigm that a node follows after receiving a message. The "Store" phase is adding the message to the node's buffer which allows the data to wait for a suitable time or peer to forward the message. "Carry" is the stage that allows the message to propagate to other regions of the network physically through the movement of the node carrying the data instead of relying on its transmission through the limited available network media. Finally, "Forward" is the stage when the node decides to send the message to another node due to the availability of other better candidates or to the message's final destination [19]. Figure 2 clearly illustrates these stages.

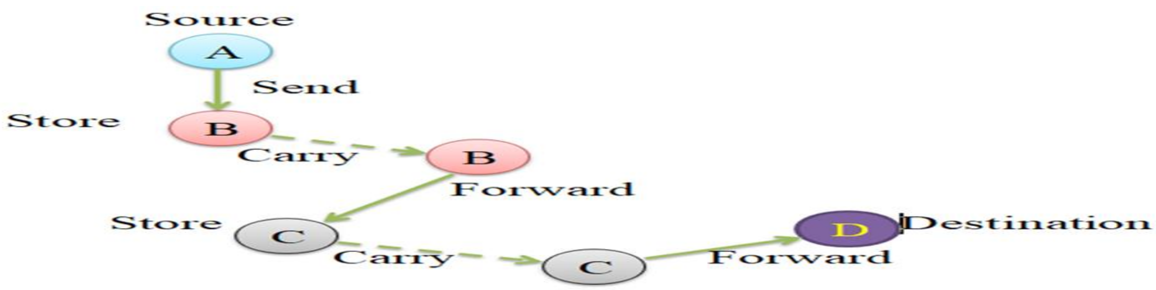

Figure 2 Architecture of Store Carry Forward

2.2.3 Routing in Opportunistic Network

Each routing protocol that has been proposed for Opportunistic Networks can be classified as either single-copy [20] or multi-copy [21], regardless of the heuristic methods that it may use. In single-copy routing protocols, each message is unique in the network. Therefore, when a message is forwarded to a new carrier, the previous one deletes it. On the other hand, in multi-copy routing protocols, each message may have multiple copies carried by multiple nodes in the network. However, the process of replication can be defined variously for each routing protocol.
In the literatures Routing in opportunistic network can be classified based on the choice of the next carrier of a message and they are classified broadly into three [5].

i) flooding based forwarding
ii) prediction based forwarding and
iii) social based forwarding

2.2.3.1 Flooding Based Routing Protocols

In flooding based types of forwarding nodes forward their messages to any encountered node. one of the earliest approaches to handle with the intermittent connectivity of these networks is Epidemic Routing. Each node maintains a summary vector that indicates the messages that it carries. When two nodes meet, they exchange their summary vectors and each node requests copies of the unknown messages that the other node carries. In scenarios without tight resource limitations, Epidemic Routing is able to deliver most of the messages, by spreading them to all the nodes in the network and eventually reaching their destinations. However, Epidemic Routing not only has high overhead due to the many unnecessary transmissions, but the performance may also significantly degrade if the resources are limited [5].
Several routing protocols have been proposed that aim to control the flooding of messages in the network. The Spray and Wait routing protocol reduces the overhead of flooding by bounding the number of copies each message has in the network. The routing process is divided into two phases, the spray phase and the wait phase. In the spray phase, a fixed number of copies of the original message is disseminated in the network. In the wait phase, each node that carries a copy of the message will wait to meet its destination to deliver it directly [22].

2.2.3.2 History or Prediction -Based Routing Protocols

In prediction based types of routing, only the nodes with a higher probability of delivering a message to a destination based on their contact history are selected. The most representative history-based routing protocol is PRoPHET, which stands for Probabilistic Routing Protocol using History of Encounters and Transitivity [5]. This approach is based on the assumption that if two nodes have met several times in the past, it is very likely that they will meet again in the future. Each node maintains a delivery predictability for each known destination, which indicates how likely this node is to encounter a certain destination in the future. When two nodes meet, they exchange their delivery predictabilities so that they can update their estimates. The nodes that are frequently encountered have high delivery predictabilities for each other that decrease over time to avoid obsolete information. A transitive property is also applied to these estimates, so that the messages can be forwarded to nodes that encounter their destinations indirectly. Therefore, each message is forwarded to the node that has the highest delivery predictability for its destination. An improved version has also been proposed, called PRoPHETv2 [23], where the equations that update the delivery predictabilities have been refined to solve two problems that were later observed.

2.2.3.3 Social based-Routing protocol

Social based types of routing get inspiration from social network theory. To be used in Opportunistic network in the area of human carried devices, that take advantage of mobility and social networks to create opportunities for exchanging information is OMSN [6].

Social properties suggest the social status of a node and its relationships to the social network. Typical social properties used for data routing in OMSNs are: node degree, known as the degree of a node in social graph, representing the number of friends; social centrality, suggesting the importance of node in the network, which is defined by many different ways, such as degree centrality, measuring the centrality of a node from the perspective of node degree and betweenness centrality, measuring the connectivity of the node to the rest of the network; social similarity, represented by the common friends of two nodes in social graph [2] [18] [24].

Social based routing algorithms are particularly suitable for opportunistic networks since social-aware opportunistic routing have shown great potential in information delivery. Because social information is much less volatile than human mobility, providing more robust and reliable connectivity graphs that aid routing, the rapid increase in the number of social network users increases contact opportunity. To utilize this advantage in opportunistic networks, many techniques have focused on social based forwarding [6]. The most representative routing social based forwarding is SimBET routing protocol.

The routing protocols that have been proposed for the opportunistic network use various techniques by exploiting the available information in the network, in order to determine if an encountered node is suitable to carry a message to destination.

2.2.4 Simbet Routing Protocol

SimBET is a social-based routing protocol used for opportunistic Networks which uses betweenness centrality and similarity metrics to identify some "bridge" nodes (with high values of these metrics) in networks. To avoid exchanging information of the entire network topology, they only estimated the betweenness centrality for each node N in its local neighborhood. In SimBet routing algorithm, forwarding decisions are based on local calculation and it makes no assumption of global knowledge. "Similarity is measure as number of common neighbor between current node and destination node". Centrality can be measure in three ways:

- Degree Centrality is a measure of direct ties that involve a given node.
- Closeness Centrality is measure as reciprocal of mean geodesic distance, which is shortest path between a current node and all other reachable nodes.
- Betweenness Centrality is measure the extent to which a node lies on the paths linking other nodes [25].

SimBET is a social-based routing protocol used for opportunistic Networks that relies on two social metrics called betweenness centrality and similarity. It calculates these two metrics, through a social graph, that describes the social relations between the nodes in the network. Betweenness centrality is defined as a node has over information flowing between others. The betweenness centrality of node P_i is equal to the number of shortest paths between any pair of nodes P_j and P_k that pass through node $P_{i,}$ divided by the total number of shortest paths [29].

$$C_B(pi) = \sum_{j=1}^{N} \sum_{k=1}^{j-1} \frac{gjk(pi)}{gjk} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots .. (1)$$

In Equation (1) the measure of betweenness centrality requires complete knowledge of the network topology, which is not available in Opportunistic Networks. Therefore, SimBET calculates the betweenness centrality of the ego network which is egocentric betweenness, which uses nodes in its neighbors and all the links among them which the adjacency matrix of the ego network A, the sum of the reciprocals of the entries of A2 [1 - A] is equal to the egocentric betweenness of the ego node [29].

SimBET uses the number of common neighbors to calculate the similarity metric between two nodes x and y. Therefore, based on the adjacency matrix of the ego network, the ego node can calculate its similarity with every node that has met directly [29].

$$P(x, y) = |N(x) \cap N(y)| \qquad (2)$$

Equation (2) calculates the similarity of the ego node with nodes that do not belong in its ego network; it needs a list of indirect encounters through its neighbor. When two nodes meet, they exchange their lists of direct encounters, from which each node can obtain information about its indirect encounters that can be used for the calculation of the similarity metric [29].

2.2.5 Dropping Policy

2.2.5.1 Overview of Dropping Policy

In opportunistic network data delivery is based on store-carry-and-forward. However, in order to achieve these, relay nodes require enough buffer space to store all the messages until the future communication opportunity arises. But nodes in opportunistic network usually have limited buffer size and therefore when the buffer is full nodes cannot exchange all the data which results data loss. Authors proposed dropping policies in order to deal with the buffer overload. When dropping policy is designed, it has to consider in critical to select which message to be dropped without affecting the network performance [29].

2.2.5.2 Existing Dropping Policies

This Section discusses about dropping policies and the methods they used to drop message from the node when node buffer is full. When a new message arrives at a node while buffer is full, the node must drop the stored message(s) to sustain this newly arrived message. The function of good dropping policies is to improve the performance of routing protocol by minimizing overhead ratio and maximizing delivery ratio [8]. The following are list of available dropping policies in opportunistic network which could be possibly used for any routing protocol.

No	Dropping Policies	Description
1	**Drop Random (DR)**	The selection of message to be dropped is in hit and misses order.
2	**Drop–Least-Recently-Received (DLR)**	The message with the long stay time in buffer will be dropped. The idea is that the packet with in buffer for lengthy time has less probability to be conceded to other nodes.
3	**Drop-Oldest (DOA)**	The message with the shorted remaining life time (TTL) in network will be selected to drop.
4	**DL-Drop last (DL)**	It drops the recently received message**.**
5	**Drop front (DF)**	The message that go into first in the queue is to be selected to drop first**.**
6	**N-Drop**	In N-Dropt, the message that achieves N number of forwarding will be selected to drop.
7	**Drop Larges (DLA)**	In Drop Largest (DLA), big size message will be selected in order to drop.
8	**MOFO - Evict most forwarded first**	The message that has been forwarded to maximum number of times will be dropped first.

9	**MOPR - Evict most favorably forwarded first**	Each message in node is related with a forwarding predictability FP, initially assigned to 0.
10	**SHLI - Evict shortest life time first**	The message contain smallest TTL will be selected to drop.
11	**LEPR - Evict least probable first**	"Since the node is minimum amount likely to deliver a message for which it has a low P-value. Drop the message for which the node has the lowest P value."
12	**GBD (Global Knowledge based Drop)**	GBD based on global knowledge about the network state. As global Knowledge is required, GBD is difficult to be implemented, thus, it will serve as a point of reference.
13	**HBD**	A deployable variant of GBD that uses the new utilities based on estimates of *m* and *n*.
14	**FBD (Flood Based Drop)**	FBD accounts only for the global information collected using simple message flooding, that is, without considering past history or other messages.
15	**T-DROP**	It will drop the message which lies in the threshold message size range of buffer.
16	**E-DROP (Equal Drop)**	The Message will be dropped only if its size fall with in an equal or greater than incoming message otherwise no drop.[30].

Table 1 Existing Dropping Policies

2.2.5.3 Types of Dropping Policies

Existing dropping policies can be broadly divided into two categories:

i) the one only depends on local information and

ii) the one which is based on the partial or complete network-wide information [28].

- Local Knowledge Schemes

Most of dropping policies are developed using message attribute. They are a set of message-related information that can be considered to design dropping policies namely the arrival time, replication count, number of previous hops, time to live and message size. In the literatures different dropping policies are designed based on this message related information with different assumptions as shown in the Table 1. These types of dropping policies are independent of routing information. So they used for any routing protocol in the area of limited buffer size [28].

- Global Knowledge Schemes

Global or partial knowledge based dropping policies are designed based on the network-wide information or partial information. Some of them are utility-based schemes, which use the complete information of messages related to the whole network to derive a per-utility for a certain routing metric and manage messages based on the utility. In the literatures different dropping policies are designed based the partial or global information such as encounter based information as shown in Table 1 [28].

2.3 Research Gap

By conducting this literature review, DTN uses hop by hop custody transfer for reliability protocol to transmit missing data. Custody transfer technique has some drawbacks which are; require a large amount of resources in terms of processing and storage, annoying congestion when a network is in the congestion state so node cannot deny custody of the received bundle to ease congestion, low utilization due to limited storage.

As the result of storage congestion, the network performance may be deteriorated due to redundant message duplications and over-use of the central nodes. For further improvement the researchers recommend to apply buffer management [8] which includes of message forwarder or scheduler and dropping policy.

From the literatures we understood that SimBET uses default dropping policy and message forwarder or scheduler called DF/FIFO replacement policies respectively where DF is used as dropping policy when storage is full and FIFO is used as message forwarder policy when contact duration is limited [9]. In this study we have focused only on dropping policy and the details have illustrated in the next chapter.

CHAPTER THREE

3. RELATED WORK

3.1 Overview of Dropping Policy

Data delivery in opportunistic network is based on store-carry-and-forward. However, in order to achieve these, relay nodes require enough buffer space to store all the messages until the future communication opportunity arises. But nodes in opportunistic network usually have limited buffer size and therefore when the buffer is full nodes cannot exchange all the data which results data loss. Authors proposed dropping policies in order to deal with the buffer overload. When dropping policy is designed, it has to consider in critical to select which message to be dropped without affecting the network performance.

Md. Sharif Hossen et.al. proposed a set of dropping policies for different routing protocols and also new dropping policies are developing currently in the area. The performance of new dropping policies should be compared with frequently used in existing dropping policies which are listed in Table 1. They give different results depending on the environment (Traffic load, node density, buffer size and TTL) in opportunistic network. To evaluate the performance of the droping policies appropriate routing protocol should be selected first.
Anna-Kaisa et al, [6] proposed the problem of congestion control in Opportunistic Networks and they propose a new congestion control mechanism with adjustable fairness, which provides a trade-off between efficiency and overhead. The proposed mechanism achieves high delivery ratio and low delay, without excessive use of the most important nodes, by taking into account the destination of each message and the saturation state of each node. Finally, they show that they can significantly improve the performance of the network with a slight distortion of fairness.

M. Zarafshan-Araki et al, [10] proposed an efficient buffer management scheme for DTN routing, particularly in the context of real DTN deployment. It comprises of intelligent decisions for message transfer and message drop for buffer management, as well as a smart relay selection for routing. They have compared the performance of their scheme with six other buffer management schemes and have shown that their scheme outperforms them significantly.

Anand Nayyar , Ranbir Singh Batth , Dac Binh Ha and G. Sussendran et al, [26] they have proposed Simulation based performance analysis ensures that as compared to Epidemic Routing and PRoPHET routing protocol, they conclude that SimBet performs better in terms of number of messages delivered, Average End-to-End Delay, Average number of hops per message and total number of forwarders.

Elwhishi A, Ho PH, Naik K, Shihada B et al, [31] they propose Data routing strategies in opportunistic mobile social networks. They discuss the architecture of opportunistic MSNs and study four types of social metrics, including geo-based metrics, encounter-based metrics, social feature and social properties.

Qaisar Ayub et.al.2018 [31], proposed a buffer management policy known as priority queue based reactive buffer management policy for delay tolerant network (PQB-R) to increase protocol efficiency under limited buffer space. The PQB-R observe residual TTL, Hop Count (HC), message size(M_{size}),and created time (CT) to compute the message drop priority (DP) for relay message and TTL, CT and (M_{size}), for source messages. The experiment proved that proposed PQB-R has perform better in terms of reducing latency, message drop, message transmission and increase delivery.

Roohinaz M. et. al. [33] evaluated the performance of different dropping policies such as MOFO, DF, DT and RTTL over PROPHET routing protocol with different mobility model in the area of opportunistic mobile network. The simulation result shows that the performance of RTTL dropping policy is better in average delivery ratio and average delay where node movement as per human mobility

Zhang X. et. al. [34] perform on the effect of buffer constraint on Epidemic routing protocol, the result shows that buffer constraints can severely affect the performance of Epidemic. They evaluated the performance of traditional dropping policies (DT, DF, and DR). Finally from their simulation results, DF is better than other dropping policies in terms of both delivery ratio and delay.

Chuka Oham and Milena Radenkovic [35] proposes Congestion Aware Spray and Wait (CASaW) protocol to optimize the rate of message delivery to its destination and so increase the awareness of drivers in the vehicular environment to improve road safety. The results have shown that their proposition performed better than other classical VDTN protocols in terms of message delivery probability and rate of packet drops performance measures.

Sulma R. et. al. [29] proposed effective dropping policy called E-DROP for DTN application area where random message sizes generated in the network. They compared E-DROP with MOFO. From simulation result, E-DROP policy performs better in average latency and average delivery probability.

Rizwan Akhtar et. al. [41]The factor of the rep-lication component is included in SimBetTS in order to increase the likelihood of content delivery. Message delivery of the content using SimBetTS is better than the PRoPHET and very close to Epidemic having less overhead.

Hezhe Wang et al [44] proposed an RABP algorithm to solve relay node selection and buffer management issues with constrained network resources. The RABP estimates the delay and hop count of the message carried by the node to the destination and constructs a weight function of the delay and hop count. The node with the least weight value is selected as one of the relay nodes such that the message delay and hop count from the relay node to the destination are near optimal. Simultaneously, based on the weight, the number of message copies is limited. Thus, the limited network resources are efficiently utilized. Simulation results show that the RABP algorithm outperforms the Epidemic, Prophet, and SAW routing in terms of the message delivery ratio, average delay, network overhead, and average hop count.

3.2. Summary

The summary of related works which has covered above is summarized as follows with some techniques and drawbacks.

Author/Year	**Problem focused/Title**	**Technique/Dropping Policy**	**Limitation/Drawback**
Md. Sharif Hossen et.al, 2018 [3]	Impact of buffer size and TTL on DTN routing Protocol	TTL and DF	It may drop critical message because prioritize message by their arrival time
Qaisar Ayub et.al,2018 [31]	Priority Queue based reactive buffer mgt policy for DTN	Priority Queue based buffer mgt	Social based forwarding in Oppnet routing is not considered
Ahthasham Sajid et.al, 2016 [39]	Congestion handling techniques in Opportunistic networks	Delete and Transfer Message [DATM]	To drop message use message size only
Vishnupriya Kuppusamy et.al,2019 [41]	Evaluating forwarding protocol in opportunistic network	Protocol comparison	Not considered mitigating storage congestion
Hezhe Wang et.al,2018	Delay/disruption tolerant network routing and buffer management algorithm based on weight	RABP	Dependent on specific routing protocol.

Table 2: summary of related work

CHAPTER FOUR

4. PROPOSED DROPPING POLICY

4.1 Introduction

Any routing protocol in opportunistic network is always designed with the aim of achieving high delivery ratio and low delay. Not only the routing protocol, but also dropping policy is designed with the aim of achieving high delivery ratio and low delay like that of routing protocol. To achieve this, proposed dropping policy is designed by coupling it with SimBET routing protocol. So this study combines routing and dropping policy together. The main objective is to manage messages in terms of routing and dropping policy in which delay is minimized and delivery ratio is maximized.

The study proposed a combinational dropping policy based on two parameters; RTTL values of message and the node properties, where the node property is defined by node relationship. The first parameter is derived from nodes social relationship, Since SimBET is social-based types of routing protocol used in Opportunistic Networks that relies on two social metrics i.e. betweenness centrality and similarity. Based on this two matrix nodes can determine their social relationship values among the nodes in the network in terms of node SimBET utility. SimBET utility is calculated as Equation (5) in a weighted combination of the similarity utility in Equation (3) & betweenness utility as Equation (4) [29].

Generally the nodes decide which of these messages should be transmitted, based on their utilities. In order to decide which messages should be forwarded, the two nodes have to compare their utilities. Which means, node N will forward messages, destined for node D, to node M only if SimBetUtilM (D) > SimBetUtilN (D) [5].

The similarity utility is a comparison of the similarity metrics that nodes N and M have for the destination node D. Likewise, the betweenness utility is a comparison of the egocentric betweenness of the node N and M. Node N calculates its similarity utility as Equation (3) and betweenness utility as Equation (4) for delivering a message to node D, compared to node M.

The SimBET utility is calculated as a weighted combination of the similarity utility and the betweenness utility as Equation (5).

$$SimUtilN(D) = \frac{SimN(D)}{SimN(D)+SimM(D)} \ldots\ldots (3)$$

$$BetUtilN(D) = \frac{BetN(D)}{BetN(D)+BetM(D)} \ldots\ldots (4)$$

$$SimBetUtilN(D) = \alpha SimUtilN(D) + \beta BetUtilM(D) \ldots\ldots (5)$$

The SimBet utility is used to make the routing decisions, where α, β are adjustable parameters for which it holds that α + β = 1. These parameters are usually set to α = β = 0.5, so that the similarity utility and the betweenness utility have the same importance [24].

4.2 Methods

In this section using what method is the proposed dropping policy is designed is answerd. Therefore to construct the proposed SMDP dropping policy we follow the following steps.

Step 1. Construct the opportunistic mobile social network by creating the ONE network simulator setting using the different parameters, In settings the simuation time, the total number of nodes, transmission range, transmission speed, interface, group of nodes, message create interval, report and event etc. should be included.

Step 2. Build message dropping policy for SimBET router message RTTL and SimBET utility based dropping policy. in RTTL based dropping policy when the buffer is full it will drop the message which has least RTTL thus the node will accept the new incoming message but the time to live of message is not expired so this message may have a probability to be delivered. When SimBET utility is used it will drop based on social ralationship that means when message with low SimBET utility value is there that means this message has low probability to be delivered. Thus combining this dropping policy RTTL and SimBET utility enhance the performance of the SimBET router. for comparison purpose the research work will build TTL based dropping policy and apply the two dropping policies over SimBET router.

Step 3. Evaluate the performances of the proposed SMDP and TTL dropping policies

Step 4. Finally Compare the performance of the proposed SMDP and TTL dropping policies in terms of evaluation metrics. Figure 6 shows the steps and method of building SMDP.

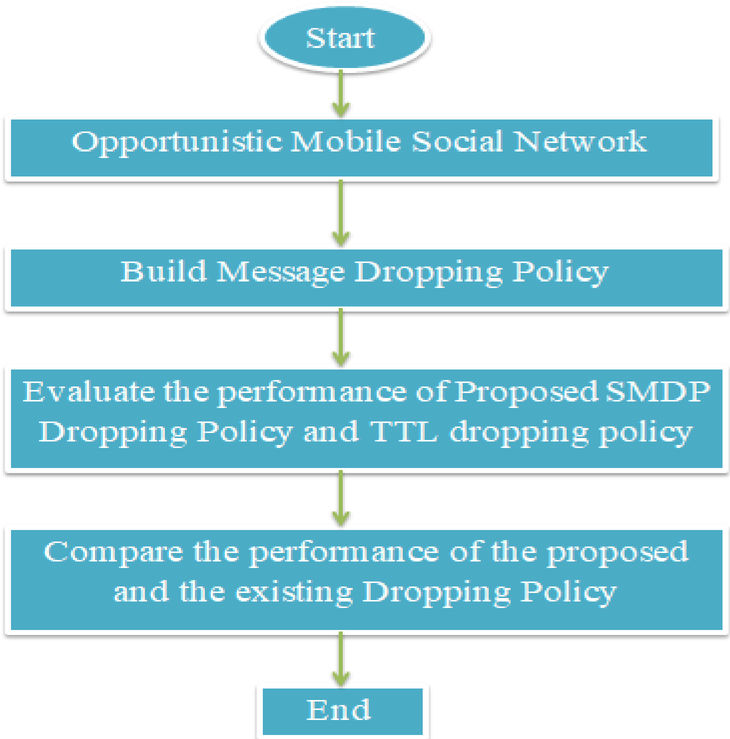

Figure 3: Methodology for SMDP constructing

4.3 Message Dropping Policies

4.3.1 Message Drop by DF

If DF dropping policy is used by node A, it gives actions based on the assumption that, data should be dropped from a node according to the arrival time or waiting time of the message in the buffer. DF only considers arrival time or waiting time of each message in the buffer which doesn’t consider other parameters such as future contact opportunity for messages in the node. DF does not provide any mechanism for preferential delivery or selects high priority messages which are not well for opportunistic network [4].

4.3.2 Time to live (TTL) Based Dropping Policy

In the literatures, TTL based dropping policy are performing well in the area of opportunistic network .The recent dropping policies are including TTL with other attributes to design better dropping policy [3]. Remaining Time to Live (RTTL) values of message is calculated from message TTL and creation time (RTTL= TTL- creation time). Message stored longer time in the buffer of the node has high delivery probability due to future opportunistic contact. Message waiting in the buffer based on remaining TTL has more transmission opportunities in the future contact. But if this message has lower remaining time to live it has lower opportunities to be delivered to its destination, so dropping this message may not have effect on delivery ratio of the network. But waiting until the TTL expire may affect the performance because the buffer is occupied by message which has low delivery probability.

4.3.3 The SMDP SimBET Message Dropping Policy

The DTN nodes store and carry source, relay and destine messages. A source message is the one which has been generated by the node itself and destine message is a message that a node receives as a final destination. The relay message utilizes intermediary nodes to reach its destination. Hence, source message may have consumed fewer network resources than relay or destine message [40]. However, existing buffer management policies obtain a single metric value to make drop decision and cannot give a fair selection. For instance, in drop front (DF) the message that go into first in the buffer is to be selected to be drop first from the buffer. Hence, a message with lowest remaining time to live can be drop from the buffer but this message may have probability to be delivered to destination.

In order to eliminate this kind of problem in opportunistic or Delay tolerant network buffer management like SimBET dropping policy is best choice for SimBET routing protocol. This study design SimBET utility based dropping policy i.e. social based dropping policy by combining SimBET utility with message RTTL. The lowest values of SimBET utility and message RTTL are combined together to drop a message stored in the buffer since they have lowest delivery probability. So dropping this message doesn't affect the performance of SimBET routing protocol.

When messages are stored in the buffer of nodes, for every message I stored in receiver buffer it has to calculate RTTL and node SimBET Utility which are stored in Packet Buffer INFO. The proposed algorithm gets the two parameters from Packet Buffer INFO for each I stored message in the buffer. Then when the node buffer is full SMDP decides which message has to be dropped. If the algorithm gets a message with smallest RTTL and node SimBET utility value from stored message I, it will drop. If this condition is not true the algorithms selects a message with least node SimBET utility values to drop it.

4.3.3.1 Building SMDP Dropping Policy

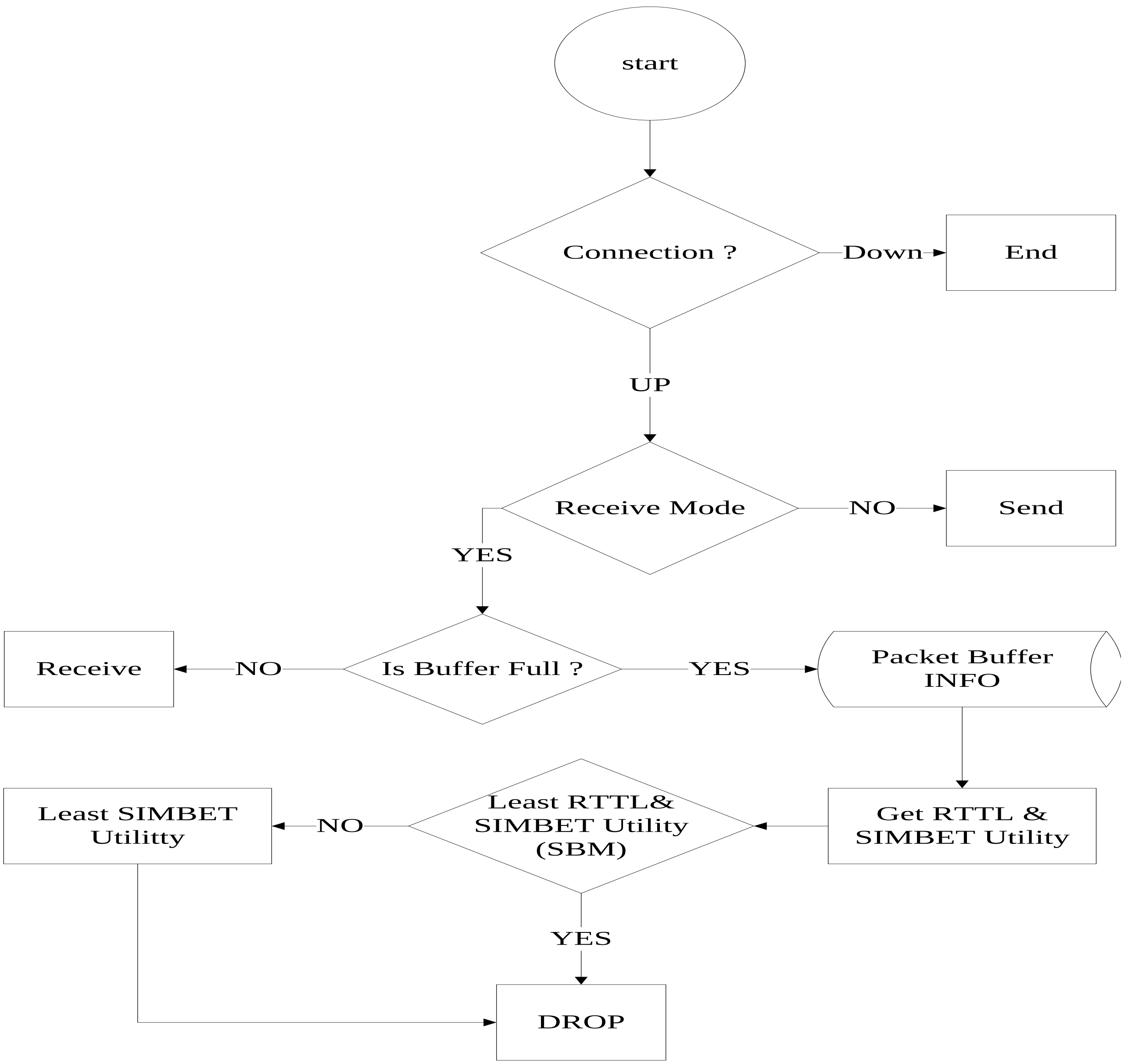

Figure 4: Architecture of SMDP

Figure 4 shows the SMDP Message dropping policy for SimBET routing protocol. The SMDP in SimBET router to accept the new coming message to the node A, the Router will check if Connection Up between sender and receiver node. If connection is UP the nodes A can exchange the packet or message in opportunistic node. But the SMDP checks if A node is on receive mode, if not it node A is Sender. If node A is on receive Mode the SMDP will check the incoming message size if it is equal or greater than the available buffer size of node A if it is not automatically it will receive the message. if in coming message size greater or equal to the buffer size means node A need to drop some message to receive the message. Therefore it will get message information about message RTTL and SimBET utility of the message stored in the buffer and sort these values. Then to drop the message it will find the least RTTL of the message if it gets it will drop the message.

4.4 Algorithm for SMDP

1. *Start*
2. *Check connection*
3. *IF connection is up and mode is in receiving*
4. *IF Receiver node buffer has space then accept the incoming messages*
5. *IF the Receiver node buffer is full*
6. *For all message stored in the buffer*
7. *Find if a message I has with smallest RTTL and node SIMBET Utility*
8. *Drop message I*
9. *End if*
10. *End for*
11. *Else*
12. *For all message stored in the buffer*
13. *Find if message I has smallest node SIMBET Utility*
14. *Drop message I*
15. *End if*
16. *End for*
17. *End if*
18. *End if*
19. *End if*

CHAPTER FIVE

5. SIMULATION AND RESULT EVALUATION

5.1 Introduction

In this section the research work describe the simulations used to evaluate the proposed dropping policy and compare with the existing dropping policy over simbet Routing protocol. The first experiment in this study examines the performance of the opportunistic network by using different message remaining time to live from lower to higher over limited storage size in order to evaluate the overall performance of dropping policy. In second experiment the study uses different storage size with fixed message remaining time to live.

5.2 Simulation Setup

The ONE is a Opportunistic Network Environment simulator which provides a powerful tool for generating mobility traces, running DTN messaging simulations with different routing protocols, and visualizing both simulations interactively in real-time and results after their completion.

The ONE is a simulation environment that is capable of

- Generating node movement using different movement models.
- Routing messages between nodes with various DTN routing algorithms and sender and receiver types.
- visualizing both mobility and message passing in real time in its graphical user interface.
- ONE can import mobility data from real-world traces or other mobility generators. It can also produce a variety of reports from node movement to message passing and general statistics.

The ONE simulator was developed at Aalto University and is now maintained and extended in cooperation between Aalto University (Comnet) and Technische Universität München (Connected Mobility) [31].

To run the ONE network simulator we need to install java jdk1.8.0_77 and later version. After installing and configuring the java application we need to install Notepad++ for writing and editing java codes.

We can Acces the latest ONE network simulator from " http://akeranen.github.io/the-one/ " then download the zip file and exteract the file. Then we wiil get the application with in the folder, the forlder contains two batch file "Compile.bat" and "One.bat". to run the simulator we need to create the setting with parameter listed in Table 2 in this research work then we will open the "cmd" from our operating sytem then type " compile.bat"

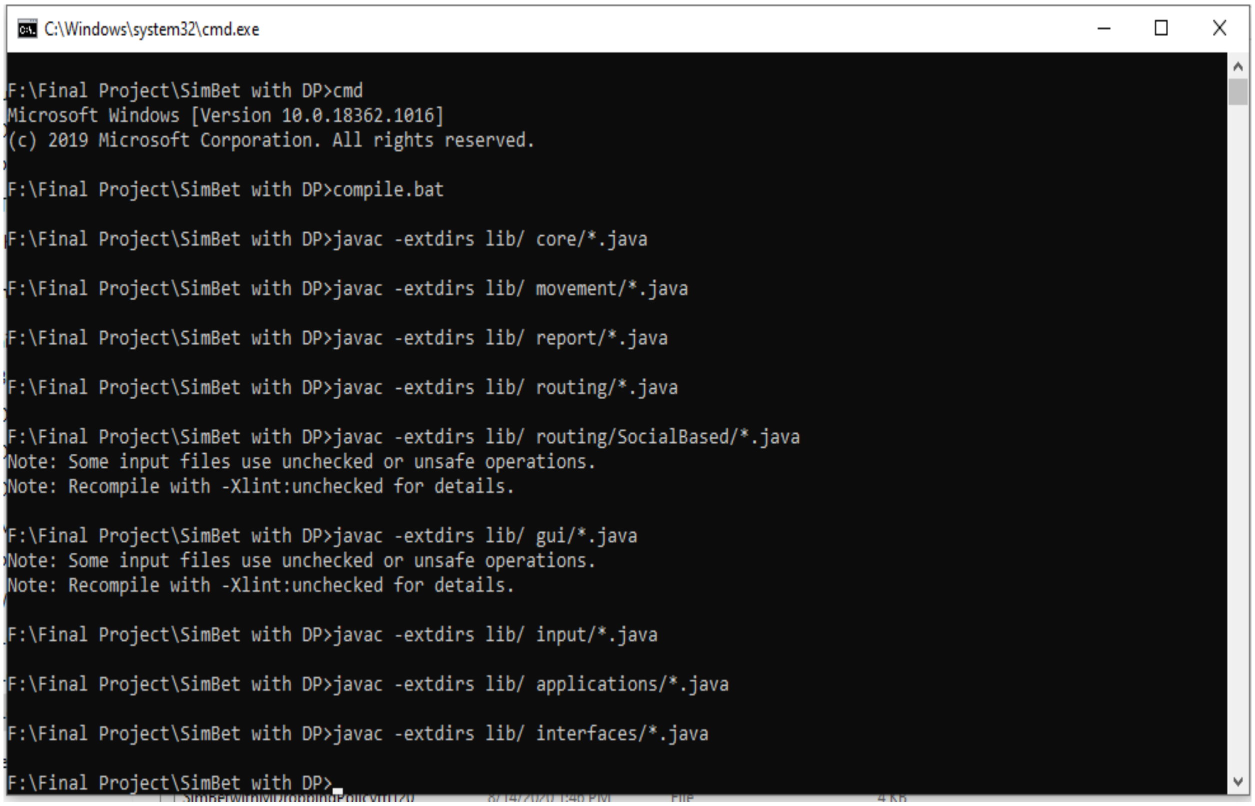

Figure 5 Compile the ONE Simulator

After compiling the program we will type "one.bat" then" setting name with file extension" then hit enter automaticaly the ONE graphic inter face will come on your screen as shown in Figure 5 then hit "Play Simulation" button from Graphic interface to start the simulation.

5.3 Simulation Tools

To design the proposed dropping policy the research work first compile the materials needed to constructs the opportunistic mobile social network. ONE network simulator and java "jdk1.8.0_77" and NotePad++ is the primary materials needed for this research work.

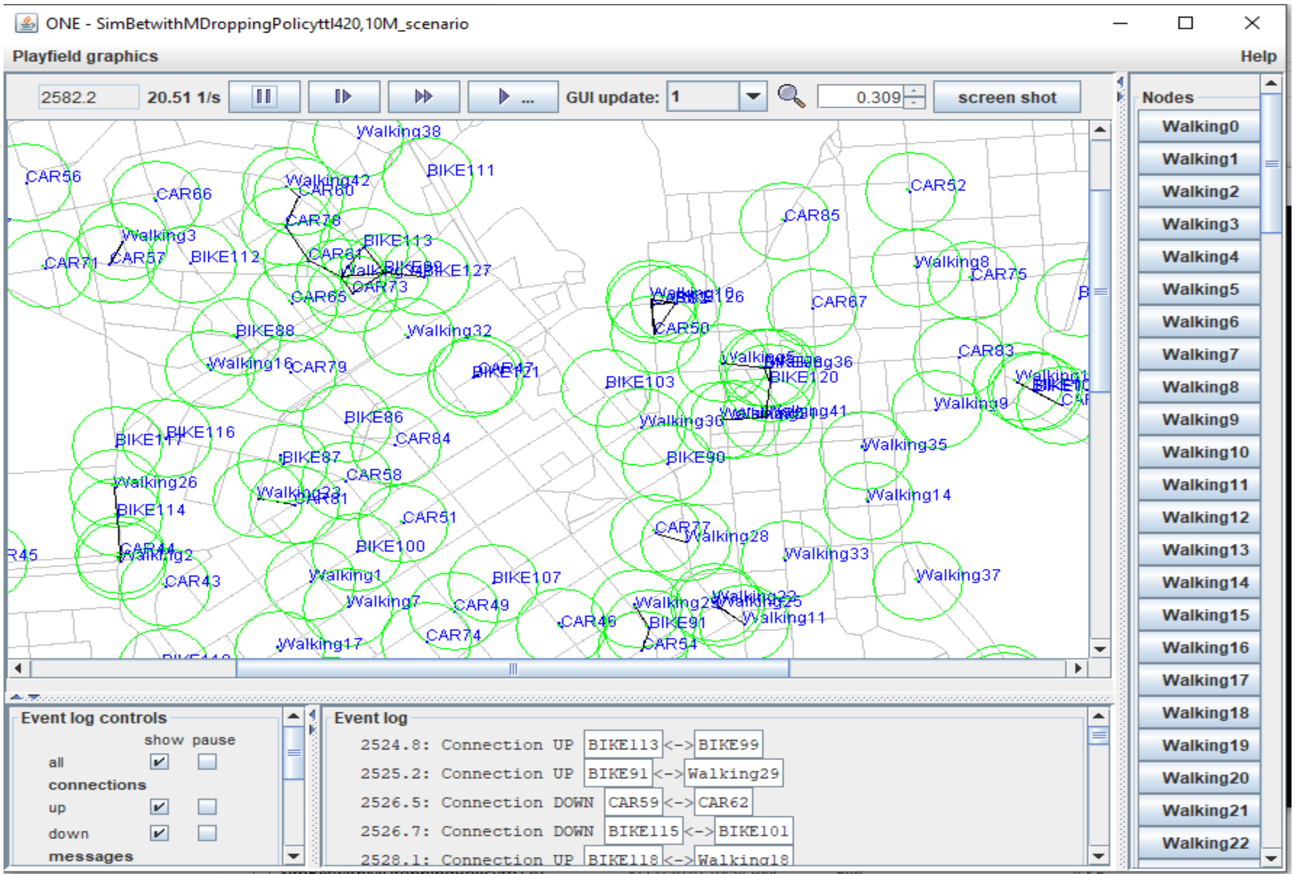

Figure 6: Snapshot of ONE simulator during operation

ONE is an agent-based discrete event simulation engine and a number of simulation modules are updated by the simulation engine at each simulation step. The simulator models node movement, inter-node contacts, routing and message handling. Results are collected and analyzed through visualization, reports and post-processing tools. Node movement is implemented by synthetic movement models or through existing movement traces. Connectivity between nodes is based on node location, communication range and bit-rate. Messages are generated through event generators or external events and unicast having a single source and destination host inside the simulation world. The Simulator is written in Java and the basic agents are nodes which model mobile end points and are capable of forwarding messages using a store-carry and forward approach. Each node belongs to a group which is assigned a set of capabilities and a node inherits the capabilities of the group to which it belongs. Capabilities such as the node buffer size, message size, transmission range, transmission speed etc. are set in the Configuration file. More complex capacities such as movement and routing are configured using specialized modules which models a particular behavior for that capability. For energy simulations, each node in the simulation world is assigned a fixed amount of energy. A node's energy profile is depleted when it transmits or receives messages, scans for the presence of other nodes during the discovery process and performs security processing. More details on the ONE simulator can be found in [37], [38]. Figure 5 shows the internal modules of the ONE simulator and how they link and interact with each other. One major limitation of the ONE simulator is that it does not implement any form of security [39].

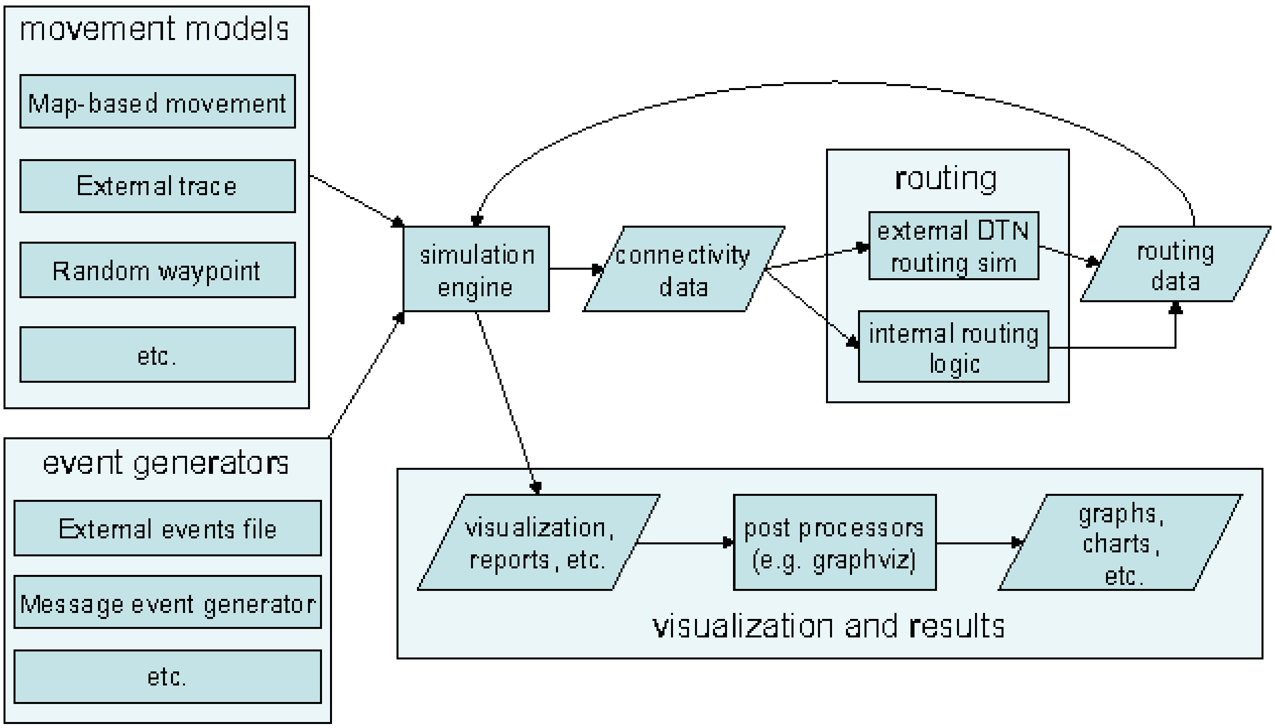

Figure 7: Overviews of ONE simulator

In this study simulation 129 nodes are grouped to walking people, car and bike uniformly deployed in a 4500 meters by 3400 meters area. Each node has a transmission range of 100m and travel at a different speed for the walking people, car and bike and 250kBps transmission speed. The study varies the message remaining time to live with fixed storage size and vice versa to see what effect it has on package delivery ratio, overhead ratio, average delay and Average Hop Count.

5.4 Experimental Data Sets

In this research work for simulation the research work chooses the Cambridge haggle6-infocom6 experimental data set that is taken from Encounter traces for the ONE simulator [42].

Cambridge data set: This data set includes a data of several traces of Bluetooth sightings by groups of users carrying small devices (iMotes) for a several days in campus environments. That small device (iMotes) were distributed mainly to two groups of students from the University of Cambridge Computer Laboratory that includes undergraduate first year and second year students, and also some PhD and postgraduate students [42]. To simulate the one network simulator the haggleg6 data set which found in “ee” folder in the ONE simulator should be includes to each settings.

5.5 Simulation Parameter

Simulation Time	43200s
Total Number of Nodes	129
Transmission Range	100M
Transmission Speed	250Kb/s
Speed of Nodes Movement	1 – 2.5M/s
Interface Type	Bluetooth
Movement Model	Map Based
Message Size	500KB – 1MB
Message TTL (Time To Live)	300s – 700s
Message Generation Time Interval	25s – 35s
Routing Protocol	SimBET Router
Buffer Size	40MB – 80 MB

Table 3: Simulation Parameters

Description for the above simulation parameters

Simulation time: How many simulated seconds to simulate the simulation.

Total Number of Nodes: How many nodes are present or participating in the simulation

Transmission Range: Range (meters) of the interface.

Transmission Speed: Transmit speed of the interface (bytes per second).

Speed of Nodes Movement: Defines how fast nodes move.

Interface Type: The interface that should be used as the interface or communicatin midea.

Movement Model: The movement model all node in the network use.

Message Size: Size of the packet transmitted through the network.

Message TTL (Time To Live): Time To Live (simulated minutes) of the messages created by the node. Nodes (with routing module) check every one minute whether some of their messages' TTLs have expired and drop such messages.

Message Generation Time Interval: Message creation interval in seconds.

Routing Protocol: Router module which is used to route messages.

Buffer Size: Size of the nodes' message buffer (bytes). When the buffer is full, node can't accept any more messages unless it drops some old messages from the buffer.

5.6 Evaluation Metrics

The study used four evaluation metrics in the simulation to evaluate the performance of the four algorithms: message delivery rate (delivery ratio), network transmission delay (average delivery delay), routing overhead (overhead ratio) and Average occupied or buffered time (Average Buffer time).

5.6.1 Delivery Ratio

It is the ratio between the number of delivered messages and the total number of created messages. The ideal value of the successful delivery ratio is 1.0 when all created messages are delivered to their destinations. High delivery ratio means that more messages are delivered to the destination.

$$\text{Delivery Ratio} = \left(\frac{\text{Number of Delivered messages}}{\text{Number of Created Messages}}\right) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.. (6).$$

5.6.2 Overhead ratio

This is defined as the ratio of total number of packets transmitted in the network and the number of uniquely delivered packets.

$$\text{Overhead ratio} = \left(\frac{\mathrm{R-D}}{\mathrm{D}}\right) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (7)$$

Where R is the number of messages relayed during the simulation and D is number of messages delivered to the base station.

5.6.3 Average Delay

It is the average of the time elapsed between message creation and delivery. This is calculated as the average time it takes a packet to be delivered to a base station.

$$\text{Average Delay} = \sum_{\mathrm{k=1}}^{\mathrm{Nr}} \left(\frac{\mathrm{Tr - Tc}}{\mathrm{Nr}}\right) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.. \quad (8)$$

Where Tr is the time when message received, Tc is the time when message created and Nr is the number of received messages.

5.6.4 Average hop count

Average Hop Count is the average of the number of hops that messages must take in order to reach the destination.

5.7 Experimental Results

In this section, the study uses simulations to evaluate the performance of the proposed Message Dropping policy (SMDP). One of the major purposes of SMDP Message Dropping policy is to reduce the amount of occupied buffer or Storage and enhance the delivery ratio wich enhance the performance of the network.

5.7.1. Result get by Varying TTL

The first scenario is to evaluate the proposed dropping policy it to vary the TTL of message in the network. Because as the time to live increases the message have an opportunity to be forwarded to the destination but if message has low time to live that means it has low probability and it will be dropped from the buffer when TTL time ends. For the SMDP and TTL based dropping policies by varying the time to live of message the following reports are gained from ONE simulator.

5.7.1.1 Result gets by Varying TTL for SimBET with SMDP

Table 3 shows the report generated by the ONE network simulator by varying the TTL to SMDP dropping policy in SimBET router. To simulate the simulation we need to build different settings with different time to live. In this table five simulation result are included these are setting TTL 300s, 400s, 500s, 600s and700s.When TTL is set to 300s and buffer size is 50MB simulated for 43200s then simulation result shows 1461 messages are create in the network in 43200s and 84 messages are aborted while forwarded by network problem, 171 messages are dropped from the buffer and 1042 messages are delivered to the destination. As the time to live increased 300s to 400s the number of message created is the same as in TTL=300s 1461 messages are created in 43200s.but the number of delivered messages is increased from 1042 to 1083 but the number of message drop is decreased from 171 to 105 thus the delivery ratio of the network is increased from 0.7132 to 0.7413. This shows when low TTL is set to message there will be message that dropped by the dropping policy but this message has probability to be delivered thus the performance of the dropping policy and also performance of the network will be affected when low TTL is set.

No		TTL 300s BS=50MB	TTL 400s BS=50MB	TTL 500s BS=50MB	TTL 600s BS=50MB	TTL 700s BS=50MB
1	Simulation time	43200s	43200s	43200s	43200s	43200s
2	Message create	1461	1461	1461	1461	1461
3	Started	4344	4378	4390	4384	4386
4	Relayed	4260	4294	4307	4302	4304
5	Aborted	84	84	83	82	82
6	Dropped	171	105	85	74	63
7	Delivered	1042	1083	1086	1092	1098
8	Total copy forward	3218	3211	3221	3210	3206
9	Delivery ratio	0.7132	0.7413	0.7433	0.7474	0.7515
10	Overhead ratio	3.0883	2.9649	2.9659	2.9396	2.9199

11	Average delay	5111.1088	5847.2518	6001.1101	6126.4950	6317.1071
12	Median delay	4037.1000	4348.6000	4391.6000	4460.2000	4473.7000
13	Average hop count	3.0854	3.0674	3.0552	3.0476	3.0355
14	Median hop count	3	3	3	3	3
15	Average buffer time	1882.8376	1899.9175	1856.3760	1841.0431	1813.5998
16	Median buffer time	446.9000	444.0000	440.5000	442.6000	440.7000

Table 4 Experimental result by varying TTL for SMDP dropping policy

5.7.1.2 Result get by Varying TTL for SimBET with TTL

Table 4 shows the performance of SimBET with TTL when TTL is varied from 300s, 400s, 500s, 600s and 700s. By using the same setting as used in SimBET with SMDP the simulation time is set to 43200s and 50MB buffer size. As the report implies the number of message created in the network is 1461 and drop 150 messages when TTL is set to 300s and delivered messages is 1050 then the network delivery ratio is 0.7187 but when TTL is set to 400s the number of message created is the same as created in 300s TTL but number of messages dropped in the network decreased from 150 to 102 and delivered message increased from 1050 to 1079 thus the research work concludes that when TTL is increased the opportunities of messages stored in the buffer for transmitting will increase to be delivered.

No	Status	TTL 300s BS=50MB	TTL 400s BS=50MB	TTL 500s BS=50MB	TTL 600s BS=50MB	TTL 700s BS=50MB
1	Simulation time	43200s	43200s	43200s	43200s	43200s
2	Message create	1461	1461	1461	1461	1461
3	Started	4359	4395	4394	4395	4398
4	Relayed	4274	4309	4310	4311	4314
5	Aborted	85	86	84	84	84
6	Dropped	150	102	90	83	73

7	Delivered	1050	1079	1083	1086	1093
8	Total copy forward	3224	3230	3227	3225	3221
9	Delivery ratio	0.7187	0.7385	0.7413	0.7433	0.7481
10	Overhead ratio	3.0705	2.9935	2.9797	2.9696	2.9469
11	Average delay	5186.0698	5698.1599	5819.7209	5893.1670	6096.4379
12	Median delay	4213.2000	4461.1000	4512.4000	4526.4000	4663.8000
13	Average hop count	3.1248	3.1270	3.1080	3.1041	3.0906
14	Median hop count	3	3	3	3	3
15	Average buffer time	1887.9524	1919.6185	1905.3106	1895.0257	1875.9433
16	Median buffer time	451.0000	450.3000	448.6000	446.4000	446.4000

Table 5 Experimental result by varying TTL for TTL based dropping policy

5.7.2. Result get by Varying Buffer size

The second scenario is to evaluate the proposed SMDP dropping policy with TTL based dropping policy by varying the buffer size of the nodes. As the storage size increases the node will have enough storage space, thus no need to drop a message from the buffer.

5.7.2.1 Result get by Varying Buffer size for SimBET with SMDP

Table 5 shows the report generated by the ONE network simulator by varying the buffer size to SMDP dropping policy in SimBET router. To simulate the simulation we need to build different settings with different Buffer size. In this table also five simulation result are included setting BS=40MB, 50MB, 60MB, 70MB and 80MB. When Buffer size is set to 40MB and TTL is 700s simulated for 43200s then simulation result shows 1461 messages are create in the network in 43200s and 81 messages are aborted while forwarded by network problem, 151 messages are dropped from the buffer and 1034 messages are delivered to the destination. As the buffer size increased 40MB to 50MB the number of message created is the same as in BS=40MB 1461 messages are created in 43200s.but the number of delivered messages is increased from 1034 to

1098 but the number of message drop is decreased from 151 to 63 thus the delivery ratio of the network is increased from 0.7077 to 0.7515. This shows when low buffer size is set to message there will be message that dropped by the dropping policy because of storage congestion. But this message may have probability to be delivered if sufficient buffer size is available. Thus the performance of the dropping policy and also performance of the network will be affected when low buffer size is set.

No	Status	TTL 700s BS=40MB	TTL 700s BS=50MB	TTL 700s BS=60MB	TTL 700s BS=70MB	TTL 700s BS=80MB
1	Simulation time	43200s	43200s	43200s	43200s	43200s
2	Message create	1461	1461	1461	1461	1461
3	Started	4319	4386	4433	4447	4449
4	Relayed	4238	4304	4345	4360	4362
5	Aborted	81	82	88	87	87
6	Dropped	151	63	24	2	0
7	Delivered	1034	1098	1125	1141	1143
8	Total copy forward	3204	3206	3220	3219	3219
9	Delivery ratio	0.7077	0.7515	0.7700	0.7810	0.7823
10	Overhead ratio	3.0986	2.9199	2.8622	2.8212	2.8163
11	Average delay	6052.9159	6317.1071	6430.9607	6568.9946	6576.8017
12	Median delay	4155.7000	4473.7000	4703.2000	4765.1000	4807.0000
13	Average hop count	2.9536	3.0355	3.0871	3.1122	3.1137
14	Median hop count	3	3	3	3	3
15	Average buffer time	1721.1428	1813.5998	1848.9978	1852.5618	1854.4110
16	Median buffer time	422.9000	440.7000	442.6000	444.3000	444.3000

Table 6 Experimental result by varying Buffer size for SMDP dropping policy

5.7.2.2 Result get by Varying Buffer size for SimBET with TTL

No	Status	TTL 700s BS=40MB	TTL 700s BS=50MB	TTL 700s BS=60MB	TTL 700s BS=70MB	TTL 700s BS=80MB
1	Simulation time	43200s	43200s	43200s	43200s	43200s
2	Message create	1461	1461	1461	1461	1461
3	Started	4341	4398	4437	4449	4453
4	Relayed	4218	4314	4350	4360	4364
5	Aborted	83	84	87	89	89
6	Dropped	151	73	28	7	0
7	Delivered	1038	1093	1120	1131	1135
8	Total copy forward	3220	3221	3230	3229	3229
9	Delivery ratio	0.7105	0.7481	0.7666	0.7741	0.7769
10	Overhead ratio	3.1021	2.9469	2.8839	2.8550	2.8449
11	Average delay	5717.4367	6096.4379	6378.1663	6532.0533	6608.4623
12	Median delay	4155.7000	4663.8000	4791.6000	4858.2000	4862.1000
13	Average hop count	3.0530	3.0906	3.1098	3.1194	3.1216
14	Median hop count	3	3	3	3	3
15	Average buffer time	1815.3272	1875.9433	1888.7654	1872.7166	1857.0563
16	Median buffer time	452.4000	446.4000	441.3000	439.9000	439.7000

Table 7: Experimental result by varying Buffer size for TTL based dropping policy

The performance of SimBET with TTL dropping policy when buffer size is vary is shown in Table 6. This table show the number of message created, message relay, started, message dropped, message aborted and delivered etc. When the same parameter value used as in SMDP is used for SimBET with TTL based dropping policy and simulate for 43200 seconds the result is shown in Table 6. As this Table indicates when buffer size BS=50MB and TTL is set to 700s the result shows 1461 messages are created during 43200s, then the delivery ratio is 0.7481 and 73 messages are dropped. But when the buffer size increased from 50MB to 60MB the delivery ratio increased from0.7481 to 0.7666 and messages drops decrease from 73 to 28. Thus this research work concludes that as the lower buffer size increased the message probability to deliver to their destination increase that means when sufficient buffer size is available there is no drop from the router as table 6 shown when 80MB buffer size is used.

5.7.3 Effect of Varying TTL

Table 7 shows the One network simulator report using the parameter listed in Table 2 when limited buffer size (50MB) is used over different TTL (300s, 400s, 500s, 600s and 700s) on SimBET with TTL Dropping policy in case of Delivery ratio, Overhead ratio, Average Delay and Average Hop count.

No	TTL	Buffer Size	Delivery Ratio	Overhead Ratio	Average Delay	Average hop count
1	300	50M	0.7187	3.0705	5186.0698	3.1248
2	400	50M	0.7385	2.9935	5698.1599	3.1270
3	500	50M	0.7413	2.9797	5819.7209	3.1080
4	600	50M	0.7433	2.9696	5893.1670	3.1041
5	700	50M	0.7481	2.9469	6096.4379	3.0906

Table 8 Overall Performance of SimBET with TTL Dropping Policy with 50MB buffer size

No	TTL	Buffer Size	Delivery Ratio	Overhead Ratio	Average Delay	Average hop count
1	300	50M	0.7132	3.0883	5111.1088	3.0854
2	400	50M	0.7413	2.9649	5847.2518	3.0674
3	500	50M	0.7433	2.9659	6001.1101	3.0552
4	600	50M	0.7474	2.9396	6126.4950	3.0476
5	700	50M	0.7515	2.9199	6317.1071	3.0355

Table 9 Overall Performance of SimBET with SMDP Dropping Policy 50MB buffer size

Table 8 shows the One network simulator report using the parameter listed in Table 2 when limited buffer size (50MB) is used over different TTL (300s, 400s, 500s, 600s and 700s) on SimBET with SMDP Dropping policy in case of Delivery ratio, Overhead ratio, Average Delay and Average Hop count. The same parameter setting and the same raouting protocol but different Dropping policiy is used for both tables Table 7 and Table 8.

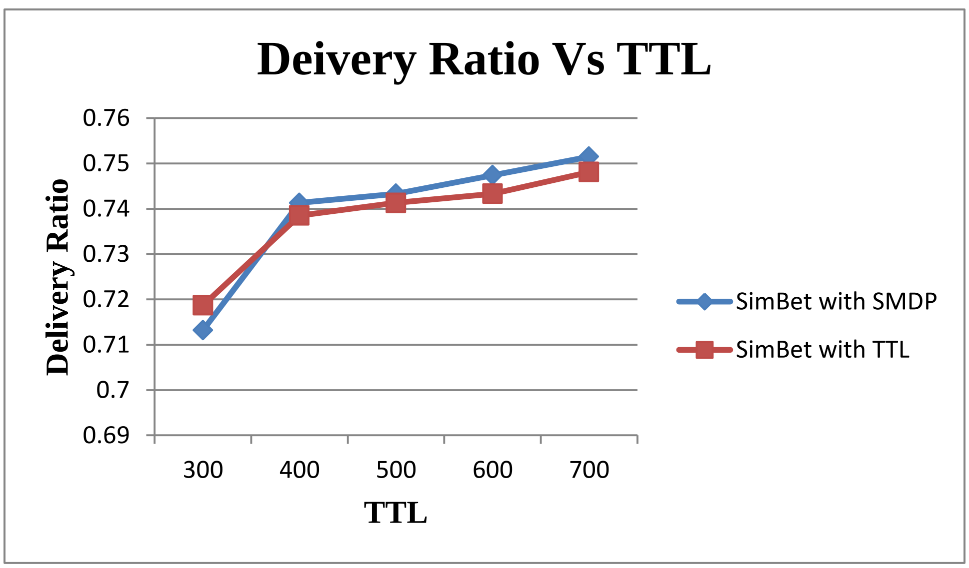

Figure 8: Delivery Ratio by Varying TTL

Figure 8 shows the effect on delivery ratio when the message time to live (TTL) increases with limited storage size 50MB implemented on both routing protocol simBet with TTL routing protocol and simbet with message dropping policy. In Simbet routing protocol for both dropping policy at the time to live increases with limited buffer time the delivery ratio also increases. When lowest message remaining time to live set to limited storage size lower delivery ratio is reported from the simulator and as the time to live increases the delivery ratio also increases. but the highest delivery ratio is scored by the SMDP. This means when the lower time to live is set to simbet with TTL the message has lower time to live (life) to stay on the specified buffer after that it will expire and dropped from the buffer by the routing protocol, therefore the buffer have enough storage or buffer size for the next incoming message. But the routing protocol dropped a message which has a probability to be delivered to its corresponding destination. That is why the delivery ratio of the network becomes lower when lower message remaining time to live is set. As the remaining time to live increases the delivery ratio also increase because the message have enough time to be delivered to its destination before TTL expired. But when the maximum TTL is set to simbet with TTL dropping policy lower delivery ratio is reported as compared to SMDP because a message which has lower probability to delivered to destination has high TTL the buffer is occupied by this message therefore storage congestion is occurred at this time. So the new message which has higher probability to be delivered will be dropped in the network because of storage congestion that is why delivery ratio becomes lower.

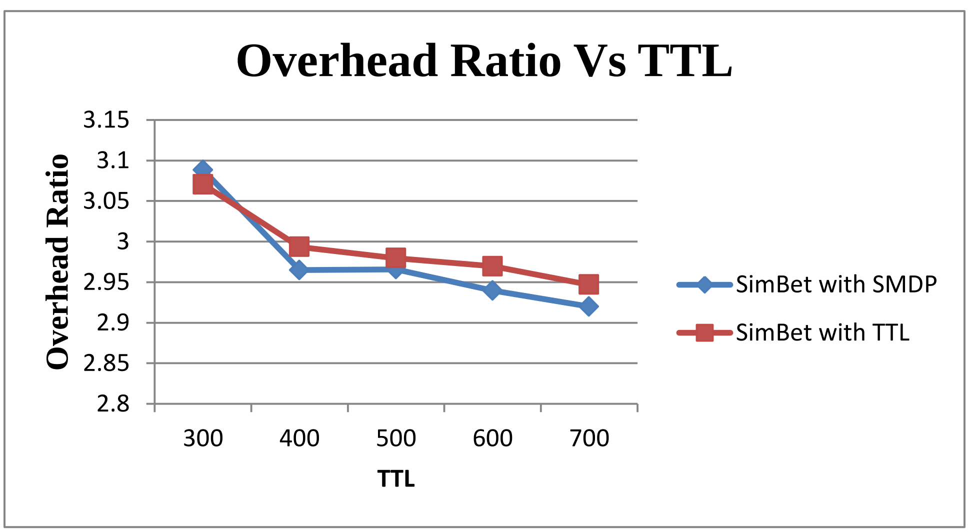

Figure 9 Overhead Ratio by Varying TTL

Overhead ratio determines the number of redundant packets to replicate a packet successfully. It simply reflects the spent of message transfer in a network. Figure 9 shows the results of overhead for proposed SMDP and existing TTL message dropping policy. The overhead has been decreasing with increasing time-to-live (TTL). The reason is that at high TTL, messages got more transmission opportunities which yields storage congestion. SMDP has shown low overhead compared to TTL dropping policy.

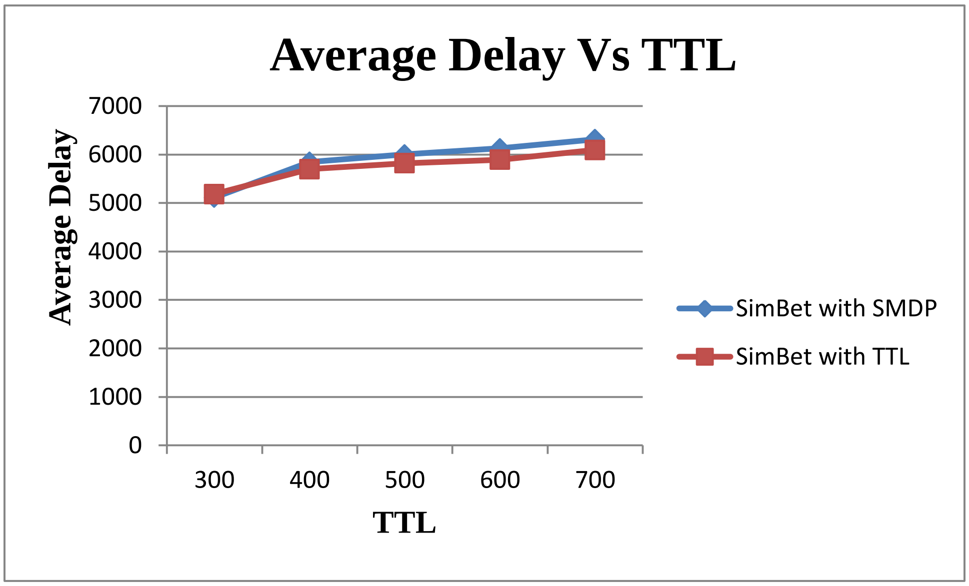

Figure 10 Average Delay by varying TTL

Figure 10 shows the result of Average delay by varying the message time to live over SimBET routing protocol using the two dropping policies. Average latency is the measure of average time between messages generated and messages received to destination. Average latency increases gradually in accordance with the increase in TTL for both dropping policies as shown in Figure 10. Here SMDP scores a litle bit higher than the TTL dropping policy which may afffect the performance of the network, so in the future work it should be inproved by using different parameter and dropping policies.

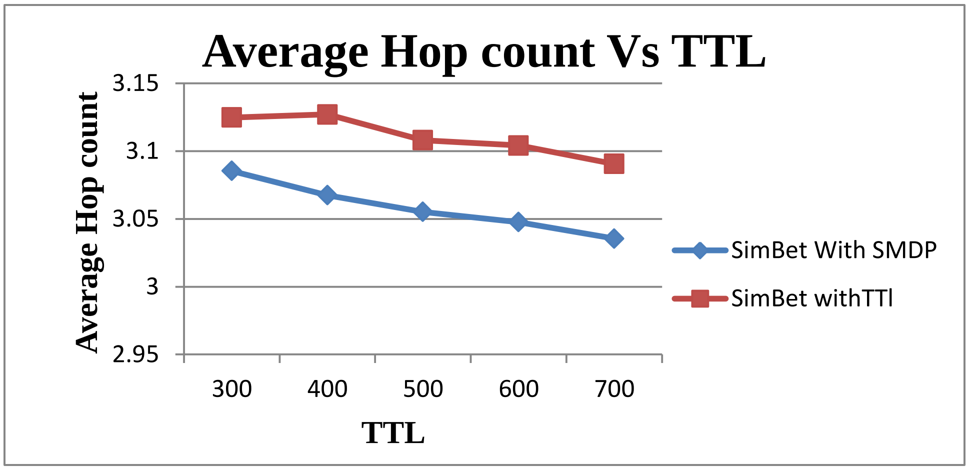

Figure 11 Average Hop count by varying TTL

Figure 11 observes Average Hop count with SMDP and TTL. It can be clearly seen that SMDP has low Value of Average Hop count with SimBet Routing protocol. Buffer time occupancy is very scared resource in the DTN as many literature's shows where store and carry paradigms are used. As the Average hop count increases means it uses many resources which may affect the performance. SMDP improved the Average hop count for SimBet routers than TTL and increases the delivery ratio as in the figure 8.

Thus the study concludes that the proposed dropping policy has higher delivery ratio and lower Overhead ratio and Average hop count as the message time to live vary from lower to higher than TTL dropping policy. but still its average Delay is higher than SimBet with TTL.

5.7.4. Effect of Varying Buffer Size

No	Buffer Size	TTL	Delivery Ratio	Overhead Ratio	Average Delay	Average hop count
1	40MB	700s	0.7105	3.1021	5717.437	3.0530
2	50MB	700s	0.7481	2.9469	6096.438	3.0906
3	60MB	700s	0.7666	2.8839	6378.166	3.1098
4	70MB	700s	0.7741	2.8550	6532.053	3.1194
5	80MB	700s	0.7769	2.8449	6608.462	3.1216

Table 10 Overall Performance of SimBET with TTL Dropping Policy with 700s TTL

Table 9 shows the One network simulator report using the parameter listed in Table 2 when when constant TTL 700s is used over different Storage capacity of nodes (40MB, 50MB, 60MB, 70MB and 80MB) on SimBet with TTL Dropping policy interms of Data delivery ratio, overhead ratio, delay and hop count.

Table 10 also shows the performance of SMDP dropping policy in terms of Delivery ratio, Overhead ratio, Average delay and Average hop count when the same parameter is set with Table 9 using constant TTL 700s and varying Buffer size from 40MB to 80MB.

No	Buffer Size	TTL	Delivery Ratio	Overhead Ratio	Average Delay	Average hop count
1	40MB	700s	0.7077	3.0986	5652.916	2.9536
2	50MB	700s	0.7515	2.9199	6017.107	3.0355
3	60MB	700s	0.7700	2.8622	6230.961	3.0871
4	70MB	700s	0.7810	2.8212	6368.995	3.1122
5	80MB	700s	0.7823	2.8163	6476.802	3.1137

Table 11 Overall Performance of SimBET with SMDP Dropping Policy with 700s TTL

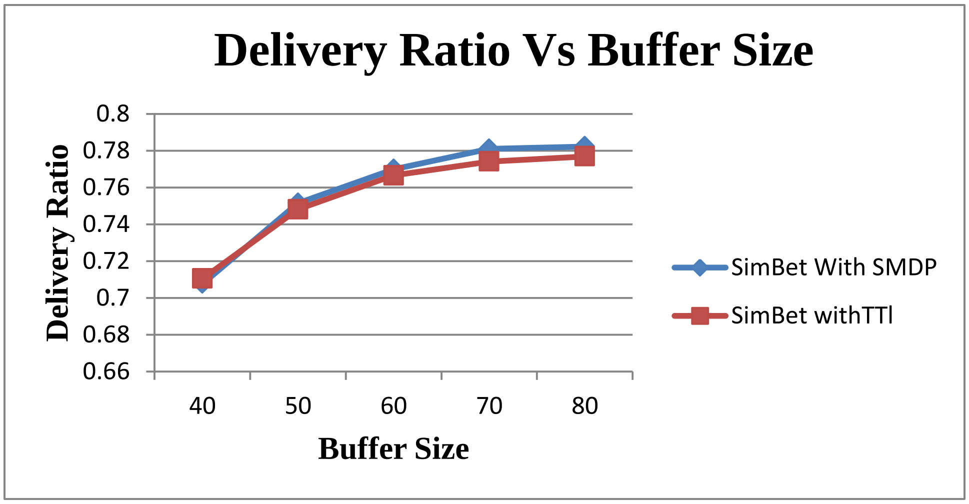

Figure 12 Delivery Ratio by varying Buffer Size

Figure 12 shows the effect of delivery ratio when buffer size is varyed from lower to higher using constant message time to live 700s. As we can see the proposed SMDP scores better than the existing Remaing time to live dropping policy.

The effect of overhead ratio is shown in figure 13 here also the propose SMDP dropping policy performs better than the existing dropping policyinterms of overhead ratio.

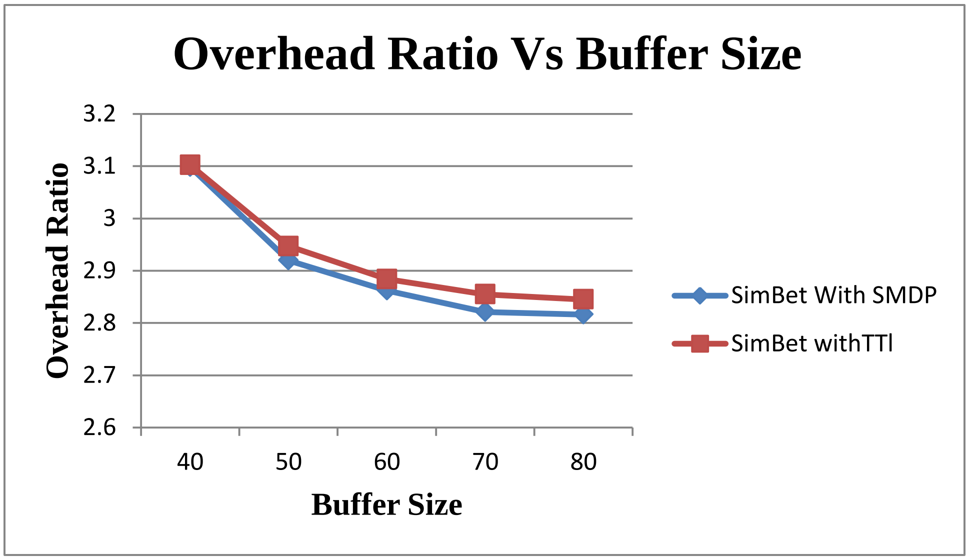

Figure 13 Overhead Ratio by Varying Buffer Size

The effect of average delay is shown in figure 14 here also the propose SMDP dropping policy performs better than the existing dropping policy interms of average delay.

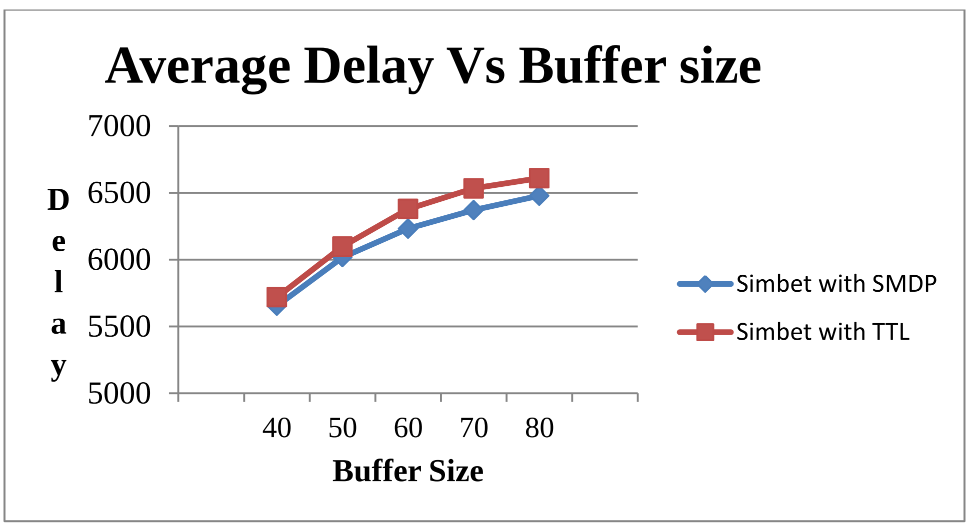

Figure 14 Average Delays by Varying Buffer Size

Figutre 14 illustrate the performance of the SMDP dropping policy interms of Average delay. As we can see the Average delay of the proposed dropping policy is lower than the existing on in which the proposed dropping policy (SMDP) scores the good performance than the existing one.

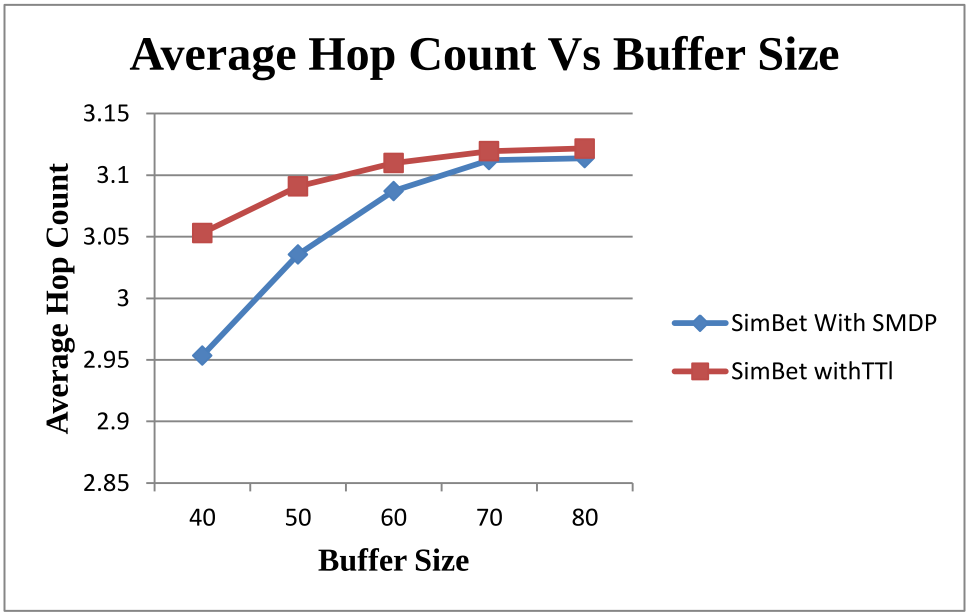

Figure 15 Average Hop Count by Varying Buffer Size

Figure 15 show the Average hop count of nodes in the network. Here the SMDP dropping policy scores less Average Hop count wich show the less resource usage. Thus the SMDP has better performance interms of Average hop count than the exixting dropping policy when the buffer size is increase frow lower size.

5.8 Discussion

In opportunistic network nodes are mobile and the network topology is undifined due to nodes mobility. this network uses store, carry and forward paradaim.Routing in opportunistic network usually utilizes multiple message copies in order to guarantee the data delivery. However, data delivery is affected by limited storage due to storage congestion problem. storage congestion is the frequent event if proper buffer management is not used wich affect the performance of the network as well as the routing protocol. Therefore designing dropping policies for different routing protocol should be the current research area for researcher. Thus the study design SMDP dropping policy by combining the TTL Dropping policy with social based Dropping Policy wich is SimBET Utility based dropping policy. the performance of the proposed SMDP dropping policiy is evaluated interms of Delivery ratio, Overhead Ratio, Average Delay and Average Hop count network metrics using ONE network simulator. As the result shown in chapter Four the proposed dropping policy scores better performance interms of Delivery ratio,Overhead ratio and Average hop count. the simulation result shows the proposed SMDP dropping policy performs better interms of message delivery in the network by varying message time to live and buffer size of the nodes then the result report shows the Average delivery of message by varying TTL is 73.93% in number 5401 messages are delivered for SMDP and 73.79% or 5391 messages are delivered for TTL based dropping policy and by varying buffer size 75.85% in number 5541 messages are delivered for SMDP and 75.52% in number 5517 messages are delivered for TTL based dropping policy for simulation time 43200s or 12hr. Thus the result shows the proposed SMDP performs better than the existing dropping policy interms of Delivery ratio, Overhead ratio, Average hop Count and delay using two scenarios TTL varying and Buffer size Varying.

CHAPTER SIX

6. CONCLUSION AND FUTURE WORK

6.1 Conclusion

Today, the rapid increasing of personal mobile devices with different wireless communication is enabling reason for the developments Opportunistic Network. In such types of network communication is through opportunistic contact and store–carry-forward paradigm. Routing in opportunistic network usually utilizes multiple message copies in order to guarantee the data delivery. However, data delivery is affected by limited storage due to storage congestion problem. Dropping policy was proposed to improve the performance of Opportunistic routing protocols in the areas of opportunistic mobile social network (OMSN), in particular for SimBET routing protocol. This research work uses the SimBet Utility and TTL based dropping policy (SMDP) to eliminate the storage congestion problems by dropping some message wich has least remaining Time to live and simbet utility.Using SMDP dropping policy the research work utilizes buffer by dropping the right message which means the message with low probability to be delivered to destination and accept the new incoming message when buffer is full wich enhance the performance of the opportunistic network.

This research work compares the proposed SMDP dropping policy and TTL dropping policy with their result gain in chapter four. From the Simulation result, when SMDP is used in SimBET routing protocol it has better performance interms of delivery ratio, Overhead ratio and Average Hop count as compared to TTL dropping policy. thus this research work conclude that using SMDP dropping policy we can enhance the performance of opportunistic mobile social network by delivering more messages than the existing TTL dropping policy wich droppes the message which has a probability to be delivered to their destination.

6.2 Future work

The SMDP message Dropping policy in this research work will provide a good direction for future researcher to improve the congestion occurs in opportunistic network and enhance the performance with differance performance metrics.This research work can be extended by applying SMDP algorithm over different routing protocols in opportunistic network and improve the node end to end delay. So for the future:

- How to allocate other resources using Social relationship is important research direction, especially for social based routing protocols.
- Integrating node SimBET utility with other parameters to design combinational buffer management for SimBET routing protocol

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APPENDIX A

Simulation Setting with SMDP

SENARIO NAME

Scenario.name = Scenario_SMDP

Scenario.simulateConnections = true

Detail map

Scenario.updateInterval = 0.1

SIMULATION TIME

12h - 43200

Scenario.endTime = 43200

NUMBER OF GROUPS

Scenario.nrofHostGroups = 3

COMMON SETTINGS APPLIED TO ALL GROUPS

#MOVEMENT MODEL

Group.movementModel = ClusterMovement

ROUTING PROTOCOL

###################### Router #################################

##simbet router

Group.router = DecisionEngineRouter extends ActiveRouter

DecisionEngineRouter extends ActiveRouter.decisionEngine = SocialBased.SimbetRouter

DecisionEngineRouter extends ActiveRouter.CentralityAlg = routing.SocialBased.BetweenessCentrality

DecisionEngineRouter extends ActiveRouter.SimilarityAlg = routing.socialBased.NeighbourhoodSimilarity

DecisionEngineRouter extends ActiveRouter.a = 0

##

TRANSMISSION RANGE 60

Group.transmitRange = 100

Group.transmitSpeed = 250k

Message TTL (minutes)

Group.msgTtl = 90

##################################

walking_nodes group

Group1.groupID = Walking

Group1.bufferSize = 50M

Group1.movementModel = ClusterMovement

Group1.routeFile = data/walking_nodes.wkt

Group1.routeType = 1

Group1.waitTime = 0, 120

Group1.speed = 0, 5

Group1.nrofHosts = 29

###3

bike Nodes

Group2.groupID = bike

Group2.bufferSize = 50M

Group2.movementModel = ClusterMovement

Group2.routeFile = data/bike_nodes.wkt

Group2.routeType = 1

Group2.waitTime = 0, 120

Group2.speed = 0, 10

Group2.nrofHosts = 50

Mobile Nodes moving between cars

Group3.groupID = cars

Group3.bufferSize = 50M

#Only cars can move on roads

Group3.okMaps = 1

Waiting time between each stop

Group3.waitTime = 300, 900

Cars Speed -   50 km/h = 13.88 m/s -100 km/h = 27.76m/s;

Group3.speed = 13.88, 27.76

Group3.nrofHosts = 50

###

MESSAGE CREATION PARAMETERS

class of the first event generator

message ID prefix

creation interval in minutes

message sizes (500KB - 2MB)

MESSAGE CREATION PARAMETERS

Events.nrof = 1

Events1.class = MessageEventGenerator

Events1.interval = 25, 35

Events1.size = 50k, 750k

Events1.hosts = 15, 24

Events1.tohosts = 0,128

Events1.prefix = M_M_

REPORTS - ALL REPORT NAMES HAVE TO BE VALID REPORT CLASSES

how many reports to load

Report.nrofReports = 2

default directory of reports (can be overridden per Report with output setting)

Report.reportDir = reports/

Report classes to load

Report.report1 = MessageStatsReport

APPENDIX B

Running simulation on Batch mode

Command Prompt

```
Microsoft Windows [Version 10.0.10240]
(c) 2015 Microsoft Corporation. All rights reserved.
C:\Users\Gir>e:
E:\>cd one_1.6.0
E:\one_1.6.0> one.bat -b 5 proposed SMDP.txt
E:\one_1.6.0>java -Xmx512M -cp .;lib/ECLA.jar;lib/DTNConsoleConnection.jar core.DTNSim -b 5
proposed SMDP.txt
Run 1/5
Running simulation 'scenario_SimbetRouter_proposed_40M'
60.0 43098: 718.20 1/s
60.5 43500: 1116.39 1/s
Simulation done in 60.53s
Run 2/5
Running simulation 'scenario_SimbetRouter_proposed_50M'
44.8 43500: 971.44 1/s
Simulation done in 44.76s
Run 3/5
Running simulation 'scenario_SimbetRouter_proposed_60M'
43.7 43500:  995.59 1/s
Simulation done in 44.76s
Run 4/5
Running simulation 'scenario_SimbetRouter_proposed_70M'
42.7 43500: 1018.43 1/s
Simulation done in 42.71s
Run 5/5
Running simulation 'scenario_SimbetRouter_proposed_80M'
41.6 43500: 1045.80 1/s
Simulation done in 41.60s
---
All done in 238.52s
E:\one_1.6.0>
```

Command Prompt

```
Microsoft Windows [Version 10.0.10240]
(c) 2015 Microsoft Corporation. All rights reserved.
C:\Users\Gir>
C:\Users\Gir>e:
E:\>cd one_1.6.0
E:\one_1.6.0> one.bat -b 5 proposed TTL.txt
E:\one_1.6.0>java -Xmx512M -cp .;lib/ECLA.jar;lib/DTNConsoleConnection.jar core.DTNSim -b 5
proposed TTL.txt
Run 1/5
Running simulation 'scenario_SimbetRouter_proposed_300s'
28.1 43500: 1547.39 1/s
Simulation done in 28.10s
Run 2/5
Running simulation 'scenario_SimbetRouter_proposed_400s'
31.6 43500: 1378.20 1/s
Simulation done in 44.76s
Run 3/5
Running simulation 'scenario_SimbetRouter_proposed_500s'
36.9 43500: 1179.60 1/s
Simulation done in 44.76s
Run 4/5
Running simulation 'scenario_SimbetRouter_proposed_600s'
36.4 43500: 1193.53 1/s
Simulation done in 42.71s
Run 5/5
Running simulation 'scenario_SimbetRouter_proposed_700s'
40.0 43500: 1080.02 1/s
Simulation done in 39.98s
---
All done in 185.70s
E:\>cd one_1.6.0
E:\one_1.6.0>_
```

DECLARATION

I, the undersigned, declare that the thesis comprises my own work. In compliance with internationally accepted practices, I have dually acknowledged and refereed all materials used in this work. I understand that non-adherence to the principles of academic honesty and integrity, misrepresentation/ fabrication of any idea/data/fact/source will constitute sufficient ground for disciplinary action by the university and can also evoke penal action from the sources which have not been properly cited or acknowledged.

Girma Bula ________________ 27/6/2021

Name Signature Date

Date of submission : August 6/2021

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