MULTI-COPY ROUTING FOR DELAY TOLERANT NETWORKS IN IZTECH

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ABSTRACT

MULTI-COPY ROUTING FOR DELAY TOLERANT NETWORKS IN IZTECH

Delay Tolerant Networks (DTNs) are approaches of communication that seeks to address the technical issues in intermittent networks that may lack continuous network connectivity between source and destination for message transmission. In these kinds of networks, opportunistic routing algorithms are needed, where the destination is reached through intermediate mobile nodes by use of store-carry-and-forward strategy.

In this thesis, Binary Spray and Wait with Routine Awareness (BSWRA) is proposed in IZTECH. IZTECH is divided into five sub-areas (EEE department, Library, Cafeteria, Gym and Dormitory) with respect to their routine working hours. In our proposed protocol, the working time frame of IZTECH is our main interest which we refer as Routine Awareness (stipulated time frame). The Routine Awareness is added to Binary Spray and Wait (BSW) to increase chances of finding destination node. The proposed protocol improves BSW protocol on delay problem, by treating a node within a new sub-area as a source node. Furthermore, this work addresses the overhead issue in DTN protocols by revising the effect of dropping repeated messages within a sub-area. BSWRA protocol has been implemented and performance analysis has been carried out using NS2 simulator. This work examines the performance of BSWRA with popular DTN protocols (i.e. BSW, ER and PRoPHET Protocols) in terms of message delivery ratio, average end-to-end delay and overhead ratio, by observing the performance parameters of all routing protocols under varying number of nodes, message size and buffer size. The simulation results shows that generally, BSWRA protocol provides a better performance, though with 100 number of nodes and buffer size equal to100MB, ER protocol outperforms all the protocols in terms of average end-to-end delay but with the worst delivery ratio and overhead ratio.

ÖZET

İYTE'DEKI GECIKME TOLERANSLI AĞLAR IÇIN ÇOK KOPYALI YÖNLENDIRME

Gecikme Toleranslı Ağlarda (GTA) kaynak ve hedef arasında sürekli ağ bağlantısı bulunmadığı için depola-barındır-ilet stratejisini kullanan yönlendirme algoritmaları gereklidir. GTA'daki mobil düğümlerin dinamik davranışı ve ağın öngörülemeyen bölümlenmesi nedeniyle bu stratejiyi kullanan çeşitli protokoller önerilmiştir.

Bu tezde ilk önce literatürde bulunan önemli bazı GTA protokolleri incelenerek, İYTE için Rutin Farkındalığı olan İkili Yayma ve Bekleme (Binary Spray and Wait with Routine Awareness (BSWRA) isminde bir GTA protokolü önerilmiştir. İYTE beş alt alana (Bölümler, Kütüphane, Kafeterya, Spor Salonu ve Yurtlar) ayrılmıştır. Önerilen protokolde, bu alt alanların rutin farkındalığı olarak adlandırdığımız çalışma saatleri, ana ilgi alanımızdır. Rutin farkındalığı hedef düğümün mesajı alma şansını arttırmak için İkili Yayma ve Bekleme (BSW) ile beraber kullanılır. Herhangi bir saatteki aktif alanların farkında olmak, düğümlerin olası konumları hakkında yararlı bir bilgi sağlar. Bu çalışma, alt alanlardaki tekrarlanan iletilerin bırakılma etkisini de gözden geçirerek fazladan yük (overhead) problemini de ele almaktadır. Ayrıca, önerilen protokol, yeni bir alt alana giriş yapan bir düğümün bir kaynak düğüm olarak davranabilmesini sağlayarak BSW protokolündeki gecikme sorununu da çözümlemektedir. BSWRA'nın amacı teslimat oranını arttırmanın yanında, uçtan uca gecikmeyi de asgariye indirmektir. BSWRA'nın performans analizi NS2 simülatörü ile yapılmıştır. Ayrıca performans mesaj dağıtım oranı, uçtan uca gecikme ve fazladan yük bakımından BSW, ER ve PRoPHET gibi diğer popüler DTN protokolleri ile karşılaştırılmıştır. Yüksek sayıda düğümün kullanıldığı senaryolar hariç, BSWRA protokolünün birçok senaryo için (100 tane düğüm ve 100MB ön bellek boyutu ile) popüler DTN protokollerinden daha iyi bir performansa sahip olduğu gösterilmiştir. Yüksek sayıda düğümün kullanıldığı senaryo için ise çok fazla ağ kaynağı kullansa da Epidemic yönlendirme protokolünün tüm protokollerden daha iyi performans sunduğu gösterilmiştir.

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LIST OF ABBREVIATIONS

BSW	Binary Spray and Wait
BSWRA	Binary Spray and Wait with Routine Awareness
DTN	Delay Tolerant Network
DP	Delivery predictability
ER	Epidemic Routing
IZTECH	Izmir Institute of technology
IPN	Interplanetary network
IP	Internet protocol
MANET	Mobile ad hoc network
NS2	Network simulator two
PRoPHET	Probabilistic routing protocol using history of encounters and transitivity
SV	Summary vector
SW	Spray and Wait
TCP	Transmission control protocol
TTL	Time to Live
WLAN	Wireless local area network

CHAPTER 1

INTRODUCTION

As the world evolves, communication has become vital that each user wants to remain connected so that the transfer of information and data can be done as fast as possible. Thoughts, data and any other information can be shared across countries within a second. All these incredible activities are being supported by what is so called internet. Internet has done a life changing movement worldwide, whereby there is no need for physical movement from one place to another for data transfer, as long as devices are connected with some communication medium (physical or wireless medium) in presence of a server.

The internet consists of well-known infrastructure for data transmission. It consists of pre-established routers, gateways and wireless or wired communication systems [24]. Due to intended area and range, servers are allocated in different places of designer's choice to achieve good management of network. Traditionally, network communications are always invented to be connected, that is, within a network, there must be an end-to- end connection between every pair of nodes.

With the help of internet which composed of devices, wired communication medium or wireless communication medium and servers, the transfer of data is possible. However, in scenarios like, remote areas, disaster areas, military communications and deep space communications where internet infrastructure is impossible, transfer of data from one end to another becomes a challenge. In these scenarios, the problem remains with no solution which is how transmission of data can be possible in absence of traditional infrastructure? Thanks to researchers for their extensive attention in communication networks that lead to Delay Tolerant Networks (DTNs) technology [13], as a solution for routing in challenged areas.

1.1 Delay Tolerant Network

Delay Tolerant Networks or Disruption Tolerant Networks are kinds of networks where end-to-end path is not stable, network is partitioned, topology is dynamic and disconnections are frequent. There is lack of continuous connectivity between source and destination for message transmission. In these kinds of networks, opportunistic routing algorithms are needed, where nodes use store-carry-and-forward mechanism as shown in Figure 1.1, to move messages form one node to another whenever an opportunity arises [6]. In DTNs, communication is achieved by exploiting the mobility behavior of nodes, buffer space and good management of resources (i.e. energy).

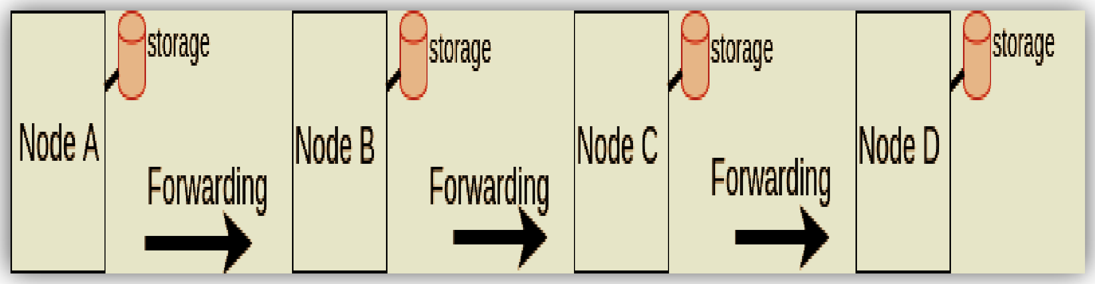

Figure 1.1. The architecture of DTN mechanism

DTNs play a big role in wildlife tracking and habitat monitoring, monitoring sensors, disaster recovery networks, interplanetary networking, military communications, remote communications and developing countries [2]. DTN is also applicable in urban and vehicular networks where disruptions are caused by the intersection of buildings, limited radio range and nodes mobility.

Traditionally, within internet based routing, pre-defined connectivity is expected between paired nodes for data transmission from source to destination. On the other hand, DTN connections rely on a mechanism of store-carry-and-forward, for data transfer and there is no prior knowledge about network. In internet, routing is basically about to choose the optimal path whereas in DTNs, routing is mainly to ensure minimum delay of data transfer from source to destination.

Kevin Fall, who is a pioneer of designing DTN terrestrial networks, adapted the DTN technology from Interplanetary Network (IPN) [20]. The IPN started in 1970s, and the aim of the invention was to handle the significant delays and packet corruption in deep-space communications. Since 1970s, more and more attention has been drawn in communication networks that researchers started developing routing technology for non-fixed infrastructure which resulted in Mobile Ad-hoc Network (MANET) [4]. Researchers and growing number of academic conferences on delay and disruption-tolerant networks have enriched their interests in store-carry-and-forward approach of DTN for message transfer to accomplish network reliability in challenged areas and address issues that are well understood in traditional network communications.

1.2 Multi-Copy and Single-Copy Routing in DTN

In DTN, both single copy and multi-copy routing strategies are used [22]. In the single copy routing mechanism [13], a single message is forwarded through the network and the nodes have full knowledge about network (i.e. passed and future movement of the nodes). With single copy based routing, good use of network resources (i.e. bandwidth and energy) is provided but with high latency as a disadvantage.

On the other hand, multi-copy routing refers to forwarding replicas of the same message to a number of nodes aiming to obtain a path towards destination through some intermediate nodes [1]. With multi-copy routing protocols, the level of knowledge about network is expected to be low and the algorithms are equipped with high delivery probability, low latency with high cost of resources as the main challenge. In multi-copy routing schemes, due to insufficient knowledge about network, paths of a message are not already established; replicas of a message from source node to destination are forwarded to other nodes with help of routing algorithms to ensure efficient delivery of the message in partitioned networks.

1.3 Characteristics of DTN

DTN shows some specific characteristics [2, 4, 9, 20, 26] which makes it different from traditional wireless networks:

- **Store-carry-forward strategy:** This is the main principle of DTN in which nodes are able to receive, store and carry messages and to forward them if destination node is available or keep them in the buffer.

- **Tolerates network partitioning:** Network partitioning is defined as sudden change of network state, which is up or down of any communication link. DTN supports these interrupted networks because of its ability to store and carry packets in absence of connectivity.

- **Supports heterogeneous environment**: This implies that, DTN provides effective integration within different network technologies such as MANET, WLAN, where the aim is to keep the benefit of end-to-end paths (if available) offered by those networks, at the same time gains the advantage of DTN whenever links are not available.

- **Prevents data loss:** Due to DTN technology's ability to store messages, every node is provided with buffer memory in which messages are stored till the node is able to transfer the messages to other nodes [25].

- **Allows asymmetric data rate**: This means that DTN allows transfer of data even though the rate of incoming data is different from outgoing data rate.

- **Tolerates long queuing delays**: In DTN networks, nodes contain a long queue of messages that are waiting to be transmitted in their order of priority. Therefore, when two nodes contact each other during time of transmission, a low priority message waits while higher priority messages in transmission queue are being transmitted.

- **Tolerates high latency:** The idea of DTN was originally developed as a technology that would support large delays within interplanetary communications. In DTN delays may be lager up to some few weeks or years depending on when the next contact is available. In other words, till the next node comes in the communication range of the sending node, the messages will be held in the sending node.

1.4 DTN Challenges

There are a number of challenges in DTN [21] such as the unavailability of fixed infrastructure, dynamic network topologies and frequent partitioning of network. This leads to high latency and low data delivery possibility that causes network overhead. The presence of overhead requires large storage and sufficient energy which are both limited in DTN. Due to all of these challenges, various algorithms to deal with the challenges were proposed and from the above challenges we design our routing strategy.

1.5 Research Objective

This thesis aims to introduce Binary Spray and Wait with Routine Awareness(BSWRA) routing algorithm which considers planned IZTECH working time frame to reduce the network overhead and ensures message delivery with minimum possible delay. The thesis' objectives include (but are not limited to) the following:

- Successfully implement the Binary Spray and Wait with Routine Awareness Routing algorithm in the network simulator NS-2.
- Analyze the implementation and compare the performance of BSWRA with DTN popular protocols (i.e. ER, BSW and PRoPHET).

1.6 Thesis Organization

The remaining of this thesis is organized as follows. In Chapter 2, we present related studies where we clarified our problem statement and presented more details on

DTN with its different routing algorithms. In Chapter 3, we present the problem statement, and give an overview and detailed information on Binary Spray and Wait with Routine Awareness as a proposed algorithm for problem stated; Chapter 4 presents simulation and analysis of our proposed algorithm, and finally Chapter 5 with conclusion.

CHAPTER 2

LITERATURE REVIEW

This chapter focuses on what has been done on multi-copy routing in DTN field as well as DTN popular routing protocols that have been used in the challenged networks. Furthermore, it provides a reader with the straightforward idea of why a new algorithm has been needed and proposed in this thesis.

2.1 Delay Tolerant Network and Bundle Layer

DTNs support long delays with a help of their ability to store-carry-and-forward messages whenever a chance arises. This ability to receive a message, store it in the buffer and forwards it when a new node arises in its radio range, gives a clear difference between DTNs and traditional routing schemes. As depictured in Figure 2.2, traditional communications require well established transmission connectivity. As described in previous chapter, the technology is composed of networking devices that are linked together by use of wires, wireless or both to pass the data from one device to another.

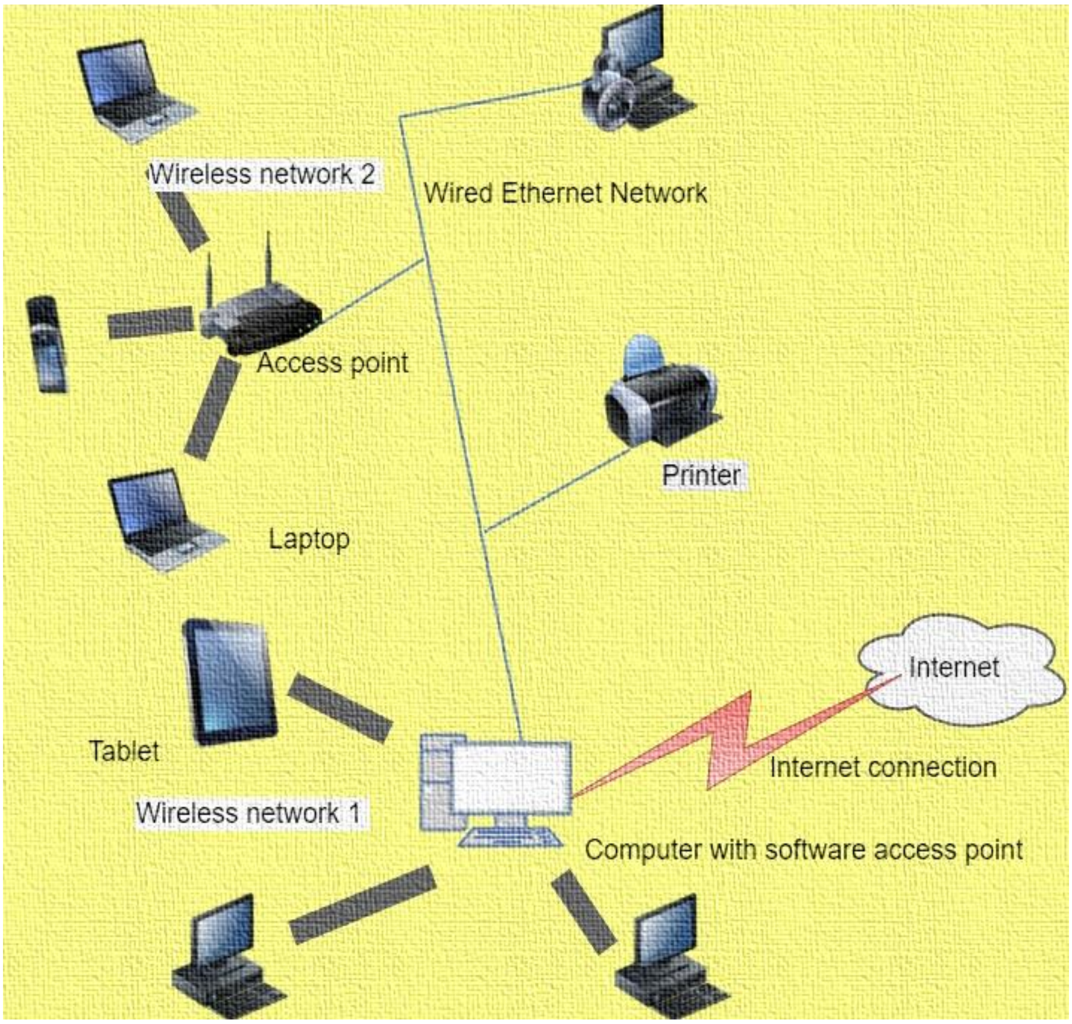

Figure 2.1. Traditional communication

Due to their high network partitioning tolerance, DTNs assure delivery of messages with inadequate knowledge about nodes mobility or the whole network in general as seen in Figure 2.2. On the other hand, in presence of network partitions, traditional protocols cannot hold on a message. When a communication link goes down in communication process, a message will be lost.

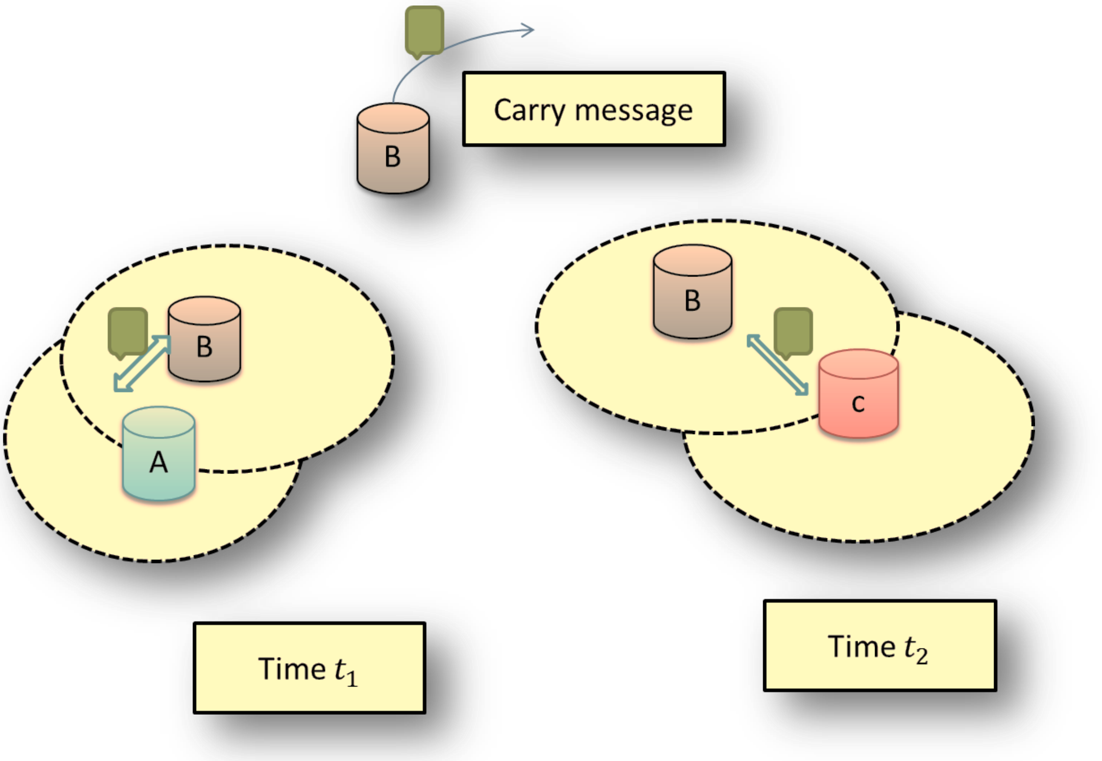

Figure 2.2. DTN communication

Unlike internet communication, in DTNs a message is stored in the sender node's buffer till the link comes up. This is due to its specialty of owning a **bundle layer** which is located under application layer and above the transport layer as seen in Figure 2.3. The figure represents both internet and DTN layers. DTN layers include a bundle layer which is a distinct unit designed for unsteady communication networks [17, 3].The bundle layer groups messages into bundles and sends them using a store-carry and-forward mechanism. Figure 2.4 presents the internet virtual communication of source and destination nodes with the help of TCP/IP to insure end-to-end delivery of the message. With internet layers, the IP works at all nodes along the path and retransmission is directly from source to destination. On the other hand, Figure 2.5 shows DTN virtual communication where the bundle protocol allows node-to-node delivery and also retransmission of lost packets is done on node-to-node. DTN nodes may operate as a host, router, gateway or a combination of all. In other words, a DTN node can be a source, relay or a destination. The bundle protocols connect separate networks into a single network by using their compatibility to different network technologies and custody transfer of messages.

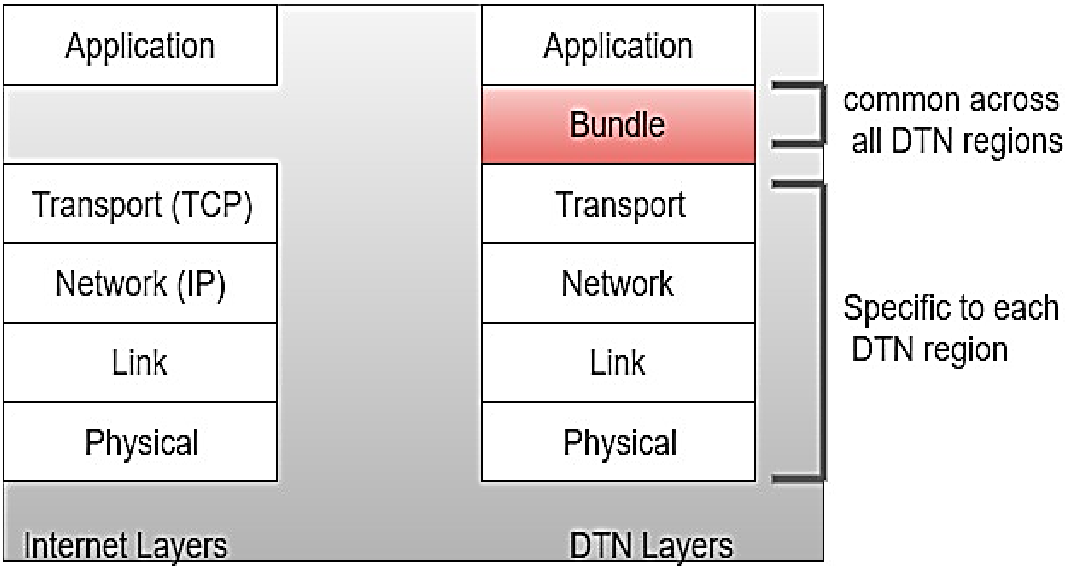

Figure 2.3. Internet and DTN layers illustration

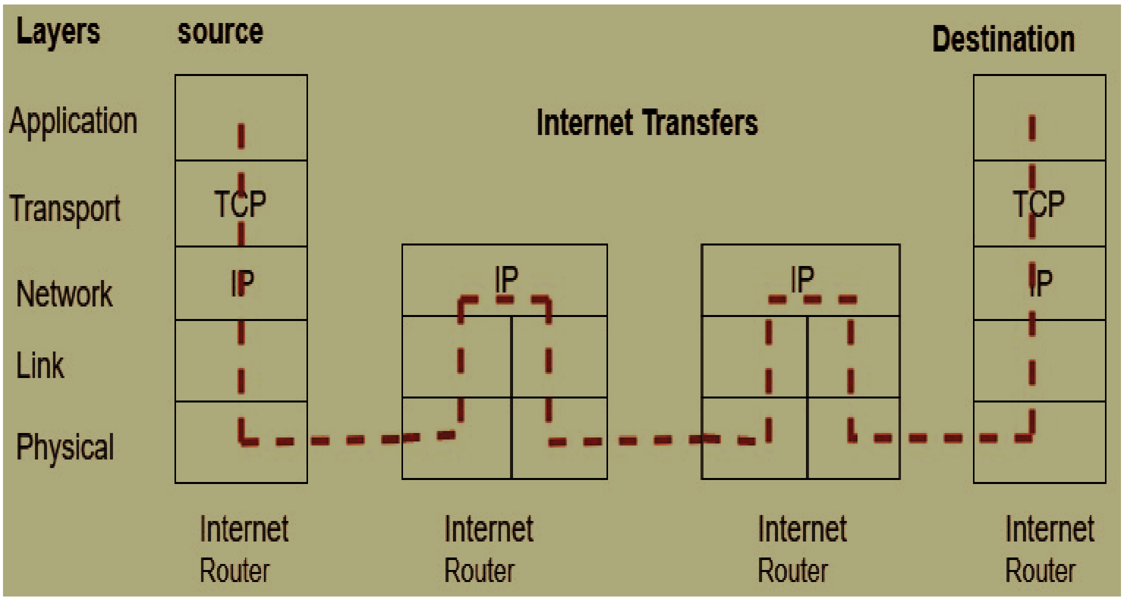

Figure 2.4. Internet virtual transfers

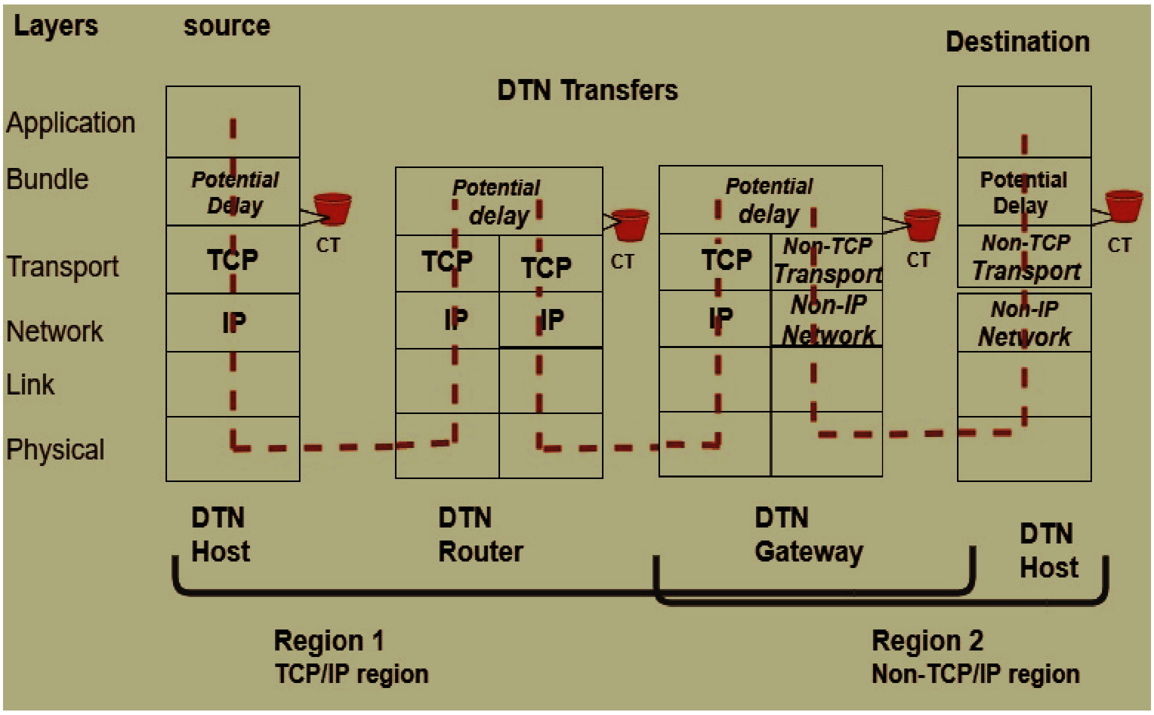

Figure 2.5. DTN virtual communication

2.2 Routing in Delay Tolerant Networks

DTNs routing protocols are grouped into deterministic and non-deterministic routing protocols as seen in Figure 2.6. Deterministic routing protocols are used if complete knowledge about future meetings and positions information of nodes is provided whereas non-deterministic routing protocols are used opportunistically with no or limited knowledge of nodes future connectivity [13, 1].

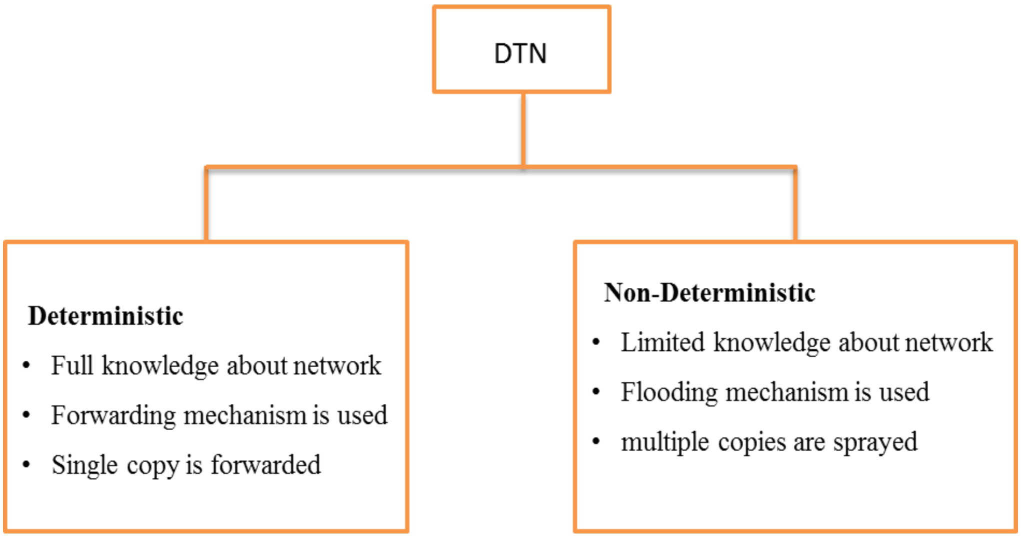

Figure 2.6. Classification of DTN routing protocols

2.2.1 Deterministic Routing Protocols

Deterministic routing protocols include a single copy of a message in the network and each node in the network has full knowledge about past and future encounters [23]. With deterministic routing protocols [5], a message is routed based on prior knowledge and forwarding mechanism is used. Deterministic protocols have good use of network bandwidth but with high latency and low delivery rate. Since deterministic routing protocols expect the existence of network information, they are not the best routing protocols for DTN networks because DTNs do not provide information about the network. We will not discuss more on deterministic routing protocols since it is out of this thesis' scope.

2.2.2 Non-Deterministic routing protocols

On the other hand, non-deterministic protocols are multi-copy and opportunistic protocols that use flooding as transmission mechanism [1]. Non-deterministic protocols have less knowledge about network information. These protocols are equipped with high delivery ratio, minimum end-to-end delay and waste of resources (i.e. buffer and energy) as the main challenge. Since DTN never provides full knowledge about the network for proper routing, various non-deterministic algorithms were proposed to address DTNs routing challenges. Some of the popular multi-copy DTNs routing algorithms namely ER, PRoPHET, MaxProp, SW and BSW are discussed in this chapter.

Nodes in DTN networks exchange a list of tables that contains information about the network. The information may be number of messages, encountered nodes, buffer size, nodes' energy level etc. As seen in Figure 2.7, when two nodes A and B come into each other's communication range, they exchange their connectivity summary vector which contains a list of messages each node has, a list of encountered nodes and each node updates information table according to the current received summary vector from another node. After they both decide on which messages should be exchanged, the exchange of messages then starts. We depicture how nodes interact during an opportunistic contact in Figure 2.7.

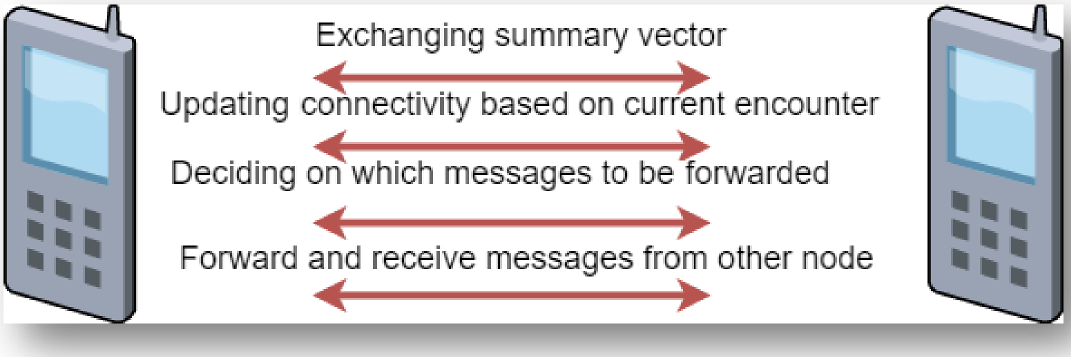

Figure 2.7. Nodes interaction during an opportunistic contact session.

If the destination is one of the contacted nodes, the message will be delivered and if not, each node will check whether the other node is a good relay for the desired destination. If both are not good forwarders of either destination, they both store their messages in the buffer till another opportunity with the best relay happens.

2.3 Multi-copy DTN routing algorithms

Multi-copy routing refers to forwarding replicas of the same message to neighboring nodes, aiming to obtain a path towards destination through some intermediate nodes [1, 13]. A lot has been done on multi-copy routing algorithms and popular multi-copy routing algorithms will be discussed in this section.

2.3.1 Epidemic Routing (ER) protocol

A multi-copy or multiple nodes carrying replicas of the same message routing algorithms in DTNs was first introduced by Vahdat Becker as Epidemic Routing [1]. With epidemic routing, when two nodes come into communication range of one another two steps are carried out. First, summary vectors (which are message IDs) are exchanged. Second, after exchange of summary vectors, each node checks for messages that are not available in its buffer and requests transfer of those messages from each other. Let SV_A and SV_B represent the summary vector at nodes A and B respectively. As illustrated in Figure 2.8 nodes A and B exchange SV_A and SV_B. After summary vector exchange, message exchange follows. Node A computes SV_B not in SV_A which is a set of messages that node B has in its buffer, that are not present in A and also node B computes SV_A not in $SV_{B,}$ which is a set of messages that node A holds which are missing in B. In this manner, both nodes determine the differences of the messages that they hold in their buffers and transmit missing messages to the other node.

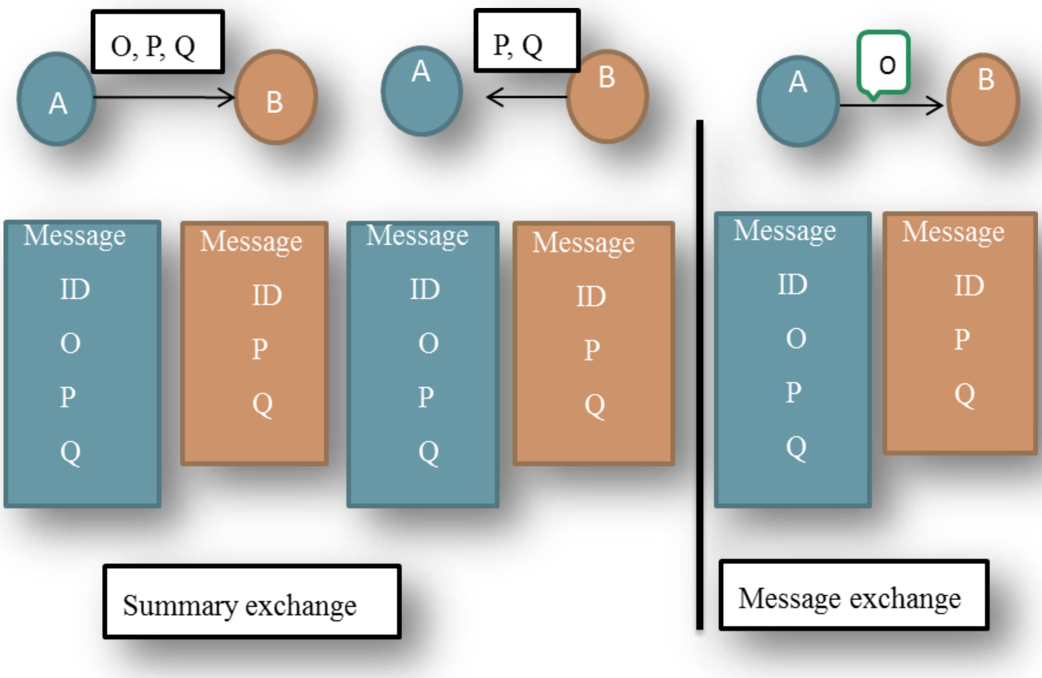

Figure 2.8. Message exchange in epidemic routing protocol

After repairing of two nodes and if there is no available path currently to the destination, the messages are buffered. This process (message exchange) is always performed when two nodes come into transmission range of each other.

Furthermore, a source node A sends a copy of a message to every node that it encounters. The nodes that receive a copy of the message also replicate a copy of the same message to every node that they meet. In that manner, a copy of the message reaches at the destination finally. But clearly large overhead cannot be denied with ER protocol since every node within the network holds a copy of the same message. Due to the algorithm's sprayed like epidemic disease, ER protocol is simple to implement, but requires significant resources (i.e. storage and energy). In case of high network traffic, node's battery may be discharged quickly and since each node keeps a copy of each message, both storage and network capacity are blindly used, yet are limited. Clearly, it can be seen that ER protocol gives the fastest spread of copies in the network as well as optimum delivery time but with high resources consumption.

2.3.2 PROPHET Routing Protocol

Probabilistic Routing Protocol using History of Encounters and Transitivity (PRoHET) is a probabilistic forwarding protocol, that uses information about the past encounters and transitivity to predict each node's delivery predictability (DP) for other nodes. PRoPHET routing protocol by Lindgren et al [15], came as a solution to epidemic routing protocol drawbacks where a node is selected based on its DP. Also, similar to [15], K.Harras et al [14] proposes a flooding control in sparse networks. Lindgren et al, believed that nodes mobility is not random as it is typically expected to be. His idea was that, if two nodes have met several times before, there is a possibility that they will meet again in the future or if a node visits a certain location frequently, there is a chance that it will visit that location again. Therefore, nodes move in a predictable manner based on their repeated habits. Based on his idea, the author introduced a probabilistic routing scheme that provides high delivery probability of messages while keeping buffer usage and communication overhead at low level compared with ER protocol.

Similar to ER protocol, in PRoPHET, two nodes exchange their summary vectors when they come into communication range as seen in Figure 2.9. In addition to the summary vector, another metric called delivery predictability of nodes is also exchanged. Delivery predictability of a node represents how each node A is likely to deliver a message to each destination B. Lindgren introduced delivery predictability metric for two nodes A and B as $P_{(a,b)}\,\epsilon[0\ 1]$ at every node A for each known destination B. The delivery predictability shows how likely a node is to encounter the destination of the message. The main difference between Epidemic and PRoPHET routing is their forwarding tactics. PRoHET allows transfer of a message to another node if and only if, its delivery predictability to a destination is lower than that of encountered node, whereas Epidemic routing protocol nodes give and receive messages that are not in their buffers. PRoPHET calculations are carried out as follows. The node mobility is assumed to be random. But, encounters of some nodes are highly probable than others. The protocol considers nodes that encounter regularly to be the most promising candidates to deliver the messages. Therefore, the protocol uses the following three equations to calculate the delivery predictability between two nodes.

$$P_{(a,b)} = P_{(a,b)old} + (1 - P_{(a,b)old})\ x P_{init} \qquad (2.1)$$

where $P_{(a,b)\,old}$ is the value of $P_{(a,b)}$ before updating, P_{init}∈[0, 1] is an initialization constant given at the beginning of the scenario. The above update is performed when two nodes are in direct contact of each other. The second equation is the ageing expression that reduces the delivery predictability of node A based on the time passed since node A last met B direct. In other words, the delivery predictability of two nodes will be aged if two nodes does not encounter in a while, hence unlikely to send messages to each other.

$$P_{(a,b)} = (P_{(a,b)old})\gamma^{k} \qquad (2.2)$$

where $\gamma \in [0, 1)$ is the ageing constant and k is the elapsed time since the last meeting of node A and B. Third equation includes a transitive property which updates the delivery predictability of node A towards node C through a transitive node between node A and C. This means that, if node A frequently meets node B, and node B frequently meets node C, then perhaps node C is a better node to send messages that are destined to A.

$$P_{(a,c)} = P_{(a,c)old} + (1 - P_{(a,c)old})\ x P_{(a,b)} x P_{(b,c)} x\ \beta \qquad (2.3)$$

where $\beta \in [0, 1)$ is the transitivity constant which impacts the delivery predictability of node a to c and b is a transitive node.

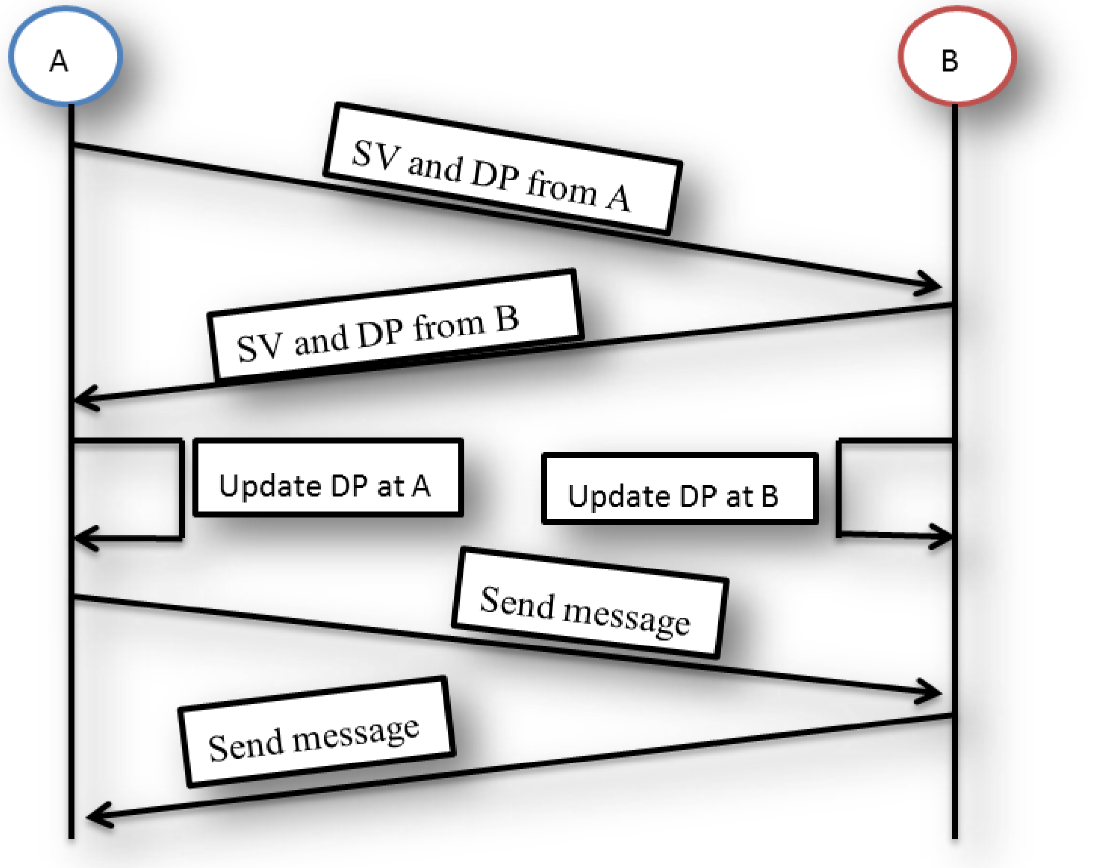

Figure 2.9. Messages and DP exchange in PRoPHET routing protocol

2.3.3 MaxProp Routing Protocol

Maxprop Routing Protocol by Burgess et al [11] is a notable work in the field of DTNs. Just like PRoPHET Protocol, MaxProp protocol forwards messages according to nodes probabilities of delivering the message to the destination but with an additional segment of dropping messages in case of full buffers. MaxProp protocol schedules both message to be deleted from the buffer and messages to be transmitted to other nodes once nodes meet. It does ranking of messages following prioritization criteria suggested by the designer.

The protocol records the probabilities of encountering other nodes by recording encounters history. From the recorded information, nodes that show irregularity in encountering other nodes are considered as low path possibility and a message which is destined to those nodes will be dropped. The nodes maintain messages in a priority order, in other words they make a queue order based on their delivery probability, and forward all the messages in that order.

Generally, as seen in Figure 2.10, the prioritization of messages is done by considering the probability of reaching their destinations. If a probability of reaching a certain destination is always high, the messages which are destined to that specific node are treated as priority. Therefore, messages are dropped or transmitted due to their path possibility of reaching destination.

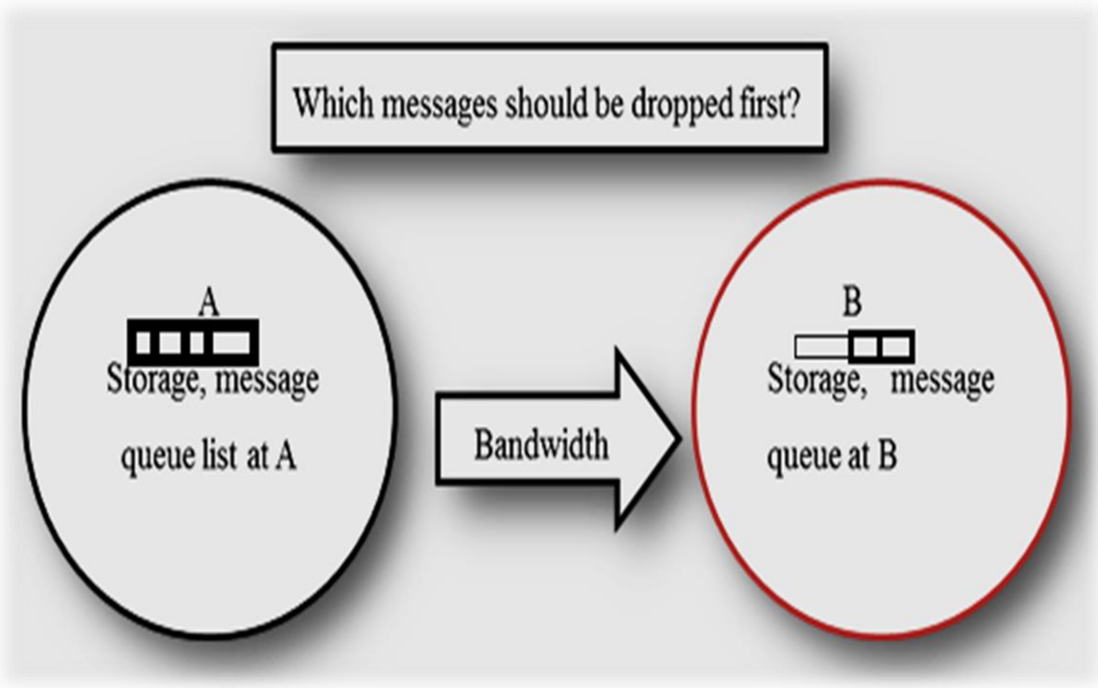

Figure 2.10. Interaction of nodes in MaxProp

2.3.4 Spray and Wait Routing Protocol

Spray and wait was introduced by Spyropoulos et al [22, 18]. The aim here is to achieve fewer transmissions than flooding based routing algorithms (i.e. Epidemic, PRoPHET and MaxProp) and deliver messages faster than single message based routing. Furthermore, the protocol has a better buffer management than flooding based routing protocols by limiting number of message replicas in the network. The authors also consider the changes that may appear within the network and the protocol is designed in the way that it would adapt to the network changes (i.e. if a new node joins the network or leaves, the performance will not be affected). The protocol has two phases and they are:

- **Spray phase**: In spray phase, a source node S spreads L number of copies of a message to N number of nodes in the network. How many copies of a message to be spread and how these copies are spread to other nodes is still an open area of research.
- **Wait phase**: After all copies of a message are spread and the destination is not found in the spraying phase, nodes with a copy enter the wait phase, where nodes will keep the copies until they meet destination for direct transmission.

2.3.5 Binary Spray and Wait Routing Protocol

Since spray and wait sprays L copies of a message in Epidemic manner but with limited number of copies, Binary Spray and Wait protocol is proposed as one of the methods to disseminate L copies. As seen in Figure 2.11, the algorithm is a modified version of Spray and Wait (SW). The only difference between SW and BSW is the way of spraying copies. With SW, a source node sprays a number of copies that is equal to the neighboring number of nodes (L=N) whereas in BSW, if L copies of M (a message) are sprayed by the source node, the total number of nodes that contain a copy is given by $2^{1+log_2 L} - 1$. Given L copies of a message, a source node forwards L/2 of copies to the first node it meets and keeps L/2 to itself. In binary spray and wait each node with L copies of a given message keeps forwarding L/2 to any node that it encounters until it is left with one copy of the given message. When nodes are left with one copy they keep their copies and switch to waiting phase for direct transmission to the destination node.

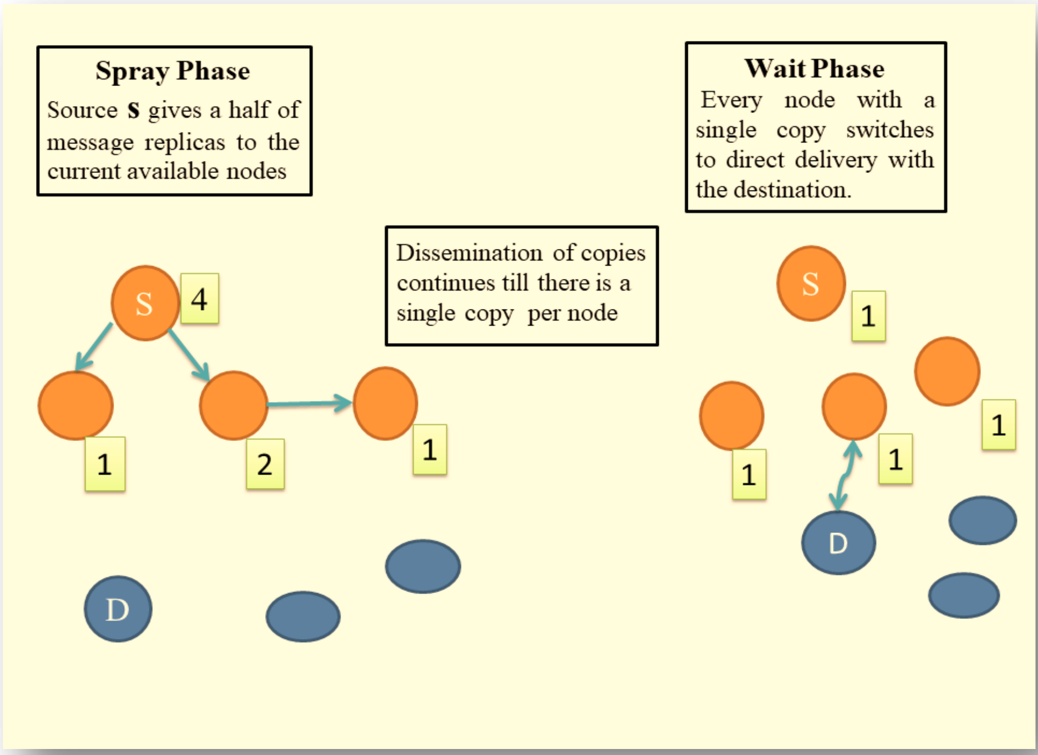

Figure 2.11. Spray and wait phase for BSW protocol

2.4 Mobility Models

In DTN, as we have discussed throughout this Chapter, nodes are mobile and routing schemes are done based either on number of replicas or mobility models [19, 7]. Mobility models can be classified as independent (i.e. random walk mobility model), where nodes move independently, choose random speed and direction from pre-designed ranges of both speed and area of interest (i.e. min-max speed and 0-2π) and dependent mobility models (i.e. community based mobility model), where nodes with common interest follow same mobility model [12, 8]. In community based mobility model, nodes imitate typical human movements.

In real world, people spend time in their favorite sub-areas and their common interests influence their movements highly. It is believed in literature that every node in a community has its local community in which it interacts more than other communities. Since nodes movements mimic real human movements, nodes are grouped due to their mobility patterns and every mobility model affects the performance of a protocol if the mobility pattern is obstructed. With mobility model routing mechanism (i.e. group model based routing), a node follows a mobility model that governs that social group it belongs to and is not expected to change its mobility (i.e. if two professors meet every Tuesday at 10AM for coffee, the protocol groups them as pattern human mobility). Generally, the mobility model in a social community is based on nodes' routine movement behavior.

Routing based on mobility model had attracted researchers' attention for some decades. However, nodes mobility can never be predictable and are independent; hence it is not guaranteed that a node will keep its routines. Furthermore, nodes which belong to different sub-areas within a community, can only deliver messages to their sub-areas. Due to the fact that, mobility model based routing requires a larger memory to store all the movements information about nodes in the network, a new routing scheme that considers routing based on planned active hours of sub-areas in the community (i.e. IZTECH) is proposed.

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CHAPTER 3

BINARY SPRAY AND WAIT WITH ROUTINE AWARENESS

In this chapter, Binary Spray and Wait with Routine Awareness algorithm is presented. First, the research problem and motivation are discussed. Then, it is shown how the algorithm makes use of IZTECH planned time frame to forward a message to active sub-areas until the message hopefully reaches its destination.

In our routing algorithm, nodes move to the sub-area of their choice following predefined IZTECH planned working hours of those sub-areas. Nodes are aware of which sub-area is active and nodes are expected to be in active sub-areas. This mechanism of routing based on predefined working time frame is more reasonable, because all nodes within IZTECH can be counted on for message delivery hence a significant decrease in latency. Furthermore, the protocol gives a break on tracking mobility of every node in the network. As it is presented in this chapter, the algorithm frees nodes from large load in the memory which slows down the functionality of nodes as well as network performance

3.1 Research Problem and Motivation

As described in the previous chapter, Delay Tolerant Network (DTN) is an ongoing area of research that has gained significant attention of researchers and which has been attributing to the suitability of DTN in challenged environments where end-to-end paths are absent. Traditionally, in BSW protocol, only a source node generates L number of copies and sprays them to a certain G number of nodes that are in its neighborhood. After each of G nodes has remained with a single copy, there is no more replication and every node holds a copy until it encounters the destination node. If none of the nodes meet the destination node, the message cannot be delivered to the intended destination. On the other hand, as discussed in literature, routing of messages is based on delivery predictability of nodes. In other words, the routing path of a message is generally estimated according to the frequency of the encounters among nodes. If nodes had met frequently in the past, a blind assumption is made that; they will meet in the future. Due to this assumption of past events to predict the future, the delivery of a message depends on a specific node that meets the destination the most. If the node routines change, this routing method results in less reliable chances of message delivery. Additionally, in the previous proposed DTN algorithms, nodes store information about all nodes in the network. In this way, the overhead increases since this information is to be disseminated to all nodes, hence wastage of network resources (i.e. energy and bandwidth).

Another routing mechanism whereby message forwarding does not depend on a specific node due to its routines (i.e. when and with who a node interacts), but on planned working hours of a community (i.e. IZTECH planned working time frame of sub-areas) whereby the path of a message depends on any node within IZTECH, is proposed. The routing due to routine time frame, in other words routing due to daily routine time awareness, has not been considered in the existing DTN routing protocols. In the new proposed approach named Binary Spray and Wait with Routine Awareness (BSWRA), the route is designed according to the IZTECH planned time frame (though can be feasible in any other networks that meet the criteria), which is used to predict the location of the destination node at any given time. The new protocol improves the blindness of BSW and provides flexible and more reliable network connectivity. Basically, the new approach should solve the problems of scenarios where nodes in different areas, under different working time frames need to communicate with each other with the help of moving nodes.

3.2 Methodology

Think of IZTECH as shown in Figure 3.1 below, where individuals at campus holding handsets as nodes, are randomly moving according to the planned university time frames. The nodes have the ability to communicate with their neighbors by exchanging messages on every occasion when nodes are in communication range of each other. IZTECH is divided into sub-areas such as dormitory, library, EEE department, gym and cafeteria. Nodes move in and out of those sub-areas at a pedestrian speed and in their choice of active sub-areas. Figure 3.1 shows that, the protocol does not group nodes as it is done in literature, where nodes are grouped based on their relationships (i.e. if individuals work together, they would be considered to be in the same group). With BSWRA, we group sub-areas based on their active time frame, and the algorithm uses the advantage of IZTECH planned time frame to provide a reference point of nodes' movement. Each node is aware of which sub-area is active, and this provides information in which sub-area a destination node at any given time may be expected.

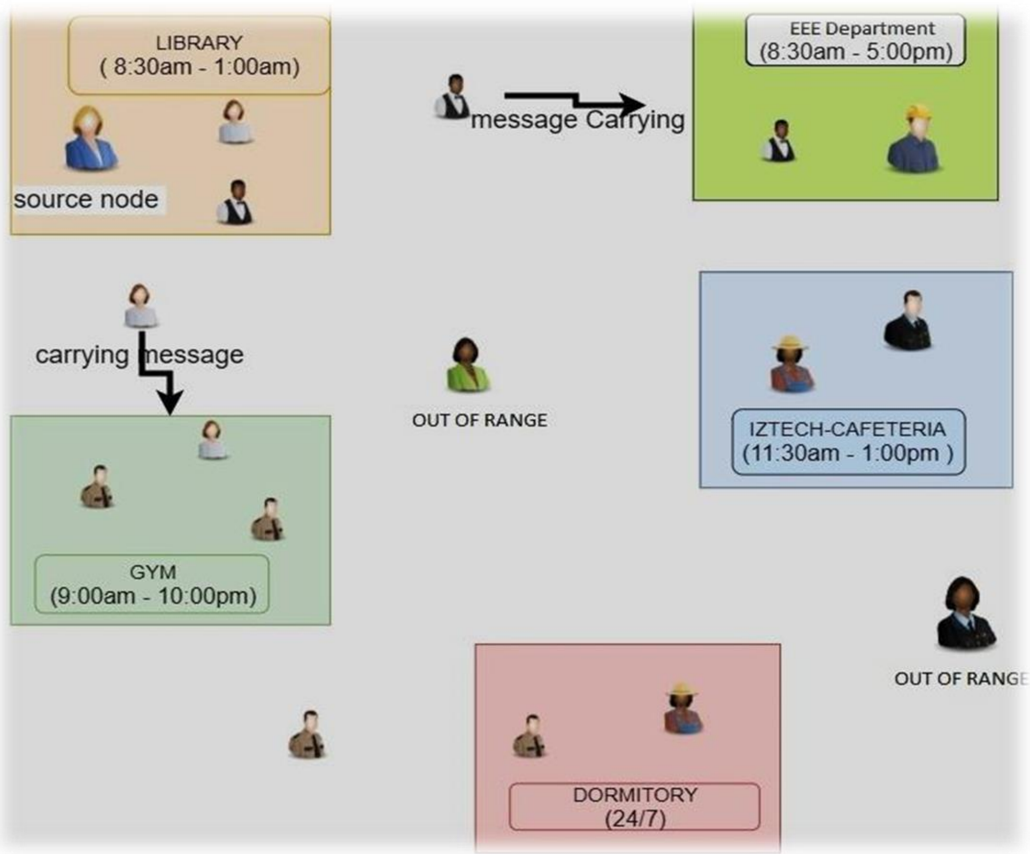

Figure 3.1. Movements of nodes in IZTECH sub-areas

3.3 Terminology

- ***Planned Time Frame:*** The range of time in which a certain sub-area is considered active. Within this time frame, nodes are actively entering and exiting this sub-area, in which they can encounter each other (i.e. from 8:30 AM up to 5:00 PM, nodes can enter and exit EEE department).

- ***Routine awareness:*** A property of the proposed algorithm meaning that the algorithm takes advantage of (is aware of) a *planned time frame* in its route estimations (i.e. the active time given to a sub-area never changes).
- ***IZTECH sub-areas:*** Discrete areas within IZTECH that were defined according to their active time characteristics as specified in the *planned time frame* of IZTECH (i.e. Library, Dormitory, EEE department, etc.).
- ***Summary vector (SV):*** Represents a list of information (i.e. messages, historical path, encountered nodes etc.) buffered at each node and is maintained by all nodes. In our case the summary vector stored at a node will include messages and a table of IZTECH sub-area planned time frame.

3.4 Proposed Algorithm

Due to all mentioned problems, it is reasonable to introduce BSWRA protocol. The new protocol reduces number of copies in the network by limiting the number of copies sprayed, and still gains a better performance of average end-to-end delay by treating nodes as source nodes when they enter new sub-areas without a copy. In our approach, we define sub-areas on the basis of IZTECH planned time frame. As seen in Table 3.1, IZTECH is divided into sub-areas based on its routine planned time frame, in other words daily working hours of different activities in the IZTECH (i.e. EEE department, IZTECH cafeteria, gym, library and dormitory). The table below gives a clear picture of planned time frame per sub-area in IZTECH.

Table 3.1. Activity time frame of IZTECH sub-areas

Sub-areas	Planned Time frame
EEE department	08:30AM – 5:00PM
Dormitory	7/24
Library	8:30 AM – 1:00 AM
Cafeteria	11:30 AM – 1:30 PM
Gym	9:00 AM – 10:00 PM

3.5 Binary Spray and Wait with Routine Awareness (BSWRA)

Before explaining the details of how the algorithm works, we need to make some few assumptions:

a) If the source node and destination node are in the same group, we assume that a session is established instantaneously.
b) Transmission range is m(meters).
c) Nodes move in and out randomly following IZTECH planned time frame.
d) Nodes move at pedestrian speed.
e) Total number of nodes is M.
f) Number of copies L.
g) Total number of nodes that owns a copy of a message for given L number of copies, is given as $(2^{1+log_2 L} - 1)$. [22]
h) Area = m^2

BSWRA as seen in Figure 3.2, is basically a Binary Spray and Wait protocol, in which we improve the model by: i) adding IZTECH routine awareness (daily planned working hours) whereby the awareness of IZTECH planned time frame allows nodes to go to a certain sub-area, if and only if the area is active. ii) Treating a node that enters a new sub-area as a source node. iii) If the new sub-area already has the message, the node drops its message.

BSWRA uses Binary Spray and Wait protocol within sub-areas; this provides less copies and speeds up dissemination of copies within a sub-area. The protocol improves BSW algorithm not only by adding routine awareness but also by permitting a node within the new sub-area to be a source node and generate limited number of copies to the area. This improves the issue of delivery failing to intended destination when traditional BSW is used. This is due to the fact that in BSW, only source node can replicate copies of a message and if one copy is left per node, the nodes switches to direct transmission with destination. And if none of the nodes meets the intended destination, the delivery fails completely. Furthermore, with BSWRA protocol, the nodes are able to have an idea of which sub-area is active by the help of IZETCH time frame. The new approach provides a perfect compromise (balance) between BSW and flooding protocols (i.e. ER, PRoPHET).

All nodes contain a SV that includes messages and IZTECH planned time frame for each sub-area. The nodes use the SV to know which sub-area is open and which messages are missing in the nodes' buffer. Also, the protocol provides nodes with a mechanism of dropping messages for overhead control. Our main contribution here is to optimize and improve the Binary Spray and Wait algorithm by integrating IZTECH's planned time frame (Routine Awareness), resulting in higher delivery ratio, minimized average end-to-end delay and reduced overhead ratio. Figure 3.2, is the organization of the protocol.

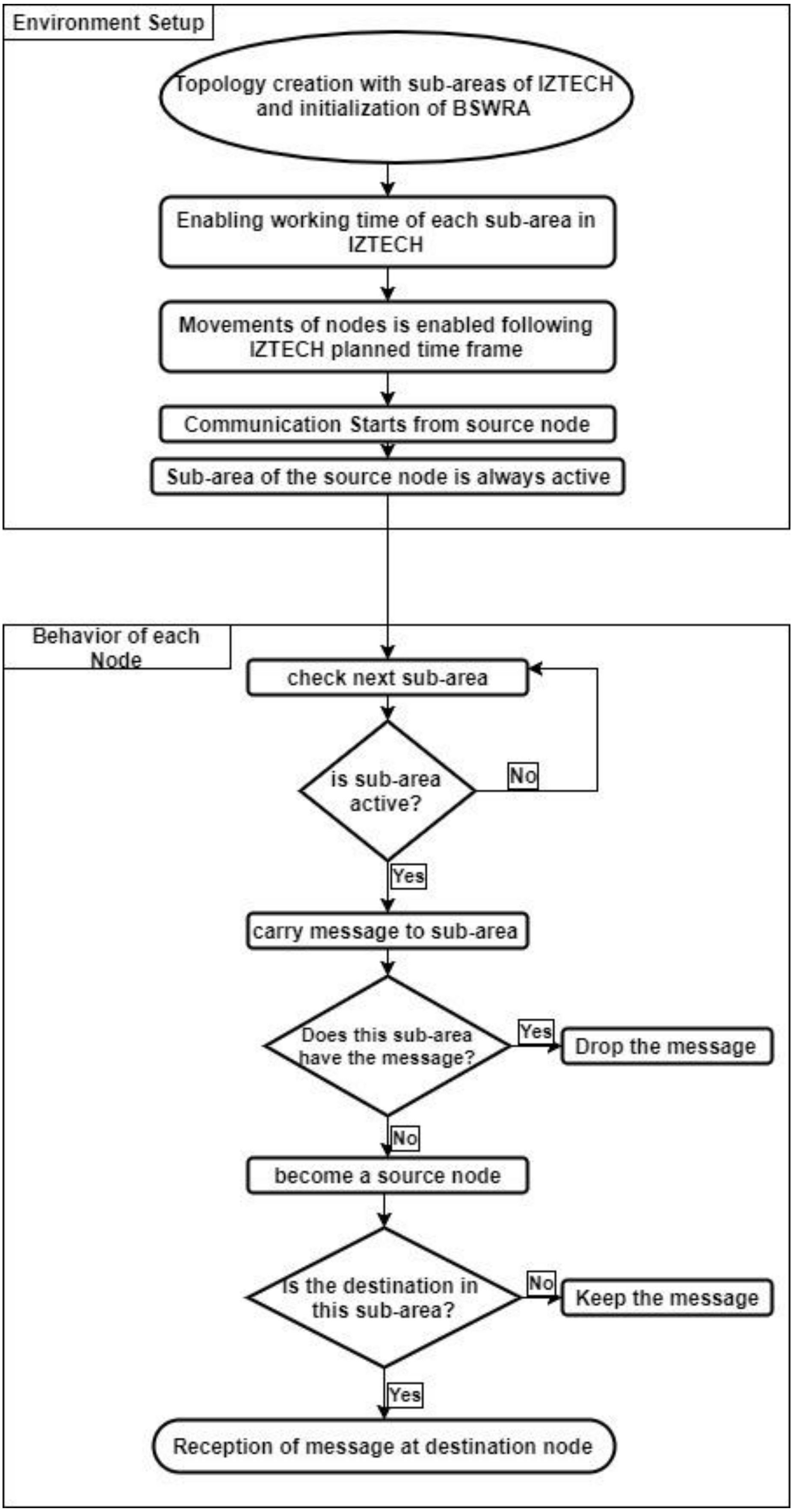

Figure 3.2. Flowchart of BSWRA protocol

With BSWRA protocol every node within IZTECH knows the time frame of IZTECH activities, in other words every node knows when the sub-areas are active and when they are not, but knows nothing about destination nodes. Since a source node does not have any idea about a destination node and whether or not its sub-are is active, it is reasonable to spray blindly a limited number of copies to its neighboring nodes to avoid clogging buffers of nodes (for the record, we have used 16 copies per source node as used in literature because there is no any specific number of copies that has been stated and confirmed as good estimate). Since nodes within the same sub-area interact with each other very often, a message is expected to reach destination as long as the destination happens to be in the current sub-area or any active sub-area within IZTECH. Routine Awareness together with BSW is implemented within IZTECH to increase the chances of delivery.

During spray phase the blinded forwarded messages by the source node, will be delivered to the destination, if the destination is in the current spraying sub-area. If not, messages will be distributed within a sub-area following Binary spray and wait model.

Binary spray and wait model as seen in Fig 3.3 is a binary tree like. In spray phase, a source node sprays L/2 replicas (copies) of a message to every node in its neighborhood, and these nodes (relay) that received copies will also disseminate the copies in the same way to their neighboring nodes during wait phase till every node remains with a single copy.

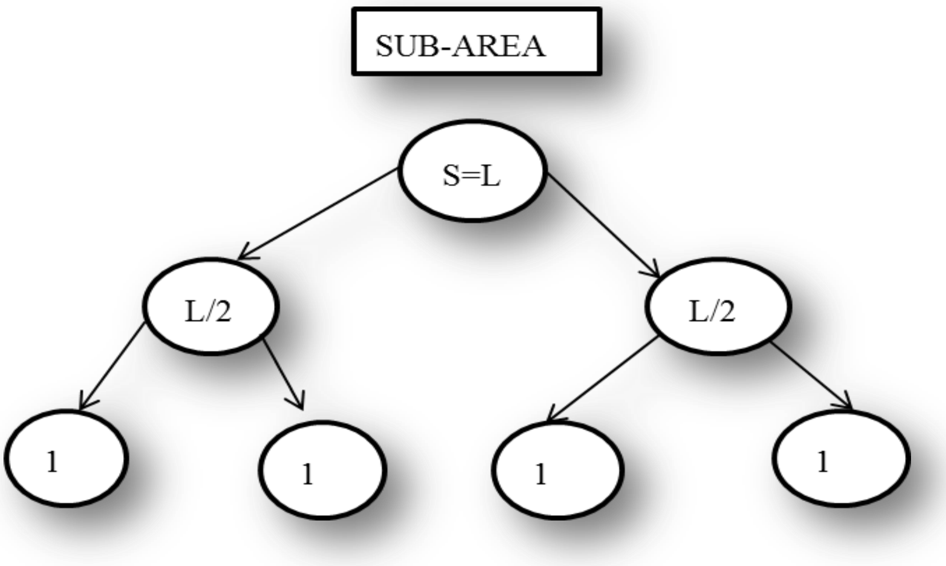

Figure 3.3. Dissemination of copies within a sub-area

In wait phase, nodes send copies to their neighbors while searching for destination to deliver the message if it is within the source sub-area, or waiting for nodes to leave the sub-area towards other active sub-areas, since the destination node can only be in one of the active sub-areas. Not to forget that, whatever the number of replicas a source node or a relay node still holds, a half of them are spread every time they come across a new node and so on until the last replica left at source node and relay nodes is one. Another point is that, if a node with a copy at source sub-area library wants to go to another active sub-area EEE department, it will become a source node to the new sub-area. Generally a node performs two important things when leaving or entering a sub-area:

i) A node leaving a source sub-area checks on IZTECH planned time frame from its SV, which sub-areas is active. In other words, where is the destination node according to the current time of delivery?

To be more specific, let's use an example as demonstrated in Figure 3.4. If node A with a copy leaves a sub-area library and reaches at EEE department sub-area at 10AM, it will become a source node and spray L/2 number of copies to the neighboring nodes till one copy remains. All nodes that receive a copy of the message from A check for which of the five sub-areas are open. At 10AM in five sub-areas that build up IZTECH planned time frame, the library and the cafeteria are not inclusive in the expected sub-areas of our destination because, node A just left the library and at 10AM, the cafeteria is not opened yet. In other words, there are no nodes in the cafeteria. So, remains three sub-areas where node D could probably be found. Due to awareness of active hours of sub-areas in IZTECH, any of the nodes that would exit from EEE department sub-area at 10AM can go towards all four active sub-areas except IZTECH cafeteria and obviously even the destination node cannot be there.

ii) A node entering a sub-area checks whether the nodes within current sub-area have the copy of the message. If the current sub-area has the message, the node will drop the copy. The mechanism of checking the presence of similar copies within a sub-area is to reduce the repeated copies of the same message in sub-areas since the mobility of IZTECH nodes is partially random and nodes can move in and out of the same sub-areas. For example, if node A from sub-area Library, meets node B at sub-area EEE department, B should drop a copy of the message given by A, if it reaches sub-area Library. From above explanation we can see that, dropping of message copies does not affect the mobility of the nodes but dropping decisions. In this way of routing, regardless of the destination node's sub-area, it will reliably be reached and every node within active sub-area is a good node (reliable).

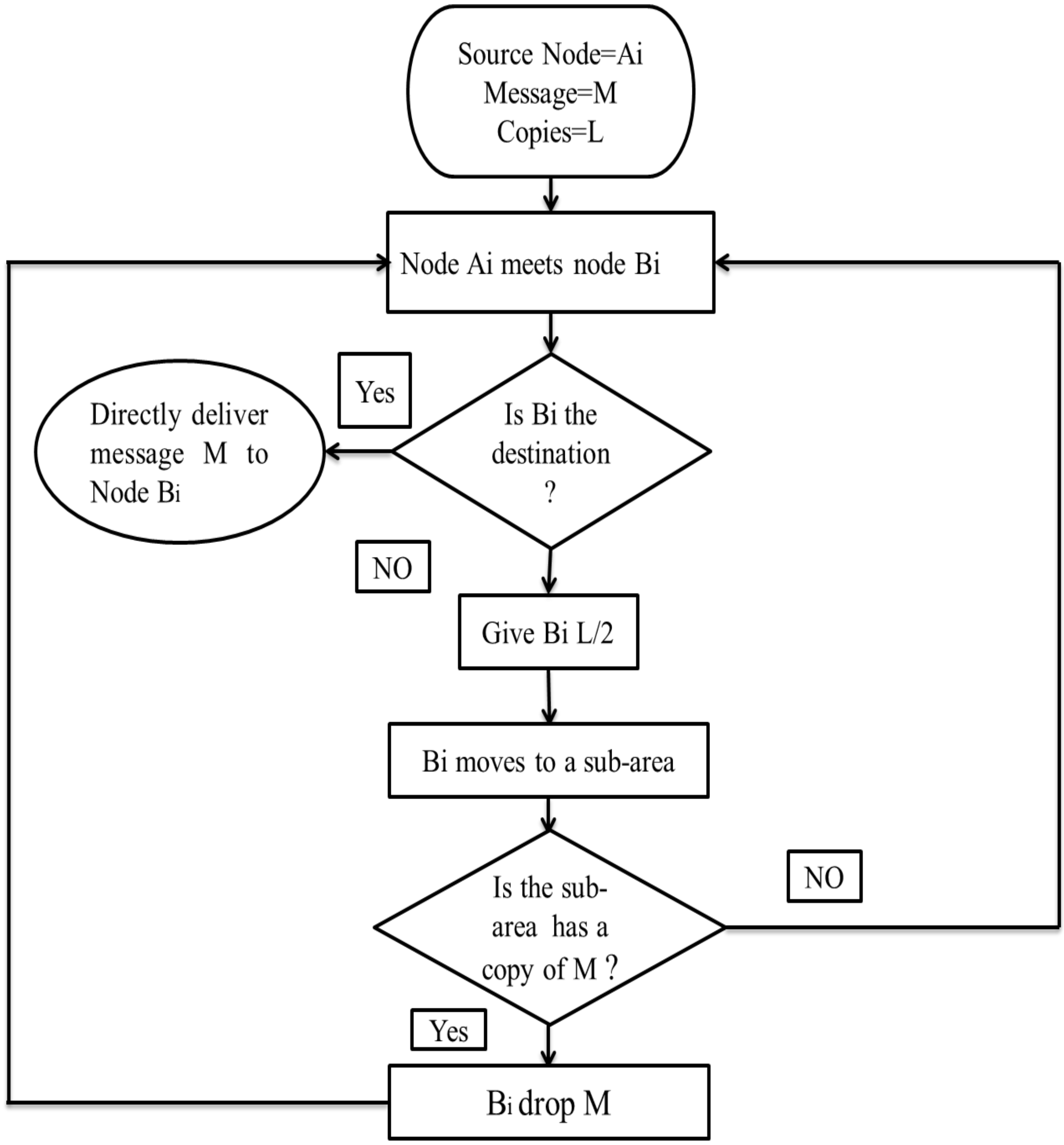

Figure 3.4. Flowchart of how a message flows in BSWRA protocol

CHAPTE 4

SIMULATION AND RESULTS

Mobile ad-hoc network can be simulated with several simulation tools (i.e. OPNET, ReactiveML [16]) that are available and adaptable, meaning that they are easy to work with. On the other hand, due to nodes' behavior of frequent and long disconnections in DTN, the implementation of DTN algorithms cannot be supported by these tools. Therefore, NS2 simulator [10] is used to implement the proposed DTN algorithm.

4.1 Simulation Parameters

The comprehensive analysis of BSWRA and DTN popular protocols namely BSW, EPIDEMIC and PRoPHET are carried out using the NS2 simulator. NS2 simulator was used because it includes some routing protocols like Epidemic, SW, BSW, AODV, PRoPHET and so on. The emphasis is on accurate assessment of these protocols within the scope of message delivery ratio, overhead ratio and average end-to-end delay. The simulation consists of varying number of nodes, varying message size, and varying buffer size. Configuring a simulation scenario in NS2 simulator as seen in Table 4.1, includes defining network size, message interface transfer and other related network parameters. The table below displays simulation settings for the analysis and was formulated from NS2 simulated examples.

Table 4.1: Simulation settings

Parameters	Values
Simulation area	1000m x 1000m
Number of nodes	20~100
Data rate	2Mbps
Communication interface	IEEE 802.11
Transmission range	10m
Movement speed	1.5 ~ 2m/s
Buffer size	20MB~ 100 MB
Message size	2000 KB ~ 1MB
Message generation interval	20s~30s
Simulation time	24hrs
Routing protocols	BSW, EPIDEMIC, PRoPHET, BSWRA

4.2 Performance metrics

As mentioned above, three metrics are considered to analyse the performance of different DTN protocols.

- **Delivery ratio** (**DR**): This is the ratio of total number of messages delivered to their destination to the total number of messages created. The protocol is said to have a better performance if many number of messages are delivered to destination node.

$$DR = \frac{D}{G} \tag{4.1}$$

where D is the number of messages delivered to the destination, and G is the total number of messages created.

- **Overhead Ratio (OR)**: Overhead ratio imitates how many extra messages that are sent to deliver one message. In other words it reflects transmission cost in a network.

$$OR = \frac{R-H}{H} \tag{4.2}$$

where R is the number of messages forwarded and H is the message received.

- **Average delay**: This is the average time it takes for messages from their creation to the destination.

$$\text{Average Delay/Average Latency} = \frac{\sum_{i=1}^{D} R_i - G_i}{D} \tag{4.3}$$

where $\boldsymbol{D}$ is the number of messages delivered to their destinations, R_i time at which message $\boldsymbol{i}$ reaches to the destination and G_i is the time when message $\boldsymbol{i}$ was generated.

4.3 Results and Discussion

We have essentially examined the performance of BSWRA with popular DTN routing protocols, BSW, Epidemic and PRoPHET under different metrics, namely delivery ratio, average end-to-end delay and overhead ratio, for three cases as follows: (i) for varying number of mobile nodes with constant message size and constant buffer size, (ii) for varying message size with constant number of mobile nodes and buffer size, and (iii) for varying buffer size with constant number of nodes and constant message size. The three metrics (average end-to-end delay, delivery ratio and overhead ratio) are evaluated to capture the performance of BSWRA within specified area of IZTECH. The required properties of DTN routing protocol are to minimize the average delay, maximize delivery ratio and minimize the overhead ratio.

As seen in Figure 4.1, BSWRA protocol is run for different parameters of simulation as presented in Figures (i.e. 20, 40, 60, 80, 100 nodes; 2000, 4000, 6000,8000, 10000 message size; 20MB, 40MB, 60MB, 80MB,100MB buffer size) and three metrics (average end-to-end delay, delivery ratio and overhead ratio) are analyzed. Every time the simulation runs, it reads different results. The results are presented on figures. The animation screenshot below represents message dissemination in the area of simulation. In other words, it shows the network simulation traces. Within this example, 20 nodes, 1000KB message size and 100MB buffer size are considered.

In Figure 4.1, the black circles around the nodes are transmission range of nodes. When play button (provided on the top of run window) is clicked, the nodes start movements as well as generation of messages. At the bottom of the run window, there is event window which shows the events that are happening during simulation such as, which node is connecting with which, message size, at which point of time nodes are paring, etc.

Figure 4.1. Nodes movement and message forwarding in NS2 simulator

4.3.1 Effect of varying number of nodes

In this section, the performance of the algorithms is analyzed on varying number of nodes with fixed message size and buffer size to 1000KB and 10MB respectively. The simulation is run within a given area, from small number of nodes to larger number of nodes as seen from Figure 4.2, 4.3, 4.4. The figures compare the performance of four protocols. To investigate the performance of BSWRA under different number of nodes, we run a simulation for five different number of nodes consecutively (20, 40, 60, 80, 100) for 24 hours each. Increasing the number of nodes improves the nodes' connectivity in the network and this implies that more messages can be delivered to the destination with less delay. As the number of nodes increases, Figure 4.2 clearly shows that the increase in number of nodes leads to less average end-to-end delay for all protocols, with both BSWRA and Epidemic having the best results. BSWRA is a routine aware protocol which uses time frame awareness to limit movement of nodes to non-active sub-areas. Since some of sub-areas are closed and nodes are still of the same number in the area (i.e. 100 nodes), BSWRA behaves almost like ER on average delay. The proposed protocol allows a node to become a source node within a new sub-area and sprays limited copies to the neighboring nodes. This improves messages pass across all sub-areas within a short period, hence reasonable average delay better than that of BSW and PRoPHET with same fewer number of nodes (i.e. 60 nodes).

Figure 4.3 shows the results comparison delivery ratio of DTN protocols. The results present that PRoPHET and BSWRA have good delivery ratio with respect to BSW and Epidemic protocols and BSW shows a worse delivery ratio when the number of nodes is large. BSW delivers the worse results because even though the number of nodes increase but the number of copies are still limited and since the source can only generate copies, the protocols fails in our area of simulation because when nodes move to other sub-areas after they have left with one copy, they switch to direct transmission which results into delivery failing if the destination is not met. This is found to slow down the delivery ratio since messages are hardly delivered. BSWRA provides a healthier performance due to its use of routine time awareness that enables nodes to move to active sub-areas and deliver more copies by treating a node within a new sub-area as a source node. Both BSWRA and PRoPHET have mechanisms of forwarding copies, hence a better delivery ratio. As mentioned in above, the buffer size is fixed (i.e.

in our simulation, it is limited to 100MB), this is not sufficient for ER in terms of delivery ratio because it requires infinite buffer size for better performance.

As seen in Figure 4.4, the results show that both BSWRA and BSW gives low overhead ratio and BSW outperforms all the protocols even with larger number of nodes. Generally, it is clear that overhead ratio increases as the number of nodes increases.

The increase in number of nodes, affects positively or negatively all of three metrics (i.e. average end-to-end delay, delivery ratio and overhead ratio). As seen from Figure 4.2, 4.3, 4.4, none of the protocols that optimizes overhead ratio and gains better performance on both delivery ratio and average end-to-end delay. Since BSWRA keeps relatively good results for both overhead ratio and average end-to-end delay as number of nodes gets bigger, it is noticeable that, BSWRA is a better protocol.

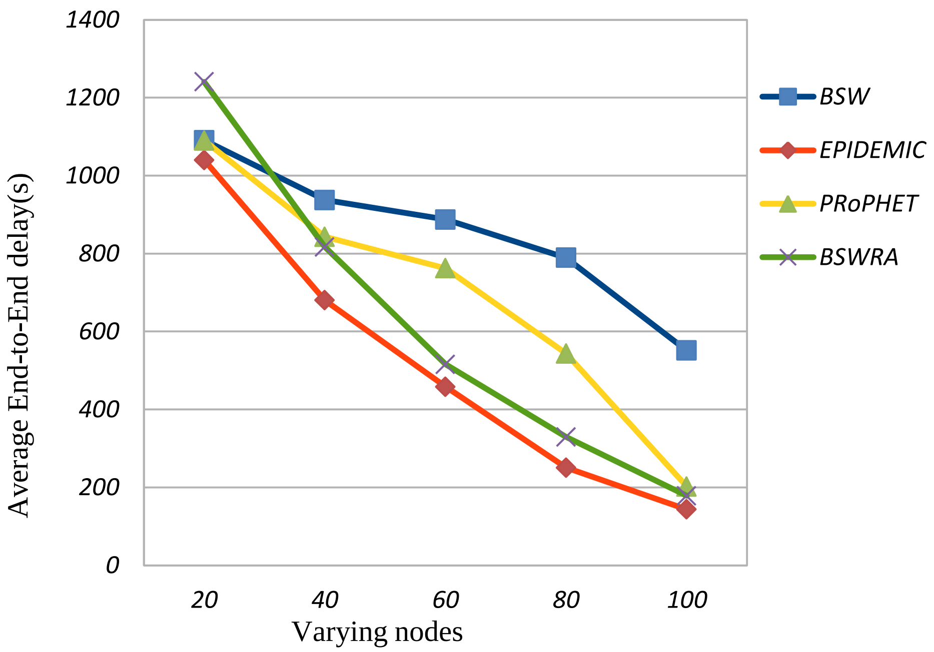

Figure 4.2. Effect of varying number of nodes on average end-to-end delay

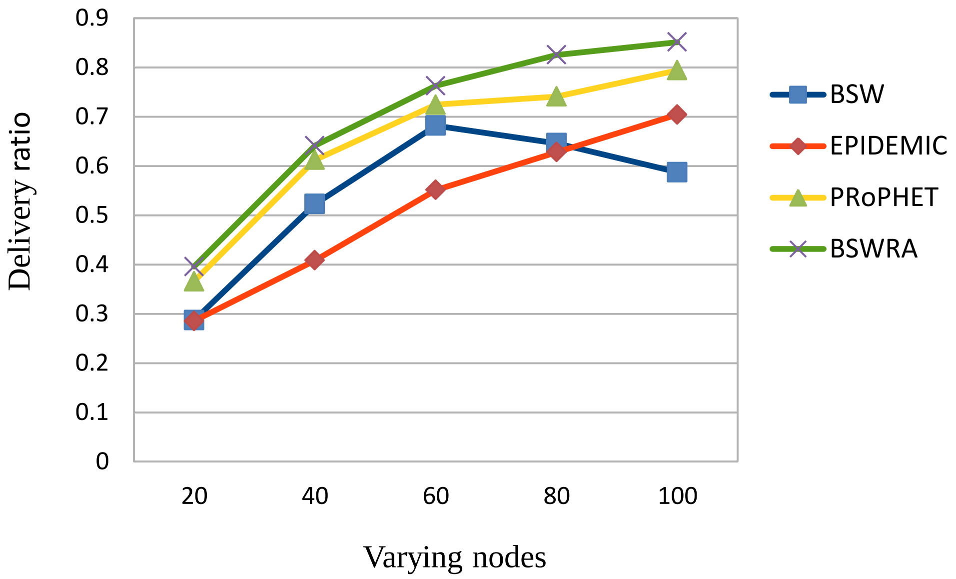

Figure 4.3. Effect of varying number of nodes on delivery ratio

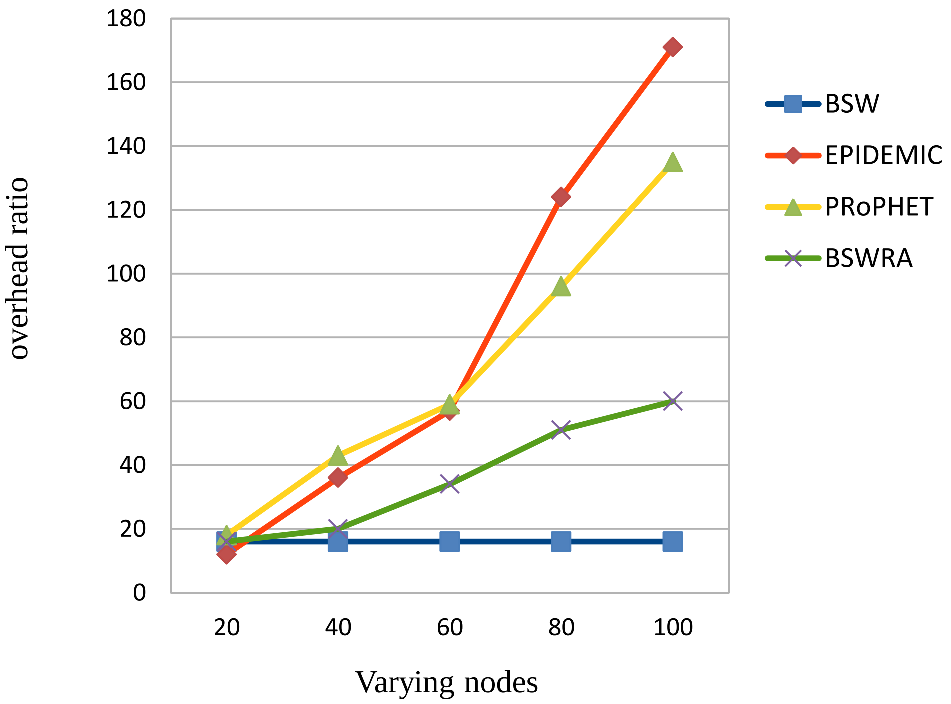

Figure 4.4. Effect of varying number of nodes on overhead ratio

4.3.2 Effect of varying message size

In this section, we analyze the performance of BSWRA, BSW, ER and PRoPHET with the varying message size by fixing number of node and buffer size to 100 and 100MB respectively, on the metrics of average end-to-end delay, delivery ratio and overhead ratio. Figure 4.5, 4.6 and 4.7 summarize the simulation results for average end-to-end delay, delivery ratio and overhead ratio, respectively. Figure 4.5, demonstrates the effect of increasing message size on different metrics for BSWRA and other protocols. When message size increases all the protocols get reduced average delay values. This is due to the fact that, when message size is larger with limited buffer size, small number of messages is carried into the buffer. The figure illustrates that, the performance of BSWRA to the increase of message size is better compared to the rest of protocols. This is due to the fact that, BSWRA uses routine awareness mechanism to speed up message delivery hence lowering delay. Furthermore, by using both limited number of copies and dropping approach, the protocol reduces copies as results of lower delay on the average delay. Therefore, increase in message size affects the performance of BSWRA protocol less.

Figure 4.6 shows the delivery ratio of the protocols. The increase in message size results also in a decrease in delivery ratio of all considered protocols. Since nodes keep generating messages, the number of messages keeps increasing in the network. And as both number of messages and message size keep increasing, this becomes a serious problem for messages to be held within limited buffer size, which leads to message dropping, hence low delivery ratio. However, the delivery ratio of BSWRA is always higher than the other protocols. By use of message control within active sub-areas even though buffer is fixed, the protocol provides enough room for incoming copies hence a better delivery ratio.

Figure 4.7 shows the influence of increasing message size on the overhead ratio. The overhead ratio gives an idea about how efficient the protocol is in terms of correct relay decisions. ER protocol is the worse and BSWRA performs significantly better than the rest of the protocols. By using the awareness of active sub-areas, BSWRA traverse messages among them, while dropping repeated messages within sub-areas. This reduces excess copies as well as providing room for incoming messages. Even though BSW limits number of copies, in this scenario it fails due to the lack of an additional mechanism of message management.

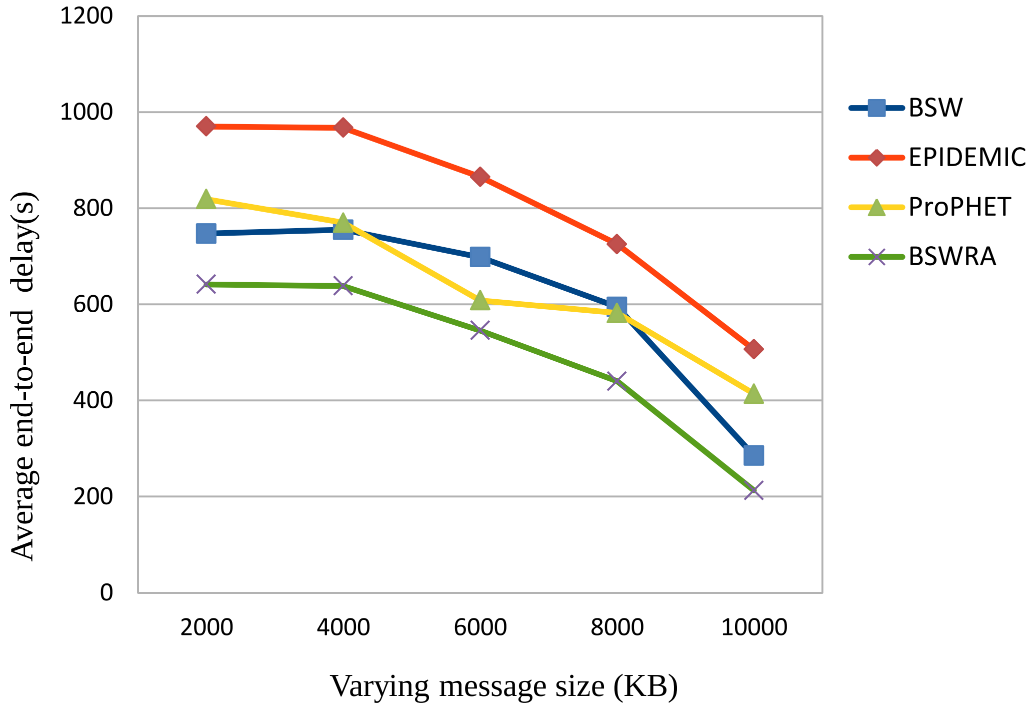

Figure 4.5. Effect of varying message size on average end-to-end delay

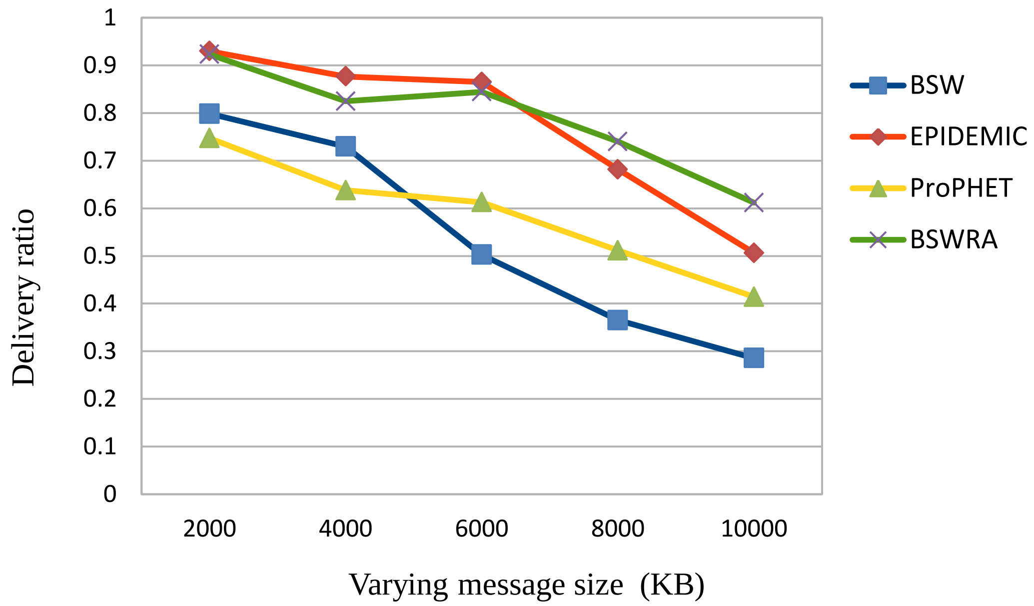

Figure 4.6. Effect of varying message size on delivery ratio

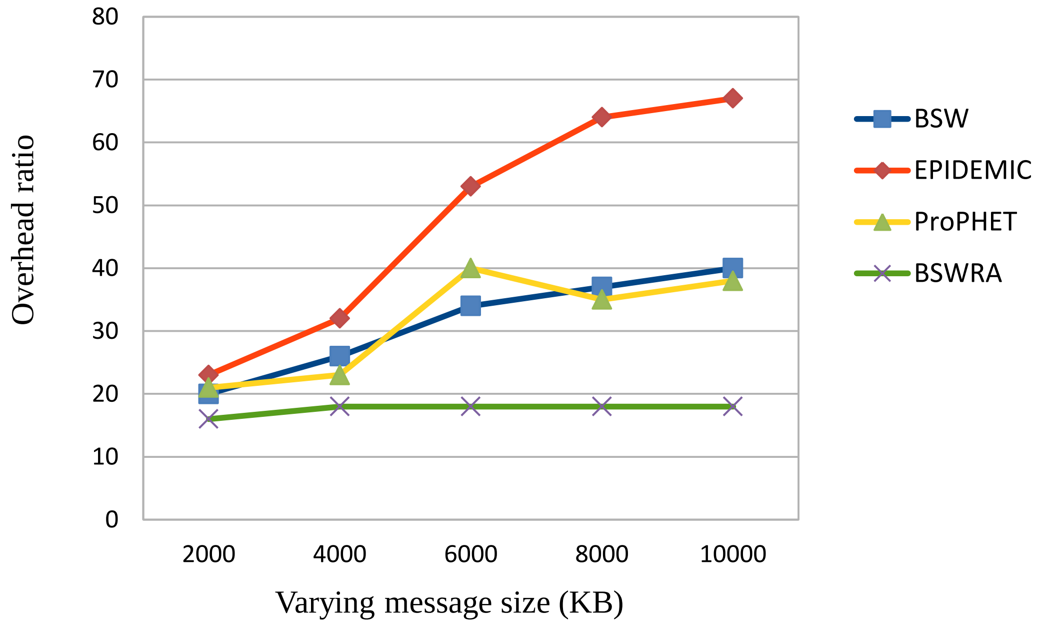

Figure 4.7. Effect of varying message size on overhead ratio

4.3.3 Effect of varying Buffer size

In this section, the performance of the algorithms is analyzed on varying buffer size with fixed number of nodes and message size to 100 and 1000KB respectively. As indicated in Figure 4.8, BSWRA and BSW give the lowest average delay for delivered messages because of their ability to manage buffer by limiting the message copies. Unlike BSW, in BSWRA a node with only one copy within a new sub-area does not wait for direct transmission. Instead it is treated as a source node and sprays limited number of messages. This speeds up penetration of messages fast, hence better average delay. On the other hand, for Epidemic and PRoPHET, average delay increases as buffer size increases. This is due to the fact that, when buffer size is larger, it accommodates messages that require larger number of relays to reach destinations and since the larger buffer size reduces drop of messages, the messages will be all delivered but with larger average delay. Since BSWRA allows nodes to drop repeated messages within the same sub-area, it provides good performance on average end-to-end delay.

As shown in Figure 4.9 it indicates that, increasing buffer size increases delivery ratio for all the protocols because increasing buffer size leads to more messages in the buffer and this means messages will not be dropped by buffer excess. It is clear that BSW and BSWRA give better results compared to Epidemic and PRoPHET, this is because they both use limited number of copies in the network and BSWRA outperforms all of the protocols because of its complementary mechanism of considering the time frame of the simulation area and sprays copies within appropriate sub-area rather than blind forwarding of messages by ER that fail in terms of buffer, since the buffer size is limited in our scenario.

Besides the increasing of buffer size leads to the increase of delivery ratio, Figure 4.10 indicates that, the overhead ratio decreases as buffer size increases for all protocols. Both BSW and BSWRA are unmoved with buffer size increase due to their effective approach on buffer management by limiting number of copies, hence low overhead ratio as seen from the Figure 4.10. Although BSWRA shows almost same results with BSW in terms of overhead ratio but both average delay and delivery ratio of the proposed algorithm are improved and they are vital metrics as far as communication is concerned in DTNs.

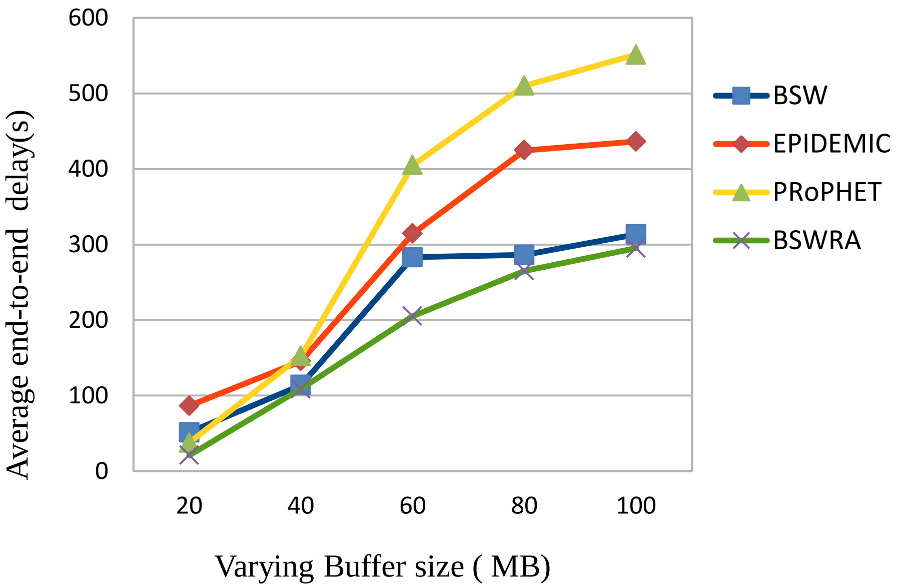

Figure 4.8. Effect of varying buffer size on average end-to-end delay

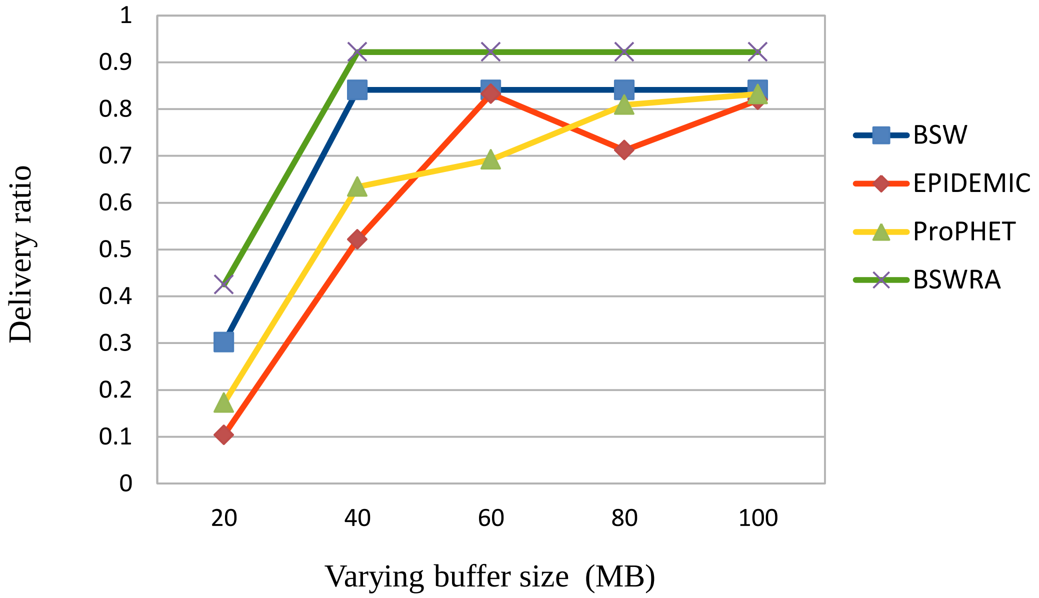

Figure 4.9. Effect of varying buffer size on delivery ratio

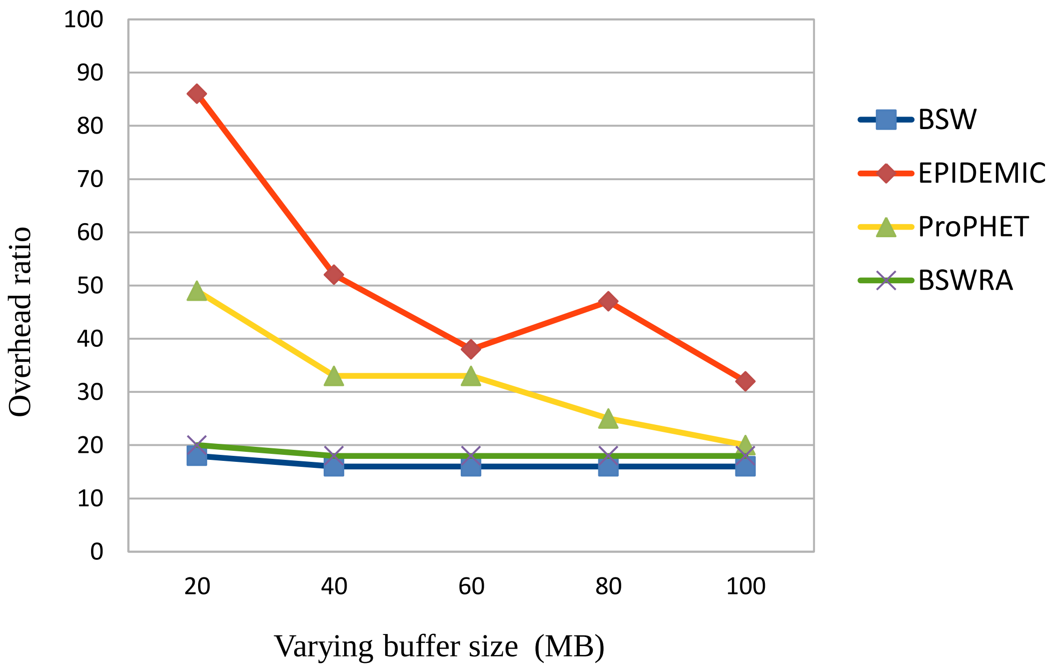

Figure 4.10. Effect of varying buffer size on overhead ratio

CHAPTER 5

CONCLUSION

In conclusion, this thesis has tackled the general overview of previous work done on DTNs protocol, and introduced a new protocol called Binary Spray and Wait with Routine Awareness (BSWRA) for IZTECH. We looked at two functionalities of the protocol: i) nodes mobility model where nodes move randomly within IZTECH sub-areas following IZTECH planned time frame. ii) We looked on message forwarding where BSWRA uses BSW protocol within sub-areas. The BSW has two phases namely: spray and wait phases; where in spray phase, a source sub-area blindly sprays messages to the neighboring nodes, and in wait phase, the nodes wait for each message received earlier, to be delivered to the destination if available or leaves the source sub-area towards other sub-areas where destination may be expected. The Routine Awareness is added to Binary Spray and Wait to increase chances of find destination node. We also used a case study where IZTECH is divided into five groups (EEE department, Library, Cafeteria, Gym and Dormitory) with respect to their routine working hours. By using Binary Spray and Wait with Routine Awareness protocol, a new grouping approach based on predefined working hours rather than existing grouping schemes where groups are being created based on nodes common interest was implemented. BSWRA protocol was compared with popular DTN protocols namely, BSW, EPIDEMIC and PRoPHET by using NS2 simulator and it turned out that its performance balances between minimizing average end-to-end delay, maximizing delivery ratio and minimizing overhead ratio. Though in some cases i.e. when buffer size is 100MB with number of nodes equal to 100, Epidemic protocols provided a better performance as far as average end-to-end delay is concerned and BSW gave a better reduced overhead ratio but they both fail in the overall performance of the three metrics. The aim was to increase delivery ratio and minimize both average end-to-end delay and overhead ratio and indeed the goal was achieved.

Finally, in DTNs nodes are energy dependent which is a challenge in communication. As a future research work, BSWRA should be analyzed on the basis of energy consumption and tested with existing popular DTN protocols.

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