Advancements in Delay-Tolerant Networking: The SPWEBR Protocol for Superior Routing Efficiency and Performance

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Abstract
In the rapidly growing field of mobile ad hoc networking, having ideal routing protocols is essential to maintaining communication. We provide a thorough simulation examination of many well-known routing protocols, including Source Spray and Wait, Binary Spray and Wait, Encounter-Based Routing (EBR), MaxPro, Direct Delivery, Epidemic, and First Contact, among others. In light of this, we are pleased to present and thoroughly assess Spray and Wait with Encounter Based Routing (SPWEBR), a unique protocol. Initial analyses show that SPWEBR is a strong competitor, attaining a pleasing equilibrium in the parameters of Delivery Ratio, Overhead Ratio, and Message Drop. Above all, SPWEBR shows a benefit: it can outperform some existing protocols by as much as 50% in Delivery Ratio, approximately 60% in Reduced Overhead Ratio, and with less Message Drops in particular node event intervals. These outcomes highlight its exceptional effectiveness and possible relevance. This comprehensive comparison analysis demonstrates SPWEBR's supremacy in the current mobile networking environment and its potential for future advancements. In light of these results, we suggest conducting additional study on SPWEBR in order to fully utilize its potential and flexibility to a variety of networking settings.

Introduction

The way that devices connect in the current day is undergoing an enormous transformation due to developments in networking technologies [1], [2], [3]. Innovative solutions that are efficient in transmitting data and adaptive to changing topologies are needed to meet the demands of the expanding network of networked devices. Undoubtedly, mobile ad-hoc networks play a crucial role in this matrix, and efficient communication between them depends on strong routing algorithms [4], [5].

Several routing protocols, including Direct Delivery, Epidemic, First Contact, Two Hope, and others, have been suggested and put into use in the past. Each has been customized to fit particular network requirements and operational requirements [6], [7]. However, some of these protocols show inherent limitations as the complexity and needs of modern networks increase, especially with regard to adaptation, efficiency, and scalability [8], [9].

This research introduces the Spray and Wait with Encounter Based Routing (SPWEBR) protocol in order to address these highlighted gaps and obstacles [10]. The idea behind SPWEBR is to take the best aspects of the existing protocols and make them even better in order to combat common problems. The core values of SPWEBR center on its increased flexibility, lower costs, and faster delivery, which position it as a strong competitor across the wide range of routing protocols [11], [12].

Motivation

The continually changing and decentralized nature of mobile ad-hoc networks, which are rapidly expanding, highlights the necessity for sophisticated routing systems [13], [14]. The research was motivated by a real need, as conventional routing algorithms struggle with the problems of changing topologies, limited resources, and heterogeneous data traffic [15], [16]. The ongoing flaws and restrictions found in the current protocols provided a strong incentive to develop a robust and flexible alternative [17], [18].

Research Contributions

1. Holistic Examination: A detailed analysis and evaluation of the current routing protocols, including their advantages and disadvantages from an operational point of view [19], [20].

2. SPWEBR Unveiled: Leading the way in the development of the SPWEBR protocol, a cutting-edge routing paradigm that creatively addresses the limitations of previous approaches while balancing their benefits [21], [22].

3. Empirical Evidence: Extensive simulation results demonstrate the effectiveness of SPWEBR, with special attention to its improved Delivery Ratio, Overhead Ratio, and Message Drops as compared to its peers [23], [24].

4. Paving the Path Forward: This work not only introduces a novel protocol but also establishes a standard for future research, encouraging more investigation and improvement in the field of mobile ad hoc network routing [25], [26].

Proposed Protocol: Spray and Wait with Encounter Based Routing (SPWEBR)

Intermittent connectivity and dynamically shifting network topologies are common problems for delay-tolerant networks (DTN). In order to overcome these obstacles, the Spray and Wait with Encounter Based Routing (SPWEBR) protocol leverages the advantages of encounter-based and spray-and-wait routing techniques to provide effective routing and improved delivery performance.

Encounter Value Calculation:

The calculation of encounter value based on current window counters and encounters values. To track the encounter rate of each node, every node maintains two pieces of local information: an encounter value (EV), and a current window counter (CWC). EV represents the node‘s past rate of encounters as an exponentially weighted moving average, while CWC is used to obtain information about the number of encounters in the current time interval. EV is periodically updated to account for the most recent CWC in which rate of encounter information is obtained. Updates to EV are computed as follows [31]:

$$EV = \alpha * CWC + (1- \alpha) * EV$$

EV	Define the node‘s past rate of encounters.
CWC	Current window counters
α	Average Weight

Simulation Environment

The table below illustrates the parameters that were used to test SPWEBR in order to give an understanding of the environment:

Table 6.1 Basic Parameter in ONE Simulator for simulation

Parameters	Value	Appropriate
Scenario.endTime	20000	All
Scenario.nrofHostGroups	1	All
Group.movementModel	RandomWaypoint	All
Group.router	SPWEBR, Direct delivery, Epidemic, First contact, Two Hope, Encounter-Based routing(EBR), MaxPro, Prophet, Source and Binary Spray and Wait protocol	All
Group.nrofHosts	10, 20, 30, 40, 50	All
Group.bufferSize	MessageEventGenerator	All
Events1.interval	1-5	All
A	0.85	SPWEBR
SPWEBR.nrofCopies	10	SPWEBR
ProphetV2Router.secondsInTimeUnit	30	Prophet only
SprayAndWaitRouter.nrofCopies	10	Source and Binary Spray & Wait
SprayAndWaitRouter.binaryMode	False	Source Spary & wait
EBRRouter.nrofCopies	10	Encounter-Based Routing
EBRRouter.alpha	0.85	
EBRRouter.updatePOPInterval	30	

This controlled simulation environment ensures consistency in testing across all the protocols being evaluated.

SPWEBR Algorithm Description

In order to maximize the route selection process, the SPWEBR algorithm integrates encounter-based routing with the advantages of the spray-and-wait methodology.

<u>Algorithm</u>

Input: Number of nodes, Average Weight

Output: message states report (message delivery ratio, overhead ratio, and message dropped)

1. Node *i* generates a message *Mij(L)*
2. Node *j* is not in the range of *i* then

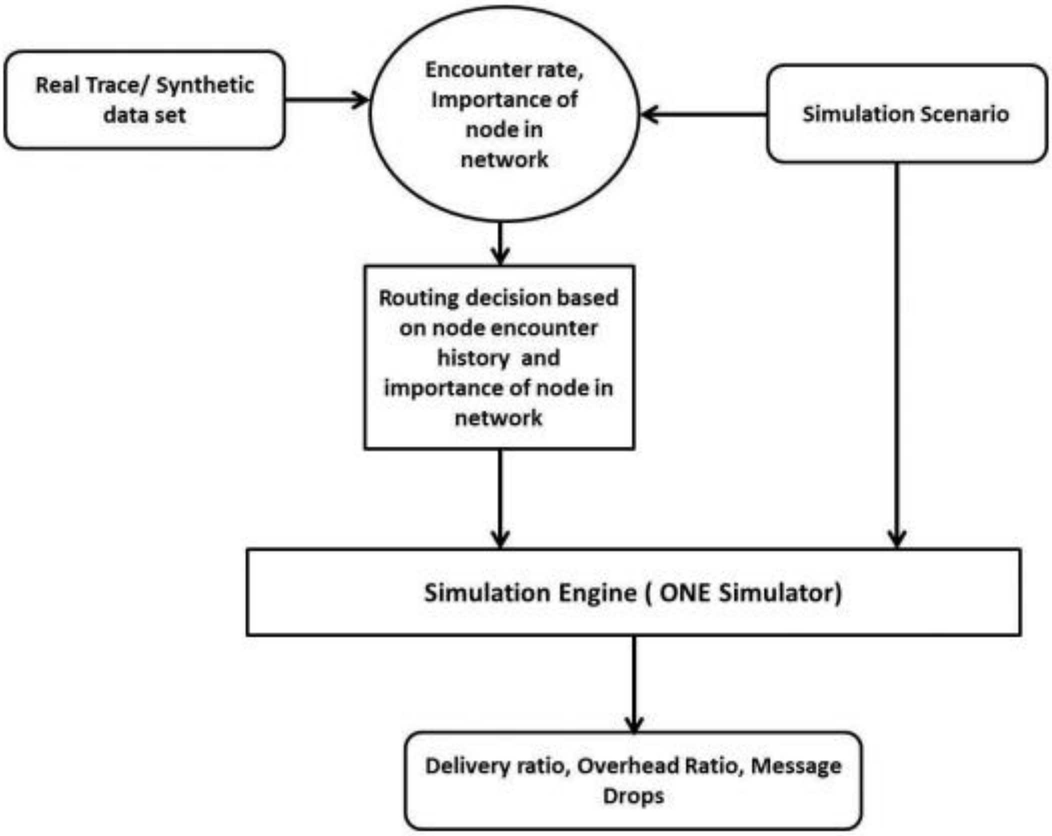
a. Calculate *EV* of nodes, those are in the range of node *i*

b. Give *Mij(L)/2* messages copies to the node having higher *EV*

3. Update the *EV* of nodes.

4. Repeat step 2 and 3 until *Mij(L)* = 1

5. Deliver message *Mij* to node *j*



Explanation of SPWEBR Steps

1. Initialization: A certain number of message copies are given to nodes at the beginning. The network begins by "spraying" these copies to different nodes.

2. Encounter-based Decision Making: Two nodes exchange summary vectors with one another when they meet each other. Decisions are made on which messages to forward based on these vectors.

3. Wait Mechanism: Nodes enter a "wait" mode following spraying. They hold on their copies of the messages until they come across the destination node in this manner.

4. Optimal Route Selection: By taking into account previous encounters and their success rates, the encounter-based process helps choose the best route.

5. Copy Control: The algorithm makes sure that there are only a set number of copies of each message floating around the network in order to prevent network congestion.

The SPWEBR protocol is explained in detail in this section. A comparative performance study and possible future improvements to enhance the protocol covered in subsequent section.

Results Analysis

The detailed simulation analysis of the established routing protocols carried out in an appropriate environment provides an accurate foundation for assessing the efficiency of each. With a particular focus on the new SPWEBR protocol, we will examine the performance metrics in this section and emphasize the comparative potential areas for development for each protocol.

Delivery Ratio

The delivery ratio is essential for determining if message transmission inside a protocol is reliable.

Table 6.2 Delivery ratio vs Number of nodes during event interval 1-5

Delivery Ratio during event Interval 1 – 5					
	10	**20**	**30**	**40**	**50**
DD	0	0.000623	0.001253	0.002004	0.001377
Epidemic	0.000252	0.001121	0.00188	0.003381	0.002759
First Contact	0.000252	0.000872	0.002005	0.002755	0.001881
TwoHope	0.000252	0.000872	0.002381	0.003256	0.002508
EBR	0.000126	0.000747	0.001755	0.003005	0.002007
MaxPro	0.000503	0.001245	0.001629	0.00313	0.002634
ProPhet	0.000378	0.001121	0.002131	0.003757	0.002007
SourceSPW	0.000126	0.000996	0.001755	0.003005	0.002258
BinarySPW	0.000126	0.000996	0.002131	0.003256	0.002634
SPWEBR	0.056387	0.101631	0.111668	0.141121	0.1516367

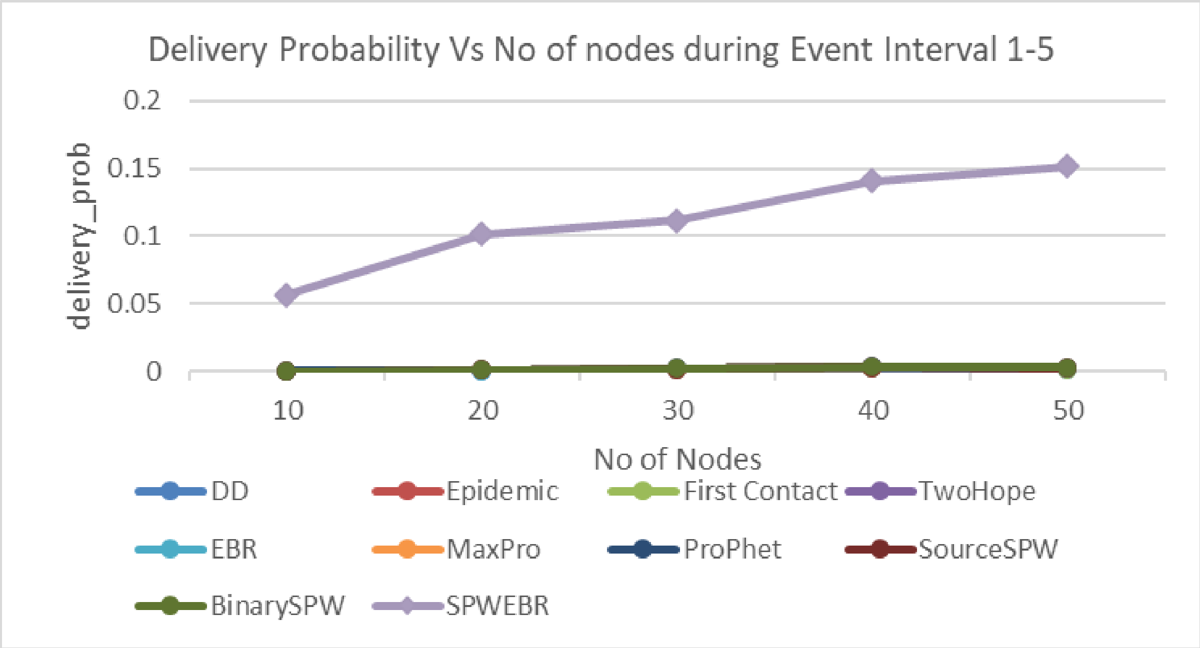


Fig. 6.2 Delivery ratio vs No of Nodes in Event Interval 1-5

Direct Delivery (DD) demonstrated a gradual but insignificant growth across a range of nodes, indicating its challenge in effectively scaling. Although Epidemic, Prophet, and MaxPro demonstrated incremental progress with the increase of node counts, they were unable to manifest substantial expansion in their delivery ratios. On the contrary, the SPWEBR demonstrated a substantial improvement in performance, commencing considerably higher than the majority of other protocols and maintaining this advantage, suggesting its efficacy in transmitting messages, particularly as the network expands.

Overhead Ratio

The overhead ratio, a critical metric, assesses the efficacy of the protocol with regard to the dissemination of redundant messages.

Table 6.3 Overhead ratio vs Number of nodes during event interval 1-5

Overhead Ratio during event Interval 1 – 5					
	10	**20**	**30**	**40**	**50**
DD	0	0	0	0	0
Epidemic	36.5	32.7778	34	28.963	59.3636
First Contact	38.5	33.2857	26.1875	32.0909	74.6667
TwoHope	32	30.8571	23.8947	27.1923	58.5
EBR	43	22.3333	24	20.4583	56.5
MaxPro	15.75	26.7	35.8462	30.08	66.4286
ProPhet	23.3333	21.4444	21.1176	21.4	69.3125
SourceSPW	32	15.25	18.0714	18.1667	39.1111
BinarySPW	66	27.5	25.1765	27.1154	55
SPWEBR	5.9531	10.0625	14.1145	14.6664	15.8792

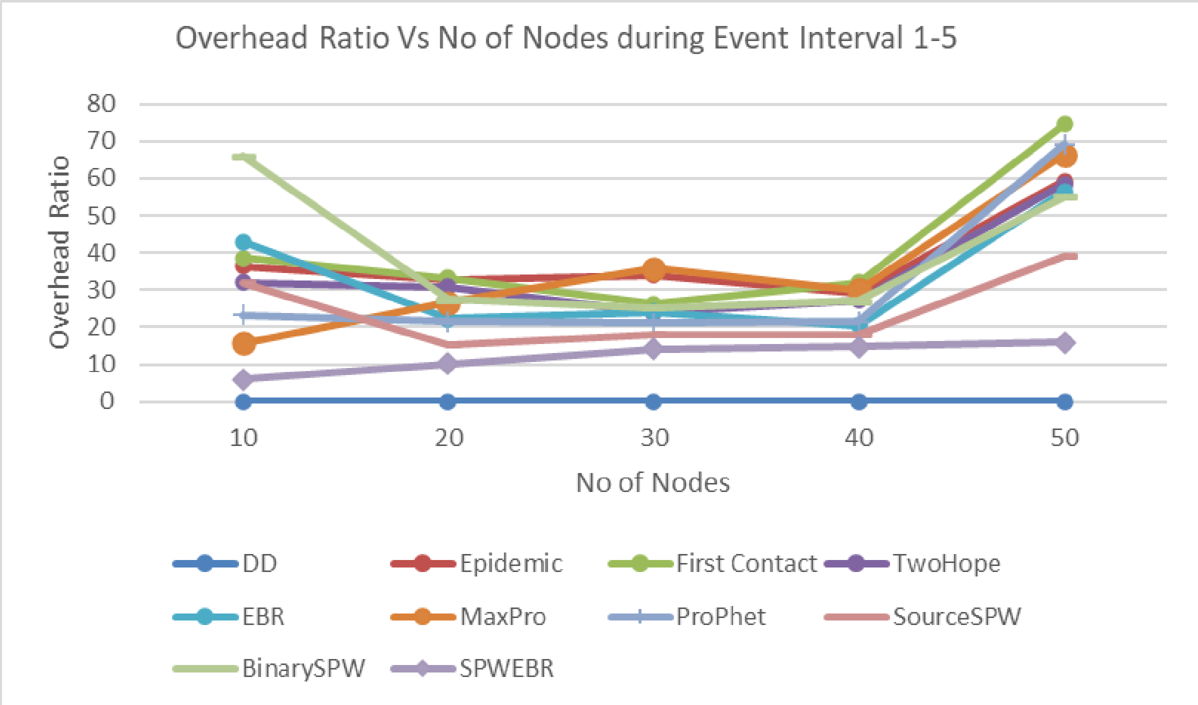


Fig. 6.2 Overhead ratio vs No of Nodes in Event Interval 1-5

Direct Delivery (DD) remarkably maintained zero overhead across the entire spectrum, which highlights both its efficiency in this aspect and the absence of message replication it performs. This may explain the decline in its delivery ratio. In contrast, Epidemic and Prophet exhibited discernible increases in overheads with the expansion of nodes. Source Spray and Wait and MaxPro also exhibited expansion, however at lower rates. SPWEBR maintained a balanced performance, as its overheads increased gradually but never reached the levels observed in other protocols. In contrast to its high delivery rate, this moderate overhead highlights SPWEBR's proficiency in transmitting messages without excess redundancy.

Number of Message Drops

This metric examines potential bottlenecks in protocols and sites of congestion on the network.

Table 6.4 No of Message Drops vs Number of nodes during event interval 1-5

Number of Messages drops during event Interval 1 – 5					
	10	**20**	**30**	**40**	**50**
DD	7888	7909	7799	7749	7749
Epidemic	7913	8062	8074	8132	8496
First Contact	7866	7839	7676	7551	7434
TwoHope	7910	8023	8016	8069	8369
EBR	7901	7947	7946	7922	8134
MaxPro	7918	8076	8049	8139	8549
ProPhet	7909	8016	7982	8025	8311
SourceSPW	7898	7964	7916	7907	8043
BinarySPW	7905	8020	8006	8064	8296
SPWEBR	9312	14210	18208	21616	23810

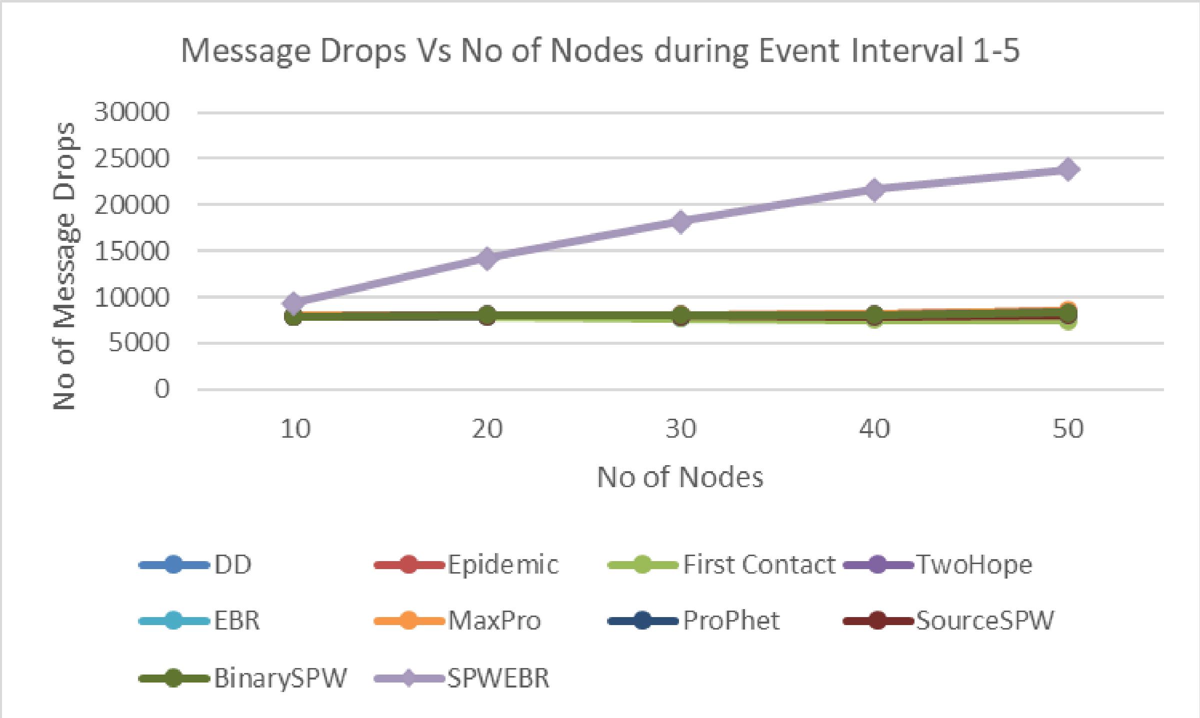


Fig. 6.3 No. of Message Drops vs No. of Nodes in Event Interval 1-5

There was a steady rise in messages dropped observed with Direct Delivery (DD), which may indicate the presence of inefficiencies or congestion problems. Similar trajectories were followed by Epidemic, Prophet, and MaxPro, each experiencing an increase in messages dropped as the number of nodes grew. Binary Spray, Wait, and First Contact exhibited a degree of consistency in the dispatches of their messages, indicating that their routing mechanisms might have been optimized. SPWEBR, despite exhibiting a greater quantity of messages dropped in comparison to certain protocols, can be understood in the context of its exceptional delivery ratio and moderate overhead. This provides insight into a protocol that adeptly manages multiple network pressures.

In summary, SPWEBR, in its current state, offers a compelling case for its implementation in DTNs. Although there are still aspects that could be improved, its exceptional performance on critical metrics solidifies its position as a leader in this field. The protocol's promise is demonstrated by its careful balance between network congestion, overhead management, and delivery efficiency, which also establishes the foundation for further improvements.

Conclusion:

Opportunistic networks, particularly with regard to routing protocols, require pathways that are both efficient and effective in order to facilitate the seamless dissemination of information. In these networks, a wide variety of established protocols, spanning from control replica-based to forwarding-based, have been instrumental. Nevertheless, the network has consistently faced obstacles including diminished delivery ratios, increased overhead, and frequent message failures, which frequently resulted in the squandering of resources and compromised the overall performance of the system. The SPWEBR protocol was introduced in this research through the ingenious utilization of techniques that identify dependable nodes and optimize forwarder selection. SPWEBR accelerates the dissemination of information and reduces costs while increasing the delivery ratio by delegating multiple copies to accomplished forwarders while on the way to the destination. When these improvements are compared to the current state of protocols, they demonstrate the potential of SPWEBR to enhance the information flow pattern in opportunistic networks.

Future Work:

The introduction and analysis of SPWEBR represent a critical turning point in this line of inquiry. However, there are still numerous unexplored possibilities in the field of opportunistic network routing. One potential approach could involve the adaptive determination of copy distribution in the course of simulations. Present-day protocols that advance to subsequent nodes, such as Spray and Wait, Binary Spray and Wait, and SPWEBR, rely primarily on the generation of random copies. As an alternative, you could figure out the optimal number of copies that are needed by looking at the network's density and its adaptive parameters. These simulations might also work better if buffers are better managed and messages are sent at better times when they interact with nodes. Putting these parts together with the SPWEBR routing protocol could be the next big thing, giving future implementations a routing solution that is more complete, flexible, and effective.

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