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SPRAY AND WAIT ROUTING IN OPPORTUNISTIC NETWORK WITH DYNAMIC STABILITY ADAPTATION

Ashish T. Bhole[1], Girish Kumar Patnaik[2]

[1,2] Department of Computer Engineering, SSBT's College of Engineering & Technology, KBC North Maharashtra University, Jalgaon – 425001, India.

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Corresponding author: Ashish T. Bhole (ashishbhole11@gmail.com)

ABSTRACT

Opportunistic Network (OppNet) is a specialised class of Delay Tolerant Network (DTN) and Mobile Ad Hoc Network (MANET) designed to facilitate communication in extremely dynamic and sporadically linked environments. DTN is a networksing architecture that ensures reliable data delivery despite of long delays, intermittent connectivity, node mobility and sparse network density. The OppNet utilise a store-carry-forward mechanism to facilitate data transmission. However, existing routing protocols in OppNet such as Epidemic, PROPHET and Spray and Wait often suffer from inefficiencies in routing. To address the issue, the article proposes a novel stability aware opportunistic routing framework that provides the STCESW-DSA (Stability-Aware Spray and Wait routing using Dynamic Stability Adaptation) algorithm. The STCESW-DSA enhances routing efficiency by dynamically selecting relay nodes based on node stability, buffer size, transmission capacity and residual energy thereby improving overhead and delivery ratio, reducing latency, buffer time and energy consumption.

KEY WORDS: MANET, DTN, Opportunistic network (OppNet), Routing, Spray and Wait, STCESW-DSA

1. INTRODUCTION

OppNets is one of the evolutionary MANETs, where the communication links suffer from disruption, while their networking paradigm is attracted by extensive attention [1]. Opportunistic Routing is also called as any path routing. It is recently emerged routing technology for wireless network [2]. OppNets defined MANET, is an interesting evolution and is used to support the communication with no end connectivity. When node moves, it cause of frequent link disruption and difficult to establish a stable routing OppNets. Node addresses the different networks which are not unique, so it takes new mechanisms for trust and authentication [3]. In OppNet, it uses a cell medium as a communal opportunity instead of the obstacle. The “broadcast nature of wireless medium” decreases the irregular Wi-Fi transmission. The store carry forward method provides transferring of node from sender to receiver [4]. OppNets are classified as Self-Configured Networks is a development of MANET. OppNets with users as important components obtain upon the devices [5]. “Mobile social networking (MSN)” involves interaction between the participants with similar interests through the mobile devices in virtual social networks [6]. The “Mobility model” is a social network that connects people using (mobile devices) to generate realistic artificial network structures [7]. MANET is a short-range telecommunication protocols and is used to explore the communication between the mobile devices. DTN is a routing mechanisms use a store-carry-forward mechanism in which nodes temporarily store messages until they come across a different node that can continue the delivery channel. These protocols are intended for networks with sporadic connectivity, high latency, and disturbances. The opportunistic computing and mobile cloud computing is used to analyses the resource information and computing capability which is provided by the mobile devices. The store-carry-and-forward paradigm is shared by all of the existing routing techniques, which use contact opportunity to communicate in intermittently disconnected networks including opportunistic networks and delay tolerant networks (DTN) [8]. OppNets is also known as pocket switched networks and people centric networks. OppNets is a type of MANET in which human carries mobile (called as nodes), which is used to communicate directly via shortage wireless technology [9]. In OppNets, not assume an end-to-end connectivity between sender and receiver. Instead of delivering the data on pair wise contact opportunities. The communication is called as multi-hop, where each intermediate node is explored as a router that stores the messages until the contact opportunity for further forwarding arises [10]. To overcome the issues like limited deice capability, sparse network density and frequent disruption, the MANET is designed [11]. The Epidemic routing is an exchange of messages among the mobile hosts which is used to ensure the delivery of messages. The goal of the Epidemic routing is to minimize the total delivery of message, maximize message delivery rate and minimize the message latency [12]. The PROPHET is a “probabilistic routing protocol” providing high delivery of messages than the Epidemic Routing with the lower communication overhead. The PROPHET is compared to the Epidemic Routing Protocol simulations. The architecture has been established within the framework of Delay Tolerant Networking (DTN), of which this type of network is a particular case [13]. The “spray and wait” are another routing protocol, that sprays the number of copies in to the network and it waits till one of the nodes meet its destination. The overall performance of “spray and wait” routing schemes is close to the optimal scheme. “Spray and wait” outperforms all existing models on both average delay of “message delivery” Mobile networks with sporadic connections fall under the broad concept of Delay Tolerant Networks (DTN). DTN routing techniques, particularly in networks with "opportunistic" connectivity. This could be because DTN encompasses a wide range of applications and network features. Routing for DTN networks with consistent connectivity was investigated. There are several algorithms with growing understanding of network properties such as impending "contacts," queue sizes, etc [14]. The internet-inspired security development that might apply to space missions is delay-tolerant networking. some issues that affect space operations as well as the Internet security community. Expertise in internet security has been established over the last decade to investigate security concerns for space missions, especially the generalisation of those represented by delay-tolerant networks. Cryptographic data confidentiality and integrity services may be used by DTN or space-mission networks. However, due to the lack of end-to-end connectivity and the potentially severe asymmetries in capability and connectivity, we require an uncommon formulation for such services, where we may have different security sources and security destinations in addition to data sources and destinations [15]. Simulation is the vital tool for evaluating the performance of opportunistic networks. Some security issues occurred, like unauthorised access and message dropping. The available models and tools are used to compare their performance and precision [16]. To overcome these issue, the proposed model presents STCESW-DSA.

1.1. Motivation & Objectives

In OppNets, data can be transmitted using traditional mechanisms like "store-carry-forward"; it can allow communicating the nodes without a continuous end-to-end path. To provide more efficiency and reliability in communicating in the OppNets, using "routing protocols" are "Epidemic", "Spray and Wait", and "PROPHET". However, existing works are limited by many challenges, such as inefficient routing and security-based issues. The major issues are described below:

Data Reliability and Inefficient Routing: In OppNets, "routing protocols such as Spray and Wait, Epidemic, and PROPHET" are used for data transmission between intermittent connections of nodes. However, these routing protocols can face routing inefficiencies. The Epidemic routing protocol can cause node cache overflow and increase the average latency. In some conditions where message overload is high, the PROPHET routing protocol performance can significantly drop and give a delivery ratio as low. The Spray and Wait protocol can take a high average overhead. So, these can lead to minimised performance of delivery and increased latency.

The main objective of the research is to improve the routing in opportunistic networks based on protocols. The other objectives are described as follows:

- To enhance the routing efficiency in the opportunistic network by considering the existing protocol to compare and to design an improved routing protocol that evaluates the protocol's performance.

1.2. Article Organization

The rest of the research is analysed as follows: The research gaps in the previous works and existing methods, are identified and the Problem Statement is presented in Section 2. The Section 3 describes system model. The Section 4 presents the methodologies for proposed model. The experimental findings and a comparison of the proposed and existing approach is presented in Section 5. The Section 6 discusses conclusion and future work of the proposed framework.

2. PROBLEM STATEMENT

The numerous existing works and their associated responses are arranged in sequence of publication in this section. Furthermore, the study offers research solutions for the mentioned issues.

2.1. Specific research works & Issues

In article [17], the "user-optimised data transmission scheduling based on edge community service in opportunistic social networks (ECSUO)" is proposed, which builds the "edge community service model" by presenting "mobile edge computing into the opportunistic social network". In research paper [18], "social relationships and location information (SRLI) routing algorithm" is proposed which achieves "1.5% lower routing overhead" while outperforming "CHOP-NET, Prophet, and Epidemic by at least 16.9%" in "average message forwarding latency" and 7.7% in "message delivery ratio". In article [19], it is presented that, in the "coverage breadth" of the "forwarding node in the network", the "Markov Random Field-Induced Protocol (MrFbP)" is built on "spatial entropy". To determine the efficacy metric for making forwarding decisions, the task depends on a node's tracked "historical mobility". In terms of "throughput, delay, hops, overheads and energy consumption", MrFbPs is contrasted with the well-known "Direct Delivery (DD), Epidemic (EP), Spray & Wait (SW), and Prophet (PR) systems".

The issues identified are

1. The spray and wait protocol can take a high average overhead.
2. In such circumstances of "high message overload", the "prophet protocol's performance" can considerably drop, resulting in a "lower delivery ratio".
3. In "Epidemic", when the number of nodes can be maximized, it suffers from "buffer overflow" and "high average latency".

2.2. Research Solution

Using the proposed STCESW-DSA algorithm, the routing efficiency for the protocol will be improved in the opportunistic network with increasing delivery ratio & minimizing overhead and increasing the reliability of the forwarding messages through adaptivity, which is based on mobility and stability.

3. SYSTEM MODEL

The proposed system establishes stability-aware OppNet environment using 400 mobile nodes deployed in the ONE simulator. The system enhances routing efficiency using STCESW-DSA. Together, the modules ensure adaptive message forwarding and cooperative communication in dynamic opportunistic network conditions.

3.1. Network and Communication model

Consider an opportunistic network consisting of N mobile nodes, represented as $\{n_1, n_2 \dots n_N\}$, moving within a bounded area A. Each node communicates using short-range wireless links whenever contact occurs within transmission range R. The network at any time instant t is represented by a graph:

$$G(t) = (V, E(t)) \quad (1)$$

Where V denotes set of nodes and $E(t) \subseteq VXV$ is a time-varying edge set. A link $e_{ij}(t) \in E(t)$ exists if $d(n_i, n_j) \leq R$. The message transmission latency includes transmission, propagation and queuing delays:

$$D_{oneway} = D_{ts} + D_{prop} + D_{queue} \quad (2)$$

D_{oneway}, total time taken for packet travels from sender to receiver. Packet loss follows a Poisson process with rate parameter λ; hence probability of no loss within time interval Δt is:

$$P_{no\_loss} = e^{-\lambda \Delta t} \quad (3)$$

3.2. Routing Efficiency Module (STCESW-DSA)

The stability aware spray and wait with dynamic stability adaptation (STCESW-DSA) algorithm enhances routing efficiency by selecting relay nodes based on contact stability, link reliability and node resources. The encounter rate between nodes is estimated as:

$$\lambda_{ij}(t) = \alpha\lambda_{ij}(t-1) + (1\alpha)\, I_{ij}(t) \quad (4)$$

Where $I_{ij}(t)$ indicates whether a contact occurred at a time t. $\lambda_{ij}(t)$ is the updated link quality and previous link quality estimate computed at time $t-1$. The mean contact duration is obtained as

$$D\bar{}_{ij} = \frac{1}{K}\sum_{k=1}^{K} D_{ij}^{(k)} \quad (5)$$

The delay $D_{ij}^{(k)}$observed in the k^{th}transmission from node. Node mobility normalised as:

$$M_i = \frac{v_i}{v_{max}} \quad (6)$$

M_i is a mobility factor of $i.v$ is a maximization available velocity. Using these parameters, each node computes its stability score

$$S_i = \beta_1\lambda_i + \beta_2 D\bar{}_i + \beta_3(1 - M_i) \quad (7)$$

S_i is a stability score. Where $\beta_1 + \beta_2 + \beta_3 = 1$. The forwarding utility for neighbor j is defined as

$$U_{ij} = \delta_1 S_i + \delta_2 P_{del}(i,j) + \delta_3 \frac{E_j}{E_{max}} \quad (8)$$

$P_{del}(i,j)$ is a delivery node and $\frac{E_j}{E_{max}}$ is a normalized energy node. $\delta_1, \delta_2, \delta_3$ are the utility weights. The next hop is selected as

$$j^* = arg\ max_{\,j \in N_i} U_{ij} \quad (9)$$

j^* represents selected optimal next-hop node. The routing model is used to reduce the transmissions and preserving delivery performance in a secure and authenticated OppNets.

4. PROPOSED METHODOLOGY

In OppNets, there are some protocol performance-related issues, such as message flooding, high overhead. To overcome these challenges, the research proposes algorithm and mechanism to combine these, thus ensuring routing efficiency and enhancing the communication in opportunistic network. The suggested work include process as Routing Efficiency Module.

4.1. Routing Efficiency Module (REM)

The proposed STCESW-DSA is Stability–Aware Spray and Wait Routing Algorithm using Transmission Capacity Evaluation and Dynamic Adaptation. This method evaluates every node’s stability to maintain a connection and successfully, messages can be forwarded based on metrics such as “mobility node, contact duration, residual energy and buffer size”. The message forwarding can be chosen based on where nodes can have high stability scores. So, this can decrease the unnecessary transmissions and ensure reliable delivery. Often, the conditions of the network can be changed because of the mobility node and intermittent communications. The DSA mechanism helps to dynamically modify the amount of message copies and decision forwarding based on the current stability of the network. When network circumstances are not stable, the system can decrease the message loss and adjust by selecting the most stable relay nodes. Otherwise, spread fewer copies. It ensures decreased latency, increased delivery ratio and achieves stability among resource efficacy and reliability. The Routing Efficiency Module (REM) integrates stability estimation, link capacity, energy awareness, buffer utilization and secure cooperation to enhance routing performance in Opportunistic networks. Figure 1 represents Routing Efficiency Module.

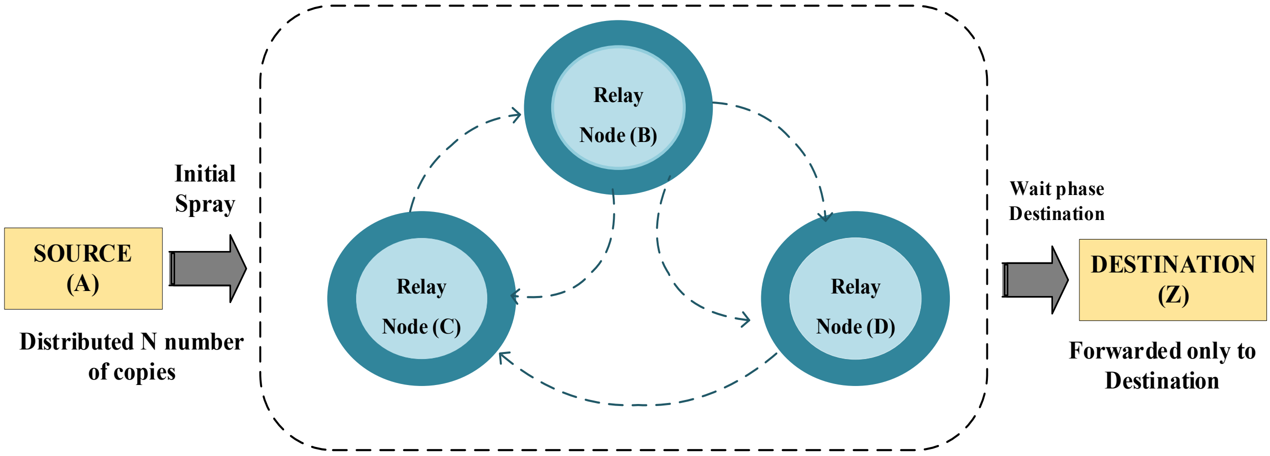

Figure 1: Routing Efficiency Module

The routing efficiency module is presented in following Algorithm.

4.1. Algorithm: Routing Efficiency Module (STCESW-DSA)

Data: Node encounter records $\{\lambda, D\}$, mobility status $\{v\}$, buffer usage{B}, residual energy {E}
Input: Stability weights $(\beta_1, \beta_2, \beta_3\}$, utility weights $(\delta_1, \delta_2, \delta_3)$, copy control factor k
Result: Efficient and stable next hop selection for message forwarding

1. Initialize stability parameters for all nodes
2. Compute initial encounter rate λ_{ij} and contact duration D_{ij}
3. Compute node stability S_i using λ_{ij} and contact duration D_{ij}
4. **While** message is active **do**
5. Update S_i and link capacity C_{ij} for current neighbors
6. Evaluate buffer ratio B_j and energy ratio E_j
7. Compute forwarding utility U_{ij} for each neighbor j
8. Select next hop $j^* = argmax(U_{ij})$
9. Adapt message to j^* only if resource constraints are satisfied
10. Forward message to j^* only if resource constraints are satisfied.
11. Suppress redundant transmissions by ignoring low utility nodes
12. **End while**
13. Return Optimal Forwarding decision and updated stability metrics

5. EXPERIMENTAL RESULTS

In the section, the experimental results for proposed and existing approaches are presented and discussed.

5.1. Simulation Setup

The section shows set up for ONE simulator. To simulate the proposed research method, Java language version JDK 21.0.5 is used. The Table 1 displays ONE Simulation Parameters.

Table 1: ONE Simulation Parameters

Category	Parameter	Value(s)
Scenario	Data Propagation	STCESW-DSA (Proposed Approach)
	Update Interval	0.1 s
	SimulationTime	43200 s (12 h)
Interfaces	Interface	Bluetooth
	btInterface Type	SimpleBroadcastInterface
	btInterface Speed	250 kbps
	Group Buffer Size	5 MB (default), 50 MB (trams)
	Group Speed	0.8–2.5 m/s (pedestrians), 2.7–13.9 m/s (cars), 7–10 m/s (trams)
Mobility	Movement Model	ShortestPathMapBasedMovement, MapRouteMovement (trams)
	World Size	4500 × 3400 m
	Map Files	roads.wkt, main_roads.wkt, pedestrian_paths.wkt, shops.wkt
	Interval	10–18 s
	Message Size	500 KB – 1 MB
	Hosts	0–399
	TTL	20000 s

5.2. Comparative Analysis

To make a fair comparison, the ECSUO ("Edge Community Service in Opportunistic Social Networks") model [17] is used since it is currently one of the most established methods for routing in opportunistic networks. While ECSUO works well with community-based forwarding, it tends to have higher overhead when network conditions change, which makes it a good benchmark for testing improvements in the new STCESW-DSA routing model. The new method is evaluated by comparing it with ECSUO across several metrics: Number of nodes vs. overhead ratio, delivery ratio, average latency, average buffer time and energy usage. The STCESW-DSA method is generally more effective in comparison to ECSUO. Figure 2 shows how the ONE simulation environment is configured to realistic contact patterns, movement and wireless communication of nodes so as to closely resemble real-world network behaviour. The opportunistic network has 400 nodes to depict a normal dynamic network configuration.

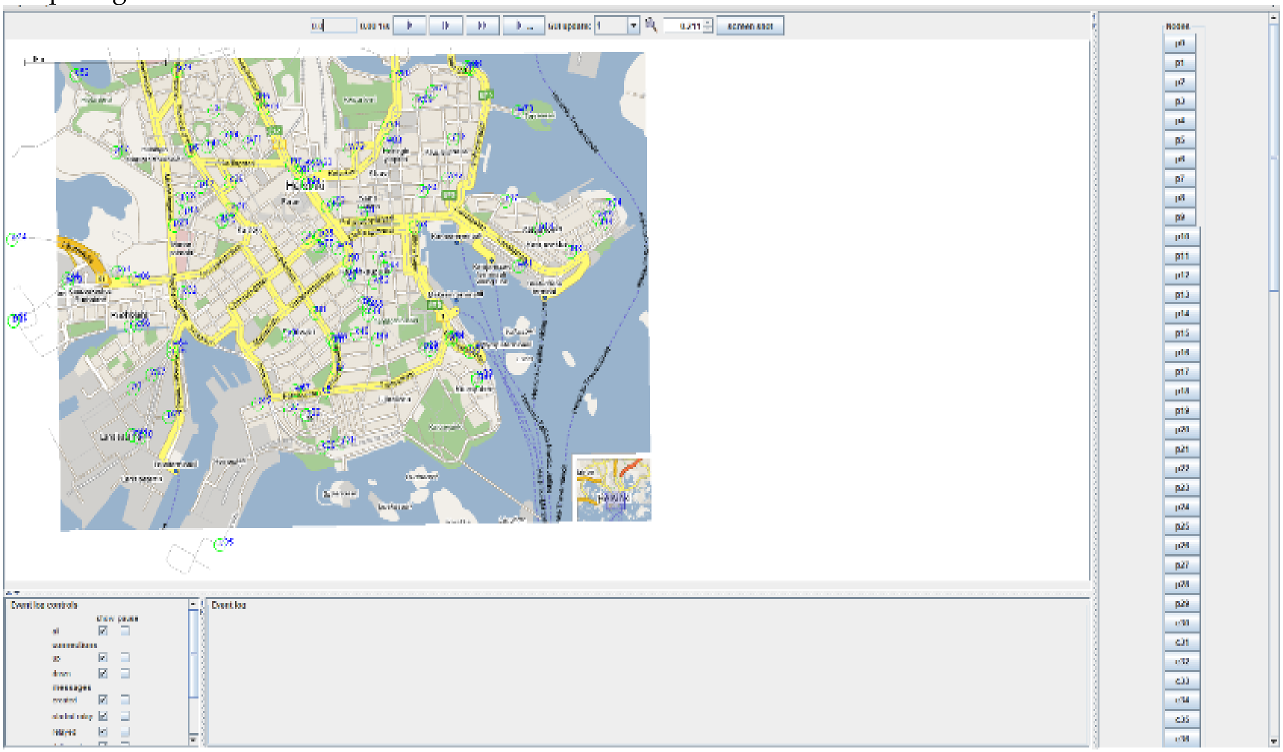

Figure 2: ONE Simulation Network

5.2.1. Number of Nodes vs Overhead Ratio

The overhead ratio is used to determine the efficiency of the routing protocol in operation by examining the level of redundancy in the transmission of messages. Overwhelming replication can be avoided in dense networks, though STCESW-DSA deals with this by applying adaptive forwarding and selective replication, reducing the number of such redundant messages through the assistance of Node Stability Metrics (NSM). The fact that the overhead is slightly increasing with the number of nodes indicates that the protocol scales well. The reduced overhead implies that the network resources are being put to better use, implying that the routing decisions are highly optimized, even in large and complicated opportunistic networks.

Table 2: Number of Nodes vs Overhead Ratio (%)

Number of Nodes	Overhead Ratio (%)	
	STCESW-DSA (Proposed)	ECSUO (Existing)
50	7.0	9.0
100	6.8	8.8
150	6.5	8.5
200	6.0	8.3
250	5.5	8.2
300	5.3	8.1
350	5.2	8.0
400	4.0	7.5

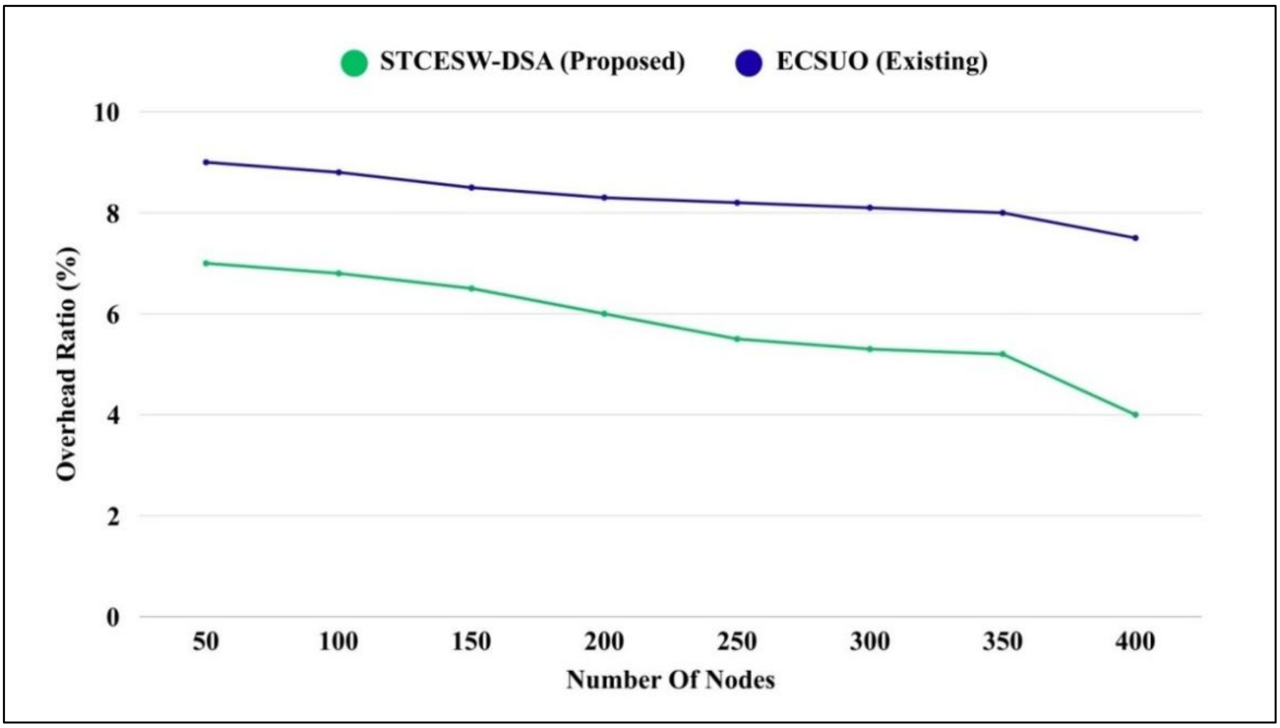

Figure 3: Number of Nodes vs Overhead Ratio (%)

The Table 2 and Figure 3 indicates that routing overhead increases with the network size in comparison between the new STCESW-DSA and the current ECSUO. The routing overhead of the two protocols decreases as the number of nodes increases. Regardless of the number of nodes in the network, the STCESW-DSA maintains the overhead lower than ECSUO. Such reduction in overhead demonstrates the efficiency of stability-conscious forwarding strategy and assists in preventing unwarranted duplication of messages and reducing the number of redundant transmissions.

5.2.2. *Number of Nodes vs Delivery ratio*

The delivery ratio informs us of the reliability and efficiency of the network in terms of passing messages. The size of the network is important as the larger the network, the greater are the possible paths to which the messages can be forwarded. The STCESW-DSA algorithm is optimally suited to high-density opportunistic networks, in which the STCESW-DSA algorithm exploits both the stability of the nodes and their likelihood to be encountered, selecting the most suitable ones to send messages. In contrast to the old techniques that simply saturate the network with messages, the Routing Efficiency Module (REM) of STCESW-DSA minimizes redundant messages and sends messages via stable and well-equipped nodes. This routing strategy is relatively efficient, as the delivery ratio demonstrates, and it can effectively cope with the variations in the network density.

Table 3: Number of Nodes vs Delivery ratio (%)

Number of Nodes	Delivery ratio (%)	
	STCESW-DSA (Proposed)	ECSUO (Existing)
50	50	55
100	58	60
150	65	65
200	66	70
250	68	75
300	78	80
350	85	85
400	95	90

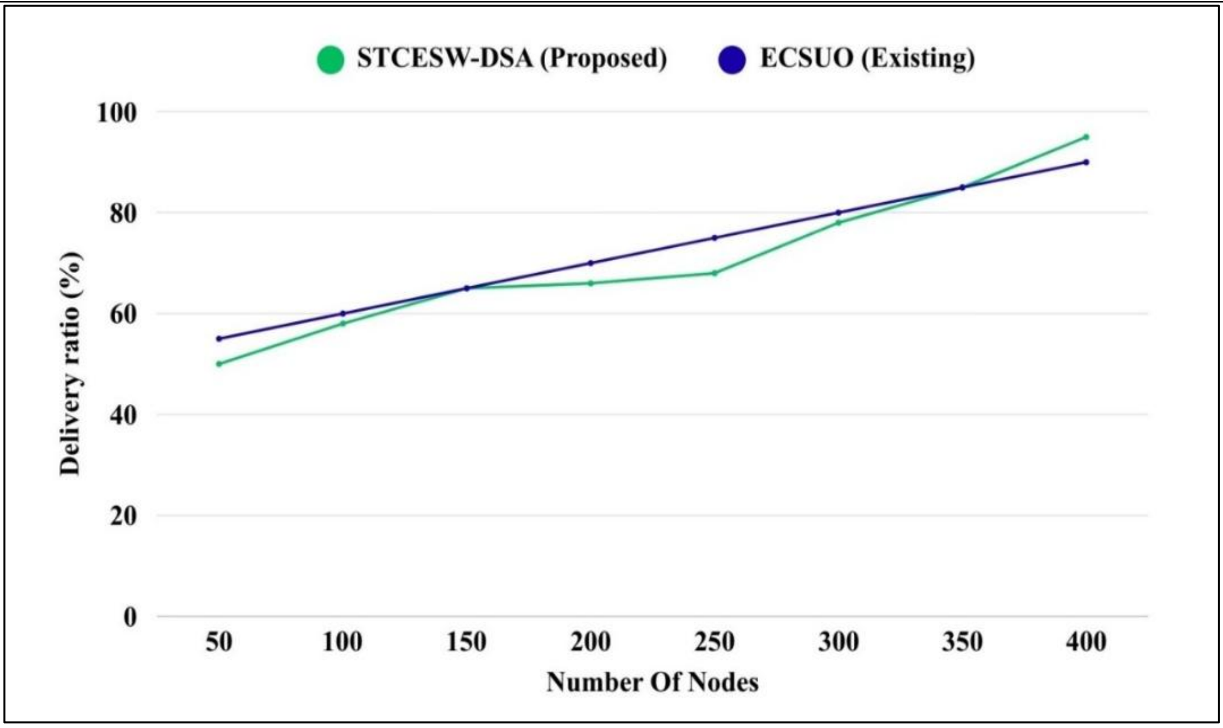

Figure 4: Number of Nodes vs Delivery Ratio (%)

The Table 3 and Figure 4 demonstrates improvements in the number of successful transmissions of the first source node to the final sink node with the increase in the network. The STCESW-DSA and ECSUO routing protocols performed better with the increase in the number of nodes between 50 and 400. The more the nodes, the more the chances of nodes connecting and communicating. ECSUO was approximately 5-6 percent more effective than STCESW-DSA in networks with low node density (50-100 nodes), as there was not enough encounter to enable the stability-conscious nature of STCESW-DSA. In the moderate density of nodes (150-250 nodes), the two protocols were similar with the STCESW-DSA steadily improving. Nonetheless, at high-density networks (300-400 nodes), the success rate of STCESW-DSA was approximately 95 percent and the success rate of ECSUO was 90 percent, which provided STCESW-DSA a 5.6 percent higher success rate. These results demonstrate the effect of the stability conscious spray and wait strategy with STCESW-DSA in minimising the unnecessary transmissions, enhancing the consistency of message delivery, particularly in high density opportunistic networks.

5.2.3. Number of Nodes vs Average Latency

Average latency is simply the amount of time that a message takes to go through the source to the destination. The average latency is likely to increase with the number of nodes in the network due to factors such as buffering delays, forwarding and hops competition, and the number of hops that the message has to traverse. The routing algorithm can reduce that delay and accelerate the delivery of messages by prioritizing those nodes that are most likely to be met and whose movement is predictable. The copy-control mechanism is dynamic in the algorithm to ensure that things do not slow down due to message congestion that occurs due to excess duplicates. Ultimately, such a strategy leads to reduced latency over older opportunistic routing schemes, which utilizes available contact opportunities more effectively and provides messages with reduced latency.

Table 4: Number of Nodes vs Average Latency (s)

Number of Nodes	Average Latency (s)	
	STCESW-DSA (Proposed)	ECSUO (Existing)
50	5	7
100	8	10
150	12	15
200	15	17
250	16	18
300	17	19
350	20	21
400	31	33

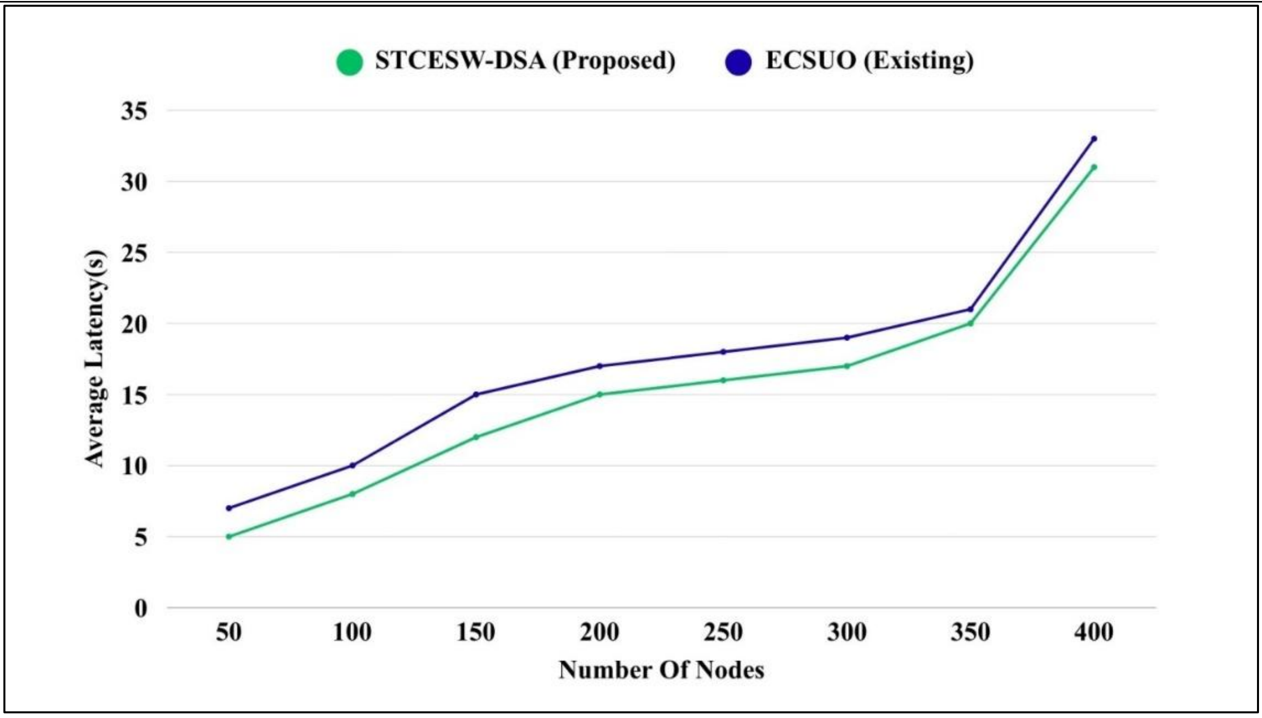

Figure 5: Number of Nodes vs Average Latency (s)

The Table 4 and Figure 5 shows how average latency changes as the number of nodes in the network increases. The STCESW-DSA routing method and the ECSUO routing method are similar. The latency of both nodes increases with the number of nodes added on the same wireless link, and thus more users share the same wireless link, resulting in increased competition, increased buffering and wait time of packets to be forwarded. STCESW-DSA is however more effective at reducing delays between the source and destination even in sparse or moderately dense networks. Even in large scale networks, it can maintain delays relatively low and still achieve the same performance as the other method.

5.2.4. Number of Nodes vs Average Buffer Time

Average buffer time is the amount of time a message sits in a node's buffer before it's forwarded or delivered. As networks grow, poor buffer management can lead to more packet drops and congestion. The STCESW-DSA protocol helps solve this by choosing relay nodes that have enough buffer space and stable contact patterns. By cutting down on unnecessary message copies and focusing on the most efficient ways to send messages, the protocol reduces how long messages stay in the buffer. This leads to less congestion, higher throughput and overall, a more stable network.

Table 5: Number of Nodes vs Average Buffer Time (s)

Number of Nodes	Average Buffer Time (s)	
	STCESW-DSA (Proposed)	ECSUO (Existing)
50	18.0	21.0
100	17.8	19.8
150	15.5	17.5
200	12.3	15.3
250	10.0	14.2
300	9.3	12.1
350	7.5	8.0
400	6.0	6.0

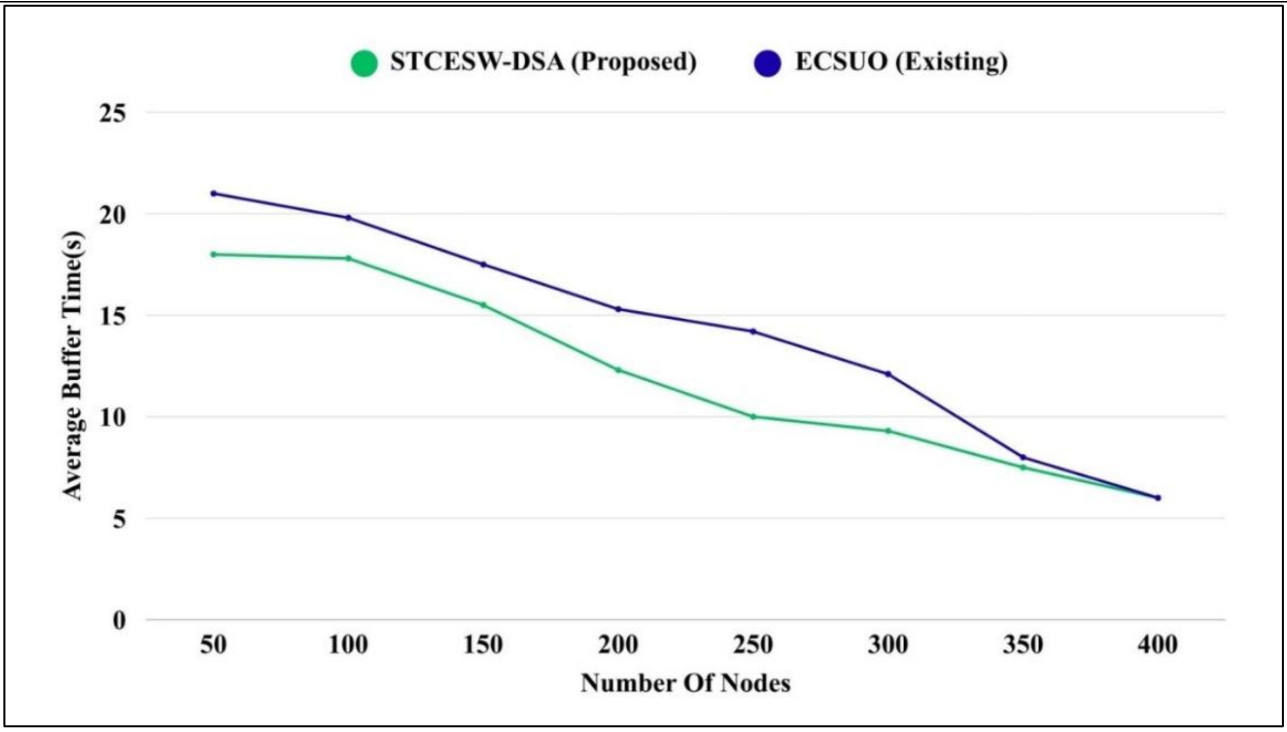

Figure 6: Number of Nodes vs Average Buffer Time (s)

The Table 5 and Figure 6 show how long it takes for packets to be delivered after they arrive in the buffer from the network. The results highlight that STCESW-DSA spends less time in the buffer than ECSUO. For instance, at 50 nodes, STCESW-DSA takes 18 seconds, while ECSUO takes 21 seconds. As the number of nodes increases, the time spent buffering decreases for both protocols because there are more chances for packets to connect with other nodes. By the time there are 400 nodes, both protocols have almost the same buffer time—about 6 seconds—meaning that dense networks are better at using their buffers efficiently. The fact that STCESW-DSA has lower buffer time than ECSUO shows it does a better job at scheduling and controlling packet duplication.

5.2.5. Number of Nodes vs Energy Consumption (J)

In opportunistic networks, where nodes have limited resources, energy consumption is a big issue. As more nodes are added, energy use tends to go up because nodes are transmitting and receiving more messages. The STCESW-DSA Routing Protocol tackles this by cutting out unnecessary message forwarding and choosing stable, energy-efficient nodes to act as relays. By reducing the time spent processing and transmitting messages, this approach helps save energy on each node. The results show that this routing method works well for large-scale opportunistic networks, especially when energy is limited.

Table 6: Number of Nodes vs Energy Consumption (J)

Number of Nodes	Energy Consumption (J)	
	STCESW-DSA (Proposed)	ECSUO (Existing)
50	2	5
100	5	15
150	10	25
200	12	35
250	15	45
300	20	55
350	25	75
400	26	95

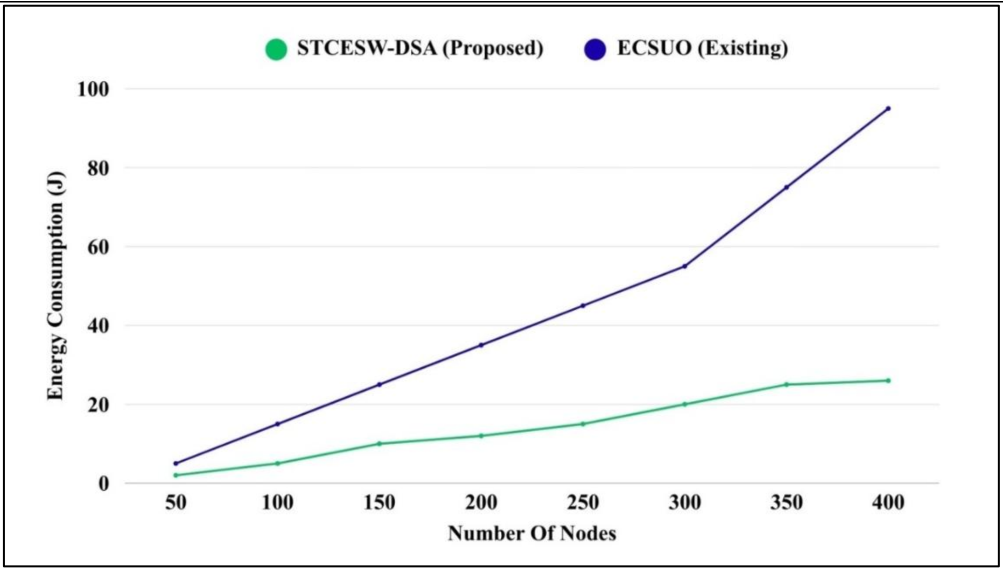

Figure 7: Number of Nodes vs Energy Consumption (J)

The Table 6 and Figure 7 compares how much energy the STCESW-DSA and ECSUO routing protocols uses. As the network grows, so does the energy consumption per node, mainly because of the increase in forwarding and control messages. However, STCESW-DSA stands out by using significantly less energy than ECSUO. For instance, at 50 nodes, STCESW-DSA uses just 2 J, while ECSUO uses 5 J. This energy efficiency comes from STCESW-DSA making smarter, more controlled decisions about how messages are sprayed across the network. By the time the network hits 400 nodes, STCESW-DSA only consumes 26 J, compared to ECSUO's 95 J, showing a clear advantage in energy savings with the proposed routing approach.

5.3. Research Summary

The network is established in the research work with the help of the ONE Simulator platform, where 400 mobile nodes are introduced in a large-scale OppNet. The configuration is configured to be as close to the real-world network conditions as possible with realistic contact patterns and wireless communication properties. Following the development of the network and the simulation, important indicators such as the time of packet transmission, the size and the number of packets received are recorded. The performance of the proposed SECESW-DSA routing model is then tested that enhances the forwarding of messages based on the factors such as delivery efficiency, stability of the node and link length in dynamic environment. To evaluate how well the model performs, several metrics are measured and plotted, including the number of nodes vs. overhead ratio, delivery ratio, average latency, average buffer time and energy consumption.

6. CONCLUSION

The article presents a novel stability-aware routing framework for OppNets employing proposed STCESW-DSA model. The proposed STCESW-DSA model selects relay nodes by evaluating buffer capacity, node stability, transmission capability and residual energy. It provides the communication environment for enhancing routing efficiency.

When compared to existing ECSUO model, the proposed STCESW-DSA model achieves superior performance by achieving lower overhead ratio, higher delivery ratio, reduced latency, buffer time and energy consumption thereby establishing a more reliable, communication environment for intelligent opportunistic networks. Overall, the proposed STCESW-DSA model is successfully used to enhance the routing efficiency in opportunistic network. It develops strong basis for secure and privacy aware data transmission, providing the way for future research in trust-aware communication and adaptive opportunistic networks in social and intelligent networking systems.

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