Sustainable Next-Generation Network Design using Social Aware and Delay Tolerant Approach

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***Abstract*—With the ever-growing popularity of smartphones, new services are emerging where the local and positioning aspects become more important. Additionally, new routing algorithms are being developed based on various networking technology such as Delay Tolerance Networks (DTN), Device-to-Device communication, Opportunistic Network, etc. DTN is categorized as stable and unstable, a continuous path between the source and the destination node. Here, communication is done by carrying the message through the intermediate relay node on the store and carry forward paradigm. In this work, a Sustainable Energy Delay Tolerance Approach (SEDA) considers nodes mobility patterns for energy-efficient data transmission. This routing model is based on the appropriate usage of node information along with node mobility and its contacts for data dissemination. Next step is applying some techniques to predict the most likely position for next encounter. We will design and implement a social relation-aware routing relation-awareness the social relation as a part of the routing matrix. We assume that most of the movement of nodes are included in various numbers of social contacts; therefore, there is a higher probability of message delivery to the destination. Simulation results show that the proposed routing protocol improves the delivery ratio by reducing network size and distance, which also impacts energy saving.**

***Keywords*—routing model, mobility pattern, data transmission, mobility**

I. Introduction

In the OppNets, the formation of nodes works on store-carry-and-forward pattern. Intermittent connectivity is yield when the links are frequently disconnected among the nodes, due to nodes' mobile behaviour and random movements. Limited battery power, storage, and inconsistent links are some of the primary characteristics of OppNets [1]. These facts result in a non-guaranteed packet delivery from source to destination. Nevertheless, there is variation in OppNets' application and features as it relates to various practical and real-life situations like wildlife and healthcare monitoring, disaster relief, and name a few more [1, 2].

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Routing becomes challenging as there may seldom be an end-to-end way between source and destination. A relay node can opportunistically establish a communicative connection with another node quickly, because of its highly mobile behaviour. After that, it passes along with the message expecting the receiving node to do the same to the encountered node. It happens unless the message is gradually delivered to the final destination [1–3].

Due to the short range of wireless communication, power failure, and limited mobility of nodes, packets-drops occur frequently. To avoid this, nodes should be allowed to keep the packets in their buffer for a longer duration of time until a suitable next hop is allocated for their forwarding. This will increase the chances of successful message delivery. It is important to note that this should be done without compromising the network's performance. Additionally, the node should be configured to adjust its transmission power levels so that packets can be transmitted over the required distance. Furthermore, nodes should be configured to adapt to the changing network conditions and environment, which will enable them to select the most suitable next hop for packet forwarding. Finally, the routing protocols used in the network should be designed to account for any potential node mobility and power consumption constraints.

The rest of the paper is organized as follows. Section II detail some related work. Then, Section II describes the proposed SEDA protocol, working with the history table and initial location table. Next, the SEDA approach is in presented Section IV. Section V discusses the energy consumption model with an optimal solution with a case study's help, compares the energy-based internet and the D2D model, and explains the simulation setup and results. Section IV concludes the paper by providing some final remarks on future work.

II. Related Work

The routing problem in OppNets has been addressed formerly by proposing various routing protocols. In [4], a direction-finding protocol based on dissemination, namely Epidemic routing, has been introduced by Vahdat and Becker (2000). The network's ability to gradually distribute message(s) to the desired destination(s) through flooding is the basis of this protocol. To begin with, the Summary Vector forms when each node retains separate lists of the messages then currently saved in its buffer. An anti-entropy session is initiated by the node having a smaller identifier between two meeting nodes. The two nodes exchange each other's Summary Vectors and uncommon messages between them. One, several copies of similar messages stream within the network and the other, all the nodes have alike messages in the buffers. These two stages of action happen after the exchange of messages has been accomplished successfully. As a result, the messages spread over the network in a thorough or epidemic fashion. Such activities generate many inessential messages in the network. Consequentially, great demand for buffer capacity and bandwidth is noticed due to these unnecessary messages. Such a protocol uses no acknowledgment system and thus some nodes still carry on delivering the message even though the destination has received the message. Henceforth, the outcome is no waste of network resources.

The authors of [5], the Prophet-Probabilistic Routing Protocol utilizing History of Encounters and Transitivity has been introduced in an article in 2003. The structure of this protocol for delivering a message is designed to use transitivity and encounter history. It supposes that the nodes have a predictable repeated mode but not a random movement. Such a motion can result in the usage of delivering a quick and effective message. Delivery predictability for an individually known destination can together be termed as a probabilistic metric. Each node calculates this probabilistic metric before sending the message, and the probability of node A meeting node B is the probabilistic metric P(a,b) [0,1] Furthermore, predictability vectors are exchanged when two nodes meet each other. The carrier node only transfers the message to the neighbouring node when there is a high probability of the neighbouring node to meet the destination node. Otherwise, the message is not delivered further and kept to itself. Moreover, for buffer management at the nodes PRoPHET utilizes a FIFO (First In First Out) queuing or communicating mechanism. After forwarding to a minor number of concentrated nodes, it can result in the consistent dropping of packets. It is independent of including any message scheme. This protocol might perform slow and inefficient responses to changing trends in regard to nodes' movements. Additionally, for deciding the best carrier of message later on PRoPHET uses nodes' delivery predictability only. Whereas, for choosing the finest next hop to the destination, PRoPHET+[10] makes use of various parameters like Buffer, Location, Popularity, and Power. Certain weight assigns these values of parameters also, for obtaining an ultimate value from 0 to 1, these parameter values are normalized, By the obtained values of these parameters and their comparable weights, a final metric is calculated at this stage. This final metric then determines the best next hop. Such a particular protocol uses a lot of parameters for selecting the next hop. For these values, the calculations are hard, giving an outcome of different overhead in passing a message. Discussing further on, it does not use any parameter to predict the upcoming behaviour in nodes' movement in the network. In [6], Boldrini et al. Proposed HiBOp - 'history based routing protocol for opportunistic networks. To identify a better path, this protocol uses node s' current context. A screenshot (snapshot) of the current environment in which a node resides. Identity Table (IT) and History Table (HT) store the local context. They are exchanged and current context (CC) is built when nodes meet one another. Previously, the values that nodes see from the ITs are stored by the History Table. A Continuity Probability (Pc), Redundancy (R) and Heterogeneity (H) counters are related to every value. A node's every feasible context information is stored and used by HiBOp. These are very difficult to find generally. Withal, a huge measure of memory space on each node is required by IT, CC, RT, and H T. The authors of [7] the topics and details of the discussion are similar to the description in [8].

Spyropoulos *et al.* proposed an extension to the Epidemic routing protocol by calling it Spray and Wait protocol. This protocol works by assisting in reducing the spread of the number of copies across the network. Hence, the congestion is reduced, which is because of flooding. In detail, the forwarding process has two phases: Spray Phase and Wait Phase. When a message only spreads to L nodes, L copies of messages are constructed or created. It is then called Spray Phase. The relay nodes with a copy of the message wait for the destination to transmit it directly. The chosen value of L indicates the probability of message delivery and is strongly responsible for this action. Again, the determined value of L is dependent on the network parameters. The protocol undergoes issues like delays and consumption of resources, despite the fact that L is selected to limit flooding. The authors of [9], an improved version of spray-based routing schemes was presented by Makhlouta. This improvement version can be classified by naming Adaptive Fuzzy Spray and Wait. The aim of this study is to predict pedestrian's similar location even researchers can revise the location update form a movement trajectory. Mobile phones or other devices will sometimes be switched off, unremembered or entering urban canyons or other places with such low GPS coverage. User updates i.e. significant time lapses between location updates are one of the crucial facts on those Applications such as Facebook [10] and Twitter are dependent. Additionally, to confirm maximum privacy policies users shall have access to record deletion or prevent recording as per choice [11]. Bauer and Deru [12] Suggests to ways of predicting future destination along with previous histories. A Market Basket Survey of several purchasers can identify the connection between locations and produce rules. As for example, when someone goes to a coffee shop, he or she may buy a cake or biscuits; this algorithm determines the same path the author on paper show, the algorithm but didn't show the appropriate results. Lymberopoulos, Bamis and Savvides [13, 14]. At the cellular system of a based station, two algorithms, PPM-C and LAST, were used to anticipate the number system. A heuristic model that predicts two factors is considered to be LAST. One factor is no user movement, and the other is the similarity of the former and next base stations. For a given portion of historical data, the correct algorithm is determined by the movement of the Market Basket breakdown. This movement takes place through various pattern formations. For four-time steps, the user remained connected to a similar base station as shown by historical Market Basket analysis data. The LAST algorithm predicted the most recent base station accordingly. In cases where the historical data showed the pattern of a base station, there is another case in Market Basket Analysis did not find a common movement at that Time. PPMC (Paris Process on Mobility and Climate) predictor was applied, and those algorithms return the prediction on the single best location, and this was the author's hard decision. The author uses the vectors for all predictions refund, referred to an as soft decision, and aggregates the hard decision with the soft decision. Vu, Do, and Nahrsted *et al.* results of their locations, and period of time prediction were recently published in [15]. They used Nave Bayesian classifier-based model, the model consists of the time slot of days, weekends, and time slots of 1 to 8 hours. Everyday time stamp is divided into multiple records that consist of a list of Bluetooth MAC addresses and locations.

When the MAC address match with people encountered by the user looking forward to the type and Time of time slot predictions, predict the most likely (up to three) position, mean measurement, standard deviation, and people (Bluetooth Max) mostly encountered at that location. They test the 50 users and achieved the results of 80 % using 2 hours' time slot. However, when they used the time slot of 1 to 8 hours, the result [16] was not significantly changed, which means the predictions of the most commonplace (for example, office) can be returned and places cannot be offered which have been briefed for short Time. The collective movement patterns, daytime, land use, and interest-point approach to a stable model It can predict 60% right within an hour according to the next position of an individual. This work can be one of the first to add to the geographical models, and this geographical model movement pattern of the group to an individual for location predictions. Applied spatiotemporal data mining to trajectories in order to predict the next area and arrival time of a vehicle. Monreale et al. Prediction algorithm [17] have been used for data allocation onto public transport in many areas. after encoding the change-overs between regions into a trajectory tree, the GPs location data are put together according to the areas. The transition to the child area from the parental area is denoted by each child. The child area supports categorizing this transition. Moreover, it frames arrange of Time for the movement to the child area from the parental area. For predicting upcoming areas, partial trajectories are matched in non-permanent tolerance with pathways.

In this way, the accuracy of prediction gets better than 54% of models, which can predict the Time of arrival and accumulate vehicle behaviour to put on separate predictions. The algorithms in [17] use duration at the last location to determine the next location. It requires continuous data use duration information and Time of arrival to predict future locations.

III. Proposed SEDA Protocol

Certain suppositions were made for the design concept of SEDA (Sustainable Energy Delay Tolerance Approach). In the Fig. 1 the past history of a node's mobility pattern over a certain period of Time, the course of its movement and the Time taken by it to encounter the other nodes within the system are the principal steps that are dependent upon these certain suppositions which are used to confirm the message forwarding.

The suppositions are as follows:

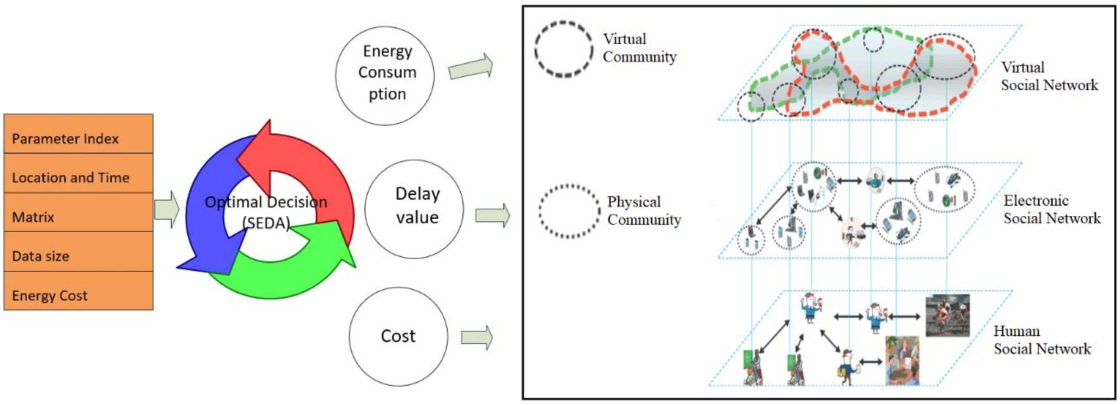

Figure 1. SEDA model.

The nodes can move to some locations inside a system more often than the others by following the Customized Mobility Model (CMM) path.

The nature of nodes is cooperative, and they exhibit no harmful effects.

There are multiple subdivisions inside the simulation area of the system. Each subdivision corresponds to a location of a certain node at that particular Time, whereas the subdivision which a particular node visits more often than the others is called its home location.

A. History Table

Firstly, the history table is a kind of recording table inside a system in which the node itself registers the initial location and timer of the node. At the beginning of every simulation, the note timer is set to 0 and the records are registered in the history table in the format of Time and then location. However, in order to maintain memory storage space inside the history table, the 1st entry of the table is automatically eliminated from the table to make space for the 101 entries, considering the fact that the nodes can preserve suppose data up to 100 to 200 movements only. This system of eliminating the first entry is called First In-First-Out mechanism. Shown below in Table I is the example of history table with cell numbers (storage areas) 23, 45, 45, 40, and 45.

TABLE I. HISTORY TABLE [3]

Time	Location
0.45	23
1.2	45
2.6	45
2.9	40
3.3	45

B. Office Location Table

Office Location table is a certain kind of table which stores the location of the certain node in a format Host ID, Office Location. As described above, Office location is the memory unit or cell that a node visits more often in a system. Every node inside the system is aware of the office location of each other node but if a node visits another node's office location, then it registers this visit. This particular process is called office location initialization. Every node after every encounter shares their office location tables. Each node has its own history table and in case of not finding the same entries, the office location tables get updated according to the most recent home location entry of that node from its history table. Shown below in Table 3.2 is the example of the initial table with cell numbers (storage areas) 31, 43, and 84.

TABLE II. OFFICE LOCATION

Host ID	Office Location
P1	31
P5	43
C2	43
T2	43
C4	84
T4	84

IV. SEDA APPROACH WORK

The proper operating of SEDA approach by using the above-described data structures, can be explained by these points:

A. Initial Location Initialization

Each node inside a system is residing in a certain specified Initialize location (cell number), so in the beginning the network is started by initializing these nodes. Each and every node advertises its initalize location to every other node inside the network so that all can be aware of it. They share each other's initialize locations in their Initialize Location Table (as described above). This step is called initialization.

B. Message Generation and Initial Location Update

Message Generation and Home Location update is a process in a network in which certain nodes are selected from all the nodes and they are used for generating and sending messages to some other nodes inside a system asking them to update their Home Location Table because of some recent occurred changes in their locations.

C. Next Hop Selection

Suppose there's a node 'k' which has to select the next best forwarder, for this purpose a utility metric U(k) is calculated which is dependent on the following three points: • Stability of node's movement • Prediction of the future movement of the node

Perpendicular distance of the neighboring node from the SD Line (the line of sight of source and destination) A message copy to arrive at the destination is attached to every other node whose utility value is greater than or equal to the prescribed parameters.

D. Stability of Node's Movements

This is concerned with the average speed of the node, which can be significant i.e., it's unstable or it can be nominal i.e., it's stable. The average speed of the node is measured at two different locations or positions by using the Timestamp parameter from the History Table of the node. Then, numbers of average speeds are recorded in the table upon which it can be Fig. 2 out whether the change in average speed is stable or unstable. In the beginning, all nodes are assigned the certain stability value which is 'S'. However, if the change between two consecutive average speeds is less than 10 units over second, then 'S' is unchanged. Otherwise using the following equation, it is decreased.

$$S = S\times(1-S)\times Si \tag{1}$$

E. Prediction of the Next Location of a Node

To predict the next location of the node, a 2-state Markov predictor model [3] is used which is based on the History Table of the node. The predictor uses the table which records the frequencies of visits of the node to any other location to find the very next location of the node. For example, the past history of the node is Ayhbytyghiyhyklopwnyhwbkjdnyh, Y occurs the most as shown so the next location will be Y in the sequence below

Ayhbytyyhighyklopwnghwbkjdnyh

F. Perpendicular Distance of the Neighbouring Nodes from the SD Line

In order to select the nodes which are close to the SD line, and use this utility metric $U(i)$ which is calculated as. Vi (1) = Stability Matric Vi (2) = Prediction Metric Vi (3) = Perpendicular distance metric for node i W (j) = Weight parameter (j=1; 2; 3):

$$U_i = \sum_{j-1}^{3} W(J) * V_i \tag{2}$$

Any node (k) after this calculation whose utility value is in range with $U(k)$T, where T stands for the prescribed threshold, can be considered as a prime node that can be used for message forwarding. The SEDA approach works well with T=0.6 because that helps in keeping the overhead ratio as low as possible. Therefore, for all the simulation results, this value of *T* is considered.

G. Multiple Decisions

We present a case study that the data transmission distance is a key, but changeable factor contributing to overall energy consumption. It is straightforward that the shorter the transmission distance is the total energy consumption will be reduced. For example, we have two users Alice and Bob: Alice and Bob are working at the same university but on different floors, Alice is the professor at the university, and bob is studying and they normally have met to discuss the research work. Alice intends to send the file to bob, which will be required by bob after seven days as at.

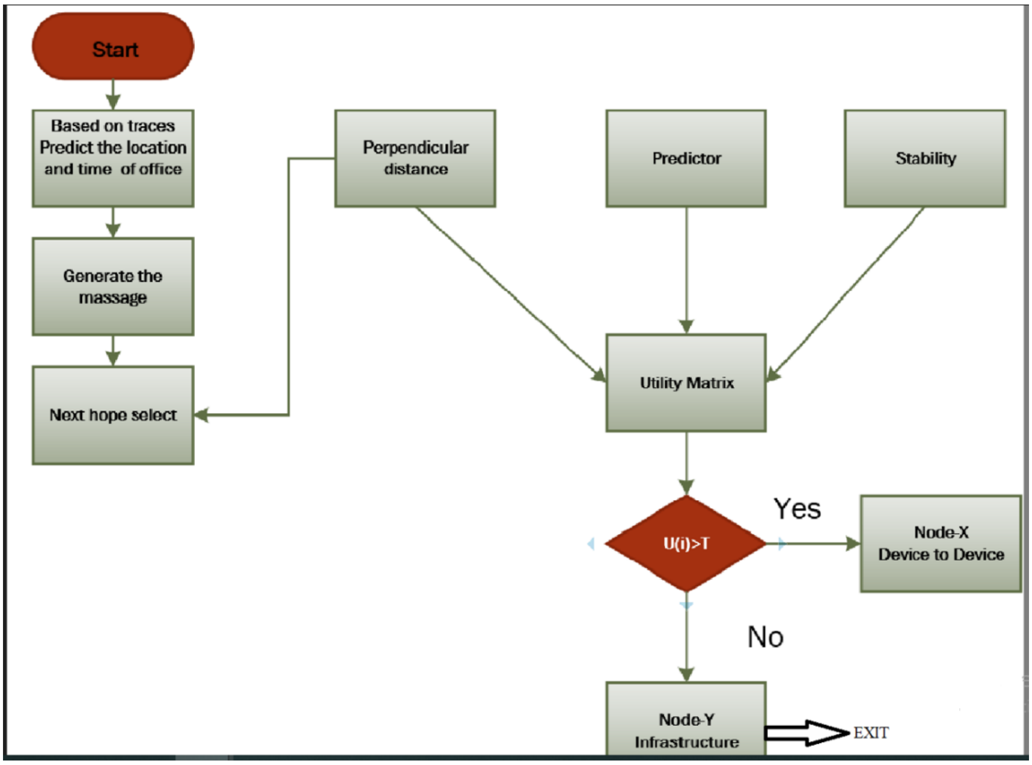

Figure 2. Sustainable energy delay tolerance approach.

Figure 3. Data transfer through D2D.

Moment Bob is working on another task. In this case, how can Alice send the file to Bob? There are several options available: Option A, Alice can send the data through the internet, passing many hops. Option B, when direct file-transfer service is available, for example, they both have their own routers, thus can exchange data between each other through point-to-point transfer. First two options are the most popular, and overall energy consumption depends upon the size and distance of data. We can consider option C, we have loose requirements of Time, and the delay tolerant indicator is decided to reach data between that duration. In option C, human mobility traces are matched according to behavior. In such a way, the proposed approach can fully utilize the benefits of mobility traces, using these traces, predict the similarity of location and Time, and if they match then data will transfer by D2D while consuming less energy. Fig. 3 also represents this case study.

V. Simulation Setup

The SEDA approach is evaluated using the ONE simulator. Here, consider the 6 groups of mobile nodes with the same speed between 0.5 to 1.5m/sec. The nodes group has a different office location, where the transmit range of nodes is 10 meters and transmit speed is 2Mbps. The movement model word size is 4500 × 3400 meters. When each simulation runs for 43000 seconds. A new message is generated every 25 to 35 seconds and change the size of the message for results in the next part, these three parameters are used for the weight, and weight is represented by W(1)=0.4, the second parameter is prediction matrix with weight W(2)=0.4 and the third parameter is distance matrix with weight W(3)=0.2. The all-simulation world size is divided into a cell of 100 X 100 meters. This model is based on structure-based movements and repeating pattern. So surely, performance is based on movement of node, distance, size of message and stability of nodes.

A. Simulation Results Using Real Traces

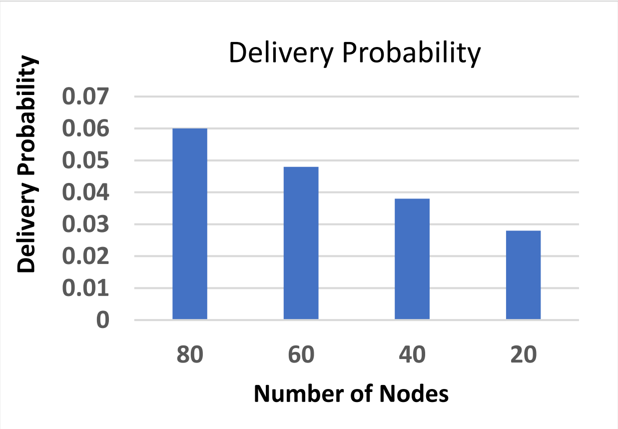

Figure 4. Distance energy.

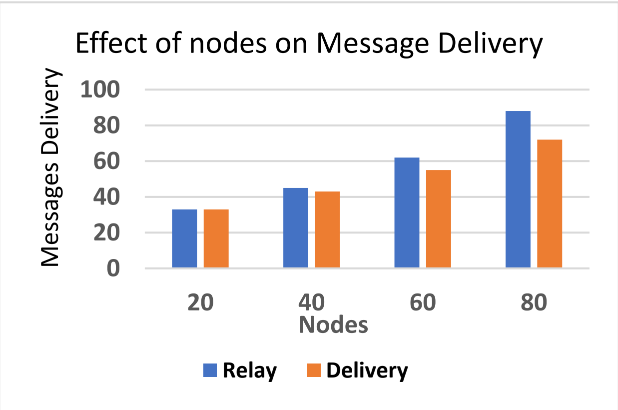

Figure 5. Effect of nodes on message delivery.

The dataset used to take the real traces contains 36 nodes of Bluetooth in the group having small devices. The blow results in Figs. 4-6 consider three parameters. The first parameter distance shows the less distance and node transfer of the data, data transfer takes less energy, and these results also support our "Sustainable energy Delay Tolerance Approach" this approach has a utility matrix condition if the condition of the utility matrix is matched, then data transfer through D2D otherwise data transfer through the Internet.

The first one is decreasing the distance between two nodes and their impact on energy. Fig. 5 explains the increasing number of nodes effect on message delivery and relay. When increasing the number of nodes message delivery also improves relay, but at the same time, the surety of message delivery also will increase as mentioned in Fig. 6.

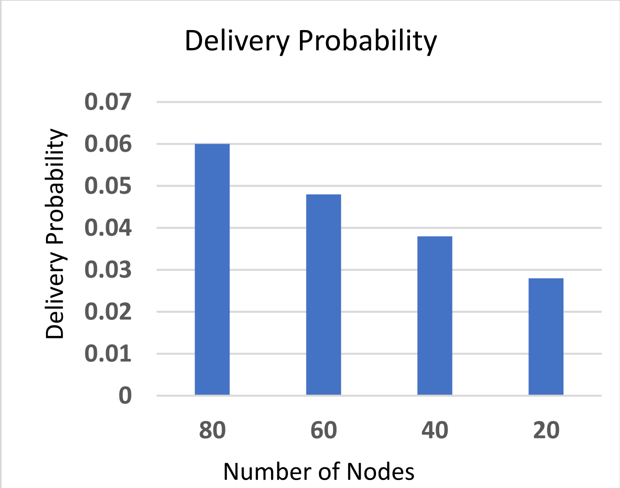

Figure 6. Delivery probability.

B. Discussion on Privacy and Profiling Issues

To run D2D (device-to-device) communication model in real time scenario, security mechanism for privacy and profiling control mechanism are essential to include within devices. To realize SEDA (sustainable energy Delay Tolerance Approach) and network architecture efficiently, multiple questions need to be answered properly.

Firstly, based on transmission implementation D2D communication system can directly exchange data or information with delay tolerant nature to deviate from the infrastructure [16, 17]. The characteristics of these devices are the limited performance in cryptographic computation and cryptographic key management through the devices being autonomous, occasionally anonymous, and rarely distributed in nature. A few questions arise when mentioning situations of such devices. The questions are likely to be: How can a device know whether its communication partner is genuine or malicious? Can the request, content, or message from any mobile device be trusted? How can the devices be able to perform self-organization processes to provide a secure network paradigm with high-quality service and absolute privacy control? Obviously, to explain the answers to those questions, SEDA architecture must be efficient in filtering traffic control. For tracing the functional state, and characteristics of packet context network connections for dynamic packet filtering and data transmission control across devices, a dispersed algorithm path is essential. Expect a significant privacy control mechanism through developing a distributed context-aware trust algorithm, traffic engineering decision, and a stateful traffic mechanism for privacy and profiling handling in SEDA.

VI. Conclusion

In this work, we proposed a sustainable energy delay tolerance approach that considers socially aware nodes' locations for energy-efficient data transmission for non-urgent data. In this approach, energy-aware constraints have been considered based on the following requirements 1) handle duplicates of delivered messages from the receiving node's buffer, (2) ensure that no additional copies of these delivered messages are made and sent within the network 3) relay node should have sufficient energy to qualify and reach the next hop. The whole process works on the mechanism of a one-hop acknowledgment to overcome the unnecessary transmission of the already-delivered messages

In this mechanism, the destination node is asked to send an acknowledgment to the last intermediate node that received the message (the so-called last sender node). This information is flooded into the network so that all other nodes know that the message has already been delivered to the destination, avoiding unnecessary re-transmission. Simulation results show that the proposed routing protocol improves the delivery ratio with the reduction in network size and distance with a significant amount of energy saving.

Conflict of Interest

The authors Jeff Kilby, Rashmi Munjal, Maria Elena Villapol declare no conflict of interest.

Author Contributions

Ambreen Memon played a pivotal role by conducting the research, collecting the necessary data, and finalizing the literature review. Additionally, Ambreen Memon designed the experimental methodology and diligently gathered the data. The contribution extended to the analysis and interpretation of the results. Moreover, Ambreen Memon played a significant role in the writing process, providing critical revisions to ensure important intellectual content was included.

Jeff Kilby and Rashmi Munjal and Maria Elena villapol provided supervision and guidance throughout the entire research endeavor. Together, the combined efforts of all authors resulted in a comprehensive and well-executed research project. all authors had approved the final version.

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