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RESEARCH ARTICLE

A Sustainable Data Dissemination Approach by Utilizing the Internet of Moving Things

AMBREEN MEMON[1], MUHAMMAD NADEEM ALI[2], (Member, IEEE), AND BYUNG-SEO KIM[2], (Senior Member, IEEE)

[1]Department of Information Technology, Western Institute of Technology at Taranaki, New Plymouth 4312, New Zealand

[2]Department of Software Convergence and Communication Engineering, Sejong Campus, Hongik University, Seoul 04066, South Korea

Corresponding author: Byung-Seo Kim (jsnbs@hongik.ac.kr)

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ABSTRACT The Internet of Things (IoT) has shown remarkable competence in uniting devices and internet connectivity to make modern life's applications a reality. These networked devices, empowered with computing and communications, usually exhibit an exponential increment in network traffic to enhance the end-user quality of experience (QoE). The exponential increase in network traffic makes the traditional communication system congested. To reduce the burden of network traffic, the data could be offloaded to device-to-device (D2D)-based infrastructure. This offloading scheme results in an innovative, eco-friendly, and sustainable data dissemination approach known as social networking and is mostly done in opportunistic ways. In this paper, we propose a scheme to explore the performance of the existing routing protocols with the movements and spatial closeness relations among 'things', termed as Internet of Moving Things (IoMT). The spatial closeness known as traces will help to make optimal data offloading decisions while considering the mobility traces of humans in the social network. The proposed mechanism is designed to optimally utilize moving physical objects to be involved as a third party in the data communication process between the sources and the destinations rather than using the traditional infrastructure while considering the quality of service (QoS). The simulation results have corroborated the proposed scheme and showed the remarkable performance of routing algorithms while incorporating mobility traces.

INDEX TERMS IoMT, SIoT, social networking, opportunistic routing, DTN, QoE, QoS, mobility encounter.

I. INTRODUCTION

The growth of mobile devices has essentially changed the way users share data. Accordingly, mobile information traffic has expanded exponentially since 2011. As per current industry predictions for the year 2030, around 30 billion physical devices will be connected to the Internet, resulting in a predicted economy of $3.35 trillion by 2030 [1], [2]. To offload the cellular network traffic burden, device-to-device (D2D) communication was proposed as an ideal candidate. D2D communication can be empowered with a wired or wireless infrastructure or can be set up among the devices without any infrastructure. Many communication systems, like Bluetooth, Direct Wi-Fi, the Internet of Things (IoT), vehicle-to-vehicle (V2V), and vehicle-to-infrastructure (V2I), require D2D communication, mostly in the absence of cellular network infrastructure, to communicate with each other to transfer the required data [3], [4]. D2D is an emerging technique in content-centric networks (CCN) that highly exploits opportunistic data dissemination. The term opportunistic in D2D implies a lack of knowledge of the network topology and connectivity graphs due to the mobility of devices constantly remaining in search of an opportunity to forward the stored data to the next node, aiming to move the data closer to the destination. Communication opportunities arise as mobile nodes travel around an area (random or mobility pattern) and occasionally enter the direct communication range of another mobile

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node. D2D communication with an opportunistic approach known as an opportunistic network (Opp-Nets) requires a careful routing protocol that can compensate for the network throughput, energy cost, replica cost, and latency problems [5], [6], [7].

A. OPPORTUNISTIC NETWORKS

Opportunistic networks (Opp-Nets) are emerging as a crucial mode of communication among wireless devices due to their convenience and computational adaptability. A communication environment is shown in Figure 1, where satellites, base stations, and wireless devices are linked to each other intending to disseminate the data; some devices are supported with traditional infrastructure links, while others communicate with each other without the infrastructure network. The wireless devices look for an opportunity to forward the data to the required destination. These wireless devices use the mobility pattern of a user to offload the data from the traditional link, resulting in lowering the congestion of the infrastructure network. The Opp-Nets can also support various applications like the Intelligent Transport System (ITS) for traffic awareness, accident information, and mission-critical situations like emergency braking systems to avoid accidents. These wireless devices, employed for communication, have witnessed significant enhancements in storage capacity, processing capabilities, and communication technologies. The great expansion of IoT networks has led to many new applications [8]. The core principle of Opp-Nets is to store, carry, and forward data along a dynamic trajectory toward its ultimate destination. However, it is worth noting that Opp-Nets frequently grapple with the issue of substantial latency [9]. Numerous applications are converging around the concept of Opp-Nets, like crisis management, wildlife monitoring, transportation engineering, pocket-switched networks, and disaster management. Notably, conventional ad-hoc networks and internet routing protocols often prove inadequate in the context of Opp-Nets [10], [11].

B. DELAY TOLERANT NETWORK

The Delay Tolerant Network (DTN) was originally proposed by NASA for the inter-planetary network (IPA), which inherits the properties of the Mobile Adhoc Network (MANET) and Wireless Sensor Network (WSN) to communicate in extreme environments even without a stable connection. Military operations, natural disasters, and earthquake emergency networks are common examples of the use of the DTN. DTN can support different data transmission rates, as the DTN is an abstract network model and does not point to any particular layer of the network. In DTN, delay tolerance means that the network can communicate even in extreme crashing conditions, i.e., topology crashing, unstable channels, and nodes having different processing capabilities. DTN is specially designed for those particular scenarios where particular communication does not exist between the source and destination [12].

C. SOCIAL AWARE NETWORK AND IoT

IoT has facilitated diverse applications by enclosing versatile smart devices and providing seamless connectivity to meet the real demands of end users. However, these devices can have social relationships among them, and this vision led to the Social Internet of Things (SIoT), resulting in a network known as Social Network. In recent years, a notable trend has emerged in this social network, focusing on various representations of social similarities to enhance opportunistic routing. This trend leverages social relationships, benefits, popularity, workplace affiliations, and more to optimize routing decisions. The motivation behind introducing this concept lies in the stability of social relationships rather than solely relying on human mobility behavior to make forwarding routing decisions [13]. Indeed, it holds that social similarity increases the likelihood of successful content dissemination. Several approaches have been explored, taking social aspects into account, to improve delivery probabilities while conserving network resources. For instance, the Energy Efficient and Buffer-Aware Routing (EBRP) Protocol selects relay nodes based on the sociality of the nodes [14]. This approach thoroughly considers dynamic changes in a node's attributes to assess protocol performance and compares results against three real-time traces. However, it assumes that the social attributes of users remain relatively stable. In actual scenarios, though, users' social attributes may change over time, impacting their service requirements [15], [16].

D. HUMAN MOBILITY WITH OPP-NETS

New mobility necessities were required with the fame of the Mobile Ad-Hoc Network (MANET) and the random way-point mobility model was the first model designed for the MANET [17], [18]. The designed model was excellent for its effortless and traceability features for remote correspondence; however, soon it prompted unlikely results and was even named ''destructive''. Key and strategic mobility portray a large-scale point of view of node developments. While considering previous contributions, we have considered that humans interact with each other if they belong to any social network, and most probably this human interaction also follows some regular pattern. This regular interaction of human mobility can invoke the point to consider this interaction for data offloading. Which could eventually result in a reduction of energy consumption [18], [19]. We proposed to explore the effect of human mobility on data dissemination to make the IoT device more energy efficient.

E. CONTEXT-AWARE TRAFFIC CLASSIFICATION FRAMEWORK

Classifying Internet traffic according to the application that generates it is an important task for network planning and

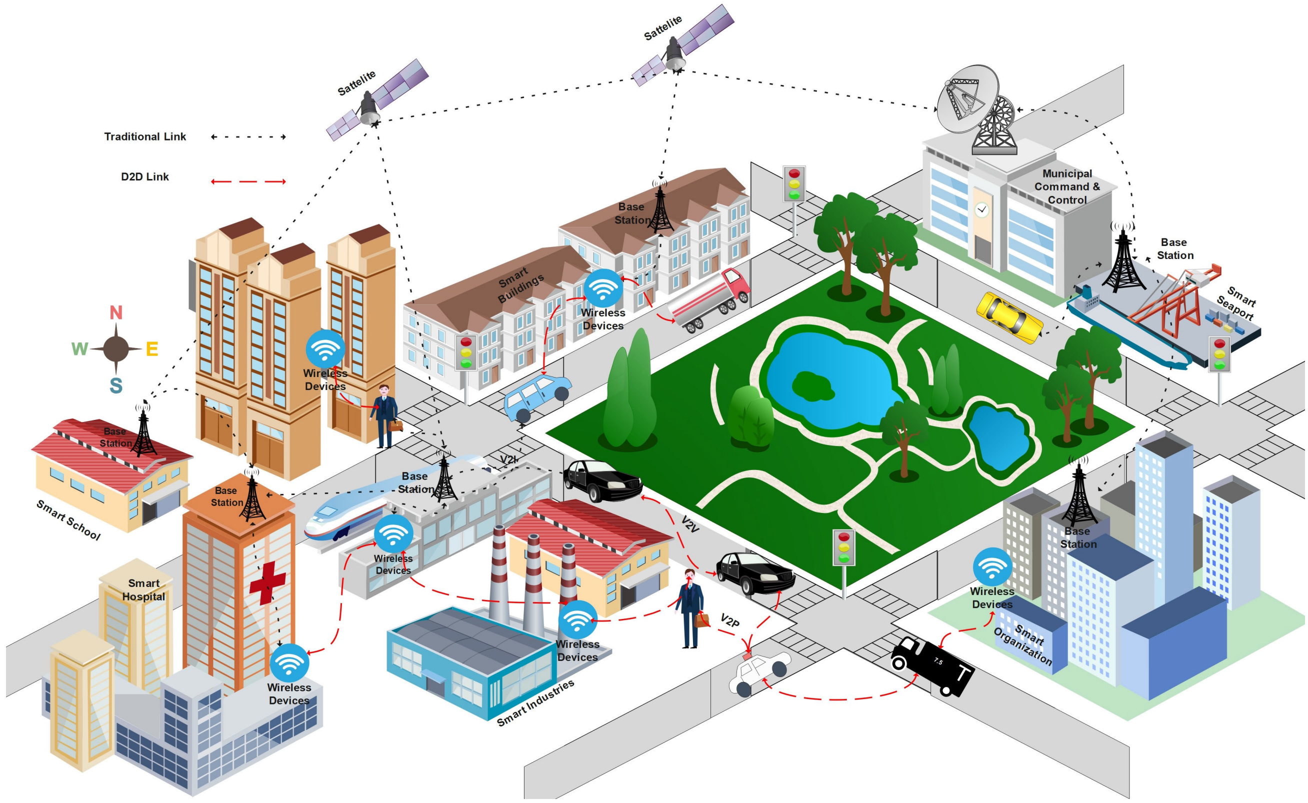

FIGURE 1. **Opp-Nets with traditional infrastructure and D2D link.**

designing, QoS, and traffic management [16], [20], [21]. In particular, detecting traffic with a delay-tolerant nature is a potentially important problem for this project that targets offloading it to transportation and social networks. Detecting delay-tolerant traffic also has particular interest since it represents a large portion of internet traffic. Payload-based, signature-matching methods, flow-level statistical approaches, and host-level methods are well-known techniques for Internet traffic classification. All of these approaches are lacking to reach the level of context awareness, which is a critical component to enable the CatchMe paradigm [22]. Therefore, we will propose a novel context-aware traffic classification framework that can (a) detect and recognize the context of traffic flows including physical world-related features such as source and destination locations, communicating peers' movements, and the logical context of the peers such as their identities, service requirements, preferences, and relationships; (b) utilize this context-based information to separate, group, and add group classifiers (or say tags) for traffic classifications. We expect this framework to efficiently classify the traffic and effectively provide accurate information for making the next stage of traffic engineering decisions [23].

Our main objective is to design an optimal data dissemination approach that can sustain an optimal QoS level in a heterogeneous network, which directs D2D communication to fulfill all aspects. We are considering human mobility patterns varying according to date, time, and location, which helps to transfer content more efficiently without using infrastructure; however, if historic movement does not allow them to meet within the specified period, it will look for other options to forward data using infrastructure while considering QoS factors. The main contributions of the paper are as follows:

- An introduction to a new socially aware network layer for successful data delivery between sources and destinations. Data will offload from infrastructure towards social relationships and find the best suitable relay node to forward data to a destination with less cost, average latency, and high throughput.
- Using the mobility trace and generating a time-space matrix to capture user mobility preference, there will be a similarity check of the node's movement's behavior; if it matches another node and they come into contact with each other, data will be transferred through infrastructure-less (D2D) in a heterogeneous network; otherwise, data will be transferred through

infrastructure-based communication, constraining the required latency.

F. ENERGY CONSUMPTION MODEL

A network is mainly comprised of the various nodes that are linked to each other to form a communication environment. The main entities of any network are the data sender and the data receiver, as shown in Figure. 2. The data sender is mainly comprised of a channel encoder, modulator, and transmission amplifier, while the data receiver consists of the demodulator and channel decoder. The transmitter dissipates the power to generate the radio signal for data propagation, and the transmission amplifier consumes the power to boost the radio signal. Similarly, the receiver side also consumes energy to receive and decode the data. By considering the general and simplified energy model, we can model the transmission and receiver electric consumption using Eq. 1-2, given below.

$$E_{T_x}(k,d) = E_{T_x-elec}(k) + E_{T_x-amp}(k,d) \tag{1}$$

$$E_{T_x}(k,d) = E_{R_x-elec}(k) = k \cdot E_{R_x-elec} \tag{2}$$

By closely observing Eq. 1–2, it is very obvious that the energy consumption is mainly comprised of the number of bits k and the distance between the data sender and receiver d. To reduce the energy consumption of the communication system, we are required to reduce the number of bits being processed by the communication system or the distance between the data sender and receiver. In our proposed scheme, we have incorporated human mobility traces and used the existing opportunistic routing algorithm. With the incorporation of human mobility traces, the routing algorithm will use fewer copies (replicas) of a message, which will eventually reduce the energy consumption profile of D2D communication as compared to the traditional infrastructure-based solution.

The rest of the paper is organized as follows: Section II is related work that outlines the existing routing protocols to disseminate the data; Section III explains the proposed methodology; Section IV outlines the evaluation parameters; simulation results are given in Section V, results are discussed in Section VI-A, future direction is given in Section VII, and finally, the paper is concluded in Section VIII.

II. RELATED WORK

This section will elaborate on the existing routing protocols used to disseminate the data in the Opp-Nets with user mobility. In [24], Lu et al. proposed a privacy-aware data dissemination approach for data offloading in the Opp-Nets. The proposed scheme provides privacy and security for the node's identity, data, social profile, and location. The authors proposed the data dissemination approach by first securing the mobile node's attributes mentioned above, which work more efficiently.

Spaho et al. proposed single-copy and multiple-copy routing protocols in Vehicular Delay Tolerant Networks (VDTN) and validated that the multiple-copy protocols perform better than single-copy in terms of delivery probability. The remarkable performance of multiple-copy is due to the highest number of hops and the higher latency consumed by single-copy protocols. The authors also verifies the performance of the proposed scheme in terms of overhead ratio, average latency, average number of hops, and average buffer time [25].

Gautam and Dev in [26] presented several challenges in Opp-Nets, implementation issues, and compared the performance of the existing routing protocols. The author outlines the various aspects of the Opp-Nets, including the store-carry-forward scheme, variable link performance, dynamic route, topology-less network, and infrequent connection.

Duong et al. proposed the probability routing protocol using a history of encounters and transitivity (ProPHet) routing algorithm that employs non-random mobility and contact patterns in conjunction with a probabilistic measure known as delivery probability. It considers the history of connections, which is not random, and allows for the identification of migration patterns. This model is based on the prediction of each node's delivery probability for all known destinations. The predictability of delivery is denoted as $P\{A, B\}$ between the two nodes A and B, and its range is defined as $P\{A, B\} \in (0, 1]$. Many researchers have used the concept of Opp-Nets while forwarding their message from source to destination. However, all of them were failing due to less contact and a lower probability of meeting each other. A new concept of social relationships made it easy for transmission within the same community or inter-communities [27].

The Bubble Rap algorithm operates on the premise that every individual in the DTN belongs to at least one community, while each node possesses two ranking positions associated with them. A node is assigned a relative rank within its community, known as local ranking, while the second ranking is global ranking, which is the node's overall ranking in the environment. The main concept of Bubble Rap is taken from society, where every individual has their own role and popularity in society. People form multiple communities in their society, so they can possess multiple local rankings. The sending paths are chosen considering the related connections between people in a community where highly famous people have a huge number of associations. The same intuitions can be considered for the network and its nodes. The nodes with high local and global rankings should be selected for data dissemination. Message transmission in the Bubble Rap approach essentially involves traversing ordered ranking trees. The data is propagated by nodes using their relative global rankings until it reaches a node belonging to the same community as the destination node. Bubble utilizes the real mobility patterns of wireless devices as a metric for forwarding information in DTNs. In DTN, the nodes are divided into communities based on social

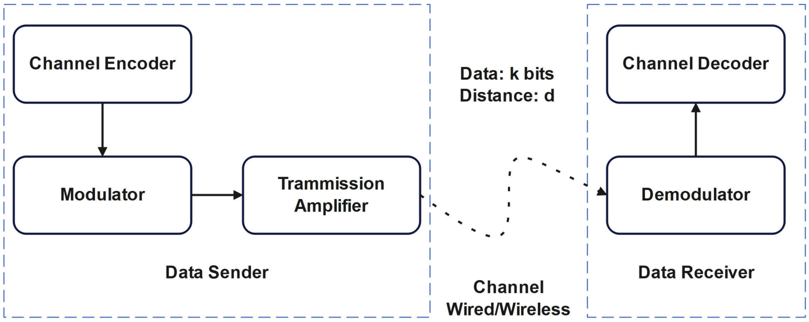

FIGURE 2. Energy consumption model.

interaction (or social links) among them; this can effectively improve the routing performance. Considering the community, every node has two diverse sorts of centrality, as follows: local and global centrality. Bubble Rap outperforms when the destination node group's part has a high rank while neglecting to work when the destination node has a place with groups whose individuals have low worldwide centrality values [9], [28].

Kumiawan et al. [29] evaluate the performance of dLife protocols in DTN concerning the impact of buffer and message size. dLife is a well-known protocol in DTN, which mainly comprises Time-Evolving Contact Duration (TECD) and TECD importance (TECDi). The author observes the performance of the dLife routing algorithm in terms of overhead ratio, delivery probability, and average latency and validates the proposed scheme. dLife Comm extends the DLife protocol by introducing two complementary utility functions, both centered around time spent in communication.

- The TECD utility function tracks the evolution of social interactions among user pairs within the same daily time frame, spanning consecutive days. TECD assesses the duration of contacts, which reflects the strength of social connections between users, and the evolving patterns of interactions, representing users' habits across different daily samples.
- The TECDi measures the evolving importance of a user, considering factors such as its node degree and the social strength it shares with its neighbors across varying periods.

The literature has contributed a lot toward optimal data dissemination in opportunistic networks, and existing routing algorithms have played a vital role in enhancing the average delivery probability, average cost, and average latency. However, these algorithms didn't consider the mobility traces while deciding the data offloading. The performance of the routing algorithm can be boosted while incorporating the mobility traces, which indicate the maximum mobile encounter of the user, resulting in a better data dissemination approach.

III. PROPOSED METHODOLOGY

To fully understand the proposed methodology, let's consider two users and their mobility patterns, Alice and Bob: both are working at the same university, on a different floor. Alice is a professor at the university, and Bob is a student. Both have several encounters with each other to discuss multiple items like research, work, and other activities. Both want to share some files, however, it is highly possible that one user is occupied with some other task and will access the file later (a loosely time-bound file). There are several options available for data dissemination:

- Alice uses cloud-based storage services, such as Dropbox, the most popular way we use today, to upload the file to Dropbox and then send the link to Bob. Bob can use the link to download the video when ready.
- Both users use the already-deployed infrastructure, like their own routers, to exchange the file, resulting in a point-to-point transfer.
- Let's think about it another way: Both users can have multiple possible encounters with each other, besides the only research meeting. The data to be disseminated is also loosely time-bound, so utilize their mobility encounters to disseminate the data.

The mobility patterns of both users, Alice and Bob, are shown in Eqs. 3 and Eq.4 respectively. Both Eq. 3-4 are the time-space matrix's representation of the mobility preferences, showing the day and location of a user and depicting the normalized percentage of time spent at a particular location on a particular day or time. In this matrix, the various locations L_1, L_2, L_3, L_4, L_5 show the possible locations visited by a user in his or her routine life. From the time-space matrix, it is evident that a user, for example, Alice, is spending more time on L_1 for all weekdays as compared to the other location. L_1 could be the university campus or job office place for Alice. However, she also visits various other locations during the weekdays and at the end of the week. Similarly, Bob also has some specific mobility patterns in his routine life; from Eq. 4, it is clear that Bob also spends a higher amount of time in the L_1 as compared to the other location. Both users have a high tendency to meet or encounter each other with high frequency at the L_1, it is also possible that both users can encounter each other in some other location, like a gym, market, or city library.

$$Alice = \begin{bmatrix} Day/Loc & L_1 & L_2 & L_3 & L_4 & L_5 \\ Mon & 0.8 & 0 & 0 & 0 & 0 \\ Tue & 0.8 & 0 & 0.2 & 0 & 0 \\ Wed & 0.8 & 0 & 0 & 0 & 0 \\ Thu & 0.8 & 0 & 0.2 & 0 & 0 \\ Fri & 0.8 & 0 & 0 & 0 & 0 \\ Sat & 0.4 & 0.2 & 0.2 & 0 & 0.2 \\ Sun & 0.8 & 0 & 0 & 0.4 & 0 \end{bmatrix} \quad (3)$$

$$Bob = \begin{bmatrix} Day/Loc & L_1 & L_2 & L_3 & L_4 & L_5 \\ Mon & 0.8 & 1 & 0 & 0 & 0 \\ Tue & 0.4 & 0.6 & 0 & 0 & 0 \\ Wed & 0.7 & 1 & 0 & 0 & 0 \\ Thu & 0.3 & 1 & 0.2 & 0 & 0 \\ Fri & 0.9 & 0.3 & 0 & 0 & 0 \\ Sat & 0 & 0.3 & 0.4 & 0 & 0.3 \\ Sun & 0 & 0.6 & 0 & 0.4 & 0 \end{bmatrix} \quad (4)$$

Human mobility traces can be matched according to the routine behavior of a person. In such a way, the proposed approach can fully utilize the benefits of mobility traces and check the similarity of location and time; if they match within the stipulated time, then data will be transferred by D2D. We have designed a model that describes how D2D is better than infrastructure in terms of QoS requirements and energy consumption.

The proposed methodology can fully utilize their encounter opportunities to use short-range transmission technology such as D2D to transmit the file For example: Alice and Bob can have several opportunities to meet each other, and therefore the IoT devices they carry can communicate and directly transfer the file. Suppose Alice and Bob are both scheduled to attend the meeting on the first floor of the university campus. Using the similarity analysis matrices, Alice sends the data to the best relay node (on behalf of location and time) and transfers the file to Bob. Rather than using an infrastructure-based transmission approach, after knowing the mobility schedules of each other, Alice can transfer the data by using the encounter opportunities to transfer the file to Bob but still meet the time requirement (i.e., within one week). The key idea of the proposed scheme is to use the human mobility traces in the existing routing algorithm (shown in a light blue shaded square) and observe the performance of the existing routing algorithms as shown in Figure 3. The use of human mobility traces will have a great impact on the QoS parameters of the routing algorithm, as the existing algorithms mostly use random techniques to offload the data, which cannot guarantee the QoS requirement [18]. Furthermore, this will reduce the congestion burden of the cellular infrastructure and also lessen the number of replicas of data in a network. Since the proposed scheme is more inclined to D2D communication with the prior knowledge of human mobility as traces, the energy consumption of the infrastructure-based solution will also be decreased.

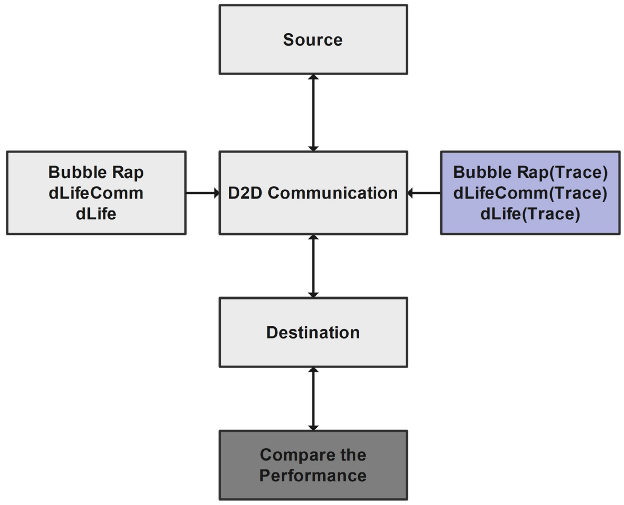

FIGURE 3. Proposed methodology scheme.

IV. EVALUATION PARAMETERS

We have used the ONE simulator to evaluate the performance of the Bubble Rap, dLife Comm, and dLife routing protocols. To compare the performance of the routing protocols, simulations are performed with and without human mobility traces. To analyze the routing protocols' performance, we have considered three performance metrics, i.e., 1) average delivery probability, 2) average cost, and 3) average latency. The average delivery probability is to be defined as the ratio of the successfully delivered messages to the total number of generated messages, the average cost is the cost involved in message transmission, while average latency is measured as the average time between each message creation and reception. The simulation graph and results are discussed in the next section.

V. EXPERIMENTAL SETUP

A. ONE SIMULATOR

The Opportunistic Network Environment (ONE) simulator is used to simulate an environment in which nodes have mobility, and the mobility is characterized by the various movement models. The ONE simulator is mainly designed for the performance evaluation of the routing algorithms in the DTN. The ONE simulator can import the mobility data from real-world traces or some other mobility generator tool. The ONE simulator supports node movement, message passing, and general statistics reports [30].

B. MOBILITY TRACES DATASET

We incorporated human mobility traces from the USC (University of Southern California) dataset. The dataset comprises the user's Wi-Fi log and user profile. The dataset contains information about the various buildings on campus and their respective access points (AP). The dataset is generated by collecting the user's information on weekdays and weekends. The motivation for choosing the dataset is that the university campus experiences a high number of active user, and their association with Wi-Fi, provides excellent location samples [31].

C. SIMULATION SETUP

Performance analysis of Bubble Rap, dLifeComm, and dLife with and without human mobility traces is performed on the Opportunistic Network Environment (ONE) simulator. Simulations are comprised of the booth schemes (traditional routing algorithms) and the proposed incorporation of the traces into the traditional routing algorithms. The performance of both schemes are observed and analyzed in terms of average delivery probability (i.e., the ratio between the number of delivered messages and the total number of created messages), average cost (i.e., the number of replicas per delivered message), average latency (i.e., the time elapsed between message creation and delivery) and average energy consumption (i.e., amount of energy required to transfer a volume of data). The ONE simulator settings are shown in Table 1.

TABLE 1. ONE simulator experimental setting.

Parameters	Values
Simulator	ONE
Routing protocol	Bubble Rap, dLife and dLifeComm
Dataset	Cambridge Traces crowded
Simulation time(s)	10-1000,00
Number of nodes	150
Number of People	36
Mobility model	Shortest Path (Map-based)
Interface Node Wi-Fi Rate	11 Mbps
Range(m)	100
Node buffer	2MB
Massage (TTL)	1,2,3,4,5 (days)
Massage Size(KB)	1-100

VI. SIMULATION AND RESULTS DISCUSSION

In this section, we will explain the results achieved by the simulation.

Figure 4. Shows that the average delivery probability is better with traces used in Bubble Rap, dLife, and dLife Comm in comparison with the traditional algorithm. The reason for better performance is due to the knowledge of human mobility patterns, which will result in the more successful delivery of messages. Another reason for better message delivery is that in traditional routing protocols, due to the replication of messages, the buffer got exhausted due to an increase in time-to-live (TTL). By incorporating the human mobility traces, delivery probabilities take less TTL to reach on destination, similar behavior is to be analyzed in both proposals (dLife and dLife Comm). This results in fewer communities' formation and almost most of the nodes belong to those communities which results in high delivery probability. It is very evident from Figure 4 that the traditional routing protocols like Bubble Rap, dLife Comm, and dLife are attaining the delivery probability of 30%, 60%, and 75% while observing at 3d TTL value. However, if we incorporate the human mobility traces, the average delivery probability of Bubble Rap has observed an increment of 28%, from 30% to 58%, dLife Comm got an increment of 20% from 60% to 80%, and the dLife also got an increment of 5%, from 75% to 80%, which shows a remarkable improvement in the average delivery probability.

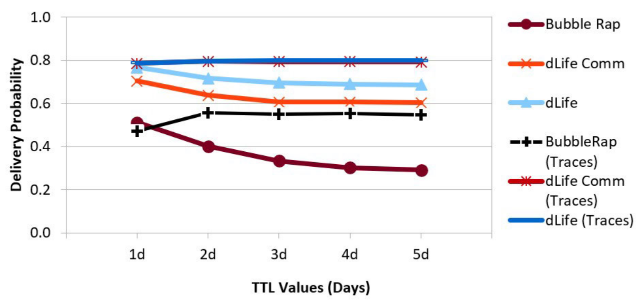

FIGURE 4. Average delivery probability Vs TTL values.

Figure 5 shows the performance of routing protocols with and without traces for average cost. Bubble Rap has the maximum average cost as compared to dLife and dLife Comm. By fixing the TTL value to 3d, the Bubble Rap is using 1200 replicas, dLife Comm is using 425 replicas, and dLife is consuming 300 replicas. The average cost reduces to a minimal value of 5 or 10 replicas in case of incorporation of human mobility traces.

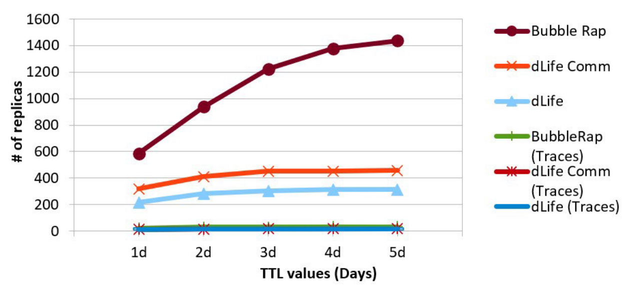

FIGURE 5. Average cost Vs TTL values.

As shown in Figure 6, Bubble Rap bears more delay in comparison with dLife and dLife Comm. dLife and dLife Comm know daily routine patterns of human movement and therefore predict the possibilities of message transmission, therefore bearing less delay in comparison with Bubble Rap. With traces used, all three protocols have less delay in comparison with the original one, however, as it is from Figure 6 the Bubble Rap algorithm is bearing almost the same or worse delay with using the mobility traces. The reason for this behavior is due to the ranking approach used in the Bubble Rap algorithm. The Bubble Rap algorithm uses the local, and global ranking and disseminates the data to its destination by finding the globally ranked entity in the destination community, it doesn't find the alternative links. Due to this mechanism, the mobility traces do not contribute so much to reducing the delay experienced by the Bubble Rap. In comparison to the Bubble algorithms, the dLife, and dLife Comm algorithms find the possible alternative links rather than relying on some specific entity in the community. dLife and dLife Comm perform well in both situations at 87.3% and 84.7% less than other algorithms. Both send their messages only if they get strong social links in their current daily samples. In such a way, messages get delivered soon with less latency. While incorporating the human mobility traces, it delivers faster because nodes are already well connected and both versions of dLife identify their best suitable social relation soon, suitability depends upon the community and probability of getting it delivered to the destination. In such a way, message latency remains less affected by considering broadcast messages.

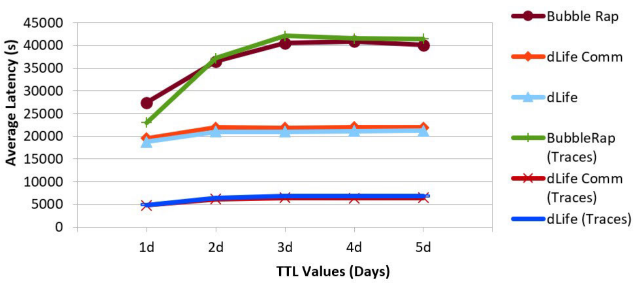

FIGURE 6. Average latency Vs TTL values.

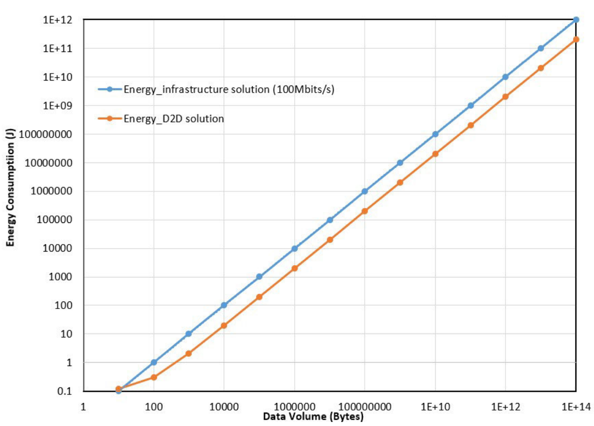

FIGURE 7. Energy consumption with D2D and infrastructure-based Solution.

As the proposed solution is based on the incorporation of human mobility traces, which eventually enhance the average delivery probability and reduce the average cost of data dissemination, this is intuitively related to energy consumption. Since the proposed model relies on D2D communication rather than traditional infrastructure-based communication, and by using the human mobility traces, the energy consumption will also be decreased, as shown in Figure 7, where the D2D energy consumption is represented by an orange color line while the infrastructure-based communication is shown by the blue line.

A. RESULTS DISCUSSION

In this section, we will provide a performance comparison of existing routing protocols with and without the usage of human mobility traces. The metrics comparison is given in Table 2, where it is obvious that when the existing routing protocols are incorporated with the human mobility traces then the performance of the routing protocols is boosted. From the results graphs given in the simulation's result section, it is evident that the average delivery probability of all three routing protocols decreases with the increase in the TTL value due to the burden on buffer capacity, while in the case of human mobility traces integration, the average delivery probability shows a stable fashion even in the case of increased TTL value.

TABLE 2. Comparison of routing protocols with/out human mobility traces at 3d TTL value.

Routing Protocols	Average Delivery Probability	Average Cost	Average Latency(s)
Bubble Rap	30%	1200	40000
dLife Comm	60%	425	21000
dLife	75%	300	20500
Bubble Rap (Traces)	58%	10	40500
dLife Comm (Traces)	80%	5	6000
dLife (Traces)	80%	5	6000

In the case of average cost, Bubble Rap shows the highest cost as compared to the dLife Comm, and dLife, due to random data offloading, while dLife Comm and dLife shows less average cost because of community-based data offloading schemes. With the integration of human mobility traces, the average cost of all routing protocols can be reduced to a very low level. In the case of average latency, the Bubble Rap does not show any remarkable even when utilizing the mobility traces, however, the dLife Comm and dLife protocols show an excellent degradation in the average latency. Finally, the energy consumption is measured against the data volume and an internet speed is 100Mbits/s is taken for the infrastructure-based solution, which shows quite a difference among both solutions i.e., infrastructure solution and D2D solution.

VII. FUTURE DIRECTION

Recently, location-based services explosively gained attention due to many mobile devices and internet connectivity. These days, mobile applications are trying to attract their audience by every means by monitoring their habits. For future work, the mobility pattern of a user can be predicted using reinforcement learning, which can predict the next place to be visited by a mobile user by learning the routine life and historical data. This prediction will help in making a better offloading decision for D2D infrastructure.

VIII. CONCLUSION

In this paper, we have analyzed the QoS and energy consumption perspectives of the Social Aware Networks (SAN). Our daily routine life has a social relation with the places we visit often and can be defined as a matrix of real-life traces in terms of time and location. In such a way, while considering the concept of Real Mobility Traces and their social ties can improve the routing in their daily routines and their performance metrics. Utilization of these traces will result in better performance of the routing algorithms and can enhance the QoS parameters while at the same time reducing energy consumption. This work aims to utilize the mobility of humans and/or IoT devices to reduce the transmission distance and, thus its associated resources such as energy as much as possible. A flexible and scalable time-space matrix has been proposed to capture the mobility preferences of each mobile peer and the similarity analysis framework is introduced to reveal the mobile encounter opportunities between two possible communicating peers.

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AMBREEN MEMON received the M.Phil. degree from the Computer Science and Software Engineering Department, International Islamic University, Pakistan, and the Ph.D. degree in electrical and computer engineering from Auckland University of Technology, New Zealand, in 2022. She is currently a Lecturer with the Department of Information Technology, Western Institute of Technology at Taranaki, New Zealand. Her research interests include sustainable next-generation network design, socially aware routing, and delay-tolerant networking. She is working especially in network dependability, survivability, sustainability, and trustworthy computing.

MUHAMMAD NADEEM ALI (Member, IEEE) received the B.S. and M.S. degrees in electronics engineering from International Islamic University, Islamabad, in 2012 and 2016, respectively. He is currently pursuing the Ph.D. degree with Hongik University, South Korea. The B.S. degree was fully funded by the Ministry of Information and Technology, Government of Pakistan, for four years. The scholarship name was ICT and RD Fund. From 2015 to 2019, he was a Senior Lecturer with the Department of Computer Science, Lahore Garrison University, where he supervised many final-year projects. Currently, he is a member of the Broadband Convergence Network Laboratory, Hongik University. His research interests include 5G wireless communication systems, intelligent transport systems and their applications, latency issues in networks, edge computing, and name data networks. He was an Assistant Editor of the Lahore Garrison University *Journal of Computer Science and Information Technology*, from 2017 to 2019.

BYUNG-SEO KIM (Senior Member, IEEE) received the B.S. degree in electrical engineering from Inha University, Incheon, South Korea, in 1998, and the M.S. and Ph.D. degrees in electrical and computer engineering from the University of Florida, in 2001 and 2004, respectively. The Ph.D. study was supervised by Dr. Y. Fang. From 1997 to 1999, he was with Motorola Korea Ltd., Paju, South Korea, as a Computer Integrated Manufacturing (CIM) Engineer of advanced technology research and development (ATRD). From 2005 to 2007, he was with Motorola Inc., Schaumburg, IL, USA, as a Senior Software Engineer of networks and enterprises, where his research focused on designing protocol and network architecture of wireless broadband mission-critical communications. From 2012 to 2014, he was the Chairperson of the Department of Software and Communications Engineering, Hongik University, South Korea, where he is currently a Professor. His work has appeared in around 242 publications and 24 patents. His research interests include the design and development of efficient wireless/wired networks, including link adaptable/cross-layer-based protocols, multi-protocol structures, wireless CCNs/NDNs, mobile edge computing, physical layer design for broadband PLC, and resource allocation algorithms for wireless networks. He was a member of the Sejong-City Construction Review Committee and the Ansan-City Design Advisory Board. He served as the TPC Member for the IEEE VTC 2014-Spring, the EAI FUTURE2016, and the ICGHIC 2016–2019 Conferences. He served as the General Chair for the Third IWWCN 2017. He served as a Guest Editor for the Special Issues of IEEE Internet of Things Journal, *International Journal of Distributed Sensor Networks* (SAGE), IEEE Access, and the *Journal of the Institute of Electrics and Information Engineers*. He is an Editor of *Telecommunications Systems* and an Associate Editor of IEEE Access.