SCORP Routing: A Novel Approach for Efficient Routing in Delay Tolerant Networks

Haseeb.V.V[1], Dr. A. Yesu Babu[2]

[1]*Research & Development Centre, Bharthiar University, Coimbatore, N.A.M. College, Kallikkandy, Kannur, Kerala*

[2]*Professor & Head, Department of Computer Science & Engineering, Sir C.R.reddy College of Engineering, Eluru, Andhrapradesh*

Abstract **-** Delay tolerant networks are sparse network. Due to mobility of nodes there is no end to end connectivity between source and destination. Routing is one of biggest challenge in DTN. The data should be reach to destination node with minimum delay and less congestion. One of the techniques used for forwarding of data is epidemic routing in which the node will relay the data to all the nodes it encounters. Utilizing the Throw boxes and placing them in point of interest locations can increase the delivery probability and decrease the latency of the networks. In this dissertation we will simulate our network with introducing the Throw box in our network. SCORP is proposed, which is a social-aware and content-based approach that is based on the interest and daily interactions of the users. This can improve the performance of the network in term of delivery probability and energy efficiency.

Keywords **-** DTN's, Networks, Throw Boxes, TTL, SCORP.

I. INTRODUCTION

The technology of wireless and wired networks has connected many different devices over different distances. It possible now a day to connected to millions of servers around the world. Still there are some networks which cannot reach everywhere due to cost and infrastructure problem. These kinds of networks do not rely on the assumption of End-to-End connectivity as in the case of Internet and other Ad hoc networks. These considerations can be in the networks where there are mobility issues, unreliable networks and power saving. As there has been an explosive growth in the mobile industry due to the rising diversity in breadth and number of handheld devices, with further expectations still continuing, the burden is shouldered by IT in this regard. The network needs to converge on a particular platform which verily eases the user experience, automatises the tasks and also assists in diversification and expansion of services. The personal communication devices and cellular phones can interact globally due to incorporation of the infrastructure networks [1]. The DTN is essentially an opportunistic network in which there is mostly no particular end to end path between a source to its destination.

A. Routing in DTN

The problem in DTN is that the connectivity between nodes is not maintained all time and there is still need to maintain communication between nodes. Therefore there should be a routing protocol designed which should send packets even if there is no end to end connectivity between nodes. This routing process cannot be done by standard internet routing protocols which assumes that there is always end to end connectivity between nodes. The designing of routing protocol in DTN is main concern as this is the basic mechanism through which the data will be forwarded. In the concept of DTN routing is usually done by store and carries approach. This approach is effective in case of DTN because there is not always end to end connectivity between nodes so the data is stored in the node. The node will meet another node and data will be forwarded to that and eventually data will be reaching to destination node. One of approach is to forward the data to all nodes it meet but congestion arises in this situation and networks bandwidth is not utilized. So one of the concerns is to which node the data should be forwarded as forwarded the data to many nodes increases the delivery probability but on other hand it increases the congestion in network too. The important consideration is the number of copies of message forwarded in a network as the number of copies of message increases the overhead and congestion can also increase so an optimal routing algorithm should be developed in which the number of copies should be minimum and higher delivery probability should be achieved.

One of the examples shown below

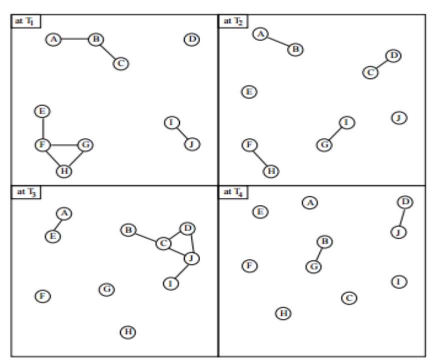


Fig.1**:** HIGHER DELIVERY PROBABILITY

B. Delay Tolerant Networks

Traditional Internet entails a homogeneous network set where every network uses similar communication protocols to send and receive data. These networks are interconnected to each other and serve through similar TCP protocols for all networks set. These networks are interconnected using satellites, wireless technologies, and wired links. A working of a traditional network is as presented in figure 2 below:

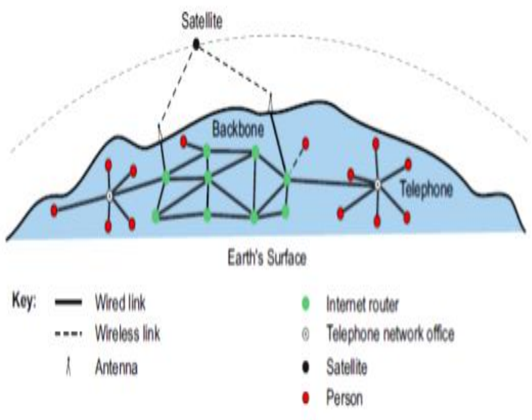


Fig.1: Traditional Network

In the Internet, the TCP protocol works when end-to-end connectivity is guaranteed between the nodes. Communication in the Internet is packet switching-based. Data is brocken in to small packet. A packet travels between sources and destinations using alternate paths when a link drops so the packet of the date travels through an alternate path. A packet has a header within which information of different routers and addresses are held so that messages can successfully reach their destinations.

C. Deployment of Throw box and Routing Framework

An emerging class of networks known as DTNs (delay tolerant networks) which are often subject to long-duration and frequent partitions. With the sporadic connectivity, the DTN is often constricted to simply supporting the needs of an application, for instance, high delay or even low throughput. For addressing the issue, the throw boxes are devices for enabling bettered delivery of data and overall performance. The throw boxes are cost-effective and smaller devices which posses wireless interface and are applied for relaying data among mobile nodes. This section will examine the issues related with throw boxes, including routing and deployment for affirming throughput enhancement. There are epidemic routing, multi-path and single path routing. The section will also examine the deployment and routing strategies. It has been observed that throw boxes are highly viable for improvement in delay and data delivery ratio, particularly the multi-path environments having a standard node movement [2].

The throw box deployment ascertains the location to place the throw boxes, which essentially impacts the communication between nodes and throw boxes. As is the case, routing dictates the data is forwarded between the throw boxes and the nodes. The throw box deployment along-with routing can particularly dictate how data is transmitted between the throw boxes and nodes. The routing and throw box can impact the data delivery performance. As a result, one needs to factor in the issues for enhancing effectively the DTN capacity. It is imperative to examine the assorted types of throw box deployment along-with routing strategies [2].

II. MATERIALS AND METHODS

A. The SCORP Proposal

In this section, the proposal on the social-aware content-based opportunistic routing is presented, considering the social proximity in between nodes as well as the content knowledge the nodes has during when taking the forwarding decisions. The SCORP relies on a utility function reflecting on the probability of coming across nodes with a given interest among those that have the same day-to-day habits. There are two reasons to why social proximity is used with content knowledge. Firstly, its because

$$ATCTI(a,x)_{ji} = \frac{TCTI(a,x)_{ji} + (j-1)ATCTI(a,x)_{(j-1)i}}{j}$$

Then, node A makes computation of the Time-Evolving Contact to Interest x(TECI) to measure its social strength (w(a,x)i) onto the nodes tagged with the interest x in the daily sample ΔTi as well as the consecutive t-1 sample, in where t represents the number of samples. The equation 3 shows the time transitive property as in the dLife [3].

$$TECI = w(a,x)_i = \sum_{k=i}^{i+t-1} \frac{t}{t+k-i} ATCTI(a,x)_k$$

B. Algorithm

SCORP's operation is quite simple as shown in algorithm 1 where the CurrentNode meets the Nodei, in the daily sampla ΔTi, it gets the list with the entire content interests Nodei encountered in the daily sample, as well as the social measure toward those nodes with such interests. In addition, Nodei sends out a list of messages it has. Then each message, in the CurrentNode buffer gets replicated to Nodei, where:

- The Nodei social measure to a node that has the interest, is larger than the measure of CurrentNode onto any nodes with similar interests.
- Nodei has interests in the message's content.

Algorithm 1 Forwarding with *SCORP*

begin
foreach $Node_i$ encountered by $CurrentNode$ **do**
receive($Node_i$.weightsToAllinterests and $Node_i$.carriedMessages)
foreach $Message_j \in$ buffer.($CurrentNode$) & $\notin$ buffer($Node_i$) **do**
if ($Message_j$.getContentType $\in Node_i$.getInterests)
then $CurrentNode$.replicateTo($Node_i$, $Message_j$)
else if ($Node_i$.getWeightTo($Message_j$.getContentType) >
$CurrentNode$.getWeightTo($Message_j$.getContentType)
then $CurrentNode$.replicateTo($Node_i$, $Message_j$)
end

With that, it is expected that SCORP will replicated only the nodes that have interest on the contents of the messages to be forwarded, or those nodes that entail strong relationships with nodes with those particular interests. Consequently, its expected that less replication improves usage of resources while minimizing delivery latency.

C. Comparison Evaluation

SCORP gets evaluated alongside dLife [3][4], the social-aware proposal that is based on the daily habits of the users; Bubble Rap, the community-aware proposal; and the Spray and Wait [5], the social-oblivious solution serving as the lower bound concerned about cost of delivery. This part begins by presenting the methods uses and the experimental setup, followed by the findings based on trace-based scenario and synthetic mobility models. The part ends with analysis of scalability.

D. Evaluation Methods

The simulations are done using the Opportunistic Networks Environment (ONE) simulator [6], taking into account for the implementations available for Spray and Wait, dLife and Bubble Rap, for the simulator. SCORP's code is also available for download by reviews and for test purposes. Findings are shown with a 95% interval of confidence and are analyzed with regard to the average probability of delivery or the ratio of the number of messages delivered and the total messages that ought to have been delivered.) and the average latency (or time taken to create and deliver a message)[8].

III. RESULTS AND DISCUSSIONS

In this experiment, two mobility methods are used; a human mobility traces-based and a one synthetic based. The synthetic based model involves various patterns of mobility. The model makes a simulation of 12-days interaction in Helsinki among 150 nodes separated into 8 divisions of people and 9 divisions of vehicles. Every node comprises of a 11-Mbps wireless interface that has a 100-meters communication range. One vehicle division (10nodes) follows the Shortest-Path-Map-Based-Movement mobility model and stands for police patrols which randomly pick destinations and follows the shortest path to arrive. The waiting time ranges between 100secs to 300secs. The other 8 vehicle divisions with 2-nodes each represent the buses that follow the Bus Movement model with wait times ranging between 10secs and 30secs. The vehicle speeds range between 7m/s and 10m/s. Therefore, in the synthetic model, 6000 messages are created and expected to be sent throughout the Spray and Wait, dLife, and Bubble Rap Simulations. To attain similar number of messages in SCORP, a total of 170 messages having unique contents are created and every division of people has 10 interests that are different and which are randomly assigned, and also which could or couldn't overlap partially or entirely with other divisions' interest. By integrating the interests' types assigned to such division and the number of messages created with contents that match the interest, the end result is 6000 messages that are to be delivered throughout the simulation of SCORP. In the scenario of human mobility trace, with dLife, Bubble Rap, and Spray and Wait, the source generates and sends our 1, 5, 10, 20 and 35 various messages to every destination. In SCORP's scenario, the source generates 35 messages having various interests at once, and every receiver is set with 1, 5, 10, 20 and 35 various interests. While node 0 is the messages' source to the rest of the 35 nodes, it means that total of 35,175,350,700, and 1225 messages reach their destinations in each of the simulation done using SCORP, dLife, Bubble Rap, and Spray and Wait. Moreover, the number of messages created by this source is not same for the receiver-driven and source-driven methods: for example, in a setting with Bubble Rap or dLife source creating 20 various messages for every one of the 35-nodes, there are a total 700-messages being created and that are expected to reach their destinations; in SCORP's case, every of the 35 nodes is set with 20 various interests, such that there are 35-messages being created and the same number of messages (700) are to reach their destination. The messages and interests' configuration are done to assure similar potential messages amount being sent and reaching their destinations. The notation (msg/int) stands for the number of various messages being sent by the sources of dLife, Bubble Rap, and Spray and Wait or the number of various interests of every one of the receivers of SCORP. Message TTL range between 1,2,4-days, 1, and 3-weeks representing the various application coping with the opportunistic networks, and the message sizes ranges from 1kb to 100kB. Even though the message TTL could not be of huge interest with the content-based paradigms, if it is considered that the content could always be kept in the network, we account for a more realistic situation where the content is limited timely. Therefore, the choice is on representing the messages in various values of TTL. Sizes of messages range between 1kB to 100kB. The nodes only have a 2MB buffering space: regardless of the content-based concept take into account no limitation on buffering as nodes are able to store large data amounts, it is assumed that users could be willing and able to share all the devices' storage capacities. Both buffer and message sizes follow the universal framework of evaluation proposed previously [7]. To assure fairness in the comparison of dLife, Bubble Rap, ad Spray and Wait in the human-trace scenario, there is no buffer restriction for node 0 to avoid discardation of messages following buffer constraint due to the number of messages it creates. In addition, the message creation rate depends on the load, such that, when the load involves 1, 5 and 10 messages being created to every node, the messages are then created at the rate of 35-messages daily. While the load has 20 and 35-messges, then the rate is of 70 and 140-messages every day, respectively. It is done to let dLife and Bubble Rap messages to be shared based on the message TTL. The human trace and synthetic mobility cases are used to analyze the various properties of the approaches under comparison; the effect of having various message TTLs in the scenario of the models of synthetic mobility; the effects of having various network loads in the scenario of the models of human traces mobility. Also observes are the effects of various network loads while altering the TTL, however, the last set of findings are not included due to limitation of space.

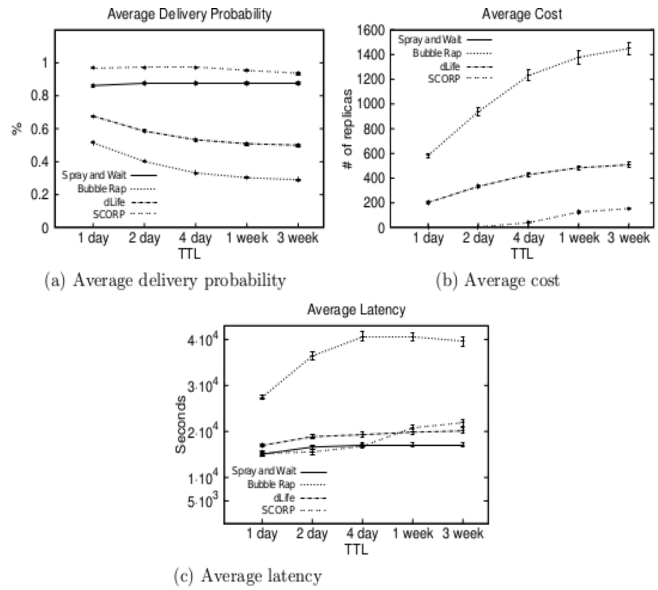
Regarding the proposals, the Spray and Paint approach operates in binary code and the number of L copies is set to 1o. The Bubble Rap utilizes algorithms for the formation of communities and computation of node centrality. SCORP and dLife use 24 daily samples [1][3].

A. TTL Impact Evaluation

The synthetic-mobility model is utilized with different TTL messages, to; i) select the value of TTL that allows for solutions to have the overall best performance; ii) asses the TTL message impact on the opportunistic routing approaches. Before checking the findings, the following is a general remark about the synthetic mobility mode: there is an average 962 contacts every hour and that happen homogeneously.

Figure 3 represents the average probability of delivery. Bubble Rap's performance is impacted by the facts that, as communities are being generated, the model mostly relies on each destination's centrality. However, in this case, there are few nodes that have high centrality (2o percent) and a majority of messages are created in the nodes with low centrality. As a result, replications increase leading to exhaustion of buffer. The scenario worsens as the TTL increases.

While nodes interact often, SCORP exploits the shared interests in the node in replication content. Therefore, messages get disseminated quickly, enhancing the rate of delivery by up to 10.7%, 44.5%, and 64.7% over Spray and Wait, dLife, and Bubble Rap, respectively. However, SCORP still suffers a significant reduction of the rate of delivery following the number of forwarding that increases with the TTL. This leads to few messages getting discarded following exhaustion of buffer, because messages are let to stay longer within the network.



(a) Average delivery probability (b) Average cost

(c) Average latency

Fig.3: Performance in the synthetic-mobility model

It is observed that TTL has very small effects on the social oblivious Spray and Wait, as having an effect on social aware solutions at various levels. In addition, content-orientation has its benefit: SCORP attains a 97.3% delivery rate and with very small related cost as well as low latency.

The performance study has resulted in the selection of value of message TTL that allows the approaches deliver more messages in less duration and with least cost. Therefore, in the next set of findings, a 1-day message TTL is used.

B. Network Load Impact Evaluation

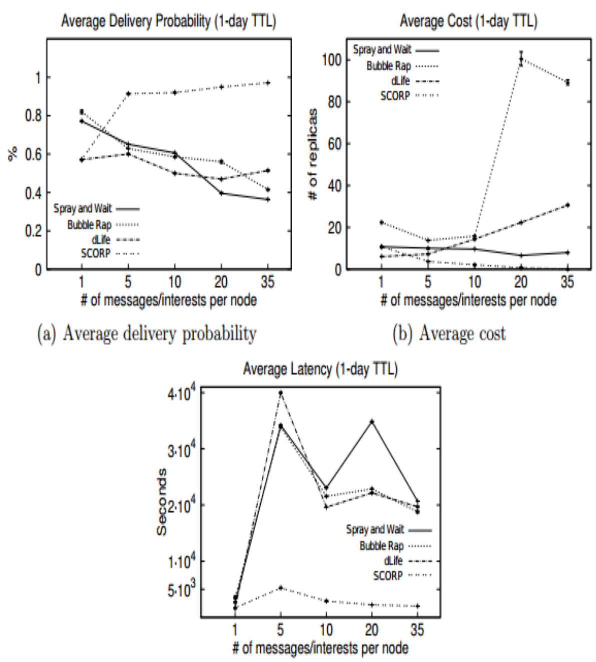
The human trace-based case is used with different loads of network in the assessment of performance behaviors of the studies approaches in a case with direct data exchange between mobile gadgets independent of the current disruption/intermittency levels.

Generally; i) with Bubble Rap, there is an approximately average number of communities formed of 6.7, with a majority of them involving all nodes.

Figure 4 shows the findings of the average probability of delivery with increasing number of interests/messages (msg/int) for every node. For the 1stmsg/int setup, Bubble

Rap delivers 24.8% and 4.9% more messages that dLife/SCORP, and Spray and Wait, respectively, because a majority of the communities include all the nodes, and replication is done in the communities, leading to more replications, and thereby, higher content delivery probability.

In the case of Bubble Rap, the issue further increases in the 20 msg/int and 35 msg/int setups, where the approach experiences exhaustion of buffer. The occupancy of buffer for the 20msg/int setup is estimated in support of this claim: an average forwarding of 39240 are available in the simulation, when it is divided by the days and nodes, an average replication of 3270 per node is gotten. When this is multiplied by the average size of message (52275bytes), the buffer occupancy for each node is 4.88MB, that exceeds the allowed 2MB. This is only an estimation of the worst-case scenario as Bubble Rap spreads copies to each node. While it is highly unlikely because also relies on centrality in controlling replication, exhaustion of buffer becomes worse as replication happens to less nodes and not all of the as in the estimation. With the increase in the rate of message creation with the load, messages may potentially take over other messages' forwarding opportunities, minimizing the probability of delivery of the latter.



(a) Average delivery probability (b) Average cost

(c) Average latency

Fig.4: Performance of various network loads

C. Improved SCORP Routing Scheme by Using Bus

The "improved SCORP routing scheme is analyzed by using all the 10 interests in the bus movement. The bus movement sub model acts as mobile throw box in the simulation which increases the forwarding opportunity and chances interaction and hence faster delivery of the message to destination."

The results are shown in the Figure 5, 6, and 7. Figure 5 shows the "comparison of the SCORP routing scheme with the proposed routing scheme. The proposed routing scheme which uses the bus movement model with all interests resulted in increase in the average delivery probability. This is because the people traveling in the bus are of different areas with having diverse interests so the chances of encountering of nodes increases which result in increase in the probability of reaching the message to the destination node."The delivery probability has increased by 0.81 in the case of propose routing scheme.

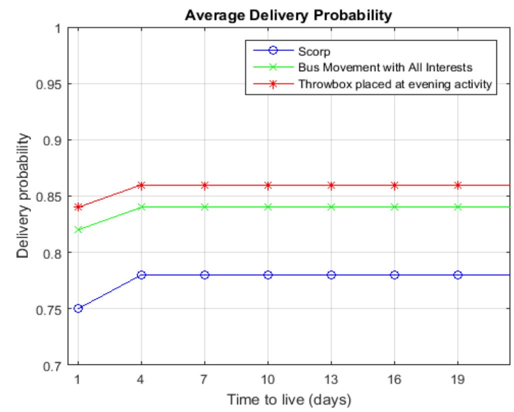


Fig.2: Average Delivery Probability

The average latency reduced by deploying the mobile throw box. The average latency is shown in Figure 6. The message is propagated quickly to the different areas through the bus movement which results in decreasing the average latency and the message takes less time to reach the destination node. The average latency has decreased to 28000 milliseconds which is the achievement in the routing scheme."

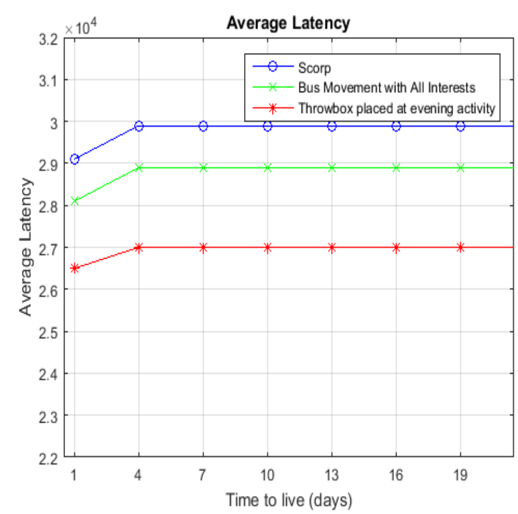


Fig.3: Average Latency

The "improved routing scheme was targeted to reduce the overhead ratio which is shown in Figure 7. This reduction in overhead ratio is due to the spreading of message quicker to different areas which resulted in increased contact opportunity and faster dissemination" of the message. The message did not remained in the buyer for that much time and was quickly transferred to other nodes.

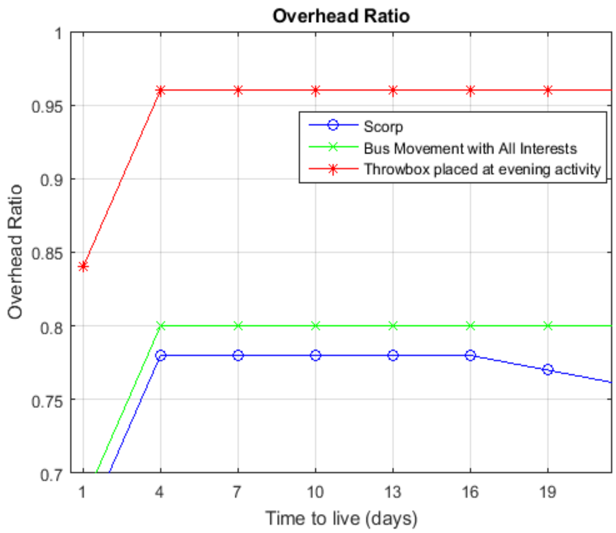


Fig.4: Overhead ratio

Summarizing the results, "as shown in the figures, It is clearly seen that the delivery probability is increased with the use of all interests in the bus movement This is due to increase in the contact opportunity by which the message spread to different areas of network.

IV. CONCLUSION

Accessing data on the go has been the desire of many users of the Internet. Despite the entire networking infrastructure available, such a goal could still be challenging, as a majority of wireless access points are expensive, closed or restricted, and the wireless network suffers from interferences. This study aims at further investigating the benefits of implementing the content-awareness such as interested parties or information type in enhancing dissemination of data in the urban and dense scenario. Therefore, SCORP is proposed, which is a social-aware and content-based approach that is based on the interest and daily interactions of the users. The results have shown the data dissemination efficiency can be enhanced over challenged networking environments when the routing is designed based on social proximity and content knowledge. SCORP shows better performances than the past content-oblivious and social-aware routing approaches such as dLife and Bubble Rap. SCORP's delivery of content is 97% in about 46.9 minutes averagely as compare to the 343.7 and 335.5 minutes required or dLife, and Bubble Rap, respectively. In addition, SCORP generates approximately 4.7 and 13,9 times less replications than dLife and Bubble Rap, respectively.

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