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Evaluating Joint Routing and Scheduling in Opportunistic Sensor Network under Levy Walk Nature of Human Mobility model

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Abstract — *In present scenario the innovation of mobile phones that are embedded with different types of onboard sensors, has brought on a new interest of using them as the main part of the sensor network, for a wide area of applications (for e.g. monitoring). In such ad-hoc network end to end connectivity cannot be established and the connection comes out to be mainly opportunistic. The connection in OSN is many to one i.e. all the nodes have a common destination. The prominent challenge faced in the opportunistic WSNs includes the Routing/Scheduling and managing the constrained memory. Here proper scheduling is defined by routing combined with proper buffer management policy and since the scheduling in OSN is node based so selection of proper Buffer management is also significant. In this paper I consider the monitoring application with the help of human carried mobile sensors and hence a performance evaluation of joint Routing/Scheduling and Buffer management using simulator called ONE (Opportunistic Network Environment) Simulator is done.*

***Keywords-* Opportunistic Sensor Network, Scheduling, Buffer management.**

I. INTRODUCTION

There is a lot of ambiguity and challenges faced in various places like underwater communication, deep space communication, wildlife monitoring, disaster monitoring and such other places where end to end connectivity can't be easily established. The primitive network solutions cannot be easily applied to such type of networks. It is even seen that the policies pertaining to ad hoc even cannot be applied to them. These network environments are subjected to long delays, persistent disturbances and even limited resources; a category falling under Delay Tolerant Environment. One possible way of communication for such type of networks is to go with the approach of store-carry and forward the data and also by exploiting mobility. This situation fall under opportunistic sensor network category. The communication in DTN is many to one while in Opportunistic Sensor Network is one to one.

In conventional DTN environment scheduling policies were basically decided based either on network node utility or message utility, that is the decisions were based on which nodes to forward the message or which message to be forwarded. The paradigm shift towards the Opportunistic sensor networks defines scheduling which is in turn the routing policy along with proper buffer management schemes.

The very recent integration of these sensors with the personal electronic devices like cellular mobile phone has attracted a large number of researchers to consider the appropriate architectures and the applications for large scale people centric sensing systems.

These intermediate mobile nodes implement the store-carry-forward message switching mechanism by overlying a new protocol layer called the Bundle layer.

The rest of the paper is organized as follows in Section 2 the system model has been presented in Section 3 the routing protocol PROPHET is explained. Section 4 gives a brief description of buffer management and queuing policies which are later on compared in this paper. Section 5 shows the simulation setup while section 6 shows the results that we obtain along with the conclusion.

II. SYSTEM MODEL

The work presented in this paper considers the system which draws out inspiration from the OSN environment in which OSN functions are carried out for monitoring purpose.(e.g. Pollution monitoring). In such type of monitoring environment all mobile sensor devices are given the task to sense the pollution data and upload them over a common Access Point or Pollution board data base. [5]

For the above mentioned scenario the work presented here propose to use sensors that are carried by humans. In such case human mobility is what is main concern for an OSN environment. By exploiting this mobility issue, a new communication opportunity can be created among otherwise network elements that are isolated. So the work proposed here highlights such type of applications (Pollution Monitoring) in which exchange of data can only take place in delay fashion, while the nodes are in range. Situation falling under opportunistic communication. The concerns here include, lack of available resources, which including storage space, execution and processing of memory, and transmission power. Thus taking into consideration one of the above problem i.e. limited storage space compels to find a solution for managing the buffer space available with each of the mobile nodes, this concept lead us to jointly use the scheduling, routing and buffer management for opportunistic sensor network environment.[2]. This paper proposes a set of queuing policies combined with probabilistic routing, along with human mobility model. A comparison of the performance of set of these different strategies for human mobility model Levy Walk is done.

III. PROBABILISTIC ROUTING PROTOCOL

In reality users are not likely to move around in a random fashion, but rather they move around in a predictable fashion which is based on repeating several behavioral patterns in such a way that if a node has visited a particular location several times before, it is possible that it will visit that particular location again. Based on this fashion of repetition probability factor is calculated and decision is made on to which node the packet should be forwarded. [8.]

The predictable delivery also follows a property of transitivity, which is likely based on the observation that if there is node X that very often encounters node Y, and there is node Y that often encounters node Z, then node Z is probably a valid node in order to forward messages which are destined for node X.

The calculation parameters of the delivery predictions have following three parts. The foremost thing that has to be done is to update the calculated metric whenever a node is encountered, such that the hosts that are likely to be encountered most probably have very high delivery predictability. The calculation that is shown in Eq. 1, where Pinit ∈ [0, 1] shows the value of initialization constant.

$$P_{(a,b)} = P_{(a,b)old} + (1 - P_{(a,b)old}) \times P_{init}$$

If the shown pair of nodes will not meet each other in a defined time, they are not to be called the ones who can forward all of the messages to each other, and thus the delivery predictability vector values should age, which are being reduced in the process. This aging equation is shown in Eq. 2, where $\gamma \in [0, 1)$ is called the aging constant, and where k shows the number of time units that might have elapsed since the last time the metric was aged.

$$P_{(a,b)} = P_{(a,b)old} \times \gamma^k$$

The predictable delivery also follows a property of transitivity, which is likely based on the observation that if there is node X that very often encounters node Y, and there is node Y that often encounters node Z, then node Z is probably a valid node in order to forward messages which are destined for node A. Eq. 3 shows that how this transitivity affects the delivery predictability, here $\beta \in [0, 1]$ is called scaling constant which decides that how large impact the transitivity property should have in order to rely on the delivery predictability vector below.

$$P_{(a,c)} = P_{(a,c)old} + (1 - P_{(a,c)old}) \times P_{(a,b)} \times P_{(b,c)} \times \beta$$

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IV. BUFFER MANAGEMENT AND QUEUING POLICIES

When the node’s buffer is full, then often in order to accommodate a new message node will an important message. If an efficient policy of dropping is implemented that can help prioritize the message drop sequence, it will give a huge impact on the delivery ratio present in the network. It’s not just dropping policies that define buffer management in, but also the scheduling policies matter. In OSN proper scheduling is defined by routing combined with proper buffer management policy, moreover it is node based so selection of proper Buffer management is also significant. Nodes shall have to buffer messages for a long time and in case of network congestion they have to decide which messages to drop from its queue. In this section we describe the different queuing policies[18] used in this paper for the evaluation in Section 5.

FIFO : First in First Out.
The node is strategized in the order of first in first out. So the message which is queued first is dropped first.

LIFO : Last in First Out
The node in this policy is strategized in the order of last in first out. So the message which is queued last is the first one to be dropped.

MOFO : Evict Most Forwarded first
The message that is forwarded most number of times is dropped first in order to the give the less forwarded messages the chance to be forwarded. The node has to keep a track on number of times the message will be forwarded.

SHLI : Evict Shortest lifetime first
Every message existing in the network has a time out value. After the time has exceeded the message is no longer useful and should be discarded. Thus here the message with the shortest lifetime is dropped first.

V. SIMULATION SETUP

In our simulation set up we used a java based simulator called ONE (Opportunistic Network Environment Simulator). The simulation is done for evaluating performance of joint Routing/Scheduling and four different Buffer management schemes FIFO, LIFO, SHLI, MOFO is done.

All the results here are evaluated under human mobility model to give more useful results. In some of the previous works the authors have used mobility models like random way point or mobility data gathered from real life measurements. Some have even used community model so that they could calculate results for scene which is relatively close to the characteristics of human mobility. We consider a 500 x 500 simulation area. The simulation time set up is 28800 seconds. The total number of nodes taken into consideration here is 15 mobile nodes destined to a single point so the total number nodes to be used for simulation is 16. Message generation takes place after every second. For this work we have evaluated the performance by generating total 1000 messages all of different sizes varying from 500Kb to 999Kb.This range is chosen because in our set up we have considered the buffer size to be 1M. The message size range can be changed along with appropriate buffer size. For our first environment we have plotted the results by varying the transmission range. During the first 10m there is hardly any change seen for the different queuing strategies, after 20m changes are more prominent. In our first set up we have varied the transmission range to {20m , 30m , 40m }, the message ttl for this case is kept to be infinite. The buffer size is kept 1M. For the second scenario we have kept the transmission range fixed to 30m and ttl to 300mins and varied the buffer size to 1M, 2M and 3M. We have considered this value of range and ttl because we get more distinguished results keeping this value. In our third setup we have varied the message ttl to {400m;500M;600M} and observed the changes by fixing the buffer size to 1M and transmission range to 30m. The performance metrics for which we have observed the results are shown below.

A. PERFORMANCE METRICS

- **Delivery Probability**

The delivery probability metric shows the probable number of messages that have been transmitted from the total number of messages available.

- **Average Latency**

The average latency is the average time delay during when the period when the message was delivered and received.

B. SIMULATION RESULTS

Firstly a total of 10 mobility traces have been generated and imported in the simulator. The values of performance metrics is averaged over these 10 traces, the more the traces; smoother graphs can be obtained.

- In the first simulation setup we have evaluated the performance of four buffer management policies namely FIFO (First in First Out), LIFO (Last in First Out), MOFO (Most Forwarded First) and SHLI (Shortest life first) by varying three different transmission ranges. From the simulation results we could find that the buffer management policy of MOFO shows better results in comparison to the other policies for both the performance metrics of delivery probability and Average Latency. Since MOFO drops the most number of times forwarded messages in the network, it takes care that the message that are spread most in the network are dropped. Due to this as the distance increases it is made sure that the messages are forwarded atleast once to retain their availability in the network. Hence the delivery probability increases with increase in the distance.

SIMULATION PARAMETERS	VALUES
Simulation time	28800s
No of nodes	16
Routing protocol	Prophet
Mobility model	TLW
Transmission range	20m,30m,40m
Buffer Size	1M
TTL	infinite

Table 1: Simulation Parameters-1

RESULTS-1

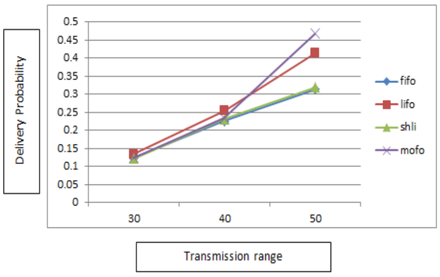

Fig a. Delivery Probability vs Transmission range

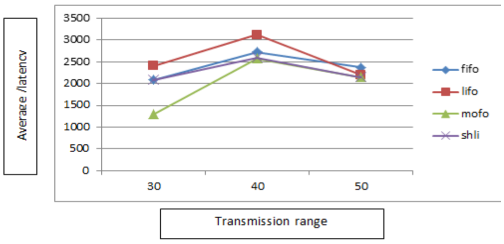

Fig. b.Average Latency vs Transmission range

- In the second simulation setup we have evaluated the performance of four buffer management policies namely FIFO (First in First Out), LIFO (Last in First Out), MOFO (Most Forwarded First) and SHLI (Shortest life first) by varying three different buffer values. From the graph obtained by varying the average latency vs. Buffer size SHLI shows better performance. In the second graph of delivery probability vs. varying buffer size again SHLI exhibits better performance. SHLI drops the message that has the lowest ttl value so for corresponding buffer sizes it will quickly deliver the message before its ttl expires and probability of delivery increases as shown in following figures.

SIMULATION PARAMETERS	VALUES
Simulation time	28800s
No of nodes	16
Routing protocol	Prophet
Mobility model	TLW
Transmission range	30m
Buffer Size	1M,2M,3M
TTL	300mins

Table 2: Simulation Parameters-2

RESULTS-2

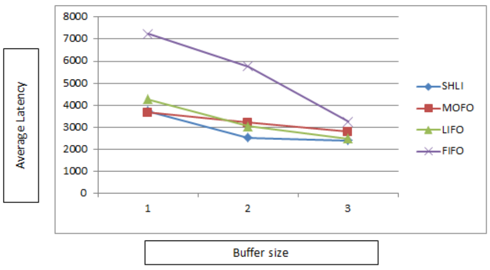

Fig c. Average Latency vs Buffer size

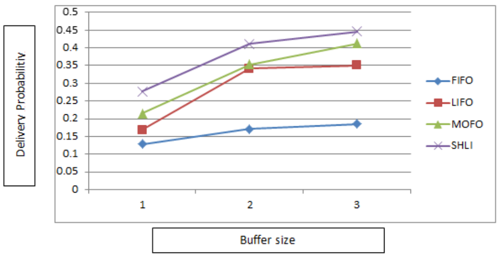

Fig. d .Delivery probability vs Buffer size

- In the third simulation setup we have evaluated the performance of four buffer management policies namely FIFO (First in First Out), LIFO (Last in First Out), MOFO (Most Forwarded First) and SHLI (Shortest life first) by varying three different title (mgs time to live) values. The graph of delivery probability here show that the buffer management policy of SHLI shows better performance results The graph obtained for average latency vs. TTL value shows that the buffer management policy of SHLI shows comparatively better performance . Here probably before the message expires it is quickly delivered, hence increasing the delivery probability.

SIMULATION PARAMETERS	VALUES
Simulation time	28800s
No of nodes	16
Routing protocol	Prophet
Mobility model	TLW
Transmission range	30m
Buffer Size	1M
TTL	400,500,600 (min)

Table 3: Simulation Parameters-3

RESULTS-3

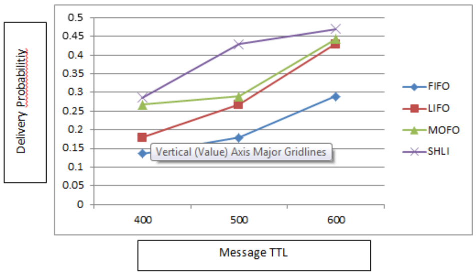

Fig e. Delivery Probability vs Message ttl

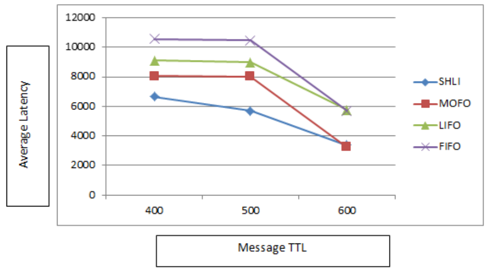

Fig. f Average Latency vs Message ttl

VI. CONCLUSION

In this paper we have evaluated the performance of various buffer management policies under human mobility. Using it along with probabilistic routing which performs delivery predictability calculations and shows better results than other flooding approach in routing. Resources like buffer space needs to be managed properly because its inclusion is inevitable in all sensing devices. Human carried sensor devices has to have a really compact size so that it can be carried easily thus the storage space is always limited. The performance evaluation also determines the significance of using queuing policy and how a good queuing policy can help to manage the available resources significantly.. The message in the system should be forwarded sufficient number of times before they are dropped as the transmission range increases. Moreover they should be delivered as soon as possible before their time to live gets expired again in order to increase the delivery probability.

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