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Minimizing Resource utilization using Particle Swarm Optimization in Delay Tolerant Networks

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Abstract: - **Delay Tolerant Networks is a store and forward approach in which messages are delivered to the nearest potential forwarder by replicating copies of the messages. But, the various node resources such as buffer, energy, etc. are limited, thus making the DTN, a bit challenging. There exists a trade-off between the delivery ratio and overhead. Increasing the number of message copies helps to improve message delivery ratio, but also increases the overhead. On the other hand, reducing the number of message copies helps to decrease overhead while increasing message delivery delay and reducing the message delivery ratio. So, the number of message copies distributed in the network has high importance. By means of controlling the number of message copies, we try to reduce overhead while maintaining the message delivery ratio in a good range (delivery ratio >90%). Since in DTN, increasing the number of message copies delivered to the destination is important, increasing message delivery ratio as much as possible is essential for us. We use Particle Swarm Optimization to choose the appropriate number of message copies. First, we limited the number of copies of the messages being transferred to 54,000 which is lesser than the original number of message replicas by five-folds. We manage to keep the value of delivery probability to 94% of the actual value, even after implementing PSODTN. Then, we implemented the prioritization of the messages so that the messages of high priority get transferred first.**

***Keywords*: - Delay Tolerant Networks (DTN), Opportunistic Network Environment (ONE), Particle Swarm Optimization (PSO), Prioritization, Overhead ratio, delivery probability**

I. INTRODUCTION

DTN [1] is a store and forward network in which a node stores the message until it finds a potential forwarder. But DTN's work over intermittent connections [8] having limited power and radio range, etc. Many researchers have worked on improving the delivery probability of messages, but at the cost of a greater overhead and higher power consumption. Some designers aim at improving message delivery ratio, while reducing overhead [2]. Some others aim to reduce message delivery delay. Increasing the number of message copies helps to improve message delivery ratio, but there exists a trade-off between the increasing delivery ratio and overhead [3]. On the other hand, reducing the number of message copies helps to decrease overhead while increasing message delivery delay and reducing message delivery ratio. So, we aim at finding the optimal number of message copies to be made while the transfer of a message takes place in DTN. For the same purpose, particle swarm optimization (PSO) [13] approach is used. This method is called PSODTN, and it focuses on considering message delivery ratio and overhead, simultaneously, to find the optimal number of message copies. So, our objective is to find the number of message copies (i.e. limit the number of message copies) such that the overhead ratio is reduced and the delivery ratio is maintained in a good range (delivery ratio >90%). Because in DTN, energy [10] is limited so it is important to save this energy and by limiting the number of message copies, we can reduce the overhead, and in turn, save energy. Along with limiting the number of message copies, we will implement the prioritization algorithm [11] that will forward the messages with high priority first and then the lower priority message will be transferred. As DTN is used in emergency application areas, like military areas, natural climatic prone areas, messages carrying important data in these areas are given a greater priority as compared to others, and hence need to be transferred first. Further, of the number of message copies made, we implement a prioritization algorithm that would give a priority to the messages that need to be delivered and delivers the messages according to the assigned priority. The rest of the paper is organized as follows. Section 2 comprises of the related work in the domain of working protocols and limiting the number of message copies in delay tolerant networks. Subsequently, we present our problem statement formally in Section 3, which is followed by the preliminaries to be able to present a solution to the problem statement in Section 4 of this paper. Then we present our idea of implementation to conduct extensive analysis and move towards the implementation and performance evaluation in Sect. 5, and finally we conclude our work with Sect. 6.

II. RELATED WORK

There have been many routing protocols [12] discovered for the message communication using DTN, mostly aim at improving the delivery probability. But hardly any of them aim at considering the number of message copies created during the message transfer which is responsible for the increase in overhead ratio. Also, as the number of message copies increase, messages being dropped also increase in number, which wastes a lot of energy [16]. As we know, that the amount of energy is constrained, hence we have to find suitable algorithms or protocols that would limit the wastage of messages, or limit the number of copies itself.

Our research has been driven by the works of researchers at the University of Iran, who proposed that the principle of Particle Swarm Optimization [9] can be used to limit the copies in DTN. Going by the same lines, we try to implement the proposed formulae of PSO for the same purpose. Further, prioritization of messages before delivering them was introduced by researchers at Bharati Vidyapeeth College of Engineering, New Delhi, which influences us to implement the prioritization algorithm over the limited copies of messages. This priority scheme is of utmost importance when it comes to application specific areas such as interplanetary networks [4][5], military [6], wildlife tracking [7], earthquake affected areas, etc. where certain messages are more important than the rest.

III. PROBLEM STATEMENT

The delay tolerant networks were designed for the areas where discontinuities are present between the source and destination and for the emergency areas. The resources associated with DTN is very limited and various methods and approaches have been defined, but none of them have been efficient in utilizing the resources efficiently. One way to utilize the resources efficiently is by limiting the number of message copies, which are created during the transmission of the messages. In this paper, we have focused on minimizing the resource utilization and applying the prioritization algorithm so that messages of utmost importance are delivered first. For this purpose, we have first implemented Particle Swarm Optimization (PSO) algorithm, so that number of message copies can be limited to a certain extent such that the overhead ratio is reduced and a good delivery probability is maintained. Then, we have applied the prioritization algorithm by assigning the priority to the messages in the ONE Simulator [14].

IV. PRELIMINARIES

First we study the various routing protocols of DTN, and find the protocol that best optimizes the delivery probability [15] while the transfer of messages. To come to a conclusion as to which protocol is best suitable for our application, we use the Opportunistic Network (ONE) Simulator which provides us a platform to perform real time simulations, also providing with the feature to visualize both mobility and message passing in real time in its graphical user interface. The simulator is capable of generating message reports that helps to draw the conclusions over a suitable routing protocol, after analyzing the statistics from the message report generated.

Our primary goal is to maximize delivery probability, but as we have discussed, the overhead becomes a major factor while delivering these messages as the energy is constrained for every node. Overhead ratio [15] depends on the number of message copies created while transfer of the messages. More the number of copies created, more the number of messages will be dropped, and more will be the power consumption. On the other hand, if we look at keeping the number of message copies low, the delivery probability would get affected, as a lesser number of messages would be available to get delivered to the destination.

So, our primary aim shifts to limiting the number of message copies while keeping the delivery ratio in a good range that is acceptable. We do not strive to achieve a 100% delivery ratio. Delivery probabilities around the 90% mark, of the original value, are also acceptable. For this purpose, we introduce the concept of Particle Swarm Optimization (PSO) to DTN which would limit the number of message copies. PSO is a mathematical method that gives an optimal solution to a problem by trying to improve a candidate solution and reaching towards a given measure of quality, with each iteration. In this approach, a number of candidate solutions, referred to as particles, are considered, which are moved in the search space according to some mathematical formulae which keep varying the particle's position and velocity. Each particle maintains a local best known solution, and moves towards the optimum global solution, and the global solution is reached by successive iterations. Our secondary aim is to prioritize the messages by using the concept of a Priority Queue, where each message placed in the queue has an additional priority associated with it. The priorities associated with the messages in the queue is according to the importance of every message which depends on the source of the particular message and the application using DTN.

V. IMPLEMENTATION AND PERFORMANCE EVALUATION

We first implemented PSO in prophet router so that we can limit the number of message copies. Now we have the PSODTN.

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Next, we applied the prioritization algorithm in order to prioritize the messages in PSODTN. We have taken simulation parameters (Table 1) and then simulate it in the ONE simulator.

Section A

If there are M nodes distributed in a square area of N2, and the node transmission range is r≪L, then the meeting probability between two nodes is found by (1) [17]:

$$p \approx 2\omega r E[V^*]/L^2 \qquad (1)$$

Parameter	Group 1	Group 2	Group 3
Number of Hosts	100	100	100
Speed (m/s)	1-1.5	1-1.5	12-17
Wait Time (sec)	0-120	0-120	0-120
Buffer Size	50M	50M	50M
Packet TTL(sec)	300	300	300
Simulation Time(sec)	4320.0	4320.0	4320.0
Movement	SPMBM	SPMBM	SPMBM

Table 1: Simulation parametrs

In (2), because of random waypoint (RWP) mobility used in our simulations,

$$\omega = 1.3683 \text{ [30].} \qquad (2)$$

The average relative speed is found by (3) [18]:

$$E[V^*] = \frac{\omega}{\pi v_1^2} \int_0^{2v_1} \left(\frac{x^2}{\sqrt{1-\left(\frac{2v_1^2-x^2}{2v_1^2}\right)^2}} \right) dx \qquad (3)$$

v1 shows the average speed of a node. As stated in [19], relative speed in RWP is found by (4):

$$\hat{V}_{rwp} \simeq 1.75 \qquad (4)$$

The expected meeting time between nodes is found by (5) [19]:

$$EM_{rwp} = \frac{1}{p\bar{v}_{rwp} + 2(1-p)} \frac{N^2}{2R\bar{L}} (\bar{T} + \bar{T}_{pause}) \qquad (5)$$

Tpause, which states the average pause after an epoch, belongs to [0,Tmax].

The average speed of a node in RWP is declared as (6)[20]:

$$\bar{V} = (v_{max} - v_{min}) / (\ln(v_{max}/v_{min})) \qquad (6)$$

Epoch duration is found by (7) [20]:

$$\bar{T} = \bar{L}/\bar{V} \qquad (7)$$

L, the epoch length for a square area, is found by (8)[21]:

$$\bar{L} = 0.5214N \qquad (8)$$

Expected delay in RWP is found by (9) [22]:

$$ED = \frac{H_{M-1}}{M-1} EM_{rwp} \qquad (9)$$

In calculating the delay of PSODTN, we have to consider PSO delay in addition to the delay caused by sparse networks.

In the proposed approach, expected delay is found as follows (10) [23]:

$$ED_{PSODTN} = ED \times D_{PSO} \ (D_{PSO} > 1) \qquad (10)$$

DPSO shows the delay caused by PSO in finding the appropriate number of copies.

Section B

The messages are prioritized by inserting the messages into a queue and assigning each message a priority value as per the group name. Then, we follow the algorithm below to deliver the higher priority message by comparing the message instances and removing that particular message from the queue.

```
While (queue.isEmpty())
queue.insert(Message id, priority)
Compare instances(o1,o2) by their messages' priority
if (o1 instanceof Tuple)
{
    m1 =o1.getKey();
    m2 =o2.getKey();
}
else
throw error message
Compare priorities (m = m1.priority () - m2.priority ())
Deliver m
```

Section C

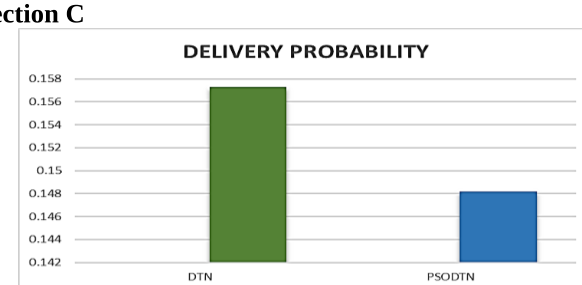

Fig 1. Delivery Probability in DTN and PSODTN

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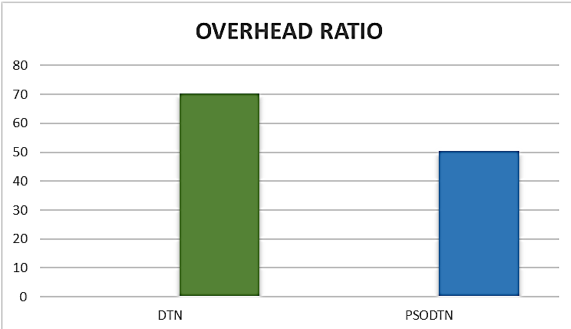

Fig 2. Overhead Ratio in DTN and PSODTN

It is clear from the graphs that on implementing Particle Swarm optimization in DTN and on applying the prioritization algorithm the overhead ratio (fig. 2) has decreased by 28.15% which is a significant change. Delivery probability (fig. 1) has also decreased but still it is 94% of its original value. So, we can say we succeeded in decreasing the overhead ratio and at same time maintaining a high delivery probability.

VI. CONCLUSION

We successfully manage to limit the number of message copies by implementing the concept of Particle Swarm Optimization. Initially, approximately 2,50,000 copies of messages were being created, which was responsible for an overhead ratio being just over 70. Upon implementation of PSODTN, we managed to limit the number of copies created to 54,000 limiting them to about five-folds the original value, and thus, bringing down the overhead ratio by 28.15% to about 50. Also, as our primary aim was always to keep a high delivery probability at the extent of bringing the overhead down, we find out that the delivery probability achieved after the implementation is a good 94% of the original value. Further, the prioritization of the messages has allowed us to implement this technique over application specific domains like earthquake affected areas, ocean monitoring, military scenario, etc. Thus, we conclude our research with fairly good results and propose that the implementation of PSODTN to limit the number of copies of messages being created and then prioritizing these messages for specific applications can be used for a greater advantage with regard to huge amounts of energy considerations.

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