Simulation based Performance Comparison & Analysis regarding Static and Mobile Throwboxes impact on Network Performance in Delay Tolerant Networks (DTNs) using ONE Simulator

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Abstract. Delay Tolerant Network (DTN) is another category of network that lacks continuous network connectivity. Nodes are dependent on opportunistic contacts for message forwarding. Every node has a buffer space where messages are stored till the messages are forwarded to other nodes existing the network, till the message reach the destination node. Buffer space is a crucial resource in DTNs. When a buffer space becomes full, to accommodate new messages, older messages are dropped from buffer space. As nodes in DTN are subject to high data loss and intermittent connection problems. To overcome this issue, relay nodes, i.e. Throwboxes are introduced into the network. Throwboxes are tiny, inexpensive devices, acting as additional storage units for nodes to enhance the overall DTN based network performance. Throwboxes increases contact opportunities and improve over message delivery ratio. In this paper, we aim to analyze the performance of DTN network by introducing Static or Mobile throwboxes in the network in terms of Message Delivery Ratio, Latency and Contacts per hour. Extensive simulations are performed using ONE Simulator by considering both random and planned office-based scenarios. And it is observed via simulation-based results, that with introduction of Throwboxes in DTN, message delivery ratio is improvised at a whopping rate of 14%, latency is reduced by 10% and contacts per hour shows improvement by 25%.

Keywords: Delay Tolerant Networks (DTNs), Spray and Wait Protocol, Throwboxes, ONE Simulator, Random Placement, Message Delivery, Latency, Contacts per Hour.

1. Introduction

Delay Tolerant networks (DTNs) also known as Opportunistic Networks (OppNets) [1-4] are those where an end to end connection isn’t present between the dispatcher node and end node. OppNets are used for sparse networks where continuous network connectivity is not possible between two nodes so intermediate nodes on the transmission path use the Store and Forward technique (SFT) [5] for assured delivery of data. Whenever an opportunity ascends resulting in a situation of two nodes coming in contact, they forward the data towards the destination. DTN’s have several applications in remote areas, satellite communication
networks, military zones, underwater, tracking of wildlife and many others. However, the routing in DTN faces data loss and poor message delivery ratio due to absence of end-to-end connectivity.

Contact in DTN is a very important feature as message forwarding depends on contact between two nodes. Also, buffer space in DTN nodes is limited. If the buffer space becomes full, it starts dropping messages from the buffer, thereby, impacting message delivery. For improving the performance of the network and for contact opportunities to increase, one of the solutions proposed in this paper, is introduction of throwboxes [6]. Throwboxes provide buffer space to the network and increase the number of contacts that gives the opportunity to the nodes to forward messages. Throwboxes are basically some additional nodes in the network that are stationary/mobile and not at all expensive. Throwboxes are special nodes equipped with buffer storage and act as relay points in the network. The basic idea of deploying throwbacks [6] in the network is to increase the message delivery ratio and to decrease the messages dropping. There are some nodes in the network that do not establish contact with one another, so, throwboxes act as a common meeting point or a hotspot. Throwbox either send the message to the destination node or forwards a copy of this message to a relay node that has a greater probability of meeting the destination node. Throwboxes have tons of real-time applications like disaster management, remote areas monitoring such as villages and can also be deployed in public transportation systems.

The main objectives of this paper are:

1. Understanding the primary need of introduction of throwboxes in DTN’s, analyzing types of throwboxes and studying the general impact of throwboxes in DTN.
2. Examining the network performance in respect of Latency, Delivery of Message and Counts per hour after deployment of throwboxes in DTN’s.
3. Simulation based performance comparison of Static and Mobile Throwboxes in DTN networks and overall network performance.

Organization of Paper

Section 2 presents a literature review regarding studies and research presented by various researchers with regard to throwboxes impact and performance enhancement in DTN network. Section 3 gives a comprehensive overview of Throwboxes- Introduction, Types and Placement techniques of throwboxes. Section 4 outlines an experimental analysis performed using ONE simulator by considering Office Scenario and analyzing performance on the basis of static and mobile throwbox based nodes on Message Delivery, Latency and number of counts per hour. The paper concludes with future scope in section 5.

2. Literature Review

This section outlines, the existing research regarding DTN networks as well as introduction of Throwboxes based techniques presented by researchers to optimize the overall network performance.

In the past few years, DTN based research is catching the attention of various researchers. And tons of novel work’s are proposed with regard to novel routing protocols, energy optimization, security, mobility, as well as new architectures to overcome significant challenges in DTN networks.

Under DTM, message transfer from node to another is done using store-and-forward methodology. Routing mechanisms in DTN are classified into two main categories- Data-Centric and Cluster-based Routing [7,8]. Spray & wait protocol [9] which basically uses two phases consisting of Spray and Wait phases, is a data-centric basic protocol used for routing mechanism. In spray phase, the protocol
transmits or spray ‘n’ number of copies of a message in the network environment and after that wait phase commences where protocol waits till the destination node receives the message packet. If this doesn’t happen then direct transmission between various nodes will occur until the destination is incurred. Bindra and Sangal [10] proposed a novel methodology better than Spray and Wait i.e. suppose a Source node ‘S’ in the network has to transmit some message to Destination node D. Node S copies ‘n’ messages to various nodes existing in DTN in different manner. When it meets the first node, it relays the [n/2] copies retaining the rest with it. The process is repeated till the time the source node as well as the nodes having n>1 message copy and only one copy is left with them. After this, the wait phase commences where it waits till the destination node receives the message. If this doesn’t happen in time, then direct transmission between various nodes occur until the destination is incurred. Compared to source spray & wait routing protocol, the method proposed has higher delivery probability and lesser latency.

Considering the resource constraint problem in DTN and to increase the efficiency in certain metric of routing such as delivery delay (worst-case), Balasubramanian et al. [11] devised a routing protocol for DTN, RAPID. The protocol proposed has three components: Selection Algorithm, Inference Algorithm and Control channel. Considering selection algorithm, its task is to determine which packets to replicate at a transfer opportunity given their utilities. Inference algorithm estimates the utility of packet given as routing metric and control channel propagates the necessary metadata required by inference algorithm. Results state that RAPID protocol is almost 10% best in message delivery in DT.

Rashid et al. [12] proposed a message drop policy which considers upper bound threshold by dropping unnecessary messages. This policy assures proper utilization of buffer space and prevents the message dropping and enhance efficient use of buffer space.

Matzakos et al. [13] proposed a Dynamic Distributed prioritization scheme for counterfeiting the issue of starvation of lower priority applications. The proposed scheme satisfies the individual QoS constraints given the amount of available resources and allocate all resources optimally to enhance the performance. Simulation based performance results state that the proposed algorithm outperforms other QoS schemes in all types of mobility scenarios.

Qirtas et al. [6] discussed throwboxes in a comprehensive manner facilitating their importance, deployment methods, issues in terms of implementation, capacity, cooperation, mobility of throwboxes. Authors propound that factors such as cardinality, buffer capacity, placement criteria of throwboxes, network topology and their cooperation among themselves and with other nodes, mobility characteristics of nodes, application requirements, need to be carefully considered for improving delivery ratio, delays, control overheads.

Han and Xiao [14] proposed an effective fault tolerance algorithm for deploying throwboxes i.e. Connection-2 (CO2). Connection-2 uses approximation algorithm for creating DTN. Within mobility range of a 2-connected DTN, every node can access other mobile node through disjoint paths of the node. CO2 was tested based on simulation of real Tuscaloosa bus transit system and performance was compared with contact-oblivious deployment and the contact-based deployment and it was concluded that CO2 requires relatively less number of throwboxes and network performance is high considering CO2.

Banerjee et al. [15] proposed the implementation of throwbox stationary battery powered nodes to enhance storage and processing capability of DTNs. Researchers proposed a novel hardware and software architecture for DTN which is highly energy efficient using multi-tired, multi-radio, scalable and solar-powered hardware platform. In the approach proposed, the researchers utilized approximate
heuristic to solve energy problems. A novel prototype for throwbox i.e. UMassDieselNet- a 40 bus was implemented and it was proved via simulation that proposed framework is better in packet delivery by 37% and makes less latency by 10% in DTN network.

Sundararaj & Vellaiyan [16] analyzed the importance of implementation of Throwboxes in DTN to improvise the contact and overall throughput in DTN. The researchers enhanced AUDTWMN using throwboxes. The complete testing and simulations were performed using Alunivdtnsim, a desktop simulator. And the simulation-based results conclude that throughput in overall network touched 93.7% when using throwboxes, which was only 38.4% without throwboxes.

Bhattacharjee et al. [17] studied the effect of changes in mobility patterns of routing protocols especially in disaster areas, of existing DTN architectures vis-a-vis energy efficient novel architecture DTN framework proposed by him. The proposed framework was tested using ONE simulator and it was observed that the proposed framework is better in delivery ration, less overhead and overall highly energy efficient.

Li et al. [18] examined a time-evolving throwbox-assisted DTN deployment and the problem of their activation and key optimization. They also studied the problems associated with min throwbox and k-throwbox replicated by weighted time-space graphs. They arrived at the conclusion that the problem could be tackled by using an algorithm for quality solution for min-throwbox problem that is NP-hard.

From the literature review, we analyzed various prospects of DTN already worked upon by various researchers. Analysis state that throwboxes improvise delivery probability, delays, and control overhead on DTN network and has huge potential of research to make it better and advanced for betterment of DTN.

3. ThrowBox: Introduction, Types and Placement Techniques

3.1 Introduction
A Throwbox is a cheap wireless storage device designed for DTN for optimizing performance in delivery and reducing overhead in message transfer. Throwboxes are used as a dumping spot in networks where connections between nodes fickle. They are not considered as a primary aspect of network infrastructure, they only act as add-ons for network to make sure that DTN network operates optimally. Throwbox forwards the message packet to the destination directly if it comes in contact with it or to a node that has a high probability of meeting the destination node. The working of throwbox can be illustrated via example- Suppose source node S dumps its message packet to throwbox T. T further relays this message to node 1 that it encounters, seeing that it has a decent probability of coming in contact with the Destination node D. Node 1 passes this packet to node 2 which in turn relays this to node 3, which finally encounters D and transmits the intended packet to the destination node.

3.2 Placement Techniques
The placement of throwboxes throughout the network is extremely important. Throwboxes must be implemented in high traffic network scenarios to reduce packet dropping, overheads and delays, thereby, optimizing network performance in terms of high delivery rates and overall throughput. Depending on the type of network, the placement and number of throwboxes can be decided. In a sparsely populated network, the number of throwboxes required are quite less and their placement is extremely strategic so that they come in contact with the majority of the nodes as well as one another to facilitate the efficient delivery and maintain overall network performance.
In the case of densely populated network, the network is divided into clusters, where every cluster has only one node. On the other hand, placement can even be done without clustering and can be placed at the busy points of the network, i.e. points where there is maximum traffic. Either way, the number of nodes used in such a network would be comparatively high.

Throwbox placement techniques are of two types:

- Random Placement
- Planned Placement

In both placement techniques, the increased number of TB deployment results in increase in the successful delivery ratio and decrease in the average delay in delivery. Thus, more TBs usually improve the routing performances.

**Random Placement Technique**

Under this technique, the throwboxes are scattered in random fashion without any planning or strategy. So, this placement results in deployment of more numbers of throwboxes for achieving the same contact opportunities, delivery time and successful delivery in DTN routing. In real practice where, optimum utilization of the Throwboxes are required, real-life tracing of data is resorted for using an algorithm for placement of TBS.

**Planned Placement Technique**

Under this technique, the throwboxes are placed in DTN after performing in-depth analysis with regard to network topology and points of maximal contact to facilitate high message relay and overall less overhead. This technique is way more useful than the random placement technique as it takes into consideration the whole network infrastructure. A large network with many nodes that needs the deployment of a large number of Throw boxes necessitates the use of algorithms to automatically place the Throw boxes. This ensures the optimal effectiveness of throwbox deployments.

3.3 Types of Throwboxes - Mobility in DTN

After the placement of the nodes, the individual mobility of the nodes is also taken into consideration. The nodes may either be static or moving.

Throwbox mobility is of two types:

- Static
- Mobile

**Static Throwbox**

Under static throwbox, the throwbox once deployed stays wherever it is. It cannot at any point of time change its position in the network. Its location is fixed irrespective of the topology change, network behavior or congestion. These types of throwboxes don’t cost much, as number can be increased at any point of time.
Mobile Throwbox

Mobile throwboxes can move throughout the network. They can either

- Move around with constraints such as congestion, topology, network characteristics and node mobility. It is termed as controlled mobility.

- Move in a planned path for instance, when it is deployed on a moving object having a fixed path. In planned mobility, public transport like bus or train that moves along a fixed path daily can be considered. Also working day movement model comes under the same category as workers have a fixed routine and path.

- Move randomly without any fixed trajectory i.e. deployed on a vehicle which has no fixed path [24]. This is termed as random mobility.

Figure 1. Static Throwboxes

The connection between three heterogenous networks with different type of connectivity models have been shown in figure 1. R1, R2, R3 represent three regions of different type of networks which use static throwboxes (x1, ..., x6) for successful delivery in DTN routing. It would be seen that moving buses (b1, b2) in different regions are able to communicate with each other with the help of throwboxes.

Figure 2 shows the deployment of mobile throwboxes (y1, ..., y6). It would be observed that these throwboxes are either an integral part of moving objects or can be moved as per the varying network topology, congestion or other factors. This type of mobile throwboxes facilitate connectivity among various establishments such as supermarket, schools, homes located in diverse regions (R1, R2, R3).
4. Simulation Results and Analysis

4.1 Simulation Setup

In order to test the viability of throwboxes in Static and Dynamic manner, an office scenario based DTN network is constructed and simulation is performed using ONE Simulator. Table 1 enlists all simulation parameters considered for the simulation.

| Simulation parameter      | Value                                     |
|---------------------------|-------------------------------------------|
| Simulator                 | ONE Simulator                             |
| Version                   | 1.5.1                                     |
| Protocol                  | Spray and wait                            |
| Simulation Area           | 3500*4000                                 |
| Simulation time           | 100000 sec                                |
| Buffer size               | 100M                                      |
| Movement model            | Working day movement                      |
| Groups                    | 12                                        |
| Total nodes               | 1028                                       |
| Group Size                | 12                                         |
| Total Buses               | 28                                         |
| Bus speed                 | 0.8, 1.4                                  |
| Message Speed             | 25-35 sec                                 |
| Bus movement              | shortestPathMapBasedMovement              |
Throwboxes are placed at meeting spots in offices in planned deployment. Throwboxes are taken in both static and mobile modes.

4.2 Results and Analysis

The performance of DTN on the basis of Message delivery, latency and contacts per hour has been analyzed by us in this research paper.

A. Message Delivery

![Message Delivery Ratio](image)

**Figure 3.** Analysis with regard to Message Delivery Ratio- No Throwbox, Mobile Throwbox and Static Throwbox in Planned and Unplanned Placement scenario of DTN

Simulations are being performed on two scenario’s- Planned Placement and Unplanned Placement with regard to three cases- No Throwbox, Mobile Throwbox and Static Throwbox. Figure 3 depicts the situation of Message Delivery Ratio. From the figure, it is analyzed, that DTN network with no throwbox has considerably less packet delivery ratio as compared to DTN with Mobile Throwbox and Static Throwbox. Mobile Throwbox based DTN has shown considerable best packet delivery ratio, which is almost 22% better as compared to No throwbox and Static throwbox.

Overall, it is analyzed that DTN with Planned Placement of Mobile Throwbox has given the best Message Delivery Ration.

The following Table 2 gives tabular based results and comparison of Message Delivery ration in varied scenarios.
Table 2. Message Delivery Ratio

|                  | No Throwbox | Mobile Throwbox | Static Throwbox |
|------------------|-------------|-----------------|-----------------|
| Planned placement| 0.65        | 0.749           | 0.71            |
| Unplanned placement| 0.65    | 0.729           | 0.69            |

Table 2 elaborates that static and unplanned throwboxes has increased the message delivery ratio by 6.15% and mobile and unplanned throwboxes has increased the message delivery ratio by 12%. When throwboxes placements are planned then with static throwboxes the message delivery ratio has increased by 9.2% and with the mobile throwboxes, the network demonstrates whooping increase of message delivery ratio by 15.2%.

B. Latency

![Average Message Latency](image)

**Figure 4.** Analysis with regard to Average Message Latency - No Throwbox, Mobile Throwbox and Static Throwbox in Planned and Unplanned DTN Scenario

Figure 4 highlights the simulation-based performance comparison of DTN networks with regard to Message Latency both in Planned and Unplanned placement scenarios when implementing the network with No Throwbox, Mobile Throwbox and Static Throwbox.

From the simulations, it is observed that, Latency is very less in Planned Placement scenario of Mobile Throwbox as compared to Static Throwbox. And with diagram, it is also observed that simple DTN’s with no throwbox face high latency rates. In planned and mobile deployment of throwboxes there is decrease in 10.39% latency where as in unplanned mobile throwboxes only 7.57% latency is reduced. Static throwboxes also improves latency. In planned deployment, static throwboxes improves latency by 8.13%, whereas latency is improved by 2.12% in unplanned deployment of throwboxes. The latency values in planned and unplanned deployment of throwboxes are provided in the table 3.
Table 3. Comparison of Message latency with static and mobile throwboxes in planned as well as unplanned placements

|               | No Throwbox | Mobile Throwbox | Static Throwbox |
|---------------|-------------|-----------------|-----------------|
| Planned placement | 33707       | 30205           | 30968           |
| Unplanned placement | 33707       | 31156           | 31945           |

C. Contacts per hour

Figure 5: Analysis with regard to Counts per Hour- No Throwbox, Mobile Throwbox and Static Throwbox in Planned and Unplanned DTN Scenario

Figure 5 highlights the scenario of Contacts per hour in planned and unplanned DTN scenarios under No Throwbox, Static and Mobile Throwbox. It is observed that Mobile Throwbox planned scenarios have highest contacts per hour.

5. Conclusion

DTNs are resource constraint networks due to limited buffer space and power of nodes. Nodes have to depend on contact opportunities to transmit and forward their messages toward the destination. Throwboxes are the solution to limited buffer space and increase the count of contacts. The paper discusses throwboxes, their need, applications, effects on the network, different placement techniques, types and deployment. In this paper, simulation-based experimentations are performed with regard to Simple DTN’s, Planned and Unplanned DTNs with No, Mobile and Static Throwbox. It is observed that, when mobile throwboxes are deployed in planned fashion, there is increase in message delivery by 15% and message latency is decreased by 10%. Though stationary and unplanned form of throwboxes also causes increase in message delivery and reduces message latency but not at high significance level.
6. Future Scope

In the near future, we like to focus more towards exploration of simulation based real-world DTN network scenarios with implementation of throwboxes and like to observe the network performance on the basis of overhead, energy efficiency and delivery ratio. We also plan towards implementing an energy efficient architecture for DTN’s with throwbox capability.

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