Implementing Dial-On-Demand Technique for Inter and Intra Cluster Communication in Energy Conserving Postbox Delay Tolerant Networks

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Abstract. The Delay Tolerant Network (DTN) was designed first as a means to communicate between interplanetary bodies in space. Gradually the concept gave way to a terrestrial DTN that was to cement the communication gaps in networks that were heterogeneous and resource challenged in nature. Due to unavailability of end-to-end routing paths, energy exhausted nodes and unreliable communication resources, traditional routing strategies failed to connect, resulting in a plethora of research work for DTN protocols. The Postbox DTN is a variant of the classical DTN wherein there are always ON persistent nodes called Postboxes in a cluster via which all other nodes communicate. The Energy Conserving Postbox (ECOP) DTN uses a trio of time-multiplexed ECOPs in a bid to reduce energy consumption and overhead for the Postboxes. This paper proposes an approach for intra cluster communication using ECOPs that aims to further lower the energy consumption and the chances of single-point-of-failure in the network. We also devise the very first energy efficient inter cluster communication algorithm for Postbox DTN. For the said purpose we utilize the technology of Dial-On-Demand routing wherein a communication channel is only activated when a request to do so arrives. Apart from energy this also saves network bandwidth. This postulate is also seconded by simulation results.

Keywords: Message priority · Bandwidth usage · Postmaster · Scheduled power ON/OFF · Energy drainage · Time-to-live

1 Introduction

DTN gained widespread popularity during the mid 2000's when Kevin Fall proposed the network as an answer to the challenged networks that the TCP/IP

J. K. Mandal et al. (Eds.): CICBA 2018, CCIS 1030, pp. 243–256, 2019.
https://doi.org/10.1007/978-981-13-8578-0_19

was unable to connect. Kevin Fall was associated with the IPN project that created the concept of DTN for space communication in order to build the first ever Solar System Internet (which eventually happened in 2016). The similarities between communication in space and that in terrestrial challenged networks like the marine networks, sensor networks, military networks etcetera, suggested that the same theology can be applied to these earthly networks. Likewise a new layer was added on top of network specific transport layers known as the bundle layer which made it possible to apply DTN procedures to existing networks. This bundle layer acted as a bridge between heterogeneous and intermittently connected networks by translating, storing, forwarding and 'tolerating' delay of messages between them. Apart from the obvious routing issues, these networks are almost always energy drained due to their vigorous neighbour searching, remote locations and uneven recharge opportunities. As such routing mechanisms need to be energy efficient to actually benefit these networks. For the past decade and a half research in this domain has sped up impressively. Few variants of this classical model of DTN has been put forward along the way that customize the network for a particular kind of communication. The Postbox DTN is one such network. This network, as the name suggests, has a single always ON Postbox node that, like a real life one, acts as a message repository. Nodes wanting to receive/send messages try to establish a connection with the Postbox and pick-up/leave their respective messages from/to this Postbox. This type of layout is suitable for sensor networks where the base station can act as a Postbox. It can also be a more cost effective alternative to nanosatellites [18] in rural networks, with the Postbox acting as a kiosk. One big advantage with this structure is that the nodes do not need to worry about connecting to each other for message sharing. The Postbox becomes the single-point-of-contact of all the nodes present in the cluster. Though simple and effective, this mode of communication is not devoid of problems. Most importantly an always ON Postbox consumes a lot of energy and this single Postbox structure gives way to the single-point-of-failure scenario, and might create heat islands. ECOPs presented a solution to both the above problems [5]. ECOPs are a collection of Postboxes (usually 3) that work in tandem with each other using a time-shared Scheduled ON/OFF routine. These are energy saving cost effective devices that are not as power consuming as the original Postbox. In this paper we propose a novel energy efficient inter cluster communication mechanism between ECOPs. To the best of our knowledge no such solution has yet been proposed for inter cluster Postbox communication. We also combine this with two different ways of communicating within (intra) a cluster. The rest of the paper is divided into sections that first discusses some related work in this genre, with the section after it explaining the proposed schemes. A complete analysis of the simulation results is presented before ending the paper with the conclusion.

2 Related Work

As mentioned earlier, the concept for a Delay/Disruption Tolerant Network was inspired from the one that was being created for Interplanetary communication [3]. This research group was headed by Internet pioneer Vint Cerf. Since Kevin Fall mapped those space oriented approaches to terrestrial applications in his path breaking paper [11] in $SIGCOMM'03$, the research community has lapped up the idea and consequently proposed many solutions and variants to the original idea. Let us discuss some of those noteworthy contributions.

Routing and Energy Studies in Generic DTN: Perhaps the first routing protocol that could be applied to terrestrial DTN was the epidemic routing [25], which though was initially designed for vehicular networks. The epidemic routing is a oracle-less flooding based protocol that replicates and shares messages to every node which does not possess a copy of that message. Though good in small, sparse and low traffic networks it starts to deteriorate once these assumptions change. Spray and Wait [22] and Spray and Focus [22] are another set of oracle-less flooding based protocol that replicate a message to only a predefined L number of neighbours in their first (spray) phase. In their second phase they either forward the message to only the destination or use an utility function to decide the next move. More such oracle-less flooding algorithms are Credit Based Routing [6] and Spraying [19], Practical routing [14], Conditional shortest path routing [2] etc. Another set of DTN protocols use network oracle to make forwarding decisions and instead of flooding the network they do selective forwarding of messages. Some of them are Seek and Focus [23], Mobispace [16] and Utility based routing [10]. The work in [21] uses acknowledgements for opportunistic contacts equipped with network coding to increase reliability in mobile DTNs.

Energy efficient mechanisms in DTN rely on either intelligent energy saving mode shifting, data compression or employ special auxiliary energy efficient nodes in the network. The Data Compression Algorithm for energy constrained Devices [20] uses data compression as a means to reduce energy usage, stating that the size of data becomes is proportional to the overall network energy usage. The paper [17] introduces a continuous-time Markov framework to model the message dissemination in DTN using which they formulate the optimization problem of opportunistic forwarding. This they do with the constraint of energy consumed for both two-hop and epidemic forwarding message deliveries and then design different kinds of forwarding policies such as static and dynamic policies. The threshold dynamic policy is considered optimal among these policies, for both two-hop and epidemic forwarding. The work in paper [24] discusses Power Saving Management (PSM). Here a node transmitting or receiving a DTO (Data Transfer Object) is in the transmitting or receiving state after which it switches to a PSM mode which consists of switching between sleeping and search states (wireless interface states). Optimal Energy Aware Epidemic routing [15] has a energy conscious rule for transmission of messages between non destination nodes. The rule states that two such nodes can only share messages if they have a predefined amount of energy (T for the transmitter and r for the receiver) left in them. There are few researchers who believe in employing inexpensive, battery-powered, stationary nodes with radio and storage called throwboxes [1] to save energy. According to them, when two nodes pass by the same location at different times, the throwbox creates a new contact opportunity by acting as a router, significantly increasing the delivery rate. Nevertheless they might increase the cost of maintenance and installation, consume additional energy and might even be not possible for all networks to employ them.

Homing Pigeon Based DTN: The Homing Pigeon Based Delay Tolerant Network (HoP-DTN) [12] is a variant of the vanilla DTN. Here the network is made of almost static nodes which are actually clusters who are represented by respective cluster heads. Communication to and from these nodes is done in a proactive manner i.e. auxiliary nodes are employed, known as pigeons, dedicated to each node. These pigeons carry messages in bulk from their home nodes and move around the network relegating them to respective destination nodes before returning to its abode (hence the befitting name). Routing in HoP-DTN is a Traveling Salesman Problem which some researchers have dealt by using the Ant Colony Optimization technique. Since scheduling of pigeons is of paramount concern here, many efficient approaches have been proposed [7,8,13] though the domain lacks any dedicated solution for energy efficiency (to the best of our knowledge).

Postbox DTN: As has already been introduced in Sect. 1, this DTN has a single persistent node in every cluster that is always UP/ON. Routing of messages is done via the Postbox itself where every node has to make a connection to the Postbox to collect or send its messages [9]. In terms of energy usage this model of operation at one hand reduced the energy consumption as nodes did not have to frantically invest energy in neighbour searching, but on the other hand the always ON Postbox did use a lot of energy coupled with the threat of single-point-of-failure that could potentially disrupt communication in the whole network. Whether in use or not, an always ON Postbox consumed energy and had the threat of building heat islands around it [4]. To deal with this problem ECOPs (Energy Conserving Postboxes) were introduced [5]. Here the single large Postbox in each cluster is replaced by a group of energy efficient Postboxes, i.e ECOPs, that are connected to each other. These nodes will have scheduled contacts with each other as well as a definite time for being ON/UP, all the while time sharing the responsibilities. To all other nodes in the network they will appear as a single Postbox, hiding all their working and splitting of responsibility. We split the original Postbox into 3 ECOPs, all of equal buffer size, numbered as ECOP1, ECOP2 and ECOP3. Initially only ECOP1 is active and the other two are in sleep mode. At first ECOP1 is ON for 1 h. Then ECOP2 is switched ON for the last 20 min of ECOP1 being ON (i.e. when ECOP1 has been ON for 40 min). The same is followed for ECOP3, and the job cycle continues.

3 Objectives

The biggest advantage to go for a structure like that of Postbox DTN is that in any other cluster based topology, the cluster heads (CH) are burdened with extra duties though they have almost the same qualities and deficiencies of a normal node. This further drains their resources. Furthermore in DTN we cannot expect a normal node to be always UP/ON even if it is a CH. Thus creating special nodes, that act like a real life Postbox, with special hardware capabilities will not victimize an arbitrary normal node. As routing of messages is done by direct-contact-with-destination-only mechanism, we eliminate any case of retransmission-to-the-same-node-it-came-from scenario. The Postbox does not have to do any node-searching and the other nodes too do not have to do any neighbour searching (other than Postbox-searching), thereby reducing energy usage. Hence Postbox DTN is our choice of model. From the literature study of existing mechanisms we have analyzed and come to agree that our proposed work should have the following objectives:

1. The proposed scheme must be energy efficient.
2. It should eliminate the problem of single-point-of-failure that is present in classical Postbox DTN.
3. The scheme must be easy to deploy and not require expensive topological changes.
4. It must act differently towards high priority messages.
5. It must optimize the use of network bandwidth.

4 Proposed Approach

There are multiple ECOPs scattered over the network. Ideally they must all be connected to each other at all times. That though is an energy rich prerogative. A more energy conscious solution would be to have connections among these ECOPs based on Dial-On-Demand. Therefore we are creating a network of ECOPs based on DoD, but other nodes are oblivious to the existence of such a network. There though is one democratically anointed head ECOP known as Postmaster. The Postmaster is that ECOP which collects and relegates all foreign-cluster bound messages.

Before explaining the new ECOP architecture, let us first explain what is Dial-On-Demand (DoD) routing. Dial on Demand Routing is a routing method where a network connection to a remote site is established only when needed. In other words, if the router attempts to send out data and the connection is off, then the router will automatically set up a connection, send the information, and impendent the connection when no more data needs to be sent. DoD is preferred for organizations that must pay per minute for a WAN setup, where a connection is always set up. Invariant connections can become needlessly pricey if the organization does not require a constant internet connection.

4.1 Intra Cluster Communication

In this section we propose two new approaches for intra cluster communication. The first method is suitable for clusters that are large in size i.e. geographically widespread with more number of cluster members. The second method applies to those clusters that are relatively more compact.

Method 1: The Close Friends Technique. Clusters that are large in size and (or) are sparse in nature, i.e. covering a considerable amount of geographical region cannot do with one central static Postbox as faraway nodes find it difficult to frequently communicate with the one stationary Postbox in the cluster. For such cases we design a Postbox cluster which has more than one ECOP scattered around the cluster network (let the number of ECOPs in a cluster be denoted by N_{ECOP}). Between them they have DoD connections. Other nodes try to connect with any one of these ECOPs in order to send/receive messages. We call this strategy the Intra cluster communication mechanism using ECOPs with Close Friends Technique (or ECOP_CF). Figure 1 shows a diagrammatic representation of the concept.

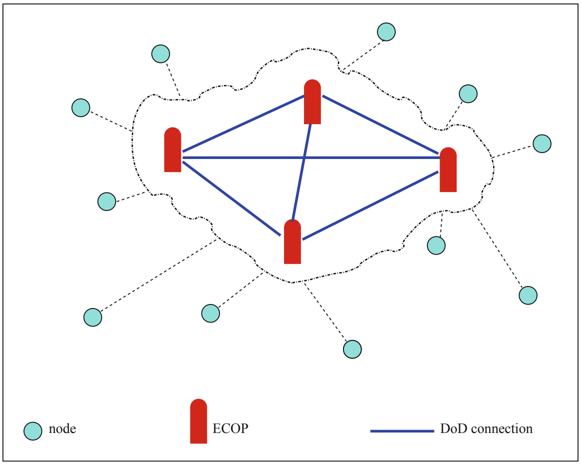

Fig. 1. An Energy Conserving Postbox DTN using the Close Friends technique with Dial-On-Demand connection

Each ECOP maintains the complete list of nodes in the cluster network. Each node is assigned a value known as the Closeness Factor (CF).

$$CF = \frac{1}{\phi_A} + \gamma_A \text{ where,}$$

$$\phi_A = \frac{1}{nd} \sum_{i=0}^{nd} \phi_i$$

$$\gamma_A = \frac{1}{nc} \sum_{i=0}^{nc} \gamma_i$$

where ϕ is the inter connectivity time period, γ is the connectivity time period, nd is the number of disconnections and nc is the number of connections all with respect to the ECOP and a node A. Every node in the list has their corresponding

CF value for that ECOP. This list will be updated at particular predefined intervals. A sample list is shown in Table 1.

Table 1. Sample list with an ECOP containing nodal Closeness Factor

Node ID	Closeness Factor (CF)
#1	2.500
#2	5.050
#3	1.034
...	...
#n	0.045

When message m for node B arrives from node A to ECOP1, them m is shared with s (or N_{ECOP}, whichever is less) other ECOPs. These s ECOPs are those who have the s highest CF values for node B, where

$$s = (P - p_m) + 1$$

where P is the lowest value of priority that any message can have in the network and p_m is the priority of message m (considering priority of value 1 is the highest). To ensure delivery we also consider a threshold value of message time-to-live (ttl), called ϵ which is the network decided percentage of remaining time-to-live of any message which should be treated as the danger line. When ttl of m (ttl_m) reaches ϵ then m should be passed onto all ECOPs (if not already done so). This value is represented as:

$$ttl_m^c = \frac{\text{current value of } ttl_m}{\text{initial value of } ttl_m} \times 100$$

Algorithm 1 elucidates the process more clearly.

Accordingly messages could be passed among ECOPs to reach the destination quicker. (To be noted is the fact that a ECOP never connects to a node, a node does. So if the local ECOP has a copy of the message intended for this node, it is more likely to reach the destination quicker). The best feature of this type or architecture is the disintegration of power. So there is no one man (Postbox in this case) rule. If one ECOP goes down there are others to fill in for it. Its more like a democratic structure of ECOPs, with each having and exercising equal capabilities. Naturally we can completely eliminate the single-point-of-failure scenario here. Just like the nodes of this cluster, the ECOPs of the other cluster are oblivious to this group ECOP structure. This scheme does smart utilization of ECOP buffer. Also the nodes waste less energy scanning for (or moving towards) the Postbox due to a local ECOP nearby.

Algorithm 1. AtEachECOP_Intra_CF

for *each node A in the cluster* **do**
  $\phi_A = \frac{1}{nd}\sum_{i=0}^{nd}\phi_i$
  $\gamma_A = \frac{1}{nc}\sum_{i=0}^{nc}\gamma_i$
  $CF_A = \frac{1}{\phi_A} + \gamma_A$

if *message m for node B arrives at this ECOP* **then**
  $s = (P - p_m) + 1$
  check for s nodes with top values of CF_B
  if $N_{ECOP} <= s$ **then**
    send copies of message m to N_{ECOP} ECOPs
  else
    send copies of message m to the s ECOPs selected
    if $ttl_m^c <= \epsilon$ **then**
      send copies of message m to the rest of the $(N_{ECOP} - s)$ ECOPs

Method 2: The DoD Technique. In this method we would be using the trio of ECOP concept earlier presented in [5] but in a more energy conscious way. We call this strategy the Intra cluster communication mechanism using ECOPs using Dial-on-Demand Technique (or ECOP_DoD, see Fig. 2). This scheme uses not one but four threshold values τ_1, τ_2, τ_3 and τ_4 where τ_1 and τ_2 work in the same periphery. τ_1 is the smaller of the two thresholds and is used to check the requirement for ECOP2 and τ_2 is used to check that of ECOP3. The thresholds work on a value (δ) which is dependent on the network traffic inflow and outflow from the ECOP and its percentage of remaining energy, i.e.

$$\delta = \alpha_1 b + \alpha_2 r$$

where α_1 and α_2 are network decided impact factors and b is the percentage of bandwidth usage at ECOP, while r is the percentage of energy used up. The mechanism works in the following way:

1. initially only ECOP1 is active and the other two are in sleep mode.
2. if $\delta > \tau_1$ and $\delta <= \tau_2$ then establish DoD connection with ECOP2 and now both ECOP1 and ECOP2 are active.
3. if $\delta > \tau_1$ and $\delta > \tau_2$ then establish DoD connection with ECOP3 and now all the ECOPs are active.
4. if all ECOPs are active and $\delta <= \tau_2$ and $\delta > \tau_1$ for time τ_4 then close DoD connection to ECOP3 and switch it to sleep mode.
5. if all ECOPs (or ECOP1 and ECOP2) are active and $\delta <= \tau_1$ for time τ_4 then close DoD connection to ECOP2 (and ECOP3 if it is active) and switch it to sleep mode.
6. if $\delta <= \tau_1$ and $r > \tau_3$ then activate ECOP2 while switching ECOP1 to sleep mode until further recharging. Repeat this process using a Round Robin scheduling.

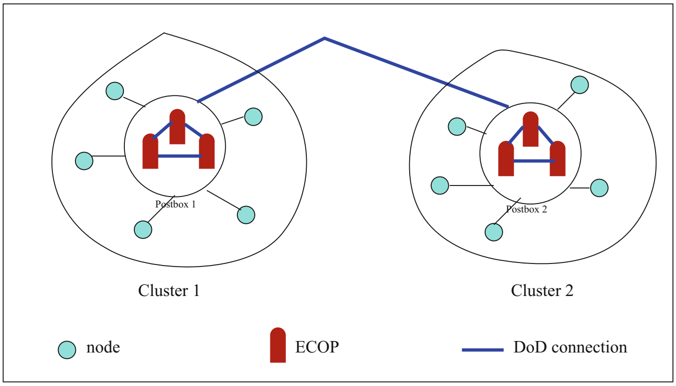

Fig. 2. An Inter and Intra cluster Energy Conserving Postbox-DTN using the DoD connection

This model differs from classical ECOP as it is not a periodic distribution of duties like in the previous case but only a demand based one. Hence if the network is receiving low traffic for quite a bit of time then ECOP DoD would waste lesser energy than normal ECOP, as it will not be unnecessarily shifting between ECOPs transferring data and control each and every time due to its fixed schedule. Thus apart from cashing on in the advantage of the normal ECOP of consuming less energy than classical Postbox model, it improves it by removing the unnecessary context switching. When a connection is set up a message is transferred from the ECOP to the destination thus employing a one hop transfer keeping in congruence with the Postbox Based Routing Protocol [9].

4.2 Inter Cluster Communication

For communicating with foreign clusters, ideally bulk messaging should be done. Regardless of what mechanism is used for intra cluster communication, there would be a single Postbox (or the one active in case of Time scheduled ECOP) that has been elected as the head ECOP. Messages destined for foreign clusters would be collected at the head ECOP known as Postmaster. If number of messages at Postmaster is more than threshold μ then the Postbox-to-Postbox link would be activated via the Dial-On-Demand protocol. If though number of messages is less than μ, and a message's ttl equals ϵ, the link should be activated even then. If any message of utmost priority arrives, then the link is activated then and there. The complete procedure is explained in Algorithm 2 (also see Fig. 2). A thing to be noted is that the value of ϵ should not be too low as the message reaching the foreign Postmaster is only half the journey done (if message is not meant for the foreign Postmaster itself) as after that it needs to be forwarded to its nodal recipient.

Algorithm 2. AtPostmaster_Inter

for *each incoming message* m *intended for foreign cluster* **do**
    accept m and add it to message queue Q_Z such that its destination cluster is Z
    if $p_m = 1$ **then**
        activate the Postbox-to-Postbox link for cluster Z via the DoD protocol
        send all messages intended for it
    if *total messages at* Q_Z *is greater than* μ **then**
        activate the Postbox-to-Postbox link for cluster Z via the DoD protocol
        send all messages intended for it
    if *total messages at* Q_Z *is less than* μ *and* $ttl_i^c <= \epsilon$ *such that* i *is a message in* Q_Z **then**
        activate the Postbox-to-Postbox link for cluster Z via the DoD protocol
        send all messages intended for it

5 Performance Analysis

5.1 Simulation Analysis

For simulation purposes, we have considered that there are a total of randomly switching from ON to OFF state 30 nodes in a cluster (in case of sparse network we have decreased the number of connections to central Postbox) and for Inter cluster communication, there are 30 such clusters. The simulation scenario has been created using the C programming language. One unit of simulation time is equivalent to 1 min. The buffer capacity of classical Postbox is of 300 units, the ECOPs in ECOP_DoD are 100 each and that of ECOP_CF (there are 6 in a cluster) are of 50 each. Energy consumption has been considered at 1 unit each at message forward/receive, 0.01 units per unit size of the Postboxes (maintenance purposes) and total initial energy is 300 units. The energy consumption due to other peripheral causes, being same in all cases, have not been taken into consideration. The plots that have been depicted here in this paper have the following values of the threshold and impact factors: the value of P is 3, ϵ (intra) is 40%, τ_1 is 60%, τ_2 is 80%, τ_3 is 70%, τ_4 is 30 min, α_1 is 0.4, α_2 is 0.6, μ is 5 messages and ϵ (inter) is 50%. We have compared our algorithms with the existing mechanisms in Postbox DTN like ECOP (the scheduled ON/OFF trio of ECOPs) and the traditional classic Postbox (referred to as simply Postbox). For inter cluster communication as there are no previous mechanisms apart from the original Postbox (vanilla version), we compared it with our proposed scheme that we have referred here as simply Postmaster.

Energy Consumption. Figures 3 and 4 shows the comparison between ECOP_CF, ECOP_DoD, ECOP and Classical Postbox on the basis of Average Percentage of Remaining energy with respect to (w.r.t.) increasing time, while the Message Traffic from all nodes is kept at a constant of 50. From results

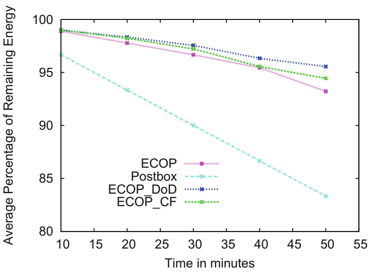

Fig. 3. Energy consumption when message traffic is 50, w.r.t. time

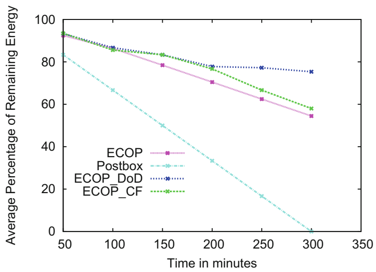

Fig. 4. Energy consumption when message traffic is 150, w.r.t. time

it can be statistically stated that ECOP_CF conserves 7.85% and 106.2% more energy than Postbox when the time is varied till 50 and 300 min respectively and 0.51% more energy than ECOP when the time is varied till 50 and 300 min respectively. ECOP_DoD uses 1.01% and 13.34% less energy than ECOP when the time is varied till 50 and 300 min respectively and 8.4% and 117.56% less than Postbox when the time is varied till 50 and 300 min respectively. On comparing each other, ECOP_DoD uses 4.27% less energy than ECOP_CF. When examining the inter cluster communication mechanisms, Postmaster conserves 14.21% and 237.37% more energy than the traditional Postbox when the time is varied till 50 and 300 min respectively.

Delivery Capability. Simply conserving energy is not enough, as the main purpose of any network is to deliver messages before their time-to-live expires. Likewise we did a simulation to test the mechanisms on the basis of message delivery capability. To showcase the robustness of our proposed schemes we have introduced random Postbox (or ECOP) failure scenarios. Figures 5 and 6 show the results of such experiments. If we compare ECOP_DoD and ECOP, when a huge message traffic is created within a short span of time during network initialization (within the first 40 min, see Fig. 5), then the performance of ECOP tends to degrade. This is so because the message traffic exceeds the buffer size of the lone ECOP when the second ECOP is yet to be active according to the time schedule. Our new ECOP_DoD scheme is safe from any such degradation as the instant it requires help it sends a DoD signal to the other ECOPs to back it up. To sum it up, ECOP_DoD delivers 27.3% and 0.64% more messages than ECOP and 1.63% and 0.57% more than Postbox w.r.t. simulation time period of 20 and 200 min respectively. ECOP_CF delivers 45.46% and 19.3% more messages than ECOP and 17.76% and 19.2% more than Postbox w.r.t. simulation time period of 20 and 200 min respectively. When the network considered is sparse, the results are a bit different as expected (see Figs. 7 and 8). In sparse network, ECOP_DoD delivers 7.38% and 5.25% more messages than ECOP and 11.34% and 4.57% more than Postbox w.r.t. simulation time period of 20 and 200 min respectively. Similarly ECOP_CF delivers 108.35% and 79.3% more messages than ECOP

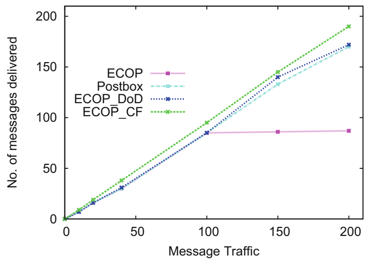

Fig. 5. Delivery capability (Time constant at 20 min)

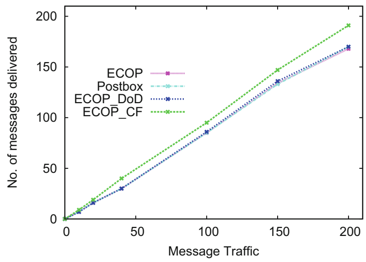

Fig. 6. Delivery capability (Time constant at 200 min)

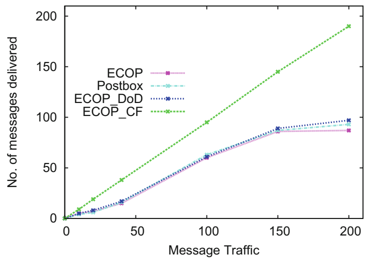

Fig. 7. Delivery capability (Time constant at 20 min) in a sparse network

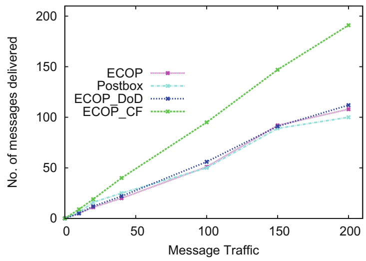

Fig. 8. Delivery capability (Time constant at 200 min) in a sparse network

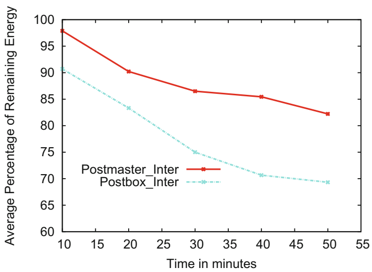

Fig. 9. Comparing energy consumption with respect to time (message traffic constant at 50) for inter cluster communication

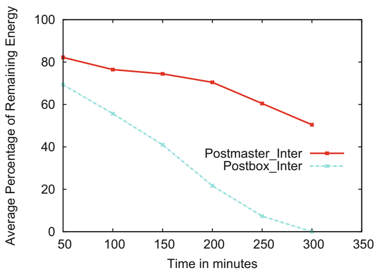

Fig. 10. Comparing energy consumption with respect to time (message traffic constant at 150) for inter cluster communication

and 116.8% and 62.5% more than Postbox w.r.t. simulation time period of 20 and 200 min respectively. When compared amongst themselves, ECOP_CF on an average delivers 17.27% and 81.45% more messages than ECOP_DoD in a normal and a sparse network respectively. For inter cluster communication the two protocols perform more or less similar and it only differs when the single-Postbox failure occurs (Figs. 9 and 10).

6 Conclusion

In today's era everything we use needs to be energy efficient. The applications in Postbox DTN are also hit by the "energy drainage" issue that has handicapped other variants of the DTN. In this work we have proposed two such energy conscious mechanisms for intra cluster communication and another one for inter cluster communication in Postbox DTN. We have, in both our intra and inter cluster communication mechanisms, inculcated all the requisite parameters that are paramount to network performance like inter connectivity time, connectivity time period, number of disconnections between a node and an ECOP in a definite time period, number of connections between a node and an ECOP in a definite time period, percentage of bandwidth usage, remaining energy levels of ECOPs, priority of a message, its remaining time-to-live and number of messages waiting in a queue at Postmaster. Applying proper thresholds and impact factors on these attributes enhances the workability and performance of our system. All together they strive to achieve the best solution possible, the consensus of which is also proven via the simulation results where we have compared these mechanisms with existing ones. Hence finally we can claim that we have achieved all the objectives that we had set out to achieve for this work.

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