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Application based Forwarding in Delay Tolerant Networks

Abdul Basit[1], Safi Ullah Khan[2], Omair Sabir[3]
[1]UET Peshawar, [2]PTCL, [3]Muhammadi Autos Corporation
abdul.basit3@ptcl.net.pk[1], Safiullah.khan@ptcl.net.pk[2], omair.sabir@gmail.com[3]
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Abstract—Delay-tolerant Networks (DTN) are wireless networks destined to serve places or functions with minimal or not well-established infrastructure. The DTNs are challenged by an intermittent connectivity between the adjacent nodes, and disconnections may occur due to power outages, technical issues or insufficient architecture. To address the transmitting phenomena of relatively large delays and error rates, an interest-based routing approach, in which different interests and data relay to each node will enhance the DTN capacity. The use of throw-boxes will increase the performance of the networks, and an efficient buffer management policy shall be administered to improve the performance of the network. In this paper, a hybrid buffer management policy is enacted in throw-boxes for increasing the performance and energy efficiency of the network. When the buffer becomes full, data with TTL less than 5 hours will be deleted first, and then the interest type with the most copies diffused or the more popular one in the network with a high hop count will be deleted from the throw-boxes so that the data would flow between nodes and other throw-boxes to reach the destination. Of course, the interest with less popularity can also reach the destination by utilizing this approach. Results show that the buffer management policy improves the performance of challenged networks by increasing the delivery probability, the overhead ratio and the delay are decreased and the average remaining energy has better performance compared to other routing protocols.

Keywords— Energy-Efficient, Delay-Tolerant Networks, Buffer Management, Computer Networks.

I. Introduction

The growing use of powerful mobile devices, together with the current global, fast-paced development of technology and consumption habits, has raised the users' expectancies and criteria; people are craving for reliable connectivity while on the move. This has resulted in a networking situation where the mobile industry focuses on overcoming the power, CPU, and memory constraints by proposing more sophisticated and better, heterogeneous devices and wireless networks. Nonetheless, the intermittent connectivity even in urban scenarios is still a problem since the availability of wireless shadowing, the expensive internet services and closed access points would contribute to the potentially low throughput and the significant delay. With the improvement of the Internet, the mobile ad hoc networks (MANET) have begun to operate by themselves, and most people already maintain those continuously connected to the Internet, thus forming a dynamic and autonomous topology of a self-configuring network of mobile and portable devices. Because they are linked wirelessly, those devices rely on almost no infrastructure, and because of the capacity of MANETs to be forwarding unrelated traffic constantly, they also function as routers. The challenge is to equip each device in such a consistent manner as to permit it to continuously maintain the information required to route traffic properly.

In the scenario of Internet and MANETs, there is always end-to-end connectivity between the source and the destination nodes. The network operates through a global protocol due to the connectivity of all nodes in the network [1]. Delay-tolerant networks are challenged networks in which there is no end-to-end connectivity between the source and the destination nodes, mostly due to the mobility of those nodes. In the scenario of DTN, the routing protocol is to forward data by using the Store-and-Carry approach. In this method, data loss prevention is ensured by storing the data in the buffer until it is transmitted to another node and reaches its destination [2].

Content-oriented routing schemes consider the nature and the interest of data, instead of the host and the location of a node, which increases the performance of the network [3]. Social networks have played a vital role in improving the performance by leveraging the challenges of the huge amount of content existing in the network. Because an entry is created in the routing table for each content item, even if we are capable of compressing data, we must cope with the situation of fast-moving content which is produced, moved or deleted with a high speed and occurrence. The paper utilizes the social benefit of different nodes, and the processed information is forwarded to the node if their interest profile matches, or else, the data is forwarded to the static throw-box. While mobile throw-boxes implement the transportation system and increase the performance of the network, static throw-boxes are placed in different locations by the point of interest [19].

Buffer management policies improve the performance of the network, but little research has been done about implementing it in throw-boxes. In the FIFO ("first in, first out") policy, the message is deleted as soon as the buffer is full. The disadvantage is that the priority messages will also be deleted [4].

The MOPR buffer management technique used a metric Fp to delete the messages based on Fp=Fpold + p, where Fp represents the most favourably forwarded message and p is the delivery probability of that message. If the buffer becomes full, the data that has highest Fp value [4] will be deleted.

The MOFO buffer management technique deletes the data that has most copies or is propagated the most in the network since that data would have travelled in the network for a period of time and so it has had higher chances to reach its destination [5].

The nodes have smartphones for forwarding and receiving data, though most research findings do not consider the energy aspect of smartphones. Our contribution in the paper is to provide options and demonstrate that an efficient hybrid buffer management policy might be implemented in throw-boxes to reduce the congestion and improve the energy efficiency when the throw-boxes get full and new data is arriving. For every user, interests are defined and data is relayed if the interest of the receiver node is the same as that of the sender. If any data arrives at the throw-box when the same is full, the data which is going to be deleted first is the one that has a popular interest or increased diffusion level and high hop count as it would have already been propagated to many nodes and other throw-boxes. This will reduce the congestion and increase the energy efficiency, and new data can be spread through the network while the previous one will have the chances to be stored somewhere else. In this hybrid buffer scheme, data with lower interest will also reach the destination node.

II. RELATED WORK

Delay-tolerant is a sparse network. There is no end-to-end connectivity due to the mobility of the nodes and the partitioning of the network so that they depend on a store-and-forward mechanism. A message is stored in the buffer and is relayed to another node when it encounters the same. Infrastructure-based communication is very expensive, and people living in the rural areas are not wealthy enough to pay for increased communication expenses, so the DTN is a more appropriate solution we must work on to deploy and develop. Direct Delivery [5] is a routing protocol in which the source will deliver the message directly to the destination, or otherwise, it will not relay the message to another node. In other words, this means that if the node of origin does not meet the target node, the message will never reach the goal. Epidemic routing [6] floods the message to every node it meets. It does not consider the buffer space. It has a maximum delivery ratio, but the resource consumption in this routing protocol is too big. In the Spray-and-Wait [7] routing protocol, the source node sprays the message to "T" nodes, where "T" is a value predefined by the user. As the node is left with only one message, the direct delivery routing protocol is used. These routing protocols forward the message to another node without having any knowledge or utility metrics. The Prophet routing protocol depends on the history of encounter nodes. If node A meets node B regularly, and node B meets node C also regularly, then node A can also send the message to node C. In this routing protocol, we also take the Aging factor into account [8].

Social networks have received a lot of interest from researchers. These are networks in which routing is done through the social ties and is characterized by strained relations and interactions between human beings. Social features rely on behavioural habits and as such are considered to be more stable and long-term [9]. A community is defined as people living in the same area and having more chances of meeting one another than the individuals living in different areas. LABEL [10] is a routing protocol which takes into account social characteristics. Residents in the same area, or people who have the same profession, are given a LABEL based on their affiliation. The message is forwarded to the node which has the same label, or otherwise, it is not forwarded. The drawback in this routing protocol is that if the source node does not meet the node having the same LABEL, the message will never be delivered to the destination. The SimBet [9] routing protocol provides the capability to forward a decision based on two social metrics, between "centrality" and "similarity."

The betweenness centrality acts as a bridge for forwarding the message to different communities. The node which has similar neighbours with the destination node is another metrics used in this routing protocol. The message is transmitted to the node having both a high betweenness centrality and a high similarity value. Bubble Rap [11] is a routing protocol which forwards the message to another node based on the metrics degree centrality. The central node can be considered the traditional node as the popular node will be connected to more people. In this routing protocol, there is a global centrality and a local (geographical) centrality. First, the message is bubbled up globally, and as soon as it reaches the destination community, it bubbles up on the local centrality. In [4], the social interests of users are exploited, and data is forwarded to the nodes with matching interests. Static throw-boxes are placed in Point-of-interest locations, and mobile throw-boxes are used for data forwarding. While improving on delivery probability, we need to reduce the congestion and apply an efficient buffer management policy. In [15] data is forwarded on the basis of the users' interests; if their interests are the same, data is forwarded, else their weight towards that interest is evaluated in that time interval—if the interest is higher, the threshold data is forwarded, otherwise, it is not. Efficient buffer management scheme is not implemented in the routing method that reduces the energy efficiency and performance of a network. Limited and insufficient research is done on implementing the buffer management policies in throw-boxes. Only two techniques are identified to use both the buffer of throw-boxes and the buffer management policies [12], [13]. In both static and mobile throw-boxes, the routing scheme implements the FIFO buffer management policy for discarding the old messages as the buffer of the throw-boxes becomes full. One of the disadvantages of this scheme is that the priority of data is not considered; there can be some messages that need to reach the destination but will simply be discarded if they are old [13]. One buffer management technique that is used is MOFO [4] in which data that has a greater number of copies in the network needs to be deleted. This technique does not consider the data that has passed over a greater number of hops from the data it receives from the nodes. These algorithms are not implemented in throw-boxes for evaluating the efficiency of a network.

Another buffer technique that is used is SHLI [3] which deletes the data whose remaining TTL is much lower; this data cannot reach the destination so it is deleted to free up buffer space. This technique performs well until the throw-box becomes full; in that case, the data with high TTL cannot be deleted so this technique fails.

The LEPR buffer management scheme [18] deletes the data based on predictive delivery probability; the data will lower predictive delivery probability is deleted first which frees buffer space.

III. PROPOSED BUFFER MANAGEMENT MECHANISM

The limitation of existing routing protocols is that they do not consider any buffer management scheme in the nodes and throw-boxes. Epidemic [6] routing protocol floods the data to every node it encounters and considers buffer capacity unlimited. Prophet [8] routing doesn't flood the data to every node it encounters, instead, it forwards the data based on past node records, i.e., if node A frequently encounters node B, there is a higher probability that they will meet again, and data is forwarded based on the history of encountered nodes. This routing protocol also considers the buffer unlimited. The SCORP [16] routing protocol forwards the data based on interests: if the interest of the encountered nodes is the same, data is relayed to the node, else the weight of that interest in that time interval is evaluated, and if it is greater than the threshold the data is relayed, otherwise it is not. This approach is good in terms of reducing the congestion of the network, but SCORP does not consider that the buffer of the nodes is limited.

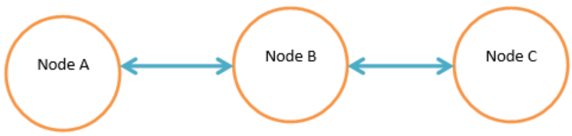

Figure 1. Encounter of Nodes.

The limitation of the protocols explained above is that they consider the nodes to have unlimited space, and so data is forwarded to the nodes as it is received, which is not a practical approach. In practice, the smartphones have limited buffer space, and so a buffer management scheme needs to be implemented. Another limitation is that the above routing scheme does not consider that the battery of the nodes can be depleted and an energy efficient algorithm needs to be implemented.

IV. PROPOSED ALGORITHM

```
If Buffer Becomes full:
Begin
 {
   Search for data with TTL<5 hours
While (TTL<5)
{
  Delete Data with TTL<5
}
Find data with largest value of Pa
{
 Search for data with highest value of Pa:
  Pa=P+1+Hp
  Delete the Higest value of Pa and Perform
Operation in descending order until space gets
Empty
}
```

The proposed algorithm considers the above two limitations of routing protocols and offers a routing protocol that takes into account the buffer's limited space and the node's smartphone limited battery capacity. Until now, very little work has been done on implementing the buffer management technique in throw-boxes, and in this research, the buffer scheme is implemented in throw-boxes and nodes. The proposed algorithm is compared with SCORP [16], Prophet [8] and Epidemic [6] routing schemes for evaluation. Above is the algorithm of the proposed routing protocol, and its flow chart is shown in Fig. 2.

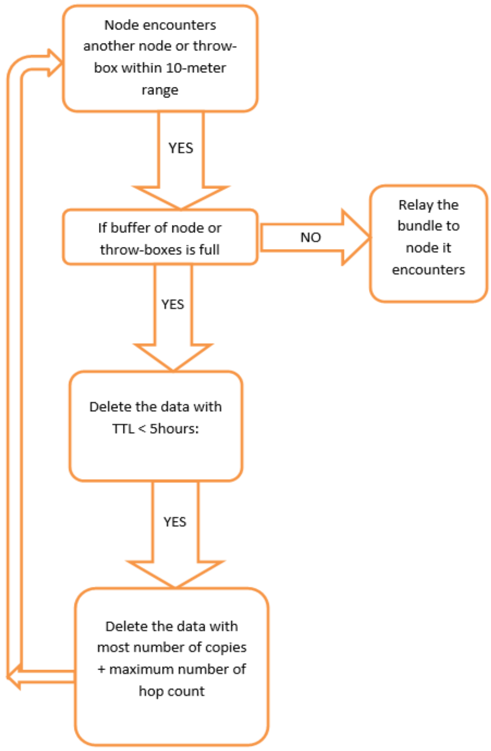

Figure 2. Proposed Buffer Management Flowchart

1. The data in delay-tolerant networks is in the form of bundles that are completely relayed to another node they encounter and which is within range. Bluetooth and wi-fi can be used for sending data to another node,

but we only consider Bluetooth for data forwarding when nodes encounter each other, as these are challenged networks and wi-fi facilities are not available everywhere. The range of a Bluetooth is 10 meters. In Fig. 1, suppose that Node A is in range of Node B (within 10 meters) so that data in bundle format will be relayed to Node B, and similarly, Node B is in range of Node C (within 10 meters), so Node B will forward the bundle to Node C and data can reach the destination.

2. Nodes are defined as different interests. The data in the buffers of the throw-boxes is labeled with interests. One of the techniques is deleting those messages that have less popularity or fewer subscribers, but in this method, the disadvantage is that data with less popularity will never reach the destination.

3. If the node encounters any other node or throw-box, the first step is to search for data with TTL<5 hours and delete it as these messages have very low chance to reach the destination node due to the lower TTL. This buffer space gets empty and new data can be relayed to the throw-boxes.

4. As the first step is completed, apply step two: Delete all those messages that have highest diffusion level and hop counts. The following equation is implemented for finding the highest value of Pa.

$$Pa = P + 1 + Hp \quad (1)$$

Where Pa is the equation used for deleting the messages from the throw-boxes, P is the number of copies spread in the network, and Hp is the hop count factor of the data.

5. The algorithm searches for data that has highest Pa value a, has highest number of copies spread and has passed a large number of hops.

6. Perform step 4 in descending order as the buffer gets empty.

7. If the node encounters any other node or throw-box, the above procedure is applied.

V. SIMULATION RESULTS AND PERFORMANCE ANALYSIS

ONE simulator is used for the evaluation of the routing schemes for the delay-tolerant networks [14]. The working day movement model is used for simulation. The nodes are distributed throughout the map. The home, offices and evening activity places have also been pre-defined in the map. There are 17 groups which deploy in the settings. Each group is defined with interest. In this simulation, there are ten (10) unique interests which are assigned randomly to specific groups of nodes that do not overlap with each other. The external event is used for generating the message in the simulation. The message is created according to the user's specifications (the user can specify the source and the destination node). The ten (10) different interests are: agriculture, tourism, sport, medicine, reading, games, business, news, movies, and weather. Each node in a group is randomly assigned with interest. The simulation was paralleled with a study without the implementation of the buffer scheme [4] and a study with the same parameters but with a buffer scheme in throw-boxes applied. For analysis of the energy efficiency of the routing protocols, the energy module [17] is developed in One simulator used for determining the energy consumption of the nodes. For reference, Samsung S6 Mobile is used with Bluetooth for configuration settings. The parameters dependent on energy consumption of the devices are scan (-38.61 mAs), receive (-51.47 mAs) and transmit (-51.57 mAs). The simulation parameters are shown in Table 1.

TABLE I. SIMULATION PARAMETERS

Parameters	Values
Simulation area	4500m x 3400m
Mobility Model	Working Day Movement Model
Simulation time	5 days
Interface	Bluetooth
Interface range	10 m
Groups	17
Nodes	150
Nodes speed	0.5, 1.5 meters
Initial energy	2000 mAh
Scan energy	38.61
Transmit energy	51.47
Receive energy	51.47

VI. DELIVERY PROBABILITY

It can be defined as the number of messages created and the number of messages delivered to a destination. The higher the distribution probability, the better the performance of the network. The simulation results are shown in Fig. 3. The first scenario, in which buffer scheme EEHIMBS is implemented, shows 0.85 delivery probability with TTL of 1 day, compared to Epidemic, Prophet and SCORP routing scheme which shows 0.73, 0.74 and 0.80, respectively. The 3-day TTL of Epidemic, Prophet and SCORP routing protocol shows 0.76, 0.77 and 0.82 delivery probabilities, respectively, and with the buffer scheme being implemented—the delivery probability increases to 0.87. The 1-week TTL of Epidemic, Prophet and SCORP routing protocol is 0.78, 0.79 and 0.84, respectively, but with buffer scheme implemented, the delivery probability increases from 0.85 to 0.90. The 7-week TTL performed on Epidemic, Prophet and SCORP routing protocol shows 0.82, 0.85 and 0.87; with the buffer scheme implemented, it reaches 0.94. The increase in the delivery probability is due to the implemented interest-based buffer scheme; the scheme uses the hybrid approach in which even the data with less popularity reaches to the destination node. On the other hand, Epidemic routing protocol has low delivery probability due to its flooding approach; the Prophet routing protocol does not implement any buffer management protocol but neither does it flood data to all nodes, so it has higher delivery probability than the Epidemic routing protocol. SCORP routing protocol forwards data based on interests, so it has a higher delivery probability as data reaches the area where the node has high chances of receiving data. The proposed routing scheme achieves highest delivery probability due to buffer management scheme implemented; the data with less priority also gets delivered to the destination.

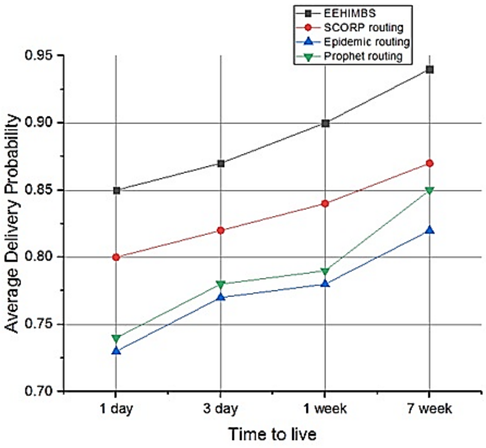

Figure 3. Delivery Probability

VII. Average Latency

It can be defined as the time it takes for the created message to reach the destination node. The lower the average latency, the better the performance of the network. The 1-day TTL using Epidemic, Prophet and SCORP routing protocol shows an average latency of 32, 28 and 27ms; with the buffer scheme being implemented the latency is 25ms. The 3-day TTL using Epidemic, Prophet and SCORP routing protocol shows 32, 30 and 28ms of average latency, and with EEHIMBS the average latency decreases from 25ms to 23ms. The 1-week TTL using the same protocol shows an average latency of 35, 31 and 28ms, and with EEHIMBS it has an average latency of 18ms. The 7-week TTL using the same protocols shows the average latency of 39, 33 and 29ms respectively, and with EEHIMBS it has an average latency of 18ms. The average latency when using the buffer scheme has reduced the average latency in comparison to the one used without enacting the buffer scheme. The Epidemic routing scheme floods the data to throw-boxes and nodes and does not have buffer scheme implemented and so it has high average latency. Similarly, the Prophet and SCORP routing protocols do not flood the data so they have less latency compared to the Epidemic routing protocol. The proposed buffer scheme deletes data with high diffusion or high popularity level, and more space is created in the throw-boxes while the average latency is reduced. The results are shown in Fig. 4.

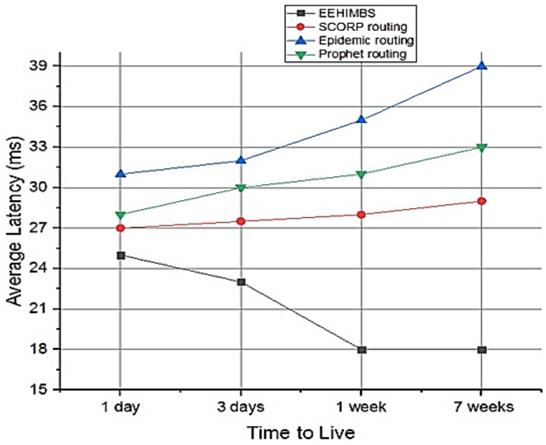

Figure 4. Delivery Probability

VIII. Overhead Ratio

The overhead ratio using Epidemic, Prophet and SCORP routing protocol with a 1-day TTL is 0.70, 0.64 and 0.63, and with EEHIMBS implemented, the overhead ratio is 0.60. The overhead ratio of the above same protocols with 3-day TTL shows 0.77, 0.69 and 0.64, and with EEHIMBS implemented, it drops from 0.64 to 0.59. The overhead ratio with 1-week TTL using the above routing protocols shows 0.80, 0.76 and 0.78, and when using EEHIMBS, it drops from 0.59 to 0.55. The overhead ratio using the same protocols with a 7-week TTL has the values 0.81, 0.76 and 0.69, and when using EEHIMBS, it decreases from 0.55 to 0.54. The Epidemic routing protocol has highest overhead ratio due to its flooding nature, compared to SCORP and Prophet routing protocol. SCORP routing protocol forwards data based on interests, so the overhead ratio is less compared to Epidemic and Prophet routing protocol. EEHIMBS has lowest overhead ratio due to deleting the data as the buffer gets full, and data will TTL less than 5 hours also gets deleted. The overhead ratio can be defined as the number of extra bytes sent in the network for data to reach the destination node. The lower the overhead ratio, the better the performance of the network. The results are shown in Fig. 5.

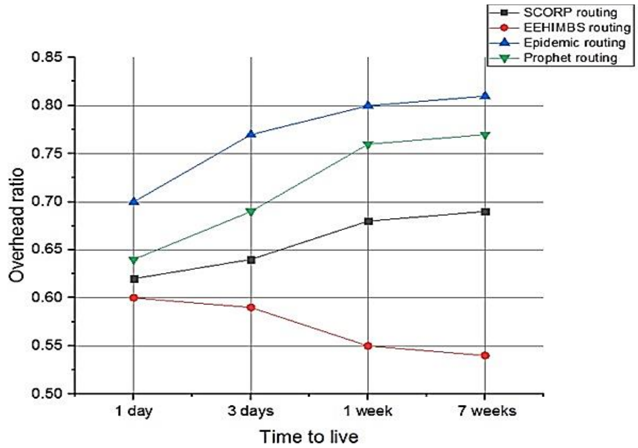

Figure 5. Overhead Ratio

IX. Average Remaining Energy

The energy efficiency of the proposed routing protocol is compared to the Epidemic, Prophet and SCORP routing protocol. The results are shown in Fig. 6. Initial energy of the nodes in all routing protocols is 2100 mAh when the number of nodes is 100. As the number of nodes is increased to 200, the Epidemic routing protocol has the lowest remaining energy of 1700 mAh, SCORP has a remaining energy of 1900 mAh, Prophet routing's remaining energy is 1800 mAh and EEHIMBS remaining energy is 2000 mAh. As the number of nodes is raised from 200 to 300, the Epidemic routing has the lowest remaining energy of 1400 mAh, Prophet routing has 1500 mAh remaining energy, SCORP's remaining energy is 1700 mAh and EEHIMBS has a remaining energy of 1800 mAh. When the number of nodes is increased from 300 to 400, Epidemic routing has lowest average remaining energy 1000 mAh, Prophet routing's remaining energy is 1300 mAh, SCORP's routing protocol remaining energy is 1400 mAh, and

EEHIMS has 1500 mAh remaining energy. Overall, EEHIMBS performed best due to the buffer management scheme, as the buffer is always free, the time is not wasted in scanning and energy efficiency is achieved. SCORP forwards data on interest metric, so it performs well compared to Prophet and Epidemic routing protocol. The epidemic has lowest remaining energy due to its flooding approach—it sends data to all nodes as it receives it so it wastes all energy in scanning and transmission of data.

CONCUSLION

An interest-based buffer management scheme is proposed in throw-boxes to increase the performance of the network. When the throw-box is full, we delete the data with high diffusion level instead of deleting the data with less popularity. The proposed scheme has good energy efficiency compared to other routing protocols. This hybrid approach increases the delivery probability of the network by also delivering the data with less popularity. The overall average latency and overhead ratio are also decreased with this buffer management policy, and we also double-checked and prevented some critical data discrepancies. In future research, this buffer management scheme can be compared with other buffer management policies.

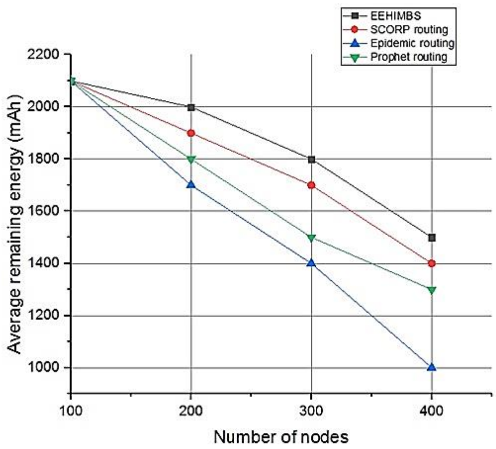

Figure 6. Average remaining Energy

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