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*Full Length Research Paper*

# Adaptive message size routing strategy for delay tolerant network

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**Delay tolerant network (DTN) is a kind of computer network that suffer from the frequent disconnections, network partitioned and unstable network connectivity, therefore maintaining an uninterrupted route from source to destination is not possible. Therefore, the transmission of message is achieved via intermediate nodes by adopting a novel transmission mechanism called store-carry and forward where node stores the incoming message in its buffer, carries it while moving and forward it when it comes in the transmission range of other nodes. DTN routing protocols can be either single copy or multi copy. In single copy protocols, the node forwards the unique copy of message along a single path. These protocols suffer the long delivery delay. In multi copy protocols, the node diffuses multiple copies of same message along dissimilar paths. Thus, message can reach destination via more than one path. However, the replication process consumes high volume of network resources such as buffer space, bandwidth and node energy. The probabilistic routing strategies for instance PRoPHET Protocol minimizes the consumption of resources and forwards a message to a custodian by using a metric of delivery probability. The probability describes the suitability of a node to meet the destination of message. However, when node mobility pattern is not symmetric the probabilistic computations cannot predict the accurate forwarding decision. In this paper, we have proposed a novel message forwarding strategy called Adaptive Message-Size Routing strategy (AMRS) by which a node handovers the copy of message to its neighboring nodes by using a metric named as mean threshold (MTH). We have compared the performance of AMRS with Epidemic and PRoPHET routing protocols. The proposed routing strategy has performed better in terms of maximizing delivery probability while minimizes message drops and number of transmissions.**

**Key words:** Store-carry-forward, routing protocols, delay tolerant network, algorithm.

## INTRODUCTION

Ad hoc routing protocols for instance table driven and on-demand (Johnson et al., 2001; Ahmedy et al., 2011) establish an end-to-end path prior to the transmission of data. However, these solutions are not applicable in applications like wild life monitoring, deep space communication, military and sensor network where the node mobility causes dynamic topology changes and frequent disconnections. As a result, source and destination cannot sustain the uninterrupted path.

The delay tolerant network (Fall and Farrell, 2008) provides the transmission of data for such scenarios by applying the novel message diffusion strategy referred to as store, carry and forward. According to this approach, the node stores the incoming message in its buffer, carries it while moving and forwards when comes in the transmission range of other nodes. These networks are also known as opportunistic because the node always searches for a connection opportunity to forward its buffered messages. The connection happens when

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**Abbreviations: MTH,** Mean threshold at active node; **BU,** buffer used by the active node; **Mn,** Number of messages at active node; $\mathbf{M_{Dest}}$, message destination; $\mathbf{M_{size}}$, message size; $\mathbf{AP_N}$**,** Appetizer Node; $\mathbf{AC_N}$**,** active node.

node(s) move in the communication range of each other. These transmissions continue and a message finds its destination via multiple hop(s). Based on this paradigm, various delay tolerant network (DTN) routing protocols have been proposed to cope with the heterogeneous network scenarios. The available routing strategies can be categorized as opportunistic, predicted and scheduled. The opportunistic protocol requires least computational resources and node simply forwards the message copy to the encounter nodes for example, Epidemic (Vahdat and Becker, 2000), Spray and wait (Thrasyvoulos et al., 2005). The predicted protocol forwards the message by utilizing the contact history of current node such as PRoPHET (Lindgren et al., 2003). While the scheduled based forwarding transmits the message by employing the human mobility movement pattern of contacts and positional coordinates, in DTN each node is hybrid, which means that it can generate and receive the random size messages. Hence, in the presence of limited bandwidth the small size messages swiftly pass through the network. This increases the message replication that results in rapid clogging on the buffer space of network nodes. Additionally, when a node by carrying small size messages receives the large size message it will drop the cluster of messages to accommodate new arrival. As, there exists multiple copies of each message, therefore same node may receive the dropped messages from other part of network. These rampant drop and re-transmissions wastes the bandwidth, energy and formulates high burden on the network resources. Hereby, a mechanism is required which control the generation of message copies and reduces the number of message drops.

In this paper, we have proposed a new message routing strategy called Adaptive Message-Size routing strategy (AMRS),where a node handover the copy of message to its neighbors by employing a metric Mean Threshold (MTH). According to AMRS, before transmitting the message ‘M’ to ‘C’, the node ‘A’ computes the mean of buffered messages at ‘C’. If the size of message ‘M’ is less than MTH of ‘C’ and ‘M’ is not the destination for ‘C’ then the ‘A’ will keep such messages in its buffer. However, ‘A’ will forward ‘M’ to ‘C’ only if message is destine for ‘C’ or the size of message is greater then MTH of ‘C’.

We have compared the performance of AMRS with Epidemic and PRoPHET Protocols. Under all simulation configurations the AMRS always reduce the transmission overhead, message drop and raises delivery probability.

## RELATED WORKS

DTN routing protocols attempts to transfer the data over the unstable communication. Thus, transmission of multiple message copies along different paths makes sure that at least one copy will reach the destination. An extreme example of such policy is the Epidemic (Vahdat and Becker, 2000) routing. In this protocol, when two nodes meet, they exchange all messages which they do not have in common. In this way, message(s) rapidly diffuses in the network and can reach the destination via multiple paths. This increases the robustness, minimize the delivery delay but consumes high volume of network resources such as bandwidth, buffer space and node energy. Some recent work (Qaisar et al., 2011) has optimized the performance of Epidemic routing by changing the default transmission order FIFO. The spray and wait routing (Thrasyvoulos et al., 2005) reduces the consumption of network resources by minimizing the transmission of message copies. In this scheme, the source node forward the ‘N’ number of its message copies to the encounter nodes called relays. This is spray phase. If the destination is not found in spray phase, then each node wait and forwards the message directly to destination. This protocol delivers the message like Epidemic fashion while it minimizes the consumption of network resource like direct delivery. Spray and focus (Thrasyvoulos et al., 2007, 2008) is another deviation of spray and wait where the node starts by spraying the N number of message copies. If the message does not find the destination then the node hands over the message to a custodian with higher utility. The utility value determines capability of node to meet the message destination.

The contribution in routing protocol continues and the researcher begins to route the message by exploiting the additional network parameters such as the mobility pattern, encounter history activity of node. For example, the PRoPHET routing protocol (Lindgren et al., 2003) utilizes the encounter history and age of last encounter. Moreover, it route a message by using the metric of delivery predictability. NECTAR (Etienne and de Oliveira, 2009) protocols controls the transmission of messages by computing the neighborhood index, which depends on the encounter history. Srinivasa and Krishnamurthy (2009) proposed a distributed proximity-based communication protocol that forwards the message using ‘conditional residual’ time metric. This metric uses the local knowledge of past contact to estimate remaining meeting time for pair of nodes. CREST protocol minimizes the end-to-end delay and increase the delivery probability as compared to other message forwarding strategies MEED and MED.

Conditional Shortest Path protocol (CSPR) (Eyuphan et al., 2010) effectively employs the human mobility pattern and computes the conditional intermitting time, which is the average meeting time of two nodes in relation to meeting time with third node. The average intermitting time represents the link cost. The node forwards the message by employing conditional shortest path algorithm that takes conditional average intermitting time as parameter. CSPR minimize the end-to-end delay and increase the delivery probability as compared to shortest path based routing protocols. Guizhu et al. (2010) improves the performance of Binary spray and wait algorithm by introducing QoN. The QoN is measured in

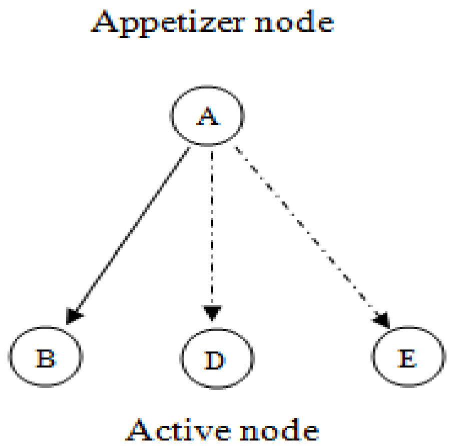


**Figure 1.** Appetizer node.

terms of mobility of node and is represented by an integer number which indicates how frequent one node encounter with other node in a given time interval. Higher value of encounters indicates the high QoN. Messages are forwarded to a node that has higher value of QoN. When a node leaves one copy, it then switches to direct transmission. QoNsW increase the delivery probability, minimize the delivery delay, overhead as compared to Epidemic and spray and wait.

PROCS (Jathar and Gupta, 2010) minimize the replication of message by adopting a forwarding strategy, which study the movement pattern of contacts and their time sequence. In PROCS, each node maintains a probabilistic contact graph that represents the contact probability among nodes at various time intervals. The node route the message by selecting a contact with greedy path calculation. PROCS protocol achieves high message delivery ratio with no message replication compared to Epidemic and PRoPHET. Daowen et al. (2009) manages the routing computation locally at each and transmits the message by using hierarchical forwarding with cluster control mechanism. This protocol split the network into different clusters. A node called cluster head controls each cluster. The node first sends the request to forward the message towards cluster head. The cluster head analyze the message header and perform Inter-cluster or Intra cluster forwarding. CHRC reduce the delivery delay and improve the delivery probability as compare to Epidemic and SMART protocols. The only drawback of CRHC is that it needs to maintain the information regarding partial nodes of the network.

The proposed Adaptive Message-Size forwarding strategy forwards a message without exploiting and relegating the complex computations. The idea is to deliver or relay the message, the mobility of node and observing the buffer of encountered terminal. For this, a metric Mean Threshold (MTH) have been defined which controls the creation of multiple copies of each message.

## AMRS routing Algorithm (adaptive message size forwarding strategy)

### *Terminology*

In proposed AMRS, each node maintains the index of its buffered messages. The node with high volume index controls the communication and is known as appetizer node. The volume index is determined in terms of number of message carried by a node. When two nodes have the same volume index then the selection of appetizer is random. The nodes ready to communicate with appetizer are known as active nodes. A node is active if it is not busy in communicating with its neighbors.

The appetizer node controls the flow of messages around the active connections. For this, appetizer fetches its buffered message one at a time and transmits it by verifying the Rule 1, 2. After the 'appetizer' completes its transmission, it changes its status to active node while the next high volume index node becomes the 'appetizer'. Figure 1 represents 'A' as appetizer while 'B', 'D' and 'E' are the active nodes.

## METHODOLOGY

**Rule 1: "The appetizer 'A' will forward message 'M' to 'B' only if 'B' is destination of 'M' and 'B' has not previously received the same message."**

The existing Epidemic protocol (Vahdat and Becker, 2000) is a multi copy routing strategy where on each encounter, the node perform the pairwise exchanges of messages. Theses nodes become the carrier and continue to infect the further encountering terminals. In this way, the message rapidly moves across the disconnected regions.

Despite delivering the messages, this protocol leaves high overhead on the network resources for instance buffer space, node energy and bandwidth. The previous work (Vahdat and Becker, 2000) has taken the buffer space, bandwidth as infinite resources that is not practical for the real time DTN applications. For example, when the bandwidth is limited, then the node may not fully exchange their buffered messages and may miss the transmission of those messages for which the current connected node is the final destination.

The message delivery to the destination is very important as when a message reach the recipients as a final custodian then that node generates an acknowledgement message. This message informs the other nodes about the status of delivered message and operates as a sweeper to remove the message copies and stop the further replication. However, when messages doest not reach the destination, their replication continues in the network.

Rule 1 of the algorithm ensures the delivery of more messages to their destinations. For this, the appetizer node scans its buffer one message at a time and validates rule 1. Hence, the transmission occurs only if 'M' is destined for current connected node. However, when the message is not destined for 'B' then Rule II invokes.

**Rule 2: "The appetizer will not forward 'M' to 'B' only when the size of message 'M' is less than the mean of buffered messages at MTH (B)."**

In DTN, each node is capable of generating or receiving random

```
for each AC_N in communication range of AP_N
    {   MTH (AC_N) = BU/Mn;
        for each message 'M' in AP_N
         {
    if (M_dest==AC_N)
              forward_message (M,AC_N);
    else if (M_size < MTH (AC_N))
              Continue;
     else
               Forward_message (M,AC_N);
          }
            }
```

**Figure 2.** Algorithm (AMRS).

size messages. Further, these messages reach their destination via multiple intermediate hops called relays. Since, message relay is directly proportional to the congestion. The high number of message relays increases the network traffic. While under the limited buffer space, the nodes could not accommodate the all-incoming transmissions. This congestion results in dropping the previously stored messages. As, there exists multiple copies of each message therefore same node may receive the dropped messages from other part of the network. These rampant drops and re-transmissions waste the bandwidth, energy and formulates high burden on the network resources.

One factor that can be used to control the congestion is to minimize the number of message relays. Rule 2 deals with controlling the unnecessary relay of messages. For this, before forwarding the message 'M', appetizer 'A' computes the mean of buffered messages at 'B' which is called Mean Threshold (MTH). The mean value indicates the average size of message carried by the active node. If the size of 'M' at 'A' is less than the MTH (B), then it shows that as compared to 'B' the current message 'M' at 'A' is small. In addition, 'B' is not the destination of 'M' therefore relaying the message to 'B' does not guarantee its eventual delivery. At this stage, both nodes are equally capable to meet with the destination. Therefore relaying the message is waste of node energy, bandwidth and buffer space. Thus, 'A' switch to the greedy mode and carry such small size messages in its buffer.

As, all network nodes has random size messages. Therefore, MTH value varies for each node. Hence, appetizer adaptively will not relay small size messages and the transmission occurs only when size of message 'M' is greater than the MTH of active node (Figure 2).

### Message exchange

***Case 1: Exchange of Messages Epidemic Protocol***

Consider a sample scenario in Figure 3 where nodes 'A' and 'B' has established the connectivity while $SV_A$, $SV_B$ represent the buffered messages at A and B. Hence, $SV_A$ = { (m1, 39 s, X, 200 KB), (m2, 53 s T, 150 KB) ,(m3, 46 s, U, 180 KB), (m4, 22 s, B, 230 KB), (m5, 10 s, B, 153 KB) | (message, arrival time, destination, size)}, $SV_B$={(m50, 41 s, X, 150 KB), (m51, 32 s, Z, 410 KB), (m52, 78 s, M, 200 KB), (m53, 15 s, Q, 240 KB), | (message, arrival time, destination, size)}.

According to Epidemic routing protocol, 'A' forwards its summery

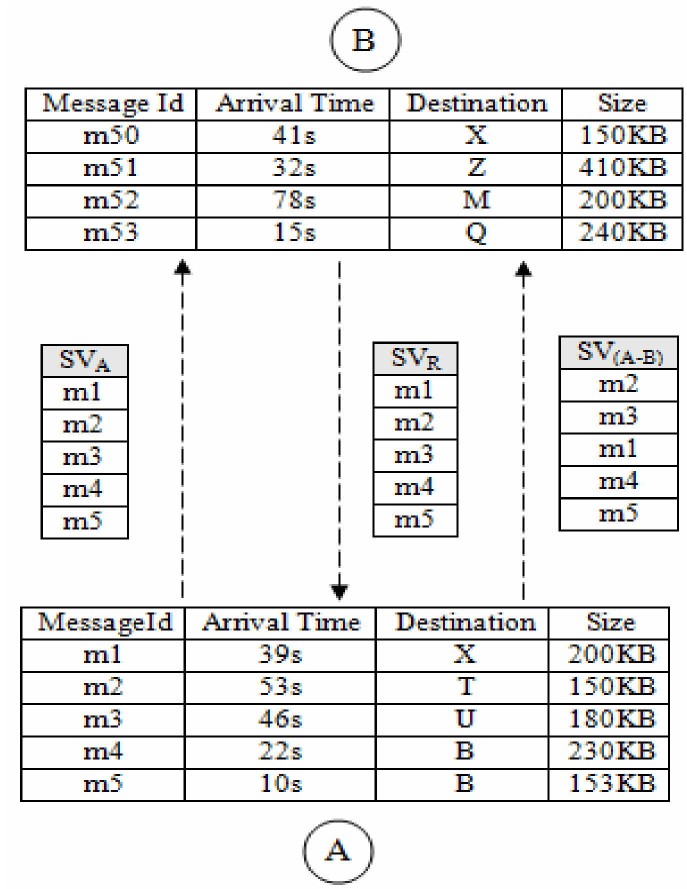


**Figure 3.** Exchange of messages using Epidemic routing protocol.

vector to 'B'. Node 'B' then computes the summery vector request SVR by subtracting the SVA from its own SVB to get the messages not buffered at 'B'.

$$SV_{R\,(B\text{-}A)} = \sum_{i=5}^{n} MB_i - \sum_{i=1}^{n} MA_i = m1, m2, m3, m4, m5$$

The node 'A' then forwards the required messages to 'B' by arranging them according to the arrival time that is, the message with high arrival time should be placed on the top of the queue such as SV(A-B) = {m2, m3, m1, m4, m5}.

Since bandwidth is the limited resource therefore it is possible that 'A' may not be able to forward m4, m5 that are placed at the end of the forwarding queue. Both m4 and m5 were destined for the current connection 'B'. Therefore, instead of delivering the messages, 'A' will continue the replication m4, m5 on the other part of the network.

***Case 2: Exchange of messages via Adaptive Message Size forwarding strategy***

Now we will consider the transmission of messages via adaptive message size forwarding strategy. Consider the snapshot mentioned in Figure 4; here, 'A' act as appetizer because it has high volume index compared to 'B'. Recall that appetizer node fetch its buffered messages one by one and forward it to the current

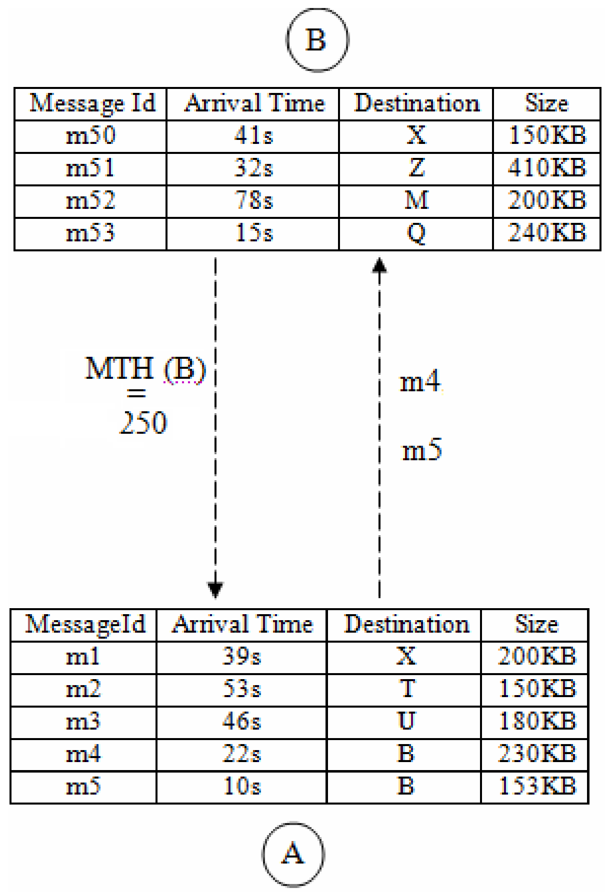


**Figure 4.** Exchange of messages using AMRS.

active node by Rule 1 and Rule 2.

In present scenario, appetizer 'A' will fetch 'm1' from its buffer and validate it by Rule 1. As m1 is not destined for 'B', thus by Rule 2 'A' will obtain the mean of the buffered messages MTH at 'B' that is MTH (B) = 250 KB. Since, the size of message m1 is less than the MTH (B) thus 'A' will keep 'm1' in its buffer and move to the next message 'm2'. Similarly, 'm2' is not destined for 'B'. In addition the size of 'm2' is also less than mean threshold MTH(B) thus 'A' keep this message in the buffer and moves to the next message 'm3' that will not be transmitted because it does not satisfy the algorithm rules. Thus, appetizer 'A' iterate the next message 'm4' which is destined for current connected node 'B'; therefore 'A' will forward this message to 'B' and iterate the next message 'm5' that is destined for 'B'; and 'A' will transmit 'm5' to 'B'.

## SIMULATION AND RESULTS

Here we will compare the performance of proposed Adaptive message size forwarding strategy (AMRS) with Epidemic and PRoPHET routing protocols by varying the various simulation parameters. The evaluation of schemes have been analyzed under ONE [22] simulator. ONE is a discrete event simulator written in JAVA and have been massively used by various researchers to measure the statistics of disrupted store-carry-forward applications.

### Network settings

The simulations were performed by considering a city-based environment consisting two groups of pedestrians (80 nodes), one group of car (40 nodes) and six trains. The pedestrians and cars are moving according to Shortest Path Map Based Movement mobility model while trains are moving with Map Route Movement mobility model. The pedestrians were configured at the speed of 0.5 to 1.5 km/h for pedestrians, 10 to 50 km/h for cars and 10 to 50 km/h for trains with the transmission range of 10 m. We have configured each network peer with a finite buffer space and limited bandwidth 2 MBPS. In addition, the connection establishment is opportunistic and nodes do not have the knowledge about the network topology.

### Performance metrics

#### *Message relays*

DTN is an opportunistic network where messages reach its destination via multiple intermediate hop(s) referred to as relays. When a message is relayed, it consumes the energy, buffer space and bandwidth. The redundant diffusion of messages puts high load on them. Therefore, it is important to minimize the number of transmissions or relays.

#### *Message dropped*

Since, the transmission of multiple message copies produces high congestion on the buffer of intermediate node(s), in result, the node overcomes it by dropping previously stored messages. It is not possible to remove the drop event; however reducing its magnitude can improve the network throughput.

#### *Delivery probability*

The delivery probability measures the successful transmission of messages to their destinations. This metric measures the overall network throughput, as more messages delivery at destination shows the optimal use of network resources.

### Performance evaluation

#### *Scenario-01: Impact of varying number of nodes on routing protocols*

Figure 5 represents the results of PRoPHET, Epidemic

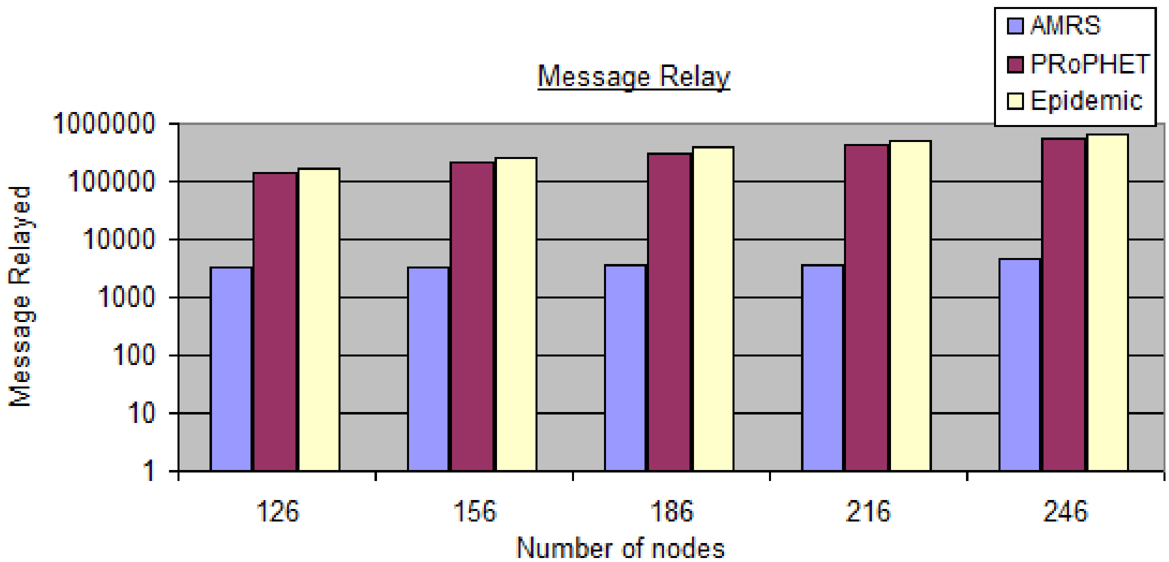


**Figure 5.** Message relays by varying number of nodes.

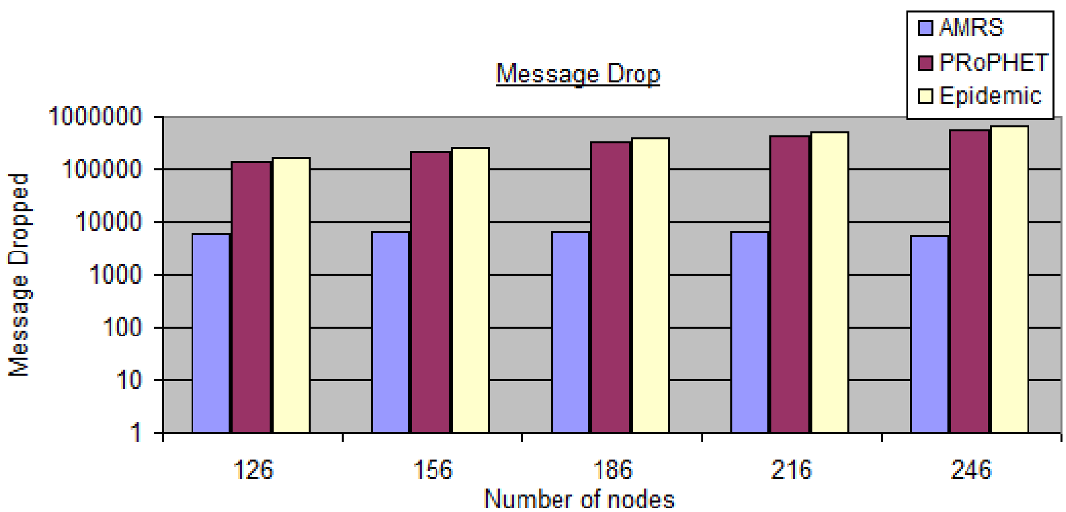


**Figure 6.** Message drop by varying number of nodes.

and AMRS in term of message relay. We can see that Epidemic protocol has the highest number of relays. The reason is that the message exchange rate of Epidemic protocol depends on the number of encounter. Thus, at higher nodes density such as 246, 216 and 186 the encounter rate among nodes also increases which in turn increase the maximum transmissions.

The PRoPHET protocol has relayed fewer messages than Epidemic protocol. The reason is that PRoPHET Protocol does not relay the message if the encountered node is less probable to meet the destination. However, when we increase the node density for example [186], [216], [246] the PRoPHET protocol begins to relay more messages. The reason is that the PRoPHET protocol uses the history of encounters to control the replication of messages, in which high density of nodes elevates the encounters rate. In response more nodes has maintained the predictability measure for each other.

The proposed AMRS shows the consistent message transmissions. The reason is that, AMPR generates the message copy only if the size of current message is greater than the MTH of connected node. In this way all nodes carry the small size messages and tries to deliver it directly to destination.

Figure 6 shows the results of message drop in term of number of nodes. We can observe that the Epidemic

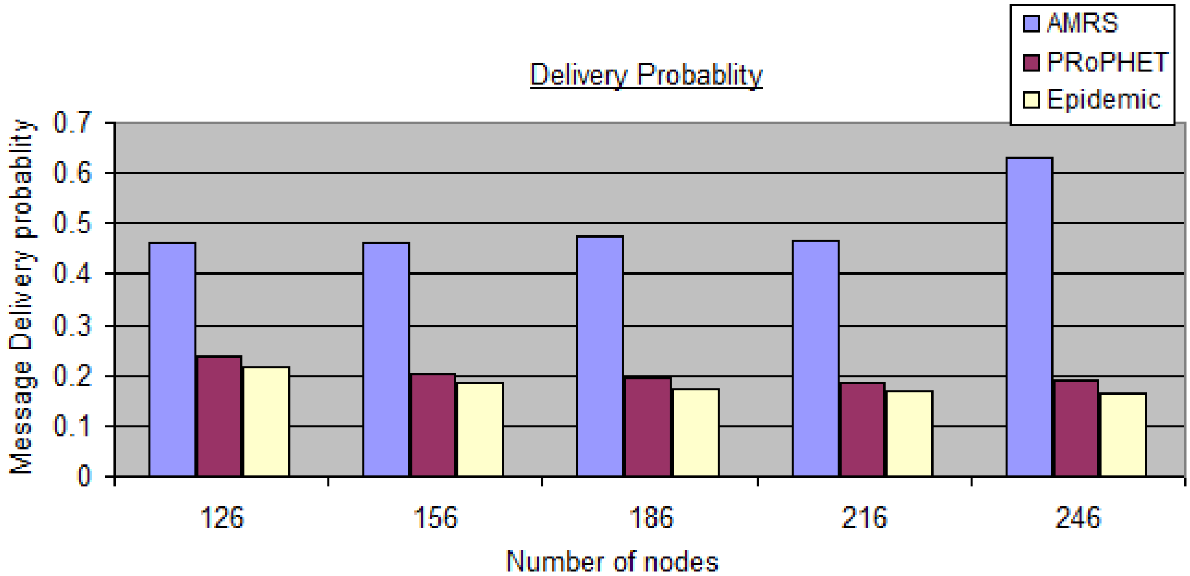


**Figure 7.** Delivery probability by varying number of nodes.

protocol has dropped the high number of massages. The reason is that the Epidemic protocol blindly floods the message copies. While, under limited buffer space the encountering terminals could not accommodate all incoming traffic.

The PRoPHET Protocol controls the replication of messages; therefore has dropped less messages than Epidemic. The AMRS reduces the message drop as compared to Epidemic and PRoPHET routing protocol. The reason for this is that, the Mean Threshold (MTH) moves the traffic to the less congested part of the network.

Figure 7 depicts the result of delivery ratio for AMRS, PRoPHET and Epidemic routing protocols with respect to the number of nodes. We can see that the Epidemic protocol delivered the least number of messages. The reason is that, Epidemic protocol does not control the replication of messages as a result produce congestion on the network. Added together, protocol also overcomes this problem by dropping its carried messages.

Therefore, high number of messages dropped before finding the destination. The PRoPHET protocol delivers more messages than Epidemic protocol. The reason is that PRoPHET protocol controls the replication of messages as well as forwards the message by computing the delivery probability.

The proposed AMPR routing protocol double the delivery of messages for all simulation instances. However, at 246, the protocol has delivered maximum number of messages. The reason is that AMRS does not generate and forwards the copy of a small size message. This in turn, minimizes congestion, less number of drops and increase the message stay time in the buffer, which results in high delivery probability.

***Scenario 2: Impact of varying buffer size on routing protocols***

Figure 8 maps the results of AMRS, PRoPHET and Epidemic routing protocols in terms of message relays. We can observe that, as we increase the storage capacity such as 4 M, 5 M, 6 M, existing Epidemic and PRoPHET Protocol has increased the message relays. This is because message relay depends on the storage capacity of encounter node.

The proposed (AMRS) routing strategy has maintained a consistent number of relays. The reason is that AMRS relays the message copy by computing the MTH and thus does not depend on the buffer size.

Figure 9 shows the result of message drop for existing PRoPHET, Epidemic and proposed AMRS. We can see that for all simulation instances Epidemic protocol has high drop ratio. Moreover, as the storage capacity rises such as 4 M, 5 M, 6 M the drop also increases. The reason is that, Epidemic protocol relays high volume of messages that results in congestion. Thus, each node iteratively drops the previously stored messages to overcome the congestion and continue the flow of network traffic. The PRoPHET routing protocol controls the replication of message thus drop less messages than Epidemic. However, the proposed AMRS has dropped least amount of messages. The reason is that, the proposed strategy (AMRS) has minimum number of message relays.

Figure 10 depicts the results of existing PRoPHET, Epidemic and proposed AMRS routing protocols in terms of delivery probability. We can see that with increase in the buffer size for example 3 M, 4 M, 5 M, and 6 M all routers has performed better. Moreover, AMRS routing

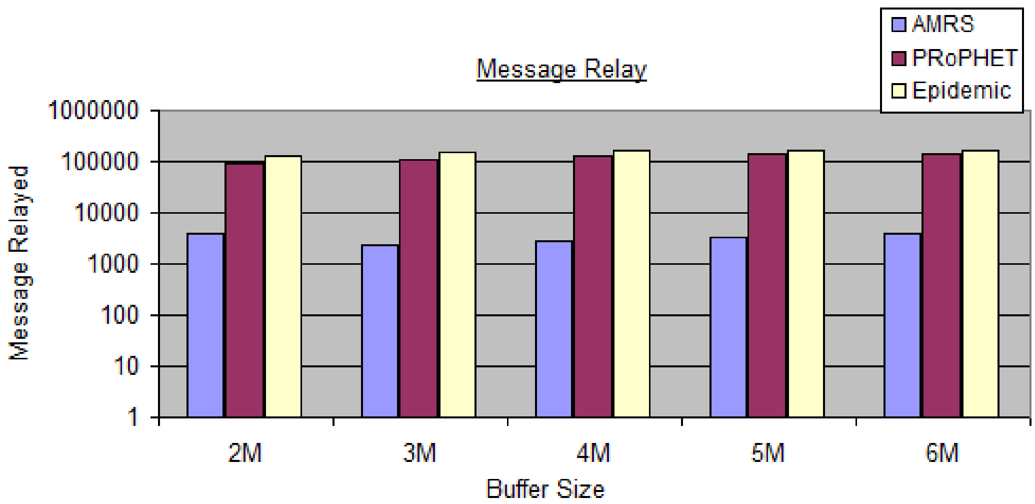


**Figure 8.** Message relay by varying buffer size.

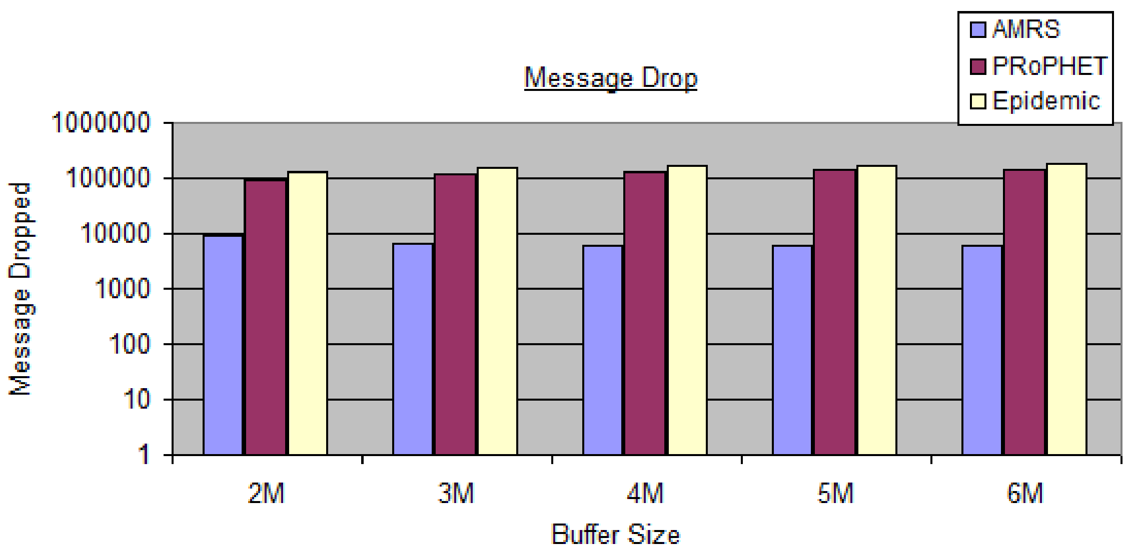


**Figure 9.** Message drop by varying buffer size.

protocol has reciprocated well for all simulation instances and delivers messages two times higher than the existing strategies. The reason is that the delivery of message depends on the buffer time of the message; a message with high buffer stay time is more likely to be delivered to its destination.

***Scenario 3: Impact of varying message size on routing protocols***

Figure 11 represents the results of number of message relays for existing PRoPHET, Epidemic and proposed AMRS routing protocols by varying the  sizes. We can evict that at the range of small size messages for instance [100 K – 600 K], [200 K – 700 K] both Epidemic and PRoPHET has the maximum number of transmissions. The reason is that the small size messages can float around the network more quickly. In addition, we can see that at large size messages for example [300 K -800 K], [400 K – 900 K] and [500 K – 1 MB] all routing protocols has reduced the message relays.

The proposed AMRS does not depend on the range of message size. We can observe that for all simulation instances the proposed protocol has shown a constant number of message relays.

Figure 12 maps the finding of message drop by varying

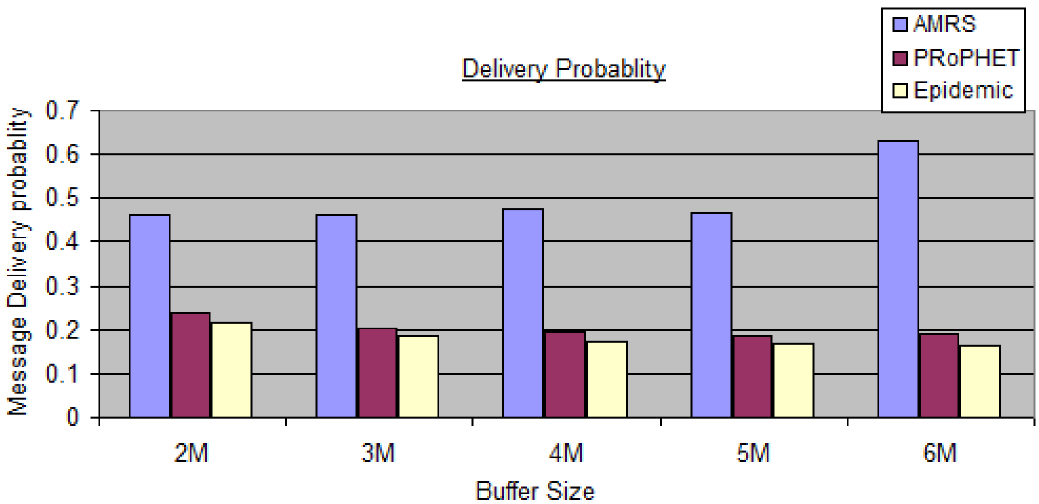


**Figure 10.** Delivery probability by varying buffer size.

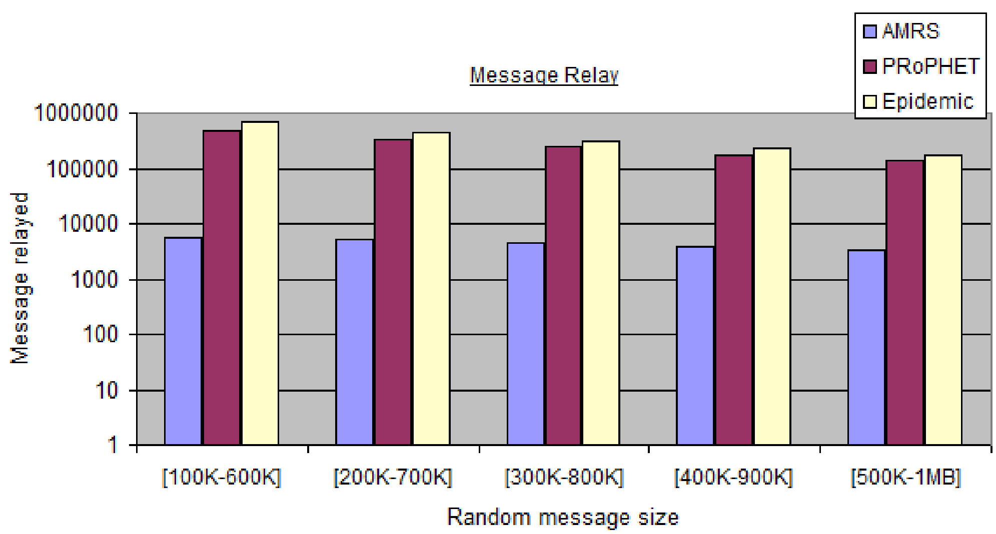


**Figure 11.** Message relay by message size.

the size of messages. We can observe that at small range of message sizes such as [100 K – 400 K], [200 K – 700 K], [300 K – 800 K] both Epidemic and PRoPHET has higher number of message drops. The reason is that small size messages tends to infect the network more rapidly and produces the congestion.

Thus, nodes begin to drop the previously stored messages. In contrast, at large range for example [400 K – 900 K], [500 K – 1 MB] fewer messages were dropped. However, in case of AMRS, each node tends to carry the small size messages.

Figure 13 conclude the ratio of successful transmission of messages to their destinations under the variable size of messages. In case of existing Epidemic and PRoPHET routing protocols, when the message range is small in size for example [100 K - 600K], [200 K – 700 K] more messages reaches the destination. The reason is that the small size messages are likely to find destination more quickly. However, the proposed routing protocol AMRS has delivered high number of messages to their destinations. The protocol has shown better results when there is high congestion in the network and message size is very small.

## Conclusion

In this paper, we propose a new routing strategy known as adaptive message-size forwarding strategy (AMRS). According to the proposed strategy, a node generates

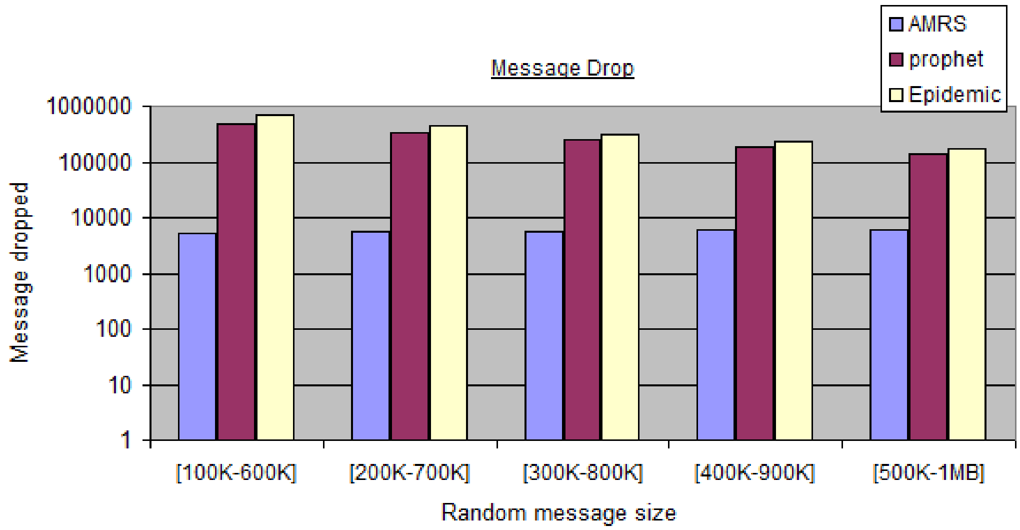


**Figure 12.** Message drop by random message size.

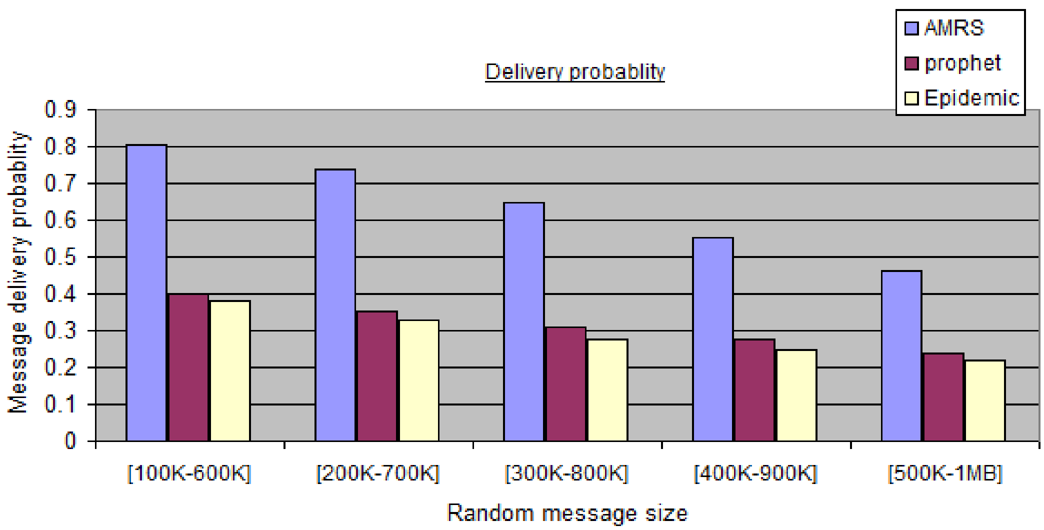


**Figure 13.** Delivery probability by random message size.

and handover the copy of message to neighboring nodes by using a metric named as Mean Threshold (MTH). We compared the performance of AMRS with Epidemic and PRoPHET Protocols. The proposed strategy has maximized the delivery probability while it controls the message drops and number of transmissions.

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