Location-aware hybrid microscopic routing scheme for mobile opportunistic network

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ABSTRACT

Mobile opportunistic networks (MON) have been used for provisioning delay-tolerant applications. In MON the device communicates with each other with no assured end-to-end paths from source and destination because of frequent topology changes, node mobility, low density, and intermittent connectivity. In MON the device battery drains very fast for performing activities such as scanning, transceiver, and other computational processes, impacting the overall performance thus, designing energy-efficient routing is a challenging task. The routing employs a store-carry-and-forward mechanism for packet communication, where the packet is composed of time-to-live (TTL) and is kept in buffer till the opportunity arises. In improving delivery ratio message replication has been adopted; however, induces high network congestion. Here we present a location-aware hybrid microscopic routing (LAHMR) scheme for MON. The LAHMR provides an effective packet transmission scheme with location awareness and high reliability by limiting unnecessary packets being circulated in the network. Experiment outcome shows the LAHMR scheme achieves a much better delivery ratio with less delay, and also reduces the number of a forwarder for transmitting a packet, aiding in the reduction of network overhead concerning recent routing method namely the social-aware reliable forwarding (SCARF) technique.

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1. INTRODUCTION

Opportunistic networks (OppNets) have been emphasized in modern delay-tolerant communication environments such as deep space exploration, underwater communication, smart transport and battlefield [1]–[3]. The network is characterized by the following constraint such as high error rate, intermittent connectivity, high delays, lack-of-end to end connection, short transmission range, the limited power of devices, low density, and highly dynamic; thus, providing end-to-end connection among source and destination is extremely very difficult and not guaranteed. The opponents are used for providing reliable communication where there doesn't exist fixed end-to-end connectivity among source to destination devices [4]–[8]. The foremost challenge of mobile opportunistic network (MON) is designing routing and message transmission between the source device and destination device [9]. In OppNets the device transmits messages through a short-range communication interface wirelessly such as Bluetooth, IEEE 802.11 and Wi-Fi. The device forwards the message emphasizing store–carry–forward method [10], [11]. Generally, every device stores the message in its respective buffer, and when it encounters another device, it forwards the replicated message to the encountered device in an opportunistic manner [12], assuming the message will be carried forward toward the destination. Most of the existing models have routed packets to only destination nodes such a type of routing is called unicasting. However, such routing mechanisms are efficient for provisioning delay-tolerant applications [13]. Thus, location-aware routing mechanisms have been emphasized; where the message is routed to a specific coordinate rather than the selected device, and later it is flooded to an entire device that resides in that location [14]–[17]. Recently, the number of routing mechanisms for transmitting messages toward destination have been presented [1]–[4]. However, considering OppNets [18]–[24] very limited work has been presented using microscopic information such as location awareness. Location-aware routing schemes aid in provisioning applications such as disaster management, smart intelligent transport and location-based warning.

2. LITERATURE SURVEY

This section surveys routing design modelled for the OppNets. Kuppusamy *et al.* [11] studied various recent routing protocols for OppNets and explored models and parameters used for validating models in terms of realism, comparability, and scalability. Zhang *et al.* [18] presented a node mobility scheme for OppNets. Establishes communication rules for transmitting data concerning node behaviour range segmentation techniques. To improve communication efficiency and reduce network overhead adopted a differential replication scheme. Further, modelled utility function using free motion degree scheme to select the reliable intermediate device for message relaying. Goudar and Batabyal [19] showed keeping a higher buffer size in mobile OppNets induce high network congestion and degrades system performance, especially when buffer size is full. Xiong *et al.* [20] presented a user interest based cooperative routing scheme for OppNets. Here for transmitting packets estimate node preference using a degree of matching strategy; the node with a higher value is given higher selectivity to a relay node. Zheng *et al.* [21] showed if bandwidth is limited and data to be communicated is significantly large, in such cases the delivery ratio can’t be guaranteed. They presented a prediction-based routing model for OppNets. Here the adjacent devices' forwarding capability is measured through the theory of matrix decomposition. A node with higher capability is selected for relaying packets; thus, improving packet transmission efficiency. Wu *et al.* [22] showed many groups might distribute packets only dependent on one or two devices. If any one of the nodes doesn’t possess enough buffers, may result in higher waiting time and buffer overflow. Using information from a neighbor the behavior of the respective device is predicted which is later used for communicating packets. Paper [23], the proposed reputation framework for provisioning service to vehicular adhoc networks. Here they employed an artificially intelligent system and machine learning technique. In precise, used Bayesian probabilistic method is used for studying the behaviour of newly joined nodes. Further, the K-means algorithm is employed for using the recommendation from another device even under the condition of unpredictable behaviour. Vegni *et al.* [24] presented probability-based routing method namely social-aware reliable forwarding technique for vehicular communications (SCARF). Here messages are transmitted to the node with high social activity and they theoretically showed its efficiency in terms of guaranteeing network dissemination with acceptable delay. Unlike previous studies [18]–[24], the proposed location-aware hybrid microscopic routing (LAHMR) scheme is composed of the following features: First, the location information of the device is predicted dynamically i.e., on-the-go, second, classifying destined cluster and establishing whether the coordinates of the present device is placed within it, third, designing buffer optimization scheme to bring good tradeoff between reliability and congestion control.

3. RESEARCH METHODOLOGY AND ITS SIGNIFICANCE

The LAHMR adopt a hybrid design using a two-stage mechanism. First, send the packets from the source device to the destined cluster (i.e., destination device) in an efficient manner. Second, send the packet to entire devices that reside within-cluster using the intelligent flooding method. Here all the packets are sent to particular coordinates by embedding location information into the packets. Here whenever a device obtains a packet, it compares its coordinate with packets' destined coordinates before forwarding it to another device. Thus, aiding in preserving the privacy of users. The main difference of the proposed LAHMR working model for the state-of-art routing method is described. In LAHMR, the location information of any device on MON is collected dynamically (i.e., on-the-go). Then coordinate information and packet endpoint coordinate information are used for identifying the destination node is within the destined cluster and a reliable and intelligent flooding method is used for distributing packets among all devices within the cluster. Finally, a buffer optimization scheme is presented for selecting the ideal relay device for carrying packets toward the destined cluster. The organization of the paper is, in section 4, a location-aware hybrid microscopic routing scheme is presented. In section 5, the performance achieved using LAHMR for the existing routing mechanism is discussed. In the last section, the research is concluded with a future research direction.

4. LOCATION-AWARE HYBRID MICROSCOPIC ROUTING SCHEME FOR MON

The architecture of the location-aware hybrid microscopic routing scheme is shown in Figure 1. First, this work establishes whether a node is within the destined cluster or not. Second, this work presents a two-stage LAHMR scheme. Third, discusses the buffer optimization scheme to improve routing efficiency.

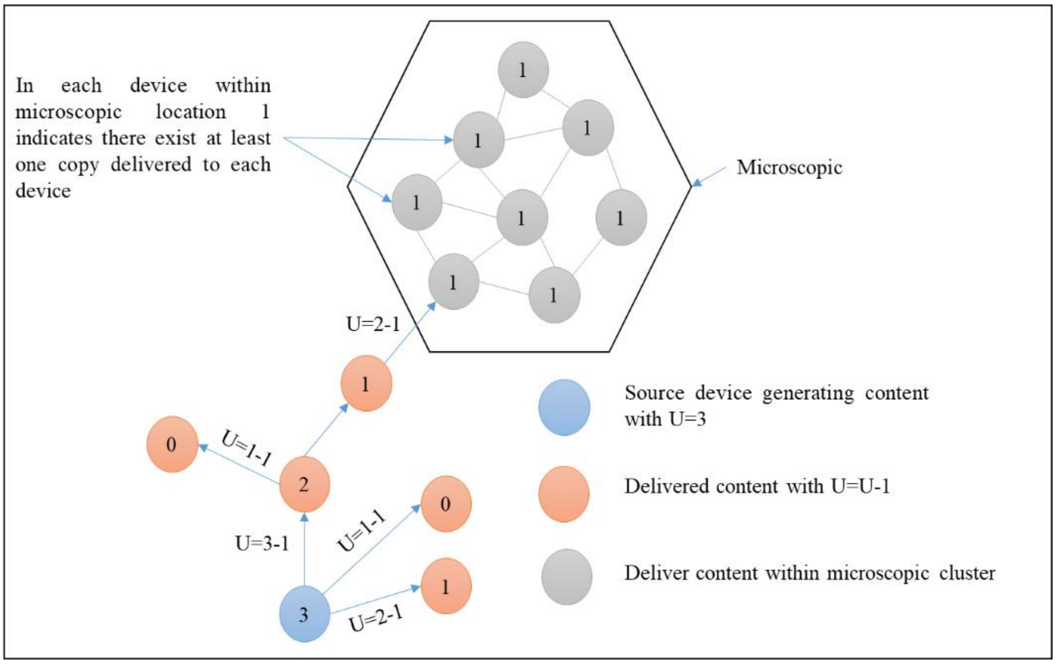

Figure 1. Location-aware hybrid microscopic routing scheme for opportunistic network

Figure 1 describes the working illustration of LAHMR. The blue node indicates the source node generating content with token U set to 3. Setting the value to 3 to assure the content will be transmitted to the destined cluster with 3 forwarders; failing which the content will be dropped from the network. The blue color nodes once meet its first neighbor node i.e., in orange and transmit the content to the orange node with token U set to 2 (i.e., $U = U - 1$. As the red node encounters every orange node it transmits the content by reducing the token size till U becomes 0. The U reaching 0 indicates the node doesn't reside within the destined cluster and content is no more forwarded and it is dropped. However, if the destination node obtains the content inside the destined cluster, it immediately employs an intelligent flooding mechanism inside the cluster region. Later, the node in grey color sends the content to all its neighbors inside the cluster. A more detailed design of different phases involved in LAHMR.

4.1. Prediction of the destination node is within the destined cluster

In this scheme, packets are transmitted to the respective cluster and every device that is inside the cluster will receive the packets; thus, it is important to outline clusters within the OppNets and packets must be sent to the outlined clusters/locations. Thus, each device that resides within the region must obtain the packets. The cluster describes a set of devices that is present in the same location and can be described as the receiver of particular packets. The destined device must be residing within the map/network. In the LAHMR scheme, the cluster is described as a set of polygons rather than a square or circles considering a two-dimensional (2D) network. In LAHMR the device randomly transmits the packet to the respective clusters; thus, offers good reliability and reduce overhead by minimizing unwanted packet transmission to many nodes. Thus, LAHMR is much more efficient than circular-based cluster definition. In circular-based cluster definition when the node is residing far away from the centre, the radius must be increased as a result of inducing bandwidth wastage. In LAHMR the device can select the coordinates for communicating its packets; thus, the cluster information acts as a delivery address, as result, eliminating the need of predefining the clusters. The LAHMR must perform the aforementioned task for each received message and also should be done with high reliability. The step involved to establish a node resides within the cluster or not is shown in Algorithm 1.

Algorithm 1. Prediction of the destination node is within the destined cluster

```
1. Start
2. ∀ collected packets with the respective device do
3. Obtain the device coordinate (x,y)
4. Compute vertical segment of network with x-coordinate of respective devices positions
5. Establish intersected array among the vertical segment and the receiver's cluster in 2D MON.
6. ∀ intersected position within the array do
7. If y-coordinate of intersected location is lesser when compared with y-coordinate of destinations position then
8. Eliminate it within the array
9. End if
10. End ∀
11. If the intersected number is not odd then
12. get False (i.e., the device is not the receiver of corresponding data and is outside the cluster)
13. Else
14. get True (i.e., the current device is the receiver of corresponding data)
15. End if
16. End for
17. Stop
```

4.2. Location-aware hybrid microscopic routing scheme

In LAHMR, using Algorithm 1, the geographical location information of the different devices in the network is available; thus, can be emphasized to establish whether a node resides within the cluster or not. In LAHMR the location information is used without sharing it with another neighboring device for routing decision making. The LAHMR is implemented as a two-stage routing scheme. In stage one, whenever a node meets other nodes, LAHMR executes the following constraint as first, establish if there are any replication tokens U leftover to allocate additional replication, second checks whether the present device is not going towards destined cluster, and third, checks whether the forthcoming device is going towards the destined cluster. If the aforementioned constraint is satisfied, LAHMR permits replication to distribute to an adjacent device. In LAHMR, the replication distribution of the message is given to the nodes that have high reliability. The step-by-step process of LAHMR is shown in Algorithm 2. In LAHMR, first, it establishes whether a replication token U is available for the distribution of more replicated content in OppNets. Thus, aid in better management/optimization of network overhead. In the second constraint, LAHMR establishes if the present device is suitable with the highly reliable intermediate node for forwarding the packets. This, constraint can be measured by checking whether a present device is moving in direction of the destined cluster. Algorithm 3 is used for establishing each device's moving direction in the MON. Here every device compares its present location information concerning the previous location using Algorithm 3 for establishing the moving direction. Furthermore, establishing direction towards the destined cluster is done using Algorithm 3 and Algorithm 4. If the present device is moving in direction of the destined cluster; then the node is considered to reliable carrier device; thus, no need of sending additional replication within the MON. Third, if the present device selected is not a reliable intermediate device, then we establish if the forthcoming device is an improved option. To do that the LAHMR scheme checks whether the forthcoming device is moving in direction of the destined cluster and must assure device location information is not shared for meeting privacy concerns. In the meeting, privacy concern location information of destined cluster information can be sent to the forthcoming device and inform the forthcoming device to carry out direction test in a remote manner. In this way, the forthcoming device can only know if the present device is moving in direction of destined packets. Thus, in the third constraint, the present device transmits packets towards the forthcoming device and desires if the forthcoming device is an ideal option for forwarding packets. Once the forthcoming device obtains destined packets, it checks whether it moves in direction of destined packets and reply Yes or No. If the reply is Yes, the source device sends a replication to the forthcoming device. In stage two of the LAHMR scheme, whenever a replication comes toward the destined cluster, the LAHMR scheme floods the packet to entire nodes that reside within the cluster intelligently. This is done because every device within the cluster is a receiver; thus, should obtain replication of packets. More detail of the intelligent flooding mechanism adopted is discussed in the next section.

4.3. Intelligent flooding mechanism for location-aware hybrid microscopic routing scheme

The proposed intelligent flooding mechanism offers the following benefits over standard epidemic-based routing models. Performs very a smaller number of transmissions in comparison with epidemic-based routing model under unknown environmental conditions. Even under high network congestion, generates significantly less contention. Offers a high delivery rate and is highly scalable considering different densities with less knowledge of network information. Let us consider the N device with communication radius L carryout selfdetermining mobility in a torus area of $\sqrt{O} \times \sqrt{O}$. The latencies for performing direct transmission are measured through exponentially distributed with mean: where δ and β are set empirically according to routing requirements. The anticipated latencies considering an optimal solution is described using (2). where H_n represent n^{th} harmonic number, which can be obtained using (3). The anticipated maximum latencies of intelligent flooding considering U token replication is constraint by (4). The above constraint is tight when $U \ll N$. It must be noted the energy overhead is tightly associated with the size of U; thus, we consider a reasonable assumption by considering latencies constraint as factor f times the optimal latencies $Lat_{opt}(f > 1)$. Generally, the network parameter is unknown, tuning U value dynamically is challenging; the U value can be tuned by estimating the number of nodes N required to carry out communication in OppNets. Let T_1 represent the time that a device meets other devices in the OppNets. Using (4) the T_1 can be measured using (5). Similarly, T_2 defines the time when two different device meets, the anticipated outcome of T_2 is measured using (6). Removing Lat_{dt} from equations, the N can be computed: Using (7) the value of N can be determined for tuning the replication parameter U.

$$Lat_{dt} = \delta O \left(\beta \log O - \frac{2^{L+1} - L - 2}{2^L - 1}\right) \tag{1}$$

$$Lat_{opt} = \frac{H_{N-1}}{N-1} Lat_{dt} \tag{2}$$

$$H_n = \sum_{j=1}^{n} \frac{1}{j} = \ominus\ (\log n) \tag{3}$$

$$Lat_{IF} \leq (H_{N-1} - H_{N-U}) Lat_{dt} + \frac{N-U}{N-1} \frac{Lat_{dt}}{U} \tag{4}$$

$$T_1 = \frac{Lat_{dt}}{(N-1)} \tag{5}$$

$$T_2 = Lat_{dt} \left(\frac{1}{(N-1)} \frac{1}{(N-2)}\right) \tag{6}$$

$$N = \frac{2T_2 - 3T_1}{T_2 - 2T_1} \tag{7}$$

Algorithm 2. LAHMR Scheme Algorithm 3. Pathfinder for microscopic routing MON

1. Start
2. ∀ interaction among two devices within the network **do**
3. One device becomes the transmitter T_1 and other becomes the receiver T_2 **Input.** Two coordinate points concerning x and y
4. If the device is the transmitter T_1 **then 1. Start**
5. Remove out of valid content from the buffer 2. $\boldsymbol{funcPath}(P(x,y), Q(x,y))$
6. Apply buffer optimization scheme 3. **If** $((x_p, x_q) \wedge (y_p, y_q))$ **then**
7. $X \leftarrow T_1$'s present coordinates 4. **Get** static location
8. $Y \leftarrow T_1$'s preceding coordinates 5. **Else if** $(y_q > y_p)$ **then**
9. T_1 path establish← $funcPathEstablish(Y, X)$ using Algorithm 3 6. **If** $(x_q < x_p)$ **then**
10. ∀ content within the buffer **do 7. Get** NW
11. If the content is already present within T_2 buffer **then 8. Else**
12. Move on to the next content present within the ∀loop 9. **Get** NE
13. End if 10. End if
14. If $(U > 0)$ **then 11. Else if** $(y_q < y_p)$ **then**
15. $U \leftarrow U - 1$ 12. **If** $(x_q < x_p)$ **then**
16. $V \leftarrow funcClusterLocation(MsgRecvCluster)$ use Algorithm 4 13. **Get** SW
17. $MsgPath \leftarrow funcPathEstablish(X, V)$ use Algorithm 3 14. **Else**
18. If $(T_1Path \neq MsgPath)$ **then 15. Get** SE
19 send the MsgPath to T_2 and waits for the reply 16. **End if**
20. Outcome←reply 17. **End if**
21. If (Outcome= 1) Then 18. **End** $funcPath$
22. send a replicated content to T_2 19. **Stop**
23. End if
24. End if Algorithm 4. Cluster location
25. Else if $(U = 0)$ **then Input.** Cluster object
26. If T_1 is within the receiver cluster (see algorithm 1) **then 1. Start**
27. Send a replicated content to T_2 2. $funcClusterLocation(cluster\ x)$
28. End if 3. ∀ vertices of cluster x **do**
29. End if 4. $x_a \leftarrow avg(x_{vtx\,1}, x_{vtx\,2}, \dots, x_{vtx\,n})$
30. End ∀ **5.** $y_a \leftarrow avg(y_{vtx\,1}, y_{vtx\,2}, \dots, y_{vtx\,n})$

31. **Else if** the device is the receiver T_2 **then 6. End** ∀
32. $X \leftarrow T_2$'s present coordinates 7. **Get** $ClusterLocation(x_a, y_b)$
33. $Y \leftarrow T_2$'s preceding coordinates 8. **End** $funcClusterLocation$
34. T_2 Path← $funcPath(Y, X)$ use algorithm 3 9. **Stop**
35. ∀ received content **does**
36. **If** $(T_2Path = MsgPath)$ **then**
37. **Get** reply to $T_1 \leftarrow 1$
38. **Else if**
39. **Get** reply to $T_1 \leftarrow 0$
40. **End if**
41. **End** ∀
42. ∀ received content **do**
43. **If** T_2 is within the receiver cluster (see algorithm 1) **then**
44. Transmit the content to the application layer
45. Keep a replicated content into the buffer
46. $U \leftarrow 0$
47. **Else if** T_2 is outside the receiver cluster (see algorithm 1) **then**
48. Keep content into the buffer
49. $U \leftarrow U - 1$
50. **End if**
51. **End** ∀
52. **End if**
53. Change scenario (transmitter T_1 and receiver T_2) and
return to **step 4** at least once
54. **End** ∀
55. **Stop**

4.3. Buffer optimization scheme

Algorithm 2 is composed of a buffer optimization scheme. There is a circumstance where user prioritizes their message considering limited buffer size and bandwidth availability. Thus, an effective buffer optimization scheme is required. Let consider for any given data D at device t, the TTL_D^t defines the maximum time the data will be kept in the buffer of the respective device after it arrives in its buffer until it will be removed from the buffer where TTL_D represent the maximum time-to-live (TTL) of respective data D and e_D^t represent session instance when data arrives in any random device t. The anticipated remaining TTL aid in modelling the meantime where data will be in buffer or it will be dropped can be defined (9). Here we employed minimum TTL based buffer optimization i.e., here the packets are forwarded to a remote device with the shortest TTL which is mathematically represented (10). Further, there is the case where two messages will have the same TTL; in such cases, we employed first come first serve based buffer optimization. The proposed location-aware hybrid microscopic routing scheme achieves much lesser delay and better delivery ratio using a smaller number of hop devices in comparison with the existing opportunistic routing scheme.

$$TTL_D^t = \max_e \{e: TTL_D - e_D^t\} \tag{8}$$

$$A[TTL] = \frac{1}{\alpha} \tag{9}$$

$$Min(TTL_D^t) \tag{10}$$

5. SIMULATION RESULTS AND ANALYSIS

This section presents the evaluation of the proposed LAHMR scheme over the existing SCARF scheme [24]. The LAHMR and SCARF scheme is validated using a real-time traffic environment, and both schemes are implemented using the one simulator [25]. This work used Helsinki synthetic traces for validating models. The nodes are placed randomly across the Helsinki city map by keeping the device size varied from 20 and 40 for validating the effect of densities. The simulated time is set to 12 hours and each vehicle moves at speed of 50 km/h on an average with random pause times ranging from 5 to 15 minutes. Further, every vehicle generates at least one message per day on a random basis. Delivery ratio, delivery delay, and several forwarding are metrics used for validating models. The main simulation parameter used are: network interface (IEEE 802.11p), transmission range (200 m), message size ([1, 2] MB), message generation rate (1,000 message per simulation), TTL (12 h) which are selected based on the SCARF method [24]. Delivery delay performance and delivery ratio performance evaluations under varied density are shown in Figures 2 and 3 respectively.

5.1. Scenario 1 considering varied device density

In this section, we varied the device size (i.e., 20 and 40) for measuring the performance of the proposed LAHMR scheme over the existing SCARF scheme. The TTL time is set to 12 hours and the device moves at speed of 50 km/h. The delivery delay outcomes achieved using LAHMR and SCARF scheme is shown in Figure 2. A message delivery delay reduction of 43.28% and 43.244% is achieved by LAHMR in comparison with SCARF when device size is equal to 20 and 40, respectively. The delivery ratio outcomes achieved using LAHMR and SCARF scheme is shown in Figure 3. A message delivery ratio improvement of 79.44% and 72.51% is achieved by LAHMR in comparison with SCARF when device size is equal to 20 and 40, respectively. The significant result achieved is due to the adoption of an intelligent flooding mechanism, buffer optimization, and using location awareness which assures unnecessary packet forwarding in the network.

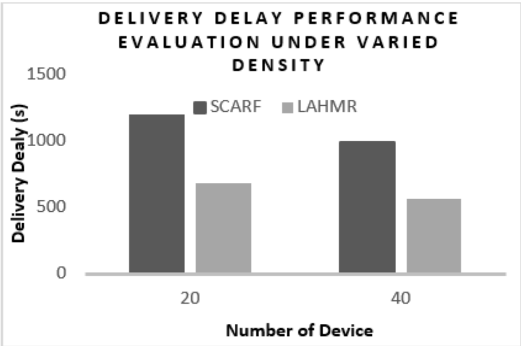

Figure 2. Delivery delay performance evaluation under varied density

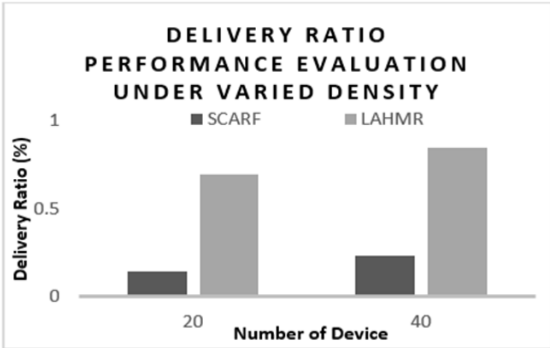

Figure 3. Delivery ratio performance evaluation under varied density

5.2. Scenario 2 for varied TTL size considering 40 devices

Here we varied TTL time from 6 to 48 hours with an interval of 12 hours considering 40 devices where the device moves at 50 km/h. Delivery delay performance and delivery ratio performance evaluations under varied TTL considering 20 devices are shown in Figure 4 and Figure 5 respectively. The delivery delay outcomes achieved using LAHMR and SCARF scheme under varied TTL considering 40 devices is shown in Figure 6. A message delivery delay reduction of 17.8% is achieved by LAHMR in comparison with SCARF when device size is equal to 40. The delivery ratio outcomes achieved using LAHMR and SCARF scheme under varied TTL considering 40 devices is shown in Figure 7. A message delivery ratio improvement of 69.51% is achieved by LAHMR in comparison with SCARF when device size is equal to 40. From the overall result achieved we can see the LAHMR is very efficient considering varied TTL under different device densities.

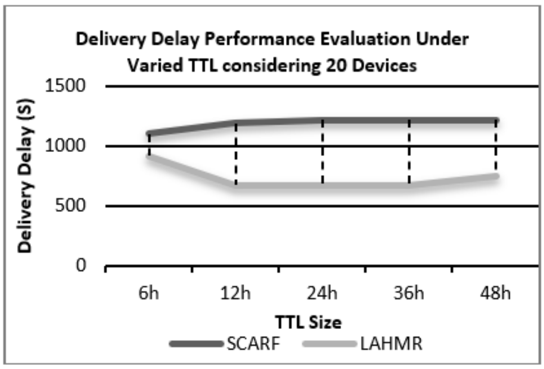

Figure 4. Delivery Delay performance evaluation under varied TTL considering 20 devices

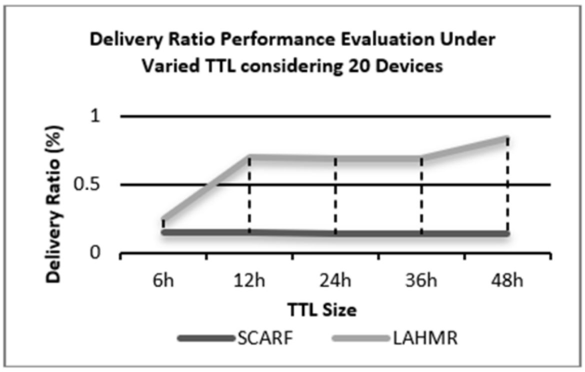

Figure 5. Delivery Ratio performance evaluation under varied TTL considering 20 devices

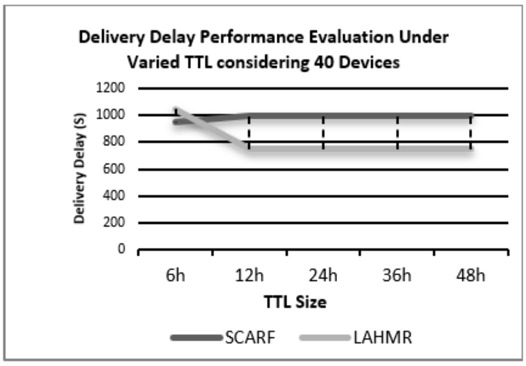

Figure 6. Delivery delay performance evaluation under varied TTL considering 40 devices

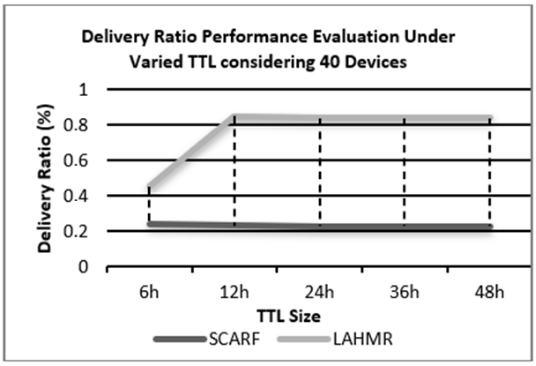

Figure 7. Delivery ratio performance evaluation under varied TTL considering 40 devices

6. CONCLUSION

In this work, we presented location-aware routing mechanisms namely LAHMR for MON. The LAHMR provide an effective mechanism of transmitting the packets to all device that resides within the destined cluster. The LAHMR limits the unnecessary packet being circulated in the network aiding in reducing congestion in the network; thereby improving latencies and delivery ratio performance. Simulation outcome shows the LAHMR performs much better than the SCARF-based routing model considering diverse parameters such as delivery ratio, delay, and the number of forwarders considering both varied TTL size and network densities. The future work considers studying the impact of buffer optimization overhead on the routing model. Alongside would consider emphasizing using the social parameter of neighboring nodes for reducing the multiple message circulation within the intracluster region. Incorporate social parameters of inter-cluster message transmission. Further, model fault tolerance mechanism for retrieving lost packet.

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