

A Storage Management Scheme and Reliable Routing in ICMNs

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Abstract: In intermittently connected mobile networks (ICMNs), an efficient storage management technique is required to utilize the available storage capacity efficiently and minimize the message overhead. Often, the existing routing protocols lack reliability in data transmission and hence recovering the data at the destination point is not easy. To overcome the issues of storage and reliability, a storage management scheme and reliable routing technique is proposed for intermittently connected mobile networks. In this technique, the data packet is initially split into Random Linear Combinations (RLCs) and transmits it to the destination via relay nodes. The destination obtains the complete data after gathering the RLCs. To enhance the storage management technique, the messages with longest delay and encounter times have been dropped. By simulation results it is shown that, the proposed technique minimizes the message overhead and maximizes the data reliability.

Key words: MANET • Random Linear Combinations • ICMN • Delay Tolerant Networks • Storage management

INTRODUCTION

Intermittently connected mobile networks are mobile ad hoc networks in which at any instance of time the path from source to destination rarely exists. The intermittent networks usually do not have supporting infrastructure for routing. As there will be frequent network disturbance and intermittent connections in ICMN, it is hard to have reliable end-to-end paths between mobile peers. Instead, the approach of delay tolerant networks (DTN), which builds upon carry and forward between mobile nodes, is widely applied to enable communication in such challenging mobile environments. Due to the intermittent connections in these networks, a node is allowed to store a message and wait until it finds an available link to the next hop that will be able to store the message. Such a process is repeated until the message reaches its destination.

The approaches for producing applications that can accept disruptions and high delays in network connectivity are essential for these opportunistic networks. Networks that include such applications are often termed as Intermittently Connected Mobile Network or Delay Tolerant Networks [1, 2, 5, 8].

Problem Identification: Hany Samuel *et al.* [4] proposed a super node system architecture, where a heterogeneous wireless access network is considered. The delay-tolerant network concept is taken here to resolve the problem of connection interruptions arise because of user mobility and long duration disconnections and ensure message delivery.

This approach provides connectivity over interconnected MANET but ignores the selection of the best possible node for carrying the message. Selecting the best possible utility plays a very important role in intermittently connected mobile networks. In the absence of feedback from the destination, the source cannot know for sure how many packets reached successfully to the destination.

The selection of message carriers or relay node should be done not only based on encounter times, but also the expected delivery delay. To effectively utilize the storage capacity and reduce the overhead of messages, an efficient storage management policy should be maintained. Also a DTN routing protocol, should ensure the reliability of the data. In order to meet the above objectives, a storage management scheme and reliable routing for ICMNs is proposed.

Literature Review: Hao Wen *et al.*, proposed a storage-friendly region-based protocol, RENA [2] for intermittently connected mobile networks. To utilize less storage space for obtaining the encounter history, routing tables are created using regional movement history in this protocol.

A Self Adaptive Routing Protocol (SARP) [3] is introduced by Ahmed Elwhishi *et al.*, for intermittently connected mobile networks. This multi-copy routing protocol uses the history of nodal encounters to select the carrier nodes to take the message to the destinations.

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A Hybrid DTN-MANET routing protocol [6] is proposed by John Whitbeck *et al.*, which uses both the DTN routing and MANET routing techniques. For disjoint groups of nodes the former routing is used and within each group the later is used. The authors also concluded that it highly adapts to the changes in the network connectivity patterns.

A two-level Back-Pressure with Source-Routing algorithm (BP+SR) [7] is proposed for intermittently connected networks by Jung Ryu *et al.* Two types of routing schemes are used in this proposal. Nodes of a network are grouped into clusters here. The traditional back-pressure routing scheme is used to route the intra-cluster traffic whereas the source routing technique is used to route the traffic from the source to the destination.

A Self Adaptive Contention Aware Routing Protocol is proposed by Elwhishi *et al.*, for intermittently connected mobile networks. A utility function is used here to take decisions on forwarding the messages to the other nodes towards destinations. This utility function works on the combined information of several parameters like buffer occupancy of nodes, wireless channel condition and encounter statistics.

Matthew K. Bromage *et al.* [9] introduced TAROT (Trajectory-Assisted Routing), a DTN routing framework that uses two algorithms namely the Path Detection and Route Decision Engine. The path library which is maintained by each node stores the list of paths that are followed commonly. The routing decisions like forwarding and making replicas of messages is taken care of by the Route Decision Engine.

To reduce the message overhead, Spyropoulos *et al.* proposed a single copy routing protocol [10] for this network where, only one copy of a message will be available throughout the network. Here, the number of message transmissions and other resource usage are much lesser than the other routing protocols, whereas its delivery ratio is very less.

Proposed Solution

Overview: In this paper, a storage management scheme and reliable routing protocol is proposed for intermittently connected mobile networks. Initially the nodes with maximum delivery probability are chosen as relay nodes. When the source wants to transmit the file of data packet towards the destination, it utilizes the reliable routing methodology. In this technique, the data packet is initially split into Random Linear Combinations (RLCs) and transmits it to the destination via relay nodes. The destination after receiving the RLCs sends the acknowledgement packet back to source which includes the degree of freedom (DoF). This indicates the number of RLC required for recovering the information packets. To enhance the storage management technique, the messages with longest delay and encounter times has been dropped.

Estimation of Delivery Probability: In this approach, the delivery probability is used for selecting the better relay node for forwarding the data packets. The delivery probability is based on the factors such as continuous encounter duration time, average staying time and expected delivery delay. The encountering time is defined as the time taken to arrive first within the transmission range R_{tx} . The estimation of delivery probability is shown below.

Let T_{enc} be the encountering time of the node

Let $E(T_{enc})$ be the expectation value of T_{enc}

Let k be the messages in the network

Let n_k be the total number of k message copies in the network

Let N be the number of nodes deployed in the network.

Let a_k be the number of nodes with empty cache. (i.e. nodes which have not yet stored message (k) copies).

The undelivered message probability (DP_k^{ud}) is given using the following Eq. (1).

$$DP_k^{uk} = \exp(-\delta n_k Z_k(TTL)) \quad (1)$$

where, $\delta = 1/E(T_{enc})$

The undelivered message probability is equal to the probability that the next T_{enc} with D greater than the remaining time to live Z_k (TTL) for message k . i.e. $\exp(-\delta Z_k(TTL))$.

The probability that message is being delivered in given using the following Eq. (2).

$$DP_k^d = \frac{a_k}{N-1} \quad (2)$$

The overall delivery probability that will be delivered is derived using the following equations.

$$DP_k = DP_k^d (1 - \exp(-\delta n_k Z_k(TTL))) + DP_k^d \quad (3)$$

$$DP_k = \left(1 - \frac{a_k}{N-1}\right) (1 - \exp(-\delta n_k Z_k(TTL))) + \frac{a_k}{N-1} \quad (4)$$

Based on the above equation, the following conditions are derived.

- When the TTL is higher, the staying time of the message copies in the relay nodes becomes long. This in turn increases the successful delivery rate.
- The long staying time causes storage spaces shortage and increased delivery delay. The storage spaces shortage leads to reduced success delivery rate.

Selection of Relay Nodes: The steps involved in the selection of relay nodes are as follows

Step 1: Each node N_i deployed in the network broadcast the hello message to its neighboring nodes.

N_i Hello Neighboring Nodes

The format of the Hello message is shown in the following Table 1.

The delivery probability in the above table is estimated in section 3.2.

Step 2: Based on the Hello Message, each N_i identifies itself and also maintains the neighbor nodes list (Nei_L).

Step 3: Based on the obtained values, following decision of relay node selection is made.

If DP_k is high

Then

N_i declares itself as relay nodes (RN_i).

End if

Table 1: Format of Hello Message

Node ID	Sequence Number	Delivery Probability
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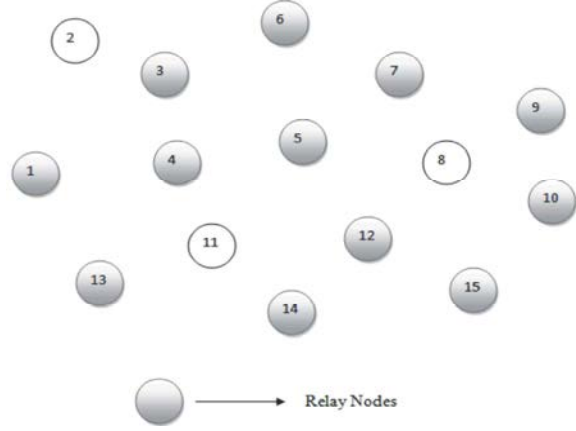


Fig. 1: Selection of Relay Nodes

Fig. 1 demonstrates the relay node selection. The nodes $N_1, N_3, N_4, N_5, N_6, N_7, N_9, N_{10}, N_{12}, N_{13}, N_{14}$ and N_{15} are selected as relay nodes (RN_i).

The proposed routing protocol makes use of the selected relay nodes for transmitting the data in two-hop forwarding fashion. In this technique, the source node forwards a message copy to the first relay node it encounters and then the encountered nodes keeps a copy of it until it meets the destination node of the message. This routing technique is described in section 3.4.

Reliable Routing: Let us consider the following assumptions.

Let S and D be the source and destination respectively

Let β_b represent the Random Linear Combinations (RLCs). ($b = 1, 2, \dots, H_i$)

Let A_r be the acknowledgement. (where $r = 0, 1, 2, \dots, i-1$)

Let T_b be the time at which β_b is sent by S .

After generating $H_i \beta_b$, source waits for two waiting time Tw_1 and Tw_2 .

Let Tw_1 be the waiting time until $H_i^{th} \beta_b$ spreads in the network.

Let Tw_2 be the waiting time of source until A_r reaches the source.

When the source wants to transmit the file of H_i data packets to the destination in reliable manner, the following routing protocol is executed. The steps involved in the reliable routing are shown below.

- In transmission phase I, when S wants to transmit the H_i data packets, it generates the $H_i \beta_b$.

- S transmits the newly generated β_b to the empty RN_i (selected using section 3.3) it encounters until $H_i \beta_b$ s has been sent.
- The exchange (or transmission) of β_b s among other RN_i is based on the following logic.
- When an RN_i with β_b copy encounters an empty RN_i at time $(T_b, T_b + Tw_1)$, the empty RN_i receives an β_b copy.
- Any RN_i , which became empty due to the dropping of β_b or A_r packets caused by increased delay or encounter time, is permitted to accept or transmit another β_b or A_r .
- When any two nodes, which have different β_b s encounters, then there is no exchange of information's.
- When D receives β_b , it updates the missing DoF_r and generates an A_r . The A_r includes the details of degree of freedom (DoF_r) which indicates the number of RLC required for recovering the H information packets.
- D with DoF_r state transmits A_r to all RN_i it encounters even if they are empty or filled apart from RN_i which contain A_r in prior.
- The exchange (or transmission) of A_r s among other RN_i is based on the following logic.
- When D encounters an empty RN_i , it does not generate A_r if it has not received any β_b in the current transmission phase.
- When RN_i with A_r encounters an empty RN_i , it transmits a copy of A_r to empty RN_i .
- When RN_i with A_r encounters another RN_i with A_r ($r' > r$), A_r is replaced by A_r . This replacement is performed as A_r with minimum DoF_r count offers latest and precise information to S.
- If A_0 reaches S, the existing β_b copies are replaced with A_0 . This reveals the files have completely been received by D and no more β_b s are required to arrive at D.
- D recovers the H_i information packets after receiving all the copies of β_b .

Fig. 2 demonstrates the reliable routing technique. The reliable paths [S- RN_3 - RN_6 - RN_7 - RN_9 -D], [S- RN_4 - RN_5 - RN_{12} -D] and [S- RN_{13} - RN_{14} - RN_{15} -D] are chosen for data transmission.

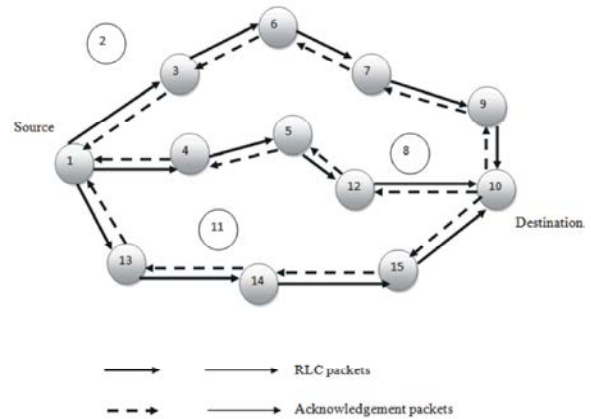


Fig. 2: Reliable Routing

Note:

- Each β_b after being transmitted by S is broadcasted for Tw_1 . After Tw_1 , it is not replicated to any further extent.
- The replication of the β_b s occurs only during the RLC-transmit phase. But the replication of the A_r s prolongs throughout the transmission phase.

Storage Management Technique: When RN_i storage is filled with the copies of β_b and A_r , it will be difficult for accepting the new transmission requests. This will further degrade the network stability. Hence, in order to enhance the network stability, the following storage management conditions are executed.

- During any transmission phase, the copy of β_b in any RN_i with longest delay and T_{enc} will be dropped.
- At the end of each transmission phase, RN_i drops the copy of β_b or A_r contained by them. This helps for attaining following two scenarios.
- RN_i becomes aware of data transfer completion of particular transmission phase.
i.e. In case the copy of β_b or A_r packets in RN_i are not dropped, then they will stay back in the network for long time.
- Other β_b or A_r s of same data flow in subsequent transmission phase in addition to other flows are accepted in RN_i due to storage availability.

Advantages of the Proposed Approach:

- The Storage capacity is utilized effectively and message overhead is decreased.

- Network stability is increased.
- The data is transmitted more reliably in reliable routes and even if any route fails, the data can be recovered successfully.

Simulation Results

Simulation Parameters: In this work, evaluate the Reliable Routing and A storage management scheme and reliable routing technique through NS-2 [13] simulation. Let as consider the bounded region of 1000 x 1000 square meter, in which the nodes using a uniform distribution. The number of nodes is varied as 50, 100, 150 and 200. The power levels of the nodes such that the communication scope of the nodes varies from 250 meters to 250 meters are assigned. In this simulation, the transmission channel capability of mobile hosts is set to the same numerical quantity: 2 Mbps. The distributed coordination function (DCF) of IEEE 802.11 for wireless LANs as the MAC layer protocol. The simulated traffic is Constant Bit Rate (CBR).

The following table summarizes the simulation parameters used.

No. of Nodes	50, 100, 150 and 200.
Area Size	1000 X 1000
Mac	802.11
Simulation Time	50 sec
Traffic Source	CBR
Packet Size	500
Transmission Range	250m
Rate	50Kb
Speed	5, 10, 15, 20 and 25m/s

Performance Metrics: In this paper, the performance of the proposed SMRR technique is compared with HPCR method. It is also evaluating mainly the performance according to the following metrics: Packet Delivery Ratio: It is the total number of packets received by the receiver during the transmission. Average end-to-end delay: The end-to-end-delay is averaged over all surviving data bundles from the origins to the ends. Packet Drop: It is the total number of packets dropped during the transmission.

RESULTS

Based on Nodes: In this work initial experiment vary the number of nodes as 50, 100, 150 and 200.

From Figure 3 shows that the delay of proposed SMRR is less than the existing HPCR protocol. From Figure 4 shows that the delivery ratio of the proposed SMRR is higher than the existing HPCR protocol.

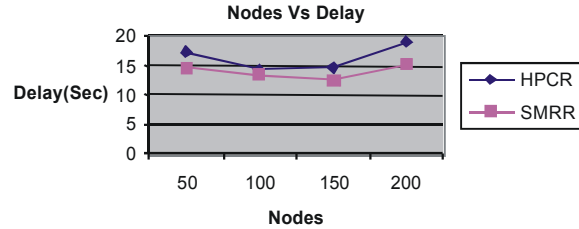


Fig. 3: Nodes Vs Delay

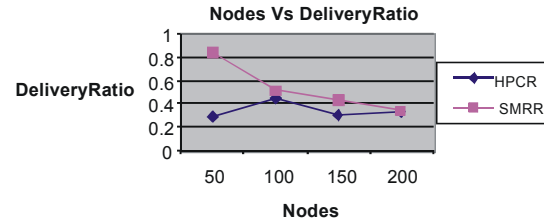


Fig. 4: Nodes Vs Delivery Ratio

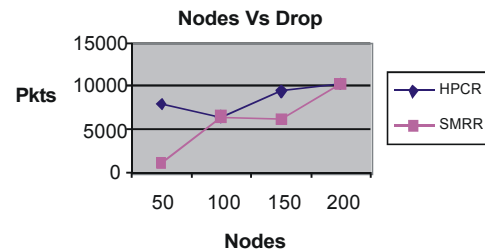


Fig. 5: Nodes Vs Drop

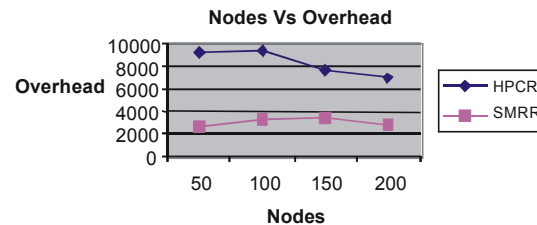


Fig. 6: Nodes Vs Overhead

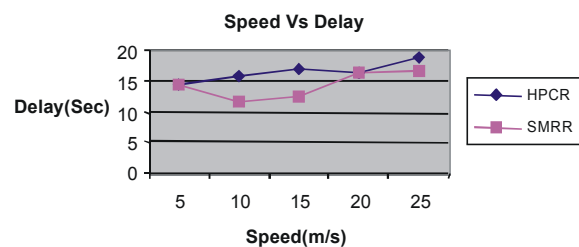


Fig. 7: Speed Vs Delay

From Figure 5 shows that the packet drop of the proposed SMRR is less than the existing HPCR protocol. From Figure 6 shows that the overhead of the proposed SMRR is less than the existing HPCR protocol.

Based on Speed: In second experiment, the system varies the nodes speed as 5, 10, 15, 20 and 25 m/s.

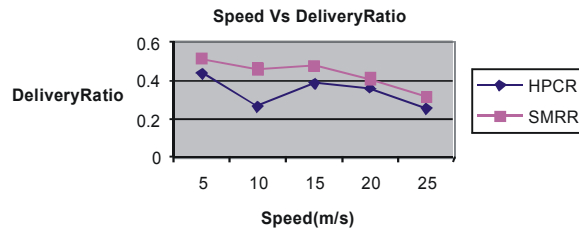


Fig. 8: Speed Vs Delivery Ratio

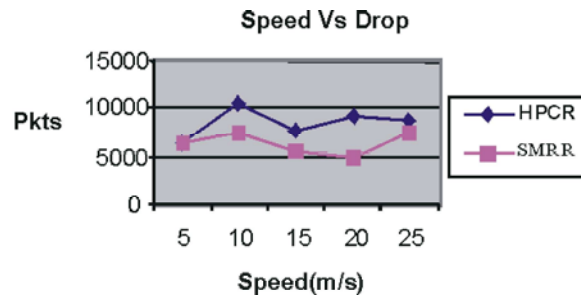


Fig. 9: Speed Vs Drop

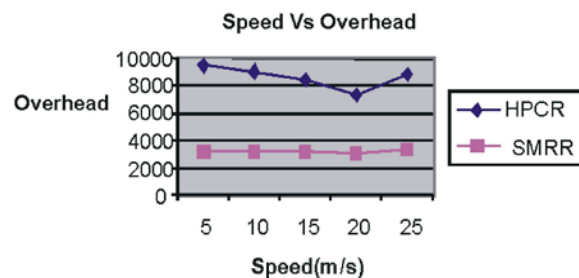


Fig. 10: Speed Vs Overhead

From Figure 7 shows that the delay of proposed SMRR is less than the existing HPCR protocol. From Figure 8 shows that the delivery ratio of the proposed SMRR is higher than the existing HPCR protocol. From Figure 9 shows that the packet drop of the proposed SMRR is less than the existing HPCR protocol. From Figure 10 shows that the overhead of the proposed SMRR is less than the existing HPCR protocol.

CONCLUSION

In this paper, a storage management scheme and reliable routing is proposed for intermittently connected mobile networks. Initially the nodes with maximum delivery probability are chosen as relay nodes. When the source wants to transmit the file of data packet towards the destination, it utilizes the reliable routing methodology. In this technique, the data packet is initially split into Random Linear Combinations (RLCs) and transmits it to the destination via relay nodes. The destination after receiving the RLCs sends the acknowledgement packet back to source which includes

the degree of freedom. This indicates the number of RLC required for recovering the information packets. To enhance the storage management technique, the messages with longest delay and encounter times has been dropped. By simulation results, it is shown that the proposed technique minimizes the message overhead and maximizes the data reliability.

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