Optimal Buffer Management Based Effective Routing In Delay Tolerant Network

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ABSTRACT

Delay Tolerant Networks are the kind of networks in which an end-to-end path between any source and destination pair may never exist. In DTN, nodes use store-carry-forward mechanism for data transmission. Currently the key method to solve information exchange in DTN is to select forwarding nodes effectively, Made the information deliver to the destination successfully within a short time and reduce resource overhead. At the same time, the load of selected nodes will be increased and the requirement to the buffer also increased, then the management of the buffer becomes particularly important. In our hybrid approach we have applied partially observed Markov Decision Process (POMDP) which predicts some properties of the optimal buffer management policy on the selective 2-phase spray and wait routing protocol which divides transmission phase into 2 parts and fulfils a data transmission in the light of condition of network.

Keyword : - *Delay Tolerant Network, Routing, Buffer Management, POMDP, Overhead, Delivery Probability.*

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1. INRODUCTION

The internet has accomplished a profound success in interconnecting communication devices across the globe. This is achieved by implementing a homogeneous set of communication protocols, called the TCP/IP protocol suite. Connectivity on the internet relies primarily on wired links, however new wireless technologies begin to appear. The wired links are continuously connected in end-to-end, low-delay paths between sources and destinations. They have low error rates and relatively symmetric bidirectional data rates. A DTN is a network designed to operate effectively over extreme distances such as those encountered in space communications or on an interplanetary scale. In such environment, long latency is inevitable. The DTNs are based on the concept of store-carry-and forward message switching. This means that all sent data are grouped into a single entity: the message. Each node has a persistent storage area. When it receives a message from another node, it stores this message until it succeeds to send it to the next node. In order to increase the probability of delivery, DTN routing mechanisms may require nodes in the network to store and carry messages in their local buffer, and for long periods of time, until new communication opportunities arise [2].

There are various routing protocols available for DTN. Generally, they differ in terms of the knowledge that they use in making routing decisions, and the number of replication they make [2]. Spray and wait routing protocol is representative of flooding based routing protocol for DTN. In DTN, nodes to which message has to be forwarded should be chosen carefully. This problem is addressed in the design of routing protocol. Another problem arises because of limited buffer space available at DTN nodes. Since DTN nodes work store and forward mechanism their buffer space gets filled up quickly. A situation can arise where each node buffer is full with messages from other nodes in the network. In such a situation, when a new encounter happens, either the node has to drop a message from its buffer or it may have to deny the sending node of a new message transfer. This problem is taken care by the buffer management policies.

In this paper, various DTN buffer management policies that have been introduced in the literature are surveyed. Each method is described in brief along with their advantages and disadvantages. The rest of the paper is organized as follows. Section 2 introduces various buffer management schemes. Section 3 describes proposed approach. Section 4 presents performance evaluation of proposed approach. The conclusion was given in Section 5.

2. LITERATURE SURVEY

Stylianos Dimitriou has proposed a system which implements a mechanism that aims to minimize packet transfers between buffers and persistent storage. The buffer consists of two queues; a low-delay traffic (LDT) queue and a high-delay traffic (HDT) queue.
Moving packets from buffer to storage and back, is allowed in following three cases:
1) From LDT buffer to persistent storage. Packets that can move in this direction are either new packets that belongs to a high-delay flow, or old packets that belong to a low-delay flow and the LDT buffer is full.
2) From persistent storage to HDT buffer, Packets that can move in this direction are packets that were previously in persistent storage and currently they have a communication opportunity.
3) From LDT buffer to HDT buffer upon packets arrival. Packets belonging to a high-delay flow, will move to HDT buffer if there is currently a communication opportunity with a next hop.
But problem with this system is to determine the sizes of LD and HDT queues. Review the WFQ scheme used to multiplex the outputs of the two queues. This will also define the bandwidth that each type of traffic will possess [5].

Behrooz Farkiani has proposed a novel buffer management policy which uses intermeeting time estimation based on time series analysis and kalman filters forecasting techniques. This policy does not need global and detailed information about mobility model and the network situation. This policy does not impose any message passing overhead. Its computation is not complex and it is not necessary to store history of meetings. The messages whose destination node will be observed in further estimated time relative to the destination of other messages, will be removed from the node's buffer. Problem with this system is, in order to improve the performance of prediction based policy (PBP), as it is not possible to estimate the next contact time of messages that their destination nodes have not been seen yet [3].

LRF is one of the latest works in buffer management policies. In this policy, each node stores the last forwarding time of each message. In times of message removal, the message which is not forwarded for the longest period of time will be removed. This policy does not remove the messages that have not been forwarded yet. If no message was forwarded by the node, FIFO mechanism will be used and the oldest message in the buffer will be removed. Utilizing LRF with routing protocols, in which there is only one copy of the message in the network, has an equal performance compared to FIFO [4].

With LPS policy, a node drops from its buffer the message with the lowest delivery probability, only if, a minimum number of replicas were previously disseminated in the network. This minimum number of replicas is defined by the spread threshold α, which is a parameter tuned according to the network characteristics such as connectivity degree and inter-contact time. The current number of replicas of a given message is estimated by using a counter added to the message's header. This counter is incremented by one whenever the message is replicated [4].

3. PROPOSED WORK

In the Selective 2-Phase Spray and Wait routing protocol [1] during a Spray phase two transmission phase will occur. During first transmission phase it will calculate the value of optional number of data transmission (Lopt) by considering amount of network traffic, buffer size of end device, data transmission range and total number of end devices in network. Ls is the default value of data copy that is decided in DTN system. If Ls is bigger or equal compared with Lopt, an end device generates data copy repeatedly Lopt times and transmit them in first transmission phase. If the data transmission is success in this phase, additional attempt to transmit data to destination does not necessary. Therefore, end device does not perform optional second transmission phase. If end device transmit its total data copy but it could not reach to destination, the end device performs second transmission phase and transmits additional data copy. It repeated α times. If Ls is smaller than Lopt, the Lopt is adjusted to equal value with Ls.

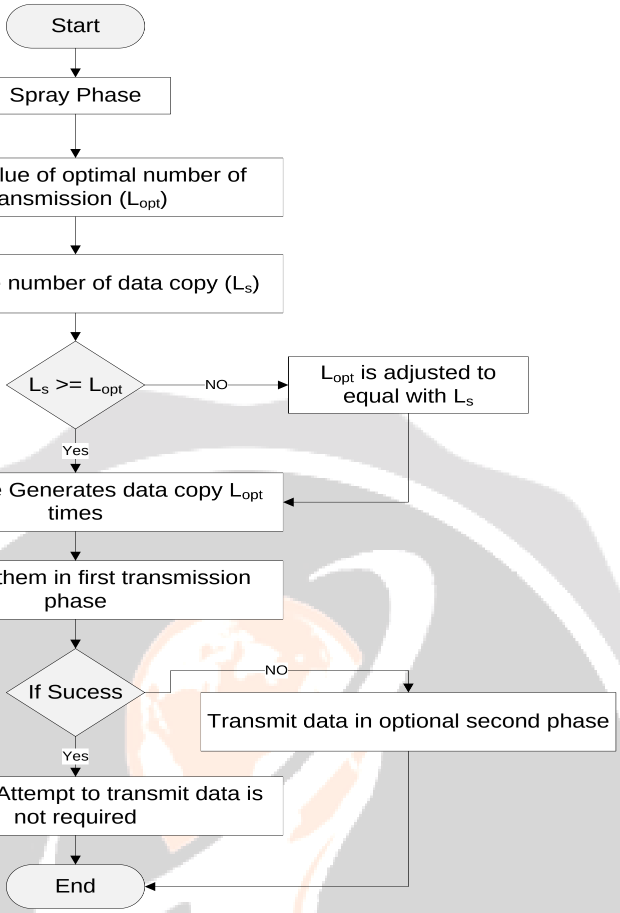

Fig -1: Working of Spray Phase

During a wait phase when node receives messages, we consider a set of nodes with full buffer, where nodes must decide what messages they can keep in a buffer and what message should be deleted. The choice of the message is determined by some factors that are State, Action, Belief State, Number of Transmission, The Instantaneous Reward.

1) State: It is assumed that each relay can store one message in its buffer. The state buffer occupancy can be denoted by $S\ (t)= \{0, 1\}$ where $s\ (t) = 0$ means that the node does not maintain cooperation (keeps its message and does not accept the new one) and $s\ (t) = 1$ means that the node maintains cooperation at time t (drops its message and accepts the new one).

2) Action: The relay can be inactive, active and keeping its own message, or active but it drops its message to accept a new one. Therefore, each relay has 3 actions:

A(t)= 0,stay inactive;
1,active and keep its own message;
2,active and drop its message to accept a new one.

3) Observation: When a node transmits a packet with custody transfer, it can observe the buffer occupancy of another node, thanks to the acknowledgment mechanism. The buffer A must decide whether to keep its message or transmit it to B, if A receives an ACK, that means the message is transmitted. Therefore, observation is obtained when both relays are in the same transmission range, and each relay can recognize the state of occupancy of the other through acknowledgment mechanism. Let θ be the observation outcome. We set $\theta = 1$ if the node has received an ACK otherwise $\theta = 0$.

4) Belief state: The state $S\ (t)$ of the buffer of a relay cannot be directly observed by other nodes. Let $\lambda(t)$ be the probability that the node maintains cooperation at time t. It is referred to as the belief of the relay immediately before the transition from $s(t)$ to $s(t + 1)$.

The update rule of the belief state is given by:

$\lambda(t + 1) = \Lambda(\lambda(t)|a(t),\ \theta(t))$

where $\Lambda(\lambda(t)|a(t),\ \theta(t)) =$

$$\begin{cases} \alpha & \text{if } a(t) = 2; \\ \beta & \text{if } [a(t) = 1,\ \theta(t) = 0]; \\ \alpha\lambda(t) + (1 - \lambda(t))\beta & \text{if } a(t) = 0. \end{cases} \qquad (1)$$

5) Number of transmission: A relay tries to transmit a packet to another relay and waits for its response. The choice is based on the number of transmissions NT. This number NT is incremented by 1 after the message is accepted by a new node.

The relay keeps the message which has the smallest value at the number of transmission. The message can be deleted if NT >= NTmax where NTmax is the number of maximum allowable transmissions.

$NT(t+1) =$

$$\begin{cases} nt & \text{if } a(t) = 0 \text{ or } [a(t) = 1,\ \theta(t) = 0]; \\ \min(nt + 1, NTmax - 1) & \text{if } [a(t) = 1,\ \theta(t) = 1]; \\ NTmx & \text{if } a(t) = 2. \end{cases} \qquad (2)$$

6) The instantaneous reward: It is comprised of two components: positive and negative. A positive component U representing the gain of the node when the transmission of the message is successful. A negative component corresponds to the consumed energy and the cost of the contact time.

The consumed energy of a node includes the following states:

- Off: this state has a lack of energy; the node can not establish connection with other nodes.
- Inactive: the node is inactive, but it can be detected by other nodes. The amount of energy expected per unit of time is negligible. It is denoted by e_{ina}.
- Scan: the node devotes energy to detect neighboring nodes, noted e_s.
- Transmission: energy is consumed during transmission of the message, noted e_t.

Then, the energy cost is given as a function of actions as:

$E(a(t)) =$

$$\begin{cases} e - e_{ina} & \text{if } a(t) = 0; \\ e - e_s - e_t & \text{if } a(t) = 1 \text{ or } [\theta = 0 \text{ or } \theta = 1]; \\ e - e_s & \text{if } a(t) = 2; \end{cases} \qquad (3)$$

where e is the initial energy of each node.

This update is repeated until $e < e_s + e_t$.

The instantaneous reward is also comprised of the cost of contact time; the contact time is the time interval for which two nodes can communicate when they are in the same transmission range. Each relay spends a cost γ to each contact.

Finally, the instantaneous reward is given by:

$r((\lambda, nt), a) =$

$$\begin{cases} -e_{ina} - \gamma & \text{if } a(t) = 0; \\ U - e_s - e_t - \gamma & \text{if } [a(t) = 1,\ \theta = 1]; \\ -e_s - e^t - \gamma & \text{if } [a(t) = 1,\ \theta = 0]; \\ -e_s - \gamma & \text{if } a(t) = 2. \end{cases} \qquad (4)$$

We look for an optimal policy μ that maximizes the rate of delivery of a message for a number of transmissions less than the threshold *NTmax*. Our aim is to maximize the expected average reward which is given by:

$$R(r,\mu) = \lim_{T\to\infty} \frac{1}{T} E\mu \left(\sum_{t=1}^{T} r((\lambda, NT), a, \theta) \right) \qquad (5)$$

The optimal policy is denoted by μ^*:

$$\mu^* = argmax\{R(r, \mu)\} \qquad (6)$$

$Qa(\lambda, NT)$ is assigned as the relative expected average reward and let $V(\lambda, NT)$ be the value function, defined as maximum expected average reward.

$V(\lambda, NT)$ is given by:

$$V(\lambda, NT) = max_a\ Qa(\lambda, NT) \qquad (7)$$

The optimal action at state (λ, NT) is:

$$a^* = argmaxQa(\lambda, NT) \qquad (8)$$

Next, we provide expressions for the relative reward $Qa(\lambda, NT)$ as a function of the chosen action a.

- Case a = 0: the relay decides to stay inactive.

$$Q_0(\lambda, NT) = -e_{ina} - \gamma + V(\Lambda(\lambda|0), nt) \quad (9)$$

- Case a = 1: the relay decides to sense and keep its own message.

$$Q_1(\lambda, NT) = -\gamma + (1-\lambda)[-e_s - e_t + V(\Lambda(\lambda|1, 0), nt)] + \lambda[U - e_s - e_t + V(\Lambda(\lambda|1, 1), nt + 1)] \quad (10)$$

- Case a = 2: the relay decides to sense and drop its message to accept a new one.

$$Q2(\lambda, NT) = -e_s - \gamma + V(\Lambda(\lambda|2)) \quad (11)$$

For every information state (λ, NT), a relay chooses to be active and try to transmit its message if $\lambda \geq \lambda^*$, where λ^* is the solution of the following equation.

$$\lambda^* = \max(S_1, S_2) \quad (12)$$

$$S_1(\lambda^*) = e_t - U + e_s - e_{ina} + V(\Lambda(\lambda|1, 0), nt) + V(\Lambda(\lambda|0), nt) / V(\Lambda(\lambda|1,1), nt + 1) - V(\Lambda(\lambda|1,0), nt) \quad (13)$$

$$S_2(\lambda^*) = - U - e_t + V(\Lambda(\lambda|2) - V(\Lambda(\lambda|1,0), nt) / V(\Lambda(\lambda|1,1), nt + 1) - V(\Lambda(\lambda|1,0), nt) \quad (14)$$

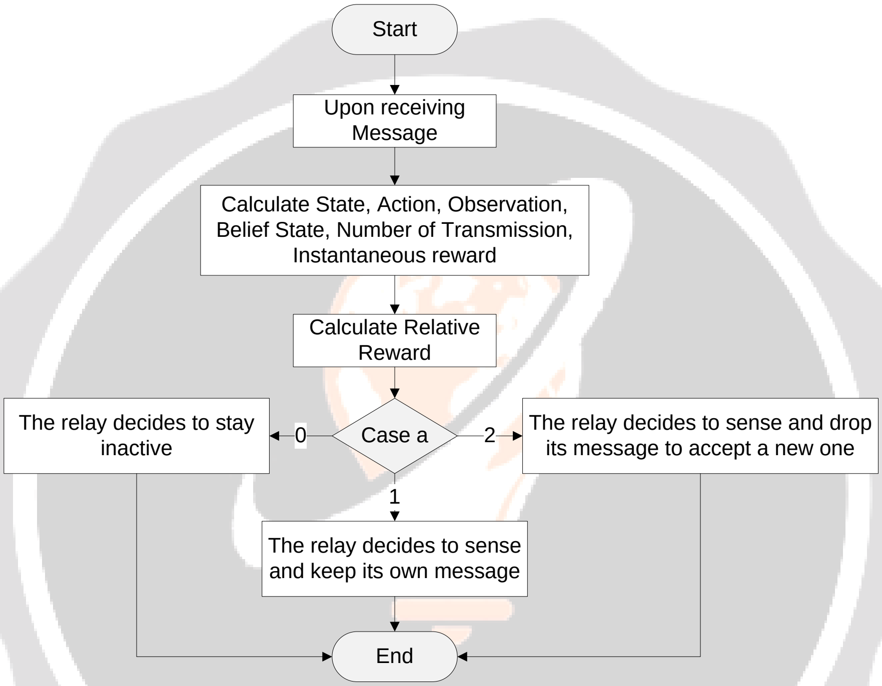

Fig -2: Working of Buffer Management Policy (POMDP)

.4. PERFORMANCE EVALUTION

We use ONE simulator [13] for performance evaluation of proposed technique. We set the simulation environment parameter as Table 1, and compared POMDP, Message Priority and FIFO buffer management techniques applying on selective 2-phase spray and wait routing protocol.

Table 1: Simulation Environment

Parameter	Value
Number of Nodes	126
Group Movement Model	Shortest path map based movement
Simulation time	43200 sec
Transmission Speed	250 kbytes/s
Transmission Range	10 meter
Message TTL	300 Minutes

Group Buffer Size	10 Mbytes
Number of Copies	10

Looking at the results in Fig 3, we can see that POMDP gives higher delivery probability than Message Priority and FIFO. We can calculate delivery probability with (15). In (15), N_D represents the number of messages that reaches to destination successfully, and N_C means the number of total messages generated in end devices.

$$Dprob = N_D/N_C \tag{15}$$

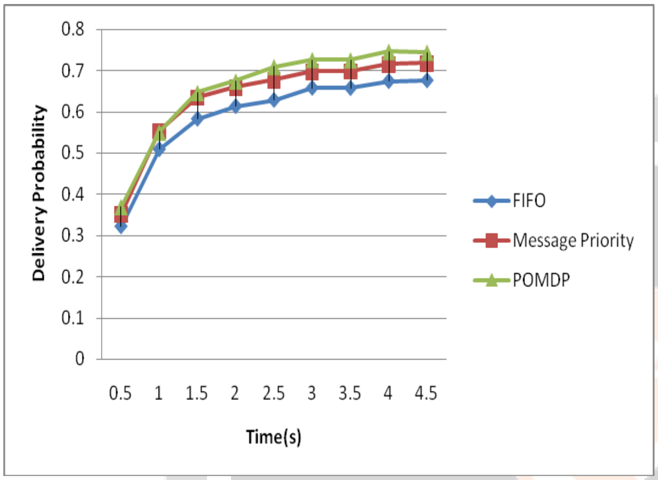

Fig 3: Delivery Probability

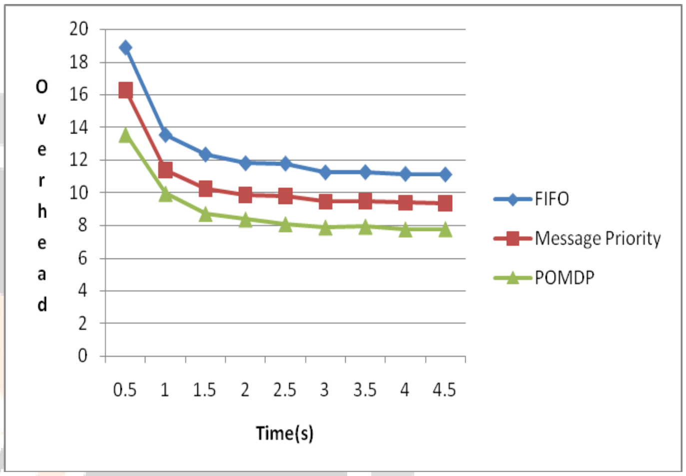

Fig 4: Overhead Ratio

Fig 4 shows network overhead of three alorithms. We can see that FIFO policy gives higher overhead ratio amongs three policy. While POMDP reduces overhead to 7.80. We can calculate network overhead with (16). In (16) N_R denotes the number of relayed message.

$$\text{Overhead Ratio} = (N_R - N_D) / N_D \tag{16}$$

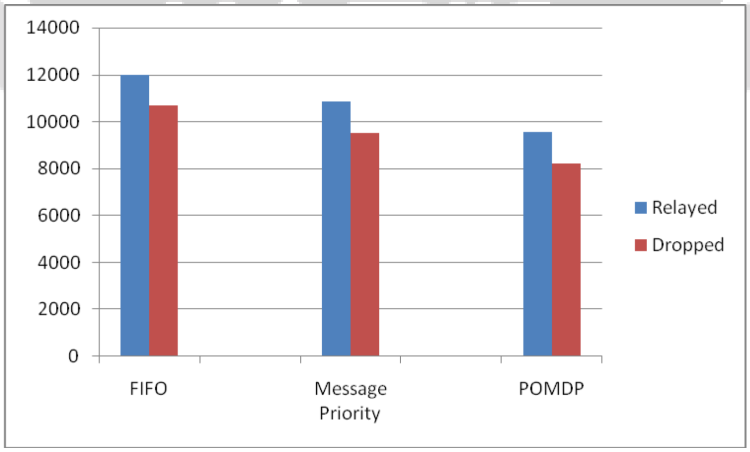

Fig 5: Relayed and dropped messages of FIFO, Message Priority and POMDP

Fig 5 shows the comparision of Relayed Messages and Dropped Messages. POMDP has less number of dropped messages as compare to Message Priority and FIFO buffer management policy.

5. CONCLUSION

To improve the performance of selective 2-phase spray and wait, we have applied POMDP buffer management policy which takes the number of transmissions of message and the level of cooperation of nodes in the network. This information will help the relay to know what strategies to adopt and what actions to take to maximize its average reward. We have compared the POMDP with Message Priority & FIFO Buffer management policy. Results show that POMDP gives higher Delivery rate than Message Priority and FIFO, also POMDP gives lower overhead ration than Message Priority and FIFO policy, also it is having less number of dropped messages.

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