Look A-Head Probabilistic energy-aware Routing Strategy For Delay Tolerant Network

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Abstract: *DTN probabilistic* routing protocols forwards message to a node that holds high predictability value to meet its destination. However, the message replication continues on the high probable peers while high probable peers continue to receive the transmissions from multiple sources. Such rampant transmissions drain out the battery and node can go to the dead state thus will not be able receive its destined messages. In this paper, we have proposed a Look-ahead probabilistic energy aware routing strategy for delay tolerant network. In proposed method, the message forwarding decision jointly observes the probability value and remaining energy of the current connected node. We have compared the performance of LaHEA with energy aware routing strategy. The proposed method has reduced the number of transmission, message drop and increase the delivery ratio.

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Key words: Delay tolerant network, Energy aware Routing protocol, Store-carry-forward, Resource scare

INTRODUCTION

Delay Tolerant Network [1] is a class of networking technology that intends to provide the communication in environments where end-to-end path is not stable or collapse shortly after it has been discovered. The message transmission is achieved via opportunistic contacts by adopting store-carry and forward paradigm. Accordingly, the node stores the incoming message in its buffer, carries it while moving and forward when comes in the transmission range of other contacts.

The objective of DTN routing protocols is to increase the delivery of the message by consuming the least volume of network resources. However, due to frequent disconnection and network partitions, the delivery like hood is raised by forwarding the multiple copies of the same message along dissimilar paths. One such strategy is called Epidemic routing [2] where each node executes the pairwise exchange of the message on all encountering nodes. This phenomenon increases the message transmissions and exhausts the network resources.

The probabilistic PRoPHET routing protocol[3] transmits the message by observing movement pattern in terms of encountering rate of nodes among each other. For instance, the node forwards the message to another node that holds high probability value to meet its destination than its own.

The PRoPHET protocol blocks the message transmission on peers holding minimum predictability value. However, the message diffusion from the least probable node continues on the higher probable connections. In this way, PRoPHET Protocol operates as the probabilistic version of Epidemic based dimension. Moreover, when a node is highly probable to meet several destinations then it is expected to receive the traffic flow from multiple sources. Since, energy is the most important resource that a node consumes to transmit and receive the messages. Hereby, with finite energy the receiver may consume its battery only in receiving the messages. As a result, the node can go to the dead state and will reduce the network throughput because the previously stored messages have lost their opportunity to be delivered.

In addition, most of the previous [4][5][6][20] work has focused on the consumption of node energy in comparison of the number of transmissions. Despite the message transmission provides a good view about measuring energy usage, the real-time traffic consists of heterogeneous data packets of random sizes. It is obvious that a message of large size requires more energy from the sender to send and receiver to receive. Therefore, the number of transmissions cannot provide a good insight about the energy measurement of the routing protocol.

The contribution to this paper is as follows:-

- We have proposed Look-Ahead probabilistic Energy Aware Routing strategy for delay tolerant network that operates under finite energy.
- We have proposed a software component called as energy manager that operates on the top of the physical device, i.e. battery.
- We have proposed a new metric called as Estimated Energy (EE) that computes the energy consumption (transmit, receive) of nodes based on the message sizes.
- We have proposed energy aware transmission method that operates with Estimated Energy (EE)

and forward the message by observing the remaining energy of transmitter and receiver.

RELATED WORK

The DTN routing protocols can be bisected into (i) single copy and (ii) multi copy. In single copy protocols, the node forwards the unique copy of the message along a single path. Apart from reduced exhaustion of network resources, the single copy protocol suffers unbounded delivery delay. The multi copy routing protocols produce the replicas of each message copy and transmit it on all encountering nodes. As a result, the message has multiple paths to reach its destination at the cost of high usage of network resources. One such strategy is called as Epidemic routing [2] where the node performs the pair wise exchange of its carried messages for all on way encountering nodes. Despite, rapid delivery, the Epidemic protocol requires infinite energy.

In [7] Thrasyvoulos Spyropoulos proposed spray&wait routing strategy that controls the energy usage by allocated a quota to transmit 'n' number of messages copies. Some work [8][9] [10] has anticipated the variation of spraying algorithms.

In [3] A.Lindgren propose probabilistic routing strategy where each node forward the message to the node that holds high delivery predictability value then its own.

Sunil Srinivas et al. [11] proposed distributed proximity-based communication protocol by which the message is forwarded to the next hop on the basis of 'conditional residual' time metric. This metric uses the local knowledge of past contact to estimate remaining meeting time for pair of nodes. In Etienne C. R [12] proposed a forwarding strategy based on the previous history in terms of neighbor hood index. The neighbor hood index is determined by the frequent contact of nodes with each other Gao et al. [14] forward the message by exploiting the transit contact duration for shorter time periods and transit connectivity. The transit contact duration determine that how frequently nodes formulate a transit contact with each other. The transit contact is the connection between two or more then two nodes at a particular time instance.

Qaisar et al. in [21] proposed threshold based locking routing method and control the resource usage by using transmission and drop locks.

In [15] Ram Ramanathan et al.. proposed prioritized Epidemic routing strategy for limited bandwidth and buffer space. Each message is associated with a drop and transmission priority. The priorities are computed by using current cost to destination, cost from source to destination, message expiry and generation time.

The Burgess et al. proposed MaxProp [16] routing for environments where transmission duration and bandwidth is limited resource. The messages were associated with transmission and drop priorities based on its hop count.

In [4] Lu X and P Hui proposed energy efficient n-Epidemic routing strategy where the node forward the message only if it is surrounded by 'n' number of nodes.

The Eitan Altman optimized the energy usage by introducing the concept of throw boxes [5] that are stationary nodes equip with battery and storage capacity. The message forwarding was based on detecting the mobility of other nodes and predicting the cost and opportunity of each possible contact.

Anisi et al. in [20] proposed an efficient data gathering for sensor network. Qaisar et al.[19] proposed Connection Frequency Buffer Aware Routing protocol and control the transmission for curbing the transmissions on congested buffer. Similar strategies [17][18][22] have been used to control the resource usage by efficient buffer scheduling policies.

NETWORK MODEL

We assume 'N' nodes in the network. Each node is equipped with finite buffer space and energy. The transmission range is limited and message transmission is accomplished via opportunistically available contacts. In this paper, we consider only communication energy (transmission, receiving) and do not report the energy consumption of other sources such as computation or mobility.

THE PROPOSED ENERGY-AWARE PROBABILISTIC ROUTING STRATEGY

Table 01: Meaning of variables used in LaEAR

ymbol	Meaning
Msize	Message size
ΔET	Energy required to transmit
ΔER	Energy required to receive
E_{RD}	Energy required to receive destine messages
E_{LD}	Energy level to receive destine messages
E_{RT}	Energy to receive relay messages.
Q_{nj}	Queue of node nj
E_{JT}	Energy in jouls to transmit
E_{JR}	Energy in jouls to receive
P_{TH}	Predictability threshold

We can decrease the energy consumption by forwarding the message to a node only if it has high probability value to meet its destination. Despite, with improvisation of accurate forwarding, it is extremely important that the sender must examine the available energy of the receiver before the actual transmission. The reason is that if the receiver cannot forward the message due to lack of energy, than the transmission to such a node will not improve the network throughput.

In the proposed routing method, we have devised a probabilistic forwarding method that defines a predictability threshold (Path) i.e. a node receives a message only if it is highly probable to meet message destination than the predefined threshold. An energy estimation module is used to estimate the energy that a node needs to forward and receives a message. Finally, energy aware transmission module is used that forward the message by looking at remaining power at sender and receiver.

PROBABILISTIC FORWARDING MODULE

DTN flooding based protocols broadcast the message copies to all neighbors. Even though the message has multiple paths to reach destination, these transmissions quickly drain the node battery and overload the network resources including bandwidth and buffer space.

Principal 1: "The node ni will forward the message to nj only if the predictability value of nj is greater than the pre-defined threshold limit P_{TH}."

In the proposed method, we have device the probabilistic routing model as mentioned in [3]. However, despite forwarding the message to high probable nodes we have defined a probability threshold P_{TH}. Hence, a node forward the message only if the probability value of peer node is greater than PTH.

ENERGY ESTIMATION MODULE (EEM)

Most of the previous work has measured the number of transmission to compute the energy consumption. However, the network is poised of heterogeneous traffic of different sizes. For instance, the size of video audio application is more as compared to the simple text. In this way, large size messages required more energy to forward and receive. Therefore, number of transmissions cannot give an accurate insight into the energy used by the network nodes. The objective of Energy Consumption module is to compute the energy a node required forward or receive the message.

Principal 2:" The EEM computes the energy required to forward or receive a message based on its size "

In the proposed method, we have used a dynamic energy estimation model that computes the required energy to forward the message based on its size by using equation 1,2 respectively.

$$Mi(\Delta ET) = [Msize/512] * EJT \quad (1)$$
$$Mi(\Delta ER) = [Msize/512] * EJR \quad (2)$$

Where, ΔET, energy required to transmit message of size M_{size}. EJT , EJR is energy required to forward or receive the message of size 512Kb.

ENERGY AWARE TRANSMISSION MODULE

The eventual aim of a routing protocol is to deliver the message to their destinations and high delivery ratio shows the optimized use of network resources. Regardless of other issues, energy is the most influential resource that a node uses to receive the traffic flow and to forward its carried messages.

Generally, a node receives two types of messages (i) Messages that are destining towards itself (Destine messages) and (ii) Messages for which the node holds high predictability value to meet its destination (Relay messages). Hereby, if a node continuously receives the relay messages, then it can drain out its battery in rapid time and will not have any energy to receive the message destining towards it.

In this context, we have proposed an overlay on the top of hardware (actual battery) called as energy manager (EM) that virtually divides a node battery power into two parts (i) Energy to receive relay messages (ERR) and (ii) Energy to receive a message that are destined to itself (E_{DR}).

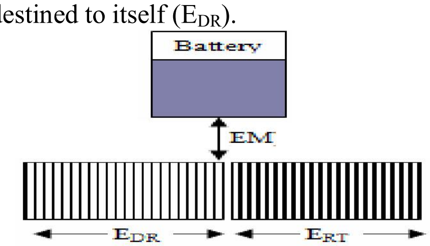

Figure 1: The Energy Manager

The energy to receive the destine message (E_{DR}) is consumed only when a node receives the message destining to itself. While, the energy required to receive non destine or relay messages (E_{RT}) consume on receiving non destine messages.

Principle 3-A: Pre-forwarding: "The node ni adds a message 'M' to its forwarding queue (Qnj) only if

- The message is destining to nj.
- E_{DR}(nj) is greater than the energy required to receive the destine message M(ΔER).
- E_{RT}(ni) is greater than the energy required to forward the message M(ΔET)"

When two node comes in contact we assume: Mn. Mm be the messages, E_{RD}(ni). E_{RD}(nj) is the remaining energy to receive the destine messages and E_{RT}(ni). E_{RT}(nj) be the energy to receive and transmit the non destine messages. A temp variable ΔE_{temp}(ni) that holds the energy level of E_{RT}(ni) is maintained on ni.

Initially, the node ni and nj communicate with EEM to find the energy required to forward the previously stored messages based on their sizes and subtract this value from E_{RT}(ni), E_{RT}(nj) to get the remaining energy (RRT). This computation allows a node to conserve its energy for previously stored message i.e. The node must be able to forward the message when comes in contact with their destinations or other better probable nodes.

The nodes advertise and exchange their remaining energy RRT(ni),RRT (nj) to each other such that ni holds the remaining energy of nj to energy level EL(nj) and nj holds the remaining energy of ni to energy level EL(ni). Similarly, the nodes also exchange their remaining energy reserve to receive the destine messages such that ni holds the E_{RD}(nj) to E_{LD}(nj) while nj holds the E_{RD}(ni) to the E_{LD}(ni).

Afterwards, the nodes exchange their summery vectors (SV) as described in the literature [2][3].

A summery vector is the list of buffered messages on each node. Figure 1 depicts exchange of messages. Hence, ni forward its summary vector (SVni) to nj. The node nj computes the summary vector request (SVR) that describes the message not buffered at nj and send it to ni.

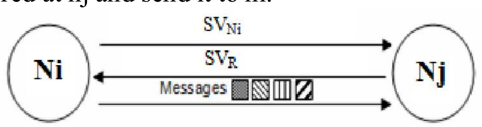

Figure 2: Exchange of messages

SVR = [SVni - SVnj]

After receiving SVR, ni prepares the list of required messages that it has to forward to nj by arranging a forwarding queue (Qnj). For this, transmitter (ni) iterates its buffered messages one at a time and communicates with energy estimation module to get the energy required to receive and forward 'M' based on size and place this value in M(ΔET), M(ΔER). According to the principle 3, the node ni places the message in its forwarding queue only if the connected node nj is the destination of 'M' , ni can forward 'M' and available energy of E_{LD}(nj) is able to receive the message. The objective is to place the destine messages on the top of the queue. After adding message, ni subtract the energy it needs to forward the message from ΔE_{temp}(ni).

$$\Delta E_{temp}(ni) = \Delta E_{temp}(ni) - M(\Delta ET) \quad (3)$$

Since the node, nj will consume its energy after receiving the message. We also want to maintain the energy level of receiver. Therefore, ni will subtract the energy required to receive the destine message in E_{LD}(nj).

$$E_{LD}(nj) = M(\Delta ET)-E_{LD}(nj) \quad (4)$$

Principle 3-B Pre-forwarding: "A node ni add a message 'M' to its forwarding queue (Qnj) only if

- Energy level EL(ni) is greater than the energy required to forward M(ΔET).
- The energy level E_{RT}(nj) is greater then energy required to receive and forward 'M' "

If the message is not destined to current connection, then ni compares the predictability value of nj with P_{TH}. Hereby, if $P(nj)>P_{TH}$ than the node ni examines the energy it requires to transmit the message. If $\Delta E_{temp}(ni) > M(\Delta ET)$, ni further computes ER(M) that represents the energy required to forward and receive 'M' by using equation 2.

$$ER(M) = [M(\Delta ET)+ M(\Delta ER)] \quad (5)$$

The node ni subtract ER(M) from EL(nj) to find whether the nj is capable to receive and forward M.

$$EL(nj) = EL(nj) - ER(M)$$

According to equation, If E_{LD}(nj) is greater than zero than it indicates that node nj have enough remaining energy to receive and forward 'M' therefore, ni add the message in forwarding queue and subtract the energy it need to forward M in a temp variable ΔE_{temp}(ni) by using equation above.

$$\Delta E_{temp}(ni) = \Delta E_{temp}(ni)-M(\Delta ETi) \quad (6)$$

With each iteration, the transmitter verifies whether its remaining energy ΔE_{temp}(ni) is large enough to forward the message to current node and current node nj should have sufficient energy to receive and further forward the message M. This strategy prevents the transmission on the node that are able to receive the message but cannot replicate it due to the lack of remaining energy.

Principle 4: Forwarding " The node ni forward the destine messages first and sort the remaining forwarding queue in descending order of predictability threshold (P_{TH})."

After completing the iteration of its required messages, ni divides the forwarding queue into two parts, (i) Destine and (ii) relay. The destine part of the queue holds the message for which current connected node is destination. The remaining messages are arranged in descending order based on the probability threshold P_{TH}. The objective is to forward those messages first for which the nj holds the highest probability value to meet their destination. The reason is that high probable nodes are expected to encounter the message destination more frequently. The messages are transferred one by one.

Principle 4: Post-Forwarding: " When a ni transmit the message

- It reduce its energy from E_{RT}(ni).
- Receiver nj reduce energy from E_{RT}(nj) or E_{DR}(nj) that it has consumed to receive the message.

The EL(nj) is the local variable to ni that gives the updated value about the energy level of nj before the actual transmission. Hence, any change to the value of EL(nj) and E_{LD} at node ni will node affect the actual energy level variable of the energy manager (EM).

Hence, when a message is delivered to a node as a destination. The receiver will update the E_{RD} by subtracting the energy it has consumed during the transmission. Similarly, the transmitter will update its

E_{RT} variable by subtracting the energy it has consumed to send the message.

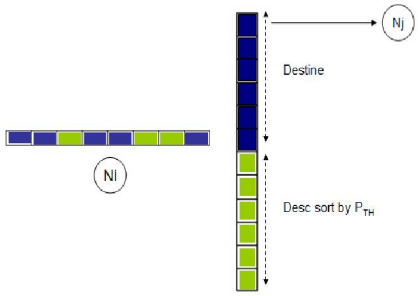

Figure 2: Message transmission order using LaHEA

SIMULATION AND RESULTS

This section provides the performance comparison of existence and the proposed Look a-head energy Aware Routing Protocol. The simulation configuration has been mentioned in table 2.0

Table 2 Simulation Parameters

Groups	alue	Movement	Speed
Pedestrians	2	SPMBM	0.5 – 1.5 km/h
Cars	1		10-10 km/h
Train	3	MRM	
Transmission Range	10 meters		
Message Creation	25s – 35s		
Simulation Area	4500m * 3400m		

End-to-End Delay: The end to end delay is a time taken by a message to reach its destination. More precisely, it is the difference of the current time to the time when the message was delivered.

Delay [Mi] = Current Time – Mi Creation Time

Energy Consumption: The energy consumption measures the amount of energy (Joule) consumed by a node to transmit and receive the messages. The metric compute the energy usage based on the size of message.

$EC(ni) = [M_{size}(ni)/ ET *512+ Msize(ni)/ER*512]$

Delivery probability: The delivery probability measures the successful transmission of messages to their destinations. This metric measure the overall network throughput as more messaged deliver to destination shows the optimal use of network resources. Thus, the objective of routing protocol is to increase the delivery ratio.

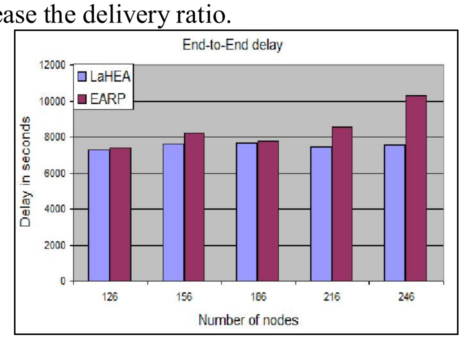

Figure 3: End-to-End delay by increasing number of nodes

Figure 3 shows the outcome of end-to-end delay for existing EARP and proposed LaHEA by increasing the node density and varying message size ranges. We can observe raised in delay with increase in the traffic load such as [216], [246]. The reason is that high numbers of messages were generated for multiple destinations. However, for each simulation instance, the proposed LaHEA has delivered the messages more rapidly. This is due to the reserved energy to receive the destine messages.

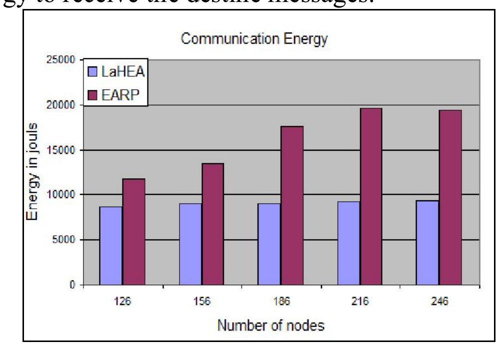

Figure 4 **Communication energy by varying number of nodes**

Figure 4 portraits the result of existing EARP and proposed LaHEA by increasing the traffic load in the context of communication energy. We can observe the raise in the energy consumption by increasing nodes density. The reason is that with high traffic loads the nodes encounter increases and triggers the pair wise exchange of messages. For instance, the EARP has used high volume of energy at [216],[246]. The proposed LaHEA has mitigated transmissions. The reason is that the exchange of messages depends on the probability value and the energy level of encountered node.

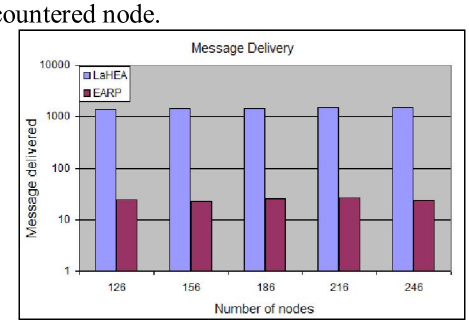

Figure 5: **Message delivery by varying number of nodes**

Figure 5 depicts the result of existing and proposed routing strategies by raising the traffic load in the context of delivery probability. It is clear that the proposed method has delivered more messages then exiting EARP. The reason is that, in proposed method the nodes reserve its energy to receive the destine messages.

CONCLUSION

In this paper, we have proposed Look-ahead probabilistic energy aware routing strategy for delay tolerant network. In proposed method, the message forwarding decision jointly observes the probability value and remaining energy of the current connected node. We have compared the performance of LaHEA with energy aware routing strategy. The proposed method has reduced the number of transmission, message drop and increase the delivery ratio.

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