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Adaptive Fuzzy Routing in Opportunistic Network (AFRON)

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***Abstract*—**Opportunistic network is a kind of Delay Tolerant Networks (DTN) where the nodes in this network come into contact with each other opportunistically and communicate wirelessly and, an end-to-end path between source and destination may have never existed, and disconnection and reconnection is common in the network. In such a network, because of the nature of opportunistic network, perhaps there is no a complete path from source to destination for most of the time and even if there is a path; the path can be very unstable and may change or break quickly. Therefore, routing is one of the main challenges in this environment and, in order to make communication possible in an opportunistic network, the intermediate nodes have to play important role in the opportunistic routing protocols. In this paper we proposed an Adaptive Fuzzy Routing in opportunistic network (AFRON). This protocol is using the simple parameters as input parameters to find the path to the destination node. Using Message Transmission Count, Message Size and Time To Live parameters as input fuzzy to increase delivery ratio and decrease the buffer consumption in the all nodes of network.

***Keywords*—**Opportunistic Routing, Fuzzy Routing, Opportunistic Network, Message Routing.

I. Introduction

OPPORTUNISTIC network is a type of Delay Tolerant Networks (DTN)[1] where network communication opportunities appear opportunistic, an end-to-end path between source and destination may have never existed, and disconnection and reconnection is common in the network. In the other words an opportunistic network as a subset of Delay-Tolerant Network where communication opportunities (contacts) are intermittent, so an end-to-end path between the source and the destination may never exist. The link performance in an opportunistic network is typically highly variable. Therefore, in the absence of reliable end to end connection between the source and destination node, TCP/IP protocol will not work. Opportunistic networking tries to simplify this aspect by providing several kinds of opportunistic routings. In opportunistic networks, communication devices can be carried by people, vehicles or animals, etc. Some devices can form a small mobile ad hoc network when the nodes move close to each other. But a node may frequently be isolated from other nodes. Therefore, a node is just intermittently connected to other nodes, and this partitioning is dynamically changing with time. Thus, an end-to-end connection between the source and the destination can be absent at the time the source wants to transmit, and even later.

Traditional routing protocols are not suitable for this scenario, because in those routing protocols, end-to-end connection between the source and the destination node is basic assumption. Devices in opportunistic network are enabled to interconnect by operating message in a store-carry-forward style and, each node can act as host, intermediate node, thus, it can store, carry and forward the message between for other nodes. The big challenge in opportunistic networks is how to route messages from their source to their destination, with the absence of end-to-end path. When there is no path existing between the source and the destination, nodes need to communicate with each other via opportunistic contacts through store-carry-forward operation. This requires different routing approaches and schemes to cope with, on one side, and to exploit, on the other side, the characteristics of opportunistic networks. There are some important factors in routing message such as the role of context information as well as social aspects, where the classification of routing approaches is based on the amount of context information used as given in [2]. Based on the context information exploited, routing in opportunistic network is classified into three classes: context-oblivious, Partially Context-Aware and Fully Context-Aware Routing protocols. In this paper we proposed an Adaptive Fuzzy Routing which is used to use the all mentioned classes in opportunistic way to deliver the message according to the situations. The rest of this paper is organized as follow: section 2 addresses the opportunistic routing protocols. Section 3 describes AFRON protocol. Section 4 compares the AFRON with the other protocols and finally section 5 draws the conclusions.

II. Related Work

The routing in opportunistic network as mentioned before does not need to end–to-end path between the source and destination node and this fact is simplified the touting protocols in opportunistic networks; however, challenges remain that are distinct from those of conventional network routing methods. According to the classifications of routing protocols (i.e. context-oblivious, Partially Context-Aware and Fully Context-Aware)[2] there are some routing protocols have been proposed. In the context-oblivious, routing protocols are based on the flooding. To increase network capacity, the maximum number of repeated messages and the total number of copies of a message are limited. When nothing else is allowed to duplicate, the node should deliver the message directly to the final node. These protocols reduce the delay in getting the message, but many resources are

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consumed. These protocols are congestion and competition from other problems. Epidemic [3], Spray and wait [4], Fuzzy-Spray [15], MV [5] and Network Coding [6] are examples of flooding based protocols. The second class protocols attempt to gain a bit of background information, to improve their process. Defining algorithms to calculate the probability of delivering message to the destination node by using the background information is the main purpose of these protocols. PRoPHET[7], MaxProp[8], MoVe[9], MobySpace[10] and Bubble Rap[11] are some examples of Partially Context-Aware protocols and in the last class of routing protocols in opportunistic network based on background information is Fully Context-Aware. All protocols in this class are using the background information in order to deliver message to the destination node. These protocols provide the ability to adapt to different environments. HiBOp[12] and Propicman/SpatioTempo[2] are some example routing protocols this category.

III. AFRON

The Routing protocols in opportunistic networks, deal with knowledge and phenomena in many fields, which cannot be clearly just by true or false. Using fuzzy knowledge to process can improve the describing ability for fuzzy knowledge, and can grasp the essential meaning of fuzzy knowledge. For using the nature of opportunistic networks parameters such as the Message Transmitted Count of nodes, Message Size and Time To Live to calculate the importance of message. Due to ambiguity and uncertainty of opportunistic network environment a fuzzy based protocol is proposed to find the destination node in shortest time with less buffer usage. In this regards the following input and output sets and have been defined for AFRON protocol.

A. Inputs Variables

1. Message Transmitted Count (MTC)

In Fuzzy-Spray protocol [15], Forward Transmission Count or FTC was proposed in order to prioritize messages in buffer of nodes. In AFRON we used the same concept to calculate the copies of message in the network. This parameter is increased when the nodes exchanges their messages so it is approximately show the number of message transmission in the network. The value of MTC is as same as FTC but the membership function had been defined again and it is depicted in Fig.1.

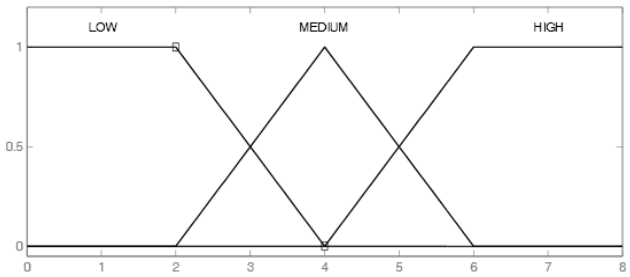


Fig.1 MTC Membership function

2. Message Size(MS)

Since that most nodes of the mobile network nodes or devices have limited buffer size and the size of message is very important so we considered it as input parameters as same as Fuzzy Spray Protocol but there is some deference in the member ship function which is defined as Fig.2.

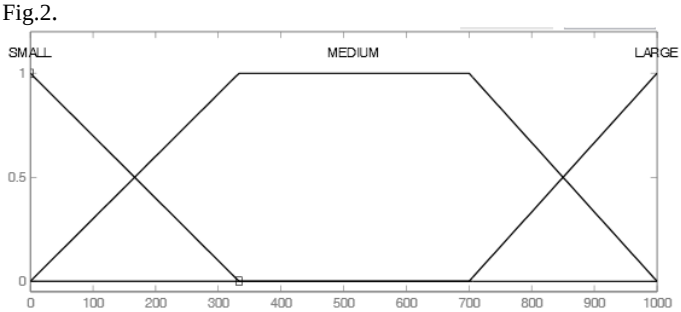


Fig.2 MS Membership Function

3. Time To Live (TTL)

In fact the TTL time is very important in routing protocol. When messages are not delivered in their TTL, the drop ration of message will be increased and the total performance of proto9cl will be decreased. TTL is considered in our protocol in order to increasing the ratio of message delivery which is not considered in Fuzzy-Spray protocol. The membership functions for TTL is depicted in Fig. 3

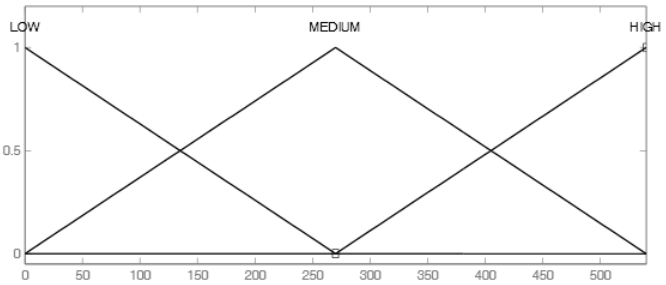


Fig. 3 TTL Membership Function

B. Output Variable (Buffer Sections)

According to the input, AFRON protocol will be divide the buffer of nodes into 19 sections and according to the input the message will be select the appropriate section. This partitioning finally will be used to prioritize the message in order to exchange it in next contact. The priority of message will be calculated as bellow:

Priority_of_Message=1-BS_of_Message.

Fig. 4 shows the membership function of BS.

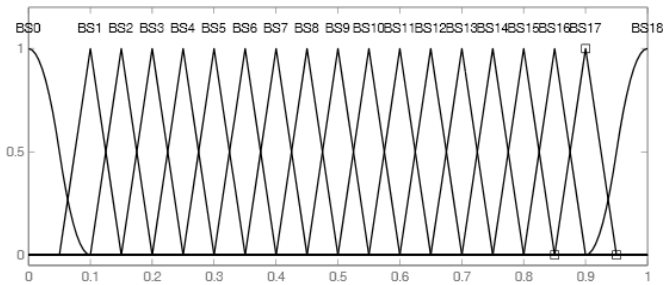


Fig. 4 BS Membership function

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C. Fuzzy Rules

In AFRON protocol Fuzzy Rules are defined to prioritize the messages in order to deliver the message in shortest time and before the end of message's TTL. Table I is shows all fuzzy rules in AFRON protocol.

TABLE I
FUZZY RULES IN AFRON PROTOCOL

MTC	MS	TTL	BS
low	small	low	BS0
low	small	medium	BS0
low	small	high	BS0
low	medium	low	BS1
low	medium	medium	BS1
low	medium	high	BS2
low	large	low	BS3
low	large	medium	BS3
low	large	high	BS4
medium	small	low	BS4
medium	small	medium	BS4
medium	small	high	BS5
medium	medium	low	BS6
medium	medium	medium	BS7
medium	medium	high	BS8
medium	large	low	BS9
medium	large	medium	BS9
medium	large	high	BS10
high	small	low	BS11
high	small	medium	BS11
high	small	high	BS12
high	medium	low	BS13
high	medium	medium	BS14
high	medium	high	BS15
high	large	low	BS16
high	large	medium	BS17
high	large	high	BS18

D. AFRON Algorithm

The following Pseudo-code is shows how the AFRON is working. It is very similar to the Fuzzy-Spray and Spray and Wait Protocol.

```
//AFRON ALGORITHM
AdaptiveFuzzy()
        {
      /*Node i is connected to Node j*/
      while(NodesAreConnected(i,j){

        /*send all message from node i buffer to node j*/
        SendMessage(i,j);

        /*send all message from node i buffer to node j*/
         SendMessage(j,i);
      }
}//end of AdaptiveFuzzy
SendMessage(i,j) {

/*deliver all messages in node i that their destinations is node j*/
DeliveredtoFinalNode (i,j);

/*each node send Ack to the other node in case of delivering*/
   ExchangeAck (i,j)

   /*set the priority of message in buffer of node i*/
   SetMessagesPriority (i);

   /*node I and j exchange the message in their buffer*/
   ExchangeMessage (i, j);

   /*remove the delivered messages from the buffers of both nodes i and j*/
   RemoveDeliveredMessage (i,j)
}//end of SendMessage

SetMessagesPriority (i)
{
   for each message_i in Buffer_i{
      if IsFoundIn(message_i, Ack_i) then
         remove(message_i)
      else
      message_i.priority=1-Fuzzification(message_i)
      }
      SortByPriority(Buffer_i)
}//end of SetMessagesPriority
```

II. SIMULATION RESULTS

The ONE [16][17] is used for simulation. There scenarios are defined in order to compare the message delivery ratio and buffer consumption of AFRON protocols with the other same protocols such as Fuzzy-Spray, Spray and Wait and Epidemic.

The simulation time is set to 12 Hours and the communication interface is Bluetooth with 10m rang. The transmission speed is 25KB/s.

A. Levy Walk[18] Scenario

The scenarios are based on the internal movement of the nodes. Nodes are divided into two groups. The first group moving model is StationaryMovement model and the second movement model is Community model. The simulation area is 400*200 square meters and the messages are generated randomly by using Exponential distribution function. The interval time between two messages is 10-100 seconds. The buffer size is 100MB and the message size is 100-200KB.

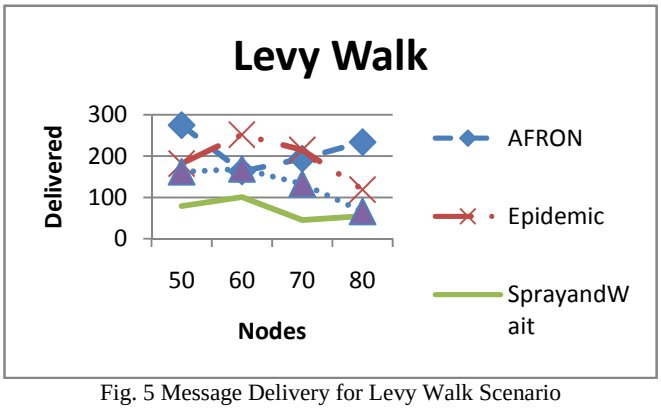


Fig. 5 Message Delivery for Levy Walk Scenario

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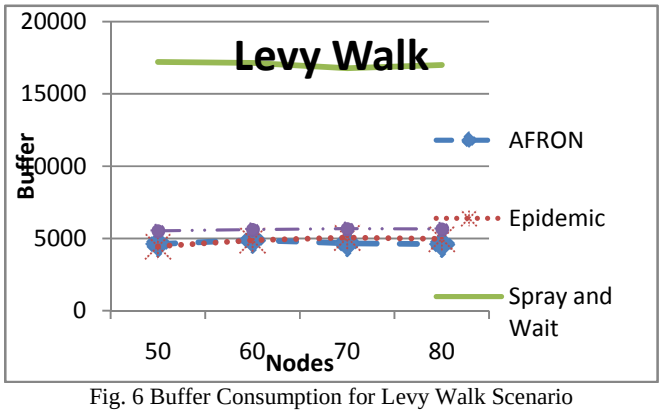


Fig. 6 Buffer Consumption for Levy Walk Scenario

B. Random Walk Scenario

In this scenario all settings are the same as the first scenario except the internal movement which is here set to Random Walk movement model.

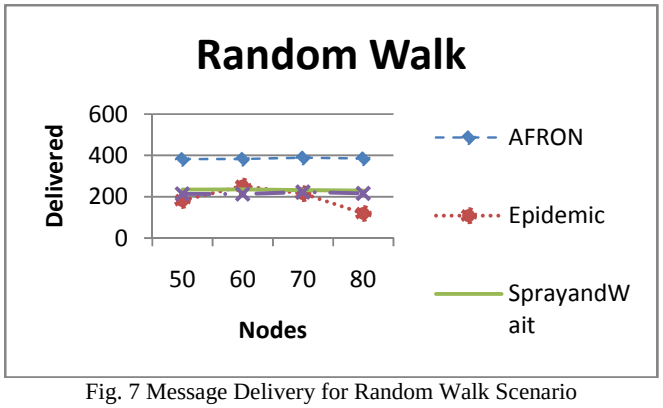


Fig. 7 Message Delivery for Random Walk Scenario

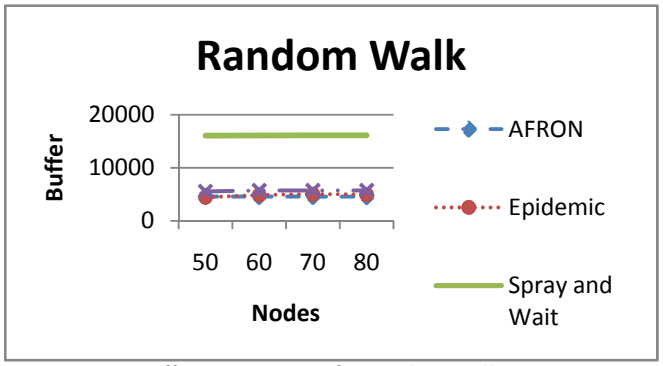


Fig. 8 Buffer Consumption for Random Walk Scenario

C. Random Waypoint Scenario

All setting is the same as the first but the internal movement is Random Waypoint model.

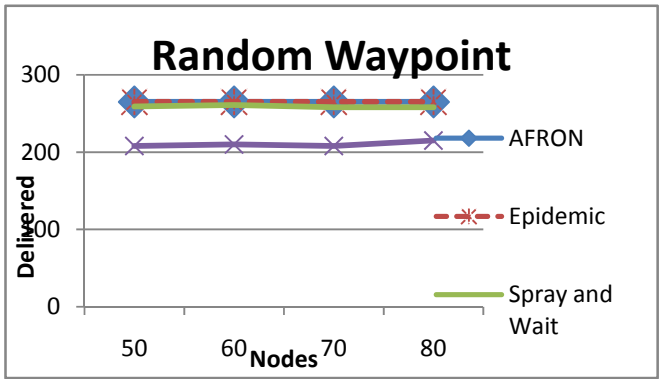


Fig. 9 Message Delivery for Random Waypoint Scenario

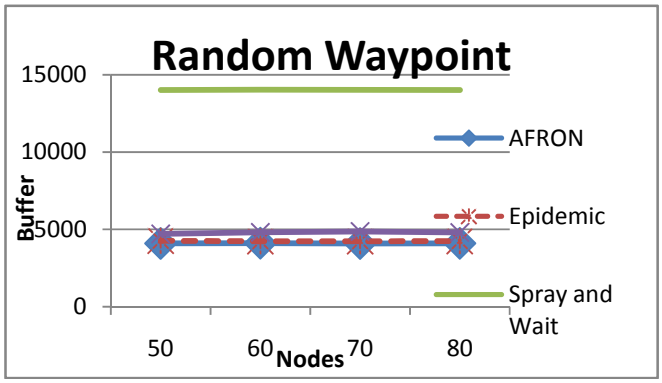


Fig. 10 Buffer Consumption for Random Waypoint Scenario

As shown above the AFRON is working better than the other protocols especially in the random movement of nodes

IV. Conclusion

This paper has presented a new method to dynamically select the forwarding list according to the situation. The algorithm is supported by an any cast transmission technique. This mechanism to select the relaying node from the available node list is supported by a fuzzy logic system which takes into account the bandwidth, energy of the node, priority of the message and the density of the network. By means of fuzzy logic, the effectiveness of AFRON protocol is able to reduce the energy consumption per transmission and also could use less resource. As future work, we intend to implement the protocol in a network simulation where realistic propagation conditions and realistic battery performance are taken into account.

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