International Journal of Computer Science and Information Security (IJCSIS),
Vol. 14, No. 1, January 2016

Intelligent and Dynamic Neighbourhood Entry Lifetime for Position-based Routing Protocol Using Fuzzy Logic Controller

Jafar A. Alzubi
Al-Balqa Applied University
Al-Salt, Jordan

Omar Almomani
The World Islamic Sciences & Education University
Amman, Jordan

Omar A. Alzubi
Al-Balqa Applied University
Al-Salt, Jordan

Mahmoud Al-shugran
Jerash University
Jerash, Jordan

Abstract—**Mobile Ad-hoc Network (*MANET*) characterized with high mobility and very limited resources. Such network requires a very high reliable routing protocol to be compatible with its limitations. In position-based routing protocols for *MANET*, each node chooses the next relay node for packet routing solely from neighbourhood stored in its neighbours' matrix (*NLM*). The lifetime of neighbors' entry in *NLM* matrix relates to beacon interval and timeout interval. Inaccurate information of *NLM* matrix may lead to a wrong selection decision, which can have devastating consequences on *MANET* resources. Thus, the freshness of the information in a node's *NLM* matrix is in a high demand. This paper presents an intelligent dynamic fuzzy logic controller refreshment period of entries in neighbourhood matrices (*IFPE*) scheme. The *IFPE* algorithm utilizes neighbour's Residual Lifetime of Links (*RLT*) in the fuzzy logic controller as an input, and the called neighbour expire entry life-time (*ELT*) as an output. Simulation results show that *IFPE* algorithm keeps neighbourhood matrices consistent, which achieve considerable improvement for position-based routing protocols performance.**

Index Terms— **Networks, Mobile Ad-hoc Network, Position-based Routing, Residual Lifetime of Links, Entry life-time.**

I. Introduction

Mobile Ad-hoc Networks *MANETs* are networks formed without a central administration. They consist of mobile nodes in the fly [1,2,3,4]. Due to the limited radio transmission range of wireless devices, such nodes, can communicate directly if they are within the transmission range of each other, otherwise they will indirectly communicate by using intermediate nodes [5,6,7]. In *MANET* all nodes participate in the routing and data forwarding process [8,9].

As a node joins *MANET* it has to announce its presence by emit HELLO message for all of its neighbours in its transmission range. Also, it should start building its own neighbours matrix to efficiently communicate with the others. The building of a node's neighbour's matrix is totally depended on the received HELLO messages from the neighbourhood. To improve routing protocol efficiency, the entries in the neighbours' matrix should be checked periodically by a node to be sure that it does not contain stale entries [10,11]. Also to solve the outdated entries problem, the frequency at which an entry is considered as stale one should be tuned, and not be considered as a fix pre-specified time. In this paper, we present an intelligent dynamic fuzzy logic controller refreshment period of entries in neighbourhood matrix (*IFPE*) as an extension to Greedy perimeter stateless routing protocol (*GPSR*) [12]. *IFPE* Algorithm adapts dynamically the residual link lifetime of neighbours in a node's neighbours' matrix.

The outline of this paper is as follows. In Section II, we present the related works. In Section III, we introduce and describe the proposed technique *IFPE*, while in Section IV; we describe the simulation environment. In Section V we crop the results and discuss them. Lastly, we conclude this work with a small hint for future works in Section VI.

II. Related Work

The neighbours' matrix is checked periodically by a node to update (add/delete) it. A node considers all others nodes in its neighbours' matrix as active neighbours and thus, a link between them is active. In the literature, researchers as in [13,14,15] use a fixed interval time to remove a neighbour from a nod's neighbor matrix in the case of no reception of a HELLO message. In those works the neighbours' expire entry life-time is set as three times of the HELLO message frequency period (*FBIT*). Such pre-specified period of time is in sufficient for adaptively follow the dynamic environment of *MANET*. Moreover, it degrades the performance of the underlying routing protocol used by participating nodes to accomplish the communication task with each other.

https://sites.google.com/site/ijcsis/
ISSN 1947-5500

The expiry entry lifetime of neighbours is much related to the frequency of emitting HELLO messages interval time (*FBPIT*). In the state of the art researchers adapt several algorithms to adaptively estimate *FBPIT*. Chen et al. [16] proposed Adaptive Position Update (*APU*) strategy, which used mobility prediction rule to estimate the accuracy of the position information and to adapt the *FBPIT* accordingly. Saqour R. et al. [17] proposed fuzzy Hello Interval method to adjust the time between the transmissions of beacon packets. They proposed Fuzzy logic-based dynamic beaconing (*FLDB*) controller in order to overcome the drawbacks of periodic beaconing (*PB*) in the ad hoc position-based routing protocols. Chou et al. in [18], proposed an approach for beacon-based geographic routing, where the mobile nodes dynamically adjust their beacon intervals based on their speed of movement. J. Tang, et al., in [19], presented an adaptive beacon exchange algorithm. Authors gave a computable method to adjust the beacon interval according to node speed and relative position. S. Bai, Z. Huang, and J. Jung in [20], presented a mobility predication-based dynamic beacon strategy (*BCF*). When executing *BCF* a node can decide the beacon sending period value according to its direction and speed. As we can noticed here that several works have been proposed to adapt the frequency of the HELLO message in *MANET*, but none of them adapts the *ELT* of entries of nodes in neighbour's matrix.

III. Intelligent Dynamic Fuzzy Logic Controller Refreshment (IFPE)

The lifetime of the entries of a neighbour in a nod's neighbours' matrix is very important and may severely affect the performance of position based routing protocol. Consequently, routing failures is proportional to the inappropriate decision of removing a neighbour's entry from a node's neighbours' matrix. Our proposed *IFPE* aims to adapt dynamically the lifetime of entries in neighbourhood matrix regarding to *RLT* of neighbours. If *RLT* of a neighbor is high, then the *ELT* will be high too and vice versa.

A. IFPE Overview

With traditional position-based routing protocols a node set its timer to send HELLO message according to *FBPIT*. The received node keeps the information of the HELLO packet in its neighbours' table. With our proposed scheme, we make some alteration for the HELLO packet as shown in Table 1 bellow. Moreover, some alteration is done for the neighbours' table as shown in equation 1, and it is re-named as neigbours' matrix.

TABLE I
HELLO MESSAGE STRUCTURE

1	2					3	4
ID_i	x	y	$vel.$	$acc.$	$dir.$	$FBPIT$	t_s
	x_{ts}^i	y_{ts}^i	v_{ts}^i	a_{ts}^i	θ_{ts}^i	t_b	

As depicted in TABLE I, HELLO message holds the following fields. Node's address ID, Nodes' identity with updating sequence number $\mathrm{ID_i}$, the geographical position of the node as (x,y) coordinates, velocity v, acceleration a, motion direction θ, *FBPIT* Interval Time t_b, beacon sending time t_s. Each node stores a neighbour' matrix (*NLM*) to save the received HELLO messages from its neighbours. Equation 1 shows the building structure of the node's neighbours' matrix for i neighbours.

$$NM = \begin{bmatrix} x_1 & y_1 & v_i & \mathrm{a}_i & \theta_i & RLT_1 & ELT_1 & t_{b_1} & t_s & t_r & \mathrm{ID}_1 \\ x_2 & y_2 & v_i & \mathrm{a}_i & 1\theta_i & RLT_2 & ELT_2 & t_{b_2} & t_s & t_r & \mathrm{ID}_2 \\ . & . & . & . & . & . & . & . & . & . & . \\ . & . & . & . & . & . & . & . & . & . & . \\ x_i & y_i & v_i & \mathrm{a}_i & \theta_i & RLT_i & ELT_i & LBPIT_i & t_s & t_r & \mathrm{ID}_i \end{bmatrix} \quad (1)$$

As depicted in equation 1, *NLM* contains all HELLO message information for each neighbour, adding the instant time (t_r) that the node receives the HELLO message. Also the received node adds *RLT* and *ELT* value for each neighbor. This addition is done after a node received HELLO packet and calculates *RLT* and run IFPE algorithm to find out *ELT*. The numbers of neighbours sent HELLO messages are equal to the rows' number of *NLM* matrix.

B. ELT Calculation Using Fuzzy Logic

Recall from the state of the art, many routing protocol parameters in *MANET* adaptively optimized by using the fuzzy logic controller. Fuzzy controller assists to determine more accurately and dynamically of those parameters. Thus, using fuzzy logic is promises to adapt the neighbour expire entry life-time (*ELT*) based on its *RLT*.

To adapt the neighbor expiry entry life-time *ELT*, in this section fuzzy logic controller is used. This adaption achieves a good balance between acceptable *ELT*, and *RLT*. An *IFPE*, as a *FLC* approach to adapt the neighbour *RLT* is utilized as crisp input and *ELT* period time as a crisp output. Nodes have high *RLT* will stay more time in each other transmission range, thus *ELT* will be high and vice versa. Fig. 1 shows the *FLC* for *IFPE* approach.

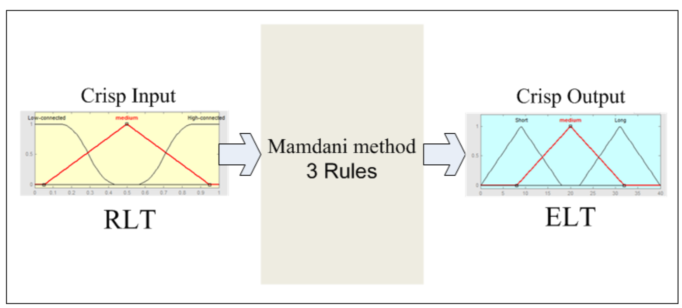

Fig. 1. FLC for IFPE

C. Residual Lifetime of the Link between Two Nodes Identification

In mobile ad hoc network pair of nodes i and j can be directly communicate if the maximum distance between them less than transmission range R. The actual distance (des_j^i) between them can be calculated by using the positions of the two nodes. Link life-time or link expiration time between nodes i and j can defined as the maximum time of connectivity between the two nodes before one of them leave the transmission range of the other node [21]. In this work, link expiration time between nodes i and j is define as residual lifetime of the link between the two nodes. As shown in Fig. 2, it assumed that nodes i and j are neighbours. Also, it assumed that the current information of nod j as reported in the latest HELLO message for node i is (x_t^j, y_t^j, v_t^j, a_t^j, θ_t^j) at time *t*. At the same time the node-self information is(x_t^i, y_t^i, v_t^i, a_t^i, θ_t^i).

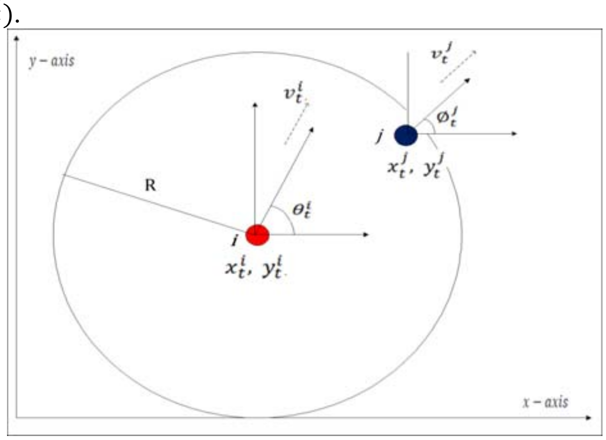

Fig. 2. Communication relation and RLT of a link between pair of nodes

To estimate the *RLT* between the two nodes, work presented in [20] was adopted with some alteration, as shown in equation 2 bellows.

$$RLT_j^i(t) = \frac{R - des_j^i(t)}{RV_j^i(t)} \tag{2}$$

Where, $RLT_j^i(t)$ is the residual lifetime of the link between node i and node j at time *t*, *R* is the transmission range of the nodes, $des_j^i(t)$ is the current distance between node i and node j at time *t*, and $RV_j^i(t)$ is the magnitude of the relative velocity (speed and direction) between nodes i and j at time t. The distance between the two nodes i, and j can be estimated as in equation 3 bellows.

$$des_j^i(t) = \sqrt{(x_t^i - x_t^j)^2 + (y_t^i - y_t^j)^2} \tag{3}$$

The relative velocity between the two nodes i, and j can be estimated as in equation 4 bellows.

$$\overrightarrow{RV_j^i} = \vec{V_i} + \vec{V_j} \tag{4}$$

The magnitude of the relative velocity is,

$$RV_j^i = \sqrt{\left(RV_i^i(x)\right)^2 + (RV_i^S(y))^2} \tag{5}$$

Where,

$$RV_j^i(x) = (v_i \cos\theta - v_j \cos\emptyset) \tag{6}$$

$$RV_j^i(y) = (v_i \sin\theta - v_j \sin\emptyset) \tag{7}$$

where, $RV_i^i(x)$ is node's j relative velocity in the x-direction for node i, and, $RV_i^S(y)$ is node's j relative velocity in the y-direction for node i, v_i and v_j are the velocity of nodes i and j respectively, θ and $\emptyset$ are the motion direction of nodes i and j respectively.

Rearranging algebraically of Equation 2, leads to the result;

$$RLT_j^i = \frac{\left(R - \sqrt{(x_t^i - x_t^j)^2 + (y_t^i - y_t^j)^2}\right)}{\sqrt{(v_t^i \cos\theta_t^i - v_t^j \cos\emptyset_t^j)^2 + (v_t^i \sin\theta_t^i - v_t^j \sin\emptyset_t^j)^2}}$$

(8)

Owing the variation of the speed, or motion direction (velocity) of the neighbor, the *RLT* will be varying too. To specify the *ELT* of a neighbour, three possibilities were been considered:

1) If *RLT* period of neighbor j with node i is long, this means that it has approximately similar values of speed and motion direction with respect to node i. In such case, waiting time *ELT* for neighbor j will be long too. A very important thing to be noticed here is that if the velocity vectors of the two nodes are equal, the value of *RV* is equal zero. In such case the *RLT* period will goes to infinity.
2) If *RLT* period of neighbor j with node i is medium, this means that it has some different values of speed and motion direction with respect to node i. In such a case, waiting time *ELT* for neighbor j will be medium.
3) If *RLT* period of neighbor j with node i is low, this means that it has high different values of speed and motion direction with respect to node i. In such a case, waiting time *ELT* for neighbor j will be short.

In this paper the used velocity range is [1,40] m\s, and thus, the maximum and minimum magnitude of the relative velocity between two nodes is 80, and 2 respectively. Furthermore, the used transmission range is fixed for all participating nodes (R=250 m). And thus, the *RLT* range with maximum magnitude of the relative velocity is [3.125s, 125s]. Also, the range of the *RLT* with minimum magnitude of the relative velocity is [0.5s, 0.0125s]. As a consequence, the total range of the proposed *RLT* is [0.0125s, 125s]. To map *RLT* range to [0,1], as a normalization process, the following formula in Equation 999, is used.

$$\Im_j^i(t_s) = \frac{(x - \min\{0.0125s, 125\})}{(\max\{0.0125s, 125\} - \min\{0.0125s, 125\})} \tag{9}$$

Where, $\Im_j^i(t_s)$ is the normalized value of the relative velocity magnitude between the nodes i, and j at time t. The nodes are fully connected if the $\Im_j^i$ is 1 and likely out of transmission range of each other if the $\Im_j^i$ is 0. Thus, high values of $\Im_j^i$ gives an indicator for the high reliability value of communication via this neigbour.

IV. Intelligent Fuzzy Logic Decision

As discussed earlier, the HELLO sending frequency is much related to the waiting time before a node deletes any neighbour's entry from its neighbours' matrix. From literature,

https://sites.google.com/site/ijcsis/
ISSN 1947-5500

most researchers use the frequency from the interval *LPBIT* [1-10 s] second. Moreover, most of those researchers used the waiting time to be three times of the frequency sending (*3* LPBIT*). As consequence, the most-used waiting time is bounded in the interval [3-30 s] second. To cater for this research demand, the waiting time adjusted to being more realistic in the interval [1-40 s]. Thus, the neighbor has high $\Im_j^i$ will also have long *ELT* time. To estimate the *ELT* time index for a neighbor, the corresponding entry will be evaluated by the Inelegant Fuzzy Logic Controller *IFPE*. The crisp input will be the $\Im_j^i$ of the neighbour. The crisp output from the fuzzy controller will be the *ELT* time index for that neighbor.

A. Fuzzify Input and Output Parameters

The fuzzifier maps the crisp data values to fuzzy sets and assigns degree of membership for each fuzzy set. Here $\Im_j^i$ is the crisp input and *ELT* time is the crisp output the linguistic values of inputs are normalized in the range from 0 to 1, and outputs in the range from 1 to 40 s.

B. Fuzzify Neighbours' $\Im_j^i$ Input

Membership functions can have different shapes. Fig. 3 shows the assignment of degree of membership functions for input used in this work. The triangular membership function is used to represent the whole set of medium values. Z-shaped is used to represent the whole set of low values, and S-shaped is used to represent the whole set of high values.

TABLE II
FUZZY SETS FOR I_J^I INPUT VARIABLE

Range	Fuzzy sets	Symbol
0.035-0.45	Low	*lo*
0.08-0.92	Medium	*md*
0.55 0.965	High	*hi*

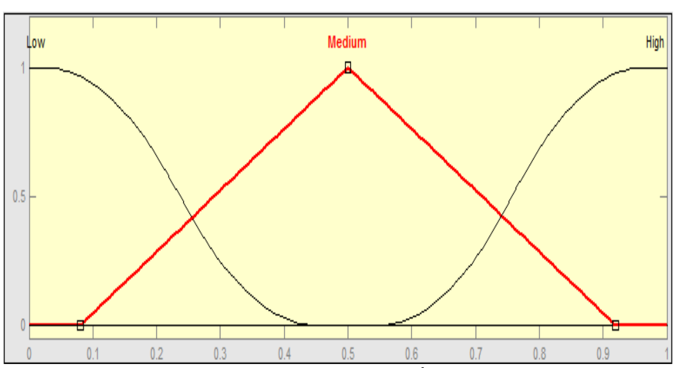

Fig. 3. Membership functions of $\Im_j^i$ input variable

The fuzzy sets for the *RLT* input variable have the following names: low (*lc*), medium (*m*), and high *(hc*). Table 2 shows the assignment of range of membership functions for input $\Im_j^i$ variable. Hence, the $\Im_j^i$ is fuzzified between $\Im_j^i$-*min = zero* and $\Im_j^i$-*max = 1*.

Equations 10 to 12 show the explicit formulas for $\Im_j^i$ membership functions.

$$\Im^i_{j\,lo} = \begin{cases} 1, & x \le 0.035 \\ 1-2\left(\frac{x-0.035}{0.45-0.035}\right)^2, & 0.035 \le x \le \frac{0.035+0.45}{2} \\ 2\left(\frac{x-0.45}{0.45-0.035}\right)^2, & \frac{0.035+0.45}{2} \le x \le 0.45 \\ 0, & x \ge 0.45 \end{cases} \tag{10}$$

$$\Im^i_{j\,md} = \begin{cases} \left(\frac{x-0.08}{0.5-0.08}\right), & 0.08 \le x \le 0.5 \\ \left(\frac{0.92-x}{0.92-0.5}\right), & 0.5 \le x \le 0.92 \\ 0, & otherwise \end{cases} \tag{11}$$

$$\Im^i_{j\,hi} = \begin{cases} 0, & x \le 0.55 \\ 2\left(\frac{x-0.55}{0.965-0.55}\right)^2, & 0.55 \le x \le \frac{0.55+0.965}{2} \\ 1-2\left(\frac{x-0.965}{0.965-0.55}\right)^2, & \frac{0.55+0.965}{2} \le x \le 0.965 \\ 1, & x \ge 0.965 \end{cases} \tag{12}$$

C. Fuzzify Neighbours' ELT Value Output

Fig. 4 shows the assignment of degree of membership functions for output used for this work. The triangular membership function is used to represent the whole set of medium, low, and high values. Fuzzy sets for the *ELT* output variable have the following names: long (*l*), medium (*m*), short (*s*). Table 3 shows the assignment of rang and membership functions for output *ELT* variable. Hence, the *ELT* is fuzzified between *ELT-min = 1* and *ELT-max = 40*.

TABLE III
FUZZY SETS FOR ELT OUTPUT VARIABLE

ELT value	Fuzzy sets
0.0 - 18	Short *(s)*
8 - 32	Medium (*m*)
22 - 40	Long *(l)*

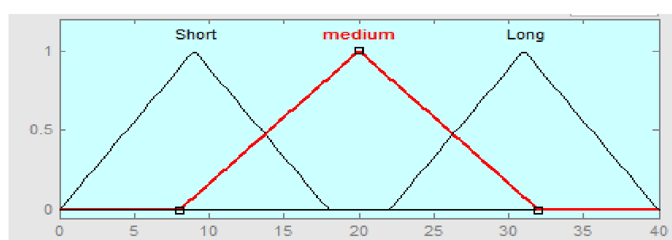

Fig. 4. Membership functions of ELT output variable

Equations 13 to 15 show the explicit formulas for $\Im_j^i$ membership functions.

$$ELT_s = \begin{cases} \left(\frac{x-0.0}{9-0.0}\right), & 0.0 \le x \le 9 \\ \left(\frac{18-x}{18-9}\right), & 9 \le x \le 18 \\ 0, & otherwise \end{cases} \tag{13}$$

https://sites.google.com/site/ijcsis/
ISSN 1947-5500

$$ELT_m = \begin{cases} \left(\frac{x-8}{20-8}\right), & 8 \le x \le 20 \\ \left(\frac{32-x}{32-20}\right), & 20 \le x \le 32 \\ 0, & otherwise \end{cases} \quad (14)$$

$$ELT_l = \begin{cases} \left(\frac{x-22}{31-22}\right), & 22 \le x \le 31 \\ \left(\frac{40-x}{40-31}\right), & 31 \le x \le 40 \\ 0, & otherwise \end{cases} \quad (15)$$

D. Fuzzy Rules and Fuzzy Inference

Fuzzy inference uses the following proposed fuzzy rules to map the fuzzy $\Im_j^i$ input sets mentioned above into fuzzy *ELT* output sets: Long, medium, and short.

RULE 1: IF $\Im$ is *high* THEN *ELT* is *long*
RULE 2: IF $\Im$ is *medium* THEN *ELT* is medium
RULE 3: IF $\Im$ is *low* THEN *ELT* is *short*

Fuzzy inference evaluates all the three fuzzy rules (RULE 1 to RULE 3) and finds their antecedent part firing strength then applies this firing strength to the consequence part of the rules.

E. An Illustrative Example for IFPE

This sub-section explains the operations of *FLC* used for *IFPE* approach. In this example suppose that the estimated $\Im_j^i$ basing on Equation 999 is 0.2.

Step 1. Fuzzify the inputs: with this step the input $\Im_j^i = 0.2$ insert as crisp input to *FLC* to determine the degree to which it belongs to each of the appropriate fuzzy sets via its membership functions. The Fig. 5 below shows how well the $\Im_j^i = 0.2$ qualifies via its membership functions (low-connected, medium, and high-connected). In this example, the rating of $\Im_j^i = 0.2$ produces corresponds to two membership functions: low-connected and medium with value 0.915 and 0.33 respectively.

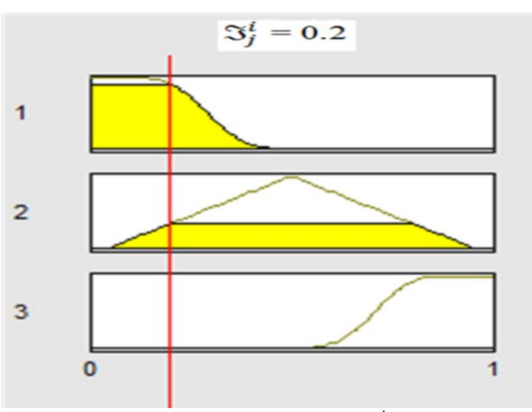

Fig. 5. Fuzzification of the $\Im_j^i$

Step 2. Apply fuzzy inference: After the $\Im_j^i$ input fuzzified, the fuzzy inference evaluates all the three fuzzy rules (RULE 1 to RULE 3) and find their antecedent part firing strength (membership functions values) then apply this firing strength to the consequence part of the rules. For example, in the input $\Im_j^i = 0.2$, two rules will be fired (Rule 1 and Rule 2) with antecedents' firing strength equal to 0.915 and 0.33 respectively as shown in Fig. 6. The fuzzy inference then applies those values (0.915, 0.33) to the consequence part to find the firing strength of each rule.

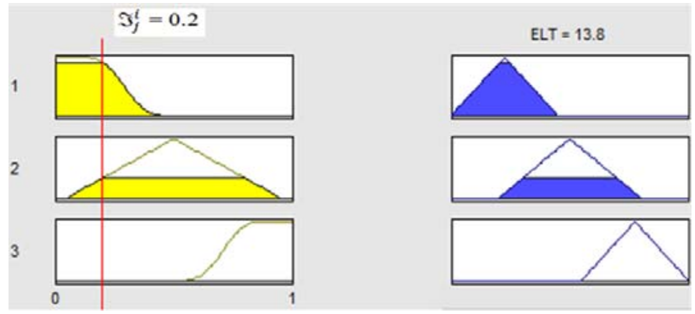

Fig. 6. Applying fuzzy inference

Step 3. Defuzzify the outputs: in this step, all the fuzzy sets that represent the outputs of each rule are aggregated into a single output fuzzy set and then the single output fuzzy set will be defuzzified to get a single output value. As shown in Fig. 7, all the output *ELT* fuzzy sets which obtained from applying fuzzy inference in step 2 are aggregated to obtain a single output *ELT* fuzzy set. After that, the weighted average defuzzification method is applied to get a single output *ELT*.

$$ELT = \frac{\sum_{j=1}^{w} x_j \cdot \mu(x_j)}{\sum_{j=1}^{w} \mu(x_j)}$$
$$= \frac{(0.33 * 9) + (0.915 * 20) + (0.00 * 31)}{(0.33 + 0.915)} = 14s \quad (16)$$

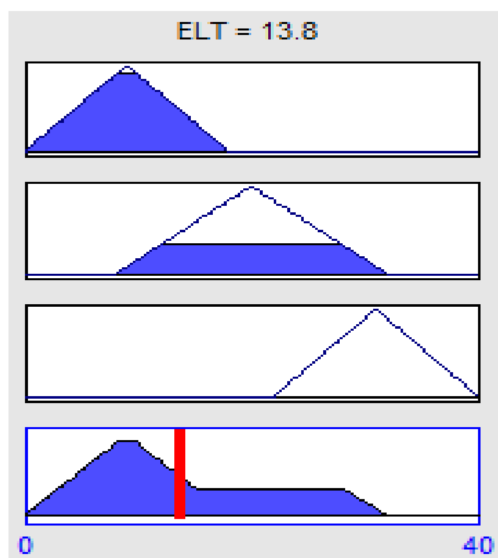

Fig. 7. Aggregation and defuzzification of the output ELT

V. Performance Analysis of the Proposed GPSR-IFPE

A. Simulation Environment

The simulations were conducted using *Ns2* version 2.33. The *GPSR* protocol is utilized as the underlying routing

https://sites.google.com/site/ijcsis/
ISSN 1947-5500

protocol. With the conventional *GPSR* the *FBPIT* interval and the *ELT* interval are set to 3s and 9s (*3*FBPIT*) respectively. The nodes move according to the Boundless mobility model. The fuzzy logic system has been coded using *C++*. Centroid was chosen as the defuzzification method [22]. All simulation results have been averaged over 10 simulation runs and include 95 percent confidence interval data.

The simulation network area is rectangle of 2500 m × 2000 m, with 250m nodes' transmission range. We use the *MAC* layer protocol 802.11 *DCF RTS/CTS*. Bandwidth (*Bw*) set to standard value of 2 mbps. Traffic model uses Continuous Bit Rate (*CBR*) traffic sources. Traffic sources transmit data at a fixed data rate of 5 packets/s. Data packet size set to standard values 512 bytes and beacon packet size is 64 bytes. Node queue size set to standard size of 50 packets and node's queue uses First-In-First-Out (*FIFO*) policy. The simulation for each scenario is executed in a period of 1200, seconds, and to avoid the effect of initializing and ending, we only gather the data between 800s – 1000s.

B. Simulation Scenarios

To study the effectiveness of *IFPE* approach in position-based routing protocols using *FLC*, a simulation study conducted varying node speed, number of nodes, and number of data traffics. Node speed 5, 10, 15, 20, 25, 30, 35, 40 m/s, number of nodes 25, 50, 75, 100, 125, 150, 175, 200 nodes, and number of data traffics 5, 10, 15, 20, 25, 30 flows are simulated . There are no obstacles and so nodes with transmission range can always communicate. The source and destination nodes were randomly selected among the nodes in the simulation scenario.

The reason why we use high-speed interval, various node density and different traffic load is to have a challenging scenario for the routing algorithms to show the goodness of the routing protocol under study.

C. Performance Evaluation Metrics

In this work's simulations, we focused on selecting performance metrics that reflect the goal of the designed algorithm. For *MANETs* evaluation sake a vast discussion was stated in *RFC* 2501 [23,24]. In *RFC* 2501 a basic fundamental consideration about routing protocol performance issues and evaluation were discussed which we adopted in selecting this work performance metrics. Based on the proposed mechanisms to improve greedy, the performance evaluation metrics were carefully derived and stated below.

1) Packet Delivery Ratio:

Packet delivery ratio (*PDR*) represents the ratio between the number of packets originated by the *CBR* sources and the number of packets successfully received by the *CBR* sink at the final destination by the used routing algorithm as a function of node speed, number of nodes, and data traffics load. The *PDR* is computed as shown in equation 17.

$$PDR = \frac{\sum Number\ of\ received\ packets\ at\ destination\ node}{\sum Number\ of\ \ packets\ sent\ by\ source\ node} \tag{17}$$

2) End-t- End Delay:

The End-To-End (*E-2-E*) delay metric is used to show the difference between the time a data packet is received by the destination (T_D) and the time the data packet is generated by the source (Ts) through the used routing algorithm as a function of node speed, number of nodes, and data traffics load. The *E-2-E* delay time includes; the buffer delay, node processing delay, the bandwidth contention delay at the *MAC*, and the propagation delay. To calculate *E2E-D* for one received packet at the destination side, equation 18 is used.

$$E2E\ Delay = T_D - T_S \tag{18}$$

Where, *E-2-E* Delay represent the delay time, T_D represent the time a packet is received at destination side, T_S represent the time a packet is sent from source side.

3) Nodes' Neighbours Matrix Credibility:

To evaluate the goodness of the used routing algorithm, an investigation is done to show the ability of the compared routing algorithms to keep the consistency of node's neighbours' matrix. Nod's Neighbours Matrix Credibility (*NMC*) represents the ratio number of false neighbours remains in a node neighbourhood matrix (not removed yet) which already leaves its transmission range to the total number of a node's entries in its neighbours' matrix, as a function of node speed, number of nodes, and data traffics load. The *NMC* metric influence other metrics such as *PDR* and *E-2-E* delay when selecting wrong next relay node. And thus, in this aspect, the *NMC* metric is essential to show the routing algorithm reliability and efficiency.To explain this metric, suppose that the degree of node i is $|N(i)|$ defined as its entire neighbor in its transmission range. Also, suppose that the neighbors that are listed in the node's i neighbours matrix is $N^*(i)$. To calculate the *NTC* at time *t* the equation 19 bellow is used.

$$NTC(i,t) = \frac{(N^*\ (i,t))\ /\ (N(i,t)}{N(i,t)} \tag{19}$$

Where, $N(i,t)$ is node i degree at time *t*, $N^*\ (i,t)$ is the number of neighbours listed in node *i* neighbours matrix at time *t*, this metric is computed at specific instance time during simulation time (after starting the simulation and reach the steady state (i.e. at; 250s, 500s, 750s). At those selected time a snapshot for the simulation is taken to find the $N(i,t)$ and the $N^*\ (i,t)$. These two values were collected randomly for 10 nodes. The reason why, because in any experiment and after reaching the steady state the collected information for any node in the environment should show same result since all participating nodes works under same conditions as related for each scenario. Next, we used the equation mentioned above to calculate *NTC*.

VI. Simulation Results

A. Packet delivery ratio

Fig. 8 shows the performance analysis of the achieved packet delivery ratio as a function of node moving speed for the *GPSR* and *GPSR-IFPE*. The result shows that *GPSR-IFPE* is much better than the *GPSR* protocol. This is because that *GPSR* needs to retransmit data packets that are lost due to

https://sites.google.com/site/ijcsis/
ISSN 1947-5500

the node's mobility. As node's mobility increases, the topology will change fast too. As topology change very fast, because using *FBPIT*, the position information of the neighbours in *NLM* matrix will become stale very fast. Selecting one of these stale neighbours as a next relay node will result in sending the data packet to inaccurate position that causes the packet to be dropped. On the other hand, with *GPSR- IFPE*, using fuzzy logic is adaptively and dynamically updates the *ELT* in a node's *NLM* matrix based on neighbours' mobility changes. *GPSR-IFPE* achieves more 95.4% in the packet delivery ratio due to the *IFPE* algorithm that increases the accurate information in a sender's *NLM* and avoids routing the data packet to inaccurate neighbours.

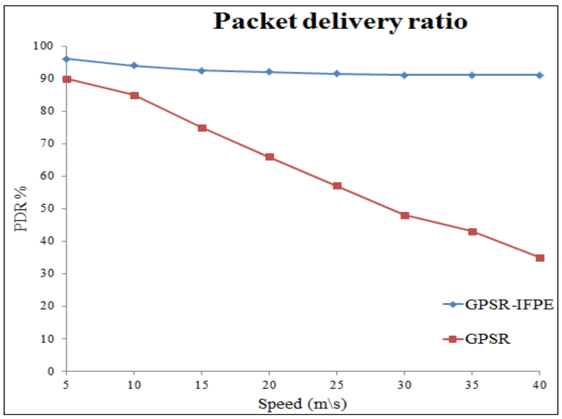

Fig. 8. Performance analysis of the achieved packet delivery ratio as a function of node moving speed for the GPSR and GPSR-IFPE.

Fig. 9 shows the performance analysis of the achieved packet delivery ratio as a function of the number of nodes. The figure shows that *GPSR- IFPE* is much better than the *GPSR* protocol. When using *GPSR* and as the a sender's degree increases the number of outdated neighbours in its *NLM* increase too, and thus the probability to select one of these outdated neighbours as the next relay node will increase too. Selecting one of these stale neighbours as the next relay node will result in sending the data packet to inaccurate position that causes the packet to be dropped. On the other hand, with *GPSR- IFPE* using fuzzy logic make the *ELT* of the neighbours in node's neighbours' matrix will be adaptively and dynamically update regardless of the sender's degree. *GPSR-IFPE* achieves more 92% in the packet delivery ratio due to the *IFPE* algorithm that increases the accurate information in a sender's *NLM* and avoids routing the data packet to inaccurate neighbours.

Fig. 10 shows the performance analysis of the achieved packet delivery ratio as a function of data traffics. For both protocols, as the number of flows increases, the number of packets in the network to be rerouted increases too. This increment in the traffic results congestion at the center of the network that increases the probability of packet loss. Thus for both protocols as the number of flows increases this means more packet loss. Another thing to be mentioned that while using *GPSR*, the used outdated neighbours as next relay nodes will significantly increase which increase the dropped packets. On the other hand, while using *GPSR-IFPE*, since the information of the neighbours in any node's *NLM* is always accurate, thus the routed packet will be correctly reached their final targets. And thus, *GPSR-IFPE* protocol achieves the highest packet delivery ratio.

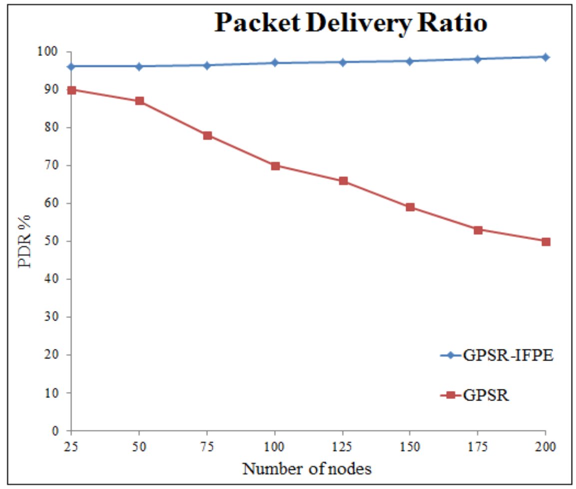

Fig. 9. Performance analysis of the achieved packet delivery ratio as a function of the number of nodes.

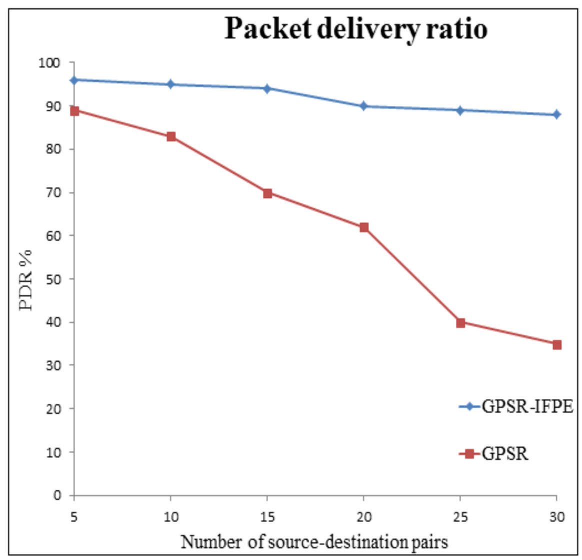

Fig. 10. Performance analysis of the achieved packet delivery ratio as a function of data traffics.

B. *End-To-End Delay*

Fig. 11 shows the average end-to-end delay in *GPSR* and *GPSR-IFPE* protocols as a function of node speed. The figure shows that *GPSR-IFPE* significantly decreases the average end-to-end comparing to *GPSR*. The reason why refer to the fact that when using *GPSR* and as the neighbours' mobility increases the number of outdated neighbours in a sender *NLM* increase too. During packet routing, the sender node selects a neighbour for the next hop. If an outdated neighbouring node is selected as the next relay one, the routed data packet will be lost. As a consequence, the sender node will retransmit the lost packet again up to 7 times, this will increase the delay since during those retransmission the data packet is buffered for extra time. After several retransmitting for routed data packet to outdated neighbouring node, the *MAC* layer would report that the next hop is unreachable, causing the sender node to pick a different neighbour and reroute the data packet again which required another extra time resulting in a significant longer average end-to-end delay. On the other hand, as the nodes' mobility increases while using *GPSR-IFPE* this will activate the *IFPE* algorithm functionality to track and remove the outdated neighbours in the senders' *NLM* very fast and in a timely manner. As a consequence, this will decrease the number of outdated neighbours in the sender's *NLM*. Therefore, the outdated neighbouring node can be avoided to be selected as the routing node compared to the *GPSR*. And thus, during packet routing, the sender node selects an accurate neighbour for the next hop from its *NLM*. *GPSR-IFPE* achieves less 95.4% in average end-to-end delay due to the *IFPE* algorithm that increases the accurate information in a sender's *NLM* and avoids routing the data packet to inaccurate neighbours.

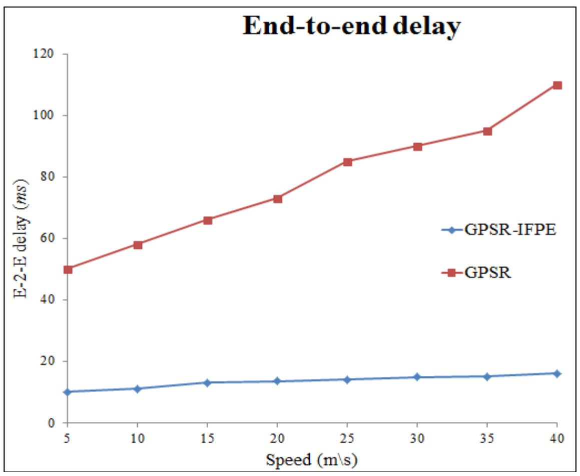

Fig. 11. average end-to-end delay in GPSR and GPSR-IFPE as a function of node speed.

Fig. 12 shows the average end-to-end delay in *GPSR* and *GPSR-IFPE* protocols as a function of the number of nodes. The figure shows that *GPSR-IFPE* significantly decreases the average end-to-end comparing to *GPSR*. The reason why refer to the fact that when using *GPSR* and as the sender's degree increases the number of outdated neighbours in its *NLM* increase too, and thus the probability to select one of these outdated neighbours as the next relay node will increase too. If an outdated neighbouring node is selected as the next relay one, the routed data packet will be lost. This will incurs more delay to buffer the data packet during retransmission time and during selecting new next relay node resulting in a significant longer average end-to-end delay. On the other hand, as the sender's degree increase while using *GPSR-IFPE* the *IFPE* algorithm track and remove the outdated neighbours in the senders' *NLM* independent of sender's degree. As a consequence, this will decrease the number of outdated neighbours in the sender's *NLM*. Therefore, the outdated neighbouring node can be avoided to be selected as the routing node compared to the *GPSR*. And thus, during packet routing, the sender node selects an accurate neighbour for the next hop from its *NLM*. *GPSR-IFPE* achieves less 92.2% in average end-to-end delay due to the *IFPE* algorithm that increases the accurate information in a sender's *NLM* and avoids routing the data packet to inaccurate neighbours.

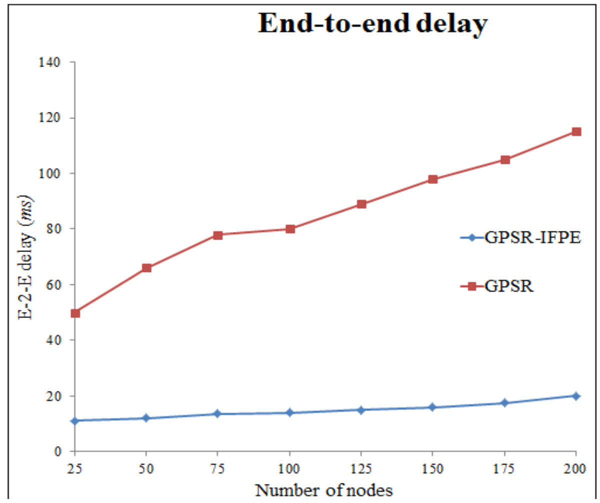

Fig. 12. average end-to-end delay in GPSR and GPSR-IFPE as a function of the number of nodes.

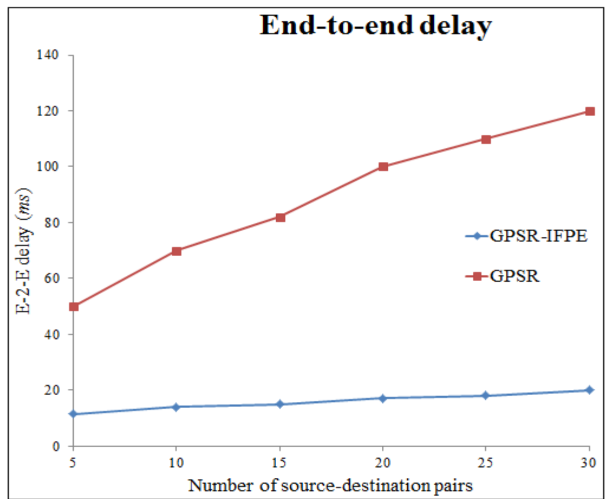

Fig. 13. average end-to-end delay in GPSR and GPSR-IFPE as a function of data traffics.

Fig. 13 shows the average end-to-end delay in *GPSR* and *GPSR-IFPE* protocols as a function of data traffics. For both protocols, as the number of flows increases, the average end-to-end delay increases also due to the increment in the number of packets in the network which caused more packets to be rerouted. *GPSR-IFPE* protocol achieves the lowest average end-to-end delay, because more packets are to be rerouted using different paths. While using *GPSR*, using outdated neighbours as next relay nodes will significantly increase the average end-to-end delay.

On the other hand, while using *GPSR-IFPE*, since the information of the neighbours in any nod's *NLM* is accurate, this result fewer ratio averages end-to-end delay compared with using *GPSR*.

C. Nodes' Neighbours Matrix Credibility

Fig. 14 shows the Nodes' Neighbours Matrix Credibility *NMC* ratio in *GPSR* and *GPSR-IFPE* protocols as a function of node speed. As nodes mobility increase under using *GPSR* routing protocol, the number of outdated neighbors in a node's *NLM* matrix is increased and thus, the ratio *NMC* is increased too. The reason behind this increment that while nodes moving through the transmission range of a node will not send a beacon message because of using *FBPIT*, which bounded the *ELT* of entries for fixed interval time.

However, by using *GPSR-IFPE* protocol, the number of outdated neighbors in *NLM* matrix is much lower and the ratio *NMC* seems to be stable. The reason is referred to the fact that nodes using *GPSR-IFPE* protocol move the outdated entries of its neighbours relaying on residual link lifetime between the communicating nodes regardless the interval of *FBPIT*. As we can see, the *GPSR-IFPE* protocol shortens the *NMC* by 93.4 percent compared to *GPSR* routing protocol.

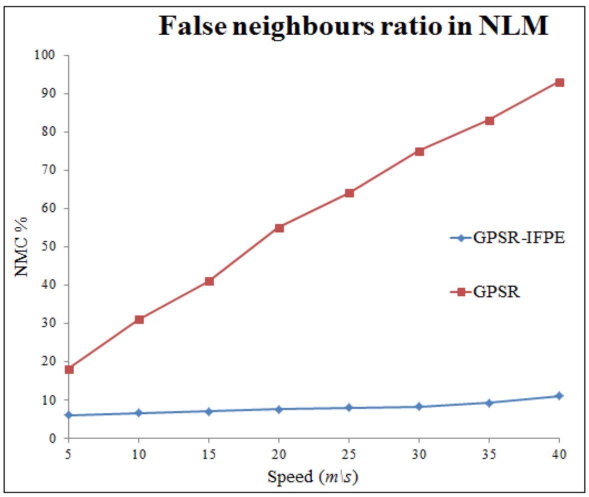

Fig. 14. Nodes' Neighbours Matrix Credibility NMC ratio in GPSR and GPSR-IFPE as a function of node speed.

Fig. 15 shows the Nodes' Neighbours Matrix Credibility *NMC* ratio in *GPSR* and *GPSR-IFPE* protocols as a function of the number of nodes. In both protocols as the number of nodes increases with the same network area the number of a node's degree increase too.

As shown in the figure, in *GPSR*, when the nodes' degree increases; the number of the detected outdated neighbours in nodes' *NLM* matrix increases too. This is because deleting the neighbour's entry is only based on the sending frequency of the HELLO packets.

However, the figure shows the effectiveness of *GPSR-IFPE* protocol; the number of outdated neighbors in nodes' *NLM* matrix is much lower and the ratio *NMC* seems to be stable. The reason is referred to the fact that nodes using *GPSR-IFPE* protocol remove the outdated entries of its neighbours more quickly relaying on residual link lifetime between the communicating nodes regardless the increment in a node's degree. As we can see, the *GPSR-IFPE* protocol shortens the *NMC* by 95.3 percent compared to *GPSR* routing protocol.

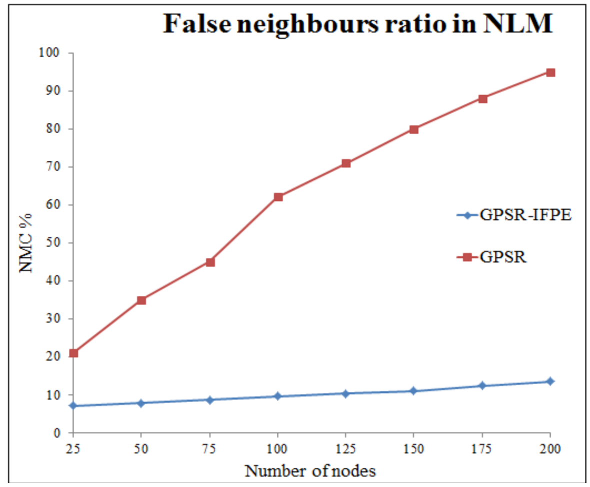

Fig. 15. Nodes' Neighbours Matrix Credibility NMC ratio in GPSR and GPSR-IFPE as a function of the number of nodes.

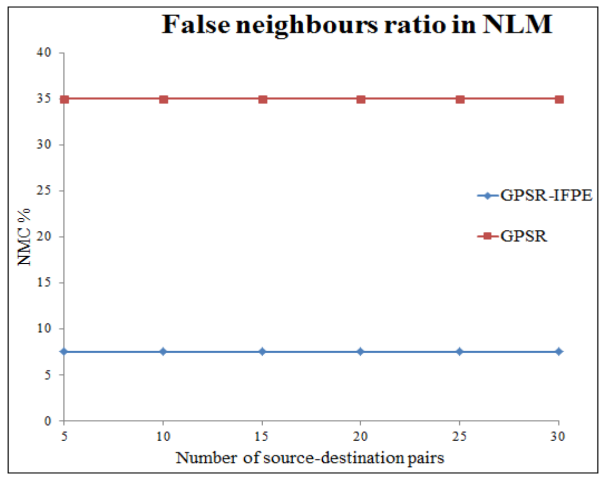

Fig. 16. Nodes' Neighbours Matrix Credibility NMC ratio in GPSR and GPSR-IFPE protocols as a function of data traffics.

Fig. 16 shows the Nodes' Neighbours Matrix Credibility *NMC* ratio in *GPSR* and *GPSR-IFPE* protocols as a function of data traffics for both protocols. As the number of data traffics increase, the number of outdated neighbors in a node's *NLM* matrix remains static since in both strategies the number of outdated neighbors in a node's *NLM* matrix is independent of the number of data traffics in the network. Furthermore, since in this scenario a fixed speed is used then *GPSR-IFPE* achieves the lowest ratio of *NMC*, the reason is referred to the fact that nodes using *GPSR-IFPE* protocol move the outdated entries of its neighbours relaying on residual link lifetime between the communicating nodes regardless the interval of *FBPIT*. On the other hand, the ratio of *NMC* in *GPSR* is the highest where entries are removed with fixed time related to *FBPIT*.

VII. CONCLUSIONS

In this paper, we first shortly mentioned the possible reasons that result inaccurate node's neighbors matrix in position-based routing. An inaccurate node's neighbours' matrix improved the risk of false routing decision make, which consider a major source of delay and packet loss. In the literature *ELT* is normally set to a multiple of the beacon interval sending time, which is not adaptive and impractical method. In this paper we showed through simulation results that when we adaptively optimized the *ELT* to be proportional to *RLT*, the risk of outdated neighbor entries is completely reduced. In every nod's neighbours' matrix, *RLT* is estimated based on the relative velocity (speed and direction) between both nodes. Basing on *RLT* a node runs *IFPE* to estimate the neighbour *ELT* and added it as another part of the entry for this neigbour. The *ELT* timer helps in determining the neighbour's existence in a node's transmission radius. By accomplish this, the neighbours' matrix can be consistence and more efficient, so that the success rate of the enhanced routing protocol is improved, through executing correct forwarding decisions.

To the best of our knowledge, all proposed works in the state of the art use a simple time outdated-based strategy with pre-specified fix time. Thus, if *ELT* is optimized as proposed in this work, the performance of position-based routing protocol could be easily improved significantly. From the result and analysis, we are now looking into further enhancement to the position-based routing protocols with an adaptive beaconing strategy.

REFERENCES

[1] M. Frodigh, P. Johansson, and P. Larsson, "Wireless Ad-hoc Networking- the Art of Networking without A Network," Ericsson Review 4 (2000) 248-263.

[2] A. Ambhaikar and L. Sharma, "Exploring the Behavior of Mobile Ad Hoc Network Routing Protocols with Reference to Speed and Terrain Range," in the Proceeding of *the International Multi Conference of Engineers and Computer Scientists* (IMECS10), Hong Kong, pp. 798-803, 2010.

[3] J. A. Alzubi, O. A. Alzubi, T. M. Chen, "Forward Error Correction Based On Algebraic-Geometric Theory," Springer International Publishing, Edt. 1, 2014.

[4] P. Ghosekar, et al., "Mobile Ad hoc Networking: Imperatives and Challenges," *International Journal of Computer Applications* IJCA, vol. 1, pp. 153-158, 2010.

[5] O. A. Alzubi, "An Empirical Study of Irregular AG Block Turbo Codes over Fading Channels," Research Journal of Applied Science, Engineering, and Technology, vol. 11 (12), pp. 1329-1335, 2015.

[6] A. Sholiyi, J. A. Alzubi, O. A. Alzubi, O. Almomani, and T. O'Farrell, "Near Capacity Irregular Turbo Code," Indian Journal of Science and Technology, vol. 8 (23), 2015.

[7] S. Abukharis, J. A. Alzubi, O. A. Alzubi, and S. Alamri, "Packet Error Rate Performance of IEEE802.11 g under Bluetooth Interface," Research Journal of Applied Science, Engineering, and Technology, vol. 8 (12), pp. 1419-1423, 2014.

[8] N. N. Qadri and A. Liotta, "Analysis of Pervasive Mobile Ad hoc Routing Protocols," in Pervasive Computing: Innovations in Intelligent Multimedia and Applications, Computer Communications and Networks, J. H. A. Aboul-Ella Hassanien, Ajith Abraham and Hani Hagras Ed., ed London: Springer, 2009, pp. 433-453.

[9] C. Lemmon, et al., "Review of Location-Aware Routing Protocols," *Advances in Information Sciences and Service Sciences*, vol. 2, pp. 132-143, 2010.

[10] Y. Jazyah and M. Hope, "A Review of Routing Protocols for UWB MANETs," *Computational Science and Its Applications*–ICCSA 2010, pp. 228-245, 2010.

[11] O. Almomani, M. Al-shugran, J. A. Alzubi, and O. A. Alzubi, "Performance Evaluation of Position-based Routing Protocols using Different Mobility Models in MANET," International Journal of Computer Applications, vol. 119 (3), pp. 43-48, 2015.

[12] B. Karp and H. T. Kung, "GPSR: Greedy Perimeter Stateless Routing for Wireless Networks," in *Mobile Computing and Networking*, 2000, pp. 243–254.

[13] E. Natsheh, et al., "Adaptive Optimizing of Hello Messages in Wireless Ad-Hoc Networks," presented at *International Arab Journal Information Technology*, 2007, pp.191-200.

[14] I.D. Chakeres and E. M. Belding-Royer, "The Utility of Hello Messages for Determining Link Connectivity," in the proceedings of *the 5th International Symposium on Wireless Personal Multimedia Communications* (WPMC) 2002, Honolulu, Hawaii, October 2002.

[15] F. Ingelrest, et al., "A Turnover Based Adaptive Hello Protocol for Mobile Ad Hoc Sensor Networks," in the *proceedings of the IEEE* MASCOTS, 2007.

[16] Q. Chen, et al., "Adaptive Position Update in Geographic Routing," in the Proceeding of *the IEEE International Conference on Communications* (ICC'06), Istanbul, Turkey, vol. 9, pp. 4046-4051, 2006.

[17] R. Saqour, et al., "Dynamic Beaconing for Ad Hoc Position-based Routing Protocol Using Fuzzy Logic Controller," in the Proceeding of the *International Conference on Electrical Engineering and Informatics* (ICEEI2007), Indonesia, pp. 966-969, 2007.

[18] C.H.Chou, et al., "Dynamic Route Maintenance for Geographic Forwarding in Mobile Ad Hoc Networks," *Computer Networks* 52 (2) (2008) 418–431.

[19] J. Tang, et al., "Reliable Routing in Mobile Ad Hoc Networks Based on Mobility Prediction," in the Proceeding of *the IEEE International Conference on Mobile Ad-Hoc and Sensor Systems* (MASS'04), Arizona State University, Tempe, AZ, USA, pp. 466-474, 2005.

[20] S. Bai, et al., "Beacon-Based Cooperative Forwarding Scheme for Safety-Related Inter-Vehicle Communications," in *the International Conference on Computational Science and Its Applications*, ICCSA 2010.

[21] P. Samar and S. P. Wicker, "On the Behavior of Communication Links of a Node in a Multi-Hop Mobile Environment," In the proceedings of *the ACM MobiHoc*, June 2004.

[22] A. Chandramohan, et al., "Two New and Useful Defuzzification Methods Based On Root Mean Square Value," Soft Computing-A Fusion of Foundations, Methodologies and Applications, vol. 10, pp. 1047-1059, 2006.

[23] J. A. Alzubi, "Optimal Classifier Ensemble Design Based on Cooperative Game Theory," Research Journal of Applied Science, Engineering, and Technology, vol. 11 (12), pp. 1336-1343, 2015.

[24] S. Corson and J. Macker, "RFC2501: Mobile Ad Hoc Networking (MANET): Routing Protocol Performance Issues and Evaluation Considerations," Internet RFCs, 1999.

Jafar A. Alzubi received a B.Sc (Hons) in Electrical Engineering, majoring Electronics and Communications from the University of Engineering and Technology, Lahore, Pakistan in 2001. In 2005 received M.Sc. (Hons) in Electrical and Computer Engineering from New York Institute of Technology, New York, USA. Between 2005-2008, he became a full time lectures in the School of Engineering at Al-Balqa Applied University. In 2008, He joined the Wireless Communications Research Laboratory at Swansea University (Swansea, UK), completing his PhD in Advanced Telecommunications Engineering in June 2012. He is now an Assistant professor at Computer Engineering department, Al-Balqa Applied University; also he is deputy dean of Engineering Faculty.

His research interests include Elliptic curves cryptography and cryptosystems, classifications, using Algebraic-Geometric theory. As part of his research, he designed the first regular and first irregular block turbo codes using Algebraic Geometry codes and investigated their performance across various computer and wireless networks.

https://sites.google.com/site/ijcsis/
ISSN 1947-5500

Omar Almomani received his Bachelor and Master degree in Telecommunication Technology from institute of Information Technology, University of Sindh on 2002 and 2003 respectively. He received his PhD from University Utara Malaysia in computer network. Currently he is assistant professor and Vice Dean of Information Technology Faculty, the World Islamic Sciences & Education His research interests involves mobile ad hoc networks, Network Performance, Multimedia Networks, Network Quality of Service (QoS), IP Multicast, Network modeling and Simulation and Grid Computing.

Omar A. Alzubi was born in Allan, Jordan, in 1968. He received Master degree with distinction in Computer and Network Security from New York Institute of Technology (New York, USA) in 2006. He also holds Ph.D. degree in Computer and Network Security from Swansea University (Swansea, UK) in 2013. He joined Al-Balqa Applied University since 2013 as an assistant professor in computer and network security.
Dr. Alzubi research interest includes network security, cloud security, application of Algebraic-Geometric theory in channel coding, machine learning, and Elliptic curve cryptosystems. He is also involved in UK-Turkey Higher Education Partnership Program 2011-2013 projects where he proposed a cryptosystem based on Elliptic curves.

Mahmoud Al-Shugran received his Bachelor degree in physics from Mutah University in 1989, Mater Degree in Computer and Information Technology from University Utara Malaysia on 2009 and his Ph.D. also from University Utara Malaysia in computer network. Currently he is an assistant professor at Faculty of Information Technology in Jerash University (Jerash, Jordan). His research interests involves mobile ad hoc networks and Cloud computing.

https://sites.google.com/site/ijcsis/
ISSN 1947-5500