

FMADM SYSTEM FOR MANET ENVIRONMENT

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ABSTRACT

MANET environment was represented by a combination of node position, mobility speed, node type, and number of nodes. In this paper, a novel system for MANET environment evaluation is proposed by involving fuzzy multi-criteria decision maker (FMCDM) to reflect the importance of the MANET environment on the overall protocols performance. The proposed system combined with another system that previously suggested for MANET protocol evaluation. the outputs of these systems are merged to produce one single crisp value in interval [0 1]. Then, a case study for an office is implemented using OPNET 14.5 simulator to test the proposed system. results proved that MANET environment could be used to enhance the QoS of the protocol. in another world, factors along with inherent characteristics of Ad-hoc networks may result in unpredictable variations in the overall network performance.

KEYWORDS

MANET, Fuzzy, FMADM, Network Environment, Adhoc protocols, QoS .

1. INTRODUCTION

QoS level for each Ad-hoc routing protocol based on three main issue, the parameters obtained from network, type of application applied in the network and other potential factors (implied factors) that cannot be controlled by the protocol designer like nodes mobility speed, keeping in mind that as the mobility speed increases the probability of hand-off and packets loss increases too. Number of nodes also an important factor that effect on network protocols performance. Due to factors importance many works tried to predict or model nodes movement like RWP in [1], mobility prediction in [2] or propose algorithms to reduce the number of hops between source and destination for providing better QoS. Generally, most algorithms that determine the least number of hops and best bandwidth available had a negative effect on network protocol performance, especially, in large network or network that supports multimedia (real time application) since it will increase the average time delay in network. However, The type and the number of MANET's nodes, manner of nodes distribution, and type of mobility had a great effect on QoS parameter (throughput, delay, jitter and PDR) which effects on protocols QoS performance as result. Dmitri D. Perkins et. al. [3] concentrated their study on investigating and quantifying the effects of various factors on the overall performance of Ad-hoc networks, while nodes cooperation is sufficient to achieve performance improvement is discussed in [4]. In addition to the QoS/HFS for MANET application evaluation that detailed [5], MANET environment evaluation system will be design in this paper, as a result of its effective role on the overall protocols performance. Environment evaluation will be done by FMADM, due to MANET characteristic as previously explain. Fuzzification is the process of changing a real scalar value into a fuzzy value. This is achieved by different types of fuzzifiers. Fuzzification of a real-valued variable is done with intuition, experience, rules set analysis and conditions associated with the input data variables. There is no fixed set of procedures for the fuzzification. Fuzzification of MANET environment factor will base on discrete membership function. As Zadeh has stated that a fuzzy set induces a possibility distribution on the universe, meaning one can interpret the membership values as possibilities. How are then possibilities related to

probabilities? First of all, probabilities must add up to one, or the area under a density curve must be one. Memberships may add up to anything (discrete case) or the area under the membership function may be anything (continuous case). Secondly, a probability distribution concerns the likelihood of an event to occur, based on observations, whereas a possibility distribution (membership function) is subjective. The word 'probably' is synonymous with presumably, assumably, doubtless, likely, presumptively. The word 'possible' is synonymous with doable, feasible, practicable, viable, workable. Their relationship is best described in the sentence: what is probable is always possible, but not vice versa [6].

2. MANET ENVIRONMENT FACTORS

The following factors have a great effect on the protocols QoS performance, these factors combined to represent the environment where the protocol applied, and as a consequence where the applications used. this section contains the description and the Fuzzification process of each.

2.1. Number of Nodes

Number of node have a considerable impact on network scalability [3], it is expected that if nodes density is increased the throughput of the network will increase. But beyond a certain level, if nodes density is increased, some protocols will face degradation in performance [7]. Authers in [8] specified how the number of nodes parameter influences on Adhoc protocol performance. Byungjin Cho [9] proves that for sparse networks, various distributed model tends to be similar to the result of Poisson Point Process (PPP). For dense case, various point processes lead to different interference distributions. M. Hammoshi[10] classifies networks according to its nodes number in the aim of measuring the performance of some Ad-hoc routing protocols by considering network with 120 nodes is a largest Ad-hoc network. Number of nodes Fuzzificatin process will assign a membership value 1 to networks contain 120 or more nodes while networks with nodes smaller than 120 will have value between [0 1], as show in figure 1.

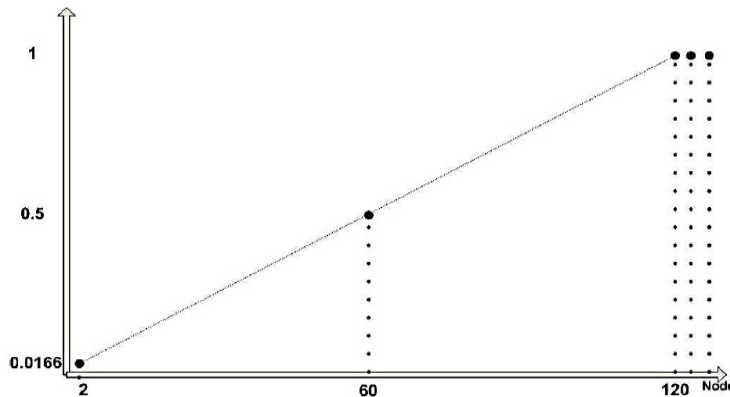


Figure 1. Number of nodes MFs

2.2. Nodes Position

One of the most important factors that effects on the protocol performance is the node location relative to the other nodes. The distributions of nodes have strongly noticeable effects on analytical and simulation-based work. In all the works mentioned so far, the common underlying assumption considers nodes in the network are uniformly randomly distributed. However, this assumption does not hold for real networks and could be considered only as an approximation for conducting simplified studies. Jakob Hoydis et. al[11], studies the effects of different node

distributions on the throughput and shows that non-uniform random node distributions have a strong impact on the local throughput, which is related to the network capacity and performance Guleria, A., & Singh, K. [12] indicates that the underlying point distributions of nodes have clear effects on the wireless network properties. This means that the node topology should be taken into account in more detailed analyses and simulations of Ad-hoc, wireless sensor and mesh networks. The fuzzification of opinions can use Linguistic Variables (LV). In this approach, due to considerations regarding the numerical efficiency of the computational process, the LV terms were assumed as a discrete fuzzy set [25]. In order to fuzzfy the effects of the nodes spatial distribution in wireless Ad-hoc networks an ideal perfect point process will assumed in addition to the most widely point process model used. The following node distribution models were arranged according to its compliance with QoS.

2.2.1. Ideal Point Process (IPP)

This model contains a few numbers of nodes with uniform distribution. IPP represents an ideal case where nodes move in a very slow and uniform speed in small area. This model always gives best result for any Ad-hoc protocol applied. According to this assumption, fuzzification of this model will have a largest membership value which equal to 1.

2.2.2. Poisson Point Process (PPP)

Generally, it's the most commonly used point process. Specially, it had been used extensively in the modelling of Ad-hoc networks [14]. The homogeneous PPP is one of the most fundamental point process models because it reflects a complete spatial randomness with no regularity or density trends. Its characteristic is statistical independence. Furthermore, PPP is often used as a basis for comparison with other point processes and it is also used as a general 'building-block' for other point process models. Inhomogeneous Poisson point process, as the name indicates, the mean number of points in a given area depends on the location of this area. As shown in Figure 2, the homogeneous Poisson point process (left) with intensity equal to 100 and inhomogeneous Poisson point process (right) with linearly varying intensity.

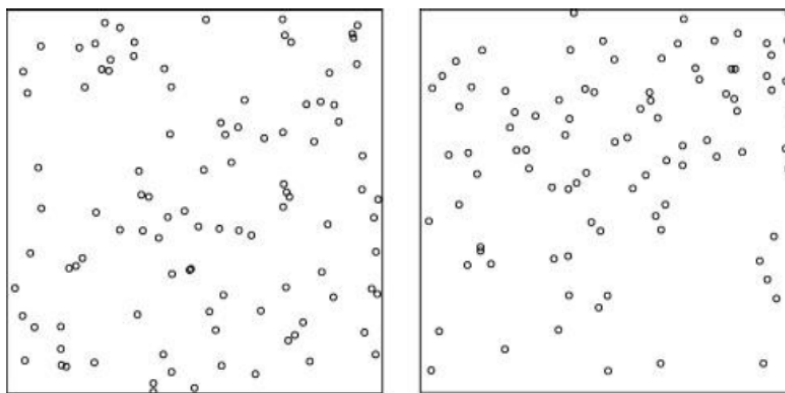


Figure 2. Computer simulation of point processes in a square area [14]

2.2.3. Matérn Point Process (MPP)

PPP is not always suitable for modelling all cases, in some situations, the nodes are independently distributed. MPP is a point process which captures this phenomenon. It belongs to the family of hard core point processes, where the points are forbidden to be closer than a certain minimum distance. Hard-core processes are widely used in the wireless communication domain.

It makes sense to define a certain minimum distance between any two communicating devices. The Matérn hard-core point process is obtained by removing overlapping spheres from a point Poisson process through a procedure called dependent thinning. As show in Figure 3.

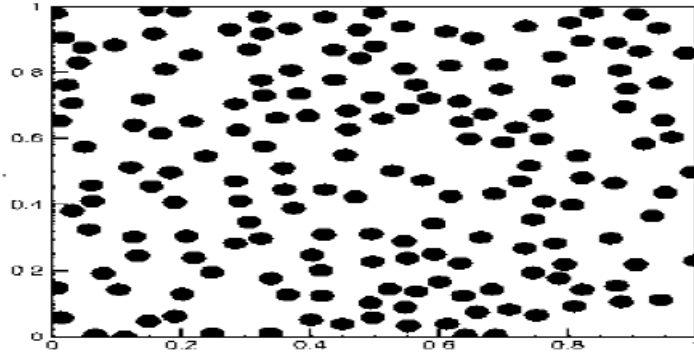


Figure 3.MPP node distribution [14].

2.2.4. Thomas Point Process (TPP).

TPP in general constructed by using a PPP as a distribution of clusters, and then generate center for each cluster. In the case of the Thomas point process (TPP), the number of points in each cluster has Poisson distribution with parameter μ (giving the average number of points (nodes) in each cluster).

Fuzzification of the nodes position will depends on the results in [14], where MPP showed result almost the same as PPP, whereas TPP shows different result (Due to the clustered nature of the distribution). The values in interval [0 1] will be divide into four pulses, the best distribution IPP (which is the virtual state) will have a membership value 1, followed by PPP (0.75), then MPP with membership value (0.5), TPP with (0.25), finally (0) which means no network connection. As shown in Figure 4. To make the fuzzification more general, for any new point process or modifying one of the processes that discussed above, after comparing its performance with PPP, could assign a membership value based on the result obtain. For example the inhomogeneous PPP in [14] is a special case from PPP, it's also suitable for modeling all the nodes of an Ad-hoc networks and can used to evaluate the capacity, connectivity and performances of routing protocols with the intensity measure. Therefore, it could assign a membership value close to (0.75).

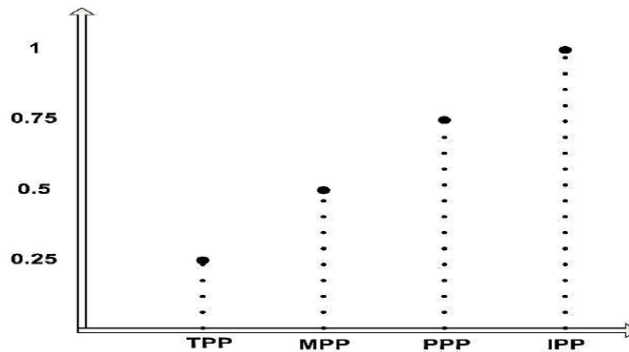


Figure 4. Node position MFs.

2.3. Mobility Speed and Models

One of the most important factors in Ad-hoc network that represent a vital aspect on the QoS support is the mobility of the nodes. Since, nodes mobility may cause link failures which will negatively impact on routing and QoS support. The main reason for degradation in network performance as a result of node mobility is traffic control overhead required for maintaining an accurate routing table in the case of table-driven protocols and maintaining routes in the case of on-demand protocols [3]. M. Benzaid et. al. [15], define four classes of mobile node. Each class defined by its maximum speed as show in Table 1.

Table 1. Speed Classes.

Class	Speed Km/h
cyclist	$20 \leq S < 45$
urban	$45 \leq S < 90$
road	$90 \leq S < 120$
highway	$120 \leq S < 150$

Bhavyesh Divecha et. al. [7], study the impact of MANET nodes mobility on the performance of Ad-hoc wireless networks. The obtained results were based on different range of speeds. First speed, is the average pedestrian speed of 1m/s. Second speed; represent the vehicular speed of 30 m/s. Also they had showed that, when nodes are moving at a higher speed, the probability that they move apart from each other is larger which leads to a degradation of the end to end parameter. Since all nodes act as a router to the other nodes, nodes movement from its vital position in network will degrade the overall network performance or cause temporary service loss. Said El Kafhali et al [16] and Tracy Camp et. al. [17], had studied the effects of various mobility models on the performance of different routing protocols and illustrated that mobility of the nodes affects the number of average connected paths, which in turn affects the performance of the routing algorithm as shown in figure 5. They also explained the most four mobility models used with detailed explanation for how they emulate real world scenario, these mobility models are Random Waypoint (RWP), Random Point Group Mobility (RPGM), Freeway Mobility Model (FMM) and Manhattan Mobility Model (MMM).

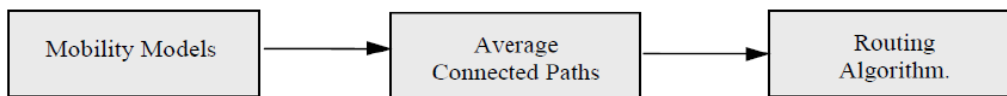


Figure 5. Relationship between protocol performance and mobility model [7].

Figure 6 shows the topography examples of node movement in these four mobility models. In order to fuzzify the membership function of the mobility speed, two limited value will be considered (0) m/sec for the fix node, which has a membership value zero, and (30) m/sec for the very fast node, which has membership value (1).

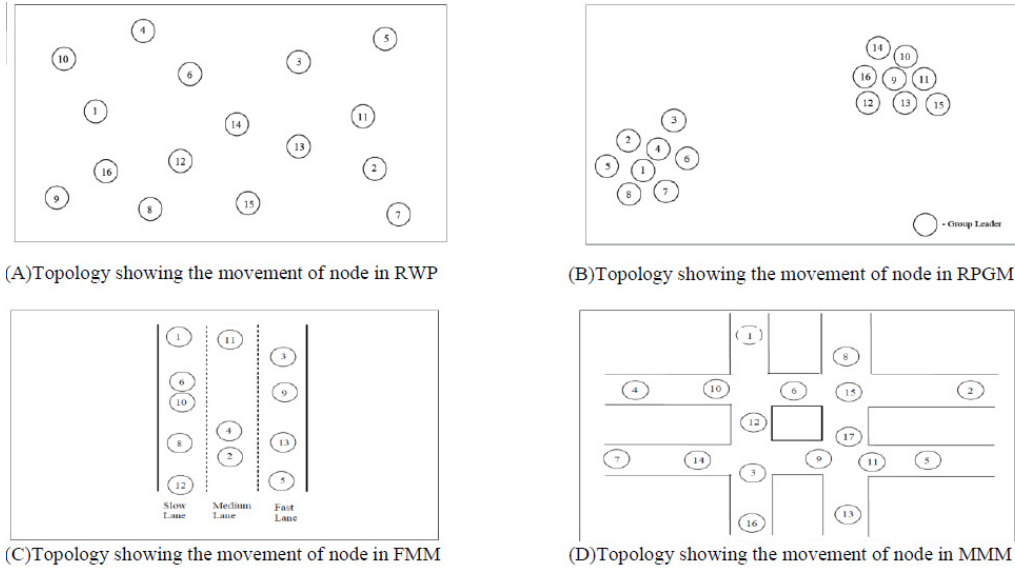


Figure 6. Types of mobility model [7].

Figure 7 shows the membership function of the mobility speed. When mobility model has different speeds, the average value will be taken as membership degree. For instance, nodes move in ranged [5-10] m/sec will have average mobility speed 7.5 m/sec. If there is a pause time, assume 5 sec in this model then average speed will be (7.5/5) m/sec.

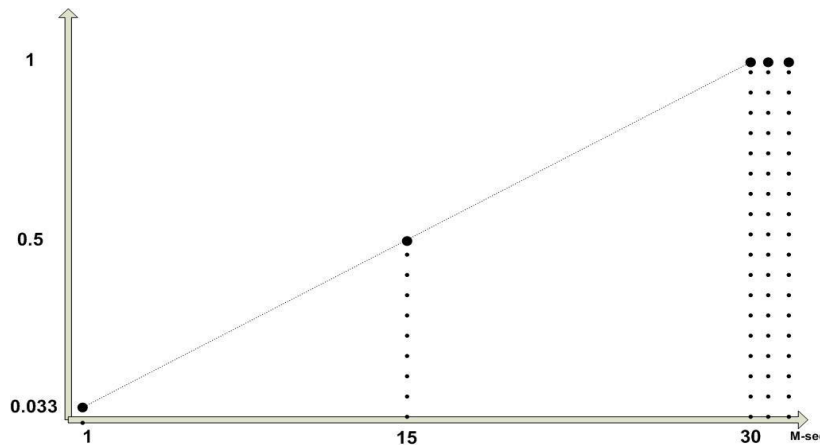


Figure 7. Mobility speed MFs.

In the case when network nodes move in random different speeds, Root Mean Square (R.M.S) will be taken to calculate the membership value for this model, as show in equation (1).

$$membership\ value = \sqrt{\frac{\sum_{j=1}^i n_j MF_j^2}{N}} \quad (1)$$

Where: i : number of group with different speed. n : number of node which move in different speed. MF : speed membership value in m/sec. N : total number of node in network. For example, when network contain 21 nodes, 20 of them move with speed 10 m/sec and one node with speed 30 m/sec, the membership value according to the equation will be 0.39 whereas the average for

these different speeds is 0.36. R.M.S is very important to demonstrate the mobility speed behaviour on the QoS performance. To show R.M.S effect, let's take a special case when all nodes static (0 m/sec) and only one node moved in speed 30 m/sec, the R.M.S for this case is 0.2236 while the average is 0.047.

Velocity, the rate at which an object changes its position, of nodes in MANET also effect on routing protocol performance, for example delay will be vary according to the direction and speed of this node with respect to the destination node. D. Agarwal [18], analyzes the effect of nodes velocity on the performance of various routing protocols in MANET. Speed, velocity and acceleration have great effect on the MANET environment and network QoS parameters (PDR, end-to-end delay, energy consumption, etc.) which could cause large changes on the QoS of Ad-hoc protocols [16].

2.4. Type of Nodes

Type of nodes also have a great effect on the protocol performance, by its processor speed, buffer size, transmission range, battery life time and its size. For example, [19] use a jitter buffer (adaptive jitter buffer) in nodes to smooth out changes in the arrival times of voice data packets. Heterogeneous networks are substantially impacted by terrain and environmental effects, these two issues may cause dramatic changes in link capacities and consequently on end to end measures of performance, throughput, and other QoS parameters. Another issue that must be considered, that low power nodes could receive transmissions from higher power nodes, but not vice versa. This posed challenges at the routing layer, and increased number of collisions at the MAC layer [20]. Node types will be categorized, according to their performance capabilities, into; cell phone or PDA with low capability, PCs or laptops with better capability, workstations and finally servers with best capability. According to these categories membership functions were formulated as show in figure 8 (where larger capability has larger membership value). Most networks may contain more than one type on nodes, in this case it will represent by Mix and its membership value represented by the average between these types. Notice that server could be act as workstation or PC or mobile node but with very small mobility probability. As example if network contain 25 % from each type of nodes, its membership value will be:

$$\text{Membership-degree} = (0.2 \cdot 0.25 + 0.4 \cdot 0.25 + 0.8 \cdot 0.25 + 1 \cdot 0.25) = 0.6 \quad (2)$$

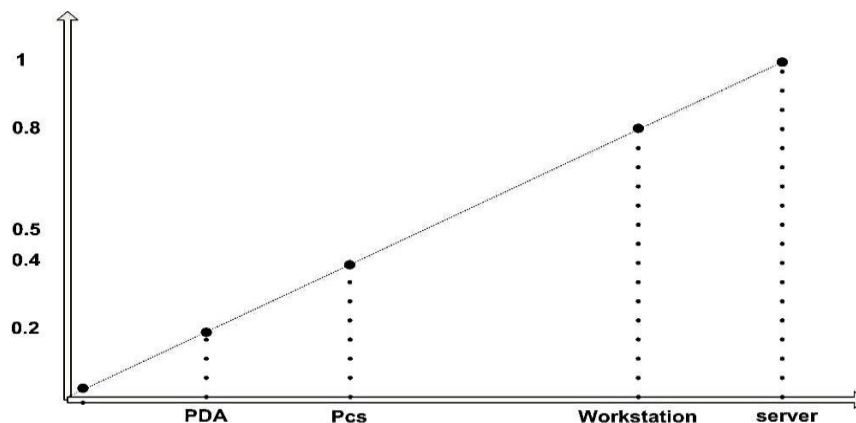


Figure 8.Type of nodes MFs.

3. FMADM MANET ENVIRONMENT EVALUATIONS

The fuzzy approach allows the use of fuzzy operators to numerically aggregate the different fuzzy attributes that characterize the criteria of the rule and assess the degree of truth. For instance, fuzzy operators ANDs or ORs can be formulated using different intersection or union operators, according to desired aggregation behavior (t-norm and t-conorm). MANET environment were represented by a combination of (node position, mobility speed, node type and number of nodes), because each of these factors alone does not represent the environment by itself, but potentiates each other. In another word, it is represented as attribute which obtain by the fuzzification process that done before. This attribute will use by FMADM. The problem of making decisions in a dynamic environment has been the object of study in many different fields. In case of MANET environment, the Fuzzy Operator Tree (FOT) in the aggregation process will be used because it's completely general, widely applicable [21], and its very convent to the MANET environment behaviour. Since nodes position and nodes type effect positively on the overall QoS (as it's indicated by its membership function) whereas mobility speed and number of nodes have a negative effect, nodes positions and type of nodes factors will aggregate separately from node mobility and number of nodes factors. In the literature, several parameterized families of t-norms (t-conorms) have been proposed for factors aggregation proposes. Dubois-Prade had been used in the proposed system mainly because of its simplicity and the fact that a bounded parameter range [0 1] is quite convenient when it comes to calibrating the model. This operator is widely used in previous evaluation works like [25][22][21] The Dubois and Prade union operator is an operator with compensation, which is controlled by the α parameter (parameterized operators). The use of this operator allows the simulation of the synergistic effect that resulting from the simultaneous presence of several potentiating factors. It's defined as the following expression:

$$\mu_{A\alpha B} = \frac{\mu_A + \mu_B - \mu_A \mu_B - \min(1 - \alpha, \mu_A, \mu_B)}{\max(1 - \mu_A, 1 - \mu_B, \alpha)} \quad \alpha \in [0, 1] \quad (3)$$

Since this is a parametric operator, the specific behaviours can be simulated by tuning the value of α , in the proposed system $\alpha = 1$, to allow various attributes values aggregation. Best QoS could be achieved from Ad-hoc protocol when (node position and node type) attributes value equal to 1 (in virtual case) or near to 1 in perfect cases with (mobility speed and number of nodes) attributes are zero (in virtual case), as it illustrated by its fuzzification process. This property made the aim of protocol designer to maximize node position and node type values as much as possible and reduce the mobility speed and number of node values as much as possible at the same time. Due to this trade-o□ between these attributes, a complement operator for the result of the aggregation between mobility speed and number of node should be taken, before its aggregate (using average operator) with the result obtained from the aggregation between node position and node type, as shown in Figure 9.

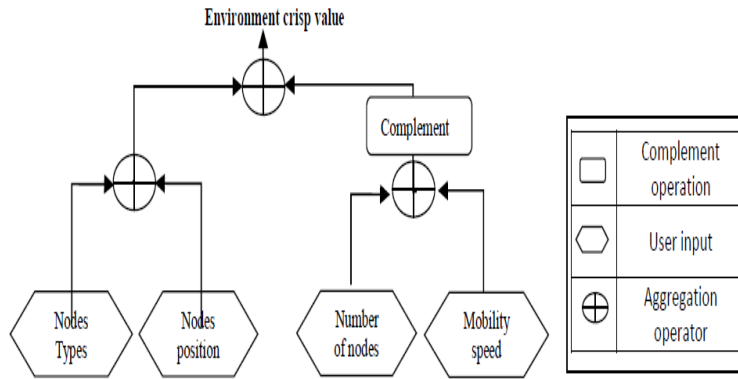


Figure 9. Environment evaluation process.

It should be noticed that IPP case is a result of all other three factors (attributes), where IPP represent a MANET with very few number of nodes (number of nodes attribute (factor) triggered with very small value), IPP nodes move very slow with uniform speed (mobility speed attribute (factor) triggered with a very small value) which made MANET environment is very suitable for Ad-hoc protocol performance. It's obvious now, why that model has membership value equal to 1.

4. SYSTEM PERFORMANCE AND EVALUATION

The Adhoc protocol evaluation system that we proposed in [5] is extended to include the environment evaluation by appended the FMADM system. MATLAB is used in the implementation process. To make the proposed system general, network parameters will be imported to the system from a spreadsheet in (.xls) form, this feature enables the network designer to collect the parameters obtained either manually from actual (real) network or automatically from network simulators to the Microsoft spreadsheet. The system is able to collect the data from any network simulator (OPNET, NS, OMNET, GloMoSim, etc.) that will make the system more general, as the network designer preferred. On the other hand, the environment factors should be providing manually to the system.

4.1. Case Study

In order to check the performance of the system, an Adhoc network has been simulated according to a camp requirement with the most well-known Ad-hoc routing protocols (OLSR, AODV, TORA and DSR).

4.2. Camp Network Equipment

A camp in area (800x800) m², needs Ad-hoc network to serve its employers and its work field. Its depends mainly on E-Mail application to serve all employers requirements, E-Mail is installed on static and mobile PCs. Voice application installed on PDA or cell phone. Voice application used by security guards to support connectivity between them or between them and the mayor cell. This camp has 41 nodes, 30 nodes for E-Mail application and 6 nodes for voice application, while the other 3 nodes are used for both voice and E-Mail application, the camp has two server nodes. OPNET Modeler 14.5 used in this study as simulator tool. OPNET is one of the most extensively used commercial simulators based on Microsoft Windows platform, which incorporates most of the MANET routing parameters compared to other commercial simulators available [23]. Generally, there are four main scenarios in this simulation, one for each Ad-hoc

protocol. All scenarios have the same values assigned to each node in the network except the protocol type where: Scenario 1 OLSR. Scenario 2 AODV. Scenario 3 TORA. Scenario 4 DSR. The parameters that have been used in this network are summarized in Table 2.

Table 2. Simulation Parameters Values.

Simulation Parameter	Value
Total number of nodes	41 (2-server, 9 mobiles, 30 static), PPP
Area	800 x 800 m ²
Mobility model	Random Way Point (RWP)
Node movement speed	(0-5) m/sec with (0) pause time
Applications	E-Mail, voice (GSM)
Simulation time	1200 sec
Transmitter power	0.006 W (7.781 dbm)
Packet Reception power threshold	-86 dBm
MAC layer type	802.11 g (12 Mbps)
Transmission range (outdoor)	100 m

All nodes (PCs and cell phones) were assumed, have the same capability (workstation), supported with high power wireless LAN module 802.11g [24] and simulation time was set to 1200 sec, since simulation needs more than 1000 sec of time to reach the steady state [25]. There are many factors that affect the transmission distance; particularly the combination of transmission power and antenna gain. There are large variety of voice coding scheme, Global System for Mobile communications (GSM) will be used in this network. For all considered simulations, the worst case was all the 33 nodes use EMail and the remaining nodes use voice application simultaneously, according to Table 3, the movement speed of mobile nodes assumed (0-5) m/sec. The nodes positions in the network are shown in Figure 10.

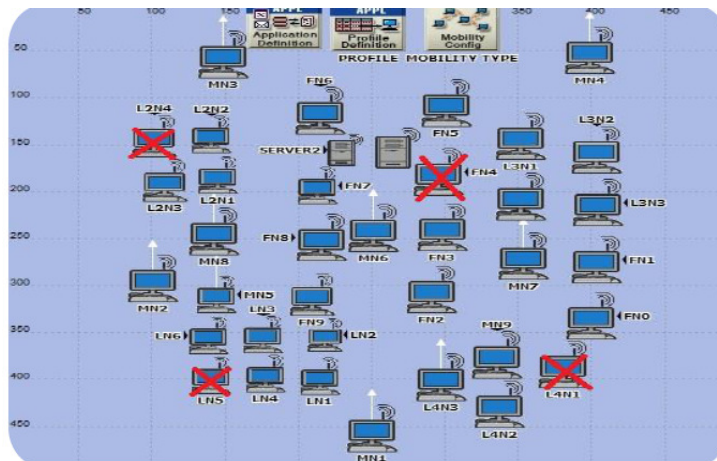


Figure 10. Camp Network Simulation.

Table 3. Nodes Use Voice Application.

Calling Node	Called Node
MN1	MN2
MN4	MN6
L4N3	MN3

4.3. Simulation Results

The environment factors (attributes) are provided by the network designer manually, according to the user requirement. The environment evaluation for this network is shown in Table 4, as it obtained from FMADM system. The output value should be the same for the entire four scenarios. All nodes, in the simulation, had been assumed have the same capability (workstation) and two servers, hybrid from static and mobile with speed in interval (0-5) m/sec, according to this movement speed, mobility speed attribute will be 2.5 according to section 2.3.

Table 4. Environment Evaluation of Scenarios

Factor (Attribute)	Value	Attribute MF	Aggregation Value	Environment Level (Crisp)
Nodes positions	PPP	0.75	0.9524	0.7925
Type of nodes	39(wrks) + 2(server)	0.8098		
Average mobility speed	2.5m/sec	0.039	(1-0.3673)	
Number of nodes	41	0.3417		

The environment of MANET and the frequent uses of applications have great effect on the Ad-hoc protocols performance. the network designer may be able to improve the QoS of some protocols that applied to the network based on the results obtained from the proposed system. For this special case study, a network is designed for a camp, according to its user's requirements the E-Mail application is more frequent use than voice application. The simulation results shown in Table 5, the protocol evaluation value obtained by QoSHFS system from the work in [5], were based on the worst case, all the 33 nodes use E-Mail and 6 nodes use voice (3 links) simultaneously. The result shows that DSR performance could be enhanced, if the numbers of nodes that use E-Mail are reduced in a time. The system shows, DSR protocol QoS jump to [0.8191] when the number of nodes that use E-Mail reduced to 29 nodes. Table 6 contains the name of the idle nodes, whereas Figure 10 shows the positions of these nodes specified in red cross line, these nodes were randomly selected.

Table 5. Final protocols QoS for all scenarios

Scenario Protocol	Protocol's QoSHFS	Final protocol QoS
Scenario1	$OLSR = [(0.3) (0.9367) + (0.7) (0.8336)]_{0.7925}$	$[0.8645]_{0.7925}$
Scenario2	$AODV = [(0.3) (0.6877) + (0.7) (0.1603)]_{0.7925}$	$[0.3185]_{0.7925}$
Scenario3	$TORA = [(0.3) (0.4518) + (0.7) (0.1603)]_{0.7925}$	$[0.2477]_{0.7925}$
Scenario4	$DSR = [(0.3) (0.9367) + (0.7) (0.3385)]_{0.7925}$	$[0.5180]_{0.7925}$

The QoS of DSR jumps from 0.5180 to 0.806 when reducing the number of nodes that use E-Mail application from 33 to 29 nodes. The number of nodes reduction also enhances the environment from 0.7925 to 0.8191.

5. CONCLUSIONS

In this paper, a FMADM system for the MANET environment evaluation had been designed and implemented to be an overall Ad-hoc protocol performance evaluation system. The environment has great benefits to get a close look to the MANET protocol performance, to decide which protocol is the best for specific network pattern. On other hand, environment could be used to

increase MANET QoS by coordinating the protocol or applications requirements with its environment factors.

it has been shown how MANET environment used to enhance the QoS of DSR protocol by matching the environment with protocol algorithm limitation. DSR packets typically carry complete route information, if the packet header overhead decrease, then the QoS performance of DSR will be increased. Based on this fact we reduce the number of nodes in this MANET to enhance the environment. Because of environment enhancement, the performance of DSR is rapidly improved. For future work, the proposed system can be more expanding to be used in the network QoS enhancement through the matching of network resources with the protocol algorithm limitations that applied to the network or developing the propose system to comprise the security level of the Ad-hoc protocols in the performance evaluation process.

ACKNOWLEDGEMENTS

The project has been supported by the European Union, co-financed by the European Social Fund (EFOP-3.6.3-VEKOP-16-2017-0000 2).

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