Designing a new MANET's Environment using Computer Simulation

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Abstract— Simulation plays an important role in the verification and implementation of the Mobile Ad-hoc Network (MANET) environments. It can be used to model any suggested environment. MANET was defined as a set of mobile nodes that moved freely and connected among each other without any infrastructure. Simulation represents a tool that evaluates the performance of an existing or proposed MANET environment under different configurations of interest and over long periods of real time. In this paper the effects of the number of nodes, their speed and their pause time were modeled and analyzed. The network simulator NS-2 was used as a tool to study and evaluate the effects of these factors. Many performance metrics such as throughput, packets loss, packet delivery fraction (PDF), average end-to-end delay, normalize routing load (NRL) and jitter were used as comparison indications. The simulation environment was implemented with different number of nodes, different speeds, and varying pause times. A mathematical model was built and implemented firstly to analyze the effects of the number of nodes and their speed on the behavior of the suggested MANET environment. The second model was built and used to analyze the effects of the number of nodes and their pause times.

Keywords— simulation, performance evaluation, MANET, mathematical modeling

I. Introduction

MOBILE ad hoc network (MANET) is a collection of wireless mobile nodes that can be set up anywhere, anytime and connected via wireless link without using an existing of any fixed infrastructure. MANET is formed dynamically by an autonomous system of mobile nodes. These nodes are wirelessly connected. It represents a dynamic distributed system of arbitrarily moving wireless devices. MANET capabilities and its applications are becoming an important part of overall the current and the next-generation of wireless network functionalities. In MANET, the nodes are free to move randomly while it communicates and can connected to each other randomly as well as organize themselves arbitrarily [1].

Such network's topology may change rapidly and unpredictably. Each mobile node can have one or more network interface, each of which is attached to a channel. Channels are the carrier that carrying packets between mobile nodes. When a mobile node transmits a packet to a channel, the channel distributes a copy of the packet to the other entire network interface on the channel. These interface then use a radio propagation model to determine if they are actually able to receive the packet [2].

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Each of the nodes has a wireless interface and communicates with each other over a radio transmission range [3]. A MANETs might consist of several home-computing devices, including cellular phone, PDAs, laptops, MP3 player, notebooks, handheld PCs and so on. These nodes can be located in cars, ships, airplanes as well as other small personal electronic devices. Each node will be able to communicate directly with other nodes that reside within its transmission range. For communicating with nodes that reside beyond this range, the node needs to use intermediate nodes to replay messages hop by hop [4].

II. System Modeling

Modeling is the process of building a model to represent the actual system with some simplifying assumptions. This process is to allow the designers or the users to experiment, test and change the system parameters to indicate their effects and relations to each other. Such process can be done without any effects on the real system as an economical scientific manner. It can save costs in system development if the modeling process is properly handled. In the system design and development stages, the modeling is important to give an idea of how the system would perform if it actually implemented.

III. Simulation

Simulation is "Imitating or estimating how events might occur in a real situation". It is widely used to analyze, develop and test different topologies, different new protocols and different architectures in the field of networks and communications. This technique offers a good laboratory to simulate and specify the behavior of the network nodes and the communication channels. Simulation methodology is always applied and used to verify analytical models, list the results of the measurements and to test and evaluate the suggested new protocols performance compared with the existing protocols. One of the main objectives of network simulation is to study network performance.

Due to the complexity, impossibility of experimenting on real networks and costs the simulation methodology has become the most popular technique in computer and telecommunication network researches and developments. It can be used to verify analytical models, generalize the measurement results, evaluate the performance of new protocols that are being developed, as well as to compare the existing protocols [5]. These simulators principally aim to model the network systems by changing the features of its built models in order to analyze its corresponding results. It can be applied in an efficient manner to test, analyze and evaluate different purposes of engineering, sciences and other general application systems. One of the available Network Simulators is the discrete event-based simulator called (NS-2) which is one of the most popular academic tools that can be used in evaluating the network topology and protocols. Due to its open source nature, NS-2 can be easily extended and modified. NS-2 is a software package developed for network simulation. It covers a very large number of applications, protocols, network types, network elements, and traffic models [6].

IV. Simulation Methodology

Simulation technique is the most suitable technique that can be used to get detailed information about the MANETs operation. It helps to study a system in repeatability well-known conditions in order to understand the system mutual activities and events [7]. To evaluate the performance of certain existed or suggested communication system, a Network Simulator NS-2 can be used to present and estimate the required main important communication network parameters and metrics [8].

V. Performance Evaluation

There are three possible techniques used to evaluate the network performance; analytical modeling, simulation and measurement. In the case of complex problems, experimenting difficulties in the real systems, new designed systems, unavailability of data, times available for evaluation and cost allocated, there is a suitable technique which is the Simulation technique [9].

As the dynamic topology, time-varying and bandwidth constrained wireless channels, multi-hop routing, and distributed control and management are the main inherent characteristics of the MANETs. The design and performance analysis of routing protocols for (MANET) is currently an active and crucial area of research. Many performances metrics can be used to compare and evaluate the available or the suggested behavior of the MANET's to measure its suitability and performance [10].

There are several important criteria that can be used for Performance evaluation of a real network. It means how well a network runs such as availability, reliability, response time, utilization, throughput, bandwidth capacity, and packet loss ratio [6].

Many performance metrics were developed and adopted to measure and evaluate the performance of the MANET networks. All of the measuring performance processes requires the use of statistical modeling to estimate these parameters values [11]. In this article, six evaluation metrics were estimated and utilized to compare and evaluate the effects and behaviors of the MANET parameters and variables related to nodes speed and nods pause times. These important performance metrics are:

1- Throughput

It is represents the amount of data received by the destination nodes in certain period of time [12].

Throughput=receive packets/simulation time

2- Dropped Packets

All the packets that had to be dropped because of mobility or full queues or by attackers are contained in this category. The number of dropped data packets may be as a consequence of the link failure. The packet loss cause considerable degradation of both real time and non-real time data. In most existing protocols, nodes keep using the link until it breaks. This performance measure helps in quantifying the amount of transmitted data packets discarded by routers in the path to destinations due to errors occurred in the physical or upper layers [7][13]. Simply, it represents the number of packets that sent by the source node and fail to reach to the destination node [14].

Dropped packets = sent packets$_{(i)}$ – received packets$_{(i)}$

3. Average end-to-end delay (average E2E delay)

End-to-end packet delay was defined as the time difference between the time instant at which the contents of a packet is played out at the receiver and the time instant at which the packet is generated at the sender. It measures the delay a packet suffers after leaving the sender and then arriving at the receiver application. Delays are due to route discovery, queuing at Internet protocol (IP), medium access control (MAC) layers and propagation in the channel. It is preferred to be low. It can be represented in mathematical manner by di, which means the end-to-end packet delay of packet i, [15]. It represents the time that spent by the packet to reach to the destination.

E2E delay [packet_id] = received time [packet_id] – sent time [packet_id]

The average end-to-end delay can be calculated by summing the times taken by all received packets divided by their total numbers [3].

4. Normalize Routing Load (NRL)

This evaluation is used to evaluate the operating cost and efficiency of a routing protocol. The NRL represents the ratio of routing packets transmitted to packets received at the destination [16]. It represents the number of routing packets transmitted per data packet delivered at the destination. The equation for calculating NRL is: It is the number of transmitted routing packets per delivery data packets [7][9].

NRL = number of routing packets/ number of received packets.

5. Packet delivery fraction

The *Packet delivery fraction* (PDF) means the number of packets successfully delivered to destinations over total number of packets sent [17]. It can be calculated by dividing the number of packets received by the destination to the number of packets originated by the application layer of the source [18]. This parameter can specify the packet loss rate, which limits the maximum throughput of the network. The better the delivery ratio, the more complete and correct is the routing protocol. PDR reduces as the pause time decreases. This is due to the mobility of the network and the probability of link failures increases as the pause time decreases. PDR is preferred to be high. Packet delivery fraction (pdf) was defined to be the ratio of the delivered and sent packets with the varied node speed [7].

*PDF = (number of received packets / number of sent packets) * 100*

6. Average Jitter

It is the absolute value of the difference between the end-to-end delays of two sequential packets [17]

Jitter = | (end-to-end delay (k+1)) - (end-to-end delay (k))|

The average jitter is obtained by summing the jitter of all received packets divided by the total number of the received packets.

VI. Simulation Environment

The following two suggested simulation environments were built and simulated in this study. The Network Simulator (NS-2) was used as a simulation tool in this article.

A. Environment 1

This environment aims to study and analyze the effect of the nodes number and their average speeds on the general behavior of the MANET. Such effect can observed through the simulated values of many output performance metrics which are (packets loss, throughput, delay, NRL, PDF and Jitter). Many variables or (parameters) were set to be fixed during all the simulation runs in this suggested MANET's environment. Certain arbitrary values were assigned to the simulation area, traffic type, simulation time, pause time and maximum number of connections. The OLSR routing protocol was used as a main routing protocol in all the implemented scenarios. Table 1 shows the first proposed MANET's parameters and their assigned values.

TABLE I

THE FIRST PROPOSED MANET PARAMETERS AND THEIR VALUES.

Parameter	Value
Nodes no.	5, 10, 15, 20
Nodes speed	5, 10, 15, 20, 25
Area	500m * 500m
Traffic type	CBR
Simulation Time	80 s
Routing Protocol	AOMDV
Speed Type	Uniform
Pause Time	5 s
Pause Type	Uniform
Max Connection	5

1) Environment 1 results

Each simulation environment was implemented and repeated 50 times in order to get near reliable stable results. The effects of varying the nodes number and speed were observed by varying the number of nodes and their speeds. Packet delivery fraction, routing load, dropped packets, average jitter, average end to end delay and throughput were calculated with the OLSR routing protocol. The results are plotted in the following figures; each point in the following graphs represents the average of 50 scenario runs. This environment was evaluated and simulated to indicate the effects of the number of nodes and their speeds on the behavior of the MANET. Each run was repeated 50 times and the average value for each metric were estimated. Fig. 1 shows the lost packets in different nodes speed and different number of nodes (5, 10, 15 and 20). The number of the lost packets was decreased with increasing the number of nodes in low speed. It will increase with increasing the nodes speed. The best situation is to let the nodes speed below 17 m/sec and the best suitable number of nodes for such area is 15 nodes.

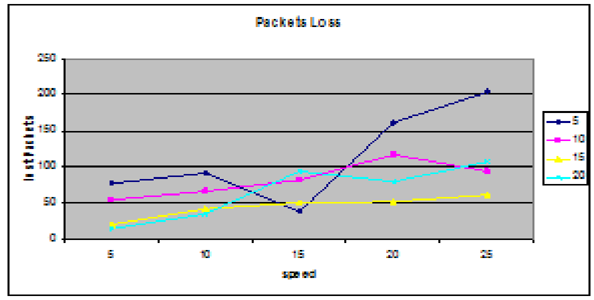

Fig. 1: lost packets in different nodes speed and different number of nodes.

Fig. 2 shows the throughput values in different nodes speed and different number of nodes.

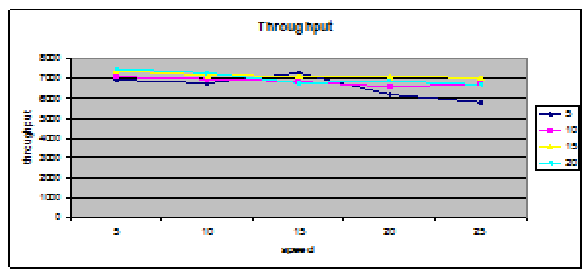

Fig. 2: throughput values in different nodes speed and different number of nodes

The best network throughput shown by this graph is to let the nodes speed below 17 m/sec for any used number of nodes. There are no significant differences between the network throughputs at these speeds.

Fig. 3 shows the average end to end delay values in different nodes speed and different number of nodes.

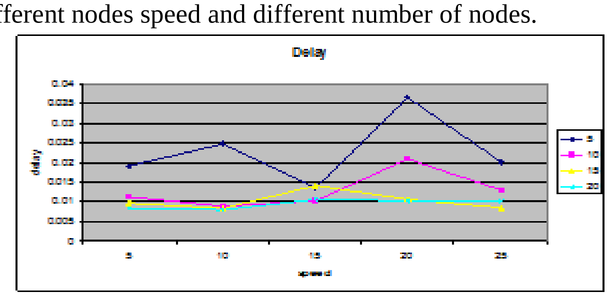

Fig. 3: average end to end delay values in different nodes speed and numbers.

This graph shows that the values of the end to end delay will be high with small number of nodes and decreased with increasing number of nodes at low speeds (less than 15 m/sec). The end to end delay values were increased with increasing speeds. As an average the speed value of 15 m/sec is the best value for this metric for any number of nodes in this area.

Fig. 4 shows the average NRL values in different nodes speed and different number of nodes.

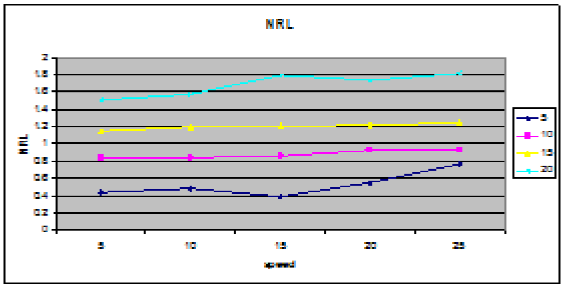

Fig 4: the average NRL values in different nodes speed and numbers.

The values of the NRL will be low with the small number of nodes and increased with increasing number of nodes at each speed. NRL values were slightly increased with increasing speeds. The speed value below 15 m/sec is seemed to be the best value for this metric for any number of nodes in this area.

Fig. 5 shows the PDF values in different nodes speed and different number of nodes.

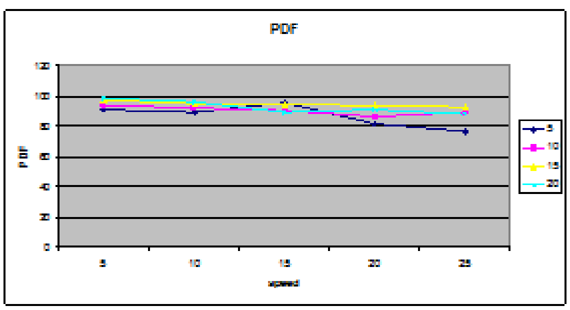

Fig 5: the PDF values in different nodes speed and different number of nodes.

There are no significant differences between the PDF values for any number of nodes with speeds less than 15 m/sec. The PDF values will decrease with increasing the nodes speed.

Fig. 6 shows the Jitter values in different nodes speed and different number of nodes.

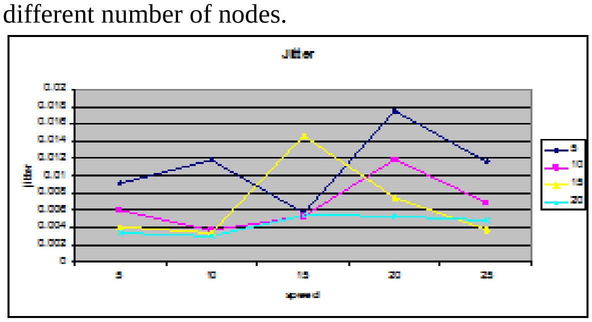

Fig 6: the Jitter values in different nodes speed and different number of nodes.

From this graph, the jitter values seemed to be decreased with increasing number of nodes. The speed value of 15 m/sec is also a critical value in which a change will happen.

B. Environment 2

This environment aims to study and analyze the effect of the nodes number and their pause times on the general behavior of the MANET. Such effect can be observed through the simulated values of many output performance metrics which are (packets loss, throughput, delay, NRL, PDF and Jitter). Many variables or (parameters) were set to be fixed (not changed) during all the simulation runs in this MANET's environment. Certain arbitrary values were assigned to the simulation area, traffic type, simulation time, nodes speed and maximum number of connections. The AOMDV routing protocol was used as a main routing protocol in all the implemented scenarios. Table (2) shows the proposed MANET's parameters and their assigned values.

TABLE 2
THE SECOND PROPOSED MANETS PARAMETERS AND THEIR VALUES

Parameter	Value
Nodes no.	10, 20, 30
Nodes speed	8m/s
Area	750m * 750m
Traffic type	CBR
Simulation Time	100 s
Routing Protocol	OLSR
Speed Type	Uniform
Pause Time	(4, 8, 12, 16, 20) s
Pause Type	Uniform
Max Connection	7

1) Environment 2 results

Each value in the following graphs was resulted from the average of 50 repeated values. The effects of varying the nodes number and pause time were observed by varying the number of nodes and their pause times. Packet delivery fraction, routing load, dropped packets, average jitter, average end to end delay and throughput were simulated and their values were estimated with the AOMDV routing protocol. The results are sketched in the following figures, each point in each graph represent the average of 50 repeated runs. Fig. 7 shows the lost packets in different nodes pause times and different number of nodes (10, 20 and 30).

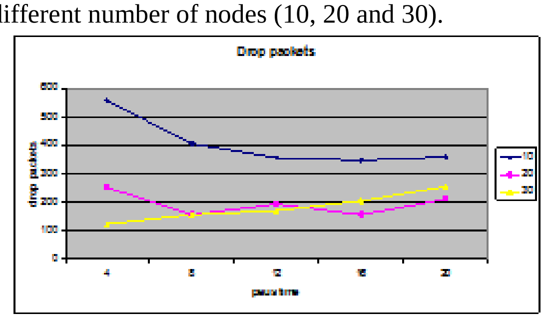

Fig. 7: lost packets in different nodes pause times and different number of nodes.

This figure shows that the lost packets were decreased with increasing the pause times for low number of nodes (less 30) with the area of (750*750 m) and AOMDV routing protocol. While with the number of nodes (equal 30) the lost packets will increase with increasing the pause times.

Fig. 8 shows the throughput values in different nodes pause times and different number of nodes.

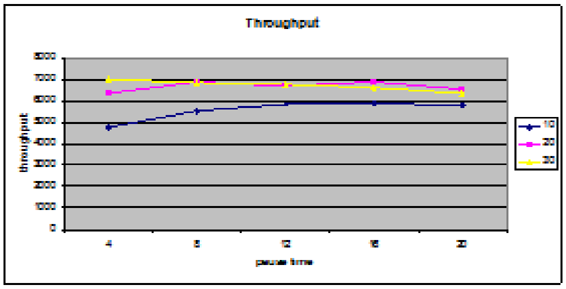

Fig. 8: throughput values in different nodes pause times and different number of nodes

When the number of nodes is 30 the throughput will decrease with increasing the value of the pause time. For other numbers less than 30, the throughput will increase with increasing the pause times.

Fig. 9 shows the end to end delay values in different nodes pause times and different number of nodes.

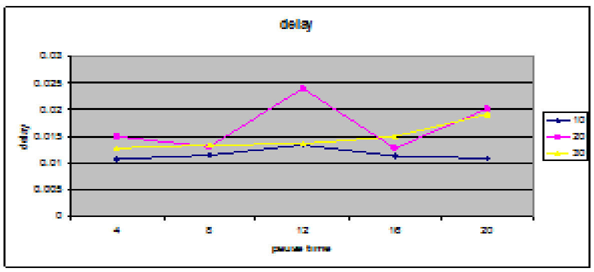

Fig. 9; Delay values in different nodes pause times and different number of nodes

When the number of nodes is 30 the delay time will increase with increasing the value of the pause time. For other numbers less than 30, the delay will reach its maximum values at pause time value of (12 sec.) and will vary with increasing the pause times.

Fig. 10 shows the NRL values in different nodes pause times and different number of nodes.

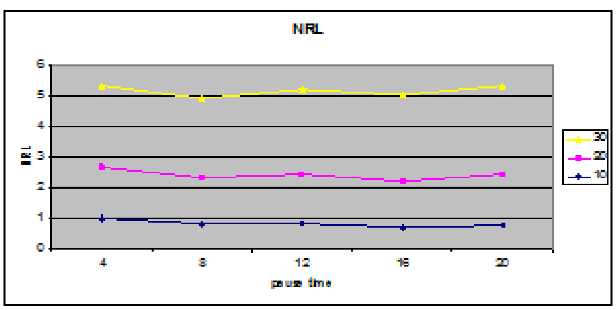

Fig. 10 NRL values in different nodes pause times and different number of nodes

The NRL values will increase with increasing the number of nodes. The value of the NRL when the number of nodes (are less than 30) will decreased with increasing the pause time. No significant change in the value of NRL when using 30 nodes but it alternates about the level of 5 with increasing the pause times.

Fig. 11 shows the PDF values in different nodes pause times and different number of nodes.

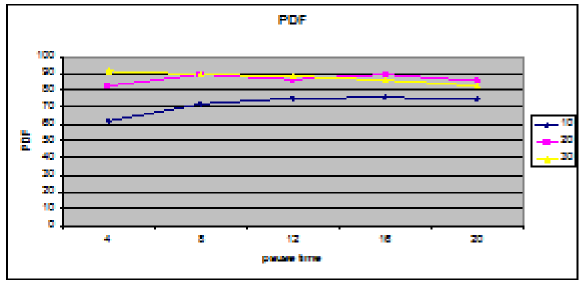

Fig. 11 NRL values in different nodes pause times and different number of nodes

The values of the PDF will increase with increasing the number of nodes and increasing the pause times when the number of nodes are less than 30. While when the number of nodes is 30, the PDF values will decrease with increasing the pause times.

Fig. 12 shows the PDF values in different nodes pause times and different number of nodes.

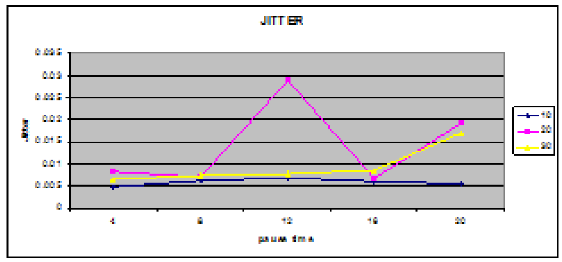

Fig. 12 NRL values in different nodes pause times and different number of nodes

The jitter value will jump to its maximum value of 0.03 when the number of nodes is 20 and pause time is 12 sec. with other number of nodes, the jitter value will increased slightly with increasing the pause times.

VII. Mathematical Modeling

A mathematical model was developed to simulate the final behavior of the MANET under varying number of nodes varying nodes speed and/or Pause times.

The following equation was used to imitate the relationship between the final output values and number of nodes with their speeds.

V1= (Lin (Number of nodes)/Lin (Nodes speed))* ((Lin (Throughput) +Lin (PDF) +Lin (NRL))-(Lin (Drop packets) +Lin (Delay))

Fig 13 shows the resulted calculations. It shows the effects of the number of nodes and nodes speed on the final MANET's behavior.

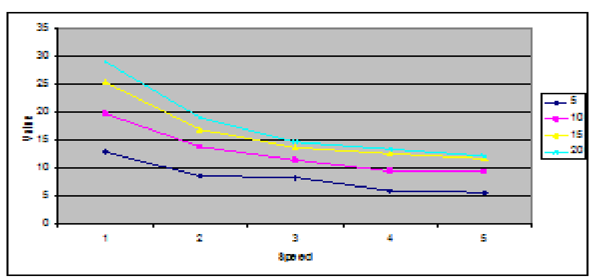

Fig. 13 effects of speed and number of nodes

This figure indicates that when the nodes speed increased the final MANET output will be affected and decreased. The output will be increased when the number of nodes increased in any speed.

Another equation was developed and used to imitate the relationship between the final output values and number of nodes with their pause times.

V2= (Lin (Number of nodes)/Lin (Pause time))* ((Lin (Throughput) +Lin (PDF) + Lin (NRL)) - (Lin (Drop packets) +Lin (Delay))

Fig 14 shows the resulted calculations. It shows the effect of both the number of nodes and nodes pause times on the final MANET's behavior.

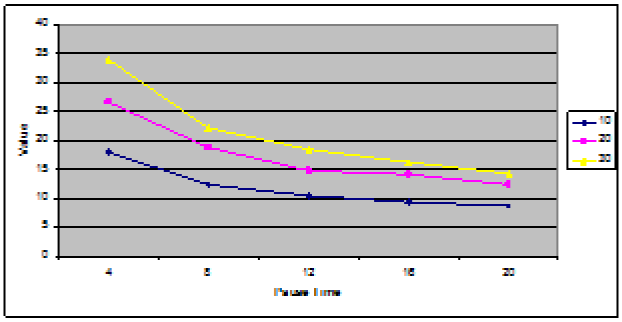

Fig. 14 effects of pause times and number of nodes

This figure indicates that when the nodes pause time increased the final MANET output will be affected and decreased. The output will be increased when the number of nodes increased in any pause time.

VIII. CONCLUSIONS

The main aim of this paper is to discuss the most relevant issues of MANETs, from the application viewpoints. These applications depend on different factors. The selected factors are the number of nodes, the nodes speed and the nodes pause times.

The effects of nodes number and nodes speed were studied and analyzed in many scenarios in order to estimate the best number of nodes and best possible speed for any new designed MANET. In the second part of this study, the effects of nodes number and nodes pause times were studied and analyzed in many scenarios in order to estimate the best number of nodes and best possible pause time for any new designed MANET. This study was devoted to discuss the constraints that must be satisfied by the MANET and the different aspects that must be taken into consideration in the designing of a new MANET.

Mathematical models were built and implemented to estimate the best possible alternative that can be used in suggesting the required number of nodes and there speeds and /or their pause times in designing any new MANET.

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