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Simulating Smart Cities Under Different Scenarios and Factors

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Abstract

In this research, we suggest building or utilizing a virtual environment of a smart city where fixed and mobile sensors are arranged in a certain way, using particular movement models and techniques for transmitting and sharing data via the virtual city. This proposal proposes to carry out several experiments for various movement models, such as:(Individual Mobility Model,Exponential movement model and Rayleigh Flight movement model), A specific data distribution (Gaussian, Littice, Power-law, Exponential) and a certain data routing methodology (Spray and Wait, Probabilistic Flooding, and Epidemic) were used to examine the impact of this on the use of network resources. In this proposal, we also want to look at the usage of various resources, including electricity and data. A movement model, an item distribution strategy, and a data routing protocol were all combined to create each experiment that was intended to be conducted in this proposal. All submitted experiments will ultimately be compared to one another, and recommendations that assist the research and design community in conserving network resources will be made. the findings show that the traffic models that were used with mobile nodes are considered one of the important factors in determining the consumption of network resources. In addition to the influence of traffic models on the consumption of network resources, algorithms and methods of routing data also have an impact. The Human Mobility Model, which accurately expresses human movement behavior, is considered one of the most stable models in terms of performance.

Keywords: *Smart Cities, Hybrid Networks, Resources Consumption*

1. Introduction

A group of devices or objects make up the Internet of Things (IoT) that have the ability to connect to the World Wide Web, and the concept of Internet of Things means the existence of a network that connects all things in one network, which in turn includes information about all those things, and through recent technological developments in Wireless fields, We can connect and interact with our surroundings thanks to the internet and micro-mechanics using multiple sensors or small wireless robots that allow the possibility of developing a range of new applications and uses, from logistical purposes and the possibility of tracking to emergency and rescue operations that are accomplished by observing volcano or wildfires. The creation of a communication channel between wireless (hybrid) items, without the need for any major aspect of the concept of the Internet of Things[1], and among the most prominent future applications of the Internet of Things are smart homes and smart cities.

By touching upon the concept of the Internet of Things, it must be clarified what are these things. As an example, there are household things such as the refrigerator, washing machine, heating and cooling systems, lighting, fire sensors, and many others that lead to their connection to the so-called smart home. And as the things outside the house, it can be surveillance cameras distributed on buildings, temperature and humidity measuring devices, sensors that are planted in the streets in order to regulate traffic, sensors that are installed on bridges to measure loads, and many other devices and sensors that lead to the so-called smart city. All things that have the ability to connect to the Internet are of two types: Fixed objects: which are of a fixed location in the network, such as fire sensors. Moving object: those that do not have a fixed location and are movable, such as: GPS devices installed in cars or ambulances, and others.

Mobile phones are sensors or movable devices whose principles depend on human movement. As for the sensors that are placed in cars and other vehicles, they depend on their movement on the street paths in the city.

The coupling of the sensors with people is very It's intriguing because human motion will cause the nodes to move. Given this, Most people carry a smartphone or tablet with them as a sensor [2]. The work of Song Choaming is one of the most precise mobility models explaining human movement, who put up a plan for personal mobility [3] and that model may be utilized for simulation and assessment purposes in wireless moving sensor networks[4].

When we advance from the "Internet of Things," the distinction among social networks & sensor networks is most likely to become less clear. The use of social media in creating wireless sensor network protocols hasn't gotten much interest, though, up until this point.

Within the context of transmitting sensors, we will concentrate on the concepts of resource consumption and information dissemination in this research. from individuals who belong to social networks. Wireless sensor networks (WSNs) are also an important field of research because they are related to many applications in transportation, agriculture, and military communications [5]. One of the information technologies that has advanced the most quickly in recent years is this one. [6].

And all of this leads to a number of technical and scientific issues, such as how to guarantee the dependability of wireless communications in various environments (non-traditional), how to manage limited resources effectively (energy, memory, etc.), or how to perform safe and sustainable maintenance. These issues are all resolved by researchers around the world, but solutions designed to address them have not yet been fully developed for the Internet of Things (IOT) need real trials to be validated. As the primary goal of using the Internet of Things is to enable the transfer of data and information with high accuracy and in a timely manner to users to change the way people behave in a way that serves their interests [7].

2. Problem Statement and Contribution

Given that all previously published work has focused on the architecture of smart cities and the Internet of things, this thesis is regarded as a key entrance point for the design of smart cities and the latter, focusing on aspects that differ from the aspects that have been worked on in this thesis. As we have noticed through previous research; There are many gaps when making certain applications in this field. Such as:

- Lack of conducting experiments to measure the effect of traffic models on network behavior.
- There are no methods capable of showing the effect of traffic models with routing protocols about the usage of network resources.

That is why we tried in this research to fill some gaps and holes, in order to improve the applications of modern technology and the Internet of Things, by implementing new experiments in this field in terms of diversity in choosing the characteristics of the environment on which the dissemination and distribution of data relied. Reliance has been made on the characteristics and features of human movement as a means to bridge some of the gaps mentioned above. We conducted new experiments to show the effects of traffic designs for how much network resources are used. We also combined movement models and routing protocols; In order to reveal the actions of network resources with regard to the event's coverage area and percentage of affected nodes, power consumption, and memory consumption.

3. Research Method

A wide range of experiments were prepared for this study with the goal of implementing and assessing their results. The experiments of this research are distinguished because of the variety of settings and options that strengthen the research by adding a distinctly practical character it with results and enhance them in terms of practicality. The purpose of this research is to look into how mobility models affect how much network resources are used and their analysis in smart cities. Therefore, the basis of the experiments are the applied mobility models. To enhance the experiments, the options used in each experiment were distributed to include various options by distributing nodes and also various algorithms for the purposes of transferring data between nodes. When doing this kind of experiment, it is important to keep in mind that a certain experiment may not provide the same outcomes if it is run again. The results may be almost identical, but they are not exactly the same, so all tests in this study were conducted with the assumption that each would be repeated twenty times before being taken into account in the data analysis. This approach is regarded as practical and scientific because it captures an experiment's behavior by counting how frequently the same experiment is carried out. Certain constants are present in each experiment in this study, for example, the range of communication, and the range of communication that was adopted is 50 meters, which is the WiFi wireless communication technology, and this extent is constant for fixed nodes and mobile nodes.

Constants in the experiments of this research is that data transfer was relied on only one event, and the possibility of its spread in the network was investigated. And the event that is placed in the experimental environment may represent a specific information that has occurred, and it is intended to be transferred and inform the network nodes of this, and this information may be a specific advertisement from a company, or it may be a fire alarm, a specific image, or a specific warning message. This event is placed diagonally close to the center of the city) in experiments, and when a certain mobile node approaches within 50 meters of this event, it will be transmitted to that node, which in turn, and by its movement and reaching the contact range of other nodes, also transmits that event again, and thus the distribution process takes place. And the process of publishing the event occurs regularly depending on the algorithm used or the communication protocol. In the event that the event appears in the range of communication of a fixed node, then the event will be transmitted to that fixed node, and if there are other fixed nodes within the range of its connection, that event will reach it. In the event that a mobile node passes within the connection range of a fixed node carrying the event, the mobile node receives that event.

The unit of time measurement in the simulator used is called tick, which is equivalent to 1.2 seconds on the ground, based on the speed of human movement (the movement of mobile nodes), which is approximately 5 km / h, which is the normal walking speed to the normal human being [8-16].

It should be noted that all experiments are executed within a undefined when the event reaches the sink. And it is by setting a condition for stopping at which the implementation of the experiment stops. It is the main reason behind setting a fixed time for all experiments is accuracy and transparency, because all experiments, with their variety of settings, will be carried out at a specific time, which in turn will reflect accurate results about the reality of the experiments to be implemented, so an experiment cannot be carried out in a time more or less than its counterparts of experiments. And the time specified above was not chosen randomly, but after several experiments, as it was found that the experiments at this time give enough time for the nodes to sense the event in addition to the movement in the virtual environment. The 345 experiments that need to be performed each indicate the pace of 20 experiments being executed under the identical conditions. According to the amount of mobility models used in the studies—three mobility models—the experiments are primarily grouped into three categories.

The designed experiments are shown in Tables 1, 2, and 3.

Table (1) The first group of experiments

EXP NO	Density	No. of mobile senser	mobile sensor distrbution	No. of static sensor	Routing protocal
eXP. 01-15	1.96, 2.94, 3.92, 4.9, 5.88	100, 200, 300, 400, 500	Power-law	100	Epidemic, Spray&Wait, Probabilistic Flooding
eXP. 16-30	1.46, 2.44, 3.42, 4.4, 5.38	100, 200, 300, 400, 500	Power-law	50	Epidemic, Spray&Wait, Probabilistic Flooding
eXP. 31-45	1.96, 2.94, 3.92, 4.9, 5.88	100, 200, 300, 400, 500	Lattice	100	Epidemic, Spray&Wait, Probabilistic Flooding
eXP. 46-60	1.46, 2.44, 3.42, 4.4, 5.38	100, 200, 300, 400, 500	Lattice	50	Epidemic, Spray&Wait, Probabilistic Flooding
eXP. 61-75	1.96, 2.94, 3.92, 4.9, 5.88	100, 200, 300, 400, 500	Normal	100	Epidemic, Spray&Wait, Probabilistic Flooding
eXP. 76-90	1.46, 2.44, 3.42, 4.4, 5.38	100, 200, 300, 400, 500	Normal	50	Epidemic, Spray&Wait, Probabilistic Flooding
eXP. 91-105	1.96, 2.94, 3.92, 4.9, 5.88	100, 200, 300, 400, 500	Exponential	100	Epidemic, Spray&Wait, Probabilistic Flooding
eXP. 106-120	1.46, 2.44, 3.42, 4.4, 5.38	100, 200, 300, 400, 500	Exponential	50	Epidemic, Spray&Wait, Probabilistic Flooding

Table (2) The second group of experiments

EXP NO	Density	No. of mobile senser	mobile sensor distrbution	No. of static sensor	Routing protocal
eXP. 121-135	1.96, 2.94, 3.92, 4.9, 5.88	100, 200, 300, 400, 500	Power-law	100	Epidemic, Spray&Wait, Probabilistic Flooding
eXP. 136-150	1.46, 2.44, 3.42, 4.4, 5.38	100, 200, 300, 400, 500	Power-law	50	Epidemic, Spray&Wait, Probabilistic Flooding
eXP. 136-150	1.96, 2.94, 3.92, 4.9, 5.88	100, 200, 300, 400, 500	Lattice	100	Epidemic, Spray&Wait, Probabilistic Flooding
eXP. 151-165	1.46, 2.44, 3.42, 4.4, 5.38	100, 200, 300, 400, 500	Lattice	50	Epidemic, Spray&Wait, Probabilistic Flooding
eXP. 166-180	1.96, 2.94, 3.92, 4.9, 5.88	100, 200, 300, 400, 500	Normal	100	Epidemic, Spray&Wait, Probabilistic Flooding
eXP. 181-195	1.46, 2.44, 3.42, 4.4, 5.38	100, 200, 300, 400, 500	Normal	50	Epidemic, Spray&Wait, Probabilistic Flooding
eXP. 196-210	1.96, 2.94, 3.92, 4.9, 5.88	100, 200, 300, 400, 500	Exponential	100	Epidemic, Spray&Wait, Probabilistic Flooding
eXP. 211-235	1.46, 2.44, 3.42, 4.4, 5.38	100, 200, 300, 400, 500	Exponential	50	Epidemic, Spray&Wait, Probabilistic Flooding

Table (3) The third group of experiments

EXP NO	Density	No. of mobile senser	mobile sensor distrbution	No. of static sensor	Routing protocal
eXP. 121-135	1.96, 2.94, 3.92, 4.9, 5.88	100, 200, 300, 400, 500	Power-law	100	Epidemic, Spray&Wait, Probabilistic Flooding
eXP. 136-150	1.46, 2.44, 3.42, 4.4, 5.38	100, 200, 300, 400, 500	Power-law	50	Epidemic, Spray&Wait, Probabilistic Flooding
eXP. 136-150	1.96, 2.94, 3.92, 4.9, 5.88	100, 200, 300, 400, 500	Lattice	100	Epidemic, Spray&Wait, Probabilistic Flooding
eXP. 151-165	1.46, 2.44, 3.42, 4.4, 5.38	100, 200, 300, 400, 500	Lattice	50	Epidemic, Spray&Wait, Probabilistic Flooding
eXP. 166-180	1.96, 2.94, 3.92, 4.9, 5.88	100, 200, 300, 400, 500	Normal	100	Epidemic, Spray&Wait, Probabilistic Flooding
eXP. 181-195	1.46, 2.44, 3.42, 4.4, 5.38	100, 200, 300, 400, 500	Normal	50	Epidemic, Spray&Wait, Probabilistic Flooding
eXP. 196-210	1.96, 2.94, 3.92, 4.9, 5.88	100, 200, 300, 400, 500	Exponential	100	Epidemic, Spray&Wait, Probabilistic Flooding
eXP. 211-235	1.46, 2.44, 3.42, 4.4, 5.38	100, 200, 300, 400, 500	Exponential	50	Epidemic, Spray&Wait, Probabilistic Flooding

4. Results and Discussions

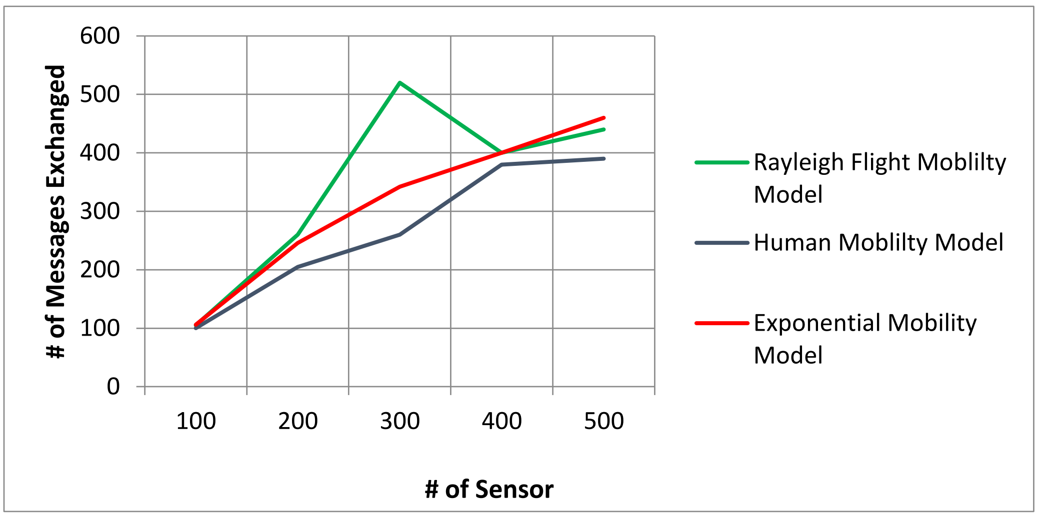
One of the most significant challenges faced by developers of smart cities is maintaining the overall effectiveness of the network resource consumption in terms of memory usage, data interchange volume, and energy resource consumption. The following explanation will explain these challenges in more detail:

4.1 Amount of Data Exchanged

This section of the research is one of the most crucial sections since it illustrates how network resources are consumed. Practically, as each time a node transmits or gets a message, its energy and memory resources are used, the amount of data sent and received shows the concurrent consumption of several sources are used. Including the use of the data transmission channel; Determining and implementing data exchange procedures between network nodes is so necessary. As shown in Figure (1), Behavior of motion models used: exponential motion of data, human mobility model, Rayleigh flight motion model, using exponential distribution of motion nodes with a method of type epidemic to transfer data. The number of nodes in use is represented by the x axis in this diagram, and a variable number was chosen in order to observe the changes that would result from adding more nodes. In all of his experiments, he employed 100, 200, 300, 400, and 500 nodes. The number of messages exchanged is depicted on the Y axis by the volume of information transmitted. Utilizing the human movement model, the amount of data delivered drops to its lowest level in this figure when compared to the amount exchanged using. This is indeed what is happening, especially since most people nowadays use mobile phones, which in turn carry a lot sensors or sensors that have the ability to measure many events around us. And all these portable smart devices follow the human behavior in their movement because they are carried by him. Moreover, based on this result, the rate of consumption of the phone battery will be lower, as well as the memory, which in turn leads to a reduction in the consumption of network resources in general.

Figure 1 The amount of data used exponential distribution with Epidemic technique of data direction when applying the three mobility models

We utilized a graphical statistical tool called a boxplot to analyze the data from a different perspective in order to examine the results more precisely and then investigate the variations that occurred during the execution of the trials. According to the variety of mobility models, changes in the amount of data exchanged are depicted in Figure (2). The mobility models utilized are shown on the X axis in this diagram, and the amount of data exchanged is shown



on the Y axis. And we see that the human movement model is a little bit more stable than the other two models. In other words, compared to other models, results from a model of human movement are more stable.

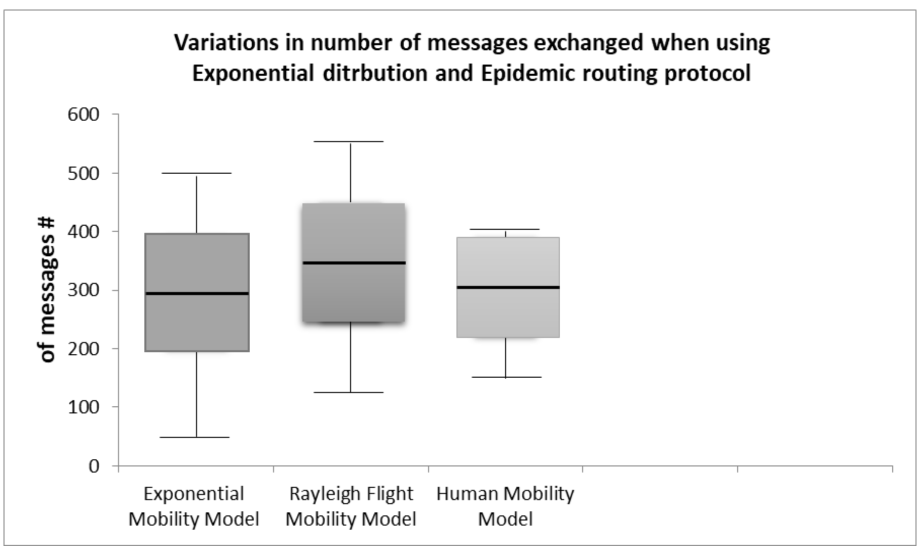


Figure 2 Measurement of data exchange stability in motion models used that adopted Epidemic's method of data transfer

All analyzes reported are for experiments conducted using the Epidemic method for data transmission, Figure (3) demonstrates the use of tests that transport data in the network using the Spray & Wait technique. The number of nodes for which we used the same technique as described in the previous paragraphs is shown on the X axis in this diagram. The amount of data transmitted and the people mentioned are depicted on the axis Y, respectively.

What is interesting about this figure is the clear superiority of the Exponential movement model compared to other models. We see that when utilizing the aforementioned form, The data transferred is at its smallest permitted quantity.

The variance movement human model reverse has more in terms of the volumes of data transferred, other two models are more stable and have lower volatility, and the figure (4) contrasts the three commonly utilized models for mobility. The image also shows how an extreme value, or outlier, might appear in a model of human movement. After reviewing the data, it was discovered that this extreme value was the outcome of one particular experiment, which was run just once. In these situations, each experiment was run twenty times and the results were implemented.

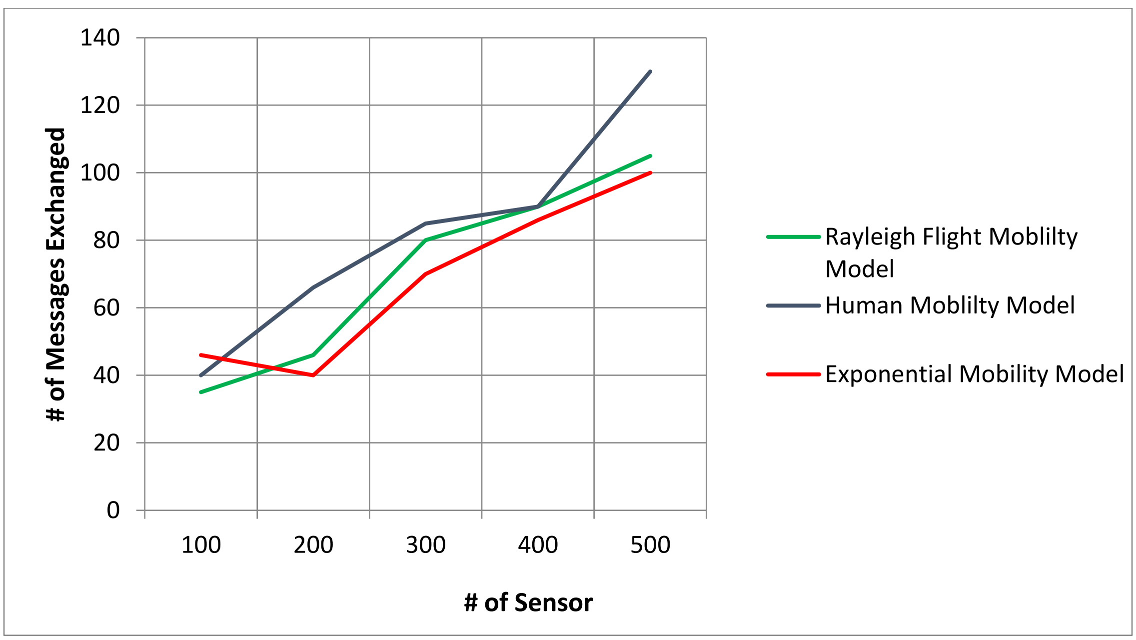


Figure 3 how much data is used when utilizing the exponential distribution with an algorithm Spray & Wait for routing When applying the three mobility models

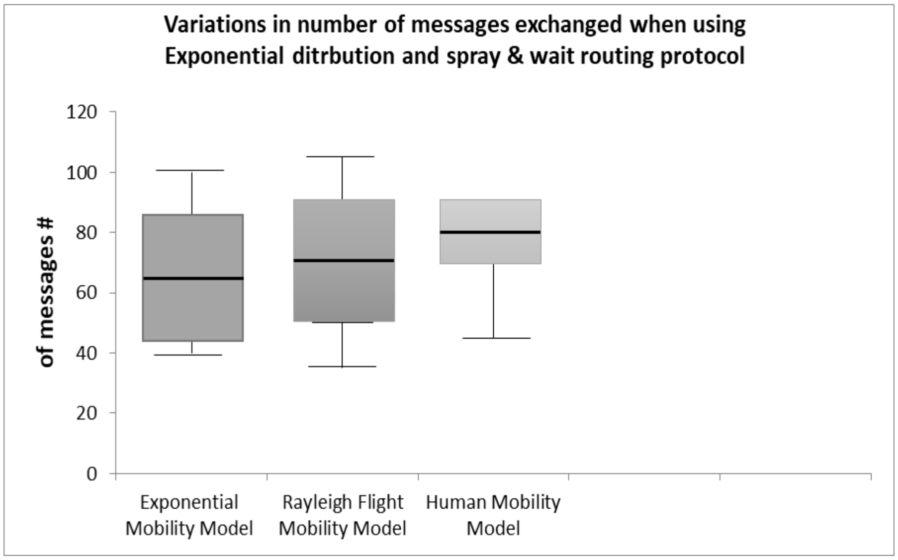


Figure 4 Measuring the stability of data exchange in the used mobility models that have been adopted Spray& Wait method of data transmission.

Now that the data transfer method has been changed to be Flooding Probabilistic, we can assess the experiment's findings.

The amount of mutual data for the three movement models used, as shown in Figure (5), clearly outperforms the Exponential movement model compared to the other models used in this research; as a result, the use of this form of movement is still effective when using the algorithm Spray& Waits Probabilistic Flooding for data transmission while conserving network resources.

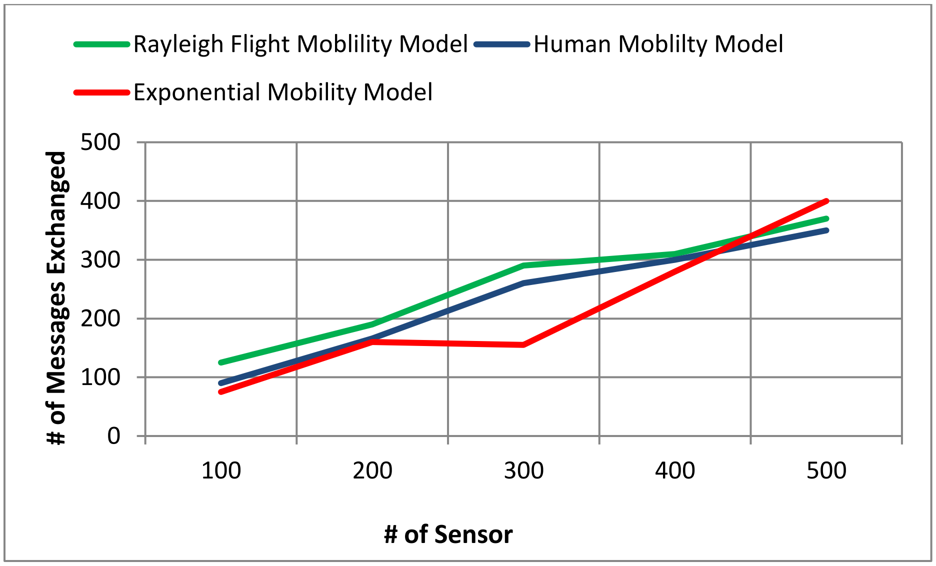


Figure 5 The amount of data consumed when using the Exponential distribution with the Probabilistic Flooding algorithm in directing data when employing the three movements models.

On the other hand, the Exponential movement model has a flaw that performance, namely the model's lack of stability and the variability of its outcomes across different tests. Figure (6) shows how the three movements models performed, and it is easy to see how the stability and variance of the volume of data exchanged varied.

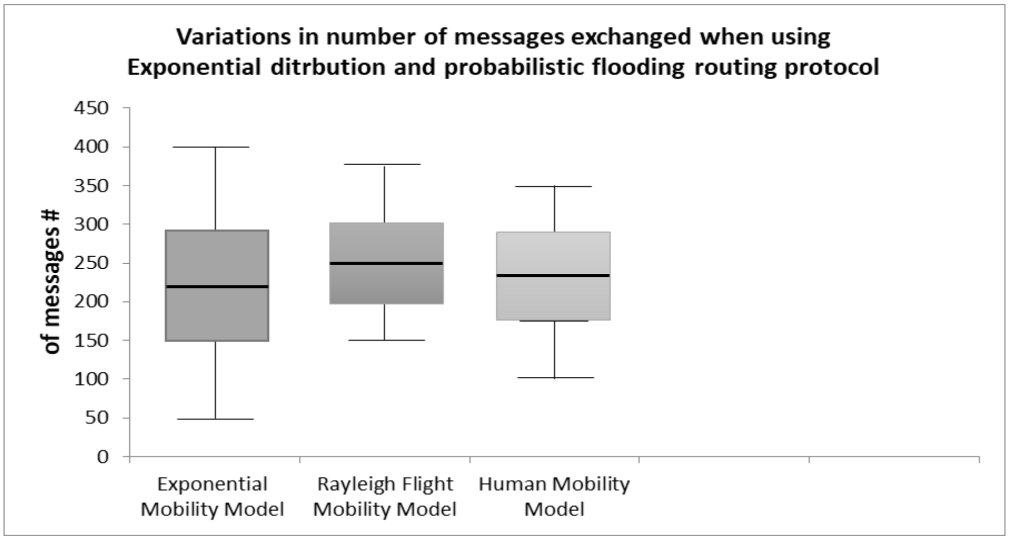


Figure 6 Measuring the stability of data exchange in the mobility models used Probabilistic Flooding method of transferring data.

4.2 Energy resource consumption

Wireless sensor networks and mobile sensors do not have a constant source of power, reducing power consumption is one of the most significant issues that smart city developers must overcome. Therefore, its primary source of energy is the battery in these sensors. The volume of data transmitted, as shown above, is one of several elements that determine energy usage, but it is also the most significant. In this research, we assume that all moving nodes in the virtual smart city are smart mobile phones carried by Human. Also, all the data exchanged is obtained mainly through WiFi or Bluetooth technology, and we have adopted the first in this research. The WiFi antenna, one of the components of mobile phones that uses the most power, drains some of the battery's power during each operation of sending or receiving data. Therefore, energy consumption decreases as the amount of data transferred increases. It is important to remember that the intended purpose of network architecture should not be sacrificed in order to reduce the amount of data shared. For instance, if the objective is to send a particular message to a particular group of network users, this objective must be met and the message must reach all intended recipients. Figure (7) employing the three acceptable traffic models in this research, illustrates the variance in the number of nodes that sensed the event propagated across the network. To fulfill the network's data transmission goals and minimize the frequency of delivering messages to the same users and energy loss during these iterations, a variety of approaches (Probabilistic Flooding, Spray& Wait, and Epidemic) were utilized to transport data. The Rayleigh flight movement model's transaction model outperformed other models in terms of the number of nodes that received data (message or event), as seen in the graph when used with a probabilistic flooding transit technique. Because the Epidemic technique of transfer is only used for comparison purposes and the end goal is always to acquire a performance that is close to its performance, all the findings produced using this method are not reliable.

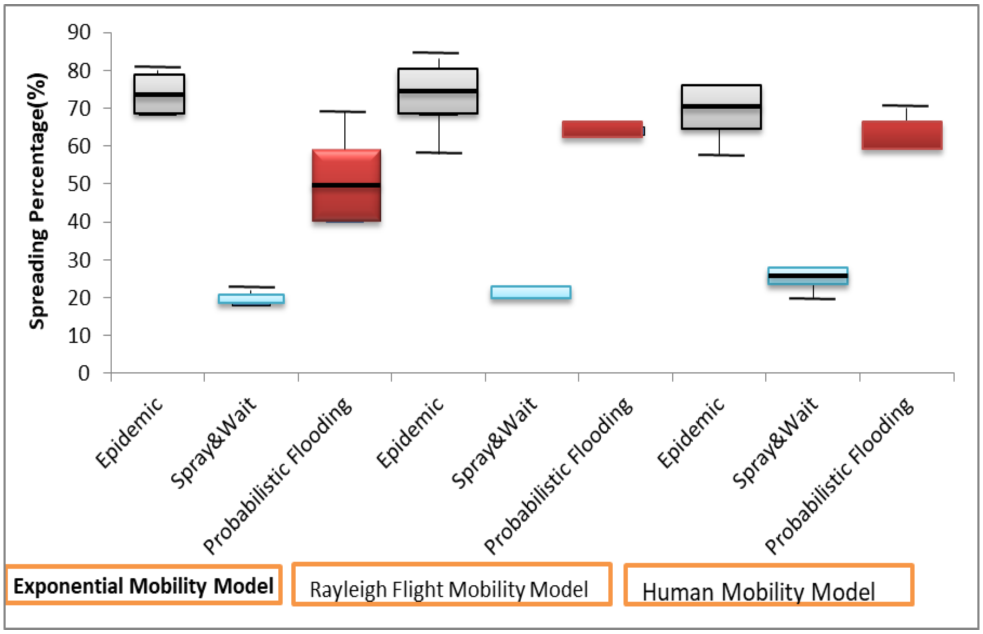


Figure 7 Percentage of the total number of nodes covered by all data transfer techniques and mobility models utilized in this study.

4.3 Memory Consumption

We assume the presence of a mobile phone that uses WiFi technology for data transfer in order to clarify this issue. Memory usage is one of the key factors in evaluating the network's overall performance. When the owner of this device is in a crowded place, like a market or a shopping mall, there are a lot of mobile phones within range of it. Assuming this is a smart city, if it receives messages from the nearby devices, the memory of this device will be able to store them. The machine will fill up in several weeks, therefore memory management is necessary. Data must be stored there, and there should be a propensity not to store unimportant data for that device. The performance of the three employed mobility models and the three transmission techniques is shown in Figure (8). This algorithm (as described in the second chapter) passes data or messages in a very specific way, and this is what results in a consequent reduction in consumption network resources in terms of memory and in other aspects such as power consumption. As can be seen from this figure, the Spray & Wait data routing algorithm using the three mobility models only represents a small number of exchanged messages.

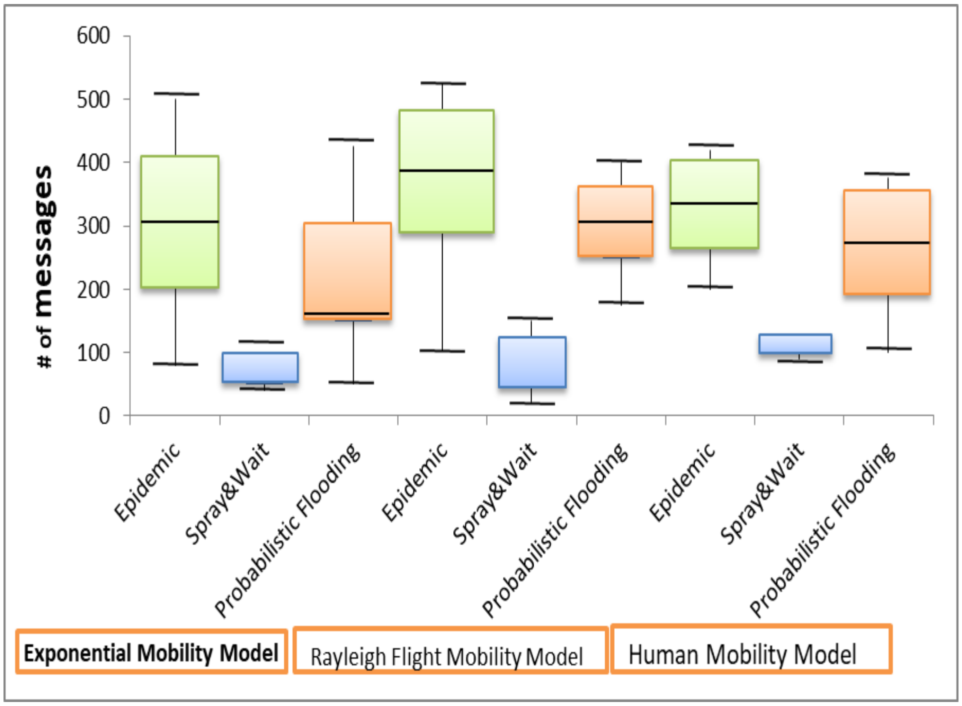


Figure 8 Number of messages exchanged across all mobility models investigated in this study, as well as across all data transfer protocols.

4.4 Coverage Area

The area that the data in the grid cover is one of the measures made in this study. To demonstrate the most effective ways to cover the most amount of ground with data, various data transfer algorithms were combined with various mobility models. When adopting an epidemic data transmission mechanism, Figure (9) clearly illustrates the Rayleigh Flight movement model's superiority over the other two models in terms of the area covered. We also observe that the performance of the human movement model was extremely comparable to that of the previous model. although obviously falling short of the Exponential mobility model.

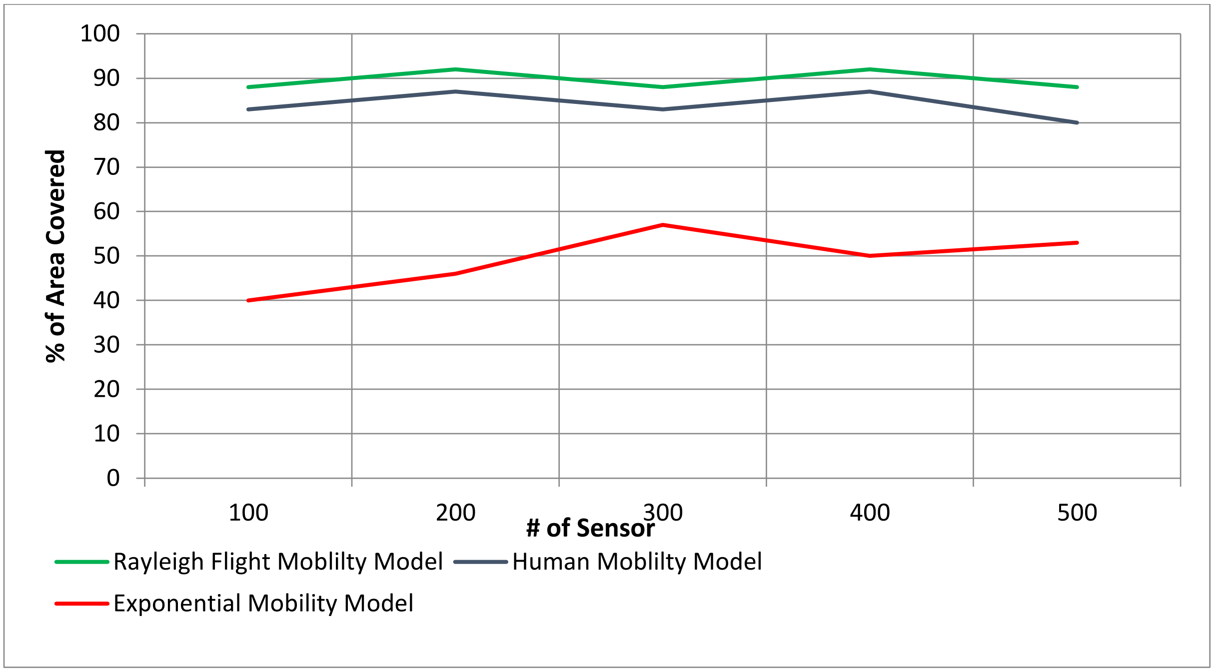


Figure 9 The area covered by the data using the exponential motion distribution with the Epidemic algorithm in directing the data when employing the three mobility models.

Figure (10) displays the same outcome as Figure (4-9) with the identical settings, but with the transfer technique changed to Spray&Wait, observing a variation in the Exponential model's functionality. This fluctuation is judged undesirable due to its instability and cannot be relied upon in this type of network since the stability of the findings of a given experiment is one of the important aspects in the assessment of its dependability.

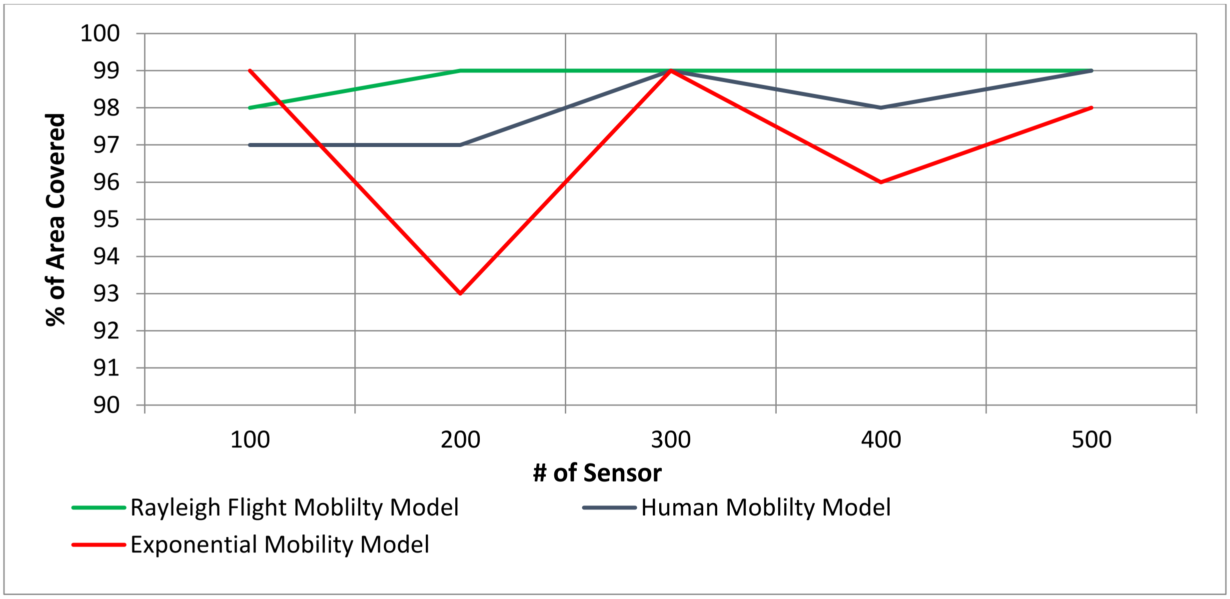


Figure 10 Area Covered by Data Using exponential motion Distribution with algorithm Spray& Wait in directing data when employing the three mobility models.

In Figure (11), changed the data transfer method to Probabilistic Flooding. Consequently, the Exponential movement model now outperforms the human motion model, which in turn covers the data's coverage area. In comparison to the other mobility models utilized in this study, the Rayleigh Flight movement model's continued to perform better. The Rayleigh Flight movement model's, one of the best mobility models that can cover the widest possible area with data in the network, was demonstrated in the preceding three figures. This outcome remains constant even when the data transmission and routing methods are modified. This discovery is intriguing because, in the smart city, if the target is present in the network at a particular time, it may be able to rely on the nodes that move in accordance with this model to spread data across the network to the greatest number of locations.

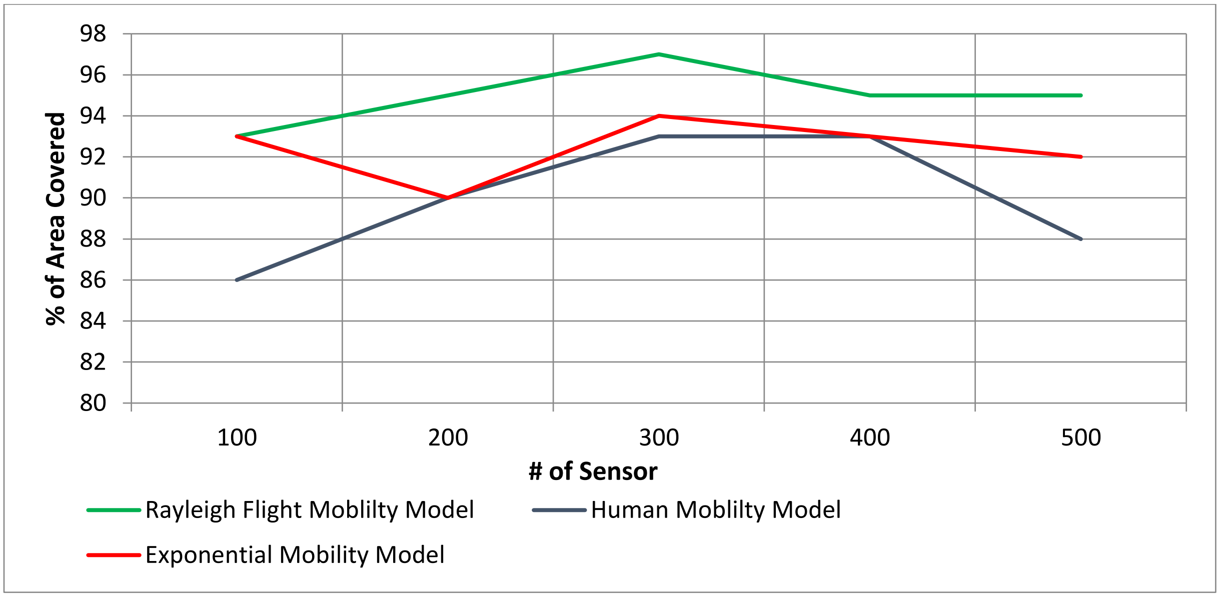


Figure 11 the region covered by the data while applying the three mobility models and exponential motion Distribution with Probabilistic Flooding algorithm.

5. Conclusions

This study examined a wide range of factors, including the volume of data transmitted, the use of energy resources, and the use of memory. Additional evaluations were performed, including the number of published data points and the proportion of nodes that are impacted by a network event. Our findings in this research can be summarized in the following points:

1. The mobility models that were used with mobile nodes are one of the important factors to determine the utilization of network resources.
2. In addition to the influence of mobility models on network resource usage, algorithms, and data routing strategies all have an impact.

3. In terms of performance, the Human Mobility Model, which accurately depicts human behavior in movement, is one of the most reliable models. For example, the volatility in the amount of data shared when implementing experiments is less than when using alternative mobility models.
4. The Rayleigh Flight Mobility Model One of the models is named Model that closely reflects the behavior of taxi vehicles, which reduces the consumption of network resources, but is less stable than the human movement model.
5. Based on points 3 and 4, it is possible to implement the two mobility models mentioned in one model, which we believe will lead to an optimal reduction in the consumption of network resources. This case is very realistic because smart cities do not include people, but also vehicles that can be exploited in the form of mobile node carriers, and portable nodes for people can help themselves.
6. With regard to the consumption of energy sources, the use of Outperforms the Rayleigh Flight Mobility Model with Probabilistic Flooding different models in terms of node count that sensed events in the network.
7. With regard to the memory consumption of the network nodes, the three mobility models used in the Spray & Wait data routing method is economical because it determines a lot the process of sending messages and exchanging data. This point depends greatly on the network design objectives, for example if the event to be published in the network is a specific advertisement or alert, this algorithm is not effective.
8. The human movement model is one of the models that can cover as much of the network as feasible using data. The reason for this is due to the fact that human movement is not restricted by certain paths, and it is possible for people to move in many different directions and paths.

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