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ON THE CONSUMPTION OF RESOURCES OF THE HYBRID OBJECTS IN THE INTERNET OF THINGS (IoT)

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Abstract

The advent of the Internet of Things (IoT) introduces a variety of challenges. One of the most frequent challenges is the consumption of resources (e.g., power and memory). The consumption of resources is considered an important aspect when it comes to the general performance of the system. Therefore, it is important to consider this kind of issue before designing such systems or applications. This research aims to assess the number of resources consumed when having hybrid objects (static and dynamic) in the Internet of Things (IoT). The objects considered in this work can be devices such as sensors, smartphones, or other sensing objects that can be used in exchanging data (resources). The settings of the experiments performed in this work vary including colorful parameters (i.e., object deployment, movement patterns, and routing protocols) and a combination of them. In this work, 4 groups of experiments are designed considering different parameters. The simulations are evaluated in terms of two metrics; the amount of data exchanged and covered areas. These two metrics are used as indicators to measure the consumption of resources. The findings showed that the Gaussian strategy in deploying the static and mobile nodes in the IoT can reduce the consumption of resources (e.g., memory and power) and cover more areas within the simulation environment regardless of the movement pattern and the routing protocols used.

Keywords: Silver Nanoatoms, Negative impact, Polymers, Environmental Hazardous, Toxicity.

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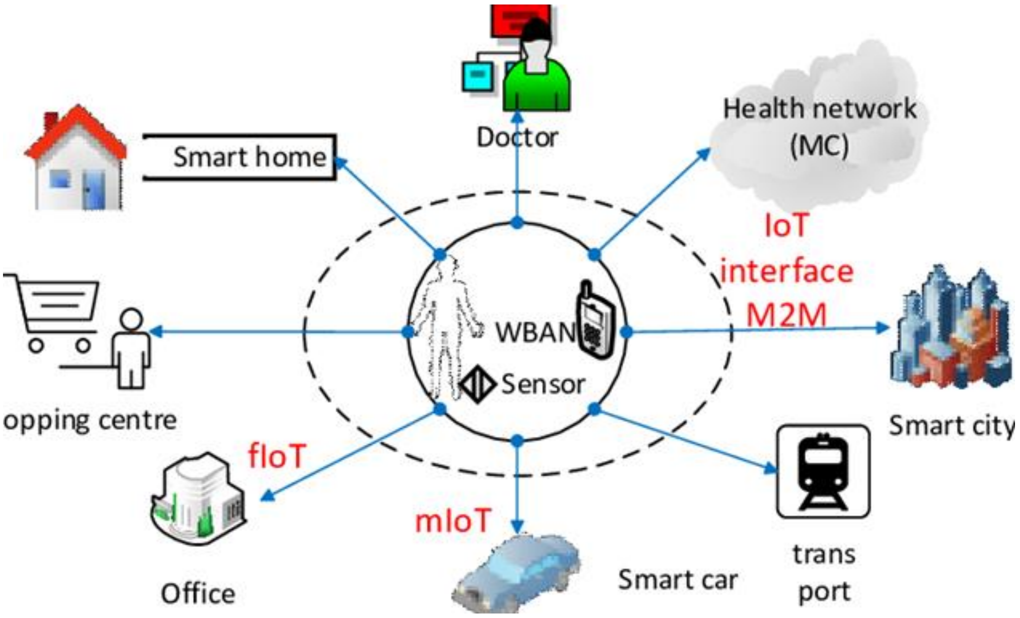
Introduction

1.1 Overview

Internet of Things (IoT) is considered a network of networks that connects a variety of devices that can be static or dynamic [1-2] (see Figure 1). These devices also represent the resources of the IoT since they have memories, power sources, connections, etc. [3]. The management of such giant components needs a lot of attention since it is challenging. Moreover, the management of network resources is important for many reasons such as reducing the amount of energy consumed within the networks [4], reducing the memory consumed [5], increasing the connectivity among the things (devices) [6], maximizing the utilization of resources [7], improve the scalability [6], efficiently propagate information [8], and more. All these aspects are considered issues in the IoT. Furthermore, handling the aforementioned issues is not an easy task due to the complexity of these aspects.

One of the most frequent issues investigated in the literature is the power consumption issue. The power consumption of static objects in the IoT has been widely investigated in the literature. In this case, one of the main factors used is the topology of the network [9]. However, the topology is not applicable when it comes to mobile objects. This is because these objects change their positions over time, which makes it more challenging to deal with this issue. The mobile objects in the IoT affect many aspects of the network such as the connectivity and the approximated power consumption within the network.

Figure 1: IoT static and mobile objects (things) [2].



As mentioned, the IoT networks are considered hybrid meaning that they contain static and mobile objects. For this reason, many factors can be considered when studying such networks. For instance, the objects within the networks are distributed according to a particular pattern such that; the nodes are concentrated in a particular region in the network or may be distributed uniformly. More precisely, according to [10, 11, 12], the deployment of the IoT objects may follow a Gaussian distribution or other kinds of distributions. Moreover, the mobile objects may also follow a particular pattern in movements (e.g., levy flight) since they are not static [13]. The other factor is the communication range of the devices which may vary from static to mobile objects due to the variety of technologies used [14]. The other factor that can be considered is the routing protocols used in exchanging information within the IoT [15-16].

According to the aforementioned description, several factors should be taken into consideration when evaluating the consumption of resources in the IoT. Therefore, when simulating IoT environments, the mentioned factors should be included aiming to accurately simulate IoT environments [17].

1.2 Literature Review

The literature includes many works that deal with the issue of resources consumed in the Internet of Things (IoT). Herrero (2020) [18] investigated the issue of the consumption of power memory resources in the IoT. The author introduced a mechanism that utilized the popular protocols that work on IoT networks. Their method was able to extend the lifetime of the power sources of the objects in the network. The method was also able to efficiently manage the mobile resources. In the same context, Quasim (2021) [19] proposed a framework that could manage the mobile resources in the IoT. The goal of this framework was to decrease the total service time of resources. The author developed a Gradient-Dependent Game Model to achieve the goal. The experimental results showed that the proposed method decreases the energy consumed. Elgendy et al. (2020) [20] proposed an offloading method that dealt with mobile IoT resources. Their suggested framework was considered multi-task and multi-user. After applying their method to the considered framework, they found that their method was efficient in both energy consumption and the scalability of the IoT networks. The work of Bolurian et al. (2022) [21] proposed a system for managing resources in IoT networks. The proposed system was based on a genetic-fuzzy approach. The system optimized the management of resources aiming to decrease the power consumed in resources. Then, they assessed the performance of the system in terms of the level of consumption of resources. The proposed system reflected efficient performance compared to other optimization algorithms in the literature such as Particle Swarm Optimization (PSO). Xavier et al. (2022) [22] suggested a resource allocation method for the IoT environment. Their method was able to increase the utilization of the resources and decrease energy consumption. The method outperformed the other non-collaborative vertical methods.

1.3 Problem Statement and Contribution

Based on the literature, there are many works that deal with the power consumption issue in the Internet of Things (IoT). However, most of the works do not pay attention to many factors such as the movement patterns of the mobile resources, the topology, or the distribution of the resources. As a result, there is a gap in the literature when measuring the consumption of resources in the Internet of Things (IoT) when the nodes are mobile and deployed in particular patterns. This issue is important to be investigated since the Internet of Things (IoT) is the future kind of network. Hence, this work considers a variety of factors that may affect the consumption of the IoT mobile and static resources (hybrid). Many simulations were performed considering a colorful mix of distributions and mobility models.

This article is organized as follows: the research method will be presented in the next section. The results and discussions will be presented in Section 3, and finally, the article is concluded in Section 4.

2. Research Method

2.1 Experiments Preparations

The environment used for the simulations was based on the NetLogo simulator which is mainly based on Java programming language. It enables the deployment of static and mobile objects according to a particular deployment strategy such as power-law distribution, uniform distribution, and gaussian distribution. In this simulator, the communication range of the static and mobile objects was determined to be (50 meters) assuming Wi-Fi technology. The simulator also provides the ability to select an event to be propagated in the environment. This event represents the information that is required to be spread to network objects. The event continues to move until the stop condition is held. The strategy followed to pass a message from one object to another is based on a particular routing protocol as will be discussed in the next section. The mobile objects move in the environment for particular steps, and each step is considered one move of the mobile objects. The strategy of how the mobile objects move within the environment is based on a particular moving method. The simulator allows the deployment of any number of objects and determines whether they are static or mobile. The event is passed from the holder object (the one that has the event) to another object when the two objects become within the communication range of each other.

2.2 Experiment Parameters

The experiments performed in this work include a variety of parameters as follows:

- *Objects Deployment*: two strategies were followed; Gaussian Deployment (GD) and Uniform Deployment (UD) (see Figure 2). The parameters used in these distributions are σ, γ, and α. In GD, the static and mobile objects were focused in the center of the environment. While the UD strategy assumes deploying the objects in a uniform way (fixed distances among objects). It should be mentioned that the deployment of the mobile objects will be changed over time due to their dynamic nature. However, the general pattern of the deployment will be kept. This specific case is completely controlled by the movement patterns chosen in this work. More specifically, when an object moves away from its original position, it will return to its position after a while. This makes the deployment fixed all the time in the simulations. This case is applicable for both kinds of deployments selected in this work.

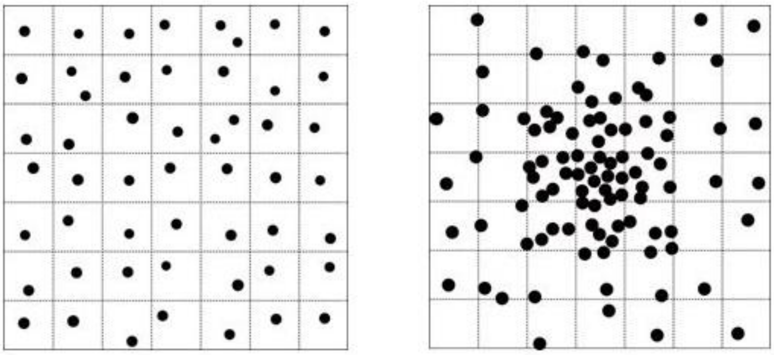


Figure 2: (left) Uniform deployment of objects, (right) Gaussian deployment of objects.

- *Objects Movements*: The static objects do not move since they are positioned in fixed locations in the environment. The mobile objects are not static and they move according to particular patterns. The movement patterns used for the mobile objects in this work are exponential moving patterns [23] and correlation moving patterns [24]. The first pattern assumes that a mobile object tends to randomly increase its visited positions over time and the number of visiting positions is decreased gradually until the object return to its original position. This case continues until the simulation stop condition hold. The second moving pattern is based on the correlations among the mobile objects (e.g., neighboring objects). Also, this method assumes that mobile objects will return to their original positions (similar to the exponential). It should be mentioned that the moving pattern methods are completely different with few similar features such as returning to the original position. The parameters used in the movement patterns are stdev-angle, which is the angle that a node use when moving in a direction, jump-size, which is the size of the step when a node moves, and x and y coordinates that represent the position of a node within the simulation environment.

- *Routing*: The routing protocol used for all the objects (static and mobile) in the simulations is the Gradient routing protocol [25]. The parameter used was β which is used to control the routing process.

2.3 Experiments Design and Metrics

The experiments designed in this work are based on the parameters described in the previous section. The strategy followed in designing the experiments uses combinations of the parameters aiming to have a comprehensive view of the performance. Table 1 presents the experiments designed, which include 4 main groups of experiments. Also, all the experiments performed in this work were based on averaging 10 runs. This is because using one run may not reflect a stable performance due to the fact that the simulations contain mobile objects that can be deployed in different positions in each run. Therefore, considering the average of 10 runs will provide robust results and stable behavior. Moreover, the number of objects involved in the experiments is 100, where 25 of them are static and 75 are mobile. The reason behind this selection is that the focus of this work was more on the IoT mobile objects that may reflect different behavior during their movements. The static objects are stationary and it is less likely to reflect different performances during the simulations.

Table 1: Description of the experiments considered in this work.

Experiment Code	Parameters Used
GDEEG_01	- Gaussian Deployment - Correlation Movement Pattern - Gradient Routing
GDCEG_02	- Gaussian Deployment - Exponential Movement Pattern - Gradient Routing
UDEEG_03	- Uniform Deployment - Correlation Movement Pattern - Gradient Routing
UDCEG_04	- Uniform Deployment - Exponential Movement Pattern - Gradient Routing

The metrics used in evaluating the performance are as follows:

- Amount of data exchanged: represents the number of messages exchanged among the IoT objects. It also reflects the power consumption level since the more messages exchanged, the more energy and memory consumed within the network.
- Covered areas: This metric is an important indicator of how many positions the mobile objects visit and cover during the simulations. Also, knowing the number of positions visited (visited areas) by the mobile objects provided us with information about how much energy was consumed to cover those areas.

Both the aforementioned issues represent indicators of the consumption of energy and memory.

3. Results and Discussions

3.1 Results

As described in the previous section, four groups of experiments were considered as presented in Table 1. Figure 3 demonstrates the performance of the 4 groups of experiments in terms of the amount of data exchanged. The figure shows the 10 runs of the experiments and the average of them on the right-side of the figure. It can be observed that the uniform deployment strategy of objects exchanged more data in the environment (experiments UDEEG_03and UDCEG_04). Considering these two groups, it can be seen that the exponential moving pattern permits exchanging data among objects more than the correlation moving pattern. On the other hand, the first two groups of experiments reflected less consumption of messages. These results showed that using the settings of the GDEEG_01 and GDCEG_02 experiments led to reducing the consumption of power and memory. Here, it should be mentioned that the required level of resource consumption depends on the goal of the application used. For instance, if it is required to spread advertising or warning messages within an environment, the groups UDEEG_03and UDCEG_04 will perform better.

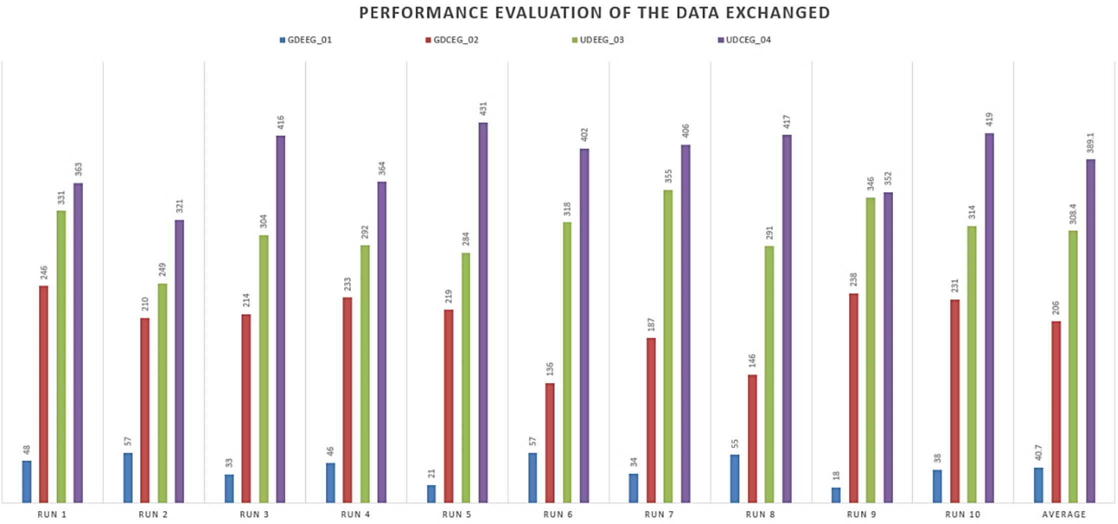


Figure 3: Performance evaluation of the experiments in terms of the amount of data exchanged. Each color represents the experiments that are grouped based on the sequence of Run (Run 1, to Run 10). The left-most group represents the average of the runs of all the groups.

Furthermore, Figure 4 demonstrated the performance of the experiments in terms of the number of covered areas. Interestingly, the use of the Gaussian deployment approach of objects covered significantly more areas compared to the Uniform approach. The reason behind this result is that the distances between objects in the Gaussian deployment strategy are significantly shorter than in Uniform, causing more covered areas.

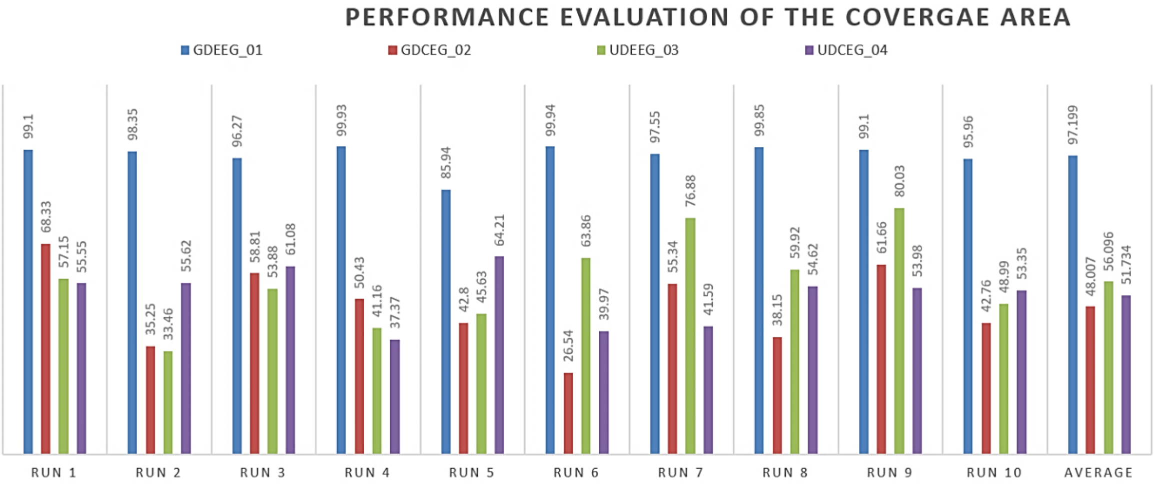


Figure 4: Performance evaluation of the experiments in terms of the number of coverage areas. Each color represents the experiments that are grouped based on the sequence of Run (Run 1, to Run 10). The left-most group represents the average of the runs of all the groups.

3.2 Discussions

According to the obtained results in the previous section (Figures 3 and 4) show an important observation. This observation states that using the Gaussian strategy in deploying the static and mobile nodes in the IoT can reduce the consumption of resources (e.g., memory and power) and cover more areas within the simulation environment regardless of the movement pattern and the routing protocols used. Practically, it is more sufficient to have an approach that reduces the number of messages exchanged and covers more areas, especially in the case of forwarding data to particular objects in the environment. Finally, this work shows different results using different settings of the objects (static and mobile) in the IoT networks. Also, network architects and developers should consider many parameters when simulating hybrid objects in the IoT. Varying these parameters may lead to different performances.

Moreover, based on the obtained results, the 10 runs performed for each experiment showed the stable behavior of the designed model. This is clear when observing the differences between the groups (Run 1 to Run 10). Also, each experiment in all the runs reflected a stable behavior even with the dynamic nature of the simulation environment. Finally, these results are in agreement with the results obtained in [25] since similar behavior is observed, which opens the road for researchers to develop IoT simulations under a variety of variables and parameters.

4. Conclusions

This research tried to assess the number of resources consumed when having hybrid objects (static and dynamic) in the Internet of Things (IoT). The objects considered in this work were devices such as smartphones, sensors, or other sensing devices that can work under the IoT infrastructure. The settings of the experiments performed in this work vary including Gaussian and Uniform objects deployment strategies, correlation and exponential movement patterns, and Gradient routing protocol. This work suggested 4 groups of experiments considering a combination of the aforementioned parameters. The simulations were evaluated in terms of two metrics; the amount of data exchanged and covered areas. These two metrics were used as indicators to measure the consumption of resources. The results showed that using some parameters reflected efficient performance in terms of the consumption of resources in the Internet of Things (IoT). Also, the findings of this work showed that Gaussian distribution might be more efficient since it decreased the number of messages exchanged and covers more areas. This is important when having an application that spread data to particular destinations (static or mobile objects). In future work, it is planned to have more parameters and metrics and evaluate the performance of the IoT networks aiming to have better insights into the performance of the IoT networks.

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