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A Method for Investigating Coverage Area Issue in Dynamic Networks

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Abstract. Coverage area in dynamic networks is considered an important issue that affects their general performance. It also affects the delay time when exchanging data and the consumption of resources in the network. Moreover, the coverage area issue in dynamic networks is directly affected by the distributions of nodes within the environment. Movement patterns may also affect the performance when it comes to coverage area. Therefore, this work develops a method that simulates different scenarios. These scenarios include a variety of settings and parameters that are believed to affect the coverage area issue of dynamic networks. These experiments enable network developers to be aware of the optimal conditions that maximize the coverage area of dynamic network nodes and eventually improve the overall performance of the network. Three distributions are used in the experiments namely, Cauchy distribution, Power-Law distribution, and Normal distribution. Also, the simulations incorporate the correlation mobility model for nodes dynamics. The findings show that Cauchy distribution is not appropriate for simulating dynamic networks due to the large uncovered areas by nodes communications. Also, the stability of an approach is considered an important factor when measuring the performance of a dynamic network. The results of this research are important to avoid wasting network resources.

Keywords: *Dynamic Networks, Coverage Area, Performance Evaluation*

1. Introduction

1.1 Overview

Recent years have witnessed a noticeable growth in the field of dynamic networks. These networks contain dynamic nodes that move within an environment [1]. The movement of nodes has a direct impact on the areas that can be covered by the communication range of nodes. Moreover, in dynamic networks, nodes are distributed according to a particular pattern. In static networks, a particular topology can be followed when deploying the nodes. This topology is static and nodes' positions are not subject to change. This makes the coverage areas of the network approximately static [3]. However, in dynamic networks, the positions of nodes are dynamic and changed over time, which leads the coverage area to be not fixed. In dynamic networks, it is necessary to describe the movement of nodes and include it when simulating these networks. Mobility models play a significant role in the coverage area issue [4-6].

Many factors can affect the coverage areas in dynamic networks. Together, the distribution of nodes and the mobility models used to have a noticeable effect on network performance [7,8]. This is because the nodes are subject to two changes in position, the first one is the original position (starting position) in the environment, while the second is the consequence of the mobility model. The focus of this study is on the first factor because to its relation to the nature of the environment. Thus, when designing networks, the nature of the environment involved may affect the whole performance of the network.

1.2 Literature Review

Coverage area and resources consumption are intertwined in dynamic networks. This is because covering more areas may consume more resources. The issue of coverage area is considered a serious challenge that should be given a special attention when designing dynamic networks (e.g., in the Internet of Things (IoT) or smart cities). Therefore, many works in the literature have been done on this issue. One of the earliest works that is close to our research was performed by Mi and Yang in 2011 [9]. They developed a method that included particular topologies and mobility models to improve the quality of communications of the coverage areas. Their method was efficient but contained many limitations. For instance, they used standard topologies that might not reflect the current trend in dynamic networks such as the environments of the Internet of Things or smart cities. For this reason, the current research trends focus on imitating the future smart environments. Barolli et al. (2022) [10] evaluated the performance of a network using variety of nodes distributions and routing protocols. They found that Normal distribution showed better performance in terms of coverage area and load balancing compared to other kinds of distributions such as Weibull and Boulevard. Sheikh et al. (2022) [11] developed a dynamic topology and evaluate the performance of the network. The method showed efficient performance in terms of improving the coverage area communications. Pooya and Gianluigi (2020) [12] suggested a cross-layer optimization method for implementing load balancing and covering more areas with loads, and improve the performance of network resources (e.g., memory and power). Moreover, a new method that was based on integrating the data-centric storage approach and distributed data storage approach was proposed to handle data loss problem due to resources (memory and energy) limitations. Dos et al. (2020) [13] proposed a model to increase efficiency of energy by minimizing energy consumption. Factors, such as processing time and data transmission cost, have been taken into consideration to achieve better performance.

1.3 Problem Statement and Contribution

Based on the related works presented in the previous section, there still a lack in methods that evaluate the coverage area under different nodes distributions in dynamic networks. This issue needs for a more attention by network developers. Therefore, this work tests the performance of dynamic networks and evaluate the coverage area metric using variety of distributions. To this end, many experiments were developed and tested.

The structure of this paper is organized as follows: Section 2 described the proposed approach and the experiments done in this work. Section 3 presents the simulations results and analysis. Finally, Section 4 concludes the work and provide some facts and recommendations to dynamic network developers.

2. Research Method

Many requirements should be prepared before simulating dynamic networks. These requirements also reflect the characteristics of the simulated network. The simulation environment represents a squared area in which the dynamic nodes are distributed. The distribution of nodes followed three approaches. The first one is using Cauchy distribution [14], it distributes nodes in an uneven way, where the nodes are focused more in some areas (see Figure 1).

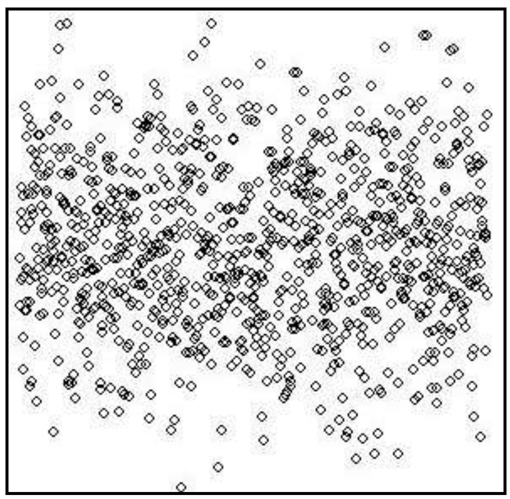

Figure 1: Cauchy distribution of nodes.

Cauchy probability density function can be formalized as follows [14]:

$$F(x) = \frac{1}{s\pi(1+((x-t)/s)^2)} \quad (1)$$

where *s* and *t* are the scale and location parameters (see Figure 1). This distribution can be observed in environments that have multi-centers.

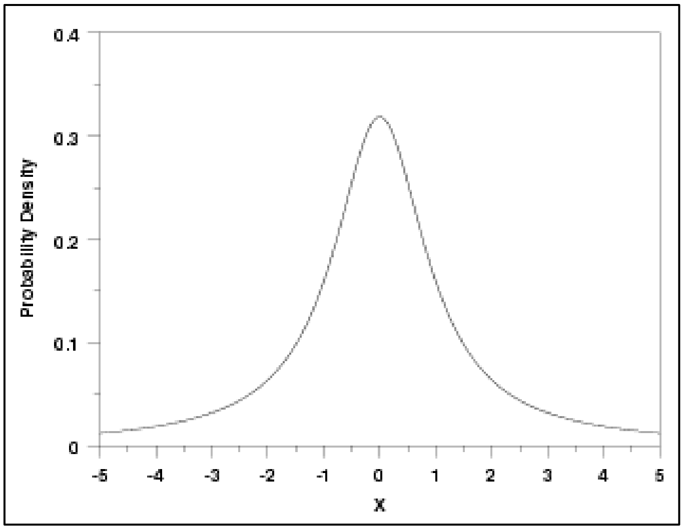

Figure 2: Cauchy probability density function (PDF).

The other distribution used in this work is the power-law distribution [15]. Distributing nodes under this type makes the center of the environment of a high density of nodes, and this density is decreased towards the edge of the environment. The variable that can feature this distribution is formalized as follows [15]:

$$P(x) = Cx^{-\propto} \quad (2)$$

Where $\propto$ controls the scale of the distribution (see Figure 3), C is constant and x is a variable that can be changed.

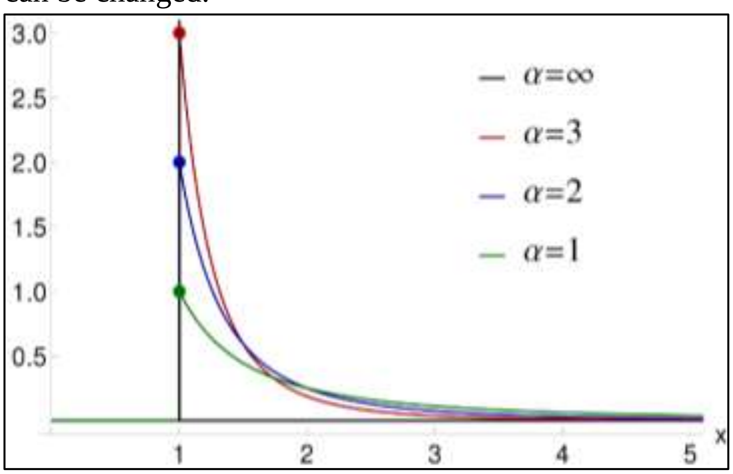

Figure 3: Power-law distribution (the impact of $\propto$ on the scaling).

The third distribution involved is the Normal distribution [16], which is well-known. This distribution deploys nodes starting from the center with a particular density, and this density is decreased slowly reaching the border of the environment.

In addition to the aforementioned, the Correlation mobility model is used to simulate the movements of nodes within the environment [17]. The moves of nodes are based on the correlation between nodes in terms of the differences in positions.

The aforementioned description represents the main requirements of simulating the dynamic network as stated in [18] and [19]. In addition, the simulations include other settings as follows: the number of dynamic nodes distributed in the environment are 100 nodes, the communications between nodes are based on Wi-Fi that covers a circle of approximately 50 meters. During the movements of nodes, a node cannot cross the edge of the environment.

To evaluate the performance in terms of connectivity, a particular strategy is followed. This strategy states that when a node moves within the environment, the areas that are covered by the communication range of the node are counted. This means, as nodes move, the covered areas are increased.

The experiments of this work are based on three main scenarios, which are based on the distribution type. Table 1 presents these scenarios and the settings of the experiments.

Table 1: The experiments of this work and their settings

Experiment #	Distribution	Mobility Model	# of Nodes	# of Tests
1	Cauchy Distribution	Correlation Mode	100	10
2	Power-Law Distribution	Correlation Mode	100	10
3	Normal Distribution	Correlation Mode	100	10

After determining the settings of the experiments, the simulations are ready to be executed. At this point, each experiment is executed 10 times for accuracy purposes [20][21]. The reason behind this strategy is that the positions of nodes are changed every time a new simulation is started. This is useful since the goal is to have different cases in the experiments considered in this work.

3. Results and Discussions

The results have been obtained based on the designed experiments and their settings. For the three distributions taken in this work, 10 tests (Test_1 to Test_10) have been executed. Figure 4 depicts the performance of each distribution and the tests performed. The metric used in this work is based on the amount of areas that can be covered by each distribution. It is obvious that Cauchy distribution underperformed the other distribution in terms of the coverage areas. This is because nodes under this distribution are not distributed in some areas, which makes a gap in the environment even with the mobility of nodes. The power-law distribution reflected better performance than Normal distribution. The reason for this performance is that in power-law the nodes are centered in the environment but they move towards all the directions covering more areas. In all the tests performed in this work, Cauchy distribution reflected low efficiency in covering areas.

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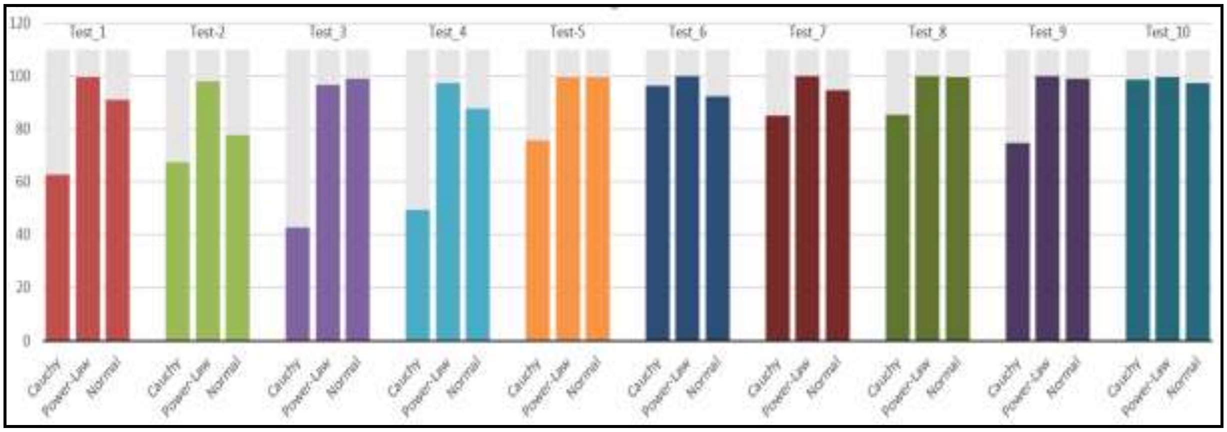

Figure 4: Performance evaluation of the 10 tests of each distribution.

The above result is not enough to judge the performance of the distributions. Therefore, we tested the stability of the performance using the 10 tests of each distribution. Figure 5 shows the stability of the performance considering the results obtained from Test_1 to Test_10. As can be seen, the stability of power-law reflected better performance than the other two distributions. The Cauchy distribution also reflected the worst performance in terms of the stability of the tests. The last step in this analysis is to calculate the average performance of the distributions. Figure 6 shows the average performance of the distributions, this average represents the mean value of the 10 tests considered in each distribution.

According to these results, in dynamic networks, Cauchy distribution reflected low efficiency in covering the simulation environment. This means network developers should consider the nature of the environment before designing their approaches. Also, stability is considered an important factor in measuring the performance of an approach.

Taking into consideration the experimental results, in the case of Cauchy distribution, it is needed to consume more resources to reach the uncovered areas, which is expensive. Furthermore, studying the nature of dynamic networks environment plays a significant role in reducing the waste in resources in these networks.

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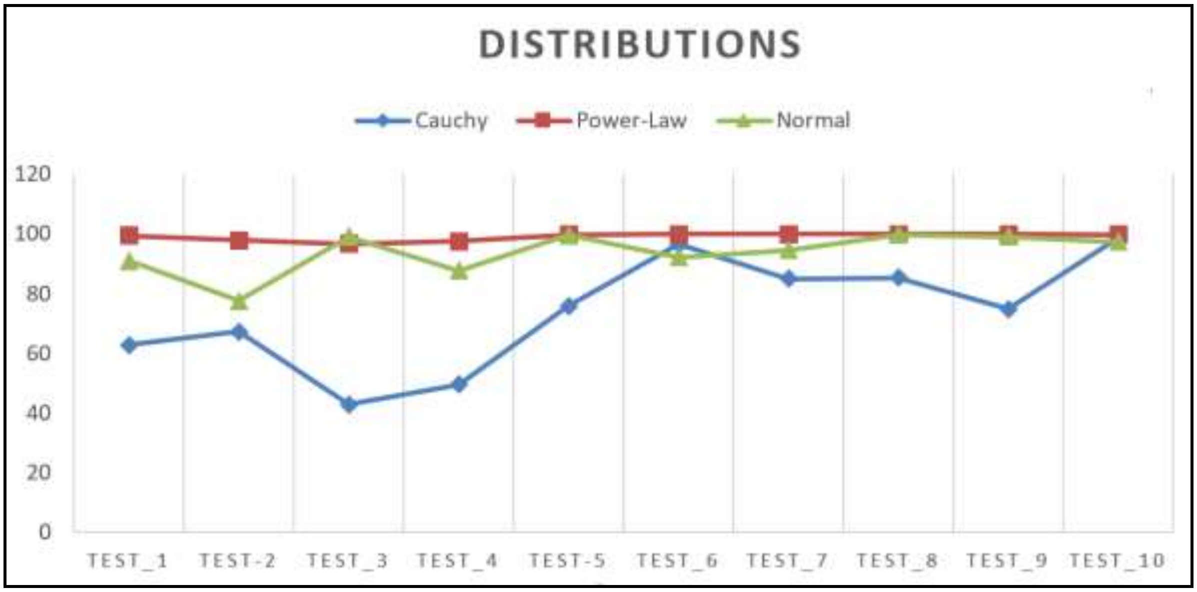

Figure 5: Performance stability of the distributions.

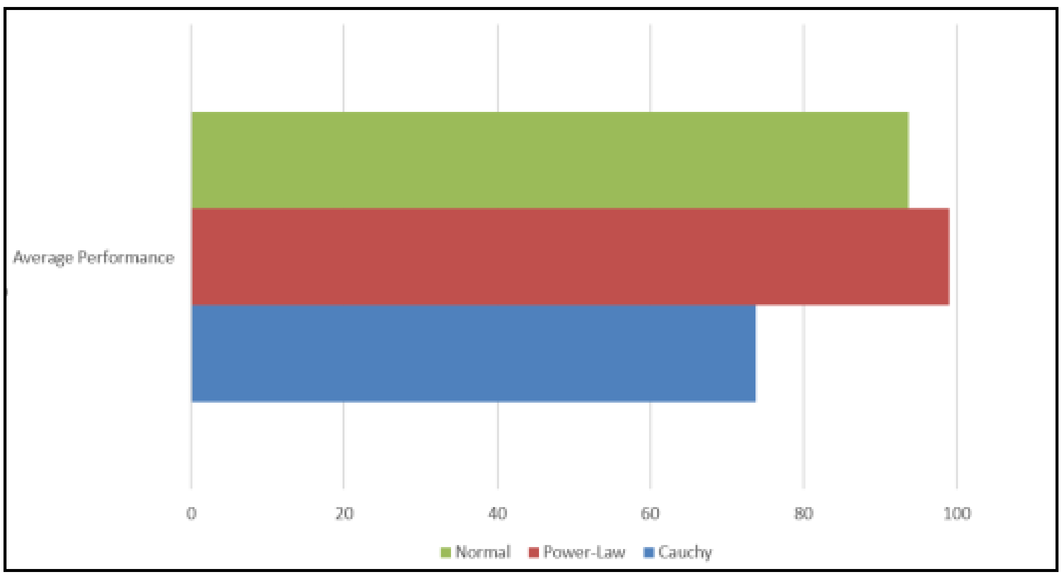

Figure 6: Average performance of the distributions in terms of the coverage areas.

4. Conclusions

This work develops a method that simulates different scenarios for measuring the performance of dynamic networks. These scenarios include a variety of settings and parameters that are believed to affect the coverage area issue of dynamic networks. These experiments enable network developers to be aware of the optimal conditions that maximize the coverage area of dynamic network nodes and eventually improve the overall performance of the network. Three distributions are used in the experiments namely, Cauchy distribution, Power-Law distribution, and Normal distribution. Also, the simulations incorporate the correlation mobility model for nodes dynamics. The findings show that Cauchy distribution is not appropriate for simulating dynamic networks. Also, the stability of an approach is considered an important factor when measuring the performance of a dynamic network.

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References

[1] Safdari, H., Contisciani, M., & De Bacco, C., Reciprocity, community detection, and link prediction in dynamic networks. *Journal of Physics: Complexity*, 2022.

[2] Mahmood, B., Tomasini, M., & Menezes, R., Social-driven information dissemination for mobile wireless sensor networks. *Sensors & Transducers*, *189*(6), 2015, 1-11.

[3] Dande, B., Chang, C. Y., Liao, W. H., & Roy, D. S. MSQAC: Maximizing the Surveillance Quality of Area Coverage in Wireless Sensor Networks. *IEEE Sensors Journal*, 2022.

[4] Yu, L., Zwetsloot, I. M., Stevens, N. T., Wilson, J. D., & Tsui, K. L., Monitoring dynamic networks: A simulation-based strategy for comparing monitoring methods and a comparative study. *Quality and Reliability Engineering International*, 2021.

[5] Mahmood, B., Tomasini, M., & Menezes, R., Social-based Forwarding of Messages in Sensor Networks. In *SENSORNETS*, 2015, 85-90.

[6] Alanezi, M., & Mahmood, B., Projecting Social Networks in Dynamic Environments for Tracking Purposes. In *2021 2nd International Conference on ICT for Rural Development (IC-ICTRuDev)*, 2021, 1-5.

[7] Hewapathirana, I. U., & Lee, D., Combining Information from Multiple Views for Vertex-Based Change Detection in Dynamic Networks: A Comparative Study. *SN Computer Science*, *3*(2), 1-29, 2022.

[8] Mahmood, B., & Menezes, R.. The role of human relations and interactions in designing memory-related models for sensor networks. *Sensors & Transducers*, *199*(4), 2016, 42-51.

[9] Mi, Z., & Yang, Y., Topology control and coverage enhancement of dynamic networks based on the controllable movement of mobile agents. In *2011 IEEE International Conference on Communications (ICC)*, 2011, 1-5.

[10] Barolli, A., Bylykbashi, K., Qafzezi, E., Sakamoto, S., & Barolli, L., A comparison study of Weibull, normal and Boulevard distributions for wireless mesh networks considering different router replacement methods by a hybrid intelligent simulation system. *Journal of Ambient Intelligence and Humanized Computing*, 2022, 1-14.

[11] Sheikh, M., Mashuda, S. M., Abedin, R., & Rahman, M., Dynamic Topology Reconstruction on Next Generation WLAN Using Spatial Reuse Gain by DBSCAN Clustering Algorithm. In *Proceedings of the International Conference on Big Data, IoT, and Machine Learning*, 2022, 315-327.

[12] Hejazi, P., & Ferrari, G., A novel approach for energy-and memory-efficient data loss prevention to support Internet of Things networks. *International Journal of Distributed Sensor Networks*, *16*(6), 1550147720929823, 2020.

[13] dos Anjos, J., Gross, J. L., Matteussi, K. J., González, G. V., Leithardt, V. R., & Geyer, C. F., An Algorithm to Minimize Energy Consumption and Elapsed Time for IoT Workloads in a Hybrid Architecture. *Sensors*, *21*(9), 2914, 2021.
[14] Arnold, B. C., & Beaver, R. J. The skew-Cauchy distribution. *Statistics & probability letters*, *49*(3), 285-290, 2000.
[15] Clauset, A., Shalizi, C. R., & Newman, M. E., Power-law distributions in empirical data. *SIAM review*, *51*(4), 661-703, 2009.
[16] Nadarajah, S., A generalized normal distribution. *Journal of Applied statistics*, *32*(7), 685-694, 2005.
[17] Tomasini, M., Mahmood, B., Zambonelli, F., Brayner, A., & Menezes, R., On the effect of human mobility to the design of metropolitan mobile opportunistic networks of sensors. *Pervasive and Mobile Computing*, *38*, 2017, 215-232.
[18] Alanezi, M., & Mahmood, B., Privacy Issue: From Static to Dynamic Online Social Networks., 2021.
[19] Mahmood, B., Indicators on the Feasibility of Curfew on Pandemics Outbreaks in Metropolitan/Micropolitan Cities. In *2021 IEEE International Conference on Communication, Networks and Satellite (COMNETSAT)*, 2021, July, 179-183.
[20] Elliott, D., Tomasini, M., Oliveira, M., & Menezes, R., Tippers and stiffers: An analysis of tipping behavior in taxi trips. In *2017 IEEE SmartWorld, Ubiquitous Intelligence & Computing, Advanced & Trusted Computed, Scalable Computing & Communications, Cloud & Big Data Computing, Internet of People and Smart City Innovation (SmartWorld/SCALCOM/UIC/ATC/CBDCom/IOP/SCI)*, 2017, August, 1-8.
[21] Tomasini, M., Zambonelli, F., & Menezes, R.. Using patterns of social dynamics in the design of social networks of sensors. In *2013 IEEE International Conference on Green Computing and Communications and IEEE Internet of Things and IEEE Cyber, Physical and Social Computing*, 2013, August, 685-692.