A Review of Gateway Placement Algorithms on Internet of Things

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Abstract- Internet of Things (IoT) is expected to grow exponentially such that devices connected to the internet reach 125 billion during the year 2030. For data transmission to the internet IoT end node devices rely on Gateways and to ensure coverage for IoT devices Gateways need to be optimally placed. However, physical infrastructure and topography as features of the target area are essential for IoT gateways optimal placement. Recently, Wireless Mesh Networks (WMN) has gained an important role in current communication technologies. It has been used in several applications such as surveillance and rescue systems. Network congestion can be minimized and throughput can be improved by placing many gateways but on the other hand cost, deployment and interference will increase. Therefore, this paper performs a review of existing Gateway Placement Algorithms and brings together the state-of-the-art in WMN and Low Power Wide Area Network (LPWAN), distinguishing each of their strengths and weaknesses that requires improvements. The main objective of this paper is to gain insight into the advantages and disadvantages of existing Gateway Placement approaches. A secondary objective is to highlight the various performance metrics being considered in the Gateway Placement literature and to analyze the trade-offs made. The conducted review shows that different algorithms have different capabilities and drawbacks such as congestion, coverage, interference etc. Various issues related to gateway placement and approaches were presented and the number of gateways needed for certain.

Keywords—WMN, LPWAN, Gateway Placement, IoT.

I. INTRODUCTION

Internet of Things (IoT) has been used in many different applications in recent years and have gained some popularity[1][2][3] and [4]. Wireless Mesh Networks (WMN) and Low Power Wide Area Networks (LPWANs) are all emerged as key technologies in a wireless communication network for the next coming generation and inspiring a number of applications. However, even today there are still research issues need to be addressed before these technologies fulfil their potential.

LPWANs technologies are suited for different IoT applications, with the enormous potential of having certain capabilities, limitations, and features. Public and private LoRa/LoRaWAN is one of these technologies and are increasing worldwide with several promising features [5][6] and [7].

The WMN is a network design consists of mesh clients (MCs), gateways (GWs) and mesh routers (MRs). A wireless backbone network is pretended as to be MRs with minimal mobility which not only relays traffic for other MRs but also provide wireless connections for MCs in their respective service areas as access points[8]. In [9] the authors address the importance of Gateway placement and some of the challenging issues, some of those issues are optimum Gateways location and the optimal number of Gateways.

Gateway placement helps to figure out the total number of gateways needed in the network and where they should be placed[10]. Since the wired links in gateway deployments are more expensive, the cost will drastically increase as more gateways are deployed. However, network throughput can be improved by adding more gateways and if gateways are well placed, network topology and traffic distribution can be enhanced. Fig. 1 shows the architecture of any IoT application connected to the gateways.

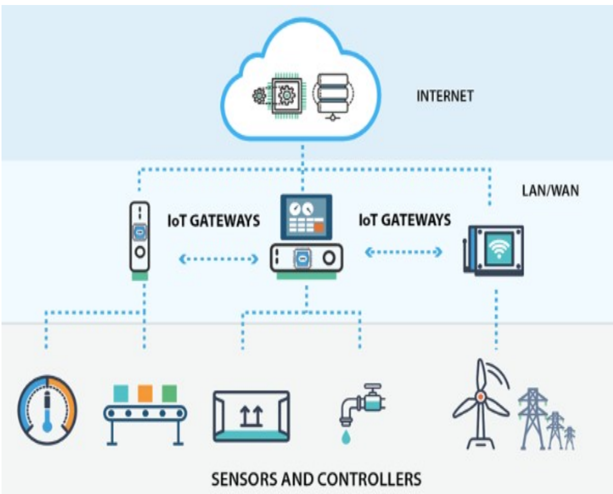

Fig. 1. IoT application architecture. [11]

Gateway placement algorithms is an important field that is commonly addressed by many researchers. As the number of IoT devices is expected to grow exponentially, Gateway placement algorithms will be more essential to improve network performance.

This paper brings together the state-of-the-art of the different existing Gateway placement algorithms, with a focus on optimization and implementation of algorithms for positioning a gateway, the placement algorithm's strengths, and their limitations.

The remainder of the paper is organized as follows: Section II presents the analysis of the existing work in Gateway placement algorithms. Section III discusses the reviewed algorithms and highlights the advantages and disadvantages of these algorithms as well as the main challenges associated with them. Section IV concludes the paper.

II. Analysis of Existing Gateway Placement Algorithms

This section presents an analysis of some of the existing gateway placement algorithms in Wireless Mesh Networks and Low Power Wide Area Networks. In this paper, we focused on the most recent algorithms that prioritize network performance and Quality of Service (QoS).

A. Two-stage load balanced gateway placement algorithm

Wu *et al*. [12] proposed an algorithm for gateway placement optimal solution in a Wireless Mesh Network. They assumed graph G, consisting of MR nodes, is connected. This algorithm is divided into two part: Mesh Router attachment and Gateway selection. Gateway selection was the first approach to be presented in the first part, which was intended to find a minimum dominating set with maximum weight. The second part which is considering load balancing among gateways, a gateway is selected as the primary gateway and one or more gateways can be attached in every MR.

B. KCMBC Algorithm

Hamdi *et al*. [13] proposed an algorithm called KCMBC algorithm. This algorithm consists of three important steps. The first step is the use of expiration time and the degree in computing node metric. The main purpose of the node metric is to figure out how long IoT nodes device can maintain their possible connection with their current neighbours and still be clusterheads eligible. The second step is simply based on using the protocols FloodMin and FloodMax for clusterhead election. and the final step node leaving and joining the cluster are the ones used in cluster structure for updating cluster and for maintenance.

In the process of electing clusterhead which is step two, the metric value of each and every node is broadcasted to the k-hop neighbours, and the candidate clusterhead election proceeds according to the reception of other metric nodes. In order to make sure which node serves as clusterhead various mechanisms are used to bring concurrence among nodes. However, the drawback of this algorithm is that: Every time before KCMBC algorithm actual evaluation proceed it is very important to consider partitioning measurements characteristics, for example, lifetime, for tuning functioning of KCMB. With this kind of an algorithm, an enhancement would be training it such that it can also be able to add new mechanism or modify KCMBC since coping with partitioning was not the only purpose but also designed for other specifications as well in the network.

C. Genetic Algorithm

Ahmed *et al*. [14] also proposed a novel approach using Genetic Algorithm with the purpose of solving Gateway placement problem and find the best solution, in terms of hopes number and Internet Gateways (IGs) number where transmission of packets takes place between Mesh Router (MR) and IG. The Genetic Algorithm approach for gateway placement problem has different types of sections such as Network encoding for real-world representation of network, Initial population that from a given number of Internet Gateways (IGs) and Mesh Routers (MR) will be generated randomly, and Selection Operation which picks the individuals number from a certain current species using probability and the crossover. Nonetheless, the algorithm can be optimized by considering many different parameters in testing such as population size, tournament size, and crossover type.

D. Two greedy algorithms Weight bipartite graph and PGL

Tian *et al*. [15] proposed two greedy algorithms which are Weight bipartite and PGL algorithms for optimization of the gateways locations. In this approach, authors were more concern about placing gateways so that jointly, the maximum number of IoT sensors are served, and all possible pairs of sensors are superimposed for the decoding crescents. In the Weight bipartite graph algorithm, two sets of vertices are defined. All possible optional points (OPs) contains in the first set, where pair of decoding crescents an intersection of boundaries point defines the OP. All possible ordered pairs of Sensor Networks (SNs) are being composed in the second set of vertices. The main drawback of these algorithms is that as the number of SNs increases it more luckily that WBG algorithm will become more time consuming because with the number of SNs OPs grows rapidly.

E. Incremental Clustering Algorithm

Tang *et al*. [16] presented a Backbone Wireless Mess Networks (BWMNs) novel algorithm to address the placement of gateways problem. Location of gateway problem is being solved by using the incremental clustering algorithm, such that iteratively assigning mesh routers to already identified gateways and incrementally identifying gateways. At least one gateway the algorithm is identified in each iteration, in the identified gateway the algorithm assigned at least one mesh router and the number of mesh routers that have not assigned to any gateway decreases by one. Thus, after at most $n - 1$ iterations the incremental clustering algorithm terminates, the total number of mesh routers is denoted by n.

In addition, for this algorithm, if the constraints are not violated then the assignment of mesh router is accepted, so when the algorithm terminates it is guaranteed that a feasible solution will be generated. The algorithm iterates many times which delays the process and make it a worst case of this algorithm, but only one gateway is identified by the algorithm in each of the iterations, and assign only one mesh router to the gateway. Optimizing the process of iteration in this algorithm can be virtual so that at least it identifies more than one gateway and assign more than one mesh router to the gateway.

F. Co-operative Traffic Transmission Algorithm

Tabbane et al. [17] proposed Co-operative Traffic Algorithm that elects a gateway to connect to the source vehicle to the Long Term Evolution (LTE) Advanced infrastructure under the scope of vehicle-to-infrastructure (V2I) communications. This algorithm is a Quality of Service (QoS) and multi-criteria based scheme optimization, the appropriate gateway decision is made by performing the fuzzy logic. The approximation theory of dealing with a complex system uncertainty can be viewed as a Fuzzy logic. The fuzzy logic contains two objectives: First objective, it develops a computational model that requires a human intelligence for problem-solving task and the model can also perform its reasoning, and second, it evaluates the importance of trade-off between cost and precision in this algorithm LTE advanced infrastructure that must be connected to source vehicle performed by a decentralized scheme. In order to transmit to the infrastructure a gateway selection based on the traffic class is basically a Quality of Service balancing scheme. However, the algorithm can be still enhanced in a way that it takes decisions on its own without being integrated into the MATLAB fuzzy module to have a decision made on the gateway by considering the class of the traffic to be transmitted to the infrastructure.

G. Network Intersection based Candidate Gateway Location Selection Algorithm

Karthikeya *et al*. [18] Proposed a Selection Algorithm, using the smart city as a scenario this algorithm shortly called NewIoTGateway-Select determines how many minimum gateways to be used in a particular network. This algorithm evaluates the position of a gateway and how many gateways to be deployed in that particular area or given scenario. For a gateway placement candidate locations are computed by NewIoTGateway-Select algorithm and optimal locations are selected from them, many times IoT Gateways (IGWs) and placement of Solution Specific Gateways (SSGWs) using computational geometry are calculated with the possible candidate locations using Selection algorithm, from the chosen locations of the candidate the algorithm selects the optimal locations for IGWs and SSGWs and handle the failures of links in the network and gateway failures by including k- connectivity and k-coverage algorithms, respectively.

Thus, the disadvantage of this algorithm is that in order to provide the full coverage to a given number of Coordinate Devices (CDs) the sum of the number of IGWs and SSGWs must be equal to the total number of required gateways, for instance, if there are 600 CDs in a network, then for full coverage 141 total gateways needed (33 IGWs + 108 SSGWs) according to NewIoTGateway-Select algorithm which may result in the unreasonable cost and objectionable. Nonetheless, NewIoTGateway-select can be optimized to develop efficient routing algorithms for IoT networks of three dimensions (3D) also optimized to address issues of gateway placement.

H. Clustering Based Gateway Placement Algorithm

Benyamina *et al*. [19] Proposed a Clustering Based Gateway Placement Algorithm (CBGPA) with perfect handling scalability of network CBGP Algorithm guarantees end-to-end bounded delay communications. Once the whole graph is connected and the set of Access Points (APs) is defined, CBGPA implements the cluster construction procedure, between the APs at halfway position start by placing a Mesh Gateway (MG). For every MG not visited any AP, among its all AP neighbours, the closest one will be selected by its peer AP, an immediate neighbour (within one hop distance) is not a candidate. When all mesh nodes marked the algorithm stops, besides it is always iterative. In some cases, the routing path is selected as MG when there is one AP left. All present nodes belong to disjointed clusters when the algorithm process terminates, each node headed by one MG. The total number of formed clusters represents then, the minimal number of MGs that guarantees the required delay with a minimum deployment cost. However, the drawback of this algorithm is that the same set experiment needs to run more than once in order to evaluate the effectiveness of CBGPA.

I. Centralized vs Distributed Algorithm

Wolfgang *et al*. [20] proposed a Centralized algorithm against Distributed algorithm for gateway placement functionality in 5G cellular networks. The Centralized algorithms are used for positioning the gateways in the middle of the position, this configuration will be used as a baseline. In the Centralized algorithm when the number of gateways increases, n biggest cities strategies are being used to assess the influence on the network. The gravity model is used to calculate the traffic between two cities. The main disadvantage of this algorithm is that even if the gateways are centralized but it is not guaranteed that all nodes around it will connect perfectly.

J. Integer Linear Programming (ILP)

Turnbull *et al*. [21] Proposed an Integer Linear Programming to reduce the network cost with respect to the total number of devices that are being deployed the main aim of this algorithm is to prioritizes the QoS. QoS refers to any kind of technology that controls data traffic to minimize delays, latency and packet loss on the network. Furthermore, in the ILP algorithm at the facility location different none-gateway communication devices are deployed. These devices differ with the total cost and capabilities of transmission. To ensure enough capacity for the flow demands that need to be addressed each device in the network is selected with respect to each specification of the transmission. Nonetheless, the cost of Gateway placement using this algorithm is still expected to grow as technology improves day-by-day which is the main disadvantage of ILP.

K. Fingerprint-Algorithm-Based Positioning

Choi *et al*. [22] in their work proposed Fingerprint-Algorithm- Based Positioning. In most IoT applications positioning is an essential element. The aim of the proposed algorithm is to track the moving object in a specific area by implementing LPWA IoT services, where LoRa networks can be developed. This study consists of an offline and online phase, a fingerprint algorithm is used in a LoRa-based gateway positioning process, in the offline phase, for each sample point from all service areas the characteristics of signals are collected and stored in a database. In the online positioning phase, through the database search the location of an end device is estimated.

In this algorithm, all uplink packet has an end device ID, timestamp and a sequence number. The firmware of IoT gateways and LoRa end-devices should be modified to send an uplink packet and to process them for positioning. End-devices send uplink packets to gateways for positioning following which Received Signal Strength Indicator (RSSI) information is accessed at the gateways. Nonetheless, power consumption is still a disadvantage in this algorithm due to the online phase. However, multiple gateways can be implemented using this algorithm.

L. Multilateration Algorithm

Fargas *et al.* [23] proposed a multilateration algorithm, for estimation of the device location purposes, and from each gateway the packet received time. When the transmitter is not synchronized with the receiver multilateration algorithm is introduced in that system as a geological technique. The receivers do not need to be synchronized each other as transmitters need to be. Thus, the intersection of at least two hyperbolas is the location in this technique. Only the gateways were synchronized with each other, the IoT tracking system does not have synchronization with the end device. Therefore, by the time packet was received by each gateway the information was available. There are several gateways supporting LoRa technology on the market. The chosen one was Kerlink because a GPS receiver is embedded in the gateway. Therefore, all gateways are synchronized by using the timestamp from the GPS satellites.

III. DISCUSSIONS

In the previous Section, we have discussed several works on existing Gateway Placement algorithms specifically for WMN and LPWAN. The importance of this study is to identify different types of existing algorithms based on WMN and LPWAN, identifying their drawbacks, possible improvements, strengths, and weaknesses. The summary of the findings is shown in Table I.

The analysis performed shows that there are several different algorithms in Gateway placement with each having its approach, advantages, and disadvantages. However, some of the algorithms seem to be the same but only different with the type of network, transmission range, strength, limitations and network size covered. For example, all the studies considered in this paper implemented algorithms for the same purpose of Gateway placement, but they were implemented in differing networks such as WMN, LPWAN, MANET, and VANET. The expected transmission range of Gateways was found to differ greatly across the various network types, resulting in differing network deployment areas [12-23]. Also shown in Table I are the general limitations faced by different algorithms such as scalability issues, complexity, and cost.

The research that was conducted based on the existing algorithms shows that there are many algorithms that provide different solutions and prioritizes different performance metrics. However, every algorithm has its own weaknesses and strength that were identified in Table 1. For example, there are some common issues related to Gateway Placement such as [8].

a) Congestion:

Gateway is forwarded by most of the traffic in a WMN, so if the gateways are not often used some of them might be overloaded. Now the biggest problem is that each gateway should be placed in such that no node is over congested and the load is balanced.

b) Coverage:

It is the served number of devices or covered by gateways in the network. More than one gateway must cover one mesh routers for backup purposes if gateway fails back up gateways still be able to cover mesh router.

c) Location:

Network performance is mostly impacted by the location of the gateway. If gateways are not well located, interference may occur and set up cost may be unreasonable and signal strength will be poor if gateways are located sparsely. So, the location of the gateway is essential.

d) Interference:

The gateway node should be placed in such a way that the throughput is maximum and interference among gateways is minimum.

e) Distance:

If the gateways are placed in a crowded manner the network throughput will badly be affected by the interference and the same thing applies the greater the distance between gateways the poor the signal strength.

IV. CONCLUSION

Gateway placement algorithms are essential in determining the location of gateways in a network. There are many challenges and factors to consider when implementing an algorithm for gateway placement in WMN and LoRaWAN. Several studies have been conducted to place Gateways and in this paper, we have conducted and presented an analysis of the different types of algorithms used in Gateway placement. The objective of the analysis is to identify the strengths, weaknesses, and common issues in existing placement algorithms. The purpose of these algorithms is to increase QoS in the network, deploy few gateways with certain parameters of the network, such as congestion, delay, link bandwidth, node capacity, network throughput and traffic demand to meet requirements of better network performance. It is essential to minimize the number of gateways without compromising the cost and network throughput.

TABLE I. SHOWS SUMMARY OF THE EXISTING ALGORITHMS

Ref.	Transmission Range	Network Model	Objectives	Strength	Limitation	Network Size	Av. Node Speed
Two-stage [12]	30 m	WMN	Optimizing number of GW average MR-GR	Better Load Balance	Uses Brute-Force search each choice it involves validation	200m x 200m	-
KCMBC [13]	70 m – 100 m	MANET-Satellite	Bridging partitioned networks	Minimize economical cost and optimize network cost	Scalability issues	100m x 100m	4.4m/s
Genetic [14]	-	WMN	Minimize variation of MR-IG-hop count	Robustness and Scalability	Only uses the sequence of 1s and 0s (Binary)	-	-
Two greedy [15]	-	LPWAN	To address gateway interference	High packet delivery ratio	Low average contention computational complex	20 x 20 m	-
Incremental [16]	-	BWMN	To find gateway placement	Provide Quality of Service (QoS) and feasible gateway placement	Limited gateways to be deployed	10 x 10 m	30 runs
Co-operative [17]	250 m	VANET	To cover most of the area. Consider QoS traffic class constraint. To make a decision on appropriate gateway placement	Better performance in terms of packet loss by using k-coverage-connectivity	Very complex to implement	-	0.3mb/s
Network Intersection [18]	10,30,50,60,100 m	IoT Networking	To minimize deployment cost. The enhance network coverage.	Take care of gateway failures and link failures	A lot of complex calculations	1km x 1km	-
Clustering Based [19]	-	WNM	To optimize the model of cost deployment. To optimize the model of average congestion	Guarantee an upper bound length for every potential path between any Mesh node and its nearby MG	-	-	9 runs
Centralized vs Distributed [20]	40 km	5G Cellular Network	-	If at least a certain fraction of traffic is transmitted over long distances the cost does not explode	cost	360.000km	-
ILP [21]	LTE-A	IoT network	To provide QoS Constraints	QoS	Expensive installations	1000m x 1000 m	-
Fingerprint [22]	Long Range	LPWAN	To evaluate the accuracy and usability of the fingerprint algorithm.	Can implement multiples of gateways	Creation of interpolated maps in the offline phase.	340m x 340m	-
Multilateration [23]	5km-15km	LPWAN	To design and implement a LoRaWAN tracking system	Transmits signals in a long range	Unlimited resources	2km – 3km	-

REFERENCES

[1] H. I. Kobo, A. M. Abu-Mahfouz, and G. P. Hancke, "Fragmentation-based Distributed Control System for Software Defined Wireless Sensor Networks," *IEEE Trans. Ind. Informatics*, vol. 15, no. 2, pp. 901–910, 2018.

[2] S. W. Pritchard, G. P. Hancke, and A. M. Abu-Mahfouz, "Security in software-defined wireless sensor networks: Threats, challenges and potential solutions," *Proc. - 2017 IEEE 15th Int. Conf. Ind. Informatics, INDIN 2017*, pp. 168–173, 2017.

[3] A. M. Abu-Mahfouz and G. P. Hancke, "ALWadHA Localization Algorithm: Yet More Energy Efficient," *IEEE Access*, vol. 5, pp. 6661–6667, 2017.

[4] D. Ramotsoela, A. Abu-Mahfouz, and G. Hancke, "A Survey of Anomaly Detection in Industrial Wireless Sensor Networks with Critical Water System Infrastructure as a Case Study," Smart industrial wireless sensor networks, pp. 1-24, 2018.

[5] J. M. Marais, R. Malekian, and A. M. Abu-Mahfouz, "LoRa and LoRaWAN testbeds: A review," *2017 IEEE AFRICON Sci. Technol. Innov. Africa, AFRICON 2017*, no. November, pp. 1496–1501, 2017.

[6] J. M. Marais, R. Malekian, and A. M. Abu-Mahfouz, "Evaluating the LoRaWAN Protocol Using a Permanent Outdoor Testbed," *IEEE Sens. J.*, vol. 14, no. 8, pp. 1–1, 2019.

[7] O. Khutsoane, B Isong, and A. M. Abu-Mahfouz "IoT Devices and Applications based on LoRa/LoRaWAN," In *IECON 2017-43rd Annual Conference of the IEEE Industrial Electronics Society* pp. 6107–6112, 2017.

[8] S. Srivastava, K. Jaiswal, and P. Rawat, "Gateway Placement Approaches: A Survey," *Int. J. Eng. Innov. Technol.*, vol. 1, no. 4, pp. 306–309, 2012.

[9] N. Sibeko, P. Mudali, and M. Adigun, "Evaluation of Realistic Topologies in Infrastructure Wireless Mesh Networks (IWMNs)," vol. 3886.

[10] H. I. Kobo, A. M. Abu-Mahfouz, and G. P. Hancke, "Efficient controller placement and reelection mechanism in distributed control system for software defined wireless sensor networks," *Trans. Emerg. Telecommun. Technol.*, no. July 2018, p. e3588, 2019.

[11] OpenAutomationSoftware https://openautomationsoftware.com/blog/what-is-an-iot-gateway/ (Accessed: 24/01/2018)

[12] W. Wenjia, L. Junzhou, and Y. Ming, "Gateway placement optimization for load balancing in wireless mesh networks," *Proc. 2009 13th Int. Conf. Comput. Support. Coop. Work Des. CSCWD 2009*, pp. 408–413, 2009.

[13] M. Hamdi, L. Franck, and X. Lagrange, "Gateway placement in hybrid MANET-satellite networks," *IEEE Veh. Technol. Conf.*, pp. 1–5, 2012.

[14] A. M. Ahmed and A. H. A. Hashim, "A Genetic Approach for Gateway Placement in Wireless Mesh Networks," no. February, 2018.

[15] H. Tian, M. Weitnauer, and G. Nyengele, "Optimized Gateway Placement for Interference Cancellation in Transmit-Only LPWA Networks," *Sensors*, vol. 18, no. 11, p. 3884, 2018.

[16] M. Tang, "Gateways Placement in Backbone Wireless Mesh Networks," *Int'l J. Commun. Netw. Syst. Sci.*, vol. 02, no. 01, pp. 44–50, 2009.

[17] G. E. M. Zhioua, N. Tabbane, H. Labiod, and S. Tabbane, "A fuzzy multi-metric QoS-balancing gateway selection algorithm in a clustered VANET to LTE advanced hybrid cellular network," *IEEE Trans. Veh. Technol.*, vol. 64, no. 2, pp. 804–817, 2015.

[18] S. A. Karthikeya, J. K. Vijeth, and C. S. R. Murthy, "Leveraging Solution-Specific Gateways for cost-effective and fault-Tolerant IoT networking," *IEEE Wirel. Commun. Netw. Conf. WCNC*, vol. 2016–Septe, no. Wcnc, pp. 1–6, 2016.

[19] D. Benyamina, A. Hafid, and M. Gendreau, "Optimal placement of gateways in multi-hop wireless mesh networks: A clustering-based approach," *Proc. - Conf. Local Comput. Networks, LCN*, no. October, pp. 625–632, 2009.

[20] W. Kiess and A. Khan, "Centralized vs. distributed: On the placement of gateway functionality in 5G cellular networks," *2014 IEEE Glob. Commun. Conf. GLOBECOM 2014*, pp. 4788–4793, 2014.

[21] E. A. V. I. Gravalos, P. Makris, K. Christodoulopoulos, "Efficient Gateways Placement for Internet of Things with QoS Constraints," *Nurs. Times*, vol. 91, no. 49, p. 54, 1995.

[22] W. Choi, Y. Chang, Y. Jung, and J. Song, "Low-Power LoRa Signal-Based Outdoor Positioning Using Fingerprint Algorithm," pp. 1–15, 2018.

[23] B. C. Fargas and M. N. Petersen, "GPS-free Geolocation using LoRa in Low-Power WANs," In *2017 Global Internet of Things Summit (GIoTS)*, pp. 1-6 no. June 2017, 2018. 1989.