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Gateway Placement Optimization using Multihop Traffic Approach in IoT Network

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Abstract

The Internet of Things (IoT) is a promising advanced technology that links large wireless communications machines and devices in the future. In effective wireless communication, Gateway plays a significant tile. The performance of IoT networks is affected by various network parameters such as the position in the network gateways and heterogenous coordinating devices. To increase the performance of the network, the placement of the gateways should be optimal, which reduces the deployment cost and increases throughput. Furthermore, more than one gateway reduces congestion within the IoT network, resulting in noise and cost increases. Most researchers focused on the placement of internet gateway or mesh routers in the Wireless Mesh Network (WMN). However, the gateway placement problem needs to focus on IoT networks where heterogeneous wireless technologies are involved for machine-to-machine communication(M2M). In this article, a revolutionary IoT network gateway positioning is proposed. It defines the locality of a gateway based on the new Multi-hop Traffic Metric (Mh_TM). The Mh_TM computing includes many factors affecting the throughput of IoT networks: the set of coordinating devices, the set of gateways, the demand for traffic from coordinating devices, locality of gateways, and potential interference between gateways. The projected gateway position strategy offers a mechanism in which IoT networks improve their performance substantially by correctly placing gateways. A non-asymptotic throughput of the IoT network is driven by using link scheduling to assess the efficiency of the current gateway placement system. The experimental results of the proposed gateway placement system are outperforming the other systems with improved margins.

Keywords— Gateway Placement, Multihop Traffic, IoT Network, Throughput

I. INTRODUCTION

The IoT networks have changed the working and play of our lives. They have changed all facets of our lives to make communicating with our peers easier. Wireless networks are an expansion of how we are subjected to interact to ensure they are more integrated into our everyday lives. By enhancing the efficiency of traditional cellular networks, the researchers push the envelope. As technology evolves, greater demand for intelligent and more powerful appliances combined to meet and help human appetite for information, communication, and entertainment through much faster wireless networks has increased. Despite all these advancements, existing wireless networks have restricted reach, poor performance, improper connections, security issues, and power limitations. Therefore, it is essential to create an economical, scalable, and tolerant fault wireless system that meets the increasing demand exponentially.

The integration of various IoT networks offers the IoT environment benefits and characteristics of each network. For instance, sensor networks are used primarily for data collection and sensing. It is

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generally regarded as a static network as well. Mobile or vehicle network communications between nodes or motor vehicles are also used. It is also known for its mobile behavior [1].

In wireless network deployment, the positioning of the wireless gateway is a significant design element. The average connectivity costs are significantly higher if the wireless gateway is located on the edge of the network than if the gateway is placed in the middle. The gateways are, therefore very essential to reduce the several gateways to mitigate costs. At the same time, their location must comply with the minimum bandwidth and upper delay end-user device efficiency metric. In addition, other factors such as reduced interference increased fault toleration, and demand growth are important factors in conjunction with QoS constraints that affect the position of wireless access ports.

In wireless networks, several research problems remain open [1]. One of the most complex challenges is the location of gateways. In wireless networks, web proxies or server replicas were performed to improve user accomplishment in various studies [2-4]. The cellular network base station positioning issue [5-7] is another instance. However, to replace the wireless connections and the multi-hop systems, an additional robust traffic modeling structure is needed to resolve the problem of the locality of backbone nodes on multi-hop wireless networks. Bejerano [8] has defined gateways' placement on wireless multi-hop systems, where system nodes have been subdivided into a minimum set of disjointed groups that meet throughput and delay requirements. WMNs have been proposed with various positioning algorithms for gateways or backbones [9–12].

The remaining sections of the article are described as follows: in section 2, the background of wireless network and related work of this research, the modeling of IoT and the projected system is defined in section 3, and at last in section 4, the experimental results discussed and in last section conclusion, and future work is elaborated.

II. Related Work

Different sensors devices feed vast volumes of data into the data systems every day in the IoT. This large quantity of data must be processed and transferred via IoT. It is a huge challenge to manage complicated, varied, and dynamic data from different sources in the current situation. Traditional approaches to achieve maximum throughput cannot be used to manage data through gateways. New intelligent gateways called IoT gateways are used in the IoT network to enhance performance to handle and process this complex and heterogeneous Data. During data transmission, the main components within the network are gateways, as the traffic path is decided based on the position of the gateway. It is difficult to find desirable gateway locations, and gateways count should be minimum in IoT network. The minimum number of gateways must be examined in the gateway placement problem, but even these gateways must be positioned in the right position. Just one internet gateway is not enough, as the IoT network has to handle a large amount of data. Suppose more gateways are placed in the correct location to boost the performance of the wireless network. It is measured as performance and optimization of distributed dynamic traffic and network topology, and optimum gateway location is a solution.

Researchers suggested various clustering approaches to the wireless networking of the gateway. Clustering Based Gateway Placement Algorithm [13] investigated restricted, scalable, time-limited end-to-end communication. In this system, the whole network is divided into several clusters considering many constraints. After cluster formation, any one of the mesh routers is chosen as an intermediate point for all cluster nodes. For the gateway placement issue to be found under the quality of service (QoS) criteria, research [13-16] utilized various clustering-based approaches (like delay and throughput performance). The author presented the gateway placing issue in paper [17] by placing a minimum number of gateways to comply with quality of service (QoS) demands and proposed an almost optimal heuristic algorithm for placement of the gateway, and later, its performance compared with a few suboptimal solutions previously identified. Author B. Aoun et al. [18] have highlighted the main issue of placement in the gateways by selecting at least a smaller number of gateway points to achieve Quality of Service (QoS), close to the optimum time, an algorithm that recurrently calculates the minimally weighted Dominating Sets (DS). Using modeling and simulation reliably demonstrated that the numbers of gateways in various situations are compared to other alternative schemes.

F. Zeng et al. dealt with the load-balanced gateway system issue [19]. The authors suggested that the GA-LBC greedy algorithm divides the WMN into load-balance and splinter clusters; every cluster manages the QoS necessities. The author projected the almost optimum hybrid HA-LBPG solution based on the GA-LBC algorithm and the genetic algorithm values. Using this method, the number of

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HA-LBPG gateways is almost the same as the outcome of other gateway placement algorithms, and HA-LBPG performs even better than other existing strategies in terms of load balancing on gateways. Capacited facility location problem (CFLP), in [20], addressed the gateway placement issue to select clustering algorithm. Each gateway serves a cluster of its neighboring MRs, and the spanning tree (cluster head) at the gateway was used for delivering messages. Two stages are included in Bejerano's method [21]. First, the minimum number of clusters for all nodes is selected in a given network as the upper limits for deciding the radius of the clusters. The next step was to construct a cluster tree that breached the relative load or cluster size limitations. The second step was to sub-divide clusters. Paper [21] described several clustering algorithms for the location of gateways in WMNs using the topology of a network already implemented. The use of many gateways in clustered WMN can dramatically improve performance.

III. Proposed System

The load-balanced gateway positioning is a challenge in the proposed system. In the system, the load is balanced by reducing unused congested network domains. The number of deployed gateways should be maintained to less count to reduce total costs also. The total cost of placing a gateway is a thousand times greater than a standard mesh router. Selection of gateway to satisfy the overall capacity of all the gateways, provided that all nodes should have at least total traffic demand. Selecting the proper gateway should be given priority along with a reduction of the number of gateways, intermediate gateways, and mesh routers with higher capacities. Here, the node's capability is its ability to handle local traffic and backbone.

Through adding more gateway, network output and the average minimum hop count needed to reach the nearest gateway can be effectively lowered and the current gateway traffic reduced. In addition, network efficiency significantly influences the locations of the deployed gateways.

An innovative gateway system to increase overall network performance through load balancing is proposed for wireless networks in the proposed system. It defines the gateway position depends on the multi-hop traffic-flow weight (Mh_TM) parameter. In this proposed system, Mh_TM operation considers several issues affecting wireless network efficiencies, such as intermediate gateways, set of gateways, the demand for traffic from the candidate's location, gateway locations, and potential interference. The mechanism to substantially improve the performance of wireless networks by placing gateways correctly in the proposed gateway placement scheme. Non-asymptotic wireless network efficiency is extracted from the consideration of connection schedule to assess the performance of the current gateway placement schemes. It also offers a guideline on the nature of wireless network scheduling schemes.

In this paper, an algorithm for the load balancing of the gateway is proposed by considering the above factors to improve the network efficiency.

The proposed system is divided into two steps:

The first step covers the gateway selection strategy is provided similar to the minimum dominant collection of maximum weights, and in the second step, each gateway interfacing with one or more gateways can be attached. For this reason, a cluster-based approach for placement of gateway is proposed that covers:

(1) The location of a candidate's gateway is chosen based on the radius of clusters and proposed route starting from the chosen gateway to all candidate locations for the same group

(2) By allowing each node to route the traffic to its nearest gateway, scalability can be achieved within a network

(3) The placing of smaller gateways leading to cost-effective topologies. This technique ensures that gateways are properly positioned, leading to lower operating costs and sufficient network power.

The whole network is represented in the form of a graph. The whole graph should be interconnected first, and subsequently, the cluster construction procedure begins by placing the intermediate gateway between two IoT gateways in a halfway location. The nearest gateway is chosen for the gateway that is not yet visited. Here the best search algorithm is used for the selection of the peer gateway. All links have the same cost as one. Several candidate location nodes in the highest Hops 'H' are not inside the newly positioned intermediate gateway, in the same group as visited. When all candidates' locations are indicated as visited, then this iterative algorithm is terminated. In the next step, the parent node is selected as the intermediate gateway in a routing path (its predecessor) when the last level of APs left,

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i.e., no peer AP exists, is divided into one internet gateway at the last step of the algorithm. The clusters in networked established at the end of algorithms are the minimum number of gateways, which guarantees a minimum deployment cost for the necessary delay.

Nc candidate locations are assumed distributed over region R. R is divided into small regions as separate cells and the intermediate gateway act as the center point for each cluster. Let Nr indicate the intermediate gateways. In this case, the constraint is more than one gateway, and the number of gateways is smaller than that of candidate positions, i.e., $1 < Nr \leq Nc$, i.e., Gateways are a wireless backbone for candidate locations to have a wireless infrastructure. The intermediate gateway or IoT gateway, like a star topology, has different candidates' locations in each cell, i.e., no direct contact is possible between the candidate positions, and the gateway functions as a hub for the candidates. There are gateways wired to the internet that act as IoT gateways for all intermediate gateways.

The number of gateways in the IoT system (Nr) should not surpass the number of intermediate gateways (Ng). However, the number of gateways is noticeable that $1 \leq Ng \leq Nr$. The fact is that the most recent studies of implementation problems [21] addressed the square grid topologies that provide the optimal network output in a more practical way.

Each applicant is a source and a destination of the information. At a particular point, the same number of packets needs to be sent and received. In contrast to candidates, intermediate gateways are not a data source or a data source; they route and forward data to applicants or intermediate gateways. All traffic via gateways is presumed. Each candidate is connected to the nearest gateway to or from packets. If the shortest path routing is implemented, the next gateway for an applicant is the gateway to which the applicant can access by a minimum of hops. If a candidate has more than one gateway, they can cost their traffic through the round-robin to all its nearest gateways. For example, an applicant would be linked to an IoT gateway if the intermediate gateway is connected to the IoT gateway. Therefore, all the theoretically linked IoT gateways would also be shared by traffic loads of candidates and intermediate gateways.

A. *Transmission Model*

A transmission model is defined to help develop the current gateway placement system and its performance measurement.

Two radio interfaces are provided for each candidate or intermediate gateway: backbone communications with W1 bits/s and local communications with W2 bits/s. In limited broadcastings, every coordinating device forwards W2 bits/s. Assume, W1 and W2 are orthogonal to prevent interference from local contact with the backbone. The two radio interfaces of an intermediate gateway or candidate location could consist of two environmental edges or two simulated radio edges. It should be noted that for the latter case, for a candidate or intermediate gateway and time switching channels for backbone or limited broadcasting, two simulated edges would be needed only for one environmental radio edge.

In addition, only one sender can accept packets from a candidate or intermediate gateway at a time. Candidates are subject to the same constraint. Both Frequency Division Duplex (FDD) or Time Division Duplex (TDD), transmission and reception may occur according to how the environmental and MAC layers are implemented.

B. *Evaluation parameters*

This section elaborates on two different parameters, throughput, and load-balancing, to evaluate the system's performance.

i. *Throughput*

The aggregate performance and worst-case per client performance must be derived to test the execution of gateway locality algorithms. Two problems for enhancing performance are devised in this section that leads to two performance metric descriptions.

Case 1: To maximize aggregate throughput of wireless network by optimizing gateway placement strategy, Ng Gateways are selected from Nr intermediate gateways. Some customer distributions, distribution of gateways, data transmission, link scheduling, and routing protocols as represented in Equation 1.

$$\sum_{k=1}^{N_c} \mathrm{Tr}(k, N_g) \qquad (1)$$

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is maximized when the Ng gateways are deployed, where *Tr* (k, *Ng*) indicates the throughput of each client for the k^{th} intermediate client.

Case 2. To maximize the worst-case client throughput in the wireless network by optimizing gateway placement strategy, in this case, Ng gateways are chosen among Nr intermediate gateways in the wireless model as unique candidate location distribution, internet gateways distribution, data transmission, link scheduling, and routing protocols as shown in Equation 2.

$$\sum_{k=1}^{N_c} TH(k, N_g) \qquad (2)$$

is maximized.

ii. Load Balancing

To maximize the throughput of the wireless network as per the equation 1 and 2 explained in the above section, a load-balanced approach is integrated along the Mh_TM algorithm to ensure gateways utilization to maximum by the parallel transmission of data for heterogeneous wireless technologies used in the system. In this approach, two important parameters are considered to balance the load. The first parameter is considered as the distance between intermediate gateways and internet gateways. Distance is calculated dynamically during network deployment, but if there is a change in network topology, the process of calculating distance is to repeat. In our approach, both Euclidean and Manhattan distances are calculated for the linear and nonlinear scenarios. The second parameter is next-hop gateway selection to achieve a load-balanced IoT network. To select the next hop, the Load Index (LI) parameter of each gateway is considered, as shown in equation 3,

$$LI = \frac{D_s + Q_d}{E_b} \qquad (3)$$

Where D_s: Amount of data to be sent by intermediate gateway G_i.
Q_d : Amount of data in the queue for neighbor gateway G_j
E_b : Expected bit rate as per channel access probability

IV. Multi-hop Traffic Gateway Placement

Recent gateways can improve backbone communication performance by successfully cutting the standard set of hops that every packet requires to reach gateways and cutting the stream of traffic on current gateways. However, the above improvements can be greatly reduced as the gateways are inadequate, as new gateways would often cause more confrontation with existing gateways. Therefore, the best positioning algorithm for the gateway should alleviate the traffic within the network by reducing interference at a minimal level. Generally, an intermediate and internet gateway system needs to adapt to the number of gateways deployed. A relatively limited number of used gateways means that a packet must pass through gateways, resulting in an enormous traffic load. Thus, geometry-balanced placement algorithms, such as standard placement, can produce very good results as the average hop count can be reduced effectively. On the other hand, positioning internet gateways in network regions with maximum traffic load could probably be the best choice if a reasonably high number of gateways are used.

A novel gateway algorithm is proposed in this section. It has all the above strengths:

The algorithm iteratively calculates the traffic-flow weight indicated by Mh_TM (j) on the intermediate gateway $G_{i,j} = 1 \cdot \cdot \cdot N_r$. Thus, the highest weight is put on the router every time with the newly designed gateway. This weight calculation adapts to the following factors: numbers of intermediate gateways, i.e., Nr and IoT gateways, i.e. Ng, dynamic traffic requirements from interconnected networks, the position of existing gateways on the network, and interference within the network for existing gateway.

A variable named gateways radius, named R_g, is determined in the first step of the algorithm. R_g, is the group of hops that run from an IoT gateway to its most remote gateways. In the second phase, the need for local traffic is stated in T(i) for each intermediate gateway is evaluated. As T(j) corresponds to the necessity for traffic from all the interconnected users linked to R_g and all the interconnected users in the network are presumed to be the same, T(j) can be expressed with the number of R_g candidate locations. The Mh_TM (j) is determined with T(j), and R_g in the third step is the summation of local traffic considering multi-hop traffic generated at each intermediate gateway. The first gateway on the router with the greatest weight is put with Mh_TM(j). Only one gateway can be deployed in this example, hence Ng=1. Thus, the gateway is positioned in the center of the intermediate gateway of the highest Mh_TM weight wireless network.

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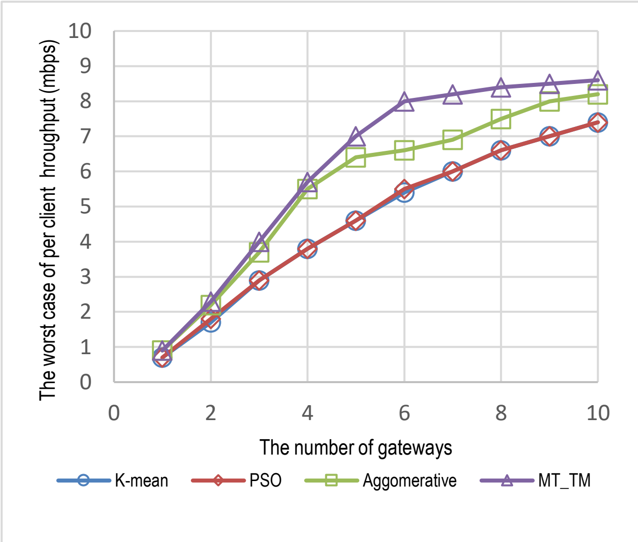
Thus, the Mh_TM algorithm explained in this section, proved gateways utilization to maximum by the parallel transmission of data for heterogeneous wireless technologies used in the system.

V. RESULTS AND DISCUSSION

The performance of this wireless network is explored by using the method of computation for the proposed system. Presume Nc = 30 to 200, Nr = 3 to 35 and l = 800-1000 m during the experiment. In other words, in a square region of 1000 m, there are 200 candidates, spread to 800-1000 m, The square off is divided into 36 tiny square cells uniformly, and the middle of each cell has an intermediate gateway. The study compares the proposed (Mh_TM) algorithm to the other three placement gateway algorithms: K-mean gateway placement, PSO-driven gateway, and agglomerated gateway placement. The communications are evaluated in between the intermediate gateway channel capacity and the set of gateways. We presume all coordinating devices are distributed equally and can be transmitted in downlinks at 10 Mbps for each device. The gateways are located with the proposed Mh_TM algorithm, and the intermediate gateway channel bandwidth ranges from 10Mbps to 25Mbps with a 5 Mbps increase. The experimental outcome shows that the set of gateways can be greatly condensed by using more efficient intermediate gateways in the backbone. For instance, 6 intermediately transmitted IoT gateways of 25 Mbps can attain far restored performance than 15 intermediate gateways with 10 Mbps intermediate transmission.



In the second scenario, the results of gateway positioning algorithms inside the wireless network are compared in Figures 1 and 2. We believe that all coordination devices are distributed consistently, with a transmission of 10 Mbps and 20 Mbps for each coordinating system or intermediate device. The results show that both the combined throughput and the worst performance are outperformed by the projected Mh_TM algorithm.

The agglomerative gateway placement algorithm produces the second best performance, as it is a balanced geometry algorithm that can successfully lessen the mean gateway-to-connect distance from connected coordinating devices or intermediate gateways.

In the third case, as Figure 3 illustrate, when coordinating devices are spread unevenly in the wireless network. In the system, we compare the throughput performance of four gateway algorithms, or the density of the nodes is very different in the sub-networks. In this case, at every individual stage, Mh_TM exceeds the other three algorithms. In this scenario, we duplicate the coordinating system channel capacities provided that both coordinating devices and intermediate gateways can transmit at 20 Mbps. In other cases, gateway algorithm changes cannot be seen as very low efficiency is the biggest limitation to achieve the maximum performance of the entire wireless network due to the extremely elevated node density in certain areas.

The Mh_TM algorithm has the highest throughput increase for the second scenario and third scenario, shown in Figures 1 and 2 when selecting from 10 to 15 gateways. The following is an explanation:

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Gateways begin to interfere with each other with more than four gateways in IoT networks. Mh_TM has a distinctive structure to lessen this interference between gateways in comparison with the other three algorithms. For a gateway placement algorithm, countering interference between gateways is very important.

Fig. 1. Aggregate throughput comparison for uniformly distributed coordinating devices

The implementation cost involved in setting up the gateways is an important problem facing IoT network service providers. So, the aggregate throughput per gateway can be an output metric to assess the efficiency of the gateway positioning algorithm. Figure 4 demonstrates the combined performance of the coordinating devices uniformly distributed. These results show that an outstanding number of gateways are available that best balance the cost and throughput of the gateway.

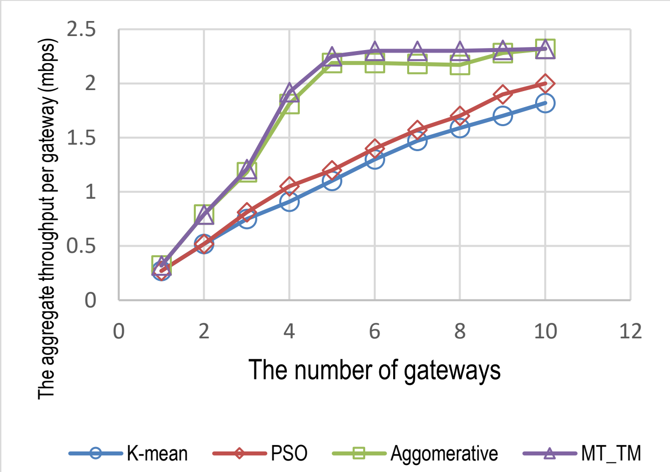

Fig. 2. Comparison of throughput for each client

More importantly, the Mh_TM is shown to be the most cost-efficient system, as every gateway has the highest combined performance.

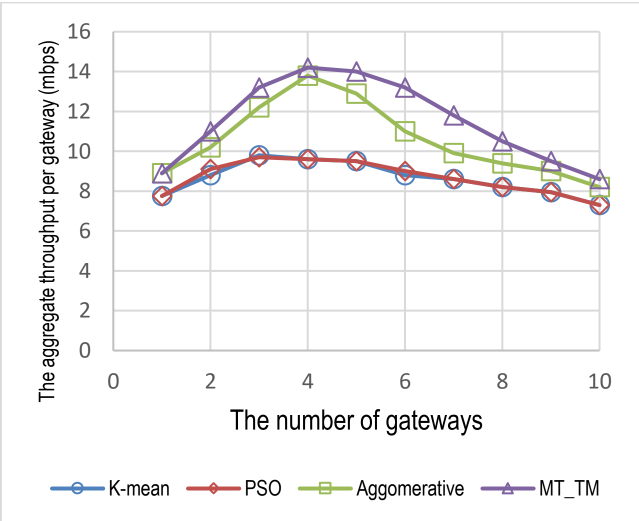

Fig. 3. For uniform distribution case comparison of aggregate throughput for each gateway

VI. CONCLUSION

The problem of optimal positioning of the gateway in wireless networks to increase efficiency is illustrated in this article. A multi-hop traffic weight gateway positioning algorithm was proposed. An asymptotic analytical model was also developed in a gateway positioning algorithm to evaluate the achieved throughput. The results of the proposed placement algorithm have been analyzed based on this model. Numerical results demonstrated a much better performance than other systems of the

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proposed algorithm. Even it was also demonstrated as a cost-effective approach. However, the Mh_TM algorithm projected in this article does not contemplate cross-optimizing gateway positioning with wireless network performance. Thus Mh_TM's output is not inherently optimal and can be lower than the optimum performance. The next objective of our research is to optimize the location of gateways and maximize throughput. The fault tolerance assurance issue of the gateway placement was discussed here. We suggested two step-based gateway placement approach in wireless networks. The first step is the selection of a gateway, to find the minimum number of gateways with maximum weight. In the second step, each coordinating device is attached to one or more intermediate gateways or internet gateways. Gateway with maximum throughput is selected as the main internet gateway directly connected to the cloud for data transmission, given the tolerance of defects among gateways.

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