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Improving Service Delay in Smart Parking System in Smart Cities with 5G

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Abstract— Rapid urbanization and population growth leads to substantial increase in vehicular traffic while reducing empty spaces. This necessitates an enhanced parking systems to efficiently address the parking space management. The smart city and Internet of Things (IoT) holds a very high potential to solve this problem. However, the data traffic generation at the edge is increasing rapidly. Tremendous growth in IoT is putting a high congestion on cloud services. To ease up the congestion issue, we have proposed an efficient fog-based communication model for the smart city parking management. In this work, we have proposed a parking system management model based on 5G with low latency and green communication. Our model reduces congestion at the cloud and enable faster processing by addressing the parking system locally. Furthermore, our model finds out the nearby parking without putting additional load to the cloud. Simulation result shows the performance efficiency of the proposed model in terms of response time, average cost and service delay.

Keywords- Fog Computing; Cloud computing; 5G; IoT; green communication

I. Introduction

Today, around 55% of the world's population lives in cities. According to the UN's report, the expected rise in population will be about 68% in the coming decades [1]. Urbanization is key to economic development. People prefer migrating to urban areas for better opportunities and lifestyles. These migrations and the slower expansion of urban areas led to overpopulation. In most cases public transports are inefficient and inconvenient. At the same time personal vehicles are becoming more affordable. This collectively leads to increase in the use of personal vehicles for daily commutes. There is also a surge in residential and commercial spaces to cater to the increasing population. This leads to reduced empty spaces to develop proportional parking spaces. The ever-increasing number of personal vehicles with limited parking spaces leads to road blockage around commercial and public places. This also leads to slower traffic movements and congestion during peak hours around such places. This situation contributes to low vehicle mileage and increases in CO_2 emissions, thus leading to global warming. If the parking system is improved, people can park efficiently and these problems can be avoided. All this can be realized through smart parking systems.

Since the last decades, smart parking systems have been essential to smart city developments [2,4]. In smart cities, transport and traffic congestion are two targeted areas that affect city residents in their everyday lives. The global parking management market size is about USD 4.38 Billion. From 2023 to 2030, the CAGR (Compound Annual Growth Rate) is expected to be 12.1% [3]. The existing parking system needs to be more efficient to handle the rapid growth of vehicles. Parking system improvements have been an important research topic considering wireless sensor networks, cloud computing, and fog computing [4-7]. Thus, it is necessary to manage the parking system to maintain proper transportation and reduce traffic congestion.

The primary goal of a smart parking system is to reduce waiting time, fuel consumption and emissions during finding a parking spot and/or waiting to park the vehicle, and overall parking costs. In this work, we proposed a fog and cloud-based parking system, which works in between the cloud and the parking lot's IoT devices. Fog performs real-time computations like parking space allotment and also gives information about the nearest parking lot in case of unavailability of parking space in the current parking lot. Moreover, fog performs the processing in place of the cloud to reduce load. Based on periodic update from fog, the cloud handles the necessary situations and make future decision making.

A. Issues in the Traditional Parking System

Parking system management is complex due to the ever-increasing number of vehicles with limited parking space. Parking cannot be adequately managed through existing city parking systems due to insufficient parking space and vehicle parking requirement information. The traditional parking space management system has various challenges:

Increase Overall Parking Cost: Due to inefficient management of limited space, vehicles roam around, which increases the overall cost of parking, including waste fuel, emitting more CO_2, and wasting valuable time of citizens.

High Operating Cost: With a lack of progress in parking management, it is challenging to manage the system, especially during peak hours, which raises the parking system's operating costs.

Manual and Unsystematic Payment System: Manual payment takes more time than an automated system, and vehicles must wait in a long queue to pay, which increases traffic congestion.

Slow Speed: Parking a vehicle with a nonautomated and unsystematic parking management system takes longer, wasting time and increasing traffic congestion.

Manual Processing and Less Operational Efficiency: With the rapid growth of vehicles, it is difficult to provide security to parked vehicles in the traditional parking system.

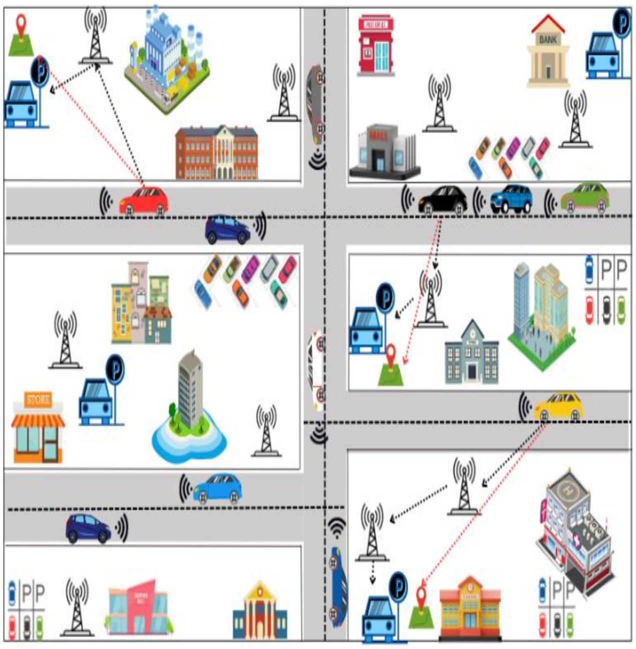

Figure 1. Overview of Smart Parking System in Smart City

In smart cities, parking vehicles during peak hours in an overcrowded place is challenging; it wastes cost, effort, gasoline, and the citizens' valuable time and causes environmental pollution. Citizens suffer a lot because of the unavailability of parking slots for time-critical work like medical issues or official time. Because of the unavailability of parking space, people park their vehicles here and there, which affects traffic and transportation management; it also makes the place overcrowded and unmanageable, which may cause an unhealthy situation or accidents. Efficient parking system management can improve society's lifestyle and reduce unnecessary trouble for citizens. Parking systems should be managed to avoid the above undesirable situations.

B. Parking System Architecture and parking Space Reservation

Forwarding the parking request and updating the status of the parking lot in the cloud by directly connecting the sensors increases latency, which is not tolerable for delay-sensitive applications like traffic management and parking vehicles, specifically at peak hours; it may cause unhealthy situations like road jams and accidents. Increased latency or delayed response occurs as a result of network congestion. For this purpose, we have considered two steps: first, we have adopted 5G wireless technology for data communication, and second, we have tried to minimize cloud overloading by processing the parking request locally using fog computing. Figure 1 represents the overview of the smart parking system; it shows the cloud and fog implementation in the parking system and the use of 5G communication technology in the parking system for efficient and faster communication.

Forwarding the data to the cloud for computation increases latency, consumes more energy, increases network congestion and the flow of control packets, and also causes significant data loss. Therefore, fog computing is introduced between cloud and end IoT devices to overcome the limitations of cloud computing. Fog acts as an intermediate device between cloud and end devices. It is an extension of the cloud, closer to the IoT end devices. Fog has less capacity than the cloud, based on computation, communication, and storage. However, It reduces overloading, latency, and network congestion. Fog receives data from the end IoT devices and performs necessary processing, and the required processed data is communicated to the cloud for analysis and future decision-making.

Parking space reservation supports drivers to park their vehicles in the reserved space directly [4-7], saving time and overall parking costs and reducing parking space searching-related issues. However, it increases traffic congestion, especially during peak hours, because the vehicle that arrived first may have to wait for the space, i.e., the parking lot has a parking space, but due to reservations, it cannot be allotted to another vehicle in the queue, that increasing the waiting time. Moreover, sometimes, the vehicle may not arrive after the reservation. Thus, reservation has added benefits for vehicles, but reservation should have some constraints based on the circumstances to overcome its limitations.

Many researchers focused on cloud-fog-based parking systems for serving vehicle parking requests [4-7]. However, in overcrowded areas at peak hours, fog nodes frequently forward vehicle requests to the cloud to find the nearest vacant parking lot, which increases overloading. To overcome cloud service overloading and network traffic congestion, our proposed model serves the request locally without sending the request frequently to the cloud. The fog node locally finds the neighboring parking lot with vacant slots and allocates the parking space to the vehicles. After processing, the essential data is communicated to the cloud for analysis and future decision-making.

Efficient utilization of limited parking space and management of the overall operation and performance of the parking system are of utmost necessity. 5G communication is necessary because of the increased network traffic and high data rate requirement. Overall energy consumption compared to throughput should be reduced to improve efficiency, which can be handled by implementing a fog-based smart parking system. We have two-fold our work as follows:

1. **Efficient Parking Slot Management**
   a. We have use 5G as underlying communication for parking system.
   b. The use of fog computing locally processes vehicle parking request and allocate optimal parking slot based on vehicle destination, and lower parking cost.
2. **Reduce Processing Load in cloud**
   a. The use of fog node in our proposed model reduces service overloading. Moreover, an analytical model proposed to estimate overall parking cost and service delay reduction.
   b. The simulation result shows that the proposed model has less response time and average cost as compared to the existing cloud-fog-based parking system, performance measure based on latency comparison within cloud and fog computing based parking approach.

The rest of the sections are organized as follows. Section 2 discusses the related works to discuss different legacy parking systems for efficient searching and allocating suitable parking slots for the vehicle requesting to park. The proposed features of the fog-based smart parking system are discussed in Section 3. Section 4 shows the experimental result for performance comparison among proposed and existing cloud fog-based smart parking systems. Finally, section 5 concludes the paper.

II. RELATED WORK

An urban smart parking system to assign and reserve optimal slots as per drivers' cost function has been presented in[2]. The model solves Mixed Integer Linear Programming (MILP) for each decision for optimal allocation. It considered the current state for optimal slot allocation and updated for the subsequent decision to avoid conflict in slot allocation and reservation. The system also reduces the average time to find slots and parking costs.

Cloud computing-based parking systems can handle the issues due to unmanaged vehicle parking, like traffic congestion, wastage of time, fuel consumption, and environmental pollution. However, latency is a primary concern in the cloud. Therefore, authors in [4] proposed a fog-based parking model to overcome the limitations of the cloud by extending the cloud to the network edge. Fog overcomes major cloud issues like latency, on-demand scaling, resource mobility, and security. The author's primary concern is minimizing latency and network usage, which insists on using fog computing for the parking system. Fog and cloud-based smart parking architecture for real-time parking slot information and to process parking requests proposed in [5]. The main challenges in the parking system are communication within vehicles (author used Vehicular Ad hoc Network (VANET)) and optimal parking slot allocation. The authors mentioned two methods for parking request processing. Firstly, fog nodes deployed at different parking lot determines the optimal slot based on traffic and parking information. Secondly, the cloud allocates optimal slots based on global parking area information and provides global optimization. The author proposed a Greedy Parking Slot Allocation (GPSA) algorithm for real-time parking slot allocation, where parking requests are processed chronologically. However, GPSA is not efficient for concurrent parking requests. Therefore, the authors also proposed Enhanced GPSA (EnGPSA) for more efficient parking request processing.

In [6], Tando et al. proposed a model for online parking slot reservations to reserve a slot in advance to avoid last-minute rush and roaming around, which leads to a wastage of time and fuel. Also, they proposed an algorithm (modified greedy algorithm) for vehicle total cost calculation. The main focus is to reduce waiting time for the vacant slot to park the vehicle, minimize parking costs, and reduce vehicle exhaust and waste of fuel to make the environment safe and green. In [7], Oanh Tran Thi Kim et al. focus on the use of fog computing and roadside cloud to locate vacant vehicle parking spaces, which has the potential to reduce traffic congestion and environmental pollution and improve road safety. It also looked into and applied matching theory to parking problems.

VANET is a network where vehicles can communicate with themselves and act as a node to communicate. In VANET, OBU (Onboard Unit) and RSU (Roadside Unit) are responsible for communication among vehicles about free space updates in the nearest parking lot and the vehicle's arrival and departure. Nowadays, various companies manufacture cars to communicate with each other [8]. In [9], authors proposed a model for parking management concentrating on a vehicle's overall travel time and finding nearby parking locations concerning users' destination. The designed parking system is based on ILP (Integer Linear Programming) and proposed a heuristic algorithm to measure the performance.

It is very challenging to allocate parking slots and to protect vehicles against theft in a large parking area. In [10], the authors proposed a smart parking scheme considering real-time parking navigation and intelligent vehicle security against theft through vehicle communication and showing the efficiency by performance evaluation. In [11], authors proposed a parking slot allocation model by considering half of the slot's reservation with a hard deadline (it canceled the reservation after a fixed time interval, i.e., the vehicle has to occupy the slot within the given duration) and rest half with reservation time flexibility. However, it still needs to present the optimality of the model.

The use of 5G communication technology improves communication efficiency compared to other existing communication technologies (i.e., 3G, LTE (Long-Term Evolution)). In [12], the authors proposed a model for secure parking, finding parking slots per vehicle size, and real-time interaction for slot reservations. The authors used 5G communication technology in the parking model for reliable, low latency, and secure communication.

Many researchers work on parking management and try to overcome parking-related issues. In [13], the authors proposed a parking model for optimal parking slot allocation and smart parking guidance for smart cities. The author primarily focuses on reducing CO_2 emissions instead of travel distance and cost for greener cities. Thiessen Polygon-based zoning method used for distribution of traffic and estimation of parking demand to reduce traffic congestion. And GA (Genetic Algorithm) for optimal parking location was used to improve the performance. In [14], Seongjin Park et al. (2017) proposed a fog computing and SDN (Software Defined Network)-based model for an environment of connected vehicles, divided nodes into three classes based on their mobility type to reduce control message overhead, and proposed a connection recovery technique. Mobility information is used to handle connection failure and suggest real-time scheduling techniques for service recovery of the vehicle due to the failure of the fog server.

Many challenges need to be focused on to prove QoS (Quality of Service) of IoT applications using fog computing, including service delay. In [15], a delay minimizing and offloading policy for fog is proposed to reduce service delay, and an analytical model is proposed to represent it. In [16], authors surveyed parking-related recent literature and included many desirable factors influencing the parking system, such as market-oriented solutions for the pricing of slots and vehicle driver's desirable social behavior for slot preference (like some drivers prefer to pay more to get more utility whereas some prefer less waiting time and some prefer less price). Authors also considered comparison with on-street and off-street parking for various aspects like pricing, security, less waiting time, less walking cost, and so on [16].

Authors in [17] proposed a smart parking system to allocate and reserve slots using matching theory. The authors emphasized maximum waiting time and dynamic fee estimation. Numerical methods show the performance estimation in comparison to others. In [18], a ML (Machine Learning) and game theory-based parking system was proposed for parking slot allocation and dynamic pricing. The authors mainly focus on-street parking, and performance estimation results show the efficiency compared to state-of-the-art systems. Fog and IoT-based parking systems proposed in [19] maximize parking usage and revenue by delivering essential real-time data to drivers and parking lot owners regarding slot availability, slot reservation, and other parking-relevant services like pricing, slot availability, and occupancy estimation.

VFC (Vehicular Fog Computing) uses underutilized vehicular resources as an infrastructure for computation and communication. It attempts to improve computing and communication in vehicular applications for computationally intensive and latency-sensitive tasks. It utilizes mobile fog computing to provide low-cost, on-demand fog computing for vehicular applications[20-21].

A virtual voting and hash-graph consensus algorithm-based smart parking model proposed by Vikas Hassija et al. in [22] for accurate parking slot allocation, cost reduction with optimal resource utilization, and adaptive pricing. In [23], proposed BLE (Bluetooth Low Energy) based smart parking model for indoor and outdoor parking and used particle filtering to improve accuracy. The author focused on free parking space guidance, secure e-payment, and prediction of the slot and distance estimation. A fog-based smart parking model to reduce traffic congestion for optimization of parking service and management is proposed in [24]. Lightweight cryptographic methods are used for security purposes. Real-time information

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for slot detection, reservation, and e-payment are considered [24]. In [25], the main focus is on parking issues like inefficient parking space utilization, lack of parking at event sites, and various parking management and improved parking solutions like shared parking, parking cost and time convenience, and on-street parking. An IoT-based parking system to reserve optimal parking slot is proposed in [26] by considering vehicle driver's preferences like maximum tolerable parking price and walking distance from parking slot to destination. In [27], the author proposed a cloud-based smart parking architecture for smart cities to predict vacant parking slots. IoT and cloud are used for traffic information status near parking lot and parking count. Through the Kernel least mean square algorithm, predict future parking slot vacancy (using autoregression). Validate the approach through the real-time data set and perform a numerical investigation on smart city parking lots to show the performance efficiency on parking slot vacancy prediction [27].

The highly dynamic and heterogeneous IoV (Internet of Vehicles) (comprises VANET, IoT, and cellular mobile network) seeks real-time computation. However, delay is inevitable in centralized cloud computing. Fog computing is used to overcome the limitations of cloud computing by performing computation in edge devices instead of the cloud. In [28], Wenyu Zhang et al. proposed a cooperative fog computing-based intelligent vehicular (CFC-IoV) network model to deal with big transportation data in the IoV using fog computing. Dealing with massive IoV data, the authors show the utility of fog computing, such as reducing packet drop rate, energy consumption, resource management, lower latency, increased throughput, and supporting mobility, localization, and scalability.

Fast response time, low latency, and low bandwidth usage attract the use of fog computing, which can move computation from cloud to end devices. In [29], Bin Cheng et al. focus on handling the limited flexibility of fog computing in the case of dynamic services. This article proposed a data-centric programming model for flexibility and efficiency, i.e., fog function. The performance estimation result shows that fog functions can save up to 95% of internal data traffic compared to cloud functions.

The existing parking models work well within the parking limit capacity. However, when no parking space is available, they don't tend to suggest nearby parking slot availability. Moreover, existing work did not study the load on the central cloud server. By employing a fog node for parking management, our work tries to reduce the computational load and delay of parking management. Moreover, fog nodes collaborate with nearby nodes to provide a list of nearby parking when the current parking lot has no vacancy.

III. PROPOSED ARCHITECTURE OF SMART PARKING SYSTEM

Let 'p' parking lots be in an area k x k. Most of the time, less than p lots are occupied. We have considered a three layer architecture as shown in Figure 2, the topmost layer has cloud servers, the middle layer has fog nodes with RSU, base stations, etc., and the third layer or lower layer consists of IoT end devices. In this proposed model, the respective fog node manages parking-related services.

Fog manages activities in each parking lot locally and delivers critical data to the cloud. To carry out the operations, the fog node has limited resources. The fog node performs certain tasks, such as allocating parking slots to vehicles on a first-come, first-served basis, computing parking costs, directing the vehicle to the assigned parking space, and assigning the vehicle to the nearest parking lot if there are no vacant parking spaces in the respective parking lot.

The article's primary objective is to reduce cloud overloading, lower latency, reduce congestion, reduce cost, and faster processing. Instead of centralized cloud computing, inter-operative and cooperative computations are carried out among local fog servers for parking management. The fog nodes perform real-time computations, and the data is updated to the cloud periodically for more decision-making and improving the parking system. The fog node of each parking lot has various functions, such as:

Receive Parking Requests: The fog node receives parking requests directly from vehicles within its communication range or through the RSUs.

Search vacant Parking Space: Fog node searches unoccupied parking space for the requested vehicle according to the vehicle's destination.

Slot Allocation: The fog node responds to the requested vehicle with the parking slot location if the corresponding parking lot has a vacant slot. Otherwise, it will find out the nearest parking lot with minimal cost.

Direct the vehicle: In the parking lot, the fog node directs the vehicle to park in the appropriate allocated slot.

Online Payment: Fog generates a parking fee, and the vehicle's drivers can easily pay the parking fee, which is carried out autonomously, unlike the manual fee payment of the traditional parking system.

Security: Parking systems provide security by a surveillance camera, 24x7 monitoring of vehicles, and secret code generation at the time of slot confirmation and completion of payment.

The fog node has the added feature of allocating nearby parking lots in case the respective parking lot has no vacant space for parking.

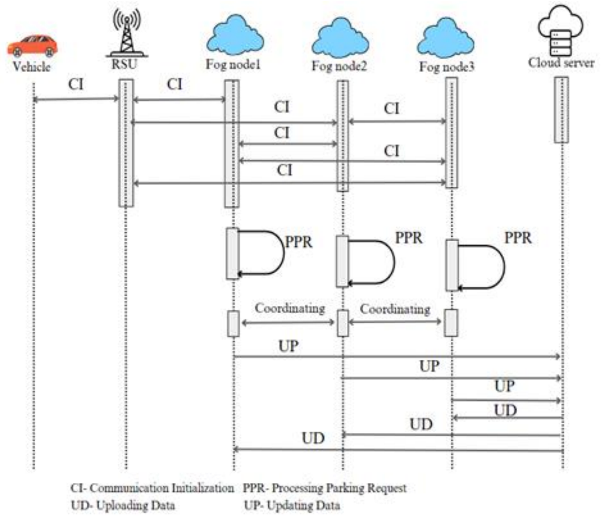

Figure 2. Fog and Cloud based Smart Parking System

A. *Periodic update to the Cloud*

The fog nodes perform real-time computations, and the data is updated to the cloud periodically. Essential parking related data in the cloud are also used for analysis and future advancement of the parking system. Figure 2 shows the structure of the fog and cloud-based parking system, where each parking lot is connected with a fog node through the base station and the use of 5G communication technology in the parking system for efficient and faster communication. Figure 3 represents the overview of the fog computing-based system processing.

B. *Slot Reservation*

Reserving parking space allows drivers to park their vehicles without wasting precious time and roaming here and there. However, it increases traffic congestion, especially during peak hours, because the vehicle that arrived first may have to wait for the space, i.e., the parking lot has a parking space, but due to reservations, the slot cannot be allotted to another vehicle in the queue, which, increases the waiting time. Sometimes, the vehicle does not arrive after the slot reservation. Thus, reservation has some benefits for citizens, but reservation should have some constraints based on the circumstances to overcome its limitations.

The proposed model has a reservation facility for the vehicle to get the parking space directly. Moreover, this parking slot reservation has some constraints, i.e., within a specified distance, vehicles can book reservations for a limited period, i.e., the vehicle has to occupy the slot within that period. Cloud calculates the reservation duration, i.e., within how long the vehicle can reach the reserved slot. This reservation duration changed at peak hours to reduce traffic congestion. Cloud computes the maximum reservation duration based on traffic congestion, everyday parking request data, slot occupancy in a particular duration, and the number of vehicles waiting at the entrance.

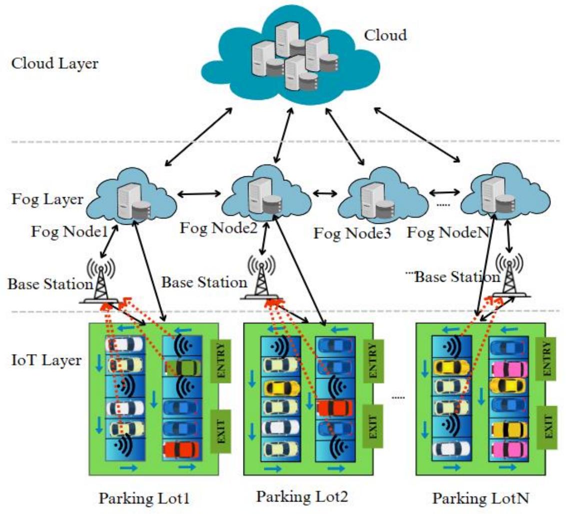

Figure 3: Overview of Fog and Cloud based Smart Parking System Processing

C. *Parking Space Upgradation*

Parking lot status upgradation carried out in the fog server after each slot allocation to the vehicles and after each vehicle departure from the parking lot. In the legacy models, this status update is carried out in fog and cloud for each processing. In contrast, in the proposed model, this status updating is carried out only in the fog node in real-time. It will be periodically updated in the cloud, which can reduce network traffic congestion, energy consumption, and overloading.

In the fog node the neighbour list is always sorted according to distance from current fog/parking lot.

Algorithm1 (For parking slot allocation)

Input: Fog Nodes (Fog_N), Parking Slot Status(Park_ST), Parking Request (Park_Req)

Output: Parking Slot Allocation

Procedure:

1. If Fog_N_j receives a parking request (Park_Req)
2. Do
   Check unoccupied parking space
3. If $Available_j > 0$ then// for all parking lot
4. Find nearest parking slot with min cost and allocate parking slot Park[i]
5. Else
6. Broadcast Parking requests to the neighboring fog nodes

```
     For k= 0:N
        If  Available_k >0 then
            Calculate minimum parking cost (using equation7)
                If  slot reservation==1(True) then
                    Generate Rev_Dur with Park_Loc
                Else
                    Allocate Park_Slot with Park_Loc
                Endif
        Endif
     Endif
  Endif
End
```

D. *Request and Response Message*

In the existing parking models [4-7], the vehicle has to send the request message to the parking lots till it gets the unoccupied parking space [6], i.e., vehicle to Fog_N_1, Fog_N_2, ...Fog_N_n. Similarly, the response messages from fog nodes to vehicle, i.e., Fog_N_1, Fog_N_2, ...Fog_N_n to vehicle. Whereas, In our proposed model, the vehicle sends the parking request message to the nearest fog node. i.e., vehicle to Fog_N_i. The corresponding fog node receives the parking request and searches for the vacant slot. If a slot is available, it allocates a slot with location information. Otherwise, the fog node broadcasts the request message to the neighboring fog node within one hop distance to search for the nearest parking lot with a vacant slot. Similarly, the vehicle receives the response message from the fog node with parking slot information, i.e., *Fog_N[i]*, to the vehicle with parking location information *Park_Loc[j]*. The fog node calculates the minimum parking cost, finds the nearest optimal parking slot, and minimizes vehicle drivers' unnecessary burden of searching for the nearest parking space and network congestion.

E. *Reduced service Delay using Fog*

Service delay is the interval between sending a request for service and receiving a response for the respective service request. In our model, the network is an undirected graph $P = [N, L, w]$ where N represents a set of vertices or nodes, i.e., $N = IoT\_N \cup Fog\_N \cup Cloud\_S$. N includes a set of IoT nodes (*IoT_N*), fog nodes (*Fog_N*), and cloud servers (*Cloud_S*). L represents a set of edges or communication links between vertices or nodes. For instance, If the Fog_N_j communicates with IoT node *IoT_N*, they have a link. w represents the weight of the edge within nodes, and edge weight considers propagation delay (*PD*) and transmission rate (*TR*). The communication link within the IoT_N_i and Fog_N_j is used to send locally processed requests by the IoT node to the fog node, and again, communication links within the fog node and cloud are used to send further requests for processing, which takes more time or increases service delay. In our model, fog locally performs the processing and periodically updates the cloud for future decision-making. Therefore, as compared to existing models [4], [5], [6], our proposed model has a lower service delay. Overall Service delay (O_SD_i) for node i is given by

$$O\_SD_i = IoT\_N\_SD + Fog\_N\_SD + Cloud\_S\_SD \qquad (1)$$

$$Iot\_N\_SD = Pro_i^{IoT\_N} \cdot (AvgPD_i) \qquad (2)$$

$$Fog\_N\_SD = Pro_i^{Fog\_N} \cdot (PD_{ij}^{Fog\_N} + TD_{ij}^{Fog\_N} + AvgWT_j + PD_{ji}^{Fog\_N} + TD_{ji}^{Fog\_N} + D_{ij}) \qquad (3)$$

$$Cloud\_S\_SD = Pro_j^{Cloud\_S} \times (PU_j) \cdot (PD_{jk}^{Cloud\_S} + TD_{jk}^{Cloud\_S} + AvgPWT_k + PD_{kj}^{Cloud\_S} + TD_{kj}^{Cloud\_S}) \qquad (4)$$

Overall Service Delay for node i considers Service Delay in IoT layer (*IoT_N_SD*), Service Delay in the fog layer (*Fog_N_SD*), and Service Delay in the cloud (*Cloud_S_SD*). $Pro_i^{IoT\_N}$ is the probability that IoT node/RSU i processes its own request, i.e., can give vacant parking slot information to the requested vehicle with respect to vehicle destination. (For instance, when a vehicle is near the lot with vacant slots, send a slot request, and RSU can show the vacant slot information). Service delay for a node is estimated by considering the Average processing delay (*AvgPD*), the probability that IoT node /RSU i sends its request to the fog node of the parking lot ($Pro_i^{Fog\_N}$), the probability that fog node j periodic update to the cloud k ($Pro_j^{Cloud\_S}$), propagation delay ($PD_{ij}^{Fog\_N}$, $PD_{ji}^{Fog\_N}$, $PD_{jk}^{Cloud\_S}$, $PD_{kj}^{Cloud\_S}$), Transmission Delay ($TD_{ij}^{Fog\_N}$, $TD_{ji}^{Fog\_N}$, $TD_{jk}^{Cloud\_S}$, $TD_{kj}^{Cloud\_S}$), average waiting time at fog node j ($AvgWT_j$), delay in processing and handling request in fog layer (D_{ij}), periodic update offloaded to cloud k from fog node j (PU_j), average periodic waiting time in cloud k ($AvgPWT_k$). Overall service delay for node i is estimated in eq(1). Service delay in different layers, such as in the IoT layer, fog layer, and cloud, is estimated in Eq (2),(3), and (4). Table 1 represents a list of parameters used and their descriptions.

Table 1: List of Parameters with Descriptions

Parameters	**Descriptions**
AvgPD	Average processing delay of request at IoT node/ RSU
$Pro_i^{IoT\_N}$	Probability that IoT node/ RSU i process its own request from vehicles
$Pro_i^{Fog\_N}$	Probability that IoT node /RSU i sends its request to fog node of the parking lot
$PD_{ij}^{Fog\_N}$	Propagation delay from IoT node/RSU i to fog node j

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$TD_{ij}^{Fog\_N}$	Transmission Delay from IoT node (RSU) *i* to fog node *j*
$AvgWT_j$	Average waiting time at fog node *j*
$PD_{ji}^{Fog\_N}$	Propagation delay from fog node *j* to IoT node (RSU) *i*
$TD_{ji}^{Fog\_N}$	Transmission Delay from fog node *j* to IoT node (RSU) *i*
D_{ij}	Delay in processing and handling requests in fog layer
$Proj_j^{Cloud\_S}$	Probability that fog node *j* periodic update to the cloud *k*
PU_j	Periodic update offloaded to cloud *k* from fog node *j*
$PD_{jk}^{Cloud\_S}$	Probability that fog node *j* periodic update to the cloud *k*
$PD_{jk}^{Cloud\_S}$	Propagation delay from fog node *j* to cloud *k*
$TD_{jk}^{Cloud\_S}$	Transmission delay from fog node *j* to cloud *k*
$AvgPWT_k$	Average periodic waiting time in cloud *k*
$PD_{kj}^{Cloud\_S}$	Propagation delay from cloud *k* to fog node *j*
$TD_{kj}^{Cloud\_S}$	Transmission delay from cloud *k* to fog node *j*

F. Prediction of Possible Vacancies of Slots

In the proposed model, we have taken three queues: one for vacant parking slots or Vacant Queue (*VQ*), second for occupied parking slots or Occupied Queue (*OQ*), and third for to-be vacant slots or Exit Queue (*EQ*).
EQ queue represents the information for to-be vacant slots. In case of the parking lot is fully occupied, i.e., with no vacant slot, *EQ* can help to predict the number of vehicles to exit; therefore, those no. of vehicles can wait in the queue without going to the next search.

$$Len(EQ) = SP + \sum_{i=1}^{len(OQ)} OBU_i \quad (5)$$

Where Len(*OQ*) represents the number of slots occupied or the length of *the OQ* queue, and OBU_i denotes the exit information received from the OBU of vehicle *i*.

$$\text{Slot prediction from previous record } (SP) = w_1 + w_2 X_i^1 + w_3 X_i^2 + e \quad (6)$$

X_i^1 is the number of vehicles entering on an hourly basis, X_i^2 is the number of vehicles staying at the parking lot simultaneously, e is the difference between actual value and predicted value, and w_1, w_2, *and* w_3 are weighting factors. Length of *EQ* estimates the number of slots that will be vacant in the near future in eq(5), and slot prediction is estimated in eq(6).

G. Parking Cost Estimation

In the existing parking system, the cloud searches for the nearest parking lot with a vacant slot and calculates the minimum parking cost. For this purpose, all the data is transferred and updated in the cloud, which increases the overloading and network congestion. In contrast, minimum cost calculation in the fog can reduce overloading, energy consumption, latency, and network traffic.

In our proposed work, we calculate the overall parking cost for a vehicle based on parking lot fee, waiting for cost, driving cost from the vehicle's location to the parking lot, and walking cost of the vehicle's driver, i.e., after parking the vehicle how much distance driver needs to walk to reach the destination.

$$\text{Total parking cost}(TP\_cost) = Cost_{parking} + Cost_{waiting} + Cost_{driving} + Cost_{walking} \quad (7)$$

TP_cost is minimal, i.e., only the parking lot fee($Cost_{parking}$), and there is no need to calculate the total cost when a vehicle gets the slot in the requested parking lot immediately at the time of requesting the slot. However, overall parking costs need to be calculated when there is no vacant slot in that parking lot, and the fog needs to find the nearest parking lot. In the proposed work, we focus on waiting for cost $Cost_{waiting}$, i.e., how long it will take to respond to the request.
In the existing model,

$$Cost_{waiting} = Cost_{Req\_Msg} + Cost_{Resp\_Msg} \quad (8)$$

Where,
$Cost_{Req\_Msg} = Cost_{Req\_vehicle\ to\ fog} + Cost_{Req\_fog\ to\ cloud}$,
$Cost_{Resp\_Msg} = Cost_{Resp\_cloud\ to\ fog} + Cost_{resp\_fog\ to\ vehicle}$

In proposed model,

$$Cost_{waiting} = Cost_{Req\_Msg} + Cost_{Resp\_Msg} \quad (9)$$

Where, $Cost_{Req\_Msg} = Cost_{Req\_vehicle\ to\ fog}$ and $Cost_{Resp\_Msg} = Cost_{Resp\_fog\ to\ vehicle}$

In the proposed work, the fog node has the neighboring parking lot information. The fog node calculates the minimum total cost of the parking lot. It sends the response message to the vehicle with the parking location information locally without forwarding the request message (*Req_Msg*) to the cloud. Whereas in the existing model, the cloud calculates parking costs and searches for the nearest parking lot [2][3][6][12]. Overall parking cost is estimated in eq(7). Eq(8) and eq(9) represent waiting costs in the existing and proposed model, respectively.

H. Parking System Performance

Reducing waiting time, fuel consumption, and CO_2 emission is important in transportation. Enhanced parking-related processing and faster allocation of unoccupied parking space

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can handle the above situation. Parking system performance are be measured by considering different factors such as:

1. *Response time = Allocation_time – Request_time*
2. *Allocation success rate = rate of (no. of request – no. of allocation)*
3. *Overall_Cost = minimal waiting time + minimal distance covered + minimal searching time + minimal distance from slot to destination (i.e., minimal walking distance) + minimal parking price. (Estimated using eq (7))*

The proposed model focuses on Average response time, success rate, service delay, and minimum parking cost. Fog locally handles the parking-related processing, which can improve response time and increase slot allocation success rate.

IV. EXPERIMENTAL RESULT

The primary focus in the proposed model is on overall energy consumption (i.e. energy consumption due to transfer of more control packets, transfer of data to remote distance, network traffic congestion, data loss, and retransmission), low latency, and minimization of parking cost. In the legacy models, when all the parking requests are directly communicated to the cloud for processing, it will increase response time and network congestion. In the proposed model, when a vehicle requests a vacant slot, the respective fog processes the request and provides the vacant slot information. In the proposed model, packet overhead and requests to the cloud occur in special cases like updates of processed data; otherwise, it is handled locally. In this article, to show the performance of the proposed model, the simulated result compares response time per second in the proposed and existing models with respect to the number of parking requests received from vehicles. Initially, 100 requests are considered, and each time the request is increased by 50 for comparison. Figure 4 shows the comparison of the response time of the existing and proposed model. Table 2 represents the simulation parameters for smart parking management system.

Table 2: list of simulation parameters with descriptions

Parameter	Value
Number of parking lots/ fog nodes	5
Parking range	5km X 5km
No. of RSU	20
Radio range	200m
Uplink packet size	1200b
Simulation time	2-3hrs
Mobility Model	City walk

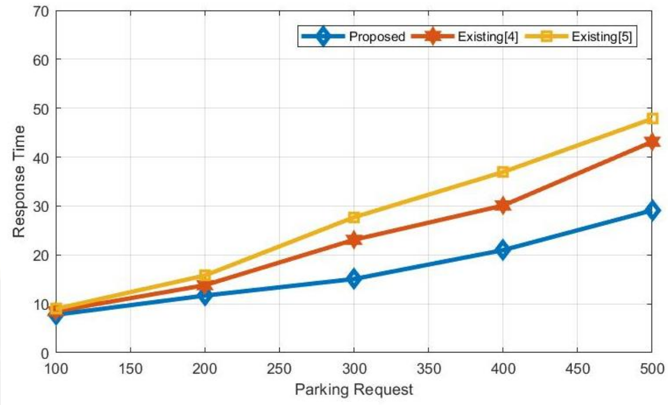

Figure 4. Response time Comparison in proposed and existing smart parking model

There are several fog-based legacy models for smart parking; however, they depend on the cloud for the nearest parking lot search. Due to traffic congestion, network overloading increases in legacy models as processing is carried out remotely. In our proposed model, the fog process services locally, and only periodic updates to the cloud are carried out remotely. Figure 5 represents the latency comparison between fog and cloud. For simulation, we initially considered 100 parking requests and increased it by 100. We have considered a few parking lots with different parking capacities; some are half-filled, and some have a few vacant slots. The simulation result shows the latency differences between fog and cloud.

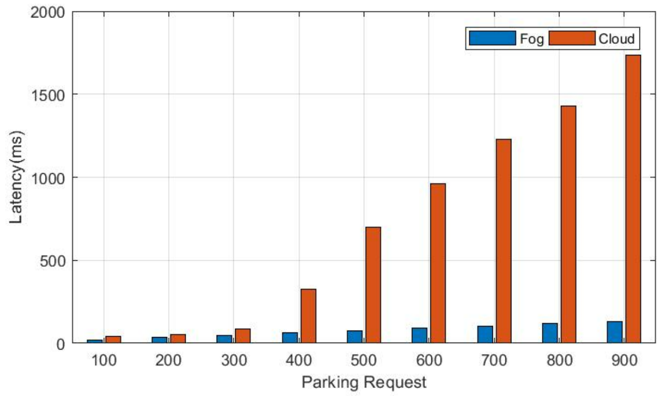

Figure 5. Comparison of Latency in Fog and Cloud Computing based smart parking system

In the article, to represent the performance of the proposed model, the simulated result compares average costs for each parking request in the proposed with two existing cloud-based and fog-based [4][5] smart parking models. Initially, 200 requests were considered, and each time, the request increased by 100 for comparison. Figure 6 compares the average cost of the proposed and existing smart parking models for each parking request. The fog node generates a beacon message about the presence of a parking lot for the vehicle, which consumes energy and congests the network traffic, especially during peak hours [4-7]. In contrast, the proposed model works with fewer beacon message and control packets to reduce network overloading.

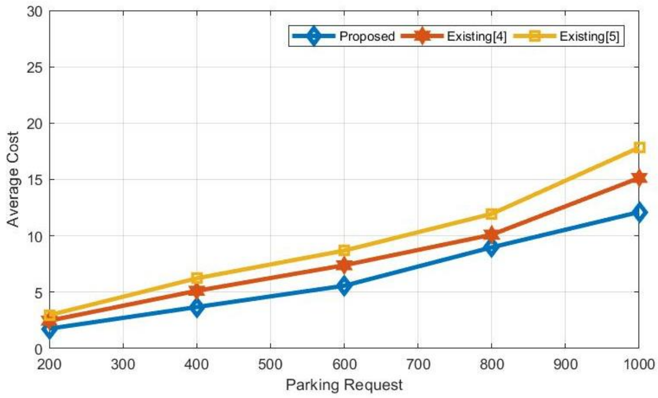

Figure 6. Average Cost comparison in proposed and existing smart parking models

V. CONCLUSION

The smart parking infrastructure in smart cities is very complex based on responsibility, timeliness, and dedication, i.e., proper planning, timely decisions, proper management of citizens' needs, and availability of required facilities with the convenience of the citizens. Thus, the advancement of ICT, efficient management of the IoT-based infrastructure, and prediction and decision-making through AL/ML can handle these critical situations. In this work, we proposed a parking management system using fog to reduce overloading and 5G communication technology for faster and more efficient communication. Our proposed system reduced the load in the cloud as compared to the system without fog. Although the capital expenses of fog devices may seem more, it is more worthy than the existing network infrastructure, which can be integrated with an ICT to handle such a task.

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