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A Survey of IoT-based Smart Parking Systems in Smart Cities

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Abstract: *Parking problems have become much more acute in urban areas with an increasingly vehicular population. These include congestion, inefficient usage of space, and time spent looking for parking places. A smart parking system based on Internet of Things will, therefore, be able to provide an efficient alternative: it can automatically search and manage places for parking. It uses sensors to detect the parking spot's availability and transfer such information in real time to a central platform. Drivers would then be able to use mobile applications to be led directly to vacant spots within minutes. This system reduces consumption of fuel, minimizes traffic congestion, saves time, and promotes generally more satisfactory parking experiences. The integration of IoT devices, like sensors, gateways, and cloud-based analytics, provides seamless operation and efficient management of space. It also supports extra features like online payment and reservation and, thus, serves as a comfortable and environmentally friendly solution for modern cities. This study discusses the design, functionality, and benefits of an IoT-enabled smart parking system, paving the way to smarter urban infrastructure.*

Keywords: Smart Parking System, IoT (Internet ofThings),Real-Time Parking Management, Urban Traffic Congestion, Automated Parking Solutions, Cloud-Based Systems, Mobile Application Integration

I. INTRODUCTION

The tremendous increase in vehicles in cities, effective parking space management has been quite challenging in urban settings. A considerable amount of time is spent by drivers looking for vacant parking slots, which results in frustration as well as causes congestion in roads, more fuel consumption, and more air pollution. Traditional parking management systems are not effective to meet the requirements of modern cities.

The Internet of Things presents the transformative solution to this by allowing the creation of Smart Typically, it involves sensors in the parking spaces to sense whether there is occupancy, an IoT gateway to forward this information to a central cloud platform, and an interaction application through a mobile or web application. It allows users to do online reservations for parking slots and automation for fees collection and usage analysis[1].

This introduction sets the need for a smart parking solution and serves as a precursor to further exploring the architecture, benefits, and future potential of IoT-based parking systems, all while focusing on their role in building smarter and more sustainable urban ecosystem.

As urbanization rises across the globe, the amount of automobiles on the road grows, so do the problems that come along with managing fewer parking areas. In most cities, a big percentage of the traffic is caused by people circling streets or parking lots searching for vacant space. This leads to frustration and delays besides increased fuel consumption, greenhouse gas emissions, and unnecessary wear on road infrastructure. The traditional parking systems, which usually depend on manual monitoring and static allocation, cannot keep pace with the dynamic demands of modern urban living[2].

The Smart Parking System using IoT is a cutting- edge solution that can deal with these issues by using technology to build efficient, automated, and user- friendly parking systems.

The IoT integrates physical devices, such as parking sensors, cameras, and gateways, with a centralized digital infrastructure for real-time data on the availability of parking space. This information is available through mobile apps, web interfaces, or digital signboards that help the drivers locate and book the parking a head of or while in the room.

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Beyond improving the experience of its users, smart parking systems present significant advantages to city planners and parking lot operators. These systems provide them with the ability to optimize the use of space, decrease costs of operation, and extract insights into patterns of parking. For example, it can predict peak usage times. In that case, administrators can offer dynamic pricing models or manage resources effectively. Integration with an automated payment system streams the whole process. Then, there is no need to use manual ticketing or cash transactions.

IoT-based parking management, therefore, becomes the next step towards the push for sustainability and smarter urban ecosystems across the globe. Since less time is spent in searching for a parking lot, fuel consumption will automatically go down along with emissions to bring in clean air, and wastage of energy will also reduce. Other smart city initiatives include intelligent traffic management and green transportation solutions, and these smart parking systems complement such moves to foster more connected and sustainable urban infrastructures.

II. LITERATURE SURVEY

A broad survey of literature about IoT-based Smart Parking Systems will indicate much work that has been done regarding technological approaches toward the parking challenge. This section highlights some major studies in detail, elaborating on their methods, contributions, and shortcomings as an overall background for further improvement.

2.1 Sensor based parking system:

Different studies are observed in terms of the usage of IoT sensors such as ultrasonic, infrared, and magnetic sensors for identifying the occupation of parking slots. For instance, X et al. proposed an ultrasonic sensor-based system for real-time monitoring of parking slots. Sensors were placed in every parking space and connected to a cloud platform, which gave live updates on availability. Although the system was highly accurate, its implementation was limited by the cost and maintenance of physical sensor[3].

2.2 Cloud and IoT Integration:

Another area of emphasis was on integrating cloud platforms with IoT devices to support real-time data collection and processing.

Literature survey, A wide literature survey about IoT-based Smart Parking Systems will indicate much work that has been done in regard to technological approaches toward the parking challenge. This section points out some of the major studies in detail, explaining their methods, contributions, and shortcomings as an overall background for further improvement.

2.3 Smart Parking Using Mobile Applications:

Observably, various studies are recognized regarding the usage of ultrasonic, infrared, and other magnetic sensors in identifying what is occupying parking slots. For example, X et al. proposed an ultrasonic sensor-based system regarding real-time monitoring of slots. Sensors were placed under every parking space and consequently connected to a cloud that provided live updates on how the slot was occupied[4].

2.4 AI and Machine Learning in Parking Optimization:

Very recently, AI and ML concepts are being used to enhance allocation decisions and predict parking space vacancies with the help of recent works from authors W et al. Authors W et al. built a machine learning model with access to historical parking data on demand during peak hours that facilitate real time computation and dynamic pricing and adequate resources utilised but high computational power demands massive volumes of training data[5].

2.4 IoT in Sustainable Urban Development

A wider outlook of IoT in smart cities presents the aspect of sustainability. V et al. emphasized that the implementation of IoT-based parking systems reduces carbon emissions and fuel consumption. In this research, the authors presented the idea of connecting smart parking with other IoT-based systems, like smart traffic lights and electric vehicle charging stations, to create an urban ecosystem that is more friendly to the environment[6].

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While studies have established the prospectiveness of using IoT in parking systems, quite a lot still lingers; these range from high deployment and maintenance costs, among others. Such limitations do not mitigate the fact that the use of IoT indeed transforms issues regarding parking in cities as it builds up the prospect for smarter, more livable[7].

This literature survey presents an in-depth analysis of previous research and evaluates their contribution, gaps, and future directions. The future work may target improving system scalability, data security, and cost-effective implementation[8].

There are enough literatures that can depict the benefits of IoT-based smart parking. They largely cut on the time that is wasted by drivers to look for available car parking spaces that leave less traffic congestion and in turn, the emissions are minimized. With this, the systems have therefore created efficient management of the revenue as they allow a dynamic pricing besides efficiently exploiting spaces already in existence. Lastly, reducing senseless idle drives and vehicle idling remains helpful to sustain an environmentally amiable system.

With some benefits that the system also imposes, it has still managed to present a fair percentage of challenges. Firstly, the initial costs with other technical complexities have mostly rendered it impractical. Sensors are vulnerable to environmental conditions such as weather or lighting conditions and sometimes fail to detect the parking space. Data privacy and security is a critical issue because sensitive personal and financial information is being exchanged. The next big challenge was scalability, especially for cities, which required a lot of infrastructure for large cities.

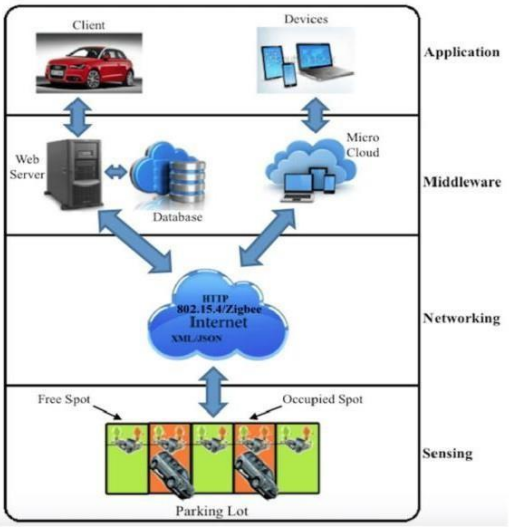

Fig. Smart parking system: Revieving the literature, Architecture and ways forward

III. METHODOLOGY

Methodology in implementing an IoT-based Smart Parking System This would entail developing an integrated framework incorporating hardware, software, and advanced communication technologies to better the management of parking. Deployment of sensors is a critical first step in the monitoring of parking spaces. Deployed sensors can be ultrasonic, infrared for movement, or camera- based visual analysis. Each sensor is located in a parking space to automatically detect the occupancy or vacancy of the space[9].

These sensors collect data in real time and transmit them to a centralized server by making use of IoT communication protocols such as Wi-Fi, Zigbee, or LoRa. Wi-Fi is mainly used for short-range communication in cases where high data requirements are there. Zigbee and LoRa are preferred for long-range applications with low power. These technologies ensure seamless data flow from the physical infrastructure to backend systems even in large scale deployments[10].

The central system, typically accessed through a cloud computing platform, runs the received data. Cloud computing fulfills the scalability needed in processing big volumes of information in real-time, especially across high-density urban environments involving heavy usage of vehicles. All these data are analyzed and interpreted by advanced algorithms as well as machine learning models to make decisions on parking space availability, predict future demand

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patterns, or manage dynamic pricing strategies. For instance, machine learning would be able to determine peak parking hours and then optimize allocation so that the spaces get optimized in reducing congestion[11].

Data from the system is also made available to the user for usage through a mobile application which acts as an interface of the system with the end-users. The app gives timely information on parking space availability, letting a user find the nearest free one.

This is accompanied by navigation features, which leads the driver to their preferred parking area. It also allows safe and secured payments for parking using the mobile wallet or other available payment methods integrated within the app. The interface of the app is developed with ease of use by a user, including friendly navigation and minimal latency on display of real time information[12].

The system works in a real-time manner because feedback mechanism is used to update parking status perpetually. When there is movement of a vehicle coming in to or going out from one parking space, it instantly recognises the variation and reflects the same at the servers and the mobile applications. All this happens through dynamic activity, so all information in the application is right and refreshed[13].

The system evaluates performance with critical metrics like detection accuracy, reliability of the system, satisfaction from users, and benefits of the environment. Sensors are kept calibrated and maintained properly for detecting vehicles accurately. Moreover, cybersecurity measures are ensured strongly to prevent unauthorized access and to protect user data as well[14].

Further, the design of the methodology is scalable and adaptable to any environment, whether it is urban streets, commercial complexes, or university campuses. Future enhancements could include integration with autonomous vehicle systems, renewable energy sources like solar-powered sensors, and AI-driven predictive analytics for efficiency and sustainability improvements. This comprehensive approach ensures that the IoT-based Smart Parking System addresses modern parking challenges while making life easier for users and reducing environmental impact.

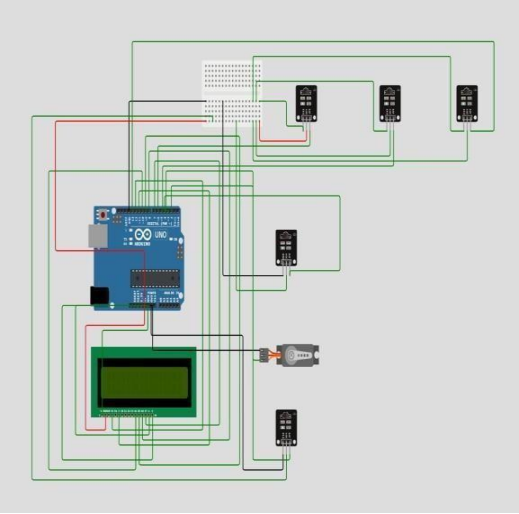

Fig. Smart parking system using Aurdino.

IV. CONCLUSION

The great jump in IoT-based smart parking systems would solve all parking-related problems in the urban cities of the world that struggle to mitigate mushrooming parking problems. All these, such as advance sensors, communication networks, cloud computing, and mobile applications, would help find a holistic solution towards maximizing the utilization of available space for parking, reduction in traffic congestion, and further improvement in overall convenience for the users.

Real-time monitoring of parking availability allows a driver to quickly find available space for parking, saves time driving in search of a parking lot, and prevents negative environmental effects from an idling vehicle and the systems

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that allow for easy processing of payments further enhance convenience and usability with mobile apps and real-time information related to parking availability[15].

Thus, huge environmental benefits are realized from IoT-based smart parking systems. Those are indeed the systems that ensure their reduction of time a car spends in circulation by allowing reduction in carbon emission besides curbing fuel consumption thereby sustaining an urban environment better. Dynamic pricing models together with optimal space allocation increase a parked vehicle's revenue which actually increases efficiency and profitableness. With such considerations of AI and MLs, the system might find its ability to enhance such conditions using demand prediction for its park lot services[16].

Although there are so many positive implications, there are some challenging factors that need to be achieved[17].The infrastructure involved requires high initial costs to maintain these systems, and most areas with small cities or those within smaller budgets cannot adopt the wide implementation of such a system. Environmental conditions like lighting or weather conditions would disturb the accuracy of sensors involved and thus influence the dependability of the entire system. Data privacy and security is also an issue since the users' sensitive information like payment details and personal data have to be protected against breach. Moreover, it will require an enormous planning and investment in terms of technology and infrastructure to scale the systems to a larger urban area[18].

Future development of IoT-based smart parking systems is immense. One area to be a thrilling frontier of integration with autonomous vehicles where the driverless cars may navigate and park directly without the intervention of humans, improving the effectiveness of the process. Sustainable energy solutions for such a system may use solar-powered sensors to make these systems much more sustainable[19]. Further development in AI- driven predictive analytics would increase the ability of such systems in handling the real-time parking demand in smarter and more adaptive manners to the urban mobility system.[20].

Smart parking systems, then, based on IoT technology, would revolutionize how cities manage its urban space by providing even a far more efficient, convenient and sustainable solution to the users and residents of such an urban area. Costs, scalability, and security remain a challenge, but as the technology advances, and innovations are made, those should be overcome in the near future. As the evolution of smart cities is developed, integrating these systems is vital in shaping the future of urban mobility and making for a more seamless, green, and user-friendly space for all.[21]

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