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SURVEY

A Survey on IoT Driven Smart Parking Management System: Approaches, Limitations and Future Research Agenda

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ABSTRACT In developing countries around the globe, the number of vehicle users has exceeded the optimum threshold and is increasing rapidly due to speedy economic growth. Consequently, roads are getting more congested in the cities. This has resulted in increased difficulties in meeting the minimum parking demands. Moreover, most of the parking lots are at the underground level of buildings. Due to the lack of natural light sources, there is a need for a massive power source to light up a large quantity of lighting equipment continuously. This results in waste of energy, equipment losses and causes a tremendous financial burden on property management. However, an IoT driven parking management can significantly aid in the utilization of parking resources. Availability of a sensor based smart parking spot with its location information identified and transmitted using wireless communication technology can immensely benefit the vehicle owners as well as parking spot authorities. It is a comprehensive solution both for the user and the owner of the parking space. Besides, it can fulfill the lighting requirement of the parking lot with minimized energy. Some eminent features of such IoT based systems are online reservations, user authentication for ensuring security, parking guidance, online payment, and energy saving. This paper reviews IoT driven smart parking management systems. It gives insights into various approaches for the parking system, related technologies, widely used components, communication standards and concerned system security issues. Besides, the paper gives researchers a direction for future work as it directs towards some open issues in this area.

INDEX TERMS Sensors, communication, IoT, smart parking, security.

I. INTRODUCTION

The number of registered vehicles in the world is increasing everyday which creates an enormous demand for the parking space symmetrically. For example, according to Bangladesh Road Transport Authority (BRTA), there are around 3.1 million registered vehicles in the country. A study shows that private cars use Dhaka (the capital of the country), city's 80% road [1]. Another study shows that U.S's registered Motor Vehicles were updated yearly, averaging 248 thousand Unit from December 2005 to 2015 [2].

Thus many parking-related issues require much attention and are needed to be solved on an urgent basis [3]. Due to the lack of an intelligent system, it takes a long time for drivers to find an empty spot. This delay directly impacts the economy. Some other vital impacts are extra fuel consumption, noise, environmental pollution, and a considerable workforce maintenance cost. Security of the parked vehicle is another primary concern. It is an extra burden for both user and the owner of a parking area. Unauthorized parking cannot be avoided effectively with the

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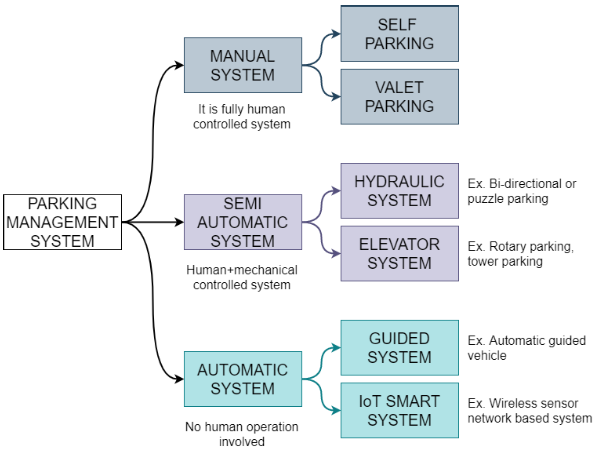


FIGURE 1. Classification of parking management system.

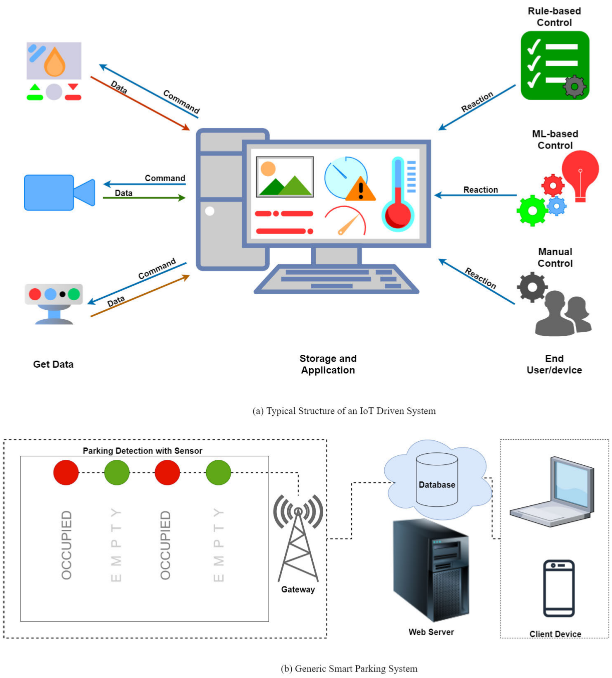


FIGURE 2. Smart parking system using IoT.

existing manual system. A smart parking system can play a vital role to mitigate all of these issues.

A parking system can be categorized into three types: manual system, semi-automatic system, and automatic system. Manual system is fully human-managed. Self-parking and valet parking are examples of manual system. In self-parking, driver himself drives along and searches for a parking spot. However, in valet parking, somebody else does the parking on behalf of the driver. Whereas, semi-automatic system is controlled by both human and machine. Hydraulic and elevator parking are examples of this type of system. Finally, the automatic system is fully managed by the machines. Fig. 1 shows a typical classification of a parking system.

Internet of Things (IoT) plays an important role in making our lives comfortable and easier through connecting and automating various smart devices. An IoT driven system contains sensors to collect information. These sensors are then integrated with some programmable hardware to process collected data. Thereafter, the processed data is stored and shared via a network to an authorized user. Fig. 2 illustrate a typical IoT system and a smart parking system, respectively.

In manual parking system, a driver needs to search for the available parking spots in person. However, a smart system can help the driver easily find a suitable parking related information i.e., i) Information about available parking space, ii) Online reservation and payment, iii) Automatic navigation system, iv) Automatic indoor light control, v) Monitoring and Security and vi) Automatic access control.

This paper surveys the state-of-the-art methods in smart parking system and proposes a taxonomy for a smart car parking system. Furthermore, in this article the most important technologies used in the system including sensors used, network storage methods, and communication protocols have been highlighted. Moreover, the security issues concerned with different communication protocols and technologies have also been explored while conducting this research. In addition, the problems associated with the implementation of smart parking systems have also been analyzed and presented in this paper as well. Compared to the contemporary survey papers in the area, the paper is more comprehensive which covers most major technologies in this area.

To be precise, the contribution of this research are as follows: Firstly, a systematic review of several contemporary review papers from several scholarly databases has been done in order to identify potential and existing research gaps. Secondly, a taxonomy based on the characteristics of different types of parking systems and the features of the technologies used have been proposed and described which is believed to aid in further researches associated with smart parking. Thirdly, a review of the technologies both at hardware as well as software level has been done in order to present a clear idea regarding the working principle of smart parking related technologies and finally the limitations related to smart parking systems and probable future works to address the limitations have also been provided to serve as path towards newer research objectives.

The rest of the article has been organized as follows. There is a brief discussion on the research methods that were followed to prepare this report in Section II. Existing survey papers are described in Section III. Section IV contains the taxonomy of the parking system. Discussion on the sensor components, cloud storage, communication, and related security issues covered in Section V. Finally, Section VI discusses the future scope and open issues following with concluding remarks in Section VII.

II. RESEARCH METHODOLOGY

A. SEARCH STRATEGY

We developed a particular search strategy so that relevant literature can be identified easily. Web of Science, Scopus,

TABLE 1. No. of extracted article.

Selection Criteria	Number of Articles
Articles found with search string: Smart Parking	1440
Articles found with search string: IoT, Smart Parking	191
After removing duplicate articles	189
After removing articles, not in English	178

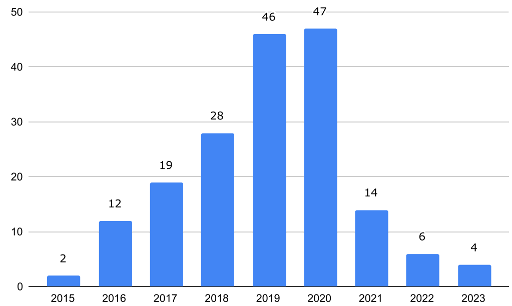


FIGURE 3. Yearly distribution of the article.

and Google Scholar were the databases that we used for searching the related articles. Several searching keywords were used including: "Smart Parking,","IoT based Parking,", "Parking Management," etc. All searches spanned from database inception until 2023. A total of 1440 articles were obtained by following this process.

B. SELECTION CRITERIA

The article selection criteria was based on the PRISMA Statement [4]. We further narrowed our search to the subject areas of IoT. The search span was from the year 1990 to 2021, and all articles before 1990 were excluded from the search. There were 191 records extracted at this stage.

C. QUALITY ASSESSMENT

The study is based only on research articles, review papers, and conference papers. For maintaining the quality of the review, all the articles were checked thoroughly for duplication. Abstracts and introductions of the articles were checked deeply. A careful evaluation of each research paper was carried out at a later stage. The next exclusion criterion was to limit the papers published in the English language only. There were five articles in the non-English language, thus they were excluded from the study. A total of 178 articles were selected after this stage.

D. DATA EXTRACTION

The characteristics of the data extraction phase were as follows:

- The article must be an original paper, review paper, and conference paper. Case studies were excluded.
- The article must be in the English language and from the field of Engineering.
- Extracted articles were published from 2000 to 2021.
- The article should have more citation.
- The article should contain discussion on particular parking systems, i.e., I. Wireless sensor based, II. RF-ID based, III. GPS based, IV. Vehicular communication based, V. Fuzzy logic based and VI. Smart phone sensor based.

Our article selection criteria is summarized in Table 1 and Fig. 3 is the yearly distribution of extracted articles.

III. RELATED WORK

The need for a parking system started with the invention of the car. Many parking management systems have been developed since then. Ticket-based parking system exists from the mid-80s. It was the smartest system at that time. Over the years, the definition of smart systems have changed and new methods techniques to develop smarter parking system came into being. Authors in [5] described several car parking management systems in the article. These are expert system, fuzzy logic-based system, wireless sensor-based system, GPS based system, vehicular communication system, vision-based system, etc. The paper has detailed out the used technologies only. However, no discussion on sensors or communication protocol are observed.

A comprehensive comparison of different parking systems is the main focus of [6] where authors have meticulously presented the parking system classification based on used sensors and technologies. There, a very high-level discussion on the related works is presented at the beginning of the paper where the advantages and disadvantages of various parking systems are discussed. The authors have also shown a classification of the parking system based on six factors, namely 1. Data Collection (Sensors), 2. Deployment (Networking system), 3. Services (System features), 4. Connection (IoT connectivity), 5. Processing (Data processing techniques), and 6. IHM (Device support for the end-user). However, the discussion of the methods was too brief.

The main focus in [7] is the classification and used sensors in parking systems. It offers a clear idea to the reader. However, the discussion mainly focused on classification of the parking system. In the beginning, the authors have divided the parking systems into three types: Manual Parking System, Semi-Automatic Parking System and, Automatic Parking System which is made based on user requirements. Later on, they have made six categories depending on the features of a smart parking system. These are 1. Blind Search, 2. Parking Guidance and Information System (PGIS), 3. Transit-based Information System (TGIS), 4. Smart Payment System, 5. E-parking, and 6. Automated Parking System. There is also a section about sensors and the vehicle's license plate detection algorithm in the last part of the article, where practical applications are also included, though the discussion on methodologies not considered.

In paper [8], the authors first described the history of parking system and demonstrated an overview of different techniques used in the parking systems. The authors then discussed briefly various challenges regarding operational and technical issues. The paper also described the methodologies of parking systems that are based on fuzzy logic, wireless sensors, vehicular to infrastructure communication, GPS, computer vision, RFID, and other hybrid systems. However, a detailed information on sensors and communication protocols are missing in the article.

In the article [9], a comprehensive study of the current smart parking systems by emphasizing the design considerations for implementations were done. The authors classify various smart parking systems and discuss the technologies and sensors associated. Finally, a hybrid-parking model was proposed in the research for smart city ecosystems.

The authors of [10] provides a detailed survey of 274 publications on Smart Parking Systems, vehicle detection techniques (VDT), and associated algorithms. The authors determine that most of the systems are predominantly Parking Recommendation Systems (PRS) and Parking Guidance Information Systems (PGIS). The authors determined that Optical Recognition Systems (ORS) were the most used VDT but it was also found to be a cost-ineffective system.

In paper [11] traditional parking methods along with Smart Parking (SP) systems are discussed along with Autonomous Valet Parking (AVP). This paper classifies the SP into several types including digitally enhanced parking, smart routing, high-density parking, and vacant slot detection, It also further classifier AVP into Short-range and Long-range types. The authors refer to several avenues for future work, including route optimization, high density parking, reservation system design, data fusion, privacy, dynamic scheduling, etc.

In the article [12], it is focused on the role of IoT and context-awareness technologies in addressing the parking issues of densely populated areas. The authors conduct a review of recent literature and determines the impact of smart parking sensors and technologies in saving time, fuel, and energy, and reducing driver stress. Furthermore, the authors examine various smart parking solutions, including those based on algorithmic innovations, different frameworks, as well different prototype level solution.

Several researches have been conducted for developing smart parking systems focusing on game theories. The authors of [13] proposes a parking slot allocation framework using an Adaptive Pricing Algorithm and a Virtual Voting based algorithm. The proposed system facilitates optimal and economic parking slot allocation, by properly ordering allocation requests and reducing average parking time. It also proposes an adaptive pricing model for increasing both the overall revenue for parking lot owners and enhancing the user experience. The authors of [14] presents a smart Vehicular Fog Computing (VFC) system that combines Parked Vehicle Assistance (PVA) and smart parking. It introduces a VFC-aware parking reservation auction to direct moving vehicles to available parking spaces and utilize the fog capability of parked vehicles to assist in delay-sensitive computing services.

The survey paper reported in [9] covers the classification of parking systems, sensor type, privacy and security, and communication protocol. At first, the authors have shown the classification of the parking system. They have then discussed four types of parking systems and their sub-classes. Sensors used in the parking systems are also described. Thereafter, they have included the design factors considering both software and hardware. However, the parking system methodologies that were described are too brief.

This survey paper mainly focuses on the numerous methodologies based on technology. Additionally, it briefly covers the sensor type, communication system, security protocols, and open issues in the parking system. The presented paper offers the reader a comprehensive study on earlier proposed smart solutions. Firstly, taxonomy of different parking systems that lack in earlier survey papers are proposed, where a reader can easily understand the systems as various figures are used to portray systems. Secondly, the paper includes the working principle of proximity sensors. Thirdly, the paper covers security issues and various attacks on parking systems. Table 2 depicts a comparison between our survey and other survey papers. While the other survey articles have addressed several important associated topics including the classification of parking systems, analysis of various parking mechanisms, discussion about sensors and communication methods, associated security challenges and relevant open issues, none of the research works were found to provide a holistic examination of all these topics in detail. This survey research aims to bridge this gap by providing a comprehensive and detailed examination of each of these topics.

IV. TAXONOMY OF CAR PARKING SYSTEM

In this section, we propose a taxonomy for research in smart car parking system based on the technology used in the system (see Fig. 4). We broadly divide them into five categories, namely RFID Based Car Parking System, Wireless Sensor Based Car Parking System, GPS Based Car Parking System, VANET Based Car Parking System, and Smart Phone Sensing Based Car Parking System. A detailed discussion on related technologies are presented in the subsequent subsections.

A. RFID-BASED CAR PARKING SYSTEM

The main principle of a Radio Frequency Identification (RFID) based parking system [15] is to authenticate a car or vehicle by reading the attached identification tag onto it. RFID uses electromagnetic fields as a communication channel to read and transmit radio tags attached to objects. A radio tag [16] consists of three things: (1) transmitter, (2) receiver and (3) transponder. An RFID reader transmits electromagnetic pulse that triggers the radio tag to transmit data. Fig. 5 shows how an RFID tag is triggered.

In the RFID based car parking system, an RFID reader is installed at the gate. Users of a parking area receive RFID

TABLE 2. Summary of other survey and our survey.

Name of the Survey Papers	Classification of Parking System	Technical Study on Different Parking System	Discussion on Sensors	Discussion on Related Communication	Discussion on Security Issue	Highlight the Open Issues
A Survey of Intelligent Car Parking System – 2013	-	✓	-	-	-	-
Smart parking systems: A survey – 2016	✓	✓*	-	-	-	-
Smart Parking System: Survey on Sensors, Technologies, and Applications – 2019	✓	-	✓	-	-	-
Investigation of Smart parking Systems and their technologies – 2016	-	✓	-	-	✓	✓
Smart parking in IoT enabled cities: A survey – 2019	✓	✓*	✓	✓	✓	✓
Our survey	✓	✓	✓	✓	✓	✓

- Not Considered in Discussion
✓* Brief Discussion
✓ Detail Discussion

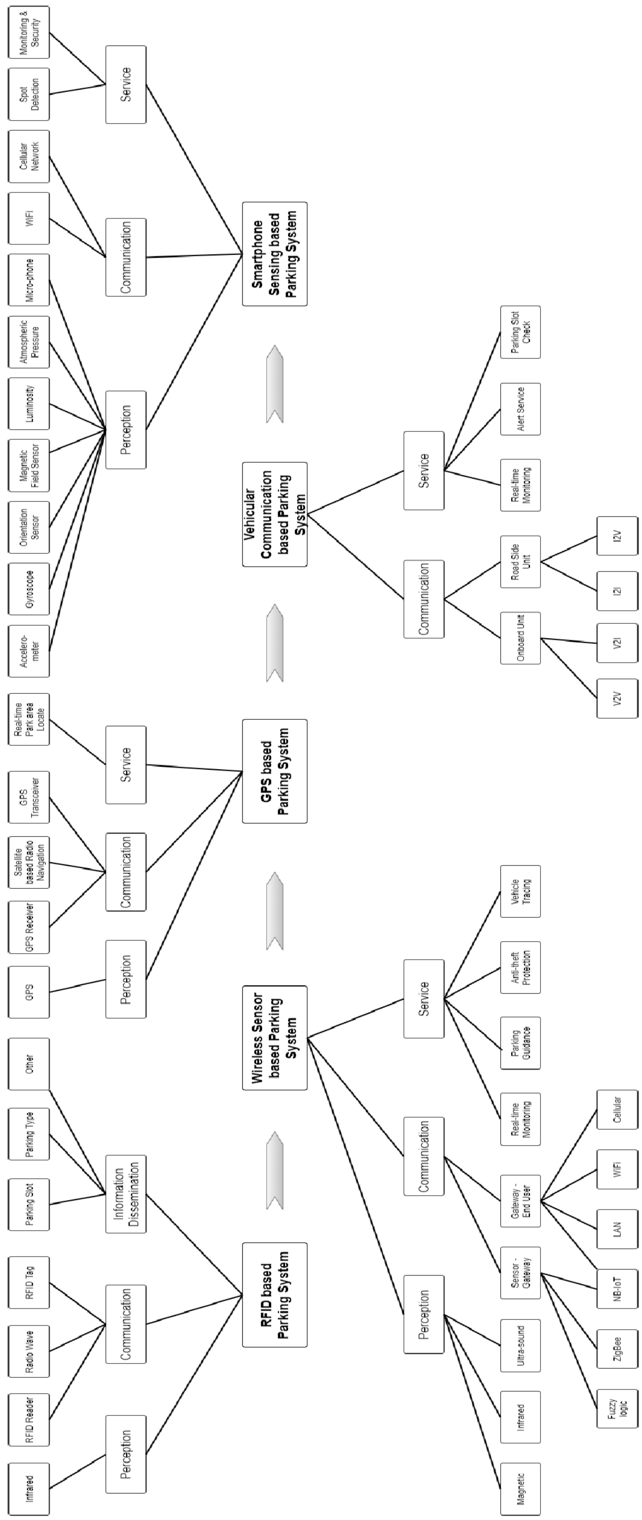


FIGURE 4. Taxonomy of smart car parking system.

cards from the parking authority. When a reader reads a valid tag, it allows the barrier gate to open. Fig. 6 demonstrates how the system works.

A car though having a valid ID, cannot enter if there is an outgoing car from the opposite direction. A green

FIGURE 5. Triggering of RFID tag.

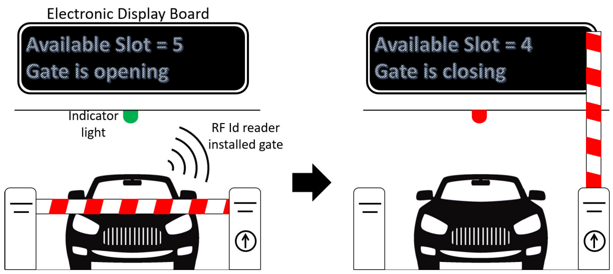
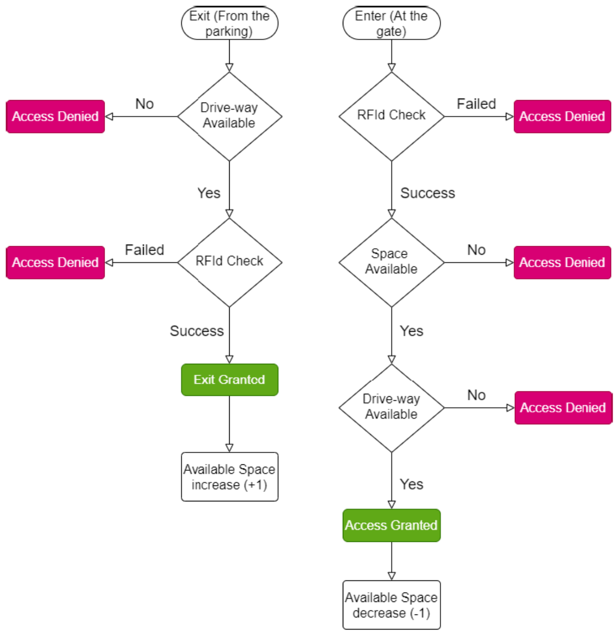
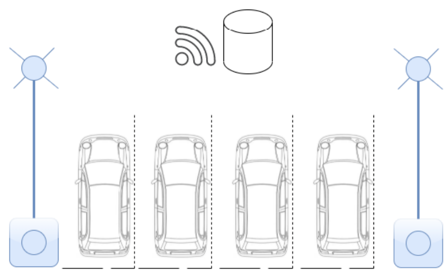


FIGURE 6. Automatic digital parking system.



(a) Working flowchart of smart parking system



(b) System architecture

FIGURE 7. Smart parking system using RFID.

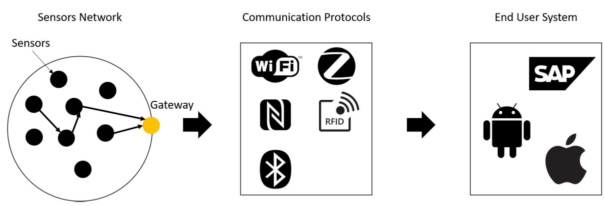


FIGURE 8. Structure of wireless sensor network.

light is turned on when the area is accessible, whereas a red light indicates that it is forbidden to enter into the area.

An automated parking system' architecture has been described in [17]. The system consists of five elements: RFID reader, passive RFID tags, barrier, retractable bollards, WiFi spots, and a database. RFID readers activate the passive RFID tags on the passing cars at the entry and exit points and read the identification number stored in the tag. For constant monitoring and acquiring parking lot occupancy information, additional RFID readers are installed at two sides of each parking array. RFID readers report all the collected data to the central database using WiFi connectivity. The system's main working flow and architecture is presented in Fig. 7.

An RFID node consists of an RFID reader and a passive RFID tag. Each RFID node is equipped with a directional antenna. The reflection power of each passive RFID tag can be calculated by considering the antenna gains of the RFID reader and passive RFID tag, backscatter gain [18] of passive RFID, and free space path loss [17].

Despite the discussed feasibility and the cost-effectiveness of the RFID Based Car Parking Systems, there are several issues [19], [20] associated with these systems which are important to take into consideration. Firstly, the reliability of RFID systems can be affected by environmental factors including signal interference and obstruction. Moreover, the RFID sensors are easily impacted by environmental factors such as weather. Furthermore, RFID systems are only limited to serving vehicles with RFID tags and hence there are challenges in integrating the technology in a mass scale.

B. WIRELESS SENSOR-BASED CAR PARKING SYSTEM

A Wireless Sensor Network or WSN [21], [22] is a system where various environmental data is collected from a large area through various sensors. The collected data is then transferred over the network using any suitable form of communication protocol to the end-user. In WSN, sensors may have a wired or wireless connectivity. However, sensors can only communicate with a gateway to send data or receive commands in a single-hop and multi-hop manner. Fig. 8 shows the structure of a wireless sensor network.

Fig. 9 is the simplified architecture of a wireless sensor based parking system, described in [23]. It is a typical

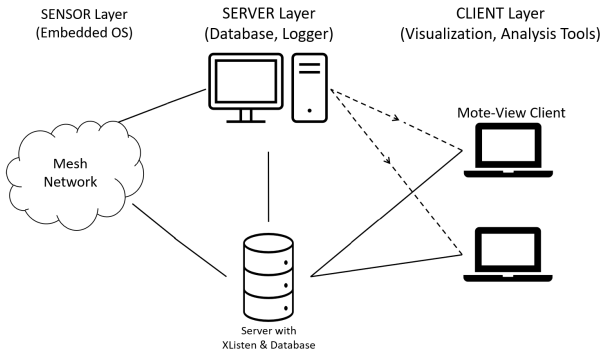


FIGURE 9. Typical architecture of WSN parking system.

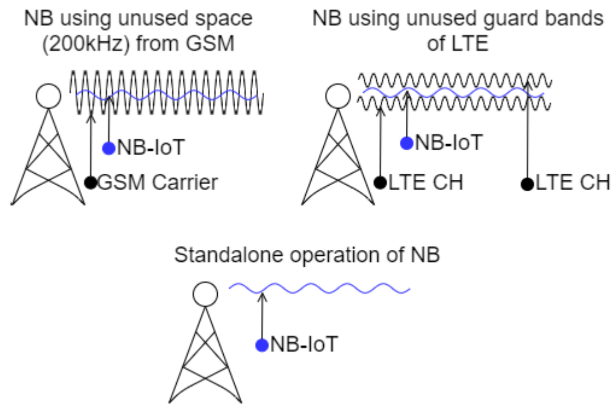


FIGURE 10. Operation mode of NB-IoT.

architecture for any system which has an application-based wireless sensor network.

The system has three layers: (1) Sensors, (2) Database and Server, and (3) Client. Sensors collect real-time slot occupancy and vehicle information from the parking area. In [23], a sensor device MTS310 is used, which has three sensing capacity types: light, temperature, and sound. However, only light and sound sensor are used in the proposed system. We recommend using a geomagnetic sensor because it works well in a harsh environment. There are other sensors such as ultrasonic, capacitive, infrared, etc. also available. Unlike geomagnetic sensors, others that detect objects using the reflected signal need to consider a few additional parameters e.g. the sensors' installation position [24].

Sensor nodes send collected information to a gateway using wireless communication. In [23], as the communication type, XMesh networking stack is used that supports IEEE 802.15.4. Other communication protocols are Bluetooth, ZigBee, WiFi, etc. We recommend using ZigBee because of its coverage area, long operation life of the ZigBee device, and the ability to connect more nodes simultaneously [25], [26].

The database and server are connected with the gateway via Internet. A gateway has some fundamental components, namely processing unit, RF transceiver unit, power unit, and communication (GPRS/3G/4G) unit [27]. The server is mainly a computational device e.g. a desktop computer. The database and server layer in [23] consists of a Postgress server. Postgress is an open-source relational database.

Finally, the last layer of the system is the client layer. This layer runs on top of the database layer and is loosely coupled with the server. The application layer can be programmed with any languages, e.g. Java, Python, C++, etc. to provide managerial support. The proposed solution of application layer in [9] has four modules based on the provided feature: (1) Parking lot module, which monitors and detects the parking lot, (2) Toll module, which manages the payment system, (3) Security module, which prohibits unlawful activity like car theft and unauthorized access of the system, and (4) Reporting module, which generates default and on-demand reports that provides a sanity check for the whole system.

Some other core features of the WSN system are:

- Real-time update of available parking lot
- Guide the driver to find a parking spot
- Trace moving cars along the path
- Trace parked cars in unregistered spot
- Security protected login system

1) CAR PARKING SYSTEM USING NB-IoT

In this WSN system, communication protocol NB-IoT [28], [29] is used. The basic concept of NB-IoT is developed on LPWAN or Low Power Wide Area Network. As the term LPWAN suggests, it consumes low power and gives coverage for a larger area in the network. The tradeoff of LPWAN is bandwidth and latency. NB-IoT can operate using the existing cellular carrier network or can have a standalone system as well. If there is a demand for massive data transmission with low latency, then NB-IoT is not the option. However, it can be the best solution for systems like smart car parking. The main reason behind this is that sensors integrated with transmitters can have a long-life span and can run on small cell power as they use narrow band. Unlike wide bands, narrow bands have less penetration loss. It is another main reason to choose NB-IoT for a smart parking system. Fig. 10 shows different operation modes of NB-IoT.

There is a proposal of an NB-IoT-based system with magnetic sensors in [30]. They have used the BC95-B5 NB-IoT module. NB-IoT is directly applicable to GSM and UMTS [31]. The working principle of the system is straightforward. Sensors check the vacancy of the spot. It sends data to the NB-IoT module or receives commands from it through a micro-controller, namely STM32. Finally, the BC95-B5 module sends that data to the client through a telecommunication channel.

Unlike other sensors, geomagnetic sensors are easy to install in the ground of the parking spot. When a car pulls in or out of the parking space, it causes the magnetic field change. The sensor can sense this change very accurately. Thus, whenever there is an update in the parking information, it is transmitted to the application platform. After parking a car, the vehicle owner also needs to put the parking lot number

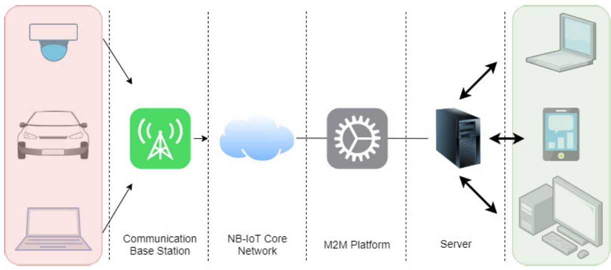


FIGURE 11. NB-IoT communication-based parking system.

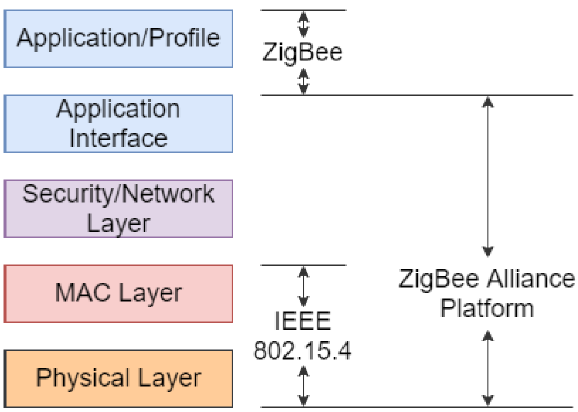


FIGURE 12. ZigBee network architecture.

and the expected time duration in the application if there was no prior reservation. When the car leaves the parking spot, the application automatically calculates the fee and charge the amount from the owner's account. The proposed system in [30] have used a third-party payment platform that is called WECHAT PAY. Fig. 11 shows a typical architecture of NB-IoT communication-based parking system.

There are some limitations [32], [33] prevalent in NB-IoT network based wireless sensor car parking systems despite the fact that it covers wide area coverage, ensures low consumption of power and can support high connection density. One of the key limitations in this regard is the fact that this system relies on cellular network providers [34] and hence its availability can be compromised particularly in the rural areas.

2) SMART PARKING SYSTEM USING ZigBee

ZigBee is a wireless-based technology that enables low power, low-cost machine-to-machine communication. It is an open-source standard that was developed by ZigBee Alliance. The standard is specially built for control and sensor networks. The ZigBee network architecture consists of five layers, as shown in Fig.12.

The ZigBee network can connect many devices simultaneously (practically 240), which is remarkable compared with other short-range networks like WiFi and Bluetooth. That is why the ZigBee network is the best option for a smart parking system. Fig. 13 shows the block diagram of ZigBee based parking system, which is proposed in [25].

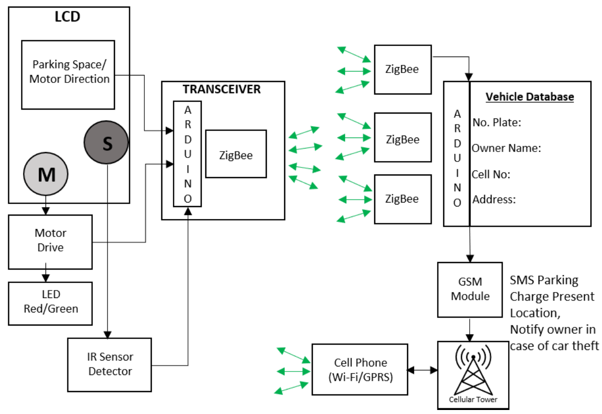


FIGURE 13. Block diagram of ZigBee-based parking system.

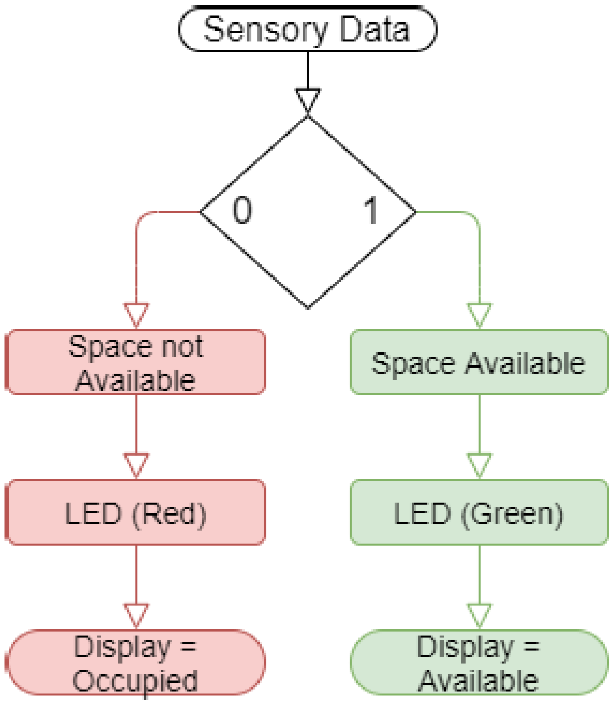


FIGURE 14. Flow chart of available space check.

The major components of the system are: (1) IR sensors, (2) Arduino, (3) ZigBee devices and (4) Servo motors.

The sensor network uses mesh topology because if any node fails, data can be re-routed using another path. The Arduino is a primary interface between all the components. Fig. 14 shows the gate open and close procedure. If the parking space is vacant, IR sensor transmits '1' to the Arduino input, which triggers the servo motor. Thus, cars can enter the parking space. On the other hand, if the space is not empty, then the IR sensor sends '0' to the Arduino input. As a result, the car in not allow to enter the parking space.

Despite the efficiency and overall feasibility of Zigbee network based wireless sensor base car parking systems, there are challenges in regards to network scalability [35]. Short range of Zigbee can contribute to limited coverage and

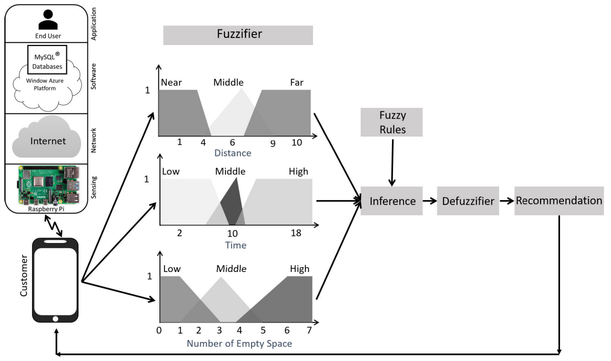


FIGURE 15. System architecture of fuzzy-logic based parking system.

it is prone to requiring high maintenance services due to dependence on battery power supply for the sensors being used [35].

3) SMART PARKING SYSTEM USING FUZZY LOGIC

A parking system can be a time-varying and complex one considering two main parameters: (1) time and (2) traffic. Therefore, reference [36] has proposed a human-like intelligent parking system based on fuzzy logic. Fig. 15 shows the proposed system with a multi-layer framework.

There are four layers in the framework, and these are:

Sensing layer: This layer consists of a micro-controller (Raspberry Pi Zero) and an infrared or IR sensor (E18-D80NK).

Network layer: It is a wireless LAN that provides internet connectivity to the Raspberry Pi Zero module. The layer sends all the sensory data to the database.

Software layer: This layer consists of the cloud platform and MySQL database. The layer allows it's upper layer (the application layer) to connect with the lower layer (the network layer).

Application layer: The layer consists of the operational applications. It is the standard interface (Android-based) for both car park users and car park owners.

The system recommends park space to the customers. Fuzzy rules are applied to generate this recommendation. The system requires three inputs before it can generate the recommendation. These are: (1) the number of available space, which is determined and stored in a database at the sensor layer, (2) the distance of user from the car park, and (3) the estimated time to reach the parking spot. After a successful fuzzification, users can get the parking space's coordinates (latitude & longitude) on their mobile.

Though there are widespread application of Fuzzy Logic and researches are conducted based on this technology on a considerable basis, there are some issues [37], [38], [39], [40] which are to be addressed. Fuzzy Logic based systems are prone to design complexity which may result in challenges at the implementation level. Moreover, Fuzzy Logic based systems require to perform computationally intensive tasks to process different rules and calculations which may create hindrances in effective parking system design.

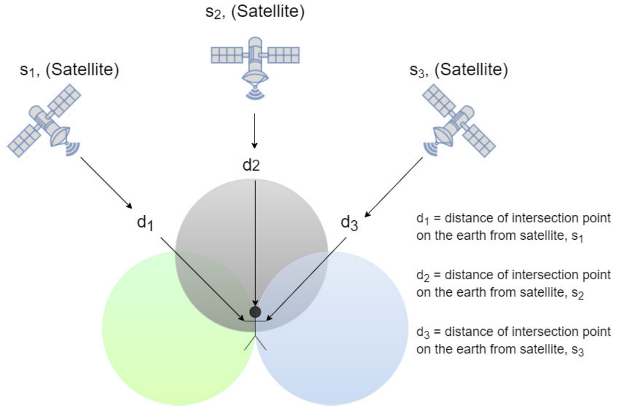


FIGURE 16. Trilateral mechanism in GPS.

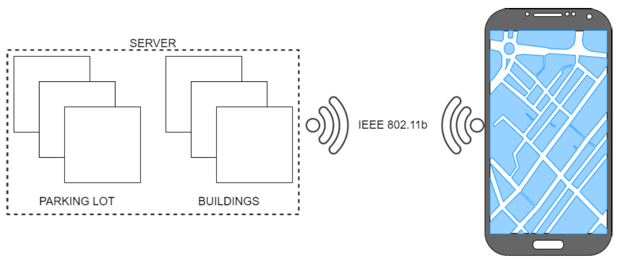


FIGURE 17. A NAPA architecture.

C. GLOBAL POSITIONING SYSTEM (GPS)-BASED PARKING SYSTEM

GPS receivers [41], [42] are among the most familiar gadgets which come as a feature with mobile devices or cars. GPS receiver follows signals from the satellites to determine how far it is from them. It uses the trilateral mechanism [43]. In this process, four imaginary circles intersect in a point on the earth, and satellites lie at the center point of those circles. The radius of circle is the distance of receiver from those satellites. The intersected point is the position of a GPS receiver, which contains mainly three pieces of information: latitude, longitude, and altitude. Fig. 16 is an example of the trilateral mechanism.

Article [44] has presented a location-based system. It is called Nearest Available Parking-lot Application or NAPA. Fig. 17 shows the typical layout of NAPA.

It was a part of a digital campus project. The system consists of two parts: server and GPS enabled end device. The server holds pre-processed data, which is the nearest parking spot adjacent to a campus building. The server runs in a notebook that communicates with the end device (iPAQ 3650) via a wireless protocol, 802.11b. The user manually updates the parking status through application, i.e. start and end time of parking. Based on this system the amount to be paid is then calculated. This type of system can locate a parking area but cannot guarantee the availability of a spot.

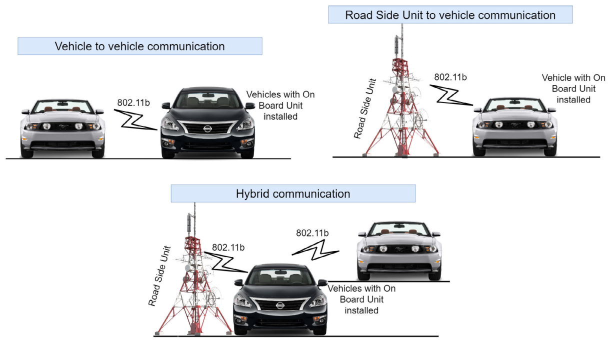


FIGURE 18. Vehicular ad-hoc network.

In [45], the authors have proposed a GPS-based street parking system that uses a GPS transmitter to find out the parking area. In this system, location of the parking facility or zone can be identified on the map. The authors have formulated an algorithm that has two parts: the shortest path calculation and check availability of the spot. The first part followed Dijkstra's algorithm, and the computation of the second part followed a non-homogeneous Poisson process. However, it is only the probability, not the real-time availability information. The algorithm cannot run without the previous data about the occupancy of each lot. However, both the collection and processing of previous data are complicated.

Though GPS-based systems are widely and frequently being used around the globe, such systems are also not free from limitations as well [46]. One of the core issues associated with GPS-based parking systems is the fact that GPS signals can be blocked or weakened by obstacles. Also since the use of data relayed through Satellites is done in GPS based systems, data transmission can be considerably delayed which may cause issues in real time parking management.

D. VANET-BASED CAR PARKING SYSTEM

A new wireless communication system, Vehicle Ad-hoc Network or VANET [47], was invented while keeping road safety in mind [42], [48]. The VANET communication works in three ways: (1) Inter vehicle communication, (2) Vehicle-infrastructure communication, where infrastructure means Road Side Unit or RSU a transmitter that uses cellular network, and (3) Packet routing communication, that means the vehicle itself will act as a router. This communication protocol supports the IEEE 802.11p technology. Fig. 18 is the overview of the VANET.

Authors in [49] have proposed a parking system using this VANET. The system is called Smart Parking or SPARK, which aims to provide real-time parking navigation. Additionally, it also provides anti-theft protection and parking information sharing with other moving vehicles. The system model has four elements: (1) Trusted Authority or TA, (2) Vehicle with OBU, (3) Parking lot RSU and (4) Parking space. Each OBU has a unique id, i.e. ID_i, and given a pseudo ID, i.e. PID_i, while registration by the TA. TA also

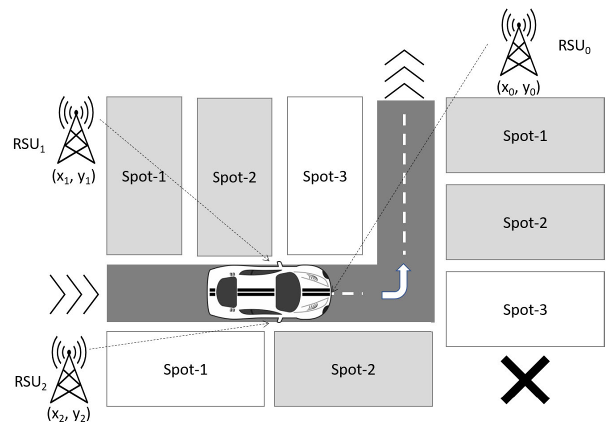


FIGURE 19. Identify the parking lot.

shares a secret key, i.e. ski and the corresponding pseudo ID, to generate a ticket before accessing the parking lot. The ticket is a digital signature that identifies the OBU or vehicle.

Road-Side Unit or RSU is required to identify the parking lot. Fig. 19 shows the parking lot finding process with RSU.

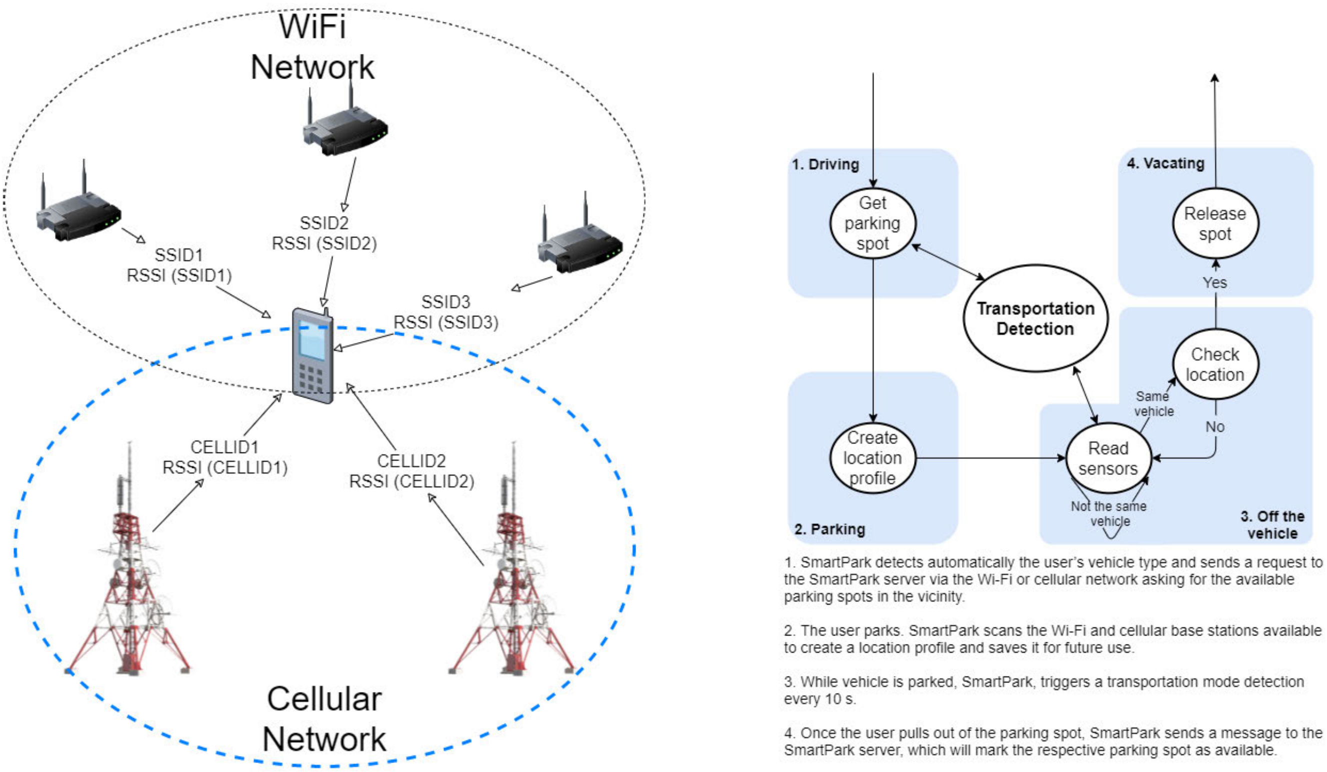
The position of the corresponding parking space is determined using the coordinates of each RSU. The parking space is nothing but a 2G plane. Therefore, the same rule which determines the Euclidean R2 plane is also applied here. Some basic features of this system are: (1) Real-time navigation, (2) Anti-theft protection and (3) Privacy.

The proposed system is not feasible, considering the implementation cost. It is expensive to build RSU infrastructure with each parking space. Moreover, the allocated frequency spectrum for VANET wireless communication might not be available in every country [48].

E. SMARTPHONE SENSING-BASED PARKING SYSTEM

Authors of [50] have proposed a system called ParkSense. It is a smartphone sensing-based system intended for the on-street parking. The system is designed only to check the driver's status and availability of the parking spot. Smartphone's localization technology detects the particular activity of a diver who is vacating a parking space. Another SmartPark design showed by Krieg in [51]. The system depends on some information, i.e. transportation type, transport mode, location profile, etc. to show a vacant parking spot. The ParkSense collects those data from its user and computes the probability of non-ParkSense users' locations in a parking area.

Smartphones are handy with multi-level sensing capability, and on the other hand, cellular network is ubiquitous. SmartPark works on leveraging these two things. Transport type detection is vital because smartphone users may use different transportation types, i.e. bus, train, airplane. However, only a car, motorbike, bicycle needs to park. To avoid erroneous detection, SmartPark uses multiple sensors of smartphones: Accelerometer, Gyroscope, Orientation, Magnetic field sensor, Luminosity sensor, Atmospheric pressure sensor, and



(a) Location Profiling by Cellular & Wifi Network (b) Architecture of the SmartPark system

FIGURE 20. Smartphone Sensing-based Parking System [51].

Microphone [51]. The second important step is to generate a location profile of each ParkSense user. Every time a vehicle is parked, the driver needs to enter some parking information, for example, parking lot number, in the application. The location profile consists of certain information, i.e. SSID & RSSI of a WiFi access point, CELLID & RSSI of the serving cellular BTS [51]. Fig. 20 shows how this location profiling works and the architecture of the system adopted from [51].

SmartPark checks the user's vehicle type and sends a request to the SmartPark server for a parking spot. After the user parks, SmartPark starts scanning the WiFi and cellular network to create a location profile and then store it. While the vehicle is parked, SmartPark, triggers a transportation mode detection every 10 seconds. Once the user leaves the parking spot, SmartPark sends a message to the SmartPark server to mark the spot as available [51]. There is a comprehensive summary of all the discussed parking system presented in Table 3.

Though Smartphone based parking systems have been gaining popularity due to the increasing trend of mass use of smartphones, there are several limitations that are to be considered while building parking systems based on Smartphones [52]. The first and foremost concern in this matter, is the fact there is a dependency of smartphone ownership. Though there is a mass use of smartphones around the world, most of the users are unaware of its several usable features [53] which can be attributed to their level of digital literacy. Moreover, there are concerns related to user privacy too as smartphones are the primary careers of a person's personal information nowadays, and any technology associated with smartphones are prone to causing leakage of sensitive information.

V. TECHNOLOGY BEHIND THE SYSTEM

In recent time, the concept of Smart City has gained much attention due to the advancement of Internet of Things. Smart parking plays a vital role in building a smart city as it significantly reduces the stress and time for a driver along with CO2 emission in the environment when s/he is looking for a parking. A smart parking system can help the driver to identify and book an available parking space. In this system, the parking spaces are populated with a sensor or a set of sensors which collect data from a parking lot and send the sensed data to a cloud system. A user running the system from his laptop or cellular phone then can access to the system to check the status of every parking.

Some factors need to be considered before designing a smart parking system because its performance lies on those factors. This section talks about those technologies which play a vital role in a parking system. The most crucial part of the system is to detect an object correctly, store the data, and access data through effective communication. A proper analysis is required to have a balance between the solution

TABLE 3. Overview of the parking system.

Parking System	Sensor	Network	System Solution
RFID based Car Parking System	Infrared	RFID	Secure gate controlling and vehicle movement indication
Wireless Sensor-based Car Parking System - using NB-IoT	Magnetic	NB-IoT	Cutting edge technology and high precision car detection
Wireless Sensor-based Smart Parking System - using ZigBee	Infrared	ZigBee	Implementation and maintenance cost is low, reliable system
Wireless Sensor-based Smart Parking System - using Fuzzy Logic	Infrared	LAN	A system with human-like intelligence
Global Positioning System (GPS) based Parking System	GPS	Satellite	Accurate park area detection
Vehicular Communication based Parking System	-	DSRC	Real-time parking navigation, anti-theft protection
Smartphone Sensing-based Parking System	Accelerometer, Gyroscope, Orientation, Magnetic field sensor, Luminosity sensor, Atmospheric pressure sensor, and Microphone	WiFi & Cellular	Low cost due to no new infrastructure cost

and the cost of the solution. For example, if the parking area is small, adopting a system requiring new infrastructure will become a burden. This section talks about those technologies, which play a vital role in a parking system.

A. SENSORS AND TYPICAL PROXIMITY SENSORS USED FOR PARKING SYSTEM

A sensor is a device that can detect the change in physical quantity, where pressure, temperature, force, electrical current, or any form of energy is known as physical quantity. Based on the excitation method, sensors can be of two types: 1) Active and 2) Passive. Active sensors need an external excitation supply to generate the output signal. On the other hand passive sensors produce output without any external excitation/power supply. Sensors that produce continuous signal with the time is called analog sensors. Again, sensors that generate a discrete signal is called the digital sensor. Below we describe the most popular available sensors used in a parking system.

1) ULTRASONIC SENSOR

Ultrasonic sensor is the most popular sensor among research community which converts electrical energy into acoustic waves and vice-versa. These sensors are used to detect objects based on reflected energy and emit 25-50 kHz of sound waves. These type of sensors are sensitive to rain and snow, thus they are suitable for indoor parking. Fig. 21 shows the working principle of an ultrasonic sensor, where the emitted waves are used to determine the distance of an object that stands in the wave's path [54]. Whether a parking lot is free or occupied can be determined using wireless ultrasonic sensors which are connected using wireless sensor network e.g. ZigBee protocol.

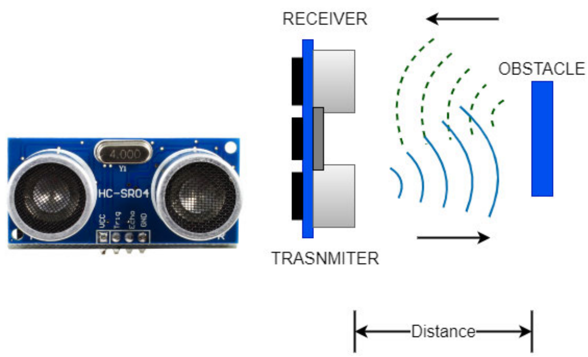


FIGURE 21. Working principle of ultrasonic sensor.

2) CAMERA SENSOR

Cameras are used to identify the presence of vehicles on individual parking bays. A camera is capable of processing images without the help of an external device or even algorithms. Wide-angle cameras are often used to detect parking lines and determine the position of a parking space. Whereas, rearward cameras are used to help a driver to park in a specific spot through a touch screen. Moreover,

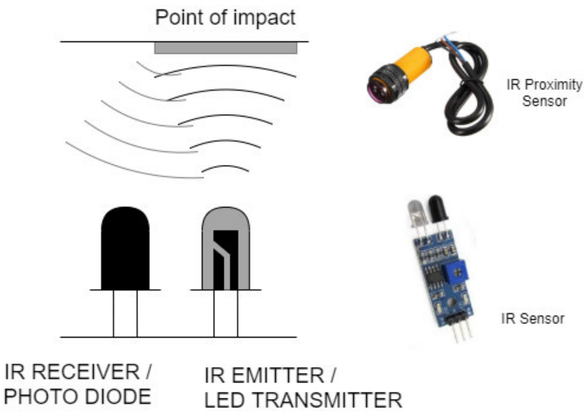


FIGURE 22. Working principle of IR sensor.

some applications are available that helps a driver to determine whether a parking lot is preoccupied or empty which collect images using a video camera on real-time [55], [56], [57].

3) IR SENSOR AND IR PROXIMITY SENSOR

Infrared Sensor (IR) converts electrical energy into light (Infrared) and vice-versa and works based on a method named as object detection. In this method, if there exists an object in it the LOS (Line of Sight) of a sensor an echo signal is reflected back [97]. Thus in the parking lot, if a vehicle is found in the LOS, it will trigger an echo signal indicating that the lot is occupied. Fig. 22 shows the working principle of an IR sensor.

4) LIGHT DEPENDENT RESISTOR (LDR) SENSOR

Light Dependent Resistor (LDR) Sensor is used to determine the availability of a parking slot. It works a method named as shadow detection where if the is a light or luminous source it calculates the luminous intensity. For example, if an LDR is deployed under a car, the car creates a shadow which indicates that the parking slot is occupied. On the other hand, absence of a car indicates that the parking slot is available.

5) CELLULAR SENSOR

These days, cellular phones are widely used as very useful tools for smart parking. Cellular phones include sensors e.g. gyroscope, accelerometer, GPS, magnetometer, etc. For example, gyroscope and accelerometer of a cellular phone determine whether a vehicle is moving. GPS sensors helps a driver to confirm whether s/he has parked the car in the right position or even whether the parking slots are available for parking the car [51], [58].

6) INDUCTION SENSOR

The oscillator of the sensor creates an electromagnetic field [59]. When a metallic object comes near to this field, an eddy current generates on the object's surface. It causes the amplitude of the oscillator's e.m.f. to reduce. Another threshold circuitry detects this rise or fall of e.m.f. and

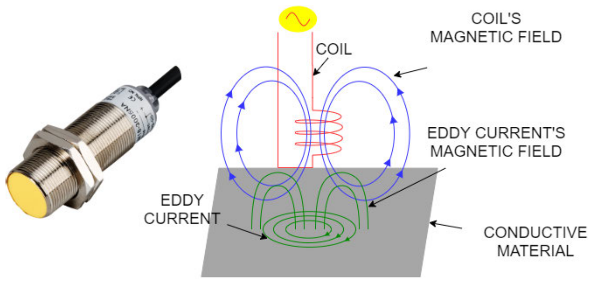


FIGURE 23. Working principle of induction sensor.

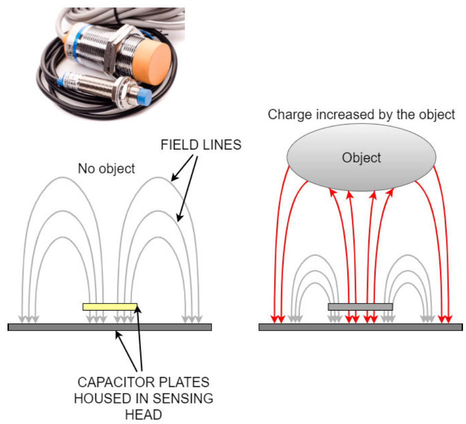


FIGURE 24. Working principle of capacitive sensor.

changes the output of the sensor. Fig. 23 shows the working principle of an induction sensor.

7) CAPACITIVE SENSOR

There are two conduction plates in the sensing head of which one holds positive and the other negative charge. The air between the object and the sensing head acts like an insulator. The charge or current increases and come into or out of the plates only if there is an object. Fig. 24 shows the working principle of an induction sensor.

8) RADAR SENSOR

Radar sensors are used to estimate the velocity of a moving object (not stationary object) which does so by transmitting microwave beam and then calculate the velocity based on the reflected signal. Dual microwave Doppler radar is used to the objects. Typically, they are installed under the surface to detect a vehicle and as they are not environment sensitive they can be placed in the indoor and outdoor parking lots.

9) MAGNETIC SENSOR

This type of sensor works based on the Hall Effect (Produce voltage difference across an electrical conductor by applying a vertical magnetic field) [60]. Another type works based on mechanical principle (Reed switch). Fig. 25 demonstrates the Hall Effect and also shows a reed switch. Using these type of sensors, the presence of a vehicle is detected by sensing any modification in the electromagnetic field. Usually, they are placed close enough to a vehicle, thus often placed

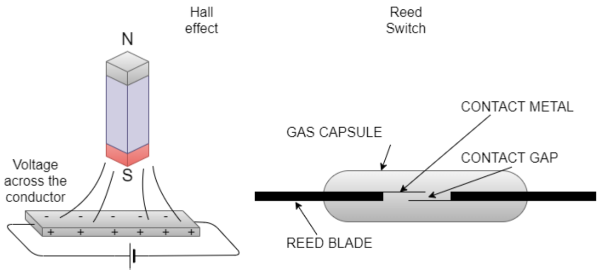


FIGURE 25. Working principle of magnetic sensor.

TABLE 4. Overview of all the proximity sensors.

Type	Inductive	Optical	Magnetic	Capacitive	Ultrasonic
Working Principle	Uses current induced by the magnetic field	Light energy converts into electrical energy and vise-versa	Works based on the Hall effect and mechanical (Reed Switch) principle	Works based on electro-magnetic characteris-tics	Sound energy converts into electrical energy and vice-versa
Detection Type	Non-contact	Non-contact	Non-contact	Non-contact	Non-contact
Detection Ob-ject	Metal Object	Everything	Magnet Object	Everything	Everything
Operating Distance	Low	Moderate	Moderate	Low	High
Cost	Low	Moderate	Low	Moderate	High
Sensitivity	Anything	Dust, oil	Hall: EMC, Reed: Magnetic field	Humidity & vapors	Air, tempera-ture
Application	Toll, auto industry, fast-moving parts	Object detection, counting, and sorting	Object detec-tion	Fluid level checking through package, wall, or other barriers	Object detection, cavity and fluid level check

beneath the surface. Table 4 depicts the overview of the major proximity sensors.

10) LIMITATIONS OF SENSORS

Though the use of different kinds of sensors have greatly eased the design of several IoT based systems including parking systems. There are some limitations which a user must take into consideration before choosing to proceed with one in the implementation phase [61], [62]. The knowledge about the limitations will greatly aid in determining whether the selected sensors are conformable to the objectives of the user.

Inductive sensors, which can only detect metallic items, have a comparatively short detection range and are affected by temperature changes and electrical interference. These sensors can be more expensive than others [63]. Optical sensors, affected by the surrounding light conditions, can result in false readings specially due to the presence of reflective objects. Moreover their performance can be compromised by the color or texture of the detected object [64]. Magnetic sensors are sensitive to changes in the environment's magnetic field and can only detect ferromagnetic materials. Nearby magnetic as well as metallic objects can interfere with performance of such sensors [65]. Capacitive sensors can be influenced by changes in temperature, humidity, and other environmental factors, and these sensors are sensitive to the object's material and size. The operation of these sensors can be interfered with by nearby electrical equipment

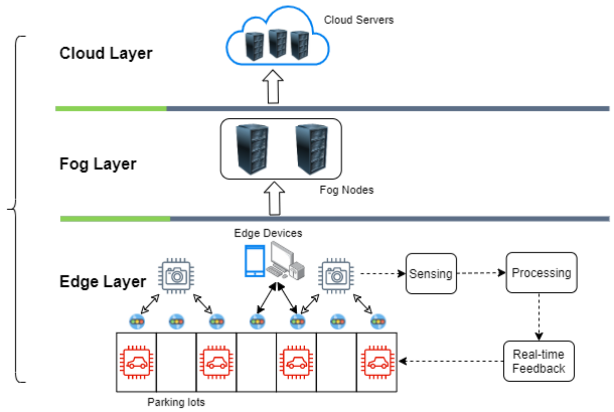


FIGURE 26. Fog applied in parking system.

[66]. Ultrasonic sensors' performance can be hampered by environmental factors including sound-absorbing obstacles, sound wave reflection, and background noise; these sensors require a relatively unobstructed path and have slower response times compared to other sensors [67].

B. NETWORK STORAGE (CLOUD/EDGE/EDGE)

A smart parking system can generate an enormous amount of data. Therefore, it is necessary to find an efficient way of storing data and practical analysis to improve the parking system's efficiency and performance. Sometimes, local storage is not reliable, elastic, and cost-effective option to handle such action. In such a case, cloud could be a choice as it can provide broad access, on-demand usability, and shared resources [68]. Additionally, it is rapidly elastic with measured or metered service. In smart parking, the cloud should be at a level of the architecture that is visible to the end-user. Cloud can enable many features like remote monitoring, automatic management services, and other analytic. It can disseminate information in real-time to a remote location on a web page or smartphone [69], [70].

Typically, in a cloud-based solution, sensors are used to detect a parking slot and the result is then updated in the cloud-based application. In such a case, sensors are directly connected to the cloud, therefore the computation occurs in the cloud server. Thus, when a car leaves or enters a parking lot, some delay or high latency may occur before a user receives the updates, especially when the connectivity is unstable. Fog and edge computing come here to overcome these shortcomings (see Fig.26).

In a fog-based solution, fog nodes are deployed at the middle, where it brings some of the cloud resources closer to the network edge. For example, parking lot related information such as parking lot images can be processed in the fog nodes and then displayed on the LED. When a parking lot does not have any empty slot, information of nearby parking lots may be acquired and displayed on the corresponding LED, which can be done in association of the fog nodes. In this model, image data is stored in the cloud only when the data is not required anymore by the fog node, where

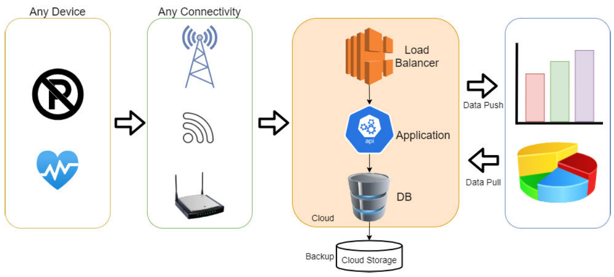


FIGURE 27. Non-redundant 3-tier architecture.

communication is ensured amid fog and cloud nodes via a proxy server. In such a scenario, after a certain period, cloud may provide the data if it is required by the fog nodes [71].

In an edge-based solution, computation occurs close to the location of data collection. Many car parking systems have embraced cloud-based reasonable and smart solution that need to sense, transmit, store and process a large amount of data. However, due to the high latency and the large volume of data that needs to transfer on regular basis, the solution becomes costly. Edge computing mitigates the issue by introducing an extra layer between the devices of end users and the cloud servers. The edge servers offload some processing work of the users and cloud and also make a bridge between devices and the cloud servers. Therefore, applications that require low latency can run faster. Edge-based solution has five benefits: (1) Security, (2) Scalability, (3) Reliability, (4) Speed, and (5) Efficiency e.g. lower bandwidth usage. The edge server offloads some processing work of the user and cloud. As a result, other applications can run faster, which requires low latency. Fig. 27 shows the application of cloud with non-redundant 3-tier architecture [72].

C. COMMUNICATION PROTOCOLS

Sensors are deployed on a parking lot to form a network so that they can communicate with the outside world. Communication is done in one of two methods: short range communication and long-range communication. In short range method, messages may be re-transmitted a number of times through some intermediate devices e.g. relays. Technologies that are used in short range communication are IEEE 802.15.4, IEEE 802.11ah (Wi-Fi HaLow), Zigbee, NFC, etc. Whereas the long-range communication method lets the sensors communicate with infrastructures. The short-range technologies are widely used. However, they are unable to adjust when it requires them to conduct long range transmission. Cellular communications (e.g. 2G, 3G, 4G, etc.) can fulfill the need, however, they need a lot of energy. Thus, the necessity for the IoT applications has driven the emergence of LPWAN (low power Wide Area Network). It provides approx. 5 km in urban areas and approx. 40 km in rural areas, and also energy efficient i.e. battery lifetime is more than 10 years. Sigfox, NB-IoT, and LoRa are examples of LPWAN technologies used for wide-range of IoT devices' deployment. Fig. 28 shows the type of communication used

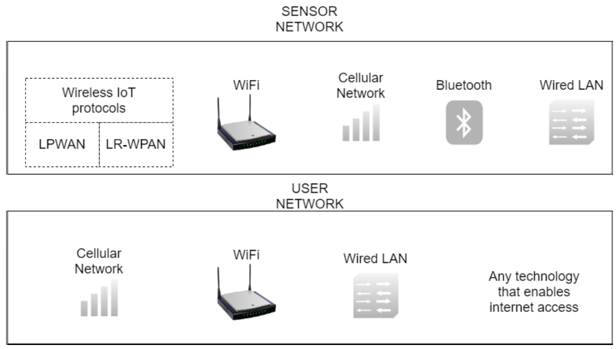


FIGURE 28. Communication type for the user and sensor.

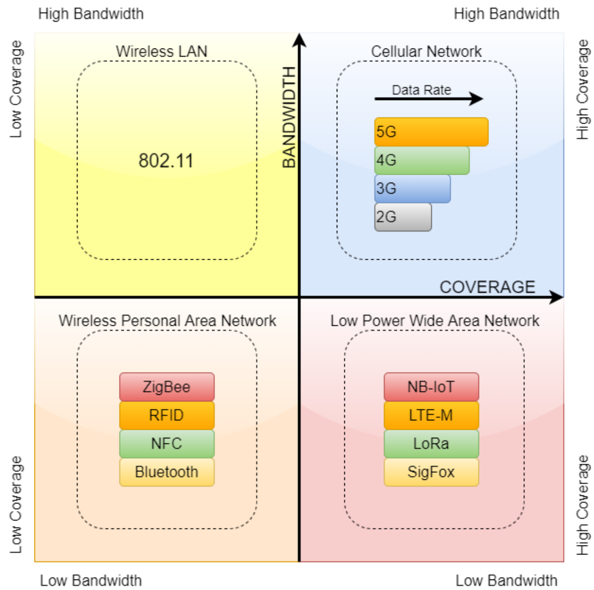


FIGURE 29. Bandwidth Vs. Coverage plot of protocols.

for sensors and users, where Fig. 29 shows the Bandwidth vs. Coverage of communication protocols.

1) IEEE 802.15.4 STANDARD

IEEE 802.15.4 standard is defined as LR-WPAN (low-rate wireless personal area network) and focuses on low-cost communication with the nearby devices (i.e. within 10-meter range), that has no fixed infrastructure. Most of the sensors disseminate data using IEEE 802.15.4 standards as it can be installed rapidly and does not require any subscription to a mobile operator (it operates in an unlicensed 2.4 GHz band). Compared to other technologies e.g., Wi-Fi, it requires low power and low bandwidth as a result the data rate is also low (i.e. 250 kbps). ZigBee works on this standard [73].

The IEEE 802.15.14 Standard has some demerits as well [74]. This standard has been designed for short range communications. Moreover, the data rate of this standard is comparatively low and hence can cause issues in real time parking. Moreover, the communication under this standard is conducted in unlicensed bands which are shared with other technologies (like Wi-Fi), potentially leading to interference.

2) IEEE 802.11ah (Wi-Fi HaLow) STANDARD

IEEE 802.15.4 technology is not suitable when it requires to communicate with a large number of devices covering long distance. Thus, here IEEE 802.11ah comes to rescue, which combines low power sensor network with WiFi technologies, namely Wi-Fi HaLow. Wi-Fi HaLow covers up-to 1km (i.e. nearly twice of WiFi). of communication range. IEEE 802.15.4, CSMA-CA (Carrier Sense Multiple Access with Collision Avoidance) based MAC is unable to handle collision, especially when the number of devices is very large. Thus, IEEE 802.11ah uses RAW (Restricted Access Window) based technique instead to improve the performance. As a result, it achieves data rate of 78Mbps [75].

Despite being more efficient than traditional Wi-Fi based technologies, this standard consumes more power than other LPWAN technologies like LoRa or Sigfox. Furthermore, the technology is complex can be more expensive to implement compared to other low-power, wide-area network technologies.

3) SIGFOX

Sigfox is an LPWAN protocol that uses unlicensed ISM band (e.g. Asia-433 MHz, Europe-868 MHz, and North America-915 MHz) to transmit data. It focuses on using very long waves unlike 4G, therefore, experiences an increase in range up to 1,000 km. In Sigfox, BSs (base stations) are equipped with Cognitive SDR (Software Defined Radios) and using an IP based network they are connected to the servers. The data rate of Sigfox can be either 100 bps or 600 bps, depending on the region.

Sigfox has several limitations which should be mentioned in order to be ensure that the limitations are addressed during the implementation of real time systems [76], [77]. Sigfox has a limitation on the number of messages a device can send per day, and the size of each message is very small. Furthermore, Sigfox is designed for uplink-heavy communication (device to cloud), and its downlink capacity (cloud to device) is even more limited. Morever, Sigfox does not offer any Quality of Service guarantees, and its performance can be affected by many factors.

4) LoRa

LoRa is also a low power and long range (Crowded urban area - 2 to 5 km) IoT protocol, which is designed for WAN applications. The data rate of LoRa is between 300bps and 50 kbps. Similar to Sigfox, it also uses unlicensed ISM bands (e.g., Asia-433 MHz, Europe-868 MHz, and North America-915 MHz) to transmit data.

Similar to Sigfox, LoRA is prone to various errors and issues as well [78].

While LoRa is excellent for long-range, low-power communication, it has a limited data rate, making it unsuitable for applications that require high data throughput. LoRa devices share a common frequency band and are potentially subject to interference from each other if not managed correctly. Like Sigfox, LoRa is also more uplink-oriented, with more limited downlink capacity.

5) NB-IoT

NB-IoT is a Narrow Band IoT technology, which can coexist with GSM and LTE under licensed bands such as 700 MHz, 800 MHz, and 900 MHz. In NB-IoT, end devices require a very little amount of energy, which makes it economical. Furthermore, in NB-IoT, approx. 100 thousand devices per cell can be connected and the number can be even further increased by adding more carriers. The data rate is 200 kbps for the downlink and 20 kbps for uplink. The battery life time is 10 years, when the average transmission is 200 bytes/day.

There are some disadvantages of NB-IoT as well [34]. While NB-IoT provides good building penetration, it might not provide coverage in more remote or rural areas where LTE coverage is not available. The data rate in NB-IoT is limited, making it unsuitable for applications that require high data throughput. The availability and cost of NB-IoT can depend on the policies of individual cellular providers.

Networking protocols or communication protocols are the key to pass data from sensors to the controlling unit of a smart parking system. It may need two different communication protocols, one for the users and another for the sensors. However, some parking systems can have the same protocol for both sensors as well as users. For the users, it requires higher internet bandwidth with low latency and more power. The gateway is required to interpret a wireless protocol to a TCP/IP based information. In a smart parking system, thousands of concurrent devices connect and interchange information every second. Therefore, the sensor network must follow mesh topology to avoid connection loss due to a single node failure. There is summary about popular communication protocols presented in Table 5.

D. SECURITY ISSUE

It is certain that if humans can build a system, they can also break it at some point. Traditional internet security is very week [86]. It is more vulnerable to attacks in the case of IoT [87]. Although, there have been many developments going on to stop cybercrimes. Typically, a smart system should provide all the features like- email id-based user login, online booking, and payments using debit or credit cards [88]. All this information is incredibly private. Any breach into the system can lead to leakage of sensitive information and cause data integrity issues with financial damage.

1) ATTACKS ON RFID SYSTEM

The user's private data embedded on the RFID card is transferred to the authentication server using electromagnetic signaling. Although the information is encrypted, decryption algorithms of this type of data are available, just a search away on the internet. Again, the attacker can use a signal jammer and cause the whole system to stop working. Nowadays, technology has become so advanced that any misplaced RFID

TABLE 5. Technical specification of some popular communication protocol.

Protocol Name	Bluetooth [79]	ZigBee [80] [81]	WiFi [82]	Cellular (GSM) [83]	NB-IoT [84] [85]
Protocol Standard	IEEE 802.15.1	IEEE 802.15.4	IEEE 802.11ac		3GPP Rel 13
Allocated Frequency Band	2.4 GHz ISM (2400 – 2483.5 MHz)	2.4 GHz (China – 784 MHz; Europe – 868 MHz US – 915 MHz)	5 GHz	850 MHz, 900 MHz, 1800 MHz, 1900 MHz	US – 600 MHz, 700 MHz, 850 MHz, 1700 MHz; Europe – 800 MHz, 900 MHz, 1800 MHz
Coverage Range	10 m	10 to 150 m	45 - 90 m	1 - 8km	10 km
Used Channel Bandwidth	1 MHz	2 MHz	20, 40, 80, 160, 80+80 MHz	200 kHz	180kHz
Modulation Type	GFSK, π/4-DQPSK, 8-DPSK	BPSK, ASK, OQPSK	OFDM, BPSK, QPSK, 16QAM, 64QAM, 256QAM	GMSK, 8PSK	OFDM, SC-FDMA
Max Node Connectivity	8	240 (Practically)	2007	124 $(8user/channel)$	40
Data Rate	1 – 3 Mbit/s	250 kbit/s	1.3 Gbit/s	300 kbit/s (EDGE), 1 Mbit/s (EDGE Evo)	234.7 kbps (DL), 204.8 kbps (UL)

card can be copied in the blink of an eye using gears that are available to all.

2) ATTACKS ON NB-IoT

Security of NB-IoT is guaranteed till now but not free of vulnerability. Various IP related attacks i.e., Port scanning, ARP spoofing, DNS spoofing, etc. may be possible. A mobile under an APN (Access Point Name) can start receiving data after creating a PDP (Packet Data Protocol) context [89]. If a naïve user intentionally or unintentionally keeps open a communication port to the server, the attacker might get a chance to send malicious data and pretend to be the original server. However, to do this, an attacker needs to get access to the same APN or PDN-GW (Packet Data Network Gateway) first. Another type of possible attack is the DoS (Denial of Service) attack. Attacker with a compromised UE (User Equipment/Mobile) can send continuous ping requests to other UEs. As a result, UE will drain its battery and go to shut down mode.

3) ATTACKS ON ZigBee NETWORK

ZigBee uses a 128-bit key with AES (Advanced Encryption Standard) encryption algorithm. It is nearly impossible to break. However, there are some issues in one of the two security profiles, the Standard Security Profile [90]. The ZigBee devices using this profile share key in plain text. An attacker can capture this key and compromise the network. Attackers can make sniff attacks and capture packets if the communication of the ZigBee network is unencrypted. ZigBee end device runs on battery and remains in sleep state unless the ZigBee coordinator sends a wake-up beacon [91]. An attacker in the proximity of the ZigBee network can produce a false beacon to make the ZigBee end device response and stay awake till its battery drain out.

4) ATTACKS ON BLUETOOTH

Bluetooth is a widespread technology, supported by almost every devices of the current time. It is vulnerable to several attacks. An attack called BlueSmacking sends oversize packets using the L2CAP layer of the Bluetooth network, making a DoS attack. Attacker with Bluetooth devices can generate spam messages and perform BlueJacking attacks on other Bluetooth devices. However, this type of attack has no significant effect but should not take it lightly. BlueSnarfing is another typical attack but more dangerous for a Bluetooth device and its user. Attackers can sneak and take personal data from victim's devices i.e., text messages, email, photos, and other identification documents. There is another dangerous attack in Bluetooth called BlueBugging. The attacker creates a backdoor in the victim's device, allowing other malicious outsiders to access that compromised device [85].

To make a system secure, both the system administrator and the system's user should work together. They can follow a few standard rules:

- Check and update the operating system regularly
- Before login, the user must check if the page is secure and supports encryption
- Do not browse to any suspicious link which can contain phishing data
- Do not open any attachments or image received from an unknown address
- Do not share personal information over the phone to an unauthorized person
- Report stolen items to the police instantly
- Avoid sharing passwords or PINs over the chat or email
- Do not use any public open WiFi
- A naïve user should use antivirus software
- Use network firewalls and do not allow any unnecessary port forwarding
- Always use a strong password
- Do not use the same password for all accounts
- Try to use the password generator tool
- Try not to use any crack software

VI. DISCUSSION AND OPEN ISSUES

Throughout the world, the increasing number of vehicles have greatly impacted the parking management systems [92], [93]. However, research has shown that the use of IoT based technologies can greatly mitigate the parking associated problems [94]. Over a decade, Dhaka city's average speed has dropped to 6.8 kph from 21.2 kph [95], [96]. Unplanned urbanization and increasing dependency on private cars have a significant contribution to the city's traffic jam. There is a lack of adequate car parking area, and though there are some but underutilized due to manual management system. Dhaka City Corporation has decided to introduce a smart parking system.

Thus a city's management authority must bear in mind a few issues before adopting a smart parking solution. Suppose the system is developed based on a smartphone sensor. In that case, there is a need to set a transparent data collection polity first. A smartphone is a multi-sensor device. It can collect personal information of the user or owner of the parking area. There is a high risk of losing personal data and breach information security. The systems that require applying image processing techniques may require edge computing to perform efficient operation. However, from the park owners' point of view, still the edge computing is not popular considering the related cost. Bangladesh is prone to cyber-attacks for many reasons, i.e. most users are naïve and unaware of different attack possibilities. There are also lack of cyber-security expert. So, we need to focus on train up both the user and the owner of the car park. A smart car parking system has sensors in the perception layer. A sensor that requires a change in the infrastructure may not be suitable for Dhaka. There is a requirement for driver's behavior-based analysis in the context of smart parking system uses.

Sensor and communication are the two vital components of an intelligent smart parking system. Perfect calibration of sensors is quite challenging because they are often affected by the extreme weather situation. Furthermore, it may become a financial burden on the management by Installing sensors that require infrastructural changes. In an intelligent parking system, sensors often need access to the personal information of the user. It may raise serious privacy and security concerns. There is a research scope to find an optimum IoT based solution so that privacy issues can be tackled. The computational cost of local sensors cannot be ignored at all. It is also inversely proportionate to the communication cost. The communication cost means the number of interactions between the sensors and their operating application or global server. Therefore resource optimization is another critical part where researchers should focus next. Most of the sensors are battery-powered. The battery will drain out faster with higher energy consumption. Thus, a sensor may become offline or disconnected from the system. So an energy-aware process is required to save battery power.

Communication mode is the next big problem in the smart parking system. Among the different available communication modes, NB-IoT seems to have advantages over other communication protocols as per our study. NB-IoT has high coverage with a narrow bandwidth. Further analysis is required to select a or multiple communication modes for each parking system.

This research has several limitations as well, which we intend to take into consideration in our future research pursuits. There are several latest technological trends which could not be covered within the scope of this research. The AI based parking management systems including computer vision and deep learning technologies can be an interested area to focus on when considering smart parking. Moreover, several recent, state of the art and promising communication technologies and protocols were not covered in this research including the use of 5G technologies, latest trends in Software defined Networking(SDN), the use of Federated learning for decentralized parking systems, etc. These limitations can serve as interesting avenues for further promising future work.

VII. CONCLUDING REMARKS

Currently, cities around the world are being subjected to several challenges due to urbanization. The oldest and most vital issue is the existence of unplanned and congested city roads. This research has carefully reviewed several of the innumerable researches that have been done on developing smart parking systems. Since this is the era of rapid development and expansion of IoT based technologies, there are ample scopes for improving the parking and congestion related problems using these state-of-the-art tools. This research has also presented a detailed study of some existing parking solutions along with a brief discussion of the working principle behind each type of parking systems and focused heavily on different kinds of sensors, communication protocols and the technologies incorporating these sensors. Furthermore, the security related and other concerns associated with the hardware as well as software components of IoT based parking systems have also been presented to help serve in future research agendas. The key contribution and novelty of the research, the proposed taxonomy will serve in further researches from theoretical as well as practical perspectives. We strongly believe that the findings from this study will serve as a solid groundwork and offer important insights that will guide our future research efforts. We intend to build upon these results, and also aim to explore new areas that this research has shed light on. We believe that with each subsequent study, we can push further expand our objectives and contribute significantly to this field of study.

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