SMU
SINGAPORE MANAGEMENT UNIVERSITY
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IS614 Team Project Proposal
IoT Smart Parking System

Team 5

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1. Problem Statement

As urban populations continue to grow, the number of vehicles on the road increases correspondingly. This surge has led to significant challenges in finding parking spaces, especially in high-traffic areas like shopping malls. Drivers often face prolonged searches for available spots, resulting in wasted time, increased frustration, and heightened traffic congestion. The IBM Parking Index highlights several key challenges that exacerbate these issues (PR Newswire, 2011)

- **Longest Time Spent Searching for a Parking Spot**: Drivers can spend an excessive amount of time circling parking lots without success.
- **Difficulty in Locating an Available Spot:** Limited visibility and lack of real-time information makes finding open spaces challenging.
- **Conflicts Over Parking Spaces:** Competition for limited spots can lead to disputes and unsafe driving behaviours.

Importance

Two important factors can be considered.

- **Environmental Impact**: Prolonged driving while searching for parking increases carbon emissions. This contributes to environmental pollution and accelerates global warming due to higher greenhouse gas concentrations. According to a study by IBM, 30% of city traffic is caused by drivers searching for parking spaces, leading to congestion and frustration(PR Newswire, 2011).

- **Customer Satisfaction and Business Revenue:** Difficulty in parking can deter customers from visiting shopping malls, negatively impacting their overall shopping experience and leading to reduced revenues for retailers, as dissatisfied shoppers may choose competitors with better parking solutions.

Existing Solution

Traditional parking systems allow drivers to search for available spots independently without any technological assistance. However, they tend to be:

- **Time-Consuming**: Drivers may spend significant time without finding a parking spot.
- **Inefficient**: Random searching leads to inefficient use of parking space.
- **Not Scalable**: As vehicle numbers increase, these systems fail to accommodate the higher demand effectively.

How IoT-Based Solutions Help

The integration of IoT-based solutions in car park systems addresses the pain points of the current solutions by allowing customers to reserve parking bays near elevators before arriving. The parking lot will be split into different gated sectors, and for customers who don't want to book, there will be an area of open parking at the entry. Upon arrival, RFID-enabled gates grant access to each sector, and the IoT system navigates them directly to their booked sector. When leaving, the system guides customers back to their vehicle, eliminating the hassle of searching for their car. Contactless payment using the ERP system ensures a seamless exit. This solution reduces the time spent finding parking and locating vehicles, improving customer satisfaction. At the same time, it enables malls to collect valuable data for dynamic pricing and boosts overall parking efficiency.

Reservation System

- **Advance Booking:** Customers can book parking spaces in advance using a mobile app.
- **Sectional Allocation:** The parking lot is divided into sections (A to D and walk-in areas) based on proximity to amenities like elevators. Section A is the most convenient, while Section D is the least.

Automated Entry and Exit

- **Frictionless Access:** The use of RFID tags or license plate recognition automates barrier systems, allowing vehicles to enter and exit without stopping.
- **Reduced Congestion:** Streamlines vehicle flow at entry and exit points, decreasing wait times.
- **Centralized Monitoring:** Real-time tracking of vehicle movements enhances security and operational efficiency.

Real-Time Parking Availability

- **Sensor Installation:** Occupancy sensors are placed in each parking bay to detect availability.
- **Instant Updates:** Availability is updated in real-time on a central system accessible via a mobile app or digital signage.
- **Reduced Search Time:** Drivers can navigate directly to available spots, minimizing time spent searching.

Guided Navigation

- **In-App Directions**: The mobile app provides step-by-step navigation to the reserved parking bay using GPS-like features.
- **Exit Assistance**: Guides customers back to their vehicles and directs them to the nearest exit when leaving.
- **Enhanced User Experience:** Simplifies the parking process, reducing stress and improving satisfaction.

Potential Challenges

Device and Infrastructure Costs Implementing the system involves significant upfront investment in sensors, cameras, and other IoT devices. In addition to these initial costs, ongoing maintenance expenses are required for system updates, repairs, and technical support to ensure the infrastructure remains operational and efficient.

Data Processing Capabilities: The system needs to be scalable, and capable of handling large volumes of data without compromising performance. Additionally, ensuring high reliability is crucial, with consistent uptime and fast data processing to maintain real-time updates and system responsiveness.

User Adoption: Technological barriers may arise as less tech-savvy individuals could find the new system confusing or intimidating. Additionally, there may be resistance to change, with some customers preferring traditional parking methods and hesitating to adopt new technologies.

Compliance and Enforcement: Unauthorized access could occur if drivers attempt to park in reserved sectors without proper authorization. To prevent misuse, an effective penalty system must be implemented, including fines or access restrictions as deterrents.

2. Proposed IoT Solution

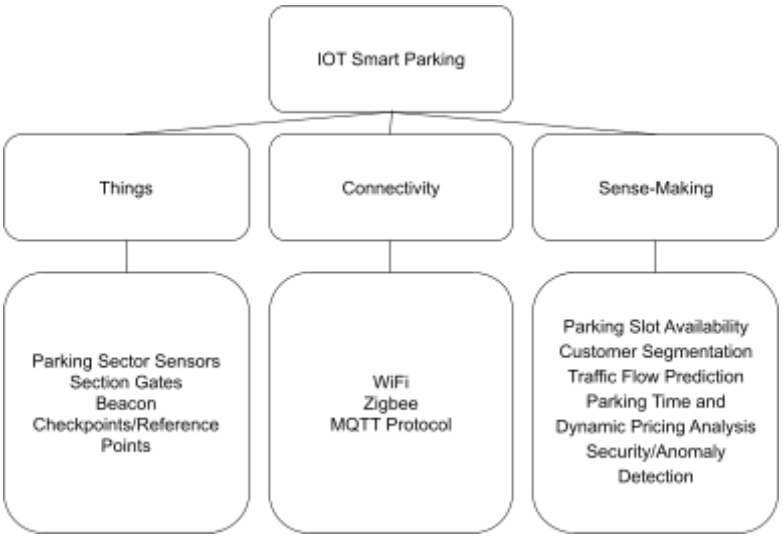

Figure 1. High-Level Architecture Diagram

Hardware

Parking Slot Sensors (Ultrasonic/Infrared with Zigbee Communication)
Ultrasonic or infrared sensors are cost-effective and reliable for detecting parking slot occupancy, offering accurate measurements in confined spaces and easy deployment and maintenance. Integrating these sensors with Zigbee enhances efficiency due to its low power consumption, ideal for battery-operated devices. Zigbee enables wireless, real-time transmission of occupancy data to the central system, eliminating the need for extensive cabling. Its mesh networking capabilities improve communication reliability in environments with limited direct line-of-sight.

Section Gates (Motorized Barriers with RFID)
Motorized barriers with RFID control access to different parking sections based on customer levels (e.g., VIP, regular), enhancing the customer experience while maintaining strict access control. RFID readers are efficient for frequent users, allowing regular customers to link RFID tags to their accounts for fast processing and reduced wait times at entry and exit points.

Connectivity

Zigbee Network: Zigbee is a low-power, short-range communication protocol ideal for sensor-to-sensor communication in environments with multiple sensors like parking lots. It conserves energy and is highly efficient for battery-powered devices such as parking slot sensors. Its mesh networking allows devices to relay data through each other, extending network range and improving reliability. Scalability is facilitated by easily accommodating additional sensors as the system grows. Careful network planning is required to manage interference from other devices operating in the 2.4 GHz band, and deploying Zigbee routers or repeaters ensures consistent signal coverage throughout the parking facility.

MQTT Protocol: MQTT is a lightweight messaging protocol designed for devices with minimal bandwidth, ensuring fast and reliable communication between sensors and the central system for near real-time transmission of parking slot data and control commands like opening barriers. Integrated with Zigbee via a Zigbee-to-MQTT gateway that converts Zigbee messages to MQTT format, its publish/subscribe model facilitates efficient data distribution and scalability, seamlessly handling numerous devices. Key advantages include low bandwidth consumption—optimizing network resources for managing large numbers of devices—and high reliability, with MQTT Quality of Service levels ensuring message delivery according to system needs.

Beacon Checkpoints/Reference Points: Beacon checkpoints enhance navigation and location services within the parking facility. Utilizing Bluetooth Low Energy (BLE) technology compatible with most smartphones, these beacons interact with a mobile app to help users locate reserved parking spots or find their vehicles, and deliver personalized, location-based notifications like promotions or alerts. Key

considerations include ensuring the mobile app effectively integrates beacon signals for accurate positioning and strategically placing beacons to provide comprehensive coverage and reliable location data.

Sense-Making

Parking Slot Availability: Monitoring the number of available parking slots is the core function of the smart parking system. This information allows users to view the number of vacant spots per sector in real-time, reducing time spent searching for parking. Also, the system can better use available space by dynamically adjusting section availability, saving time. We will use ultrasonic sensors to collect data on the available parking slots.

Customer Segmentation: By analyzing data from RFID readers at section gates, the system classifies customers into levels like VIP, regular, or open parking. When vehicles enter or exit, their RFID tags are scanned, and this information is sent via Zigbee using the MQTT protocol to the central system. This allows the system to recognize customers and their parking habits, enabling features like reserved sections or dynamic pricing based on customer categories, enhancing user experience and optimizing revenue. The data can also integrate with the mall's customer management system for targeted promotions and personalized offers.

Traffic Flow Prediction: Real-time data from parking slot sensors and section gate devices helps in understanding and predicting traffic flow within the parking area. Ultrasonic or infrared sensors detect vehicle presence and transmit occupancy status via Zigbee. RFID readers at section gates record when customers enter or exit sections. This data communicated efficiently through MQTT, allows the system to monitor vehicle movements and analyze traffic patterns. The system can then guide users to less congested areas through the mobile app or digital signage, improving flow and reducing bottlenecks.

Parking Time and Dynamic Pricing Analysis: Entry and exit times are recorded when customers scan their RFID tags, and parking slot sensors confirm when a vehicle occupies or leaves the sector. This data, transmitted via Zigbee and managed using MQTT, lets the system calculate each customer's total parking duration. This enables dynamic pricing strategies, such as charging based on time spent or during peak hours, and provides insights into parking patterns, helping the mall optimize space usage and maximize revenue.

Table 1: Cost Structure of the Project

Components	Quantity	Cost per unit	Total Cost
Parking Sensors (Ultrasonic)	100	$10	$1000
RFID Readers	10	$25	$250
Sections Gates	4	$250	$1000
Wifi routers/ Zigbee Hubs	5	$100	$500
Microcontrollers	20	$30	$600
Total			$3350

3. Project Plan

The project will be completed in three phases. The first phase would be to conduct research, development, and testing, followed by implementation, and finally by data analysis and machine learning. Sub-tasks for each phase will be listed below in detail:

Table 2: Project Timeline

Task Description	Description	Start Date	End Date	Elapsed Time
Project Planning & Research	Conduct initial research on micro capabilities, IoT architecture, and software requirements. Finalize hardware/software stack.	1	7	7
Hardware Setup & Testing	Set up micro for parking slot availability detection. Prototype testing for sensor integration (e.g., ultrasonic sensors for slot detection).	8	15	8
Parking Slot Segmentation Design	Design segmentation of parking spaces (near door/elevator too far) and integrate with reservation and payment systems (online & ERP-based options).	16	24	9
System/ App Development (Reservation & Payment Integration, Navigation System, Frontend Development, Backend and Database Setup	Develop a comprehensive parking management system that includes features for reserving parking slots, integrating with online and ERP-based payment gateways, providing navigation guidance to reserved slots, and creating a user-friendly interface for managing reservations, payments, and parking availability. Additionally, develop a robust backend system to handle parking data, reservations, user information, and payment history.	25	67	43
Data Analysis & ML Planning	Plan future machine learning integration to analyze parking trends and implement dynamic pricing based on availability and demand.	68	74	7
Testing & QA	Perform system-wide testing to ensure the proper functioning of all modules (hardware, frontend, backend, navigation, payment, etc.).	75	82	8
Deployment & Maintenance	Deploy the system in the parking area, ensure smooth functioning, and plan for ongoing maintenance, bug fixes, and updates.	83	90	8

Timeline Overview:
The total duration of the project will be around **90 days**.

Milestones:

- Week 1: Project Planning & Research Completed
- Week 3: Hardware Setup & Segmentation Design
- Week 5: Reservation, Payment, and Navigation Systems Implemented, Frontend, & Backend
- Week 7: Data Analysis & Machine Learning Planning
- Week 10: Testing, Deployment, and Maintenance

4. Current Progress/Preliminary Work Done

We attempted to conduct some research on how to implement it through Micro Bit. We use the Ultrasonic Sensor HC-SR04 to determine whether or not a parking space was occupied. As shown in the image below, it can be checked over time.

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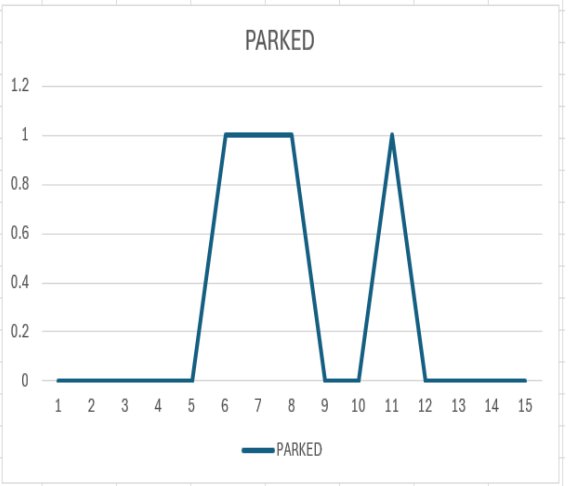
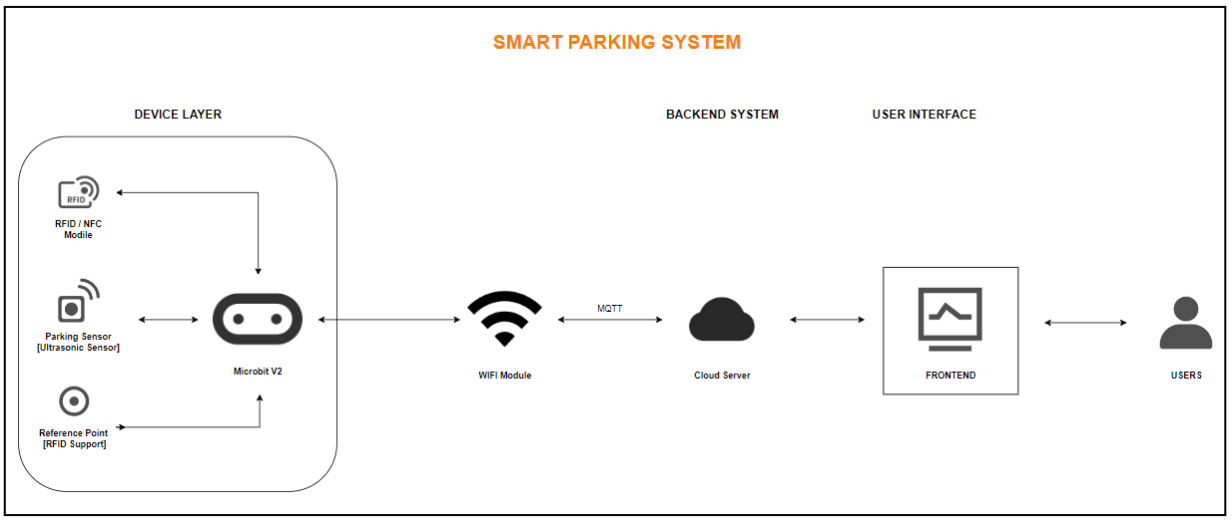
```
park = False

def on_every_interval():
    datalogger.log(datalogger.create_cv("X", park))
loops.every_interval(1000, on_every_interval)

def on_forever():
    global park
    if grove.measure_in_centimeters(DigitalPin.P1) < 10:
        park = True
        basic.show_leds("""
            . . # . .
            . # # # .
            . # # # .
            . # # # .
            . . . . .
            """)
    else:
        park = False
        basic.show_leds("""
            # # # # #
            # . . . #
            # . . . #
            # . . . #
            # # # # #
            """)
basic.forever(on_forever)
```

time (Hour)	PARKED
0.002	FALSE
1.003	FALSE
2.004	FALSE
3.009	FALSE
4.019	FALSE
5.032	TRUE
6.043	TRUE
7.058	TRUE
8.064	FALSE
9.074	FALSE
10.081	TRUE
11.09	FALSE
12.092	FALSE
13.103	FALSE
14.114	FALSE



To improve the implementation, we will set the sensor to check every minute or 30 seconds. We will also include different kinds of vehicles like sedans, SUVs or motorbikes.

Our smart parking system architecture consists of three layers: the device layer, the backend, and the user interface. The device layer consists of ultrasonic sensors for parking spot detection and RFID/NFC modules for reservations, all managed by a Micro V2. Data is sent to the backend via a Wi-Fi module and then processed using MQTT on a cloud server. Users can access real-time parking data, reservations, and payment options via a frontend interface, with future machine learning integration for dynamic pricing.



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Product Search

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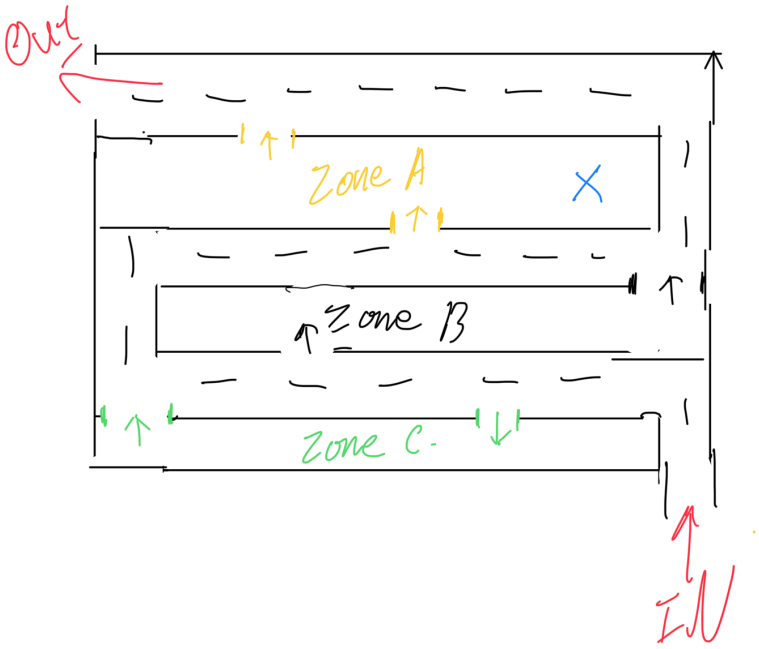
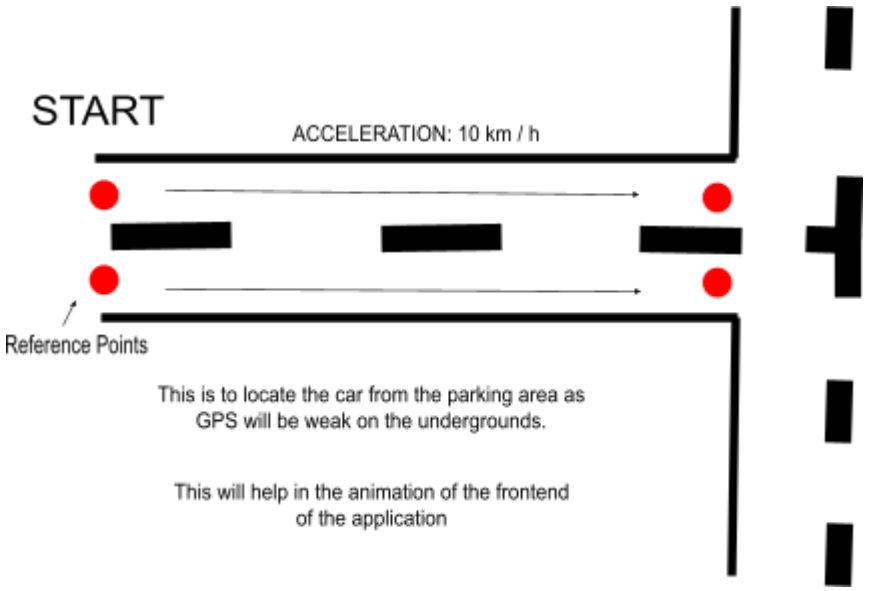
Appendix



Sample Illustration for Parking Architecture - 1



Sample Illustration for Parking Area Reference Point

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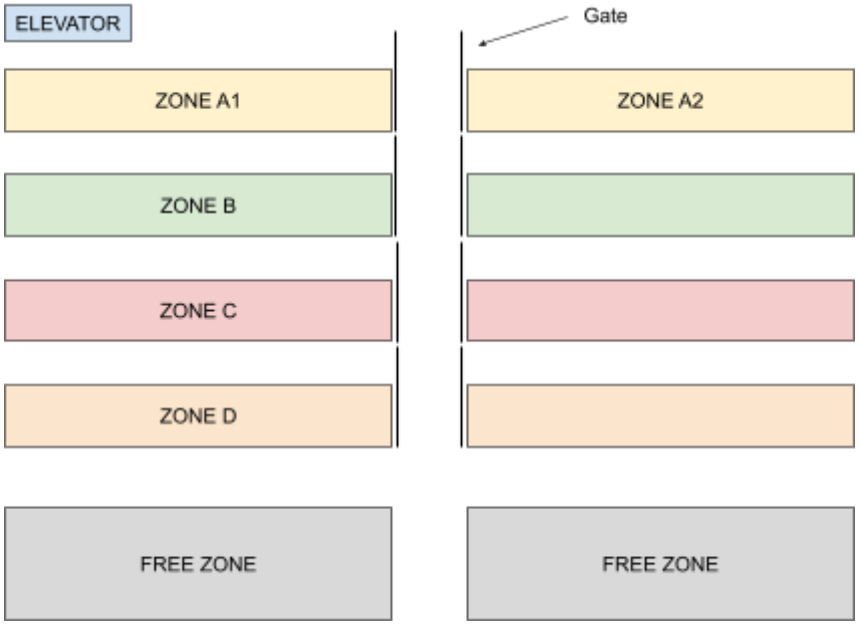

Sample Illustration for Parking Architecture - 2