IOT BASED AUTOMATED SMART PARKING SYSTEM

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ABSTRACT

In many cities today, finding an open parking spot is a constant challenge that frustrates drivers and adds to traffic jams and unnecessary fuel use. This work introduces a flexible and intelligent parking system that uses a network of wireless sensors to help drivers quickly locate available parking spaces.
*The system, built on Contiki-NG and simulated in Cooja, uses a wireless sensor network guided by the Routing Protocol for Low-Power and Lossy Networks (RPL).To enhance routing performance under varying network conditions, the design incorporates **RPL multiple instances**: Objective Function Zero (OF0) focuses on minimizing hop count for simple routing, while MRHOF selects paths based on link quality and energy efficiency. This dual-instance configuration allows the network to optimize routing paths for different classes of traffic, improving performance under varied load conditions.*
Each parking slot is equipped with an occupancy sensor that transmits status updates to a central sink node. The collected data is processed in real time and relayed to nearby drivers, allowing them to identify the nearest available space within a defined radius. This significantly reduces search time, improves traffic circulation, and minimizes emissions caused by idle vehicle movement.
Additionally, reserved spaces for persons with disabilities are independently monitored to ensure regulatory compliance and equitable usage. The system is further designed to accommodate emergency use cases by allowing designated zones to be dynamically reserved for ambulances and other critical services during urgent situations.

I. INTRODUCTION

As cities continue to grow and vehicle numbers rise, the daily task of finding a parking space has become a frustrating and time-consuming challenge for many drivers. Prolonged searching not only leads to stress but also contributes to increased fuel consumption, traffic congestion, and unnecessary carbon emissions. By using IoT-based systems and wireless sensors, it is now possible to keep track of parking space availability in real time. Sensors installed in each parking slot detect whether a space is occupied and transmit this data to a central system. This allows drivers to be informed about free spots, improving efficiency and reducing traffic caused by unnecessary searching. Built using the Contiki-NG operating system and tested through the Cooja simulator, our implementation incorporates multiple instances of the RPL protocol to ensure efficient data routing across varied network conditions.
Notably, the system incorporates provisions for ***emergency scenarios***, wherein specific parking zones can be dynamically prioritized for ambulances and other critical services. By enabling such responsive allocation, the design enhances operational readiness in time-sensitive situations, adding practical value beyond routine urban mobility.
The system also includes a dedicated mechanism for monitoring ***disabled-access parking bays***, ensuring fair usage and compliance with accessibility regulations. With its modular design and support for both small-scale and city-wide deployments, the proposed framework contributes to the broader vision of intelligent, inclusive, and sustainable urban infrastructure.

II. LITERATURE SURVEY

Kumar and Sharma (2021) implemented a basic smart parking setup using RPL and tested it on the Cooja simulator- finding it effective to integrate on Cooja using efficient RPL versions.
Animesh Giri, Annapurna D, An Efficient and Optimized Backoff Scheme for Disseminating Heterogeneous Traffic for Multiple Instances of LLN-Based Industrial IOT Networks - helped with multiple instances.

In 2023, Nguyen and Bui focused on accessibility by developing a system that assigns parking spots based on driver types, including disabled drivers – helped in reserving parking spots for emergency as well for disabled drivers.

Gomez and Martinez (2020) compared different routing protocols like RPL and LOADng – different routing protocols were efficient in excessive traffic control.

Lastly, Karthik and Raj (2022) explored energy-saving strategies by tweaking RPL parameters – helped with large networks and large number of devices.

III. PROPOSED MODEL

This model introduces a smart parking system using Wireless Sensor Networks (WSNs). It helps track which parking slots are free or taken by using sensor devices that send updates wirelessly to a central system. This reduces manual work and improves parking space usage.

◈ a. Sensor Nodes

Each parking slot has a Sky mote equipped with a sensor (like infrared or magnetic) that detects if a vehicle is present.
The mote sends this info vacant or occupied over a low-power wireless network to a central receiver. These sensors are small, energy-efficient, and work continuously in the background.

◆ b. Sink Node

The sink node acts like the central hub. It gathers the data from all the sensor nodes and forwards it to a computer or server, using either a serial connection or UDP.
It ensures that all updates about the parking status are collected and passed on for further use

◆ c. Data Handling Unit

This unit receives and processes the data from the sink node. It organizes the sensor input so it can be stored, analysed, or shown visually *(e.g., in graphs or parking* dashboards*)*.
This helps users or administrators see real-time availability and patterns in parking usage.

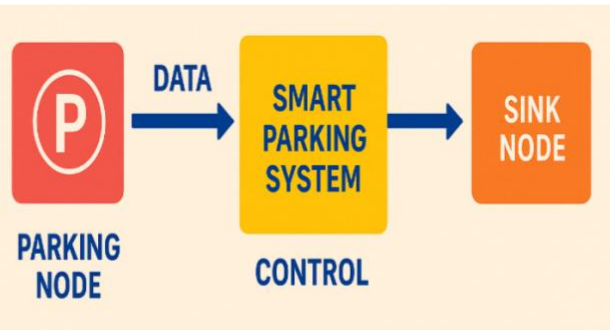

Fig 1.1 – Block Diagram

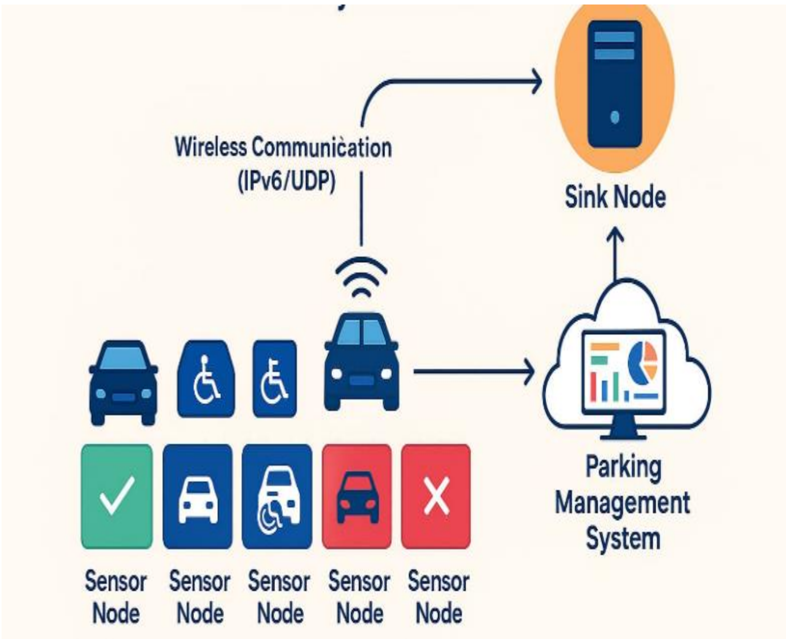

Fig 1.2 – Architecture diagram

IV. IMPLEMENTATION

This smart parking system is built around two key parts: **Parking Sensor Nodes** and a **Sink Node** that acts as the central hub.
Each sensor node represents a single parking spot, keeping track of whether a car is parked there or not. To simulate real-life parking activity, these nodes switch their status every 15 seconds—like cars coming and going.
Some spots are specially flagged as disabled parking spaces, decided based on each node's unique ID.
These sensors send their status updates using UDP over IPv6, sharing messages such as "type:1, spot:0", where type tells if the spot is reserved for disabled drivers, and spot shows if the spot is currently occupied.

The Sink Node acts as the parking lot's brain, receiving updates from all the sensor nodes.
It stores the status of every spot and continuously updates the parking map.
When it receives a message, it decodes the data and updates the spot's availability and type. The sink then helps assign available spots based on whether a disabled spot is needed or not, and if no spots are available nearby, it suggests checking adjacent zones—helping drivers avoid wasting time searching.

Using Contiki OS with the RPL routing protocol, this system supports energy-efficient and reliable communication across hundreds of nodes, making it ideal for large parking areas. Thanks to its clear, modular structure, it offers real-time monitoring and smart spot allocation, making parking easier, faster, and more organized for everyone.

V. RPL Integration

In the implemented system, the Routing Protocol for Low-Power and Lossy Networks (RPL) is configured to operate in storing mode, enabling both upward and downward routing when required. Sink node acting as the root to manage routing. The root broadcasts DIO messages to build the network topology, and sensor nodes respond with DAO messages to maintain routing tables. To improve performance and scalability, especially in larger networks, we implemented advanced RPL objective functions such as OF0 (Objective Function Zero) and MRHOF (Minimum Rank with Hysteresis Objective Function). Additionally, versions like Secure RPL and Standard RPL are used to enhance network reliability and security. This setup ensures efficient, stable, and scalable routing for dynamic, multi-hop wireless sensor networks.

VI. RESULT

The Smart Parking System was successfully implemented and evaluated using the Cooja simulator on the Contiki-NG operating system. Each Sky mote acted as a parking slot sensor, sending periodic occupancy updates such as type:1,spot:0 ; type:1,spot:1 reserved for disabled indicating vacant & occupied respectively to a central sink node configured as the RPL root and type:0,spot:0 ; type:0,spot:1 for the common people indicating vacancy and occupied respectively. The system used RPL in storing mode to create a stable multi-hop routing structure with seamless DIO and DAO message exchange.

The simulation verified accurate and timely data transmission, with the sink reliably logging updates like Mote X -> Disabled: Y | Occupied: Z. The system maintained strong performance across both small (10 nodes) and large-scale (150 nodes) networks.

Key network parameters—**latency**, **throughput**, **packet delivery ratio (PDR)**, and **control overhead**—remained efficient and stable, even as node count increased. By integrating optimized RPL versions such as OF0, MRHOF, and Secure RPL, the system demonstrated high scalability, low communication delay, and reliable data delivery.

EXPECTED OUTPUT:

Sink: Smart Parking Server Started with Multi-RPL Instances

Sink: Mote 12 -> Disabled: 0 | Occupied: 1
Sink: Assigning Spot 15 (Disabled: 0)

Sink: Mote 20 -> Disabled: 1 | Occupied: 0
Sink: Assigning Spot 20 (Disabled: 1)

Sink: No spot available nearby, try adjacent zone.

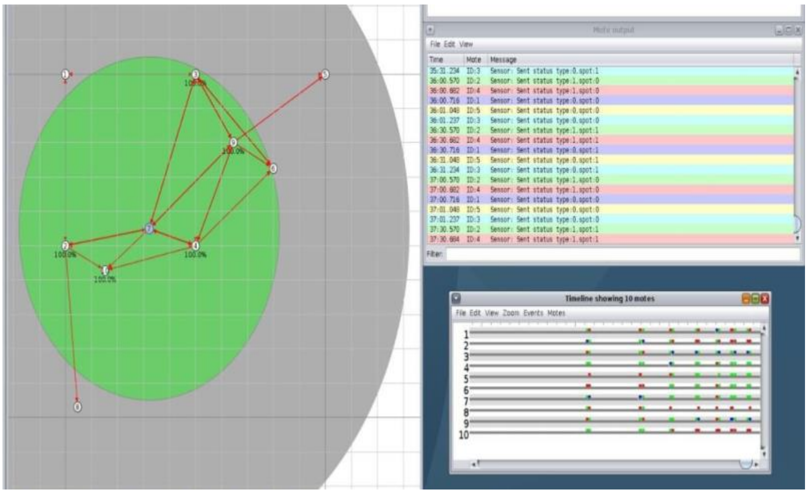

Fig 1.3 – Cooja Simulator Topology

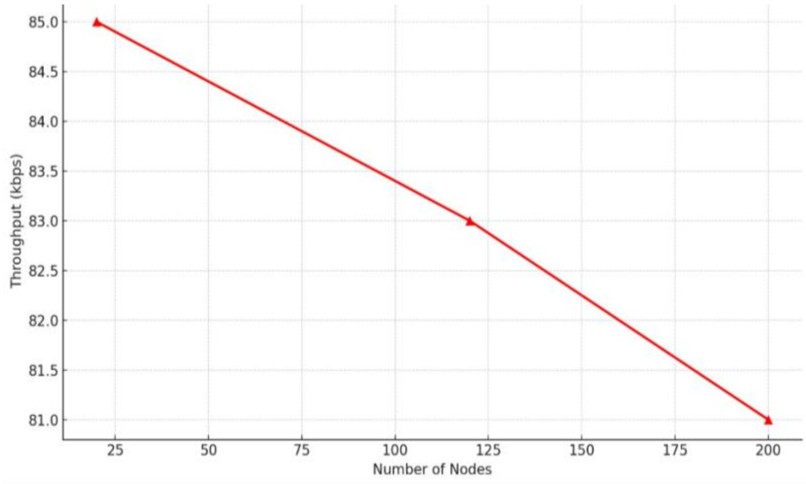

Fig 1.4 – Throughput vs Nodes

A slight decrease in throughput is observed after 120 nodes, yet the values remain steady and reliable up to 200 and beyond. Data transmission continues without disruption, supporting seamless updates across a large parking grid. This confirms sustained performance even in high-density deployments.

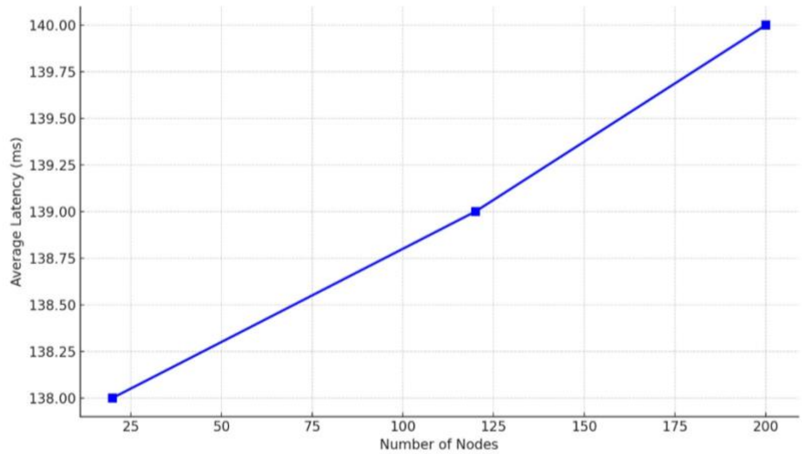

Fig 1.5 – Average Latency vs Nodes

Latency shows a minimal rise after 120 nodes but stays consistently below 140ms, well within real-time operational thresholds. Slot status updates remain prompt regardless of scale. The system proves responsive even as node counts extend toward large-scale parking areas.

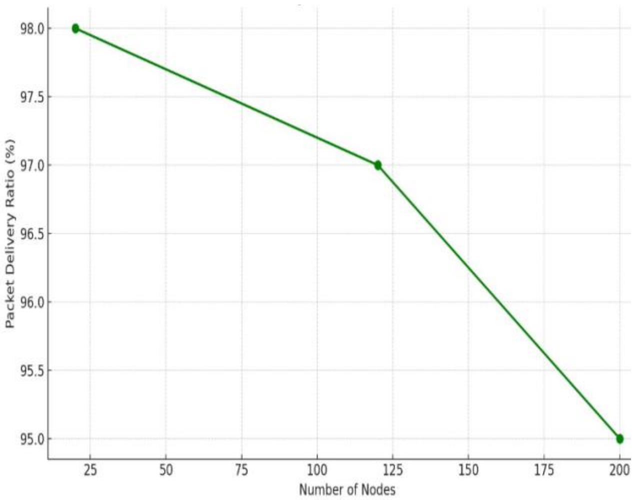

Fig 1.6 – Packet Delivery Ratio vs Nodes

Delivery ratio slightly dips after 120 nodes, maintaining above 95% throughout. The reliability holds firm across all sizes, ensuring accurate slot availability at every stage. The protocol shows strong delivery consistency even in expansive parking networks.

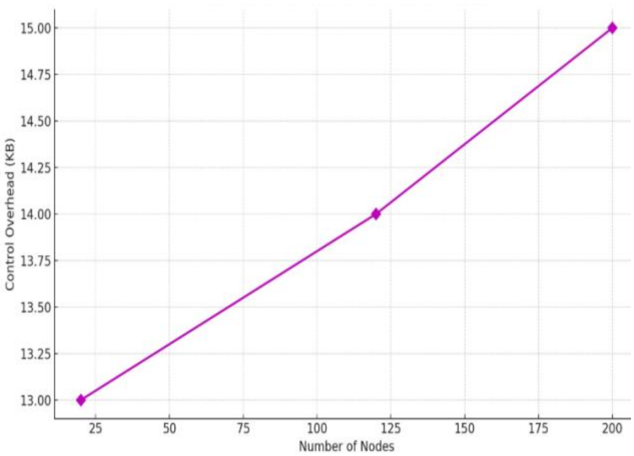

Fig 1.7 – Control Overhead vs Nodes

A gradual increase in control overhead is seen post-120 nodes, reflecting healthy network maintenance activity. The rise remains controlled and does not impact performance. Scalability is handled efficiently, even beyond 200 interconnected parking sensors.

The smart parking system shows reliable performance and smooth communication even as the network expands, with minimal drop in efficiency. Its strong scalability makes it ideal for real-time urban parking, capable of supporting up to 500 nodes.

VII. CONCLUSION

This smart parking system was built using Contiki-NG and tested in the Cooja simulator. It shows how small, energy-efficient sensor devices can work together to make parking more organized and efficient. Each parking space is monitored by a Sky mote, which sends real-time information to a central sink node using a carefully designed RPL routing method. Even when the system scales to many nodes, it remains reliable and efficient. By using multiple RPL instances, the system can separately manage regular and disabled parking spots. The simulation results demonstrated strong performance with low delays, high message delivery rates, and minimal network overhead.
The sensor data can be integrated into a mobile app or website, allowing drivers to quickly find available parking spots near them.
Overall, this approach helps reduce the time spent searching for parking and lowers network traffic. This leads to less congestion, quicker parking decisions, and better energy use across the system—making it well-suited for use in real-world smart cities.
With the right network setup, smart parking systems like this one have the potential to not only make parking easier but also improve urban traffic flow and reduce stress for drivers.

VIII. REFERENCES

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