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Review on Response Time Based Iot Middleware for Smart City Application

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***Abstract:* -** This paper investigates the significance of response time in Internet of Things (IoT) middleware for smart city applications. Our proposed middleware prioritises quick data transfer, which improves real-time decision-making, which is crucial for managing various city functions like waste management, traffic control, and energy distribution.

In the busy landscape of modern cities, the integration of smart technologies has become imperative for efficient management and improved quality of life. One critical aspect is the timely exchange of data between various devices and systems, facilitated by IoT middleware.

In this review, we examine the body of research, assessing various methods and tools used in response time-based Internet of Things middleware. We look at their advantages, disadvantages, and suitability for smart city settings.

We also address other issues like interoperability, security, and scalability, and we provide suggestions for future research directions and possible solutions.

Overall, our article underlines the critical importance of reaction time optimization in IoT middleware for developing smarter and more responsive cities.

We hope to offer insightful information to scholars, developers, and legislators who are committed to promoting smart city infrastructure through an review.

Keywords: Response Time, Smart City Application, IOT Middleware, Edge Computing, Data Analytics.

I. Introduction

Cities are getting smarter by utilising cutting-edge technologies to boost productivity and raise resident quality of life in today's quickly changing urban landscapes. The Internet of Things (IoT), a key technology facilitating this transition, links disparate systems and gadgets to gather and share data. IoT middleware is essential to the concept of smart cities since it acts as the connecting element between various systems and devices, facilitating easy data exchange and communication [2]. But in a city, where everything moves quickly and seconds matter greatly, how quickly data is processed and shared is critical.

The importance of response time in IoT middleware for applications related to smart cities is the main topic of this review study. In the context of smart cities, response time—which is the length of time it takes for a system to respond to a request or input—directly affects the efficiency of decision-making and the general performance of operations throughout the city [1].

We seek to investigate how reaction time optimisation can improve the operation of IoT middleware in smart city settings by reviewing current literature and technological advancements [5]. We will explore several strategies, tactics, and obstacles related to reaching ideal reaction speeds, providing knowledge that can guide upcoming innovations and applications.

Ultimately, we can create more responsive, efficient, and integrated urban ecosystems that benefit both citizens and local government officials by realising the significance of response time in IoT middleware for smart cities.

In conclusion, a review of response time-based IoT middleware for smart city applications is required to understand its significance, assess current advancements and limitations, and guide future research and development efforts to build more resilient and responsive smart city infrastructures.

II. Literature Survey

In [1], the study goes into the challenges and potential for creating sustainable smart cities using IoT technologies. It evaluates the available literature and identifies critical research directions for constructing efficient and environmentally friendly urban environments. One important point raised in the study is the use of reaction time-based IoT middleware. This middleware is critical to improving the efficiency and responsiveness of IoT systems

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in smart cities. Response times are optimised, which increases real-time data processing, decision-making, and overall system performance, contributing to the sustainability and effectiveness of smart city efforts.

In [2], the study introduces DASTData, a fog-cloud paradigm for managing distributed storage and traceability of IoT data in smart cities. It addresses issues connected to managing the massive amounts of data created by IoT devices in urban settings. The emphasis is on building a strong infrastructure for data storage and tracing, which will improve the usefulness and reliability of smart city apps and services. Ferries, Righi, and Rodrigues' study focuses on the application of reaction time-based IoT middleware. They investigate how such middleware solutions help to reduce latency, improve system responsiveness, and maximise resource utilisation in smart city contexts.

The study article in [3] looks into the scalability problems that real-time IoT-based systems confront in smart cities. It delves into the complexity of dealing with massive amounts of data created by IoT devices, as well as the necessity for scalable solutions to support the expansion of smart city infrastructure. The research investigates the use of reaction time-based IoT middleware as a possible approach for increasing the scalability of real-time IoT applications in smart cities. It examines how such middleware can increase system responsiveness, reduce latency, and optimise resource utilisation, allowing IoT-based applications to expand successfully in response to the growing demands of smart city environments.

Paper [4] describes a generic IoT middleware developed primarily for smart city applications. It intends to solve the many requirements and complexity of IoT deployments in urban areas. The study focuses on creating a flexible and scalable middleware solution that can support a variety of IoT use cases in smart cities. The authors investigate the use of reaction time-based IoT middleware as a key component of their generic middleware system. They talk about how this middleware improves the responsiveness and efficiency of IoT systems in smart cities by lowering latency, optimising data processing, and overall system performance. This integration emphasises the critical role of reaction time-based middleware in allowing successful and dependable IoT deployments for smart city applications.

In [5], the study investigates smart city IoT data management from a proactive perspective. It attempts to overcome the issues of successfully managing and utilising IoT-generated data in urban settings. The research focuses on establishing strategies and methodologies for improving proactive data management in smart city situations. The report makes no specific mention of the usage of reaction time-based IoT middleware in its investigation.

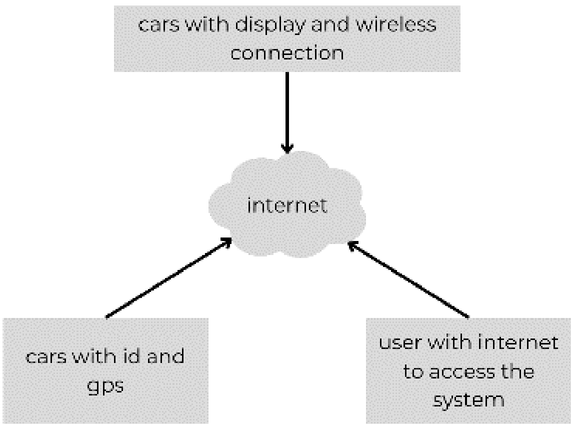

Fig. 1. Architecture of Smart Parking

The article [6] investigates the integration of artificial intelligence (AI) applications and self-learning capabilities into 6G networks to improve smart city digital ecosystems. It looks into how these technologies might improve different elements of urban life, such as transportation, energy management, and public services, hence accelerating the development of smart cities. The report does not particularly address the usage of response time-based IoT middleware. Instead, it focuses on AI applications and self-learning capabilities in 6G networks to enhance smart city digital ecosystems.

Research paper [7], introduces an Internet of Things (IoT)-based smart car tracking system. It investigates the design and execution of a real-time vehicle tracking and monitoring system. The system gathers data and sends it over the internet for analysis and visualisation using Internet of Things gadgets like sensors and GPS trackers. Response time-based IoT middleware is not specifically mentioned in the paper's research. Rather, it concentrates on the creation and operation of the Internet of Things-based smart car tracking system.

In [8], a middleware solution designed specifically for wireless Internet of Things applications in sparse smart cities is presented in the research paper. It tackles the difficulties brought up by spotty IoT device deployment and poor connectivity in such settings. In its role as an intermediary layer, middleware improves the dependability and efficiency of wireless IoT installations in sparsely populated metropolitan regions by enabling communication and data exchange between IoT devices and applications. Depending on its topic, the article may or may not discuss the use of reaction time-based IoT middleware.

In research article [9], an information-centric platform designed for location- and social-aware Internet of Things applications in smart cities is presented. It focuses on integrating location and social data into Internet of Things technologies in order to meet the changing needs of urban areas. The platform makes it easier to create cutting-edge apps that use this data to improve public safety, healthcare, and transit, among other facets of urban life. Depending on its topic, the article may or may not discuss the use of reaction time-based IoT middleware.

The study in [10] presents an aspect-oriented strategy for addressing time-constrained strategies in smart city IoT applications. It presents a framework that enables the modularization of time-sensitive capabilities, resulting in better resource management and optimisation in IoT deployments in smart cities. By embracing aspect-oriented programming ideas, the technique makes it easier to create efficient and scalable IoT systems that are tuned to the real-time needs of urban environments. The paper may or may not explicitly cover the usage of reaction time-based IoT middleware, depending on its topic.

The study in article [11] provides a comprehensive assessment of the available literature to investigate the role of big data analytics in promoting data-driven decision-making in smart cities. It investigates diverse research, theories, and approaches linked to big data analytics in urban environments, with the goal of providing insights into the problems, opportunities, and best practices for exploiting big data in smart city efforts. The report does not specifically address the usage of response time-based IoT middleware. Instead, it concentrates on examining the literature on big data analytics for smart cities.

The research paper [12] offers a thorough examination of IoT applications inside a smart traffic management system. It explores numerous studies, methods, and applications including the use of IoT devices and sensors in traffic management to improve efficiency, safety, and sustainability. The report seeks to explore trends, difficulties, and opportunities for using IoT for intelligent traffic control and optimisation. Depending on its topic, the article may or may not address the use of response time-based IoT middleware. Overall IOT information is described with the help of IoT = Real-Time Physical Information + Appliances +Network Media.

The research study [13] describes an integrated framework for managing information successfully in smart cities. It describes the design and execution of a comprehensive system for gathering, processing, and analysing data from a variety of sources in urban settings. The platform's goal is to give decision-makers with vital information into how to improve city operations, enhance services, and manage urban concerns. The report may not explicitly mention the usage of response time-based IoT middleware.

study paper [14] conducts a survey on the notion of smart cities, with an emphasis on the implementation of the Cloud of Things (CoT) paradigm. It investigates the concept and paradigms connected with smart cities, covering topics such as infrastructure, services, government, and sustainability. The paper's goal is to provide insights on the growth of smart city concepts and the role of CoT in advancing urban development. The report does not specifically address the usage of response time-based IoT middleware. Instead, it examines the smart city vision and paradigms, including the incorporation of CoT.

In [15] research study analyses current trends and makes recommendations for developing and implementing IoT-based smart city applications. It investigates the changing landscape of IoT technologies in urban settings, highlighting emerging issues such as edge computing, interoperability standards, and data privacy. The paper discusses best practices, challenges, and possibilities for using IoT to build more efficient, sustainable, and liveable smart cities. The usage of reaction time-based IoT middleware may not be particularly discussed in the article, depending on its topic.

III. IDEA BEHIND SMART CITY

Smart cities are optimised by integrating technology and data-driven solutions to increase efficiency, sustainability, and people' quality of life. Here are some techniques for optimising smart cities:

a) Integrated Infrastructure: Create integrated systems that link many parts of city infrastructure, including transportation, energy, water, waste management, and public services. This connection enables better resource management and service delivery.

b) IoT Sensors and Data Analytics: Install IoT sensors across the city to collect data on numerous characteristics such as traffic flow, air quality, energy usage, and garbage generation. Analyse this data with modern analytics tools to generate insights and make data-driven decisions to improve city operations.
c) Smart Mobility: Implement intelligent transportation technologies, such as real-time traffic monitoring, smart parking solutions, and public transportation optimisation [8]. This can help to minimise traffic congestion, shorten commute times, and promote sustainable mobility options like biking and public transportation.
d) Energy Efficiency: Encourage energy-saving methods and technology such as smart grids, energy-efficient buildings, and renewable energy. This can help to cut energy usage, lower carbon emissions, and improve the resilience of the city's energy infrastructure.
e) Digital Governance: Use digital platforms and e-governance technologies to simplify administrative processes, improve service delivery, and increase public engagement [11]. This comprises online portals to government services, digital permitting systems, and open data projects.
f) Resilience and Disaster Management: Create methods and technologies to help the city withstand natural disasters and other catastrophes [14]. This could include early warning systems, catastrophe response strategies, and robust infrastructure designs.
g) Use urban planning and design approaches that emphasise walkability, mixed land use, and green spaces. This has the potential to make cities more habitable and sustainable, while also lowering dependency on automobiles and mitigating the urban heat island.
h) Citizen Engagement and Participation: Create a culture of citizen engagement and participation by including residents in decision-making processes and requesting feedback via digital platforms and community forums [10]. This can assist guarantee that smart city programmes are meeting the needs and preferences of the local populace.

IV. Feature Applications Of Response Time Based IoT Middleware

Response time-based. IoT middleware manages and optimises connectivity between IoT devices, edge computing nodes, and cloud services. Here are some use cases for response time-based IoT middleware:

a) Real-time Data Processing: The middleware processes data provided by IoT devices in real time, allowing for quick reactions to events and aiding time-sensitive applications like industrial automation, smart grid management, and emergency response systems.
b) Dynamic Resource Allocation: The middleware provides compute and network resources to IoT applications based on their reaction time needs [1]. This assures that vital apps have priority access to resources, hence improving overall system performance.
c) Edge Computing Offloading: The middleware evaluates response time limitations to determine whether data processing activities should be handled locally at the edge or offloaded to cloud servers. This decision-making mechanism reduces superfluous data transfer, lowering latency and conserving bandwidth.
d) Quality of Service (QoS) Enforcement: The middleware enforces QoS assurances by monitoring response times and ensuring that performance measures like latency, throughput, and reliability adhere to specified service level agreements (SLAs). This guarantees constant and predictable performance for IoT applications.
e) Adaptive Routing and Network Optimisation: Using reaction time data, the middleware dynamically adapts routing patterns and network settings to improve communication between IoT devices, edge nodes, and cloud services [12]. This adaptive technique boosts network efficiency and lowers latency.

V. Example Scenario – Smart Parking System

A city intends to deploy a smart parking system to maximise parking space utilisation, minimise traffic congestion, and improve the overall parking experience for residents and tourists. The system combines IoT devices, edge computing nodes, and cloud services, with reaction time-based middleware to provide efficient communication and real-time decision-making.

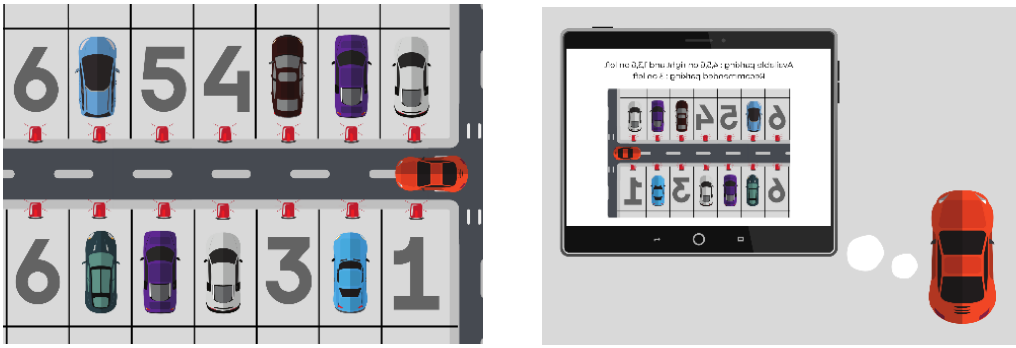

Fig. 2. Car Parking Flow

The Response Time-Based IoT Middleware in this scenario has the following features:

a) Real-Time Data Processing: IoT sensors deployed in parking lots detect vehicle presence and provide data to edge computer nodes [12]. The middleware processes this information in real time, calculating the availability of parking spots and updating the parking occupancy status.

b) Dynamic Resource Allocation: Depending on reaction time requirements, the middleware deploys computer resources at the edge and cloud levels to efficiently perform data processing activities. Critical activities, such as parking space identification and occupancy updates, are prioritised to reduce reaction times and assure timely availability of parking data.

c) Edge Computing Offloading: To decrease latency and preserve bandwidth, the middleware sends some processing activities, such as data aggregation and analysis, to edge computing nodes near parking lots [9]. Edge nodes execute localised calculations and connect with cloud services only when necessary, maximising resource utilisation and reducing data transmission times.

d) Quality-of-Service (QoS) Enforcement: The middleware provides QoS guarantees by monitoring response timings and ensuring that parking availability updates arrive within set time limits. It prioritises key parking-related signals above non-essential data to provide consistent and predictable performance for both drivers and parking operators.

e) Adaptive Routing and Network Optimisation: The middleware automatically adapts communication paths between IoT devices, edge nodes, and cloud services based on reaction time measurements and network circumstances. It optimises overall system performance by selecting the most effective data transmission pathways, taking into account aspects such as latency, bandwidth availability, and network congestion.

f) Fault tolerance and resilience: The middleware has fault tolerance methods to manage network outages, device malfunctions, and other interruptions [12]. In the case of a breakdown, redundant communication lines are activated, and data processing activities are redirected to other resources, ensuring the smart parking system's continuous operation.

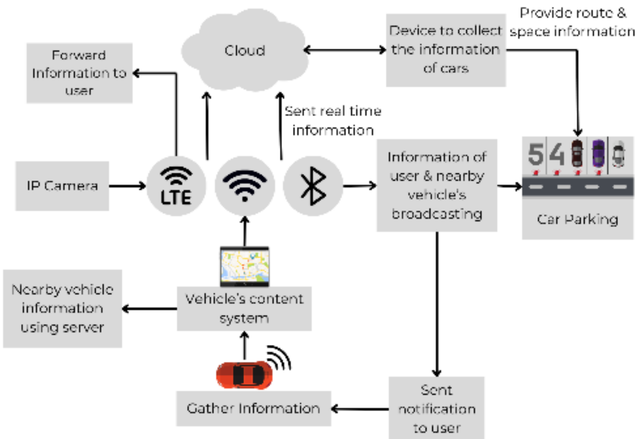

Fig. 3. Overview of Car Parking System

Example interaction: A vehicle approaches a parking lot and checks the availability of parking spaces via a smartphone app linked to the smart parking system. The app makes a request to the cloud-based middleware, which then routes it to nearby edge computing nodes for processing.

Edge nodes collect real-time data from IoT sensors, analyse parking occupancy status, and react to the app with available parking alternatives in milliseconds. The motorist receives real-time input on parking availability and navigates to the next empty space, decreasing search time and traffic congestion.

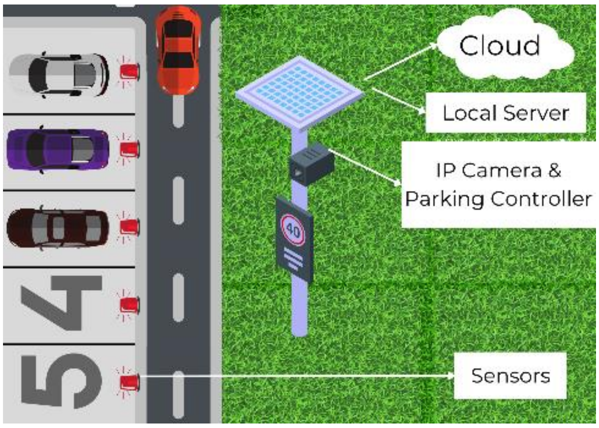

Fig. 4. IoT System of Car Parking

This example demonstrates how reaction time-based IoT middleware may improve the performance and reliability of smart parking systems, providing drivers with smooth access to parking information while also boosting urban mobility.

VI. Proposed Methodlogy Of Response Time Based IoT Middleware

The suggested approach for evaluating the effectiveness of a smart parking system includes many factors for measuring and optimising reaction times. Round-trip time (RTT), one-way delay, end-to-end delay, average response time, and queuing delay are all important measures for analysing system efficiency.

a) RTT quantifies the entire time it takes for a request to reach a server and the accompanying answer to return, providing information on overall communication delay.

RTT = Time of Arrival of Response - Time of Sending Request

b) One-way Delay refers to the time it takes for a request to go from sender to receiver or vice versa, which is especially important in real-time systems such as smart parking.

One-Way Delay = (Time of Arrival of Response - Time of Sending Request) / 2

c) c) End-to-End Delay measures the whole processing and response time cycle, indicating overall system performance.

End-to-End Delay = Time of Arrival of Response - Time of Sending Request

d) d) Average Response Time measures the average time spent processing requests for a given period, providing a full picture of operational efficiency.

Average Response Time = Σ (Response Time) / Number of Requests

e) Queueing Delay also accounts for delays caused by waiting for resources, exposing possible system bottlenecks.

Queueing Delay = Average Queue Length / Arrival Rate

By analysing these indicators together, stakeholders may get useful insights into the smart parking system's performance and suggest areas for development in order to increase user experience and operational effectiveness.

VII. Challenges And Limitations Of Response Time Based IoT Middleware

In the constantly growing field of Internet of Things (IoT) technologies, reaction time-based middleware in smart parking is critical for optimising system performance and improving user experience. Response time-based middleware seeks to address IoT applications' demanding latency requirements by prioritising timely communication and effective resource allocation. However, despite the great potential of this middleware approach, a number of obstacles and limits arise, ranging from technical complexities to operational constraints. Addressing these problems is critical to realising the full potential of IoT devices and guaranteeing their seamless integration into multiple sectors. This conversation goes into the numerous obstacles and constraints encountered by reaction time-based IoT middleware in smart parking, offering light on the intricacies involved in optimising system responsiveness and dependability.

a) Fault Tolerance and Resilience: Response time-based middleware must be resistant to failures, disturbances, and cyber assaults in order to maintain continuous operation and data integrity. Implementing fault tolerance methods, redundancy techniques, and disaster recovery plans is critical for reducing downtime and risk [4].
b) Cost and Complexity: Creating, installing, and maintaining reaction time-based middleware solutions may be expensive and difficult, especially for small-scale deployments or resource-constrained organisations [2] . Balancing performance needs and cost concerns is critical to ensuring the profitability and longevity of IoT installations.
c) Security and Privacy: Ensuring the security and privacy of data transported and processed by reaction time-based middleware is a significant difficulty. To protect against cyber attacks, ensure data integrity, and comply with privacy rules, strong security measures and encryption methods must be in place.
d) IoT networks may encounter interference, congestion, and resource contention, resulting in longer response times and worse performance [5]. Middleware must alleviate these consequences by implementing effective traffic management and congestion control algorithms.
e) Resource constraints: Edge computing nodes and IoT devices usually have limited compute resources, memory, and electricity. To optimise reaction times when working with limited resources, effective resource management methods and lightweight processing algorithms are required.

VIII. Conclusion And Future Scope

In conclusion, reaction time-based IoT middleware has enormous potential for revolutionising smart parking systems by optimising response times, improving user experience, and increasing overall system efficiency. Despite encountering obstacles and restrictions such as security and privacy, cyber threats, and resource constraints, reaction time-based middleware is evolving, fueled by technological improvements and new solutions. As smart parking systems become more integrated into urban transportation, overcoming these problems and harnessing the capabilities of reaction time-based middleware will be critical to achieving their full potential.

Looking ahead, the future of reaction time-based IoT middleware in smart parking seems promising, with room for additional innovation and growth. Future Research and Development efforts may focus on using artificial intelligence and machine learning algorithms to forecast and respond to changing traffic patterns and user behaviour, improving security procedures to protect sensitive information and reduce cyber risks. By tackling these issues and adopting new technologies, reaction time-based IoT middleware in smart parking may continue to promote innovation, enhance urban transportation, and build more sustainable and efficient cities in the future.

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