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An Internet of Things (IoT) enabled tracking system with scalability for monitoring public buses

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Abstract

The significance of reliability in public transit is paramount in contemporary society. A significant number of individuals who utilize public bus transportation have considerable time inefficiencies since they are compelled to wait for extended periods at bus stops. This study aims to propose a solution for addressing the aforementioned challenge through the use of the Internet of Things (IoT) technological stack. The provision of precise real-time bus position information, along with estimated arrival times at bus stops based on real-time traffic circumstances, will enhance the overall dependability of public bus transportation for passengers. The approach presented in this research paper entails utilizing the already internet-enabled devices found aboard buses, such as the e-ticketing system, or alternatively, employing a basic android tablet. These devices are utilized to capture and transmit the current position of the bus in real-time to designated servers. The retrieval of location data from servers will be eased by the use of Representational State Transfer (REST) APIs, which may be accessed by users via android applications, SMS, or online portals. The suggested system would adopt a distributed design to effectively handle a large volume of user requests.Despite the availability of current systems that utilise the Global Positioning System (GPS) for bus tracking, these solutions are not adequately equipped to manage the anticipated increase in demand on the backend in the near future. The matter at hand has been effectively addressed. The main value of this study is in its demonstration that employing Message Queue Telemetry Transport (MQTT) as a backend, as opposed to the conventional usage of Hypertext Transfer Protocol (HTTP) based Representational State Transfer (REST), offers advantages in terms of being lightweight, efficient in data transmission, and capable of scalability. The backend and frontend components necessary for the tracking system were suggested, developed, and subsequently discussed in this study. The enhancements made to the system were also provided.

Keywords: GPS, RTC and Arduino UNO, Internet of Things(IoT), Smart transport, Location basedservices, Android, MQTT, HTTP, GPS, smart phones, public transport, bus tracking

1. Introduction

Within our educational institution, a considerable number of students and faculty members exhibit a lack of knowledge regarding the precise schedule and designated pick-up points of the college transportation service. Our proposed project involves the implementation of a smart bus tracking system utilising Internet of Things (IoT) technology [1]. The primary objective of this system is to enhance the efficiency and convenience of transportation services. The bus's location is monitored through the utilization of GPS technology, which then transmits the gathered data to

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a server situated at a remote location via a GSM module. Through the utilisation of a mobile application, both students and staff members possess the capability to conveniently ascertain the precise location of the bus at any given moment, hence facilitating their transportation needs. The server retrieves and processes the collected data using an application that has been deployed for the College bus transport system. This system includes many buses and is designed to provide comfortable travel options for students and staff members, particularly for long distances. However, there exists a lack of awareness among certain students and staff members regarding the schedules and routes of the buses. In this particular instance, we have formulated a proposal to undertake a project aimed at developing an efficient transit system. In this project, we want to create a mobile application for smart phones that utilizes IoT technology [2-5] to track and record the location and time of the college bus. The system operates by utilising GPS and GSM technology to consistently track the movement of buses. This is achieved through the serial interface between a microcontroller and a GSM Modem, as well as the integration of a GPS receiver [6]. The purpose of this setup is to transmit the geographical coordinates (namely, the latitude and longitude) of the buses from a remote location. The Internet of Things (IoT) plays a significant role in delivering comprehensive information about buses to students and staff members through a smartphone application, hence facilitating a convenient transportation system. This Android application is expected to provide assistance to both students and staff members by offering a comfortable transit system.

The issue of transport poses significant challenges for urban areas in contemporary times. Given the escalating demand placed on public transport networks, there is a pressing need to enhance the efficiency of these systems. Public buses suffer from a lack of timeliness and reliability due to factors such as severe traffic conditions, overcrowding, and several other related concerns. There exists an urgent necessity to address this matter. The proposed approach should not only enable enhancements in the quality of services, but also serve as a catalyst for fostering more confidence in public bus transportation networks. The enhancement of reliability in public transportation is contingent upon the traveler's precise awareness of the anticipated arrival time of buses at designated stops, as well as the estimated time of arrival at the intended destination [7].The technique presented in this research use the real-time location data of buses to compute the expected time of arrival at a certain site. By storing location data on a server together with associated timestamps, it is possible to make estimations regarding the arrival time of a bus at a specific bus stop or the time required to reach a particular destination. This may be achieved through the use of services such as Google Maps.This study proposes a straightforward and economical approach to enhance the intelligence of public transit systems. This paper will provide an overview of the concept, technological stack, components, and outcomes associated with the implementation of the proposed solution. The main objective of the suggested solution is to reduce the expenses associated with installation and provide a backend system that can easily accommodate increased demand.The accessibility of location data acquired by buses should be extended to both users and developers in order to effectively utilize the obtained data and generate more value from it.

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2. EXISTING SYSTEM

The necessity for an effective public transit system arises as a result of the fast growth in population. The growing population has resulted in an escalated demand for public transit, particularly buses, leading to an increasing pressure on these services. Hence, it is imperative for distant users to have access to an intelligent system that offers up-to-date information about bus schedules and routes. We have put forth a novel method that addresses the limitations of the existing public transit infrastructure. Our system is responsible for managing several aspects of bus operations, including the collection and processing of data such as the present position of buses, bus management, and scheduling. Our suggested system enables the real-time tracking of buses, providing this information to remote users that need up-to-date bus information. Various technologies, such as GPS (Global Positioning System), Google Maps, and GPRS (General Packet Radio Service), are employed for developmental purposes [8-10]. Our solution offers a web-based application that provides real-time bus position information on Google Maps to remote users.

Bus tracking systems commonly display information pertaining to the arrival of buses, including the time till their arrival and the expected departure time. This data is derived from the bus's position, which is acquired through the use of a Radio Frequency (RF) transceiver [9].Transceivers are installed on each bus and at bus stops to provide communication between buses and bus stops, enabling the transmission of location information. The microprocessors located at the bus stop are responsible for doing calculations to determine the projected time of arrival for buses. This information is then displayed on a screen for passengers to view. SMS services on the Global System for Mobile Communications (GSM) are employed in certain solutions as a method of communication [11]. The bus is equipped with GSM modules that incorporate Global Positioning System (GPS) technology. These devices transmit their position to databases at regular intervals via SMS. The retrieval of location data can be facilitated by transmitting SMS messages to recipients stored inside the database servers.GPS-based tracking devices put on automobiles can be utilized to get location data. These systems utilize the Hyper Text Transfer Protocol (HTTP) for the transmission of location data to databases [12]. The Android devices installed in buses transmit location data to servers, which may be viewed by users through Android applications or online portals.Nevertheless, all of these systems are incapable of effectively managing a surge of incoming demands. The data transmission required for transmitting data from buses to servers is substantial. If the number of people utilizing the service experiences a surge, it is quite probable that the backend system may encounter a crash. Hence, it is vital to investigate a solution that possesses scalability and efficiency.

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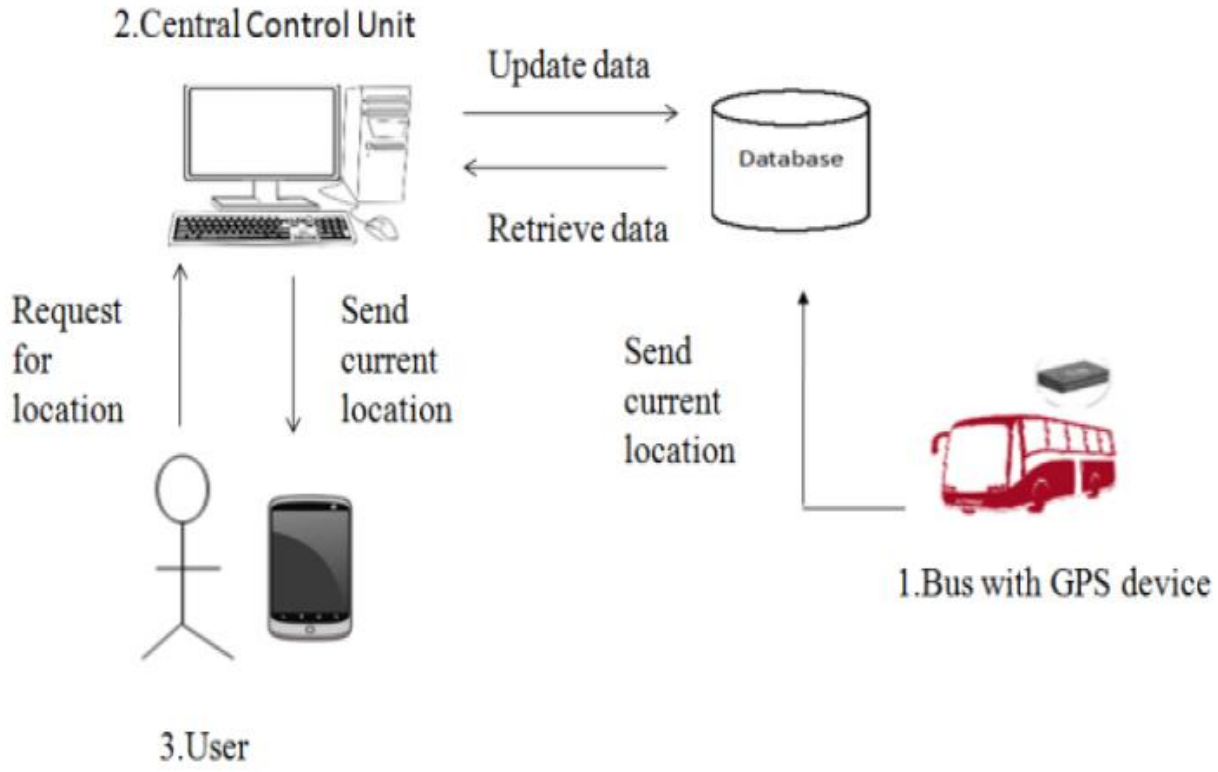

Figure 1 .Existing system block diagram

3. System Model

Today, the global population is continually growing. The number of people using public transit will grow exponentially in the future. Increased population leads to increased demand for public transportation, necessitating more buses. The number of buses will significantly enhance the amount of real-time data collected. The backend must reliably handle location data for thousands of buses. A scalable backend is necessary for systems. A more efficient and lightweight protocol should replace the old HTTP protocol. Using MQTT reduces internet bandwidth use and increases flexibility compared to other protocols [13-14]. According to [15], MQTT requires minimal bandwidth even on restricted networks. Using MQTT protocol allows for a distributed backend. With MQTT broker clustering, the system becomes highly available, fault-tolerant, and scalable. Bus location data may be utilized for data analytics applications. This data can provide valuable insights into traffic situations. Encouraging developers to access this data through APIs is crucial for generating apps that benefit society.

The system we have developed offers comprehensive information on bus numbers, including their routes, real-time locations, and availability, for users travelling between their specified source and destination. Typically, the operation of our system is facilitated by the utilisation of GPS technology, which is integrated into the bus. Initially, the Global Positioning System (GPS) acquires satellite signals, which subsequently enables the determination of location coordinates, including latitude and longitude. The determination of position is facilitated by the utilization of Global Positioning System (GPS) technology and a transmission method.

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Upon receipt of the data, the tracking data has the capability to be transferred via various wireless communication networks. A real-time clock (RTC) is a timekeeping device in a computer system that is responsible for accurately tracking and maintaining the current time. The Arduino UNO microcontroller is utilized in this project for programming purposes alongside the Real-Time Clock (RTC) module. The Android application allows students and staff members to obtain bus information based on their source and destination, utilizing the Internet of Things (IoT) technology. The technology we have presented provides real-time tracking of bus whereabouts. The utilization of intelligent bus tracking technology confers several benefits in the context of tracking and monitoring a college bus [16].

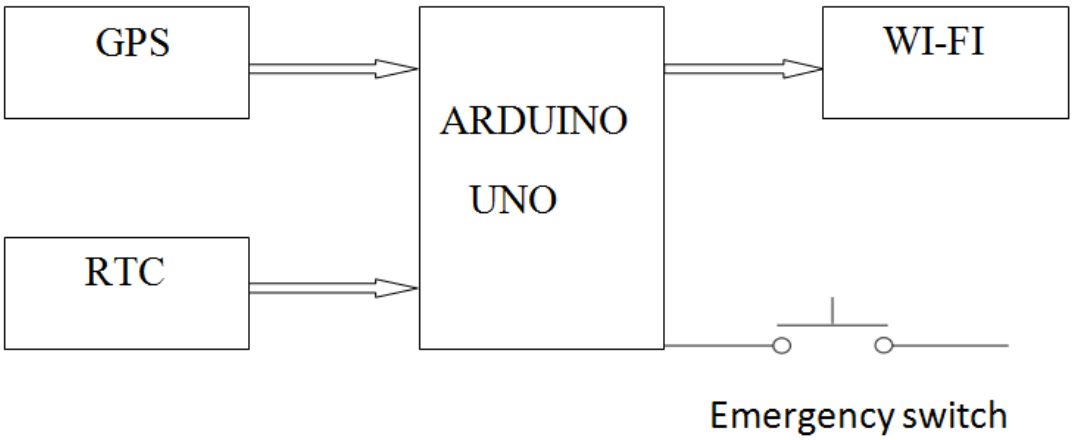

Figure 2. Transmitter

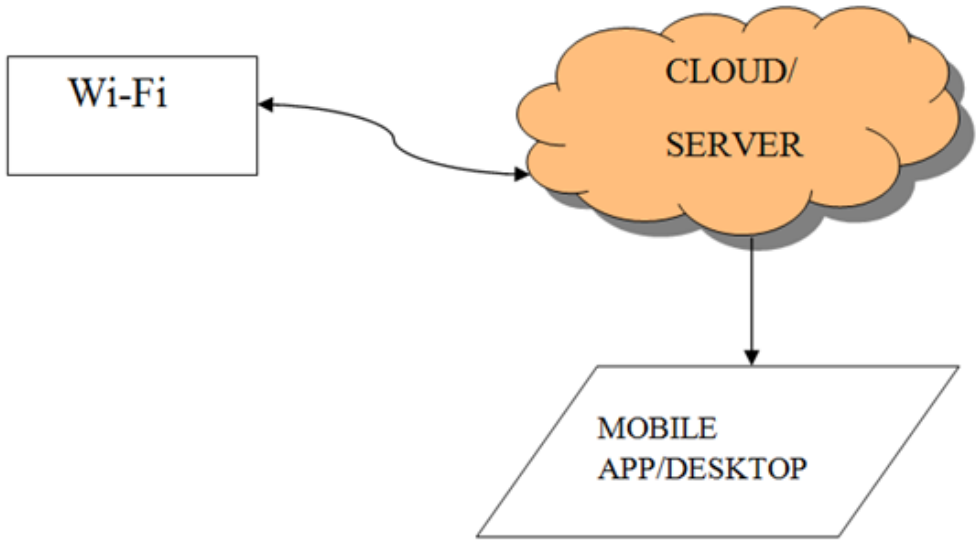

Figure 3. Receiver

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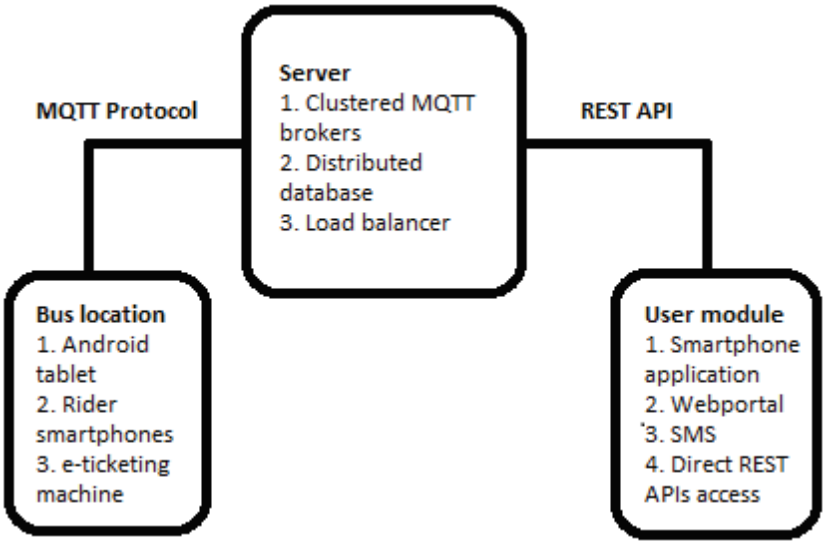

Figure 4. Overview of the proposed solution

GPS (GLOBAL POSITIONING SYSTEM) : The Global Positioning System (GPS) is a navigational system that utilises signals transmitted by a constellation of satellites to determine precise geographical coordinates. In order to precisely ascertain the location and effectively identify robust signals. The GPS tracking system is characterised by its user-friendly nature, compatibility with mobile devices, an intuitive interface, and its ability to establishcommunication with a diverse range of GPS devices. The GPS receivers of the past were comparatively less complex than their contemporary counterparts, since they just gave the latitude and longitude coordinates. The responsibility of generating a comprehensive map fell upon the user, who had to do the necessary calculations.

Real Time Clock :A real time clock is a computer clock that maintains track of the current time. Real-time clocks (RTCs) are commonly used in a wide range of electrical devices that require precise timekeeping. The use of the phrase "real-time clock" serves the purpose of distinguishing it from conventional hardware clocks, which just function as signals regulating digital devices, so preventing any potential mistake. The DS3231 is supplied in both commercial and industrial temperature ranges, and is available in a 16-pin, 300-mil SO box. The Real-Time Clock (RTC) is responsible for the storage and tracking of several temporal units, including seconds, minutes, hours, day, date, month, and year. The timekeeping device functions in either a 24-hour or 12-hour configuration, accompanied with an AM/PM sign[17].

WI-FI: In addition to facilitating internet connectivity, Wi-Fi technology also supports peer-to-peer mode, enabling devices to establish direct connections with one another. Devices that are capable of utilising Wi-Fi technology encompass personal computers, smartphones, and tablets [18]. Devices that are Wi-Fi compliant have the ability to establish an internet connection by

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utilising a Wireless Local Area Network (WLAN) network and a wireless access point. Wireless communication systems are comprised of three essential components: transmitters, antennas, and receivers.

ARDUINO UNO : The Arduino/Genuino Uno is a microcontroller board that utilises the ATmega328P as its foundation, as stated in the datasheet. The device is equipped with a total of 14 digital input/output pins, out of which 6 may be utilized as pulse-width modulation (PWM) outputs. Additionally, it offers 6 analogue inputs, a 16 MHz quartz crystal for precise timing, a USB connection for data transfer, a power connector for external power supply, an ICSP header for in-circuit serial programming, and a reset button for system initialization. The microcontroller is equipped with all the necessary components for its operation. To initiate its functionality, one may establish a connection to a computer using a USB cable or power it using an AC-to-DC converter or battery[6].

IoT : The concept of the Internet of Things (IoT) refers to the interconnection of various physical devices, such as automobiles, buildings, and other objects. These devices are equipped with electronics, software, sensors, actuators, and network connections, enabling them to gather and share data among themselves. The IoT is often anticipated to provide enhanced connection for devices, systems, and services, surpassing the scope of machine-to-machine (M2M) interactions. This connectivity encompasses a wide range of protocols, domains, and applications.

4. Bus and IOT backend architecture data collection

Collecting real-time location data is challenging owing to the necessity for costly technology. The standard solution is to put GPS and GPRS equipment in every bus. These expensive gadgets deliver vital functions as a one-time expenditure.

E-ticketing systems : Many buses in Pune, India contain the appropriate gear for real-time position tracking. Using an e-ticketing system can eliminate the need for expensive hardware upgrades. These systems are GPRS-enabled. Using network triangulation, real-time device location is feasible. Location data may be shared with users with little adjustments when location and internet connectivity are available.

Android tablet phones : Numerous affordable Android smartphones with internet and GPS are available. These tablets can serve as bus entertainment systems. They can display basic information such as route number, destination, next stop, time, weather, and surrounding tourist places. Public transport operators can display ads on tablets.

Crowd sourcing location data : This solution does not require GPS/GPRS devices in the bus. Today, most individuals have cellphones. Smart phones of bus passengers can provide location data for that bus. The data may be crowdsourced.

IOT Backend Architecture:Efficient and reliable transmission of data obtained from a source is necessary for its transfer to servers. The data should be kept in a manner that allows users to perform queries, even during periods of high server demand resulting from a large number of

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concurrent queries. Figure 5 illustrates the suggested architectural design.The proposed method entails the utilisation of a lightweight protocol for transmitting the gathered data to databases. There exist several protocols that can be utilised to accomplish this objective. However, MQTT is considered to be the most suitable option for this particular use case due to its ability to minimise bandwidth utilisation and its support for scalability.The scalability of the MQTT backend may be effectively enhanced by the implementation of broker clustering. After receiving the data, the server will proceed to store it in a NoSQL database such as MongoDB [19]. This database will be distributed and have numerous instances in order to provide load balancing. Users have the capability to retrieve information regarding bus locations by querying the databases.The MQTT protocol involves the presence of a broker, sometimes referred to as a server, which hosts a collection of topics.Topics serve as a means to ascertain the recipients of the data that is created by a sender. In order to receive data that is released by any sender on a certain subject, a receiver must subscribe to that topic [20]. The position data transmitted via MQTT from the buses will be categorised by the route number, which will serve as the subject. The publication of location data, including the present latitude and longitude of a bus, will occur at a frequency of 5 seconds. This data transmission will need less bandwidth due to the utilisation of MQTT. In order to achieve scalability, the MQTT brokers will be organised into a cluster, as seen in Figure 6. The clustered MQTT brokers function collectively as a unified broker. Each broker within the cluster will be responsible for maintaining the list of subjects. In the event that a broker becomes inaccessible, an alternative broker assumes responsibility for processing the request. In this manner, the brokers achieve equilibrium within their own selves. The implementation of clustering in the system guarantees a high level of availability. In the event of a server failure, other servers will be available to assume the responsibility of processing requests and managing data.The position data will be sent to the server over the MQTT protocol and thereafter stored in a designated database collection corresponding to the specific route number. One possible approach to achieve this objective is to implement modifications to the MQTT broker itself, enabling it to write incoming data directly to a database. Alternatively, another option is to develop a separate MQTT client that is specifically designed to do this database writing functionality.

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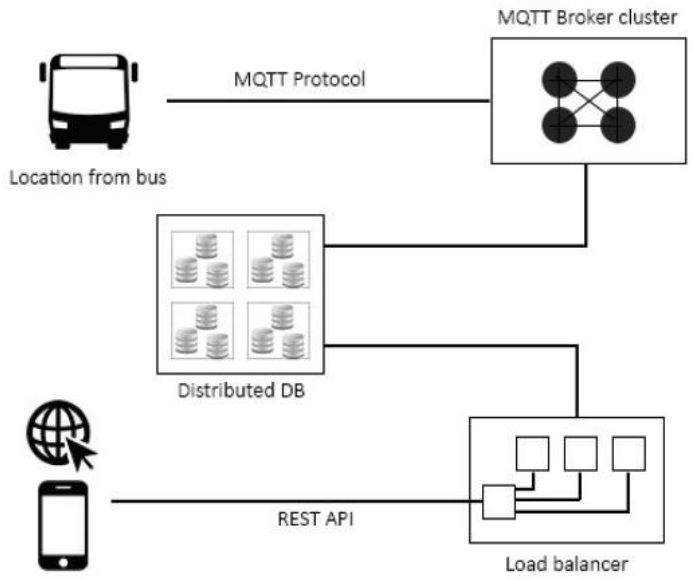

Figure 5. Architecture Components

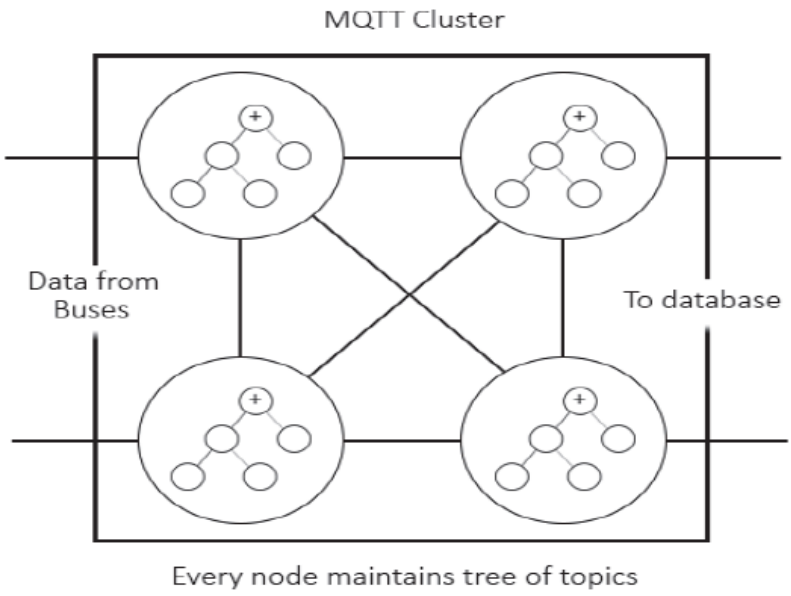

Figure 6. Cluster of MQTT brokers

5. Results

The suggested system would facilitate users in retrieving real-time bus positions, allowing them to determine the projected arrival time as well as the time required to reach their destination. By acquiring knowledge about the current time, users would get advantages as they will be able to meticulously strategize their journey plans. The enhancement of real-time data availability is expected to contribute to the increased efficiency and reliability of the public bus service. Users have the option to use this service either through a website or by SMS. The Android application

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provides information on the college bus service for both students and staff members. The system that has been proposed exhibits a higher level of user-friendliness as compared to the current existing system. Additionally, it provides enhanced performance.

6. Conclusion

This study provides a comprehensive overview of different available strategies for tracking college buses. The implementation of this concept has the potential to enhance transportation safety and increase the quality of services provided by college buses. The system will be equipped with state-of-the-art technology and highly efficient algorithms, while maintaining a reasonable cost. The primary emphasis of the system is in ensuring the precision of the bus's arrival time and geographical coordinates.A novel approach for monitoring public buses has been developed and deployed, replacing the conventional HTTP protocol with MQTT. The proposed method exhibits scalability and preparedness for future use. The utilisation of the suggested architectural design enables the achievement of horizontal scalability for the offered solution. The utilisation of MQTT can lead to reduced bandwidth consumption and facilitate on-demand retrieval of bus location data.The utilisation of MQTT enhances the overall efficiency of the system by enabling lightweight data transport. The implementation of a distributed backend system to manage the growing number of users allows for scalability. This technology aims to enhance the reliability and efficiency of public transit networks.

7. Future Scope

The objective is to develop a real-time application within a smart college bus tracking system that facilitates efficient transit for all college buses.

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