Webology (ISSN: 1735-188X)
Volume 19, Number 5, 2022

Design Of A Monitoring System For Multimodal Transport Using The Internet Of Things (Iot)

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Abstract

Urban mobility faces many drawbacks with the increase in the demand for transport, both for people and the movement of goods. New technologies, including the Internet of Things (IoT), allow better traffic management and different variables that imply the optimization of multimodal transport. This article proposes a monitoring system for multimodal transport using IoT in a cloud platform that uses non-relational databases to acquire information in real-time. The platform has a dashboard for the visualization and management of the variables generated by the different sensors of the multimodal system.

Keywords: Monitoring, telemetry, internet of things, multimodal transport.

I. INTRODUCTION

The world's population is increasingly concentrated in urban areas, and this trend shows no signs of stopping. Urban centers have faced numerous problems arising from high population density, which has promoted increased demand for people's transport (Jacob et al., 2020). Urban mobility generates significant impacts related to traffic congestion, increased logistics flows, and noise and air pollution. This implies an increase in the complexity of mobility management, loss of efficiency, and high costs of public and private resources, with a level of sustainability that is no longer acceptable and influences the competitiveness of a country. Many countries in the world, both developing and developed, face problems in managing transport facilities. However, countries' approach is evolving from infrastructure development and construction to the best use of available infrastructure (Singh et al., 2021).

Transporte multimodal

Multimodal transport can be defined as "Ordinary public networks in urban areas, particularly in metropolises where citizens can use combinations of various modes of transport, such as personal cars, taxis, two-wheeled vehicles, metro, bus and walking'" (Tagiltseva et al., 2021). Multimodal transport has been well received as a sustainable and exciting alternative to solve mobility problems concerning the deterioration of accessibility of urban centers, recurrent congestion, and environmental impact.

These transport methods provide tangible benefits for citizens by saving time and costs and greatly help cities' sustainability and development. Managing the entire process of a multimodal transport system without interruptions is complex. It involves different actors such as freight forwarders, logistics service providers, post offices, and carriers of different modes of transport. Communication between these parties must be accurate, timely, and efficient to ensure an impeccable and visible delivery process that could be challenging due to the different technologies implemented by different companies in the same city.

Multimodal networks are characterized by dynamically changing conditions and multiple modes of transport operating simultaneously; for example, in an urban transport network, you can drive a car, ride a transit line, ride a bike, or walk. The optimal route between two nodes before the rush hour may consist of driving to a parking lot near the destination node and then walking to the final destination, while later, during rush hour, it may consist of driving to a parking facility, traveling by bus or train to a transit stop near the destination, and from there walking to the final destination.

Recent developments in the field of ICT, such as cloud computing, IoT, Big Data, social media, and wireless communication, have further revolutionized the way information is shared and supply chains are structured. Likewise, geographic information systems (GIS), which are an instrument that provides capabilities to handle georeferenced data, perform data management (data storage and retrieval), manipulation, and analysis, are currently an essential part of multimodal transport systems (Roda et al., 2017).

Internet of Things (IoT) devices relies on wireless communication protocols to transmit and receive application data. For this purpose, network operators have been deploying low-power wide area networks (LPWANs) such as LoRaWAN and Sigfox on a large scale (Raza et al., 2017). Through these sub-gigahertz (sub-GHz) networks, IoT devices can exchange data over several kilometers at poor performance while maintaining low power consumption.

1. PROPOSED SYSTEM

Telemetry and Monitoring System

The telemetry and monitoring system thinking about the conditions of multimodal transport has been designed to be scalable, flexible, and configurable depending on the instrumentation developed for the acquisition of variables through IoT. The proposed system is presented in Figure 1. The system has a monitoring portal (Front End) developed in Nodejs with a responsive theme based on Bootstrap, which allows the registration and login of users.

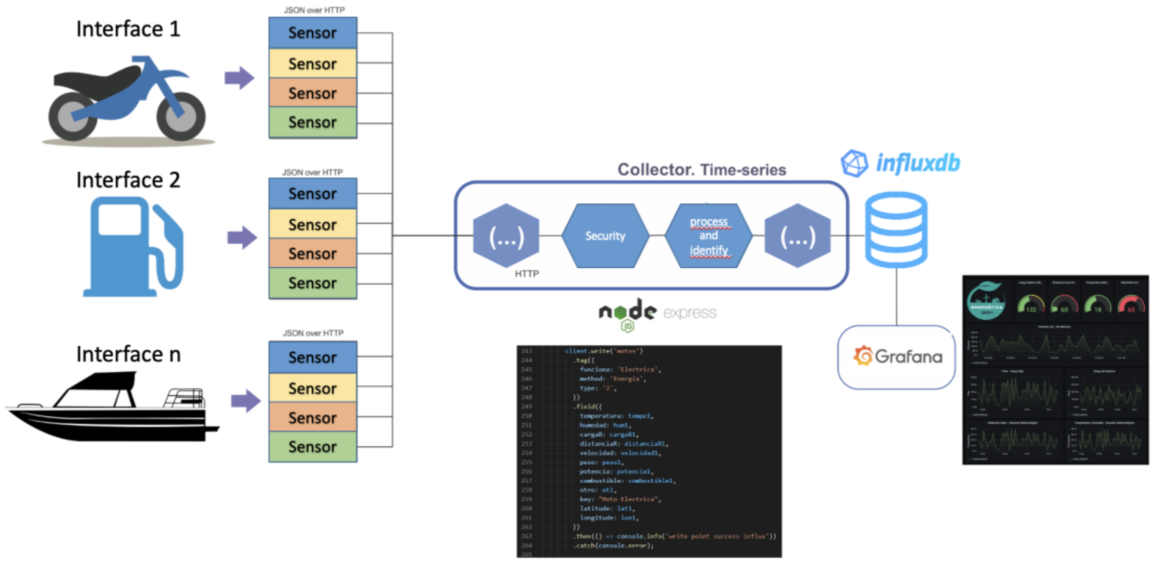

Figure 1. Proposed model telemetry and monitoring system

Service deployment

The monitoring portal is composed of various software that works interrelatedly to provide the user with a comprehensive view of the data collected from the different subsystems that make up a multimodal transport system, as shown in the technological infrastructure in Figure 2. For storage, it is possible to separate the data in different database engines, thus sending the system management data to MongoDB and the sensor data (time-series) to InfluxDB. Each component and its function in the monitoring system will be explained below:

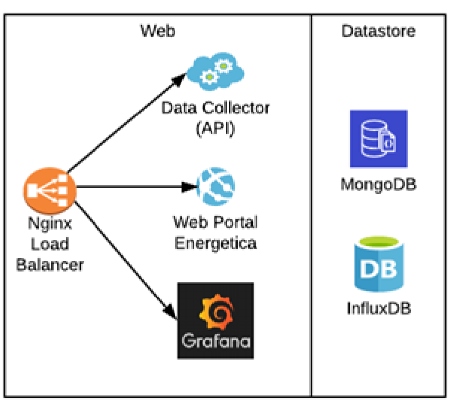

Figure 2. Deployment of monitoring portal services

- The centralized storage of telemetry data is critical since the instrumentation equipped in each vehicle and charging station has a constant flow of information corresponding to the measurements of the installed sensors. Exponential data growth is expected once it is used and massified. The above situation creates the need to determine which database system best satisfies the requirements for the monitoring system, having as initial criteria the ability to handle large volumes of data, integration capacity with Grafana analytics software, ease of use of the query language for the construction of new reports and simplicity for the aggregation of new subsystems and sensors without the need to make significant changes in the information systems.

- For the interaction between the monitoring system with the vehicles and the charging station, there is an internal development web service called DataCollector. The interfaces (card and sensors) report information from the sensors via HTTP. All telemetry is saved in InfluxDB and MongoDB for later use.
- For the visualization of information and data analysis, the Grafana software is available, where the dashboards, time series graphs, and statistics for decision-making are shown.
- The web portal was developed to manage all the control information of the monitoring system, such as the registration of data, profiles, credentials, and sensors, among others, in addition to serving as an access point to the Grafana data analysis software.
- The deployment has a load balancer based on Nginx that unifies the routes to the different software in a single link.

Operation of the system

In the proposed model, users can add data acquisition interfaces to the platform. Each interface can have the information of a group of sensors, including a name, where it is installed, and the sensors it has. When creating the interface, a Token is generated, which must be used for the configuration of the device (the interface that includes a development card and sensors) in charge of sending the data to the application.

The Collector object has been developed, responsible for receiving the data from the electronic devices configured to send the signals from the sensors. The Collector developed in Nodejs-express is configured to receive the data through the HTTP protocol. The data can come from different sources, either from the configured mobility system or external sources, such as a weather station with real-time variables that can be used to manage the mobility system. Figure 3 shows the structure of the developed software. When receiving the data, the Collector, through the Token, identifies the interface, and the data is registered in the InfluxDB database. Figure 4 shows an example of data storage in InfluxDB

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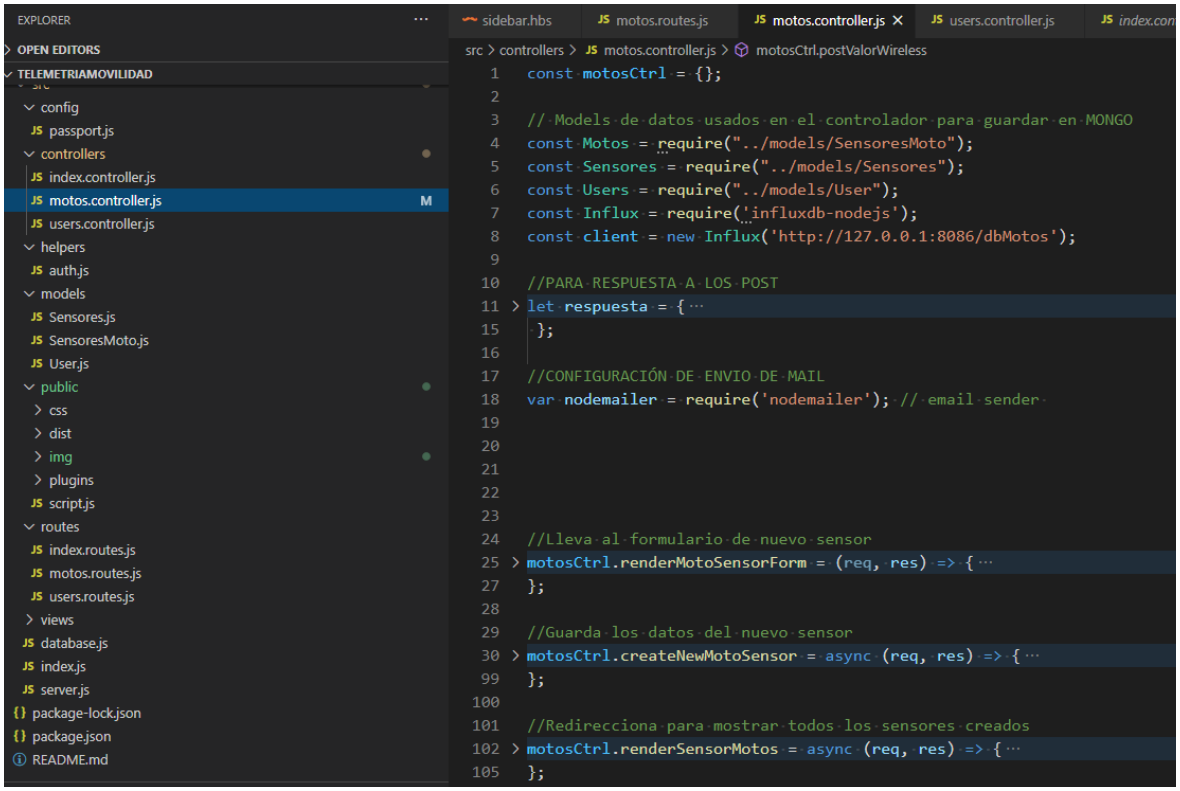
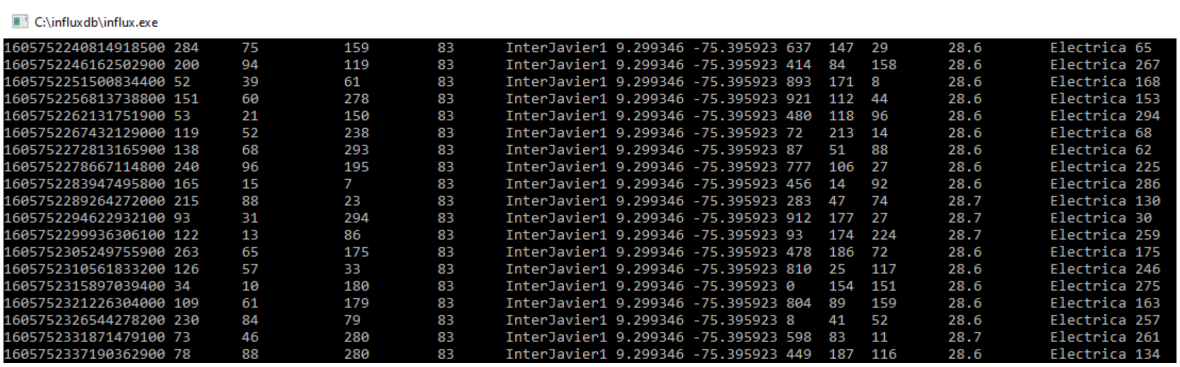


Figure 3. Developed software structure


C:\influxdb\influx.exe

1605752240814918500	284	75	159	83	InterJavier1	9.299346	-75.395923	637	147	29	28.6	Electrica	65
1605752246162502900	200	94	119	83	InterJavier1	9.299346	-75.395923	414	84	158	28.6	Electrica	267
1605752251500834400	52	39	61	83	InterJavier1	9.299346	-75.395923	893	171	8	28.6	Electrica	168
1605752256813738800	151	60	278	83	InterJavier1	9.299346	-75.395923	921	112	44	28.6	Electrica	153
1605752262131751900	53	21	150	83	InterJavier1	9.299346	-75.395923	480	118	96	28.6	Electrica	294
1605752267432129000	119	52	238	83	InterJavier1	9.299346	-75.395923	72	213	14	28.6	Electrica	68
1605752272813165900	138	68	293	83	InterJavier1	9.299346	-75.395923	87	51	88	28.6	Electrica	62
1605752278667114800	240	96	195	83	InterJavier1	9.299346	-75.395923	777	106	27	28.6	Electrica	225
1605752283947495800	165	15	7	83	InterJavier1	9.299346	-75.395923	456	14	92	28.6	Electrica	286
1605752289264272000	215	88	23	83	InterJavier1	9.299346	-75.395923	283	47	74	28.7	Electrica	130
1605752294622932100	93	31	294	83	InterJavier1	9.299346	-75.395923	912	177	27	28.7	Electrica	30
1605752299936306100	122	13	86	83	InterJavier1	9.299346	-75.395923	93	174	224	28.7	Electrica	259
1605752305249755900	263	65	175	83	InterJavier1	9.299346	-75.395923	478	186	72	28.6	Electrica	175
1605752310561833200	126	57	33	83	InterJavier1	9.299346	-75.395923	810	25	117	28.6	Electrica	246
1605752315897039400	34	10	180	83	InterJavier1	9.299346	-75.395923	0	154	151	28.6	Electrica	275
1605752321226304000	109	61	179	83	InterJavier1	9.299346	-75.395923	804	89	159	28.6	Electrica	163
1605752326544278200	230	84	79	83	InterJavier1	9.299346	-75.395923	8	41	52	28.6	Electrica	257
1605752331871479100	73	46	280	83	InterJavier1	9.299346	-75.395923	598	83	11	28.7	Electrica	261
1605752337190362900	78	88	280	83	InterJavier1	9.299346	-75.395923	449	187	116	28.6	Electrica	134

Figure 4. Example data stored in InfluxDB

1. RESULTS

Motorcycle Telemetry Architecture

An interface is established for a motorcycle as part of a multimodal transport system to test the proposed system. The instrumentation architecture for the motorcycle has been defined in such a way that it can be integrated with the instrumentation equipment, which has some measures that are required to be reported in the monitoring system. The architecture developed for this subsystem is shown in Figure 5.

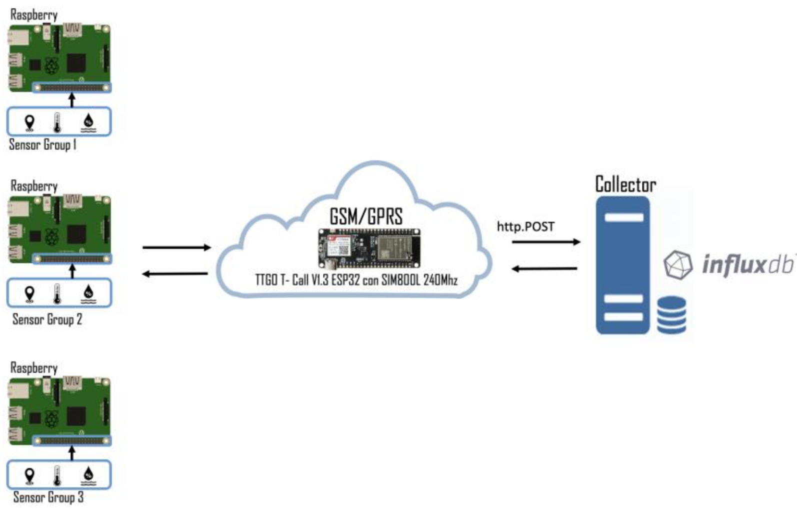


Figura 5. Motorcycle telemetry architecture

The architecture is mainly made up of the device "TTGO T- Call V1.3 ESP32 with SIM800L 240Mhz", a development card based on the ESP32 that integrates the SIM800L GSM / GPRS module in the same way it has an interface to connect and charge batteries of type up to 500mA. The development card is geared towards the Internet of Things (IoT) solutions. It has the following characteristics:

- Dimensions: 74.5mm x 28.8mm x 7.7mm Weight: 15g
- ESP32-WROVER-B
- SIM800L
- USB a TTL: CP2104
- USB: Tipo C
- Card Holder SIM: Compatible Nano SIM
- Connector JST de 1.25 mm para cargar batería de Lipo de 3.7V
- Antenna connector IPEX/IPX SMD
- Interface: UART, SPI, SDIO, I2C, PWM, PWM, I2S, IRGPIO, capacitor touch sensor, ADC, DAC.
- Operating voltage by USB: 5V 1A and by a battery of Lipo of 3.7V
- Charging current for battery Lipo: 500mA
- Current of work and in sleep: At work 70 mA and in sleep 300uA
- Temperature range: -40 ℃ ~ + 85 ℃

- Wi-Fi Mode: Station / SoftAP / SoftAP + Estación / P2P
- Security mechanism: WPA / WPA2 / WPA2-Enterprise / WPS
- Network Protocol: IPv4, IPv6, SSL, TCP / UDP / HTTP / FTP / MQTT
- Protocol: 802.11 b / g / n (802.11n, velocidad de hasta 150Mbps) Polimerización A-MPDU y A-MSDU, soporte 0.4μ Intervalo de protección
- Frequency range: 2.4GHz ~ 2.5GHz (2400M ~ 2483.5M)
- Transmission power: 22 dBm
- Communication distance: 300 m
- Bluetooth protocol v4.2BR / EDR y estándar BLE
- Quad band: 850/900/1800 / 1900MHz, 2G GSM / GPRS

Information visualization system - Dashboards

The Collector received the data sent by the motorcycle interface, who, according to the Token and the user data, recorded the information in the InfluxDB database. For the information visualization, a visualization server was configured in Grafana that connects to the InfluxDB database. In Grafana, it is possible to visualize different types and data sources with a configuration or operation on the data intended to be displayed (integral, mean, min, max, sum, derivative, others), filtering or making queries by time. It is possible to configure different panels to be displayed according to the needs. In case of not finding a panel according to the needs, additional panels can be developed. Figure 6 shows how the information to be displayed is configured, where the user who registered the acquisition interface is chosen, and the sensors you want to visualize.

Figure 6. Configuring data in InfluxDB

Figure 7 shows the dashboard for motorcycles, where it is possible to visualize measures such as battery charge, distance traveled, temperature, humidity, weight, and others. It is also possible to show the motorcycle's geographical location (GPS). Each graph or display panel is editable in real time and allows information filtering.

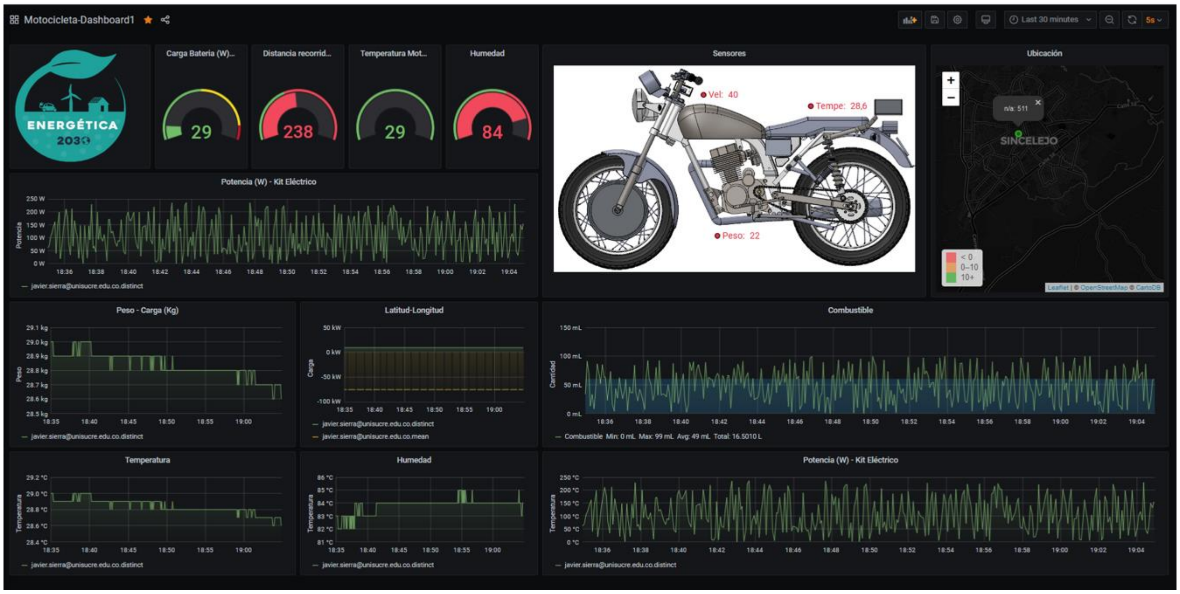


Figure 7. Motorcycle Interface Data Dashboard

II. CONCLUSIONS

New technologies, including the Internet of Things (IoT), allow better management of different variables that imply optimizing multimodal transport. Urban mobility benefits from the proposed monitoring system, given the number of drawbacks that arise with the increase in the demand for transport, both for people and for the mobilization of goods. The proposed system helps to visualize different variables for decision-making and improve cities in terms of mobility.

ACKNOWLEDGMENTS

This research has been developed in the framework of the "ENERGETICA 2030" Research Program, with code 58667 in the "Colombia Científica" initiative, funded by The World Bank through the call "778-2017 Scientific Ecosystems", managed by the Colombian Ministry of Science, Technology, and Innovation (Minciencias), with contract No. FP44842-210-2018.

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