Linkage of IoT Technologies with the SWE (SOS) Standard for the Development of a Heterogeneous Intelligent Transport System (Case Study Quito)

Ana Zambrano[1], Eduardo Ortiz M.[1], Marcelo Zambrano[2], Xavier Calderón[1], and Luis Urquiza-Aguiar[1(✉)]

[1] Departamento de Telecomunicaciones y Redes de Información, Escuela Politécnica Nacional, Quito 170525, Ecuador
{ana.zambrano, eduardo.ortiz, xavier.calderon, luis.urquiza}@epn.edu.ec

[2] Carrera de Ingeniería en Telecomunicaciones, Universidad Técnica del Norte, Ibarra 100110, Ecuador
omzambrano@utn.edu.ec

Abstract. Transport plays a fundamental role in the economic development for big cities. Quito, the capital of Ecuador, presents serious mobility problems, with a significant amount of traffic both in the city center and in its main access roads. The detailed proposal in this article aims to link Quito with several new generation technologies such as *Internet of Things (Iot)*, *Sensor Web Enablement (SWE)* standard for heterogeneous sensor communication, and a system of real-time notifications using the communications protocol *Message Queue Telemetry Transport (MQTT)*. These technologies will be used for the development of an Intelligent Transport System (ITS) that takes advantage of the massive deployment of smartphones in the society as main sources of information, including *Arduino* and *Raspberry* modules to check efficient communication. This ITS bases its operation on the paradigm of the *Crowdsensing*, which allows to reflect more accurately the reality of the object of study when more collaborators use the system; reaching up to 30% improvement in the situational consciousness of the environment variable, the traffic.

Keywords: Internet of Things · Sensor Web Enablement · Message Queue Telemetry Transport · Intelligent Transport System · Crowdsensing

1 Introduction

Currently, one critical problem affecting Quito is urban mobility [1] as it has not been properly managed and planned when designing the city. Indeed, this problem is so serious that has caused several economical, cultural and even health problems among inhabitants (stress and fatigue of drivers). As a result, Quito has demonstrated to have a slow growth in development in its infrastructure and quality of life standards.

B. Hilt et al. (Eds.): Nets4Cars/Nets4Trains/Nets4Aircraft 2019, LNCS 11461, pp. 60–69, 2019.
https://doi.org/10.1007/978-3-030-25529-9_6

This is demonstrated by statistics showing considerable growth of the automotive park in recent years [2], the import of vehicles in 2016 was 31,761 units and 70,203 in 2017 respectively [3]; this data shows a growth of more than 121% compared to 2016. Likewise, vehicle sales for 2017 [4] present an increase of more than 65% with respect to 2016 [5]. This incremental growth impacts on society due to the lack of proper vehicular planning and management systems. As a result, many products and services cannot be delivered. There is not available in Ecuador, an Intelligent Transport System (ITS) [6] that combines the benefits of existing information systems and tools, such that people in the society can be aware about transportation conditions in real-time. Thus, citizens rely on social networks mostly to be aware about incidents in the traffic. Unfortunately, this information tends to be mostly inaccurate and unreliable.

To counter these issues, in this paper, we propose the development and design of an ITS that mitigates the problem of urban mobility. We implement a prototype and use Quito as case study. Our ITS allows the distribution of information in real time about the state of traffic in the different road rings of the city, both in terms of incidents raised in the tracks, as well as different types of information relevant to the drivers can improve their situational awareness and make appropriate decisions (available pathways, derivations, jams, etc.). The prototype presents a distributed architecture of communications that makes it possible to obtain information from any type of devices, either a smartphone, *Raspberry* or *Arduino* devices and more. This heterogeneity has allowed to implement *Sensor Web Enablement* (*SWE*) standard in particular its main component *Sensor Observation Service* (*SOS*).

The heterogeneity achieved delivers as an advantage, being able to cover extensive geographical areas as in the case of Quito at almost zero cost, taking advantage of community sensors. As a group *SWE* and *SOS*, the master protocol IoT [7], *Message Queue Telemetry Transport* (*MQTT*) [8] is used, this one manages the sending/receiving of messages in real time, benefiting the architecture with its low energy consumption, bandwidth, and processing capacity within the devices where it is hosted. This provides useful information for drivers to prevent or avoid massive delays in displacement, excessive fuel consumption, increases in greenhouse gases, failure to schedule [9]. With the development of this system is intended to improve the effective mobility of people, merchandise and even aid bodies, with the ultimate goal of contributing positively to the wellbeing and development of communities.

This article is divided as follows. Section 2 discusses the related work regarding frameworks that solve the mobility problem of big cities. The proposed architecture is then presented in Sect. 3, where we describe the system's action scenario, as well as the role played by each of the technologies employed. Next in Sect. 4, the detail of the features of the mobile application is presented with its respective analysis of results. In the light of our results, we present a discussion in Sect. 5. Lastly, we present our conclusions and future work in Sect. 6.

2 Related Work

ITS is a new proposal to reduce the impact of transportation-related problems in large cities. To mitigate these problems, ITS propose the development of computer systems oriented to efficient transport management, integrating in a single system vehicles, technology and road infrastructure, mobile devices and society [10]. One of the most relevant examples of ITS is in Michigan USA, called "ItsMichigan" [11]. It has a system of video cameras and adaptive traffic lights for the optimization and control of traffic within the city. In Moscow Russia [12], the authorities of vehicular administration have implemented an adaptive traffic system called "ITS-Russia". This system uses sensors of vehicle presence and radars of photo detection in open sky to discover incidents in Road as vehicles unprepared or in the opposite direction, among others. On the other hand, in Ambato Ecuador [13] in certain avenues, vehicle counting cameras were installed along with an artificial vision system [14]. Obviously, this implies a great investment by the authorities and it is known that these systems were relegated to abandonment due to lack of resources, common problem in developing countries. Another problem to mention is that the results of these systems are not disseminated to the citizenry so that it can plan and make decisions about their mobility, forcing it to organize through social networks that although widely used, are not a reliable source of information and often information is often decontextualized and untimely.

This article presents an ITS-Quito, which is part of the Ecuador Intelligent Roads project (E-iRoads), whose main objective is to improve the situational awareness of the transport routes of a city, for the timely making of decisions in developing cities, such as Quito, whose budget is reduced. It is intended that this solution be a feasible and economic ITS for any city, which takes advantage of the large deployment of smartphones in the citizenry as the main source of sensors. For example, it contemplates the development of an opportunistic mobile application [15], that takes advantage of any type of heterogeneous sensor (like smartphones of any characteristics and SO), both for the visualization of results and for the compilation of data respectively.

To allow the communication of all these heterogeneous sensors, the Sensor Observation Service (SOS) component, belonging to SWE, standard was implemented. The SOS is a web interface for data collection and consultation that defines interoperability interfaces for the coding of the metadata obtained by each of the system sensors. The objective is to increase the number of sensors and to analyze the data obtained to get *Crowdsensing*, which is a technique that involves a large number of people with mobile devices capable of measuring data of a common interest. These data are shared collectively to improve or predict any processes. In addition, as the number of users increases [16], the data will be described with greater veracity of the object of study.

On the other hand, users benefit from real-time notifications, through the protocol MQTT [17]. The integration of these technologies allows, at an almost null cost, unlike the aforementioned projects, create a real situational and timely awareness in the drivers, which in turn allows improving the decision-making. In addition, this proposal exceeds projects such as [11, 13] by granting the ability to incorporate heterogeneous sensors and can cover large territories.

3 Architecture

Before The proposed system, consisting of three main blocks, is detailed in Fig. 1. This system is formed, in the first instance, by the "Information Source Block" which represents a set of sampling devices for the collection of data. It also includes the development of a mobile application for sampling. The "Sensor Block" is an implementation of the SWE standard; in particular, the Sensor Observation System (SOS) component is used to implement an interface through a web service, with the objective of obtaining information in the form of observations and the sensor descriptions. Moreover, the "Notification Block", that uses the MQTT protocol that represents a channel dedicated to the circulation of incident messages for notification to carriers. In summary, the MQTT protocol is used for the implementation of a real-time notification system and the HTTP protocol, for sending the data to the SWE-SOS web interface. There is no geographical limit for the use of this system, because the server is reachable through the Web. The Union of these three blocks forms the ITS described.

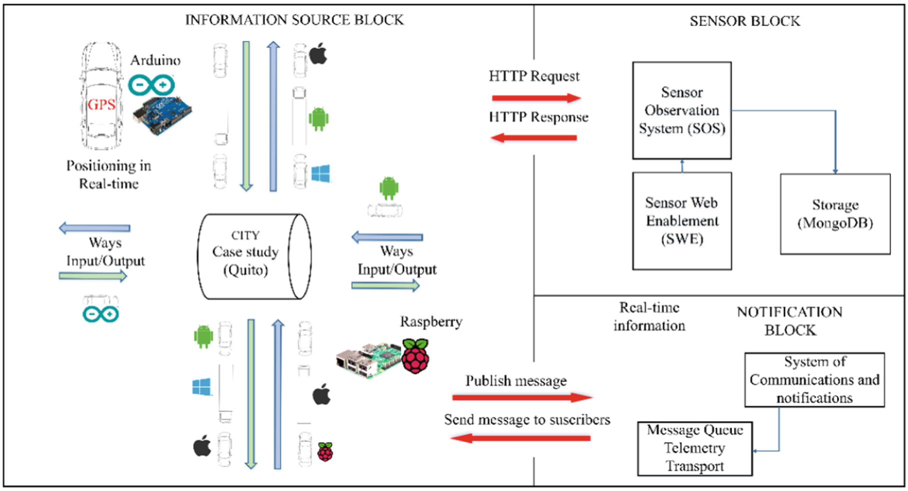


Fig. 1. Technical block of the system.

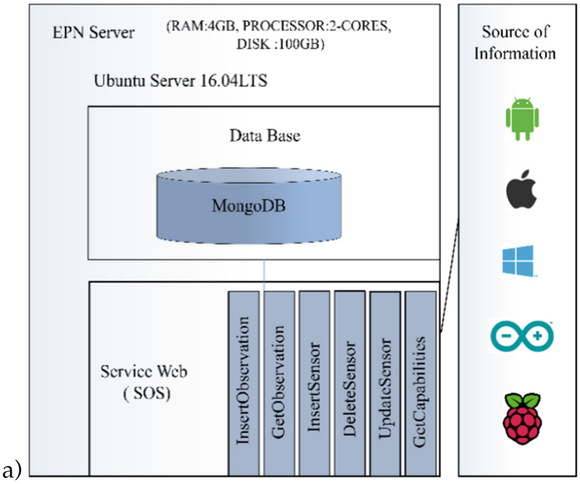
For this research smartphones, Arduino and Raspberry modules have been used as source of information. This data is part of the SWE-SOS standard message that is sent in JSON format to the server to be stored in the database. All devices (smartphones, Arduino and Raspberry) are responsible for measuring their own vehicle´s travel speed. To achieve this goal, first, a mobile application has been developed that obtains geographic locations (double) through the GPS sensor, and determines its velocity. This data is obtained periodically (sampling frequency = 2 min) and then is sent to the server. In addition, this application has the ability to connect to the MQTT server to send or receive incident messages from the route (String) which are sent manually by the end users. Second, devices as Arduino Uno [18] and Raspberry Pi 3 [19], together with a GPS module (GY-GPS6MV2 [20]) has been added to perform the vehicle's location in order to obtain its velocity. In addition, a GSM module (GSM 900 [21, 22]) has been added to both devices to send the data to the remote server through the Web. These devices, which can be smartphones, Arduino or Raspberry, were installed in the vehicle cabin to perform sensorization tasks and notify drivers. It is important to note that the energy necessary for the operation of these devices has been obtained from the vehicle power output. For example, for an Arduino, first in the laboratory the components have been assembled, which are the GPS module, and the GSM module. Then the functionalities have been codified, which are the sensing of the speed of the vehicle and notification in real time. Finally, these physical components have been installed in the vehicle verifying their autonomy and correct operation.

The tools that allowed developing this proposal were a non-relational database service *MongoDb* for the storage of the measured information of the route to study and the description of the sensors. The PHP programming language was used to make the web interface achievable for heterogeneous clients. To implement the alert notification system, the MQTT Eclipse Mosquitto Broker server has been used. These components, with the exception of the mobile client, are hosted on a host with Ubuntu server 16.04 LTS operating system, which is instantiated on the VMware ESXi virtualization platform of a physical server at the Escuela Politécnica Nacional [23] with a public IP accessible through the Web [24]. The Fig. 2a shows the integration of all these technologies for the implementation of the system, where it is observed that the main source of information is a set of heterogeneous devices. It is worth mentioning that the standard establishes the guidelines for communication and messages. The *SWE-SOS* defines six messages to achieve a heterogeneous web interface: *insertObservation, getObservation, insertSensor, deleteSensor, updateSensor, getCapabilities* [25]. For example, for the entry of new data to the server, the *insertObservation* operation must be implemented as shown in Fig. 2b. This operation is a JSON message that flows from the heterogeneous client to the server. The message shown in Fig. 2b, contains the main value of the measurement (velocity) and the metadata that allow identifying: the standard version, the type of query, route identifiers, the geographical location of the data, the date and time in the fact that the data was taken.

The mobile application allows the visualization of the analysis of the data found in the *MongoDb* database. In addition, the mobile application allows to know using spatial and temporal filters the average velocity and the arrival time. For example, the data corresponding to the velocity are analyzed to show to the end user the average velocity and the possible delay in the route. On the other hand, an interactive map presents the geographical location of the user and the incidents reported by other users in a period of time in order to improve situational awareness.

4 Preliminary Results

For the validation of the system, we had the collaboration of FENATRAPE (National Federation of Heavy Transport of Ecuador) that facilitated agreements with companies of heavy transport for the design of the scenario and the validation of the developed system. The stage was kept in each company for the time of a month getting promising



b)


```
{"type": "insertObservation",
 "service": "SOS", "version":
"2.0.0",
 "offering": "90:00:4E:87:BF:3C",
 "OM_Observation": {
  "result": {"value": 83,
   "type": "Quantity", "uom":
"kmh", "name": "velocity"},
  "featureOfInterest": "SDaQ",
  "location": {"type": "Point",
   "coordinates":
    [-0.287783, -79.066007]},
  "phenomenonTime": {
   "TimeInstant": {
    "timePosition":"2018-09-
12T00:53:18-05:00",
"id":"PHENOMENON_TIME"}},
"observedProperty": "velocity",
  "proce-dure": [
   "90:00:4E:87:BF:3C"],
  "resultTime": [
   "#PHENOMENON_TIME"
  ]}}
```


Fig. 2. (a) System architecture. (b) SOS standard code example.

results and welcome. Taking into account that the vehicles where the driver does not have a smartphone, an Arduino or a Raspberry prototype have been installed. The mobile application in the areas of average consumption of the battery in mw, has been evaluated, and the use of the CPU compared to applications known as WhatsApp y Messenger, to discard possible causes of uninstallation which can reduce the *Crowd-sensing* damaging the system. These results are observed in the Fig. 3.

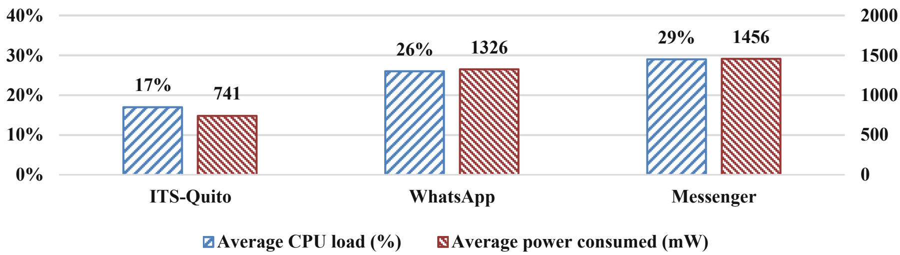


Fig. 3. ITS-Quito comparison with known social applications.

It has been performed a series of tests in different places in the city, where it was evident the improvement of the situational consciousness by 30% through a survey of 65 volunteer carriers. This means that at least 18 people made a better decision based on the information provided by this system. Even so, some of them did not go on a trip when observing accidents or work on the road; other drivers took alternating routes when observing that on the route there was intense traffic. These volunteers indicated (in the survey) that this information was not obtained by any other applications. In this way it is able to optimize the decision making in the planning of trips, reducing the traffic as a consequence. Likewise, the *Crowdsensing* was reaffirmed because the results shown to the carriers improve considerably by increasing the number of users.

In turn, it has validated the performance of the server along with all its tools to corroborate its design. First, the server hosts the Web interface, which implements *SOS* operations for heterogeneous clients. This interface has been tested with the *JMeter* software to evaluate the average in *ms* of the service requests, among other parameters. The results show that even for 10000 samples/requests the average response time is less than 1 s, verifying its character in Real Time. In addition, it is emphasized that no errors were presented in the applications made. These results show that the *SOS* interface implemented has a large amount of data processing capacity, sufficient and necessary for a large number of sensors addressing large cities such as Quito, as shown in Table 1.

Table 1. Load the server test results.

Samples	Average (ms)	Min (ms)	Max (min)	Received KB/sec
100	355	261	531	30,92
1000	466	267	951	37,73
10000	698	265	1159	35,59

5 Discussion

According to the results obtained, this section is presented to show the benefits and drawbacks of the heterogeneous ITS to Quito city developed, as well as the criteria used to solve the difficulties.

According to the results of the mobile application, it was observed that the consumption of the host's hardware resources was not significant, and even less than social mobile applications known as *WhatsApp* among others. However, these results may vary by altering the frequency of data sampling of the route. If the frequency would increase, the mobile application would consume more resources such as CPU, battery, RAM, and bandwidth. Which can cause the uninstallation of the application affecting the *Crowdsensing*. On the other hand, by decreasing the frequency the system would not have enough data to emit relevant results for users. In this sense, these criteria must be taken into account for every system in real time. Consequently, a balance must be found to avoid stressing mobile devices without losing the amount of data necessary for the system.

Our research, in contradistinction to projects such as ITS-Michigan or ITS-Russia provides a solution to the Quito community at low cost, that is, it does not require a large technological deployment which obviously will require a large economic investment, this is not feasible for countries in the process of development like Ecuador. Smartphones are the main source of information; first the data collection and second, for the publication of results. Allowing everyone with a smartphone to be part of the system.

Crowdsensing has been measured in a scalable way. That is, users have been progressively added to the system to observe its technical behavior. As shown in Table 2, the forecast time provided by the system has been compared with the actual travel time to measure the efficiency of the system. The trend in this table indicates that the greater the number of users, the system data is closer to reality.

Table 2. Comparison of real time with delay time (Application).

Number of users	Real time (min)	Forecast time (Application) (min)	Error rate (%)
10	186	167	10,21%
30	170	155	8,82%
60	189	175	7,40%

A problem to mention in the research could be in terms of security. First, to send sensor data to the server, sensors must register in the system following the standard SWE-SOS. Later, in order to achieve the results of the route, the identification of the sensors is revealed, which can cause vulnerabilities in the system. A possible solution could be, the encryption of the identification of the sensors to avoid attacks due to insecurity.

6 Conclusions and Future Work

Population and vehicular growth in large cities must go hand in and out of the improvement of transport management systems. In Quito Ecuador drivers experience hours of delay due to the amount of traffic in the city. This article presents the prototype for an Intelligent Traffic System (ITS) that allows to notify in real time to the drivers about any incident provoked in the pathways, and in general way, of the state of traffic in the whole city. In this way, the drivers acquire a real and timely situational awareness that allows them to make appropriate decisions and in time.

The proposed architecture envisions the implementation of a system of notifications in real time, by means of the Protocol of Communications *MQTT*, whose performance has been paramount to multiplex the channel of communications in several subchannels, same that represent each of the access roads to the city of Quito. On the other hand, the data on the state of the pathways are measured and provided by different types of heterogeneous sensors (smartphones, *Arduino, Raspberry*), i.e. the system has the ability to accept as customers any type of sensor that can measure a route parameter and send this result through the web. These data have been modeled according to the guidelines of the *SWE - SOS* standard.

In the future, it is considered to incorporate new technologies for the visualization of the system data as a *SPA* (*Single Page Application*) that allows to experiment in a fluent way the data obtained from the mobile clients, because these data are dynamic and vary after a time interval. In addition, it provides for the implementation of other features of the *MQTT* protocol such as the media hierarchy and the connection with remote servers *MQTT*, to avoid possible points of failure of the developed system.

Acknowledgment. Authors gratefully acknowledge the financial support provided by the Escuela Politécnica Nacional, for the development of the project PIJ-15-20 "E-iRoads: Ecuador - Inteligent Roads. Un Sistema inteligente para la gestión de tráfico en las periferias de grandes ciudades (Caso de Estudio: Quito)".

References

1. Freire Mullo, J.E., Nájera Puente, J.F.: Estudio de movilidad en la ciudad de Quito en horarios pico, utilizando datos móviles de la empresa telefónica, Ecuador (2017)
2. AEADE: Sector automotor en cifras. http://www.aeade.net/wp-content/uploads/2018/03/boletin%2018%20espanol%20resumido.pdf
3. SENAE: Servicio Nacional de Aduana del Ecuador. https://www.aduana.gob.ec/
4. AEADE: Asociación de Empresas Automotrices del Ecuador. http://www.aeade.net/
5. SRI: Matriculación vehicular. http://www.sri.gob.ec/web/guest/matriculacion-vehiculos
6. de Castro, A.F.: Quito: crecimiento y dinámica de una ciudad andina. Revista Geográfica, 121–164 (1989)
7. Singh, M., Rajan, M.A., Shivraj, V.L., Balamuralidhar, P.: Secure MQTT for Internet of Things (IoT). In: 2015 Fifth International Conference on Communication Systems and Network Technologies, pp. 746–751 (2015). https://doi.org/10.1109/CSNT.2015.16
8. Luzuriaga, J.E., Cano, J.C., Calafate, C., Manzoni, P., Perez, M., Boronat, P.: Handling mobility in IoT applications using the MQTT protocol. In: Internet Technologies and Applications (ITA), pp. 245–250. IEEE (2015)
9. Hidalgo. N., Narváez, M., Arteaga, J., Mena, P., Rojas, K.: Plan maestro de movilidad 2009–2025. http://www.flacsoandes.edu.ec/libros/digital/39700.pdf
10. Vanajakshi, L., Ramadurai, G., Anand, A.: Intelligent Transportation systems lecture notes. https://www.thesisscientist.com/docs/StudyNotes/de9b8b1b-3cfc-4d82-8ab0-b4468ff5b3eb
11. ITS-Michigan: Sociedad Inteligente de Transporte de Michigan. http://www.itsmichigan.org/
12. ITS-Rusia: Intelligent Transport Systems of Russia. http://itsrussiaforum.ru/en/
13. Mendez, P.: Red privada virtual como alternativa para el respaldo de información digital en el ilustre municipio de Baños (2017). http://186.3.45.37/bitstream/123456789/7384/1/PIUASIS013-2017.pdf
14. Pigné, Y., Danoy, G., Bouvry, P.: A vehicular mobility model based on real traffic counting data. In: Strang, T., Festag, A., Vinel, A., Mehmood, R., Rico Garcia, C., Röckl, M. (eds.) Nets4Cars/Nets4Trains 2011. LNCS, vol. 6596, pp. 131–142. Springer, Heidelberg (2011). https://doi.org/10.1007/978-3-642-19786-4_12
15. Kamar, E., Horvitz, E., Meek, C.: Mobile opportunistic commerce: mechanisms, architecture, and application. In: Proceedings of the 7th International Joint Conference on Autonomous Agents and Multiagent Systems, vol. 2, pp. 1087–1094. International Foundation for Autonomous Agents and Multiagent Systems, Richland (2008)
16. Ma, H., Zhao, D., Yuan, P.: Opportunities in mobile crowd sensing. IEEE Commun. Mag. **52**, 29–35 (2014). https://doi.org/10.1109/MCOM.2014.6871666
17. Naik, N.: Choice of effective messaging protocols for IoT systems: MQTT, CoAP, AMQP and HTTP. In: 2017 IEEE International Systems Engineering Symposium (ISSE), pp. 1–7 (2017). https://doi.org/10.1109/SysEng.2017.8088251
18. Official Website Arduino: Arduino UNO R3 (2014). https://arduino.cl/arduino-uno/
19. Official Website Raspberry: Raspberry Pi 3. https://www.raspberrypi.org/products/raspberry-pi-3-model-b/

20. CoderProf: gy-gps6mv2 datasheet PDF. http://coderprof.com/PDF_Examples_Free_Download.php?q=gy-gps6mv2+datasheet
21. Rhydo Technologies (P) Ltd.: SIM 900-RS232 GSM/GPRS Modem User Manual (2011). http://www.rhydolabz.com/documents/gps_gsm/sim900_rs232_gsm_modem_opn.pdf
22. Itead Studio: Raspberry PI GSM Datasheet (2013). ftp://imall.iteadstudio.com/Modules/IM131224002/DS_IM131224002.pdf
23. Página Oficial EPN: Escuela Politécnica Nacional. https://www.epn.edu.ec/
24. Lim, H.-T., Weckemann, K., Herrscher, D.: Performance study of an in-car switched ethernet network without prioritization. In: Strang, T., Festag, A., Vinel, A., Mehmood, R., Rico Garcia, C., Röckl, M. (eds.) Nets4Cars/Nets4Trains 2011. LNCS, vol. 6596, pp. 165–175. Springer, Heidelberg (2011). https://doi.org/10.1007/978-3-642-19786-4_15
25. OGC® Standards: Sensor Observation Service. https://www.opengeospatial.org/standards/sos