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# Design and Development of an IoT-based System for Truck Load Tracking and Monitoring

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**Abstract.** Freight transport of goods and raw materials is a main part of the supply chain in the commercial exchange between nations or cities. The control and monitoring of this activity are vital for an efficient economic flow and more importantly without losing money. Most of the problems that generate economic losses occur in cargo freight by land (cargo trucks). Losses due to changes in the weight of the payload to be transported or fuel/time losses due to capricious changes by the driver on the scheduled route. This work aims to demonstrate the use of Internet of Things (IoT) techniques to propose a prototype of a telemetry system to monitor in real-time the payload weight and location of a cargo truck, and become a technological tool that supports the tasks of monitoring and control of the use of cargo trucks, and together with other logistics measures, leads to minimizing economic losses. The development of this project was based on the IoT architecture reference model: an ATmega32u4 microcontroller was used together with a SIM808 GSM and GPS module as the main component of the IoT Node. In addition, Amazon Web Services (AWS) tools were used as an IoT web platform and cloud data storage. The main result was a prototype of a telemetry system to track a cargo truck via the web, the weight and position data are accessible from any device with internet access through a website. Preliminary field tests have been successful and have shown the proposed system to be an efficient and low-cost option.

**Keywords:** IoT, sensors, GPS, GSM, microcontroller.

## 1 Introduction

In Latin America, the exchange of merchandise and raw materials is carried out mainly through land transport. Its main advantage is the use of universal road infrastructure and its relatively low cost, is widely used for distances less than 1,000 km and loads less than 44 tons. Thus, each region or country has a large fleet of cargo trucks and its own legislation for this important economic activity. However, despite its wide use, it is in the transport of goods where there are some problems that lead to economic losses, these due to multiple factors [31, 37, 29]. One problem is the non-control of the weight of the payload in the trucks, from the time it is loaded at the dock of origin until it is delivered to the customer. This creates inconsistencies between what is shipped and what is delivered, resulting in a loss of money for the carrier. It is estimated that these weight discrepancies are due to factors such as robberies on the highways, theft by drivers or the lack of technical standards in the scales of the weighing points along the route. Overloading in road freight transport is a common problem that occurs all over the world. Of the negative effects generated by the overloading of trucks, perhaps the one with the greatest impact is the deterioration of the roads, reducing their useful life and, in turn, higher maintenance costs. Other negative effects are the increase in road accidents, the increase in emissions, fines, and longer transport times [9, 11, 14]. Another problem is the disproportionate expense of time and fuel during truck trips, due to the negligence of drivers in changing or modifying the established route, which generates delays in delivery times that produce monetary losses [42, 5, 29].

Therefore, control and monitoring of trucks along the distribution route has become a necessity, specifically, real-time monitoring of variables such as weight of the load and the geographical position of the truck, in the order to take action to avoid problems due to changes in route or changes in the weight of the truck [36, 17, 28].

Previous works have been related to the development of positional tracking systems for vehicles [2, 30, 16]. But these have focused on the use of high-cost technological tools [23, 43, 1, 22] or are not connected to a website in real-time. The use of GPS technologies together with development boards for microcontrollers such as Arduino is very common in previous works [41, 7, 27, 2]. Other works have focused on developing devices to monitor the weight of cargo trucks [35, 21, 32] however, they also focus on technologies with a high budget or that do not report in real-time [15, 25, 33]. Some of these previous works only focus on monitoring one variable, either weight or location of the cargo truck. In most of the developments, analog type weight sensors have been used, these are based on deflection of shock absorber supports of the truck suspension, converting this angle of deflection into an analog voltage [33, 44, 46] , however also digital weight sensors have been used less in similar systems [38, 33].

The architecture of an Internet of Things (IoT) system is defined by two main blocks: Sensor Nodes and the Internet Platform. The sensor nodes are the telemetry device equipped with sensor elements that take readings of different behavioral variables of the equipment to be monitored. The Internet platform, also called the cloud, is where the data collected by the Node will be stored, in addition to its visualization through web dashboards [3, 24]. The link between these Nodes and the Platform can be implemented using radio technologies such as WiFi, Bluetooth, GSM/GPRS, LoRa, among others [10, 18, 26, 19, 40]. The Atmega and ESP microcontrollers are the most widely used option in the sensor node processor implementation [8, 32, 6, 34, 45]. For the Internet platform, most used options are Amazon Web Services, Google IoT Core, Tingspeak and Ubidots [45, 39, 20, 4].

This work proposes a low-cost real-time telematics system based on IoT Technologies. The IoT stations are equipped with sensors that can take a reading of the weight and location variables of a cargo truck and send this data over a GSM/GPRS cellular link to the Internet. IoT platform for storage and web deployment accessible through any device connected to the Internet so that personnel can monitor and control possible anomalous situations on the transport route. This paper is structured as follows: Section II summarizes the development of the IoT system prototype. Section III presents the experimental results and a discussion of the proposal, and Section IV concludes and presents some final comments and ideas to be addressed in future work.

## 2 IoT System to Monitor Cargo Truck Location and Weight

This work aims to demonstrate the use of IoT techniques to propose a prototype of a telemetry system to monitor in real-time the payload weight and location of a cargo truck. The methodological development of this proposed system was based on the IoT Architectural Reference Model [3].

### 2.1 Purpose & Requirements Specification

Purpose: Automated monitoring of the weight and position of a cargo truck with a GSM cellular link to report in real-time through a web dashboard. Behavior: an electronic station with sensors capable of taking measurements of weight (Tons) and position (GPS) of the truck, and a central digital controller programmed to perform periodic sensor readings and send the collected data via GSM/GPRS cellular link to an Internet platform. Management: the system can be monitored through the Internet and management of programming and configuration of the sensor station can be done locally through a USB port provided in the station itself. Data Analysis: The data collected by the sensor is processed at the station itself and then sent in formatted payload values to the "cloud" service platform. Implementation of applications: the station control software or firmware remains inside the flash memory of the microcontroller and is encoded in C programming language. An IoT platform with web visualization panels is used to monitor the data produced by the node. Security: the system must have user authentication and a JSON protocol with token authentication to receive data payloads from the station to the platform. Access to the web data dashboard will be publicly accessible.

### 2.2 Process Specification

A single case of operation in a repetitive cycle is defined through the firmware in the digital controller: when the system boots, it executes actions to configure

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Algorithm 1: IoT Node Station Process Specification
Result: Periodically t read GPS and weight sensor inside cargo truck
        then send it to IoT platform via GSM/GPRS cellular link.

Setup microcontroller hardware;
Setup GSM/GRPS hardware;
Define t ;                                      // minutes between read/send
while True do
    read digital GPS sensor ;                   // long, lat, timestamp
    read analog weight sensor output;
    calculate the weight of the truck ;         // w
    format JSON payload with lon, lat, w, time data ;
    connect to GSM network;
    activate GPRS data use;
    make a HTTP POST into web storage server;
    wait to server reply;
    if replay == 200 then
        turn off GRPS;
        wait for t;
    else
        try again without delay t ;             // retry POST
    end
end
```

**Fig. 1.** Single case algorithm for electronic station process.

the internal and external hardware of the microcontroller, then reads the weight and position sensors, formats them in a loads JSON and finally sends them to the IoT platform through a GSM/GPRS cellular network, this whole process is periodic (see Fig. 1).

### 2.3 Domain Model Specification

Physical Entity: the cargo truck whose weight and current global position will be read. Virtual Entity: represents a physical entity in the digital world, so only one is defined for the cargo truck. Device: programmable digital controller with GPS position and weight sensors, with GSM cellular network transceiver. Resource: firmware running on the device and a configuration script running on the IoT cloud. Service: the station service runs native on the device.

### 2.4 Functional View Specification

A functional view defines functional groups (FG) for the different functions of the IoT system. Each functional group has functions to interact with instances

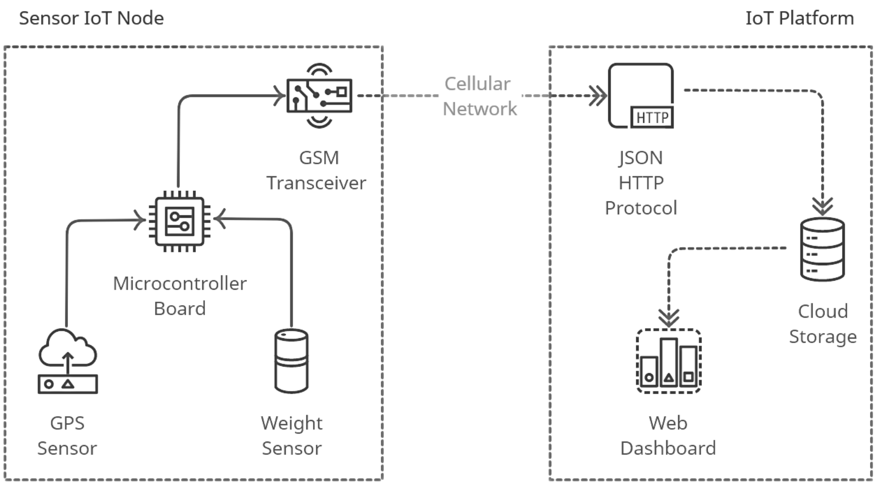


**Fig. 2.** Overview of functional blocks architecture of the proposed IoT system.

defined in the domain model or with information related to them. Device FG: includes the microcontroller, the GSM transceiver, weight and GPS position sensors. Communications FG: the protocols used are 802.11 link layer, IPv4 network layer, TCP transport layer, HTTP application layer and JSON protocol to send data payload to the IoT platform. Services FG: there is only one service running inside the IoT station control service. Management FG: performed by firmware resource inside the microcontroller. Security FG: the security mechanism is an authentication user credential for the IoT cloud configuration. Application FG: web interface to monitor values produced by the IoT node is in the ”cloud” as an internet page.

## 2.5 Operational View Specification

Options for deployment and operation of the IoT system are defined. IoT node station: mains components are a microcontroller, a GSM network transceiver for internet access, a sensor for weight, a sensor for GPS position. Communication API: Amazon Web Services API. Communication protocols: 802.11, IPV4 / 6, TCP and HTTP. Services: controller service hosted on the device written on C programming language and running as a native service. Applications: Web and database Application – AWS web toolbox. Administration: device – Arduino IDE for electronics station and AWS for cloud applications (see Fig.2).

## 2.6 Device & Component Integration

Components for the IoT Node: an ATmega32u4 microcontroller is used as CPU, SIM808 chip is used as a transceiver for the GSM/GPRS cell network, which

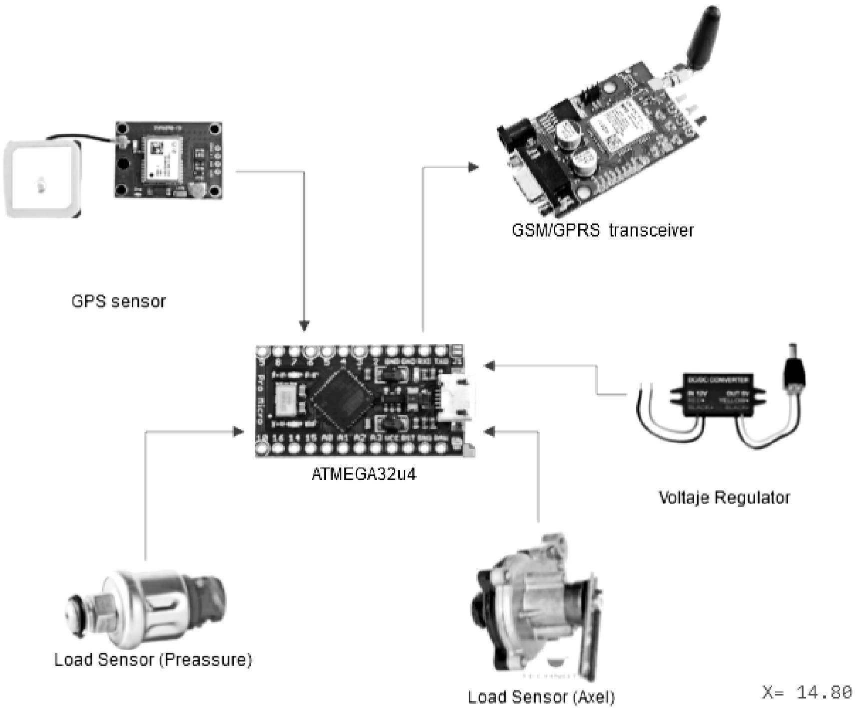


**Fig. 3.** Electronics components integration for sensor station of proposed IoT system.

also includes a GPS receiver sensor in the same encapsulation. As a weight sensor, GNOM DP sensor with analog output is used, which is placed on the suspension axle of the truck (see Fig. 3). Also in a second prototype, the weight sensor with analog output GNOM DDE is used, which detects changes in the pressure of the truck's damping hoses. As a development hardware platform SIM808 GSM/GPRS/GPS IoT Board from the manufacturer DFRobot is used, that includes the ATmega microcontroller along with the SIM808 in the same board [13].

### 2.7 Application Development

From the point of view of the software applications developed to run the IoT system 1) IoT node firmware: written in C programming language, the program follows a single loop structure and specific tasks that are repeated cyclically in a period of configurable time (see Fig.1). 2) IoT platform software configuration: "Cloud" service script: developed in JavaScript language hosted in the Amazon Web Services (AWS) cloud. The JavaScript telemetry protocol Object Notation (JSON) is used to send and receive data between the sensor's IoT node and the IoT platform. AWS services were selected for their low cost, high reliability, and

**Fig. 4.** Assembled electronic prototype for IoT Node Station.

availability versus other similar services. In addition to having a relatively short learning curve. 3) Web Dashboard – Developed using AWS hosting services, using a web toolbox to configure the website with data tables and a graphic dashboard to display the data generated by the sensors.

## 3 Results and Discussion

The main result of this work was a prototype of an IoT System to monitor the weight and location of a cargo truck in real-time.

### 3.1 IoT monitoring station

IoT Sensor Node: station with electronic sensors that allow taking measurements of weight and GPS position of a cargo truck and sending them to the IoT platform in the cloud (see Fig.4).

It is a design that takes into account the needs of the conditions of the Latin American region, based on state-of-the-art electronic components that are affordable, efficient and available in the local market. The hardware station design allows for more sensors to be added to the station to increase the variables

**Fig. 5.** Tests for IoT Node Station prototype attached to a cargo truck.

to be measured. Two detected magnitude values are reported to the website by the station every 10 minutes or can be configured in the microcontroller firmware.

The physical installation of the station is simple, it can be embedded in the structure of a truck. The technical requirements for the installation site are: a 12 VDC power supply near the truck battery and Cellular Network coverage, the station is configured for Internet access through a GPRS link and uses a 2G cellular network (see Fig.5).

The start-up only requires defining via firmware, the network access credentials and a SIM card with an active data plan. In the field tests, a waiting time between shipments to the IoT platform of 5 to 10 minutes was configured, this is changeable from the firmware of the station.

Among the electrical characteristics of the station prototype we have: Operating voltage: 12 VDC @ 0.4 W max. Operating temperature: +60 °C max. Measurement operation: Weight range from 1 to 10 tons. GPS location Horizontal position accuracy: ¡ 2.5m CEP. Communication performance: Link: GSM/GPRS Quad-band 2G Network. GPRS connectivity: 85.6kbps max and standard SIM Card.

### 3.2 Web Platform and Field Test

As a field test, the designed system was implemented in the fleet of the company CORPORIN S.A de C.V, which focuses on cargo transportation services within the territory of El Salvador and to some cities in Guatemala and Honduras [12]. To keep track of the data collected, the user can access the website with the URL through any device with Internet access: https://bit.ly/3lcSe5X. This website includes tables and dashboards to view the history of weight, longitude and latitude values reported by the station installed inside the cargo truck (see Fig.6). System performance so far has been satisfactory. The telemetry link has not suffered losses and has remained stable. Several tests were carried out with different IoT Nodes located at different points within the structure of the truck, one of the best link results was obtained with the station located behind the truck cabin and with an open sky view. Looking at the data collected during the field test period, no out-of-the-average changes were observed in the data for the truck in question. The weight and GPS position data have been consistent with the preset route in the company's headquarters.

## 4 Conclusion and Future Work

Development of an IoT system to monitor in real-time the weight and positioning of a truck along its route is a fundamental step for the study of behavior, impacts and actions on possible data anomalies on the route and weight of the truck. This work demonstrates the use of Internet of Thing (IoT) techniques to design and build a prototype of a telemetry system to monitor in real time the weight of the payload and the location of a cargo truck, and become a tool technology that supports the monitoring and control tasks of the use of cargo trucks, and together with other logistics measures, leads to minimizing economic losses due to inconsistencies in the weight of the cargo. The proposed system was developed using state-of-the-art techniques in electronics, programming and the Internet of Things, which allowed the production of low-cost equipment that works according to the expected requirements. Tools like Atmega Microcontroller together with the C programming language enable efficient IoT development prototypes at low cost, with short development times and high performance. In addition, the use of AWS toolbox has enabled quick and easy monitoring of the web development platform and site to data from any device and in real-time.The contribution of this work was to show new and innovative techniques for the use of hardware and software components in the implementation of IoT Systems. In addition to being an ad-hoc application for need and context of cargo transportation in El Salvador, where aspects such as low cost and customization

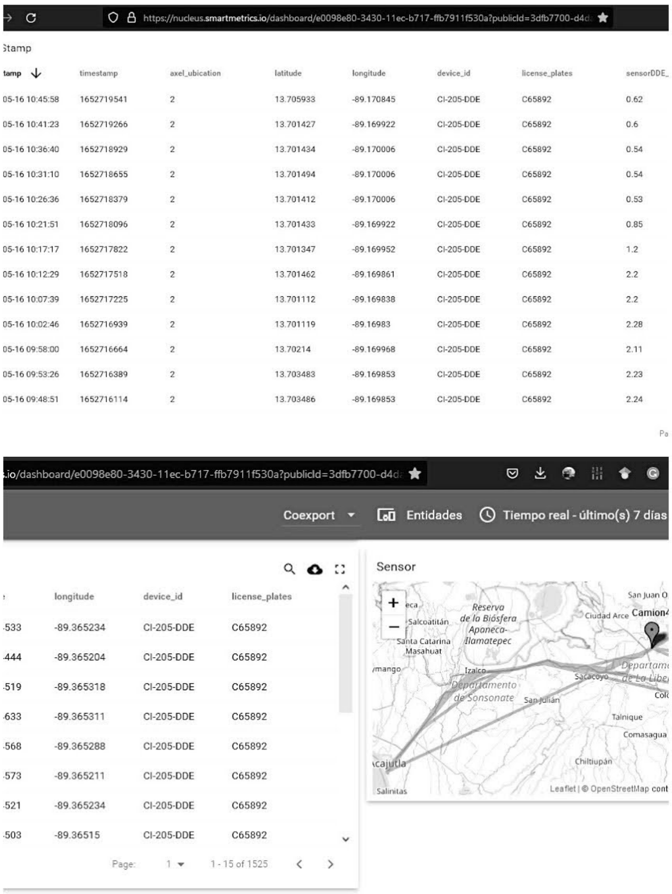

**Fig. 6.** Web site tables and dashboards for collected truck data coming from the sensor station.

are valuable aspects for innovative technological proposals. These can be applied in new developments, allowing rapid and efficient prototyping. To be done, this research is tasked with developing more stations by adding different sensors to capture more variables about truck performance and establish more field test validation. Implement a more robust cloud platform, with powerful dashboards and tables with ready-to-read data. Additionally, we seek to implement a monitoring network through radio frequency links and analyze big data or forecasts based on the data produced by the stations. The result of this work can be used in the development of new lines of applied research, in areas such as land or aquifer analysis, monitoring in agricultural and livestock fields, sports performance analysis, etc.

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