Development of an Automated Ticketing and Tracking System for the Monitoring of Surface Mine Hauling Operations

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Abstract-Telematics systems that integrate wireless communications and automation for equipment tracking and trip monitoring in mining operations have an advanced impact on the operational efficiency and optimization of the mine's asset inventory. In this study, a system was developed for solution in a mining area with low mobile network signal coverage and no internet service available to monitor and analyze the actual utilization executed by heavy equipment using microcontrollers with communication capabilities (GSM/GPRS, WiFi, and Bluetooth) and sensor modules for fuel monitoring and location tracking. Open-source software was utilized, such as PHP framework and MySQL, to provide a fast and real-time display of daily mine operations. The study provides an online tracking and ticketing system on mine hauling vehicles, introducing a cost-efficient, reliable, interactive platform for web-based monitoring and real-time telematics. The data acquired in real-time provide significant information which will allow innovative equipment optimization.

Keywords-telematics; microcontrollers; GSM; GPRS; WiFi; PHP; MySQL; tracking and ticketing system; web-based monitoring

I. INTRODUCTION

By allowing the extraction of important information from industrial processes, the industrial revolution, which includes automation, information, and communication technology, can improve production and commercial processes. Due to the infrastructural limitations in communication, data management, storage, and information exchange, the mining industry is rather traditional and slow to change [1]. The hauling system has been a mainstay of the mining industry for many years. While machines have increased in size and scale and

automation has become an important development, there have been few innovations to the actual load and haul process [2]. Most recent efforts focused on using robotics and automation to assist the extraction and transport of minerals and ore [3]. Trip analysis in mining hauling operations can lead to a series of important analytics applications for asset managers. Analyzing trip data helps fleet managers and dispatchers understand and estimate asset utilization, route deviation, and ETA (Estimated Time of Arrival). This system is extremely crucial when making production decisions and adjustments to improve the efficiency and use of equipment. Implementing good monitoring systems plays a vital role in achieving this. Nowadays, the competitive global economy is forcing mining companies worldwide to modernize their operations through increased mechanization, automation, and monitoring [4–8].

Historically in fleet management, trips are logged manually or semi-automatically, whereas using GPS-based data to infer trips provides an automated approach to trip management and analysis [9–11]. This system alleviates the labor of manual recording and avoids the possibility of unauthorized or misreported trips, and improves the accuracy of actual trip data. One of the most common asset tracking technologies is an embedded GPS receiver and other sensors to track a movable asset such as a trailer, which connects with a central data server via satellite or cellular communications. Every telematics communication typically contains location data, vehicle identity information, timestamps, and an event code [12].

Monitoring systems implemented in various fields utilize different technologies like unmanned vehicles, GSM, IoT, and WSN to retrieve information from the monitored equipment or area [13–17, 21-22]. However, in mining area settings where

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mobile network connection and internet coverage are difficult to acquire, it is necessary to implement a one-of-a-kind data transfer system. This study developed such a system to solve the transmission problem and to monitor and analyze the actual utilization executed by the mining company's heavy equipment, by using microcontrollers with wireless communication capabilities (GSM/GPRS, WiFi, and Bluetooth) and sensor modules for fuel monitoring and location tracking. Open-source software, such as PHP framework and MySQL database, was utilized to provide a fast and real-time display of daily mine operations. The study provides an online tracking and ticketing system of mine hauling vehicles, introducing a cost-efficient, reliable, and interactive platform for web-based monitoring and real-time telematics [18–20]. This system is specially tailored for the mining industry and their environmental conditions. Measures are made in order to accommodate areas with low mobile network and internet coverage. Unlike other tracking systems [23-27], this tracker module is integrated in the mining industry process, and the data it sends include some mining hauling operation parameters. This helps smoothen out their operations in terms of equipment monitoring and management. Table I shows the differences of the proposed method and the current process used by this project's partner mining company.

TABLE I.   PROPOSED SYSTEM VS CURRENT COMPANY OPERATIONS

Parameter	Proposed method	Status quo
Vehicle status	Check status/location instantly	Check status at the end of day, no location tracking
Checker transaction	Wireless transmission, automatic data transfer to server	Paper transactions, Data is manually encoded to the server at the end of day
Data summary	View data in the web anytime of the day	View data in Excel after they are manually encoded after shift (end of day)

II.   SYSTEM ARCHITECTURE/METHODOLOGY AND FLOWCHART

Figure 1 indicates the system overview of the study. The details of the system components are shown in Figure 2 and are analyzed below.
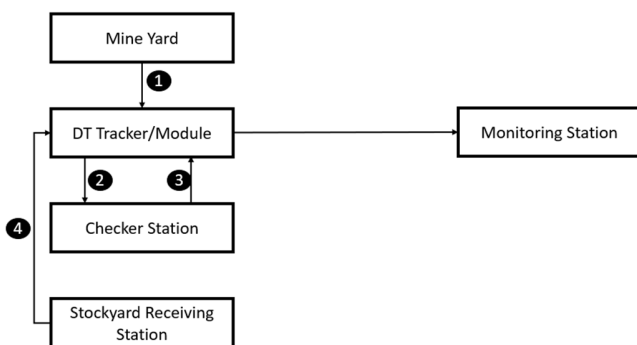

Fig. 1.   System overview.

- Loading Station: In this station, the Dump Truck (DT) is being loaded with ore in the mine yard. The installed tracker module in the DT is started. DT location and fuel status are always periodically sent to the cloud every 30s for the whole duration of the trip. This module uses GSM/GPRS communication to send all the data acquired by the DT module to the cloud. If a mobile network signal is not available, the tracker module can save all the acquired data and send them when it acquires a signal later on the trip.

- Checker Station: After ore loading, the equipment, specifically the dump truck, passes through a checker station. There, checker personnel create a trip ticket or Delivery Receipt (MDR) to track the ore's trip. Trip Ticket data are sent back to the DT module to the cloud since checker stations don't have mobile network signals or internet connections. The DT module will send the MDR information once it acquires a mobile network signal later on the trip.

- Receiver Station: In this station, the equipment, specifically the DT, arrives at the stockyard where the ore is expected to be delivered. Receiving personnel send the destination information to the DT module. The DT module then sends it to the cloud. This process completes one trip data and can be viewed on a web application.
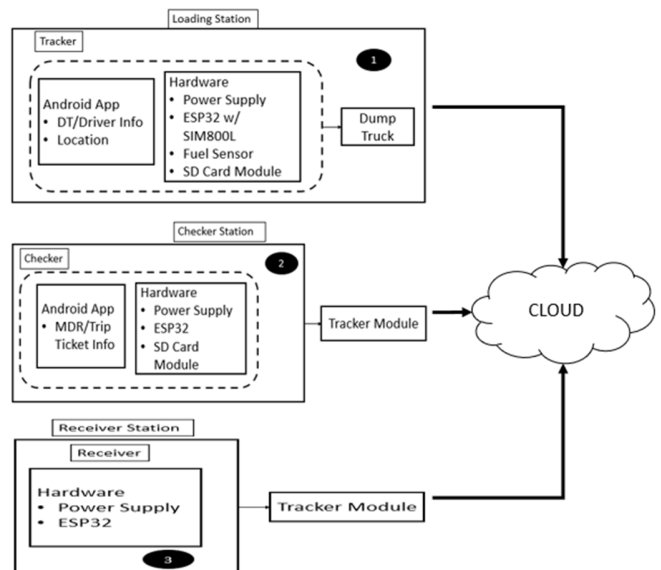

Fig. 2.   System architecture and flow.

III.   HARDWARE, SOFTWARE, AND SYSTEM INTEGRATION

A. Hardware Design

The tracker module design for this system used methods slightly different from the existing technologies [10-13]. This tracker module sends the location and status of the monitored vehicle and carries essential operations' data generated during the trip. Table II shows the comparison of the proposed system with the existing tracker modules [23-27]. The proposed system includes fuel monitoring and integration to smartphones in order to add additional information like vehicle status and driver info. Also, the proposed system is specially tailored for

mining industry conditions in the Philippines, where mobile network coverage is very low. Also, this tracker module is integrated in the mining industry process, and the data it sends include some mining hauling operation parameters.
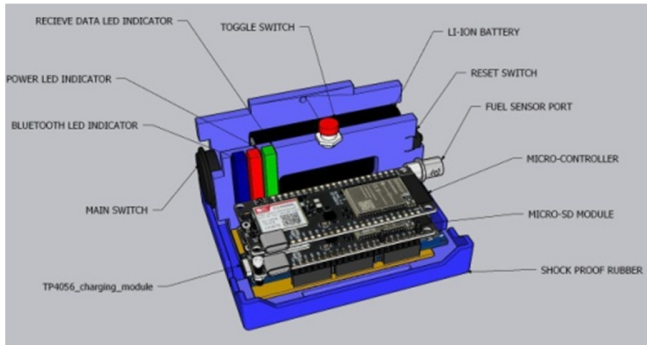

Fig. 3.   Tracker module.

TABLE II.   PROPOSED TRACKER VS EXISTING TRACKER MODULES

Parameters	Proposed	Existing tracker modules
GSM/GPRS transmission	Existing	Existing
GPS module	Existing	Existing
Smartphone integration	Existing	None
SD card backup	Existing	Existing
Fuel monitoring	Existing	None
Web integration	Existing	Existing

Two interconnected ESP32 modules with SIM800L, a fuel sensor, and a Micro SD module make up the primary tracker module. A processor unit, short-range wireless communication technology (WiFi and Bluetooth), and a cellular network unit make up the ESP32 module (SIM800L). The two ESP32 modules are connected in a serial communication protocol. The first ESP32 module will receive the external data from other modules such as the checker module, weighbridge, and receiver modules through wireless communication and then send them to the second ESP32 module through serial communication. The second ESP32 module, which is equipped with the SIM800L(GSM/GPRS) module, will send the received data to the cloud. The tracker module is also equipped with a fuel sensor port, which receives the fuel level data of the vehicle. The system also has three indicator LEDs that help the user identify the device's working status. The first LED is the Power LED, which lights up when the system is turned on and has performed all needed initializations, the second is the Bluetooth LED, which lights up when the module is connected to an external device, and the third is the receive data indicator, which lights up when external data are received.

Three switches were also installed in the module. The first switch is the Main Switch, which is responsible for turning the device 'on' and 'off,' the second switch is the reset which can be used to reset the device when restarts are needed, and the third is the toggle switch which is used to tell the device to receive external data. An SD card module can also be found in the system. It serves as a temporary data storage device while the data are not yet sent to the server. The data on the SD card are erased once a transmission confirmation is received. If the transmission is not successful, the SD card retains the data until

the module acquires signal to resend them. The SD card is not manually erased since it will not be full from the stored data. A Li-ion battery was used as the system's power supply, which was also partnered with a charging module that controls the system's charging and discharging and protects the battery from overvoltage and undervoltage situations. The modules will be tapped directly into the vehicle's internal power supply. The batteries in this case will act as backup every time the vehicle is turned off, so the tracking may continue. When the vehicle is turned on again, the batteries are automatically recharged. With the battery's capacity of 13.3Wh, and 1.3W average power consumption of the tracker, the battery can last up to 10hrs, until the vehicle is needed to be turned on again to charge it. Since the vehicles are used daily in day and night shifts, there is only little time that the battery is being used, only during transition of drivers and maintenance after shift. A shock-proof rubber was also used in the enclosure to protect the modules from possible external vibrations. The dimensions of this module are 10cm×7cm×4cm.
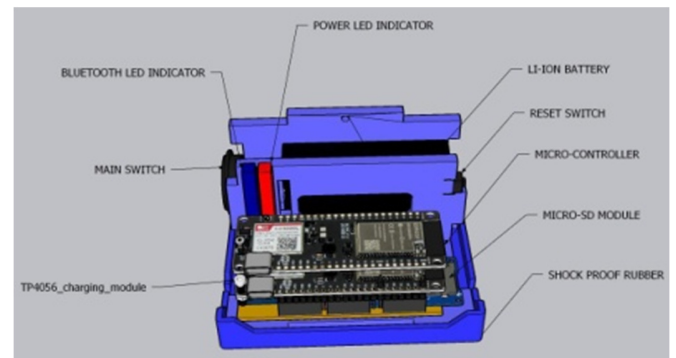

Fig. 4.   Checker module.

The checker module consists of two interconnected ESP32 modules with SIM800L and a micro SD module. The two ESP32 modules are connected in a serial communication protocol. The first ESP32 module will receive the data from an external device with a user interface to create the trip ticket through Bluetooth communication and then send it to the second ESP32 module through serial communication. The checker application has the interface for the checker personnel to enter additional information for the trip (e.g. source of material, destination, shift, department, ore composition, etc.). The app has the ability to check the authenticity of the user checking the current trip. The checker personnel are registered in a database, and the checker app is being synced into that database in order to get the list of the valid personnel. The app then checks the person who is logged-in in the app if he/she is in the list before he/she can proceed with the transactions. The second ESP32 module transmits the received data to the tracker module through WiFi communication. The system has two indicator LEDs that help the user identify the device's working status. The first is the power LED which lights up when the system is turned on and has performed all needed initializations and the second is the Bluetooth LED, which lights up when the module is connected to an external device. Two switches are also installed in the module. The first is the main switch, which is responsible for turning the device 'on' and 'off' and the

second switch is the reset which can be used to reset the device. An SD card module is also installed. This system serves as temporary data storage while the data are not yet forwarded to the tracker module. Like the tracker module, the data on the SD card are also being erased once a transmission confirmation is received to avoid data overflow. A Li-ion battery was used as the system's power supply, which was also partnered with a charging module that controls the system's charging and discharging and protects the battery from overvoltage and undervoltage. The checker station is expected to also have a stand-alone solar station to accommodate the module's charging. Like the tracker module, a shock-proof rubber was also used in the enclosure to protect the modules from external vibrations. The dimensions of this module are 10cm×7cm×4cm.

B. Software

- Arduino IDE 1.8: An open-source software platform used to write programs, while programs can be uploaded directly to the board. This IDE is compatible with ESP32 microcontroller chips and is used to compile and upload programs to an onboard microcontroller unit in the system.

- PHP 7.2 and MySQL 5.5: The system utilized open-source software such as PHP scripting language towards the web development of the study and MySQL database to display the data acquired by the modules during operations.

IV. RESULTS AND DISCUSSION

The full system was tested for 10 days straight, and the testing gathered over 4300 lines of raw data. The system enabled quick tracking/monitoring of the equipment used during hauling operations. The biggest benefit from the system was the easy access in monitoring by the management, which allowed them to have production data in their operations in contradiction to their old methods. In their old method, they were only able to check their production data at the end of the day, which limits them to make adjustments in their operations mid-day. Being able to monitor data so close to real time helped them improve efficiency and optimize their operations.

This system also reduced paper usage, which is responsible for a good amount of their budget. Implementing this system would provide savings to the company in terms of operation cost in the long run. Figure 5 shows the tracker module interacting with the developed android app, which provides the necessary data needed for monitoring. The tracker module sends parameters like the equipment ID, operator ID, department, MDR, status, location, speed, and fuel level and the sensor sends the data. The location sent by the tracker was validated by comparing the values to the readings of Garmin Oregon 750 during field testing. The raw data were received by a web server (Figure 6), which displays the data in tabular form for easy reviewing. The web server also processes the data and translates the latitude and longitude data into actual map locations (Figure 7).

Fig. 6.   Monitoring data display on the web.

Fig. 7.   Map showing actual track traversed by the equipment.
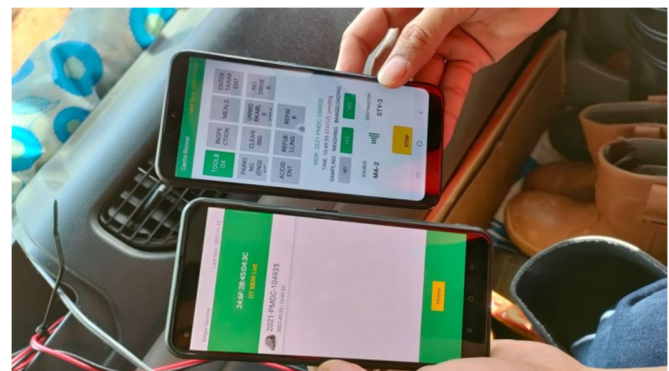

Fig. 5.   System testing.

Fig. 8.   Checker app sending data to the checker module.

Figure 8 shows the checker app interacting with the checker module. The checker app and module together send the MDR data to the tracker module consisting of parameters like shift

schedule, activity, ore type, source, destination, distance traveled, fuel consumed, and other mining operation-related parameters. The MDR data are being recorded on the server (Figure 9) and can be tracked if the trips are already completed or still on pending status. The reliability assessment of the data transmission aspect of this research was done by comparing the raw data logs shown in Figure 10 and 11 received from the modules to the data being displayed in the server. The data sent by the modules were sampled periodically and compared to the current display on the Web.

Fig. 9.   Tabular display of the checker data (trip tickets) on the Web.

Fig. 10.   Sample raw data logs from the checker module.

Fig. 11.   Sample raw data logs from the tracker module

V.   CONCLUSION AND FUTURE WORK

In this research, an automated ticketing and tracking system for mining industry applications was developed. The system was able to monitor pieces of equipment even in areas with low mobile network coverage and no available internet connection. Based on the results, the system showed a big contribution in making the daily operations of mining industries more efficient by providing real-time monitoring and ticketing tools that can be used in process decision- and adjustment- making during operations. The system was able to improve the company's data transfer, from the End-of-Day status to real-time. It was also able to provide faster ticket issuance, improve the safety of the personnel since the operations are done wirelessly, and save on the cost of paper used on the tickets. Eventually, using this automation system will lead to more efficient daily operations, thus potentially increasing the overall output and profitability of the company.

Therefore, the proponents highly recommend this project to the mining industries in the Philippines, which are still using manual ticketing systems and no equipment monitoring, especially those located in low mobile network coverage areas. However, the required personnel responsible for the maintenance and operation for its sustainability in a full-time basis are needed to be trained. Moreover, for future work, the researchers recommend looking for a cheaper alternative in data sending technology since GSM load is relatively expensive in the Philippines.

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