On Board Intelligence for Public Transportation in Developing Countries using IoT

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Abstract. This study is carried out for indigenous development of an ITS (Intelligent Transportation System) device aimed particularly for public transport buses in the developing countries with poor infrastructure and unaccountable transportation services. The developed system uses IoT technology, extendable hardware and open source software in order to achieve commercial scalability by government and transportation authorities in such countries. The proposed device essentially collects and store data from the bus fleet and communicates the information to a central server from which software applications for passengers and transport operators are developed accordingly. The device functionality is divided into three categories which are Environment Sensing, Vehicle Management and Safety. The acquired dataset can be used to produce useful insights that can benefit the social and commercial sector of the city. Analytics such as fuel consumption, vehicle health, predicting driver behaviour, forecasting of rush-hours and vehicle maintenance requirements can be estimated. The device is packaged into a box with proper considerations of reliability in terms of power, weather proofing, storage and cabling. The proposed device will allow the passengers, especially in developing cities, to plan their journeys ahead of time and provide a holistic decision support system to the transport authorities.

1. Introduction

Transportation is one of the most pressing issues in developing countries like Pakistan. This study is situated at the confluence of issues such as passenger accessibility to transportation infrastructure, access to science and technology, design thinking, and rights and entitlement. This low-cost prototype is designed to address the issue of lack of dependable public transportation and infrastructure in developing countries, a case which is reasonably complex due to social, political and economic challenges in such countries. This study aims to propose and investigate new methods of improvement in public transportation of developing countries where some form of transportation mechanism exists.

This paper proposes an indigenously developed ITS device, aiming to build a sustainable model that shall encourage the citizens to reduce the usage of private vehicles and start using the public transportation. Inspired by commercial vehicle telematics devices, the proposed Onboard intelligent unit is designed with features of Fleet Management/ Automatic Vehicle Location System (AVL) and Real Time Passenger Information (RTPI). This paper is structured as follows: Section II provides a brief overview of similar devices and solutions developed globally. Section III presents the proposed system model and its characteristic features. Section IV describes in detail about the hardware and software...
model along with its design and interface for various users. Finally, Section V discusses the conclusion and on-going future work.

2. Related Survey

Different solutions are practiced at different parts of the world. A brief analysis of the products and services used in public buses as part of ITS, in the past decade, includes: TMS (Transportation Management System) [1], Real-Time Bus Information System [2], APTS (Advanced Public Transportation System) [3] and DVR based systems. These systems take input from using smart sensing and cyber-physical systems and output collected information using various M2M (Machine-to-Machine) or IoT protocols. Some alternatives focus on the passenger safety and information availability, while others focus on improving the quality and accessibility of public transit systems. In essence, most of the recent advances in ITS devices focus on allowing the passengers and bus operators to take advantage of the data and provide users with the necessary information to enhance the transit service quality.

In the past decade, the IoT based Gateway systems have gained significant commercial attention of technology developers and transport fleet managers. Efforts from Intel Corporation are noteworthy in designing state-of-the-art vehicle fleet management systems that are geared towards optimizing fleet operations and maximizing the revenue opportunities. They are designed as end-to-end solutions for smart city transportation needs and are currently under operation in several countries [4] [5] [6].

However, such systems are overtly expensive and are not affordable by poor countries. Further, it was found that such devices lack the feature of monitoring the vehicle health as it is an essential parameter for the bus operators due to high investment in vehicle assets. This feature is also of vital importance to the drivers because in some cases the drivers themselves are vehicle managers and oversee their businesses operations. Nonetheless, this feature can be easily integrated in the design of such devices by taking aspiration from study conducted in [7]. Some innovative ideas of building low-cost models for vehicle tracking and providing decision information through various methods to passengers are proposed in [8][9][10] that are similar to the design objectives of this study, a solution feasible for poor countries.

3. Proposed System Model

The proposed solution is a device named as OBID (On board Intelligent Device) and was designed and continuously developed to leverage the accessibility of the public transportation by introducing technological intelligence in the buses currently running in Karachi, some of which are either old reconditioned buses or conventional run-of-the-mill buses, operating since early 1970s [11].

The essential task of this device is to gather, record and transfer real-time data to the back-office system. It is developed using common available components and open-source software for maintaining scalability while making it an ultra-low-cost, robust, accurate and extendable Internet of Vehicle data recording platform. This factor is very important as the platform shall be able to integrate in any of existing as well as the new model buses introduced in the public transit projects in such countries. The generated dataset is categorized in three main branches as shown in figure 1. All data streams are sampled, timestamped, geotagged and then logged into internal SD card storage. Simultaneously, the data packet is also transmitted to an IoT cloud application as well to the MQTT broker, thereafter forwarded to database server for long-term storage.

4. Hardware and Software Design

The backbone of this IoT Gateway solution is the hardware and low-level firmware that performs the data collection and communication. It consists of a single board computer embedded system connected with digital and analog sensors, vehicle dashboard through CAN Bus and cellular network via HSDPA/WCDMA or GPRS/EDGE network. Raspberry Pi 3 is used as the main computing platform due to the availability of HDMI, Wi-Fi and Bluetooth interface and simplicity of use in a single board.

The developed test prototype is shown in figure 2 and the hardware components used in the proposed model are illustrated in figure 3. The software model is built upon the robust and reliable hardware architecture of OBIB and it handles all raw sensory data recordings and data transmissions to
cloud applications and data servers. It enables the framework of Internet of Vehicles in the public transportation systems – helping to transforming into a smart city.

4.1.1. System Script. After the system boots, the Rasperry Pi runs a series of scripts to perform its operational requirements, following the same procedure listed in [7] Software section. The main script, after initialization, proceeds to check the current status of the vehicle and subsequently shift into the required operating mode as shown in figure 4.

4.1.2. IoT Analytics and Visualization. The OBID software framework leverages on open source IoT connectivity protocols. The data pipeline journey relies on front-end and back-end interfaces. The back-end office system comprises of an MQTT based Eclipse Mosquitto broker. It is a machine-to-machine lightweight published-subscribe based protocol used for IoT messaging with low-power devices [12]. The fleet management and smart transportation model is based on three layers: Sensing Layer, Communications Layer and Services Layer. In the Sensing Layer the Gateway publishes metadata messages to the MQTT broker located at the bus station or central office, connecting the ground fleet with the back-office system. Similarly, several bus stations can be extended to connect with each other using publish-subscribe model at the Communications Layer, thus serving as a centrally connected data infrastructure. Finally, at the Service Layer the MQTT broker serves as the bridge for operation and

![Figure 1. Set of features employed in OBIB. Note the task marked with ‘*’ are still work in progress](image)

![Figure 2. Prototype version of OBID. Showing hardware enclosed in a 5mm Plexiglass with weather-proof I/O, and power connectors](image)

![Figure 3. List of hardware components with specifications](image)
The continuous development of web services, mobile apps and business analytics. The data pipeline journey and communications model is illustrated in figure 5.

4.2. User Interface and Mobile App

The acquired data is sent to a third-party IoT platform, named Ubidots, which provides an internet service to display the data in a user-friendly dashboard and design mobile apps [13]. The collected data is sent via API structure provided by Ubidots. Based on a systematic requirement, three separate accounts were developed: Developers, Transport Operators and Passengers. Figure 6, 7 and 8 shows an instance of the passenger’s mobile app, homepage and dashboard view for bus operators respectively.

Figure 4. OBID main script procedure showing the process of multiple operating modes.

Figure 5. Developed Communication framework of OBID illustrating the data transfer among the bus fleet, passengers and business owners.
4.3. Sensor Mounting and Packaging

The peripherals and sensing hardware are placed on the bus ceiling. There can be several placement layouts with different number of sensors aiming to cover a particular cross section area of the bus. However, two sensors placed equal distance along the ceiling is found as optimal layout in the considered scenario. Despite the limitations in the coverage area, the combined average value of the two measurements lies in the acceptable tolerance rate, e.g., ±1°C in the case of ambient temperature. The CAD illustration in figure 9 shows the proposed sensor layout and device mounting in the bus, while figure 10 shows the illustrated component placement inside the OBID box.

5. Design Challenges

During the on-going development process and iterative field testing, the OBID has evolved into a robust platform of IoT Gateway in ITS applications. Each project section went through numerous iterations and we met some design challenges during the research, development and testing of this research project. This prototype was successfully instrumented with select vehicles along with a pilot test in Gulistan-e-Jauher, Karachi, Pakistan.

While the component placement inside the bus seems like a straightforward procedure, however, a great deal of efforts are required to securely place the box and other peripherals inside a public transport vehicle. The data and power cables have to be secure, hidden and of minimum length as possible to avoid signal degradation and power losses. With little to no information openly available about OBD protocols by vehicle manufacturer in the CAN bus, only a very minimal information can be captured by commercial OBD readers. To overcome this limitation, raw CAN data coming into the OBD port has to be recorded and interpreted. In some cases, the OBD port was found to be completely inaccessible by manufacturers due to warranty terms and conditions.

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**Figure 6.** App for citizens.

**Figure 7.** Login webpage for bus operators.

**Figure 8.** Dashboard screen showing field experiment recordings of a test vehicle.

**Figure 9.** Proposed installation layout inside bus.

**Figure 10.** Component placement inside OBID box.
6. Future Work
The next generation of smart transportation solutions builds up on massive datasets generated from IoT gadgets installed in the transportation infrastructure. Recently, the use of AI in producing business insights are some of the areas that have attained considerable attention from business owners and technology developers. Since, humans are not great drivers because we often multitask and take most actions based on emotional and social variables. Therefore, the prediction of driving patterns, in particular, is of great advantage to transport operators as the driver performance plays a key role in maintaining the health of the vehicles, which are one of the biggest assets of the business owners. It can help reducing the vehicle operating cost, contributing to less carbon emissions, and indirectly helping in achieving of a sustainable transportation model.

Moreover, the prediction of rush hours, analysis of average daily traffic volume, the speed of traffic, forecasting of road congestion and, a newly proposed concept of environmental parameters gathered from sensors mounted on vehicle’s rooftop, can serve as a data bank for businesses and organizations. These results can help to make a positive impact on the city by helping the businesses and policy makers to identify key areas that need intervention. By providing centrally coordinated services this solution can make the cities safer, foster the gender equity and will boost private sector investment. Hence, the on-going future work includes the applications of computer vision and deep learning techniques on the data sets of transportation systems to yield useful insights that can benefit the social and commercial sector of the city.

7. Conclusion
ITS devices comprise of innovative hardware and software based solutions that aim to provide user services to passengers and transport managers to make safer and efficient decisions regarding their interaction with transportation infrastructure and services. The proposed solution demonstrates its feasibility for poor countries utilizing the existing infrastructure and requires minimal investment cost. It also does not require any additional civil works or procurement of new buses. The biggest advantage is that this device serves as a data collection tool for the government and transport authorities, acting as a primary step for mechanisms leading to reshaping the policymaking culture and service improvement. In addition, it also serves as a gateway to improved traffic flows by reducing commuting time delays, fuel wastage and air pollution.

8. References

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