

Smart School Bus: Ensuring Safety On The Road For School Going Children

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Abstract—A vital part of providing quality education to children is ensuring their safety while traveling between school and home. We developed a low cost, effective smart school bus system utilizing various homemade as well as off the shelf components. This paper discusses the hardware-based smart school bus system for monitoring and ensuring the safety of school going children onboard a school bus.

Keywords—road safety, child safety, smart system, Arduino, reed switch, pressure pad, HC-05 Bluetooth module, Java, Android, PHP, XML.

I. INTRODUCTION

Being a small country with the 8th largest population in the world [1] and having insufficient road structures have caused traffic conditions in Bangladesh to deteriorate over the years, especially in the metropolitan cities of the country. According to a World Bank report, within the last ten years, the average speed of vehicles on the roads of Dhaka, the capital city of the country, has plummeted from 21 kilometers per hour (kmph) to a staggering 7 kmph. During rush hours, situations become abysmal near school areas as each student prefer to travel using their family car for the lack of a reliable public transport system. According to the same report, it is assumed that by 2035, the average traffic speed in Dhaka might drop down to 4 kmph, which is below the average human walking speed [2].

Incorporated with a few other factors, this ever-declining average traffic speed and frequent road congestions have been posing an adverse effect on the overall driving behavior of people [15]. When these data are combined with the fact that Dhaka is the most densely populated city in the world, with almost 45,000 people living in per square kilometers of the city [14], it's no wonder that the roads of the city are not safe for school going children because of fatal road accidents [13].

Hence, we focused on developing a smart school bus system which will provide a low cost but effective hardware-based solution of the problem of monitoring safety status of the school going children onboard school vehicles in Dhaka as well as in other major cities with similar traffic conditions.

II. RELATED WORK

As the topic of providing road safety to school going children while onboard school vehicle is of paramount importance, a considerable number of different approaches have been taken to address this issue by various researchers.

Tanaka and Naito [3] implemented a system for cooperative location tracking of buses with smartphones, wireless LAN, and Bluetooth Low Energy devices. However, their system had bandwidth as well as security limitations. Rengaraj and Bijlani [4] described an alternative system using RFID technology for ensuring the security of school children while driving to and from school. Shaaban et al [10] implemented a smart school bus tracking system using passive RFID technology as opposed to active RFID based school transport security system implemented by Al-Lawai et al [9].

While Dhivya and Kathiravan [5] implemented a hybrid security & vigilance system for vehicles, Bojan, Kumar, and Bojan [6] took an IoT (Internet of Things) based approach for an intelligent transport system.

Both Al-Ismaili, Al-mahruqi, and Vrindavanam [7] & Shah and Singh [8] utilized RFID and GSM technology to implement safety and tracking systems for school buses. However, in addition to sending the vehicle location data to the parents via SMS as done in [7], [8] also implemented an early accident warning system utilizing buzzers and ultrasonic sensors to alert the driver of the bus. Similarly, Khan and Mishra [11] took a GPS-GSM based approach for developing a tracking system.

III. OVERVIEW OF THE SYSTEM MODULES

The system which we propose here comprises of the following hardware-based and application-based modules and sub-modules:

A. Hardware-based Modules

- 1) **Seat Occupation Sensing Module:** This module will sense the change in pressure on the seat resulting from a student occupying that seat utilizing a custom-made pressure pad device. This module will be connected to a microcontroller module through conventional wire connections.
- 2) **Passenger Safety State Sensing Module:** This module will sense whether the student occupying the seat has fastened the seat-belt properly or not utilizing a magnetic reed switch. This module will be connected to a microcontroller module through conventional wire connections.
- 3) **Microcontroller Module:** This module will be implemented using the Arduino Uno microcontroller. The seat occupation, and passenger safety state sensing modules from each seat shall send their analog signal data to this module via conventional wires. A single Arduino Uno will be connected to sensing modules of three such passenger seats of the bus. This Arduino will utilize an HC-05 Bluetooth module attached to itself for establishing data communication channels with the central data receiver module.
- 4) **Central Data Receiver Module:** An Android-based smartphone kept with the supervisor of the bus will act as the central data receiver module or, CDRM in short. This CDRM will receive all the digital signal data sent from all the microcontroller modules over Bluetooth communication channels.

B. Application-based Module and Sub-modules

- 1) **Central Data Processing and Storage Module:** This central data processing and storage module (or CDPSM in short) is an Android app which will be running on the CDRM device. It will centrally process the digital data received by the CDRM and will be generating necessary output events for controlling the behavior of the following application sub-modules.
- 2) **Real-time Seating Data Display Sub-module:** This sub-module is a part of the CDPSM app. This sub-module will display the current seating status of each seat on the screen of the CDRM device where the CDPSM app will be running.
- 3) **Parental Alert Sub-module:** When a student occupies his/ her allocated seat on the school bus

and fastens the seat-belt, the CDPSM will detect the change in sensor data received by the CDRM and will activate this sub-module for sending a SMS containing the seating and safety status of that student and GPS coordinates obtained from the CDRM device's built-in GPS sensor to the registered cellphone number of that student's parent.

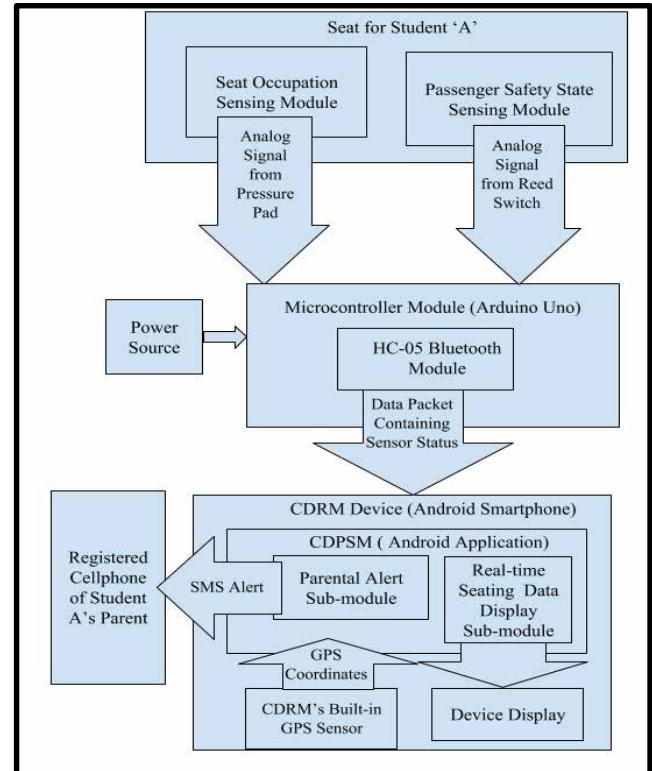


Fig. 1. Block diagram showing connections & flow of data for a single seat between various modules & sub-modules of the system

IV. DESIGNING AND IMPLEMENTING SYSTEM MODULES & SUB-MODULES

For designing and implementing various modules & sub-modules of the system described in the previous section, we utilized custom-made components as well as different off the shelf hardware & software components.

Following subsections give a brief description of the designing and implementation process for each of those modules and sub-modules:

A. Seat Occupation Sensing Module:

For implementing this sensing module, we needed a pressure pad device which would provide a signal if a student takes/ leaves the seat. Separating the aluminum foil covered inner sides of two opposing cardboards from each other by placing a thick foam lining along their borders, we constructed a homemade pressure sensitive device which would act as the pressure pad required for this module. The pressure pad is connected to the Arduino via a

potentiometer through conventional breadboard and wire connections. When pressure is applied on the outer side of any of the cardboard, their aluminum foil-coated inner sides touch each other at the center and completes the circuit, thus producing the analog signal indicating the presence of a heavy object/ pressure being placed on the pressure pad.

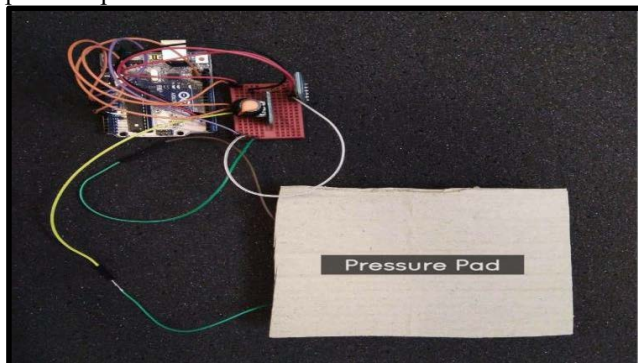


Fig.2. Homemade pressure pad connected with Arduino

B. Passenger Safety State Sensing Module:

This module was implemented by incorporating a reed switch inside a conventional seat-belt. When the seat-belt is unbuckled, the magnetically sensitive reed switch remains open. When the tongue of the seat-belt goes inside the slot, the reed switch becomes closed and completes the circuit [12]. Thus a signal is sent forward to the microcontroller via conventional wire connections indicating that the student has occupied his/ her allotted seat, fastened the seat-belt and is now in a safe state.

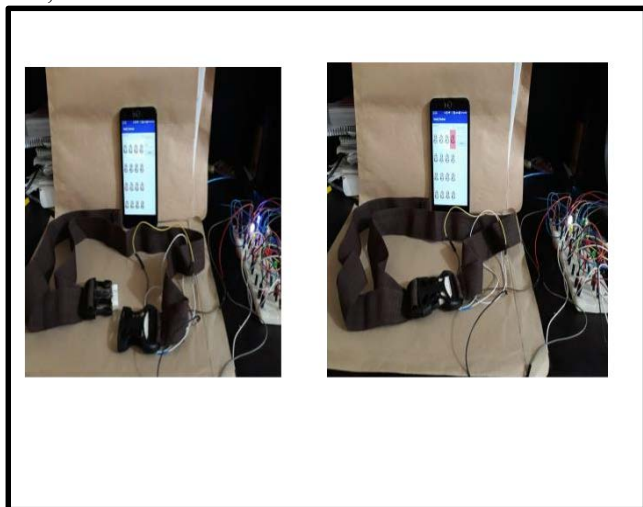


Fig. 3. Magnetic reed switch sensor attached seat-belt in opened (unsafe) state on the left and in closed (safe) state on the right

C. Microcontroller Module:

For performing the functions of a microcontroller necessary for the proposed system, we utilized Arduino Uno microcontrollers. A single Arduino Uno could handle connections from sensing modules of three seats at a time. After receiving analog voltage signals from the sensing

modules on each seat, the program running inside the Arduino converted the analog signals to digital signals.

We utilized an HC-05 Bluetooth module to connect each Arduino to the central data receiver module device (an Android smartphone with Bluetooth connectivity kept with the driver/ supervisor onboard the vehicle) for sending the data packets containing individual sensing module status (based on the converted digital signal data) wirelessly.



Fig. 4. An HC-05 module used with Arduino(on the left) & sensor status data received from Arduino on the CDRM over Bluetooth channels

D. Central Data Receiver Module:

An Android-based smartphone kept with the supervisor of the vehicle acted as the central data receiver module (or, CDRM in short) of our proposed smart school bus system. All the microcontroller modules of the are connected using Bluetooth to this CDRM device. All of the data packets containing all the sensing modules' status data from each Arduino onboard the vehicle are sent to this CDRM over the Bluetooth channels established by the HC-05 modules between the microcontrollers and the CDRM.

E. Central Data Processing and Storage Module:

This central data processing and storage module (or CDPSM in short) was designed and implemented using the JAVA programming language for running on the Android-based CDRM device kept with the supervisor onboard the vehicle.

All the sensor data received over the Bluetooth channel were processed centrally by this module and then combined with GPS coordinates received from the CDRM device's built-in GPS sensor to produce data in an appropriate format for saving on a remote database

(utilizing the 'Firebase' platform) and also for deciding further actions to be taken by the following sub-modules:

- 1) **Real-time Seating Data Display Sub-module:** Whenever a student activated the pressure pad by just occupying his/her allotted seat, this module marked the seat as 'occupied' and displayed it as such on the display screen.
- 2) **Parental Alert Sub-module:** This sub-module detects the signal whenever a student fastens his/her seat-belt while sitting on the allotted seat, thus activating the reed switch circuit. The program running under this sub-module then sends a SMS to the registered phone number of that particular student's parent/ guardian providing the safety status and location information indicating that the student has safely occupied his/ her seat on the school bus. A similar process is repeated whenever that student unbuckles his/ her seat-belt and leaves the seat.

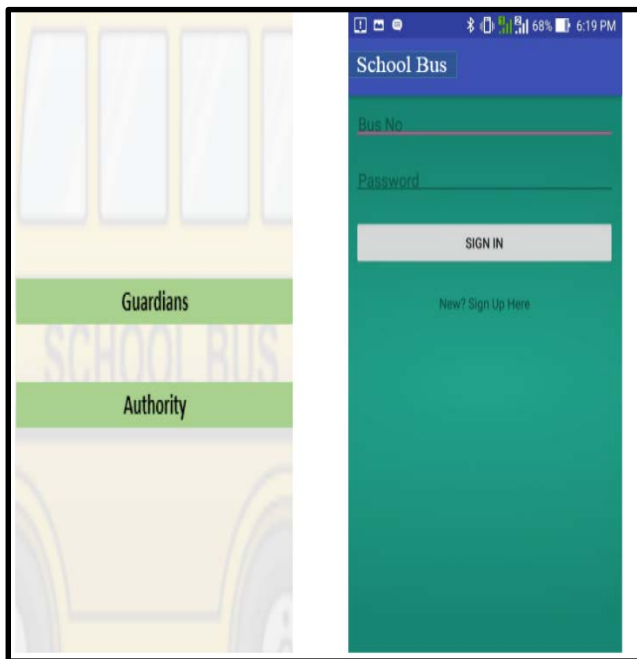


Fig. 5. Login interface for the Real-time seating data display sub-module

V. RESULTS AND DISCUSSIONS

We tested our system against seating arrangements for three students on three different seats. Whenever a student sat on the seat, the pressure pad device could successfully detect the change in pressure and sent the appropriate signal. On the real-time seating data display sub-module, an occupied seat was shown as marked in red color. The CPDSM could successfully send this data to the remote server utilizing the cellular data network available on the CDRM device.

We also tested the functionality and effectiveness of our homemade pressure pad device against objects with different mass to figure out the lowest weight limit for activating the pressure pad device.

TEST NUMBER	WEIGHT (KG)	RESPONSE	METER READING	SEATING PATTERN
1.	0	0	Not seated	-----
2.	2	0	Not seated	-----
3.	4	0	Not seated	Unknown
4.	8	0	Not seated	Unknown
5.	12	0	Not seated	Unknown
6.	16	0	Not seated	Unknown
7.	18	0	Not seated	Unknown
8.	20	1	Seated	Normal
9.	30	1	Seated	Normal
10.	44	1	Seated	Normal
11.	57	1	Seated	Normal
12.	61	1	Seated	Normal
13.	75	1	Seated	Normal
14.	89	1	Seated	Normal

Fig. 6. Testing effectiveness of the pressure pad device against varying weights

As seen from the data in Fig. 6 above, it is evident that the lowest weight required to activate the pressure pad device was 20 kg which is approximately 44 lbs.

We also tested the functionality of the seat-belts with reed switches acting as the passenger safety state sensing module. Whenever a student fastened his/ her seat-belt, the reed switch circuit was activated and the necessary signal was generated and forwarded to appropriate modules and sub-modules. The parental alert sub-module could successfully send SMS to the respective parents' cell phones.

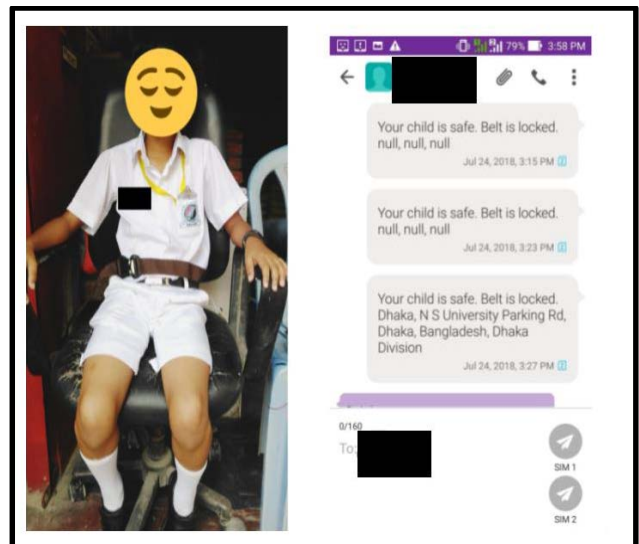


Fig. 7. Alert SMS received on registered parent's cell phone (on the right) when the student occupied the seat and fastened the seat-belt (on the left)

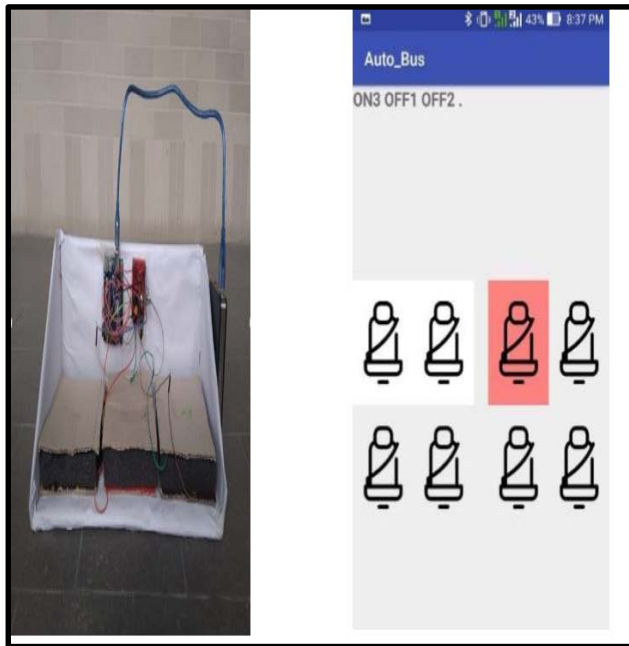


Fig. 8. Pressure pads (on the left) for testing against varying weights and an 'occupied' seat shown in red color by the real-time seating data display sub-module.

VI. FUTURE WORKS

In the future, we intend to add 'live video streaming' capability to our system so that the parents, as well as the concerned authorities, can view the video showing the condition inside the vehicle in real-time.

We also plan to improve the sensitivity and quality of our pressure pad devices. As we mostly used home-quality materials in constructing the pressure pad devices, they tend to malfunction after being used for a long time. We plan to address this issue by trying out different materials with higher longevity while keeping the material cost as low as possible.

In addition to ideas above, we intend to develop a web-based interface where registered parents or authorized personnel can log into the system from anywhere in the world using a web browser and internet connection and view sensor and other data of a vehicle in real-time.

VII. CONCLUSION

The system proposed here by us can serve in ensuring and monitoring the state of safety of school going children while traveling between school and home on a school bus which will help in providing quality education to the school going children in a safer manner.

As this system can inform parents about the safety status of their children inside the school bus in real-time, it possesses the capability of swaying the opinion of the parents in favor of introducing a centralized smart school bus system in Dhaka city as well as in other places with similar traffic and safety issues. This might, in turn, play a pivotal role in reducing traffic congestions near school areas and in other critical road-junctions during rush hours, thus improving the overall traffic conditions of a city.

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