BOSCON

Blank Out Sign Connectivity Over Cellular Network

ELECOMP Capstone Design Project 2017-2018

Sponsoring Company:

SES America
21 Quinton St, Warwick, RI 02888
Phone: (401)-232-3370
https://www.sesamerica.com/

Company Overview:

Founded in 1986 in Rhode Island, SESA is a high quality multi-sign solution manufacturer for the intelligent transportation system (ITS) industry focused on providing Dynamic Message Signs and retrofit packages to clients across the United States. Manufactured in the US at their new facilities, they are fully equipped to meet clients' unique needs by delivering quality, innovative ITS products and customized solutions. Having undergone rigorous site condition testing, both hardware and software burnout test, and ITS fault simulation tests, signs produced by SES America are built to stand up in any environment. SES America's product line includes: Dynamic Message Signs (DMS), Lane Control Signs (LCS) and Blank Out Signs (BOS).

Technical Director:

David Connolly
R&D Engineer
Email: dconnolly@sesamerica.com
LinkedIn: https://www.linkedin.com/in/dave-connolly-b3037b89

Project Motivation:

Within the intelligent transportation system (ITS) industry, two major formats of signs are utilized: Dynamic Message Signs (DMS) and Blank Out Signs (BOS). Dynamic message signs are designed similar to computer monitors and are driven by designing a matrix of LED groups (called 'pixels') to create letters, shapes, and images. Blank Out Signs (BOS) offer users a means of relaying different messages to motorists in a cost-efficient package. By lighting a specific selection of the total LEDs on the sign, the sign can display up to three messages. Because the messages are predefined, a sophisticated control apparatus is not necessary. In fact, the SESA designed BOS operate with a simple dry-contact closure (relay or switch) driven by a low-cost microcontroller. This alternative to full-featured DMS makes BOS attractive for a wide variety of applications and regions. However, these BOS ***lack a means of communication*** - a feature necessary for operators to control and monitor signs for faults. The expensive installation of hardwired communications infrastructure necessary to control and monitor signs negates the cost advantages of the BOS products and renders remote use economically untenable.

To address this challenge, SES America is working to harness the ubiquitous cellular phone and data network to provide a communications mechanism that provides the necessary control and monitoring functionality while preserving the lower cost of operation of the BOS products.

This solution consists of two main elements; an embedded cellular communication module interfaceable with the existing BOS hardware and a mobile-friendly web application that allows the user to monitor and control the operation of all of the BOS signs in their deployment.

Anticipated Best Outcome:

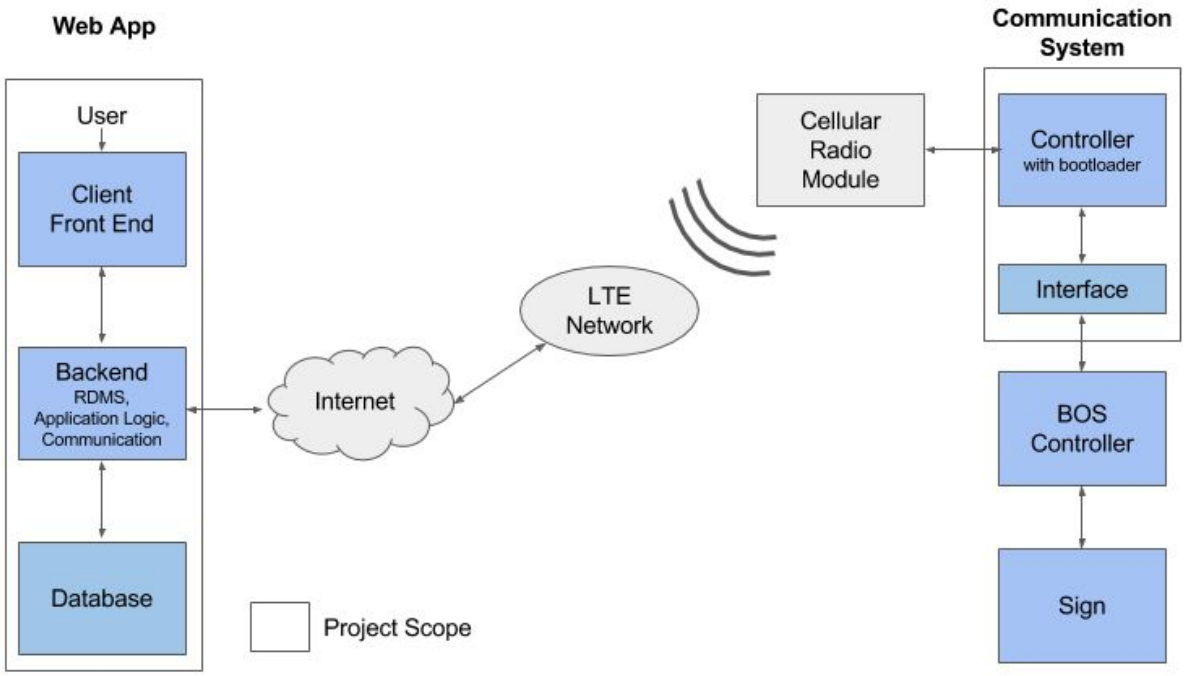
A production-ready, modularized cellular communication system interfaceable with the current BOS architecture. The module must allow asynchronous transmission of both the sign's status to a remote server and control operations from a web application. Data integrity and validity must be assured to avoid both accidental and/or malicious modification, alteration, or destruction. The web application will be secure and mobile-friendly, and support multiple users and their signs. The end user will be able to manage the BOS signs, relay commands to other signs, and each sign will be able to send its current status through the cellular network as defined by a proprietary over-the-air (OTA) protocol designed by SESA. In situation where a fault is detected, the web application sends email alerts to preconfigured addresses. Following a cost-benefit analysis, design modular PCBs and firmware such that the cost is under $100, power consumption is under 5 Watts, and the dimensions fit within the sign. The sign must operate at a temperature range from -34C to +74C in 0-95% humidity non-condensing. The

firmware will have a bootloader to allow operators to interface through an available external maintenance port and perform updates as needed.

Project Details:

Overall system concept: The end user will be able to control and view the status of multiple BOS signs. The information of the sign, including: name, status, location, current message - as well as customer data - will be stored in a database. The web application will be database-driven and use a server-sided scripting language to drive application logic. Using a socket connection, data will be transmitted over a cellular data network between the server and the device using a proprietary OTA protocol. At the sign, the cellular module will receive commands and forward them to the microcontroller designed by the team. This controller is responsible for translating the commands into signals usable by the BOS controller through, as well as generating and sending status messages back to the website. A final relay-interface delivers the signals to the BOS controller for execution. The students do not modify the BOS controller, the sign, or the cellular radio module.

Block Diagram:



Hardware tasks:

- PCB that interfaces the cellular module to the controller
- Design and implementation of the controller PCB. The controller board will support memory and processing requirements and interface with both the cellular radio module and the BOS relays to translate commands and send status messages.
- PCB that interfaces the controller to the BOS controller to support the execution of commands.
- Detailed schematics and prototype builds are required for all PCBs.
- Hardware must be designed to physically fit into the dimensions of the sign.
- PCBs must work at a temperature range of -34C to +74C and 0-95% humidity non-condensing.
- Implement a serial port on the hardware to allow maintenance to communicate to the sign and access the bootloader.
- (Possible) implementation of a hardware authentication device

It is important to note that SES America would like the total cost of the hardware to be under $100. Ideally, the design would be modularized and allow SESA to not only customize BOS per customer specification, but also support and upgrade individual components rather than the entire system as a whole. However, this often leads to a greater increase in cost. Students are expected to perform a comprehensive cost-benefit analysis of different design approaches.

The expected cellular module that will be used is the Nimbelink cellular module which is LTE cat-1 and is end user certified. The students may locate a better module as needed. The cellular module must be LTE cat-1 and end user certified.

Firmware tasks (Controller):

The embedded controller must have firmware specifically designed to meet specifications. Implementation and design pattern is up to the students. Functional requirements of the firmware include:

- Using the cell module
    - Establish a socket connection with the web server to facilitate data transmission
- Interpret commands received from the cellular module
- Using the BOS controller interface, execute commands.
- Monitor the status of the BOS including power, command execution, faults, message status.
- Include a bootloader capable of performing firmware updates and management of the

system.
- Authenticate all data traffic and perform necessary steps to ensure data integrity and validity.

Software tasks (Web Application):

- Review the existing web application
- Implement a secure multi-user application where users are only able to monitor and control their own signs
- Ensure the web application is mobile-friendly across phones, tablets, and other devices
- Design and implementation of a DBMS capable of storing user and sign info
- Implement customization options for the web app for clients so that their logos and other assets may be used
- Implement a dashboard where users are able to view sign datas such as name, location, cellular module serial number, current message, etc
- Implement a control system where users are capable of send AT commands to individual signs, as well as view the signs response
- Implementation of a communication script that interfaces the website and cellular network module.
- AT commands may include changing the message of a sign, relaying a command to another sign, powering a sign on or off, or updating firmware.
- When a sign is detected as faulty, send an email alert to the operator. Emails will be stored in the database. SMS notification is also an option.

Composition of Team:

One Computer Engineer and one Electrical Engineer.

Skills Required:

Electrical Engineering:

- Strong understanding of circuit fundamentals and power electronics
- Experienced in hardware design with microcontrollers
- Ability to read and write detailed circuit schematics
- Basic understanding of cellular network protocols
- PCB layout experience (preferred)

Computer Engineering:

- Strong Programming Fundamentals
- Knowledge of C, HTML, CSS, Javascript, and PHP
- Basic understanding of cellular network protocols
- Experience with databases and database-driven web apps (preferred)
- Experience with firmware design (preferred)

Anticipated Best Outcome's Impact on Company's Business:

By providing a low-cost monitoring solution for BOS, SES America will increase their marketability and differentiate themselves from their competitors. Increased monitoring and control functionality will also allow SESA to meet the demands of different markets including cities - increasing their products scope.

Broader Implications of the Best Outcome on the Company's Industry:

With proper fault detection, BOS can be implemented to indicate hazards without the possibility of danger due to hardware failure. With this increased functionality, BOS can be deployed in rural areas of the nation and on long stretches of highways and freeways wherever a cell network is available. Further implications include response-based BOS signs interfaced with speed or traffic sensors to alert motorists of danger. The low-cost, manageable and smart system proposed by SES America will directly affect and improve road safety in the United States.