UCSC Bus Tracking System 3.0 (BTS 3.0)

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Introduction

Students & faculty at UCSC require accessible, reliable, and accurate information to create an efficient schedule for moving around, and off (to/from) campus.
We aim to provide an integrated bus tracking system that will be accessible to all campus bus users. Bus Tracking System 3.0 (BTS3) will address the cost issues encountered with the previous systems, create a scalable maintenance plan for TAPS, and add an Estimated Time of Arrival (ETA) feature at major bus stops.

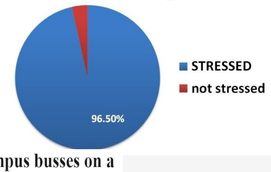
Our Product Compared to our Competitors:

1) **Compared to off-the-shelf tracking systems such as GMV Syncromatics, our system is:**
   a) Cheaper
   b) Without monthly fees for cellular service
   c) Equipped with a route sign
2) **Compared to Bus Tracking System 2 (BTS2), our system is:**
   a) Cheaper
   b) Compatible with all types of campus buses
   c) Easier to implement
   d) Longer lasting
   e) Properly documented (Technical and user manual for TAPS)
   f) Equipped with an ETA feature

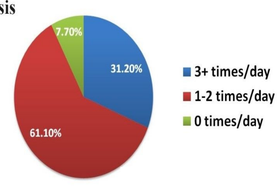
Why is a bus tracking system necessary for UCSC?

We surveyed **288 UCSC students** in order to understand the needs of the campus' residents. We were interested to know the dependency of students on the buses to commute around the campus and which features are more desirable to the students: a digital ETA board at each bus stop or a mobile-phone application. We also cared about the effect of a reliable bus tracking system on the mental and physical health of the students and staff.

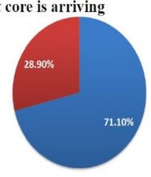
96.5% of UCSC bus users are stressed out by not knowing when the bus is coming



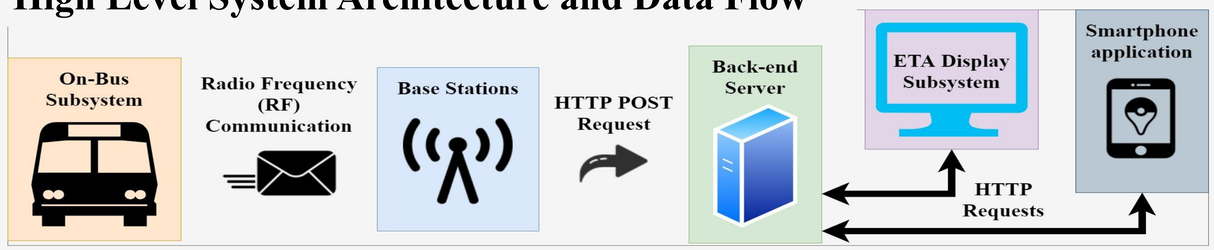
92.1% of UCSC affiliates use campus busses on a daily basis



71.1% of UCSC affiliates would like to know when the night core is arriving

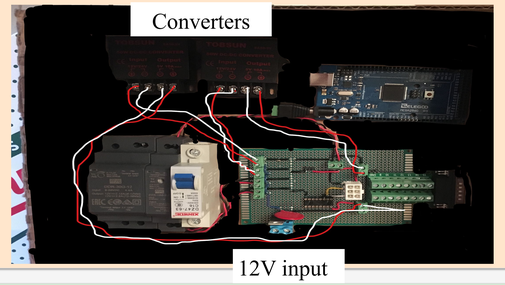


High Level System Architecture and Data Flow



On-Bus System

Responsible for acquiring GPS data, displaying bus routes, and sending bus data to the base station subsystem.



Back-end Server

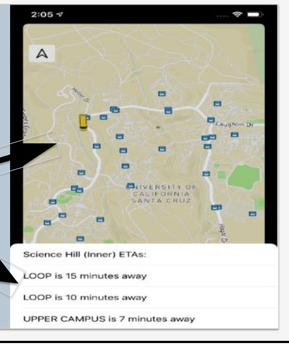
Responsible for data storage and interfaces the data-collecting subsystems with the user interface subsystems. Major components include:

- **MySQL database server** for storing bus data
- **FreeBSD web server** for interfacing with the database server

Smartphone Application*

*This is implemented by a CSE Capstone Team.
The app is responsible for providing all bus data in a user-friendly fashion featuring:

➔ real-time location map
➔ ETAs for each bus stop
➔ direction of buses

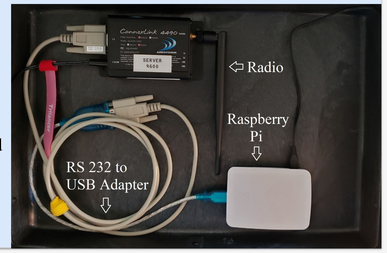


Base Stations

Responsible for receiving bus data and sending it to the server There are five base stations on campus to ensure full data coverage of the campus.

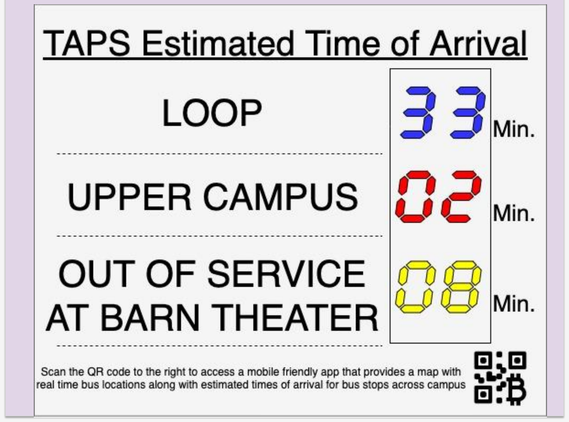
Major Components:

- **Radio** - Receives data from buses.
- **Raspberry Pi** - Processes data from the radio and sends it to the back end server.



ETA Display System

Responsible for displaying bus ETAs for the main routes such as UPPER, LOOP, OUT AT BASE.



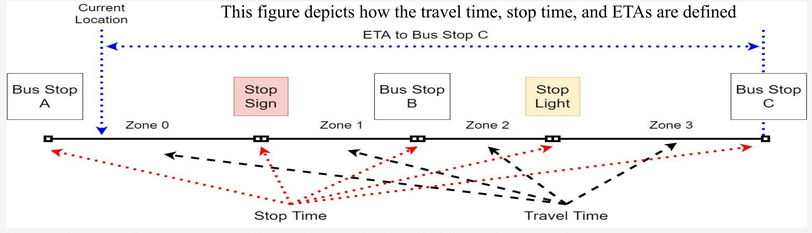
ETA Algorithm Design

There are two different approaches to the ETA algorithm by two different teams: one based the MapBox Direction API (CSE team) and one based on a machine learning (our ECE team). The machine learning method calculates the ETA by averaging historical travel and stop time data.

Consists of two main systems:
Travel and Stop Time Calculation and Storage:

- Travel time - the time to travel between defined locations on the route (bus stops, stoplights, and stop signs) called “stopping points”
- Stop time - the time a bus is stationary or near stationary at each stopping point

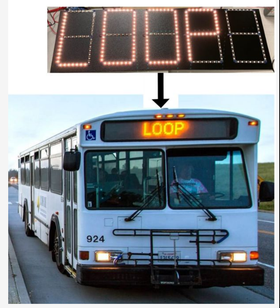
ETA Calculation: ETAs are the summation of the averaged travel times and averaged stop times based on the current zone and the destination bus stop.



Results

On-Bus System Improvements to BTS2:

- The system now operates on a **12-V** power system, allowing us to include bike shuttles and cutaway buses used for the night core route.
- The route sign cost decreased from **$800** to **$92.21+labor cost**, while still providing the main routes: LOOP, UPPER, BASE, CORE.
- The tracking part of the system now **operates independently** from the route sign. This feature is important for buses that do not need a route sign like the bike shuttles.

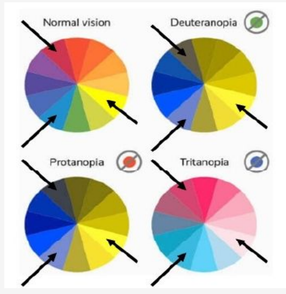


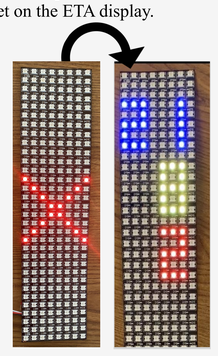
Base Station Improvements to BTS2:

- The system no longer uses any custom parts, allowing for easier installation and maintenance for the system.
- New micro SD cards have been chosen for the Raspberry Pi to increase the lifespan from 4 years to an estimated lifespan of more than 4 years.

Addition of the ETA Display System:

- The ETA display retrieves ETA data from the web server via WiFi.
- The ETA display can display 3-5 different routes, which can be changed by the client via the web server.
- ETA colors change from blue to yellow to red as the ETA counts down to indicate approaching buses. The three colors are distinguishable for people with any of the four types of color vision depicted in the left figure below. Arrows indicate the selected colors in each color wheel.
- If the system disconnects from WiFi, the timestamp of the disconnect is logged in the web server and a red ‘X’ is set on the ETA display.





Addition of the ETA Algorithm:

The framework for the algorithm is implemented in web server and is currently collecting travel and stop time data from the BTS2 system. Proposed ETA accuracy specification was not met, but the accuracy will improve over time, as more data is collected.

Conclusion

Each system within the BTS3 design was successfully constructed according to their respective requirements. However, due to limited access to UCSC campus, we were unable to do the full system field testing. A Standard Operating Procedure (SOP) along with the Technical and User Manual will be provided to TAPS for future testing and implementation.

Acknowledgments

We would like to thank you the following people for their help:

- Kerry Veenstra, developer and implementer of BTS2
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