Halo Smart Drink Protector

Zirui Chen, Alan Dautov, Gabrielle Kuntz, Pengyu Wu, Chenyuan Zhao

Abstract—Unfortunately, over the last few years, there has been an increase in drink spiking in Boston as well as across the world. Halo Smart Drink Protector is a battery-powered device that can seal the top of common glass types, it comes with a smartphone app and the ability to connect to the app via Bluetooth. Halo aims to reduce the number of drink spiking cases by introducing a smart drink cover that can effectively detect potential drink spiking and send a smartphone notification if potential removal is sensed, as well as providing users with an option to contact authorities in case of an emergency. Halo hopes to be accessible and affordable for everyone who wants to prevent the potential drink spiking and stop people from getting harmed by it. In addition to the app, there will be a website where users can submit feedback about their experience with the Halo Smart Drink Protector. This feedback will be used to improve the device and make it even more effective at preventing drink spikings

Index Terms—Applications, Embedded Systems, Sensors, Software Engineering.

1 Introduction

DRINK spikings are not just heard about on the news, they are the crimes that are happening around us constantly. On October 7, 2022, BU today warned students about the rise of spiked drinks incidents that have happened in Boston. BUPD has recorded a total of 71 allegations of drugged drinks during this year [1]. With this large number of incidents happening each year, and not to mention the cases that have not been discovered or reported, 90% of the incidents recorded are from beverages that people drink every day. Still, there has not been a viable solution that can protect everyone.

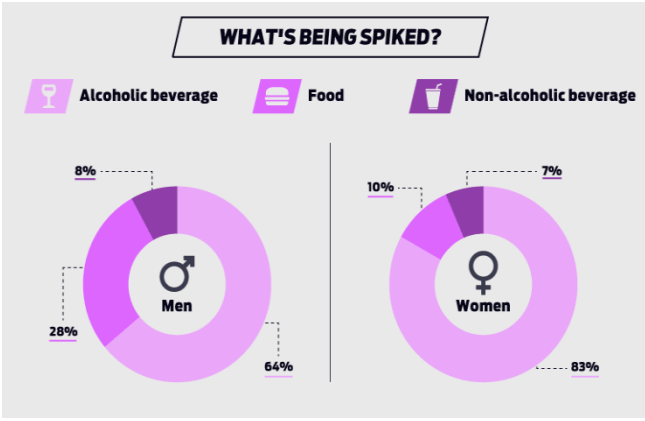

Figure 1. The chart shows that over 93 percent of female victims and 92 percent of male victims reported being spiked by drinks instead of food.

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Therefore, to prevent this rampant crime from happening, this project aims to resolve the issue by introducing the Halo Smart Drink Protector, which can detect and report when an intruder attempts to tamper with a drink. In addition, Halo Smart Drink Protector is needed because consuming a drugged drink has short-term side effects including memory loss, inability to speak, and blurred vision but also significant long-term effects that could permanently damage the victim's health. The criminals are often hidden in the crowd or could be the people accompanying the victim, such as friends, dates, or acquaintances, therefore, the best way to be protected from drugged drinks is to know that your drink is protected.

The plan is to design a product that is low cost, effective, and adjustable, that can be easily purchased and replaced in case of it being stolen. This product will be able to fit over most drinking cups and glasses and will not only reduce the number of spiked drinks incidents but will also raise overall awareness of the crime. This solution will allow people to worry less about leaving their drink unattended since Halo will let every user know that there might be a possibility of spiking. The idea is to create something that will truly impact society and reduce the number of drink-spiking victims.

The final product consists of four primary components, which are the Arduino nano 33 BLE, the outer layer cover, an app, and a website. The Arduino has two sensors, a gyroscope and an accelerometer, which can sense rotations and acceleration. By combining the two-sensor data, our device will be able to recognize and detect cup openings instead of simply moving the cup. However, the accelerometer and gyroscope sometimes provide inaccurate measurements, and for this reason an additional sensor might be used. Also, the Arduino is equipped with a Bluetooth module that can send signals and connect to other devices, and with an on and off switch, it is able to reset the data and calibrate the device. The outer layer cover will be made of waterproof material that does not react with alcohol and it is also capable of implementing Arduino inside it. There will also be a battery and USB port to power the

device. The battery should last at least 5 hours so that people can use it long enough when they are outside or at a bar. The app can connect the Arduino via Bluetooth and will send a notification to the user whenever the device senses a potential cover removal. The app will allow users to contact 911 or family members quickly and will include tips that might help the users when they are in danger. Lastly, the website will be a part of a service to advertise the product, as well as receive feedback and case reports that help improve the product and collect data about how drinking spiking happens.

2 Concept Development

One of the main challenges in designing a device that can accurately detect the removal of a cup cover is to avoid false positives and negatives. This means that the device should only trigger an alert when the cover is removed, and not be influenced by other movements or actions that might cause the cover to move slightly but remain in place. However, if the cover is removed, even partially, or removed then replaced, the sensor should go off. This is the main problem when designing a device: finding a solution that will trigger when the cover is removed but not influenced by any other movements in which the cover remains in place. The hardware specifications for this device include size, battery life, waterproofing, and overall cost. These specifications were given by the customer. The device should be small enough to fit on top of a cup and should also be able to fit in a purse or pocket. It must be compact and lightweight, while still being able to fit around cups of different sizes. The device must provide a battery life of at least 5 hours. The device must also be waterproof in case it encounters any liquids. On the software side, there were not many specifications given by the customer. The app's main function is to clearly indicate when the cover has been removed. At first, there will only be an iOS app. The Android application will be built in the future.

With these constraints and specifications in mind, the first step was to choose a microcontroller, ideally with a built-in bluetooth module. After the research, it was found that the Arduino Nano 33 BLE meets all requirements. The Arduino features a microcontroller, 2.4 GHz Bluetooth, and an IMU (inertial measurement unit) featuring a 3D accelerometer, gyroscope, and magnetometer. The small size and these features will be useful to process data and connect to the iOS app via bluetooth.

The first considered design was using the Arduino's built-in accelerometer. The design would be easy to implement and if it worked, the overall device would be small and inexpensive. The design, however, may be prone to false positives and negatives. An alternative approach we considered was a mechanical approach. This idea was more likely to avoid false positives and negatives. However, this design would have been difficult to implement, would make the device significantly heavier, and mechanical parts have a high chance of breaking. Another approach we considered was using a sonar/ultrasonic distance sensor. However, upon research, the sensors needed are large and it would be difficult to connect the sensors to the main unit. For the first prototype, the design with the accelerometer was built. There were some issues, such as if the cap is taken off slowly, there is no trigger or if the cup is dropped or suddenly placed on the table, there is a false trigger. After more considerate research it was found that a strain gauge sensor can eliminate the problems of the accelerometer only design. This approach was chosen because it offers the most reliable and accurate solution to the problem, while also meeting the customer's constraints of size, battery life, waterproofing, and cost. The idea behind the strain gauge is to place it on the elastic that goes around the circumference of the cup. When the cover is removed, the elastic will be forced to bend inwards, causing a change in the electrical resistance of the strain gauge. The Arduino microcontroller can be programmed to monitor this change in resistance and trigger an alert only when it exceeds a certain threshold.

3 System Description

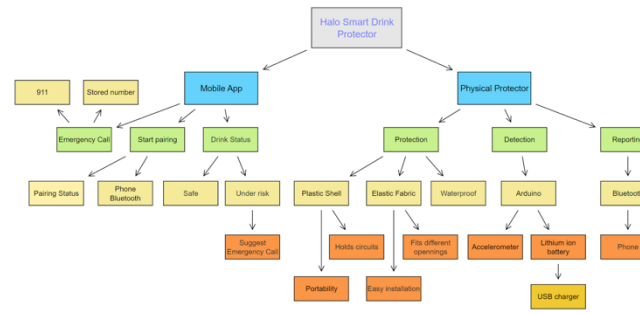


Figure 2. System block diagram for the drink protector and mobile application.

The system includes physical protection of the user's drink and a mobile application that receives the status of the drink showing whether it has been exposed to the risk of being opened. The protector has a solid plastic shell holding its battery and microprocessor. There is a press/press again on-off button on the surface of the shell controlling the power of the protector. By adding elastic fabric underneath the shell, the protector can be easily installed in any container that has a diameter greater than 2 centimeters and less than 20 centimeters. After installation, the button will be covered under the shell remaining untouchable. Before turning on the detections function, the user should pair with the physical processor to the phone on the app. The app then sends a signal through the phone's bluetooth function to the receiver in the microprocessor in our smart protector. When the microprocessor receives the signal from the phone, it activates the accelerometer in the system and records its current values as initial values that indicate that the drink is untouched. After activation, the accelerometer will reach any moves that intend to remove the physical protector. The Z value, indicating acceleration, in the accelerometer will change from the initial value 1, gravity G, to new status because of the displacement. Either removing the protector fast or slowly will cause the accelerometer to have a change greater than 0.15 G because of acceleration caused by the sudden

shrinkage of the elastic fabric once removed. The microprocessor detects such a change in the Z value of the accelerometer and sends a signal back to the phone through Bluetooth. The mobile app displays it in the GUI showing that the drink has been in danger. Then the app will provide a suggestion of dialing 911 or a friend's number stored by the user.

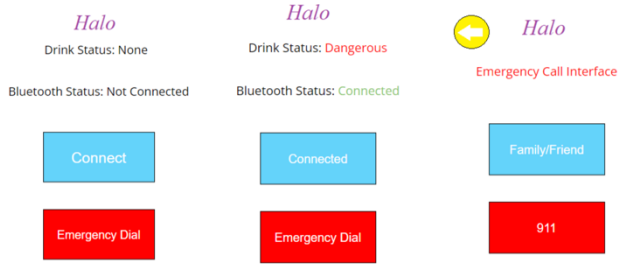


Figure 3. GUI demonstration of three possible cases: Bluetooth not connected/No cup status, Connected/Not safe, Emergency Dial interface/Back button

4 First Semester Progress

The first prototype was tested at the end of the semester, which provided useful testing data. There were two main components of the prototype: a traditional cloth drink cover, and an Arduino. The Arduino Nano 33 BLE is attached onto the middle of the cloth drink cover using 3M tapes. The script uploaded to the Arduino constantly measured linear acceleration using its built-in accelerometer, and if the change in the z-axis value of the accelerometer was significant enough, the program halted and printed out the "Cap might have been taken off" message. Otherwise, when the cover remained on the cup the "Cap is on" message was continuously printed. The Arduino is connected to a PC, which will display the program's messages.

There were three different types of tests. First is the displacement test. The cup will be moved in the direction of the x, y, and z-axis to test if moving the cup will trigger the warning, in which are the false-positive cases. This is a critical function of the Halo device because the device should have the ability to distinguish the difference between cover displacement and cup displacement. Otherwise, the device could send incorrect messages to the users and cause misunderstandings, such that the app alerts the user that the drink is spiked when the drink is simply moved by others. Therefore, ensuring that a false-positive case would not appear when moving the cup in different directions is the fundamental feature of this product.

The second test is a rotational test. Simply testing the movement of the cup along the three axis is not enough because the cup may not be moved strictly following the axis. Thus, in addition to the displacement test to check for the appearance of false-positive messages, a rotation test is also necessary. When drinks are being moved around, the cup may tilt in different directions and angles. The device should be able to remain inactive and not show any alert message when the cup is being tilted. With both the displacement test and the rotation test, most of the false-positive cases can be tested.

The third test is a cover removal test. This test is designed to confirm that when the cover is removed, the prototype can detect it and send the warning message. We tested different ways of removing the cover, such as removing it carefully, quickly, and removing the cover with two people and removing only part of the cover.

As a result of our first prototype test, our product has an overall success rate of 77%. The prototype passed the first two tests suggesting that all the false-positive cases and the warning messages will not be sent when the cup is simply being moved around. However, the prototype had some difficulties determining when the cover was being taken off. It has failed to send warning messages when the cover is being removed carefully, when the cover is removed by two people, and when the cover is only removed partially. For this reason, design with the strain gauge sensor will be the next prototype that will be tested.

5 Technical Plan

Task 1. Strain Gauge Design Testing

A strain gauge design shall be designed, fabricated, and tested. It can sense forces stretching the cover and will transmit signals to Arduino, reflecting the outer force used to remove the cover. It should be able to connect with a string or materials that are flexible and unbreakable and detect when the cover is stretched by 50mm. It should also be able to communicate with Arduino and transmit its data for the Arduino to process and determine positive cases. A series of tests will be conducted to find the forces suitable for most cups to trigger alarms and our group will test extreme cases to detect their limits and potential bugs that people could take advantage of.

Lead: Gabrielle Kuntz; Assisting: Zirui Chen.

Task 2. Developing an App

An iOS app will be developed. It will be able to connect to the Arduino on the drink cover via bluetooth. It will display warning messages to the user when the drink cover is removed. It will have an emergency button for the user to quickly call 911 when needed; in addition, it will also have an emergency contact list, and the user can notify their emergency contacts quickly when needed. Moreover, a manual for safe alcohol drinking is provided inside the app to provide help and remind users of the common mistake people make when drinking alcohol. A feedback form is also implemented in the app to allow users to report any errors encountered using the app or the device and suggestions that are helpful in improving the device.

Lead: Alan Dautov; Assisting: Gabrielle Kuntz.

Task 3. Designing a Processing Unit Enclosure

A processing unit enclosure will be designed, and 3D printed. It will be able to protect the Arduino and power supply. Since the product may be in contact with water, it should prevent water from leaking into the enclosure. The cover should also be able to include a USB port and strain gauge and be made of materials that do not react with

alcohol and drinks.

Lead: Chenyuan Zhao; Assisting: Pengyu Wu.

Task 4. Implementing Battery and USB port

A 5V battery power supply shall be designed, fabricated, and tested. It shall be rechargeable from an external connector and meet specifications for weight, and battery life. The design should be tested with a dummy load of 500 ohms. The USB port should be placed in a fixed position that should not encounter the drink. The battery will also be safely sealed inside the enclosure and can not be opened by the user easily.

Lead: Zirui Chen; Assisting: Alan Dautov.

Task 5. Collecting Data from Local Bars and Crime Record

Collecting information about spiked drinking cases that happened locally to investigate the type of drug used for the crime and the locations where the cases happened, and the methods being conducted. Map out where crime commonly happens and record the possible means people can use to avoid detection to improve the success rate of the device based on the information collected. Survey people's willingness to use the device and their suggestions and thoughts on our product to locate potential customers in the market and improve customer satisfaction with the device. Communicate with the managers of bars and places where the crime is likely to happen to find out if they are willing to promote our product at their locations.

Lead: Pengyu Wu; Assisting: Chenyuan Zhao.

Task 6. Testing and collecting Feedback from users

Completing the new prototype, we will find at least 10 users to try the prototype and to complete a survey. The tests will include common spiked drinking cases and emulate what could happen when using the device to search for any false positive cases. The survey from users will allow the Halo team to collect information about user experience, the prototype's functionality, and the overall performance of the product.

Lead: Chenyuan Zhao; Assisting: Alan Dautov.

Task 7. Developing a Website

A website is designed to include four components of the product including the user manual, product introduction, user feedback, and case report. A user manual assists users in understanding the functionality included in the device and instructions on how to properly connect Halo's bluetooth to the phone and how to turn on notifications for the product to work. The product introduction will include statistics that discuss the risk and danger of drink spiking and how our product can prevent this situation. It serves to demonstrate the product functionality and the configurations of the device, including materials used, power consumption, phone compatibility, and price. Moreover, the user feedback provides a form that is available for people with verified purchases to leave their comments or complaints associated with the product, helping the Halo team improve the product and fix problems promptly to build up a reputation in the market. Lastly, the case report is a system that allows users to anonymously report their cases of spiked drinking and assist to collect more information that would be helpful to prevent them from happening.

Lead: Pengyu Wu; Assisting: Gabrielle Kuntz.

Task 8. Final Design

Based on the feedback from the survey, Halo team will move to fabricating the final design of the product. Any testing errors that were discovered will be eliminated and upgraded; any received suggestions will be carefully considered. The Halo team will also modify our designs to reduce the unit cost. For example, the plan is to replace the finalized circuit with PCB. The redesign will also be conducted if needed to finalize the product's appearance and core components. Ideally, Halo should have an overall success rate of 95% of spiking detection.

Lead: Pengyu Wu Assisting: Zirui Chen, Alan Dautov, Gabrille Kuntz, Chenyuan Zhao.

6 BUDGET ESTIMATE

The cost of acquiring five Arduino Nano 33 BLEs has been the biggest expense so far. It was determined to purchase five in case of any failure and for each team member to have one. The next costs involved obtaining parts for the strain gauge design, including strain gauges as well as strain gauge modules that can convert the output of the strain gauge to a voltage. The costs of the materials needed to build the cover itself was estimated as well. Elastic materials, such as cloth or rubber, will be used to make the cover which allows it to fit over different sized cups. For the iOS app a Mac Mini and an Apple Developer Account have been provided by Professor Osama.

Item	Description	Cost
1	Arduino Nano 33 BLE (5)	$157.79
2	Night cap drink covers (2)	$21.58
3	Strain Gauge Modules (4)	$14.14
4	Strain Gauges (10)	$9.11
5	Gauge wire (30)	$9.98 (estimated)
6	Elastic	$8.99 (estimated)
7	Spandex Material (for the cover)	$11.99 (estimated)
	Total Cost	$233.58

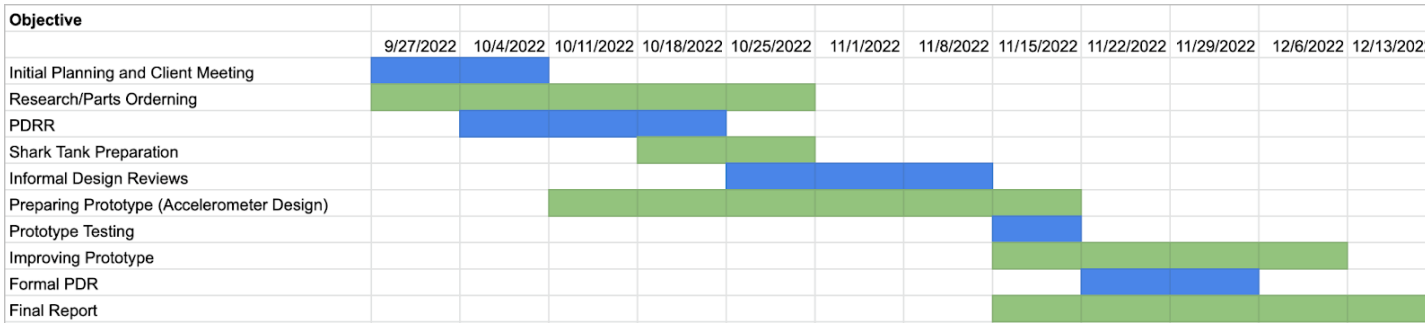
Figure 4. Budget estimation table

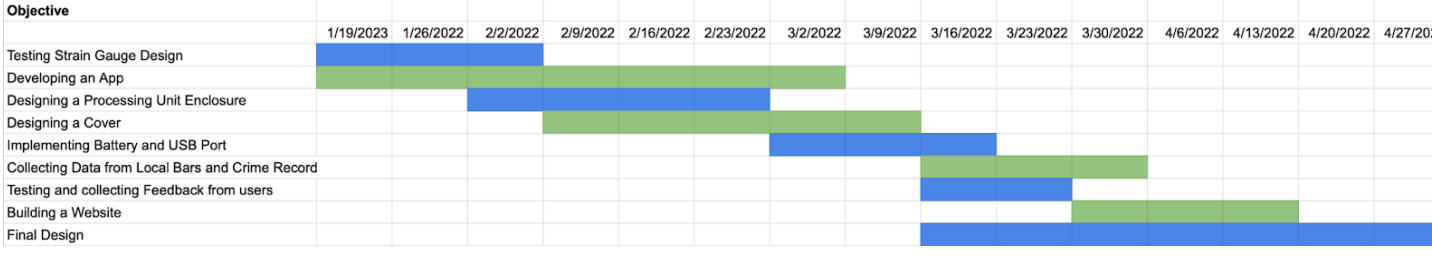
7 ATTACHMENTS

7.1 Appendix A – Engineering Requirements

Requirement	Value, range, tolerance, units
Size (able to put in pockets and bags)	65mm x 65mm maximum
Power	5V battery (Rechargeable)
Long Battery Life	at least 10 Hours
Long range Blue-tooth	50 m to 100 m
Waterproof	IPX5 (can withstand water splashes/sprays from every direc-tion)
Able to fit most drink cups	can fit cups between 2.5 cm diam-eter and 15 cm diameter
Reasonable price	<$35 unit cost
App Compatibil-ity	iOS
Connection	Bluetooth

7.2 Appendix B – Gantt Chart





7.3 Appendix C – First Prototype Test Results

Test	Pass/Fail
Move the cup horizontally on the x-axis to check if Alert Message shows up.	Pass
Move the cup horizontally on the y-axis to check if Alert Message shows up.	Pass
Move the cup vertically on the z-axis to check if Alert Message shows up.	Pass
Randomly move the cup in the x, y, and z directions and check if Alert Message shows up.	Pass
Knock the cup over and check if Alert Message shows up.	Pass
Tilt the cup horizontally on the z-axis from 0 to 90 degrees to check if Alert Message shows up, then return to the original position and tilt to the opposite side from 0 to 90 degrees.	Pass
Tilt the cup horizontally on the y-axis from 0 to 90 degrees to check if Alert Message shows up, then return to the original position and tilt to the opposite side from 0 to 90 degrees.	Pass
Tilt the cup horizontally on the x-axis from 90 to180 degrees to check if Alert Message shows up, then return to the original position and tilt to the opposite side from 90 to180 degrees.	Pass
Tilt the cup horizontally on the y-axis from 90 to180 degrees to check if Alert Message shows up, then return to the original position and tilt to the opposite side from 90 to 180 degrees.	Pass
Gently remove the cover while making as little movement as possible.	Fail
Quickly remove the cover and check if the alarm system is working.	Pass
Two people cooperate and try removing the cover by avoiding the detection algorithm.	Fail
Remove part of the cover from the cup.	Fail
Success rate	=77%

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[1] REFERENCES

[2] Callahan, Molly. "With Reports of Spiked Drinks on the Rise in Boston, Here Are Tips for Staying Safe." *Boston University*, 6 Oct. 2022, https://www.bu.edu/articles/2022/spiked-drinks-in-boston-tips-for-staying-safe/?utm_campaign=bu_today.