Project Proposal

Collective Child Tracking System

Team 39

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2 INTRODUCTION

2.1 OBJECTIVE

According to the Federal Bureau of Investigations, there were 465,676 reports of missing children in 2016 alone [1]. Therefore, it is no surprise that parents and other adult supervisors consistently worry about the safety of the children in their care. Teachers and counselors especially worry about ensuring the safety of groups of children when on an excursion or field trip, fearing that a child could easily slip away. With this target market in mind, the problem of supervising many children at once, and without the high-demand dependence on the internet, remains highly relevant and presents a large area of opportunity.

The Collective Child Tracking System (CCTS) that we propose addresses the supervision of multiple children through wearable devices in a unique configuration. The adult supervisor would be equipped with a radio receiver that would consistently read signals periodically from wearables worn by the children. Once a wearable exits the 50-100 meter range of the transmitter, the wearable will send a GSM signal to the supervisor's phone, carrying an alert message with a last-known location. The innovation of the system lies with how the location is determined: GSM technology allows the wearable to detect nearby cell phone towers and their relative signal strengths. Google's Geolocation API implements this raw data to determine an approximate location that is shown to the supervisor through their smartphone. Altogether, the CCTS provides a quick and seamless system that pinpoints the location of a child as they wander too far away from the central group.

2.2 BACKGROUND

Among all the cases of missing children, the vast majority of them are fortunately resolved within the first few hours [2]. This indicates a massive opportunity for the prevention of wandering and straying children in large and public group settings. It is also important to note that on average, children receive their first smartphones at around the age of 10 [3]. As a result, there is no direct method of tracking a child's whereabouts until they enter middle school age. Moreover, it is important to address the sensitivity of location data concerning children. Constant GPS tracking may cause privacy concerns that pose as barriers of entries for adults to use such devices. The 1998 Children's Online Privacy Protection Act specifically states that parents, or teachers in *loco parentis*, must approve the transmission of children's personal information, including location [4]. Implementing a system with useful, but limited, location data would achieve a satisfactory medium between security and privacy.

There are countless child-tracking devices that are currently on the market, but they all suffer from similar problems: relatively short battery life, complete reliance on GPS technology, or short range of tracking [5]. In terms of battery consumption, GPS consumes up to 166mW of power when active; conversely, GSM will only consume an average of 66mW when sending a text message [6]. Moreover, a reliance on GPS makes indoor surveillance spotty and unreliable, placing great limitations on indoor applications. Alternatives to GPS, like Bluetooth trilateration, are less accurate and limited in range. Because of this, CCTS strives to employ the combined use of universal GSM communication and Google's geolocation API to address these problems.

2.3 High-Level Requirements

Our proposed CCTS design contains multiple facets, but its modular nature makes it easy to define several key requirements:

- The system must be able to determine whether a specific child device is within 50m range of the adult device at any given time, though this will most likely happen at intervals of 10s.
- The child devices, upon loss of contact with the adult device, must transmit via SMS the current cellular telemetry data from the GSM modem for geolocation.
- The child devices must be wearable, and able to function for a reasonable period of time between charges. As the average school day in the US is about six hours, this is a reasonable target.

3 Design

3.1 Block Diagram

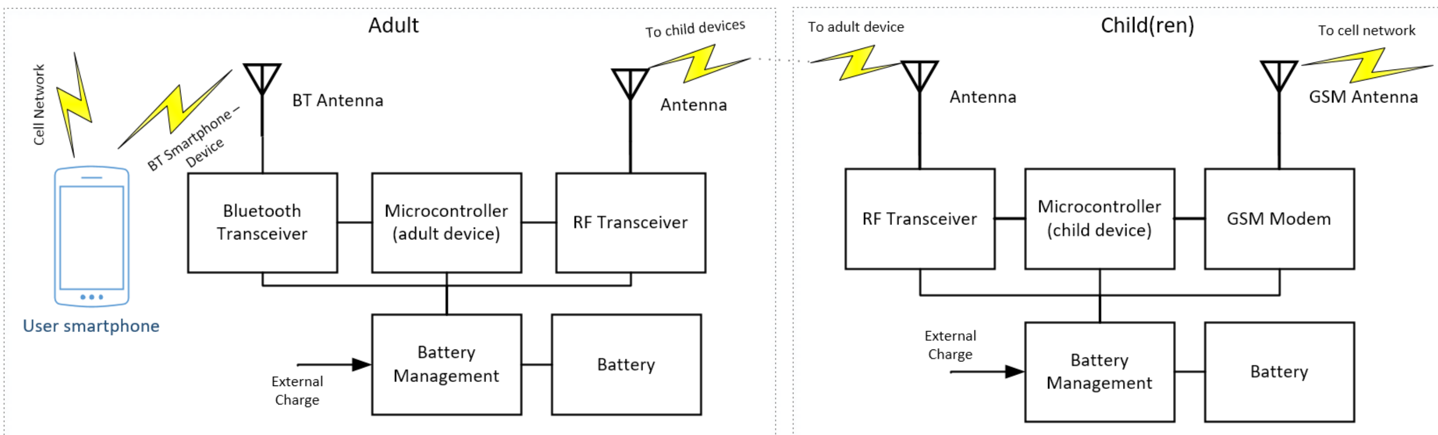

Figure 1: High Level Design Block Diagram

Once the devices are configured and deployed, the adult device will monitor an RF channel for periodic "ping" signals from the child devices, and will respond with a similar "ping" message to notify the child devices that they are in range. Upon losing contact, the adult device will alert the adult user to the condition, and the child device will activate a GSM modem which will transmit location data via SMS to the adult cell phone, which can be translated into a GSM geolocation using a google API. The devices must be able to work in a reasonable range- 100m in ideal conditions (outdoors and line of sight) to simulate a playground or children's sports activity, and 50m indoors (average building, brick/wood/concrete, not line of sight) to simulate a museum trip or other indoor activity.

3.2 System Design

In addition to the technical components illustrated in the high-level block diagram, a more concrete view of the CCTS design is shown in *Figure 2.* The diagram demonstrates the how the child device would work in conjunction with the adult radio device and what other technology is involved in our response system.

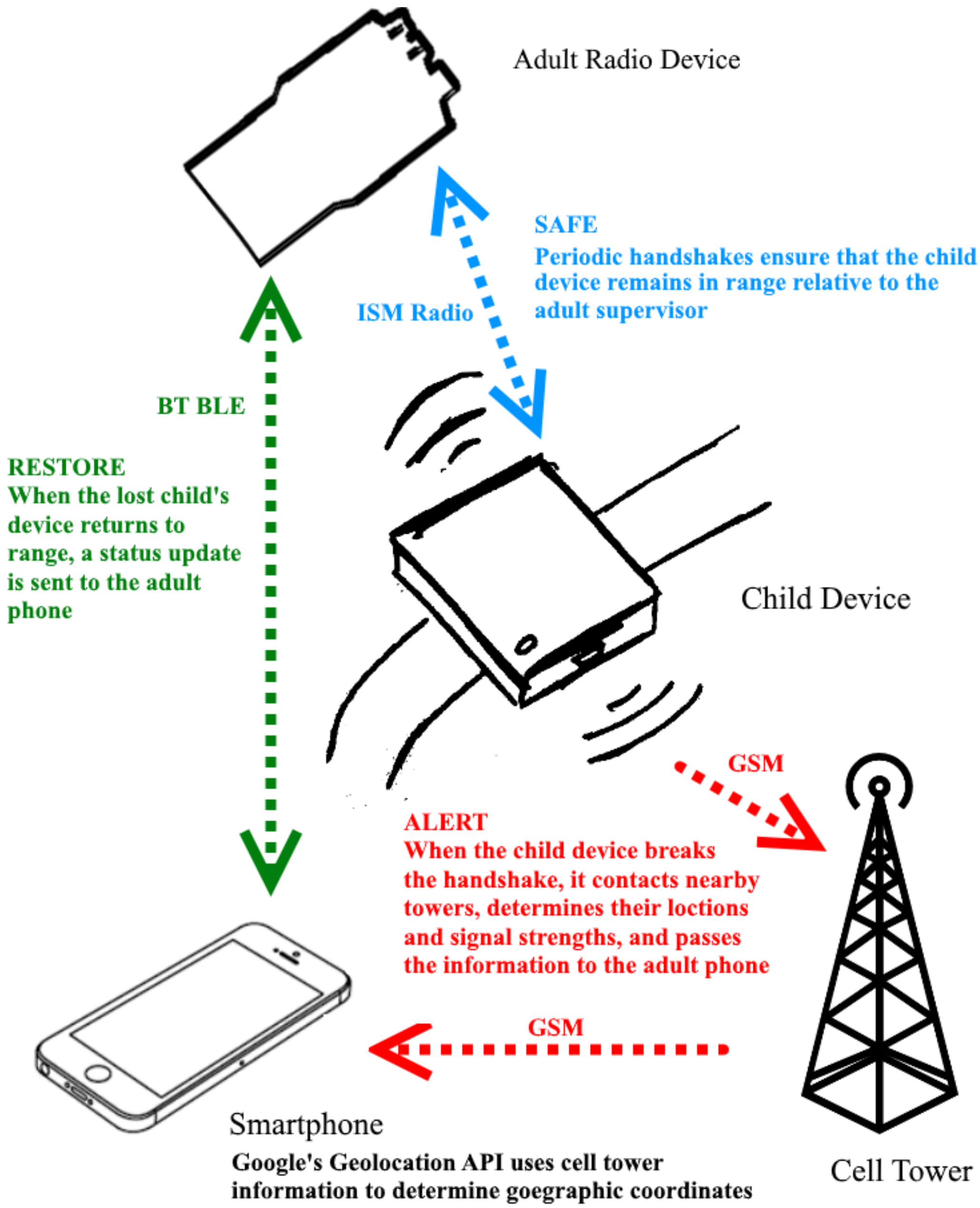

Figure 2: Diagram of CCTS Implementation

3.3 Functional Overview- Adult Device

3.3.1 Microcontroller

A 3.3 volt VCC power source will be supplying the unit with appropriate power to function. Serial connections are established between the microcontroller, RF transceiver, and Bluetooth transceiver.

This unit provides initialization and ongoing control to the Bluetooth transceiver and RF Transceiver via serial links. Logic functions are performed here including maintenance of the child device database and initiation/interpretation of any signals from other devices and modules. The microcontroller will be programmed to receive “ping” signals from child devices, and periodically inform the child devices that the system is still in range.

Requirement 1: Microcontroller contains two digital, serial inputs and outputs connected to the Bluetooth and radio transceivers. It will appropriately serve as the middleman between the transceivers.

Requirement 2: Logic will be implemented appropriately to indicate a child device wandering out of range.

3.3.2 LiPo Battery

The battery will be Lithium Polymer, which is an industry standard in power control. As such, the battery will simultaneously control the microcontroller, Bluetooth transceiver, and radio transceiver. The battery will carry a minimum capacity of 500mAh and provide voltage reaching up to 3.7 V.

Requirement 1: LiPo battery will have a minimum capacity of 500mAh to ensure at least about 5 hours of battery power.

3.3.3 Battery Management and Voltage Regulation

Battery management logic will ensure that the LiPo battery is appropriately charging and discharging when needed. It will include a microUSB charger that will detect the battery’s full charge, along with power management when a Bluetooth connection is or is not established. A voltage regulator will be included alongside battery management to pull voltage down to appropriate levels required from the transceivers and microcontroller.

Requirement 1: Battery management will include a microUSB module to enable LiPo battery charging; charging time is not in scope of this project.

Requirement 2: Battery management logic will appropriately regulate power going to microcontroller and transceivers; if Bluetooth is not established, neither transceiver will consume full power.

3.3.4 Bluetooth Transceiver

This unit will setup and maintain a connection with the adult smartphone in order to provide the smartphone with status updates regarding the location and health of the child devices. Standard Bluetooth 4.0 or BLE protocols will be implemented to communicate with the adult smartphone. This transceiver must be able to receive serial bits from the microcontroller and send a ping in return to confirm communication. Bits will contain the identifier of any child devices that are out of range.

Requirement 1: Operate at 2.4 GHz at a very small distance. We assume that the transceiver will be close to the adult smartphone.

Requirement 2: Bluetooth transceiver will operate at a 3.3 V input.

3.3.5 RF Transceiver

This unit will communicate received "pings" from the child devices and send that data to the microcontroller for processing. The data will primarily contain the binary existence of a child that is in range or out of range. Simply if a handshake is no longer detected between the transceiver and child device, the radio transceiver will pass the alert along to the microcontroller. If allowed within the scope of the project, the transceiver will have a custom-designed antenna implementation

Requirement 1: Operate at an ISM band of 900 MHz or lower, allowing for longer range with lower power consumption.

Requirement 2: Radio transceiver will operate at a 3.3 V input.

Requirement 3: Radio transceiver antenna will be omnidirectional and no larger than 5cm.

3.3.6 Mobile Smartphone and Software

The auxiliary phone software will take in raw cellular tower information—their unique identifiers, distances from the lost child device, and signal strengths—and communicate with Google's Geolocation API. The API will output a best estimate of geographical coordinates, which we may display on a simple Google Map display.

Requirement 1: Successfully convert raw information sent via SMS into geographical coordinates.

3.4 Functional Overview- Child Device

3.4.1 Microcontroller:

This unit provides initialization and ongoing control to the GSM modem (when required by the system state) via serial links. Logic functions are performed here including determining location and assembling data for transmission. The microcontroller will be programmed to send "ping" signals to the adult device, and if it does not receive the appropriate reply in a set timeframe, it will go in to lost mode during which the GSM modem will be activated and will transmit the GSM cell tower data via SMS to the adult smartphone for geolocation.

Requirement 1: Microcontroller contains two digital, serial inputs and outputs connected to the GSM and radio transceivers. It will appropriately serve as the middleman between the transceivers.

Requirement 2: Logic will be implemented to appropriately detect loss of contact with the adult unit. This will be indicated by the illumination of an LED and/or triggering of a GSM transmission.

3.4.2 LiPo Battery

Like the adult device, the child device will contain a Lithium Polymer battery. The battery will simultaneously control the microcontroller, radio transceiver, and GSM modem. The battery will carry a minimum capacity of 500mAh and provide voltage reaching up to 3.7 V.

Requirement 1: LiPo battery will have a minimum capacity of 500mAh to ensure at least about 5 hours of battery power.

3.4.3 Battery Management

Battery management logic will ensure that the LiPo battery is appropriately charging and discharging when needed. It will include a microUSB charger that will detect the battery's full charge. A voltage regulator will be included alongside battery management to pull voltage down to appropriate levels required from the transceivers and microcontroller.

Requirement 1: Battery management will include a microUSB module to enable LiPo battery charging; charging time is not in scope of this project.

Requirement 2: Battery management logic will appropriately regulate power going to microcontroller and transceivers; if GSM is not enabled, neither transceiver will consume full power.

3.4.4 RF Transceiver:

This unit will transmit "pings" from the child devices and relay any response to the microcontroller for processing.

Requirement 1: Operate at an ISM band of 900 MHz or lower, allowing for longer range with lower power consumption.

Requirement 2: Radio transceiver will operate at a 3.3 V input.

3.4.5 GSM Modem

The GSM unit will establish communication with the global GSM cellular network as an SU (Subscriber Unit). The modem will gather data about the GSM towers in range of it such as provider and tower code so that the data can be sent via SMS to the adult device cell phone. The adult cell phone will use the google geolocation API to translate that data into a location of the child device.

Requirement 1: Operate in the GSM bands of 850 MHz and 1900 MHz as required to connect with the US GSM cellular network.

Requirement 2: GSM modem will operate at a 3.3 V input.

3.4.6 Physical Enclosure of Circuitry

The physical enclosure will ensure that all circuitry is kept in one place. The ideal goal is to make this enclosure about 4cm by 4cm so a child may wear this with a strap around their wrist.

3.5 Risk Analysis

The child device is a significant risk to successful completion of the project. The device must be easily wearable, compact, lightweight, safe, and low-power. Due to the high power requirements of radio transceivers, we will need to be very careful in our design not to drain the battery too quickly, lest the device run out of power before the user is finished with it. The device also requires the integration of two separate RF technologies which will require the placement of the respective antennas. It is very possible that these two components will not be able to operate at the same time due to radio frequency interference concerns.

We can minimize these difficulties by being very careful to select a microcontroller that draws very little power, and can cycle between sleep and active modes per our design. A low power design will naturally reduce the heat and safety concerns associated with a wearable product. In addition, using an RF technology for communication with the parent device that does not require a connection to be set up will greatly reduce the overhead associated with radio communication. We will need to devise a timing protocol to allow up to 30 devices to all transmit their "ping" signals in a specified period, as well as to receive a simple response from the adult device. One possible solution is the use of the GSM network for timing, but this may cost too much power.

4 ETHICS AND SAFETY

Wearable technology has vastly grown in the market, anticipating to exceed more than $100 billion in annual sales by 2018 [7]. With this growth, though, there are safety issues as well as ethical concerns associated with the technology. Our CCTS is no different.

We will be using a rechargeable lithium battery because they have greater energy density, greater energy per volume, and longer cycle life. As always, there are possible safety risks. The thermal stability of materials in the battery at high temperatures and the occurrence of internal short circuits may cause "thermal runaway" [8]. This is a concern because our device is a wearable and any type of high increase in temperature could cause harm, such as burns, to the user. Lithium batteries are safe and heat related failures are rare, but is an important concern to be aware of when designing our device. We will test our wires and circuitry thoroughly to make sure all connections are good, as well as, closely monitor the temperature of the battery when testing to mitigate potential risks.

An issue with the design of the wearable technology is how close the technology will be to the skin of the users. We will have to be aware of what materials are being used to create the device. People can have an allergic reaction to the "stainless steel casing, materials used in the strap, or adhesives used to assemble the product, resulting in redness, rashes or blistering where the skin has been in contact with the tracker." [9]. There will come a time when testing will need to occur on humans. This will only occur after rigorous testing, out of range of humans, of the device. In accordance with IEEE Code of Ethics, #1 and #9: "To accept responsibility in making decisions... " and "Avoid injuring others..." [10] we will confirm all materials are safe to use, test on humans only when 100% certainty of safety, and ensure the well-being and health for the users of our device, the general public, and the environment.

A safety risk, specifically for the children, to be aware of is that the CCTS can be used to capture the location of the children, in real time. The location data needs to be safely unreachable from wanted eyes; Hackers, kidnappers, and other people that could cause harm to the children cannot be able to find this data. We will need to abide by IEEE Code of Ethics, #2: "To avoid real or perceived conflicts of interest..." [10]. The parents of the children will need to be well informed of all concerns related to the CCTS.

One of the most controversial topics surrounding children tracking is do children have privacy rights, just like adults, do parents and legal guardians have the right to track their children? It is still unclear. Parents do have the right of control over their children, meaning they should have the right to govern where the children go, up to a certain age. The courts, from the United States Supreme Court have recognized that children are different than adults when it comes to rights. "In the 1979 Bellotti case, the Supreme Court said: 'We have recognized three reasons justifying the conclusion that the constitutional rights of children cannot be equated with those of adults: the peculiar vulnerability of children; their inability to make critical decisions in an informed, mature manner; and the importance of the parental role in child rearing'" [11]. This enforces parental authority over the child, but in our case what about a school teacher or chaperone in loco parentis, the responsibility of a person or organization taking on the responsibilities of a parent. There could be legal issues of tracking a child that is not "your own." Teachers by law must assume the role of "replacement parent," meaning they have the right of control over the children, but this may be not as clear in other areas the CCTS could potentially be used.

As in many areas of family life, open communication can defuse many of the potential privacy problems with GPS tracking. "A teen who knows the family car is equipped with a GPS tracker is likely to drive it responsibly. Children who know their parents are watching their cell phone location signal will probably not take side trips on their way home from school. And an honest conversation with an elderly loved one may be enough to convince her that that wearing a GPS tracker will help keep her safe, even if she does not suffer from dementia or Alzheimer’s disease" [12]. In our case, children who know they are being tracked in a large group will be less likely to wander off. Though there are risks associated with wearables and tracking devices, overall the benefits that the CCTS will produce for everyone will outweigh the potential negatives. Most importantly, throughout the project we will follow the IEEE Code of Ethics, #5, "To improve the understanding of technology; its appropriate application, and potential consequences" [10].

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