SFU

TRIWAVE SYSTEMS

ENSC 440

Akriveia Beacon

Prototype Refinement

Team 5

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1 Introduction

The Akriveia Beacon by TRIWAVE SYSTEMS focuses on improving the localization and rescue process of personnel trapped in buildings during or after small scale disasters. These disasters may range from small fires to low magnitude earthquakes. This is achieved by incorporating a combination of advanced Ultra- wide-band radio modules, micro-controller units and data processing units to create a dependable indoor positioning system using trilateration techniques. Such trilateration techniques have been reliability used in the search and rescue industry for decades.

There are three main development phases for the Akriveia Beacon system including: proof-of-concept phase, prototype phase, and final product phase. Throughout each phase of development various design changes are made to improve the functionality and reliability of the system. Currently in the refined prototype phase there are major component addition and changes which modifies the core functionalities of the beacon components. One major optimization of the beacon system is that the transceiver for ranging switched from Bluetooth low energy to ultra-wideband. Other additions include WiFi modules for networking capabilities, backup battery packs to mitigate external power failures, and beacon casing designed to provide security and structural integrity.

The following document discusses a brief outline of all necessary design changes and optimization for the refined prototype and production-ready version of the Akriveia Beacon system, as well as to provide relevant standards applied to the proposed designs. Furthermore, an assessment of potential risks and any safety issue is presented and user interaction and usability of design are addressed.

2 Design Optimizations

The Akriveia Beacon system has received major design changes and optimizations in terms of hardware, electrical, and software components. These changes were made to ensure the final production ready version cohere to safety standards, regulations and requirements specified in the design requirements, as well as to ensure a quality and reliable product.

Previously, Received Signal Strength Indicator (RSSI) with Bluetooth Low Energy (BLE) was used in the proof-of-concept for estimating distance. This yield undesirable ranging results as RSSI is affected by a wide variety of factors such as temperature, humidity, multi-path, and many other environmental factors and uncontrollable RF interference. To ensure ranging accuracy is well within 50 cm as specified in the design requirements, the system's radio technology was changed to time of flight (TOF) associated with ultra-wideband (UWB) for its superior accuracy in distance measurements. Beacon and ID Tag BLE transceivers modules was replaced with DWM1000 modules paired with 3.3V 8MHz Ardunio Mini Pros as the microcontroller unit (MCU). As a result of these changes the ranging capability was improved up to 30m indoors with an accuracy of +/- 25cm.

WiFi communication has been adopted in place of wired serial connections between beacons and data processing server (DPS) to increase scalability and to eliminate wire management issues introduced during installation. This was done by introducing the addition of ESP WiFi modules which will establish network connection with DPS through a closed private WiFi network. As a result each beacon was redesigned to accommodate the addition of WiFi modules. The MCU communicate with the WiFi modules via hardware serial to be able to receive and send UDP packets from the DPS.

Beacon recovery mechanisms was also designed into the core circuit. A MOSFET trigger switch composed of a N-type MOSFET has been added to enable hardware reboot which can be initiated by server commands in-case of beacon failures. However, since the output voltage from MCUs are 3.3V and the MOSFET trigger needs a higher potential of 5.0V, in order to be triggered, a Bi-directional logic converter consists of a 10K and 100K resistor and a N-type MOSFET has been added into the design.

Other design changes and optimization aimed for the production ready version include the addition of rechargeable battery packs equipped with power switches to beacons, removal of breadboards by assembly beacon and ID tag components onto perfboards, 3D printed cases designed for housing all hardware and electrical components, which can also be mounted, and important functionality and usability additions to the Akriveia web server.

Furthermore, there are some design optimizations that are planned but is beyond the scope of the current timeline. In the final production ready version, the beacons components are encased in a 3D printed casing made with PLA which could sustain structural integrity up to 65 degree celsius. Which is fairly low considering building fires could reach a temperature of 600 degree celsius. As a system to be operating under emergency disaster situation, the Akriveia Beacon must meet safety standards of fire safety equipment. The beacon casing must be designed with fire-safe polymers or perhaps coated with fire retardant paint to remain operational under high temperature environments. The internal electrical components could also be insulated with fire-resistant material such as polybenzimidazole fiber - a synthetic fiber which does not exhibit a melting point, or light carbon foam.

3 Engineering Standards

The Akriveia Beacon will be designed and optimized to meet various engineering standards published by the IEEE, the IEC, the ISO, and the CSA Group to ensure performance and safety of the final product. The system contains electronics devices, software stack, and communication devices with different protocols, which must follow the specific safety standards. Ranging and data communication on the physical, data link, and network layer with the use of 2.4GHz WiFi and the ultra-wideband spectrum, operating in unlicensed frequency bands, and wireless standards that apply to the operation band must be followed. Furthermore, the Akriveia Beacon system is designed to operate during disaster situations, material, safety, and design must follow the structural and durability standards for disaster equipment.

IEEE 1625	IEEE Standard for Rechargeable Batteries for Multi-Cell Mobile Computing Devices
CSA-C22.2 NO.61508-1:17	Functional safety of electrical/electronic/programmable electronic safety-related systems - Part 1: General requirements
CSA-C22.2 NO.0.23-15	General requirements for battery-powered appliances
CAN/CSA-C22.2 NO.0-10	General requirements - Canadian electrical code, part II
IEEE P360	Standard for Wearable Consumer Electronic Devices - Overview and Architecture
IEEE 802.15.4q-2016	IEEE Standard for Low-Rate Wireless Networks –Amendment 2: Ultra-Low Power Physical Layer
ISO/IEC 26907:2009	Information technology – Telecommunications and information exchange between systems – High-rate ultra-wideband PHY and MAC standard
ISO/IEC 24730-62:2013	Information technology – Real time locating systems (RTLS) – Part 62: High rate pulse repetition frequency Ultra Wide Band (UWB) air interface
IEEE P802.15.4z	Standard for Low-Rate Wireless Networks Amendment: Enhanced High Rate Pulse (HRP) and Low Rate Pulse (LRP) Ultra Wide-Band (UWB) Physical Layers (PHYs) and Associated Ranging Techniques
IEEE 12207-2017	ISO/IEC/IEEE International Standard - Systems and software engineering – Software life cycle processes
IEEE P2510	Standard for Establishing Quality of Data Sensor Parameters in the Internet of Things Environment
ISO 2382-9:1984	Data processing – Vocabulary – Part 9: Data communication
IEEE 1221-1993	IEEE Guide for Fire Hazard Assessment of Electrical Insulating Materials in Electrical Power Systems
IEEE 848-2015	IEEE Standard Procedure for the Determination of the Ampacity Derating Factor for Fire-Protected Cable Systems

Table 1: Table of Standards

4 Risk Management

This section discusses the possible risks associated with design changes of the Akriveia Beacon system, and discuss the possible methods for mitigating these risks. There are three major risk categories associated with design changes, mainly management, technological, and external risks outside the control of the project team.

Management risks pertain to possibilities of error in company operations due to design changes of the core product. As system design iterates, new materials and components are needed which creates a variety of risks. These include escalating costs, delayed schedule and logistical issues from production, manufacture, and shipping. Delays in project schedule could severely impact development and delivery time of milestones. To avoid delays, a purchases must be planned in advance. Sufficient background research are conducted on suppliers and vendors to ensure correct delivery times and sufficient supplies. Backup components, vendors and suppliers must be considered.

Technological risks from design changes prevents the system from meeting requirements and performance expectations. These contain component or system failures, software bugs and performance issues. Beacon failures pose the highest risk associated with the system with design changes. The current design does not include recovery mechanisms. Therefore having multiple beacons dispersed throughout the monitored area can ensure redundancy. The system needs a minimum of three working beacons within the area, wherefore having more beacons ensures that the system remains operational during unexpected situations. To further optimize the failure recovery design in the production ready version, the beacon firmware and server software will be incorporated with recovery functionalities such as reboot or beacon order re-orientation.

The accuracy of location tracking are also a potential risk to be considered. Inaccurate location could result in misinformation for first responders and hinder their rescue procedures. As more design changes are incorporated into the system, ranging accuracy could be affected by properties such as casing material, casing design, and other environmental factors. This can be mitigated in the installation and calibration process for the system. Each deployment of the Akriveia Beacon system will be calibrated with its environment and complete system test drills. During these process engineers and technicians will be checking for system accuracy and reliability of location to make further.

The refined prototype also includes many major updates to the core beacon hardware. This includes the additions of ultra-wideband transceiver modules and WiFi capabilities. With the addition of electronic components the impact of external electrical failure is much greater. This is mitigated by incorporating 10000 mAH backup battery packs that will sustain the necessary power level for each beacon for upto 10 additional hours after external electrical failure.

Lastly, external risks from design changes may include changes in user market or financial markets, possible patent or litigation issues, and external environmental hazards such as fires or natural disasters. In the final production ready version, the beacons components are encased in a 3D printed casing made with PLA. PLA could only sustain structural integrity up to 65 degree celsius considering building fires could reach a temperature of 600 degree celsius. To meet safety standards of fire safety equipment, the beacon casing must be designed with fire-safe polymers or even coated with fire retardant paint to maintain operation under high temperature environments. The internal components could also be insulated with material such as polybenzimidazole fiber a synthetic fiber which does not exhibit a melting point or light carbon foam. However, with these design changes the project, and manufacture cost will increase as these fire retardant materials mentioned are fairly expensive.

5 Human Factors & Usability

Hardware components are designed and implemented with usability and serviceability in mind. It is crucial for the product to be intuitive to use since it is to be used in emergency situations. On ID tags, a simple toggle switch is used to activate and deactivate the device. The switch is labelled by text, a simple color scheme, and LEDs indicating on and off state. Access to internal components is restricted to discourage unwanted tampering. For beacons, similar measures with color scheme and LEDS are used to indicate device power state. The internal components will not be permanently inaccessible like ID tags, and will be allowed for maintenance if needed. The beacon casing provides a sliding lid which can be locked into place to prevent tampering, since accessibility will only be given to authorized personnel. Once unlocked, the lid can slide open to allow easy access to internal circuitry and components.

Software UI are designed and implemented with the user in mind. The target users, first emergency-responders and adminstators, should be able to use and navigate the software intuitively. Entering the URL when connected to the wifi network, the user is greeted with a selection between *Admin* and *First Responder* Login confirmation. This ensures that the first responders only view the immediate and important pages instead of any configuration pages. To improve usability, a traditional website layout theme with navigation tabs at the top is used. However, first responders do not have access to user, beacon or map list and any configuration settings. Only adminstrators have access to all details of the system including adding and editing users, beacons and maps. Making easibility a priority, the *Start* and *End* emergency buttons are enlarged and shown at the top of the navigation bar. Users should be able to locate the emergency buttons succintly and with ease in times of high stress emergencies.

6 Conclusion

As a company TRIWAVE SYSTEMS is focused on creating the most reliable and accurate indoor location rescue system. As aforementioned, Akriveia Beacon is a system of Ultra-WideBand (UWB) radio beacons and ID tag systems communicating via UWB and using trilateration to accurately obtain near real-time location of personnel within buildings during the event of a disaster. The location information which then can be reported to emergency responders and operators to provide accurate and reliable information for the search and rescue effort.

The most efficient way to test and ensure new designs work as desired is through prototyping and product refinement. Since the product is designed and developed in three phases: proof-of-concept phase, prototype phase, and final product phase there are plenty of opportunity to improve system functions and design. Throughout each phase of development design changes and optimizations are made to ensure quality and reliability of the final product. As a system that could be critical for first and rescue operations, it is crucial that a reliable and robust system design can be improved upon to better aid disaster search and rescue operations with human safety as the pivotal focus.