TRIWAVE SYSTEMS

June 09, 2019

Dr. Craig Scratchley
Dr. Andrew Rawicz
School of Engineering Science
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Burnaby, British Columbia
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RE: ENSC 405W/440 Functional Specifications for Arkriveia Beacon

Dear Dr. Scratchley and Dr. Rawicz,

The following document contains the Requirement Specifications for Akriveia Beacon - The Indoor Location Rescue System created by TRIWAVE SYSTEMS. The Akriveia Beacon focuses on locating persons trapped in buildings during small scale disasters such as fires and low magnitude earthquakes. This is achieved by incorporating a combination of advanced Ultra-wide-band radio modules and microcontrollers to create a dependable indoor positioning system using trilateration. We believe that the Akrievia Beacon system can aids search and rescue operators by allowing them to safely and reliably locate victims during an emergency or disaster.

The purpose of this document is to provide a detailed description for the overall system architecture and requirements of the product according to the different development stages (proof-of-concept- prototype, and final product). This document consists of a system overview, system requirements, engineering standards, as well as safety and sustainability overviews.

TRIWAVE SYSTEMS is composed of five dedicated and talented senior engineering students. The members are Keith Leung, Jeffrey Yeung, Scott Checko, Ryne Watterson, and Jerry Liu. Coming from various engineering concentrations with a diverse set of skills and experiences, we believe that our product will truly provide a layer of safety and reliability to search and rescue operations.

Thank you for taking the time to review our requirement specifications document. If there are any further questions or comments, please direct them to our Chief Communications Officer Jeffrey Yeung at zjyeung@sfu.ca

Sincerely,
Jerry Liu
Chief Executive Officer

Enclosed: Requirements Specification for Arkriveia Beacon

SFU

TRIWAVE SYSTEMS

ENSC 405W

Akriveia Beacon

Requirement Specification

Team 5

09/06/2019

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Abstract

The Akriveia Beacon by TRIWAVE SYSTEMS focuses on improving the locating and rescue process of personnel trapped in buildings during or after small scale disasters such as fires and 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 reliable trilateration techniques. Akriveia Beacon allows search and rescue operations to safely and reliably locate victims during and after an disaster situation. By pinpointing the exact location of any victim wearing an ID tag, the search and rescue time is minimized; which is crucial in any disaster rescue operations.

This document addresses the functional and non-functional requirements for Akriveia Beacon: The Indoor Location Rescue System created by TRIWAVE SYSTEMS. From this document, the reader will be able to obtain a full understanding of the functions and higher-level system design of the Akriveia Beacon. The specifications details system components, and requirements for each of the specified domains. Additionally, aspects of engineering standards, responsibilities, safety, and sustainability (C2C [1]) of this project are outlined to provide an overview for practices followed by the engineers at TRIWAVE SYSTEMS.

TRIWAVE SYSTEMS is dedicated to creating a reliable and robust system for disaster search and rescue operations with human safety as the pivotal focus.

Glossary

C2C Cradle to Cradle development to ensure innovating and sustainable products. 29

CSA Canadian Standards Association is a standards development organization. 26

DC Direct current voltage. 14

GUI Graphical User Interface. 11

ID Identification. 8

IEC International Electrotechnical Commission. 26

IEEE Institute of Electrical and Electronics Engineers. 26

iOS Operating system released by Apple Inc.. 23

ISO the International Organization for Standardization.. 26

MCU Micro-controller unit. 12

PCB Printed circuit board. 15

PoC Proof of concept is the sample product assembled to explore project feasibility. 12

RF Radio Frequency. 12

RSSI Received Signal Strength Indicator. 8

SBC Single-Board Computer. 20

ToF Time-of-Flight is a method for measuring the distance between a sensor and an object. 12

UI User Interface. 23

UWB Ultra wide band. 8

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1 Introduction

1.1 Background

Over the last couple of decades urban centers around the world have faced substantial population growth. As a result, the number of larger and more complex buildings in these areas around the world is rapidly increasing. With a large population and massive buildings in relatively small areas, in the event of a disaster there can be a much higher risk for damage and casualties. Due to increased urbanization and complexity of urban structures, search and rescue operations in indoor urban environments face various complications and uncertainties. According to Statistics Canada an average of 135 fire related deaths occur each year from 2010 to 2014 [2].

In current practices, emergency management know little about the building until they arrive at the scene; where they have to quickly evaluate new information and take actions appropriate to the situation [3]. Once responders are on scene, assessments of the structure are conducted with readily available blueprints of buildings. Situational data are created dynamically during this process and the actual rescue process heavily depends on the situational awareness of the first line of emergency response operators [4].

An important issue that must be considered is how emergency first responders should be dispatched inside the building in the event of a disaster in order to minimize search and rescue time. In order to pinpoint locations of trapped victims quickly and accurately it is critical to have precise data. Proper emergency planning and organization takes a substantial amount of time, and having additional information on the locations of trapped, incapacitated or immobile personnel would improve first responders' situational awareness which would then improve their own safety and possibly reduce fatality rates.

As such, the need for a distinct indoor positioning rescue system is crucial in getting fast and reliable information that allows the first responders to be dispatched in such a way that the most optimal route is taken during the search and rescue operations. The Akriveia Beacon by TRI-WAVE SYSTEMS focuses on improving the locating and rescue process of personnel trapped in buildings during or after small scale disasters such as fires and low magnitude earthquakes. This is done through a system of Ultra Wide-Band (UWB) Beacons and ID tags for accurate, near real-time location of personnel.

Ultra-Wideband radio modules are small radio transceivers using ultra-wide band radio spectrum to communicate with one another. Each ID tag uses a UWB transceiver module to communicate with the beacon system. Given the time between sending and receiving transmission data, the distance can be estimated via RSSI or time of flight. The Beacons will then forward these distance estimations to a data processing unit, where it will use trilateration algorithms to calculate the near real time location of each individual ID tag. This system design allows for multiple ID tags as well as more than three anchor beacons to provide more accuracy through redundancy, making it modular and extendable.

1.2 Scope

This requirement specification document outlines functional and non-functional requirements expected of the Akriveia Beacon product through three different phases of development as shown in Figure 1. The three different phases including: the proof-of-concept phase, prototype phase, and final product phase.

Figure 1: Development Cycle

A high level design of the system hardware and software is also presented to demonstrate the overall system architecture and functionality of the product. The requirement section of this document is divided into five main categories as shown in the numbered list below. These requirements will indicate the constraints, demands, necessities, needs, and parameters that must be met or satisfied within the project time frame.

1. General requirement
2. Hardware requirement
3. Electrical requirement
4. Software requirement
5. Performance requirement
6. Safety Requirements
7. Sustainability Requirements

Furthermore, any relevant engineering standards, safety and sustainability practices are illustrated to demonstrate how the engineers at TRIWAVE SYSTEMS will ensure that the final product is both economically and environmentally safe and sustainable. By following strict engineering standards and proper engineering practices TRIWAVE SYSTEMS can guarantee that the final product will use materials, processes and services fit for their intended purposes.

1.3 Intended Audience

This document is presented by engineers at TRIWAVE SYSTEMS as a guide for the functional and nonfunctional requirements of the Akriveia Beacon product. The intended audience of this document includes but is not limited to, potential clients and/or partners, the supervising professors Dr. Craig Scratchley and Dr. Andrew Rawicz, associated teaching assistants and fellow TRIWAVE SYSTEMS members. The hardware and software engineers of the project can reference this document during the development and/or testing stages of the project for clarification.

1.4 Requirement Classification

For consistency purposes, the following requirement classification code convention is used to describe and organize requirements listed throughout this document.

[REQ.SE.# - X]

Code	Definition
REQ	Requirement abbreviation.
SE	Requirement Domain Abbreviation Code correspond with each requirements. (see Table 2)
#	Requirement number ID
X	Development Stage Encoding (see Table 3)

Table 1: Requirement Encoding

Requirement Domain	Abbreviation Code
General	GE
Hardware	HW
Electrical	EC
Software	SW
Performance	PE
Safety	SF
Sustainability	SU

Table 2: Requirement Domain Abbreviation Code

Development Stage	Encoding
Proof of Concept	C
Prototype	P
Final Product	F

Table 3: Development Stage Encoding

2 System Overview

2.1 System Layout

The Akriveia Beacon indoor locating rescue system combines electrical, hardware and software systems to detect and locate multiple occupants within a building during an emergency disaster situation. Each component of the system is developed separately in the PoC (Proof of Concept) phase; then partially integrated in the Prototype phase and fully integrated in the Final Product phase.

A high-level system overview displays three Locator Beacons, an ID tag, a data processing unit and an user interface (Figure 2). The Locator Beacons transmit wireless signals to the ID tag to acquire a response. When the beacons receive a response, the received signal data will be forwarded to the portable data processing unit via a closed Wi-Fi network. Then the processing unit will calculate the distance and location of the ID tag through a trilateration algorithm. Afterwards, the location results are displayed on a GUI for operators.

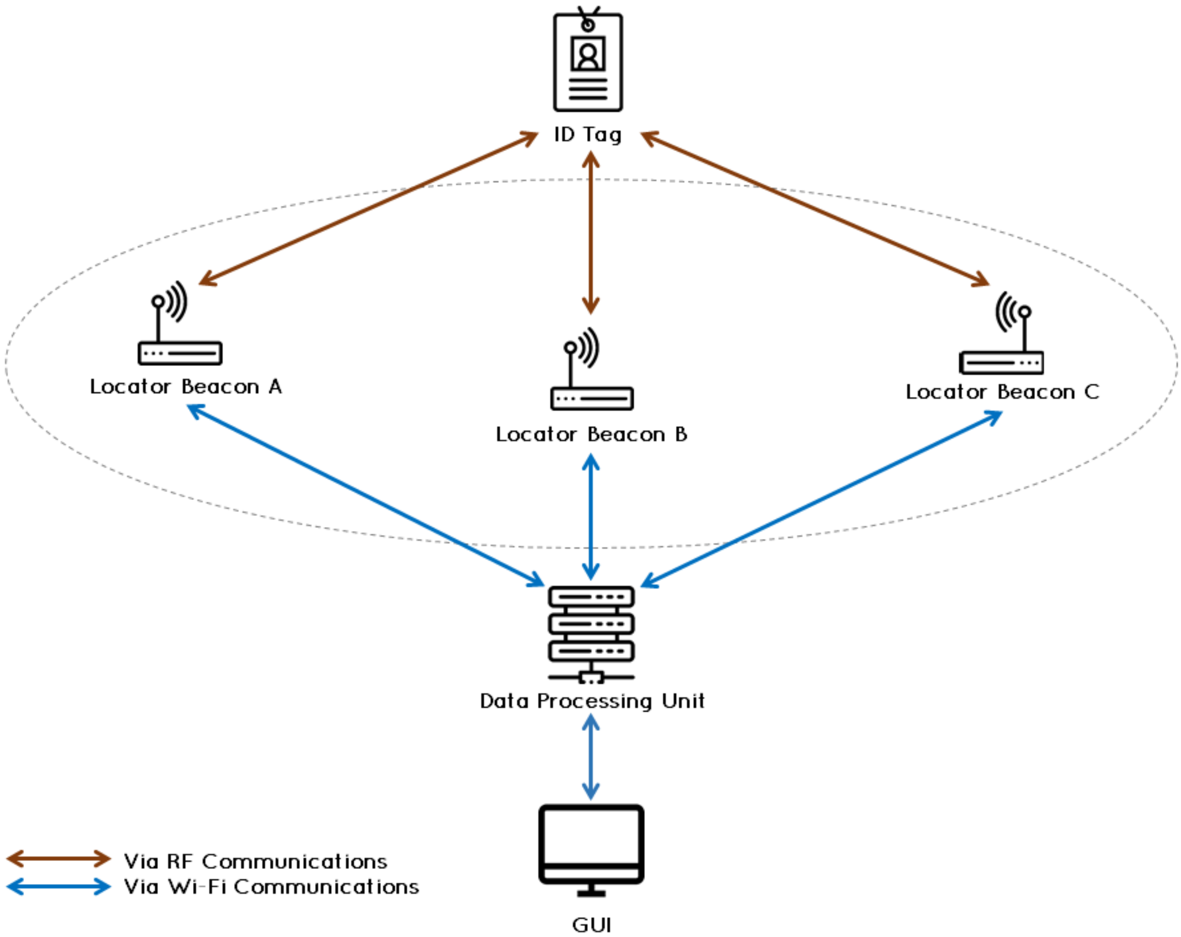

Figure 2: System Layout Overview

2.1.1 Proof Of Concept (PoC)

The Proof of Concept (PoC) demonstrates the feasibility of the location determination system using Beacon to ID tag distance estimation along with trilateration. Such a system should show the effectiveness of a trilateration algorithm for determining distance and location of the ID tag in two dimensional space. For the PoC, all equipment will be powered by an external power supply; as the main goal of the PoC is to demonstrate the feasibility of the main function of the system; locating ID tags with trilateration algorithms.

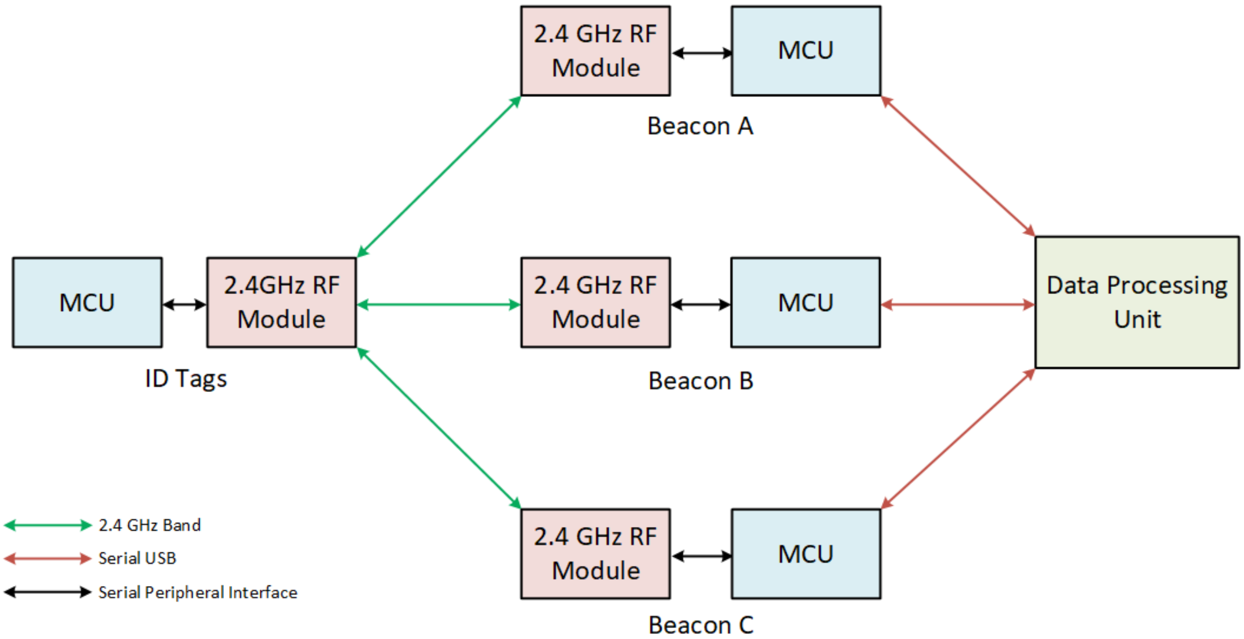

Figure 3: PoC System Block Diagram

This system will use four 2.4 GHz RF modules, four micro-controller units (MCU) and a Raspberry Pi as the data processing unit. The proof-of-concept demonstrates the following objectives:

1. Utilization of 2.4 GHz RF module chips as signal receiver and transmitter
2. Establish functioning RF data communication between the RF modules with one module as the ID tag and three as the locator beacons
3. Perform radio fingerprinting process to determine transmitter properties such as RSSI, time of flight (ToF), and other data
4. Send distance data from the location beacons to the data processing unit for data processing
5. Implement trilateration algorithms using distance estimation to determine ID tag location in 2D space

2.1.2 Prototype

The Prototype demonstrates the same objectives from the PoC except the transceivers will be using Ultra-wideband (UWB) signals instead of 2.4 GHz signals. UWB uses the radio frequencies of 3.5 to 6.5 GHz and would significantly reduce the issue of signal interference or multipath propagation. Although 2.4 GHz is more widely used for its versatility, UWB is more well suited for the Akriveia Beacon system. Selecting UWB chips would result in a higher wave propagation effect, lower signal interference and signal multipath [5]. In addition, an early prototype RF harvesting circuit would be implemented during the prototype phase to test the feasibility of the concept.

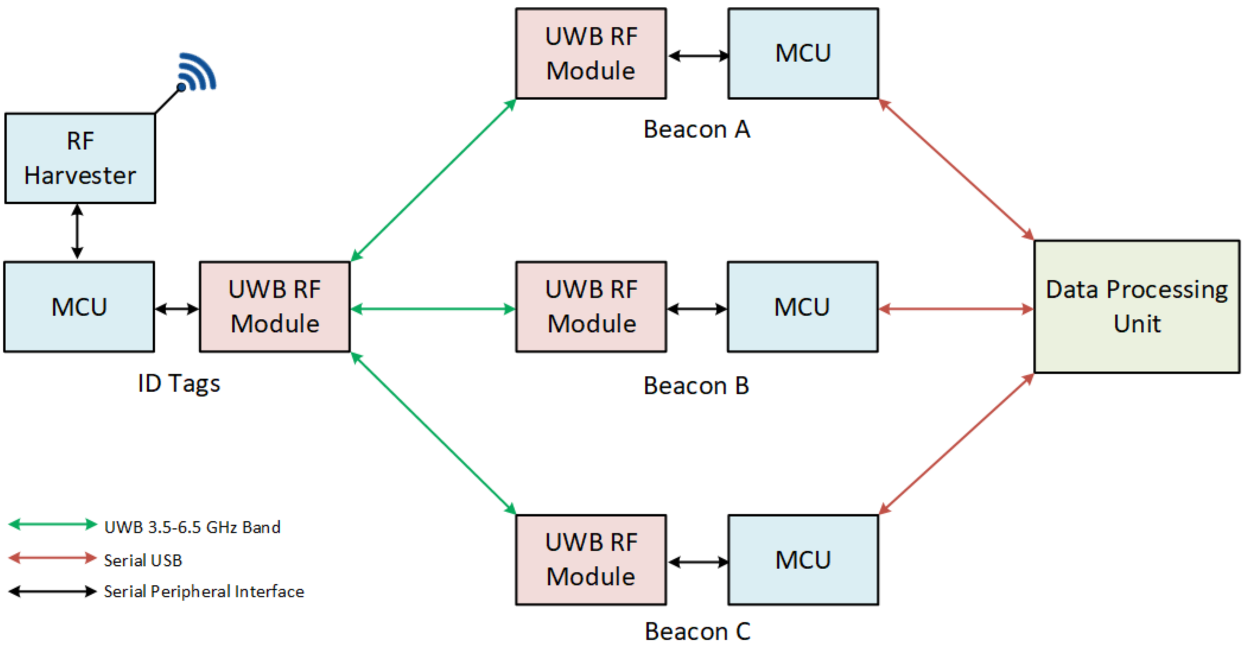

Figure 4: Prototype System Block Diagram

The objectives of the Prototype remains largely the same with the PoC besides using UWB chips and developing RF harvester circuit. Prototype phase objectives are stated below:

1. Utilizing UWB RF module chips in the UWB frequencies of 3.5 to 6.5 GHz as signal receivers and transmitters
2. Establishing functioning RF data communication between the four UWB modules with one as the Access Card and three as the Locator Beacons
3. Using signal fingerprinting to determine transmitter properties such as ToF, RSSI and unique identifier
4. Implement manual off/on activation switch to RF module circuit on ID tags
5. Apply trilateration algorithms on data processing unit to determine ID card location
6. Implementation of software stack on data processing unit and initial development of GUI
7. Prototype and early implementation of RF harvesting circuit or device charging

2.1.3 RF Harvester Prototype Design

RF is an abundant source for energy harvesting especially in a radio wave rich environment. When Radio Waves reach an antenna it causes a changing potential difference across the antenna. The potential difference causes charge carriers to move along the length of the antenna in an attempt to equalize the field, and the RF to DC integrated circuit (Figure 5) is able to capture energy from the movement of those charge carriers. The energy is stored temporarily in a capacitor and then used to create a desired potential difference at the load [6].

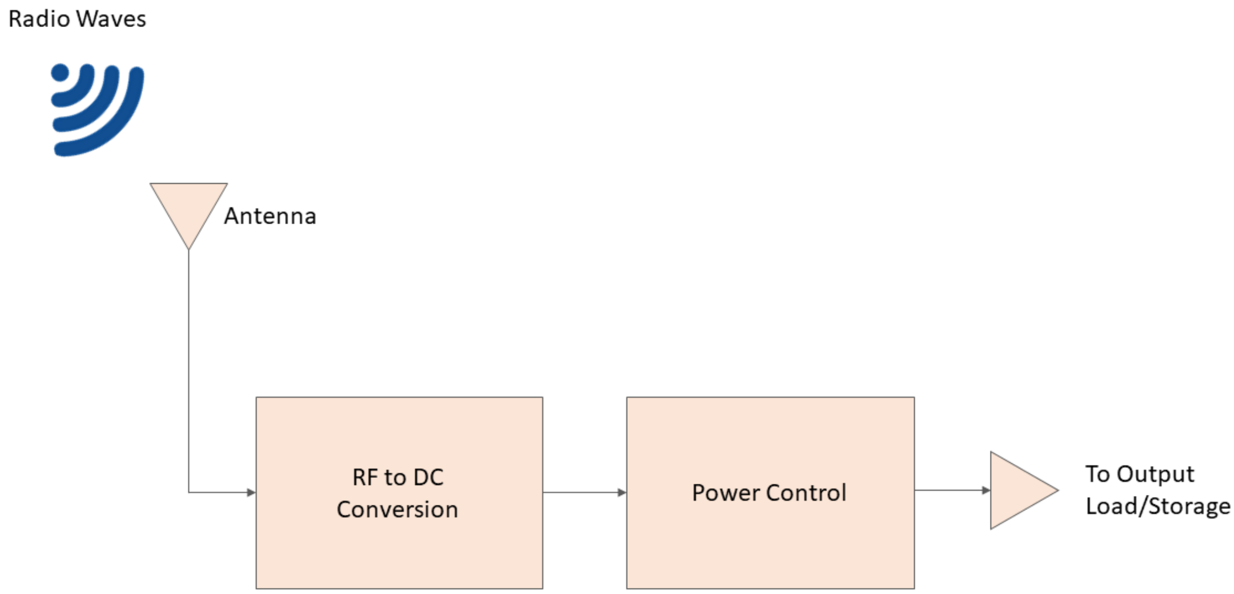

Figure 5: Prototype System Block Diagram

There will be a demonstrable RF harvester circuit similar to Figure 5 that would convert ambient radio signal to DC voltage to charge the ID tag battery. The harvester will operate at the standard 2.4 GHz band as ambient RF signal is most comment at this frequency (ie. WiFi, Cellular). The received signal would be put through a rectifier to generate a DC voltage. Through the RF harvester circuit the RF signal power would be transferred to the circuit battery to maintain charge. The yield of the power generated would be small but the effect would be constant in an RF rich environment.

2.1.4 Final Product

The final product will demonstrate the final fully functional indoor rescue system that detects the location of the ID tags and displays it accordingly on a GUI. Here the additon of Wi-Fi modules can be seen, as the Beacon will use wireless Wi-Fi communication with the data processing unit. The Wi-Fi network will be a closed network meaning that the network is only share between beacons and the data processing unit to ensure reliability and stability. All the components of the systems will be fully integrated as a close-to-production product. Component circuits and PCB footprint will be minimized and proper casing will be made to house all electronics. The data processing unit will provide the user with a full GUI to interact with the system along with the fully implemented features such as importable blueprints and multi-floor tacking.

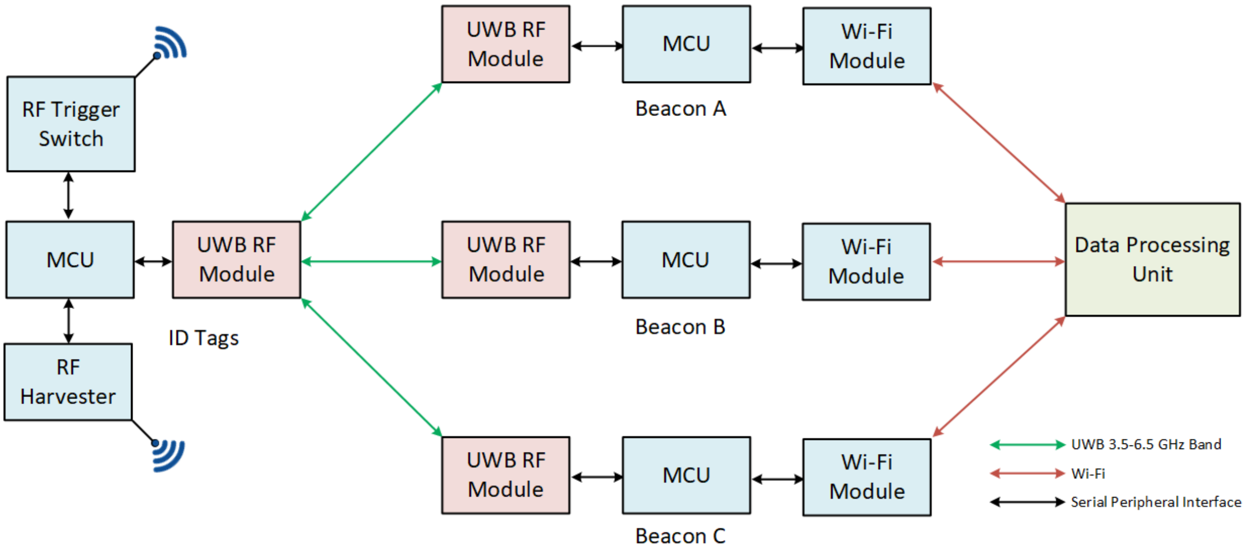

Figure 6: Final Product System Block Diagram

The final product should satisfy these objectives below:

1. Establishing functioning RF data communication between the four UWB modules with one imitating the Access Card and three imitating the Locator Beacons
2. Using signal fingerprinting to determine transmitter properties such as ToF, RSSI and unique identifier
3. Utilizing UWB RF module chips in the frequencies of 3.5 to 6.5 GHz as signal receivers/transmitters
4. Develop an ID tag with manual (ON) RF module activation, one RF harvesting circuit for charging and one RF harvester as a RF Trigger switch
5. Send distance data to the data processing unit to be processed
6. Have the data processing unit apply trilateration algorithms to determine ID card location
7. Optimize trilateration algorithms to increase accuracy and speed of location calculation
8. Integration of Wi-FI modules for wireless data communication between Beacons and Data Processing Unit

2.1.5 RF Harvester Final Design

Once the RF harvester test circuit produces adequate results in the prototype phase, there will be two RF harvester circuits implemented on the ID tags in the final design. The first will act as a RF trigger switch to activating the RF module in case of an emergency, the second will be for charging the ID tags using ambient RF signals.

The first RF harvester circuit will activate the ID tag RF module circuit, this harvester will operate on a different frequency and power level, making it distinguishable from UWB or other ambient radio frequencies. The second RF harvester circuit designed for charging the ID tags will be operating at the standard 2.4 GHz band as ambient RF signal is most common at this frequency (i.e. Wi-Fi, Cellular). The charging RF harvester would have been implemented and tested in the prototype phase. Minor modification and optimization of the circuit would occur in the final phase.

Both RF harvester circuits and the RF module circuit will be combined to produce the final version of the ID tag.

2.2 Trilateration Overview

2.2.1 Proof of Concept (PoC)

The Akriveia Beacon System will employ a two dimensional trilateration positioning method to locate the mobile sensors within the ID tags in the Proof-of-Concept (PoC) phase as illustrated in Figure 7. The 2-D position of an ID tag can be located by the intersection of three circles, where their radii are determined individually by the measured distance between each beacon and the ID tag. The method will abide the scheme of lateration with absolute distances, which uses distance-related measurements to describe the distance between mobile sensors and several fixed sensors. The metric used to calculate these distances are from RSSI which would be measured from the 2.4Ghz wireless modules using equation (1).

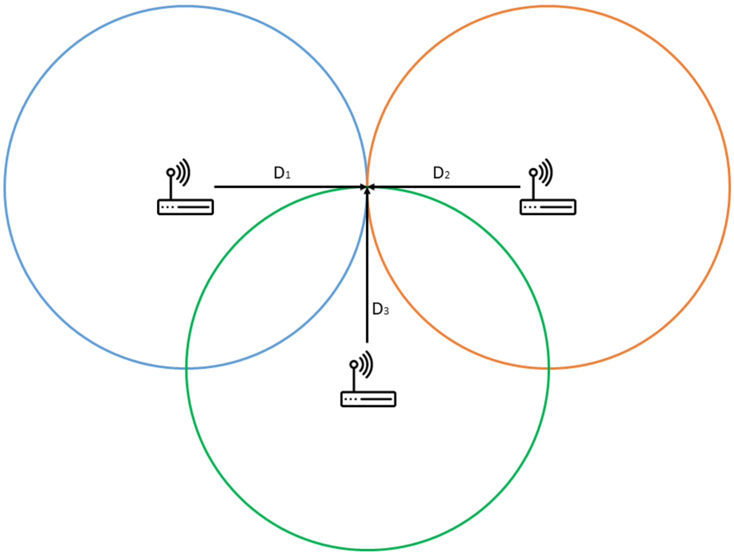

Figure 7: Trilateration Diagram

$$Distance = 10^{(Measured\_Power - RSSI)/(10 * Environmental\_Factor)} \tag{1}$$

2.2.2 Prototype/Final Product

In the Prototype and Final Product phase, the Akriveia Beacon System will continue to adhere to the concept of lateration with absolute distances for positioning computation, but also extend its application into three dimensions. However for the prototype and final product, trilateration calculations will be based on Time of Flight (ToF), the metric to be used for distance-related measurements. Equation (2) describes the signal propagation time in a one way communication between a transmitter and a receiver [7]. ToF data will be collected from 2.4 GHz RF medium and converted to distances based on a form of Distance Speed Time formula shown in the equation below. Time will be ToF and Speed will be the speed of light since RF wave is a form of electromagnetic radiation. In 3-D trilateration positioning, ID tags will be located based on the intersection of three spheres instead of three circles as in the case of 2-D. In combating the vulnerability of signals being multipathed in a 2.4 GHz RF medium, the transceiver modules of the beacons and ID tags will be replaced with ultra-wideband (UWB) modules, which have an operational frequency range from 3.5 GHz to 6.5 GHz [5].

$$D_n = Speed\_of\_light * ToF \tag{2}$$

2.3 Software System Overview

Akriveia's software design is specifically chosen for safety, robustness and performance. It's primary computation unit is powered by a Raspberry Pi 3 B+ running a Rust web server to leverage type-safety and memory access guarantees while still maintaining C++ like performance because of compiled binaries and lack of garbage collection. Figure 8 below is a diagram of the software architecture, which serves content through the web server to first responders while processing real time location data of users from beacons in the background. The data processing unit will make use of the widely used model-view-controller architecture to reduce development costs and leverage modern software development practices. Sqlite was chosen for its simplicity and minimal system footprint, which is intended to be used to persist data such as user and beacon location information, and building blueprints.

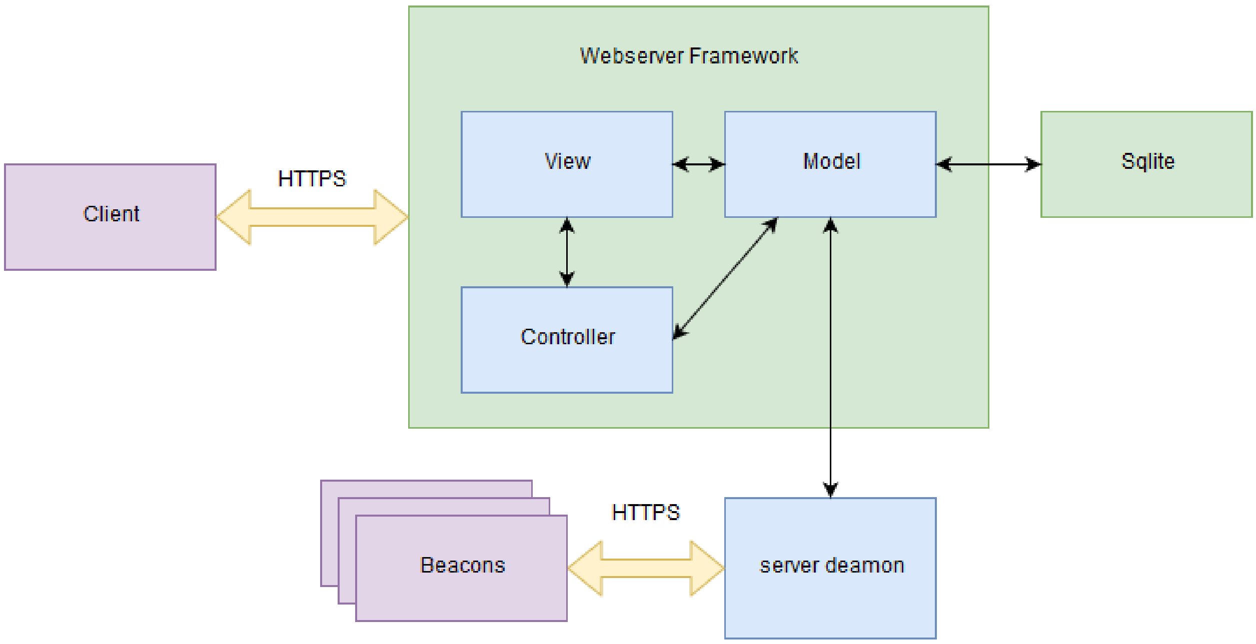

Figure 8: Akriveia Software Overview

3 System Requirements

TRIWAVE SYSTEMS is dedicated to producing a high-quality product. To ensure production quality, various requirements at different stages of development will be stated clearing in this section. These requirements will be covering all aspects of the Akriveia Beacon technology. TRIWAVE SYSTEMS has decided that the following requirements, when met, will ensure that this product will be an asset to all first responders that use it, in as many emergency situations as possible. TRIWAVE SYSTEMS puts a high price on safety, reliability, and ease of use, so that this product may help save lives and keep first responders safe. The functionalities that are labelled with a '**C**', as Proof-of-Concept, will be presented at the end of ENSC 405W.

Note: Requirements marked with '' are not carried over into subsequent development phases*

3.1 General Requirements

In order for the Akriveia Beacon system to be reliable, general high-level requirements describing the important core functions of the system are detailed in the table below. By following these requirements, TRIWAVE SYSTEMS ensure the overall system function and intended purpose are met at every phase of the development cycle.

REQ.GE.1 - C	The system must be intended for indoor use only
REQ.GE.2 - C	The system must have two modes of operation: idle mode and emergency mode
REQ.GE.3 - C	The system must pinpoint ID tag location within one floor buildings
REQ.GE.4 - C	Access to the system and system data must not be available to the general public
REQ.GE.5 - P	First responders must only have access to the system during disaster situations
REQ.GE.6 - P	The system must track more than one ID tag
REQ.GE.7 - F	The system must locate ID tags in a building with multiple floors
REQ.GE.8 - F	The system must remain operational after earthquakes with magnitude below 6.9
REQ.GE.9 - F	The system must remain operational after or during small scale fires
REQ.GE.10 - F	The final marketed product consisting of one data processing unit, three beacons and one ID tag must not cost more than CAD $200.00

Table 4: General Requirements

3.2 Hardware Requirements

Robust and reliable hardware will be absolutely necessary in any system that interacts with emergency and disaster management. TRIWAVE SYSTEMS has chosen to develop the proof-of-concept prototype using 2.4 GHz radio modules as feasibility testing, before upgrading the system to using Ultra Wide Band (UWB) modules for further prototyping. Micro-controller Units (MCUs) will be used to control the beacons and ID tags. The requirements below detail the requirement for hardware functionality of the Akrivia Beacon system.

REQ.HW.1 - C	The data processing unit must use a SBC for data processing and display
REQ.HW.2 - C	The beacons must use a MCU for intermediate data processing
REQ.HW.3 - C	The ID tags must use a MCU for request processing
REQ.HW.4 - C	Each MCU must use Serial Peripheral Interface (SPI) to communicate with transceiver
REQ.HW.5 - C*	The beacons must use 2.4 GHz radio modules as transceivers*
REQ.HW.6 - C*	The ID tags must use 2.4 GHz radio modules as transceivers*
REQ.HW.7 - C*	The beacons must communicate with the data processing unit via serial USB*
REQ.HW.8 - P	The beacons must communicate with the data processing unit via a closed Wi-Fi network
REQ.HW.9 - P	The beacons must use 3.5-6.5 GHz UWB radio modules as transceivers
REQ.HW.10 - P	The ID tags must use 3.5-6.5 GHz UWB radio modules as transceivers

Table 5: Hardware Requirements

3.3 Electrical Requirements

Since the system is designed for emergency disaster situations, it is crucial that sufficient power is provided to each device at any given time. In order for the system to be reliable and effective, the electrical systems must be robust and efficient. TRIWAVE SYSTEMS has compiled a strict set of electrical requirements that ensures the beacons and ID tags will operate in a safe and efficient way.

REQ.EC.1 - C	Each beacon shall be powered through standard North American power outlets (120V AC, 60Hz, type A/B)
REQ.EC.2 - C	Each ID tag must have its own 3.3 V battery power source
REQ.EC.3 - P	Each ID tag must have an on-off toggle switch
REQ.EC.4 - P	Each ID tag must remain in an idle, low power state with no more than 5W of power consumption while not in a disaster
REQ.EC.5 - P	Each beacon must remain in an idle, low power state with no more than 5W of power consumption while not in a disaster
REQ.EC.6 - P	Each beacon shall have its own backup power source (9V battery)
REQ.EC.7 - P	Each ID tag will use RF power harvesting technology to maintain charge on its batteries
REQ.EC.8 - F	Each ID tag must have a primary switch using an additional RF harvester as the trigger and a secondary manual switch to turn device on only
REQ.EC.9 - F	Each beacon shall incorporate a power caster device
REQ.EC.10 - F	The data processing unit must have a battery backup (UPS)
REQ.EC.11 - F	Users must no longer be capable of turning off the ID tag power switch manually

Table 6: Electrical Requirements

3.4 Software Requirements

The Akriveia system will be composed of an intricate software stack containing a database and a web server hosted GUI. The data processing unit is the main computational unit and will be implemented with trilateration algorithms to locate ID tag positions in near real time. In order for the software system to be reliable, secure and accurate the following requirements were made.

REQ.SW.1 - C	The system must use time of flight to locate ID tags
REQ.SW.2 - P*	The system must use 2D trilateration methods to locate ID tags*
REQ.SW.3 - P	Distance calculations must be performed using RSSI data received from beacons
REQ.SW.4 - P	Admin shall have access the the data processing unit through credential verification system
REQ.SW.5 - P	Admins must be able to create employees account associated with each ID tag
REQ.SW.6 - P	First responder ID tags must be assicated with a pre-defined first responder account
REQ.SW.7 - P	The data processing unit must be able to periodically check ID tags to verify tags are in working condition (correctness of data, device not broken)
REQ.SW.8 - P	The system must detect and report ID tag defects, if any
REQ.SW.9 - P	The data processing unit will store location history through out the event of an emergency
REQ.SW.10 - F	Scaled blueprints of the monitor area must be able to be uploaded to the data processing unit for accurate layout and location
REQ.SW.11 - F	The ID tags broadcasting must be able to be turned off from the servers
REQ.SW.12 - F	The data processing unit must distinguish between different floors and be able to provide locations of ID tags for any floor serviced at any time during an emergency
REQ.SW.13 - F	The system will provide floor plans for operators to track locations of disaster victims
REQ.SW.14 - F	The system must use 3D trilateration methods to locate ID tags
REQ.SW.15 - F	The system must use a closed Wi-Fi network for data forwarding from Beacon to data processing unit

Table 7: Software Requirements

3.4.1 Software - UI Requirements

Emergency first responders will be the first to interact with the Akriveia beacon system during a disaster. As such, the user interface must be intuitive and quick to use in a highly chaotic environment, when time is precious. The following table highlights important user interface requirements of the system.

REQ.SW.15 - P	The UI must be intuitive to use for operators
REQ.SW.16 - P*	The system must display a simple floor-plan/blueprint represented as simple geometry (ie. rectangle)*
REQ.SW.17 - P	The system UI must display location of ID tags in near real time
REQ.SW.18 - P	Each ID tags must be identified on the UI map by distinct symbols and/or tags
REQ.SW.19 - P	The system UI application must fill the entire screen but not obscure any system-wide status bars.
REQ.SW.20 - P	UI tag for rescue operations must have distinct indication from civilian ID tags
REQ.SW.21 - F	The System UI must support mobile devices such as laptop PCs and IOS tablets
REQ.SW.22 - F	The UI must be able to display blueprints and location markers for all serviced floors in building

Table 8: Software - UI Requirements

3.5 Performance Requirements

Reliability and accuracy are the most important attributes of the Akriveia system as it is a system designed to be widely used by first responders during emergency situations. Performance of the product maintains top priority before the system reaches general availability. The requirements below reflect the importance TRIWAVE SYSTEMS puts on the performance of the Akriveia Beacon system.

REQ.PE.1 - C*	The system shall locate users within the building with an accuracy of 1m*
REQ.PE.2 - P	The system shall track each ID tag in near real time with a latency of no more than 3 seconds
REQ.PE.3 - P	The system must undergo a calibration process on start-up before usage
REQ.PE.4 - P	The data processing unit must restart within 120 seconds
REQ.PE.4 - P	The data processing unit must be fully functional within 120 seconds after booting
REQ.PE.4 - P	The system UI must be accessible with in 2 seconds when operators directly connect to the system data processing unit
REQ.PE.5 - F	The system shall locate users within the building with an accuracy of 0.5m
REQ.PE.6 - F	The data processing unit's location processing throughput must be at least 100 employee locations per second
REQ.PE.7 - F	Each beacon must be capable of detecting at least 100 employees within a 100m radius per second
REQ.PE.8 - F	The ID Tags must remain operational in temperatures less than 60 degrees Celsius
REQ.PE.9 - F	The Beacons must remain operational in temperatures less than 60 degrees Celsius

Table 9: Performance Requirements

3.5.1 Performance Requirements - Signal

In addition to basic performance requirement, the Akriveia beacon heavily relies on wireless signal communications. The following table details the requirements for signal communication and processing.

REQ.PE.10 - C*	50% of data transmitted via wireless communication must not be lost or corrupted*
REQ.PE.11 - C*	Wireless communication must be done using 2.4 GHz wireless frequencies*
REQ.PE.12 - C*	Wireless communication between transceivers must not have a latency of more than 100ms*
REQ.PE.13 - P	The latency of wireless communication between transceivers must be less than 50ms
REQ.PE.14 - P	Wireless communication must be established on 3.5-6.5 GHz UWB frequencies
REQ.PE.15 - F	5% of data transmitted via wireless communication must not be lost or corrupted

Table 10: Performance - Signal Requirements

4 Engineering Standards & Responsibilities

The Akriveia Beacon will be designed 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, software, and communication protocols, which means that suitable standards must be followed. The data communication on the physical layer is done using frequency on the ultra-wideband spectrum operating in unlicensed frequency bands, wireless standards that apply to the operation band will be followed. Akriveia Beacon is designed to operate during disaster situations, material and design must follow the structural and durability standards for disaster equipments.

4.1 Electronics Standards

IEEE 1625	IEEE Standard for Rechargeable Batteries for Multi-Cell Mobile Computing Devices [8]
CSA-C22.2 NO.61508-1:17	Functional safety of electrical/electronic/programmable electronic safety-related systems - Part 1: General requirements [9]
CSA-C22.2 NO.0.23-15	General requirements for battery-powered appliances [10]
CAN/CSA-C22.2 NO.0-10	General requirements - Canadian electrical code, part II [11]
IEEE P360	Standard for Wearable Consumer Electronic Devices - Overview and Architecture [12]

Table 11: Electronics Standards

4.2 Wireless Standards

IEEE 802.15.2-2003	IEEE Recommended Practice for Information technology– Local and metropolitan area networks– Specific requirements– Part 15.2: Coexistence of Wireless Personal Area Networks with Other Wireless Devices Operating in Unlicensed Frequency Bands [13]
IEEE 802.15.4q-2016	IEEE Standard for Low-Rate Wireless Networks –Amendment 2: Ultra-Low Power Physical Layer [14]
ISO/IEC 26907:2009	Information technology – Telecommunications and information exchange between systems – High-rate ultra-wideband PHY and MAC standard [15]
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 [16]
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 [17]

Table 12: Wireless Standards

4.3 Software Standards

IEEE 12207-2017	ISO/IEC/IEEE International Standard - Systems and software engineering – Software life cycle processes [18]
IEEE P2510	Standard for Establishing Quality of Data Sensor Parameters in the Internet of Things Environment [19]
ISO 2382-9:1984	Data processing – Vocabulary – Part 9: Data communication [20]

Table 13: Software Standards

4.4 Material Standards

IEEE 1221-1993	IEEE Guide for Fire Hazard Assessment of Electrical Insulating Materials in Electrical Power Systems [21]
IEEE 848-2015	IEEE Standard Procedure for the Determination of the Ampacity Derating Factor for Fire-Protected Cable Systems [22]

Table 14: Material Standards

5 Safety & Sustainability

5.1 Safety

The Akriveia Beacon system is a combination of electronics, wireless communication, and software systems all functioning together to create a reliable solution. Since the system is designed for disaster related situations, safety is paramount. There are essentially two conditions the system would be under; an idle mode from day to day; and an emergency mode where the system is triggered to transmit location data during a real disaster situation.

During idle mode or normal day to day operations the ID tags would be worn much like an access card. As such, electronic components on the ID tags must agree to standardized safety measurements. During emergency mode, in a disaster situation, the beacons are turned on to transmit and receive data from the ID tags. As the associated ID tags will be transmitting ultra-wideband radio frequency both to and from the radio modules which will be worn by a person, the power frequency level must be within limits that are safe for human exposure [23].

Additionally, the Akriveia Beacon system will satisfy the following safety requirements:

REQ.SF.1 - F	All 2.4 GHz transceiver must operate at a safe transmitting power level
REQ.SF.2 - F	All UWB GHz transceiver must operate at a safe transmitting power level
REQ.SF.3 - F	All electrical components of the system must be electrically insulated
REQ.SF.4 - F	The ID tags must not cause minor ergonomic issues such as pinches or discomfort on the wearer.
REQ.SF.5 - F	The ID tags must not cause major safety issues such as shocks, burns, or lacerations on the wearer
REQ.SF.6 - F	The Beacons must have proper labeling on electrical components detailing safety and standards
REQ.SF.7 - F	The Beacon casing must have fire resistant shielding
REQ.SF.8 - F	The data processing unit must have a fire resistant shielding

Table 15: Safety Requirements

5.2 Sustainability

The engineers at TRIWAVE SYSTEMS is committed to ensuring the final products is not only functionally effective, but also in compliance with the best environmental sustainability practices. As such, TRIWAVE SYSTEMS will be dedicated to minimizing impact of the environment by making design choices that are environmentally sustainable by following the Cradle to Cradle (C2C) standards. C2C refers to the process of development where all components used in manufacturing are able to be brought back into the development cycle [24]. By following the C2C Certified standards shown below [1], the Akriveia Beacon system can be re-purposed or recycled as shown below in the figure by EPEA.

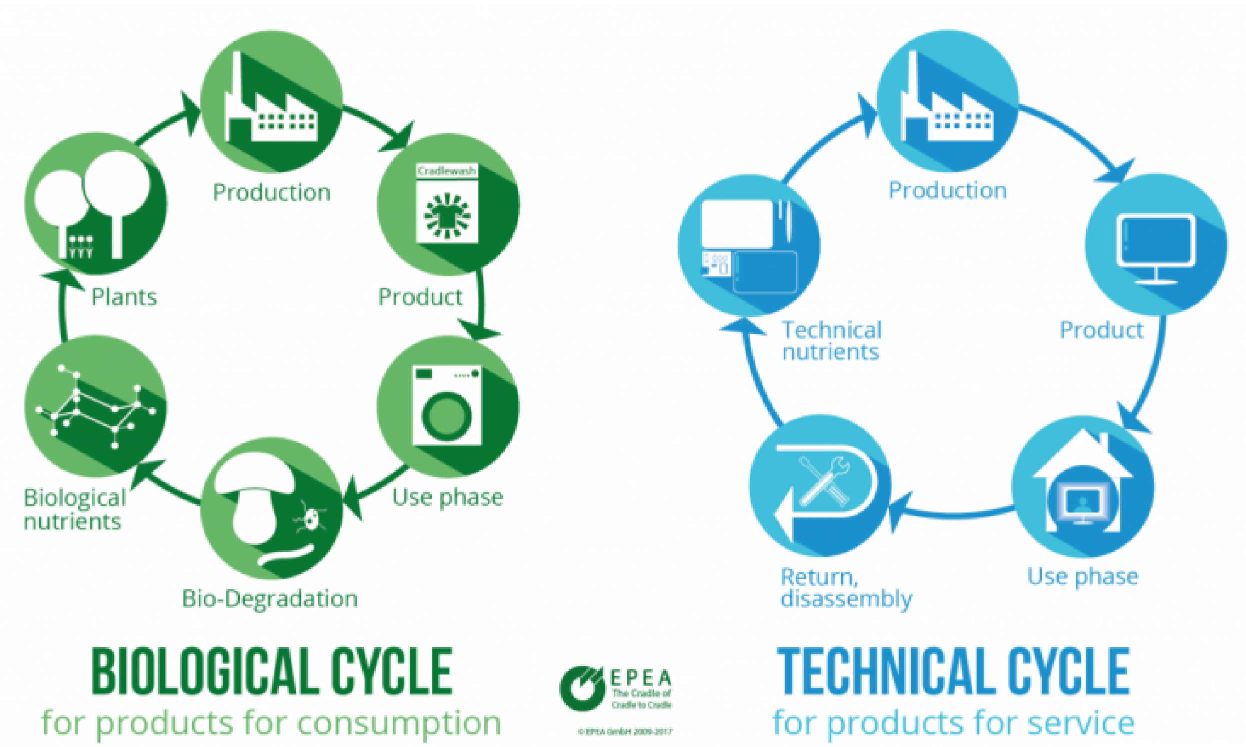

Figure 9: Biological and Technical C2C cycles

When possible, the Akriveia Beacon will be manufactured with biodegradable and non-toxic materials, as well as materials that are easily recyclable or re-purposable to ensure waste output is minimal. The material of choice for beacons and ID tag casings will be biodegradable non-toxic Polylactic acid or PLA plastics [1]. PLA is a natural, bio based alternative to petroleum laden ABS and used commonly in 3D printing processes. Electronics and circuitry of the product will be designed with a minimal footprint. Power sustainability is also considered by incorporating the use of RF harvesting. By converting radio frequency power into DC voltage to power devices, the need for constant battery replacement is minimized lowering maintenance costs. The following table includes the sustainability requirements for the system.

The following table includes the sustainability requirements for the Akriveia Beacon system:

REQ.SU.1 - F	The ID tags must not need battery replacement within 1 year
REQ.SU.2 - F	The ID tags must use rechargeable batteries as a power source
REQ.SU.3 - F	The PCB for ID and Beacons must be no larger than 25mm x 60mm area
REQ.SU.4 - F	The ID tags will be no larger than 70mm x 140mm x 15mm
REQ.SU.5 - F	The ID tags must have removable casing manufactured with PLA plastic
REQ.SU.6 - F	The Beacons must have removable casing manufactured with PLA plastic
REQ.SU.7 - F	The electrical components within the ID tag or beacon devices must not need replacement within 1 year

Table 16: Sustainability Requirements

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 system overview, design, and constraints of the Akriveia Beacon were clearly established and a detailed outline of the requirements specifications was provided. Functional and non-functional requirements expected of the Akriveia Beacon product through three different phases of development are outlined, including: the proof-of-concept (completed August 2019), prototype, and final product (completed December 2019).

1. General requirement
2. Hardware requirement
3. Electrical requirement
4. Software requirement
5. Performance Requirements
6. Safety requirement
7. Sustainability requirement

Since the Akriveia Beacon product is aimed to operate in emergency disaster scenarios, various engineering standards and safety requirements must be followed to ensure usability, durability and acceptability in the market. By following the Cradle to Cradle development cycle, the product is ensured to be both innovating and environmentally sustainable. Lastly, to ensure optimal product quality control a brief Alpha stage test plan is included in the appendix at the end of this document. It details the testing procedure for the proof of concept prototype on various parts of the Akriveia Beacon system.

While going through the three phases of development, this document will provide a reliable reference to ensure requirements are satisfied at each milestone, as well as to provide a strict criteria in which to compare with the final product.

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8 Appendix

8.1 Proof Of Concept(PoC) Acceptance Test Plan

The PoC Acceptance Test Plan includes all the testing procedures for verifying and validating the requirement specifications under a formal test environment. The goal of the PoC Acceptance Test Plan is to ensure the basic requirements stated in the ***System Requirements*** section of the document are met.

Three main goals for the PoC testing are as follows:

1. 2.4 GHz chips are able to receive and transmit data accurately
2. Arduino micro-controllers(MCU) receives the transmission data
3. Raspberry Pi receives data serially from Arduino MCU

8.1.1 Systems (General Testing)

System (General) Test			
REQ.ID	Testing Criteria		Expected Output
REQ.GE.1-C	1	Ensure all tests conducted are representative of conditions indoor instead of outdoor conditions or all-terrain conditions	System testing and design are representative of conditions within a building. System testing does not consider the all-weather conditions nor any unpredictable outdoor conditions.
REQ.GE.2-C	1	System is able to switch between two modes: idle and emergency modes	Switching between the idle and emergency modes are to be robust and reliable. There is significant differences in power consumption, signal communication and content between the two modes.
	2	Idle mode and emergency modes should show different operations	MCU serial output should show different data transfer when system is in the different modes
REQ.GE.3-C	1	System should determine the location of the ID tag on one floor of a building	Software algorithms determine the relative location of the ID tag to the beacons. Clear distances are measured between the beacons themselves or to the ID tag.
	2	System to show relative location of the ID tag	A relative location of the ID tag to the approximate floor space is calculated

Table 17: PoC System(General) Requirement Test Plans

8.1.2 Hardware Test Plan

Hardware Tests			
REQ.ID	Testing Criteria		Expected Output
REQ.HW.1-C	1	Data processing unit should use SBC to be the automated product control	SBC should take all received data and perform calculations
REQ.HW.2-C	1	Beacons to use the MCU to be the automated product control	MCU should control signal transmission through the 2.4 GHz chips and be fully operational when used as the automated product control
REQ.HW.3-C	1	ID tags to use the MCU to be the automated product control	MCU should control signal transmission through the 2.4 GHz chips and be fully operational when used as the automated product control
	2	MCU should receive signals from the beacons and transmit signal back through MCU	Arduino serial output for ID tag should show data received and send proper data output
REQ.HW.4-C	1	SPI should be used as the interface with the MCU and transceiver	Arduino serial output for MCU should show proper data transfer through the 2.4 GHz transceiver
REQ.HW.5-C	1	Beacons should use 2.4 GHz radio frequency as the receiver	Correct data input received from the 2.4 GHz radio module
	2	Beacons should use 2.4 GHz radio frequency as the transmitter	Correct data output transmitted from the 2.4 GHz radio module
REQ.1HW.6-C	1	ID tags should use 2.4Ghz radio frequency as the receiver	Correct data input received from the 2.4Ghz radio module
	2	ID tags should use 2.4 GHz radio frequency as the transmitter	Correct data output transmitted from the 2.4 GHz radio module
REQ.HW.7-C	1	Beacon to data processing unit communication should use USB serial	Beacon and data processing unit communicates and data transfer is functional
	2	Correct data should be transmitted through serial USB	Correct data is transmitted or received through serial USB. Data processing unit or beacons should receive or transmit intended data

Table 18: PoC Hardware Requirement Test Plans

8.1.3 Electrical Test Plan

Electrical Tests			
REQ.ID	Testing Criteria		Expected Output
REQ.EC.1-C	1	Beacons should be powered through 120 V AC, 60 Hz outlets	Beacons are powered by the AC outlets and is functional
REQ.EC.2-C	1	ID tags should have it's own 3.3 V battery power source	ID tags are battery powered and is functional

Table 19: PoC Electrical Requirement Test Plans

8.1.4 Software Test Plan

Software Tests			
REQ.ID	Testing Criteria		Expected Output
REQ.SC.1-C	1	Data processing unit should receive ToF(Time of Flight) data from the beacons	Input of ToF data is received from the beacons
	2	ToF data received from beacons should be accurate	ToF data is verified to be correct. Data is tested to be true and does not contain errors

Table 20: PoC Software Requirement Test Plans

8.1.5 Performance Test Plans

Performance Tests			
REQ.ID	Testing Criteria		Expected Output
REQ.PE.1-C	1	System should locate users within the building with an accuracy of 1m	Coordinates of the ID tags should be within a radial $\pm$1m of the actual location
	2	Approximate locations should be verified to be $\pm$1m of actual	A set of automated tests is run to check if system calculates correct Coordinates within $\pm$1m

Table 21: PoC Performance Requirement Test Plans

8.1.6 Performance - Signal Test Plans

Performance - Signal Tests			
REQ.ID	Testing Criteria		Expected Output
REQ.PE.10 - C	1	50% of data transmitted via wireless communication must not be corrupted or lost	Arduino serial output should show data received/transmitted is at least 50% correct
REQ.PE.11-C	1	2.4 GHz wireless communications should be used to transfer data between beacons and ID tag	2.4 GHz radio module transceiver for both the beacons and ID tag is communicating
	2	Beacons and ID tags only communicate to each other and other wifi/bluetooth signals should not interfere	Beacons and ID tags receive data from each other only and do not communicate with other signals
REQ.PE.12-C	1	Latency for wireless communication should be less than 100ms	Automated tests show signal transfer is less than 100ms

Table 22: PoC Performance - Signal Requirement Test Plans