TRIWAVE SYSTEMS

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Team 5: TRIWAVE SYSTEMS

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Presentation Overview

1. Background & Motivation
2. Business & Market Analysis
3. Technical System Overview
4. Risk Assessment
5. Engineering Standards
6. Self Reflection
7. Scheduled 440 Timeline
8. Summary & Concluding Remarks
9. Demo
10. Questions

Introduction

Background

- Approx. 500,000 commercial buildings in Canada (1)
- Modern emergency response methods could be optimized
  - Limited information on arrival
  - Victim location based on witness accounts
  - Unreliable and creates room for human error
- 135 fire deaths per year from 2010-2014 (2)

Motivation

- Modernize safety in urban/industrial environments
  - More buildings & people in small areas
  - Access to these areas more difficult
  - What happens when disaster strikes?
- Increase efficiency of emergency response teams
  - More information
  - On-the-fly changes
  - Limit human error
  - Safer for first responders

Akriveia Beacon System

- Indoor Positioning System (IPS)
- Designed for Disaster Search & Rescue Operations
- System of Anchor Beacons and Wearable ID Tags
- Integrated with Advance Ultra-Wideband (UWB) Technology
- Trilateration Methods for Tracking
- Near Real-Time Indoor Tracking

Indoor Positioning Systems (IPS) Attributes (3)

1. System accuracy and precision
2. Coverage and resolution
3. Latency in making location updates
4. Building's infrastructure impact
5. Effect of errors on the system such as signal interference and reflection

Business & Market Analysis

Business & Market

Search and Rescue (SAR) Equipment Market in 2017: **$113.62 billion** (4)

Projected in 2022: **$125.66 billion**

Global Indoor Location (GIL) Market in 2015: **$3.43 billion** (5)

Projected in 2022: **$29.4 billion**

Target Markets

Ideal Customers

- Commercial Building owners or property management companies
- Need for GIL for occupants in emergencies

Government Incentives

- System increases occupant safety in emergency situations
- Easily integrated into Building Code - Fire Safety
- Reduces risk to emergency personnel

Competition

Same Technology, Different Application

Production & Logistics		Medical & SAR
Pozyx ● UWB ● Tag + Node ● Expensive	**Infsoft** ● UWB/BLE ● Tag + Node ● Privacy issue	**KAUST Innovation** ● UWB ● Handheld Device ● Operator Dependency

Project Budget and Funding

Current Expenses (Up-to-Date)

- $461.46

Expected Project Total Budget

- $1000

Funding Estimates

- $500

Project Pricing

System Price for 3 beacons & 10 ID tags

- $930.00

Additional Beacon & ID tag unit costs

- $45/Beacon & $44/ID tag

Software Cost

- $200/year

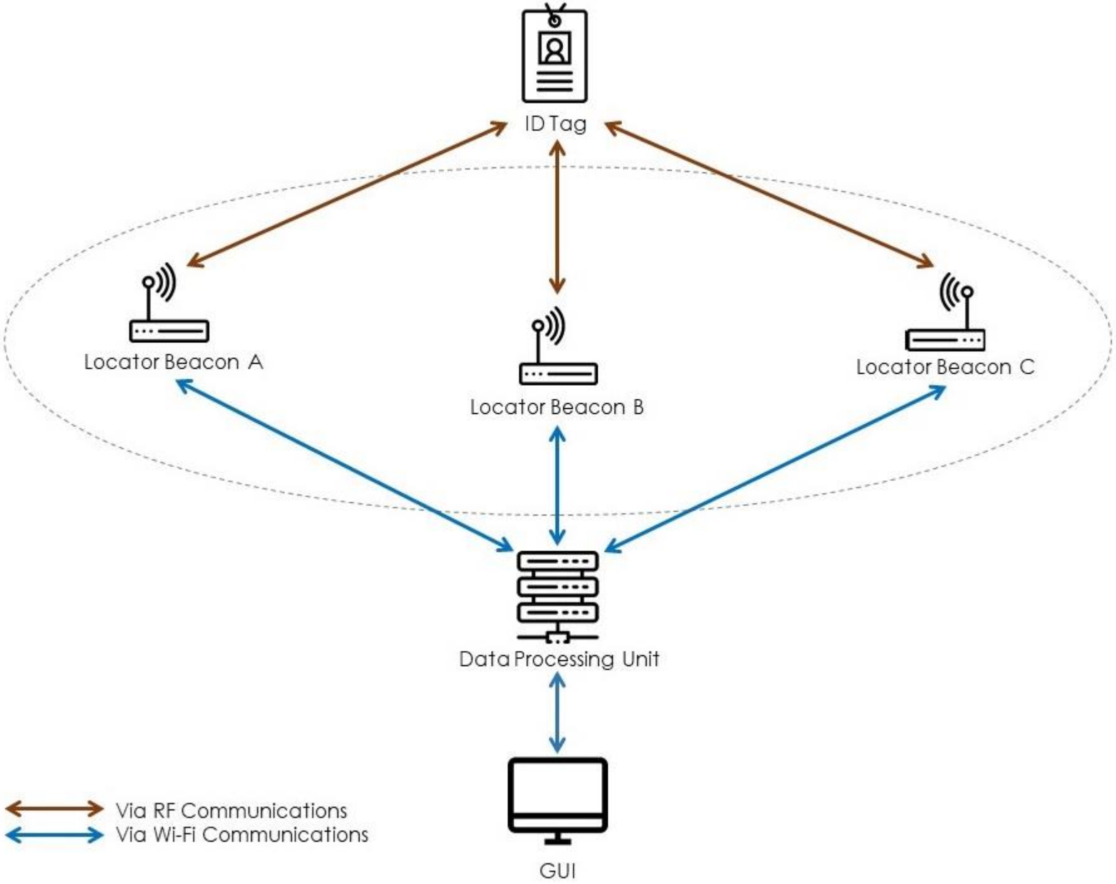
Cost of materials	
+ 10 × ID Tag	$440.00
+ 3 × Beacon	$135.00
+ Cost of labor	$100.00
+ Overhead	$100.00
= Total cost	$775.00
+ Desired profit (20% on sales)	$155.00
= Required sale price	$930.00

Technical System Overview

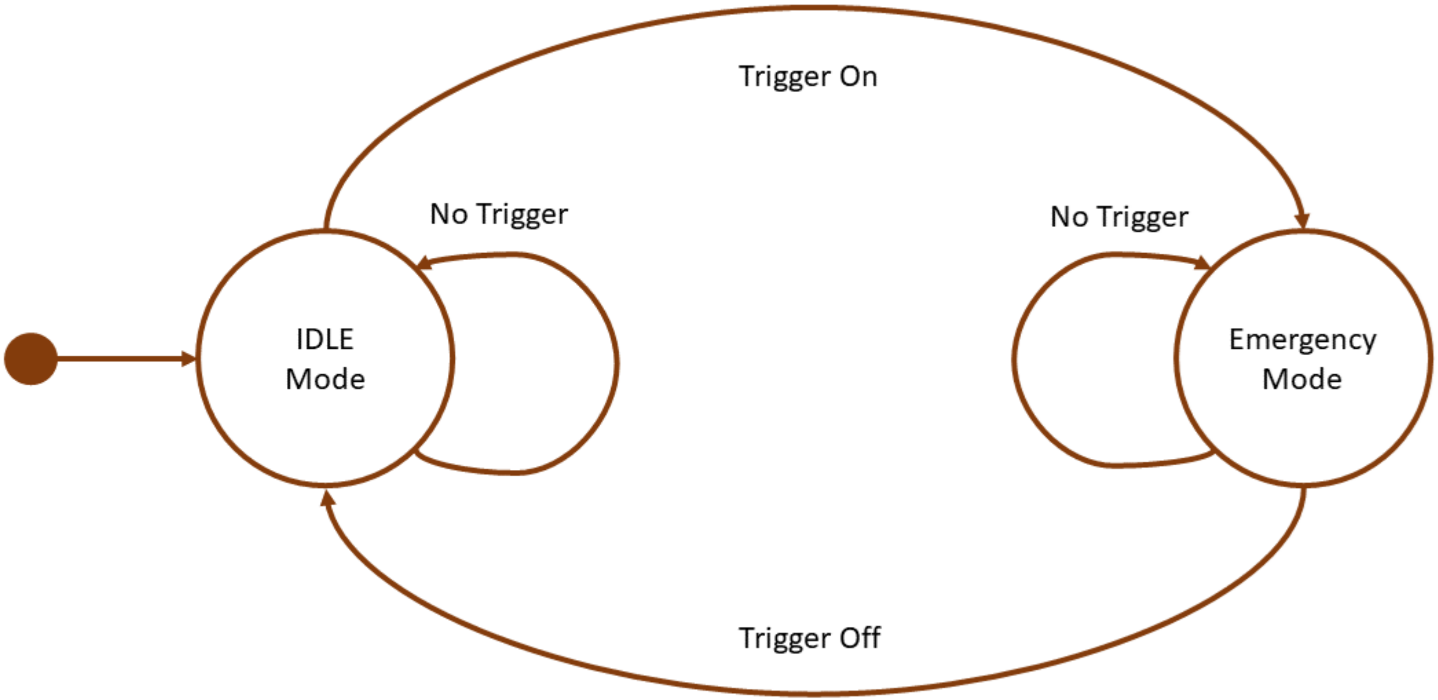
System Layout

Akriveia Beacon Consists of:

- Locator Beacons
- Wearable Tracker ID Tags
- Data Processing Unit (DPU)



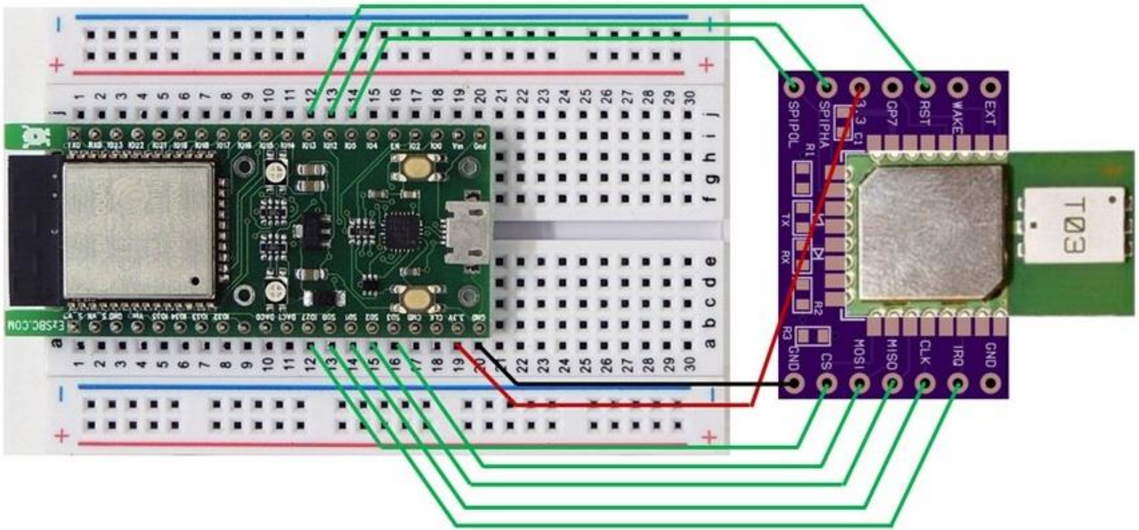
System Operation Modes



ID Tags & Beacons Architecture

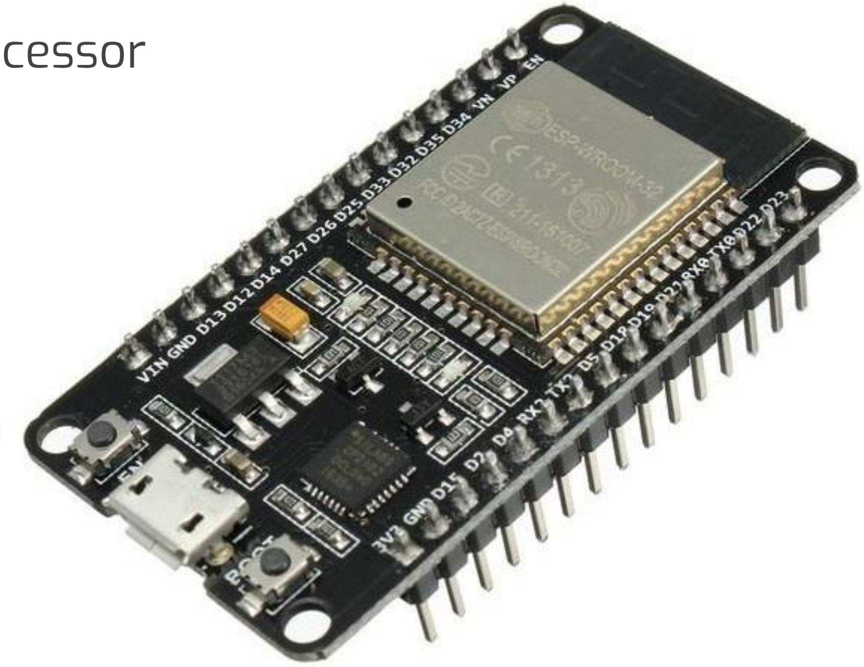
Composed of:

- Espressif ESP32
- Decawave DWM1000
- Communicate via SPI



ESP32 Microcontroller Unit

- Tensilica Xtensa 32-bit LX6 microprocessor
- Operate @ 160/240 MHz
- Integrated WiFi/Bluetooth
- Touch sensor pins
- Deep sleep low-power modes
- Low-cost

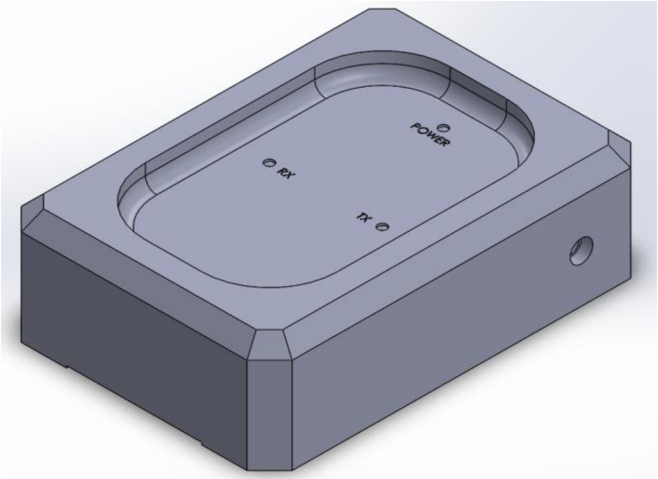


Decawave DWM1000 UWB Module

- Operation Frequency Range of 3.5 to 6.5 GHz
- 802.15.4-2011 UWB compliant
- FCC/ETSI Certified
- Precision of up to 10 cm indoors
- Excellent ranges of up to 300m
- High range of communications data rates

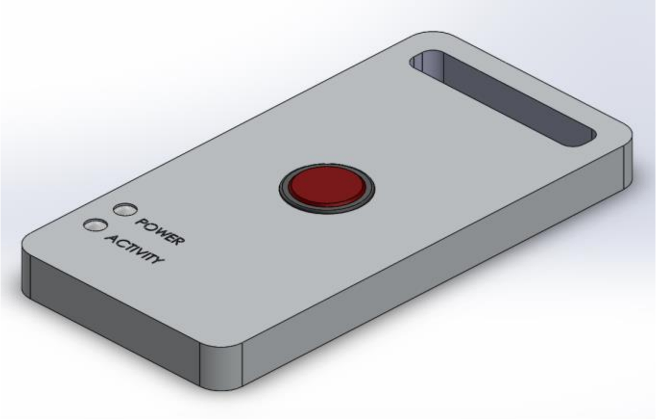
Anchor Beacons

- Stationary transceiver devices
- Communicate via UWB transceivers
- Battery Backups
- Requires minimum of 3 for tracking
- Communicate with DPU via private WiFi network



ID Tags

- Small wearable electronic tagging devices
- Uses similar UWB transceivers
- Light and Durable
- Efficient Power saving modes
- Touch sensor activation
- Integration with access cards or key fobs

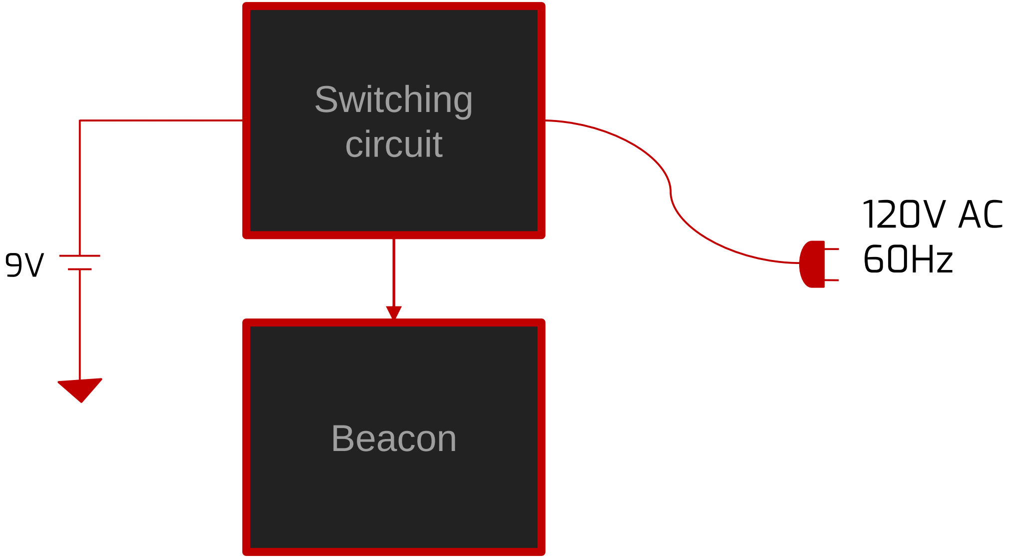


Power Management

Beacon Power Management

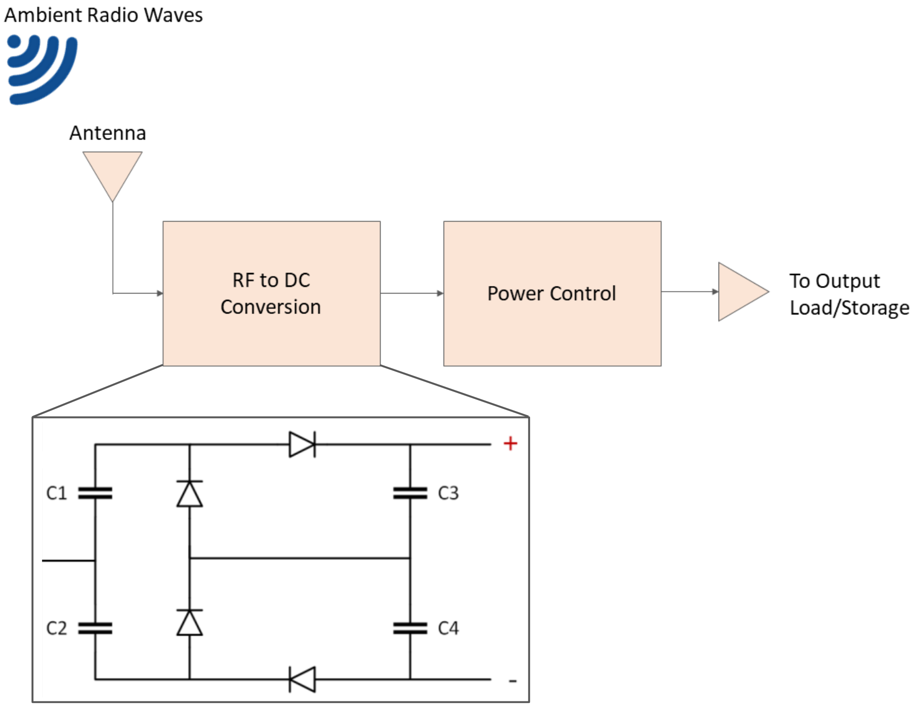
Beacons

- Switching circuitry
  - Main power
  - Battery power
- 9V 4000 mAH backup



ID Tag Power Management

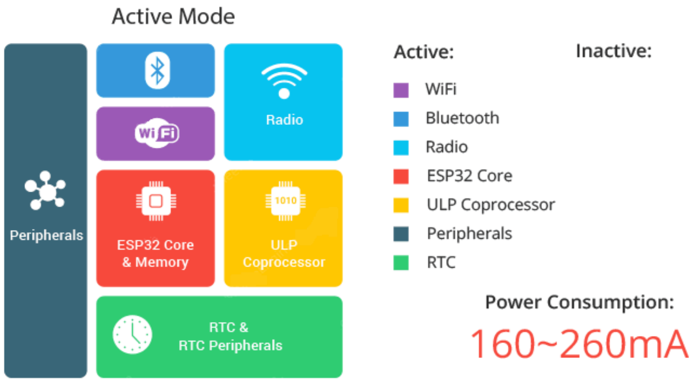
- Long battery life
  - Rechargeable 2000 mAH Li-ion
  - Deep-sleep mode
- RF Harvester

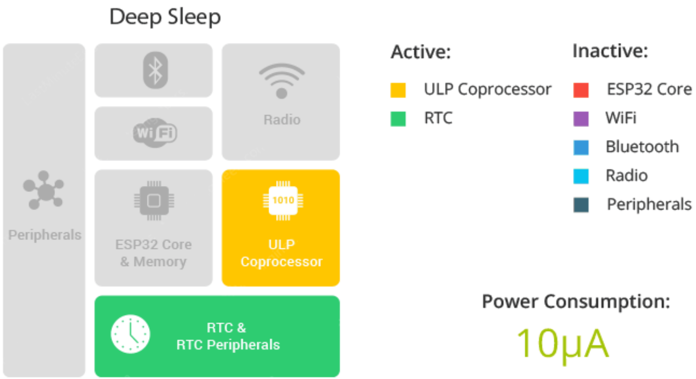


ESP32 Activity Modes

- Active
  - Much higher power
  - Only during emergency
  - Activated via button

- Deep Sleep
  - Low Power mode
  - Extended Battery Life
  - Low maintenance cost
  - Preserves user privacy





Battery Life Calculations

Active

$$\frac{2000mAH}{260mA} \approx 8 \text{ hours}$$

Deep Sleep

$$\frac{2000mAH}{10\mu A} = 200{,}00 \text{ hours } \approx 8000\ days\ \approx 22\ years$$

RF Ranging & Trilateration

RF Ranging Method

Received Signal Strength Indicator (RSSI) Based Approach

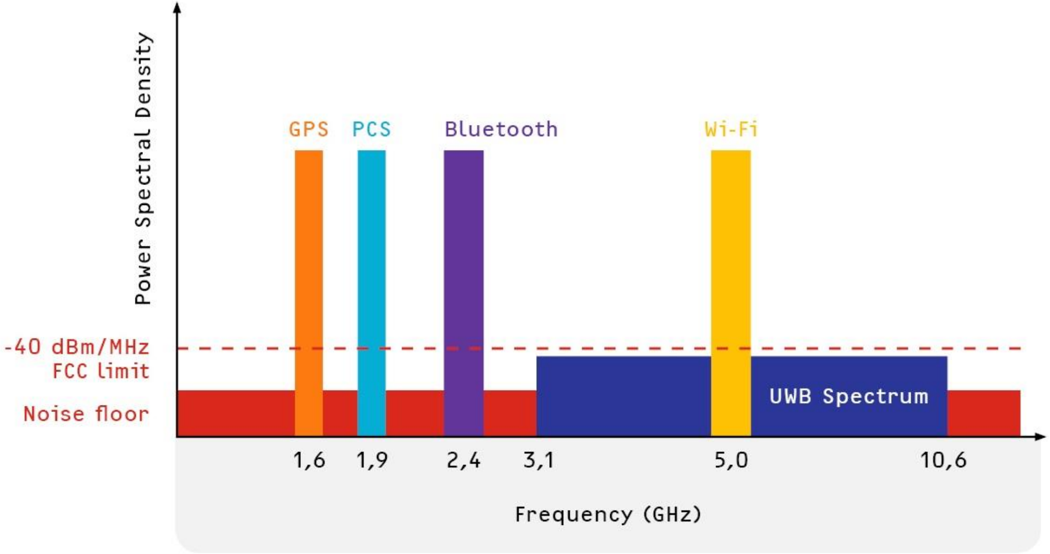
- Conversion of RSSI to distance
- Employed in PoC phase
- Bluetooth Low Energy (BLE)
- Inverse Square Law
- Prone to multipath fading and interference

Time-of-Flight (ToF) Based Approach

- Employed in Prototype phase
- Ultra-Wideband (UWB)
- Signal propagation time
- Distance Speed Time Formula
- Effective against noise and multipath

Ultra-Wideband Spectrum

- Short duration pulses
- Low transmit power
- Minimal interference
- High data rate



Trilateration Method

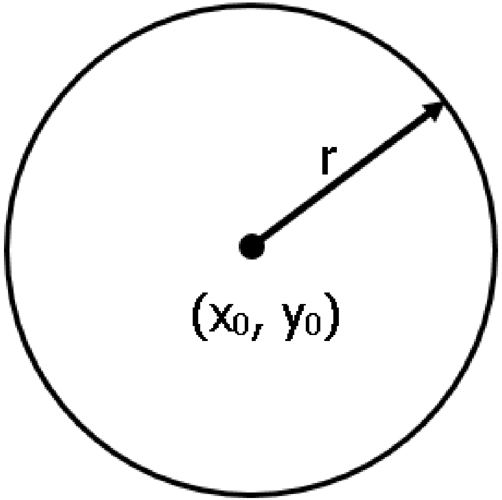
Standard Form of a Circle:

$$(x - x_0)^2 + (y - y_0)^2 = r^2$$

where,

(x_0, y_0) are the cartesian coordinates of a beacon

r is the distance derived from RF ranging



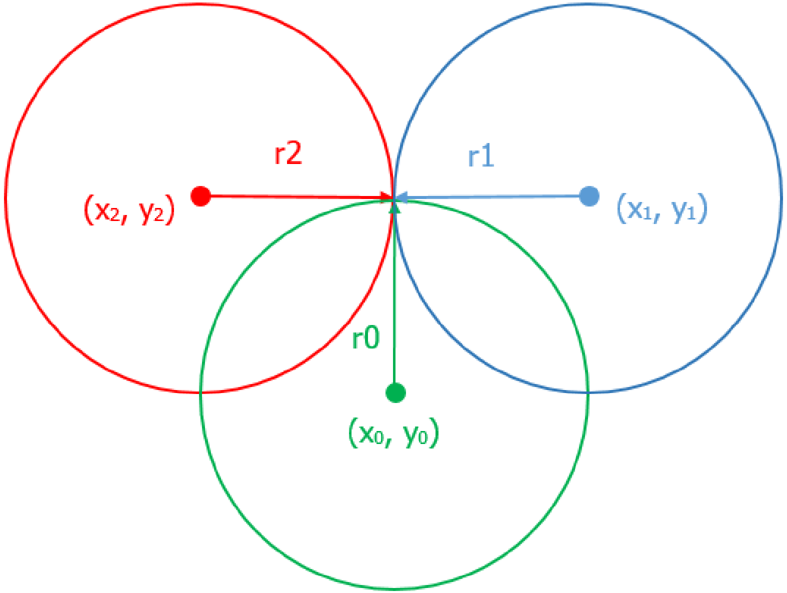
Trilateration Method

Two Dimensional Trilateration:

$$(x - x_0)^2 + (y - y_0)^2 = r_0^2$$

$$(x - x_1)^2 + (y - y_1)^2 = r_1^2$$

$$(x - x_2)^2 + (y - y_2)^2 = r_2^2$$

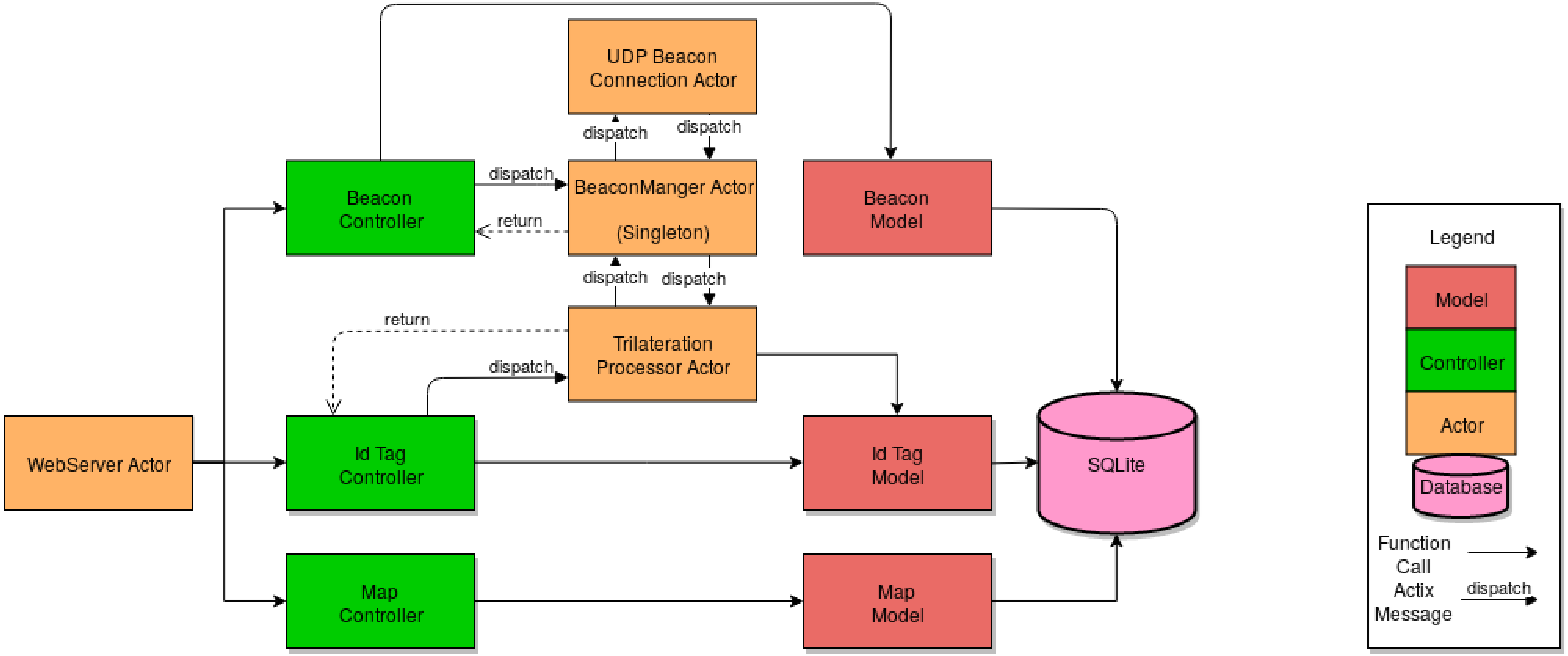


Software

Software Overview

	Client	Web Server	Data Processing	Beacons	ID Tags
Language	Rust	Rust	Rust	C++	C++
Location	Browser	DPU	DPU	Throughout the building	Employees
Major Framework	Yew	Actix Web	Actix	Arduino Runtime	Arduino Runtime
Purpose	Display data and maps, user interaction	Respond to requests from client	Trilateration calculations	TOF and RSSI calculations	Reply to beacons

DPU Software Architecture



DPU Framework - Actix

- Server side
- Actor framework
  - Inter-thread communication via message passing
  - Multithreading out of the box - no deadlocks
- Base for Web Server library “Actix Web”
- Asynchronous single threaded execution
  - Supports non blocking IO for files and database operations
- Data processing
  - Trilateration computation
  - User request handling
  - Database interaction
  - Beacon request handling

DPU Framework - Yew

- Client side - browser
- Makes use of Rust to Web-Assembly cross compilation
  - Faster than plain Javascript
- Similar to Actix
  - unified codebase
- Generates HTML on the browser to build dynamic web pages
  - Easy to develop against
  - Performant enough for a 2D application
- User interaction
  - System configuration
  - Map viewing
  - Login/Logout

Software Costs

Software	Cost	License
Rustc Compiler	Free	Apache & MIT [6]
ESP32	Free	GNU Lesser General Public [7]
Actix	Free	Apache or MIT [8]
Actix Web	Free	Apache or MIT [9]
Yew	Free	Apache or MIT [10]
GCC Compiler	Free	GPLv3 [11]

Note: List is non-exhaustive.

Risk Assessment

Risk

Categories of Potential Risks

Management Risks	Technological Risks	External Risks
• Cost • Schedule • Logistical	• System Failure • Software Bugs • Performance	• Market • Legal • External Hazards

Remediation

1. Stakeholders incoherent with project definition/scope

   Solution: Clarify project scope

1. Project schedule is delayed due to logistical issues

   Solution: Prioritize project timeline

1. Beacons are destroyed or rendered offline during emergency

   Solution: Multiple redundant backups

1. System generates inaccurate data which increases SAR times

   Solution: Calibration

Engineering Standards

Adherence to Standards

Factors to consider:

1. UWB in commercial environments
2. Wearable Technologies
3. Software Security/Design
4. Emergency Equipment Standards

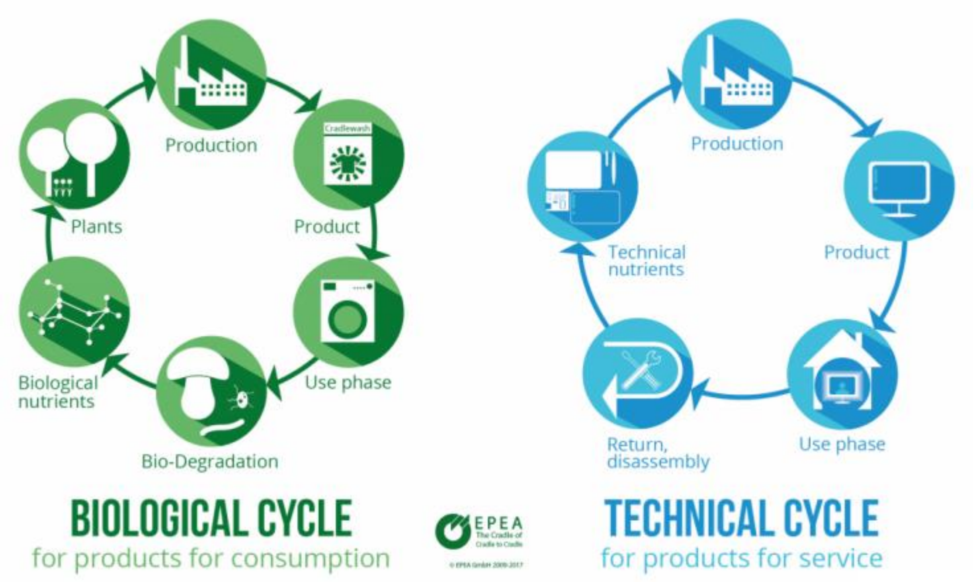
Adherence to Standards

Standard	Purpose
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 1621-2004	User Interface Elements in Power Control of Electronic Devices Employed in Office/Consumer Environments
IEEE P360	Standard for wearable consumer electronic devices
IEC 62366-1	Guidance on Usability engineering for software
C22.2 NO.0.23-15	General Requirements for Battery-Powered Appliances
IEEE 802.15.4	Low-Rate Wireless Personal Area Networks

Sustainability Considerations

Cradle to Cradle Philosophy

- Repurposable or recyclable
- Manufactured with biodegradable non-toxic Polylactic acid plastics
- Long-term Power sustainability



Self Reflection

Reflection

- Weekly meetings with agenda and minutes
- Clear communication is critical
- Time management is vital to success
- Good use of online collaboration - GitLab
- Overall our team's skills and attitudes complement each other

Progress

PoC

Prototype

Final Product

Brief Plan for ENSC 440

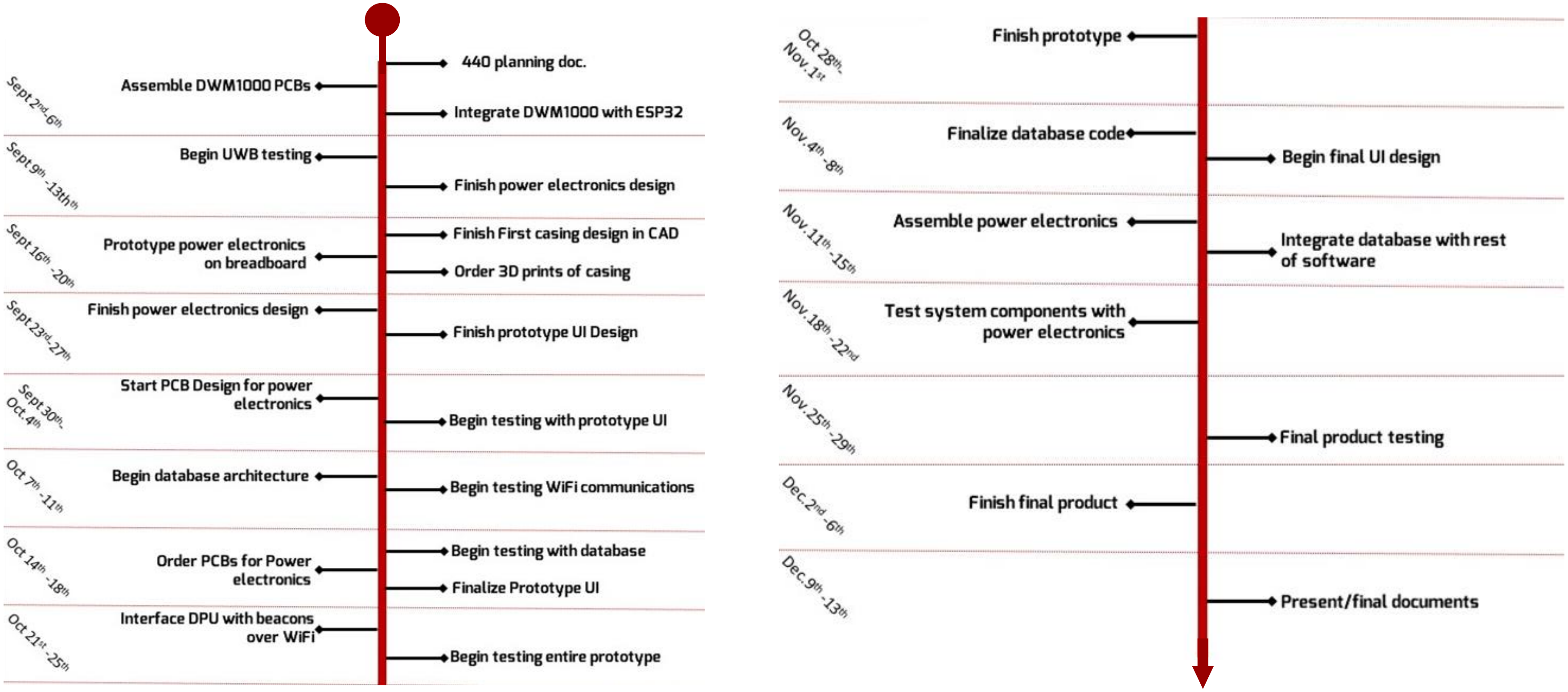
Beta Prototype

- To be completed mid-semester (OCT-NOV)
- Integration of UWB
- Development of software stack
- Improve all hardware aspect to meet requirements

Production Ready Prototype

- To be complete by end of ENSC 440 (DEC)
- Final Version of Akriveia Beacon
- Usability testing

ENSC 440 Milestones



Summary & Concluding Remarks

- Indoor Positioning System
  - UWB ToF vs. BLE RSSI
  - DPU to crunch numbers
  - Simplistic UI to reduce learning curve
- Increasing efficiency of search and rescue efforts
  - More precise information
  - Better communication abilities
  - Modernizing safety in urban environments

Acknowledgements

Quick Thank you to:

- Scott's Dad (Retired Firefighter/Fire Prevention)
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- Raymond Messier (North Shore SAR)
- Royce Ng (Amazon Warehouse Safety/SAR)
- Andrew Rawicz
- Mohammad Akbari
- Craig Scratchley

Demo

Technical Design Exploration Research

Technologies Considered

- Ultrasonic
- Infrared
- GPS
- **BlueTooth Low Energy (BLE)**
- WiFi
- 2.4 GHz ISM band
- **Ultra-Wideband (UWB)**

RF Ranging Techniques Considered

- Time Difference Of Arrival (TDOA)
- Received Signal Strength Indicator (RSSI)

$$Distance = 10^{(Measured\_Power - RSSI)/(10*N)}$$

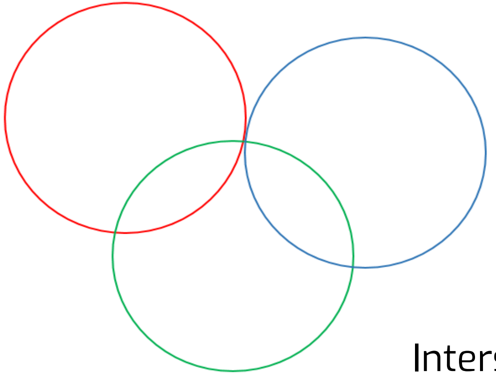
- **Time of Flight (ToF)**

$$Distance = Speed\ of\ light * ToF$$

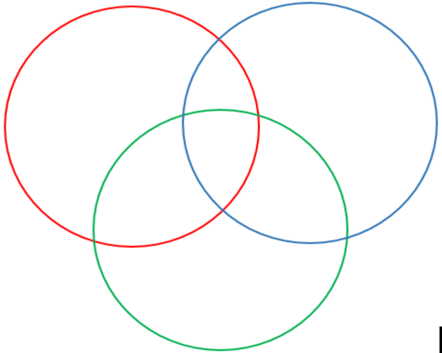
Localization Methods Considered

- Triangulation
- 2D Trilateration
- 3D Trilateration
- Multilateration

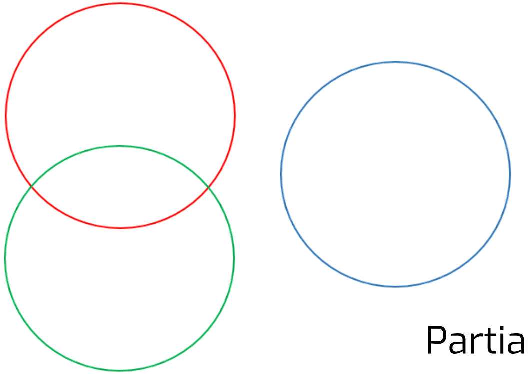
Trilateration Cases



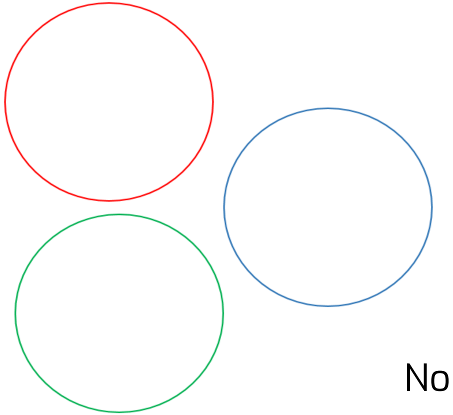
Intersection Point



Intersection Area



Partial Intersection



No Intersection

RSSI Optimization Methods

- Value Averaging
- **Rolling Averaging buffer**
- Particle filter
- Swarm optimization
- Monte carlo Methods
- Finite Impulse Response (FIR) filter

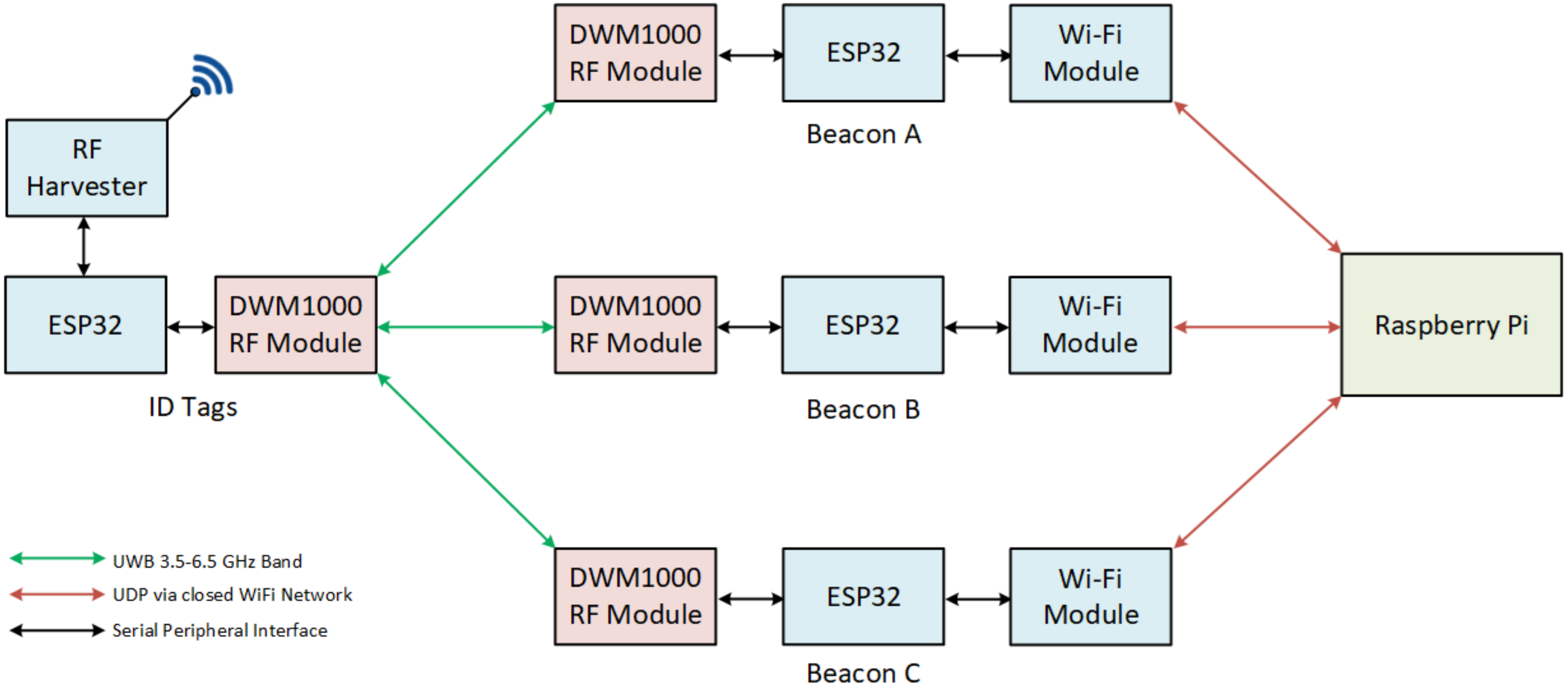
Questions?

References

1. Statistics Canada. Survey of Commercial and Institutional Energy Use, 2014. (online) Available at: https://www150.statcan.gc.ca/n1/daily-quotidien/160916/dq160916c-eng.htm (Accessed 26 July. 2019).
2. Statistics Canada, "Fire-related deaths and persons injured, by type of structure", *Www150.statcan.gc.ca*, 2019. (Online). Available: https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=3510019501. (Accessed: 26- July- 2019).
3. S. A.-H. M. A.-A. A. Alarifi A. Al-Salman M. Alsalem A. Alnafessah and H. Al-Khalifa. (2016) Ultra wideband indoor positioning technologies: Analysis and recent advances. (Online) Available: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4883398/pdf/sensors-16-00707.pdf.(Accessed:14-Jun-2019)
4. BusinessWire. (2017) Elbit systems, general dynamics corporation, honeywell, leonardo ... - research and markets. (Online). Available: (Online).Available:https://www.businesswire.com/news/home/20170901005591/en/ Search-Rescue-SAR-Equipment-Market---Forecast.(Accessed:14-Jun-2019)
5. Reuters. (2018) Indoor location market 2018 global trends, market share, industry size, growth, opportunities and forecast to 2023. (Online). Available: (Online).Available:https: //www.reuters.com/brandfeatures/venture-capital/article?id=50849.(Accessed:14-Jun-2019)
6. https://github.com/rust-lang/rust
7. https://github.com/espressif/arduino-esp32/blob/master/LICENSE.md
8. https://github.com/actix/actix
9. https://github.com/actix/actix-web
10. https://github.com/DenisKolodin/yew
11. https://en.wikipedia.org/wiki/GNU_Compiler_Collection

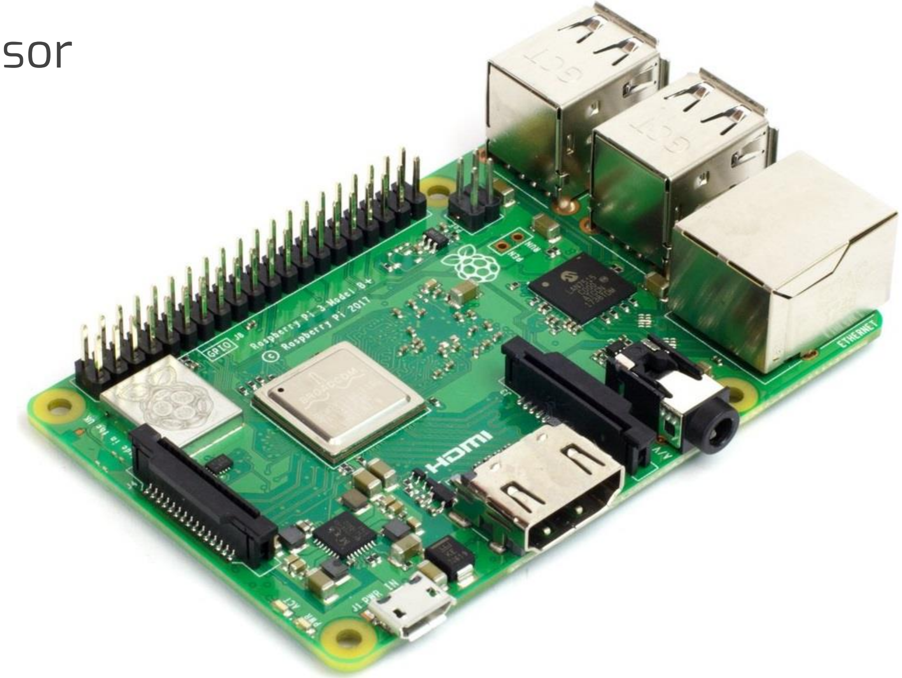
Backup Slides

System Block Diagram

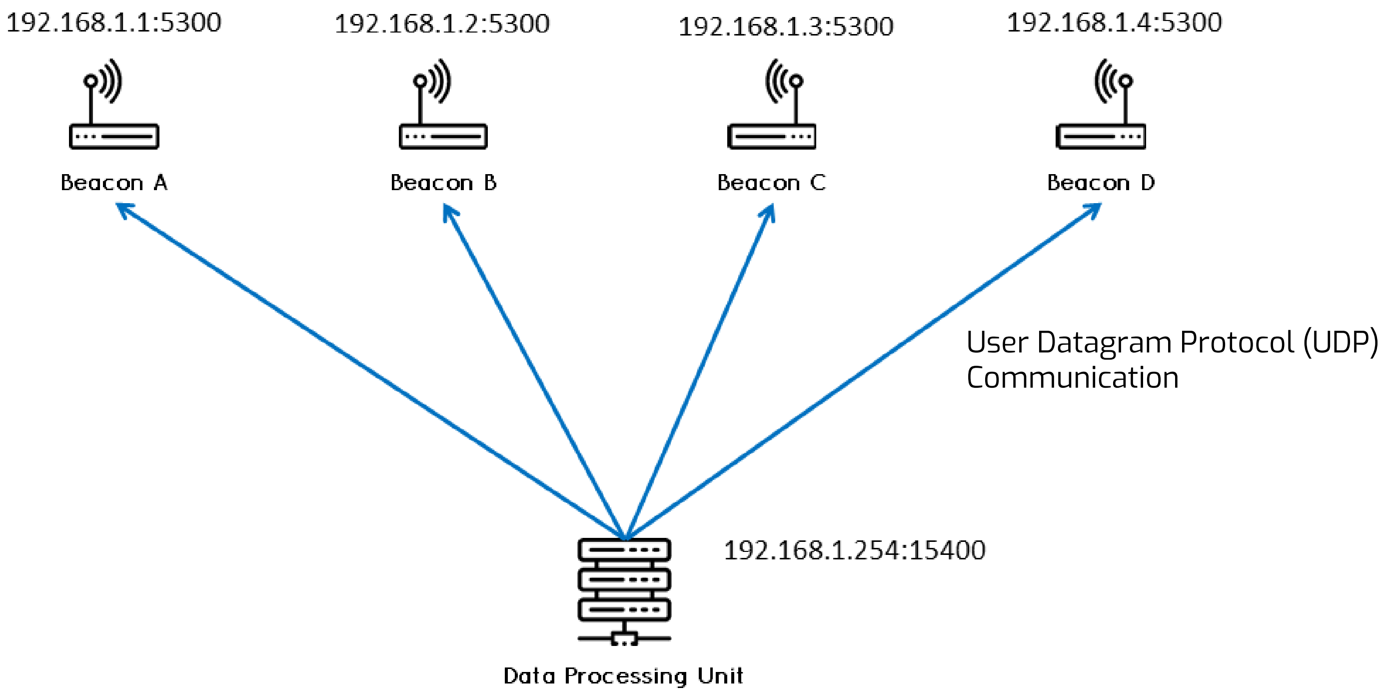


DPU - Raspberry Pi 3 B+

- Arm Cortex-A53 Quad-core processor
- 64-Bit SoC @ 1.4 GHz
- Dual-band wireless LAN
- Linux Based OS
- In Theory any SBC can be DPU



Beacons to DPU



Heisenberg Uncertainty Principle

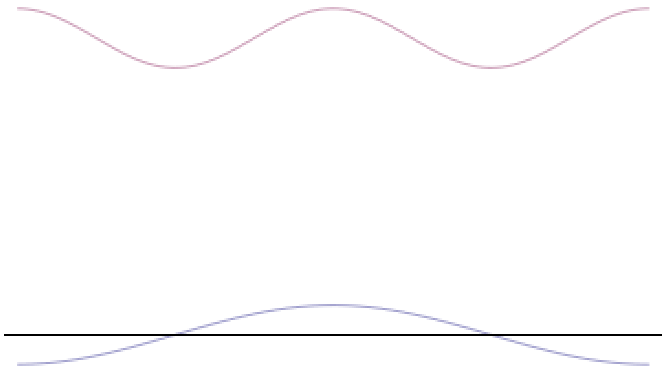
The timing and frequency of a signal cannot be localized simultaneously

$$\boldsymbol{\sigma}_t \boldsymbol{\sigma}_f \geq 1/4\boldsymbol{\pi}$$

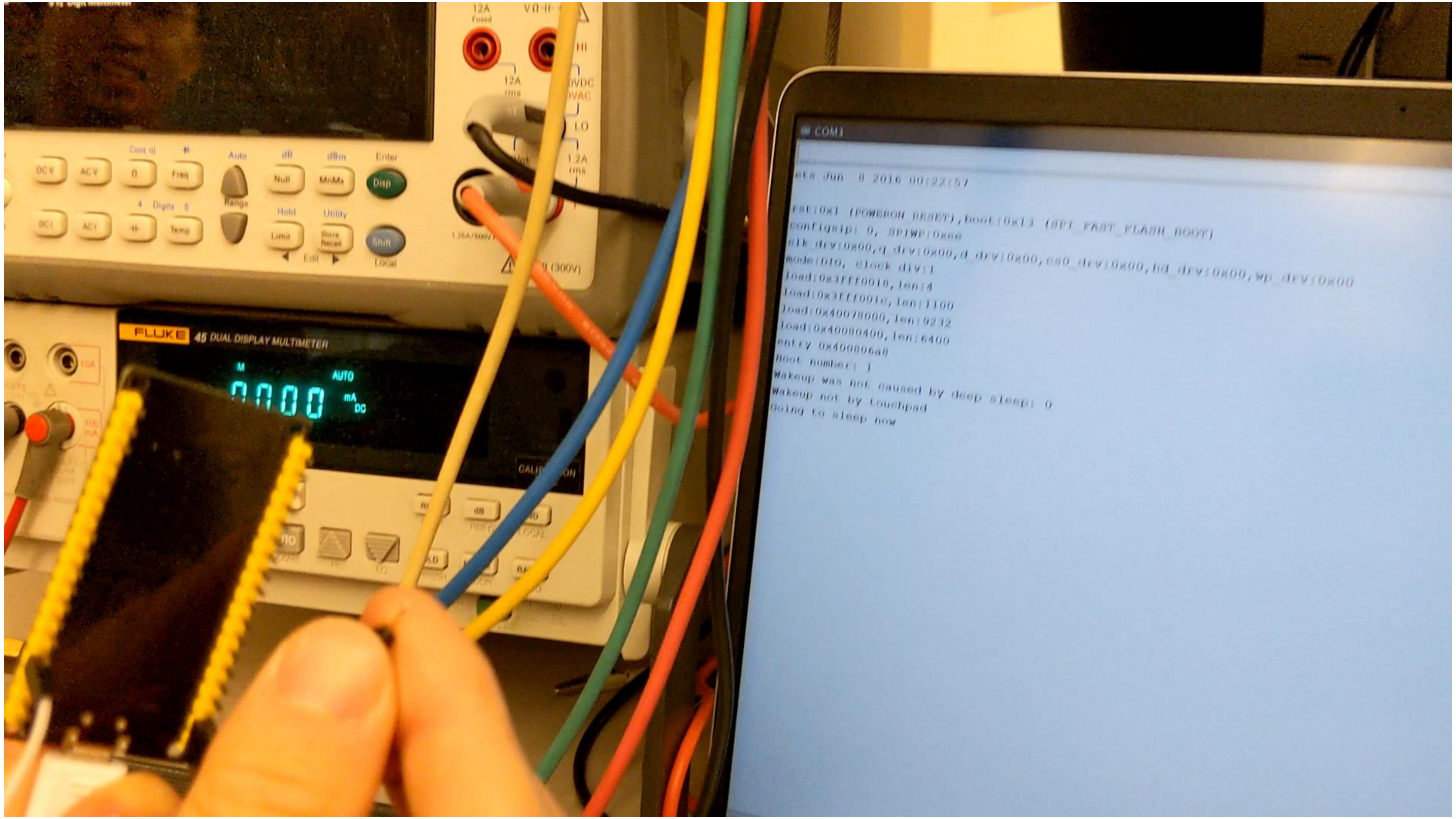
$\boldsymbol{\sigma}_t$: width of a pulse

$\boldsymbol{\sigma}_f$: range of frequencies (Bandwidth)

∴ **Narrow pulse ⟹ Larger Bandwidth**



Demo: Deep Sleep Mode



Future Development

WiFi Mesh

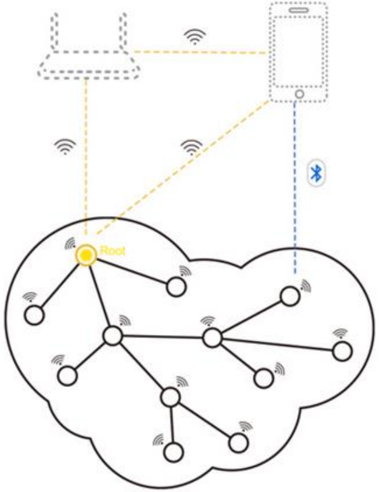
No need for expensive gateways — **Low-cost network**

Existing nodes connect to new ones automatically — **Mesh automatically formed**

Bluetooth connection between smartphone and mesh — **Wi-Fi connection**

Up to **10 Mbps** of data transfer rate — **Transfer music and videos**

Low-power sensors can connect to Wi-Fi mesh — **Low power consumption**



Every node works like a Router — Functional nodes without a Wi-Fi router

More nodes — Up to **1000 nodes** per mesh network

Long distance — Up to **200 meters** for a hop between two nodes

Wider coverage — “Hotspot” expands to a whole area

Easy implementation — Easy configuration of mesh without changing the network infrastructure

Cloud Management System