BatSignal:
System Design Document

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1 Introduction

1.1 Purpose and Scope

This document describes the hardware and software components of the BatSignal distributed sensor network. This document is intended for use by developers implementing BatSignal.

1.2 Project Executive Summary

The system is designed as a rapid response alert system capable of identifying emergencies and reporting their location. The system passively captures audio from the sensors and analyzes it for keywords or phrases. When the system detects a match it dispatches an email to a list of administrators and displays a notification on the system console.

The system is designed to be scalable according to the needs of the location of installation. Control nodes are installed at or near administrative areas with sensor nodes installed in patient rooms, inhabited spaces, common areas, etc. Messages propagate through the BatSignal mesh network allowing nodes to communicate with the controller over a distance.

1.2.1 System Overview

The system is divided into two types of nodes. The nodes form a mesh network that relays data from the first type of nodes called sensors to the second type of node called the controller node.

Python modules installed on the sensors passively read input from a microphone. The input from the microphone is fed into python's speech recognition module. The input is then sent to the control node over the mesh network either as plain text or compressed plain text.

Python modules installed on the control node passively receives the sensor's data. It then parses through the text looking for control phrases. Upon recognizing a control phrase an email is sent to a list of administrators containing the full triggering text input.

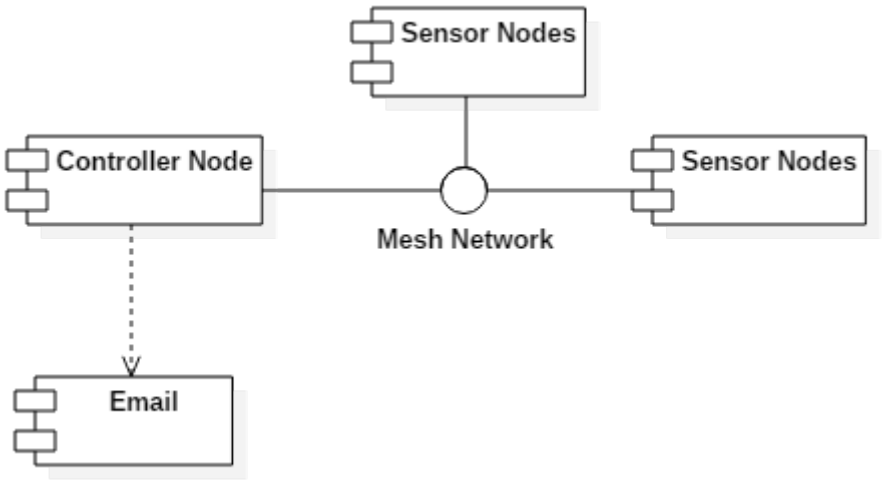

Figure 1: BatSignal system overview

1.2.2 Design Constraints

The BatSignal distributed sensor network will consist of numerous Raspberry Pi boards distributed across a physical area. This network has many constraints that must be considered.

These constraints are as follows:

- **Maximum Node Separation Distance -** The nodes must be close enough to communicate effectively with one another in order to form a reliable mesh network. This maximum effective communication distance relies on the capabilities of the Wi-Pi WLAN module and the B.A.T.M.A.N. routing protocol. This distance has not been determined yet. The communication range is also affected by physical objects in the installation environment, which may reduce the base measurement during implementation.
- **Sensor per Controller Ratio -** Due to the physical limitations of the controller node's processing power and each Wi-Pi WLAN module's transmition rate, coupled with the mesh network's maximal flow limits, there is a finite number of sensors that should be paired with any single controller node. This ratio has not been determined yet.

1.2.3 Future Contingencies

The BatSignal distributed sensor network relies heavily on the ability for nodes to be physically separate from one another, and still networked to the Internet. This is achieved by leveraging the B.A.T.M.A.N. routing protocol. Should the B.A.T.M.A.N. protocol be inadequate for wireless communication however, alternatives such as project Meshnet may prove more usable.
BatSignal also relies heavily on the ability to convert audio captures to a textual representation. The project leverages Google speech-to-text APIs to perform text conversion. The reliability and feasibility of these APIs may require better alternatives. No such alternatives have yet been identified as contingencies.

1.3 Points of Contact

1.4 Project References

- **Raspberry Pi:** https://www.raspberrypi.org/
- **B.A.T.M.A.N. Routing Protocol:** http://www.open-mesh.org/projects/batman-adv

1.5 Glossary

The glossary provides expansions for acronyms and abbreviations which appear within this document. It also provides definitions for terminology used within the document.

1.5.1 System Specific Definitions

System Specific Definitions	

1.5.2 Technical Definitions

Technical Definitions	
CPU	Central Processing Unit
GPIO	General Purpose Input Output
GPU	Graphical Processing Unit
MHz	Mega-Hertz
SoC	System on a Chip
USB	Universal Serial Bus
WLAN	Wireless Local Area Network

1.5.3 Industry Definitions

Industry Definitions	
B.A.T.M.A.N	Better Approach to Mobile Ad-hoc Networking
Wi-Pi	

1.6 Document Organization

In the following sections this document will define the overall system architecture followed by more detailed hardware, software, and communication architectures. These sections will be followed by the specifications for the system interface, both input and output. The final section will then go into explicit detail about each hardware and software component present within the system. Finally, the document ends with appendices containing reference or additional material.

2 System Architecture

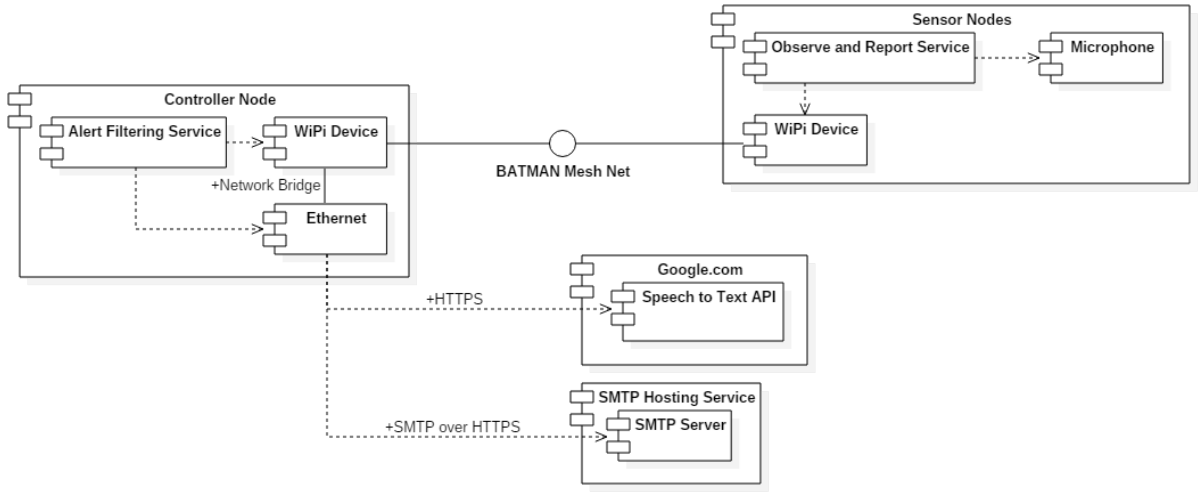

Figure 2: BatSignal system architecture

2.1 System Hardware Architecture

The BatSignal distributed sensor network consists of two types of hardware nodes, consisting primarily of a Raspberry Pi model 2 board. These boards are inexpensive and small computers which will enable the BatSignal network to perform processing and decision making tasks based on input to the system via connected sensors.

2.1.1 Controller Node

The BatSignal controller node consists of the Raspberry Pi model 2 board outfitted with a Wi-Pi WLAN module which enables wireless networking capabilities. These nodes also utilize the on board Ethernet adapter to enable a wired network connection to the Internet.

2.1.2 Sensor Node

The BatSignal sensor node consists of the Raspberry Pi model 2 board outfitted with a Wi-Pi WLAN module which enables wireless networking capabilities. The sensor nodes are also outfitted with a USB microphone which enables the audio pickup used to monitor the environment.

2.2 System Software Architecture

The system has two types of nodes in the mesh network. The first type of node is a sensor, and the second is the control node. There is only one control node per complete network. The sensor nodes and controller node run different python modules which dictate their behavior.
Sensor nodes passively wait for input from the attached microphone. Using python's speech recognition library the audio input is converted into text. It is then sent across the mesh network to the control node.
The control node passively waits for input from the sensor nodes. Upon receiving a message it searches the text for help phrases that are defined in a configuration file and read upon startup. When a help phrase is identified, an email is composed with the full text of the message and sent to the administrators. The administrators are defined in a configuration file and read upon startup. The control node is the only node connected directly to the Internet.

2.3 Internal Communications Architecture

The BatSignal distributed sensor network must be capable of communication between nodes, which will be carried out over a wireless mesh network.

2.3.1 Wireless Mesh Network

A mesh network is a topology in which each node connected to the network acts as a relay for data being passed through the network. Data passing through the network may be propagated using either a flooding or a routing technique. Not every node within the network must be connected to every other node on the network. The ability to propagate data by relaying it from node to node allows the network to be both distributed and fault tolerant. The simple fact that the mesh network is being implemented using wireless network adapters makes the mesh network a wireless mesh network.

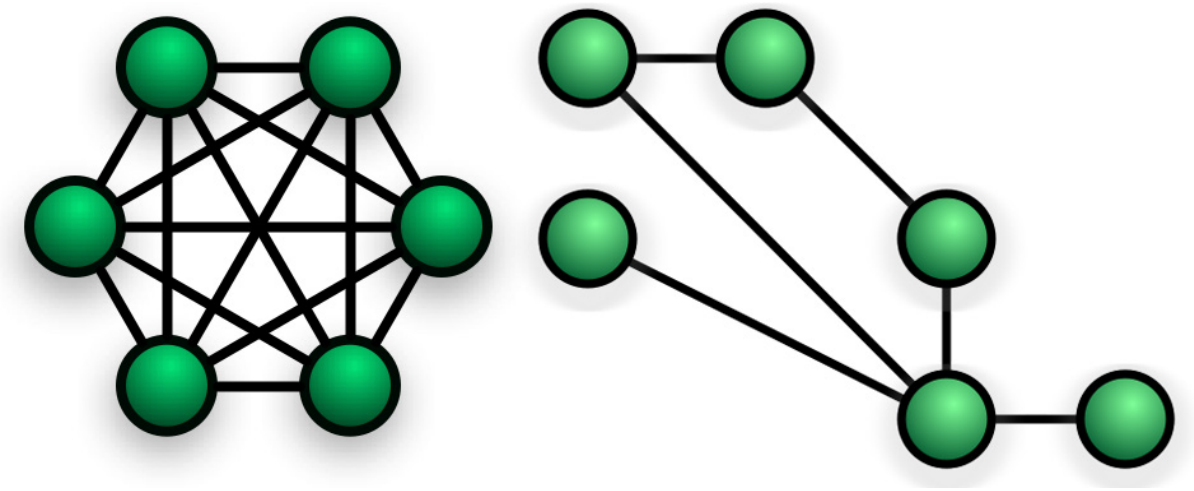

Figure 3: A fully connected, and a partially connected mesh network.

3 Human-Machine Interface

The BatSignal distributed sensor network is designed to work transparently to the user. A regular user will provide input to the system by speaking within the environment where a sensor node has been installed. An administrative user will receive output from the system via email messages.

3.1 Inputs

Input to the system comes in three forms; configuration files, the administrative console, and ambient verbal audio.
Configuration files are read by each node on startup. These files are stored on the controller node in a subdirectory of the installation folder named "config". The files are stored as "phrases.json" and "admins.json". They each contain a single json object with a list of strings. The list of string for "phrases.json" are the help phrases for the system, each of which is a single English word. The list of strings for "admins.json" are email addresses for the administrators. The administrative console may be used to modify system configuration.
The input to the sensor nodes is through verbal audio signals recorded using the attached microphone. The controller node receives input in the form of text messages relayed across the mesh network from the sensor nodes.

3.2 Outputs

Sensor nodes produce messages to the controller node as output. These messages contain the verbal audio converted into English plain-text. The controller node produces the system output in the form of email messages addressed to the administrators. These messages are sent only when a help phrase has been detected.

4 Detailed Design

4.1 Hardware Detailed Design

4.1.1 Raspberry Pi 2

Both versions of BatSignal nodes target the Raspberry Pi model 2 board. These systems have the following capabilities:

Raspberry Pi 2 Specifications	
Cost:	$35 USD
SoC:	Broadcom BCM2836
CPU:	900MHz quad-core ARM Cortex-A7
GPU:	Broadcom VideoCore IV, OpenGL ES 2.0, OpenVG 1080p30 H.264 high-profile encode/decode
Memory (SDRAM)iB:	1024 MiB
USB 2.0 Ports:	4 (via intergrated USB hub and LAN9512)
Onboard Storage:	Micro Secure Digital / MicroSD slot
Onboard Network:	10/100 wired Ethernet RJ45
Real-time Clock:	None
Power Ratings:	650 mA, (3.0 W)
Power Source:	5 V (DC) via Micro USB type B or GPIO header
Size:	85.0mm x 56.0 mm x 17mm
Weight:	40g

4.1.2 Wi-Pi WLAN Module

Wi-Pi WLAN Module Specifications	
Cost:	$15.52
Physical Interface:	USB 2.0
Wireless Standards:	IEEE 802.11n Backward compatible with IEEE 802.11g and IEEE 802.11b
Transmission Speed:	11b: 1/2/5.5/11 Mbps 11g: 6/9/12/18/24/36/48/54 Mbps 11n: up to 150 Mbps
Frequency Range:	2.4 to 2.4835 GHz
Working Channel:	1 to 13
Transmit Power:	20dBm (max)
Security Features:	WPA-PSK/WPA2-PSK WPA/WPA2 64/128/152 bit WEP Encryption

4.1.3 Microphone

Microphone Specifications	
Frequency Response:	50Hz - 18kHz
Polar Pattern:	Directional
Resolution:	16 Bit/44.1 kHz
Sensitivity:	56dB @ 1kHz
Output Voltage:	1.20Vms
Input:	USB

4.2 Software Detailed Design

A Appendix