Building an Open Source IoT Garage Controller

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*Abstract*— Internet connected technologies have become mainstays of the modern household. From Internet of Things (IoT) connected coffee makers to sophisticated adaptive climate control systems, inexpensive wireless technology and popularity of voice activated digital assistants has enabled a wide variety of connected tech. Most of this technology remains closed source however. Many of the more popular connected technologies, such as Nest or ecoBee, rely on closed source protocols and cloud service backends. What happens when these companies go out of business or shut down older services? VueZone shutdown it’s services leaving owners with severely crippled expensive IoT cameras. [1] This paper focuses on building a proof of concept IoT connected garage door real time controller and fully published interface and source: The GarageRTC! The features, design, and implementation of a reference architecture built on an ESP32 microcontroller and FreeRTOS software as well as performance and possible improvements.

Keywords—GarageRTC, IoT, Embedded, FreeRTOS, ESP32, NodeMCU, RTOS

# Introduction

As IoT become more common place in our daily lives we become increasingly dependent on the connected services that support those systems. Some of the more popular devices, such as Nest thermostat, are the product of small teams operating as a startup. As these teams grow they are sometimes bought out by larger corporations interested in entering into the IoT market. For some less fortunate start‑ups, they never break through into profitability and slowly descend into obscurity.

What happens to the devices that depend on the cloud services previously maintained and supported by those teams? Sometimes they can continue to function but with crippled or limited performance. Often, they are rendered useless as registration and web-based configuration tools become obsolete. For inexpensive devices, they can be cannibalized for parts or simply disposed of. For more expensive equipment, such as the Juicero, the founding company dissolved leaving many users with useless $400 IoT juice machines. [2]

The only guaranteed way to ensure these devices can be indefinitely supported is to implement an open source methodology including web APIs. Preferably, a completely open source hardware and software reference design would be created and published. Startups wishing to develop derivative works, could leverage the technology could then extend the designs. If the startup dissolves or can no longer support their design, as long as compatibility with the reference design was maintained, an internet user community would be able to continue support. This concept has been demonstrated profitable and sustainable in large software efforts such as IBM supported Red Hat Linux. [3]

To prove out this concept, the research team designed and built a reference design for an IoT connected Garage real time system, or simply, the GarageRTC.

The GarageRTC is an automation system for a consumer garage connected as an IoT device, Figure 1. The system makes the status of garage available to the user connected remotely through a web-based interface or locally via a display and control panel. Inside the garage, the system is connected to the garage door opener, a garage light, and an alarm. The system uses sensors to detect door position, accumulation of carbon monoxide, temperature, and objects in the path of the door. From the control panel or web interface, the user can check the status or manipulate the controls.

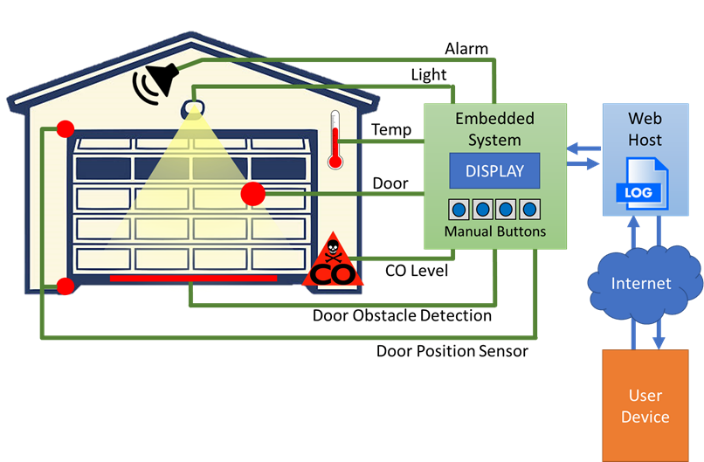


Figure 1. GarageRTC Concept Diagram

This paper documents the design process, development, implementation, and testing of a WiFi connected garage monitoring system. It implements a basic JSON based API and includes a reference web application that can easily be hosted in a personal cloud or Linux based development board.

## Organization of this Paper

This paper is organized into nine parts. This section covers the introduction and high level concept of the GarageRTC.

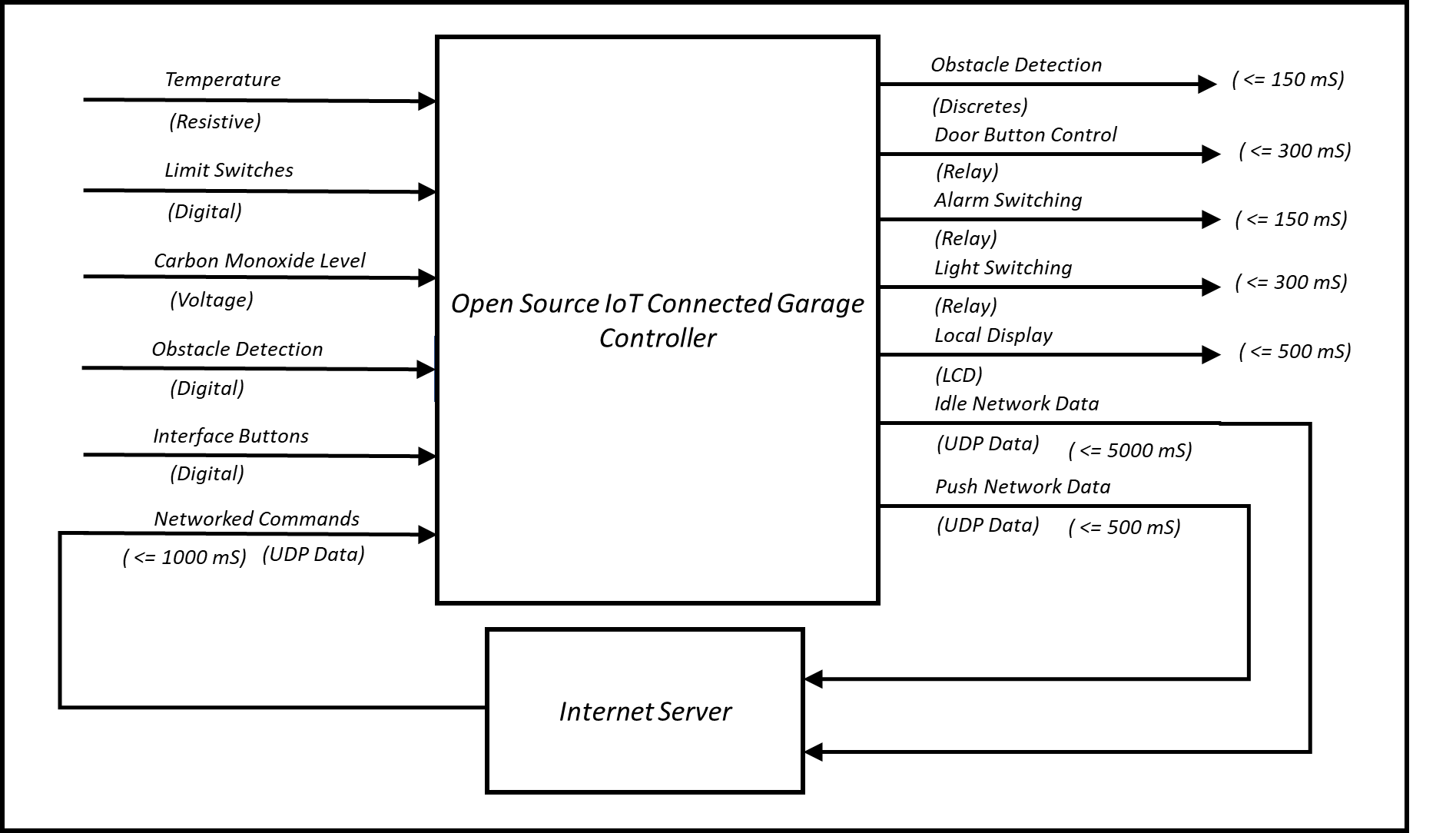
# Objective and Functional Description

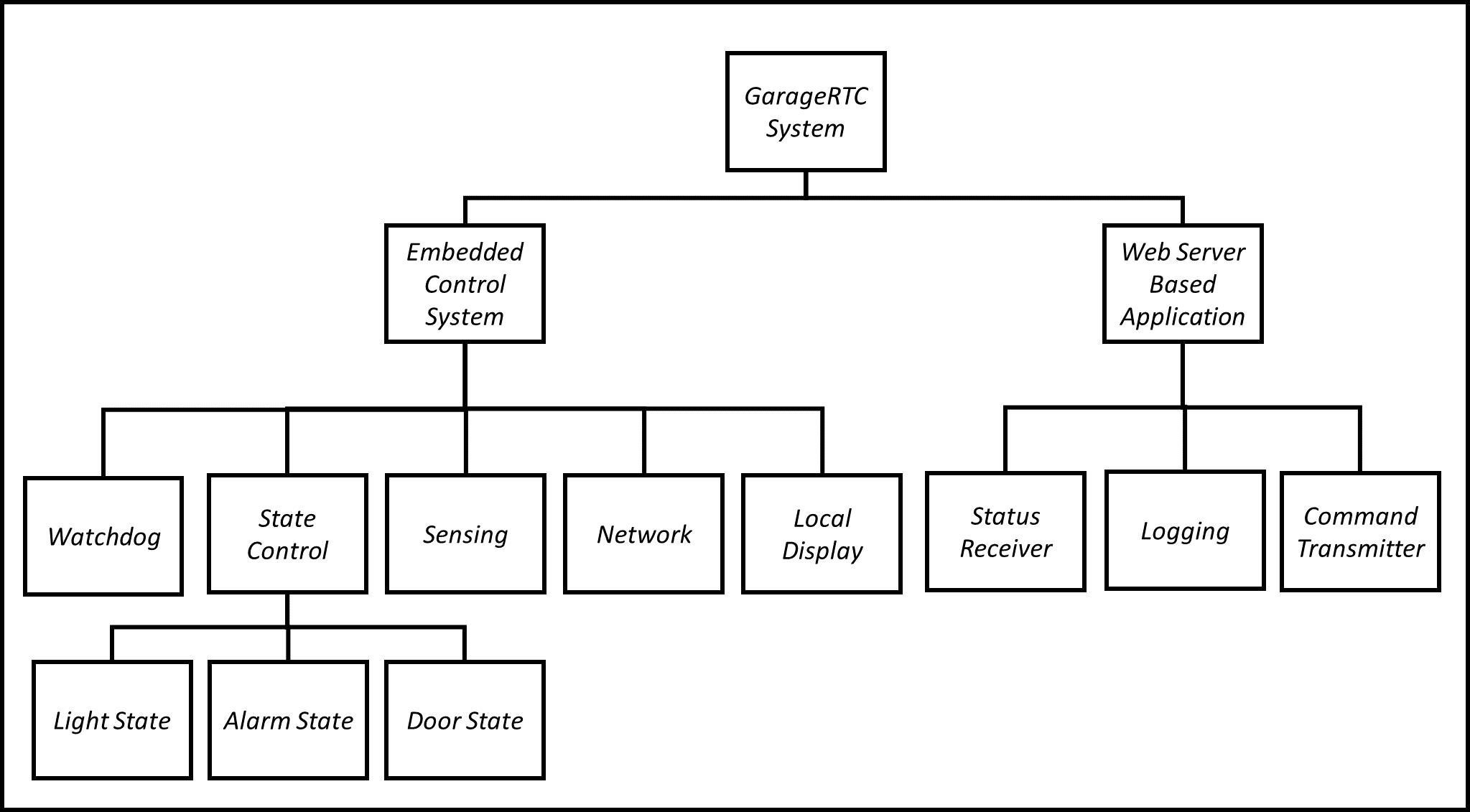
## Design Process

This project was developed using a waterfall

# Requirements

# High Level Design





## Embedded System

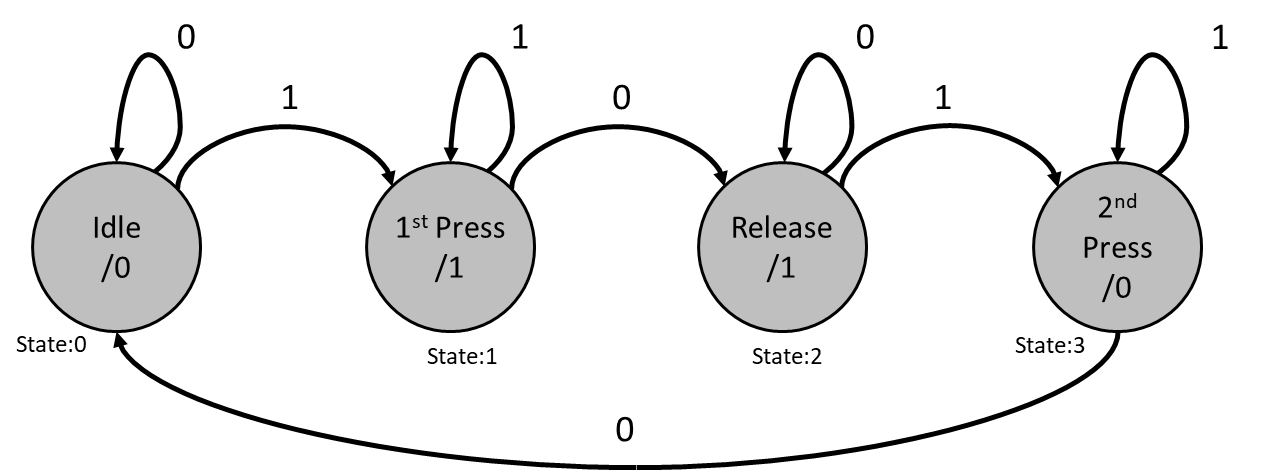
For the embedded system, a real-time OS was necessary to provide predictable response to inputs while simultaneously executing multiple tasks in a timely fashion. While scratch development of a RTOS was considered, ultimately the FreeRTOS project was selected. FreeRTOS implements a real-time kernel and schedulers targeted as low resource microcontrollers. The project is professionally developed and is available for free use in commercial embedded systems. It supports a wide variety of hardware and offers excellent documentation and, most importantly, is freely available including source. [4]

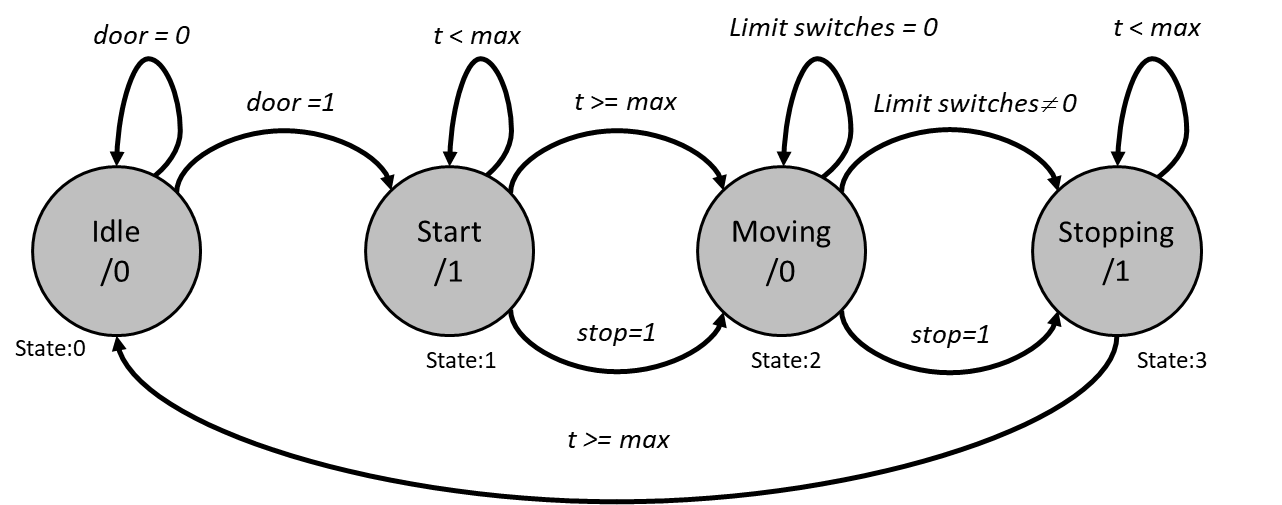
## Web Application

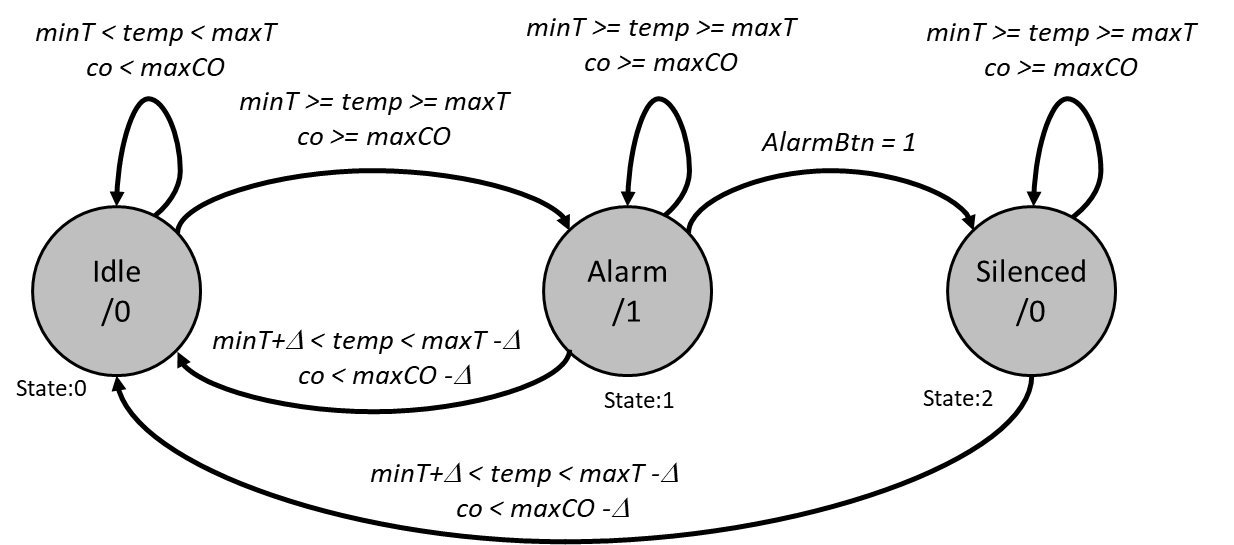
# Detail Design

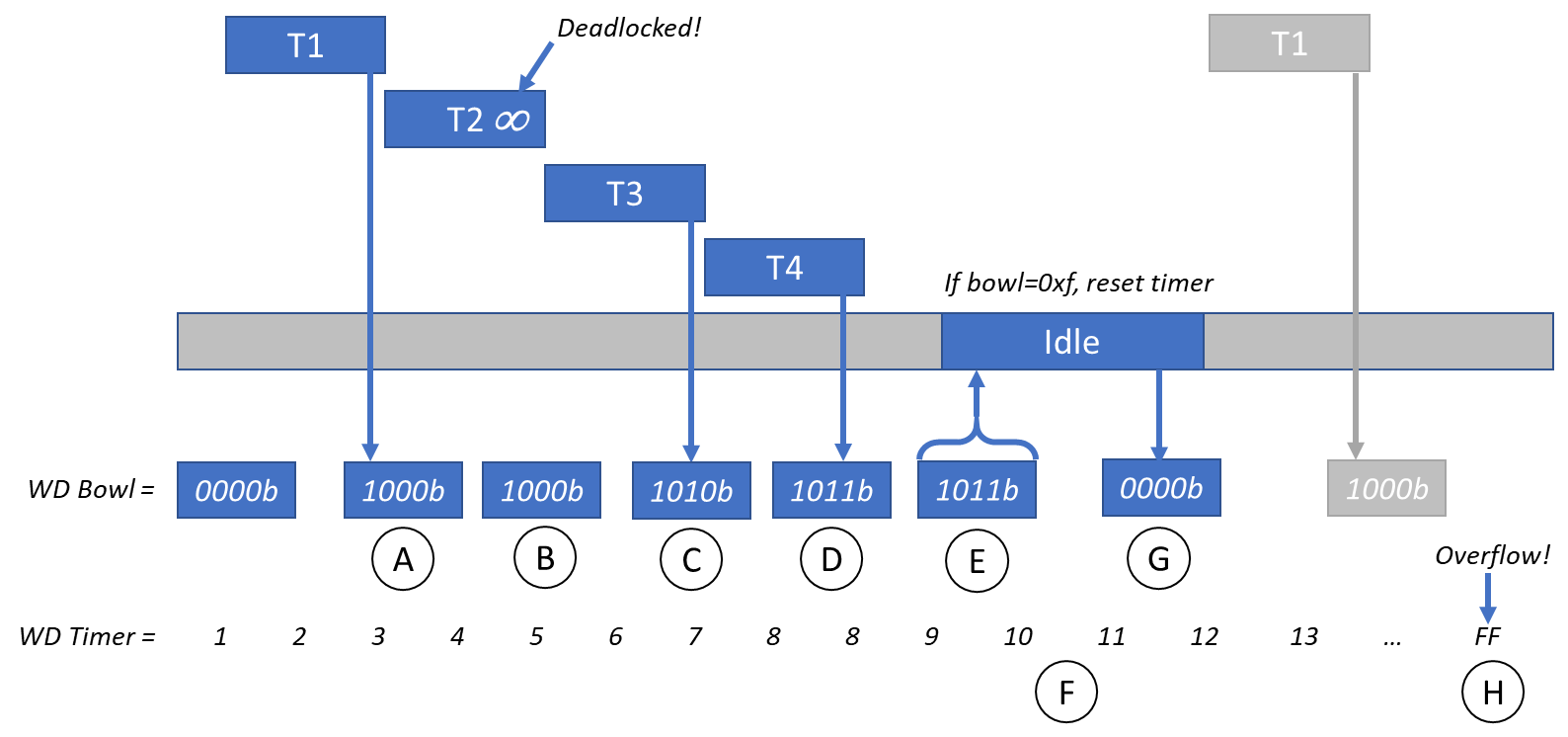
## Implementation

## Embedded System









## Web Service

# Testing

## Performance

# Accomplishments

## Objectives Met

## Limitations

## Lessons Learned

## Possible Improvements

# Commercial Offerings

Several commercial IoT garage devices are available to consumers. These devices are typically developed by major opener manufacturers and marketed as an upgrade to the existing opener electronics. This section provides a short review of several of these offerings and their compatible hardware. Surprisingly, none of these technologies offered native integration with digital assistants such as Amazon Alexa. We provide a comparison between the GarageRTC features and the commercial offerings and discuss the benefits and drawbacks of these paired solutions.

## Commercial IoT Garage Interfaces

### Chamberlain MYQ-G0301

### Aladdin Connect

### Garage Door Buddy

### GoControl GD00z-4

## Comparison with GarageRTC Features

| **Feature** | MYQ-G301 | Aladdin Connect | Door Buddy | GoControl | GarageRTC |
| --- | --- | --- | --- | --- | --- |
| Connectivity |  |  |  |  |  |
| WiFi | ✔ | ✔ | ✔ |  | ✔ |
| Bluetooth |  |  |  |  | *1* |
| ZWave |  |  |  | ✔ |  |
| Digital Assistant |  |  |  |  |  |
| Alexa |  |  |  |  | *2* |
| Google |  |  |  |  | *3* |
| Siri |  |  |  |  | *3* |
| Sense/Control |  |  |  |  |  |
| Aux Control | *4* |  |  |  | ✔ |
| Amb. Temp |  |  |  |  | ✔ |
| Amb. CO |  |  |  |  | ✔ |
| Door Position | ✔ | ✔ | ✔ | ✔ | ✔ |
| Local Control |  |  |  |  |  |
| LCD Display |  |  |  |  | ✔ |
| Door | ✔ | ✔ | ✔ | ✔ | ✔ |
| Aux/Light |  |  |  |  | ✔ |
| Open Source |  |  |  |  |  |
| Web App |  |  |  |  | ✔ |
| FOSS |  |  |  |  | ✔ |
| Published API |  |  |  |  | ✔ |
| HW Schematic |  |  |  |  | ✔ |
| Universal |  |  | ✔ | ✔ | ✔ |
| Reference | [5] | [6] | [7] | [8] |  |
| 1. ESP32 Contains the hardware but reference design does not implement.  2. Libraries exist that could easily integrate this capability. [9]  3. Can be integrated through webhook/REST API calls. [10]  4. Requires purchase of additional hardware. | | | | | |

## How GarageRTC differs from current solutions

## Benefits and drawbacks of the integrated solution

# Closing Remarks

# References

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