SMART BABY MONITORING SYSTEM

Final Project Report (CS437: Internet of Things)

Abstract

Smart Baby Monitoring System (SBMS) is a cloud based IOT (Internet of Things) system, which enables parents to check on their child remotely on their mobile devices without having to be present in the child's room. SBMS uses home Wi-Fi network for communication and therefore can be accessed from anywhere in the house via the Wi-Fi technology using a smartphone or a computer.

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Team members

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Table 1: Team members

Web links to project deliverables

Description	Link
Project Video	https://youtu.be/2Ugj8MbSi5A
Code	https://drive.google.com/drive/folders/1WET0TFP6d33DeyZq8VPYvjn0GRi14f1E

Table 2: Weblinks (URLs)

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1. Motivation

For young parents, it is important to have the capability to remotely monitor their sleeping/napping child in the crib when parents cannot necessarily be in the same room as the child. This has been a very well-known need leading to the explosion of baby monitoring systems entering the IOT market. The capabilities of these baby monitoring systems can vary but most include motion detection, sound detection, and live notifications to the parent. These baby monitoring systems can range anywhere from $100 to $500 depending on the functionalities. As raising a baby in their first year can already cost anywhere from $20,000 to $50,000, spending this much on a baby monitoring system can be too much for some families.

Therefore, we have built this Smart Baby Monitoring System (SBMS). SBMS is a cloud based IOT (Internet of Things) system, which enables parents to check on their child remotely on their mobile devices without having to be present in the child's room. Parents are instantly alerted on their mobile device via mobile app or web interface if the child makes a sound or if any activity is detected. In addition, live video from the camera (with night vision capabilities) mounted on baby's crib is streamed to the mobile device on demand. SBMS also lets parents play lullaby/music from a playlist to soothe the baby. A speaker mounted on the crib along with the camera is used to play the music remotely.

The main motivation behind this application is to further the security and well-being of younger children. In today's day and age and with the technology that can be developed, making strides to better security for children is an easy decision. Younger children need more attention, and with the implementation of this technology keeping your child safe can be made easier for parents everywhere. By using IOT devices, we can create a system that can push the boundaries of current baby monitor technology and further the safety of future generations of kids.

Traditional baby monitors come with a camera/microphone, which streams the video/audio to a handheld monitoring device via radio frequencies. SBMS uses home Wi-Fi network for communication and therefore can be accessed from anywhere in the house via the Wi-Fi technology using a smartphone or a computer. This eliminates any need for a separate hand-held screen device. One more significant advantage to parents is that they are not limited by just one display device, more than one device can be set up for notifications/video streaming.

This device will have the ability for the user (parent/caretaker) to adjust the angle of view for the camera, as well as motion detection capabilities to allow the parent to know whether the child may need to be attended.

Capabilities of the Smart Baby Monitoring System:

For the current implementation, foundational capabilities listed below are considered and implemented.

- **Detect movement and alert**: when continuous movement is detected in the crib, parents are notified on their devices
- **Video streaming on demand**: Watch the live video streaming from the crib camera via mobile app/ web interface
- **Camera Orientation:** Camera with ability to move in all four directions if the baby is out of focus. Camera is supported by a pair of motors to move the camera in all four directions

Additional capabilities (Future expansion): set of additional capabilities listed below are considered for future expansion.

- **Take pictures**: Capture memorable moments by taking pictures remotely. Parents can take pictures remotely when the baby is awake and playing in the crib candidly
- **Temperature/Humidity**: Parents can check room temperature/humidity on demand
- **Play music**: Parents can play lullaby/music from a playlist to soothe the baby. A speaker mounted on the crib along with the camera is used to play the music remotely
- **Night vision mode**: Upgraded camera with night vision capabilities
- **Secured access:** Access is restricted to a set of registered display devices only

2. Technical Approach:

In order to define technical specifications for the SBMS, each of the capabilities/use cases listed below are defined in detail and built into the end-to-end flow diagram. Below is the list of use cases considered for developing algorithm and flow chart for SBMS:

- Detect movement and alert
- Video streaming on demand
- Camera Orientation

Flow Diagram:

Algorithm for step-by-step analysis of the process has been translated into a flow chart listed below:

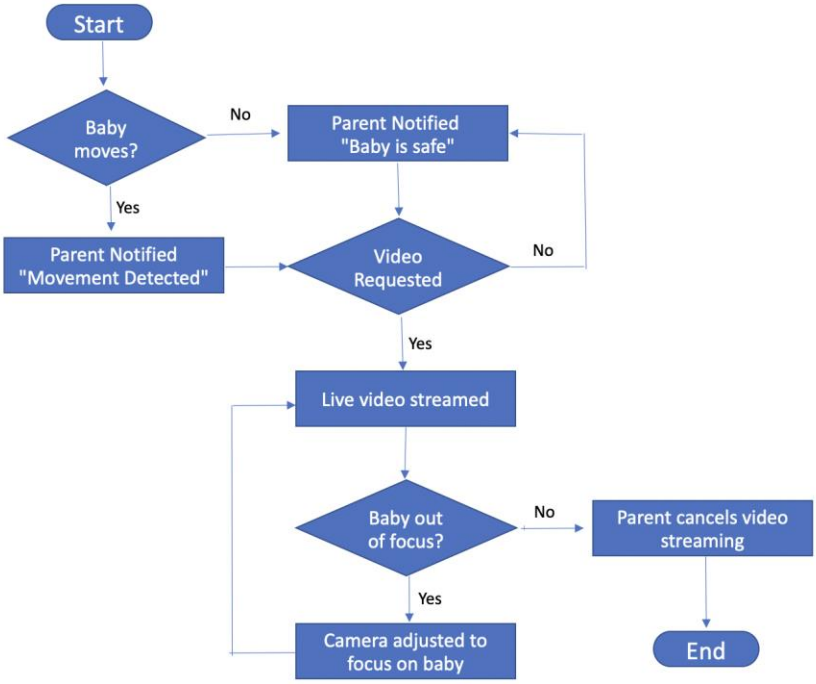

Figure 1: SBMS Flow Chart

Technical Architecture & Components:

Based on the use cases documented in the previous sections, the following IOT components have been identified to be used in the SBMS technical architecture:

Components	Functional/Technical Specifications
Raspberry Pi 	• A low-cost microprocessor-based minicomputer with the following specifications: 1.4GHz 64-bit quad-core processor, dual-band wireless LAN, Bluetooth 4.2/BLE • IOT devices camera and servo motors are connected to and powered by Raspberry Pi • Raspberry Pi is wirelessly (utilizing Wi Fi) connected to the baby monitor display devices utilizing Wi-Fi protocol

Raspberry Camera 	• The camera is used to take high-definition video, as well as stills photographs • The camera is connected to Raspberry Pi and accessed through the MMAL and V4L APIs utilizing third-party library Picamera Python library
Servo Motors 	• Two servo motors are connected to Raspberry Pi and camera is mounted on these two motors • Motors are controlled by the Raspberry to move the camera in all four directions • Third party python libraries are used to control the movement (angle) and pace of the motors
Display Monitor 	• Mobile device/computer used to run the front-end webapp (developed using Electron package) • Number of controls provided on webapp for user interaction • Notifications are displayed on the webapp

Table 3: Components

Architecture Diagram:

Broadly, SBMS consists of two parts: baby monitor mount and baby monitor display. Baby monitor mount is mounted on the crib, and it houses the following components: Raspberry Pi, Servo motors, and Camera. Whereas display part consists of one or more than one display devices that are wirelessly connected to Raspberry Pi device. Below is the overall technical architecture diagram for the SBMS:

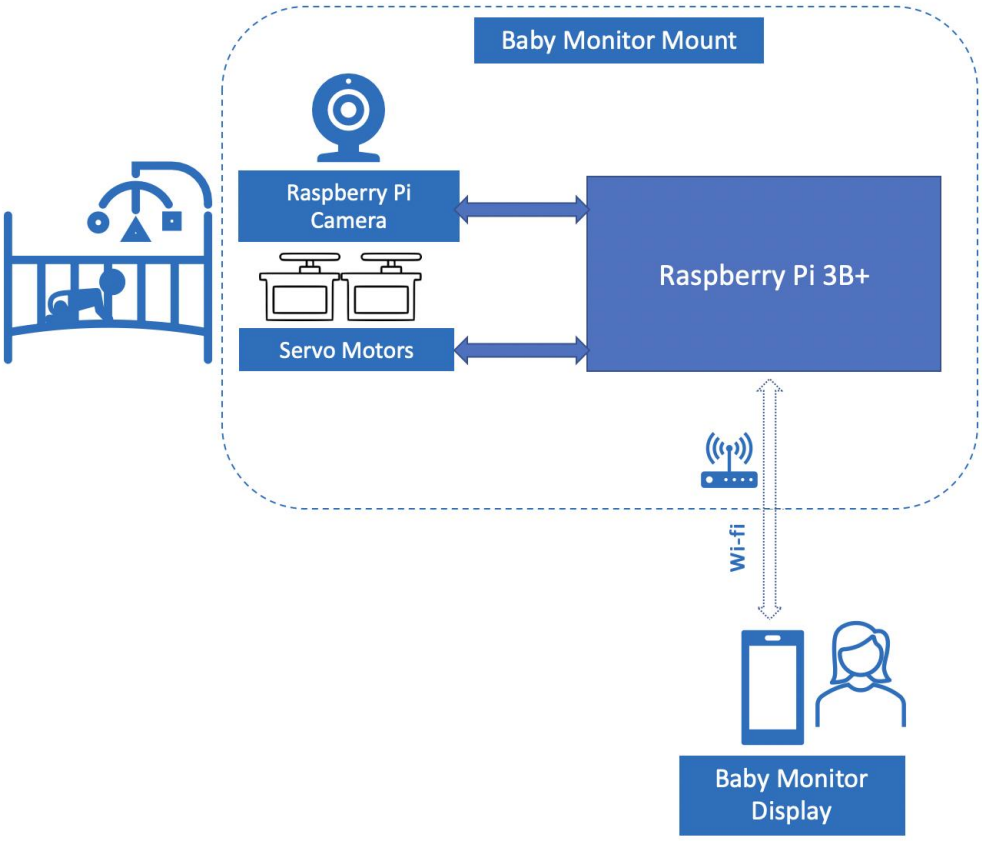

Figure 2: Technical Architecture

3. Implementation Details

As per the initial implementation plan, SBMS comprises of several IOT devices such as camera, microphone, speaker, and motion detector run by a raspberry Pi computer. Raspberry Pi is wirelessly (utilizing Wi Fi) connected to the IOT Cloud platform via the internet. Front end app running on mobile devices is also connected to the IOT cloud platform. SBMS is built on IOT cloud platforms to bring together all the

IOT devices in the Smart Home system and also to take advantage of cloud computing capabilities. For instance, SBMS can share temperature data with the thermostat to control the temperature in the baby's room or play lullaby from parents' iTunes playlist or Spotify. Importantly, using IOT cloud platforms, robust IOT security can be implemented utilizing readily deployable security controls and tools. For example, every mobile device used with the SBMS must be a registered device.

However, due to challenges in procuring some of the sensor devices in time, and to reduce the technical complexity, SBMS is implemented to support the following requirements:

Trigger/Event	Implementation specifications
Baby movement detected	• Camera is used for motion detection and for capturing the video as well • On the display device, message "Baby is safe" is displayed until the movement is detected (which implies baby is awake and needs to be attended • When the movement is detected, notification alert sent to the display device and display message changes "Movement Detected"
Live video streaming requested	• Stats streaming live video on demand (click of a button) • Once video starts streaming, user can cancel the video by clicking on a button
Camera orientation adjusted	• If user is unable to see the baby properly on the video due to out of focus, user can adjust the focus by moving the camera in all four directions by clicking on buttons • Two servo motors are manipulated to move from left to right and top to bottom, and vice versa

Table 4: Events and implementation specifications

Software packages/libraries/Modules/APIs:

Number of third-party libraries have been utilized for establishing communication between the devices and between frontend and backend. Also, software packages have been used for developing the front-end as well. Below is the list of software packages/libraries/modules that have been utilized for this project:

Packages/Libraries/Modules	Implementation usage
Electron UI	• Front-end HTML page is rendered with Electron JS • Web app is launched using Electron • Electron UI – Video is streamed from PiCam to the display device in the Electron UI. • Electron and NodeJS installed – Utilized Electron JS project.
Raspberry Wi-Fi interface	• Connection established between Raspberry Pi and display monitor via Wi-Fi
Python picamera library	• The **Python Picamera** library allows to control the Camera Module • Utilize APIs provided by Picamera library to capture photos, start recording, and stop recording
Raspberry Pi Servo Motor control	• Servo motors care controlled with a single GPIO • The rotation is controlled by the length of the pulse • The angle of the motor is set along the length of the pulse, so PWM function is used to send repetitive signals at even intervals • servos can rotate between **0 and 180°**. So, we have to adjust the pulse length in between

Table 5: Software packages/Libraries/Modules

4. Results

Post implementation, thorough testing has been performed to ensure that all the foundational capabilities are working as expected. Some of the additional capabilities that we couldn't implement in the current release, have been added to the backlog and considered for future expansion. As per the original plan, we wanted to utilize AWS IOT core for implementation, however, in order to reduce the complexity, we have gone ahead with local implementation. AWS IOT core can be considered for future expansion.

Foundational capabilities that have been successfully implemented and tested:

- **Detect movement and alert**: Camera is able to detect the movement and update the alerting message on the Electron UI/Webapp to "Movement Detected" from the default message "Baby is Safe"
- **Video streaming on demand**: On the Webapp UI, user is able to request for live video streaming on demand by clicking on a button and video from the camera is streamed successfully to the Webapp.
- **Camera Orientation:** User is able to rotate the camera left and right (0-90 degrees) on demand basis by clicking on arrow buttons

Additional capabilities (Future expansion): set of additional capabilities listed below are considered for future expansion.

- **Take pictures**: Capture memorable moments by taking pictures remotely. Parents can take pictures remotely when the baby is awake and playing in the crib candidly. As part of the current implementation, we faced issues in managing the memory for saving and archiving captured still pictures. It was also impacting the ability to stream the video simultaneously.
- **Temperature/Humidity**: Parents can check room temperature/humidity on demand. We were unable to procure the required sensors to read temperature and humidity. Therefore, we had to drop this feature from the current implementation.
- **Play music**: Parents can play lullaby/music from a playlist to soothe the baby. A speaker mounted on the crib along with the camera is used to play the music remotely. Due to complexity involved in managing music playlists locally, we couldn't implement this feature.

Overall, SBMS addresses all the basic requirements and meets acceptance criteria set forth for this project.