# Mesh-IoT Based Smart and Secure Monitoring System for Wide-Range Territory

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## Introduction

- In current practice, back-and-forth communicating between big data produced from local Internet of Things (IoT) devices and cloud computing incurs long latency and computation time, thus edge computing is getting attention.
- The existing IoT designs are application-specific with limited geographic range focusing only in a particular aspect such as AI, face recognition, and mesh network; a reliable and efficient general wide-range IoT architecture design is needed for all applications.
- To improve the communication/computation efficiency of multiple applications in wide-range, we propose a robust IoT hardware architecture of Cloud-Edge nodes-Physical Networks.

## Contributions

- The proposed IoT system has multiple contributions:
  - In Fig. 1, star topology adds an intermediate mesh-node for the IoT network to monitor the entire territory like factory, farm, or building with our own semi-customized boards.
  - Fig. 5 shows our IoT hardware architecture for Cloud-Edge-Deployed Systems.
  - Our own communication commands design for the semi-customized BLE Mesh boards are shown in Fig. 2(a), 2(b), and 2(c), with sensor TX packet, sensor RX packet, and LED configuration commands displayed, respectively.

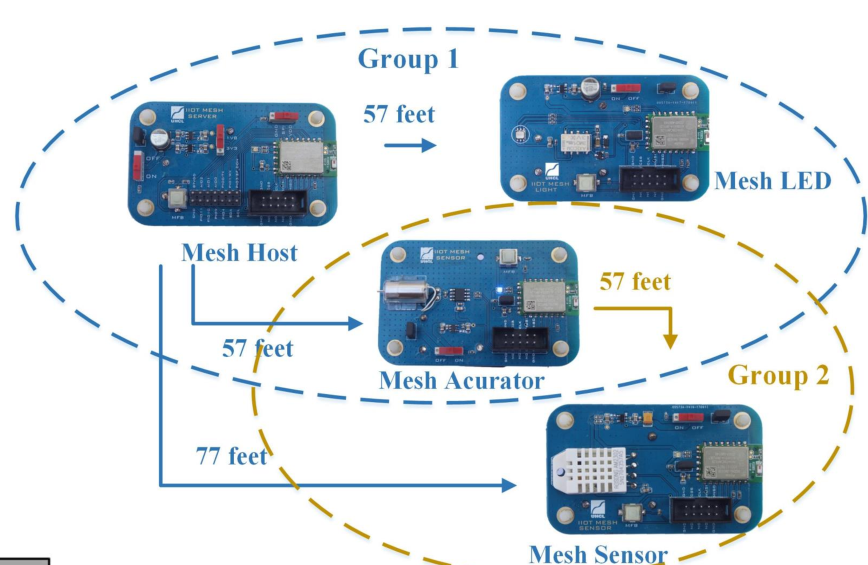



Fig. 1 Star-Topology Configuration

| Header (2B) | Length (1B) | Type (1B) | On/Off (1B) | Check (1B) | Stop (2B) |
|---|---|---|---|---|---|
| FA, F5 | 04 | F3 | 00~01 | XX | 0D, 0A |

Fig. 2(a) Command for Mesh Actuator

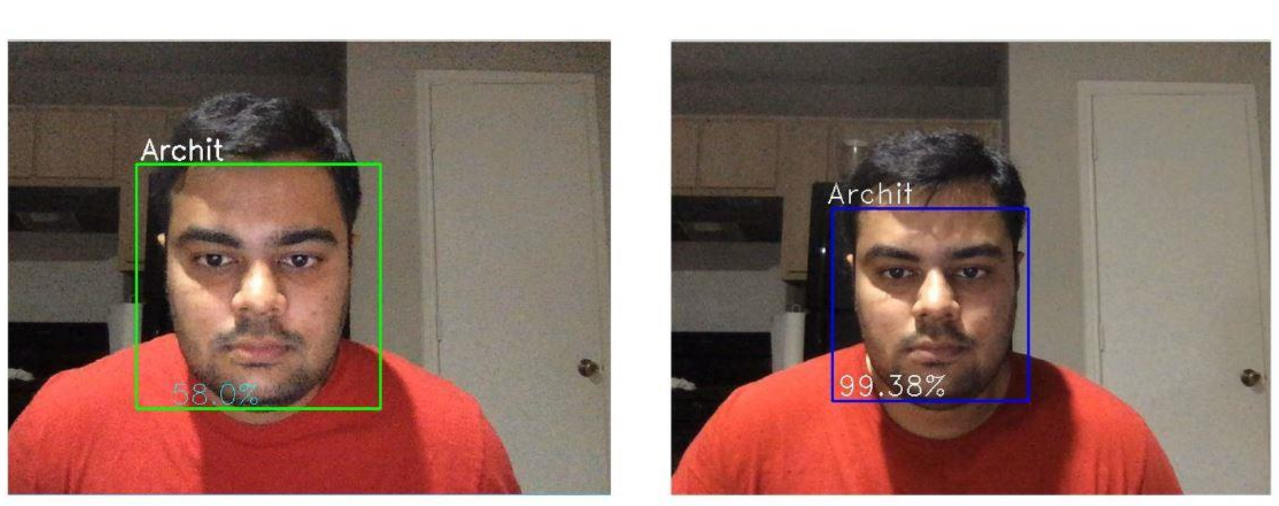
| Header (2B) | Length (1B) | Type (1B) | On/Off (1B) | Red (1B) | Green (1B) | Blue (1B) | Check (1B) | Stop (2B) |
|---|---|---|---|---|---|---|---|---|
| FA, F5 | 07 | F1 | 00~01 | 00~FF | 00~FF | 00~FF | XX | 0D, 0A |

Fig. 2(b) Command for LED

| Header (2B) | Length (1B) | Type (1B) | Humidity (2B) | Temperature (2B) | Check (1B) | Stop (2B) |
|---|---|---|---|---|---|---|
| FA, F5 | 07 | F3 | 0000~FFFF | 0000~FFFF | XX | 0D, 0A |

Fig. 2(c) Command for Sensor

- To offer security, the system is equipped with two different face recognition algorithms and cameras on various computing devices such as Raspberry Pi (4 x ARM Cortex – A53, 1.2 GHz and 1 GB LPDDR2 RAM) and CPU (Intel Core i7 – 7700HQ, 2.8 GHz and 16 GB DDR4 RAM ).




(a) LBPH Based Face Recognition (b) DML Based Face Recognition

Fig. 3 Face Recognition

- Upon the motion detection through Passive Infrared Sensor (PIR), the camera is activated, and the alert is sent to designated person if the target face is not recognized from the database via an E-Mail using Simple Mail Transfer Protocol (SMTP).

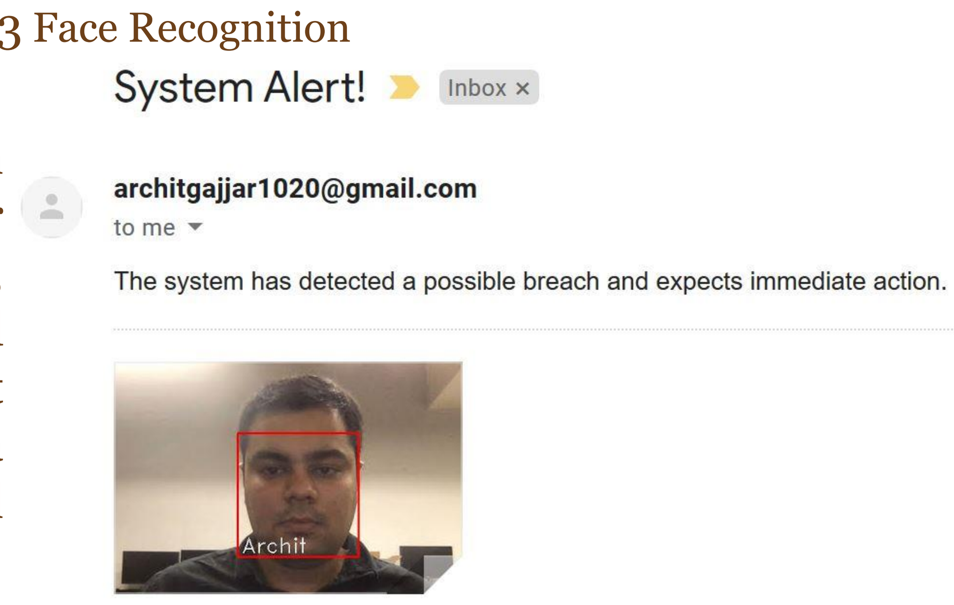



Fig. 4 E-mail Notification with the image

## An Overview of System Architecture

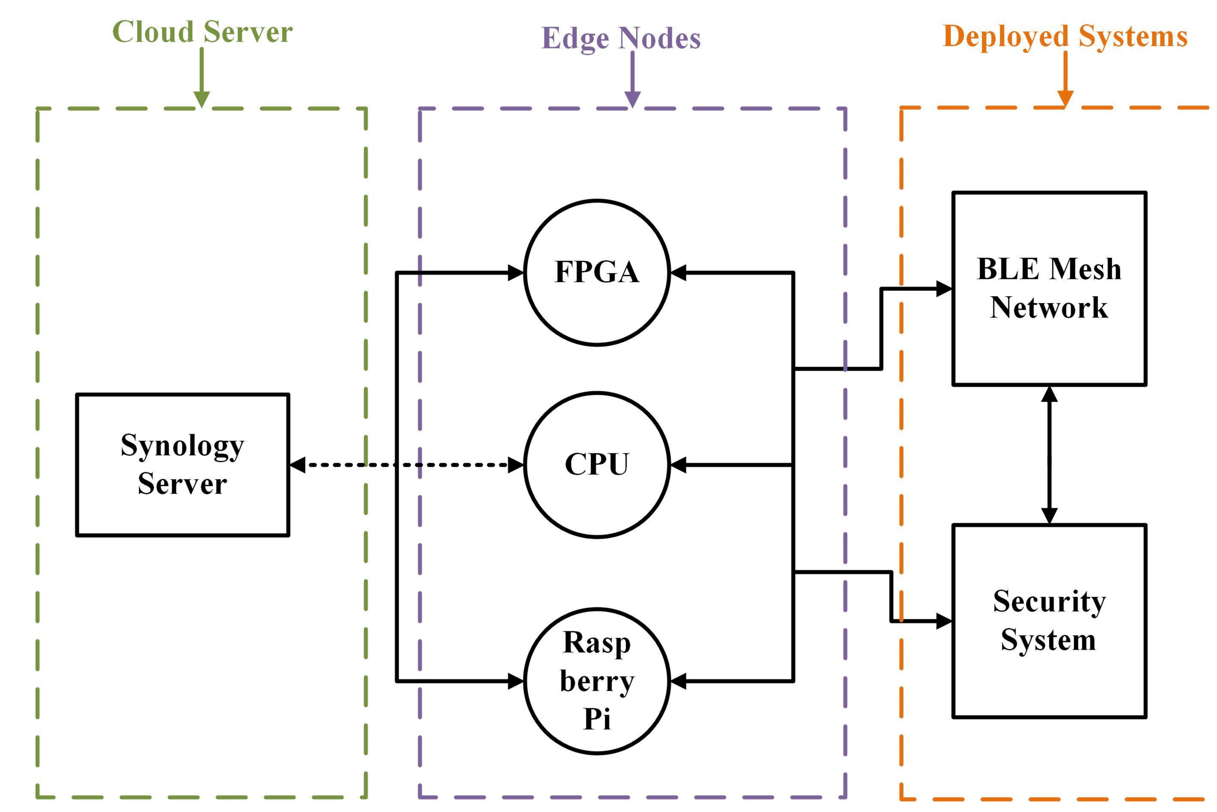



Fig. 5 Hardware Architecture

- The System Architecture can be fragmented into three stages.
  - **Cloud Server –** A cloud server (Synology DSM v6.2) is connected to edge nodes and deployed systems which can be used to store important logs and to manipulate all the connected systems.
  - **Edge Nodes –** A local edge node is, virtually, situated in between cloud server and deployed systems, to improve efficiency in computation time, data storage and communication latency. We propose various edge nodes such as FPGAs, CPUs, and Raspberry Pis in an IoT network.
  - **Deployed System –** The deployed systems are multiple integrated systems with edge nodes. In our IoT design, we have two deployed systems 1) BLE Mesh monitoring system and 2) Security System.

## Experimental Results

- This is still ongoing project with some preliminary results:
  - **Table 1** represents increased maximum distance with one mesh-node between two devices.

| Maximum Distance | No. of Node (s) |
|---|---|
| 57 feet | 0 |
| 77 feet | 1 |

  - **Table 2** provides face recognition time for algorithms on different devices.

| Devices | Recognition Time (s) | No. of Face (s) | Method |
|---|---|---|---|
| Raspberry Pi | 0.41 – 0.45 | 1 | LBPH |
| CPU | 0.035 – 0.037 | 1 | LBPH |
| CPU | 0.391 – 0.398 | 1 | DML |

  - **Table 3** exemplifies the face recognition accuracy with various algorithms and cameras on various computing devices.

| Devices | Recognition Accuracy (%) | Camera | Method |
|---|---|---|---|
| Raspberry Pi | 40 – 50% | Logitech C270 | LBPH |
| CPU | 40 – 50% | Logitech C270 | LBPH |
| CPU | 55 – 65% | 720p HD Laptop | LBPH |
| CPU | 99.38% | 720p HD Laptop | DML |

## Conclusion and Future Work

- The preliminary results demonstrates a promising IoT architecture which can be extended to wide range with star topology. Moreover, a scalable security is able to be operated by various face recognition algorithms, camera quality, and hardware's computation speed based on the requirements.
- Our future project goals – 1) to integrate Synology cloud server to host a webpage for data gathering and decision making, 2) to add Field Programmable Gate Arrays (FGPA) as an edge node for high-bandwidth computation like face recognition, 3) to provide more benchmarks for face recognition system on computation time and accuracy, and 4) to measure maximum possible nodes with acceptable delays specific to given application task for low-bandwidth mesh system.

## References

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