IoT Lab Facility Project
Lab Facility Preparation

Report By:

Alaa Badokhon

Committee Members

Dr. Mohammed Khorsheed (Chair)
Dr. Amr Alasaad
Dr. Ammar Alanazi
Dr. Abdullah Alfadhly
Dr. Abdulaziz Alorainy

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Introduction

The purpose of this report is to document and illustrate existing IoT related projects and equipment to be consolidated into a shared, common space for IoT projects and experiments at the Communication and Information Technology Research Institute at KACST. This common space will be an IoT Lab with complete facilities and resources needed for IoT research and development, to assist all CITRI and KACST researchers in their IoT related research.

The IoT Lab is projected to compose a full IoT equipment facility that includes needed hardware such as SBCs, MCUs, sensors, experimental network and servers. The lab will also include demonstrations of existing projects conducted by different research centers at CITRI.

Entailed is an extended documentation for existing and available equipment, resources, and projects that are ready to be demonstrated. Additional IoT lab needs will also be discussed within this report.

CITRI Existing IoT Projects

1) K-Node Platform

K-Node Platform provides a modular IoT MCU that is suitable for different applications, functioning as a Mobility, Industrial, Wearable and Development Module. All different module configurations are based on Silicon Labs Mighty Gecko equipped with ARM M4:

https://www.silabs.com/documents/public/data-sheets/mgm12p-datasheet.pdf

All the modules will have an identical interface for loading software to the module.

> Mobility module

The **mobility module** will be used to monitor vehicles and moving equipment.

Figure 1 K-Node Mobility Module

The mobility module has support for the following sensors:

- IMU
- GPS
- Odometer
- Supply voltage

The mobility module is equipped with the following interface set:

- IMU
- LSM9DS1
- GPS sensor
- Quectel L86: L86 is an ultra compact GNSS POT (Patch on Top) module with an embedded 18.4 × 18.4 × 4.0mm patch antenna and utilizes the MediaTek new generation GNSS chipset MT3333 that achieves the perfect performance.
  Serial interfaces (SPI, I²C, UART)
- General purpose IO
- SD card
- External Sensors: Car Odometer.

Power: mains and rechargeable battery.

Connectivity:

- LTE: NRF9160, CAT M1 (nano SIM).
- LoRa: RN2483
- IEEE802.15.4 and BLE (included in the MCU)

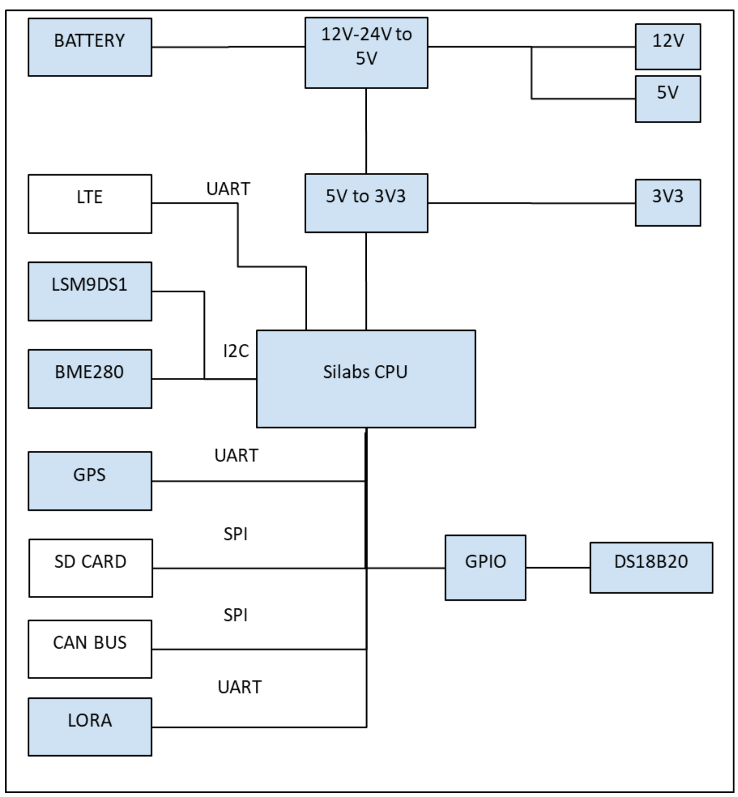

Figure 2 K-Node Mobility Module Architecture

>Industrial Module

The **industrial module** will be used for monitoring of industrial processes and environmental parameters (e.g., oil & gas pipeline and equipment monitoring).

The industrial module has support for the following sensors:

- IMU
- GPS
- Temperature sensor
- Gas sensor (CO2)
- Motion sensor
- Flow sensor
- Pressure
- Humidity

It is equipped with the following interface set:

- Temperatures as high as 80'C
- IMU: LSM9DS1
- GPS sensor: Quectel L86
- Temperature sensor (internal and external options)
- BME280 (on the PCB): The BME280 is an integrated environmental sensor developed specifically for mobile applications where size and low power consumption are key design constraints. The unit combines individual high linearity, high accuracy sensors for pressure, humidity and temperature in an 8-pin metal-lid 2.5 x 2.5 x 0.93 mm^3 LGA package, designed for low current consumption (3.6 µA @1Hz), long term stability and high EMC robustness.
- DS18B20 (External): The DS18B20 digital thermometer provides 9-bit to 12-bit Celsius temperature measurements and has an alarm function with nonvolatile user-programmable upper and lower trigger points. The DS18B20 communicates over a 1-Wire bus that by definition requires only one data line (and ground) for communication with a central Microprocessor.
- Pressure sensor (External): Sofrel CNPR
- Serial interfaces (RS485): 4...20 mA input for connecting standard industrial sensors
- General purpose IO (digital & analogue): All open inputs will be protected using optocouplers

Power: 9..30V, screw terminal

Connectivity: all external antennas with SMA connectors:

- NB-IoT
- LoRa
- IEEE802.15.4 and BLE (included in the MCU)

The device will have a total of five antenna connectors on the box: GPS, NB-IoT, BLE, 2 x LoRa.

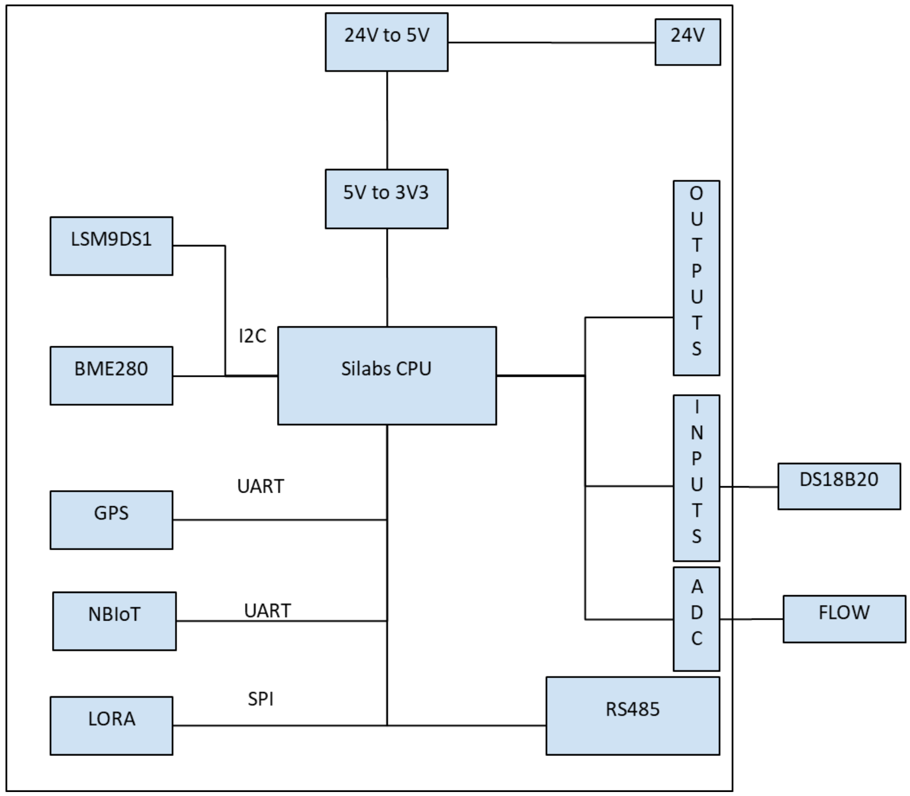

Figure 3 K-Node Industrial Module Architecture

>Wearable Module

The **wearable module** will be used for health care and fitness applications to detect the relevant parameters of a human.

https://www.okw.com/en/Products/Wearable-enclosures.htm

The wearable module module has support for the following sensors:

- IMU
- GPS
- Heart rate
- Body temperature
- Breathing
- Sunstroke (derived from a combination of multiple sensor values)

The wearable module is equipped with the following interface set:

- IMU: LSM9DS1
- GPS sensor: NRF9160
- Heart rate sensor: The MAX30102 is an integrated pulse oximetry and heart-rate monitor biosensor module. It includes internal LEDs, photodetectors, optical elements, and low-noise

electronics with ambient light rejection. The MAX30102 provides a complete system solution to ease the design-in process for mobile and wearable devices.

- Power: battery

Connectivity:

- IEEE802.15.4 and BLE (included in the MCU)
- LTE - CAT M1 (eSIM, chip antenna)

External sensors:

- Human body temperature
- Breathing sensor
- Sunstroke sensor

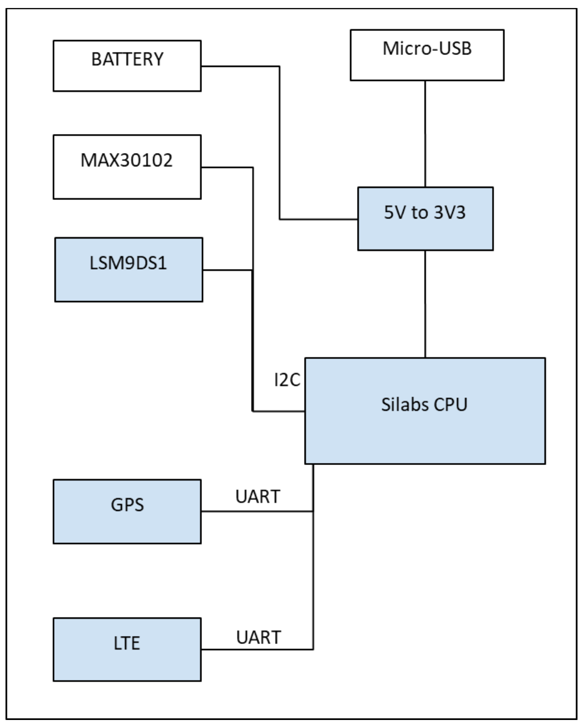

Figure 4 K-Node Wearable Module Architecture

>Development Module

The **development module** will be equipped with the following interface set:

- IMU: LSM9DS1
- Temperature/Humidity sensor: BME280
- Serial interfaces (SPI, I²C, UART)
- General purpose IO – 12 interfaces (digital & analogue)
- SD card
- Power: mains

Connectivity:

- IEEE802.15.4 and BLE (included in the MCU)
- NB-IoT (same as industrial module)

Option to connect external modules (e.g., communication modules using I2C).
NB-IoT antenna connected using SMA connector on the board.

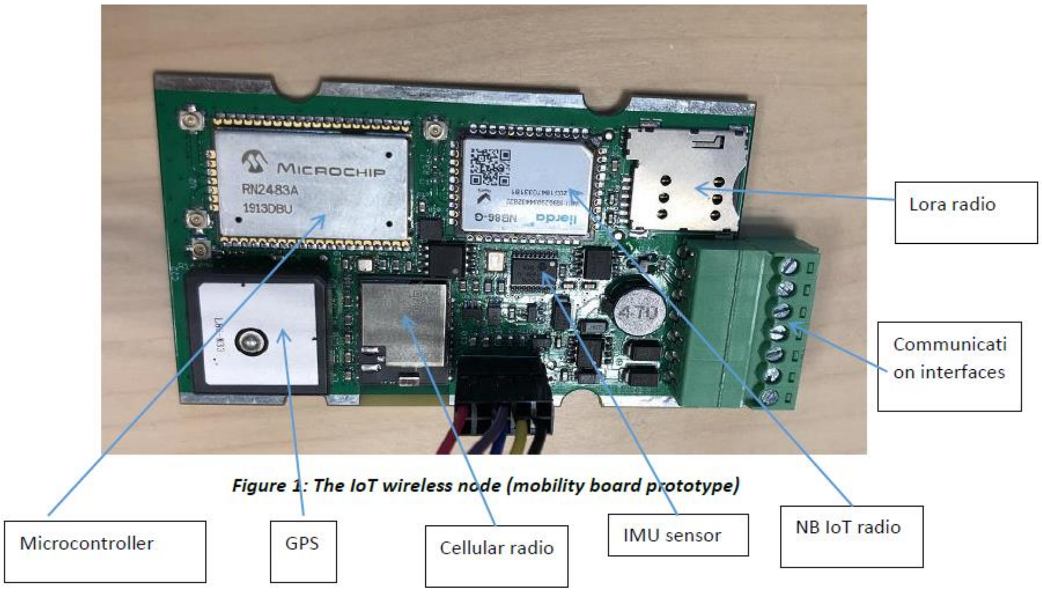

Figure 5 K-Node Development Module

2) IoT Gateway

	Short range radio		Long range radio		Internet			Attributes	
Model	**IEEE 802.15.4**	**BLE**	**LoRa**	**LoRa WAN**	**Ether net**	**WiFi**	**GSM 3G/4G**	**Power**	**Environme nt**
PuG /w LoRa	Silabs MGM12P (dual)	Silabs MGM12P (dual)	yes	yes	yes	USB add-on	yes	110-230 V AC	IP67 & -40 - +70 °C

Tables 6 IoT Gateway Interfaces

3) Interconnectivity with Commulocity and AWS IoT cloud platforms

Architecture of the Communication Protocol Stack and Cloud

Fig. 7 shows the communication protocol stack architecture of our IoT system. As we can see, the system consists of the following components.

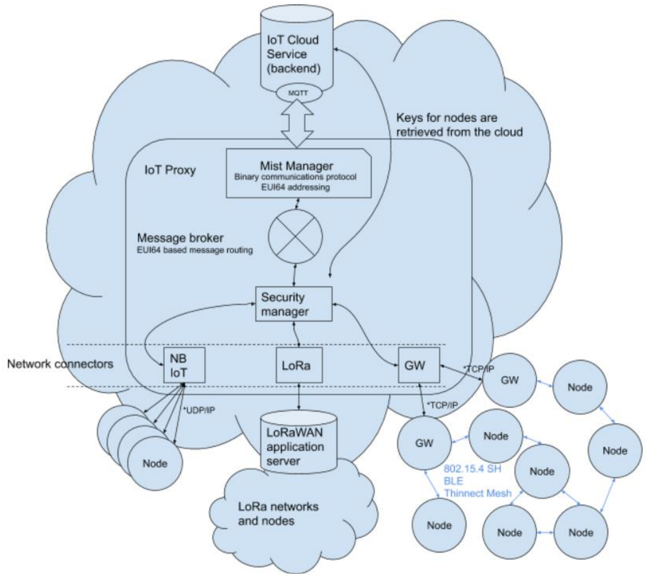

Figure 7 IoT Gateway Interfaces

IoT Cloud Service

AWS IoT cloud service instance that stores information about nodes, their configuration (rules) and sensor data. It Serves REST API and visualization / management interfaces.

IoT Proxy

A cloud server containing many software components that runs the Mist manager and router to communication interfaces.

Mist Manager

The role of the mist manager is to ensure that nodes are operating with the rules specified by the cloud and to forward data from the nodes to the cloud. It performs rule and data format translations between the XML/JSON formats used by the cloud and the binary representations used by the nodes.

Message Broker

The message broker moves messages between the Mist manager and different IoT networks. It allows using different communications technologies with one cloud instance. It uses the message broker routing capabilities to map EUI64 addresses to specific network connectors.

Security Manager

The role of the security manager is to provide node keys or connector certificates to the connector processes through a cloud-provider independent API.

NB IoT Communication Stack

NB-IoT node communicates directly over UDP with the NB-IoT network connector. The NB-IoT network connector communicates with the Message Broker and with the security manager.

LoRa Communication Stack

Communication with LoRaWAN networks is performed through a LoRaWAN application server, LoRaWAN management is left to existing LoRaWAN infrastructure (service providers) or solutions (custom setup with standard tools). Each LoRaWAN application server will have a dedicated connector.

We use AWS. The IAM, Device Shadows and Rules Engine would work together to enable the management of devices and their data. The data would be stored in one of the database solutions offered by AWS and basic functionality would be implemented in a basic device management dashboard. Each user will have its own isolated database instance (Fig. 6).

The cloud solution visualizes all the data collected by nodes using data tables and it also visualizes the current Mist layer configuration of nodes. The cloud solution also enables changing of node configuration (sensor data processing algorithm configurations) using a UI that is also provided in the Platform UI used in the development phase.

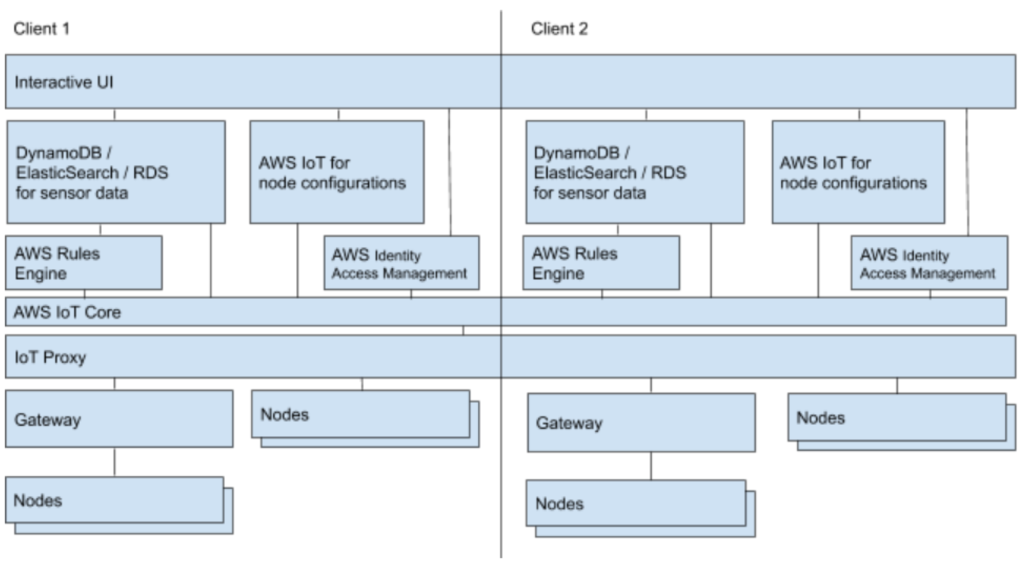

Figure 8 IoT Cloud Architecture

UI Design: Use case

We describe Platform usage with an application development use case. All solutions that the developer has created can be stored as projects in the Platform. Solutions can be saved as projects and saved projects can be opened for editing.

When starting the development of a solution the developer will create and name the project. When creating for example a pipeline monitoring solution the developer will specify the parameters of the solution using the visual UI of the Platform. The Platform visual user interface is then used to configure the embedded devices, generate code and test the solution. The following solution parameters are configured (Fig. 9):

- Hardware module used for development
- The sensors that will be interfaced to the hardware module
- Sensor data preprocessing algorithms
- Data communication interval
- Number of nodes in a deployment

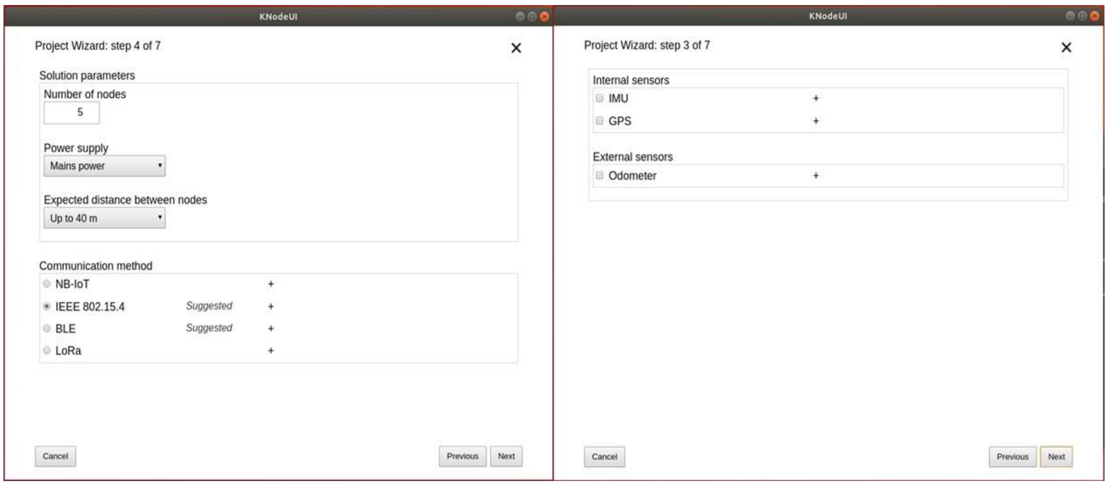

Figure 9 UI for IoT System Configuration

Once the parameters have been specified the developer can move forward with setting up the hardware, generating the software and testing the solution. These steps are described in more detail below:

- The developer connects the selected sensors to the hardware module or takes a hardware module, which already has sensors interfaced to it
- The backend software supplied by the Platform for testing the solution is automatically configured to accept data from the sensor nodes.
- The software for the embedded devices is automatically generated and loaded into the hardware module.
- The hardware module starts operation and communication of data to the backend.
- The user sees the data communicated and the number of sensor nodes providing data.
- The developer can create a test system (which could be also deployed in the field) that has the same number of devices as a real-life solution deployment would have. This provides the opportunity to validate the complete solution prior to moving forward with the actual product development.

System verification and demonstration

We tested and verified our IoT solution and all functions using a real use-case scenario. In particular, we configured our IoT mobile node to use IMU sensor and GPS that periodically send information about the motion (orientation) of the node and current location to the AWS at specific time periods. We present the results in Fig. 10. We can see that any change in the node orientation is reported to the cloud as well as the current location on the map.

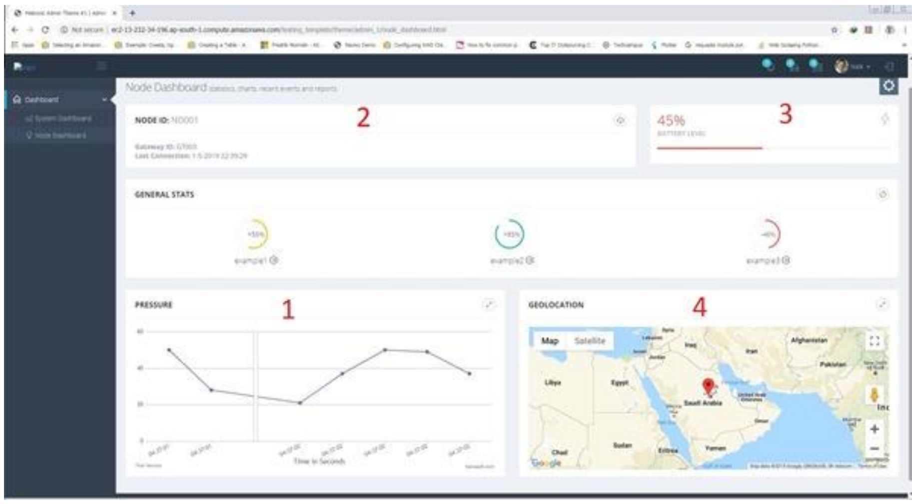

Figure 10 UI for IoT System Configuration

Applications and Case Studies

Crowd management

The Crowd Monitoring Solution is based on the wearable device created for the K-node platform. While the wearable device offers monitoring and tracking capabilities, the Crowd Monitoring Solution makes use of these capabilities to build a complete monitoring solution. Additionally, a beacon-based positioning solution is built, which enables tracking of wearable device locations in urban environments.

The current concept description covers the tracked wearable devices, the tracking solution, the sensing capabilities and the communication solution. The cloud-based visualization solution is not covered by the current concept as it is expected that an external third party will develop the visualization solution.

Crowd Monitoring Solution Description

The solution concept is usable and can be demonstrated in a fixed setting, this solution can be extended to facilitate additional features and capabilities (e.g., heart rate sensor data, cellular networking, etc).

The demonstrator can be set up outdoors on two open areas (e.g. city squares). 20 people will be equipped with wearable devices. The demonstrator will be able to provide information on which square a person is located and in which area of a specific square a person is at a given time. As people move from one square to another, the demonstrator can provide information also on this. A person can send a distress notification by raising his hand – as the person raises the hand, the identifier of the person and the location of the person can be visualized on the dashboard. The software on the wearable devices used in the demonstrator will not be power efficient as this is not a production-grade solution but is intended for demonstrating the Crowd Monitoring concepts.

Features of the demonstrator:

- Monitoring of people in two distinct areas
- Identifying the area where a given person is located
- Positioning a person within a given area
- Ability to send distress notifications by an individual (by raising the hand)

The Crowd Monitoring Solution builds on the K-node IoT Platform components and tools, extending the Platform with features needed for the Crowd Monitoring Solution

CITRI Available IoT Equipment and Resources

Enlisted below is a summary of available IoT equipment and resources. These resources were arranged from the NCAIBD and C3 research centers at CITRI. For the extended list kindly consult the attached excel file (IoT_Lab_Resources.xlsx).

#	Center	Project	Item(s)	Quantity
1	C3	K-Node Platform	Mobility Module	1
2	C3	K-Node Platform	Industrial Module	1
3	C3	K-Node Platform	Wearable Module	1
4	C3	K-Node Platform	Development Module	1
5	C3	IoT Gateway	Integrated Gateway	1
6	C3	Interconnectivity with Commulocity and AWS IoT cloud platforms	Server Software	1
7	NCAIBD	IoT Lab Equipment	Facility Equipment	7
8	NCAIBD	IoT Lab Boards	SBCs / MCUs	80
9	NCAIBD	IoT Lab Dev Kits	Development Kits / Modules	84
10	NCAIBD	IoT Lab Software	Software Licenses	3
11	NCAIBD	IoT Lab Use Cases	Applications / Development / Research	

IoT Lab Proposed Scheme

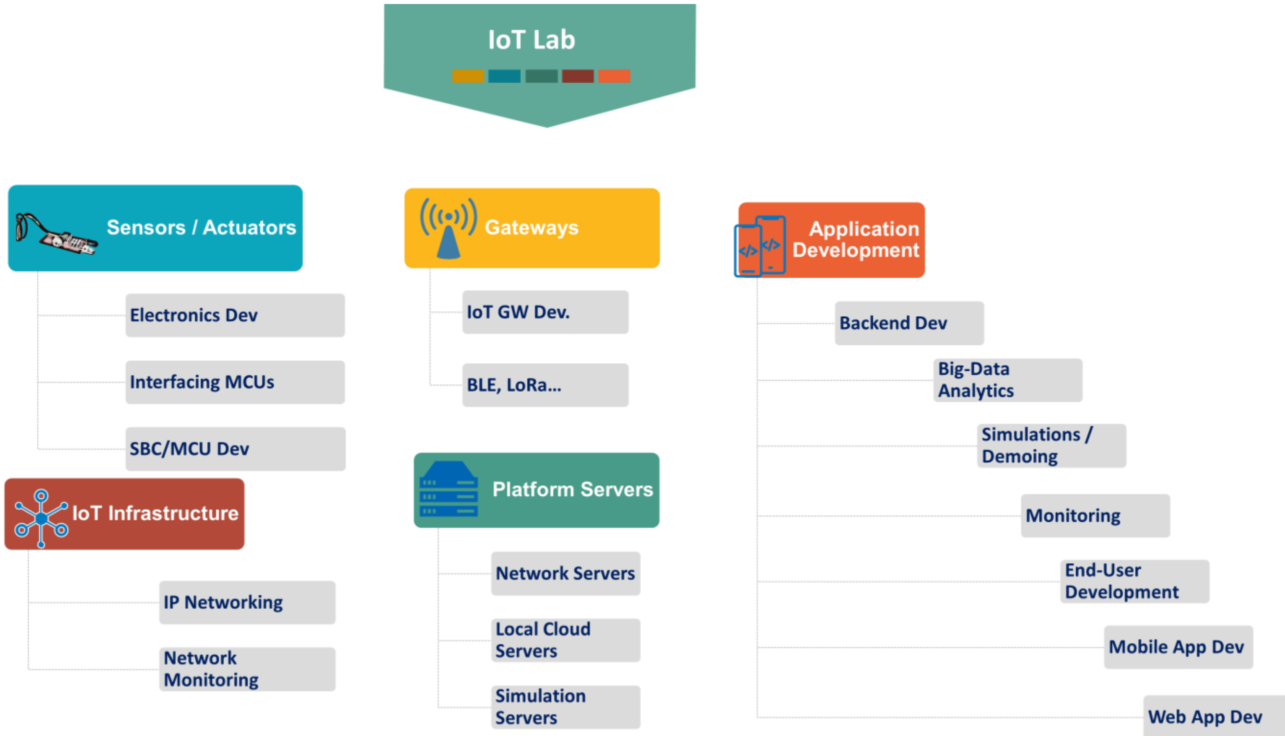

Figure 11 Proposed IoT Lab Sectioning and Scheme

IoT Lab Needed Resources

Regarding the IoT Lab Scheme described previously in this report, currently available lab equipment can be used to fulfil the Sensor/Actuator and Gateway sections of the lab. That is, the proposed lab will require equipment specific for IoT Infrastructure and Platform Servers sections. Specifically, to become fully functional, complete, and ready for research and development the lab will need the following essential facilities:

- A dedicated network for IoT experiments and all other lab connected servers and equipment.
- Platform Servers for data aggregation, analysis, simulations and advanced application development.
- Desktop computers for lab users.
- Large wall mount monitors for demo purposes.