Final Project Report
Detailed Form

I. Title of Proposed Project: IoT Open Innovation Platform

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IV. Project Report

i) Introduction

The widespread usage of smart phones and smart devices in the network today has transformed the network into a connected web of smart devices. These devices are made smart by the applications developed to provide huge benefits and services to the users. This is the Internet of Things (IoT).

To stay competitive and to be able to capture the potential IoT market, it is important to have the IoT platform and acceleration tools to facilitate the rapid development and adoption of IoT solutions for public and private markets, especially in new upcoming developing ASEAN countries. A common platform would allow integration of data and services from different systems. Thus allowing the combined operation of many different heterogeneous IoT systems onto one common open platform, the IoT open innovation platform. As illustrated in figure 1 below.

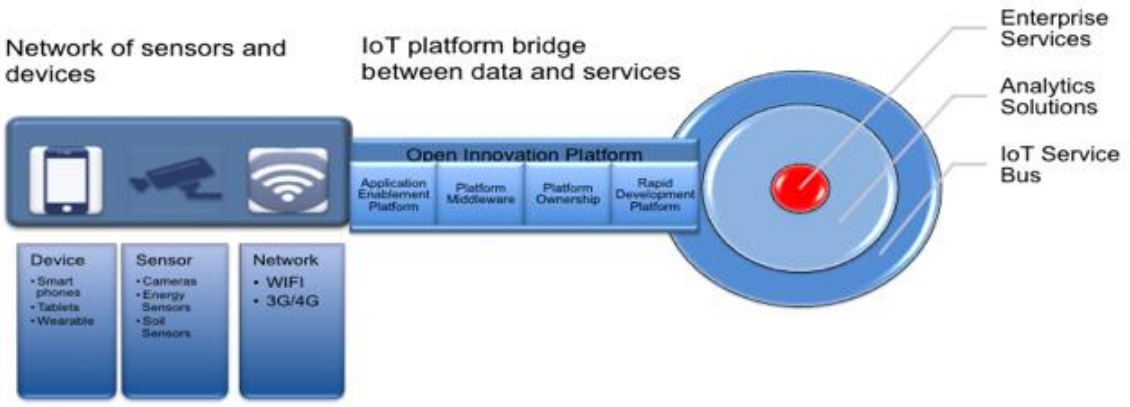

Figure 1: IoT Open Innovation Platform

The purpose of this research: IoT Open Innovation Platform, is to provide software enablement platform that is flexible and cost effective in the interest of research and development in IoT solutions for ASEAN markets. This requires the work-scope of the following:

A. Develop the software components of the application and communication middleware.

B. Demonstrate ICT solutions to the challenges surrounding Urbanization. IoT software platform to enable and improve the efficiency of developing effective urbanization IoT solutions for ASEAN countries.

C. Social Renovation in Rural Areas and/or Urban Areas

IoT software platform with required hardware infrastructure and sensor devices will be used for Proof of Concepts in healthcare, environment or aquaculture applications.

ii) Project Activities

(1) Development and Implement

The first objective of the project is to provide a software enablement platform that is flexible and cost effective in the interest of research and development in IoT solutions for ASEAN. This objective is achieved with the development of an IoT application enablement platform on the cloud which is used to develop IoT applications. The second objective is to develop Proof of Concepts (POC) solutions using this software platform in rural, healthcare, environment and aquaculture solution segments. Supporting technology in device connectivity and management are also developed to support the aggregation of sensory data to the cloud platform. This is the third objective which is to develop sensors, devices and gateways solutions for POC applications. The objectives are illustrated in figure 2 below.

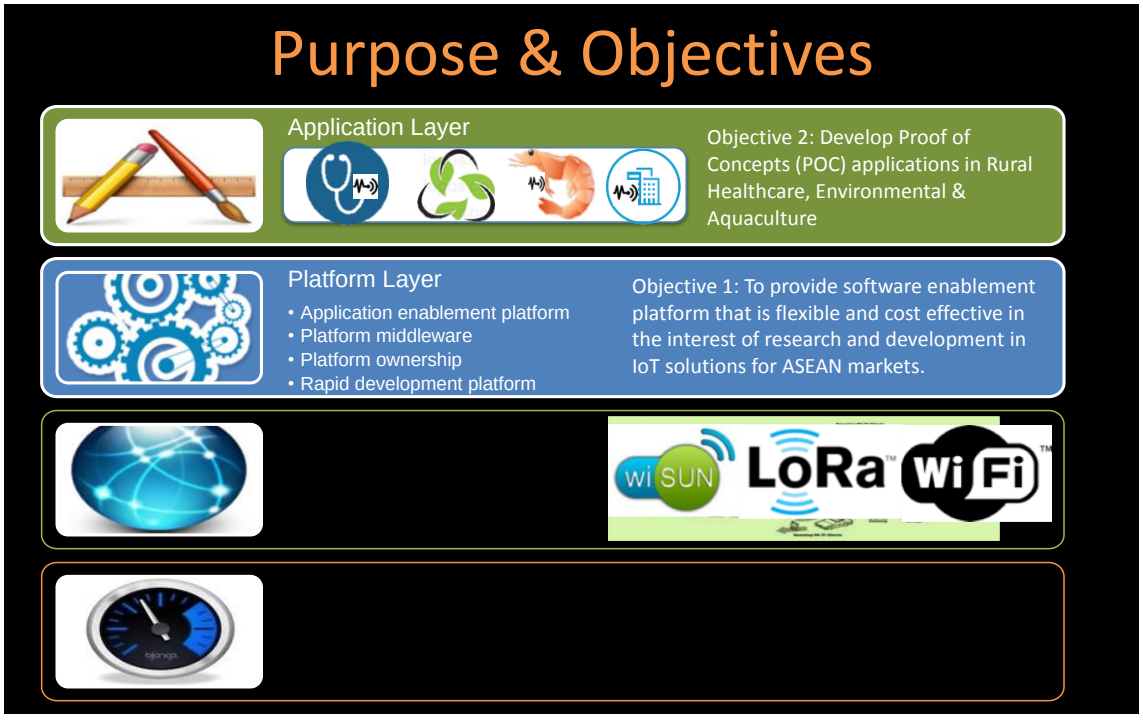

Figure 2: Project Purpose & Objectives

The first planning meeting was held in Hanoi on July 28-29, 2016. The purpose of the planning and collaboration meeting is to introduce the IoT Open Innovation platform and discuss capability alignment with ASEAN regional needs. Discussion on how collaboration can be best deployed and potential

Proof of Concept sites were identified. Visits were also conducted to IoT users in Vietnam; Vietnam Posts and Telecommunications (VNPT) Technology IoT Center and Hoa Lac Hi-Teck Park (HHTP).

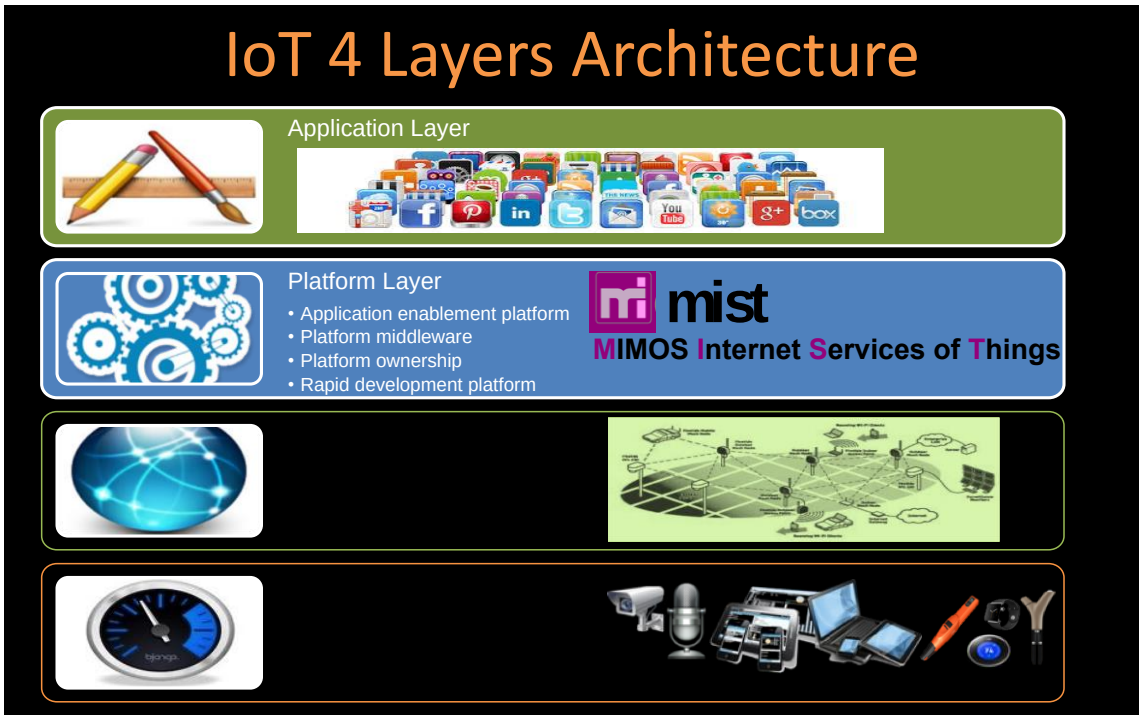

Figure 3: IoT 4 layers architecture

The first version of IoT Open Innovation Platform software was completed in August, 2016 by MIMOS and made available to project partners HUST and VNU in September 2016. A training workshop on the software platform was provided to HUST and VNU in Hanoi on Sept 27-29, 2016. The training was given by Ngoi Se Keng from MIMOS. A photo of training class is shown in photo 1 below.

Photo 1: Training Workshop in Hanoi, Sept 27-29, 2016.

To plan Proof of Concepts, an equipment purchase proposal for development was made on January 18, 2017. The equipment requested are to be used for platform and application development.

4 Proof of Concept solutions were suggested based on IoT Open Innovation Platform that would help demonstrate the purpose and objective of the research project. The Proof of Concept solutions required applications to be developed unique for it's purpose and objective. The software platform is hosted at MIMOS research center and made available for our partners and collaborators to use for development. The software platform was also made available on premise to assist in the development of devices and gateways.

In staging and development of the Proof of Concepts solutions, big screen displays were used to show information and analysis on a dashboard or in a command and control center environment. Illustration of the setup shown in figure 2.

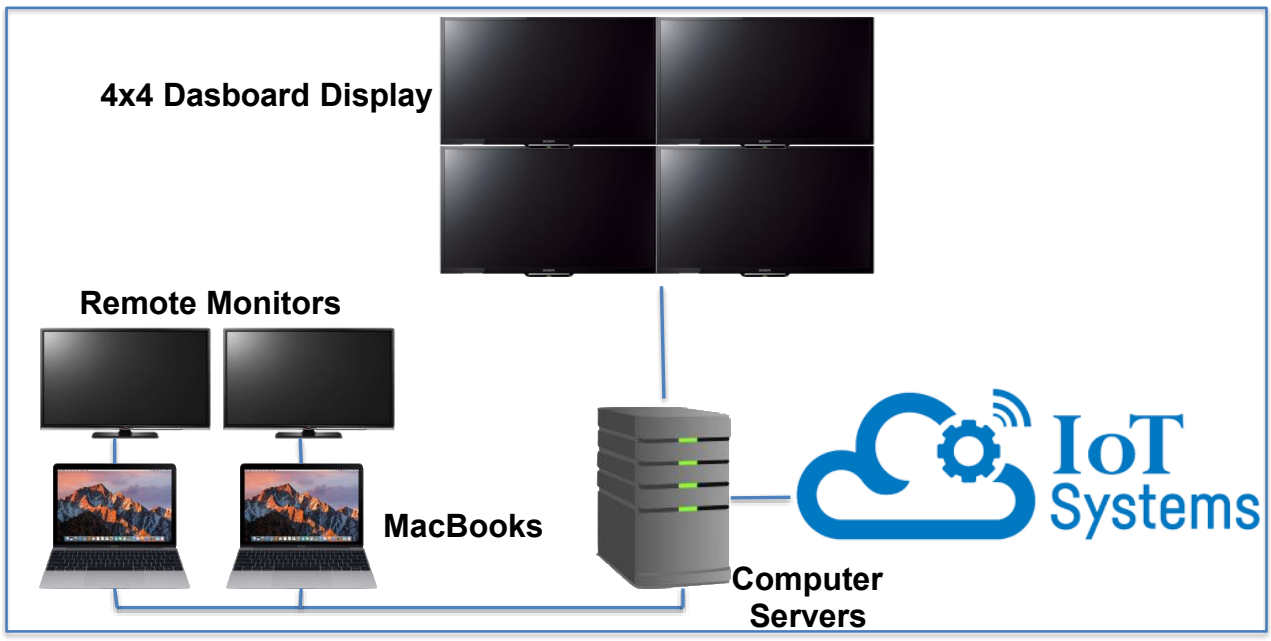

Figure 3 : Setup Illustration

During the development work, observations and feedbacks are gathered to ascertain whether the purpose of an Open Innovation Platform is achieved and whether any shortcomings can be addressed in 2017 and beyond.

On February 15-16, 2017, a system design and review workshop was held in Kuala Lumpur. The objective of the workshop is to review the collaboration progress and conduct a platform architecture design review for the POC system deployment in Vietnam. A System POC Workbook was established for each POC identified for Vietnam. The System POC Workbook consists of a high level architecture diagram, equipment list and cost and high level schedule.

The outcome desired from the development work using this equipment, are the prototype Proof of Concept solutions in a) Environmental monitoring air quality, b) Scrimp farming and c) Suburban healthcare. An actual deployment of the solutions was desired but unfortunately due to resource issues and delays in getting the equipment has made it not feasible to deploy the solution at an actual site.

An assessment of the IoT Open Innovation Platform's usability and capability was carried out. And whether any improvement to the platform, communication module and dashboard can be recommended for enhancement. A few proposals were suggested like a language pack for non-English speaking users but was not implemented in the suggested time frame.

MIST, the IoT open innovation platform identified to provide the medium of collaboration in market deployment and technical development was released in August 2016. HUST developed the BK-IoT platform to interface with MIST platform. Development of sensory and gateway systems for POC applications in the lab was completed in Q3, 2017. The accomplishments are:

- HUST completed an IoT based AQI Monitoring and Notifying System prototype. See figure 4 below.
- HUST completed CoAP/UDP/IPv6 Protocol Stack on ARDUINO MEGA under Contiki/Linux. See figure 5 below.
- HUST completed a Communication Protocol based on Reinforcement Learning and 802.15.4e TSCH that can adapt to different traffic patterns of applications. See figure 6 below.
- HUST completed a Communication Protocol based on Orchestra Scheduler of TSCH that can provide different levels of QoS. See figure 7 below.

IoT-based AQI Monitoring and Notifying System

- **Functions:**
  - **Measuring following parameters**
    - SO_2, CO, NO_x, O_3, $PM_{10,}$ PM2.5, µg/m^3
  - **Transmit these parameters to the System**
  - **Based on Vietnamese Regulation, calculating AQI Index**
  - **Notifying different Client's Subsets**
    - Sensitive People (Old People and Children)
    - Non-sensitive People
- **Our System implemented at HUST:**
  - **Measuring Box:**
    - Sensor Hardware Platform: ARDUINO MEGA
    - Sensing Components: CO – MQ7, PM – GP2
    - Sensing Components: Module Wifi ESP 8266: sends Data to Server through 802.11
  - **Server:**
    - MQTT Broker: MQTT Mosquito
    - MQTT Client: MQTT Pahoo
  - **Clients** (Sensitive and Non-Sensitive Clients)

AQI	Quality of Air	Actions	Colour
0-50	Good	Not influence to health	Blue
51-100	Average	Sensitive people (old people and children) should limit outdoor activities	Yellow
101-200	Bad	Sensitive people (old people and children) should limit outdoor activities	Orange
201-300	Very Bad	Sensitive people (old people and children) should stay at home. Other should limit outdoor activities	Red
>300	Dangerous	Every people should stay at home	Brown

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Figure 4: IoT Based AQI Monitoring And Notifying System.

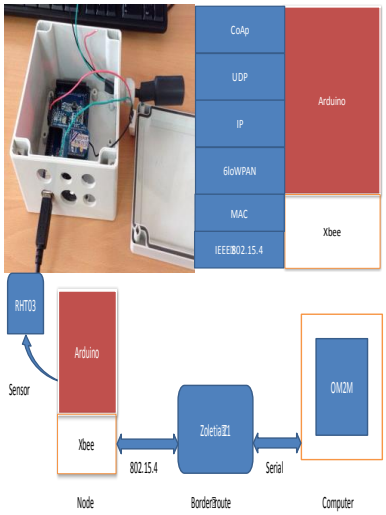
CoAP/UDP/IPv6 Protocol Stack

- **Enabling Low-Power Low-Cost Smart Agriculture, Smart City Application**
  - Selected Protocol Stack selected:
  - CoAP/UDP/IPv6-RPL/6LoWPAN/802.15.4 – CSMA/CA
- **Based on IPv6-IoT Protocol Stack**
- **Selected Operating System: Contiki/Linux**
- **Selected Hardware Sensor: ARDUINO MEGA**
  - is compatible with different sensing components
  - Is compatible with different actuators

→ **Necessary to build CoAP/UDP/IPv6-RPL/6LoWPAN/ 802.15.4 under Contiki, running on top of ARDUINO MEGA**

→ **Built System at HUST:**

- ARDUINO MEGA
- CoAP/UDP/RPL/802.15.4



Successful data transmission between ARDUINO MEGA and Server

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Figure 5: CoAP/UDP/IPv6 Protocol Stack

TSCH-based Adaptive Communication Protocol

- **A TSCH-based WSN that can:**
  - Adapt to predefined traffic of application and to additional traffic of application
  - Based on a new standard 802.15.4e
  - Wireless but provides Wired-like QoS Performance (90% Packet Delivery Rate)
    - ✓ Running TSCH within 200 initial frames
    - ✓ Calculate successful and unsuccessful transmission probabilities
    - ✓ Based on this result, defining an appropriate transmission sequence at each node
    - ✓ Successful Implementation for CoAP/UDP/RPL/6LoWPAN/6TiSCH/802.15.4e
    - ✓ Contiki/Linux
- Successful simulative evaluation and implementation in real testbed
  - Cooja/Contiki Z1/Zolertia
  - REMote/Zolertia - Multihops

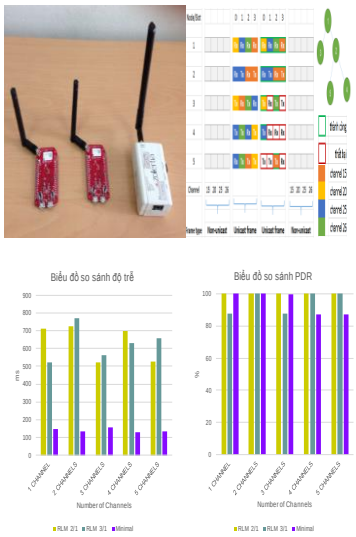

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Figure 6: TSCH-based Adaptive Communication Protocol.

MIST 2.0 (PaaS version) developed by MIMOS was released in January 2018. This version was hosted on a PaaS platform in MIMOS.

Providing Different QoS Levels by Communication Protocol

- It is important to provide different QoS Levels in WSN
- In CSMA/CA 802.15.4 WSN: difficult to control QoS Levels
- **Our proposition:** Communication Protocol that provides
  - 3 Levels: QoS 0, 1 and 2
  - TSCH-based (802.15.4e)
- **Simulative Evaluation:**
  - Contiki/Linux Z1/Zolertia
  - Different QoS Levels
- **Implementation in a Labtest:**
  - Multihop (2 hops)

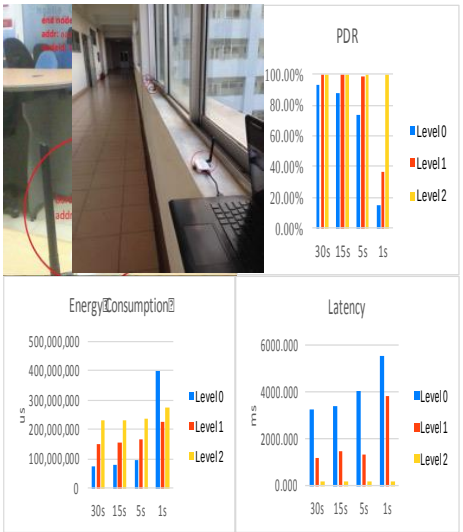

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Figure 7: Providing different QoS levels by communication protocol

IoT Solutions Workshop was conducted during Sept 25-27, 2018 in Hanoi. Accomplishments were:

- IoT Open Innovation Platform training to staffs from Hanoi University of Science and Technology; and Vietnam National University.
- IoT Solutions review
- Latest installation of MIST IoT software platform

Project equipment was received only in Q2 & Q3, 2018. The delay in procuring the equipment has made it difficult to deploy the solutions at previous planned actual site in Vietnam. However, collaboration with a Malaysian company HomeGrown to provide aquaponics monitoring system for their aquaponics organic farms took place. Please see figure 8 below. A second project also in progress, collaborating with MIMOS, UPM, BAU, UTB, PTIT, INTROP, NICT and JIRCAS; on using the ASEAN IVO IoT Hub to collect and analyse data on peat forests in Indonesia, Vietnam, Malaysia and Brunei. (NAPC: Networked ASEAN Peat Swamp Forest Communities)

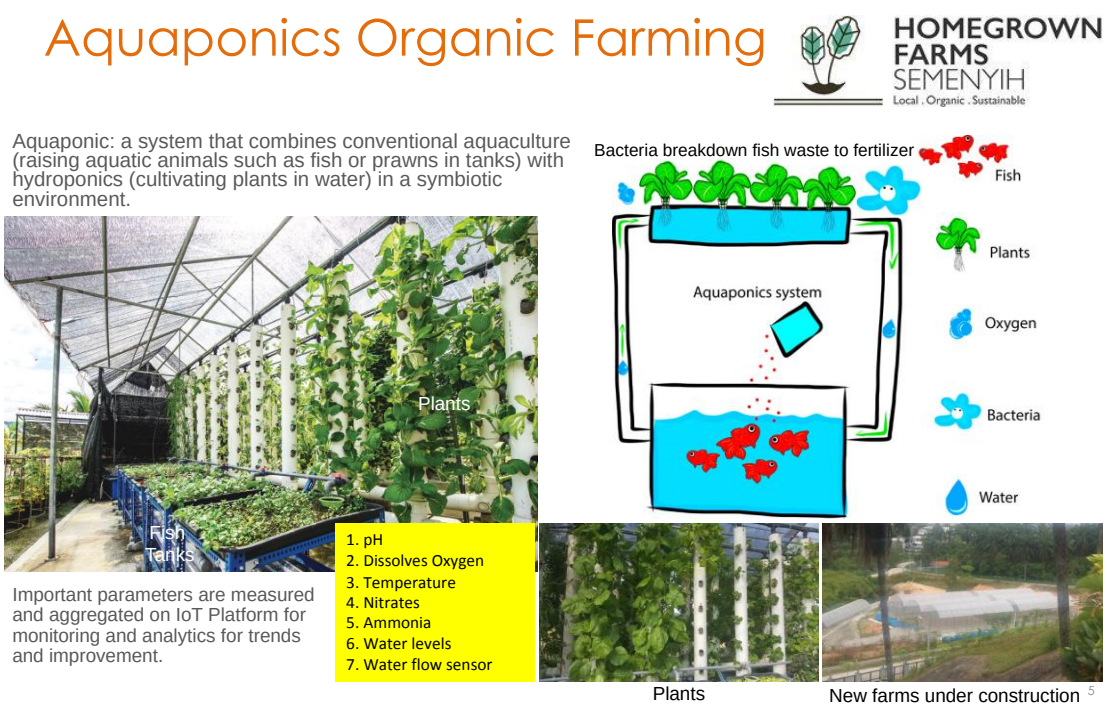


Figure 8: Aquaponics Organic Farming

MIST, IoT open innovation platform (new version) was released in Q3, 2018. Establishment of the ASEAN IVO IoT Hub at MIMOS, BITX Lab was completed in Q4, 2018. Please see Photo 3 below. The IoT Hub provides complimentary cloud IoT platform services for ASEAN IVO members to use to develop IoT solutions.

Photo 3: ASEAN IVO IoT Hub at MIMOS.

(2) Leveraged Resources and Participants

In this project, excellent collaboration took place, with each partner contributing as follows:

IoT software platform: MIMOS
Wireless sensory network and protocols: HUST, NICT
POC solutions and planning: MIMOS, HUST, VNU, I2R

MIMOS developed and provided the software platform and conducted training to partners. Instances of the platform was installed at HUST to assists in development of the system.

HUST developed the following and demonstrated in the lab.

- IoT based AQI Monitoring and Notifying System prototype.
- CoAP/UDP/IPv6 Protocol Stack on ARDUINO MEGA under Contiki/Linux.
- Communication Protocol based on Reinforcement Learning and 802.15.4e TSCH that can adapt to different traffic patterns of applications.
- Communication Protocol based on Orchestra Scheduler of TSCH that can provide different levels of QoS.

NICT and MIMOS assessed the feasibility of using Wi-SUN for wireless connectivity.

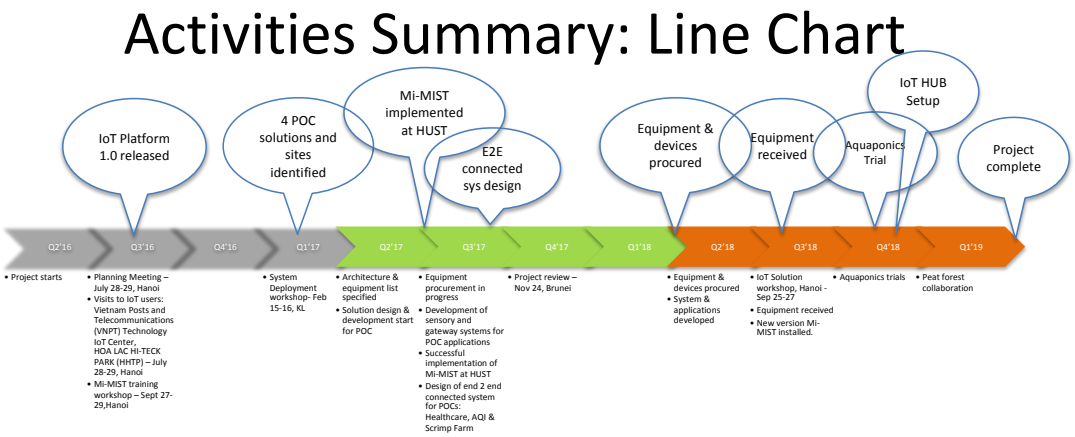
POC solutions were contributed by all partners. I2R and MIMOS evaluated using the platform for the mobile IoT project.

(3) Findings and Outcomes

The outcomes of the project are as follow:

1. Release and availability of the IoT Open Innovation Platform software.
2. Software platform training to partners in using the platform for application development.
3. Protocols and wireless networks demonstrated in the lab.
4. POC systems were identified. Aquaponics and Peat Forest POCs are still on going. Expected to be completed in 2020.
5. ASEAN IVO IoT HUB established to provide complimentary services to ASEAN IVO project members.

Please see figure 9 for a summary of the activities in a line chart.



Challenges:

1. Long procurement duration and logistics complexity to purchase and obtain equipment and devices.
2. Short of development resources. Requires funding.

Recommendation:

1. Simplify equipment purchase procedure.
2. Provide funding for research and development resources.

Figure 9: Activities Summary: Line Chart

(4) Broader Impact

The provision of an open innovation platform enables the usage by research institutes, academic and commercial entities in ASEAN, especially in countries where project funding is an issue and the purchasing capacity is limited compared to countries outside the ASEAN region. This platform and the supporting connectivity solutions can be used either from the cloud or on premise, giving flexibility to deployment and commercial commitment.

The ASEAN IVO IOT HUB is an example where projects can be developed utilizing services provided on the HUB. This cloud-based solution is provided complimentary to ASEAN IVO project members to minimize development and operations expenses. Members with an approved ASEAN IVO project funding can subscribe to the complimentary services provided.

Talent is also an important requirement in the development and adoption of IoT solutions. This platform can be used to educate the growing talent resources in the ASEAN region to learn about IoT and practice development work.

(5) Future Developments

The platform will be made available at ASEAN IVO IOT HUB for ASEAN IVO project members. Training can be provided. There are plans to further enhance the platform with recommendation from users and customized project proposals.

iii) Social Contribution

2 patents pending filing. 1 patent filed. Platform is used to educate trainees in training sessions at MIMOS. Small POC projects in aquaculture and agriculture are using the platform for dashboard and data collections.

iv) Summary

This three-years project has commenced in 2016 with the release of the first version IoT Open Innovation platform software in August 2016 and the identification and high level specifications of 4 Proof of Concepts in IoT applications in Vietnam. The POCs were demonstrated in the lab on it's capability and connectivity. On site POCs are being conducted in Malaysia with HomeGrown on aquaponics and Peat Forest in Selangor, Malaysia. The latest version of the platform software was available in Q3, 2018 and is available on the cloud at ASEAN IVO IoT HUB at MIMOS to provide complimentary IoT services for members to conduct projects and research.