IVO FORUM 2018, 26th - 29th November, Jakarta

Mobile IoT- IVO Project 2016-2018

Institute for Inforcom Research (I2R), Singapore
Hanoi University of Science and Technology (HUST), Vietnam
MIMOS, Malaysia
NICT, Japan

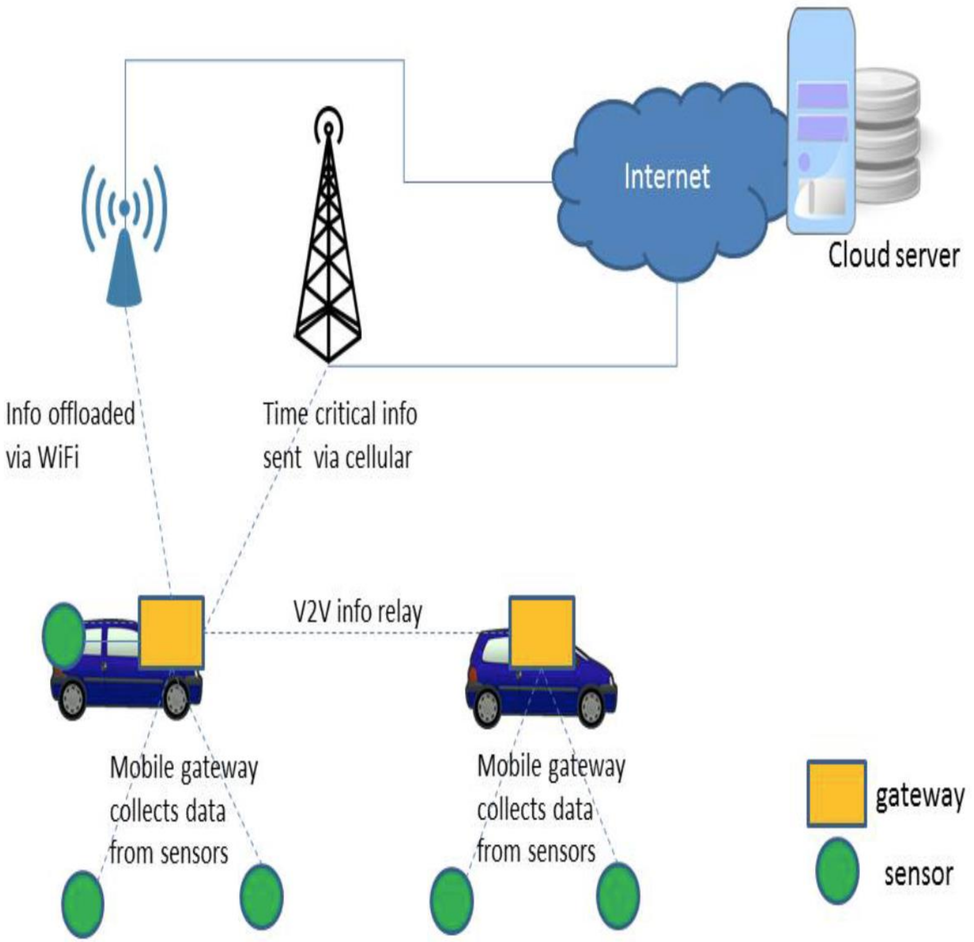
Mobile IoT Project (March 2016 → March 2018)

- **Project's Target - Addressing many challenges in a Mobile IoT System:**

→ Pertaining to connectivity optimization, node placement, protocol stack development, and low latency scheduling

→ Developed some testbeds to demonstrate the potential of the technology in addressing real world problems such as

→ Agriculture, environment monitoring, video surveillance, as well as wireless grid application.



Mobile IoT Project (March 2016 → March 2018)

- **Collaboration:**
  - → Discussions and idea exchange among the members from NICT, I^2R, HUST, and MIMOS.
  - → Joint authorship of papers by HUST and I^2R.
  - → Jointly develop system testbed of Mobile IoT addressing different application scenarios.
- **Social Contribution:**
  - → Published several research articles on international conferences and journals
  - → Contributed to standardizations and patents.
  - → Participated in public exhibitions and forums.

Mobile IoT Project (April 2016 → March 2018)

❑ Broader impact and Future Development:

→ System testbeds of Mobile IoT applications

→ Wider application of the technology in other countries, especially in the developing countries.

→ Benefits other projects within ASEAN-IVO such as smart farming and smart aquaculture.

❑ Finding and outcomes:

→ Dynamic prioritization mechanism in LTE network

→ Node placement for coverage and connectivity optimization among sensors, gateways, and sinks.

→ Low latency scheduling for large scale networks

HUST Contribution – In collaboration with I2R, NICT, MIMOS

- Challenge of a Mobile IoT System: to minimize low-delay between Sensors and Mobile Gateway in order to assure reliability

→ If delay is not small enough → MG will lost data

→ Especially in low-power low-cost Wireless Sensors Networks (CoAP/UDP/RPL-IPv6/6LoWPAN/802.15.4), also MQTT/TCP/IP/802.11

- Propose Large Scale Heterogeneous Mobile IoT Architecture

→ Design different algorithms for this architecture to minimize delay

→ Evaluate simulatively according current well-known IoT protocol stacks

- Development of a part of this Architecture in a Labtest
- Submitting journal of HUST, I2R, MIMOS, NICT

HUST's Contribution – Large Scale Heterogeneous Mobile IoT

- **Large Scale Architecture consists of:**
  - Networks of Sensors – Relay Node
  - Networks of Relay Nodes – Mobile Gateways
- **Requirement: Minimizing End-to-End Delay due to mobility property of Mobile Gateway**
- **Design algorithms**
  - **In Network of Sensors – Relay Nodes**
    - →**By designing a new Communication Protocol utilizing Reinforcement Learning Algorithm for IEEE 802.15.4e**
    - →CoAP/UDP/RPL-IPv6/6LoWPAN/802.15.4
  - **In Network of Relay Nodes - Mobile Gateways**
    - →**By designing Optimization Algorithm (MMWSF) for Path Scheduling between RNs-MG**
    - →TCP/IP/802.11

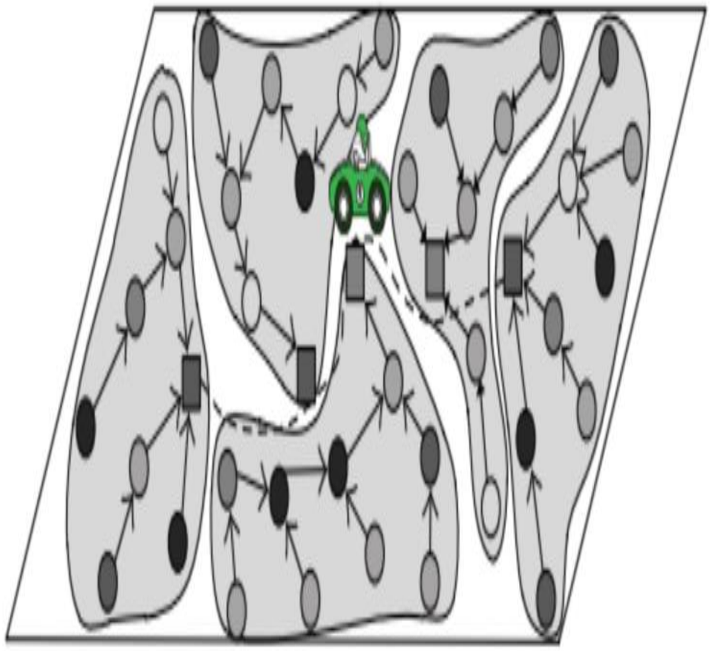


Figure 1. Large Scale Heterogeneous Mobile IoT Architecture

HUST's Contribution – Large Scale Heterogeneous Mobile IoT

❑ Networks of Sensors-RN

- RL (Reinforcement Learning) based on TSCH and Utilize a joint model of data transmission of scheduling and routing algorithm
- A strategy to select an action based on feedbacks from previous actions
- Define a new schedule based on a previous schedule
- The new schedule is adaptable to the application's traffic
- Integrate the scheduling algorithm to the IoT protocol stack CoAP/UDP/RPL-IPv6/6LoWPAN/802.15.4e

❑ TSCH (Time Slotted Channel Hopping)

- Time is divided into timeslots, timeslots are grouped into slotframe.
- Delay is bounded.
- Utilize network throughput.
- Increase network capability: Use upto 16 channels at the same time.
- Channel hopping: Reduce interference, Improve Reliability, Channel Hopping Formula

HUST's Contribution – Large Scale Heterogeneous Mobile IoT

- **Network of RNs-MG**
  - Minimize moving distance
  - Minimize packet delay between RNs-MG

  → Propose of MMWSF, Integrated with street systems

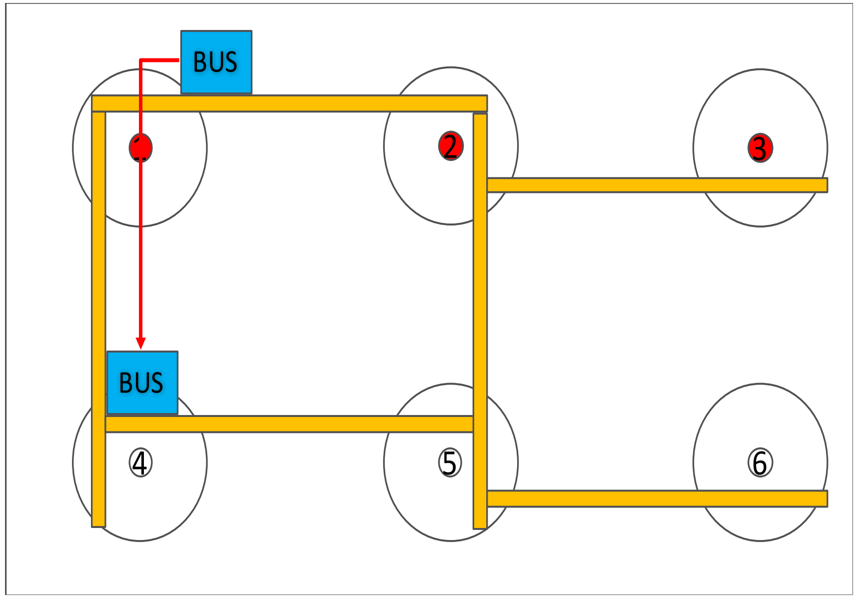
- **Description of MMWSF**
  - Defining an Objective Function:

$$f(MG, RN) = \alpha * distance(MG, RN) + (1 - \alpha) * totalDelay\_of\_Packets\_Up\_to\_NowAt(RN)$$

ɑ is set to a small value → precede total delay of packets

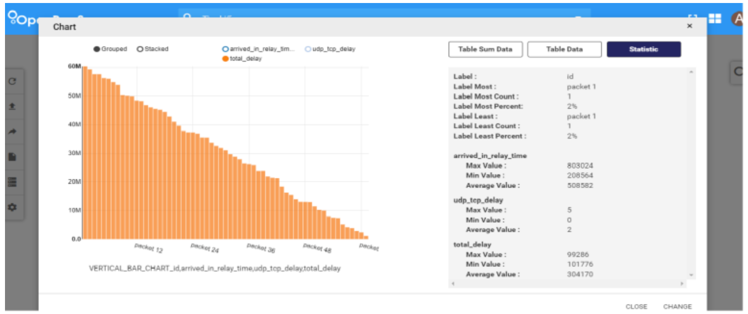
ɑ is set to a large value → precede the distance that the bus has to move

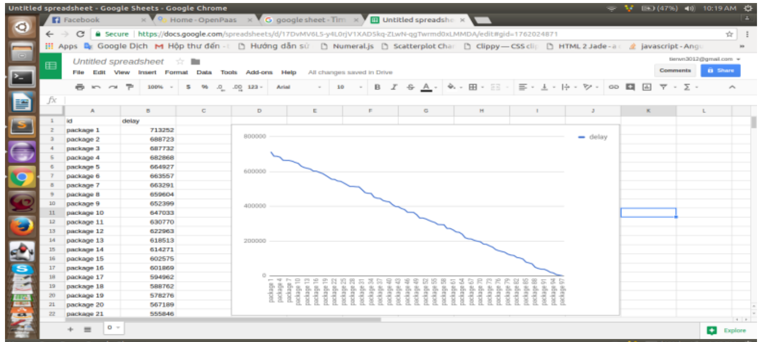
  - Operations: 2 Steps
    - ✓ **Step 1:** The MG chooses a RN to visit
      - The RN whose optimization function's return value is minimum.
      - Mark the node as visited.
    - ✓ **Step 2:** The MG repeats Step 1 until all RNs are visited.
    - ✓ If all RNs are visited →2 choices
      - Continue collecting data: reset 'visited' state of all RN then back to step 1
      - Stop collecting data

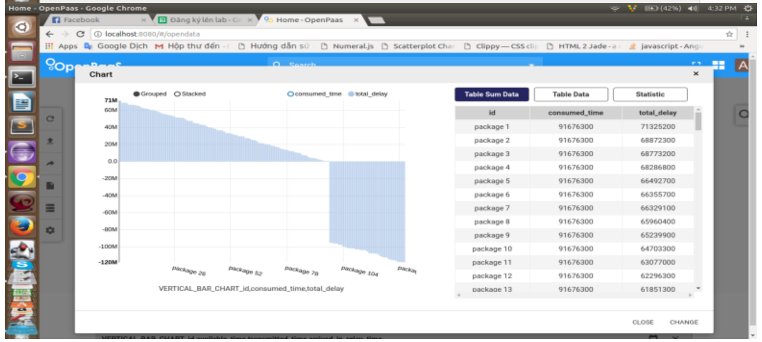


HUST’s Contribution – Large Scale Heterogeneous Mobile IoT

- **Simulative Evaluation:**
  - Successful modelling according to IoT Protocol Stacks
  - Implementation with Contiki/Linux and Java/Linux
  - Topology Scenarios:
    - ✓ Networks of Sensors – RNs: 9 nodes/1 WSN, each WSN is represented by a MG
    - ✓ Network of RNs – MG: 30 RN, 1 MG
  - Each WSN: data emitted once per 30s, 45s…
  - RNs: 30 RNs, situated within an area of 1000*1000m
  - Sensors features setup similarly to Z1,
  - RNs hardware setup: Raspberry Pi3
  - MG: unlimited Buffer with high processing capability
- **Performance Evaluation:**
  - End-to-End Delay:
    - ✓ Simulated Delay at RN: small and negligible
    - ✓ Delay appeared within WSN and network of RNs-MG

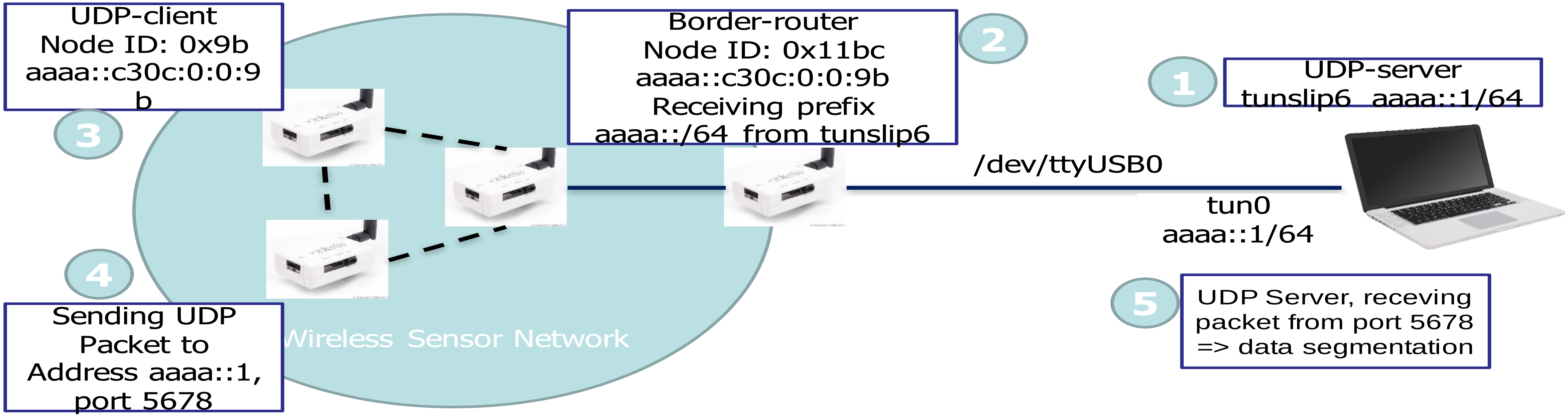






HUST's Contribution – Lab-test for this Architecture

- **We have built demo of Network of Sensors – Relay Node**
- → A small Labtest with 3 Zolertia, running under Contiki/Linux
- → CoAP/UDP/RPL-IPv6/6LoWPAN/802.15.4
- → Connected to OM2M Platform
- → Data visualizing (from Sensors – Gateway) in Webbrowse
- → Data controlling from Smartphone to Sensors



I2R Contribution – In Collaboration with

I^{2}R's Contribution (in collaboration with HUST):

- **Based on ideas discusses during project's meeting:**
  - → Propose a connectivity optimization method for mobile sensors with static relay nodes
  - → Propose a coverage optimization method with connectivity constraint for static sensing nodes with mobile gateway
  - → Propose a hybrid group paging scheme to support dynamic prioritization
  - → Develop a connected lab testbed of MG with multiple sensor nodes to collect temperature and humidity information

I²R's Contribution – Connectivity Optimization in Mobile WSN

- **Network Deployment setup:**
  - Sensing area of size $W \times L$
  - M mobile sensors with communication radius R_c
  - Sampling period of T
  - One base station as information sink, to which all sensors must be connected
- **Requirement: At each sampling period, the must be a valid link connecting mobile sensor to the base station**
- **Goal: Minimize the number of static nodes to achieve the connectivity requirement**

I²R's Contribution – Coverage Optimization with Connectivity Constraint

- **Network Deployment setup:**
  - Sensing area of size $W \times L$ with N targets at pre-defined locations
  - M mobile sinks with random trajectory and transmission radius R_t
  - Sensing radius of R_s and sampling period of T
  - One base station as information sink, to which all sensors must be connected
- **Requirement: All target locations must be covered by at least one sensor, and all sensors must be connected to at least one mobile sink**
- **Goal: Minimize the number of static nodes to achieve the coverage as well as the connectivity requirements**

I²R's Contribution – Hybrid Group Paging

- **Network Deployment setup:**
  - Sensing area covered by a single cell base station
  - Sensors are grouped into *F* sub-groups, and they may have different priority at different time
  - Some sub-groups may have the same priority, and some groups may be inactive
- **Requirement: Support a paging mechanism which is able to assign dynamic prioritization to different sub groups of nodes**
- **Goal: Modify the LTE group paging method to support this feature**

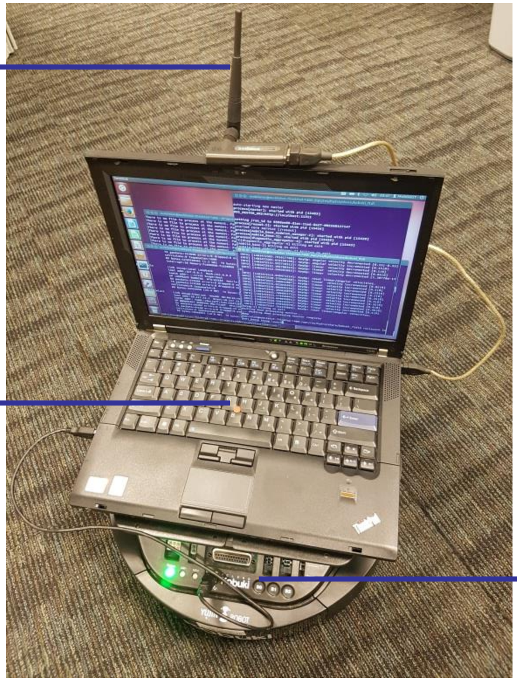
I²R's Contribution – A connected Lab Testbed of Mobile Gateway

Network Deployment setup:

- Single mobile gateway implemented using Iclebo Kobuki robot base, carrying a laptop with WiFi dongle configured as access point
- Sensing node is implemented using Raspberry Pi with temperature and humidity sensor

WiFi Dongle

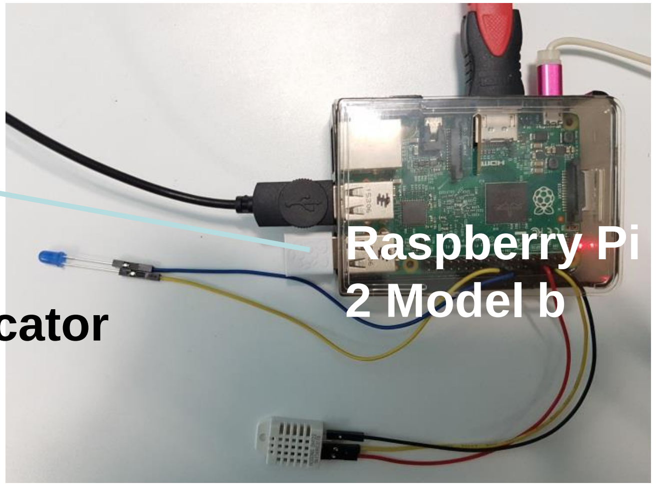
Linux Server running Hostapd and ROS



Iclebo Kobuki Robot base

WiFi Dongle

LED indicator

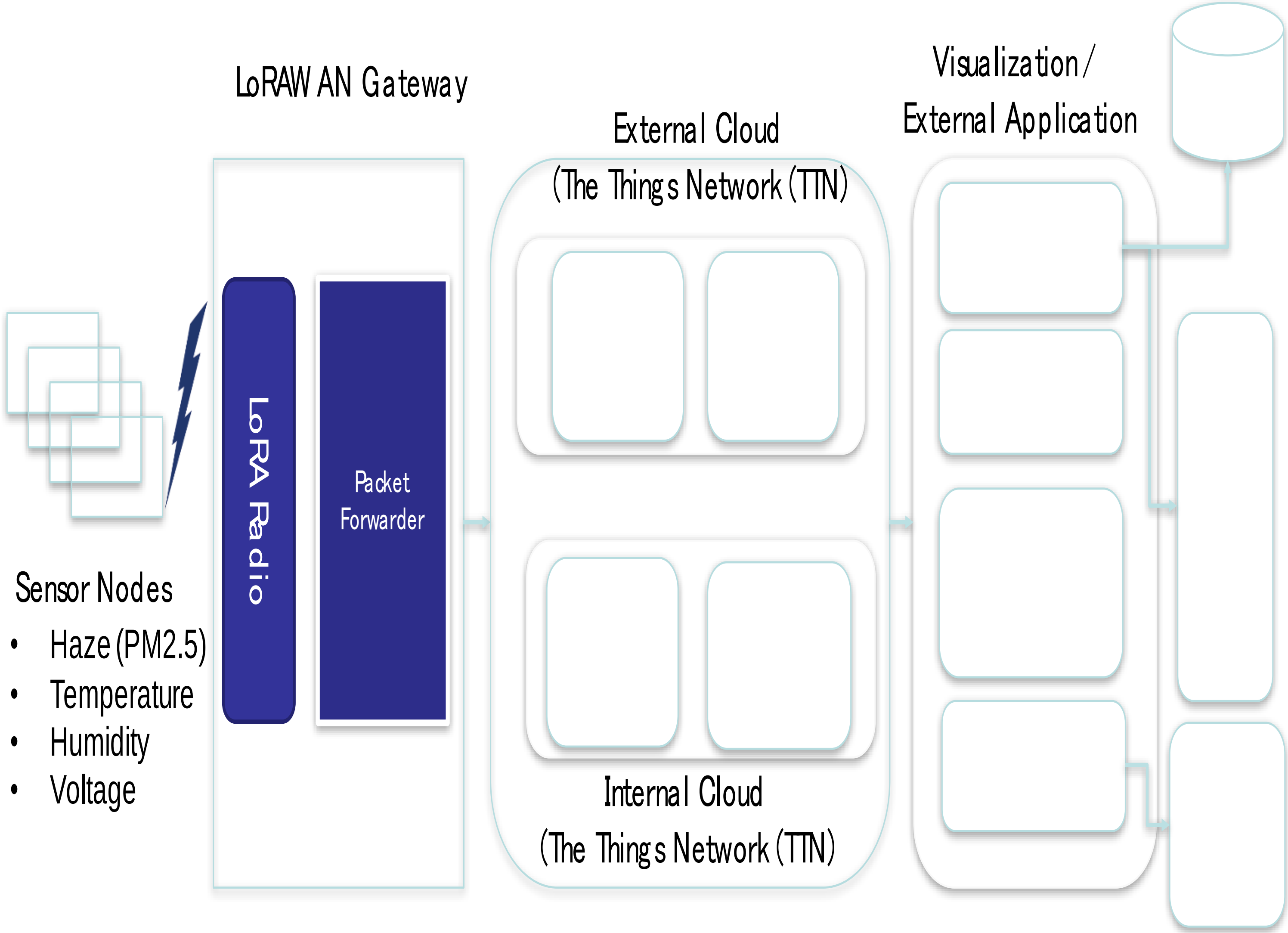


DHT 22 sensor

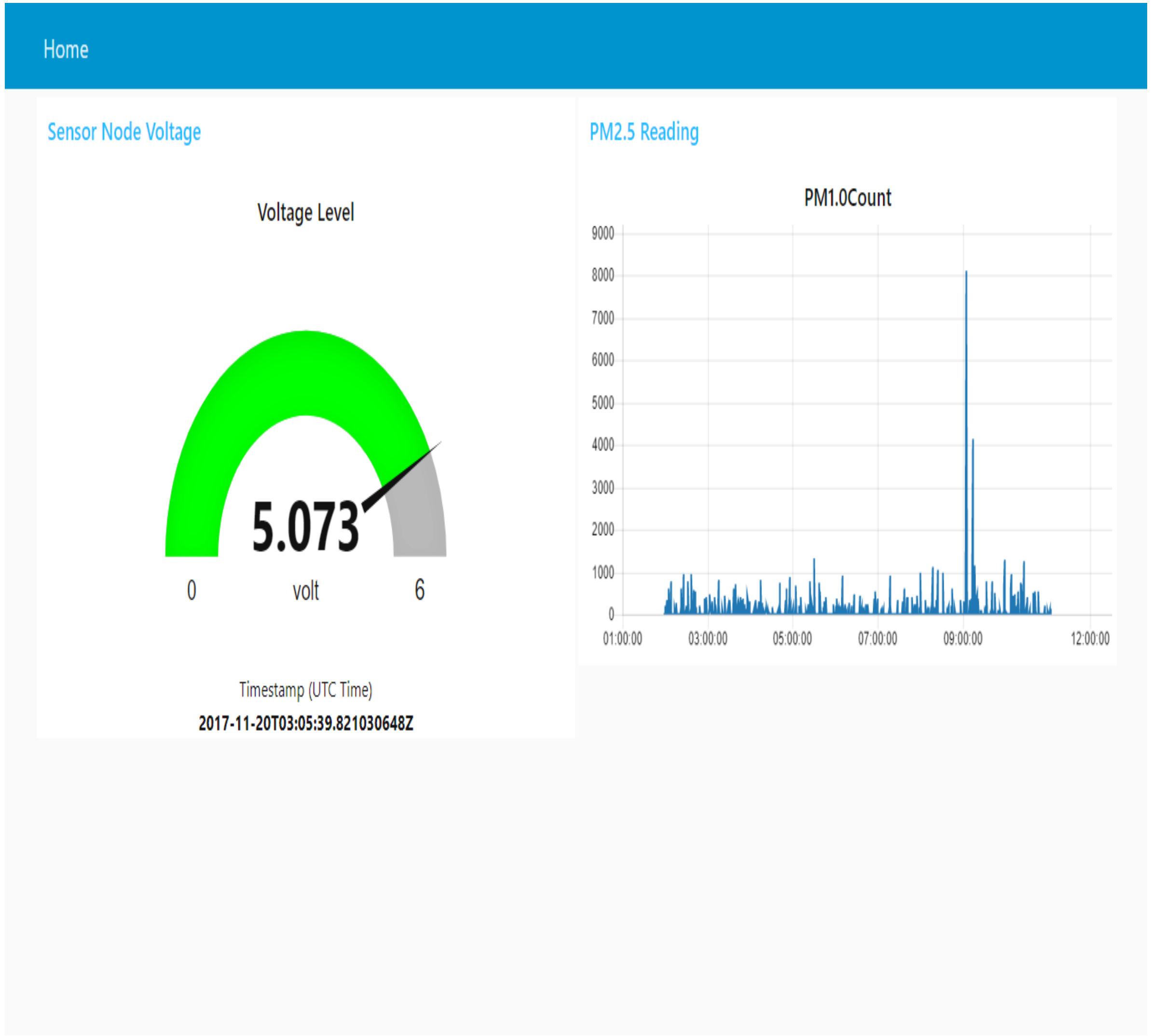
MIMOS's Contribution

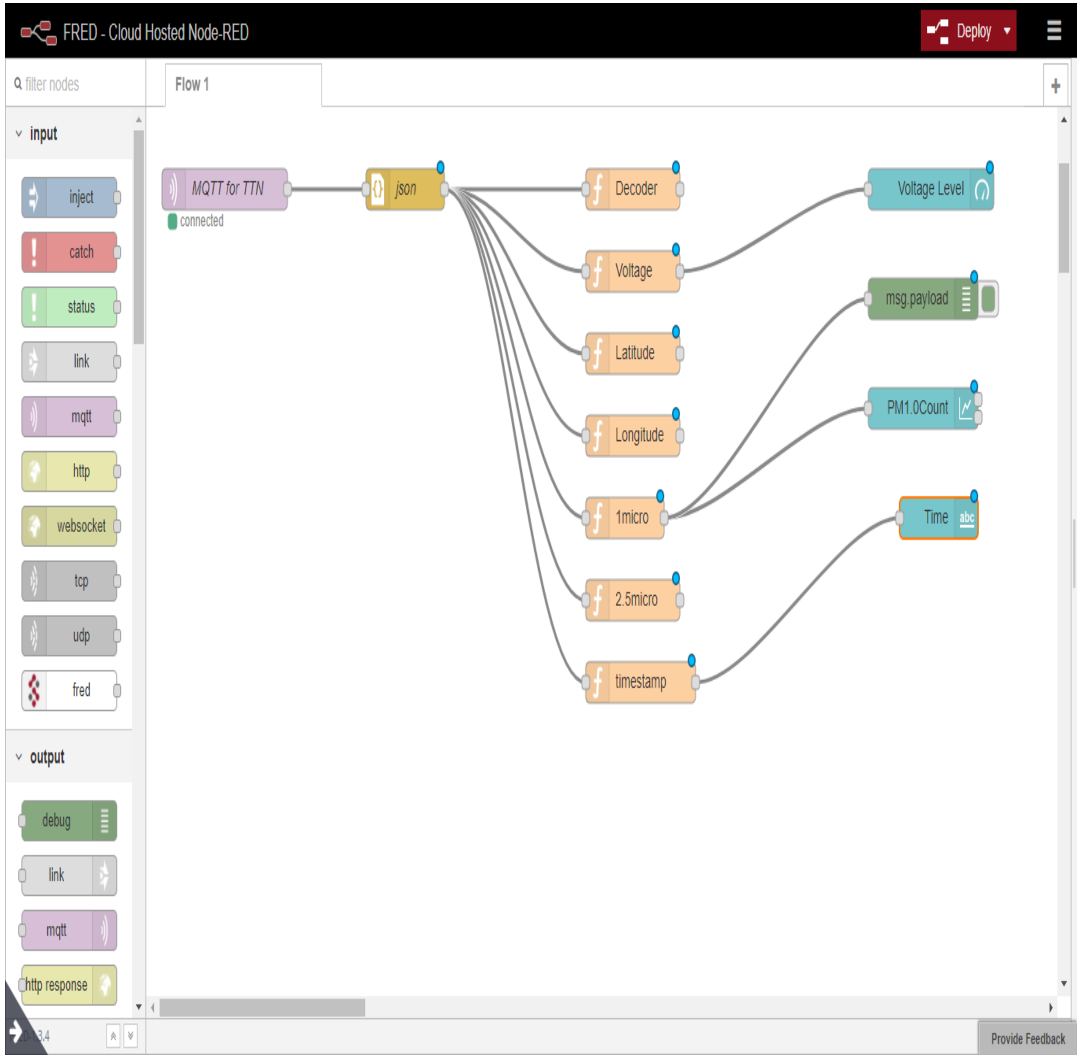
- **In environmental monitoring**
  - **monitoring air** for quality, carbon dioxide and smog-like gasses, carbon monoxide in confined areas, and indoor ozone levels
- In particular, we developed a solution on Low Power Wireless Access (LPWA) with LoRAWAN technology to monitor the PM2.5 air pollutant index (fine particles that naked to eye)
- Here, we developed a HYBRID LoRAWAN Gateway
  - External LoRAWAN Cloud
    - Push the sensor data to the external cloud
  - Internal LoRAWAN Cloud
    - Push the sensor data to the internal cloud (local setup)

MIMOS's Contribution



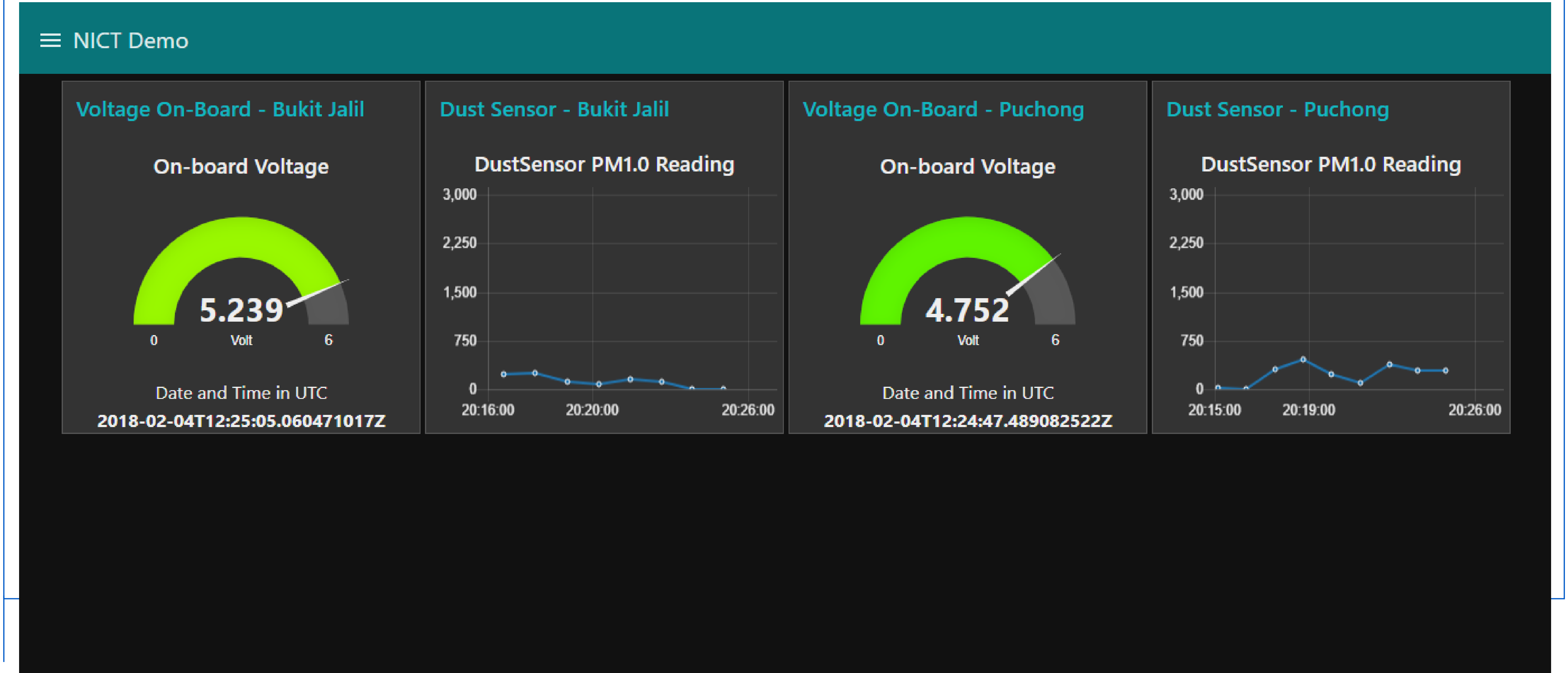
MIMOS's Contribution





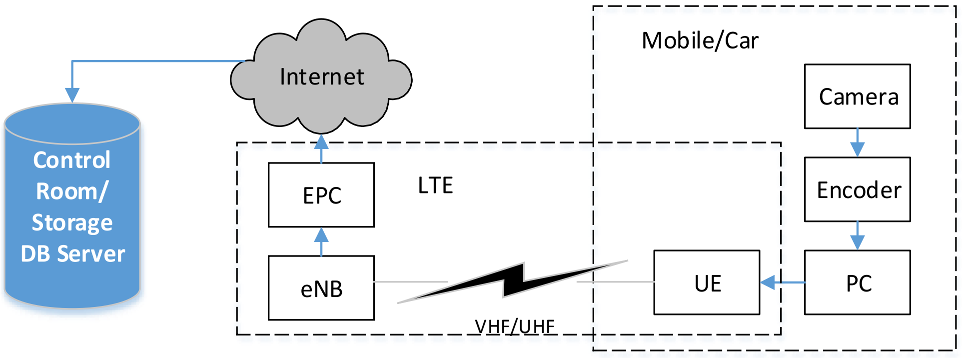
Haze Sensor & Hybrid IoT Gateway

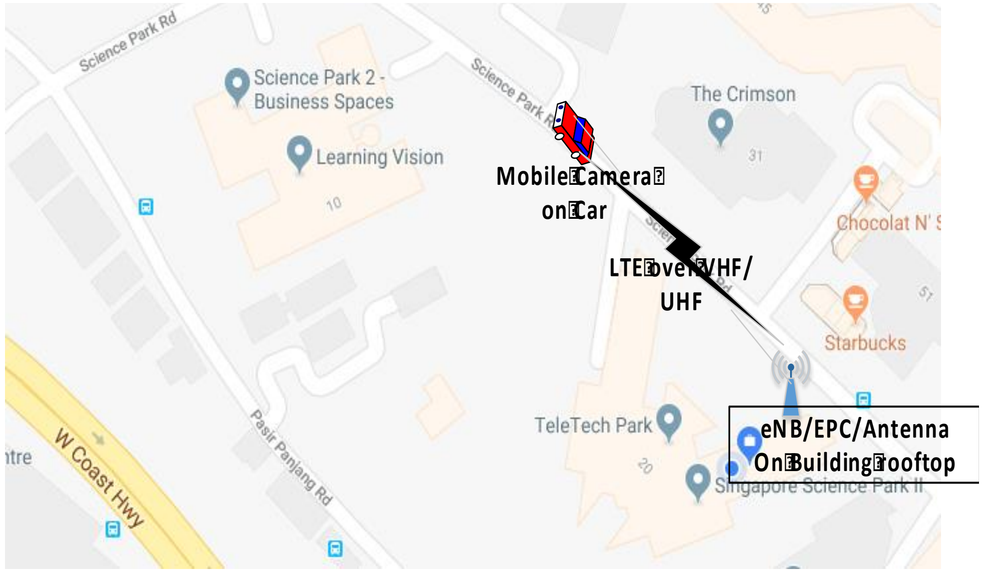
Dashboard


NICT Demo
Voltage On-Board - Bukit Jalil
On-board Voltage
5.239
0
Volt
6
Date and Time in UTC
2018-02-04T12:25:05.060471017Z
Dust Sensor - Bukit Jalil
DustSensor PM1.0 Reading
3,000
2,250
1,500
750
0
20:16:00
20:20:00
20:26:00
Voltage On-Board - Puchong
On-board Voltage
4.752
0
Volt
6
Date and Time in UTC
2018-02-04T12:24:47.489082522Z
Dust Sensor - Puchong
DustSensor PM1.0 Reading
3,000
2,250
1,500
750
0
20:15:00
20:19:00
20:26:00

NICT Contribution - Mobile surveillance technology applications

- Terrorists consider Singapore as prized target due to.
- Terrorist thread in Singapore is growing bigger than ever before
- Mobile surveillance related experiments by NICT
- Mobile surveillance using channel aggregation





NICT Contribution – Wireless Grid Technology Applications

- The applied areas for the SUN radio are expected to become diversified
- Depending on the diversification of the future radio communication service demand or the diversification of applications
- This work assumes the effective applications of high capacity data network and ultra-low-energy operation network to the Mobile IoT System