Mobile IoT- IVO Project 2016-2018
Contribution of HUST & I²R Group

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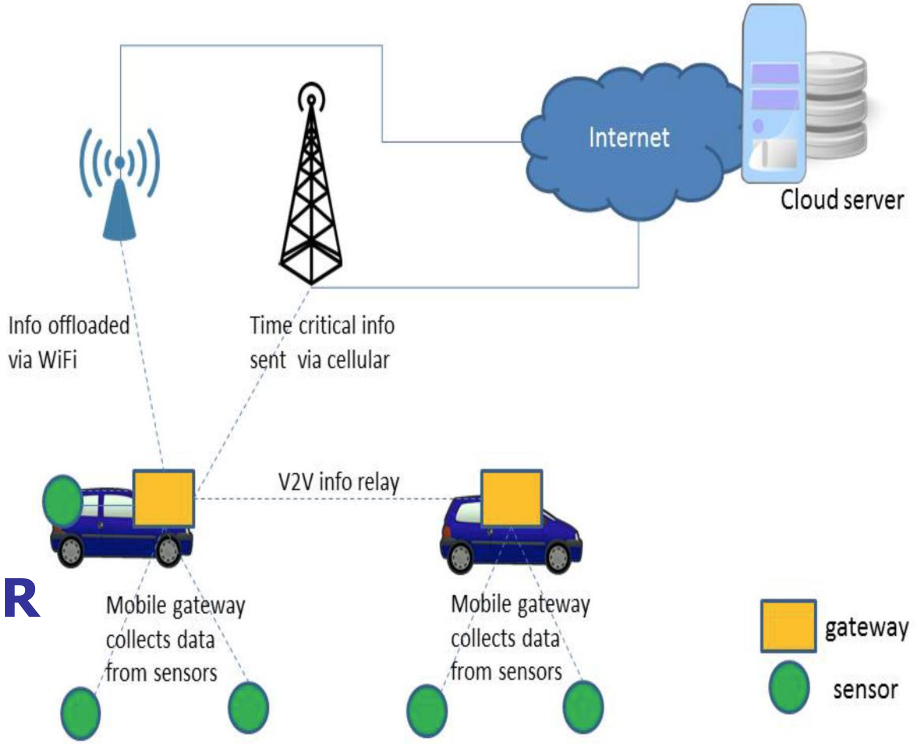
NICT (Director Fumihide Kojima)

Overview of Mobile IoT Project (March 2016 → March 2018)

- **Partners:** I²R, MIMOS, HUST, NICT
- **Focus** on implementing Mobile Gateway (MG)
  - → Improving the efficiency of WSN
  - → Simplifying the deployment and setup
  - → Improving its Scalability



- **Project Activities:**
  - **Face-to-Face Project Meeting: January 2017 at I²R**
- **HUST's Contribution:**
  - **Based on ideas discusses during project's meeting** → Propose of Large Scale Heterogeneous Mobile IoT Architecture and Evaluate simulatively
  - **According to Project Proposal** → Development of a lab connected testbed with fixed MG

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HUST's Contribution

- **Based on ideas discusses during project's meeting,**
  - → Propose a Scheduling Mechanisms for collecting data while optimizing total path and loss at buffer size
  - → Propose a Multichannel Mechanism for minimizing delay between sensors – MG while maintaining high packet delivery rate
- **After the 1st Meeting, at HUST**
  - → Propose a Large Scale Heterogeneous Mobile IoT Architecture, Evaluate simulatively in Java/Linux
- **According to Project Proposal:** Due limited facilities, development of a lab connected testbed with fixed MG
  - → 3 REMotes, OM2M Platform
  - → Data visualizing with Webbrowser and Smartphone
  - → Data Controlling from Smartphone to REMotes

I2R’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
  - **According to Project Proposal:**
    - → Develop a lab testbed of MG with multiple sensor nodes to collect temperature and humidity information
    - → Develop web application to visualize the captured data as time series chart

MIMOS’s Contribution

- **MIMOS’s Contribution:**
  - 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)
  - → 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)

HUST's Contribution – Large Scale Heterogeneous Mobile IoT

- **Large Scale Architecture consists of:**
  - Different small WSNs
  - Each WSN is represented by a RN
  - MG is moving for collecting data from RNs
- **Requirement: Minimizing End-to-End Delay due to mobility**
- **Goal: Minimize End-to-End Delay between**
  - **Sensors – RNs**

    →**By designing a new Communication Protocol utilizing Reinforcement Learning Algorithm for IEEE 802.15.4e**

    →CoAP/UDP/RPL-IPv6/6LoWPAN/802.15.4
  - **RNs – MG**

    →**By designing Optimization Algorithm (MMWSF) for Path Scheduling between RNs-MG**

    →TCP/IP/802.11

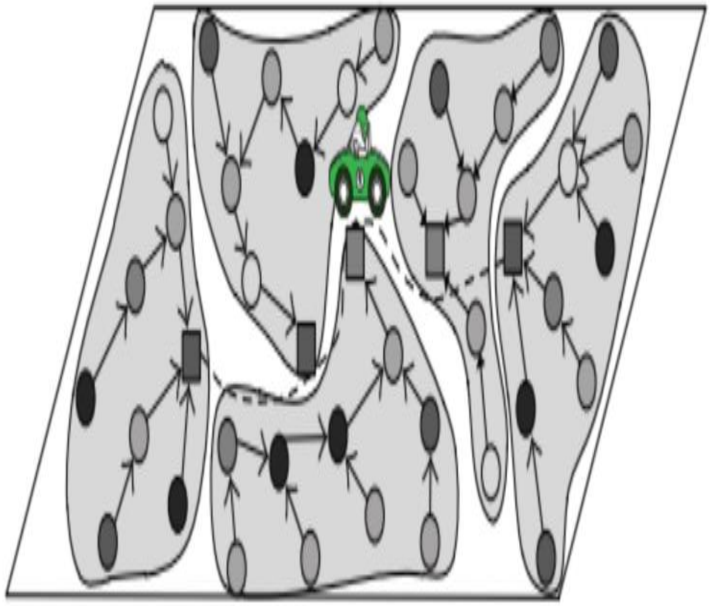

Figure 1. Large Scale Heterogeneous Mobile IoT Architecture

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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

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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

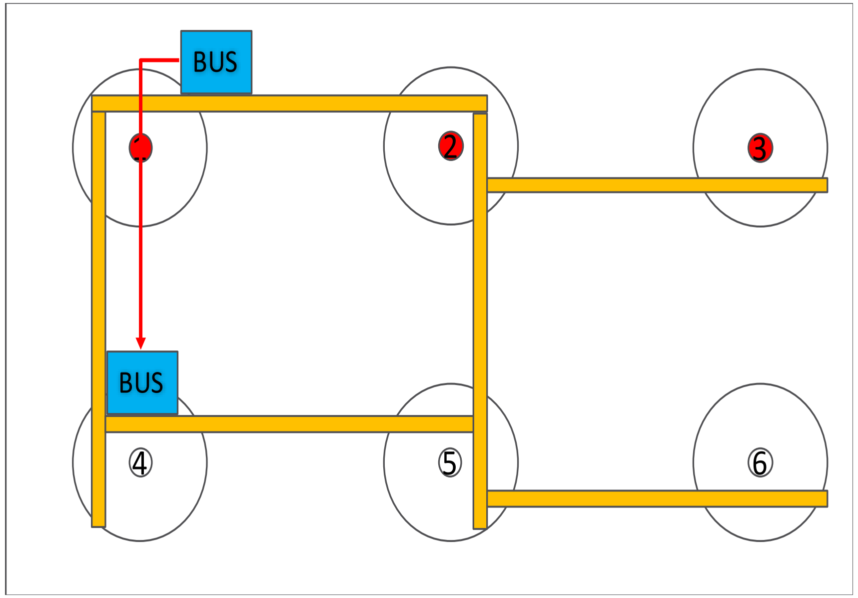
- **Description of MMWSF**
  - Defining an Objective Function:

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

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

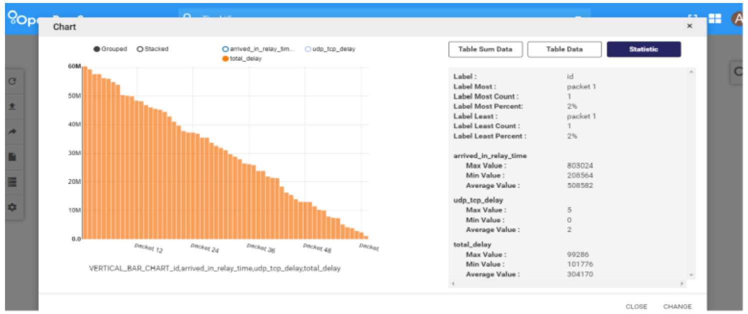
  α is set to a large value → precede the distance that the bus has to move

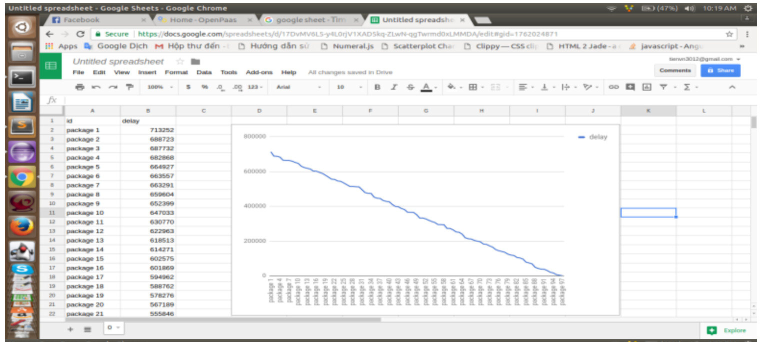
  - Operations: 2 Steps
    - ✓ **Step 1:** The MG chooses a RN to visit
      - The RN whose optimization function's return value is minimum.
      - Mark the node as visited.
    - ✓ **Step 2:** The MG repeats Step 1 until all RNs are visited.
    - ✓ If all RNs are visited →2 choices
      - Continue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

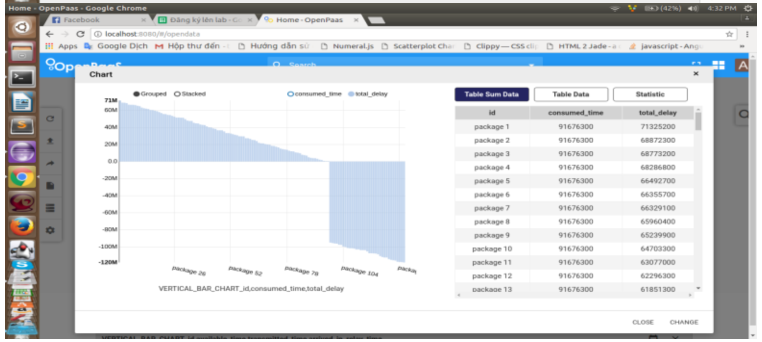


HUST's Contribution – Large Scale Heterogeneous Mobile IoT

- **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 representated 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 – Result - DONE:**
  - End-to-End Delay:
    - ✓ Simulated Delay at RN: small and negligible
    - ✓ Delay appeared within WSN and network of RNs-MG







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HUST's Contribution – Labtest with fixed MG - Conclusion

- **According to Project Proposal:**
  → At HUST, necessary to setup a testbed with fixed MG
- **Due to limited facilities at HUST:**
  - 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 Webbrowser
  - Data controlling from Smartphone to Sensors
- **HUST's Contribution - CONCLUSION**
  - **Based on ideas discusses during project's meeting**
    - → **Propose of Large Scale Heterogeneous Mobile IoT Architecture** and **Evaluate simulatively**: **DONE**
    - → **Writting a Technical Report: DONE**
    - → **Submitting to an SCI Journal: Between November 2017-March 2018**
  - **According to Project Proposal**
    - → **Development of a lab connected testbed with fixed MG: DONE**

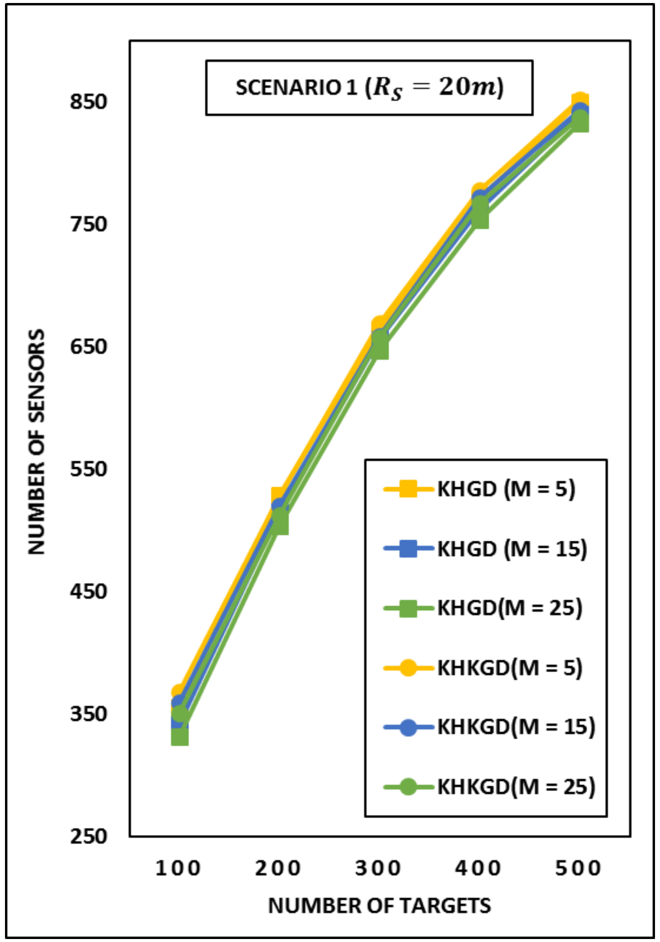
I²R's Contribution – Connectivity Optimization in Mobile WSN

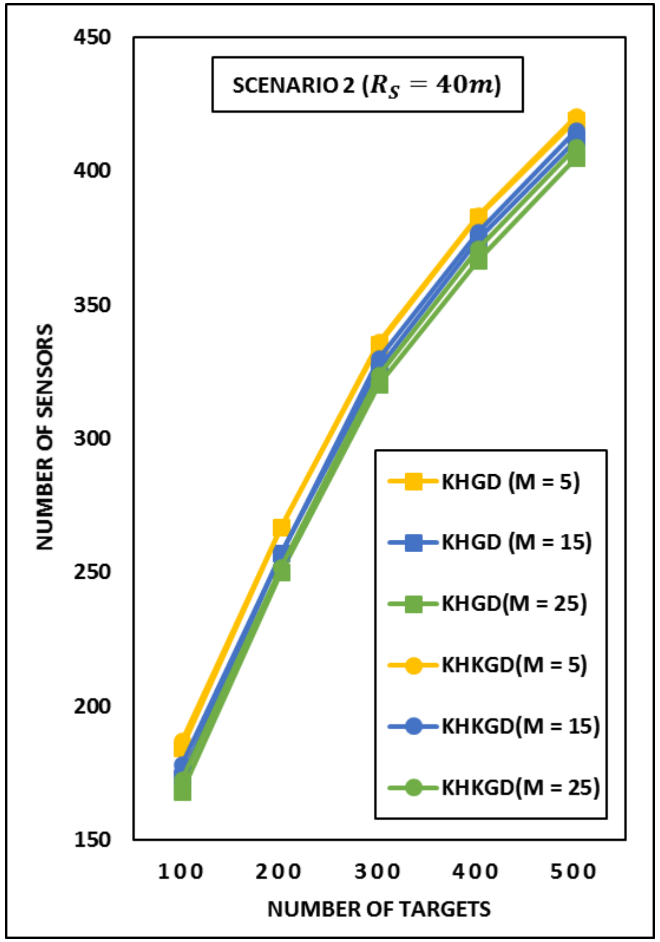
- **Connectivity Optimization in Mobile WSN or IoT?**
- **Network Deployment setup:**
  - M mobile sensors with communication radius R_c
  - One BS as Gateway, to which all sensors must be connected
- **Requirement: At each sampling period, the must be a valid link connecting mobile sensor to the base station**
- **Goal: Minimize the number of static nodes to achieve the connectivity requirement**
  - **Approach: Tackle the problem hierarchically**
  - **3 Steps:**
    - →Apply K-mean clustering method to the mobile sensors' location throughout the sampling interval
    - →Apply Integrated Greedy Method (IGM) on each cluster to connect all the points within the cluster by deploying the necessary static nodes
    - →Apply Kruskal algorithm to build a minimum spanning tree connecting all the clusters to the base station

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**
  - **Two meta-heuristic solutions are proposed**
    - →KHGD (K-means and Greedy)
    - →KHKGD (K-means, Kruskal, and Greedy)
  - **Approach:**
    - →Both solutions are two-steps approach with a common first step as described below:

I²R's Contribution – Coverage Optimization with Connectivity Constraint





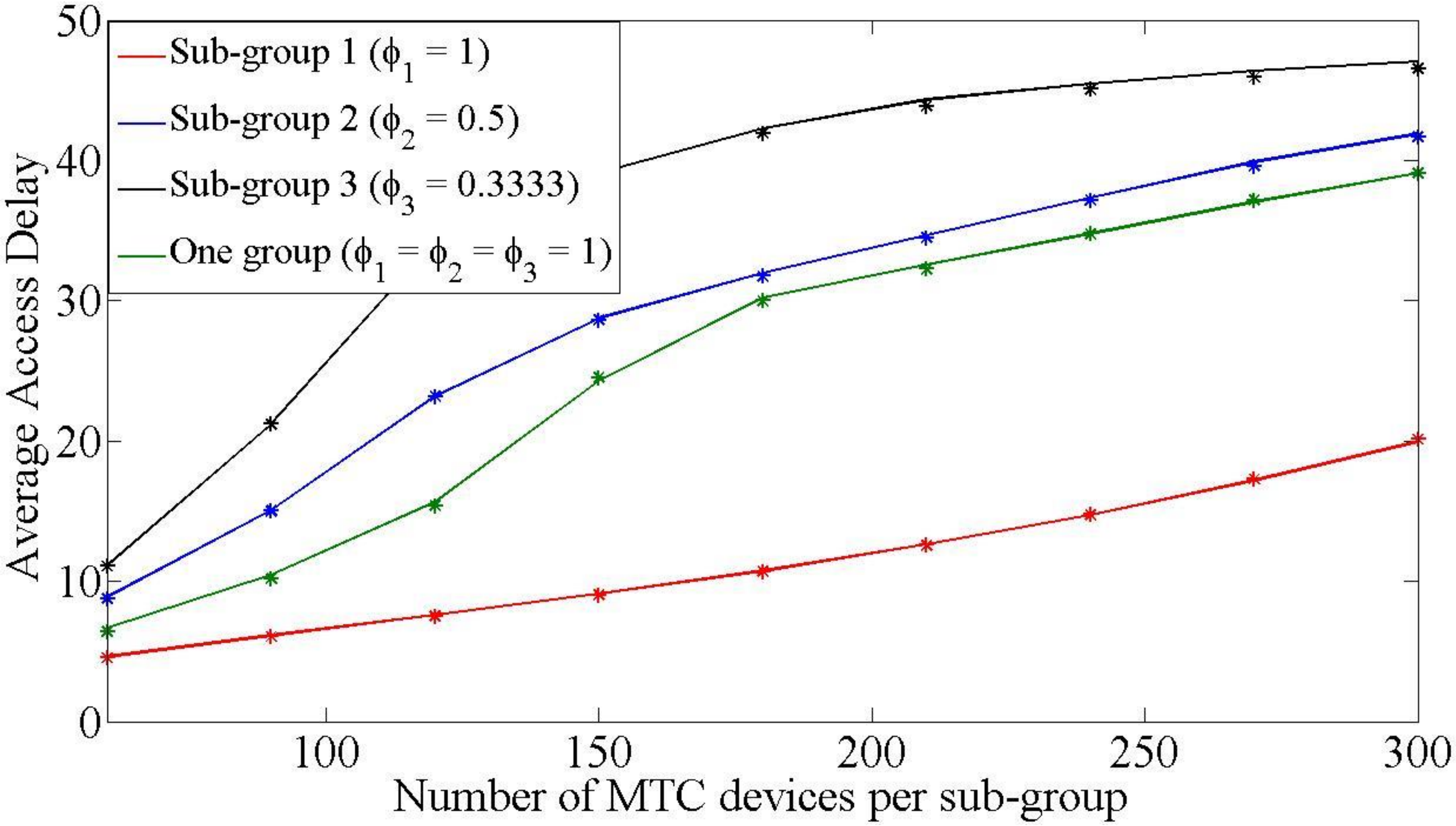
- **Results and observations:**
  - →Comparison on the required number of sensing nodes
- Sensing radius has great impact on the required number of static nodes
- KHGD outperforms KHKGD by requiring less number of nodes
- The more mobile sink is used, the less static nodes need to be deployed

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**
  - **Approach:**
    - →Instead of a single group ID, assign multiple group IDs to the nodes. Example for three sub-groups is shown as follows
    - →On the paging message, multiple group IDs are indicated. The allocation for the random access (RA) resource on each node is then determined by the number of matching IDs between those allocated to the node and those indicated in the paging message.
    - →Access prioritization is achieved, with the sub-groups having more allocated RA resources getting higher access priority.

I²R's Contribution – Hybrid Group Paging

→Performance comparison in terms of average access delay: higher priority sub-group achieves significantly lower average access delay



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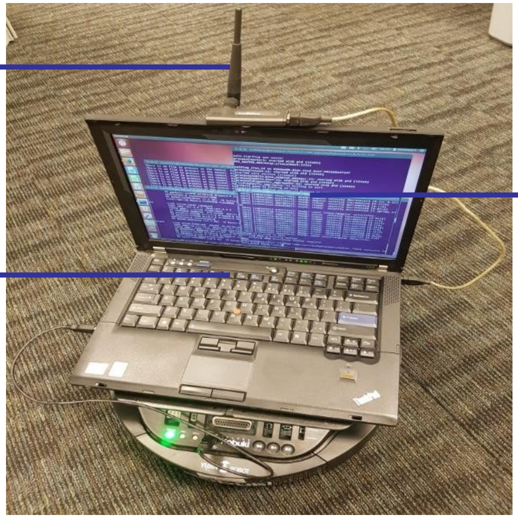
I²R's Contribution – Lab Testbed of Mobile Gateway

Network Deployment setup:

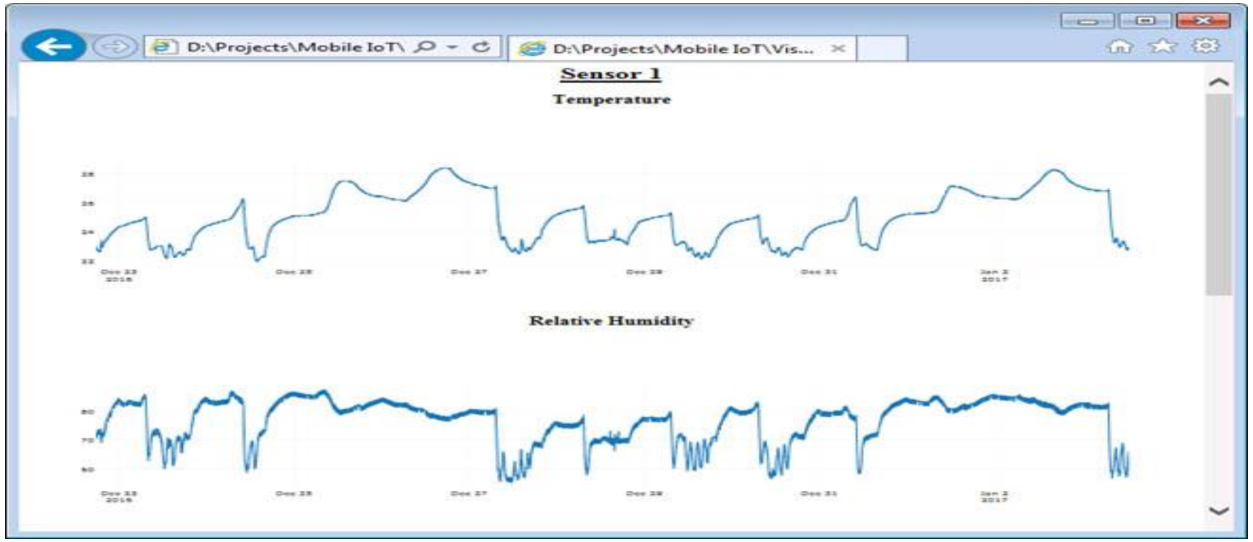
- Single mobile gateway implemented using Iclebo Kobuki robot base, carrying a laptop with WiFi dongle configured as access point
- Sensing node is implemented using Raspberry Pi with temperature and humidity sensor

WiFi Dongle

Linux Server running Hostapd and ROS



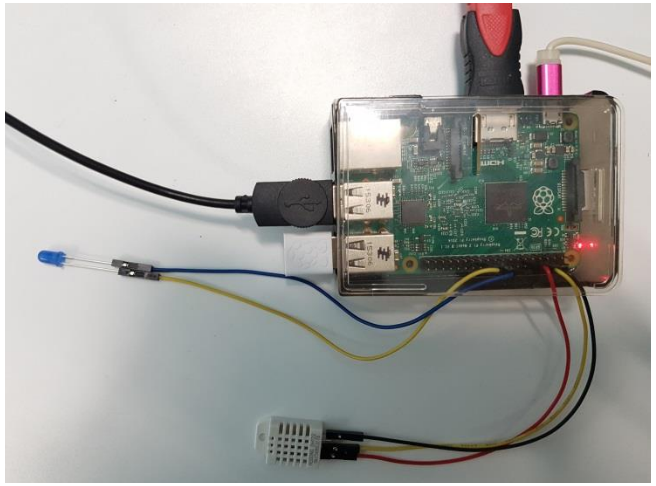
Iclebo Kobuki Robot base



WiFi Dongle

LED indicator

DHT 22 sensor



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I^{2}R's Contribution – Web Application for Visualization

I^{2}R's Contribution - CONCLUSION:

- Connectivity optimization results has been published in the following:

  N. T. Hanh, N. T. Hai, L. Q. Tung, H. T. T. Binh, and E. Kurniawan, "Connectivity Optimization Problem in Vehicular Mobile Wireless Sensor Networks," *IEEE 2016 International Conference on Computational Intelligence and Cybernetics (CYBERNETICSCOM 2016)*, In Proceedings, Aceh, Indonesia, Nov. 2016.

- Coverage optimization with connectivity constraint result has been published in the following:

  N. T. Hanh, P. L. Nguyen, P. T. Tuyen, H. T. T. Binh, E. Kurniawan, and Y. Ji, "Node Placement for Target Coverage and Network Connectivity in WSNs with Multiple Sinks," 2018 IEEE Consumer Communications and Networking Conference (CCNC 2018), Accepted for publication, Las Vegas, USA, Jan. 2018.

- Hybrid group paging result has been published in the following:

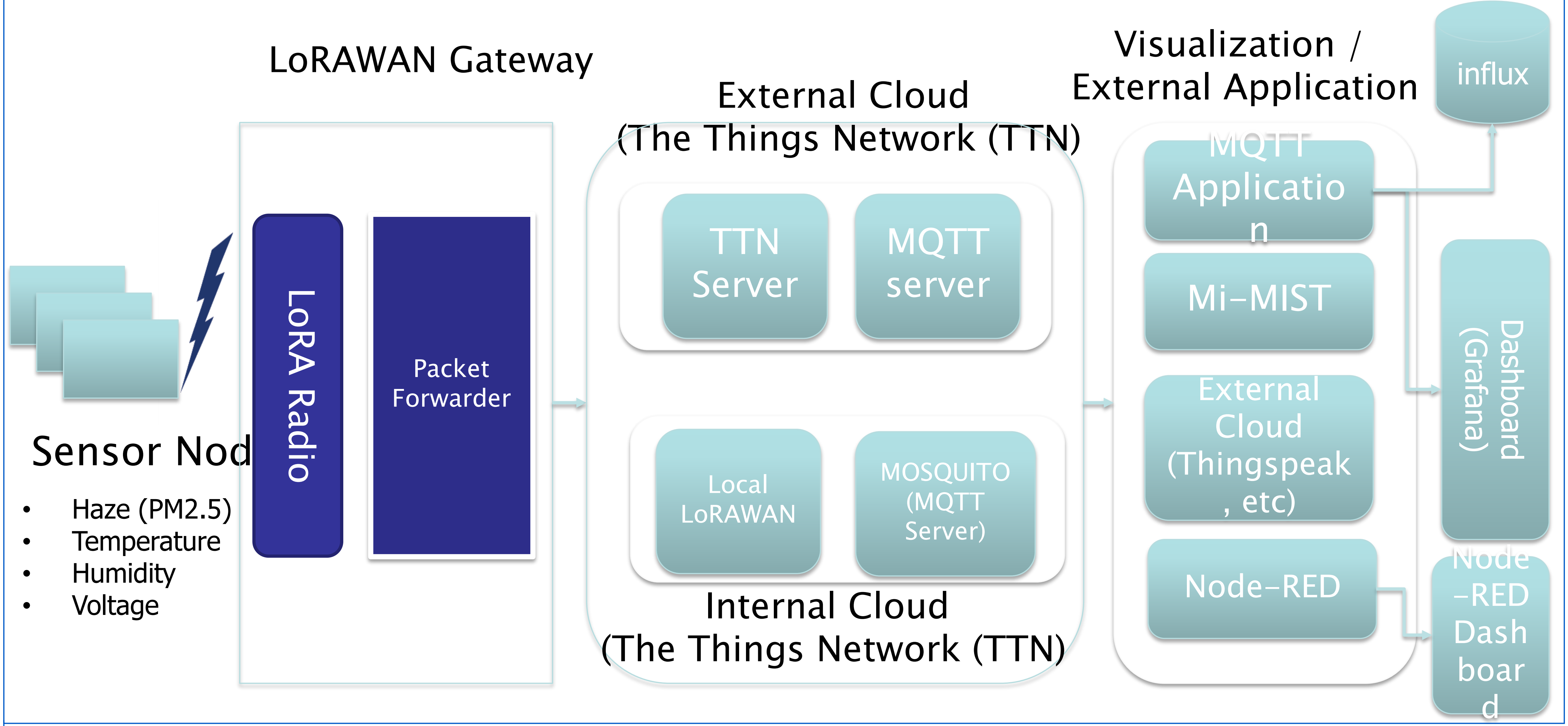
  E. Kurniawan, T. P. Hui, K. Adachi, and S. Sun, "Hybrid Group Paging for Massive Machine-Type Communications in LTE Networks," 2017 IEEE Global Communications Conference (Globecom 2017), Accepted for publication, Singapore, Dec. 2017.

- Mobile IoT testbed has been developed and tested for small number of sensor nodes

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
- 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



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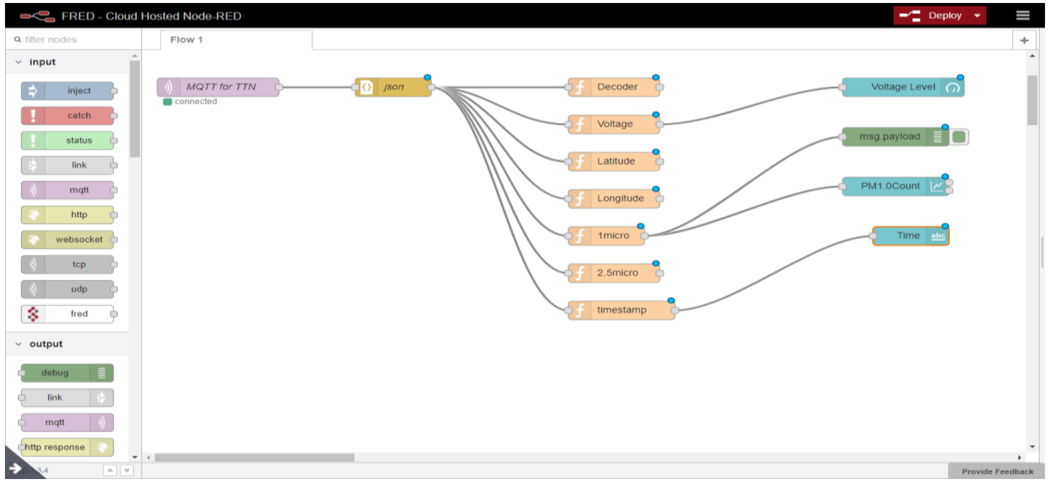

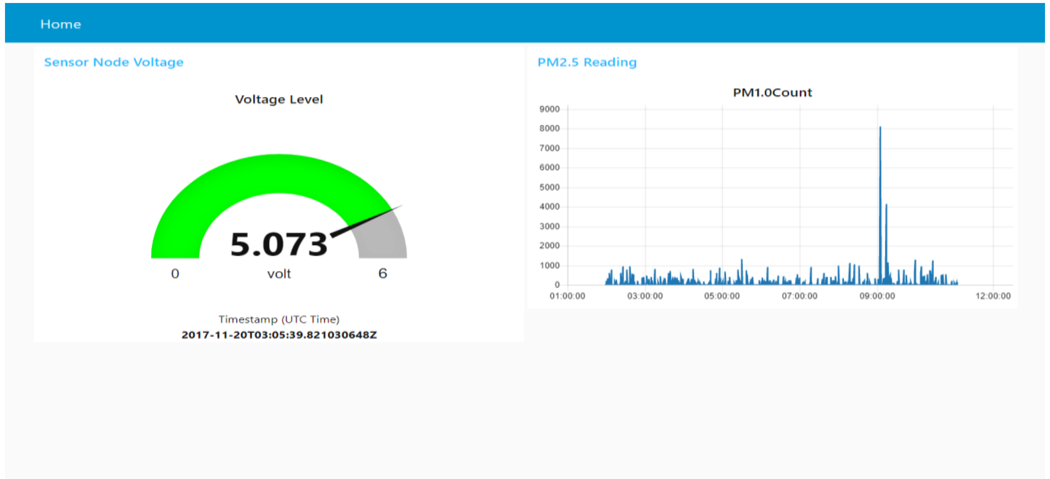

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