Project Title: A Hybrid Security Framework for IoT Networks

Project Final Report

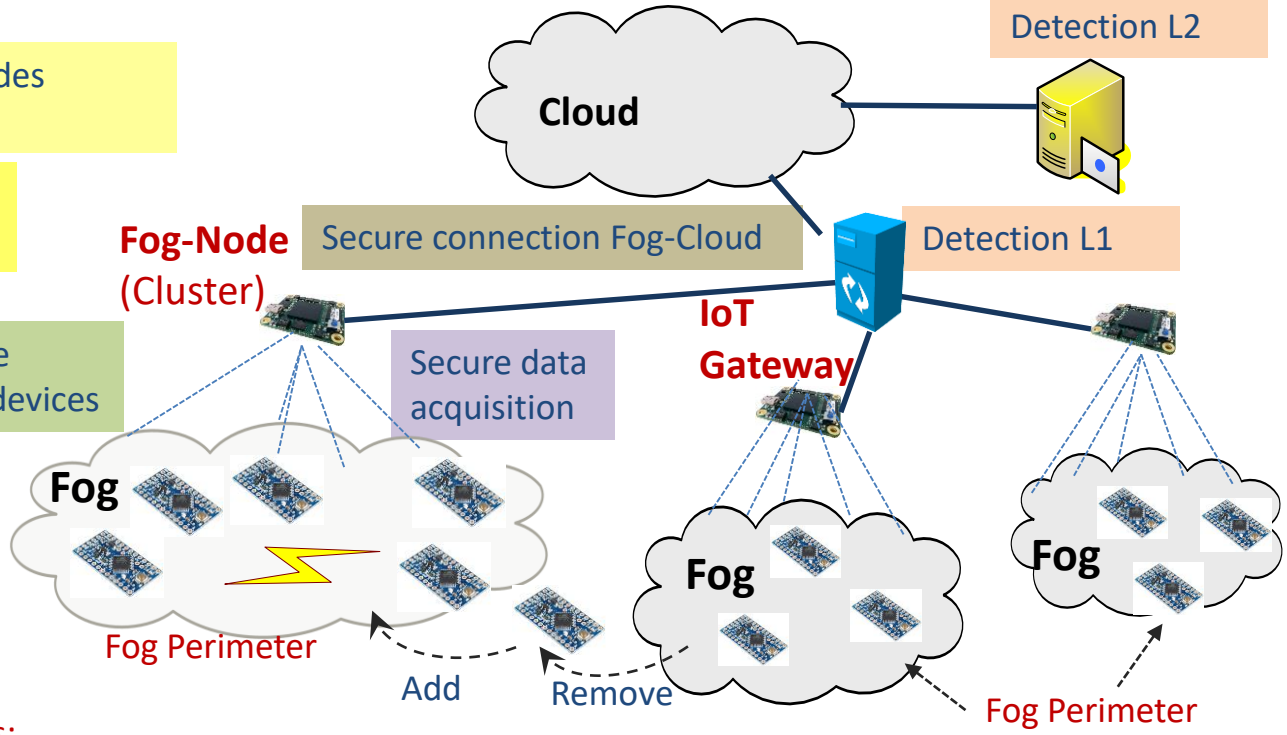
Background:

Different Security Levels of Fog-Nodes (protection priorities for fogs)

Identity, access control, authentication /watermark

Lightweight secure transmission bw. devices

- Scalable Perimeter for Fog (add, remove w. authentication)



Targets:

1. Research targets:
   - + Hybrid framework (fog architecture, level mapping, security level assignment)
   - + Lightweight secure data transmission / identity & authentication
   - + Monitoring, Detection, secure sharing
   - + Testbed for secure IoT data collection (air pollution data)
2. Research links / common paper publishing / exchanging & sharing experiences, knowledge
3. Contribution to technology/market development, promoting ASEAN IVO research

Speaker: Assoc. Prof. Dr. Dsc. Hoang Dang Hai

Project Title: A Hybrid Security Framework for IoT Networks

Project Members :

- **PTIT (Vietnam):** Assoc. Prof. DrSc. Hoang Dang Hai – Project Leader

  (others: Dr. Hoang Trong Minh, Dr. Vu Huu Tien, Hoang Manh Thang, Le Van Ngoc, Nguyen Tuan Lang)
- **NECTEC (Thailand):** Dr. Chalee

  (others: Ekkachan Ratteanalerdnusorn, Phitak Thaenkaew, Tinthid Jaikla)
- **MIMOS Bhd (Malaysia):** Dr. Choong (others: Dr. Kok, Chrishanton)
- **HUST (Vietnam):** Assoc. Prof. Dr. Ngo Quynh Thu
- **NUCE (Vietnam):** Dr. Pham Thieu Nga

  (others: Bui Thanh Phong, Nguyen Ha Duong, Le Thi Thuy Duong, Le Duc Quang, Tran Van Tho)
- **NICT Security Labs (Japan):** Dr. Takeshi Takahashi, Dr. Ryoichi Isawa, Dr. Daisuke Inoue
- **NES /NEC (Japan):** Dr. Tamoyuki Kuroda

Project Duration: from April 2017 to March 2020 (extended)

Project Budget: 80.000 USD

Project Activities (1):

Scientific & Technology Development:

- **Kick-off:** 25 July 2017
- **Organizing workshops, seminars**
  - Invited talk of Dr. Takeshi Takahashi (NICT cybersecurity labs)
  - Research presentations of members (PTIT, NICT, NECTEC, HUST, NUCE, MIMOS)
  - Internal meetings of each research team (1 for all, 1 of NECTEC/NICT, 1 of PTIT/NUCE/HUST, 1 of PTIT)
  - Meeting with NES / NEC (Dr. Tamoyuki Kuroda)
- **Doing research work of each team**
  - PTIT team works on: Modelling framework, IoT security survey, fog design, hierarchy architecture for monitoring, detection methods, honeynet, identification / authentication /watermark, data crawling, lightweight secure transmission, encryption, log collection & analysis
  - NECTEC team works on: NICTER/Daedalus, NETPIE platform, Monitoring & detection, access control, authentication schemes, smart application
  - NUCE team works on: IoT simulation, data analysis methods, secure data collection / transmission
  - HUST team works on: data transmission
  - MIMOS team works on: media gateway, secure presentation sharing
- **Conducting research results, common paper publishing**
- **Work on security report with NES / NEC, 01 report to NES/NEC**
- **Temporal reports to ASEAN IVO (3 reports)**

Project Activities (2):

Experiments including field testing:

- **Labs preparation & experiment using self existing equipment**
  - PTIT: Setup fog /cloud networks using virtual servers.
  - PTIT: Setup simulation tools (Contiki/Coja) for simulation of secure transmission, device authentication. Setup simulated honeynet (virtual machine with cowrie).
  - PTIT: Crawling data, analysis and detection using pre-built datasets
  - NECTEC: Setup NICTER/Daedalus, NETPIE platform for monitoring.
  - NECTEC: simulation using WIFI network, using IoT devices to study authentication
  - MIMOS: Setup existing media gateway, investigation of presentation sharing
  - NUCE: Simulation using Contiki/Coja, existing Waspmote sensors
- **Purchase of equipment, setting up labs at PTIT, NUCE. Experiments using equipment (since Dec.2018).**
  - PTIT: Setup test-labs, cloud/fogs using 3 servers, Arduino/Raspberry Pi boards
  - PTIT: Experiments with equipment: secure perimeter, secure transmission, etc.
  - NUCE: Setup test-labs, cloud/fogs using 2 servers, Arduino/Raspberry Pi boards
  - NUCE: Experiments with equipment: secure data collection / transmission, smart application (AirTracker).

Project Activities (3):

Other project activities:

- **Research exchange (2 of NECTEC at NICT, 1 of NUCE at NICT) on security monitoring, dataset building, etc.**
  - 3 NICT researchers visited NECTEC & install NICTER in Aug. 2017 (NICT budget).
  - 2 researchers of NECTEC visited NICT in Sept 2017 (NECTEC budget).
  - 1 researcher of NUCE joined training internship for one month at NICT in Japan, Oct. 2018 for learning dataset building, honeynet, data collection, data analysis (ASEAN IVO project budget).
- **Student projects**
  - Pollution detection machine using environmental sensors (NUCE student project – completed 8/2019)
  - Air Tracker (NUCE student project – completed 8/2019)
- **Master thesis**
  - Secure data transmission between IoT devices (01 PTIT master thesis – completed Jan. 2019)
  - Dynamic key exchange for identification and authentication in IoT Networks (01 PTIT master thesis – completed Jan. 2019)
  - Identity-based authentication for agents in network monitoring system (01 PTIT master thesis – completed in Dec. 2019)
- **PhD thesis**
  - Lightweight identification and authentication mechanism for IoT networks (01 PhD joined)

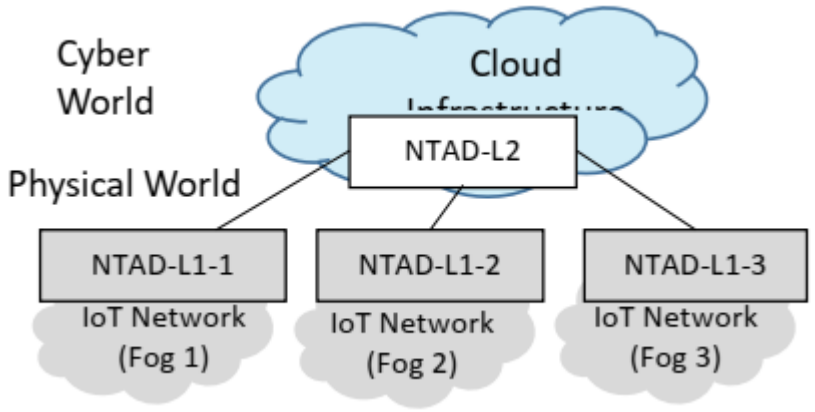
R&D results (1):

I. Scientific

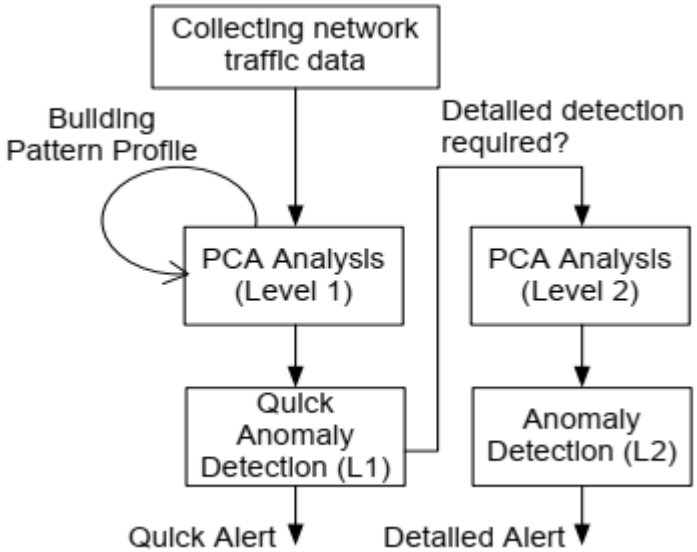
No	Scientific Topics	Contributions	Contributers	Publications
1	Secure fog architecture, IoT security framework	- Model for security level assignment using system theory, Markov chain - Model for security evaluation	- PTIT - NUCE, PTIT	1 paper 1 paper
2	Secure data transmission	- Mechanisms for secure data transmission between IoT devices using encryption (secret, public key)	- PTIT	2 master theses
3	Mechanisms for identity, watermarking, authentication	- Study of recent challenges and trends - IoT device authentication using Brownian behavior, Role-based access control, Biometric authentication	- NECTEC, PTIT - PTIT, NECTEC, NICT Security Lab	1 paper 6 papers
4	Study and Building dataset	- Setup and testing cowrie honeynet testbed	- PTIT, NUCE	
5	Method for monitoring with NETPIE platform	- Setup and testing NETPIE testbed	- NECTEC, NICT	2 papers
6	Method for data aggregation, analysis, secure sharing of data	- Secure data sharing using media gateway - Data aggregation, analysis using sensors, secure sharing	- MIMOS - PTIT, NUCE	1 paper 1 paper, 2 student projects
7	Mechanism for quick attack detection	- Security monitoring using 2 levels, network dimensioning	- PTIT, NUCE	3 papers
8	Method for security level evaluation	- Model for security level evaluation, weight assignment to 11 functional classes. Mapping mechanism for security levels	- PTIT, NUCE	1 paper

R&D results (2):

Security monitoring: Two Level detection



NTAD = Network Traffic Anomaly Detection



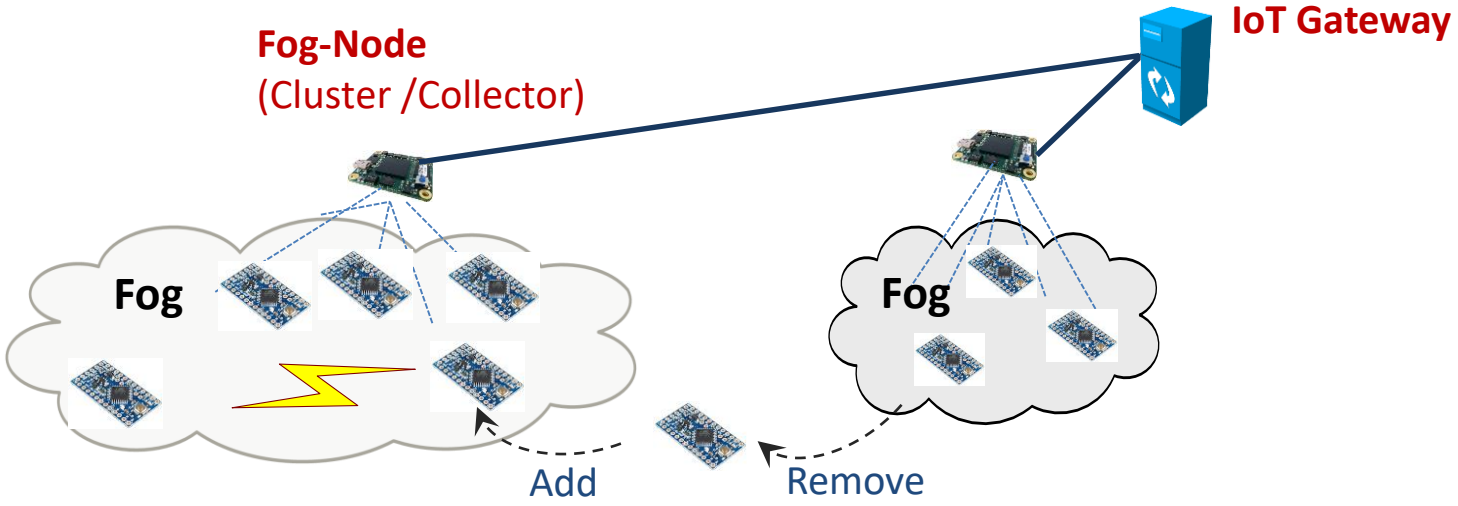
Detection model: Detection at 2 levels

- Quick Attack Detection: using Principal Component Analysis, Machine Learning Model
- Required only 2 or 3 major components for detection, two Threshold Levels
- Detailed Analysis feasible

R&D results (3):

IoT device identity management and authentication

- Device identity using MAC - ID
- Watermark data for Fog is formed for recent added nodes into Fog
- Fog-Node check authentication for IoT devices to send the collected data to the IoT gateway
- Access control to IoT devices controlled by IoT gateway using network watermark



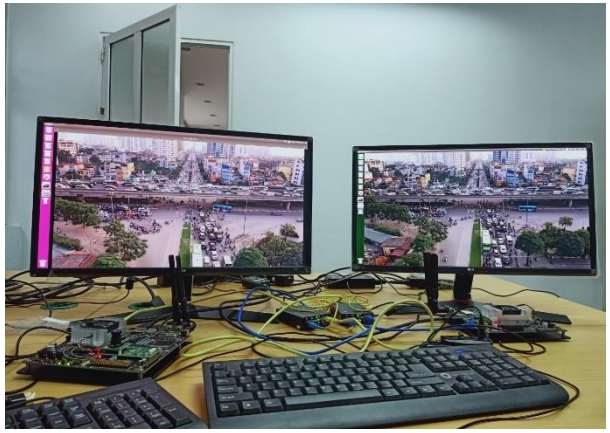
II. Technology Development

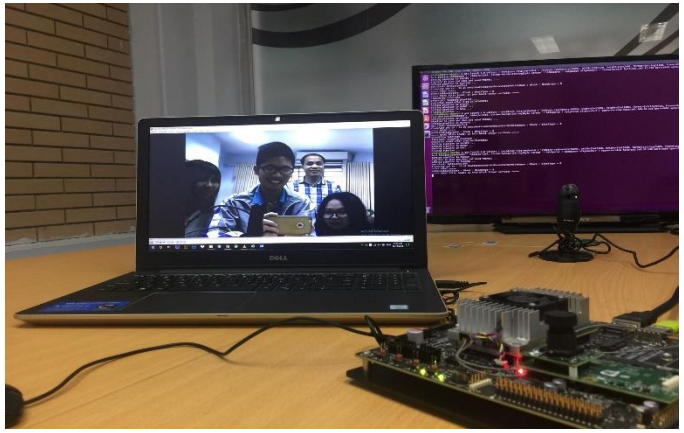
1) Method for security level assessment using ISO 15408 and fuzzy logic **(PTIT, NUCE)**
2) Method for IoT Device identification using MAC addresses, Brownian motion behavior **(PTIT)**
3) Method for IoT device authentication using watermarking, Biometric, access control **(NECTEC, NICT Security Lab, PTIT)**
4) Method for device authentication using encryption **(PTIT)**
5) Method for secure sharing of presentation data **(MIMOS)**
6) Method for lightweight secure data transmission between IoT devices **(PTIT)**
7) Application for AirTracker using environmental sensors **(NUCE)**
8) Application for controlling environmental robots **(NUCE)**

R&D results (4):

Student Research using Project Testbeds

1) Research and Development of a System for Measurement and Notification of Air Pollution
(Second Prize at NUCE Student Research 2020, 4 students of NUCE)
2) Applying HECTOR SLAM algorithm and Navigation Stack in development of Smart Vacuum Cleaner Robots
(First Prize at NUCE Student Research 2019, 4 students of NUCE)
(Ministerial Level Consolation Prize for Student Research 2019, 4 students of NUCE)
3) Applying Deep Learning FASTER-RCNN in development of English Education Application for Children
(First Prize at NUCE Student Research 2020, 4 students of NUCE)
(Ministerial Level Third Prize for Student Research 2020, 4 students of NUCE)
4) Research & Development of a Air Pollution Quality Monitoring In-House System using IoT Sensors
(NUCE Student Research 2018, 5 students of NUCE)
5) Development of a Smart Automatic Air Ventilation In-House System based on IoT Sensors
(NUCE Student Research 2019, 4 students of NUCE)
6) Using embedded Jetsson TX2 to implement experiment: video signal transmission over optical network
(PTIT Research 2020)



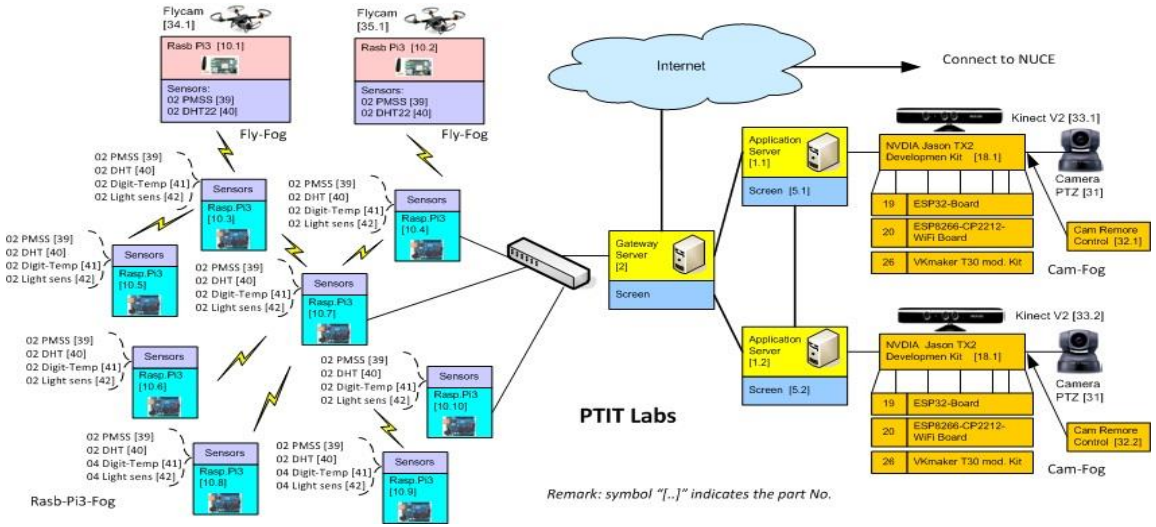


R&D results (5):

III. Experiments including field testing

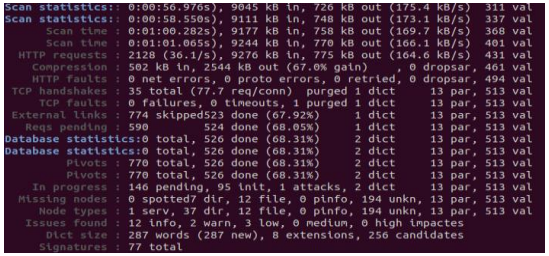
At PTIT

Diagram of Labs

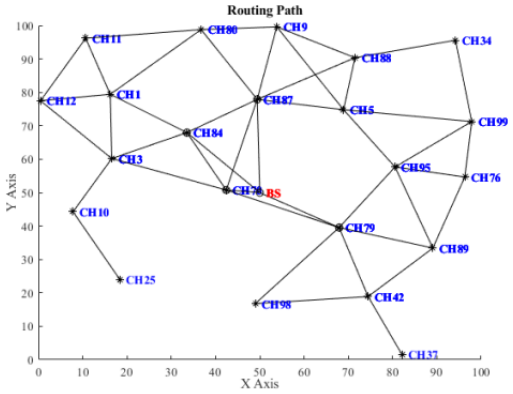


Test labs

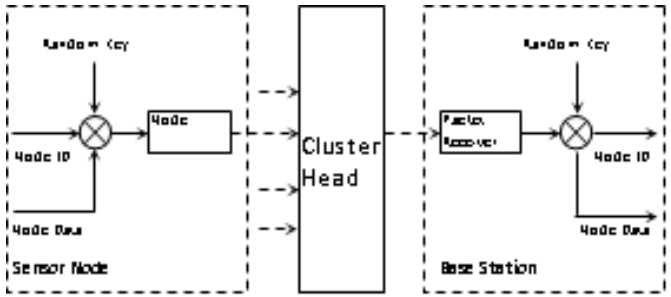
Crawling data



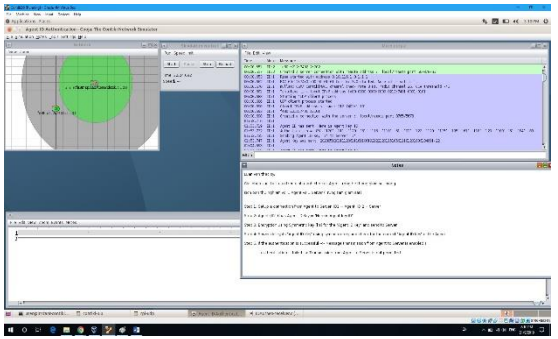
Routing path for multi-hops



Watermark block diagram



Test for secure transmission

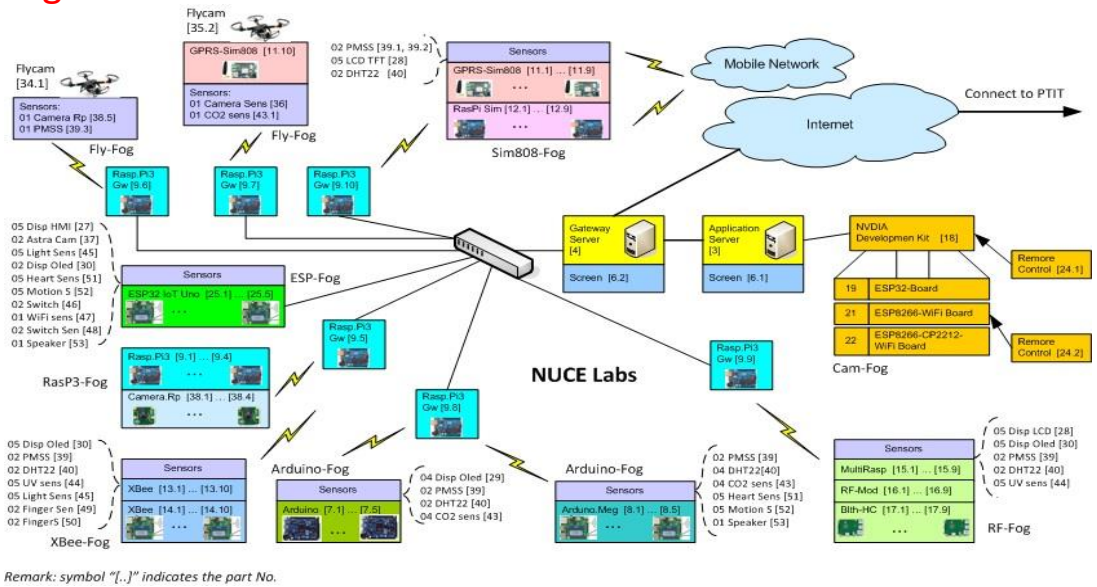


R&D results (6):

III. Experiments including field testing

At NUCE

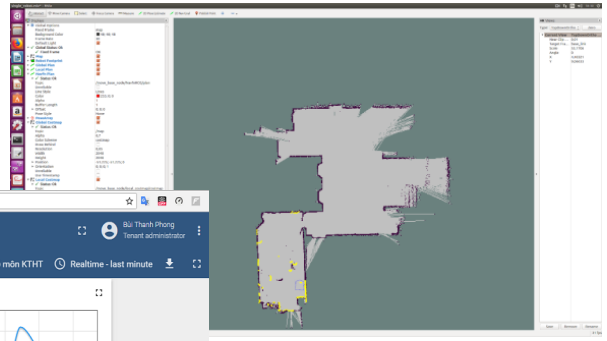
Diagram of Labs



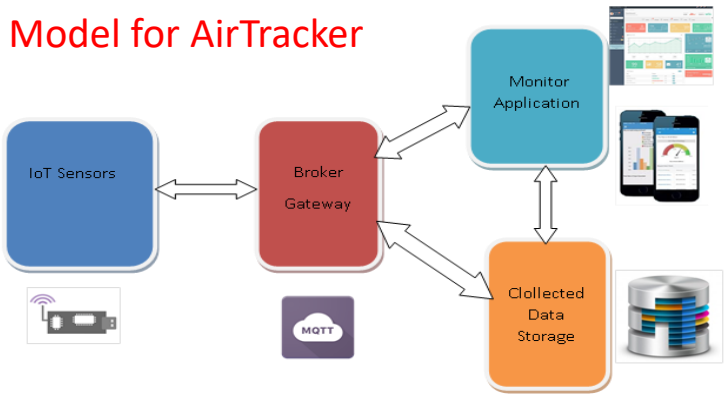
Remark: symbol "[..]" indicates the part No.

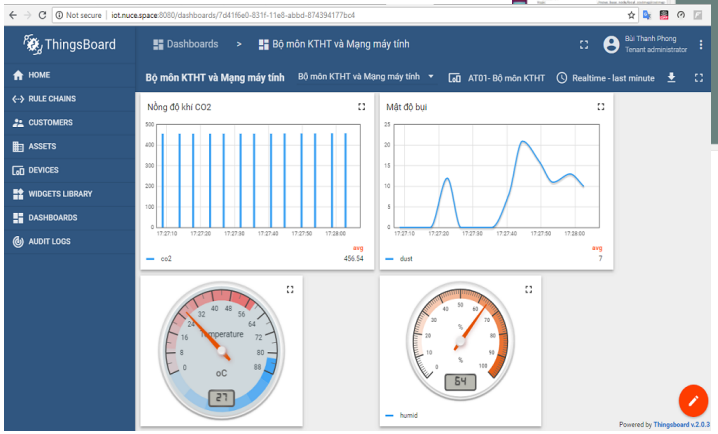
Sensors for air pollution

Web output



Model for AirTracker





Scientific Contribution (1):

Presentations at International Conferences: 14

No	Paper title:	Author names	Affiliation	Conference name	Date of conference	The venue of the conference
1	A Model for security assessment	HD.Hai, NX.Quang, HT.Thu	PTIT	Security Workshop 2017	Nov. 2017	Uni. Of Crypto Technology, VN
2	A Study on the sensor network authentication by utilizing a Brownian motion behavior	HT.Minh, HD.Hai, et.al.	PTIT	IEEE ICTC 2017	Oct. 2017	Jeju, Korea
3	Recent challenges, trends and concerns related to IoT Security	Chalee V., HD.Hai, et.al.	NECTEC, PTIT	IEEE ICACT 2018. Best paper	Feb.2018	Busan, Korea
4	A PCA-based method for IoT network traffic anomaly detection	HD.Hai, NH. Duong	PTIT, NUCE	IEEE ICACT 2018. Best paper	Feb.2018	Busan, Korea
5	Usable and secure cloud-based biometric authentication solution for IoT devices	Chalee V., Takeshi T., et.al.	NECTEC, NICT	IEEE ISCC 2018	June 2018	Rio de Janero, Brasilien
6	Automated wireless presentation system with facial images	Choong KN., et.al.	MIMOS	IEEE I2CACIS 2018	Oct. 2018	Shah Al. Malaysia
7	Evaluating the security levels of the web-portals based on the standard ISO/IEC 15408	HD.Hai, PT.Nga	PTIT, NUCE	IEEE SoICT 2018	Dec.2018	Danang, Vietnam
8	A novel fuzzy inference system based on hedge algebras to enhance energy efficiency in wireless sensor networks	HT. Minh, et.al.	PTIT	IEEE ICCIS 2018	Dec. 2018	Singapore

Scientific Contribution (2):

Presentations at International Conferences: 14 (cont')

No	Paper title:	Author names	Affiliation	Conference name	Date of conference	The venue of the conference
9	Security implementation for authentication in IoT environments	Chalee V., et.al.	NECTEC	IEEE ICCCS 2019	Feb. 2019	NTU, Singapore
10	Hybrid security framework for IoT networks (Invited talk)	HD. Hai	PTIT	ASEAN IVO workshop on Cybersecurity in Industry 4.0	Mar. 2019	VNU-UET, Hanoi
11	A Secure network architecture for heterogeneous IoT devices using role-based access control	Chalee V., HD.Hai, et.al.	NECTEC, PTIT	IEEE SOFTCOM 2019	Sept. 2019	Split, Croatia
12	A hedge algebras based fuzzy inference system for clustering in multi-hop WSNs	HT. Minh, et.al.	PTIT	IEEE CSAI 2019	Dec.2019	Beijing, China
13	Toward automated cybersecurity: visualization and machine learning techniques (Invited talk)	Takeshi Takahashi	NICT	IEEE NICS 2019	Dec.2019	Hanoi, Vietnam
14	A lightweight mixed secure scheme based on the watermarking technique for hierarchy wireless sensor networks	HT. Minh, et.al.	PTIT	ICOIN 2020	Jan. 2020	Spain

Scientific Contribution (3):

Published Journal Papers: 4

No	Paper title:	Author names	Affiliation	Journal Name	Publisher	Vol.No., pages
1	Security monitoring of IoT networks	HD. Hai	PTIT	S&T Information & Communications	PTIT	01(CS.01) 2018, p.3-9
2	Detecting anomalous network traffic in IoT networks	HD. Hai, NH. Duong	PTIT, NUCE	Transaction on Advanced Comm. Technology (TACT)	GiRI Global IT Research Institute	Vol.7, Issue 5, p.1143-1152
3	A secure authentication scheme based on Brownian motion in hierarchy wireless sensor networks	HT. Minh, HD. Hai. et.al.	PTIT	EAI endorsed Trans. on Industrial NW & Intelligent systems	EAI.EU	19(21):e1, 2019, p.1-9
4	Combined solution for security monitoring and evaluation of web-portals using standardization	HD.Hai, PT.Nga	PTIT, NUCE	S&T Information & Communications	PTIT	April 2020, 01(CS.01) 2020, p.10-20

Societal Impact:

1) Providing method for lightweight secure transmission for IoT devices

2) Providing method for anomaly detection, attack detection

3) Providing method for IoT Device identification using MAC addresses, Brownian motion behavior

4) Providing an application for AirTracker using environmental sensors

5) Providing a method for security level evaluation using standardization and fuzzy expert system

Budget use:

Expense list: Total = 50,870.47 (until 31/10/2019)

1) Project workshops / Forum attendance: 3
Total Expense: 8,321.14 USD

2) Support for participating in international conferences: 6
Total Expense: 10,906.46 USD

3) Support for 01 internship researcher at NICT: 01 person/ 1 month
Expense: 1,825.39 USD

4) Purchase fee for equipment:
Expense: 29,817.48 USD

Remaining budget (not used): about 21,000 USD

Reason:
1 planed Workshop in Februar 2020: could not realized due to COVID Pandemia
1 planed Meeting in March 2020: could not realized due to COVID Pandemia
1 planed Participation on international conference in Februar 2020: could not realized due to COVID Pandemia

Conclusion:

Key findings:

1) Hybrid framework =
security level assignment + hierarchy monitoring & detection + secure transmission + identity / authentication of IoT devices

2) Security level assessment & evaluation = using fuzzy logic and fuzzy expert system

3) Quick attack detection = using Principal Component Analysis with few key features

4) Access control = using role-based Mechanism

5) Hierarchy monitoring & detection for quick detection = using PCA, security level assignment

6) Secure data collection = Authentication Scheme with identified & authenticated IoT devices

7) Secure transmission = Lightweight protocol (tiny encryption using secret & public key)

8) Identity / Authentication for IoT devices = using MAC address, Brownian motion behavior, watermarking, biometric

9) Application for AirTracker = using environmental sensors and a mobile apk

10) Application for data crawler = a crawling method for building dataset

Future prospects:

1) Scientific and technological:
   + Further research on security level evaluation using fuzzy expert system
   + Further research on dataset analysis (big data) using AI
   + Further research on application of the developed framework for smart city/smart agriculture (namely: pollution air monitoring, tree disease prediction)
   + Further research on Identification / authentication protocol development

2) Deployment of the developed application and system
   + Deployment the developed framework for smart city/smart agriculture using fuzzy expert system
   + Deployment the developed sensing application for other areas (e.g. robotics)

3) Deployment of Testbeds and Methods for Student Projects
   + Motivation new Student Projects and Research

Thank you !

Acknowledgement:
The project team thanks NICT and ASEAN IVO for all supports to this project!