# Network Traffic Generation Framework for Automated Operation, Administration, and Maintenance in Smart Homes

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## 1. Research Content

The term *Operation, Administration, and Maintenance* (OAM) represents a group of network management activities that include fault detection, isolation, and restoration in order to keep a network operate stability and reliably. Generally, the OAM is essential for Internet Service Provider networks (commercial networks) and is accountable by experienced network operators with the support of tools and network equipment. Since networking is getting more complex due to the development of the information and communication technologies (ICT), automated OAM which relies on the *Artificial Intelligence for IT Operations* (AIOps) is a must to reduce the workload of human. The AIOps automates IT operations by utilizing concepts of big data analytics and machine learning to analyze data in order to detect and react to issues automatically. Smart homes are homes which utilize home appliances and a home network to connect those appliances to organize residential infrastructure so as to improve the overall quality of life of residents and assist them to live actively and independently. Following the development of the Internet of Things, home networks are becoming more and more sophisticated. Unlike, commercial networks which are monitored by experienced network operators, complex home network systems are now in the hand of naive users include children, older people, and people without the knowledge of network management. Therefore, providing automated OAM for smart homes based on the concept of AIOps is even more important.

Data is a fundamental source of building AIOps based automated solutions. Data is collected during daily operations and also from expensive network equipment in commercial network infrastructures, however, the situation is diverse in smart home networks. Thus, the lack of network traffic data of home networks is the biggest barrier to implement automated OAM solutions for smart homes. In the smart home context, the network traffic data reflects interactions between devices and services utilized these devices, hence it matches to the concept of the IoT Area Network where devices are connected to service gateway(s) (GW) and network traffic data is the traffic between devices and the target service gateway. Generally, network traffic data is generated by real smart homes, testbeds, or simulation. However, since network simulation is one of the promising approaches to generate traffic data which achieves the low cost in terms of time and money, a home network simulator which includes (i) a device emulator and (ii) a mechanism to simulate services is proposed as a preliminary component of the network traffic generation framework. Thereafter, a solution to convert the raw network traffic into data used as input for machine learning techniques is introduced to complete the proposed framework. In the scope of the dissertation, the ECHONET Lite protocol which is a dominated protocol for smart homes in Japan is the target protocol for the proposed framework.

## 2. Research Purpose

To implement the proposed framework, following subtasks must be accomplished:

- The implementation of an ECHONET Lite home gateway (HGW) is one of the first steps to build the simulator. The layered architecture, which includes (i) an adaptation layer to handle the interaction inside of the IoT Area Network, and (ii) an integration layer to integrate with other systems, is proposed. The proposed HGW satisfied all requirements of a GW, as stated in the ITU-T Y.4113 and ITU-T Y.2070, which clarify functional requirements for operation, management, and operation scenarios. To verify the feasibility and reliability of the proposed HGW architecture, the integration with ambient assisted living platform, namely *universAAL*, and a Machine-to-Machine ecosystem, namely *oneM2M*, has been implemented. Experiments have been conducted with the commercial devices, and the results proved the reliability and correct operations of the proposed HGW.
- Device simulation is proposed as the last piece of the puzzle of the network simulation because it is hard to have real, controllable faulty devices to generate the faulty traffic which is required for the data set. An ECHONET Lite device emulator has been proposed. The experiment results show that the emulator fully simulated behaviors of real commercial devices. The emulator can simulate faulty devices by extending the concepts of a fault model for the distributed system. Experiment results verified the correct operations of the emulator in simulating normal and faulty devices. By utilizing the Docker platform, automatic and scalable deployment is achievable, and the CPU and memory usage of the device emulator is **0.15%** and **100 MB** respectively to simulate a node.
- The deployment of the network simulator that includes the proposed HGW, normal device emulator, and faulty device emulator, network traffic data is collected in the form of raw captured packets. Data preparation is an essential part that requires to clean the input data and extract meaningful features from data. A network flow calculator, namely *Flowcal*, is proposed to aggregate captured packets into bidirectional flows, which reflect the interaction of devices and the HGW. The *Flowcal* is customized for the IoT area network and is able to appoint the flow initiator and also handle multicast flows. Data samples, which represent device behaviors, are prepared by extracting features from flows and combined into vectors. A total of **91080** samples representing **138** nodes (**384** device objects) are extracted from raw captured packets by the proposed solution. The distribution of data samples is visualized by applying the Principal Component Analysis to scale the data dimension. The visualized results prove that **IF-ELSE** is impossible to predict device behaviors.
- Problem detection is the starting point to build an automated OAM solution and network traffic data could be used to diagnose the health of a smart home network, a network traffic classification application for anomaly detection is implemented based on data generated from the proposed framework to verify the usability of the generated data. Three ML methods include Decision Tree (DT), Support Vector Machine, and Artificial Neural Network (ANN), are investigated for the experiments. All three models achieve high accuracy in classifying normal devices and devices with response fault from the rest of faulty devices. However, the accuracy of detecting omission fault devices and devices with three errors combined is low. The ANN achieves the best performance (average accuracy **96.72%**) with data normalization. The DT achieves the best performance (average accuracy **93.23%**) without data normalization.

According to the results, the proposed framework is able to generate smart home network traffic data which is usable as input to build AIOps based solution to reduce human effort on network management. The proposed framework is configurable with various scenarios which is impossible to achieve in real

deployments and contributes to the data generation processes in the field of data science. The proposed framework is essential and paving the way to build AIOps solutions for smart homes.

**Keywords:** *IoT Area Network Simulation*, *Network Traffic Generation*, *AIOps for Smart Homes*, *Machine Learning Based Network Management*, *Operation, Administration, and Maintenance*.

# Publications and Awards

## Journals

1. Van Cu Pham, Yoshiki Makino, Khoa Pho, Yuto Lim, and Yasuo Tan. "IoT Area Network Simulator For Network Dataset Generation", Special issue of Ubiquitous Computing Systems (IX), Journal of Information Processing. (**Submitted, Under Review)**
2. Van Cu Pham, Yuto Lim, Antonio Sgorbissa,and Yasuo Tan. "An Ontology-driven ECHONET Lite Adaptation Layer for Smart Homes", Journal of Information Processing, vol 27, pp360-368, May 2019

## International Conference papers (With Peer Review)

3. Van Cu Pham, Yuto Lim, Ha Duong Bui, Yasuo Tan, Nak Young Chong and Antonio Sgorbissa. "An Experimental Study on Culturally Competent Robot for Smart Home Environment", The 34th International Conference on Advanced Information Networking and Applications (AINA). (**Accepted, to be published**).
4. Van Cu Pham, Yuto Lim, and Yasuo Tan. "An onem2m interworking proxy entity for echonet lite protocol", 2019 IEEE 8th Global Conference on Consumer Electronics, pp1-5, Oct 2019.
5. Van Cu Pham, Yoshiki Makino, Yuto Lim, and Yasuo Tan. "Semantic service gateway for echonet based smart homes", 2019 22nd Conference on Innovation in Clouds, Internet and Networks and Workshops (ICIN), pp175-179, Feb 2019.
6. Van Cu Pham, Yuto Lim, and Yasuo Tan. "A platform for integrating alexa voice service into echonet-based smart homes", 2018 IEEE International Conference on Consumer Electronics Taiwan (ICCE-TW), pp1-5, May 2018.
7. Van Cu Pham, Yuto Lim, Yasuo Tan, and Nak Young Chong. "Support for echonet-based smart home environments in the universaal ecosystem", 2018 IEEE International Conference on Consumer Electronics (ICCE), pp1-4, Jan 2018.
8. Ha-Duong Bui, Van Cu Pham, Yuto Lim, Yasuo Tan, and Nak Young Chong. "Integrating a humanoid robot into echonet-based smart home environments", 9th International Conference on Social Robotics, pp314-323, 2017
9. Van Cu Pham, Tan Le, Yuto Lim, and Yasuo Tan. "An architecture for supporting ras on linux-based iot gateways", 2017 IEEE 6th Global Conference on Consumer Electronics, pp1-5, Oct 2017.
10. Van Cu Pham, Yuto Lim, and Yasuo Tan. "Management architecture for heterogeneous IoT devices in home network", 2016 IEEE 5th Global Conference on Consumer Electronics, pp1-5, Oct 2016.

## Japan Domestic Conference papers (Without Peer Review)

11. Van Cu Pham, Yoshiki Makino, and Yasuo Tan. “Support for ECHONET Lite Protocol in the oneM2M Ecosystem”, IEICE General Conference 2019, Mar 2019.
12. Van Cu Pham, Yuto Lim, and Yasuo Tan. “Integrating Alexa Voice Service Into ECHONET-based Home Networks”, IEICE General Conference 2018, Mar 2018.
13. Van Cu Pham, Yuto Lim, and Yasuo Tan. “Cloud-based Solution for Connecting Multiple Home Networks using universAAL Space Gateway”, IEICE Society Conference 2017, Sep 2017.
14. Van Cu Pham, Yuto Lim, and Yasuo Tan. “Management Architecture for Heterogeneous IoT Devices in Home Network”, Joint Conference of Hokuriku Chapters of Electrical Societies 2016 (JHES), Sep 2016.

## Workshops (Without Peer Review)

15. Van Cu Pham, Yoshiki Makino, and Yasuo Tan. “Support for ECHONET Lite Protocol in the oneM2M Ecosystem”, oneM2M Industry Day Kanazawa, Dec 2018.
16. Van Cu Pham, Yuto Lim, and Yasuo Tan. “Integration of ECHONET Lite Protocol into The universAAL Platform”, JAIST World Conference 2018, Feb 2018

## Awards

A. Best English Paper Award in 2017, IEICE Technical Committee on Information and Communication Management (ICM), March 2018, Okinawa, Japan
B. Best Poster Award, JAIST World Conference 2018, February 2018.