IEEE Global Information Infrastructure Networking Symposium (GIIS) 2020
October 28th to 30th, 2020

A SDN-based IoT Architecture Framework for Efficient Energy Management in Smart Buildings

Akram Hakiri*, Bassem Sellami**, Sadok Ben Yahia**, and Pascal Berthou***

University of Carthage, SYSCOM ENIT, ISSAT Mateur, Tunisia.*
University of Tunis El Manar, Faculty of Sciences, Dept of Computer Sciences (LIPAH).**
LAAS-CNRS Laboratory, Toulouse-France. ***

Outline

- Introduction
- What is this Research About?
- Problems and research challenges
- Solution approach
  - Novel IoT network virtualization approach based on SDN/NFV
  - Accommodate HVAC sensors and actuators with data collection
  - Powerful approach to allow smart devices understanding their own context and adapt themselves "on-the-fly"
- A proof of concept
- Conclusion

What is this Research About?

- Leverage IoT technologies to build sustainable micro-grids, achieve energy saving and information sharing in smart buildings
- Develop a novel IoT network virtualization approach to offer
  - an IoT data model for data collection from HVAC sensors and actuators,
  - a powerful approach to allow smart devices understanding their own context, and
  - adapt themselves "on-the-fly" for optimal energy efficiency and performance under all communication scenario.
- A prototype implementation in smart campus buildings using low-cost hardware and lightweight virtualization

Problem: Achieve efficient energy consumption (1/2)

- Buildings account for 35% the energy consumption and 40% of CO_2 emission in Europe
- Academic campuses are great contributors to energy consumption:
  - lighting represents 31% and space heating accounts for 28% of total energy use.
- Incentive human behavior from an energy perspective is still a challenging issue
  - There is a need for automated IoT network control, management and orchestration of micro-grids

➔ *Context Aware Application (CAA) could serve to avoid redundant and correlated sensor's readings*

Problem: processing raw data in micro-grids (2/3)

- Power micro-grids use/generate enormous amounts of raw data from different zones in buildings
  - Need for context-aware framework to filter data, predict values, and infer current readings
- Raw data pose major challenges for the underlying network
  - Need for flexible network support to handle heterogeneity, dynamic changes, and device discovery
- Existing protocols (IEC 61850, IEEE P1547.8, and Modbus) are unable to address network issues
  - Often designed in isolation to solve a specific problem and often retrofitted to address a new requirement.

  → SDN/NFV could address the problem of interoperability

Problem: access to IoT resources (3/3)

- SDN/NFV doesn't offer a built-in IoT support
  - There is need to adapt SDN to M2M ETSI standard to support
  - SDN/NFV doesn't support OpenFlow rules and resource tree to retrieve data from sensing devices
- Distributing IoT sensing data over open Internet expose data to vulnerabilities
  - There is a need for built-in security functions to protect IoT transactions,

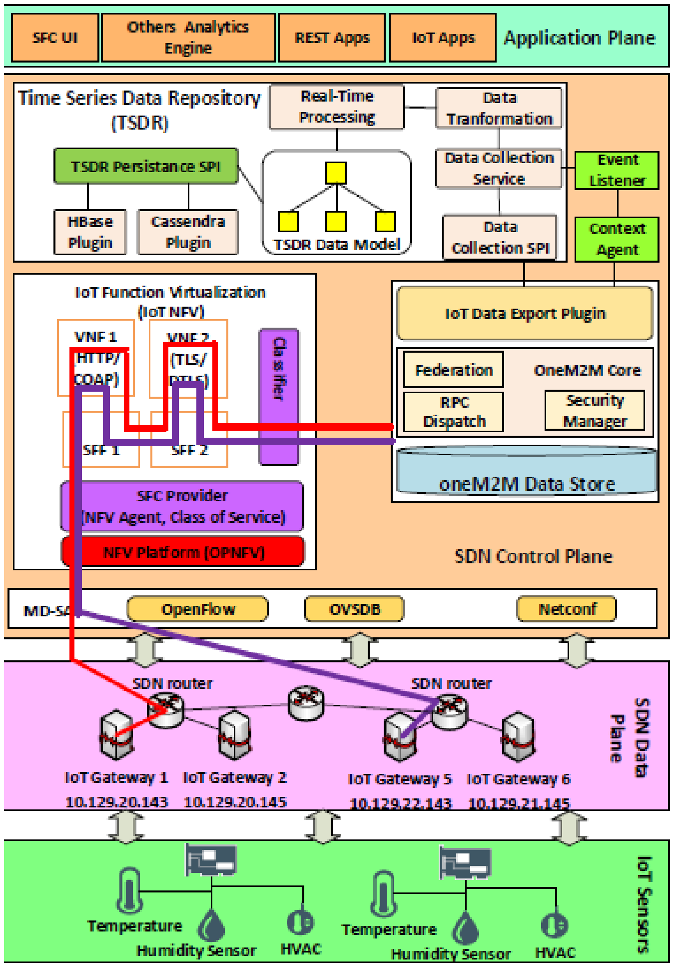
→ NFV could offer solutions towards virtualized security appliances

Solution requirements

- We need an framework that can that embraces:
  - message brokers,
  - context-aware framework,
  - virtualization and softwarization
- for flexible, cost-effective, secure, privacy-preserving IoT deployment in smart micro-grids.

Solution Approach: SDN-enabled based IoT architecture (1/5)

- The SDN control layer comprises:
  - a context agent that embeds the context-aware model to perform context reasoning
  - NFV application to trigger security decisions
  - M2M data model to realize D2D resource tree
- The fog layer :
  - all the network equipment's (IoT gateways, SDN vRouters) to realize the edge infrastructure.
- The perception layer :
  - Comprises the sensing layer and the aggregator

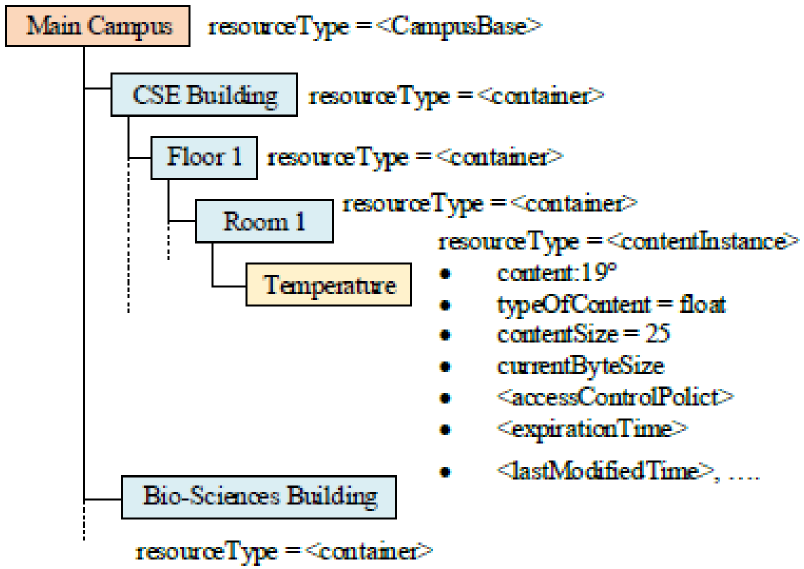


Solution Approach: IoT Service chaining (2/5)

- The **IoT Function Virtualization** (IoT NFV) module
  - for mapping IoT sensors into virtualized functions that follows the ETSI NFV architectural framework
- The IoT-NFV module uses
  - lightweight containers to create multiple isolated virtual IoT gateways inside a single physical one.
  - Example : VNF1 and VNF2 represent two independent virtualized functions chained to form a single IoT service

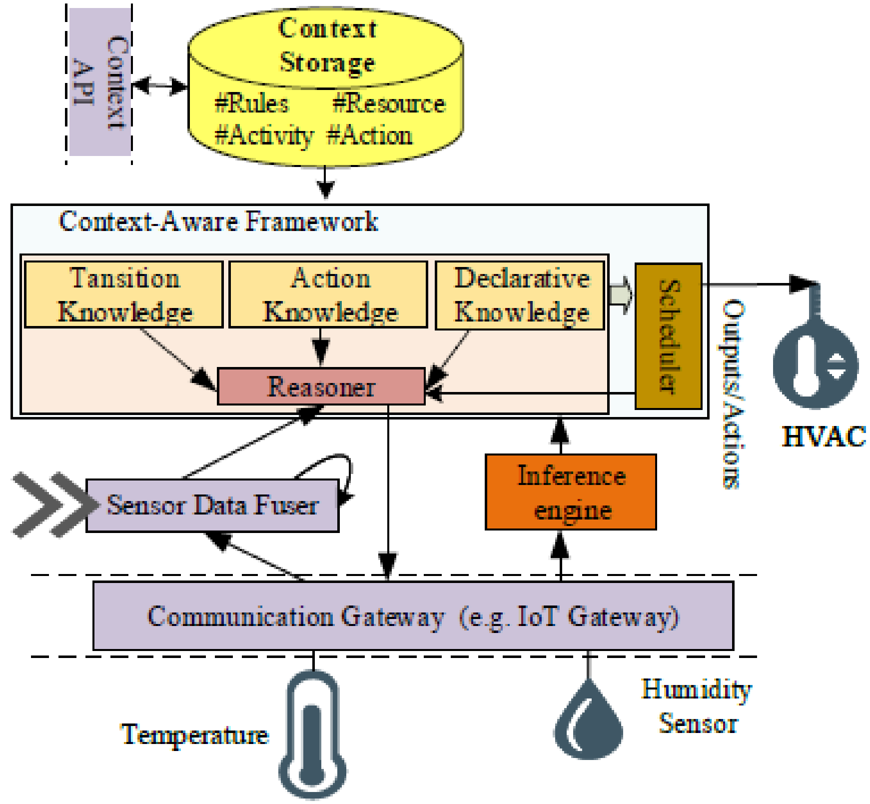
Solution Approach: IoT Data Management Model (3/5)

- Based on a data-centric IoT message broker
  - Resource tree contains different data and measurements of IoT devices and their associated attributes.
  - Each node in the tree represents a specific resource an IoT device can interact with using message broker (MQTT, COAP, REST, etc.)



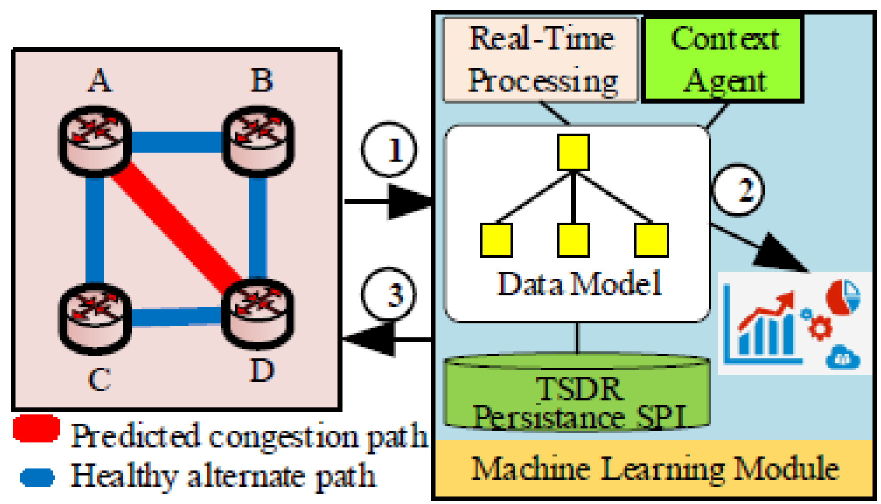
Solution Approach: Context-Aware Model (4/5)

- The context reasoning model identifies
  - Action knowledge represents the functional intelligence for a given environment
  - Transitional knowledge, specifies when a passage to another context should be performed
  - Declarative knowledge, provides description of some pre-acquired knowledge for the context

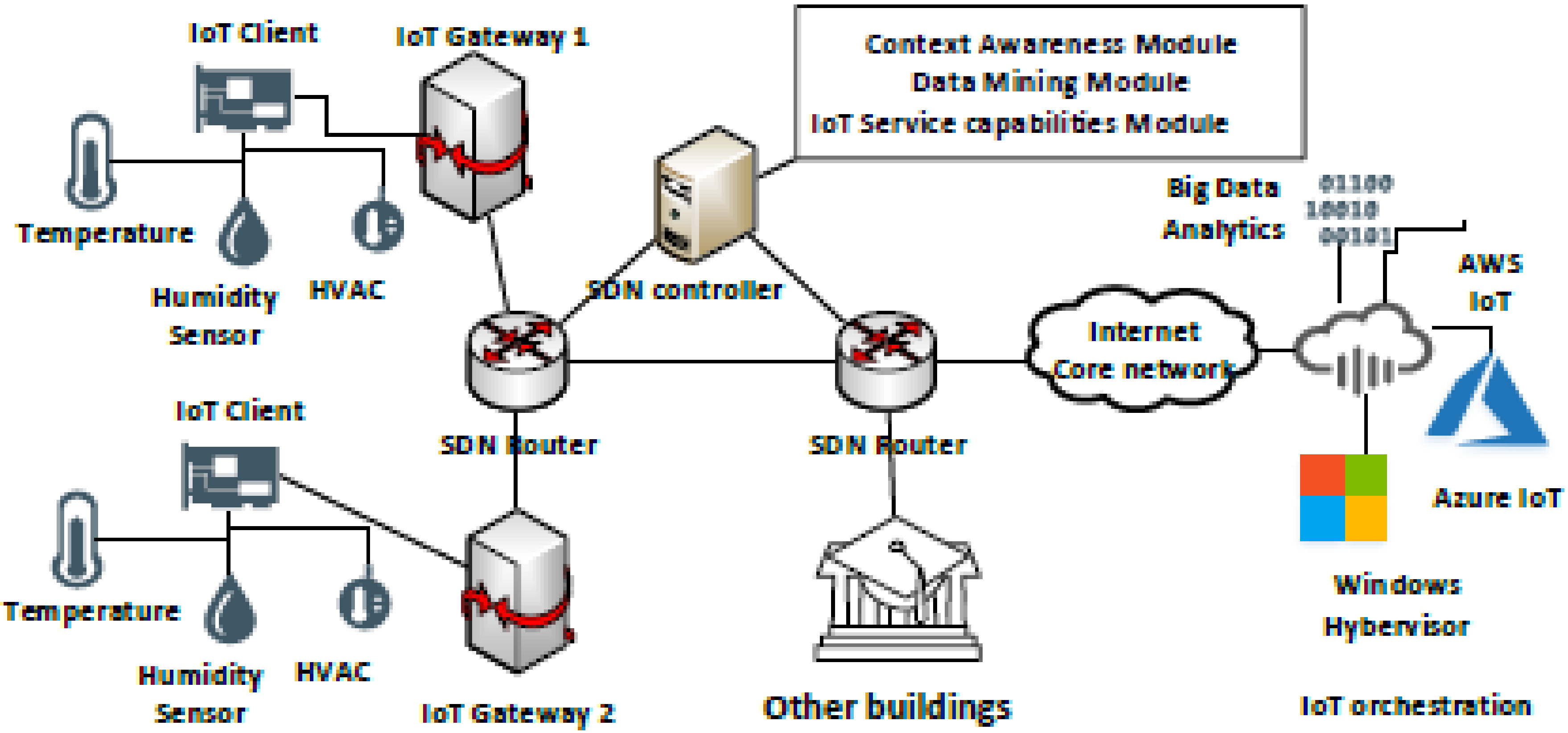


Solution Approach: Machine Learning Engine (5/5)

- Machine learning engine :
  - Helps the context reasoning framework to infer the context decisions
  - Feed back the environment changes to the SDN controller to perform automatic traffic steering and policy placement
  - Monitors current sensor's data delivery, predicts future data, and learn the optimal policy for the network management.

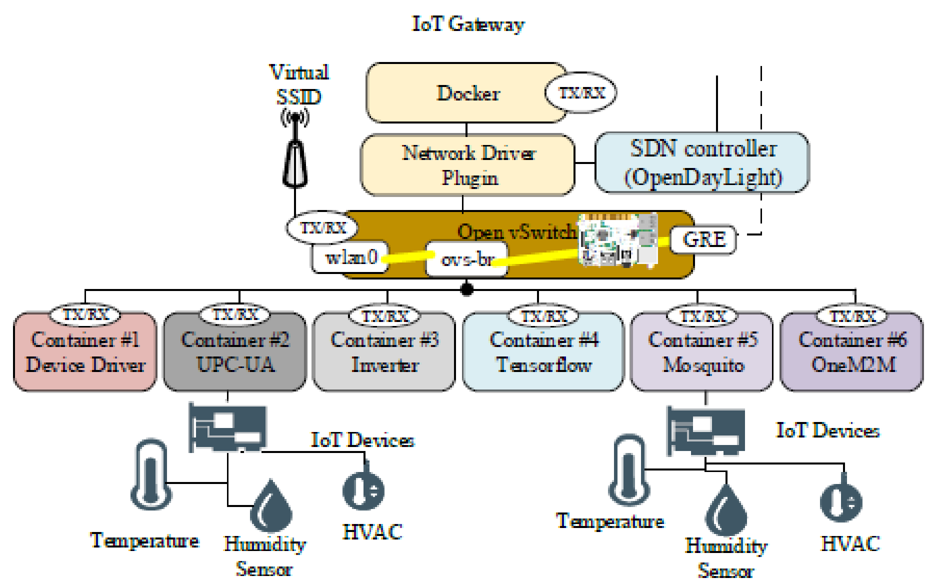


Prototype: implementation details



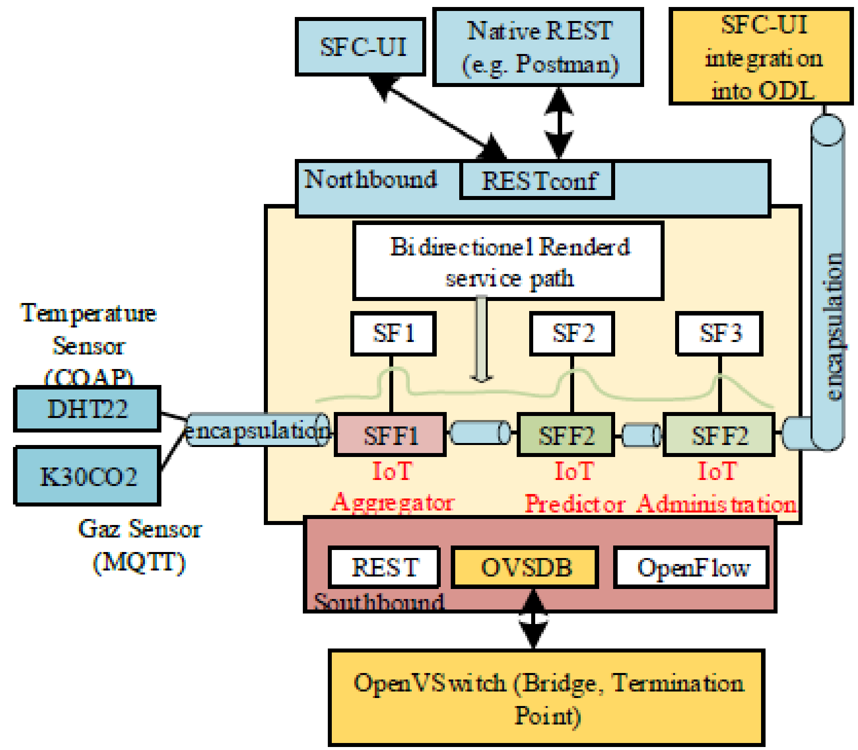
Use case 1: SFC Composition in Campus Education Building (1/2)

- SFC Composition in Education Building includes three VNFS:
  - Tensor VNF uses TensorFlow ML models to predict future data from correlated sensor’s readings.
  - Mosquitto VNF gathers sensors readings, listen to network events through MQTT protocol, and send commands to control fans and HVAC system
  - OneM2M VNF establish the access to IoT resources through the hierarchical containment tree



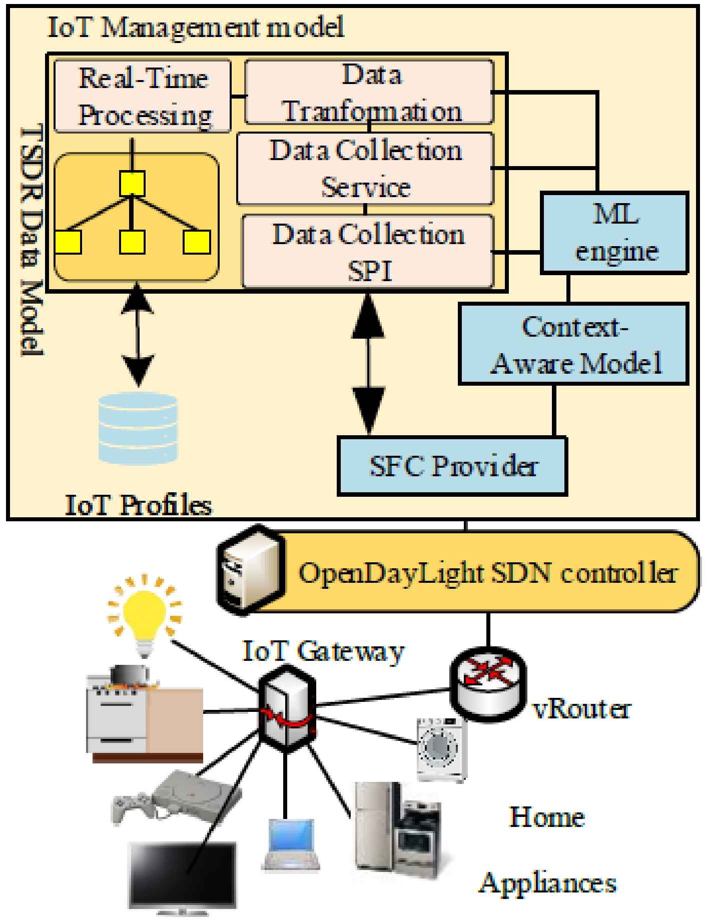
Use case 1: SFC Composition in Campus Education Building (2/2)

- OpenDayLight SDN controller Chaining (SFC) to
  - define an ordered list of network services which we stitched together to create a service chain.
  - Physical network function (PNF) that contains the IoT temperature and gas sensors,
  - Three IoT VNFs as Service Function Forwarders (SFF)
  - The SFC-UI integration into the SDN controller.



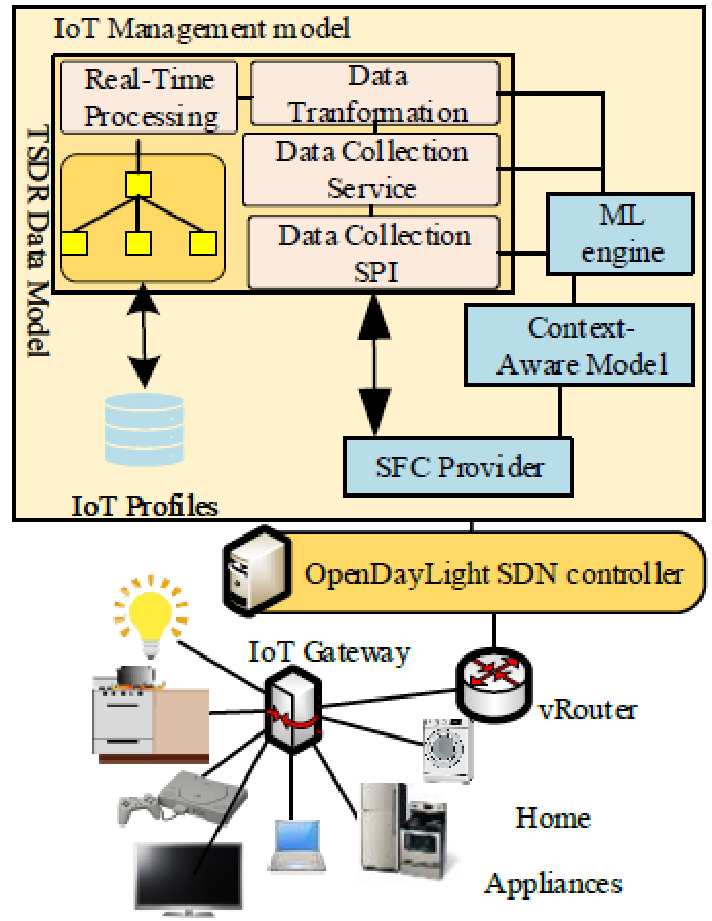
Use case 2: Activity Management in Campus Residential Building (1/2)

- We add an Activity Recognition (AR) model to the context-awareness model
  - The AR model describes the user behavior inside smart residential home.
  - The AR model is trained using semi-supervised learning model to forecast the appliances a user is using during the activities



Activity Management in Residential Building (2/2)

- Perform energy saving
  - by automatically switching ON/OFF unnecessary home appliances based on the context-awareness and AR models
- The SDN controller provides
  - comfort and assistance to building occupants,
  - apply powerful learning models on collected data to derive behaviors that impact high energy consumption.



Conclusion and learned lessons (1/2)

- We propose a QoS enabled IoT architecture framework for energy-efficiency in smart buildings that
  - Enable secured Io, context-aware IoT communication
- leverages key enablers technologies such SDN, NFV and Machine Learning,
  - to offer a flexible, efficient, and reconfigurable energy management in smart buildings.
- We introduced a IoT service chaining solution for creating and deploying customizable IoT services on-demand

Conclusion and learned lessons (1/2)

- Our solution is designed with reuse in mind:
  - It can easily be adopted in other IoT themes, e.g. smart cities, smart grids, etc.
- A wide adoption and acceptance of this idea will open up new opportunities for virtualizing IoT systems and applications.

Thank you for your attention

- Questions & Answers