Advanced Networking and Smart Applications Laboratory (ANSA) - Introduction

School of Electrical and Electronic Engineering
Hanoi University of Science and Technology

Contents

- About HUST and SEEE
- Research topics

Contents

- About HUST and SEEE
- Research topics

About HUST

HANOI UNIVERSITY OF SCIENCE AND TECHNOLOGY

ĐẠI HỌC
BÁCH KHOA

- Established in **1956**
- **37.000** students
- **1900** employees, including 1200 faculty members
- **27** schools and research institutes
- **Leading** technical university in Vietnam

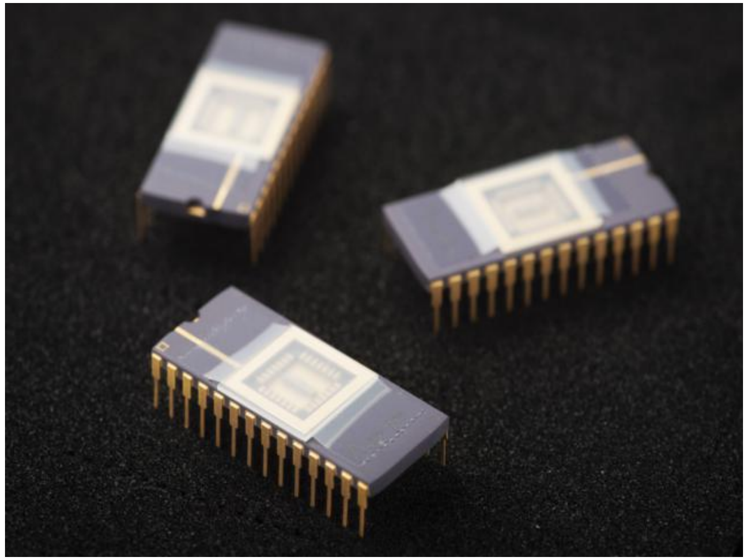
HUST's Computer Science, Electronics and Electrical Engineering Ranking

- 301 – 400 (THE 2019) for Engineering and Technology
- Top 301 - 350 (QS ranking 2022) in Electrical and Electronics Engineering

School of Electrical & Electronics Engineering

School of Electrical & Electronic Engineering

- 240 staff members
- ~ 9500 graduate and undergraduate students
- Research areas
  - Communication engineering: networking, wireless communication systems
  - Microwave, antennas and optics
  - Embedded systems and reconfigurable computing
  - Signal and information processing
  - Bio-medical engineering
  - IC design
  - Aero-space electronics
  - Electricity and renewable energy systems
  - Smart sensors
  - Intelligent control and multi-agent systems
  - High performance electric machines
  - Power electronics and electric drives/electric vehicles
  - Motion controls and robotics



ANSA Laboratory

- Members
  - 5 Professors
  - 4 PhDs
  - 2 PhD students
  - 35 undergraduate and master students
- Research topics

Future Internet technologies
Cloud and edge computing
Green edge-cloud computing and networking
Efficient network virtualization and NFV in the cloud and edge
Edge intelligence
Internet of EveryThings
Energy-efficient embedded systems
Radio resource management and scheduling in WSNs
Smart Parking & ITS
Network security
SDN-based network security
Network security for IoT
QoS and QoE in future internet
QoE for network services (Virtual Reality and video streaming)

5G and beyond: networks and services
AI-assisted network slicing
End-to-end network slicing optimization
5G core virtualization
Softwarized RANs: ORAN/CRAN

Future Internet applications and services
Smart city
Smart agriculture
AI in IoT

ANSA - Laboratory – Members

Prof. Nguyen Huu Thanh
(FI, edge/cloud, QoS, network security)

Prof. Nguyen Tai Hung
(FI, network security, network slicing)

Prof. Truong Thu Huong
(FI, IoT, network security, QoS/QoE)

Dr. Nguyen Xuan Dung
(IoT, Cloud)

Dr. Luu Quang Trung
(5G, network slicing)

Dr. Nguyen Huu Phat
(FI, IoT, AI, image/video procesing)

Prof. Tran Quang Vinh
(WSN, IoT)

Dr. Phung Kieu Ha
(WSN, IoT, Machine to Machine)

Dr. Tran Thi Ngoc Lan
(WSN, IoT, Machine to Machine)

Contents

- About HUST and SEEE
- Research topics

Research Topics

5G and beyond

- AI-Assisted Network Slicing & Virtualization
- 5GCORE
- ORAN/CRAN

Future Internet technologies

Cloud and Edge Computing
- Green edge-cloud computing and networking
- Efficient network virtualization and NFV
- Edge intelligence

IoT
- Energy-efficient embedded systems
- Radio resource management and scheduling in WSNs

QoS & QoE in FI
- QoE for network services

Network Security
- SDN-based network security
- Network security in IoT

Future Internet applications and services

- AI in IoT
- Smart City
- Smart Agriculture

Green Cloud and Edge Computing

Device level

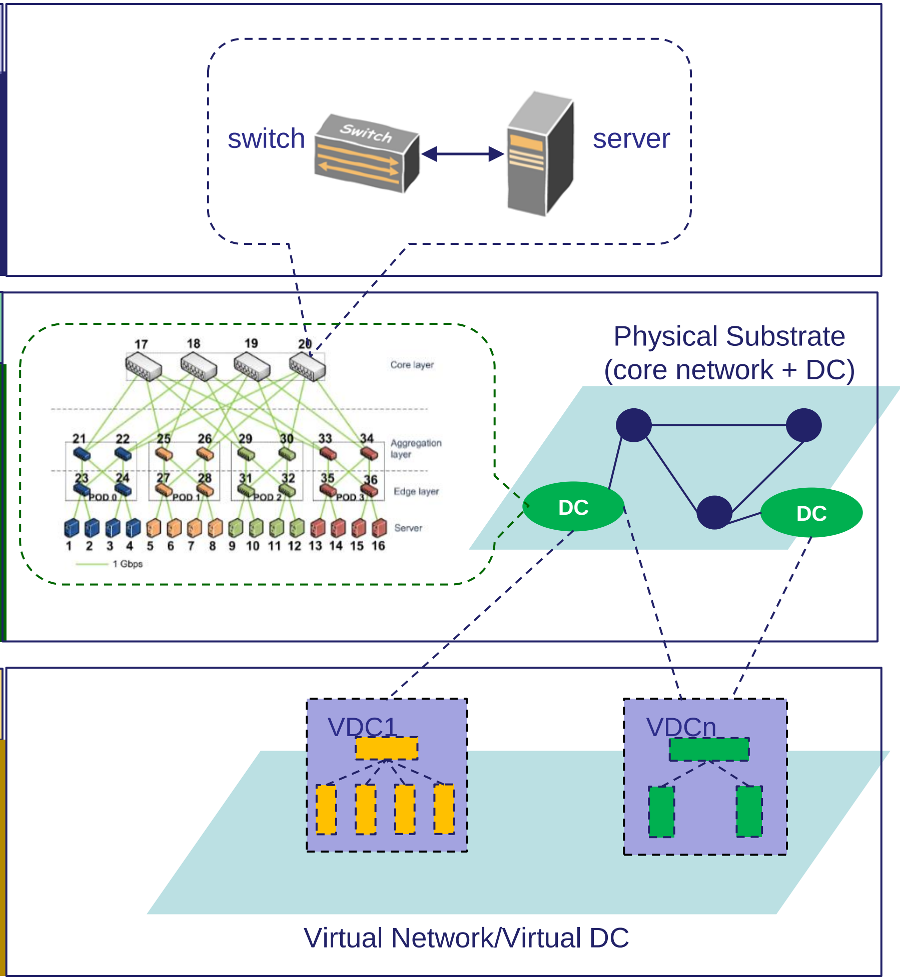
- Energy profiling of server and network devices
- Energy-aware hardware network devices (rate adaptation and standby)

Physical network level

- Real DC traffic modelling
- Energy aware network architecture design
- Energy aware optimization algorithms and protocols
- Testbed

Abstract level

- Energy aware virtual data center embedding algorithms
- Energy aware network function virtualization/SFC embedding
- Testbed



Green Cloud and Edge Computing (*cont…*)

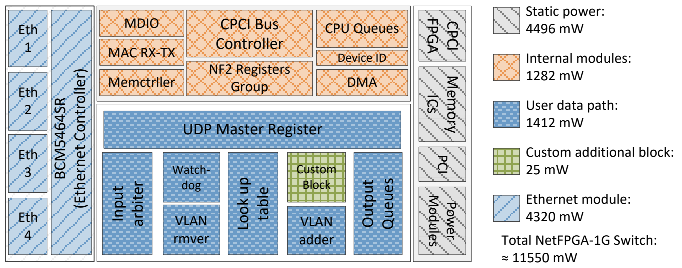
- ECODANE - *Reducing Energy COnsumption in DAta Center NEtworks based on Traffic Engineering*
  - 160.000 USD funded funded by Ministry of Science and Technology (VN)
  - Duration: March 2011 – September 2013
  - Collaboration with University of Wuerzburg (Germany)
- Towards Green Cloud Computing in Heterogeneous Network Infrastructures
  - 167.000 USD funded by the Office Naval Research Global (ONRG - USA)
  - Duration: 2017 – 2020

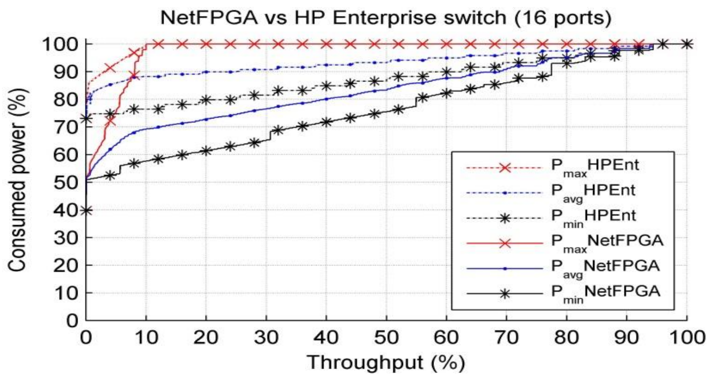
Green Cloud and Edge Computing (*cont*...)

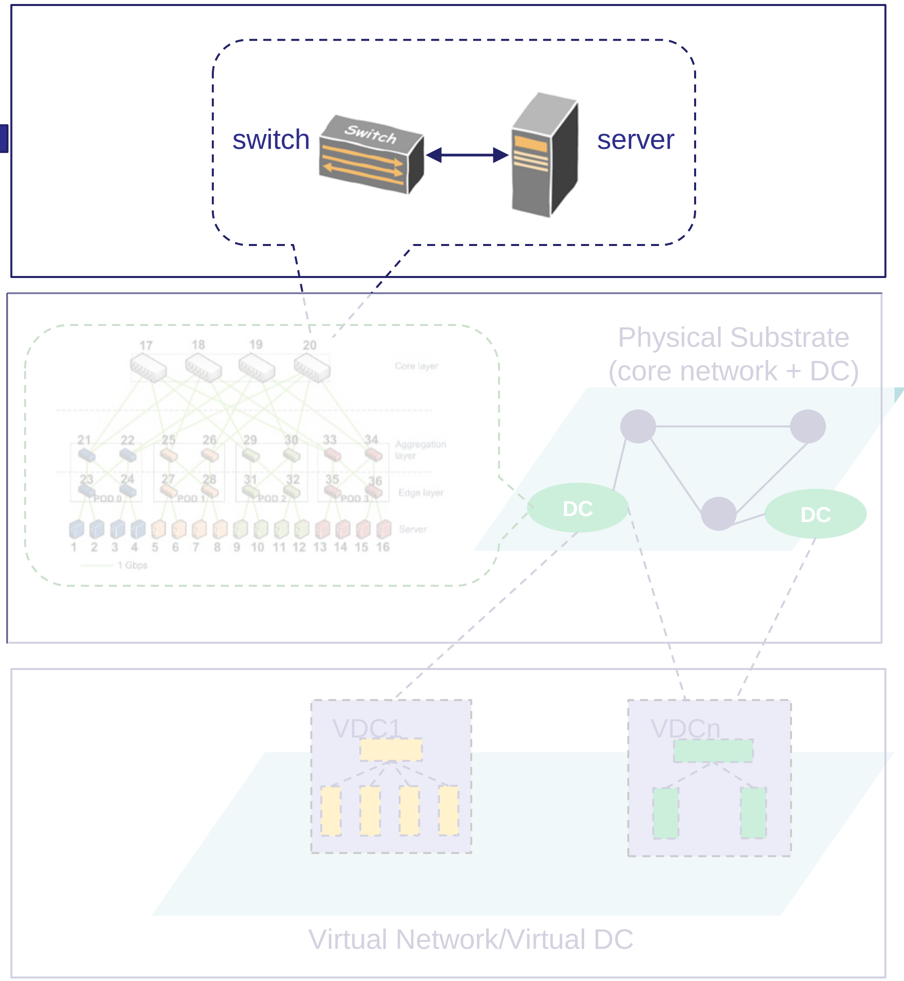
Device level

Energy-Aware Network Devices

- Study energy properties of devices
  - Energy profiling
    - Server
    - Network devices
- Design energy-aware network devices based on
  - Rate adaptation
  - Standby





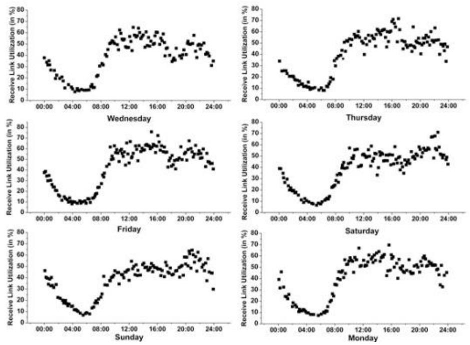


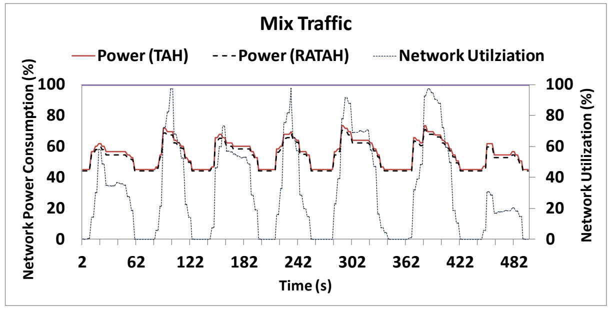
Green Cloud and Edge Computing (*cont*...)

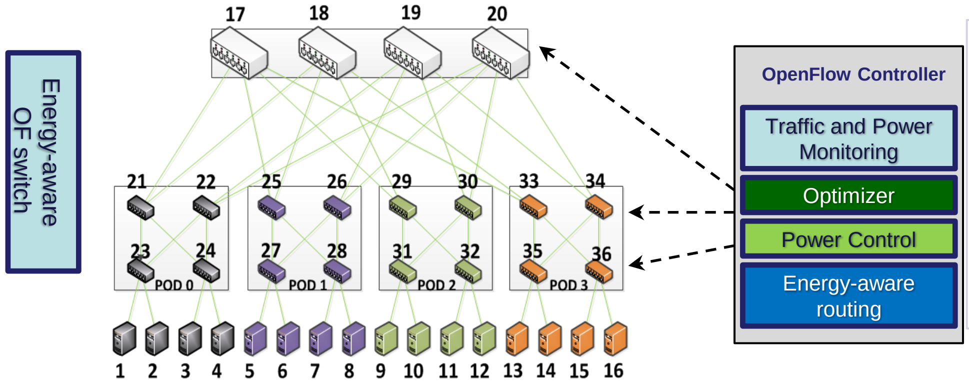
Physical network level

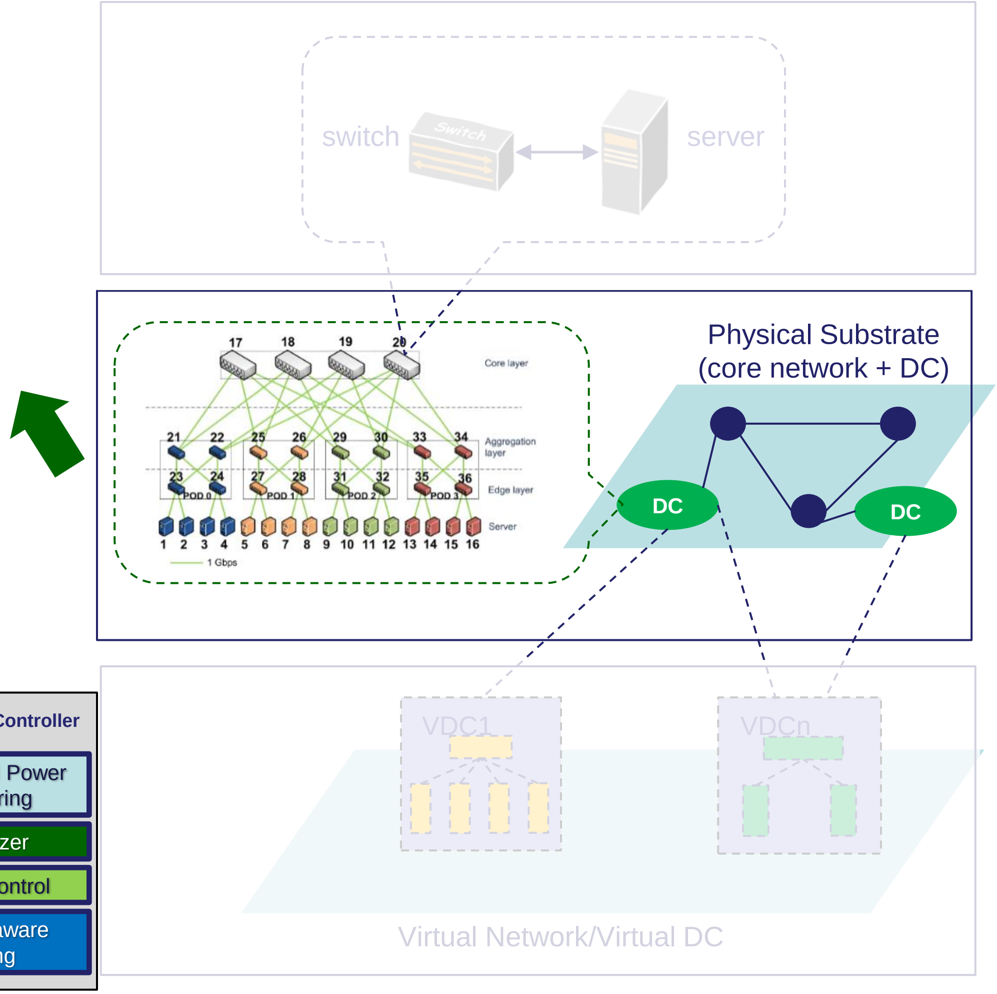
Energy-Aware Data Centers and Networks

- Real DC traffic modelling
- Energy aware network architecture design
- Energy aware optimization algorithms and protocols
- Testbed







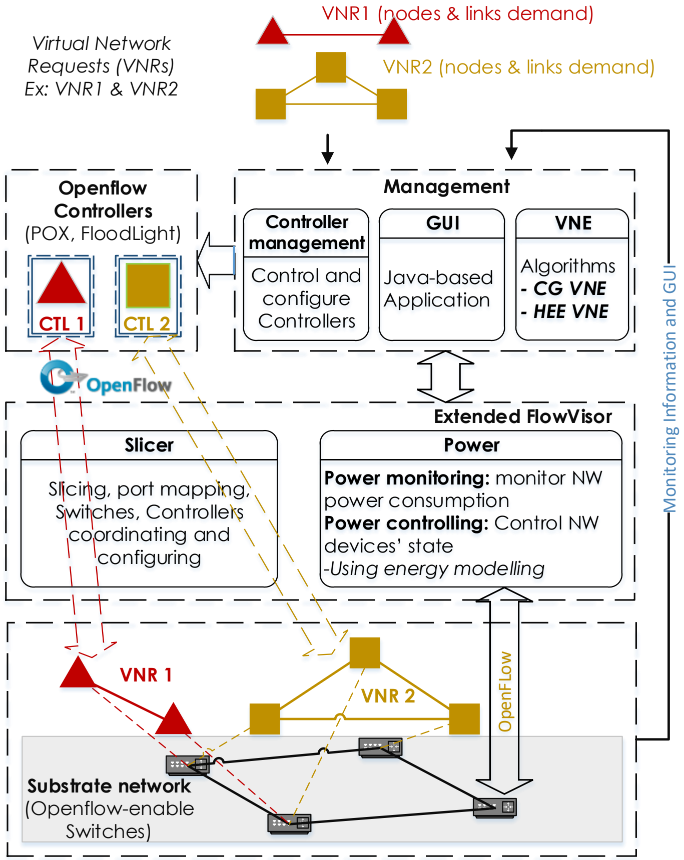


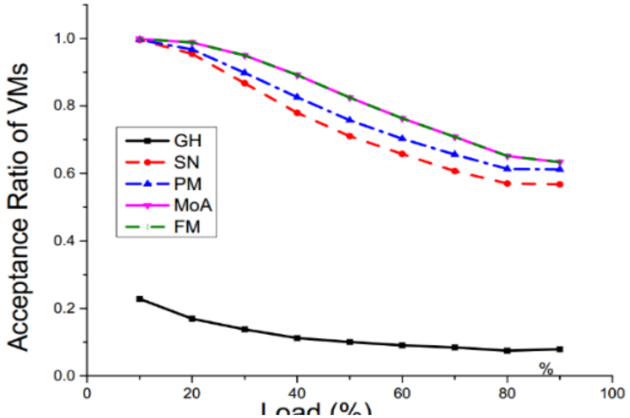
Green Cloud and Edge Computing (*cont…*)

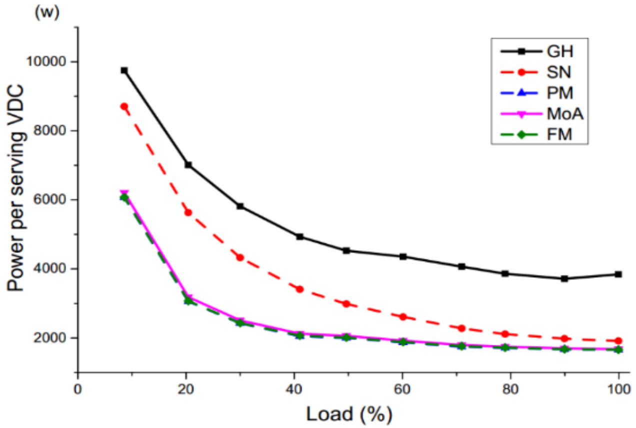
Abstract level

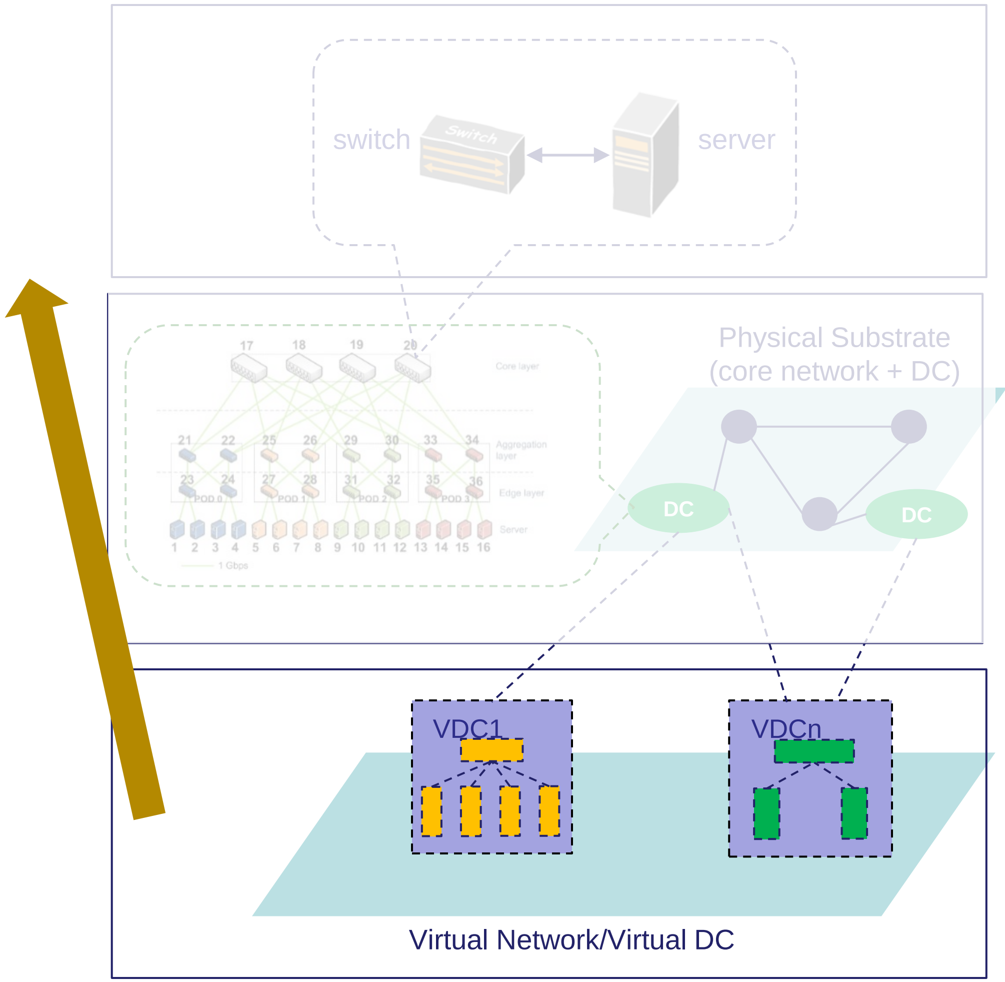
Energy-Aware NV/NFV

- Energy aware virtual data center embedding algorithms
- Energy aware network function virtualization
- Testbed









Efficient network virtualization and NFV

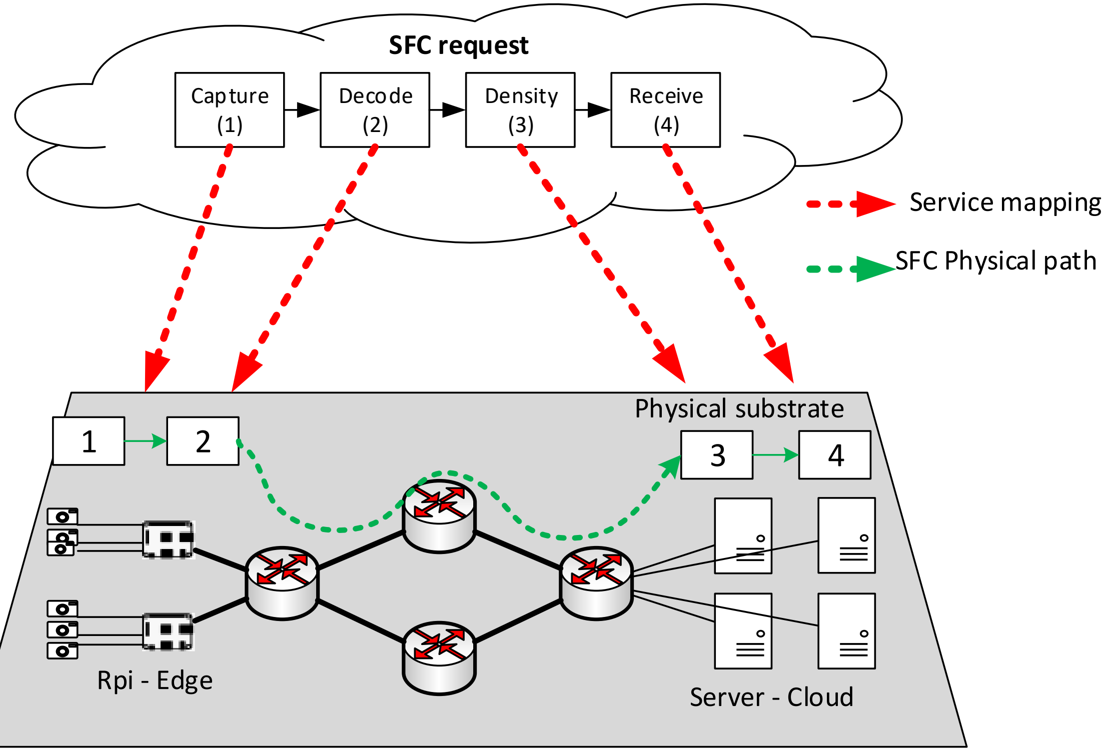
- Research activities
  - Edge-Cloud-based testbed
    - Use case: IP traffic camera network for smart city
  - Profiling and modeling
    - Resource utilization in edge-cloud
  - Edge-cloud service chain embedding
    - Efficient heuristic service chain embedding for edge-cloud paradigm

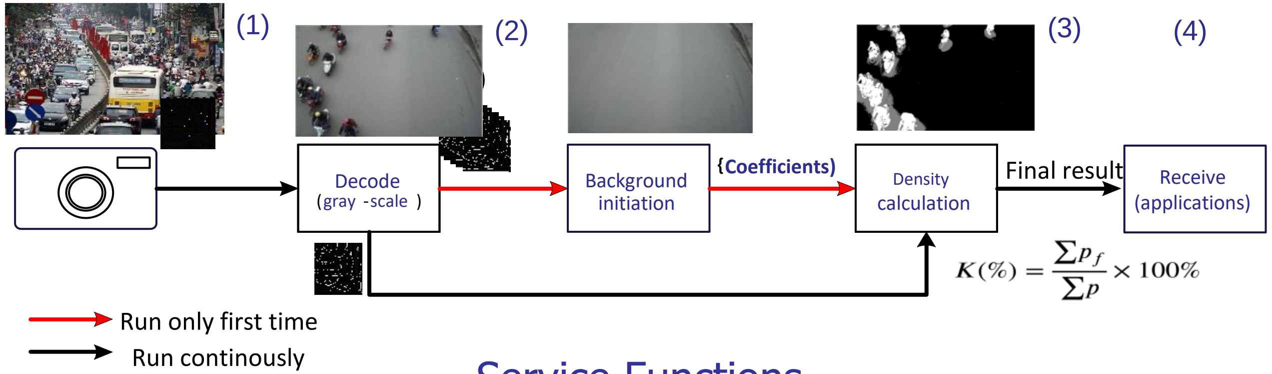
Efficient network virtualization and NFV (*cont…*)

Testbed

- Use case: IP traffic camera network for smart city
  - Intelligent traffic intensity detection at intersection
- Development of smart camera with embedded edge computing
- Edge-Cloud testbed model
  - Architecture design
  - Platform for edge-cloud virtualization and resource management

Service Function Chaining in Edge-Cloud





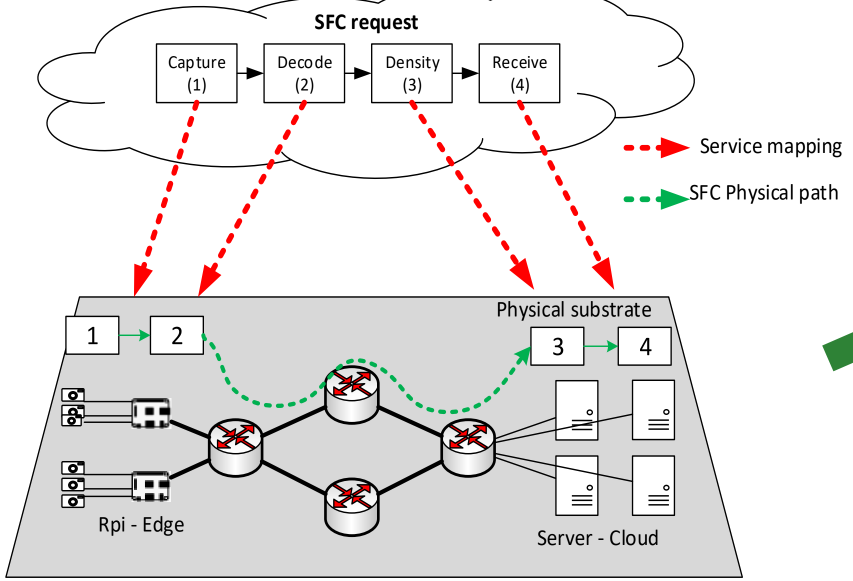
Service Functions

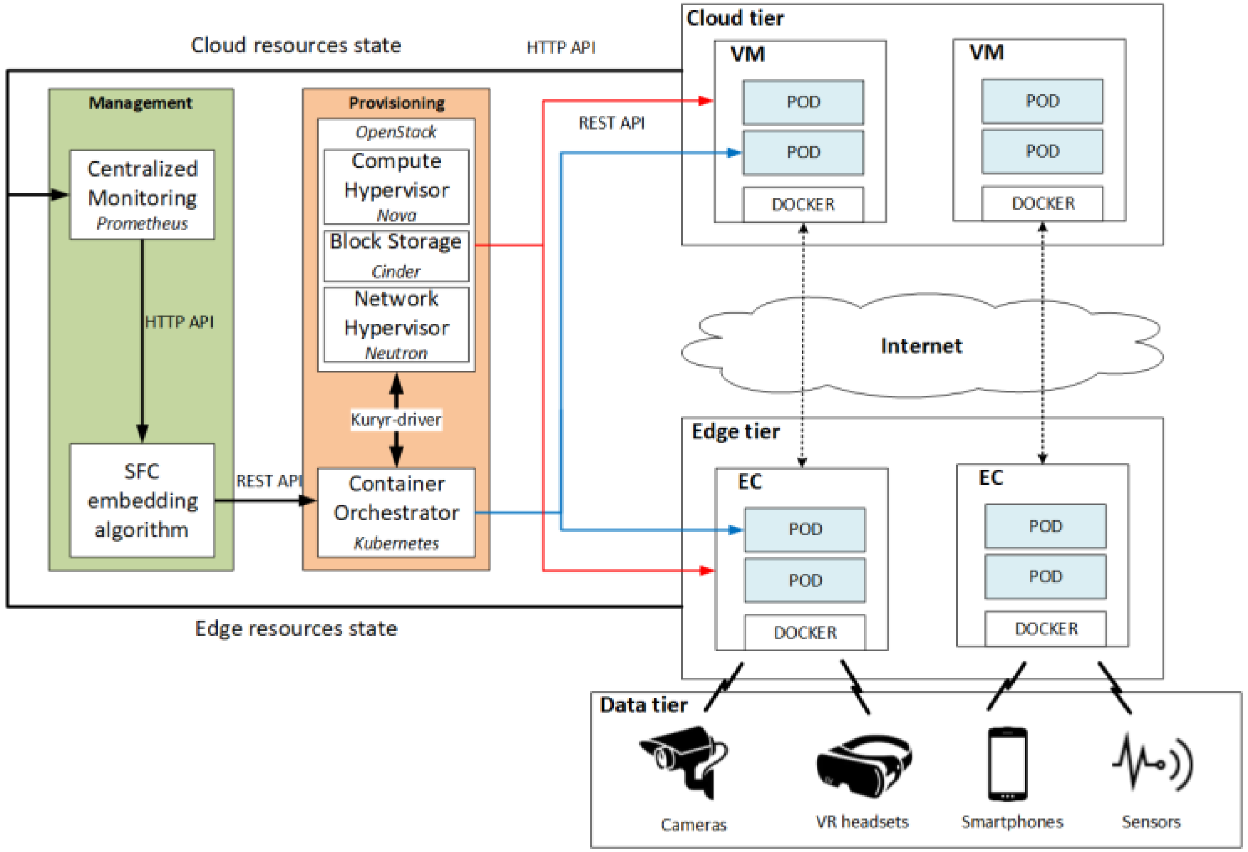
Efficient network virtualization and NFV (*cont*...)

Testbed

- Use case: IP traffic camera network for smart city
  - Intelligent traffic intensity detection at intersection
- Development of smart camera with embedded edge computing
- Edge-Cloud testbed model
  - Architecture design
  - Platform for edge-cloud virtualization and resource management

Service Function Chaining in Edge-Cloud





Efficient network virtualization and NFV (*cont…*)

Profiling and Modeling

- Measurement and modeling of SFC resource utilization
  - CPU and memory
  - Bandwidth
  - Power consumption (edge device and server)
  - Latency

- Power consumption
  1. For a Raspberry Pi

     $$P_i(t) = \left(P_{baseline} + \sum_{\forall s \in S} P_s(t) \times n_s\right) \times \gamma\,(W)$$

  2. For entire edge system

     $$P_I(t) = \sum_{\forall\, i \in I} state(i,t) \times P_i(t)\,(W)$$

  3. For server

     $$P(u) = P_{idle} + \left(P_{bussy} - P_{idle}\right)(2u - u^r)$$

- Bandwidth consumption

  $$B_i = \sum_{\forall s \in S} \beta_s \times n_s\,(Mbps)$$

- Latency

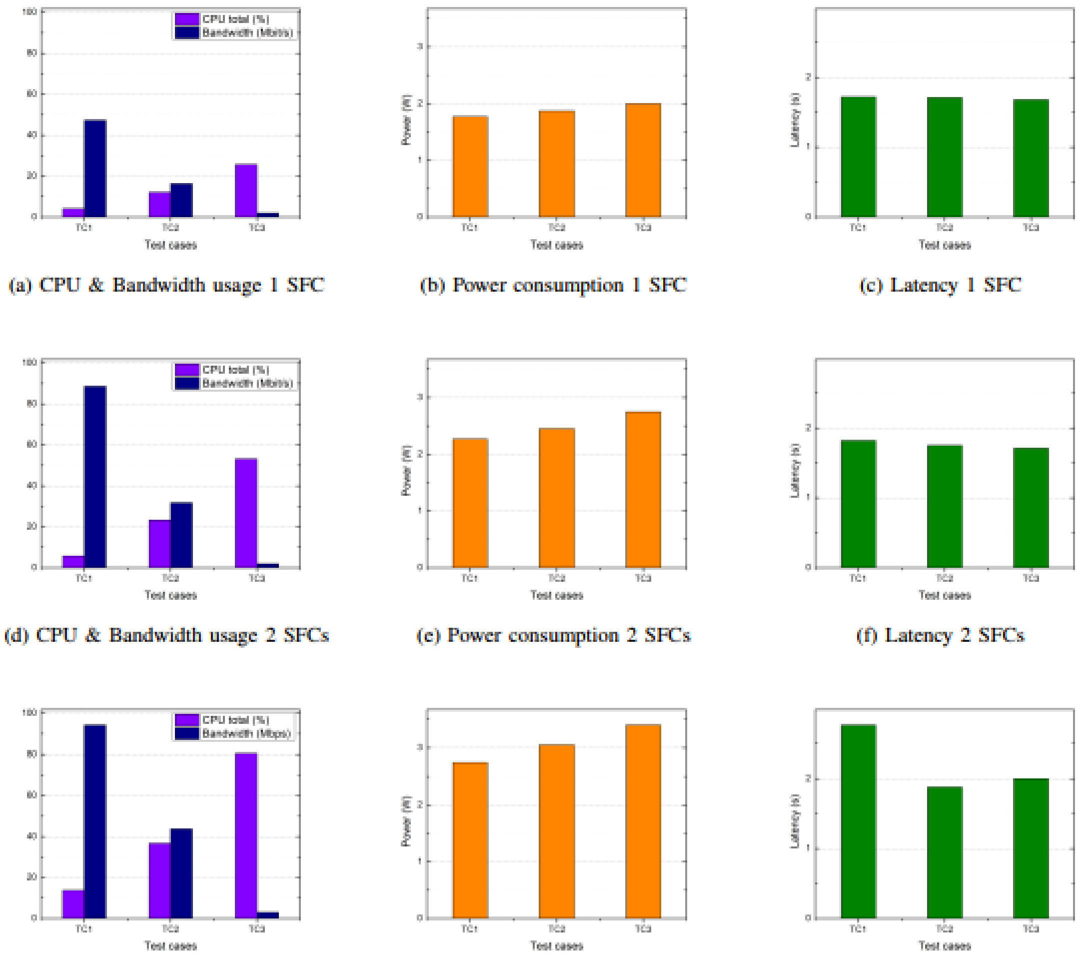
  $$l(i) = \sum_{\forall s \in S} (l_s + p_s)$$

- System temperature

  $$y = \theta_0 + \theta_1 \times x + \theta_2 \times x^2 + \theta_3 x^3$$

- CPU utilization

  $$CPU_i^P = \sum_{\forall s \in S} CPU_s^P \times n_s^p$$

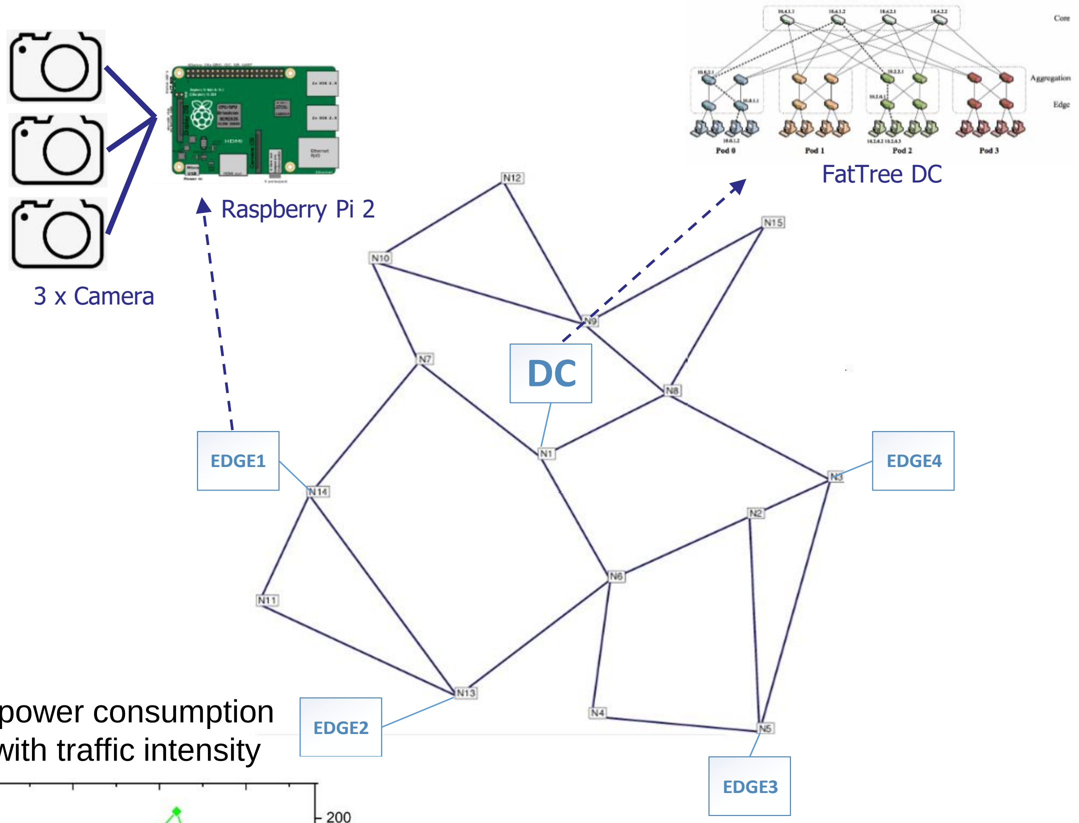


(a) CPU & Bandwidth usage 1 SFC
(b) Power consumption 1 SFC
(c) Latency 1 SFC
(d) CPU & Bandwidth usage 2 SFCs
(e) Power consumption 2 SFCs
(f) Latency 2 SFCs
(g) CPU & Bandwidth usage 3 SFCs
(h) Power consumption 3 SFCs
(i) Latency 3 SFCs

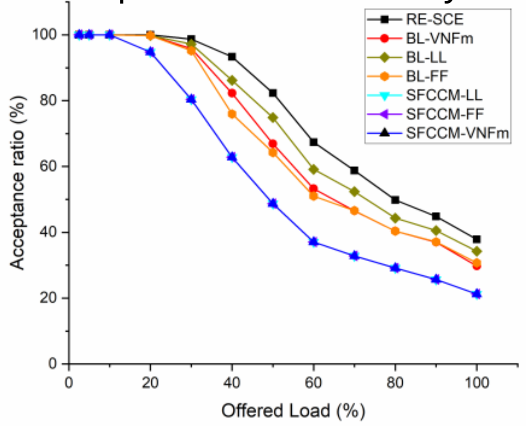
Efficient network virtualization and NFV (*cont…*)

Service Chain Embedding

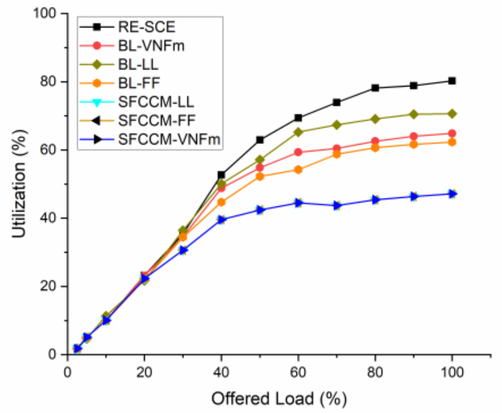
- Efficient heuristic service chain embedding algorithms for edge-cloud paradigm
  - Power and resource efficiency
  - Simulation-based, deployable on testbed



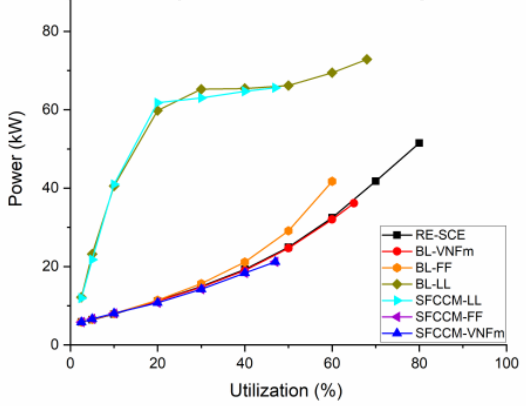
Acceptance ratio of the system



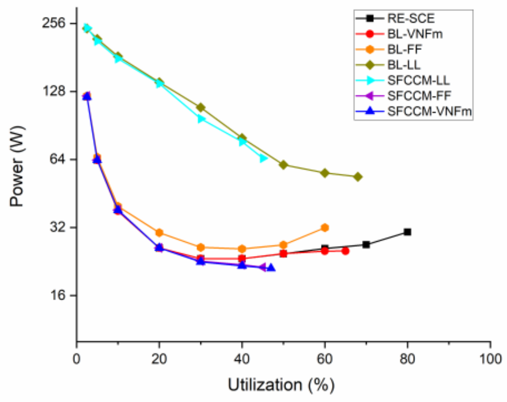
Resource utilization



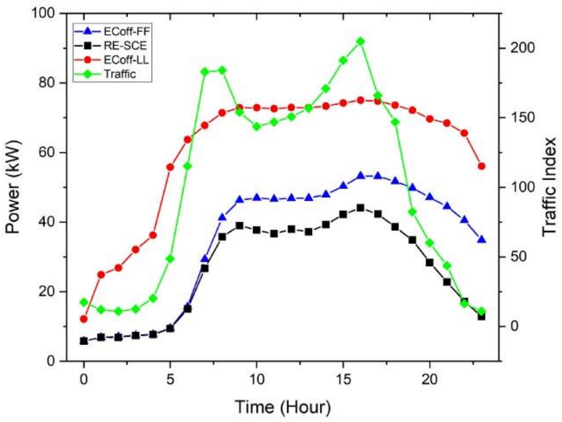
System power consumption



SFC power consumption



System power consumption varied with traffic intensity



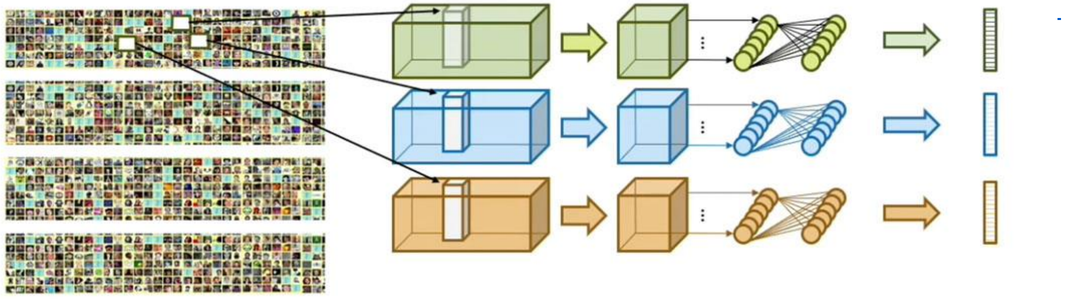
Edge Intelligence

- Problem statement
  - Centralized ML-based value-added service platforms
    - ◇ Privacy issues as data should be sent to the cloud
    - ◇ Latency and QoS as data are centrally processed
    - ◇ High network resource utilization as big data are sent over the Internet

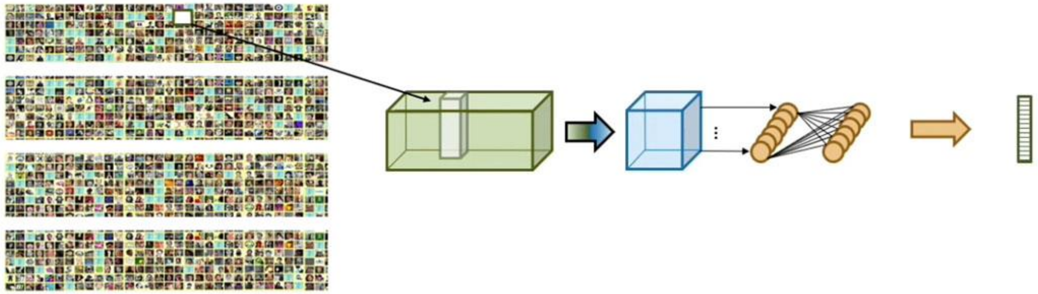
  → Distributed edge-cloud intelligent methods and platforms

Edge Intelligence (*cont…*)

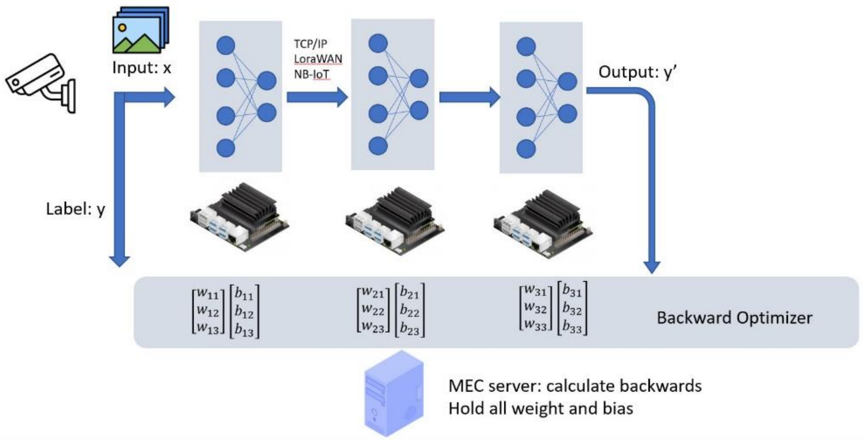
- Research activities
  - Distributed AI models and testbeds
    - Data parallelism
    - Model parallelism
  - Task scheduling for distributed AI
    - How to optimize ML-tasks for different, heterogeneous computing devices?
  - Edge intelligence for network security
    - Botnet detection at multiple network gateways



Data parallelism



Model parallelism

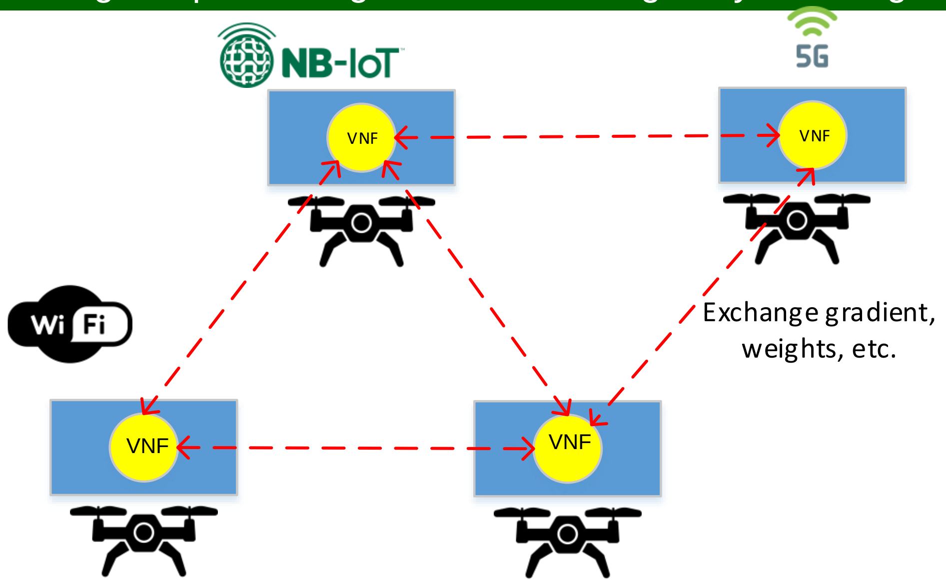


Testbed for pipeline parallelism

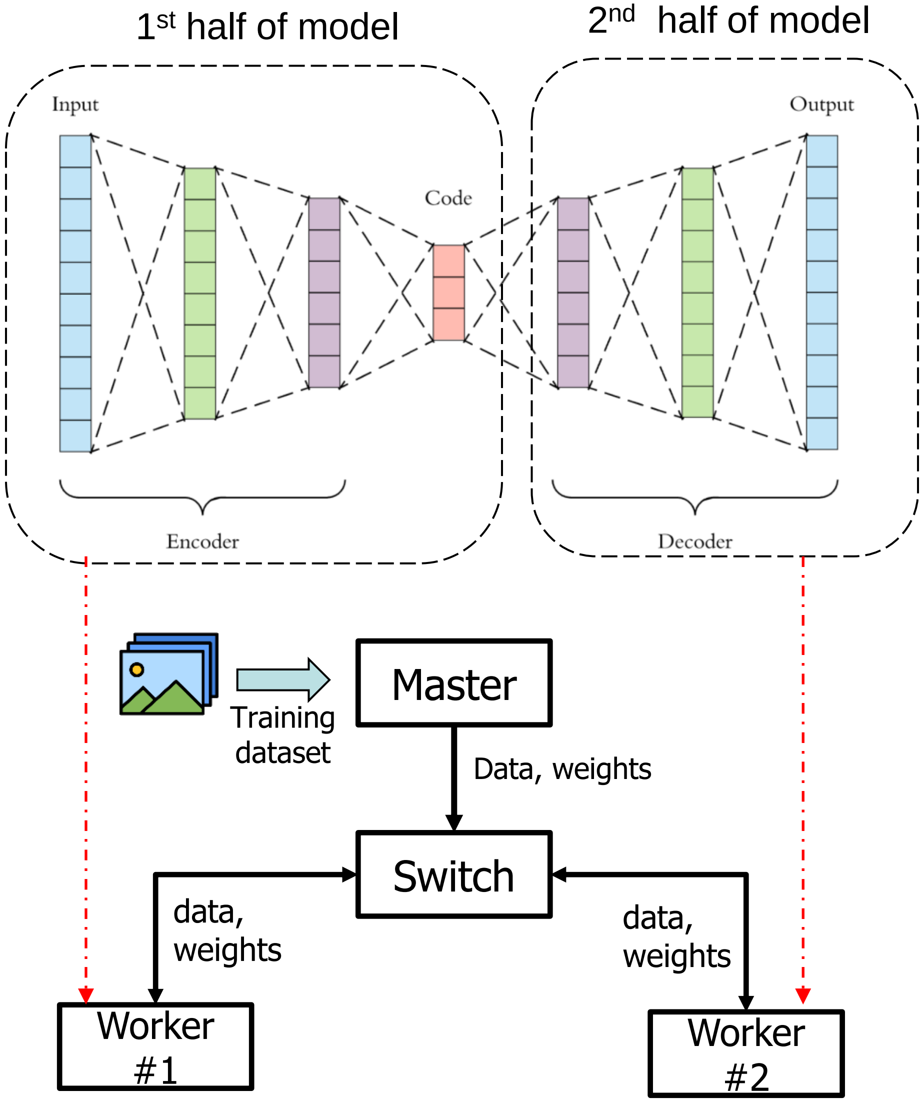
Edge Intelligence (*cont...*)

Model parallelism over edge devices

- Deep learning models are processed over multiple edge devices
  - Utilize the scattering resources of edge devices
  - Able to run massive deep learning model by collaboration between edge devices
  - Trade-off between computing and communication
- SFC model can increase elasticity
  - Part of deep learning model resides in VNFs placed dynamically at edge or cloud
  - Offloading Deep Learning tasks are leveraged by VNF migration

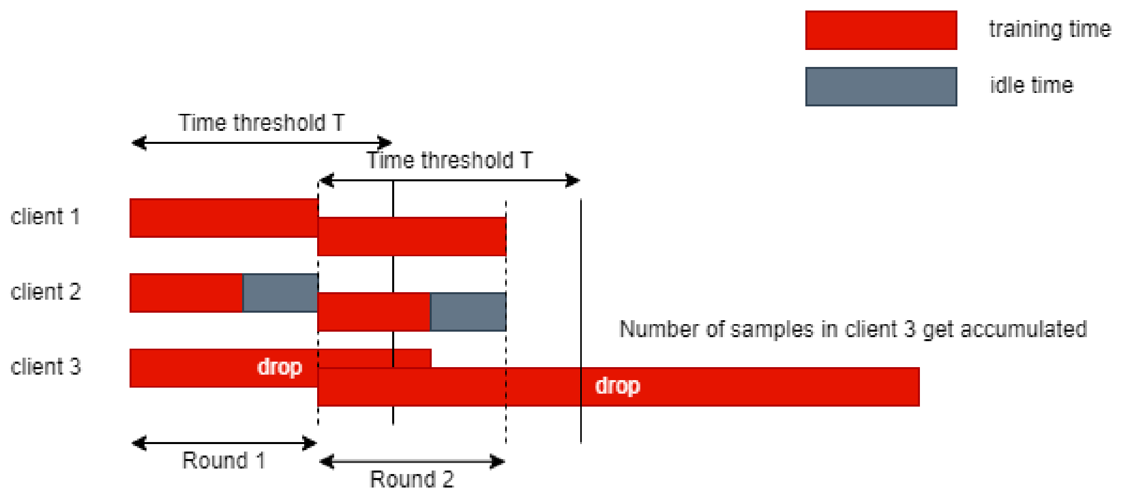


SFC-based distributed AI

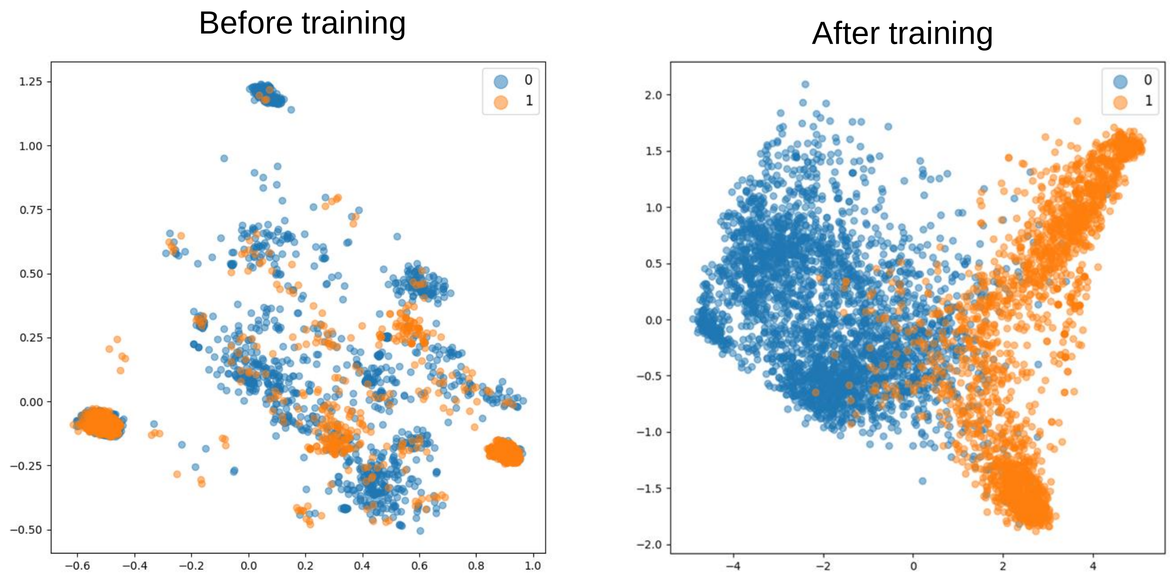


Edge Intelligence (*cont…*)

- Dynamic Scheduling for Federated Learning
  - Dealing with heterogeneous computational capacity and data distribution (IID and non-IID)
  - Evaluate "importantness" of an edge device in the training pipeline
  - Optimize training pipeline using computational capacity and importantness of each edge device



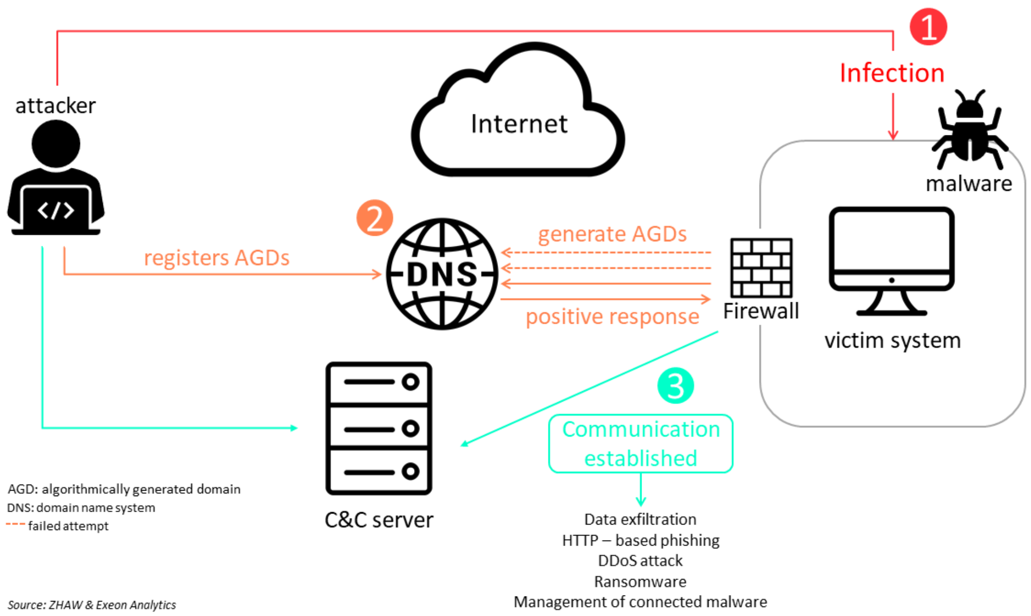
Optimize training pipeline



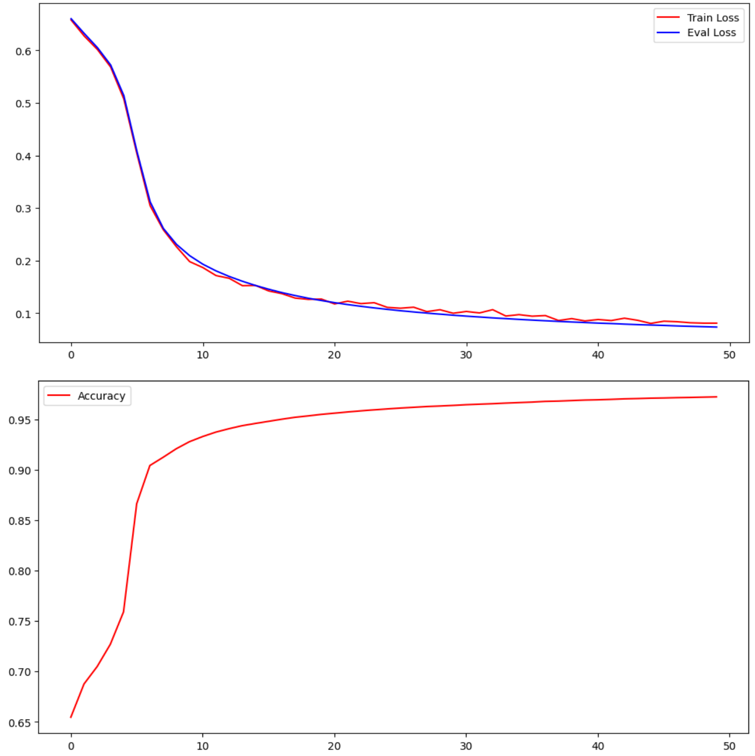
Embedding of domains reduced with PCA

Edge Intelligence (*cont…*)

- Botnet detection based on Domain Generation Algorithm (DGA)
  - Classify Benign/DGA domains based solely on domain strings
  - Deep Learning with Embedding and LSTM model



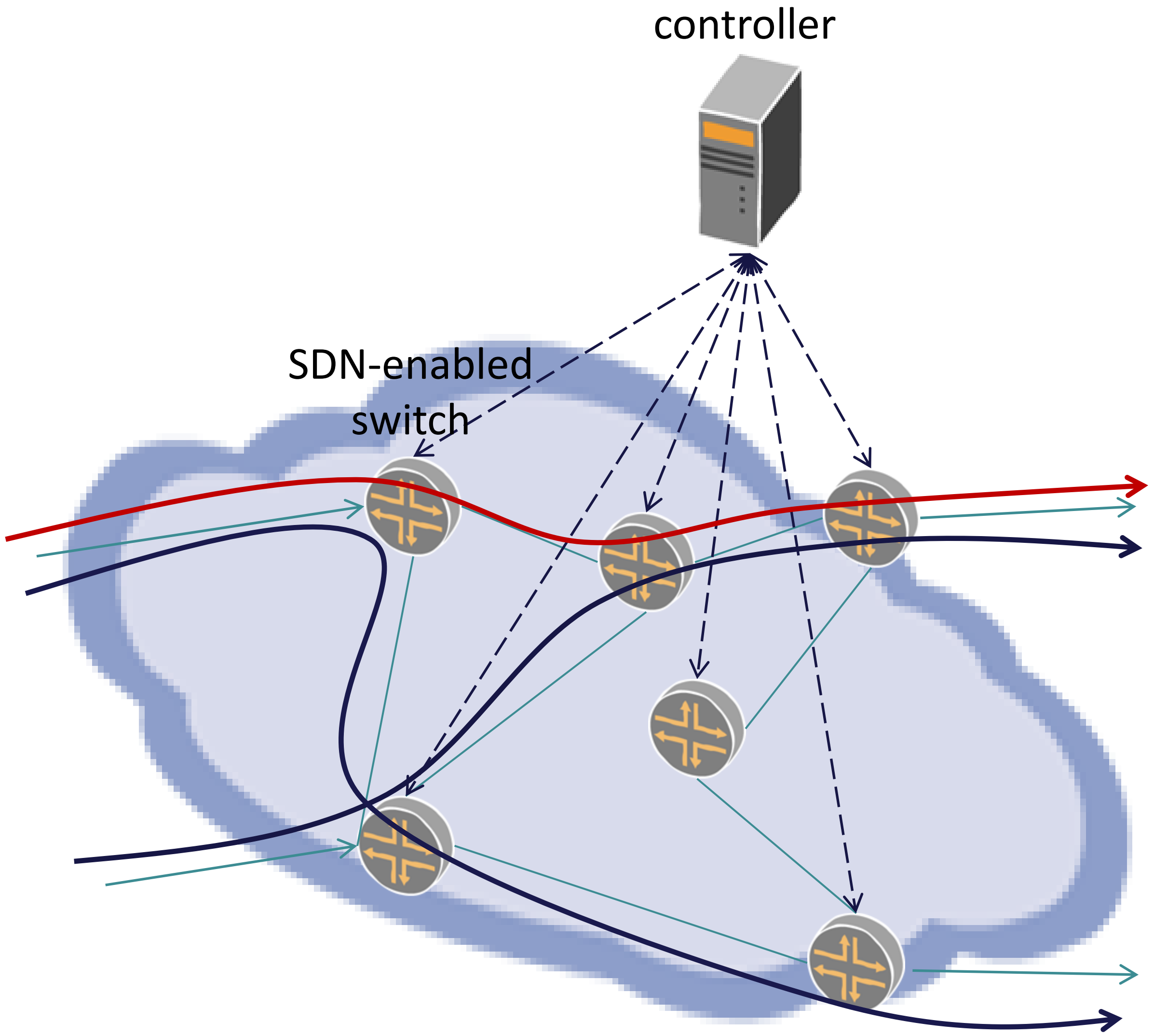
How DGAs operate



LSTM Model performance for each training round

SDN-based Network Security

- Why SDN in network security?
  - "Bird view" of network
    - Monitoring different points of network
      - Traffic states in a node
      - Traffic matrix of the whole networks
  - Flexibly deployment of intelligent security algorithms in the control plane
    - AI, machine learning, fuzzy
  - Flexibly enforcing rules in network nodes on-the-flight



SDN-based Network Security (*cont…*)

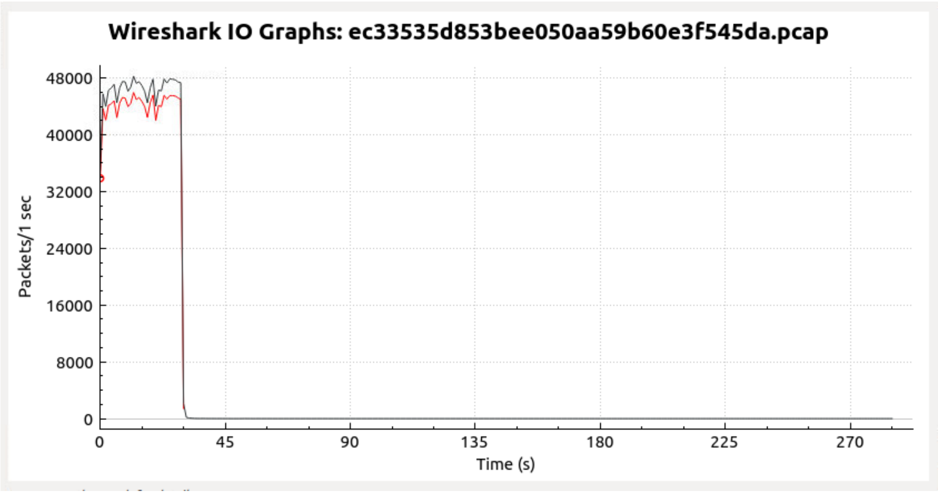
- National research project
  - *Research and Development of a Traffic Monitoring and DDoS Detection System based on Software Defined Networking Technology*
    - 195.000 USD funded by Ministry of Science and Technology
    - Duration: 2016 – 2017
    - In collaboration with University of Liverpool, UK

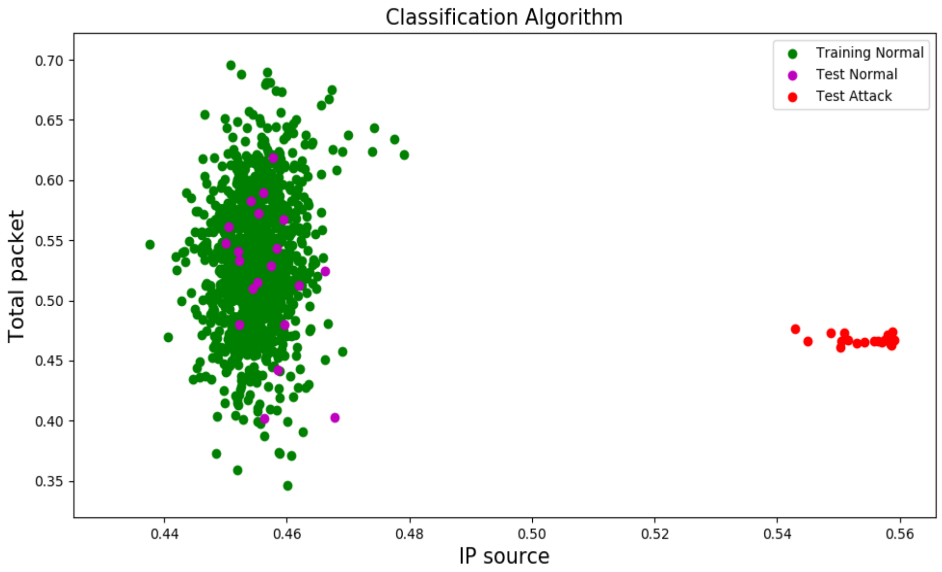
SDN-based Network Security (*cont…*)

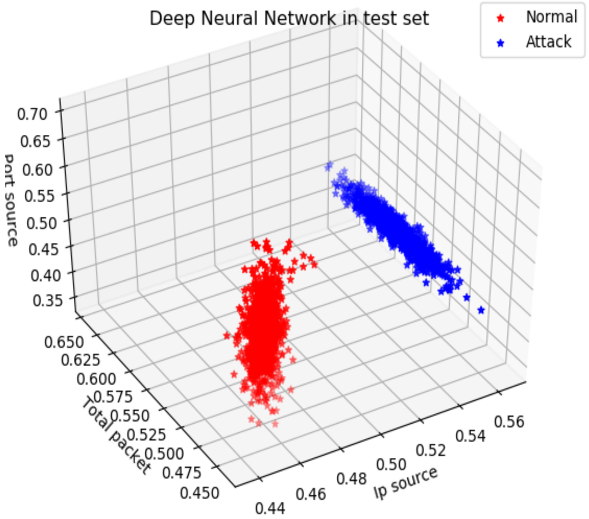
- Research activities
  - Traffic analysis
  - SDN-based network architecture design
  - DDoS detection and mitigation
  - Testbed and benchmarking

SDN-based Network Security (*cont…*)

- Traffic analysis and characterization based on real traces
  - ISPs in Vietnam (NetNam, etc.)
  - CAIDA 2007, 2013 – 2018
  - ddosdb.org
- Emulated traffic from tools such as Bonesi

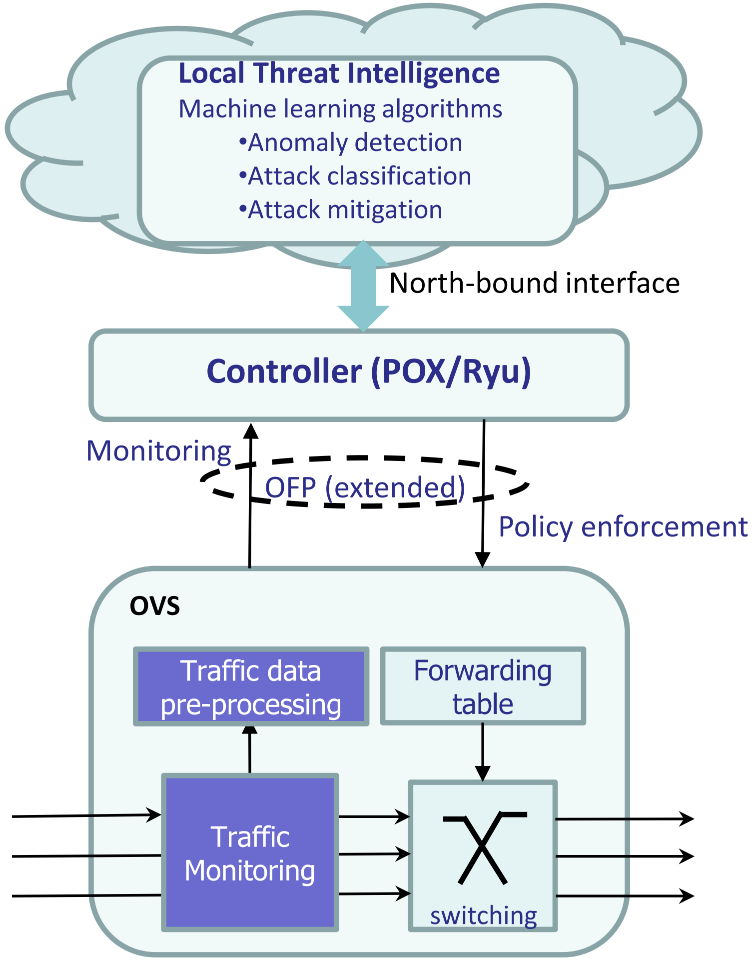


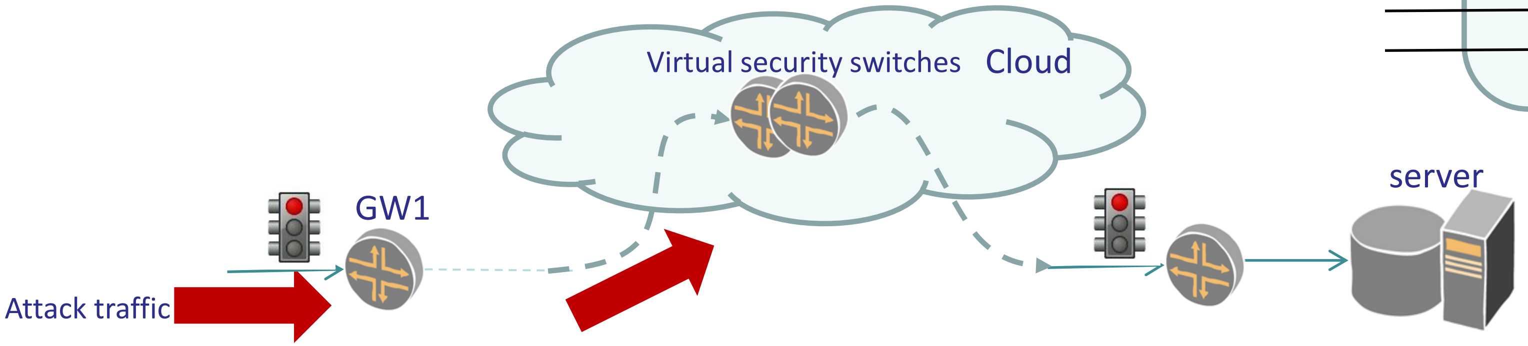




SDN-based Network Security (*cont…*)

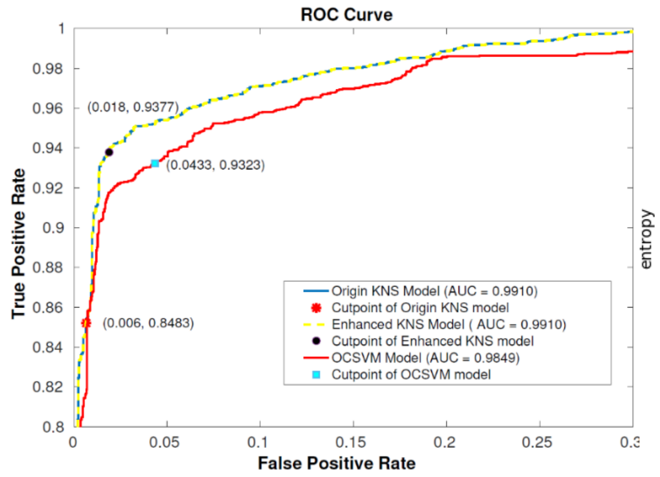
- SDN-based architecture design
  - SDN-based security gateway (OvS) - Extended OF switch with
    - Traffic monitoring functions
    - Data pre-processing
    - Anomaly detection
  - Controller (POX/Ryu)
    - Policy enforcement
  - Local Threat Intelligence (LTI)
    - Running ML algorithms for DDoS detection and mitigation
      - Attack classification
      - Attack mitigation
    - Allow decoupling the SDN controller with well-defined functionality from security-specific tasks
    - LTI on cloud can be scaled up or down depending on load
  - NFV-based Security-as-a-Service
    - Security service chain → easily scale up and down and adding more security functions

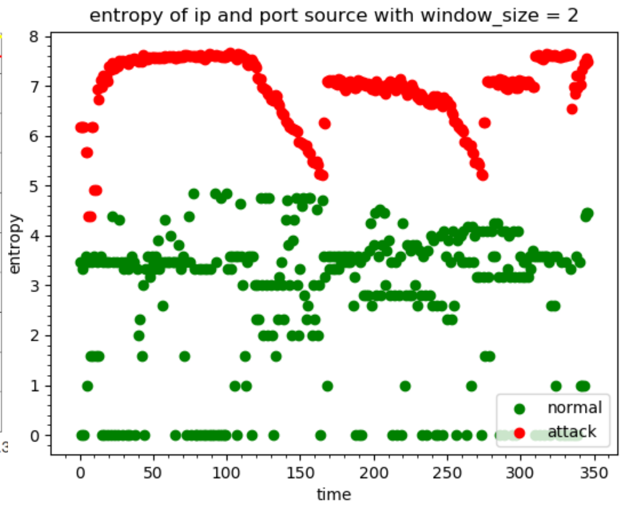


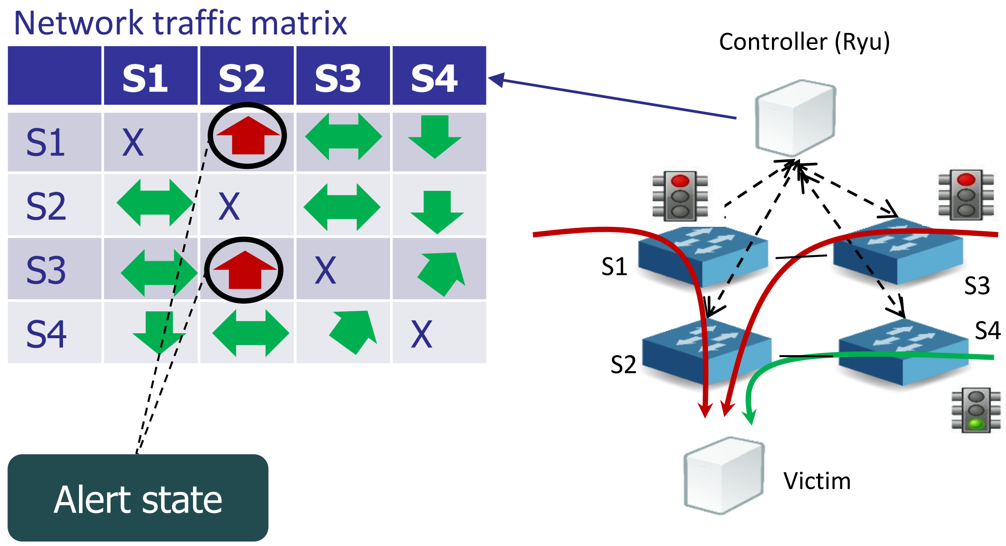


SDN-based Network Security (*cont…*)

- DDoS detection and mitigation
  - Advanced machine learning algorithms to
    - Detect anomalous traffic
    - Detect kinds of attack
      - TCP SYN flooding
      - ICMP flooding
      - DNS amplification
    - Mitigate attacks once attacked is detected and classify
    - Performance evaluation of various ML algorithms in realtime (*latency, accuracy, recall, precision, Fscore*)
  - Anomaly traffic detection based on traffic matrix
    - Destination-based traffic monitoring based on traffic matrix
  - Trace-back mechanisms and policy enforcement
    - Based on knowledge of the sources of attack
      - Corresponding policies on corresponding network nodes can be enforced

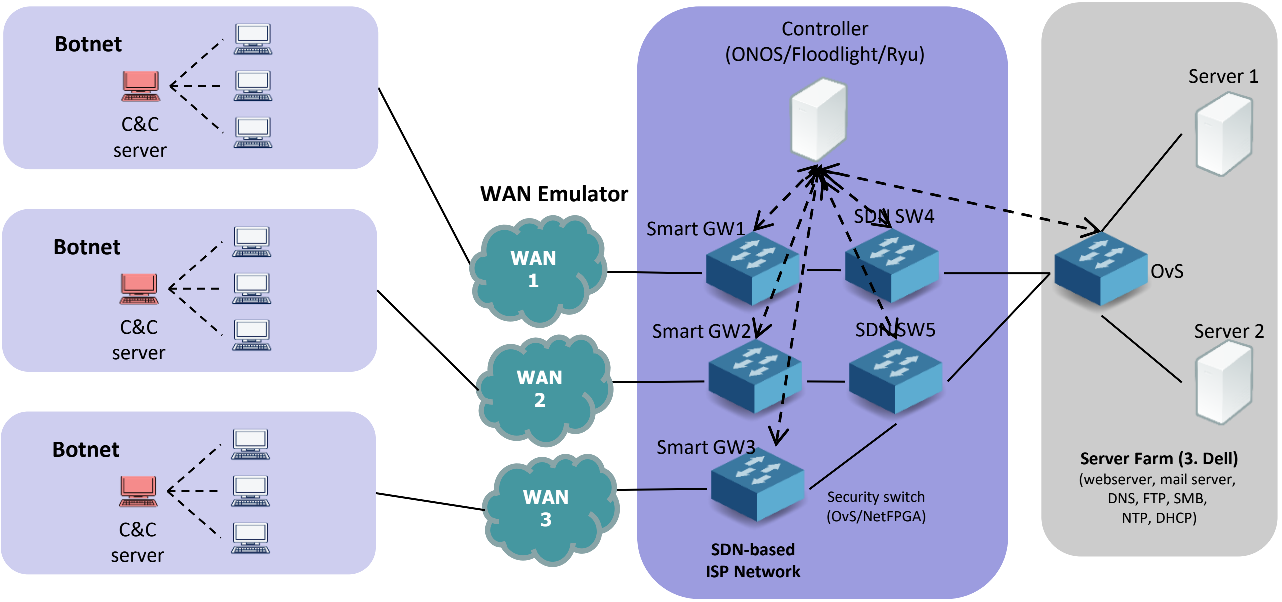


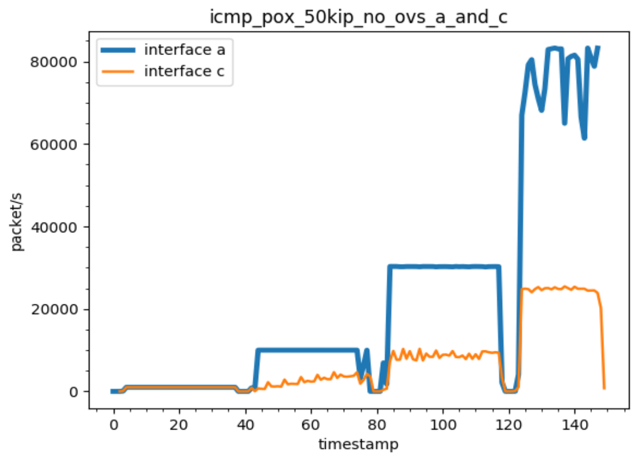


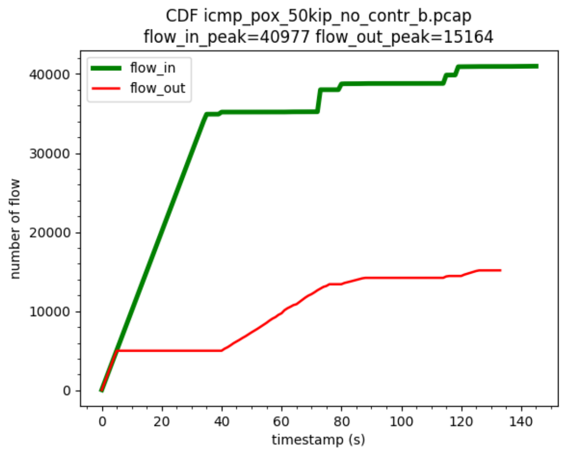


SDN-based Network Security (*cont…*)

- Testbed and benchmarking
  - Emulate real traffic in real networks
  - Evaluate behavior and performance of network devices under normal and attack
  - Create a common environment for testing and bench marking
    - Network devices, incl. controllers and switches
    - Newly developed security algorithms/mechanisms



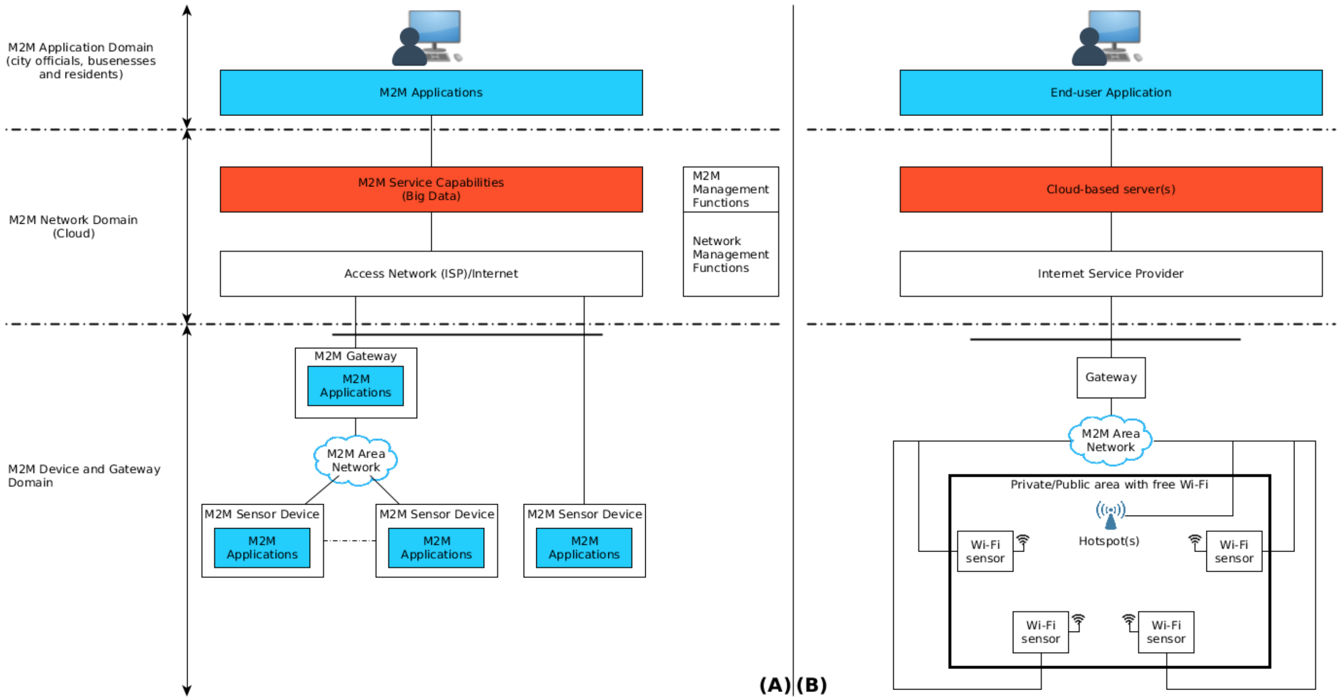


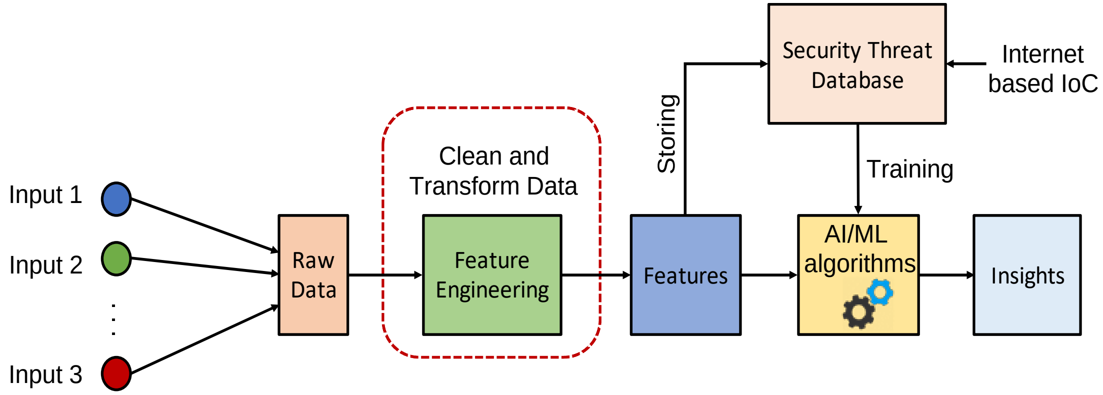


SDN-based Network Security (*cont...*)

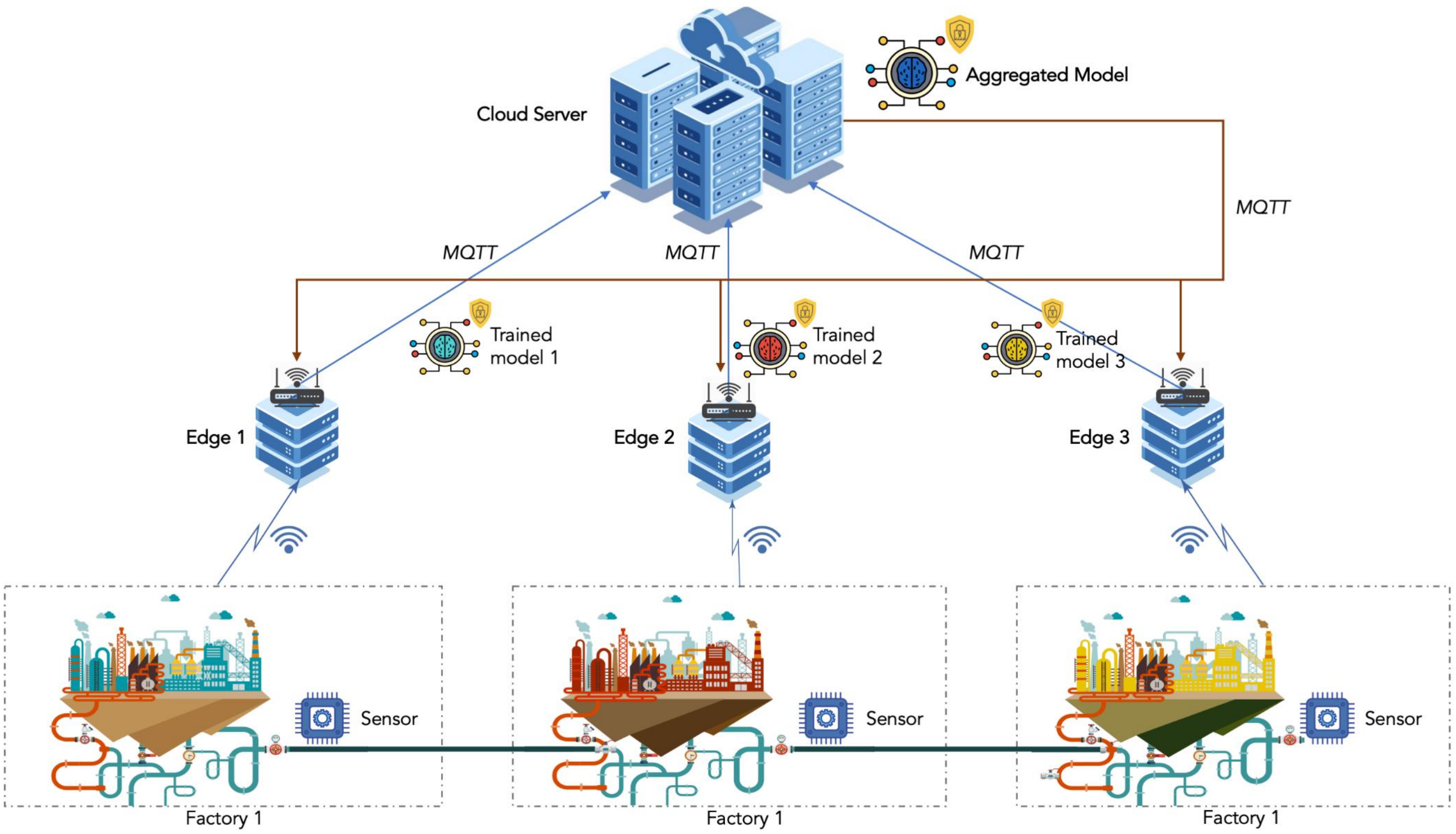
Network Security for IoT

- Anomaly detection at WIFI access interface
  - Data collection and analysis
  - Data preprocessing technique at the edge
  - Light weight protocol
  - Detection algorithms





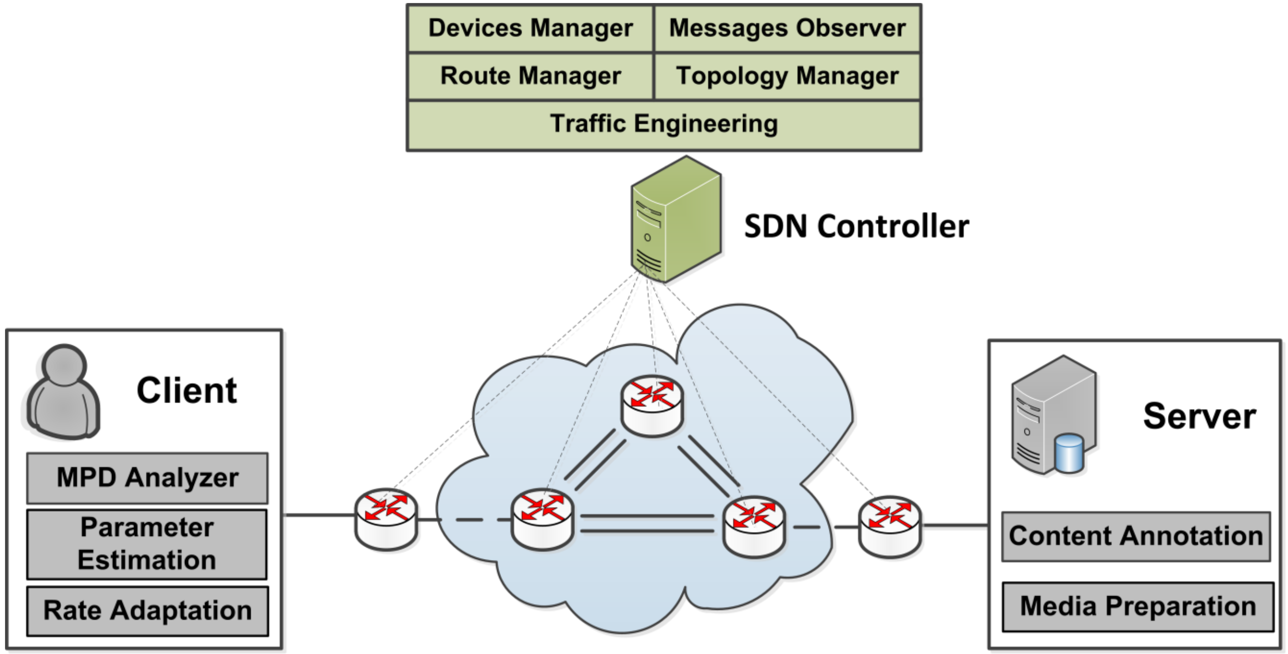
Edge-Cloud-based Network security for IoT-based ICS

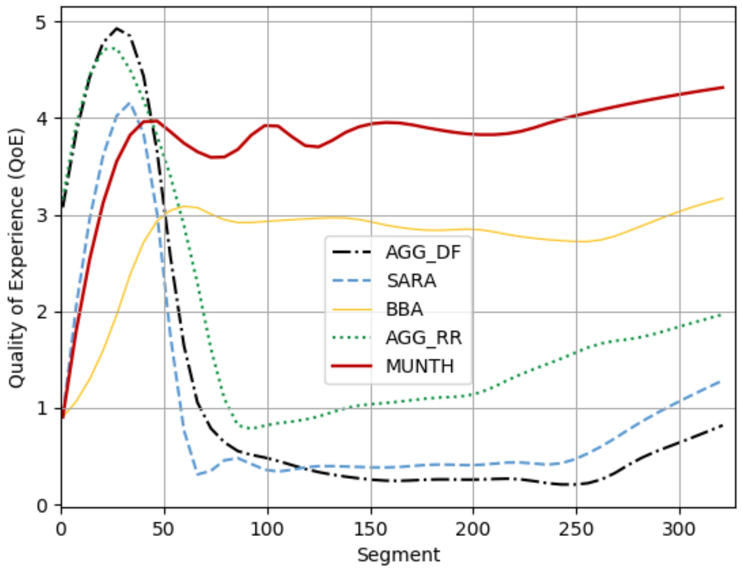


QoE for network services

QoE-based HTTP Adaptive Streaming

- Architecture HTTP Adaptive Streaming over SDN
  - Bit rate adaptation at clients
  - Routing and resource allocation by the SDN controller





Algorithm 1: Bitrate Adaptation Algorithm - MUNTH

Input: T_i, R_n, B_i,B^{Th}, D_i, RTT, D^{Th}, SD
Output: I_{i+1}

$T^e_{i+1} \leftarrow \gamma \times T_i + (1-\gamma) \times T_{i-1}$; // Estimate throughput.
$I_{i+1} \leftarrow 0$
if $D_i \leq D^{Th}$ **then**
  Request for a new path;
else
  for $j \leftarrow Q-1$ **to** 0 **do**
    $B^e_{i+1} \leftarrow B_i + SD - RTT - \frac{SD \times R_j}{T^e_{i+1}}$; // Estimate buffer level.
    if $B^e_{i+1} \geq B^{Th}$ **then**
      $I_{i+1} = j$;
    end
  end
end

QoE for network services (*cont…*)

QoE-based Virtual Reality

- Measurement methods to evaluate quality of VR (360º image)
  - Evaluate weights (w) of each pixel

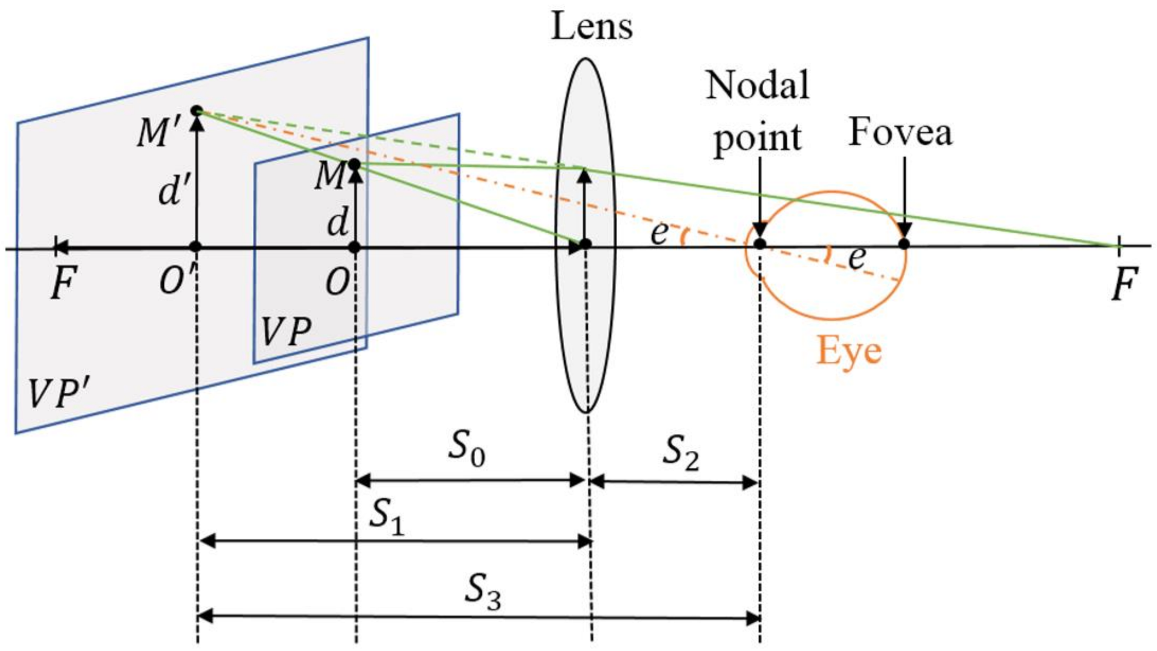


FIGURE 1: Typical viewing geometry in VR systems

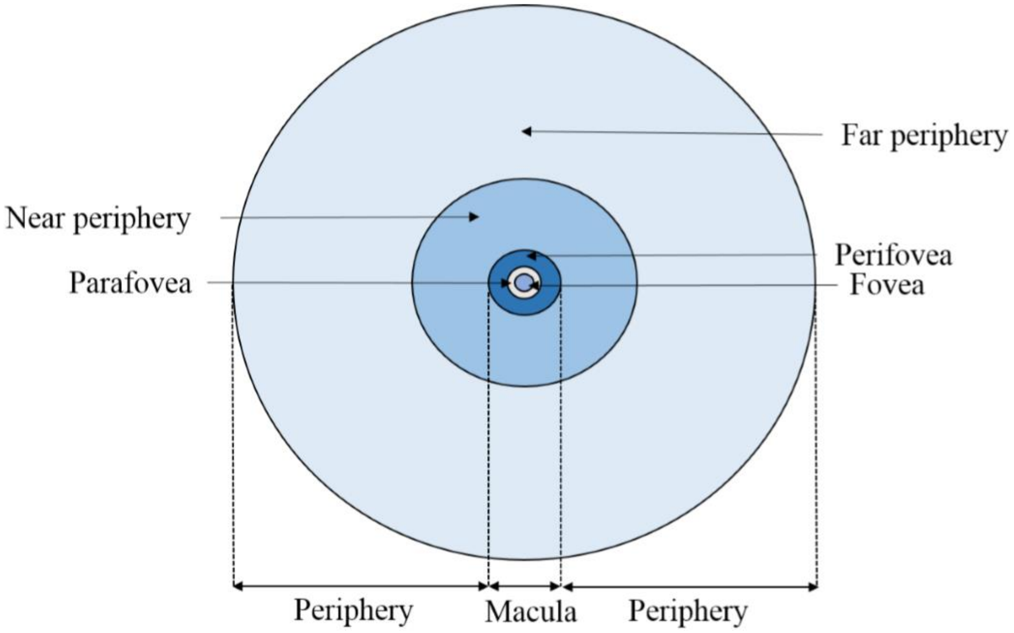


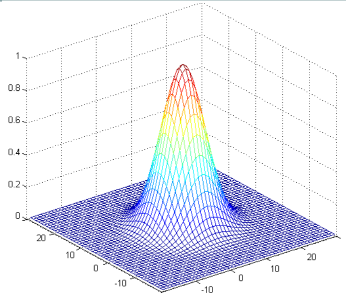
FIGURE 3: Five regions of the retina

QoE for network services (*cont…*)

QoE-based Virtual Reality

- Measurement methods to evaluate quality of VR (360º image)
  - Evaluate weights (w) of each pixel

Blurring images by Gaussian filter

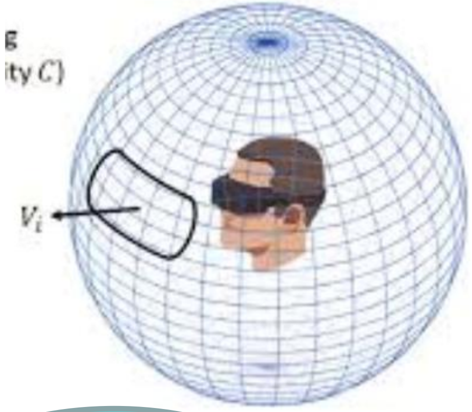


Blurred 360^o image

Software360lib[3]

Extract viewport

Viewport



MOS

Curve fitting with corresponding MOS

Coefficient for 360^o $image$

Absolute Category Rating method with 5 MOS level 1-5.

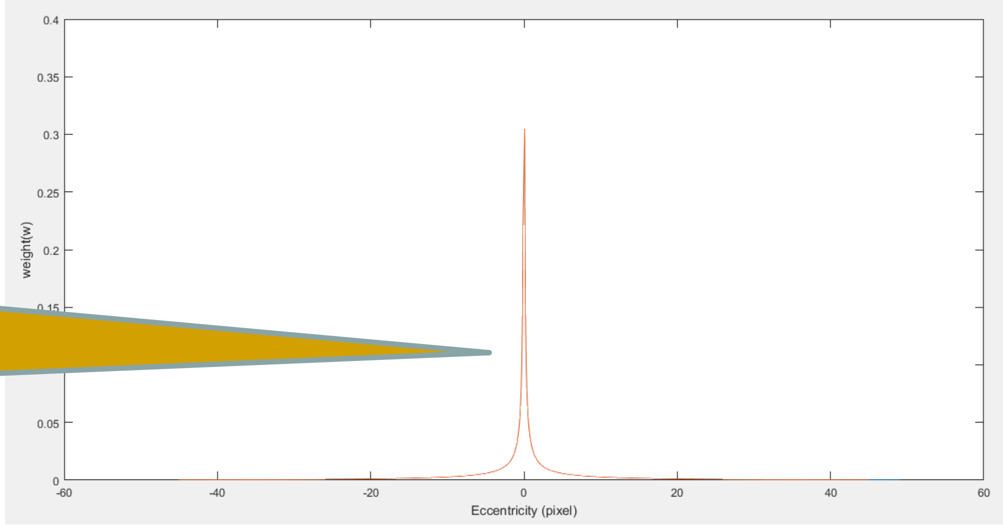
PCC optimization

QoE for network services (*cont…*)

QoE-based Virtual Reality

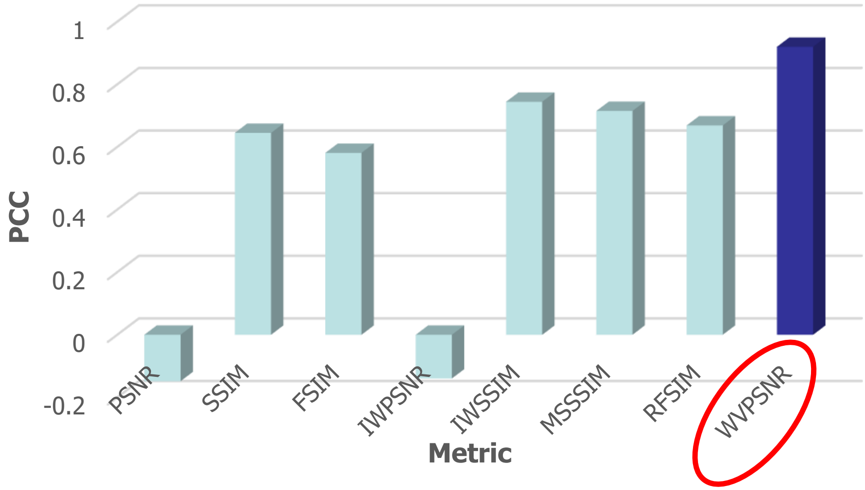
- Measurement methods to evaluate quality of VR (360o image)

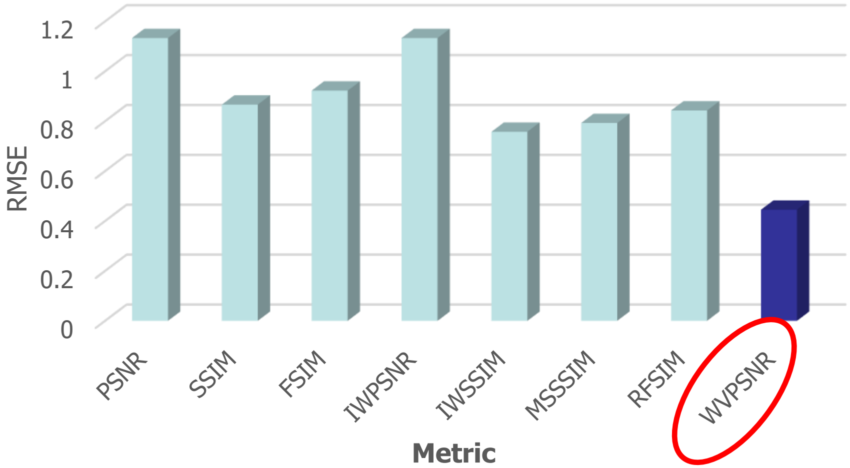
- w at area of 0-4 degree dominates of other areas
=> Should keep high quality in this area
- w at areas outside of 30 degree is low
=> Can reduce quality of 360o images



w distribution according to eccentricity

Comparison of measurement methods





QoE for network services (*cont…*)

QoE-based Virtual Reality

- Adaptation methods for Scalable 360-degree video streaming using HTTP/2
  - Reduce bandwidth required for 360-degree video streaming
  - trade off between network and user adaptability
  - Improve viewport bitrate

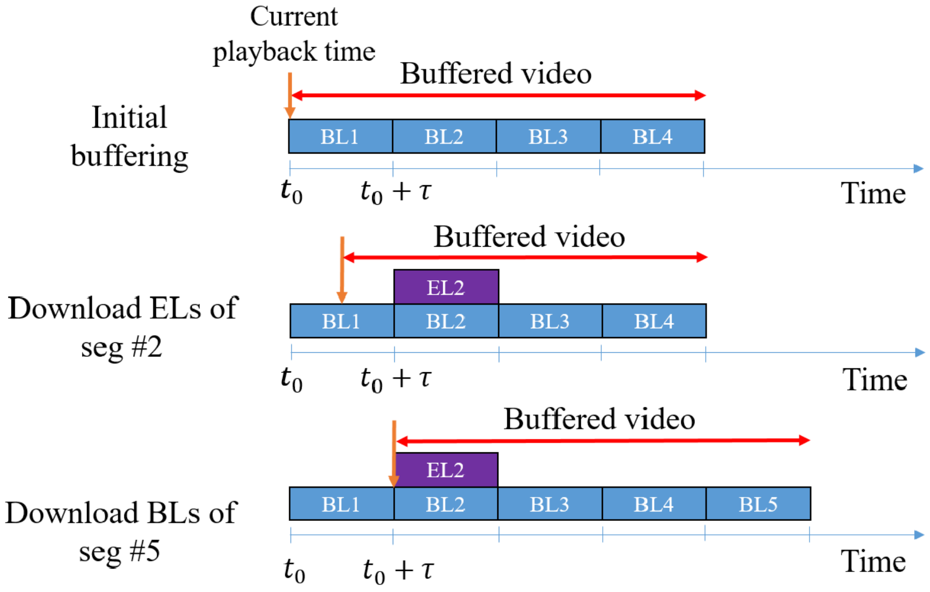
Algorithm 1: *Tile Layer Selection*

Input: $M, N, R^c, R^l_m, V_n, w_m(V_n)$
Output: $\{l_m\}_{1 \leq m \leq M}$

$l_m \leftarrow 0$ **for** $1 \leq m \leq M$;
$\Delta R \leftarrow R^c - \sum_{m=1}^{M} \sum_{l=0}^{l_m - 1} R^{l_m}_m$;
$sortedTile \leftarrow sort(w_m(V_n))$;
for $l = 1$ *to* $L - 1$ **do**
    foreach $m \in sortedTile$ **do**
        if $l_m < L - 1$ **and** $R^{l_m+1}_m < \Delta R$ **then**
            $\Delta R \leftarrow \Delta R - R^{l_m+1}_m$;
            $l_m \leftarrow l_m + 1$;
        end
    end
end
return $\{l_m\}_{1 \leq m \leq M}$;

Algorithm 2: *Late Tiles' Layers Termination*

Input: $\{l^{late}_m, 1 \leq m \leq M\}$
for $m = 1$ *to* M **do**
    foreach $l \in l^{late}_m$ **do**
        send RST STREAM frame for the stream corresponding to layer l;
    end
end

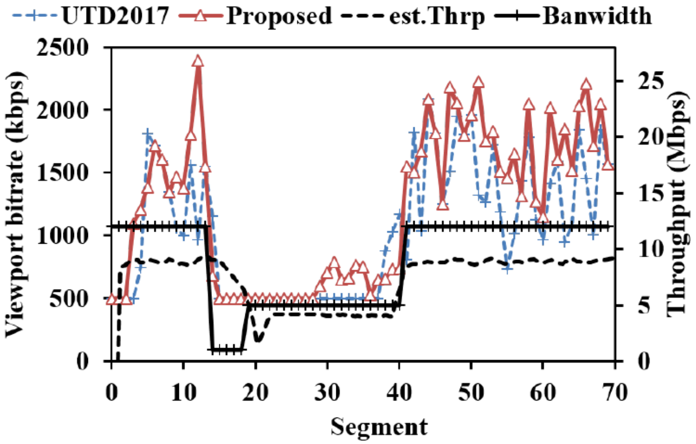


Trade off between network adaptability and viewport adaptability using Scalable Video Coding

QoE for network services (*cont*…)

QoE-based Virtual Reality

- Adaptation methods for Scalable 360-degree video streaming using HTTP/2
  - Reduce bandwidth required for 360-degree video streaming
  - trade off between network and user adaptability
  - Improve viewport bitrate

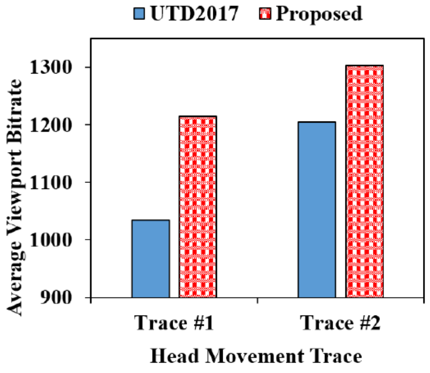


(a) Viewport bitrate (kbps)

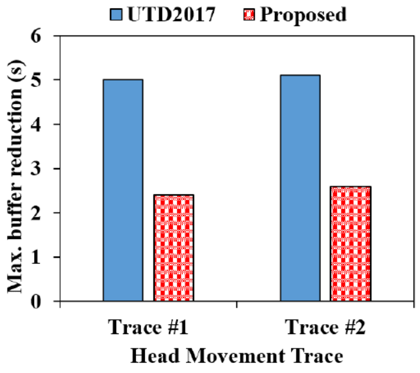
Algorithm 3: *Viewport-aware Tile Layer Updating*

Input: $\Omega(t), \Omega(t+\Delta t)$

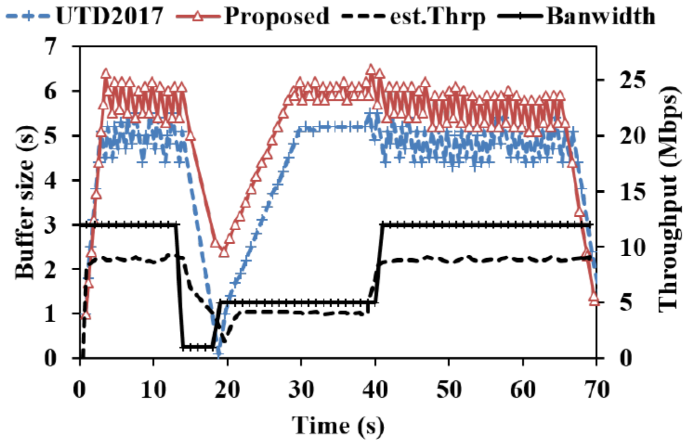
Calculate Ω^{New} and Ω^{Old} using Eq. (5) and Eq. (6);
if $|\Omega^{New}| > 0$ **then**
  Select a tile m' in Ω^{New};
  foreach $m \in \Omega^{Old}$ **do**
    set priority $(m', 1, 0)$;
    send PRIORITY frame for tiles m;
  end
  foreach $k \in \Omega^{New}$ **do**
    send request for tile k;
  end
end



(a) Average viewport bitrate (kbps)



(b) Max. buffer reduction (s)



(b) Buffer size (s)

IoT low-power wireless communications and applications

- LoRa: design and optimize low-power, duty-cycled operation scheme, for remote setup/update parameters of LoRa IoT devices

- NB-IoT: design and implement NB-IoT module (navigation, remote lock/unlock, velocity, battery monitoring…) for bikeShare application

- Zigbee/IEEE802.15.4: design and implementation of low-power protocols for time-scheduled, channel-hopping communication, network-wide time synchronization mechanism, routing and scheduling based on Reinforcement Learning algorithm

IoT applications interoperability

- oneM2M IPE for LoRa networks: design and implement Inter-Proxy Entity for LoRa Gateway to integrate with oneM2M-based networks

- oneM2M-based orchestration and management platform: design and implement platform to manage computation tasks on distributed hardware resources

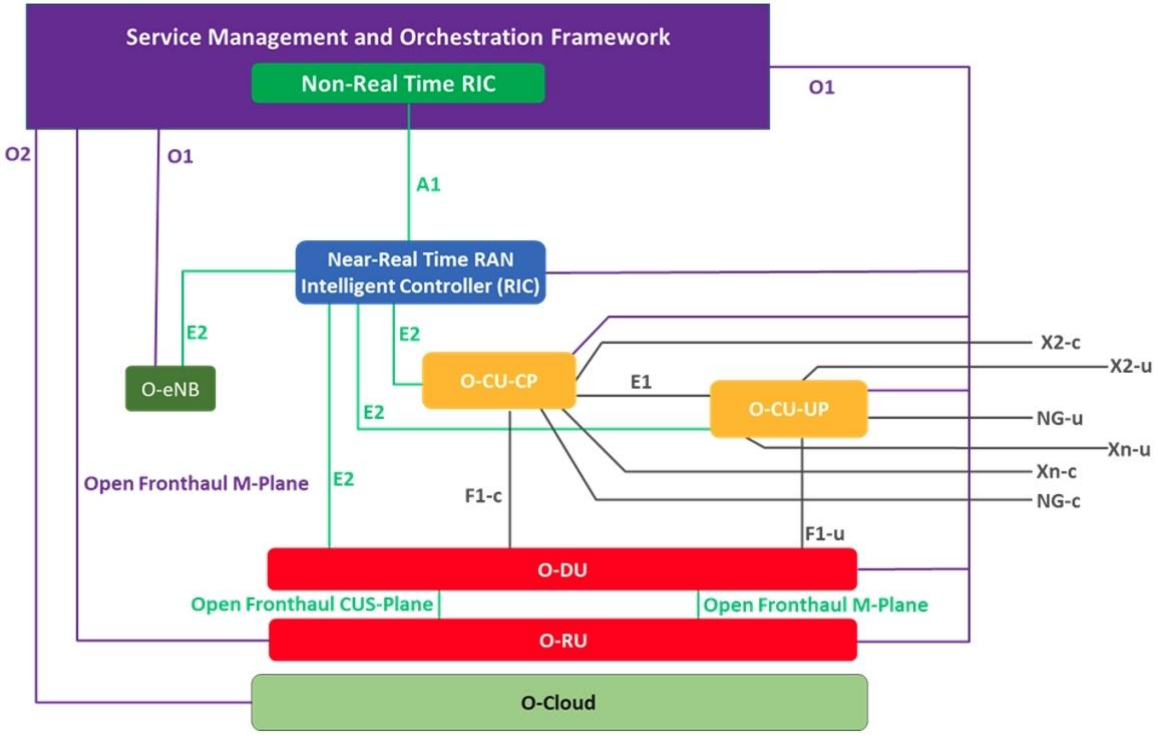
Internet of Vehicles, Intelligence Transportation Systems

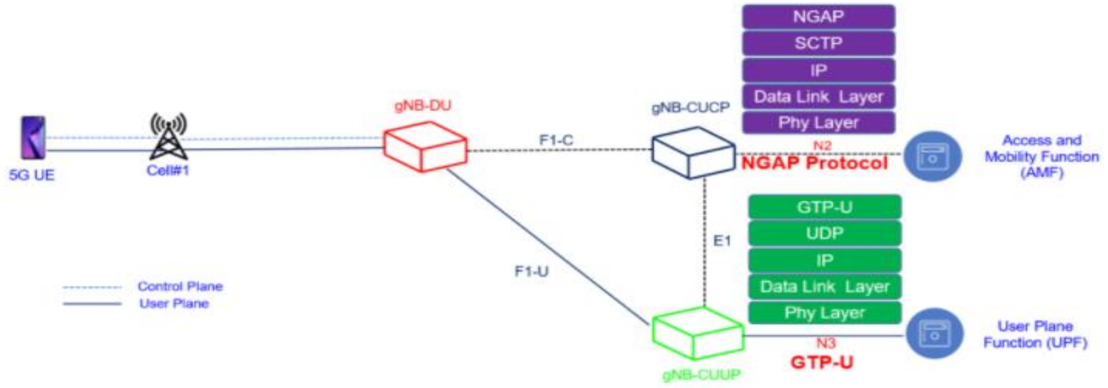
- Smart applications: smart parking management
  - Magnetic sensor-based solutions
  - Camera-based solutions
  - bikeShare app, integrated with SPM

- Vehicular Fog Computing (VFC)
  - cellular-based and DSRC-based communication
  - oneM2M-based platform: design and implement platform to manage computation tasks on distributed hardware resources
  - Resource Allocation and Task Assignment

5G Initiatives

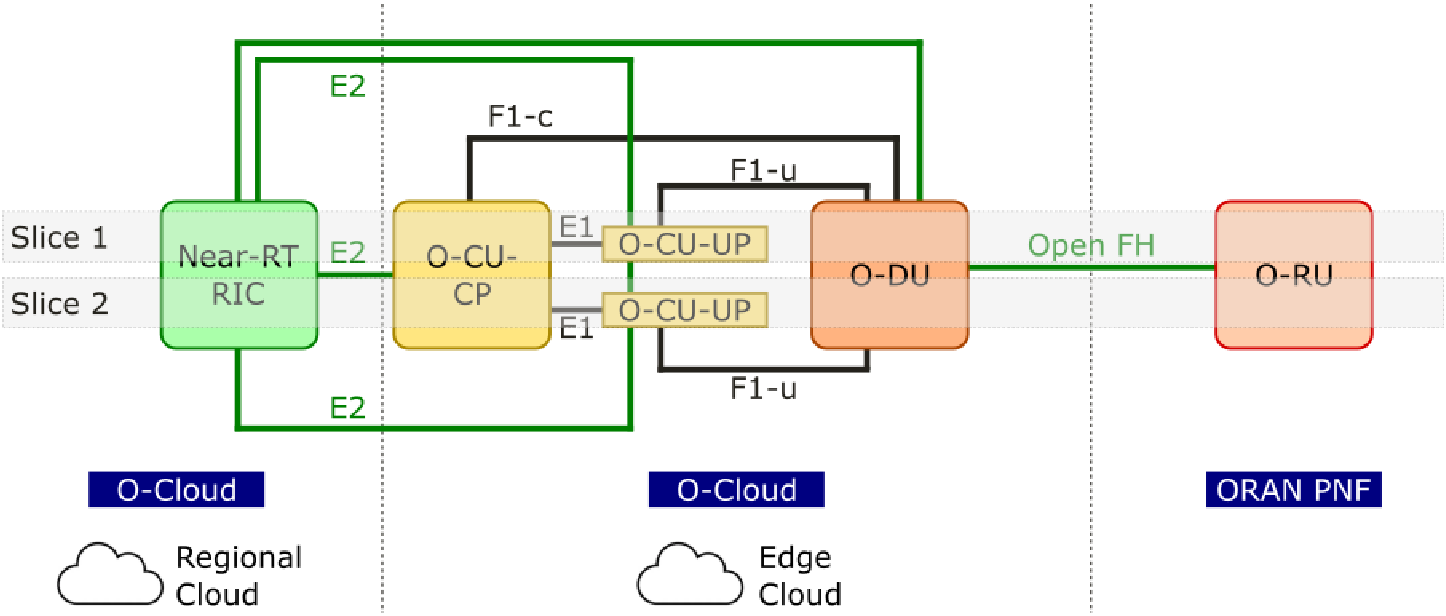
- Activities regarding 5G
  - Building the 5G Test-bed at HUST in cooperation with HCL Vietnam using ORAN and Virtualized Core functions (in progress)
  - Research project of “AI-assisted end to end Network Slicing” (in collaboration with Viettel)
  - Research project of “Prototyping of 5G/6G Relay Station using Reconfigurable Intelligent Surface for frequency spectrum of under 6Ghz)
  - Conducting of corporate training courses to mobile operators in Vietnam regarding 5G technologies: SDN, NFV, ORAN, Network Slicing, MEC, etc.





Resilience-Aware Edge Computing for Slicing-Enabled O-RAN

- Edge computing + 6G O-RAN



  - Multi-access edge computing (MEC) combined with open RAN architecture
  - Joint optimization of power control, resource blocks allocation, and mapping of virtual CU and DU functions for O-RAN slices
  - AI-assisted algorithms leveraging the capability of RAN intelligent controllers (RICs)
  - Guarantee pre-defined QoS requirements for each dedicated services: eMBB, uRLLC, and mMTC

Contact

- Future Networking Group of ANSA Lab.
  - Email:
    - hung.nguyentai@hust.edu.vn
    - thanh.nguyenhuu@hust.edu.vn
    - huong.truongthu@hust.edu.vn
    - ha.phungthikieu@hust.edu.vn
  - 618 Ta Quang Buu Library Building
  - 1 Dai Co Viet Str., Hanoi 10000, Vietnam

Thank you!