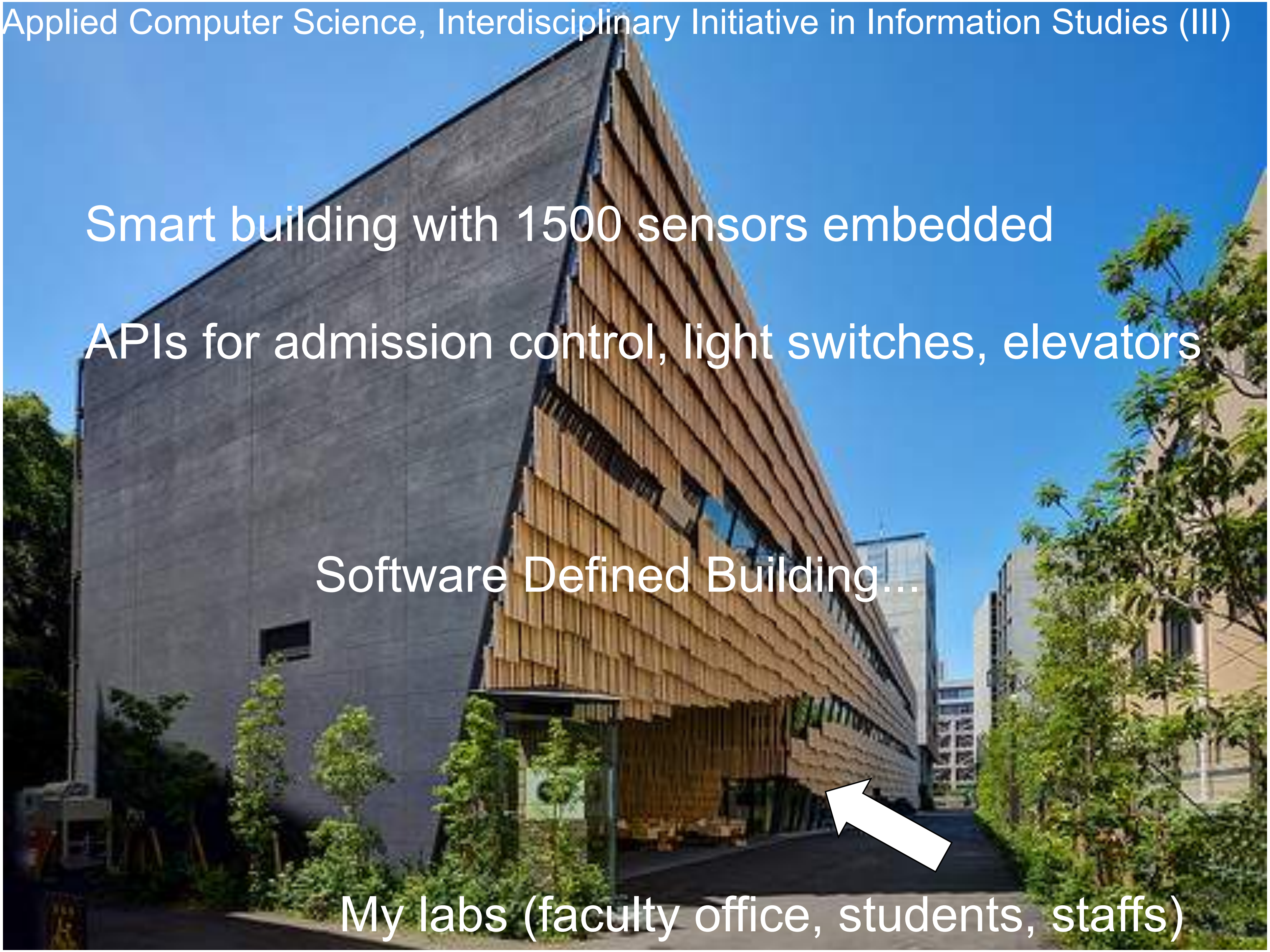
IEEE Network Softwarization (NetSoft) 2016 Keynote Speech

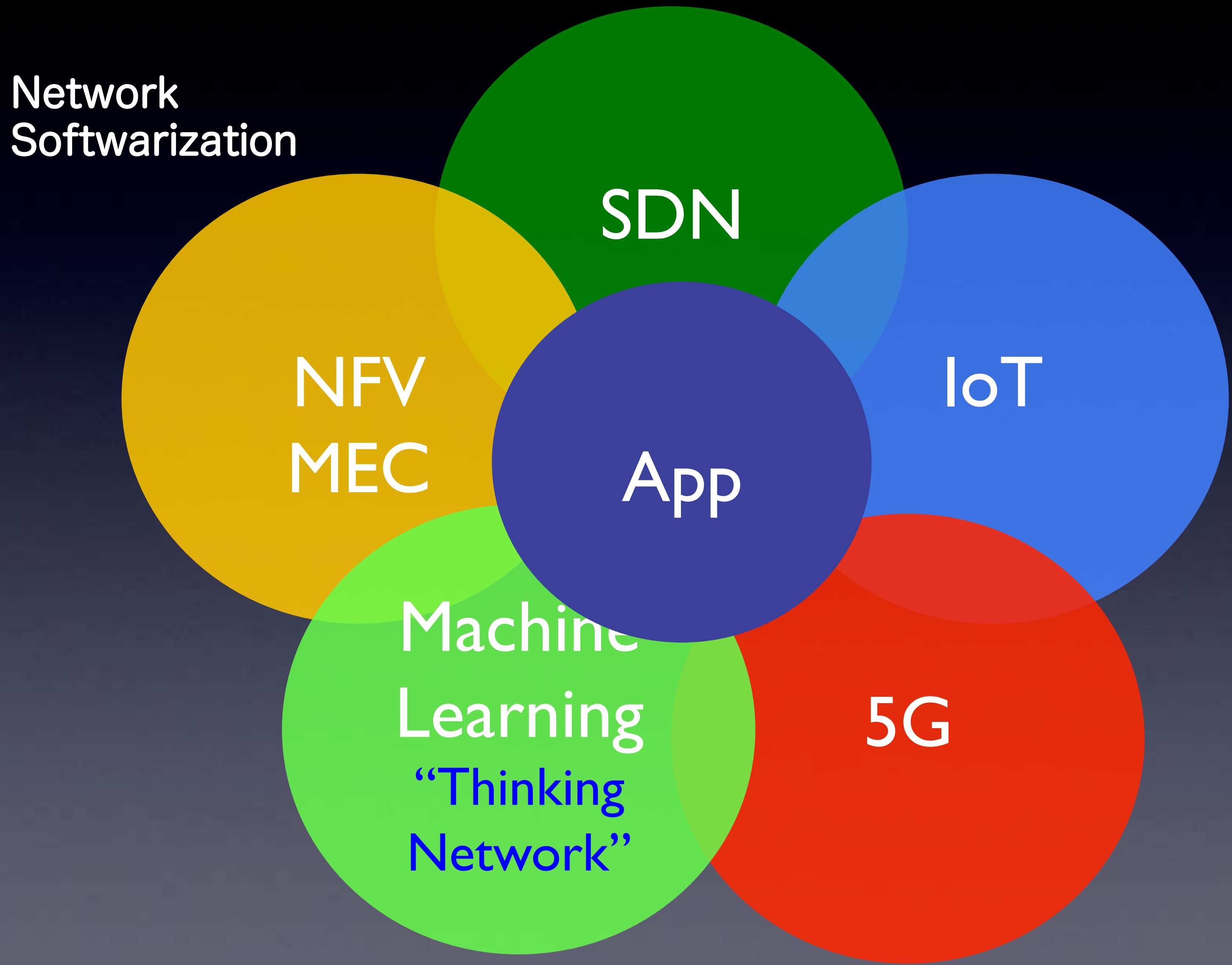
Application-Driven Network Softwarization

Aki Nakao
Professor, The University of Tokyo
Chairman, 5GMF Network Architecture Committee

2016/6/8


Applied Computer Science, Interdisciplinary Initiative in Information Studies (III)
Smart building with 1500 sensors embedded
APIs for admission control, light switches, elevators
Software Defined Building…
My labs (faculty office, students, staffs)

Research Interest in NakaoLab@UTokyo



5G Mobile Network Promotion Forum

The Fifth Generation Mobile Communications Promotion Forum

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30 Advisory Members
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General Assembly

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Chairman of 5GMF
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Strategy & Planning Committee

Chairman
Hiroyuki Morikawa, Univ of Tokyo
Acting chairman
Takehiro Nakamura, NTT DOCOMO

- Strategy & Planning of 5G mobile and develop outcomes from this forum
- Contact, coordinate and confer with suitable organizations in and outside Japan
- Coordinate among the various committees of this forum

Technical Committee (Wireless Technology)

Chairman
Seiichi Sampei, Osaka Univ.
Acting chairmen
Akira Matsunaga, KDDI
Takaharu Nakamura, Fujitsu

- Study technology and frequency requirements for 5G mobile
- Contact, coordinate and confer with international standards organizations and overseas organizations regarding technologies

Service & Application Committee

Chairman
Gota Iwanami, INFOCITY
Acting chairman
Toshiki Hayashi, GEO NETWORKS

- Study mobile applications for the 2020's

Network Architecture Committee

Chairman
Akihiro Nakao, Univ of Tokyo
Acting chairman
Ryutaro Kawamura, NTT

- Study overall network architecture for 5G mobile
- Study requirements and technologies for network infrastructure

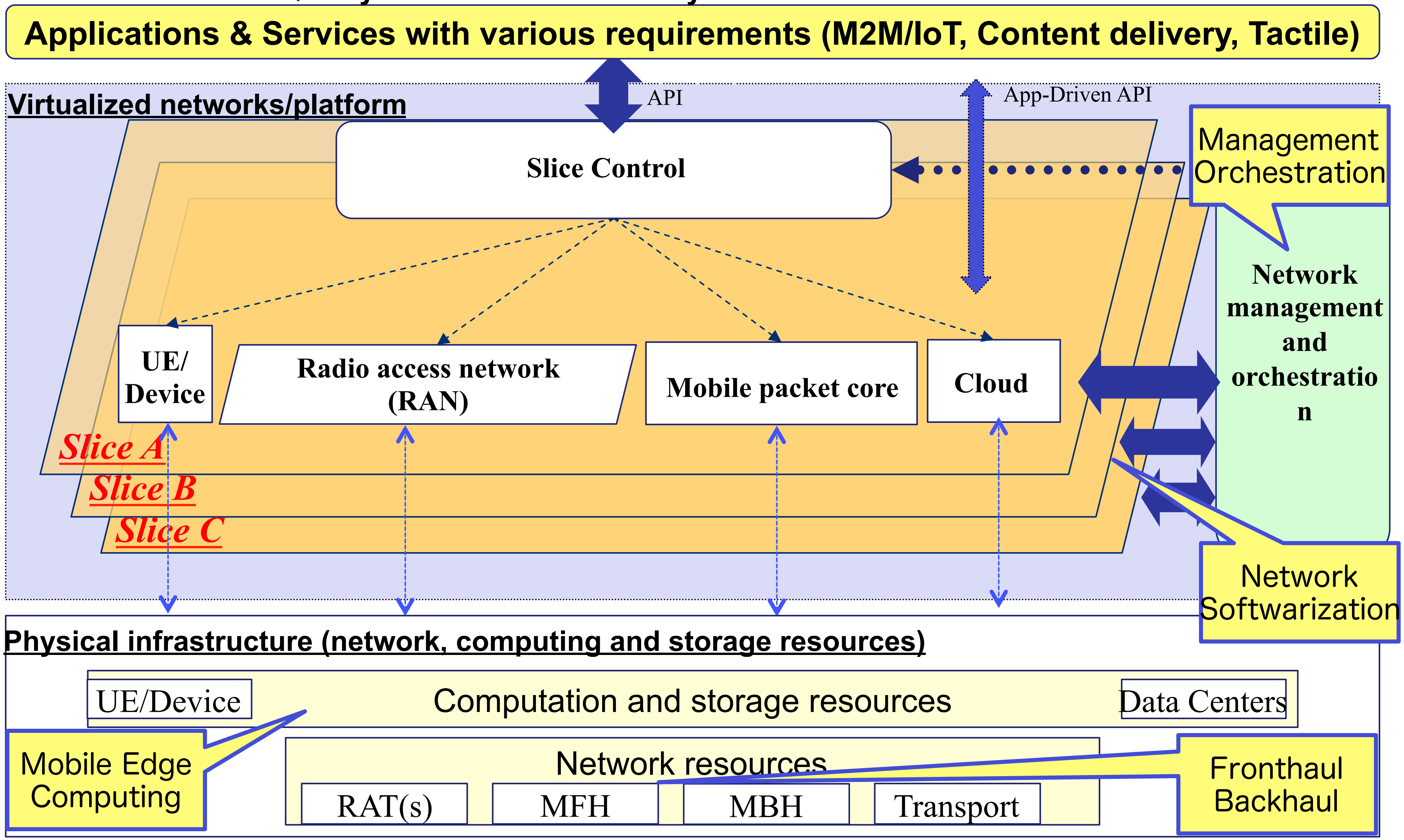
Whitepaper has been published!

- 30 May 2016　5GMF White Paper “5G Mobile Communications Systems for 2020 and beyond”, Ver. 1.0
- 30 May 2016　Executive Summary of 5GMF White Paper Ver. 1.0

http://5gmf.jp/en/archives/

Network Softwarization view of 5G mobile

Goal : End-to-End Quality and Extreme Flexibility to Accommodate Various



Network Softwarization

Network softwarization is an overall transformation trend for designing, implementing, deploying, managing and maintaining network equipment and network components by software programming, exploiting characteristics of software such as flexibility and rapidity of design, development and deployment throughout the lifecycle of network equipment and components,

Draft Contribution at FG IMT-2020 as of 2015/11/6

ITU-T FG IMT-2020 Phase2

ITU Extranet Services Newsfeed OneDrive Sites Nakao, Akihiro (nakaoaki)

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FG IMT-2020

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  - ICN
  - Fixed mobile convergence
  - E2E network management
  - Fronthaul backhaul
- Notebook
- Tasks
- Support-FAQs

FG IMT-2020

ITU-T Focus Group on IMT-2020

1956 2016 CCITT / ITU-T

Meeting in Focus

6 September (2 PM) - 9 September 2016, Palo Alto, United States, hosted by PARC

- Announcement (incl. phone numbers)
- Registration
- Documents

Future Meetings

November 2016, ITU, Geneva, Switzerland
Details coming soon

Past Meetings

1. 8-9 June 2015, San Diego, United States: Announcement - Participants - Report
2. 13-14 July 2015, Geneva, Switzerland: Announcement - Participants - Report - Photos
3. 21-24 September 2015, Turin, Italy: Announcement - Participants - Report
4. 27-30 October 2015, Beijing, China: Announcement - Participants - Report
5. 8-11 March 2016, Seoul, Korea: Announcement - Participants - Report
6. 17-20 May 2016, Beijing, China: Announcement - Participants - Report

Tools

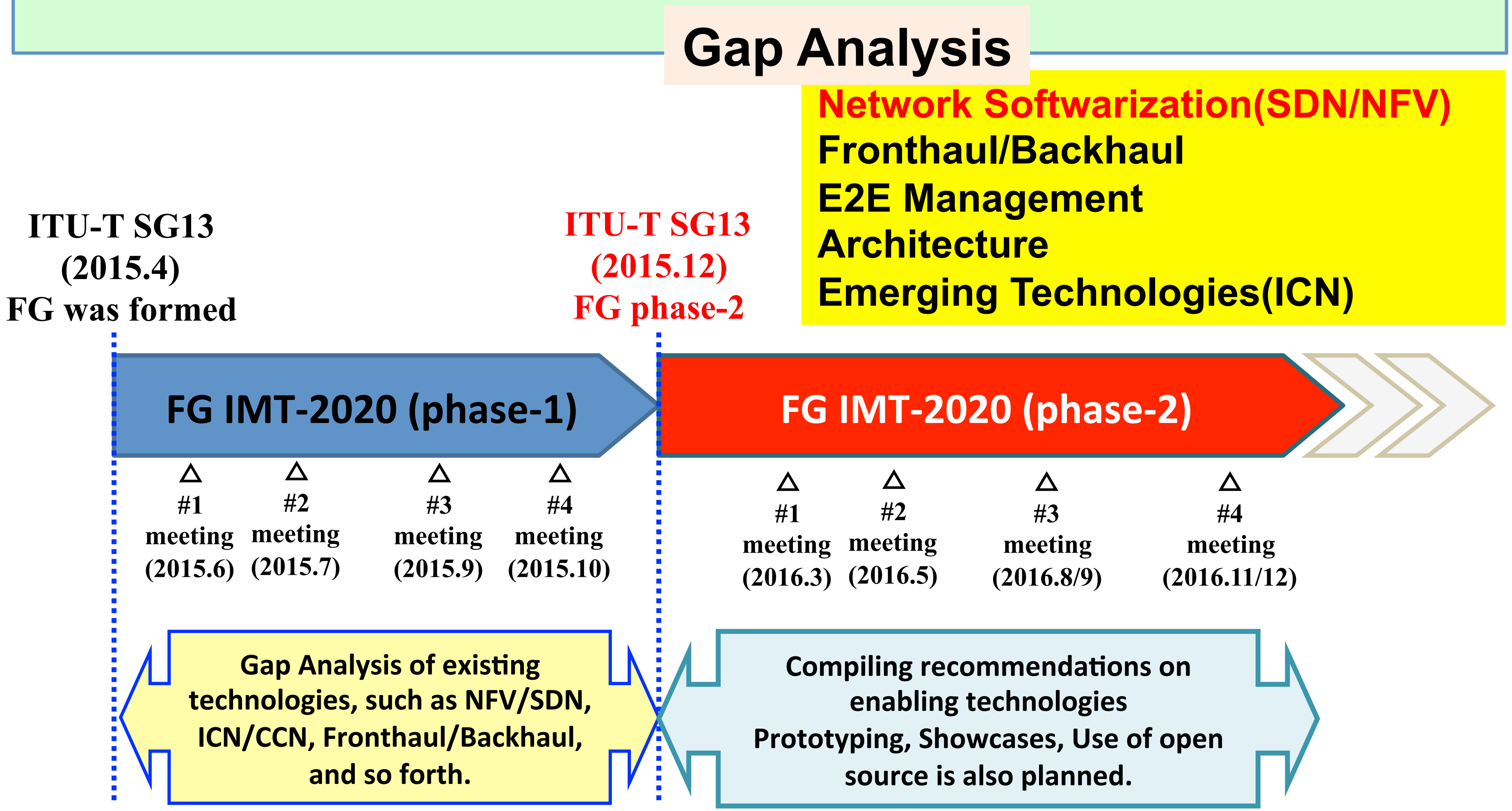
- **Terms of Reference (2016)**; (2015)
- FG IMT-2020: Report on Gap Analysis (presented to SG13 in December 2015)
- Recommendation ITU-T A.7: "Focus groups: Establishment and working procedures"
- ITU-T **basic** document template
- Manual for rapporteurs and editors
- Author's guide for drafting ITU-T Recommendations
- Quick guide for remote meeting attendees (GoToMeeting)
- Mailing list subscription
- Mailing list archive

Contact

- Focus Group Chairman: Mr. Peter Ashwood-Smith, Huawei Technologies; E-mail: peter.ashwoodsmith@huawei.com
- ITU secretariat: Mr. Martin Adolph; E-mail: tsbfgimt-2020@itu.int; Tel: +41 22 730 6828

ITU-T SG13 FG IMT-2020 From Phase1 To Phase2

- FG(Focus Group) IMT-2020 was formed under ITU-T SG13 in Apr. 2015.
- FG IMT-2020 (phase-1) studied gap analysis of existing technologies against the requirements of IMT-2020, and delivered its report in Dec. 2015.
- Based on the outcome of phase-1, FG IMT-2020(phase-2) has been started with is goal being to compile recommendations on enabling technologies for IMT-2020, targeted at the end of 2016.



FG IMT-2020 Network Softwarization Activity Plan

Further analysis of gaps of interest

- Technical gaps
- SDOs' coverage

Draft recommendations to SG

- Aligned with other groups? Such as "Requirements"/Framework etc.
- Output document should be brought to SG

Create a catalogue of open source software

- Including Impact, applicability and maturity for 5G development
- Mapping open source software in end-to-end slicing (e.g., ODL, ONOS, OPNFV, Docker, OpenStack, etc)
- To what extent, the existing software need to be extended for 5G (gap analysis).
- Successful outcome: Suggest extensions for 5G mobile network to open source community

Explore various prototyping activities

- Interaction among multiple open source softwares

6 Network Softwarization for IMT-2020

6.1 Standardization activities for network softwarization

[Editor's note: we must include discussion on 1.description of work programs, and 2. Relevance to network softwarization.]

6.1.1 Standardization activities at 3GPP SA2

The "Study on Architecture for Next Generation System" was started at SA2#112 meeting and officially approved as 3GPP TR 23.799 at the 3GPP TSG SA#70 plenary in December 2015. After that, the TR 23.799 has been updated through three more meeting including one adhoc meeting. The latest version of the TR can be found on the following links; the latest version is version 0.4.0 at the time of this writing, early May 2016).

- ftp://ftp.3gpp.org/tsg_sa/WG2_Arch/Latest_SA2_Specs/Latest_draft_S2_Specs/
- http://www.3gpp.org/ftp/tsg_sa/WG2_Arch/Latest_SA2_Specs/Latest_draft_S2_Specs/ :

The objective of the study is to design a system architecture for "5G", which is called as the next generation mobile network or NextGen aiming to support at least the new RAT(s), the evolved LTE, non-3GPP accesses with minimum access dependencies.

The study is being done based on the following studies on the requirements for the next generation mobile networks which has been carried in 3GPP SA1; the latest version of all of them is version 1.0 as of now.

- 3GPP TR 22.861 (FS_SMARTER - massive Internet of Things)
- 3GPP TR 22.862 (Feasibility Study on New Markets and Technology Enablers - Critical Communications; Stage 1"
- 3GPP TR 22.863 (FS_SMARTER - enhanced Mobile Broadband)
- 3GPP TR 22.864 (Feasibility Study on New Services and Markets Technology Enablers - Network Operation)

Network Slicing

The basic concept of the Network Softwarization is "Slicing" as defined in [ITU-T Y.3011], [ITU-T Y.3012]. Slicing allows logically isolated network partitions (LINP) with a slice being considered as a unit of programmable resources such as network, computation and storage.

FG IMT-2020: Report on Standards Gap Analysis

Definitions of (Network) Slicing

"…a slice is defined as an isolated set of computational and network resources allocated and deployed across the entire network"

Akihiro Nakao, "Network Virtualization as Foundation for Enabling New Network Architectures and Applications" IEICE TRANS.COMMUN., VOL. E93-B. No3 March 2010

"Slice = a set of resources reserved across muliple network domains"

Akihiro Nakao, "deeply programmable network", ITU-T Kareidoscope 2013, Kyoto, Japan

"Since 2008, we have conducted our research on continuously evolve-able network virtualization infrastructure, proposing the concept of "slice", i.e., a set of isolated programmable resources so as to implement new generation network protocols and services."

Akihiro Nakao,
"Research and Development on Network Virtualization Technologies in Japan"
NICT Journal, Vol62, No2, 4 Core Technologies for the New-Generation Network
"The GENI Book", Springer Press, http://www.springer.com/us/book/9783319337678

A Brief History of “Slicing”

JP

2005- PlanetLab JP

2008 VNode Project
（NICT/Utokyo/NTT/NEC/
Hitachi/Fujitsu）

2011 VNode/FLARE Project
(Utokyo/NTT/NEC/
Hitachi/Fujitsu/KDDI)

2014 O3 Project
(NTT/NEC/
Hitachi/Fujitsu)

US/EU/BR

2002- PlanetLab (US)

2005- PlanetLab EU (EU)
2006- OneLab (EU)
2008- OneLab2 (EU)

2008 GENI Kick Off (US)

International Federation

2012 OpenLab(EU)
Fed4Fire (EU)
FIBRE(EU/BR)

24 GEC’s

Worldwide

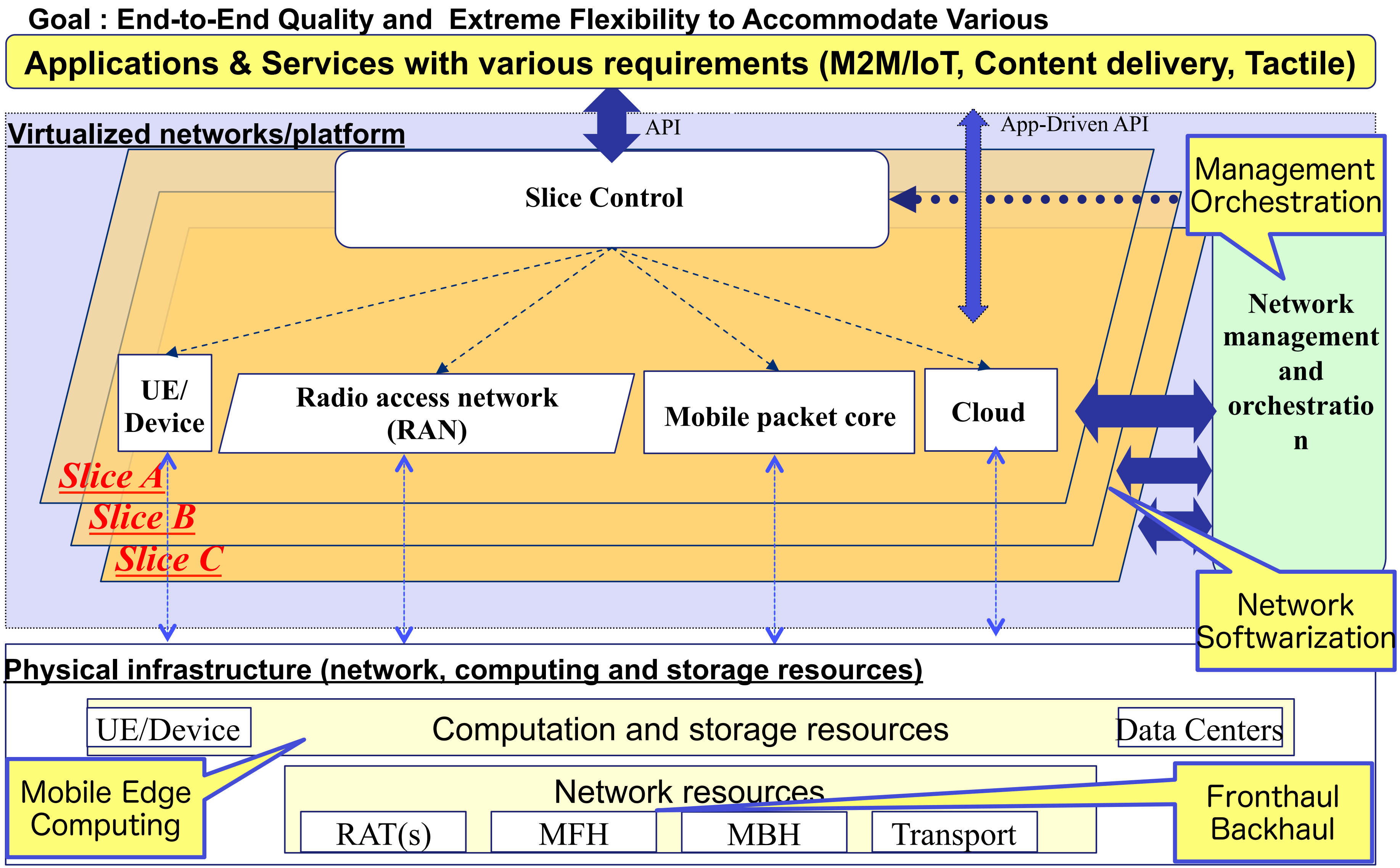
SDN

NFV

2016

Global Experimentation for Future Internet (GEFI): Brazil – EU – Japan – US collaboration

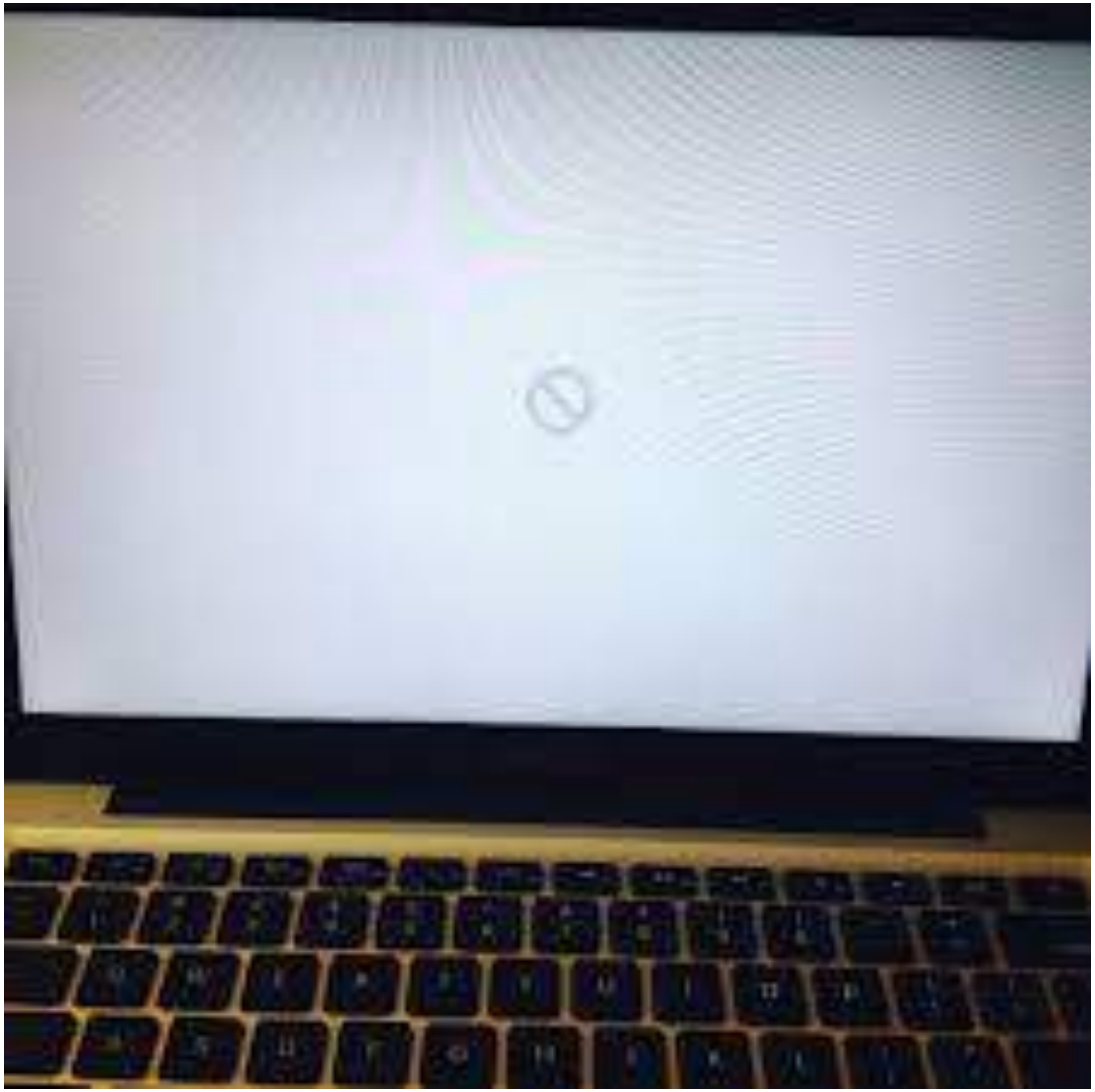
Network Softwarization view of 5G mobile



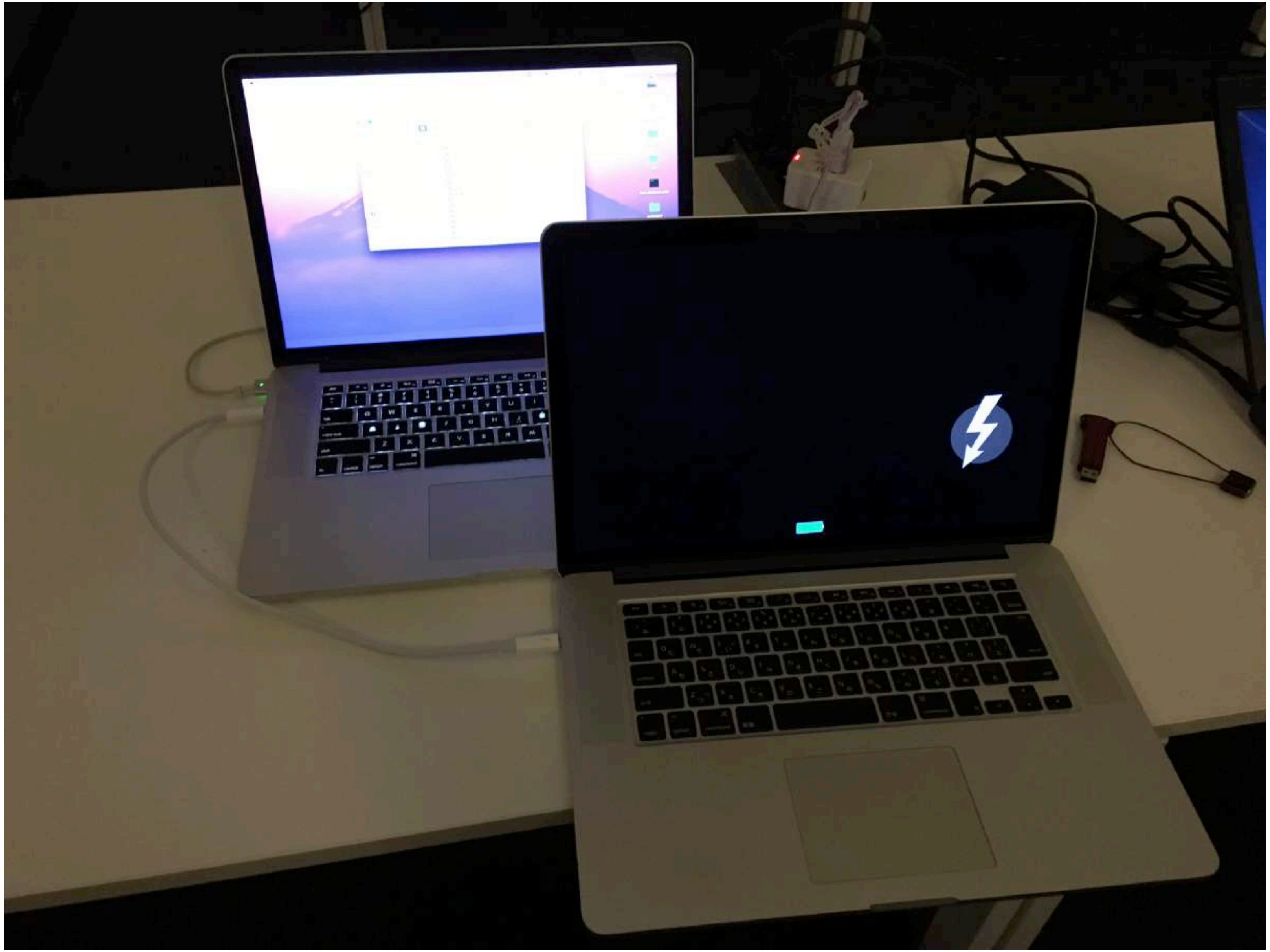
Application Driven Network Softwarization Network Slicing

Why do we need slicing from applications point of view?

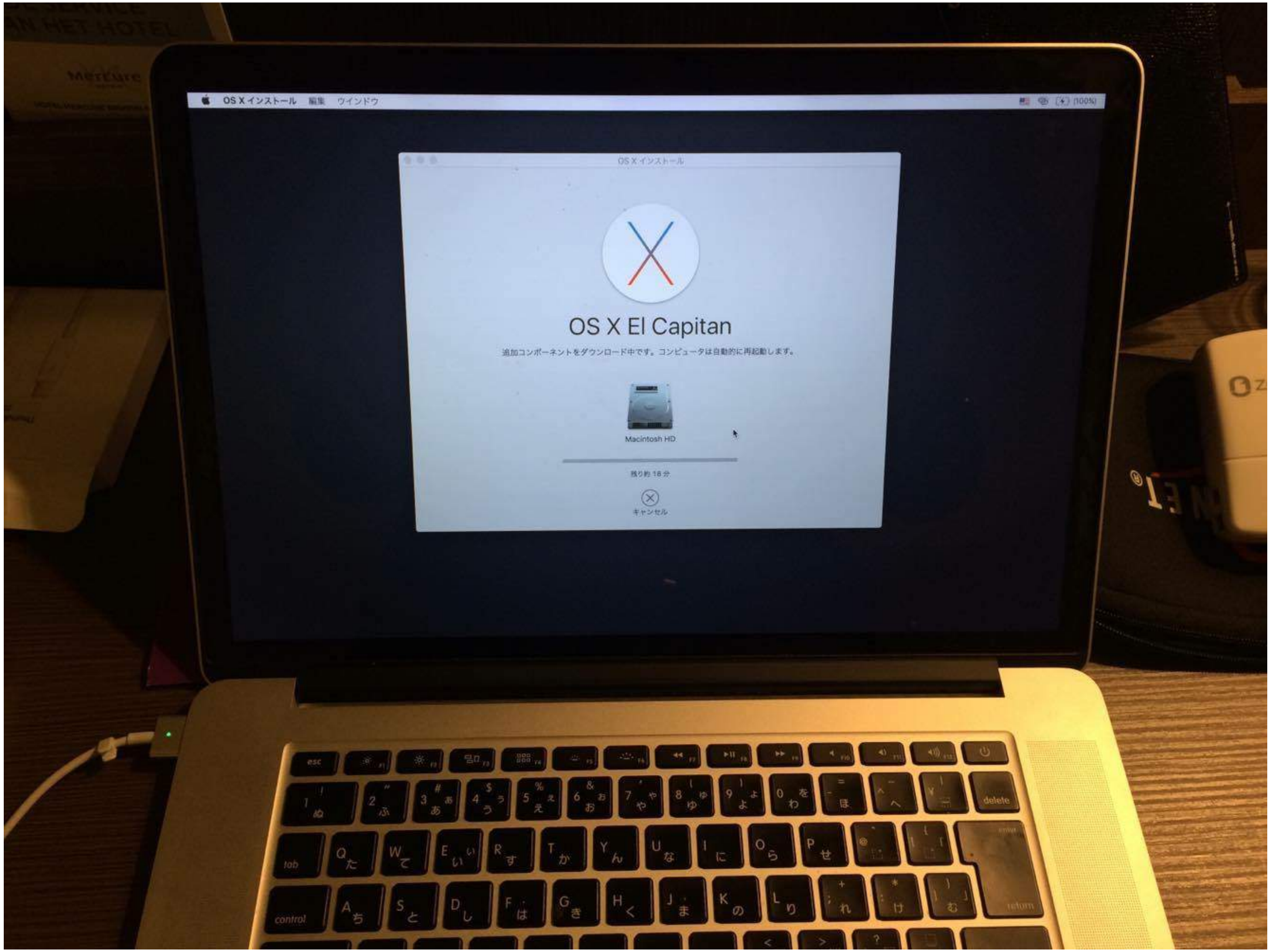
“White screen of Death”



Pulling Necessary Files Out of Broken Mac



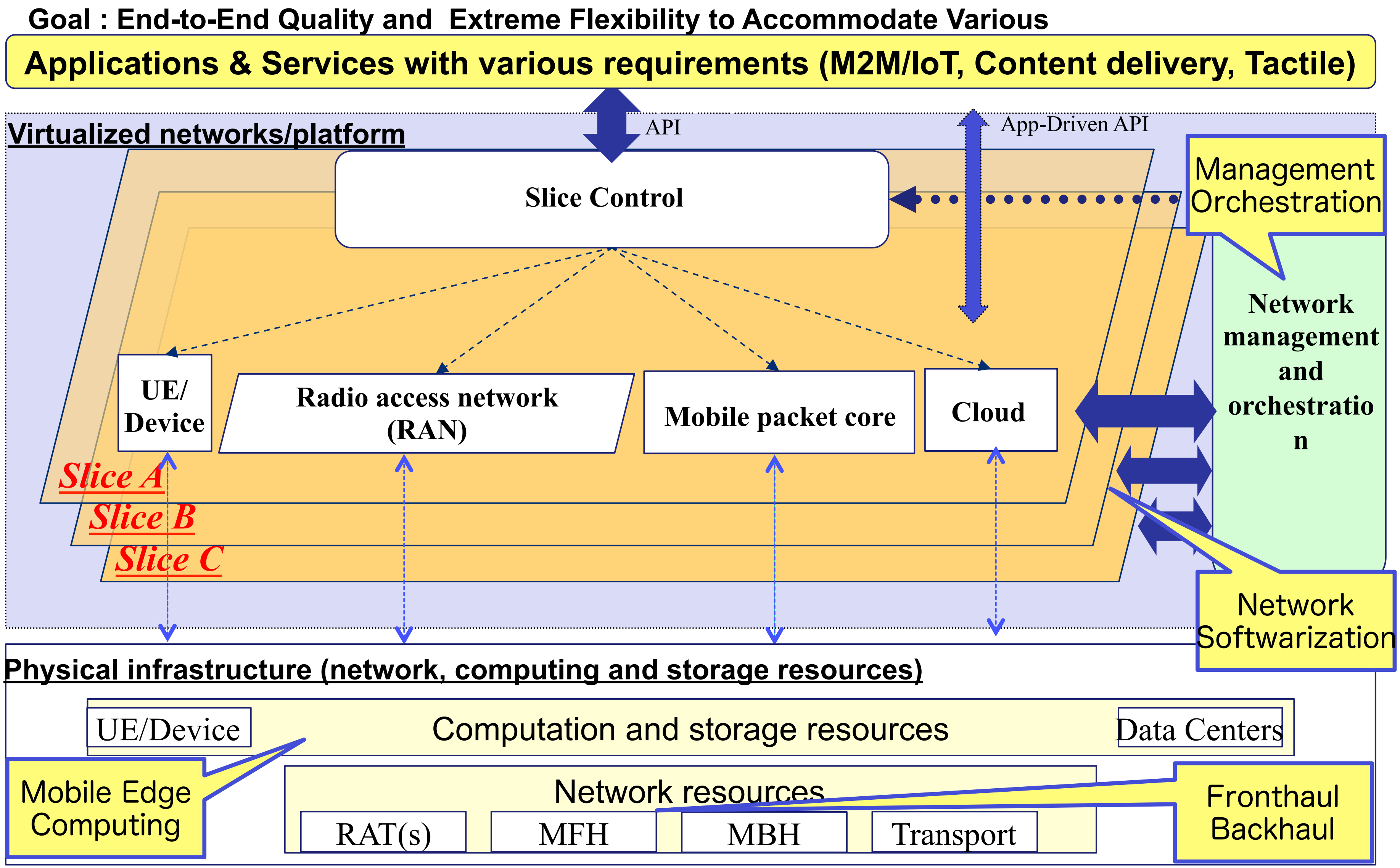
Only Option for Reinstalling “El Captain” is Network Install



That took 5 hours !!

OS upgrade via network is
a “Killer” app for operators
in a difference sense!

Network Softwarization view of 5G mobile

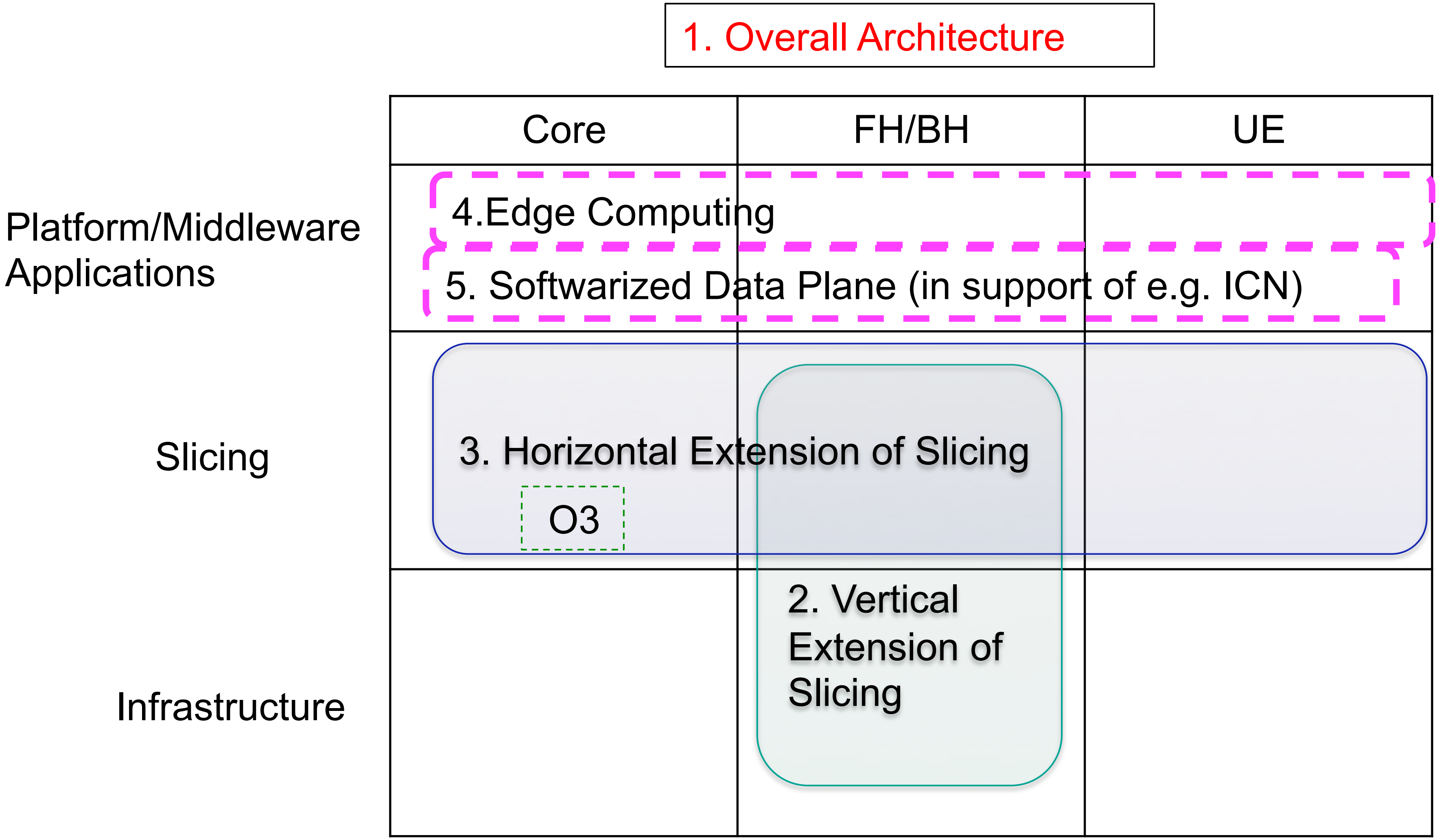


Gap : Network Slicing for 5G

Gap B.6.2.1: Efficient accommodation of various applications	Priority: High
Description: It is envisioned that such an infrastructure that efficiently supports a diversified set of application requirements across end-to-end paths, ranging from M2M communication, to autonomous and collaborative driving, virtual reality and video streaming, etc. Network softwarization technologies including SDN, NFV and their extensions for supporting IMT-2020 mobile networks are expected to provide slicing capability both in wired and wireless parts of communication infrastructure, so that each slice provides an isolated environment to efficiently accommodate individual applications meeting specific requirements. The slice should be capable of dynamically adjusting resources to meet the application requirements. The network infrastructure is expected to provide extreme flexibility to support those different capabilities with reasonable cost.	
Related work: ITU-T Y.3011, Y.3012, Y.3300, ETSI ISG NFV, Network Functions Virtualization, 3GPP , IEEE SDN	

http://www.itu.int/en/ITU-T/focusgroups/imt-2020/Documents/T13-SG13-151130-TD-PLEN-0208!!MSW-E.docx

End-to-End Slicing and RAN Slicing

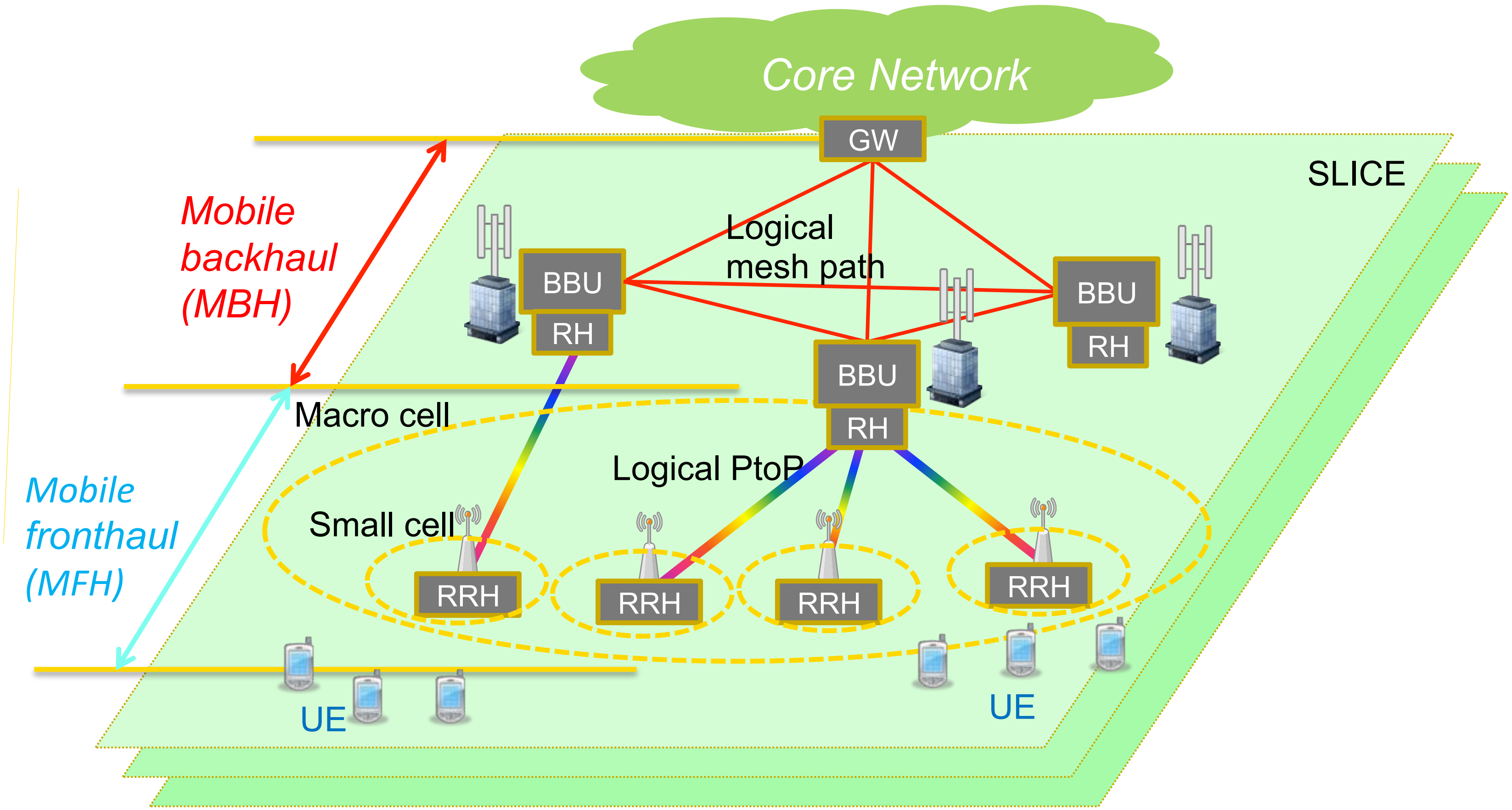


MFH/MBH Slicing

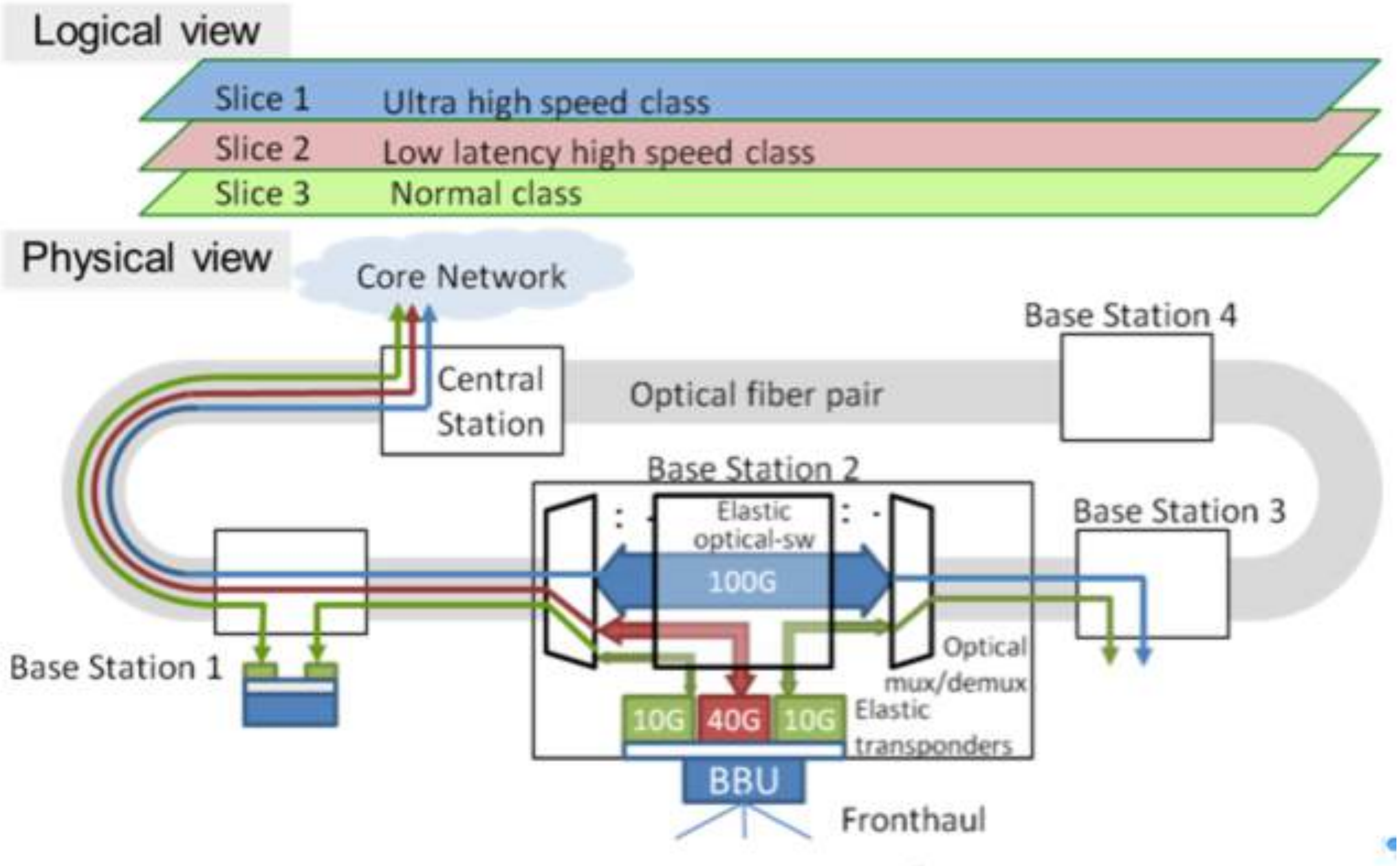
Virtualized (SLICE) MFH/MBH using wavelength

To ensure reliability and quality required for each service requires a mechanism that can be controlled independently of the resources. For example, if MFH/MBH is virtualization (SLICE), classification can be implemented in the entire network (EtoE).

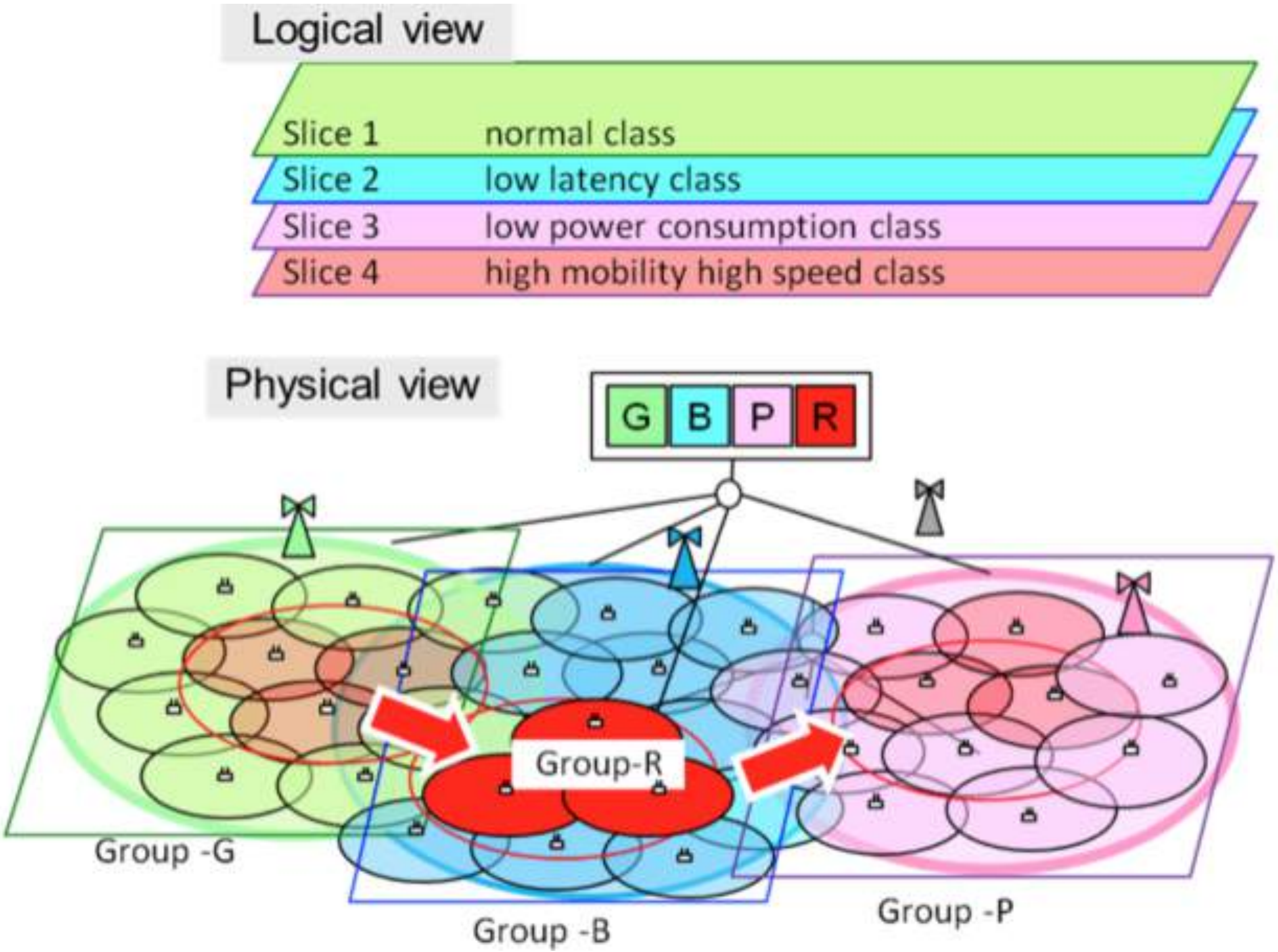
Note: Resource (SLICE) control has been discussed in “7 Network Softwarization”.



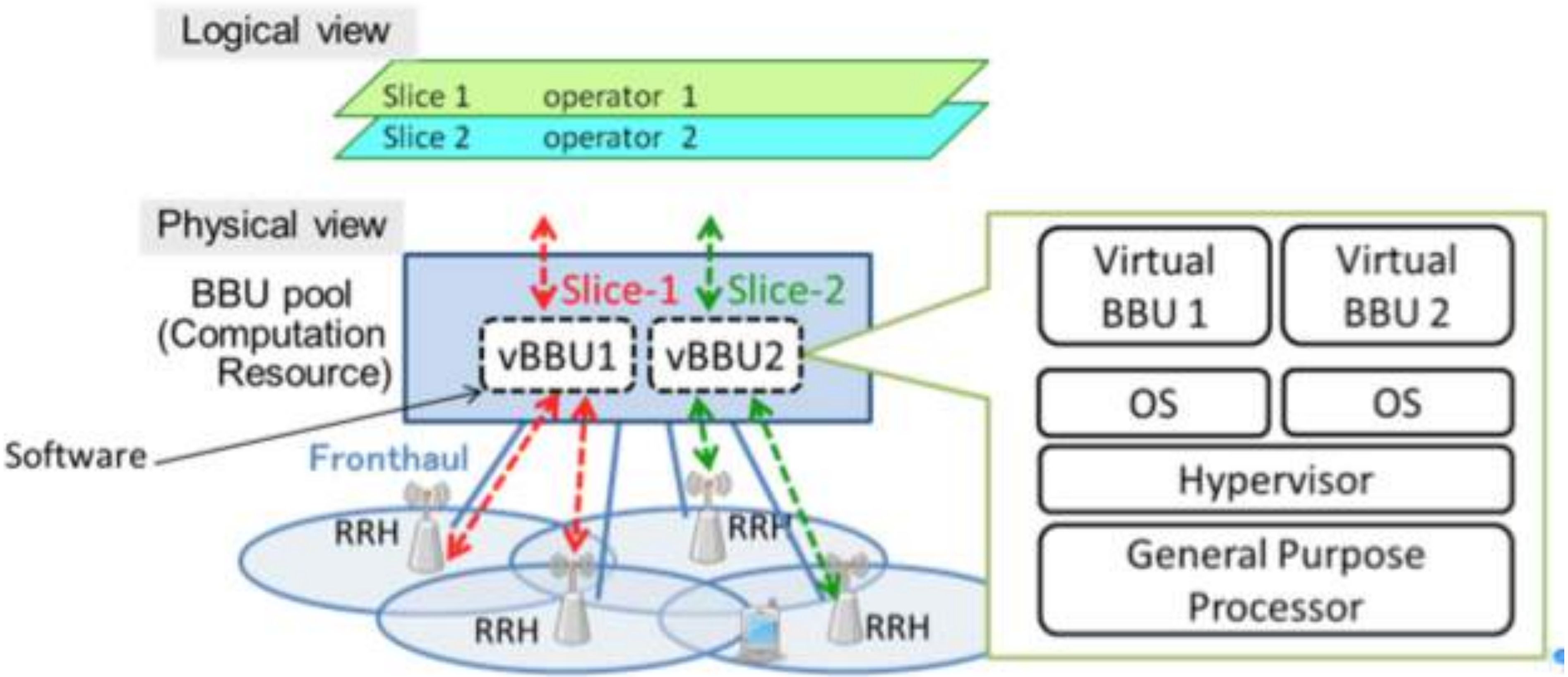
RAN (Backhaul) Slicing (Elastic OADM Ring)



RAN (Fronthaul) Slicing (Dynamic Resource Allocation for Small Cells)



RAN (Midhaul:BBU) Slicing (Virtual BBU)

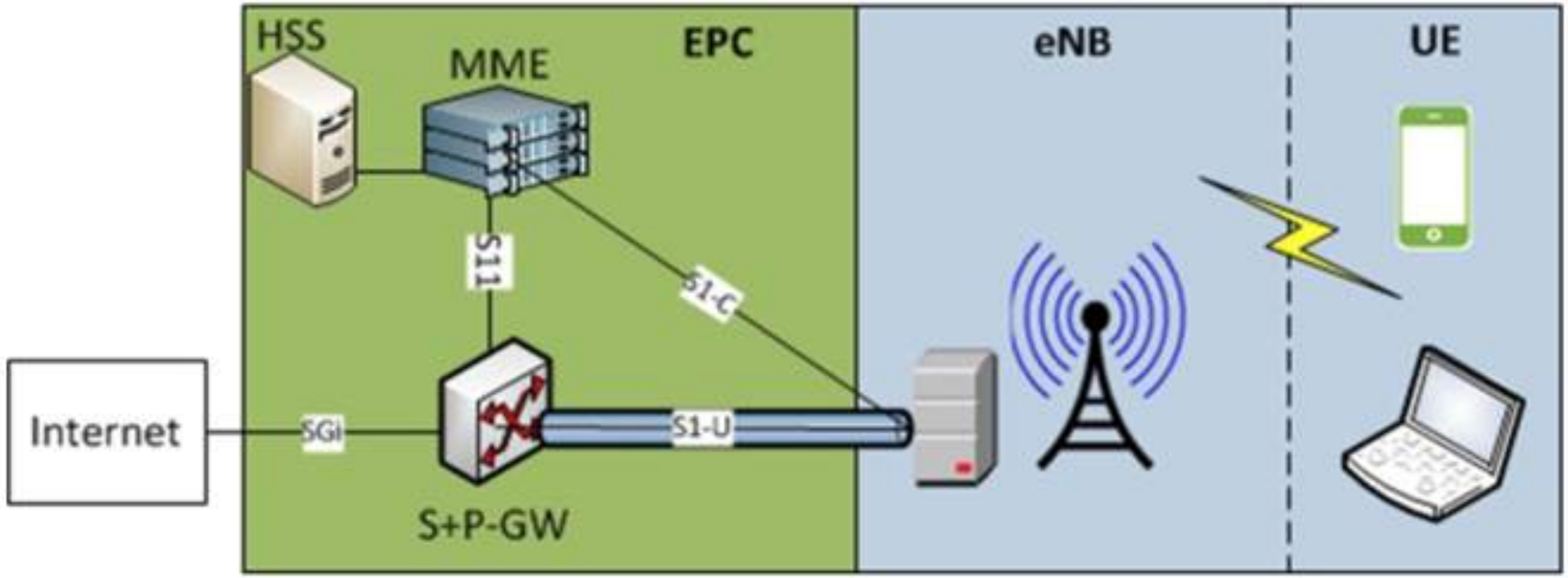


Network Slicing

In Preparation for 5G Mobile Networks

Software-defined 5G System

Software Defined Radio

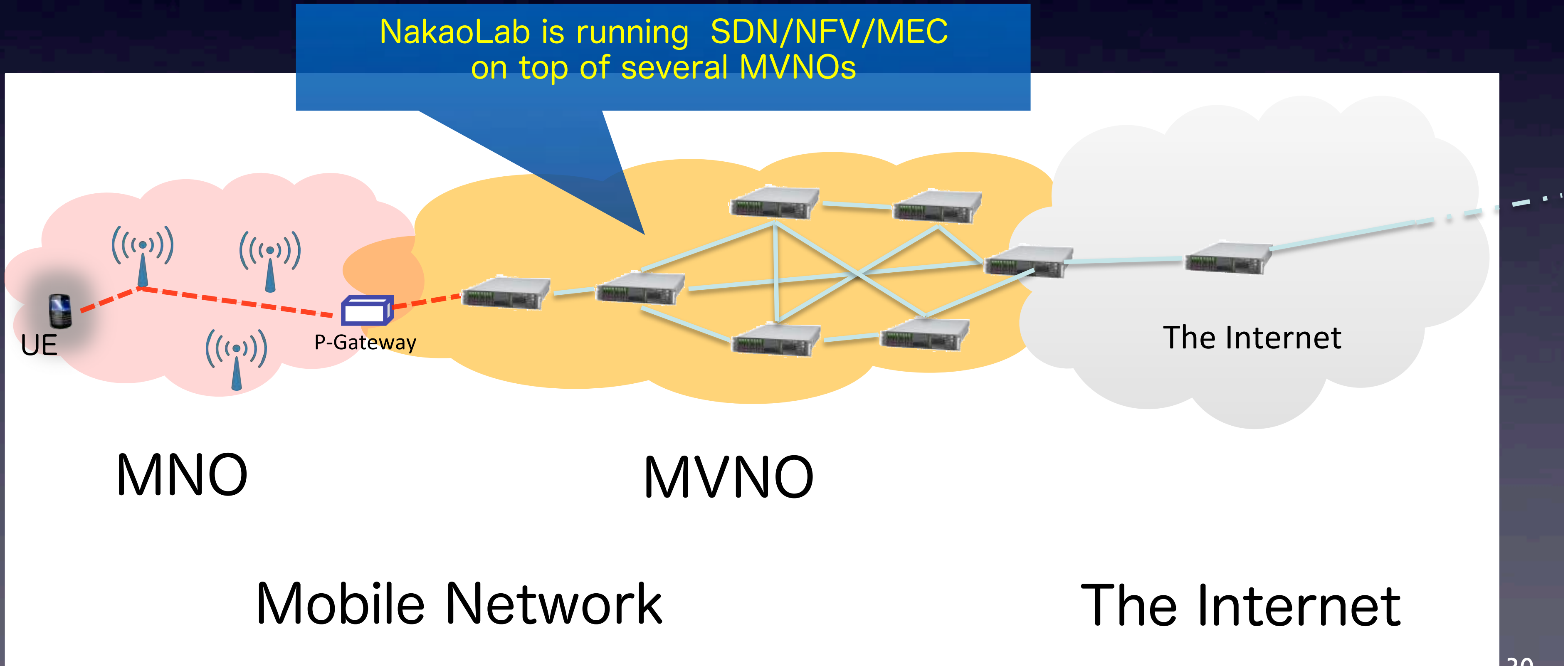


Software Defined LTE/5G Network !

Programmable SIM

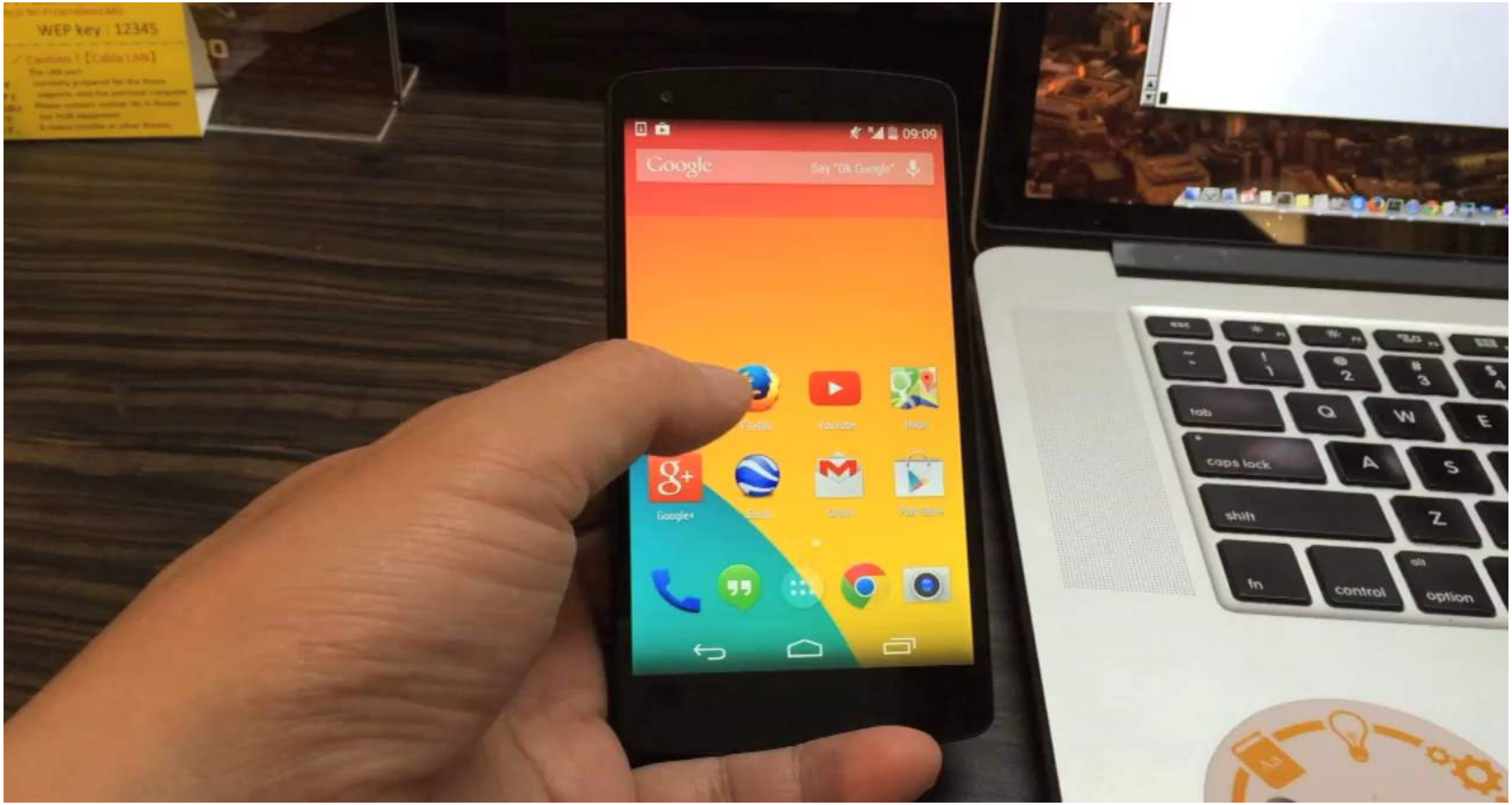
Application Specific LTE Network Slicing

A mobile virtual network operator (MVNO), or mobile other licensed operator (MOLO), is a wireless communications services provider that does not own the wireless network infrastructure over which the MVNO provides services to its customers.

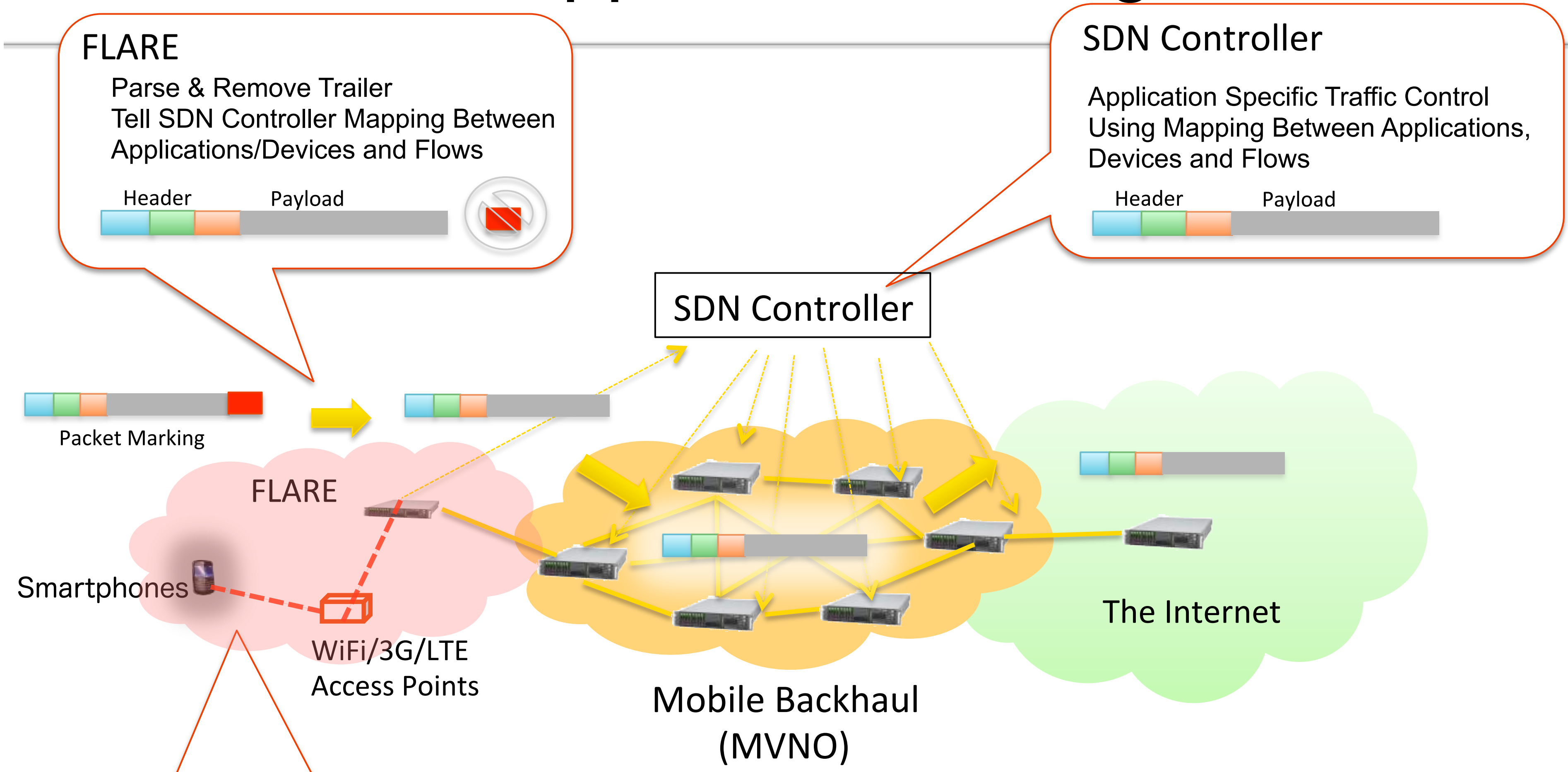


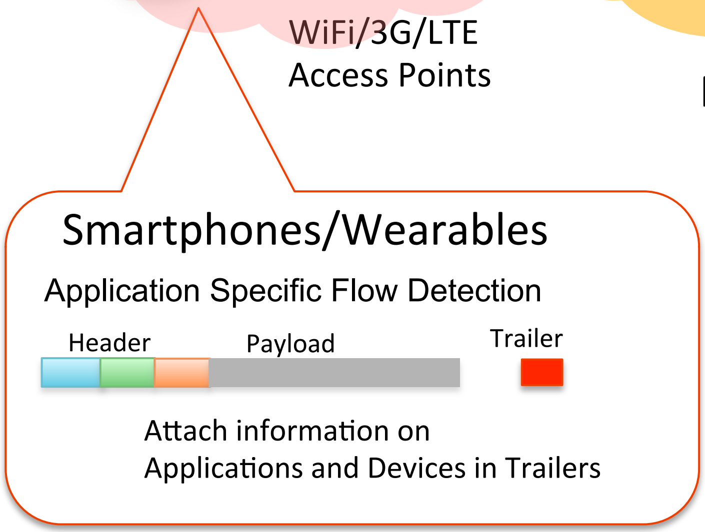
https://en.wikipedia.org/wiki/Mobile_virtual_network_operator

App-Specific Slicing Traffic Control

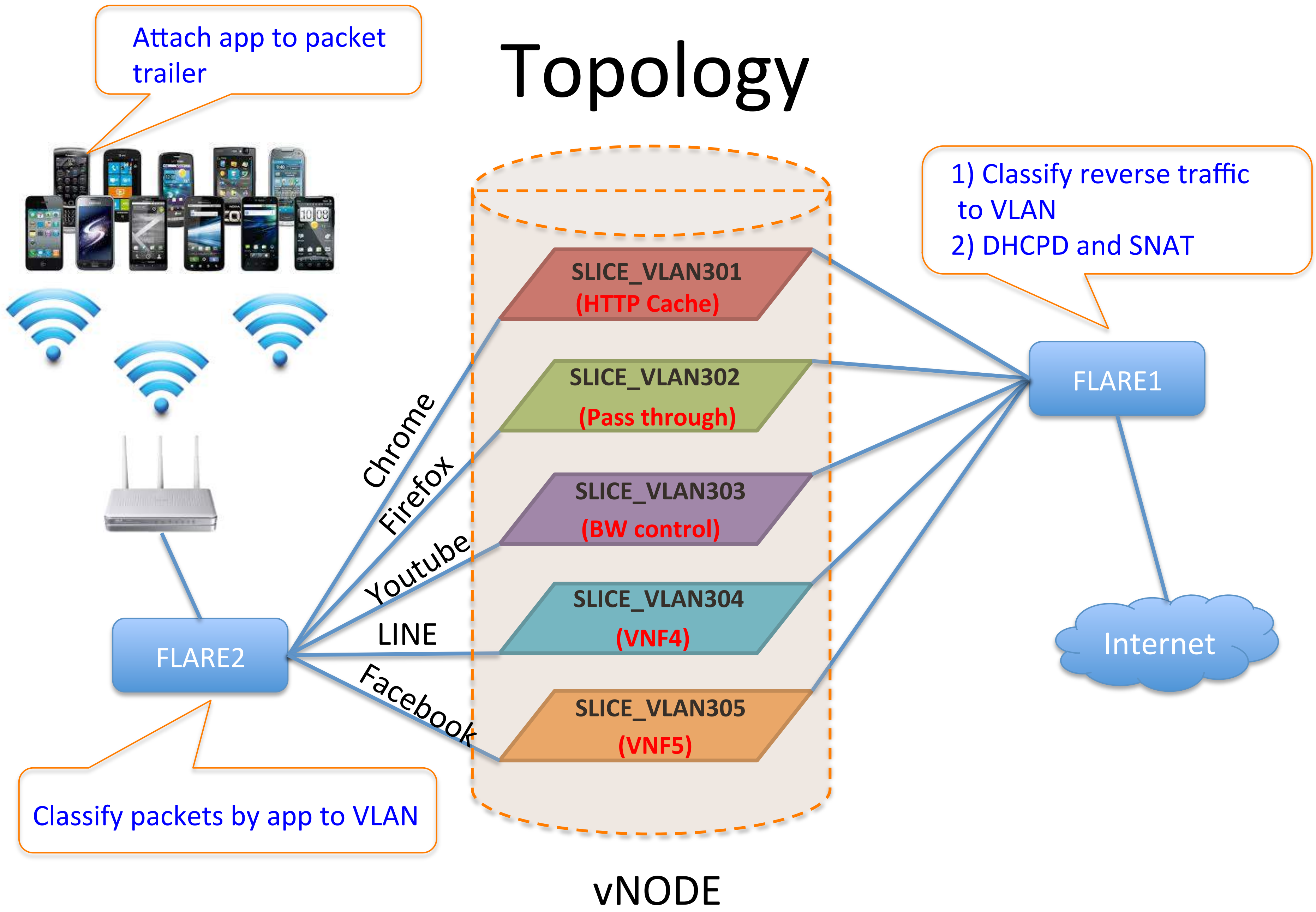


Per Application Slicing





Smartphones/wearables attach the information of applications and devices at the trailers of TCP SYNs. FLARE detects the information and creates mapping between flows and the information on applications and/or devices.



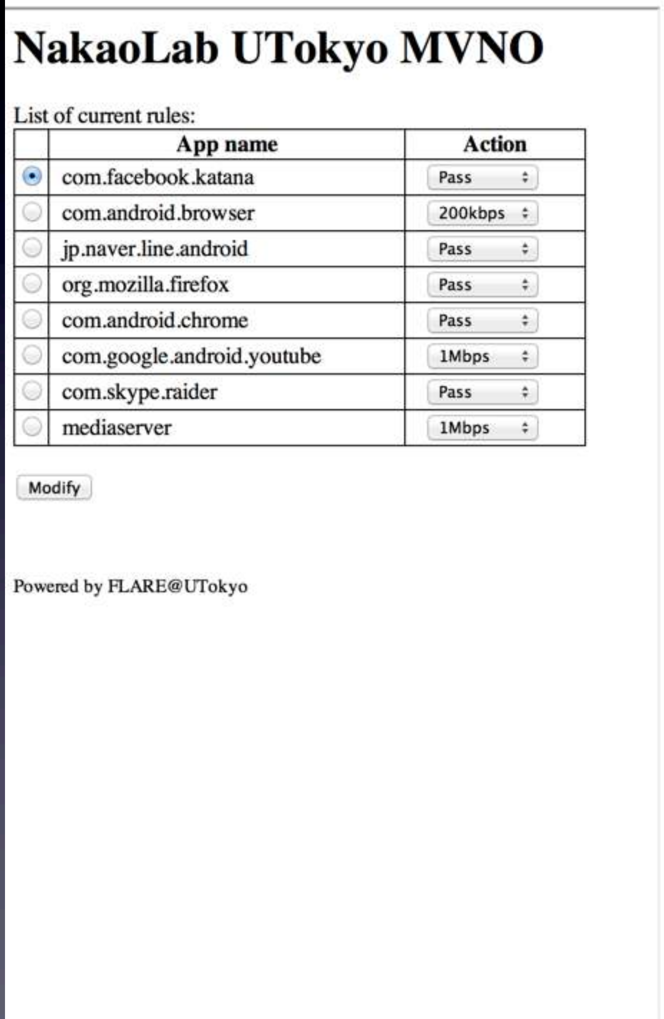
Topology
Attach app to packet trailer
1) Classify reverse traffic to VLAN
2) DHCPD and SNAT
SLICE_VLAN301
(HTTP Cache)
SLICE_VLAN302
(Pass through)
SLICE_VLAN303
(BW control)
SLICE_VLAN304
(VNF4)
SLICE_VLAN305
(VNF5)
Chrome
Firefox
Youtube
LINE
Facebook
FLARE1
FLARE2
Internet
Classify packets by app to VLAN
vNODE

Flow Characteristics of Popular App

Apps	Avg Size (KBytes)	Avg duration (s)	Avg Rate (Kbps)
YouTube	4000	107	396
Tethering	560	151	48
Google Maps	330	815	57
Instagram	192	496	71
Twitter	143	361	45
Facebook	40	438	3
Chrome	35	164	28
LINE	16	273	12
Gmail	11	8.7	56

- Observations:
  - YouTube traffic (396Kbps) is much higher than other applications (<100Kbps)
  - The average TCP rate of Tethering flow is not so large.
  - The average rate of Facebook is even smaller than that of Gmail

App Specific QoS
via custom Southbound Interface



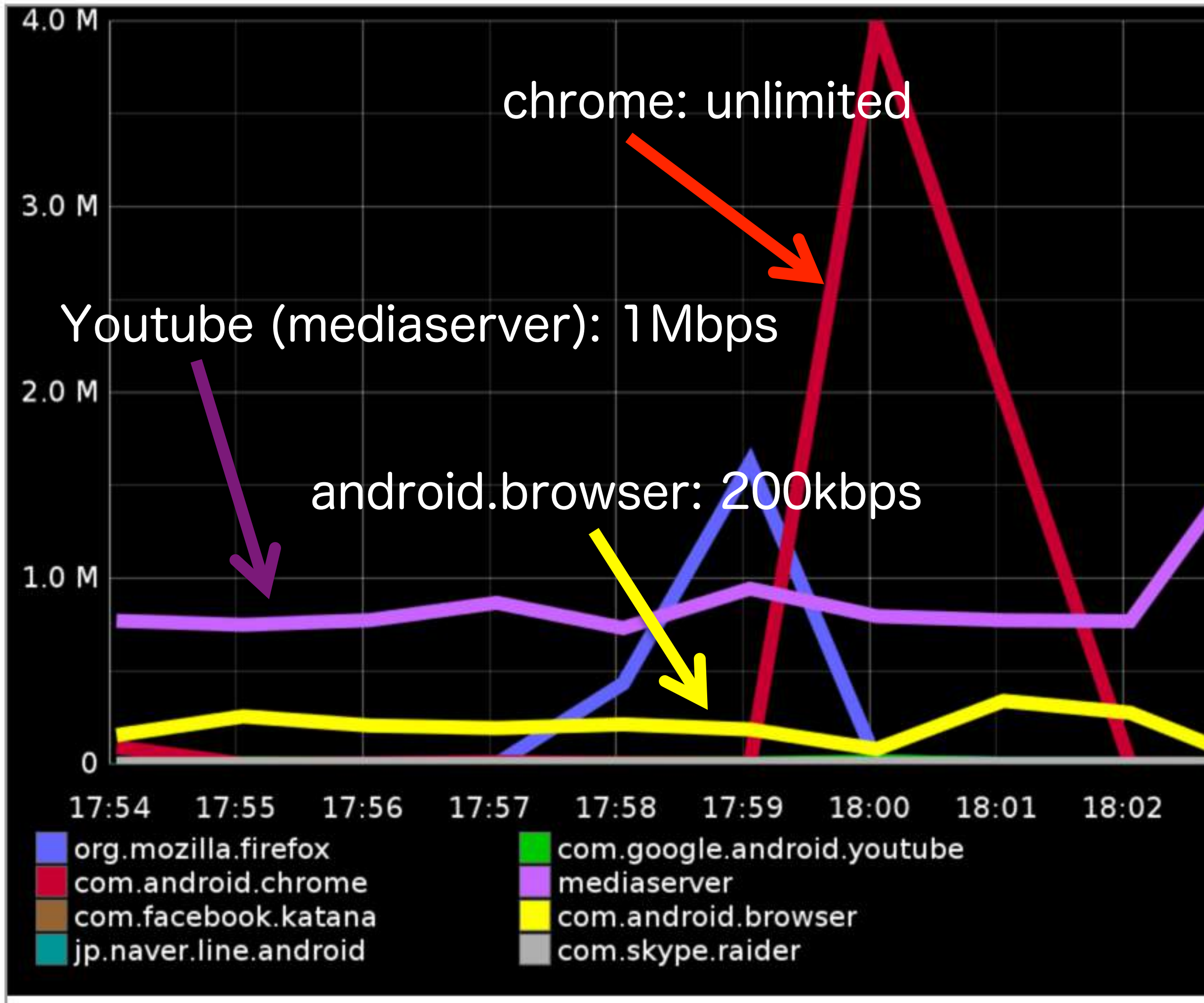
NakaoLab UTokyo MVNO

List of current rules:

	App name	Action
◉	com.facebook.katana	Pass
○	com.android.browser	200kbps
○	jp.naver.line.android	Pass
○	org.mozilla.firefox	Pass
○	com.android.chrome	Pass
○	com.google.android.youtube	1Mbps
○	com.skype.raider	Pass
○	mediaserver	1Mbps

Modify

Powered by FLARE@UTokyo



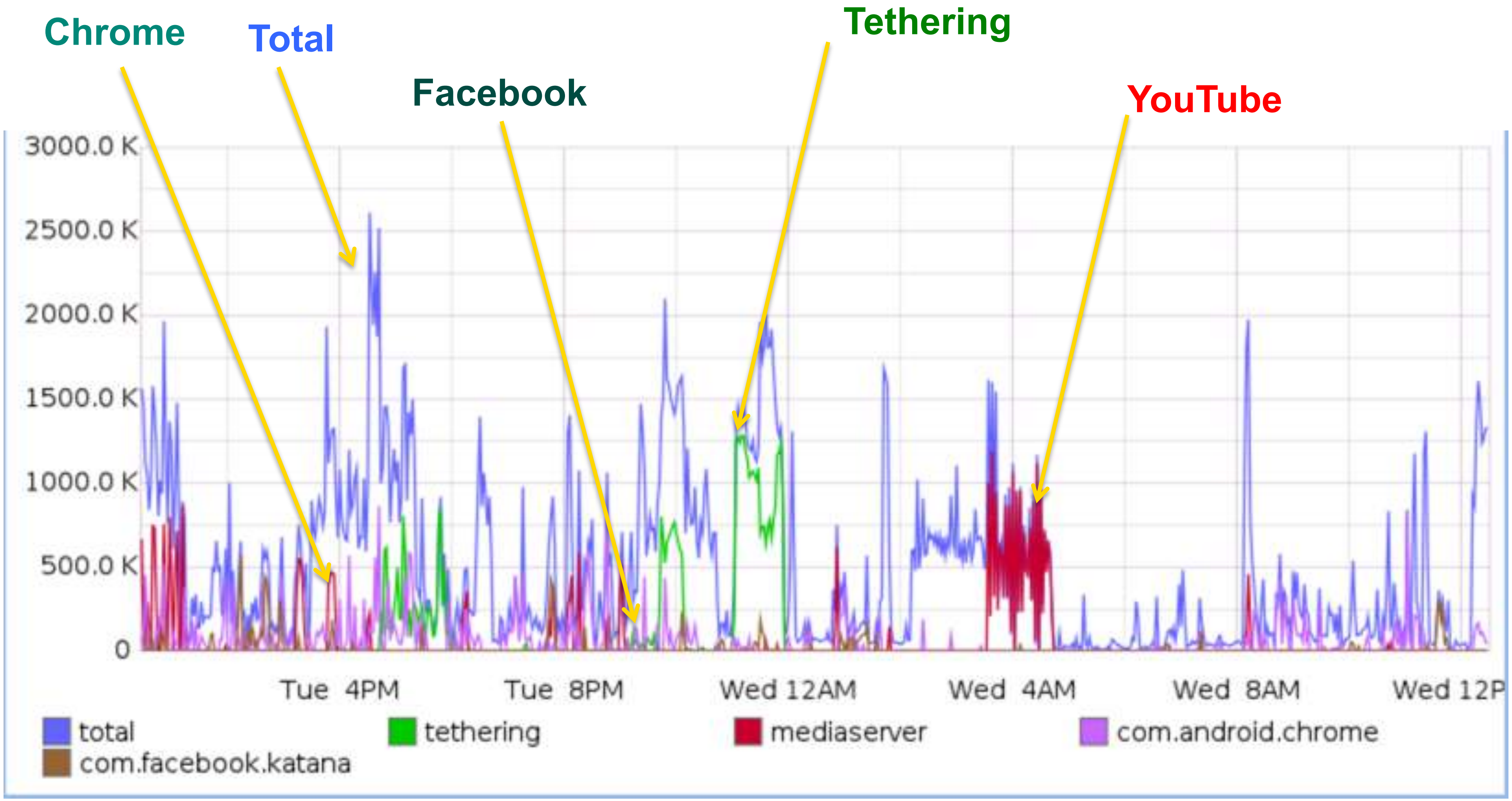
Edge Computing Experiment with FLARE x MVNO

1. ISP A
   - Period : since 2014/11/20 up to present
   - UE : 59 Android Phones (Nexus)
   - End Users: Students/Staffs
   - Service Availability : 99.8% (0.2% downtime due to scheduled blackout)
   - Total traffic amount : about 1.7 TB (4.2GB per day on average)

2. ISP B
   - Period: since 2015/9/18 up to present
   - UE: 262 IoT Gateways (Intel Edision + WiFi + 3G +BLE)
   - End Users : Limousine Bus (public transportation)
   - Service Availability:100% (by far)
   - Total traffic amount : about 1.7 TB (4.2GB per day on average)

3. ISPs C,D are in preparation for field trials

Application Specific Traffic Breakdown



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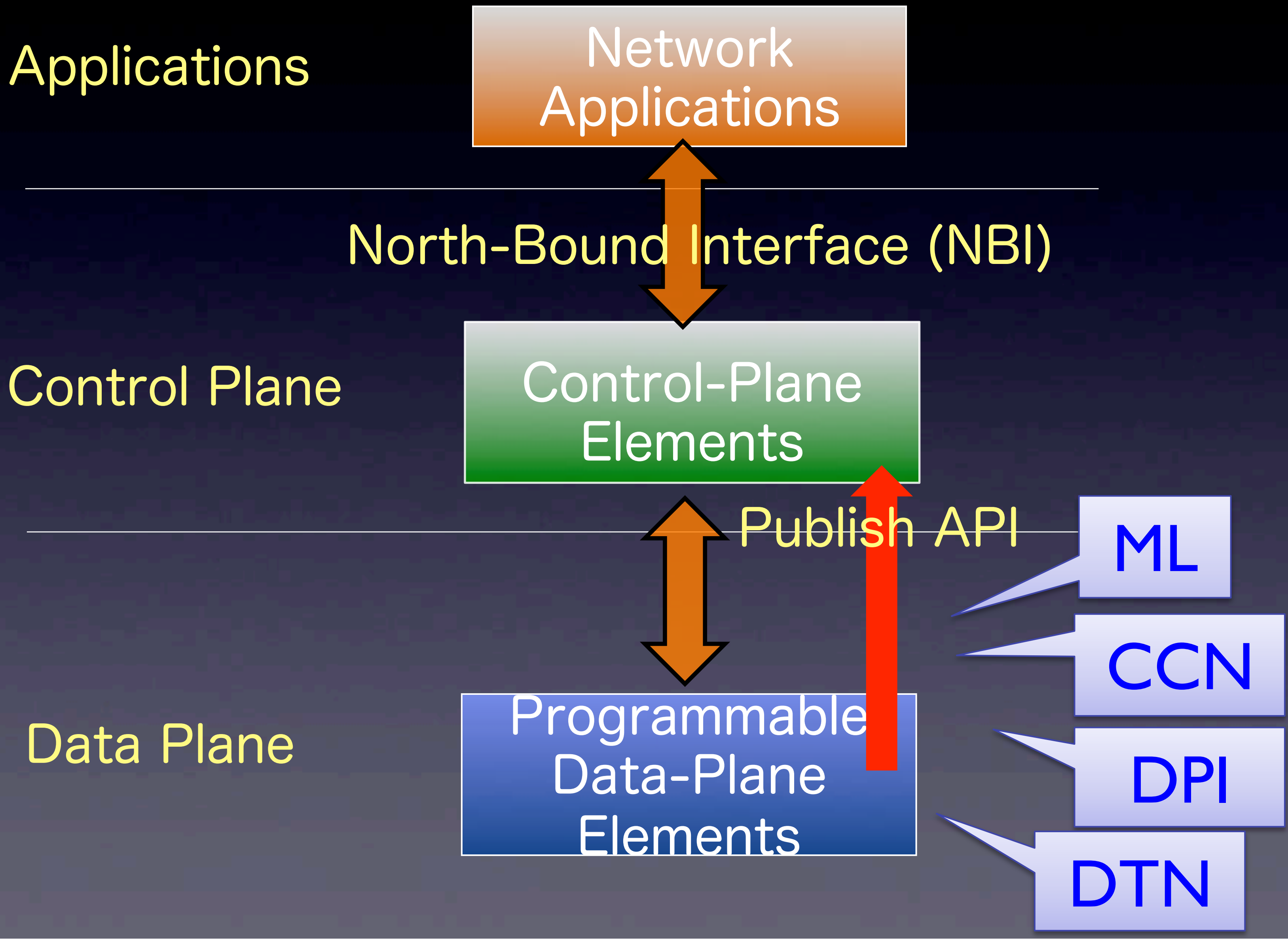
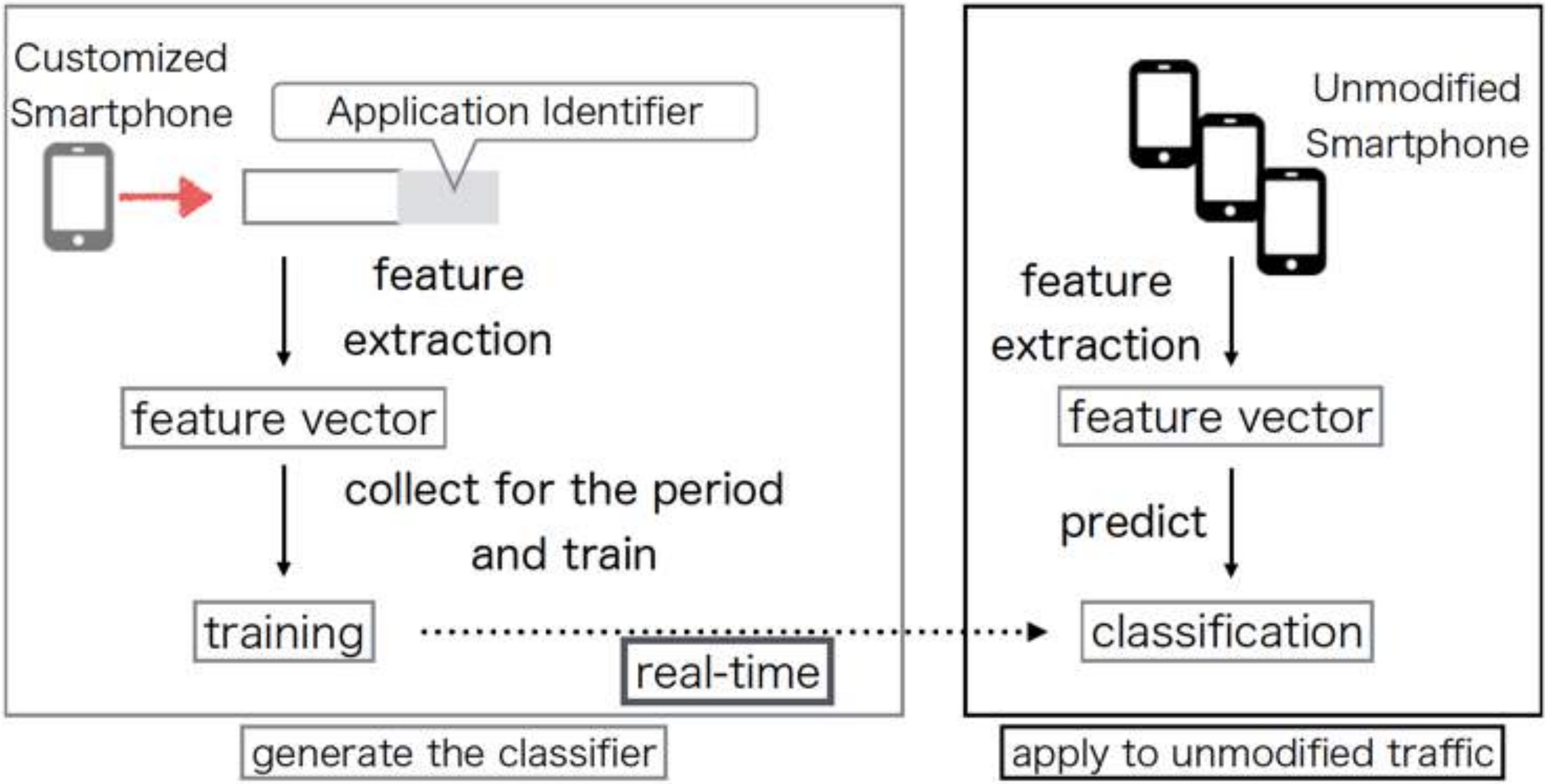
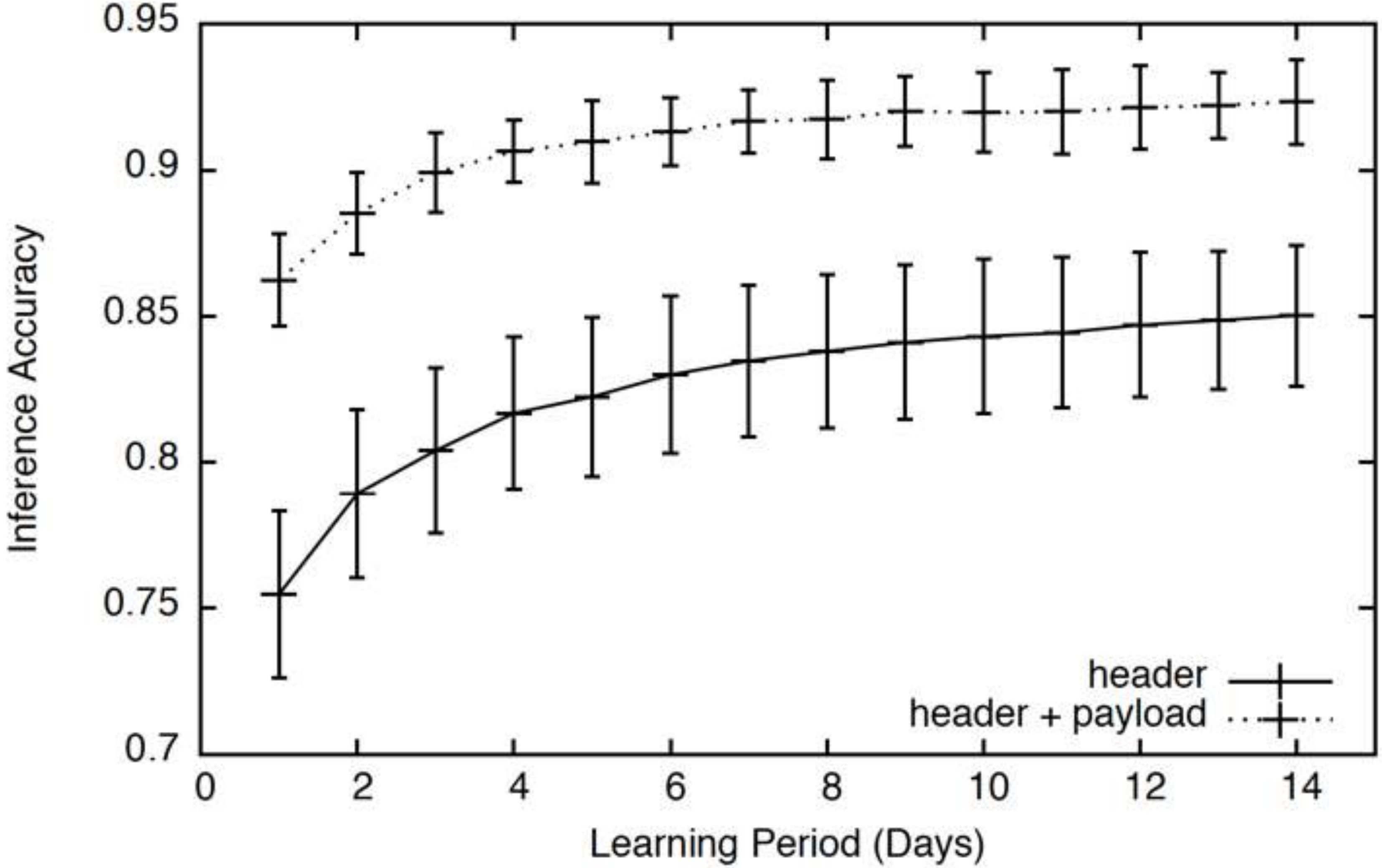
Software Defined Data Plane



Application Identification by Machine Learning



Application Inference Accuracy vs. Learning Period



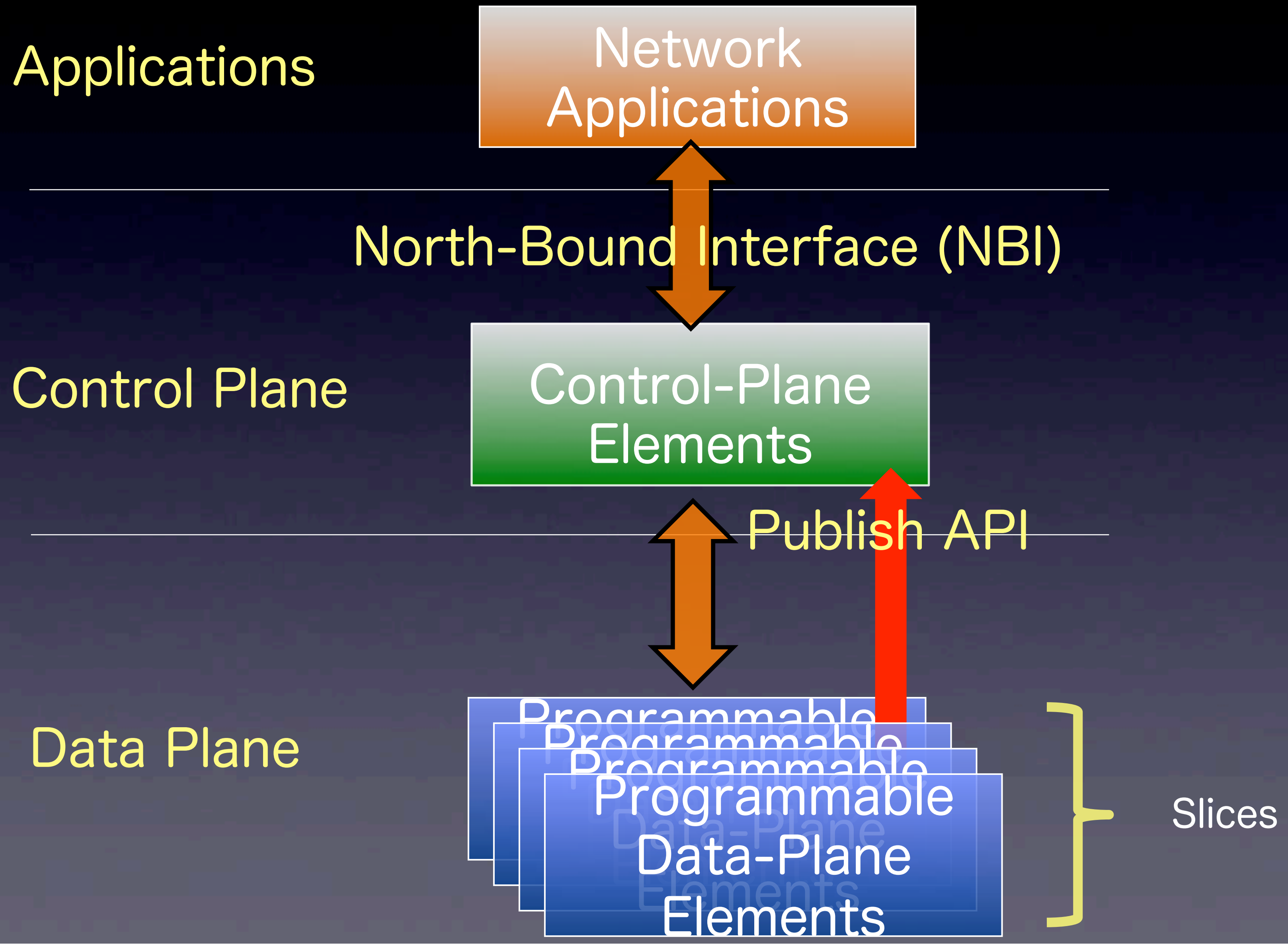
After 5 days of learning we can achieve 90+% accuracy of inferring applications

Gap : Deep Data Plane Programmability

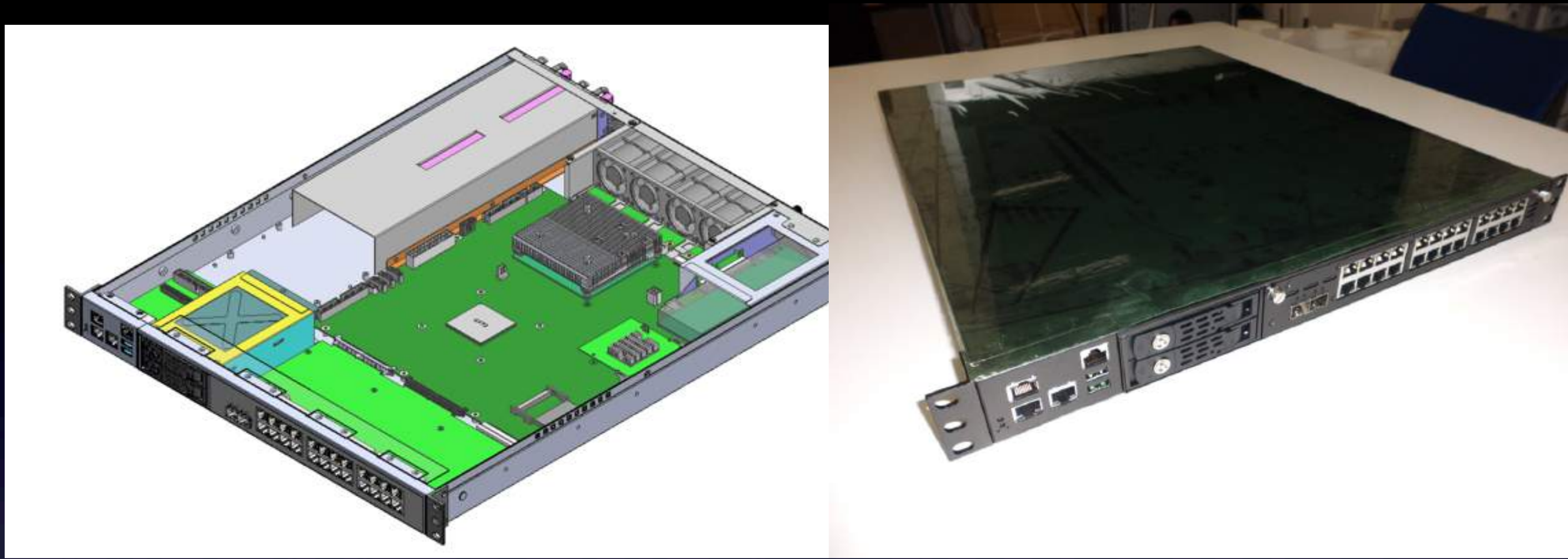
Gap B.6.6.3: Vertical extension: Deep data plane programmability (Data Plane Enhancement)	Priority: High
Description: The current SDN technology primarily focuses on the programmability of the control plane, and only recently the extension of programmability to the data plane is being discussed both in the research community and in ITU-T SG13 but without well-defined use cases. For IMT-2020 mobile networking, there are several use cases for driving invention and introduction of new protocols and architectures especially at the edge of the network. For instance, the need for redundancy elimination and low latency access to contents in content distribution drives ICN at mobile backhaul networks. Protocol agnostic forwarding methods such as Protocol Oblivious Forwarding (POF) discuss the extension to SDN addressing forwarding with new protocols. In addition, protocols requiring a large cache storage such as ICN needs new enhancement. A few academic research projects such as P4 [b-P4] and FLARE [b-FLARE] discuss the possibility of deeply programmable data planes that could implement new protocols such as ICN, but there is no standardization activity to cover such new protocols to sufficient extent.	

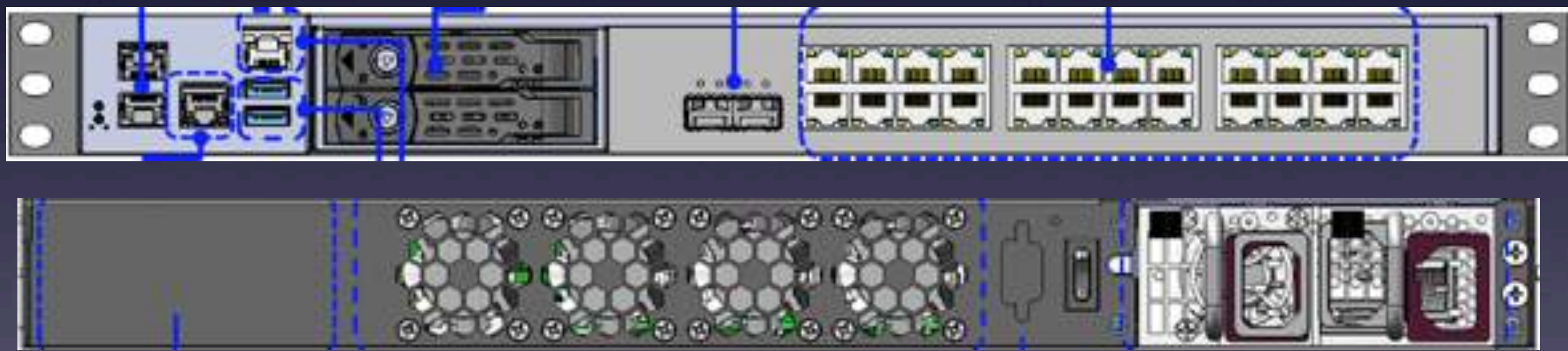
http://www.itu.int/en/ITU-T/focusgroups/imt-2020/Documents/T13-SG13-151130-TD-PLEN-0208!!MSW-E.docx

FLARE: Sliceable Software Defined Data Planes



Commercial FLARE Node

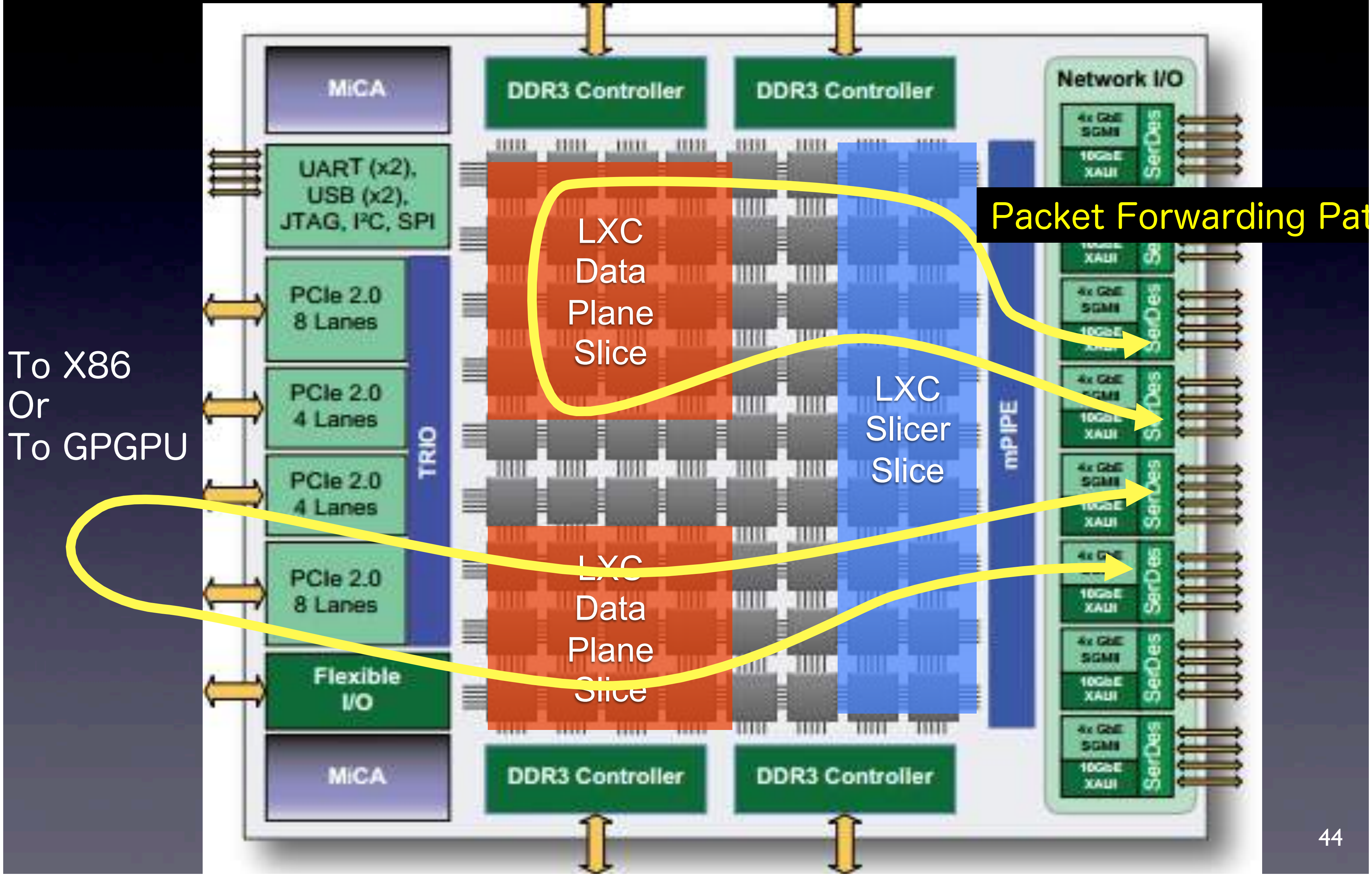




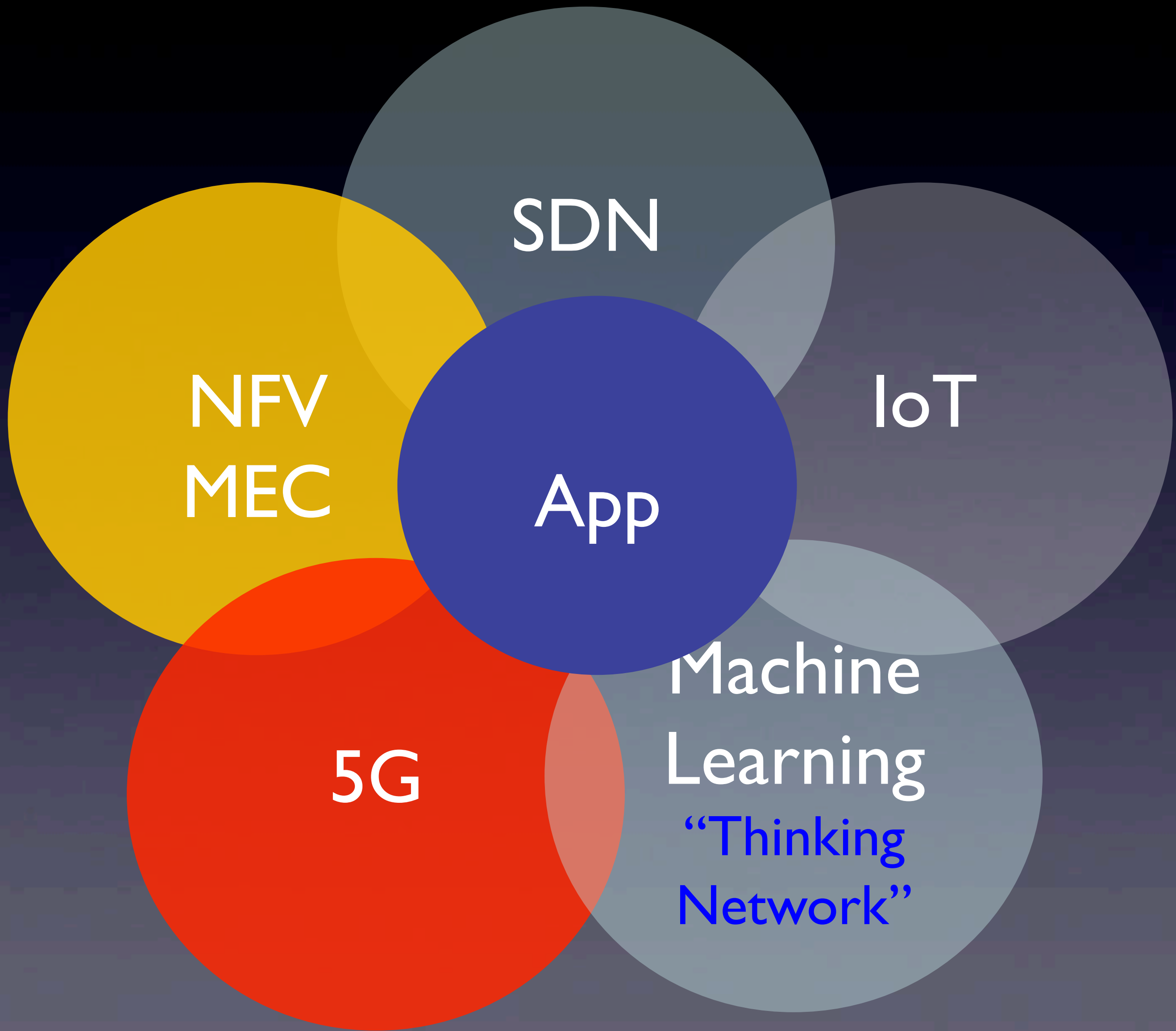
- 72 core EZ-Chip Network processor
- GbE: 24 ports and 10GbE SFP+: 2 ports
- Up to 128GB memory / 1TB SSD
- Redundant Power supply

Slice Architecture on NPU

LXC: Linux Container on Zero Overhead Linux (ZOL)



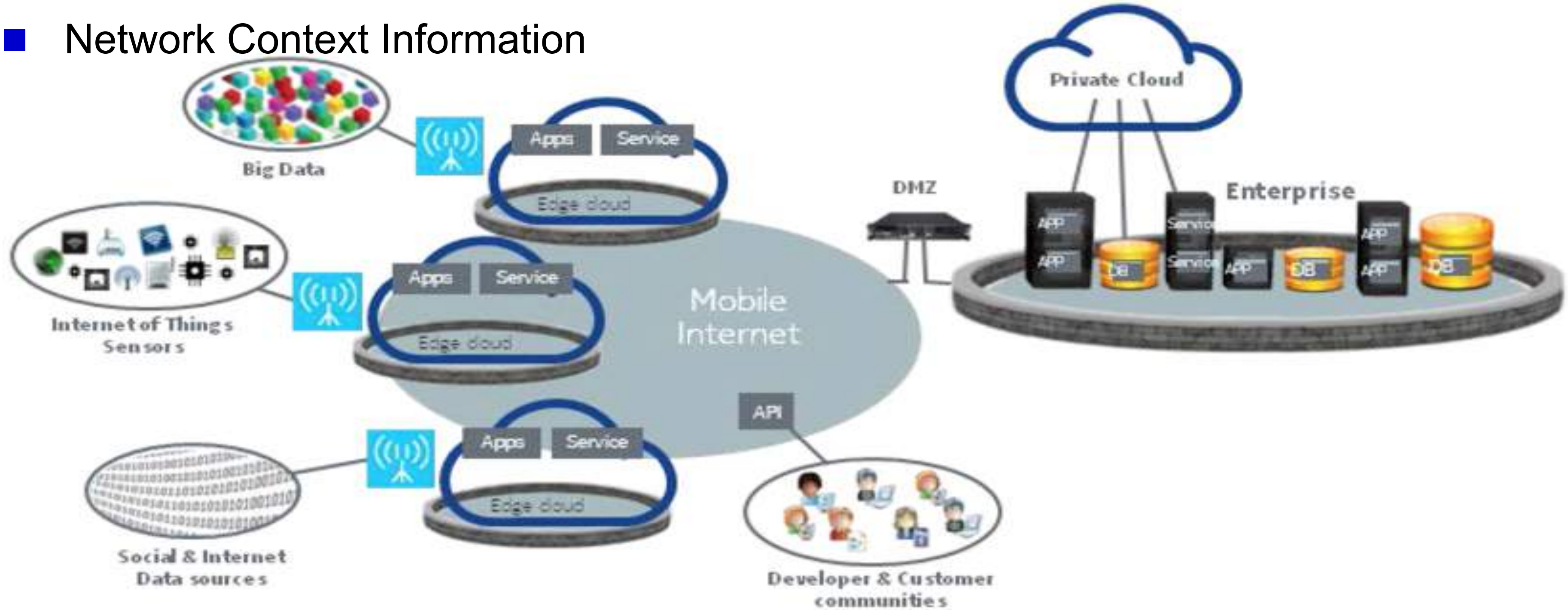
Research Interest in NakaoLab@UTokyo



Mobile Edge Computing

Mobile-edge Computing provides IT and cloud-computing capabilities within the Radio Access Network (RAN) in close proximity to mobile subscribers.

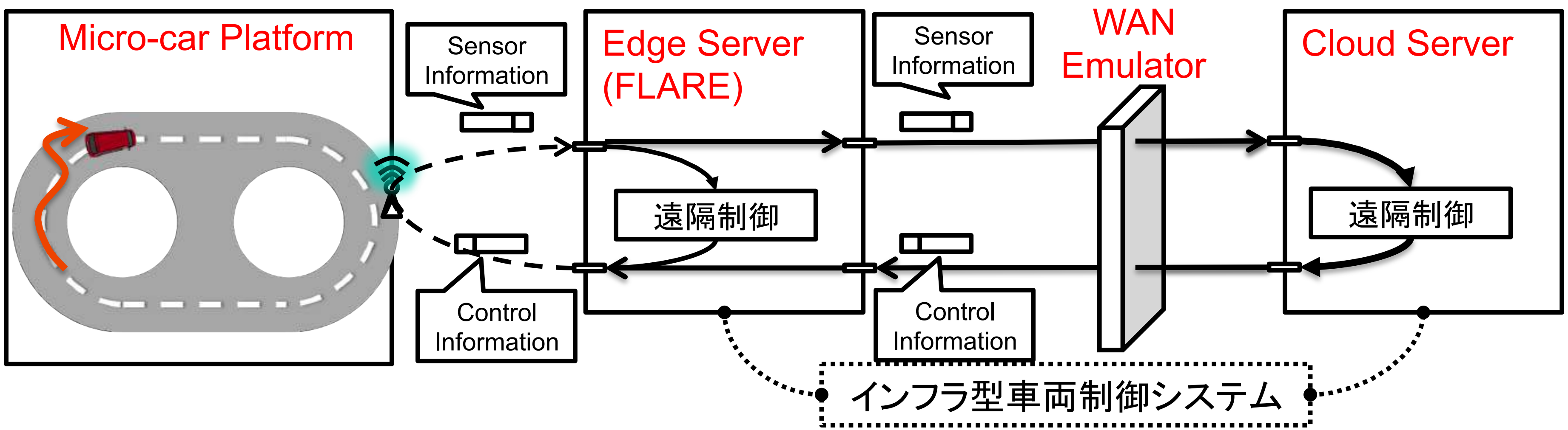
- On-Premises
- Proximity
- Lower Latency
- Location Awareness
- Network Context Information

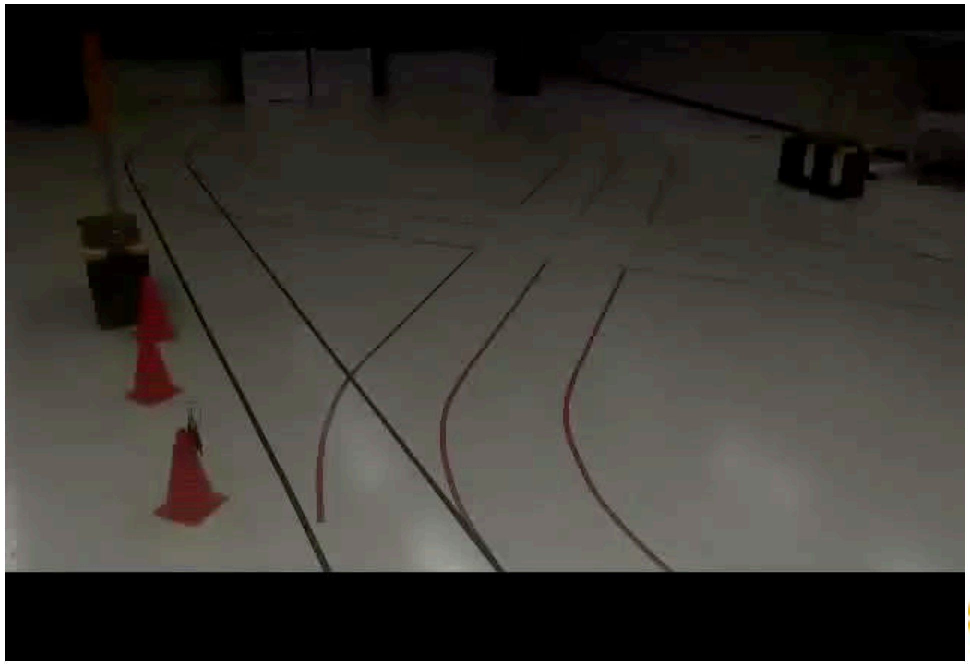


http://www.etsi.org/technologies-clusters/technologies/mobile-edge-computing

MEC Introductory Technical White Paper

"Vehicle Control System Coordinated Between Cloud and Mobile Edge Computing" Kengo Sasaki*, Naoya Suzuki, Satoshi Makido, Akihiro Nakao (To Appear in IEEE SICE 2016)





Deviation From the Center of the Road

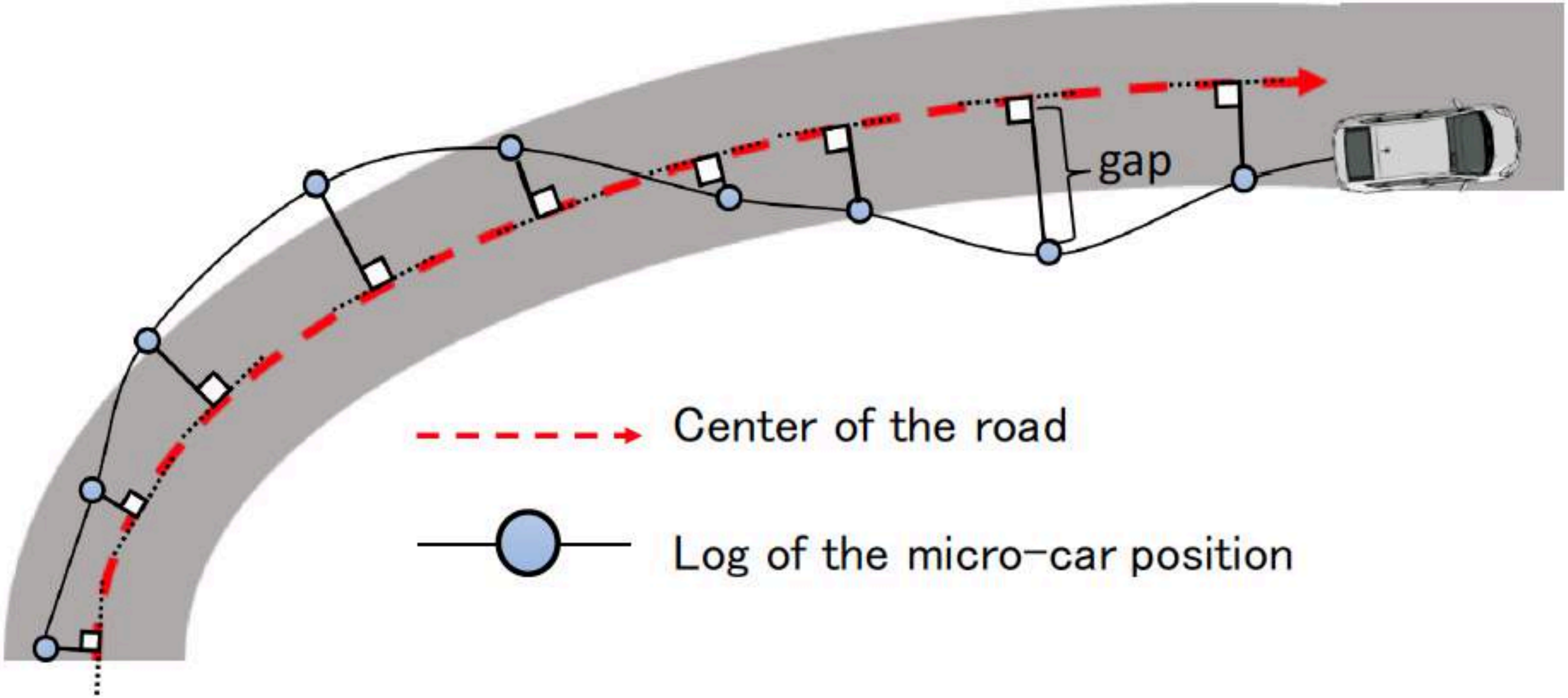
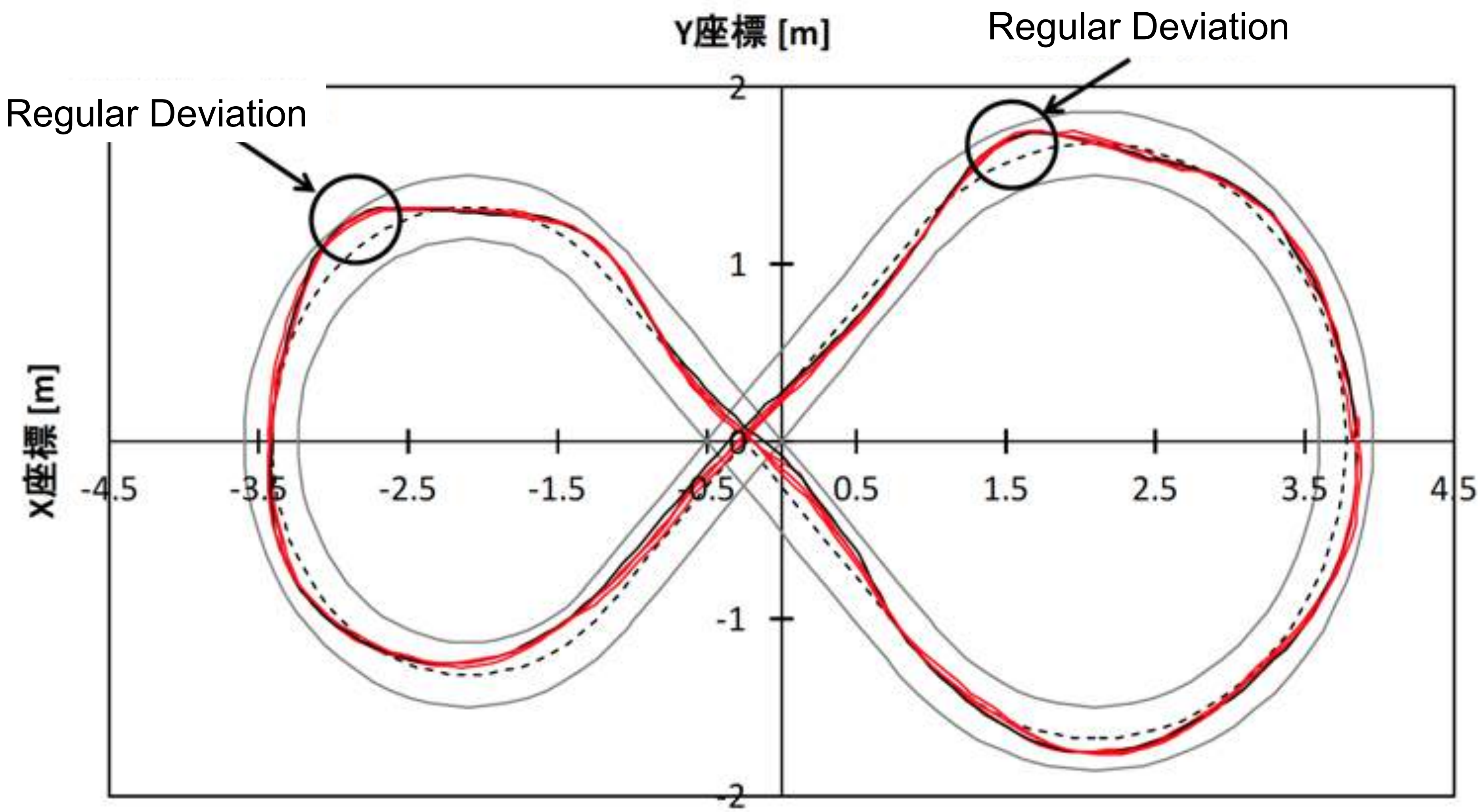


Fig. 8 Evaluation method of the vehicle path the stability

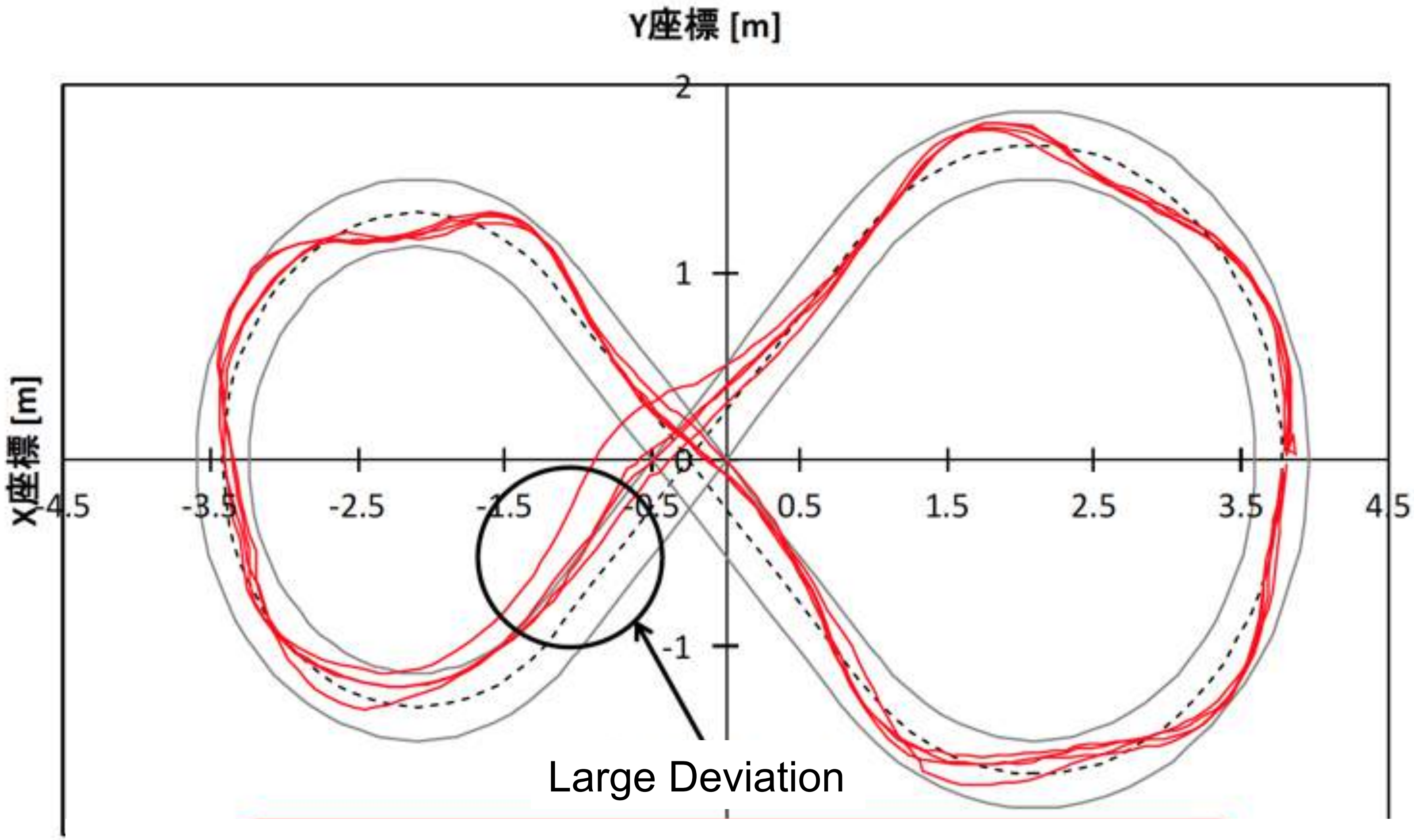
Cloud MEC Cooperative Driving PoC (Toyota&UTokyo)

With 100msec delay from UE to Cloud



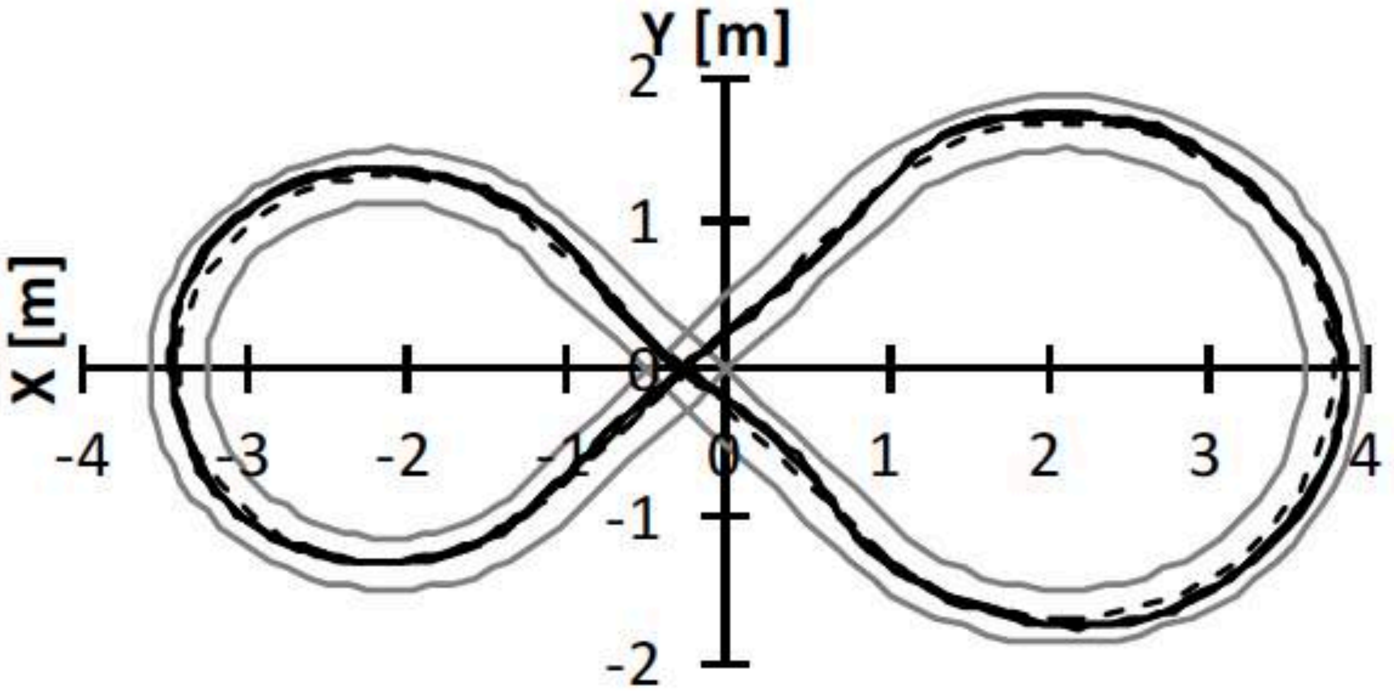
Cloud MEC Cooperative Driving PoC (Toyota&UTokyo)

With 150msec delay from UE to Cloud



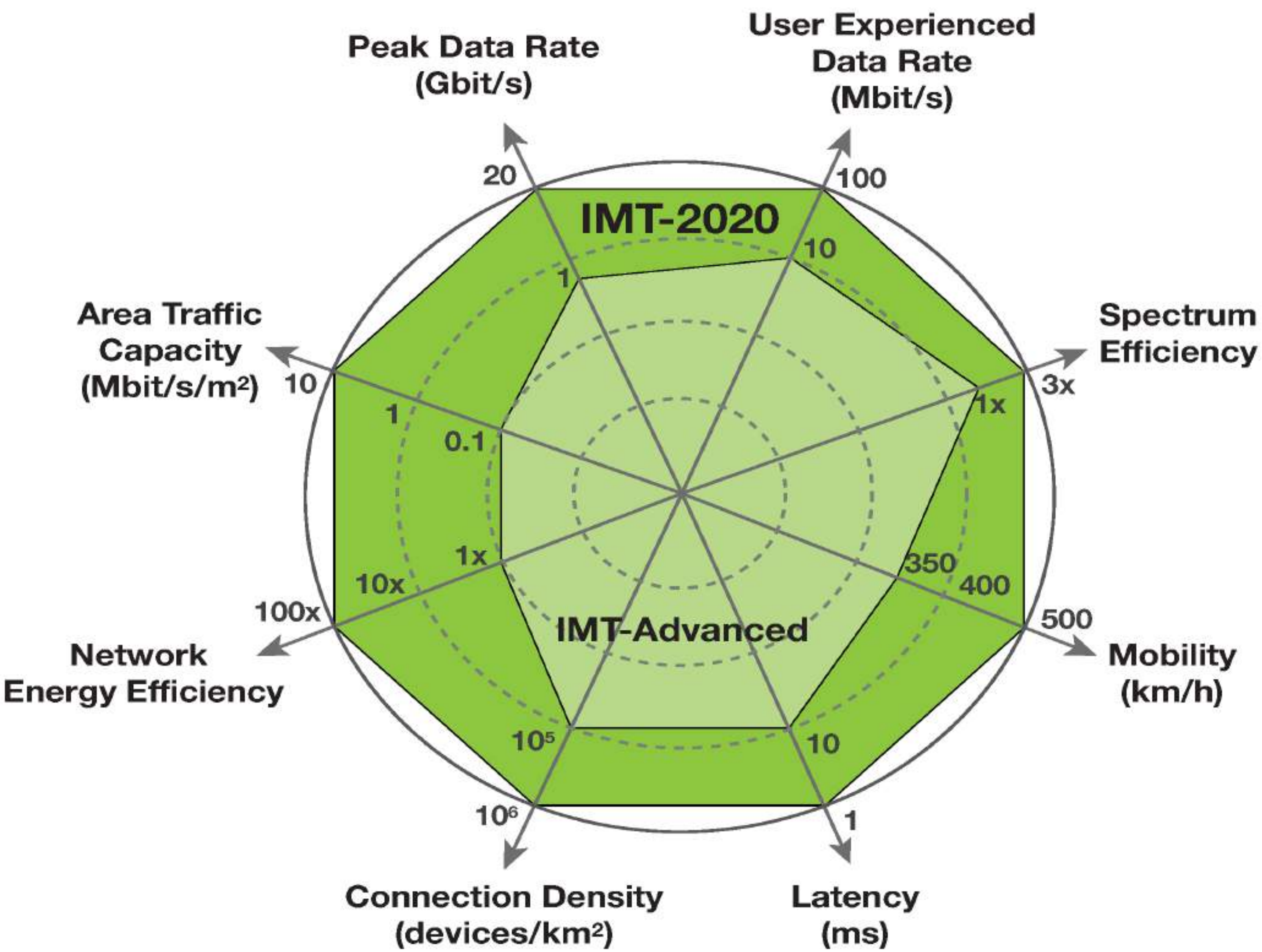
40% of the trajectory is out of the course

Edge Server Achieves Better Control

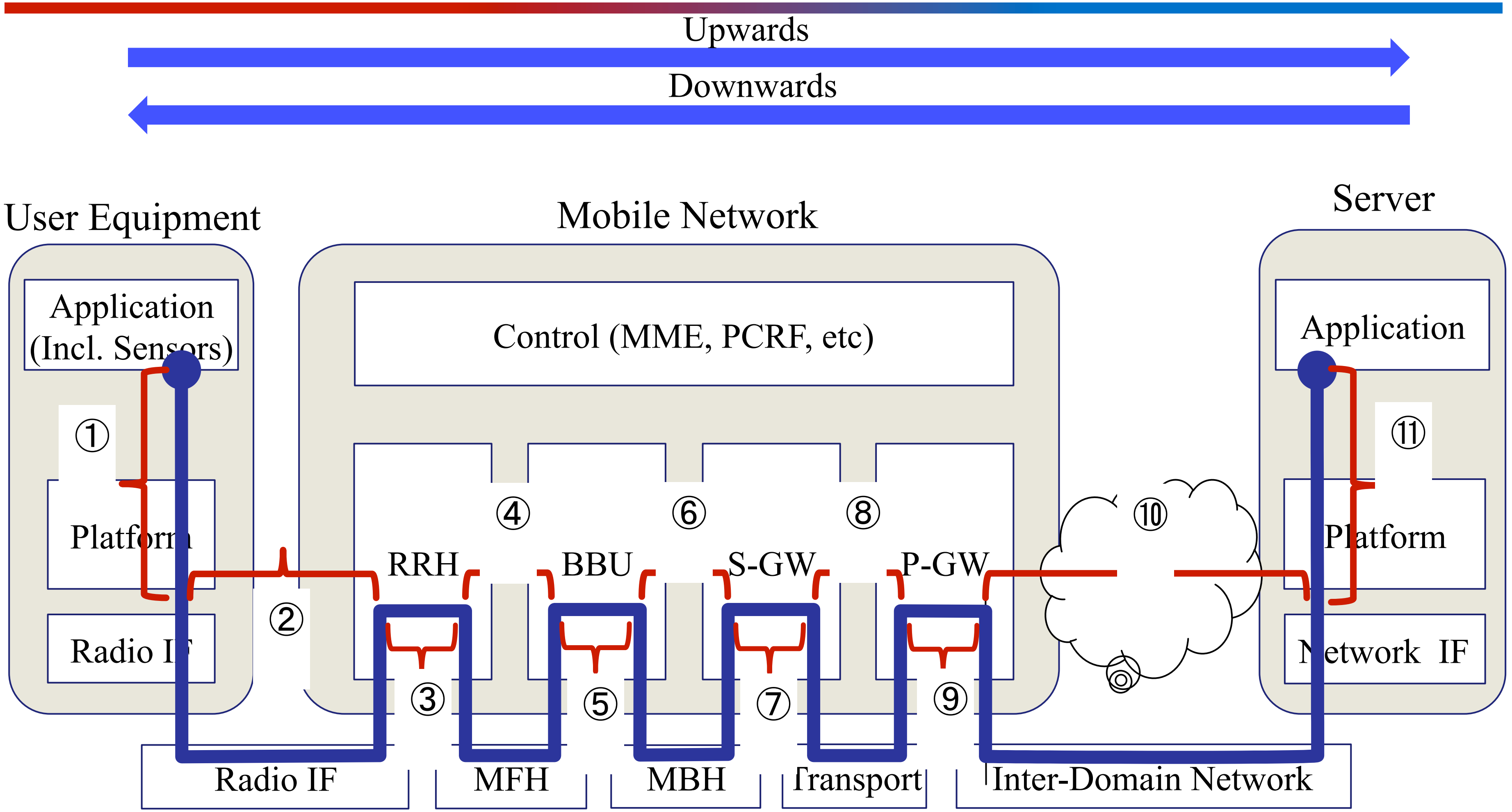


(a) Edge Server (0ms)

Wireless Performance Requirement in 5G



Breakdown of E2E Delay



RRH (Remote Radio Head)
BBU (Base Band Unit)
S-GW (Serving Gateway)
P-GW (Packet Data Network Gateway)

MFH (Mobile FrontHaul)
MBH (Mobile BackHaul)
MME (Mobility Management Entity)
PCRF (Policy and Charging Rule Function)

One way latency defined in 5G: ②+③+④+⑤

EU-Japan Collaboration Project Proposal

5G!Pagoda

"A network slice for every service"

Federating Japanese and European 5G Testbeds to Explore Relevant Standards and Align Views on 5G Mobile Network Infrastructure Supporting Dynamic Creation and Management of Network Slices for Different Mobile Services.

サービスに応じたスライス動的生成・管理機能の実証と標準化を目的とする日欧連携 5G 移動通信基盤テストベッド

Call: EUJ1-2016 - 5G - Next Generation Communication Networks

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Aalto-yliopisto, Fraunhofer FOKUS, ERICSSON, EURECOM Sophia Antipolis, KDDI R&D LABS, 東京大学 THE UNIVERSITY OF TOKYO, HITACHI, orange, MANDAT INTERNATIONAL, UNIVERSAL DEVICE GATEWAY, NEC Networks & System Integration Corporation, Waseda University

Conclusion

Key technologies to enable …

5G!Pagoda Abstract

5G!Pagoda represents **network softwarization** enhancing NFV, SDN and aimes at 5G network evolution. The top objectives of 5G!Pagoda are i) the development of a scalable 5G slicing architecture towards supporting **specialized network slices composed on multi-vendor network functions,** through the development of ii) **a scalable network slice management and orchestration framework** for distributed, **edge dominated network infrastructures,** and convergent software functionality) **lightweight control plane** and iv) **data plane programmability** and their integration, customization, composition and run-time management towards different markets. 5G!Pagoda will **develop a coherent architecture** enabling **research and standardization coordination** between Europe and Japan.