Network Anomaly Event Prediction and Optimal Resource Control in Cloud Native Network Functions

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Acknowledgement:

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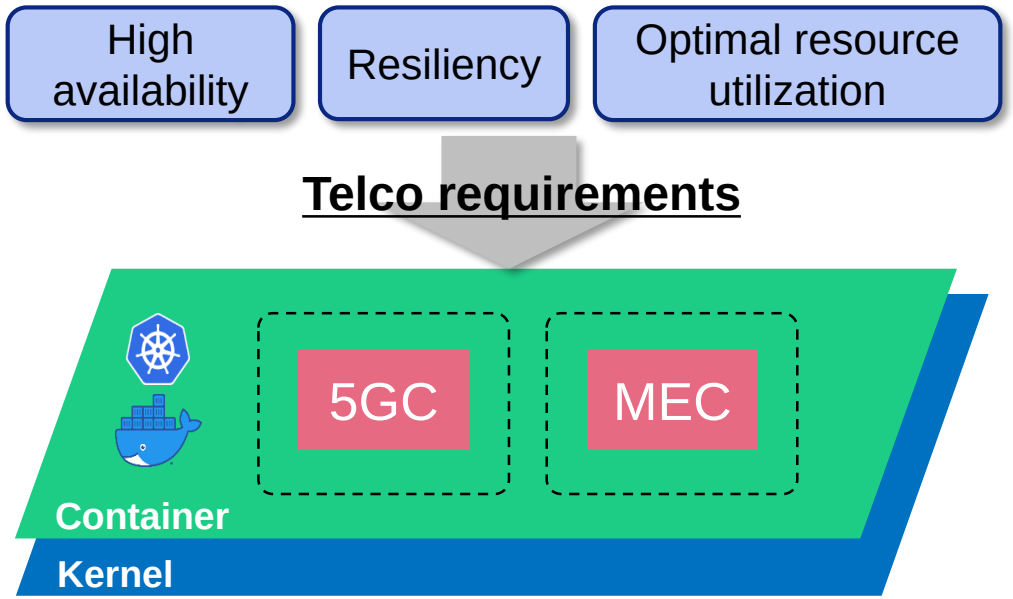
CNFs in Telco, Requirements and Challenges

- The use of Cloud-native Network Functions (CNFs) in the telco industry have started to emerge (examples: 5G and MEC)
  - Benefits
    - Quick service deployment
    - Operation and management flexibility
    - Diverse business models accommodation

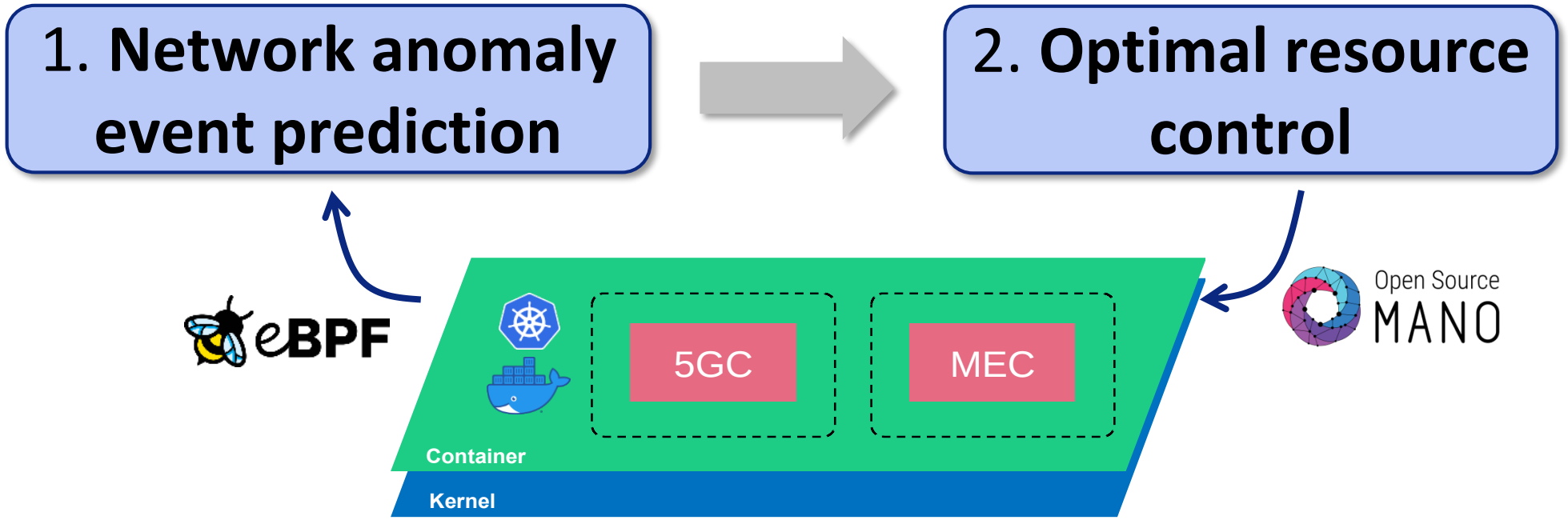


- Requirements of Telco CNFs
  - High availability
  - Resiliency
  - Optimal resource utilization, etc.

- Challenges
  - Failure prediction/anomaly detection/recovery
  - Optimized resource control

Lessons shared in today's talk

1. **Network anomaly event prediction** from Takuya Miyasaka
   - eBPF observability and deep learning
2. **Optimal resource control** from Takaya Miyazawa
   - autonomous computational resource control system for CNFs using Open Source MANO



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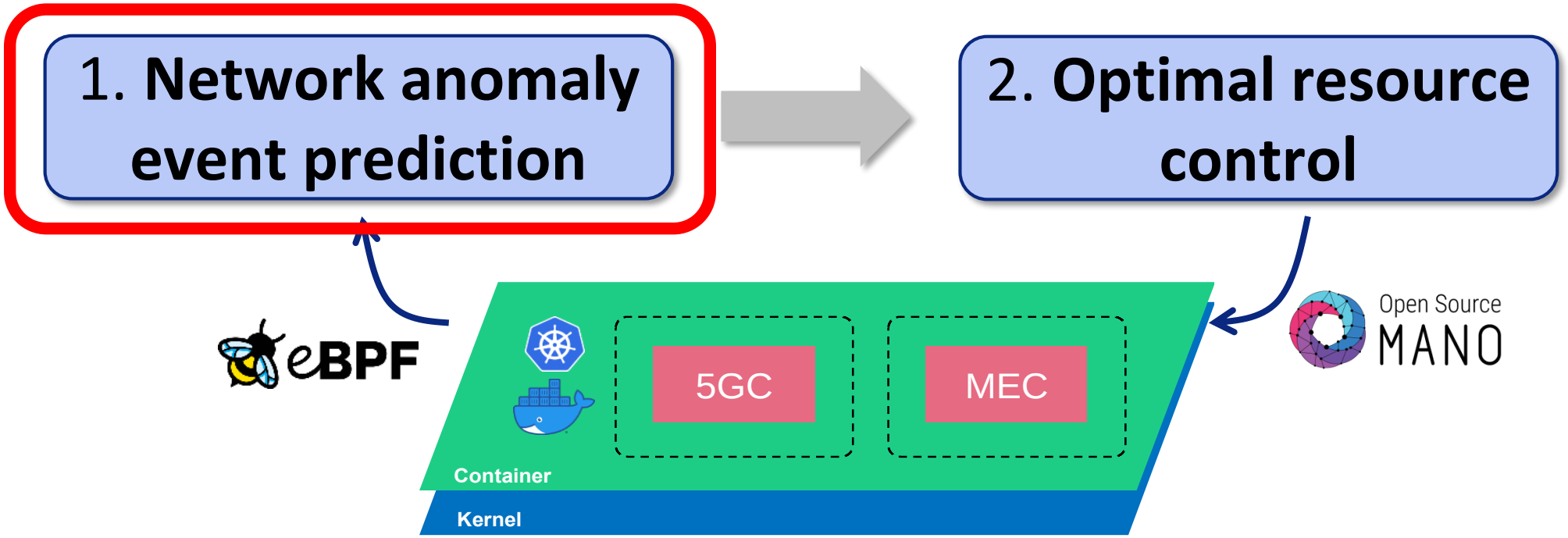
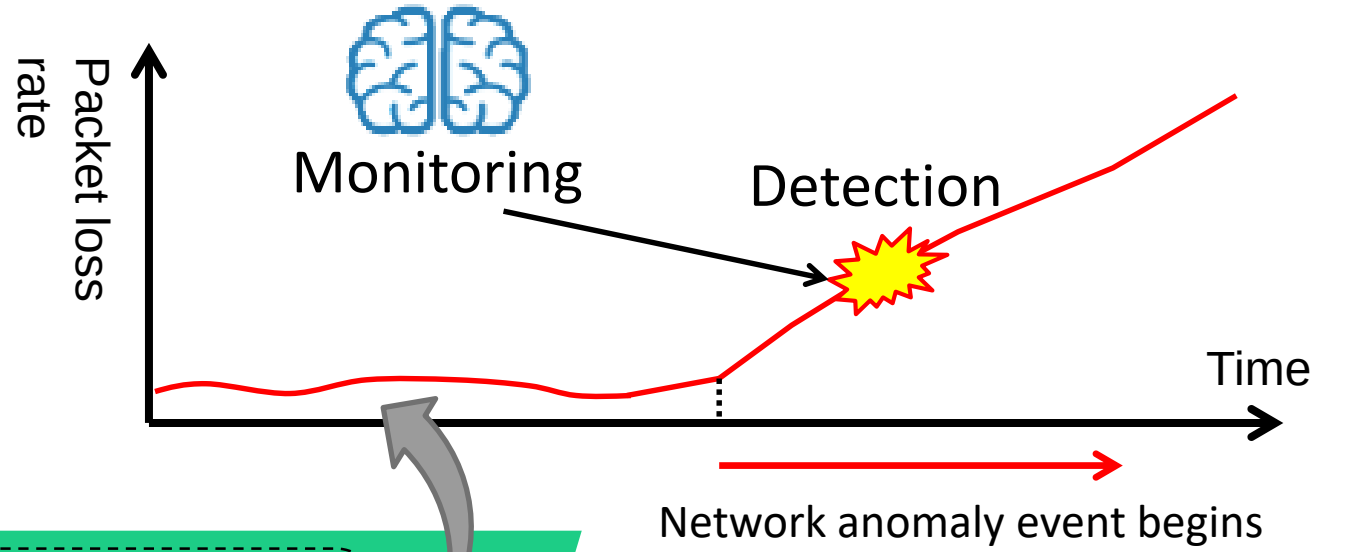
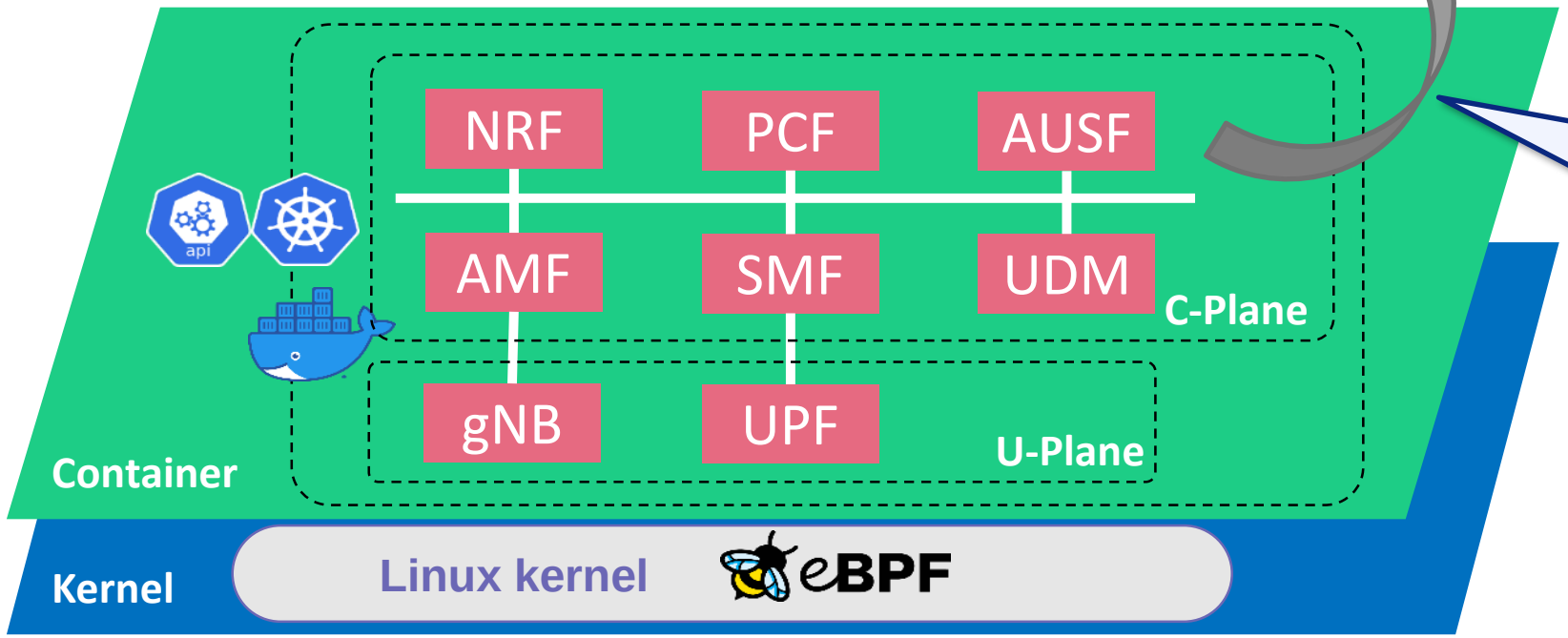


Example of network anomaly events

1. Network latency increases
2. Packet loss rate increases
3. CPU utilization rate increases

etc.





Example of the packet loss event in C-Plane.

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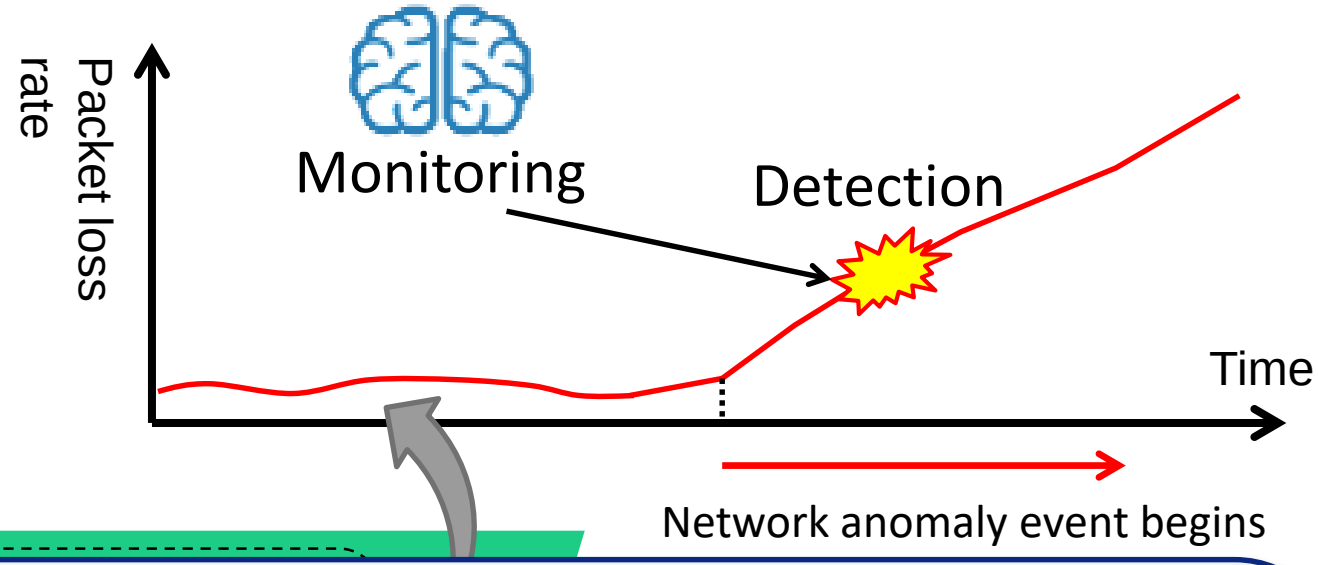
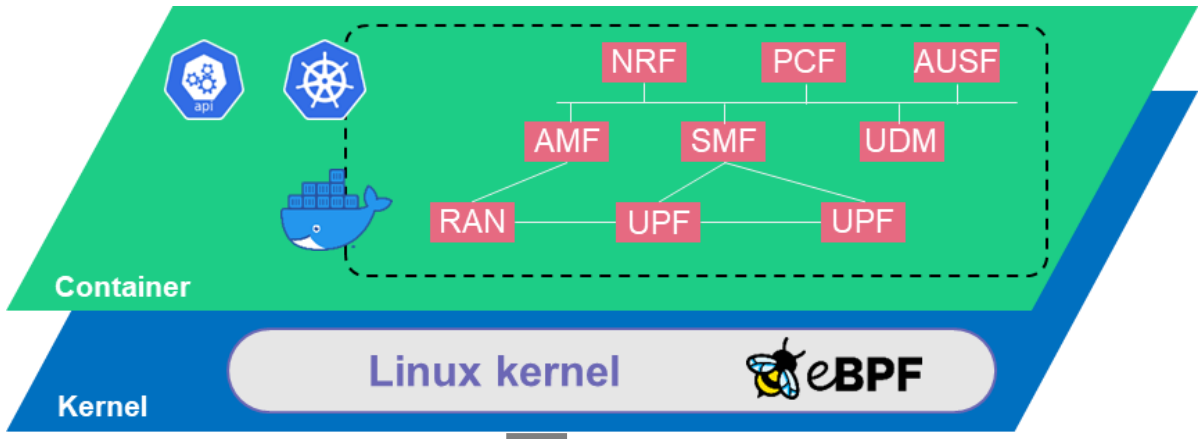


Our motivation is to detect anomaly event rapidly and precisely.

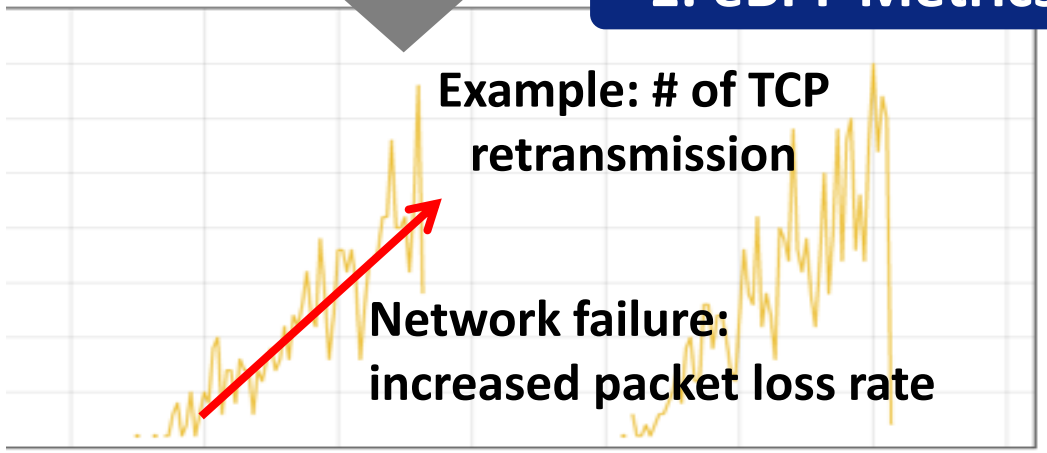
Hypothesis: Basic metrics such as CPU utilization are not enough to realize the rapid and precise detection?
=> eBPF observability may be the solution?

Overview of our approach



Target application is 5GC containers

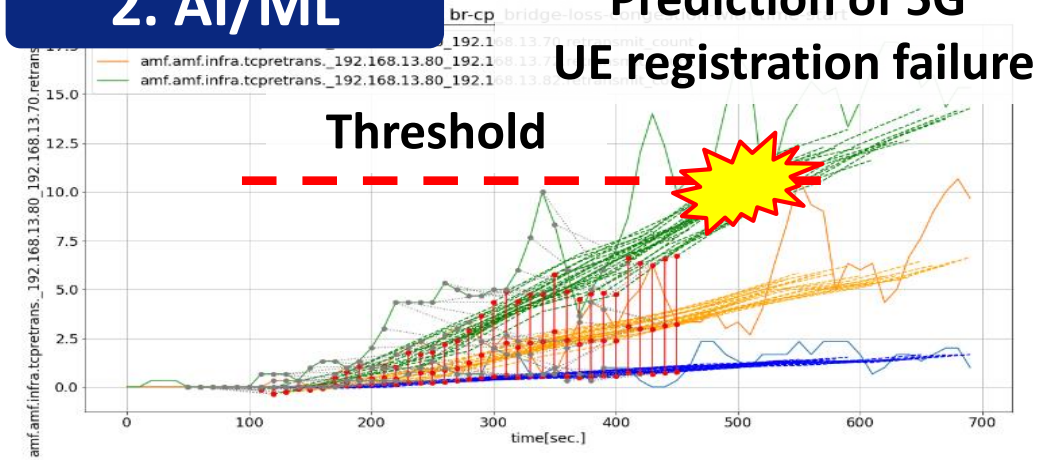
1. eBPF Metrics



Collect detail per-container metrics using eBPF

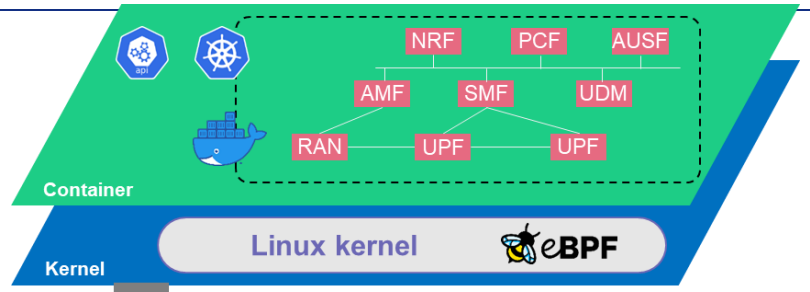
2. AI/ML

Prediction of 5G UE registration failure



Detect an anomaly event with future prediction

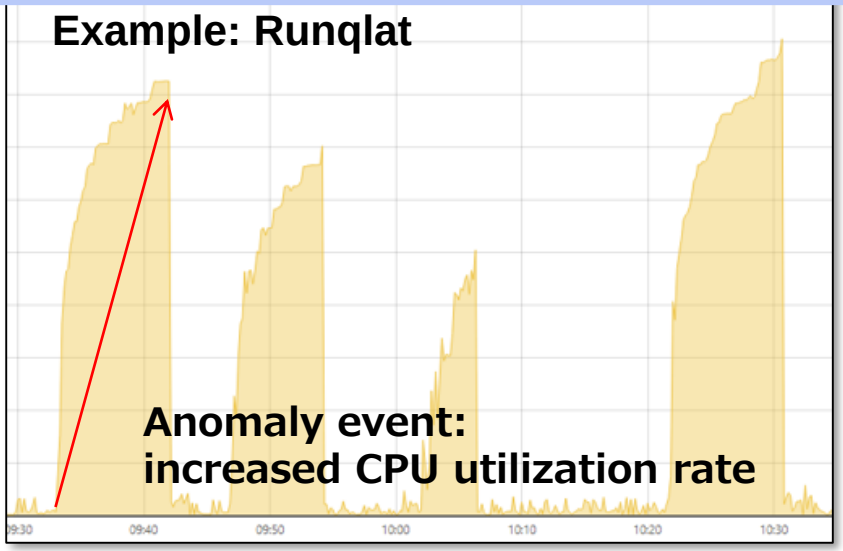
Per-container detailed system metrics collected by eBPF

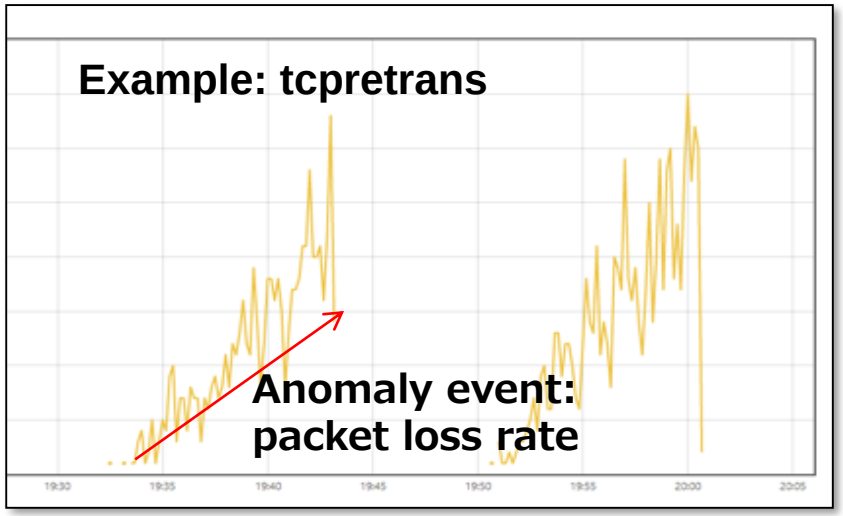


Per-container eBPF metrics are collected

eBPF metrics (BCC)	Contents
Runqlat	CPU run queue latency
Runqlen	CPU run queue length
tcprtt	TCP RTT
tcpconnlat	TCP connection and latency
tcpaccept	TCP accepted connection
tcplife	TCP life time
tcpretrans	TCP retransmission
tcpstates	TCP state
tcptracer	TCP trace
tcpdrop	TCP drop
tcpwin	TCP window size
solisten	TCP listen
execsnoop	Executed process
funccount	Called function

Several metrics can be positively correlated to anomaly event.

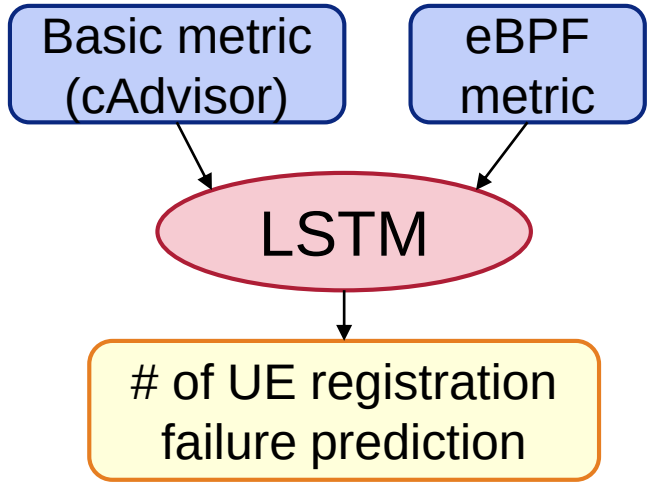


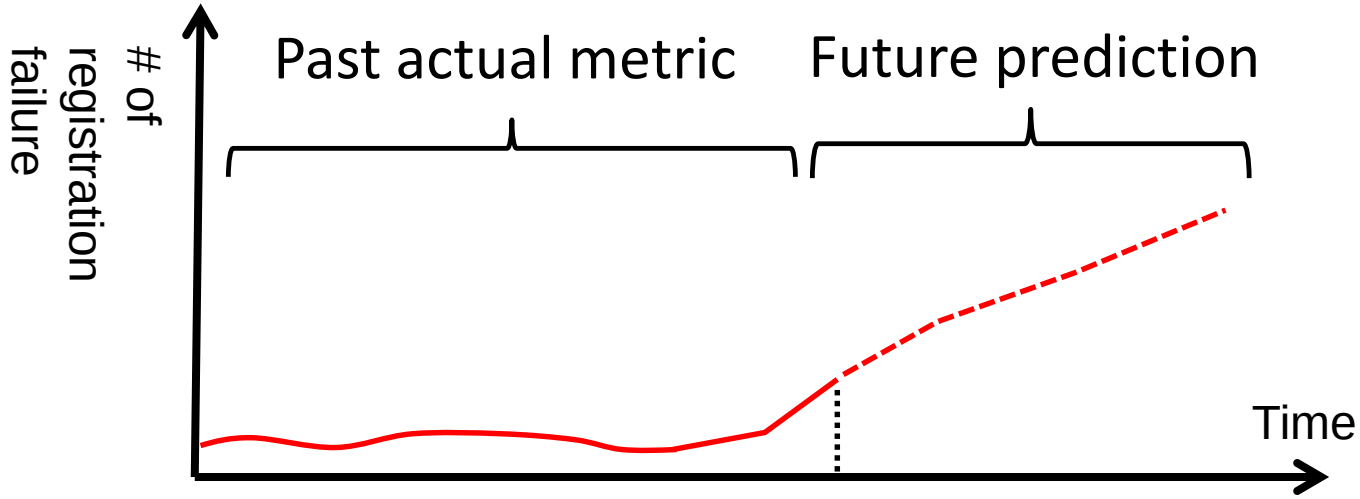


https://github.com/iovisor/bcc

Future prediction by LSTM

- Long short-term memory (LSTM)
  - RNN-based deep learning model for future prediction of time-series-data
  - LSTM input and output example
    - Input: per-container metrics (cAdvisor + eBPF)
    - Output (Prediction): The number of UE registration failure

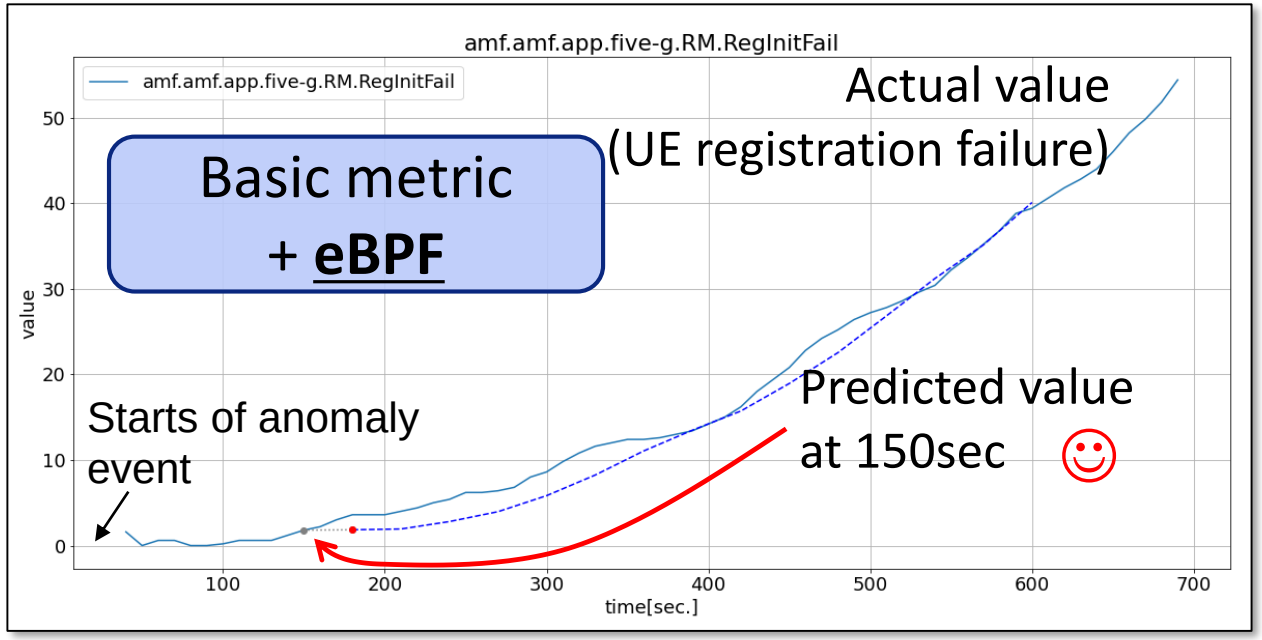


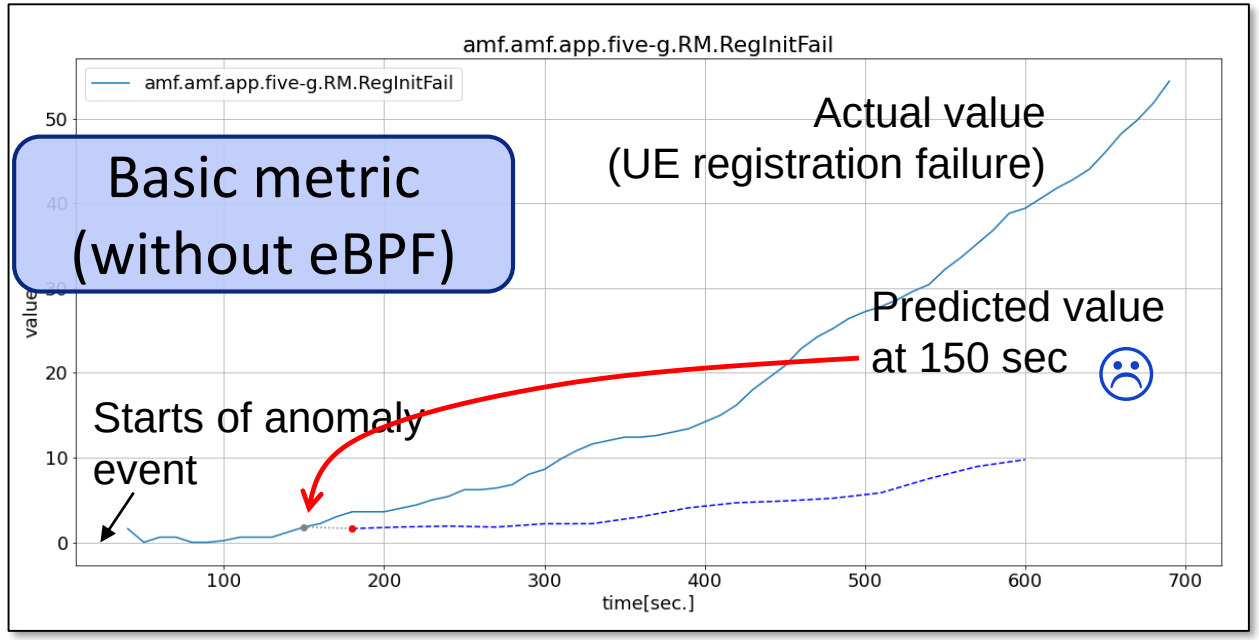


https://github.com/google/cadvisor

Result for anomaly event of packet loss

- Target anomaly event: packet loss event in our experimental 5G network (C-Plane)
- Results
  - eBPF enables accurate future prediction at 150 seconds from the start of anomaly event.





Summary of Network anomaly event prediction

- Thanks to eBPF, detailed per-container metrics can be collected even in CNFs 5G network

- eBPF and AI/ML will enable faster detection of anomaly events

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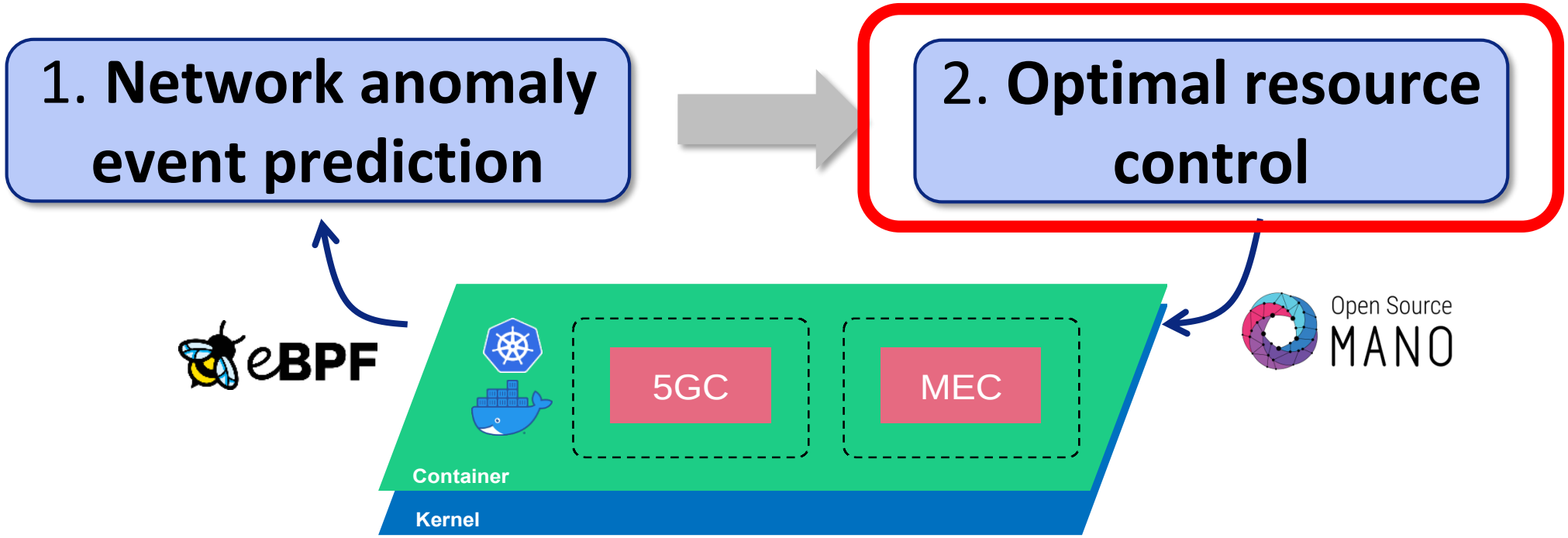
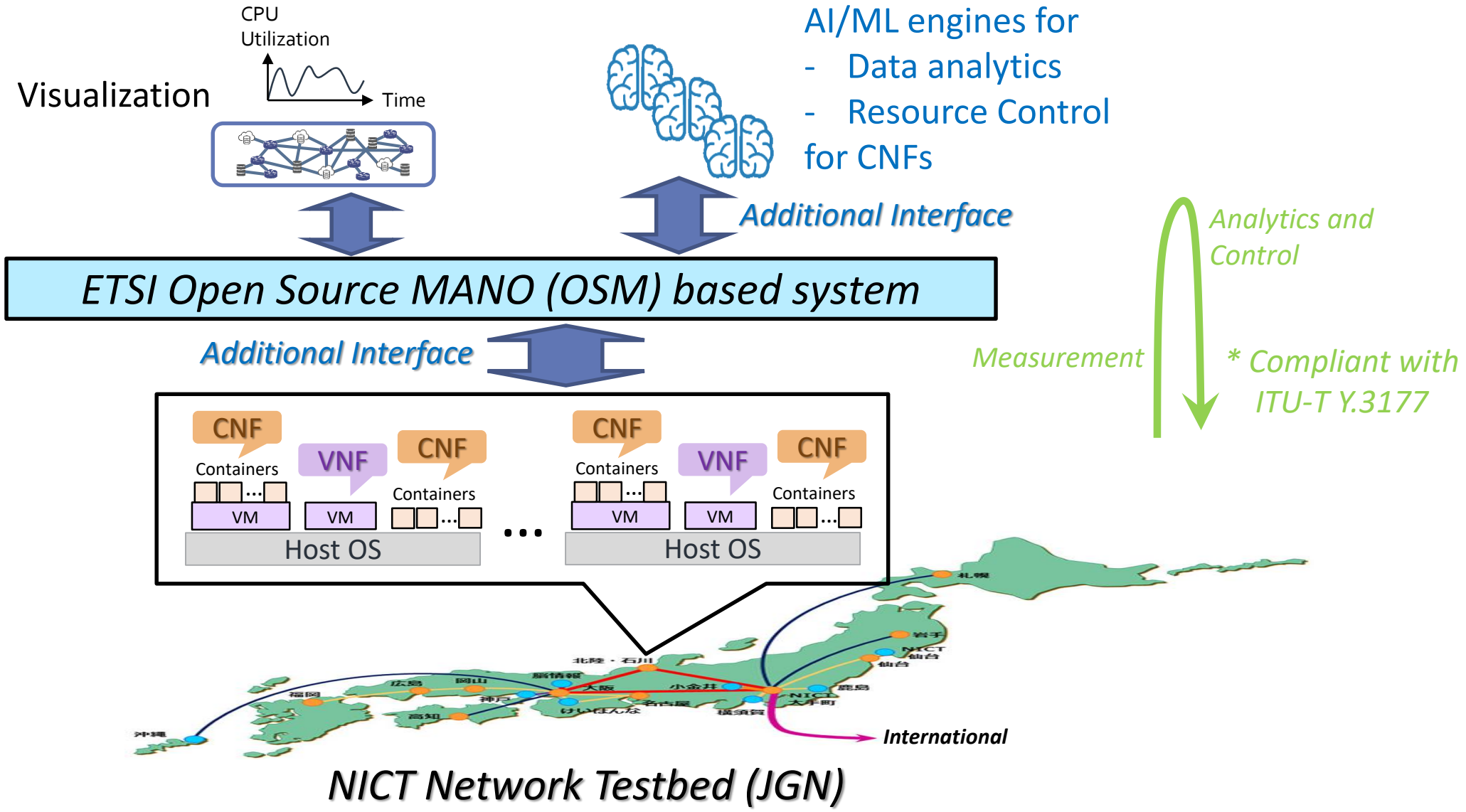
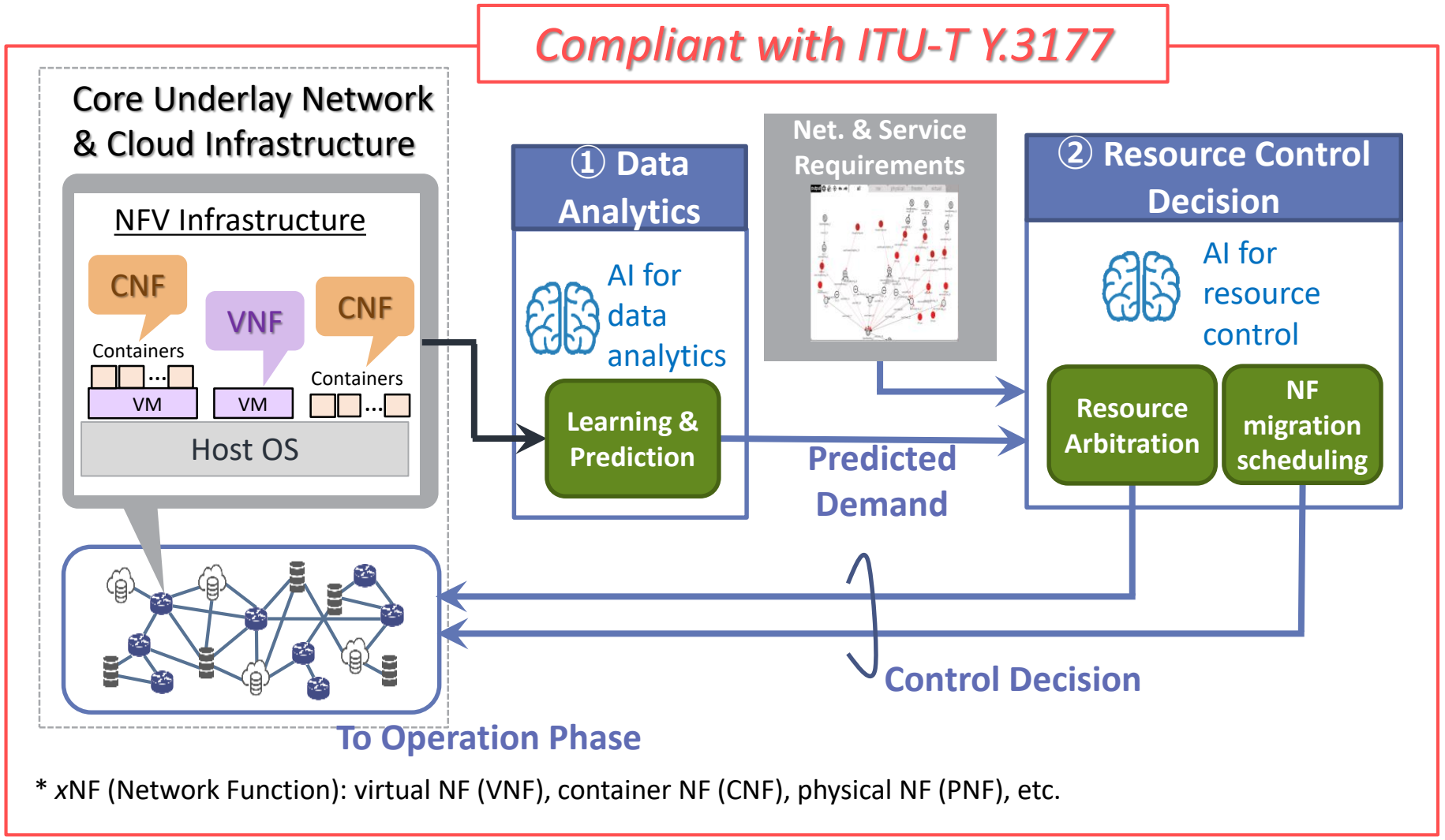


Summary - Optimal Resource Control for CNFs -



Framework of Resource Operations for *x*NFs



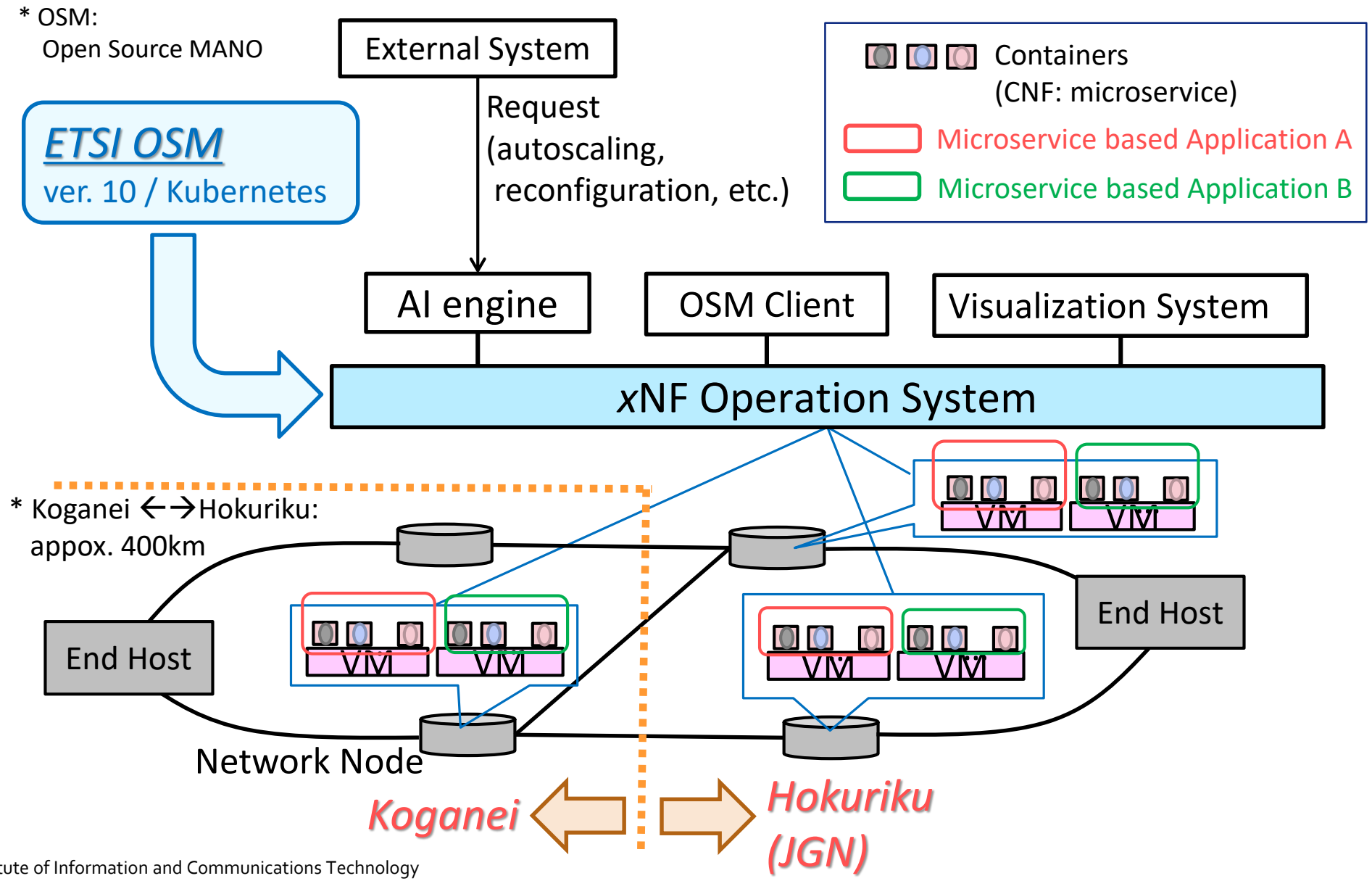
* *x*NF (Network Function): virtual NF (VNF), container NF (CNF), physical NF (PNF), etc.

Maintain and enhance QoS × **Efficient use of computing resources** × **Agile processing**

Achieve these simultaneously !!!

Verification infrastructure on a public network testbed (JGN)

Deployed an "ETSI OSM based xNF operation system" on JGN



ETSI OSM based *x*NF operation system

ETSI OSM v.10/Kubernetes

… What is lacking or insufficient ?

- Cannot obtain necessary information related to resources (with higher accuracy & higher scalability)
- No function of “Designated” Scaling
- Low manageability
- Low operability
  - Web API call & JSON reply → troublesome in arranging the form …
- No intelligent function (i.e., AI / ML)
- etc.

ETSI OSM based *x*NF operation system

Added

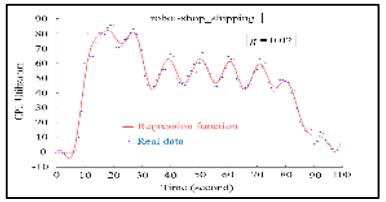
External System

AI / Machine learning for CPU data analytics & resource control

AI engine

Support Vector Regression, LASSO, Encoder-Decoder RNN, etc.

High agility & High efficiency



Added *Focus on*

"Direct Interface" for functional enhancement

OSM client

Visualization System

ETSI OSM based *x*NF Operation System

VM VM

VM VM

VM VM

End Host

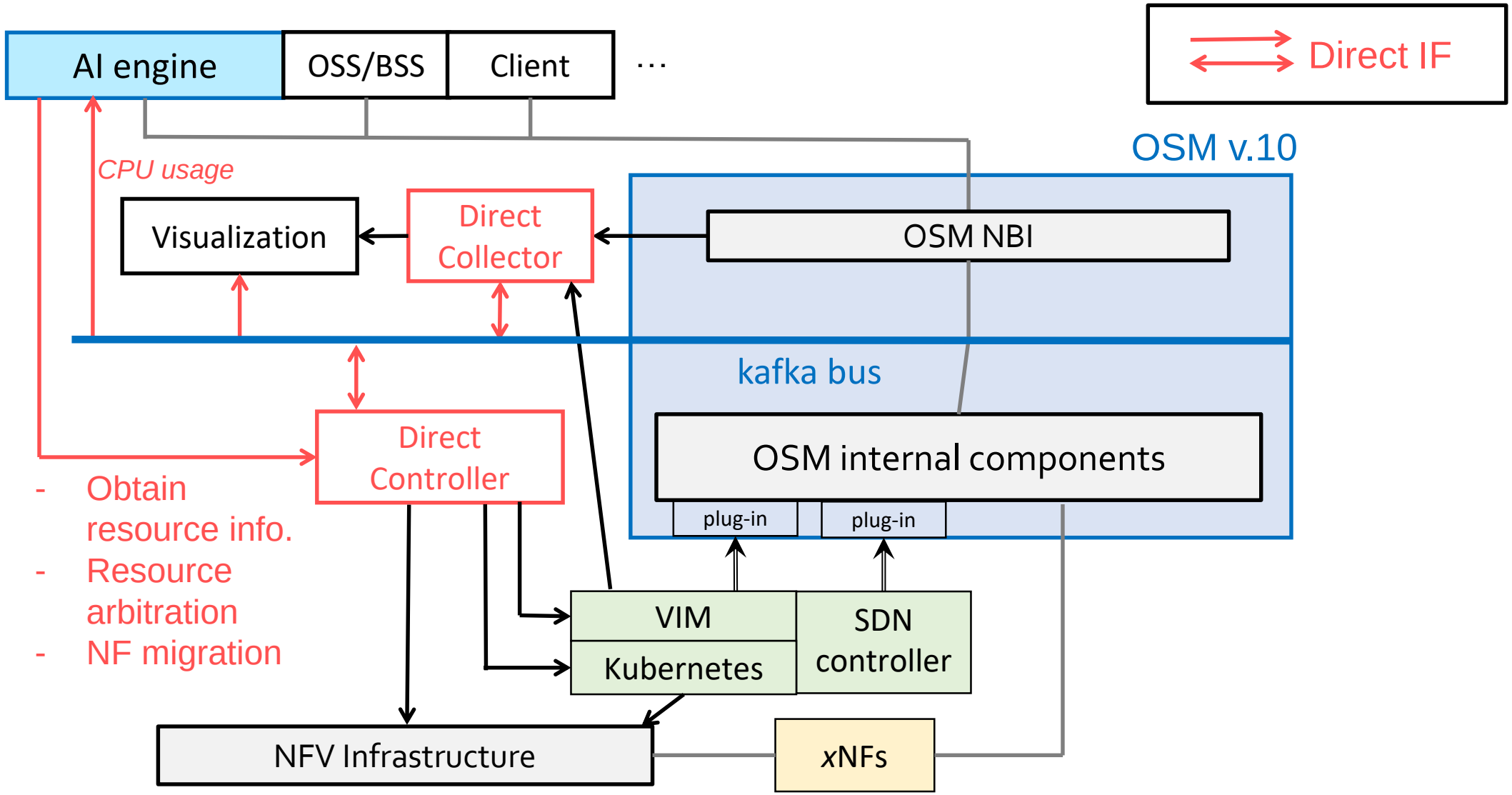
End Host

Network Node

Koganei *Hokuriku (JGN)*

Direct Interface and components

Additional interface (IF) called "Direct IF" added/connected to the OSM v.10



Benefits of Direct Interface and components

Support (i) obtaining CPU information in every second, (ii) resource arbitration among NFs, and (iii) NF migration between servers

- Obtaining VNFs/CNFs' CPU utilization in every 1 second
  - Use of *cgroup*
  - Tuned for each VIM (Kubernetes cluster) → High accuracy/scalability
- Designated Scaling
  - Horizontal scaling specifying a VM to increase a pod for each CNF
  - Vertical scaling specifying the amount of CPU allocated to VNFs/CNFs
- Higher Manageability
  - support to visualize a lot of information obtained by multiple OSM NBIs.
- Higher Operability
  - made a convenient command: "dctl"
    → easy to measure the processing time
    due to a function to designate
    "asynchronous" or "synchronous" to each request.
- etc.

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General Conclusion

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Cloud-native Network Functions (CNFs) in the telco industry
… Important to meet various requirements of telco services for CNFs

- Network Anomaly Event Detection:
  - eBPF observability in a 5G core network deployed by Kubernetes
  - Detection of future anomaly network events in the 5G with Deep Learning
- Optimal Resource Control:
  - New interface (Direct IF) added to the ETSI OSM v.10/Kubernetes
    → realizes AI-assisted designated scaling, higher manageability & operability, etc.
  - Deployed the system on a Japanese public network testbed (JGN)

Contact:

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