5G CORAL Distributed Edge and Fog Computing Network Infrastructure and AR Navigations

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- Motivation of Distributed Computing Resource Orchestration
- 5G CORAL Use Cases
- Introduction to Fully Distributed Computing Resource Orchestration
- AI CNN Training for Resource Allocation Optimization
- Performance Testing
- Conclusions

5G CORAL
Hierarchical Multi-tier Computing Infrastructure

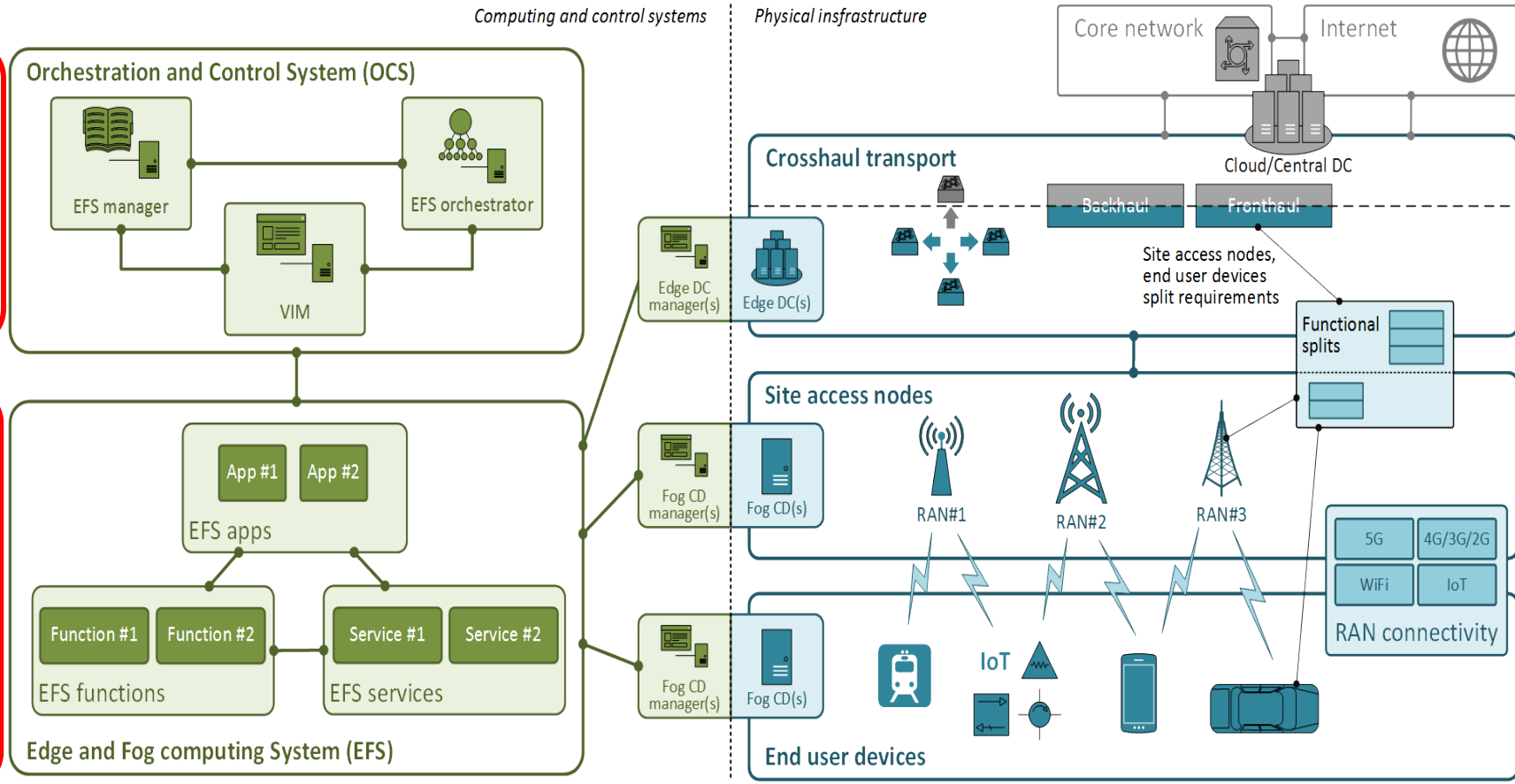
A 5G Convergent Virtualized Radio Access Network Living at the Edge

(1) EFS: hosting all proposed virtualized functions, services, and applications

(2) OCS: managing and controlling the EFS, and its interworking with other domains

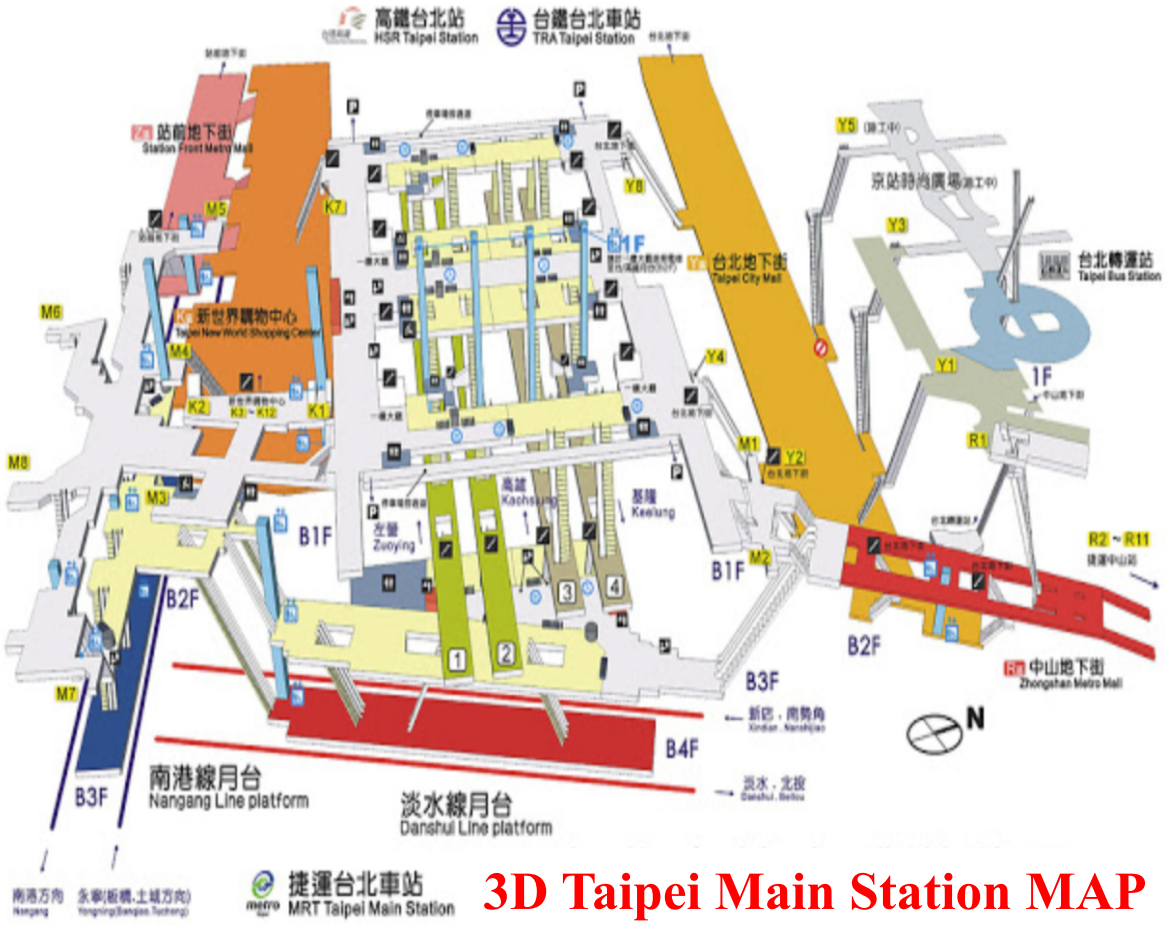
5G Edge&Fog Control Plane

5G Edge&Fog User Plane



5G Edge&Fog Hierarchical Multi-tier Computing Infrastructure and Use Cases

Motivation: Indoor Navigation in Taipei Main Station



3D Taipei Main Station MAP

- Complex 3D indoor environments in train station
  - Imagine that you are lost in a **Taipei Main Station**, looking for the entrance to MRT/HSR/TRA/Bus station/taxi ranks and up to 70 exits to parking and main roads.
  - Or you are trying to find a specific department or restaurants in an enormous shopping malls.
  - Since GPS is not working indoors, do we have any other better choose, except for the existing i-beacon and Wi-Fi positioning systems?

5G CORAL Use Case: Distributed Computing for Indoor AR Navigation/Advertisement

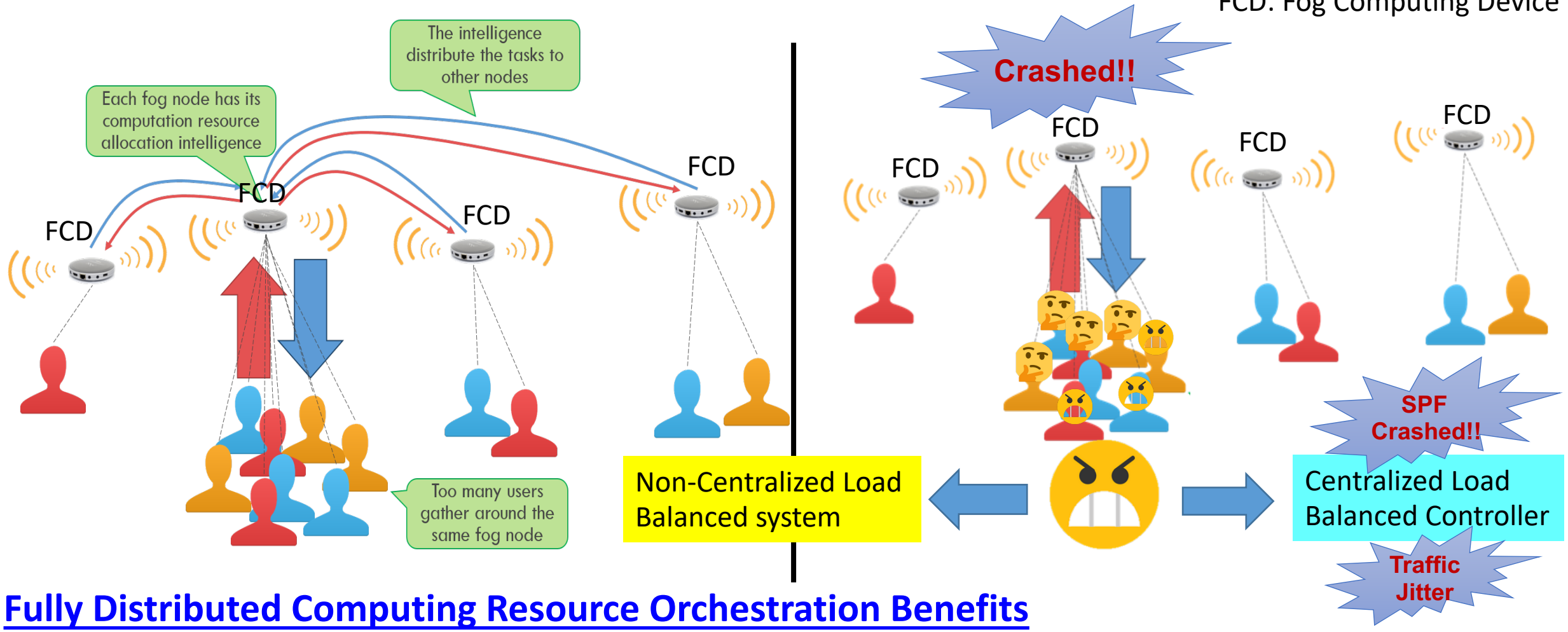
- **Taiwanese manufacture *ASKEY Computer* was requesting ITRI to provide 5G CORAL Fully Distributed EFS&OCS and AR solutions for AR Navigation and Advertisement services in Taipei Main Station.**
- **Video of an exemplary AR Service Scenario in Train Station Shopping Mall**

Performance Requirements

- Low End-to-End (E2E) Service Latency to fulfill better user experience (e.g., < 1sec)
- Support High User connection Density
- **Heavy Computing Loading shall not be happened in user's smartphone**
  - **Small Size (database) User APP**
  - **Low power consumption**
- Indoor Localization precision < 1 meter

Distributed Computing for Heavy Load AR Recognition

FCD: Fog Computing Device



Fully Distributed Computing Resource Orchestration Benefits

Low Latency (E2E): Minimize computing latency by processing image recognition and navigation tasks at the EFS

Connection density: Increase number of connection by distributing the incoming requests

Service Reliability: Overcome Single Point of Failure (SPF) by centralized distributed computing mechanism

Optimization of Fully Distributed Computing Resource Orchestration

- AI CNN offline trains the dispatching model of computing requests for Distributed FCD Cluster.
- Obtain online load balancing optimization among Distributed FCDs in Cluster.

HPF
PC

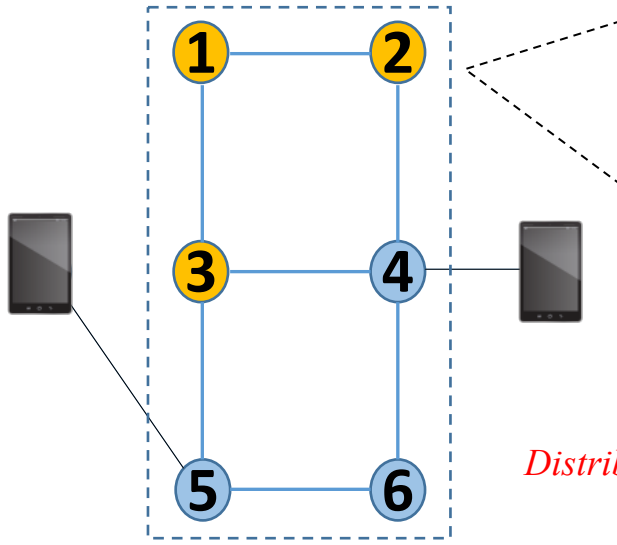
Training Input Data

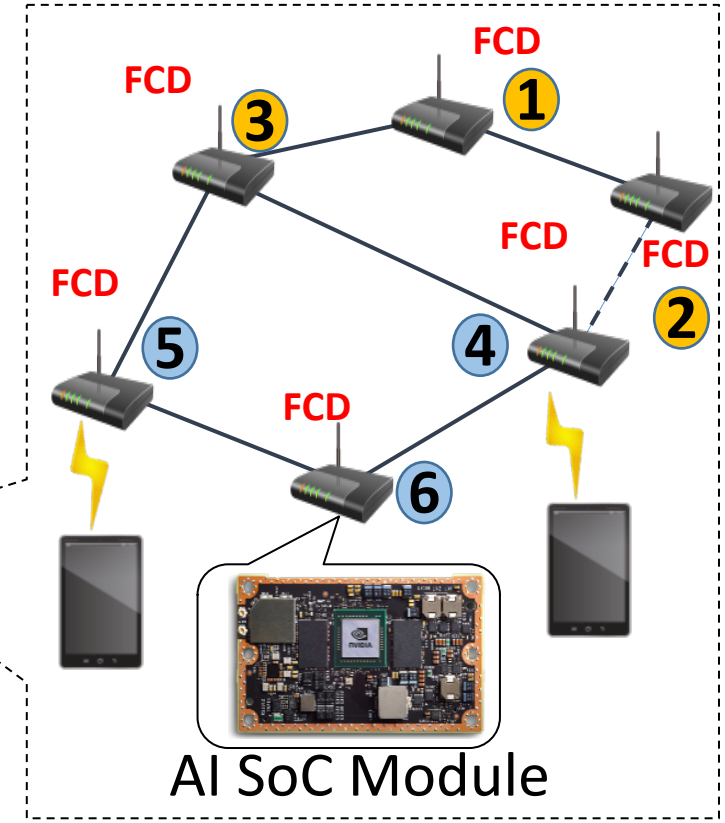
- Network Capacity Constrain
- Delay Constrain
- Network Topology
- Computing Capacity
- Load Balanced Constrain

FCD

Trained Model in each FCD for Resource Allocation Optimizer (request dispatcher)
Decision time range: 0.3ms~1ms

CNN offline Training with Fully Distributed Computing Resource Orchestration

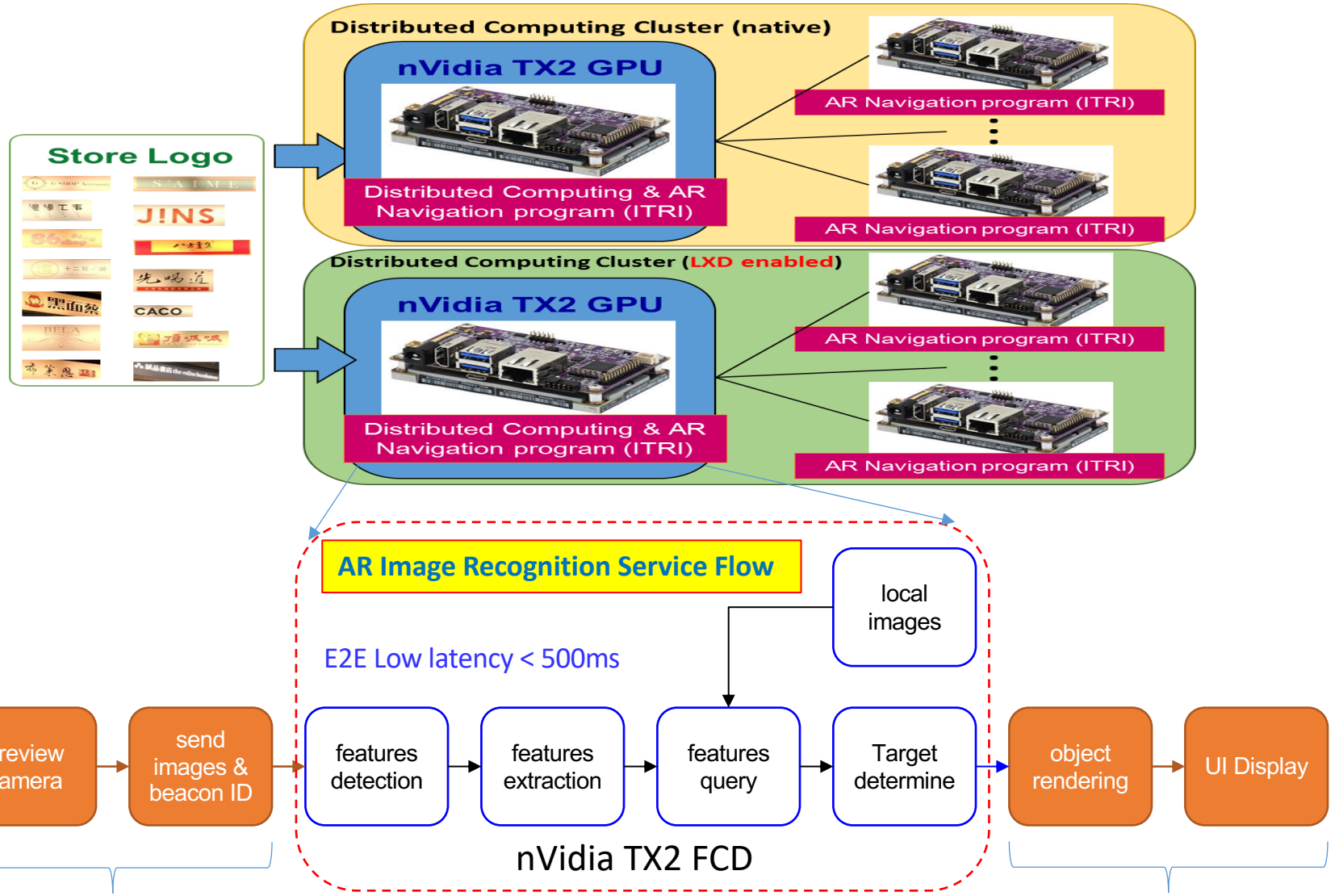




Distributed FCD Cluster (No:1~6)
No Central Controller

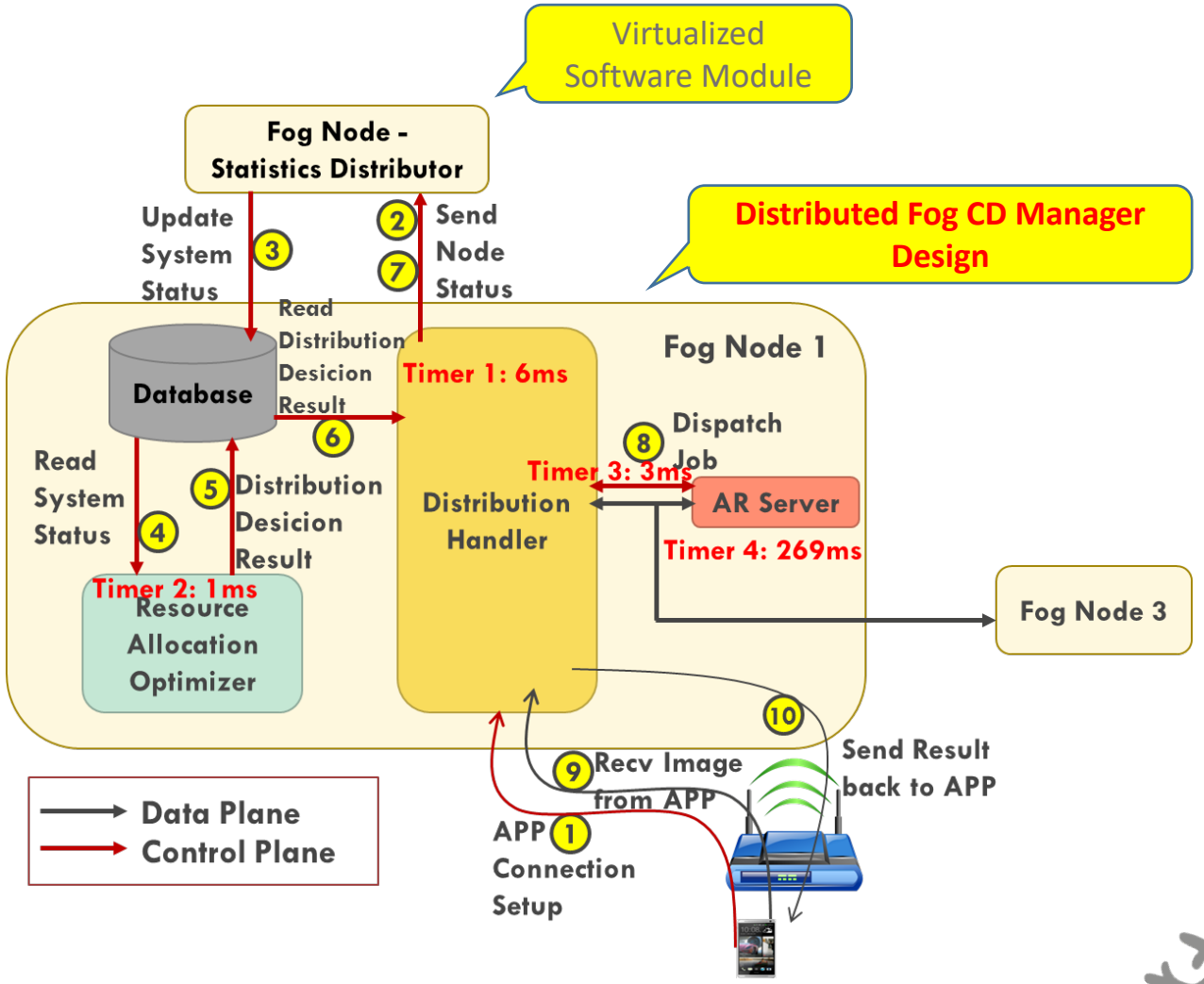
HPF: High Performance
FCD: Fog Computing Device

Performance Testing Configuration for AR Image Recognition in Distributed Fog Computing Cluster



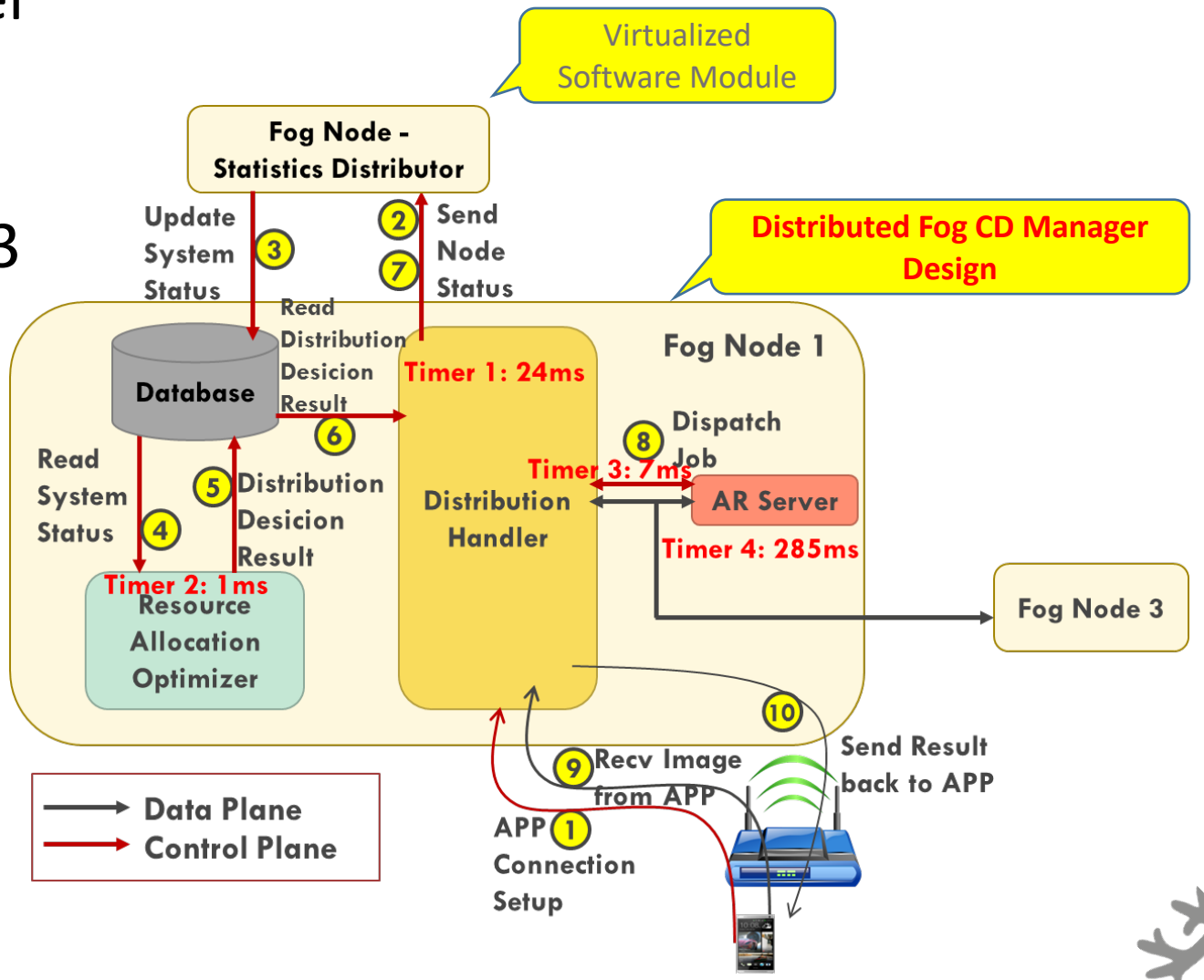
Distributed Fog Computing with Native AR application

- Using TX2 as Fog CDs without Virtual Machine
- The E2E latency, measured by Timers 1, 2,3 and 4, is 279ms.
  - Including the time for the Distribution Handler to update the Statistics with all of the databases(step 2, 3), the time cost by the Resource Allocation Optimizer(step 4, 5) and the time for the Distribution Handler to read the Distribution Decision result and dispatch the job to AR Server(step 6, 8).



Distributed Fog Computing with Container based AR application

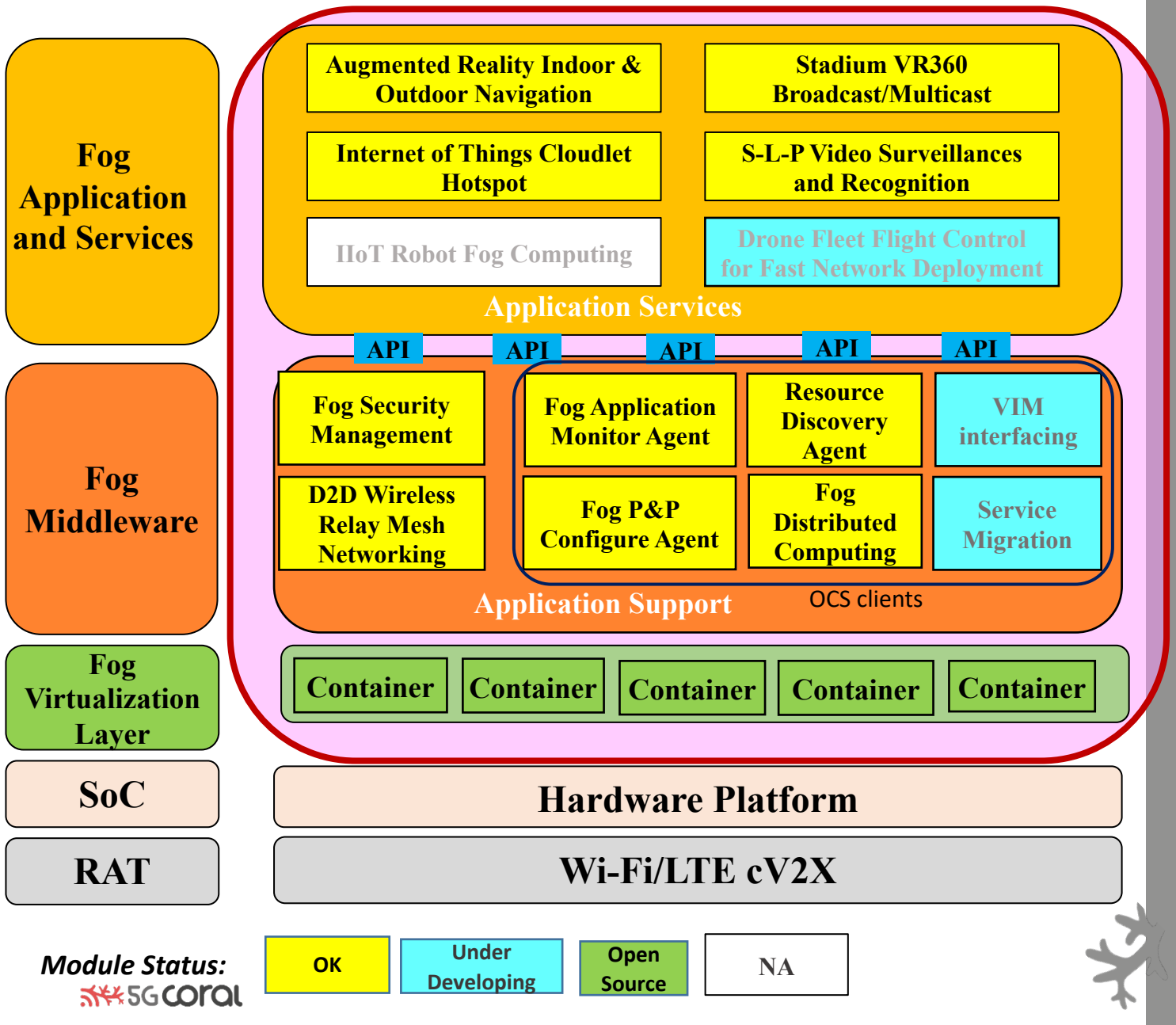
- Using TX2 as Fog CDs with Container
  - User Plane virtualized by LXD
  - Control Plane signaling by FogO5
- The E2E, measured by Timers 1, 2, 3 and 4, is 317ms.



Fog Computing Device Software Platform Spec.

Have developed modules and prototypes:

- **Fog Virtualization Layer Solutions**
  - Docker/LXD virtualized container technologies
- **Fog Middleware Solutions**
  - RESTFUL API
  - D2D based Wireless Relay Mesh Networking with Fast Deployment SON, Smart routing, and Broadband Relaying
  - **Fog Plug&Play Configure Agent**
  - **Fog Application Monitor Management Agent**
  - **Fog Parallel Computing Control**
  - **Resource Discovery Agent**
- **Fog Application and Service Prototypes**
  - AR Navigation
  - Smart Lamp Pole (S-L-P) Video Surveillances and Recognition
    - can identify/recognize illegal parking on red lines, roadside parking spaces
  - IIoT Robot Fog Computing
  - Stadium VR360 Broadcast Multicasting



Fog Computing Device Hardware Spec.

Processor
- NVIDIA Tegra X2
- HMP Dual Denver 2 / 2 MB L2 + Quad ARM® A57 / 2 MB L2

Graphics
- NVIDIA Pascal™, 256 CUDA cores
- 1.5 TeroFLOPS

Memory
- 8GB 128bit LPDDR4

Mass Storage
- 32GB eMMC5.1 Flash

LAN Port
- Gigabit Ethernet
- WiFi/BT antenna connectors

PMIC

Thermal Transfer Plate

400-pin board-to-board connector*

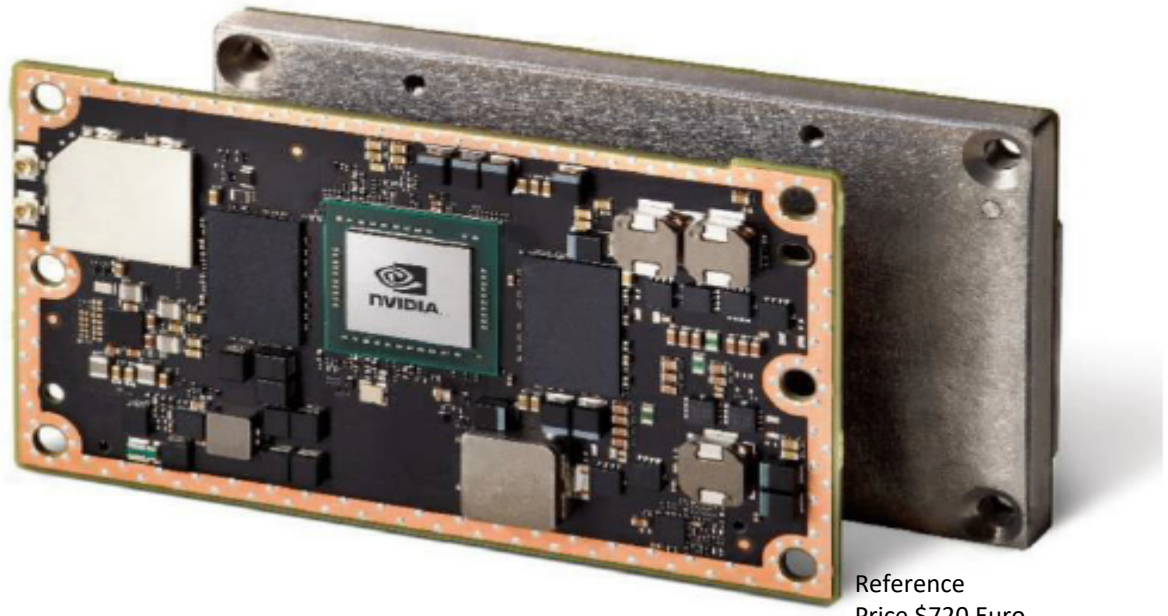
Power Supply
- $5.5\sim+19.6V_{DC}$

Dimensions
- 87 mm x 50 mm

Operating Temperature
- 0˚C ~ +55˚C (Standard Version)
- -20˚C ~ +70˚C (Optional)

Operating Humidity
- 10% ~ 90%

Storage Temperature
- -40˚C ~ +125˚C



Reference Price $720 Euro

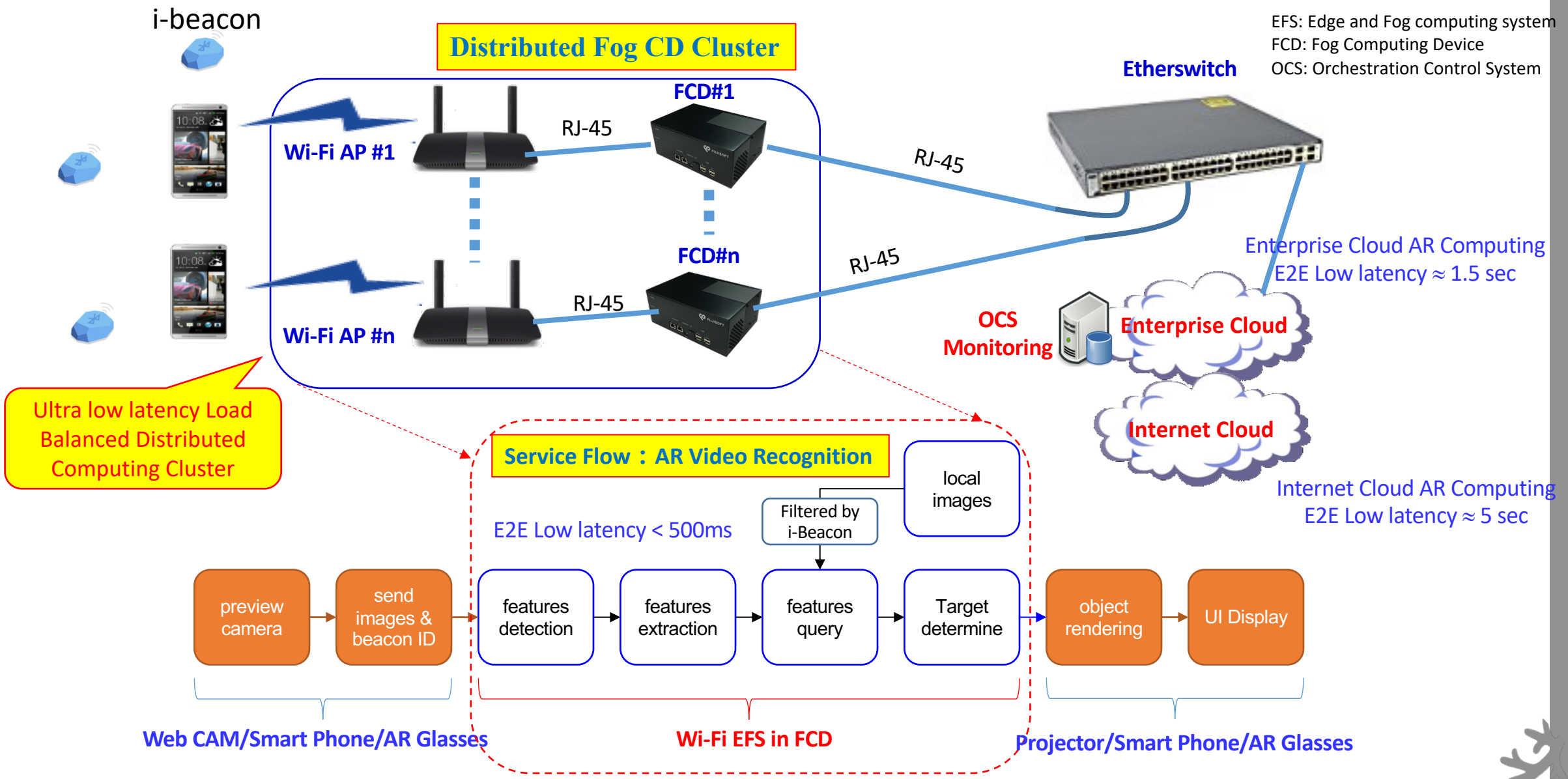
Fog Computing Device (FCD)

Conclusions

- Technology Objectives of Fully Distributed Fog Computing System

Expected Impact 1	Contribution to the ITU-R objectives for the next generation mobile network including requirements on data rates, mobility, connection density, latency, energy efficiency, spectrum efficiency, and traffic volume density.
Expected Impact 2	Contribution to the 1000-fold mobile traffic increase per area, in the context of the target application

- Industry Impacts of Fully Distributed Fog Computing System
  - New Solution for Indoor Navigations
  - New Business model by AR Advertisements
  - Successfully done the technical transformation to Taiwanese Manufactory and ongoing deploying in Taipei Train Stations
  - Potential Technologies for the Fog Computing of Car Fleet and UAV Fleet

Q&A
Thank you!!

Deployments of Distributed Computing EFS and OCS