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FogRAN: A glimpse into the 5G-CORAL solution
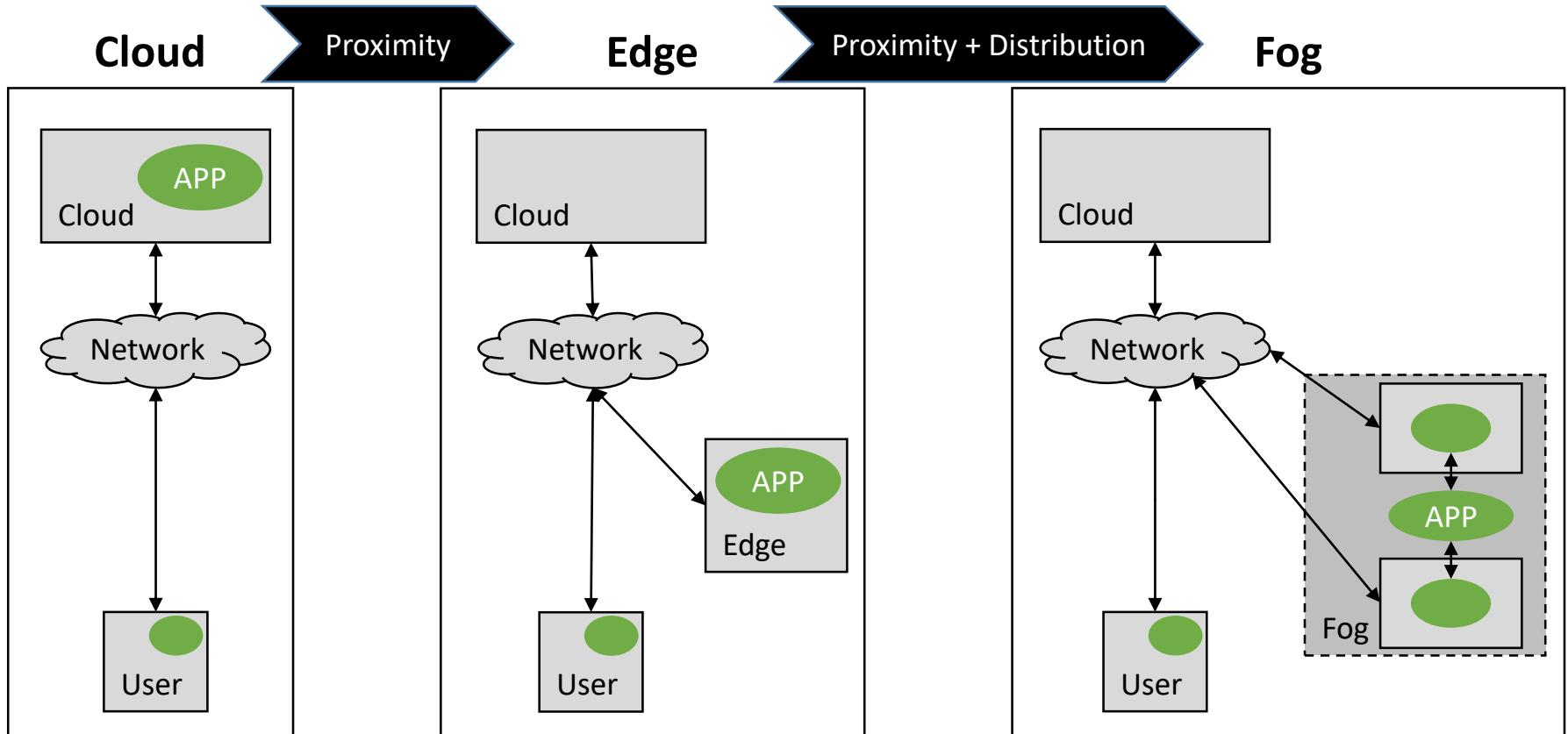
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Outline

- Setting the scene: Fog and FogRAN

- 5G-CORAL: Working towards a FogRAN solution

- Few Take-Aways and Next Steps

The Cloud, Edge and Fog – A simplistic view

Fog – Some characteristics (1)

- Fog includes Edge. Fog goes to the **Extreme Edge**, that is the closest possible to the user including on the user device itself!

- Fog is **Logical**. It refers to an overall **distributed** system.

- Fog is composed of physically distributed **Fog nodes**. A physical Fog node is a device that is capable of participating in the Fog.

- A Fog node shall be **"connected"**. BUT not all connected nodes are Fog nodes (it depends on the node's HW/SW capabilities).

- **Examples** of physical Fog nodes at the extreme edge: vehicles, robots, drones, set-top-boxes, TV units, cameras, VR/AR units, access points, etc.

Fog – Some characteristics (2)

- A Fog node may be **volatile** i.e. appear/disappear intermittently.

- A Fog node may be **mobile** i.e. on the move.

- A Fog node may be **constrained** i.e. has limited capability to host computing or networking tasks.

- Fog nodes may be **heterogeneous** i.e. not all Fog nodes have the same features and interfaces.

- Fog nodes may belong to **different owners** (stakeholders).

FogRAN – What is it?

- **RAN (Radio Access Network)** provides connectivity to the wireless terminals through wireless access points (base stations).

- RAN connectivity may use one or more **radio access technologies (RATs)**.

- **RAN and Fog** overlap at the **Extreme Edge**.

- A **RAN node** is not necessarily a Fog node, whereas a Fog node is not necessarily RAN-connected.

- A **FogRAN node** is a Fog RAN-connected node.

- A **FogRAN system** is composed of FogRAN nodes "connected" through a single or multiple RATs.
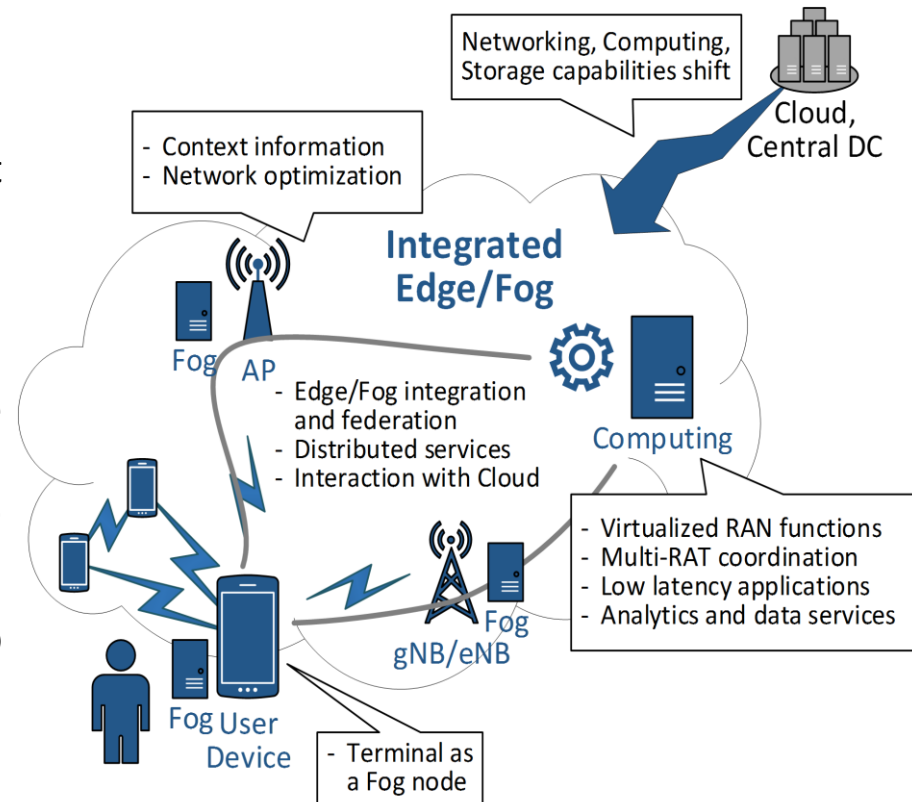
FogRAN – The value proposition

- All the benefits of Fog in terms of **proximity and distribution** (low latency, fast execution, congestion avoidance, etc.)

- Derive value from the data available in the RAN through **Fog-enabled analytics** for all sort of applications and functions, supporting (1) Better user experience; and (2) Optimized network performance.

- **Lower RAN deployment costs** and improve its **flexibility by enabling virtualization of RAN functions** over the Fog

- Improve RAN area spectral efficiency by enabling **optimized interworking between the multiple RATs** in the RAN

- **Maximize the utilization** of all computing, networking and storage resources available in the RAN

FogRAN – The key challenges

- The **integration and federation** of resources especially for resources that are heterogeneous and belonging to different Biz domains and owners

- The **orchestration** of resources, noticeably volatile and mobile resources, implying special needs for volatility and mobility management

- The **distribution, synchronization and chaining** of applications, functions and services across the Fog hosts

- The **authentication, authorization, and accounting (AAA)** for intelligently controlling access to FogRAN resources

- The **timely provisioning, abstraction and fusion** of measurement and context data for Fog analytics

5G-CORAL – Working towards a FogRAN solution

- Stands for **"A 5G COnvergent Virtualized Radio Access Network Living at the Edge"**
  - An H2020 international EU-Taiwan project from Sep 2017 to Aug'19 (2 years)

- Targets an **integrated virtualized edge and fog** RAN solution, thus a **FogRAN solution**

- Focus on the edge and fog tiers of the distributed computing infrastructure, along with their interactions with the distant tiers (cloud/data centers)

- Mobile and Volatile Fog nodes are also considered, for example a user terminal (e.g. smartphone, car, drone, AR/VR unit)

Networking, Computing, Storage capabilities shift

Cloud, Central DC

- Context information
- Network optimization

Integrated Edge/Fog

Fog AP

- Edge/Fog integration and federation
- Distributed services
- Interaction with Cloud

Computing

- Virtualized RAN functions
- Multi-RAT coordination
- Low latency applications
- Analytics and data services

Fog gNB/eNB

Fog User Device

- Terminal as a Fog node

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5G-CORAL Solution – The building blocks

Two major building blocks

OCS: A logical system for **composing, controlling, managing, orchestrating, and federating** one or more EFS(s). An OCS may interact with other OCS domains.

EFS: A logical system providing **service platforms, functions and applications** on top of Edge and Fog resources. It may interact with other EFS domains.
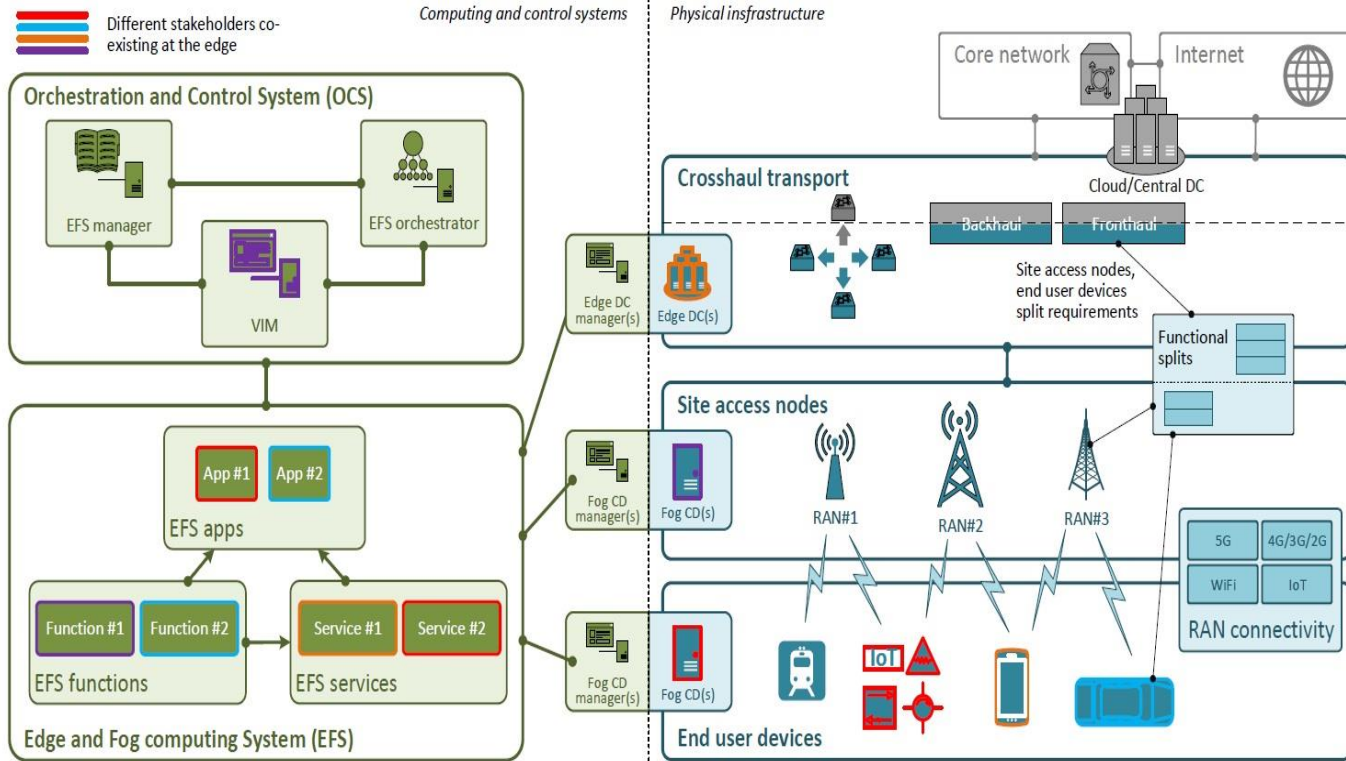
5G-CORAL Solution – The requirements (1)

ID	Requirement	Description
FT-01	Support of various Fog and Edge categories	The system shall support various categories of EFS resources as characterized in Section 2.
FT-02	Abstraction and Virtualization	The system shall support the abstraction and virtualization of the EFS resources. Different levels of abstraction and virtualization may be required.
FT-03	Automatic Discovery	The system shall support automatic discovery of possible EFS resources and their configurations.
FT-04	Authentication, registration and admission	The system shall support the authentication, registration, and admission of EFS resources.
FT-05	Integration and federation	The system shall support the pooling, integration and federation of various EFS resources.
FT-06	Placement and migration of functions and applications	The system shall support optimized placement and migration of the EFS functions and applications.
FT-07	Provisioning of data services	The system shall support the provisioning of data services through the EFS. The services may be subscribed to from the inside or outside of the EFS.
FT-08	Multi-RATs	The system shall support multiple RATs and enable their interworking. The system shall support data services based on context information extracted from the RATs.
FT-09	Mobility	The system shall support the mobility of EFS resources but also of the client applications, functions and users.
FT-10	Volatility	The system shall support occasional addition and removal of EFS resources.
FT-11	Localization	The system shall support localization of EFS resources, as well as client users, applications, and functions.
FT-12	Synchronization	The system shall support synchronization across distributed EFS resources, as well as amongst virtualized functions, applications, and services.
FT-13	Out-of-coverage	The system shall support continued yet limited operation in situations out of infrastructure coverage. Automatic re-establishment of normal operation shall be supported as soon as the system is back in coverage.
FT-14	Ad-hoc and D2D networking	The system shall support operations based on D2D and ad-hoc networking. These may be assisted with an infrastructure.
FT-15	Monitoring and self-healing	The system shall support continuous monitoring of all its resources as well as means for self-healing in the event of faults or failures.

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5G-CORAL Solution – The requirements (2)

ID	Requirement	Description
NF-01	Accessibility	Providing access to data repositories where structured information about different classes of resources and services can be queried.
NF-02	Availability	Carrier grade availability of the system (99.999%).
NF-03	Consistency	Uniformity in the service offer.
NF-04	Efficiency	Optimal use of resources.
NF-05	Isolation	Separation of logical sub-systems sharing the same physical resources.
NF-06	Multi-service	Support of different types of services at the same time.
NF-07	Multi-tenancy	Support of different tenants at the same time.
NF-08	Programmability	Support of dynamic (re-)configuration and automated provisioning.
NF-09	Responsiveness	Readiness to react to a given event or input.
NF-10	Resilience	Ability to cope with errors, faults and failures.
NF-11	Scalability	Ability to increase or decrease system load in a graceful manner.
NF-12	Security and Privacy	Support secure operations and data protection.
NF-13	Usability	Efficiency and simplicity of the interaction with the system.

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5G-CORAL solution – The architecture

- Compliant with **ETSI Network Functions Virtualization (NFV).**

- Extends on the **ETSI Multi-Access Edge Computing (MEC)** framework to support mobile and volatile Fog host resources.
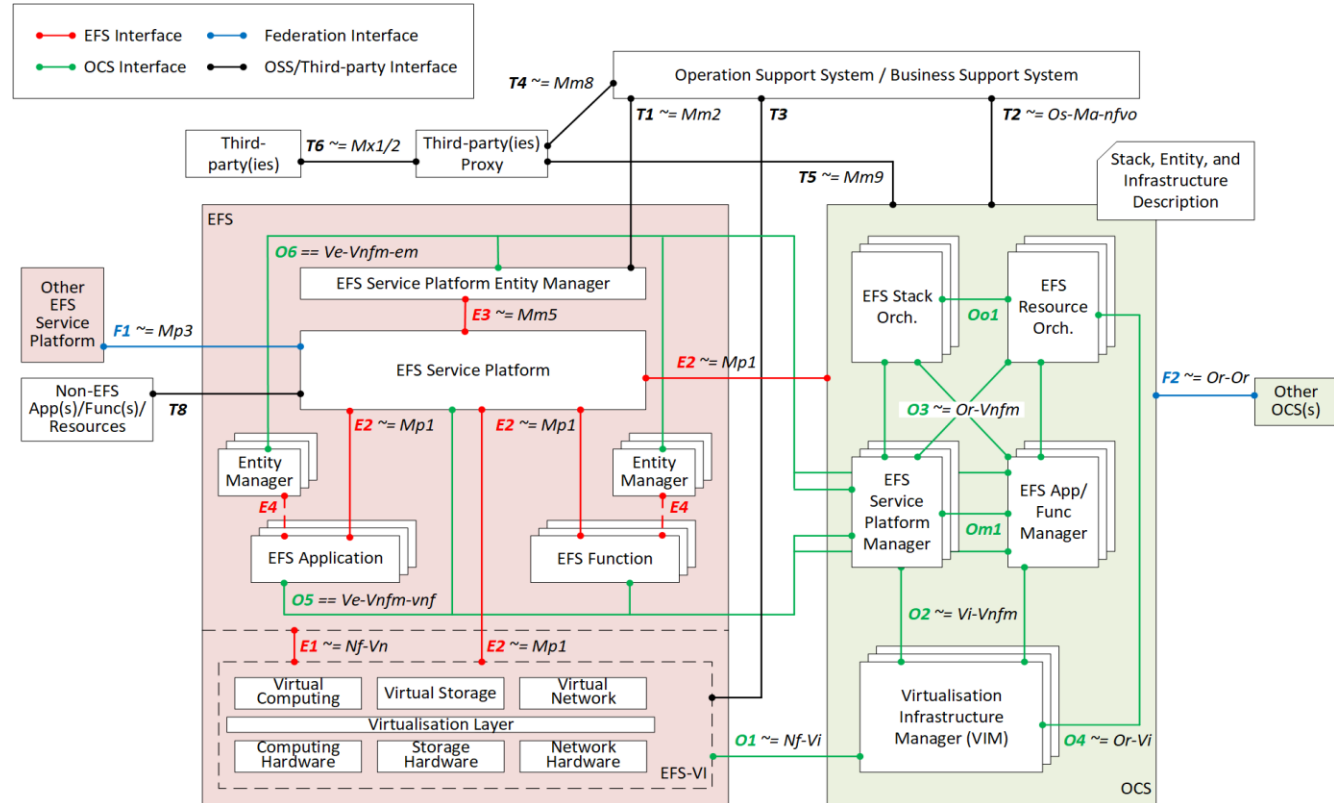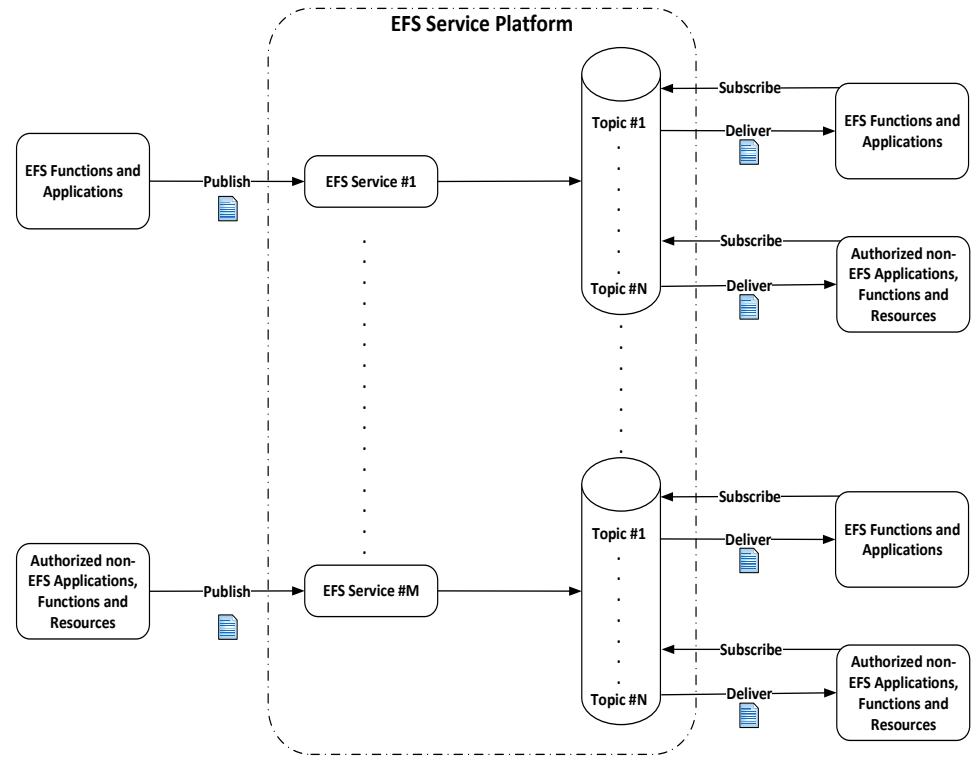
5G-CORAL Solution – The EFS

- The EFS entities comprise **EFS applications, EFS functions, the EFS service platform** and their respective **entity managers**.

- An EFS entity is comprised by at least one **atomic entity**. An atomic entity is an unpartitionable computing task executed in the EFS.

- The EFS atomic entities are implemented as **microservices**. Each microservice is a separate entity with no dependency on other microservices.

- These microservices interact with each other and communicate via **network calls** to enforce separation and avoid tight coupling.

- The network calls may be implemented using either a **request/response** model or a **publish/subscribe** model.

5G-CORAL Solution – The EFS service platform (1)

- Provides the **API framework** through which both EFS and non-EFS apps and functions can publish and subscribe to various services e.g. localisation service, radio network information service (RNIS), etc.

- Each **EFS service is essentially an API** with multiple topics that authorised apps/functions can publish to and/or subscribe to receive notifications from

- EFS and non-EFS apps and functions may publish and/or subscribe to **one or more topics**, maintained by EFS service(s).

- Performs **Authentication, Authorisation and Accounting (AAA)** of EFS and non-EFS apps and functions that publish and/or subscribe to the EFS service(s).

- Maintains a **service registry** to track all of the services consumed by the apps and functions.

EFS Service Platform

EFS Functions and Applications — Publish — EFS Service #1 — Topic #1 — Subscribe — EFS Functions and Applications; Deliver; Topic #N — Subscribe — Authorized non-EFS Applications, Functions and Resources; Deliver

Authorized non-EFS Applications, Functions and Resources — Publish — EFS Service #M — Topic #1 — Subscribe — EFS Functions and Applications; Deliver; Topic #N — Subscribe — Authorized non-EFS Applications, Functions and Resources; Deliver

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5G-CORAL Solution – The EFS service platform (2)

- **Loose coupling:** Publishers are loosely coupled to subscribers, and don't need to know about their existence or physical location.

- **System topology agnostic:** Both publishers and subscribers focus on the topic and can be ignorant of the underlying system topology.

- **Robustness:** Each publisher and subscriber can continue to operate normally regardless of the other unlike the traditional client–server paradigm.

- **Distribution:** Highly suited for ubiquitous computing and distributed embedded systems, i.e. Fog computing and networking.

- **Adaptability:** Can be varied to suit different environments, e.g. error-prone environments such as in FogRAN

5G-CORAL Solution – The EFS service platform (3)

- **MQTT and DDS selected as the baseline messaging protocols** to cater for the needs of different use cases

- **Additional protocols like NATS** are also under exploration

- **DDS achieves almost real time performance** (in some cases, 60 μs)

- DDS is completed with persistence features for fault tolerance and late joiners.

- DDS does not deploy a centralized node or broker to handle the communications, instead broadcast is used.

- Unlike DDS, MQTT requires a broker to conduct data publish/subscribe.

- **MQTT is extremely lightweight**.

Protocol	MQTT	DDS
Deployment	No limitation (LAN, WAN)	DDS routing entity is needed when deployed in WAN
Client Complexity	Light node Client does not need cache Broker can handle reliability	Medium node Reliability is maintained with sufficient cache
Broker	Required	Not required (optional)
Latency	Medium level latency	Low latency (<1ms)
Data Size	<256 Mbytes	<100 Kbytes
QoS	Support 3 QoS levels	Support many more QoS levels
Network Overhead	Low	Medium
Security	Managed by the broker	Key Sharing among clients
Web Performance	Similar to non-web performance	Latency increase in Web Applications
Implementation	Plenty of libraries	Support Fog O5

5G-CORAL Solution – The OCS (1)

- Includes a **VIM entity** to control and manage the interactions of the EFS service platforms, functions, and applications with their underlying EFS resources, as well as their corresponding virtualization (e.g. virtual machine, container).

- Includes an **EFS Manager entity** for the lifecycle management (e.g. instantiation, update, query, scaling and termination) of the EFS service platforms, functions, and applications.

- Includes an **EFS Orchestrator** for the orchestration and management of EFS resources. The EFS Orchestrator comprises an **EFS Resource Orchestrator** and an **EFS Stack Orchestrator**.

- The **EFS Resource Orchestrator** supports accessing the EFS resources in an abstracted manner independently of any VIMs, as well as governance of EFS resources sharing between service platform/functions/applications.

5G-CORAL Solution – The OCS (2)

- The **EFS Stack Orchestrator** is responsible for the EFS Stack lifecycle management operations (e.g. instantiation, update, query, scaling and termination).

- The **EFS Stack** is a forwarding graph of functions and/or applications interconnected through EFS resources and service platform.

- An **EFS Stack Descriptor** extends the ETSI NFV Network Service Descriptor by also considering interconnections with applications and service platforms and not only between network functions.

- An **EFS Entity Descriptor** extends and combines ETSI NFV VNF and ETSI MEC App descriptors as to uniformly describe the various characteristics of EFS Functions, EFS Applications, and EFS Service Platform.
  - EFS Entity Descriptors are referenced and included into an EFS Stack Descriptor as to allow the OCS to properly deploy all the entities and interconnect them.

Few Take-Aways and Next Steps

- Fog spans across the continuum between things and clouds. Yet its key challenges lie at the **extreme edge with mobile, volatile and constrained computing and networking resources.**

- **5G-CORAL** is developing a **FogRAN solution** which marries the Fog and the RAN (including M-RATs) at the extreme edge.

- The baseline solution includes **two sub-systems**: the EFS and the OCS.

- The solution is being specified, implemented and tested for **4 main use cases all involving multiple RATs**: (1) AR/VR; (2) Robotics; (3) Connected Car; and (4) IoT GW.

- **First trials** will test the baseline solution in **Nov'18 in Taiwan**. These will be followed by a **refined solution and final trials in the Summer 2019.**