



# An Integrated Edge and Fog System for Future Communication Networks

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**Presenter:**

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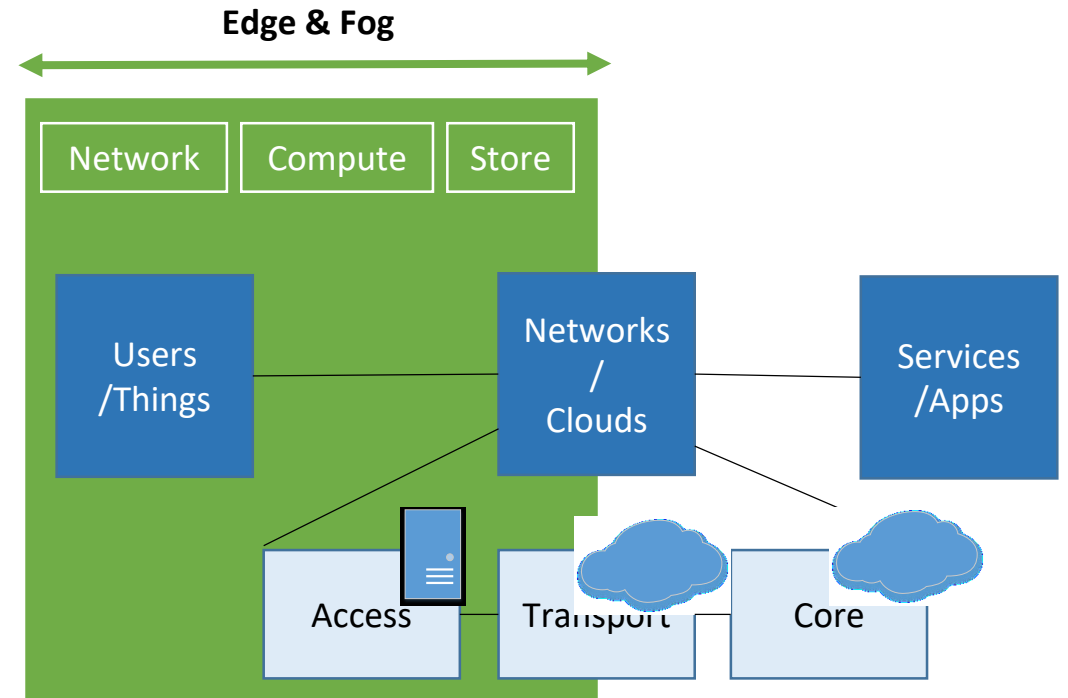
# Outline

- What are Edge and Fog?
- Edge/Fog Integration – Edge and Fog computing System (EFS)
- EFS Elements – Services, Functions, and Applications
- Multi-RATs Convergence via EFS
- Research Topics
- Concluding Remarks



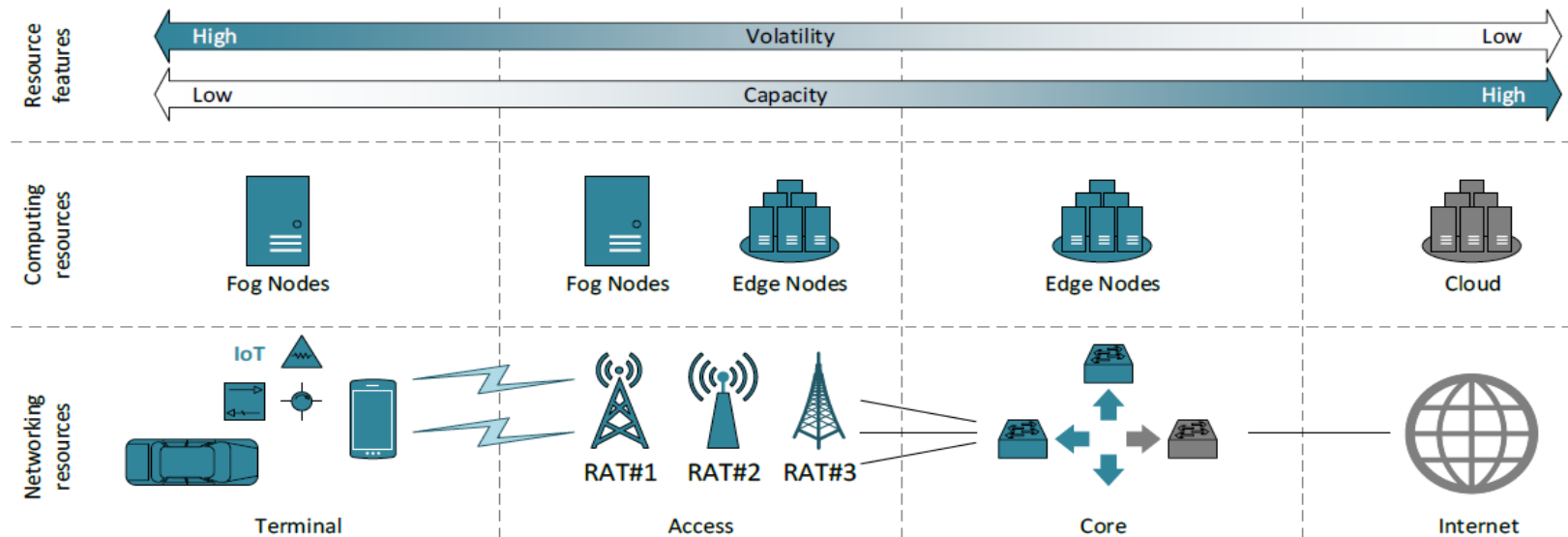
# Fog Computing or Edge Computing ?

- To fulfil ultra low-latency requirements of 5G by reducing round-trip delay, computing may be carried out in premises close to end users, as oppose to solely relying on distant cloud computing servers as in most of the existing systems. This triggers the emergence of **Fog/Edge Computing**.
- By definition, **Fog** include any computing resource available in the continuum between things and end-user terminals to Cloud, including **Edge** infrastructures owned by operators.
- In 5G-CORAL, we opted to restrict the scope of Fog to **volatile and constrained devices** complement by the Edge and distant Cloud servers, as this very distributed domain has the most appealing values.



# Computing Substrates for 5G-CORAL

- **Cloud** is the IT infrastructure that is typically distant from the RAN and users/devices.
- **Edge** is usually referred to as data centers near RAN:
  - ✓ For examples: Network aggregation points, Base Stations
- **Fog** may include any location distributed nearer the user or thing, where networking, computing and storage exist.
  - ✓ For examples: User's premise; in the device itself; in a specific chip in the device.





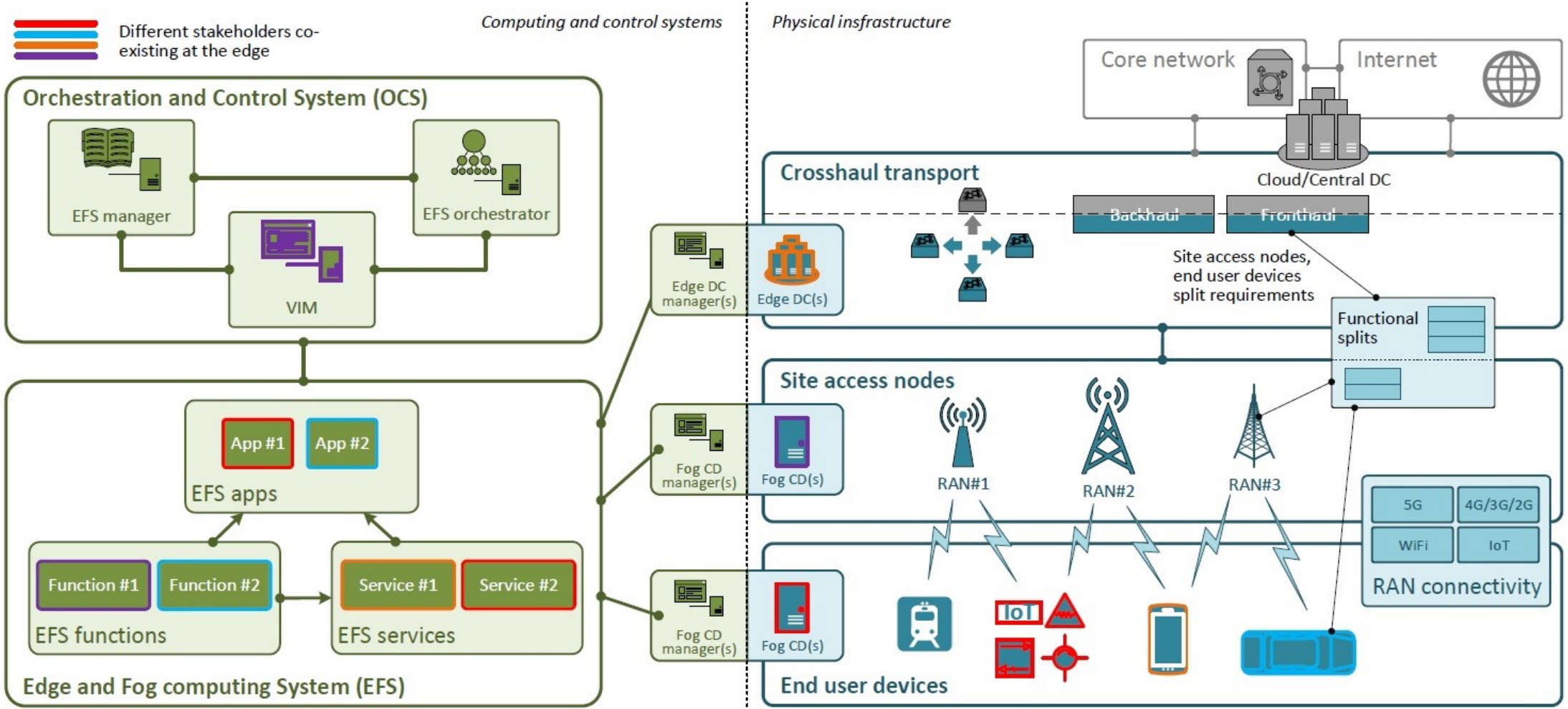
# Integration of Edge and Fog

- Edge computing tier is in general **stationary with constant power supply**.
- Fog computing tier is **even closer to end user**, despite its mobile/volatile nature which makes it relatively less stable than Edge.
- Clearly, in many cases Edge and Fog are complementary with each other, and hence a very **tight interaction between Edge and Fog tiers** gives a versatile computing platform catering for diverse service requirements foreseen by 5G mobile networks.

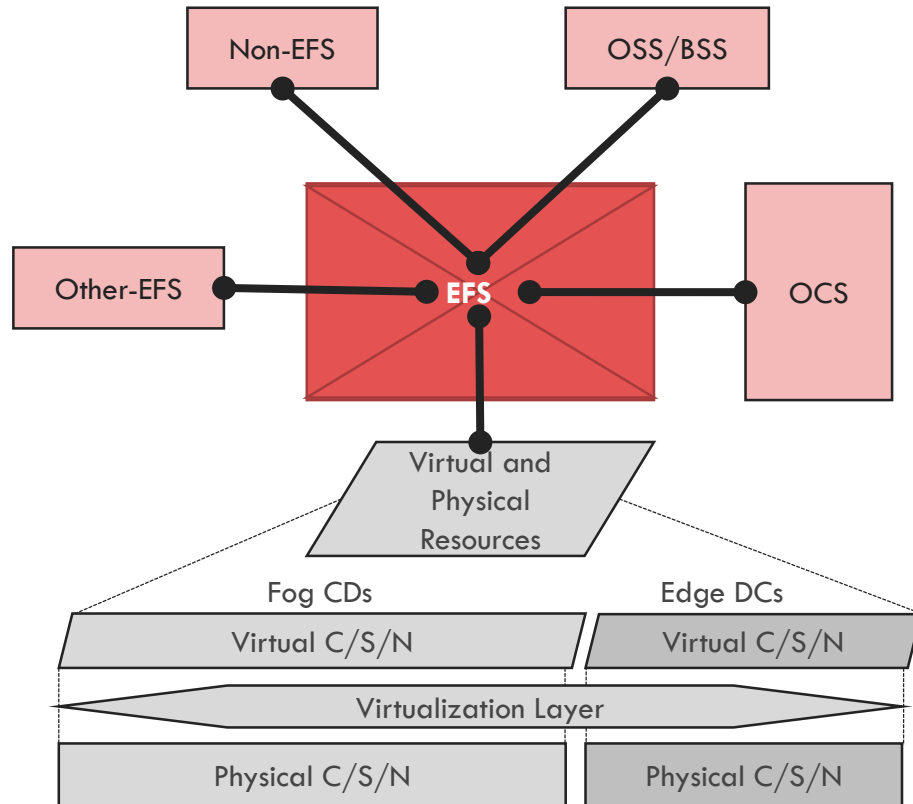
- **Proposed Concept:**

Stitch Edge and Fog tiers together to form an integrated pool of computing and networking resources of different owners, that can be leveraged towards low latency applications as well as for alleviating high traffic volume in future networks including 5G and beyond.

# Physical View of 5G-CORAL EFS



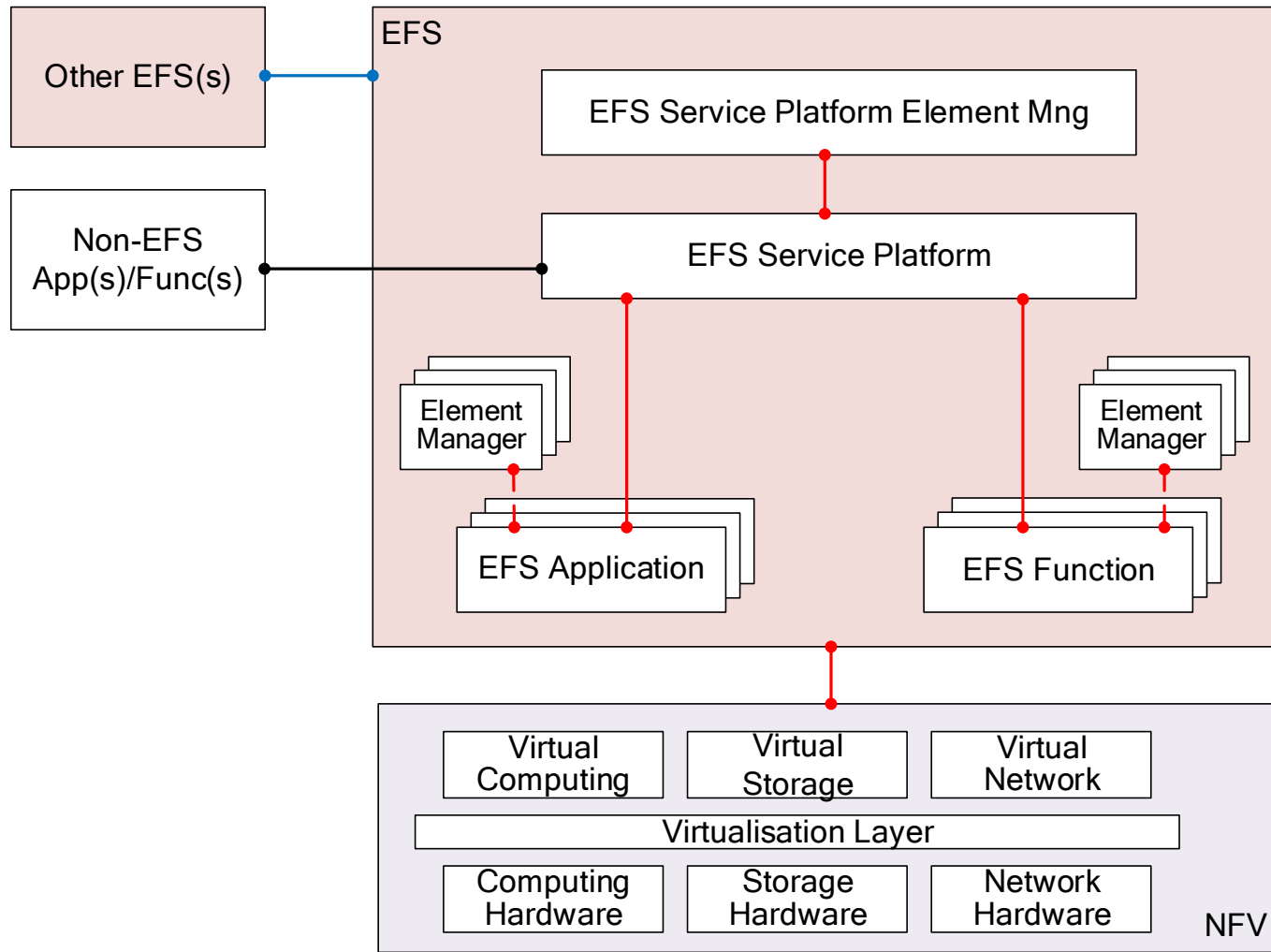
# A Nutshell of Edge/Fog computing System (EFS)



- EFS is a logical system
- EFS is controlled by an OCS
- EFS may interconnect with another EFS
- EFS may interconnect with a non-EFS
- EFS may interconnect with an OSS/BSS
- EFS is supported by an underlying infrastructure of virtual and physical resources



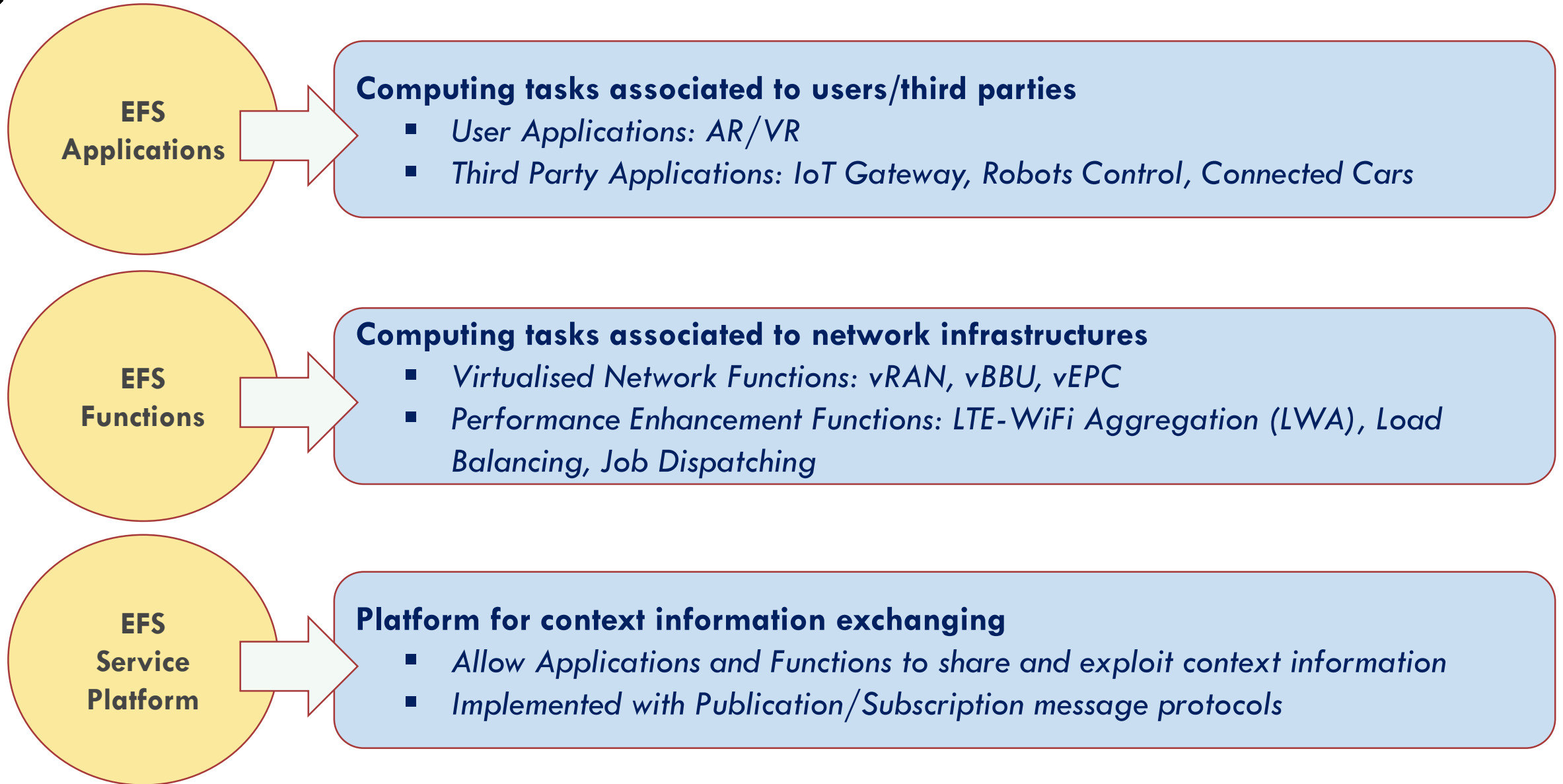
# Reference Architecture of EFS



- Edge and Fog computing tiers are abstracted, virtualized and managed in one logical platform.
- Three EFS elements:
  - EFS Service Platform
  - EFS Functions
  - EFS Applications
- Each of these EFS elements is associated to an element manager, which oversees Fault, Configuration, Accounting, Performance and Security management and the corresponding EFS element.

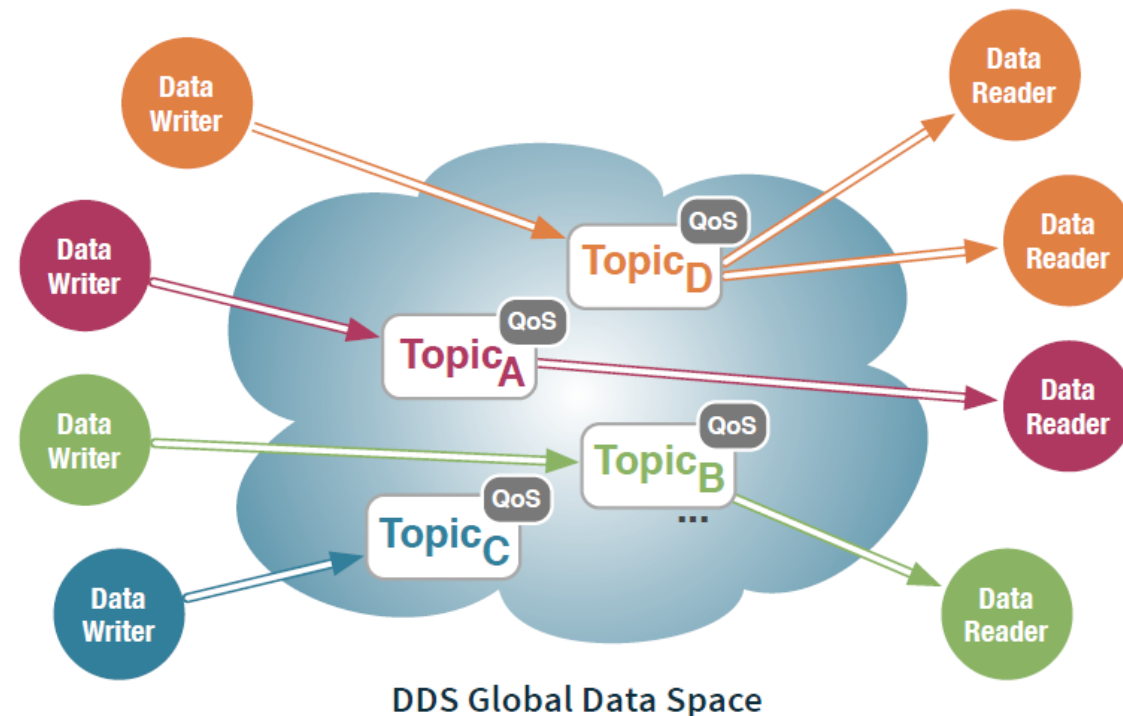


# Roles of EFS Elements



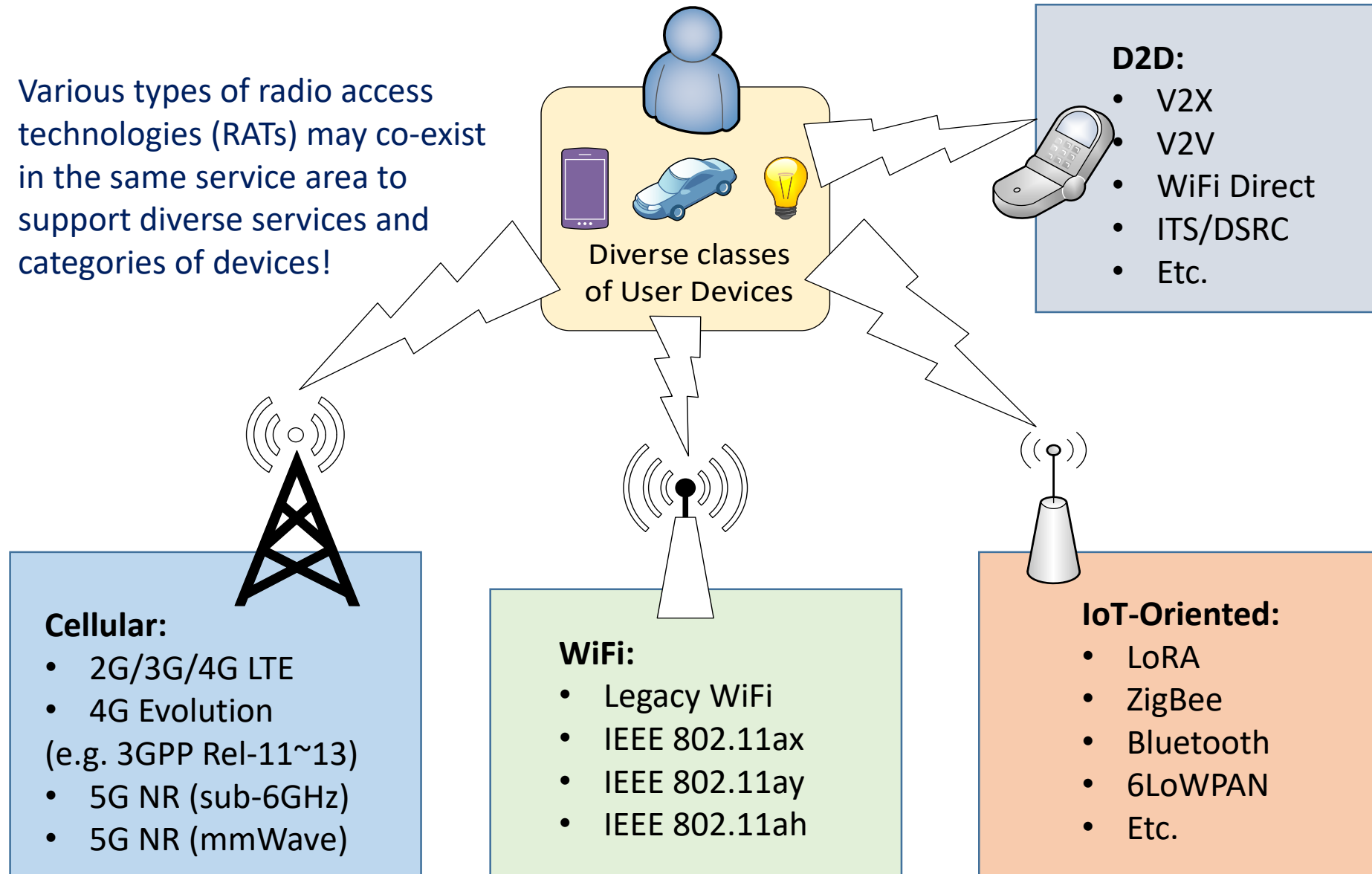
# Messaging Protocols for EFS Services

- Various types of Pub/Sub protocols (such as DDS, AMQP, MQTT, and XMPP) can be used to implement the EFS service platform.
- **Distributed Data System (DDS)**, offers a broker-free platform for data exchange. EFS Functions/Applications can autonomously and asynchronously read and write data enjoying spatial and temporal decoupling.



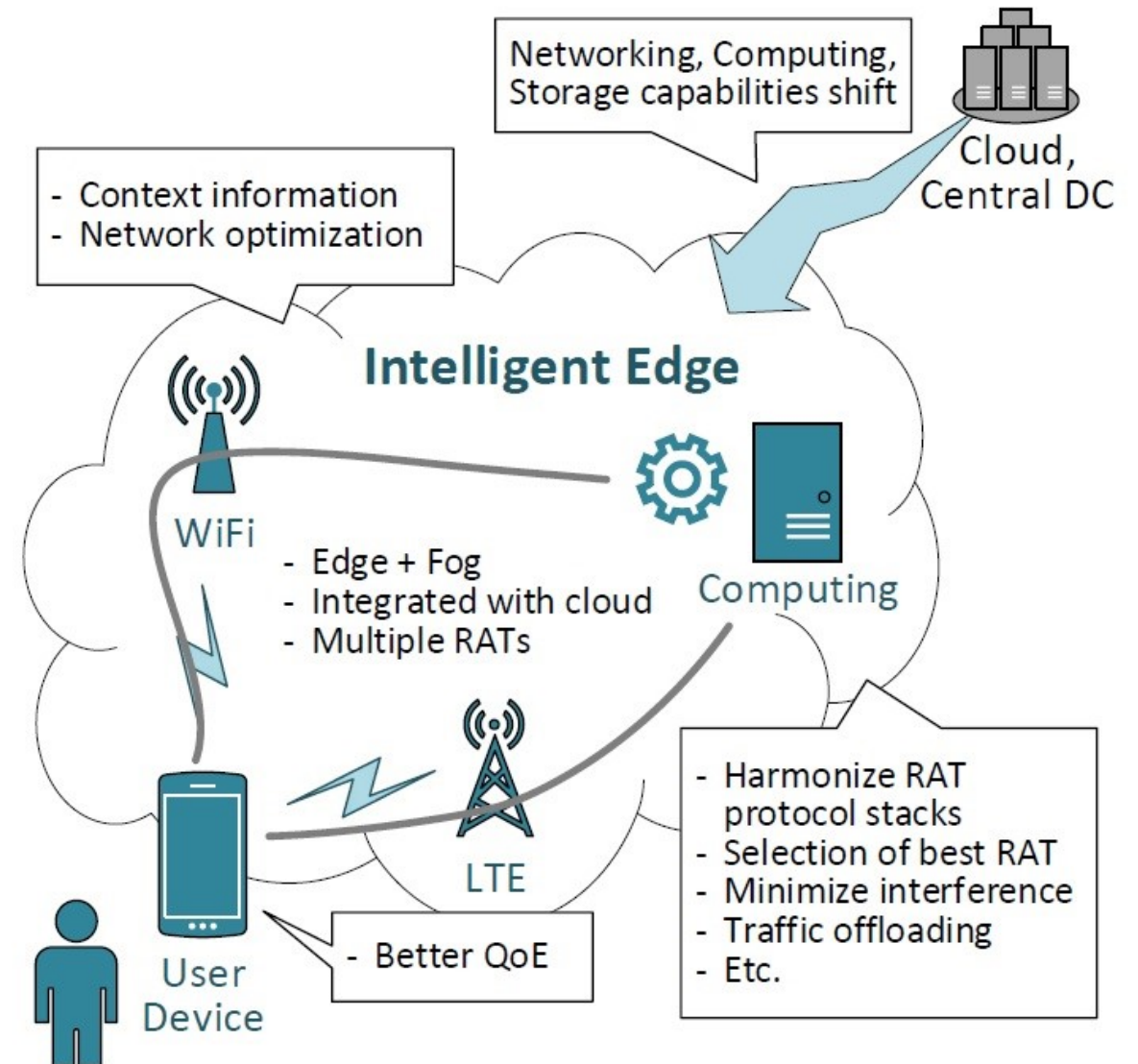
# Multi-RATs Convergence via EFS (1 / 2)

Various types of radio access technologies (RATs) may co-exist in the same service area to support diverse services and categories of devices!



# Multi-RATs Convergence via EFS (2/2)

- All the co-existing RATs in the same local access area can be made to expose their context information in that local access area into EFS.
- Capabilities are provided for abstracting and sharing this context information amongst RATs and towards applications or functions executing locally in the EFS.
- This provides a **new way of interworking** between any RATs that is **based on the sharing of RATs data**.





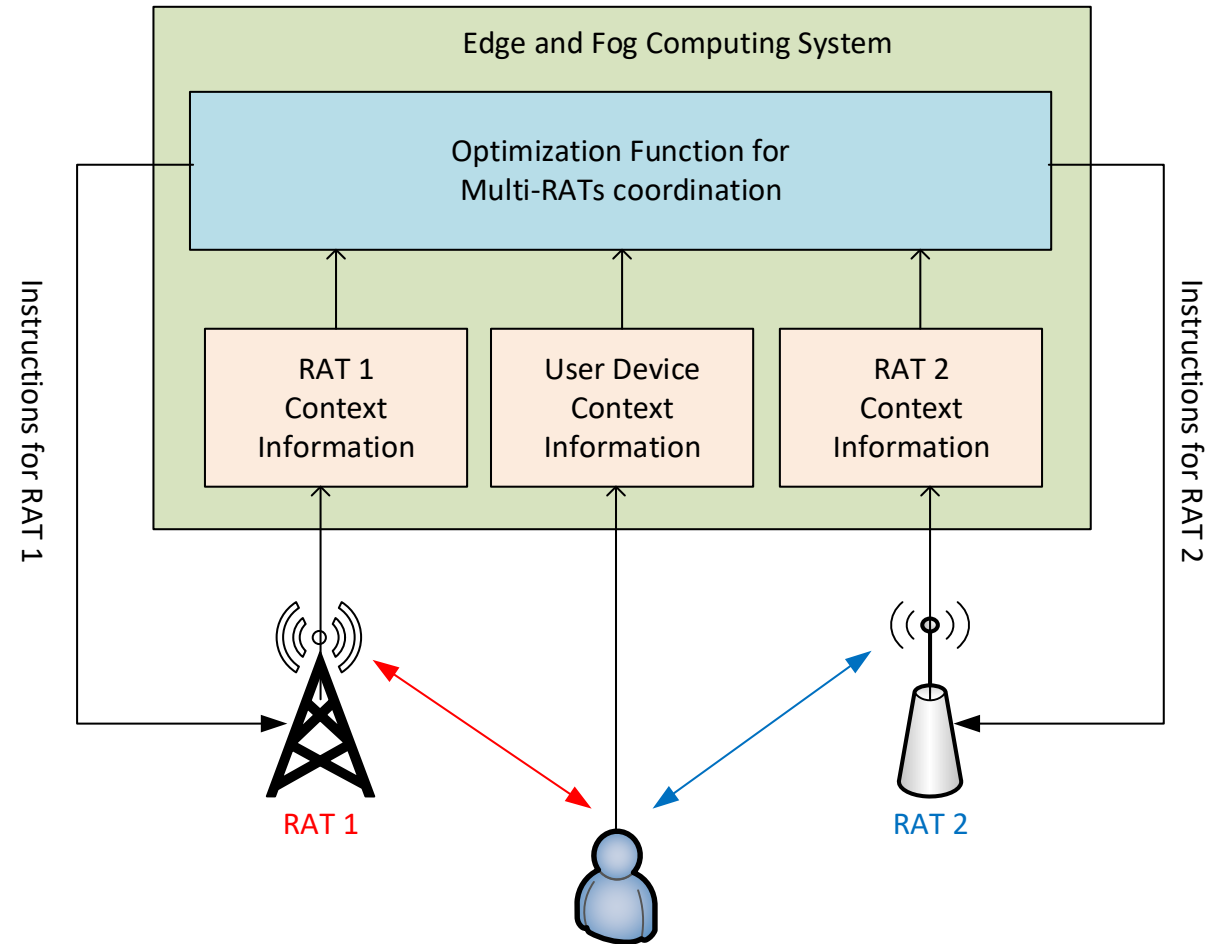
# Research Topics – Volatility of Resources

- The fog computing, storage and networking resources are borrowed from devices close to the end user, such as a smartphone, a smart TV, or a connected vehicle.
- The devices that contribute these fog resources may move away or switched off anytime, and hence causing interruptions to the operations of functions and/or applications that are hosted or facilitated by the computing system amalgamating both edge and fog resources.
- How the tasks of these functions and applications can be carried out in a seamless manner is indeed a challenging issue that needs to be addressed.



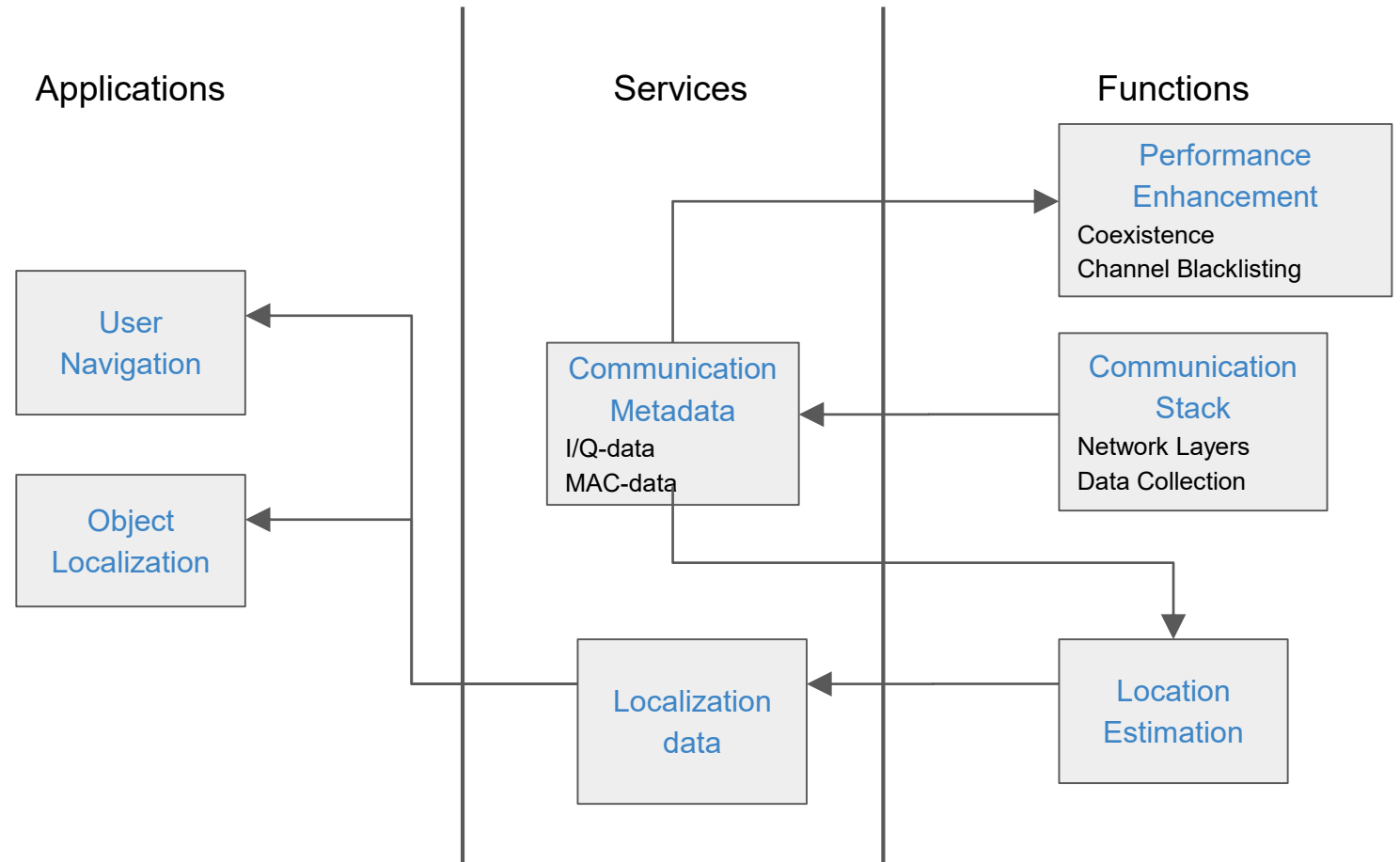
# Research Topics – Heterogeneity of RATs

- The context information that may be extracted from all these different RATs is certainly beneficial to expose into the EFS so that performance optimization can be sought for applications and network functions alike.
- Two challenges to be resolved:
  - Determining what context information may be useful to extract from the different RATs, and how to extract and expose these as services into the EFS.
  - Designing mechanisms that consume these context information services in order to optimize the performance of applications and the underlying multi-RAT network.



# Research Topics – Applicability to Internet of Things

- IoT scenarios can benefit greatly from edge and fog computing, with geo-distribution, mobility, location awareness, low latency, heterogeneity of technologies, and support for real-time interactions.
- Virtualize IoT Gateway in the EFS allows different IoT technologies and protocols to benefit from EFS services.
- For instance, communication metadata from different IoT connectivity could be used for network configuration and location estimation.







# Research Topics – User Virtualization

- The computing or networking tasks of an end user terminal may be moved for execution in the EFS to, for example, avoid fast battery depletion of a user terminal.
- For examples:
  - Some of the more battery-consuming tasks (e.g. high-complexity computations) can be offloaded to a virtualized user terminal shadow in the EFS.
  - The virtualized user terminal in the EFS may perform some networking functionalities on behalf of the physical user terminal.
- Some challenges:
  - When to create such virtual (shadow) terminal, where to host it, which scope (of tasks) is advantageous to assign to it, and how dynamically changing are all these;
  - What interface(s) are needed to connect the end user terminal with its virtualized shadow in the EFS, but also with other peers (both physical and virtual);
  - What constraints (e.g. security, privacy) may apply for deciding where in the EFS to host the shadow of a given user terminal, and how are these constraints complied with and controlled.



# Research Topics – Security Challenges

- EFS applications which can be developed by various parties may be buggy/malicious, thereby exposing the platform or benign applications to security threats.
- The EFS platform can support outside non-EFS functions and applications, which may be malicious. It should not only interact with them based on a set of secure APIs, but also deploy a firewall-like feature to defend against external attacks.
- Mutual authentication and security control are needed for distinct resources within an EFS. Multiple levels of access control on the sharing of various resources is needed to address different levels of trustworthiness among the resources.



# Concluding Remarks

- Integration of Edge and Fog computing, storage, and networking resources provide a **distributed but logically unified platform**, which offers a higher scalability, higher resource usage efficiency (pooling gain), and higher flexibility in executing various applications and functions.
- In particular, an intelligent and integrated Edge/Fog opens the door for the sharing of RATs data and hence optimizing intra-RAT and inter-RATs operations towards seamless and efficient connectivity for applications.
- To fully develop the system, the following research topics are identified:
  - How to cope with the volatility of the resources to ensure seamless execution?
  - How to design the mechanisms to gather, provide, and consume context information from different radio access technologies (RATs) ?
  - How to utilize EFS for IoT applications?
  - How to enable user terminal virtualization in EFS?
  - How to handle security issues among resources within EFS?
- **5G-CORAL targets at both technology developments and demos of EFS. Trials are planned in 2018/2019 across both Europe and Taiwan. Stay tuned!**



# Consortium partners and acknowledgment



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