Immersive user experiences in Smart Spaces

challenges for future communication networks beyond 5G

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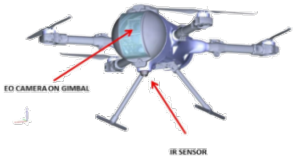
A bit of rationale and context

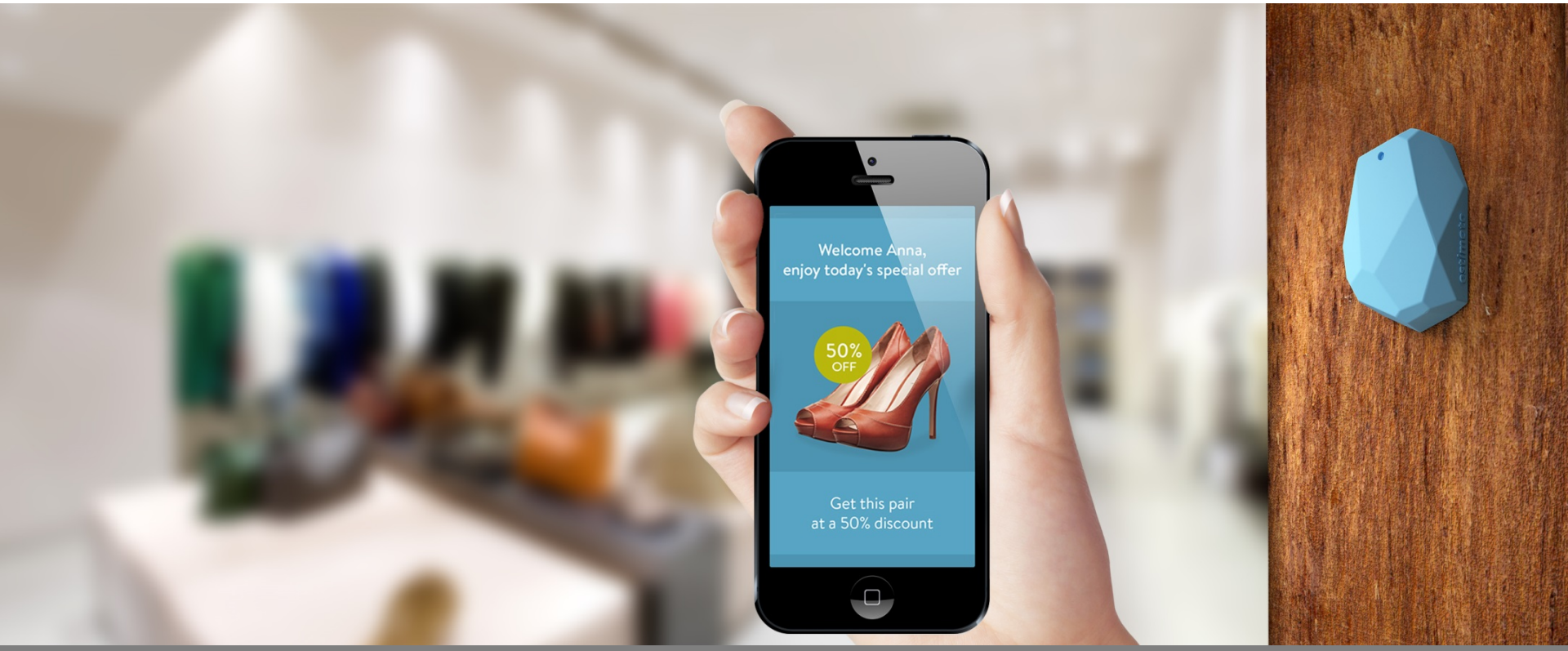
- Many **device** types
  - sensors, smart cameras, robots, drones, smart glasses, AR/VR visors



- For the increasing demand for new **value-added services**
  - Targeted content distribution based on personal behaviours
  - Innovative interactions with the ambient (immersive interfaces) for entertainment, shopping, and everywhere gaming
  - Augmented Reality (AR) for Industry 4.0
  - etc.

- Which all require a more advanced **future network starting from 5G and going beyond**
  - Truly **programmable and secure many to many connectivity**, at large scale
  - Minimum end-to-end **latency**, high service **resilience** in dynamic conditions
  - Computation and functions more from the **cloud** to the **edge**, and potentially down to the **devices** (gateways, sensors and actuators), activated only when needed

Example: *Proximity marketing in the Smart City*

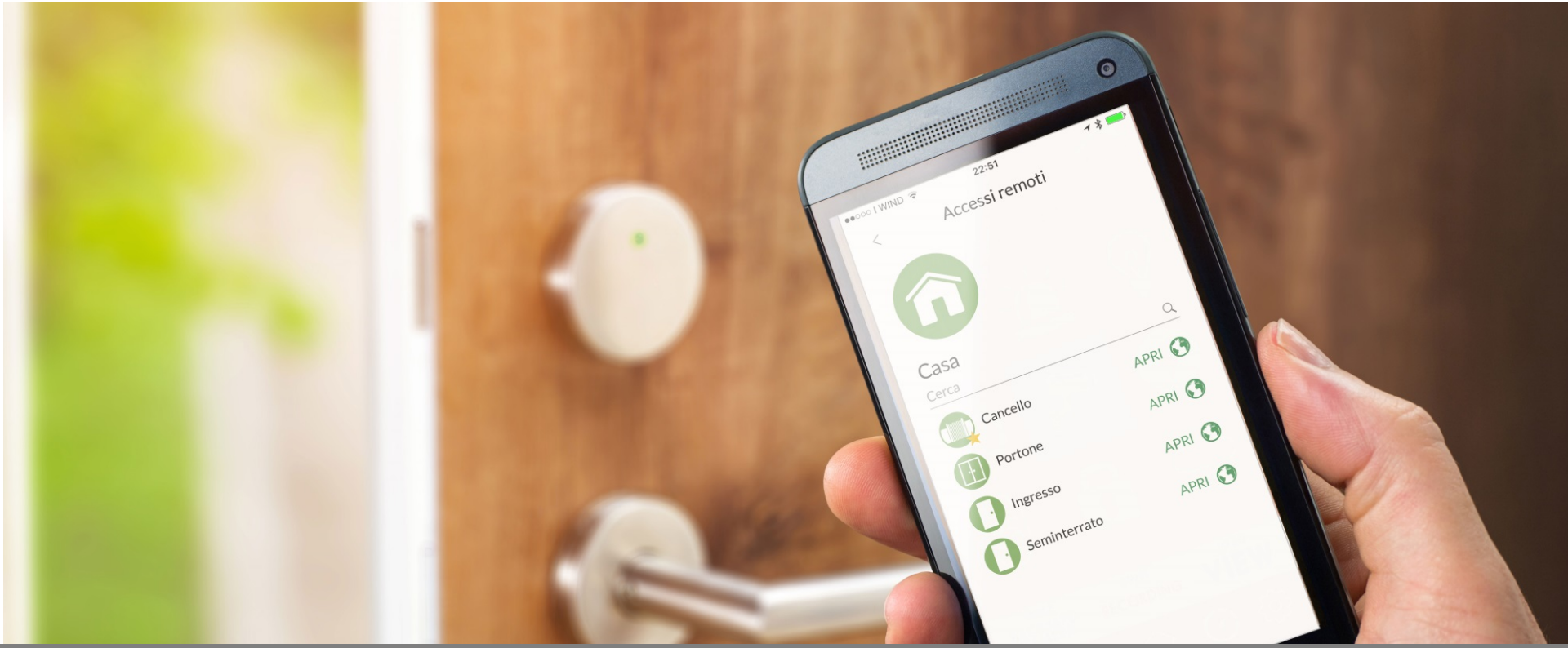


Send customised push notifications to smartphones or provide the user with "suggested shopping paths" in the mall/shopping street

Our perceived gap:

- Need very precise location info to work well
- Need integration of network & non-network information to create profiled visits: e.g. customer's preferences and usual behaviours, forecast of visit paths, crowd/queueing information

Example: *Smart locking & public safety*



Activate ad hoc access restrictions or security alerts in case “dangerous” individuals approach or enter into private/public buildings

Our perceived gap:

- Predict presence also from non-network data (face recognition systems, track position, etc.)
- Use precise location to configure the systems and interact with various types of sensors and actuators in the environment, not all under the same administrative operator
- Allocate some parts of the decision loop down to the edge, closer to the sensors/actuators

Example: Augmented and Virtual Reality for I4.0

Remote working with VR/AR, e.g. to optimize time and quality of operations in the field or to reduce human activity in harsh or insecure production environments

Our perceived gap:

- Precise positioning of users and devices in specific areas of an industrial plant
- Context information from multiple diverse sources: environment, sensors & actuators
- Highly reliable control loop with functions partly mirrored at the edge (to work in case of disconnection

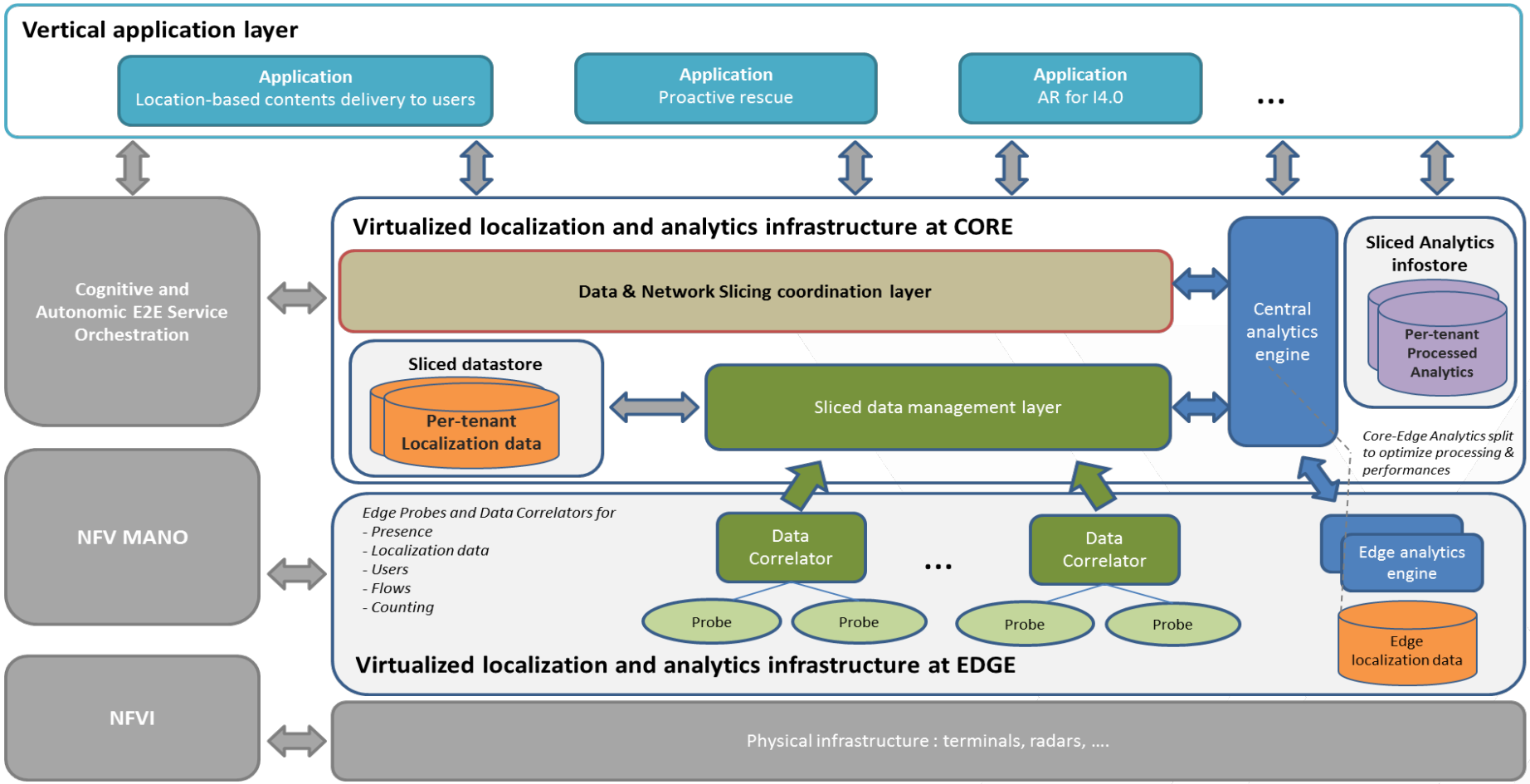
Everything new ?

- No, these scenarios are just largely marketed within the 5G vertical categories
  - Exp. under mMTC & uRLLC
- But…
  - 5G R&D seem focused mainly on the network part, virtualization, software networks and related cognitive functions
  - Still a significant gap to fill to embrace also all those functionalities which go beyond communications, e.g.
    - Truly seamless collaboration and access to **services and resources provided by different platforms**
    - Correlation of network actions/configurations with **behavioural patterns** from raw location and physical events
    - Accurate and ubiquitous information on the **location** of physical targets
    - Efficient/New **function split** between the core/cloud and at the edge
    - **Security** end-to-end, for data and communications

An attempt of vision

- We imagine future communications beyond 2020 capable to offer ***truly immersive user experiences***, across the various scenarios of smart living, e-Health and Smart Industry
- The **future communication network** beyond 5G should
  - Complement the **cognitive and autonomic network service end-to-end orchestration** with
    - **Network and non-network functions**
    - Flexible allocation of functions edge-to-edge or edge-to-cloud based on **dynamic pooling of local unused resources** from diverse participating devices
  - Offer **programmable analytics** to the application layer through open interfaces, including **raw and analytics-based location** based on multiple sources of information (network, devices, user tracking, etc.)
  - Support **more intelligence at the edge**
    - For long lasting computation: **more efficient virtual infrastructure managers for the V[N]Fs to deploy at the edge** (e.g. more lightweight VIM than a full OpenStack)
    - For inconsistent traffic patterns (e.g. from sensors): integrate with **serverless/ Function as a Service (FaaS)** approaches

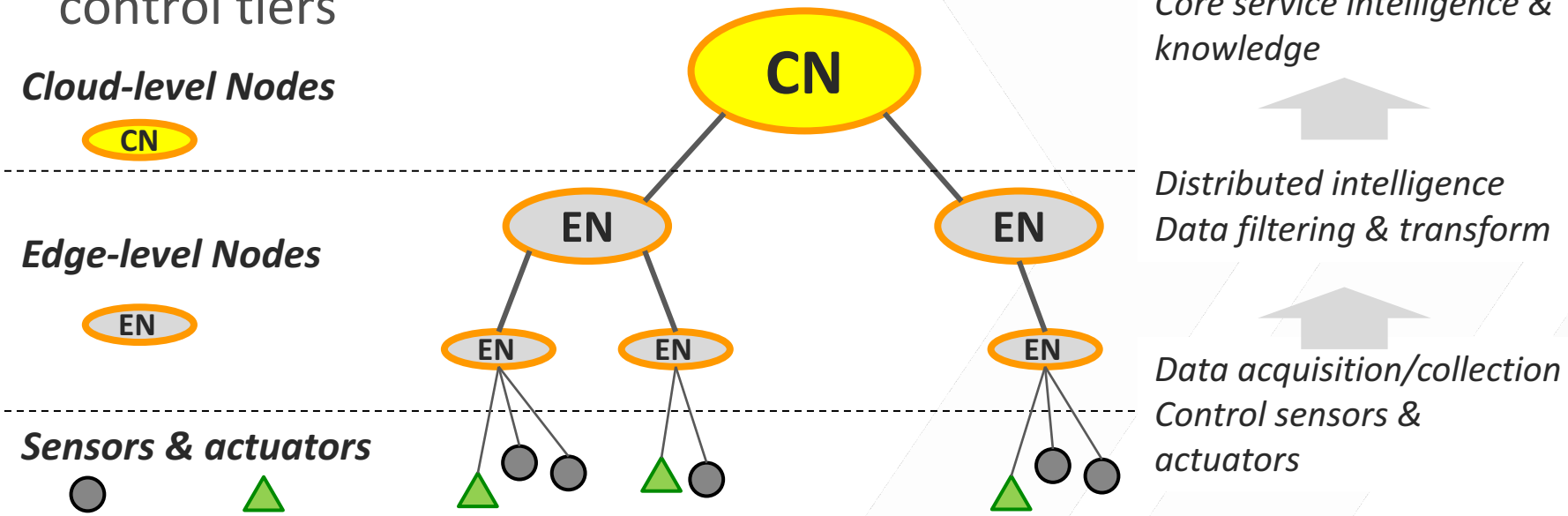
An attempt of vision (2)



- **At the edge**: virtualized sensor probes and data correlators instantiated dynamically, serverless edge analytics and local datastore
- **At the core**: the main slicing, central orchestration and analytics functions, per slice/tenant

An attempt of vision (3)

- This future network builds on the consolidated Software Network frameworks for 5G (SDN/NFV/MEC), as e.g. developed in 5G PPP
  - Cognitive/autonomic service orchestration over multi-domain slices
  - Programmatic network interfaces exposed to the application layer to instantiate and manage the dynamic lifecycles of the Network Slices
- But may need to be organized in a more complex hierarchy of control tiers



Do new critical requirements emerge?

- Plenty of different **network and non-network technologies to be seamlessly integrated** (WiFi, BLE, RFID, DGPS, etc.)
- Huge mass of data to be **correlated, federated and exposed in analytics**
- Different service requirements for different applications, e.g. location

	Navigation in Public Buildings	Proximity Detection	Nano Location in store	Augmented reality
Ranging accuracy	<1 m, same floor	<5 cm	<1 cm, same floor	<1 cm
Pointing angles (AZ, EL & Roll) accuracy	n/a	<15deg	<10deg	<2deg
Latency	< 250ms	<200ms	<10ms, for motion estimation <100ms for static estimation	<10ms
Refresh Rate	<1 Hz	<2Hz	10-100Hz (same as GPS)	0.5Hz-100Hz

Source IEEE 802.11-16 NGP

- **And many more….**

Thank you !!

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