6G Open & Resilient by design for Haptics towards achieving control in critical applications

Presented By

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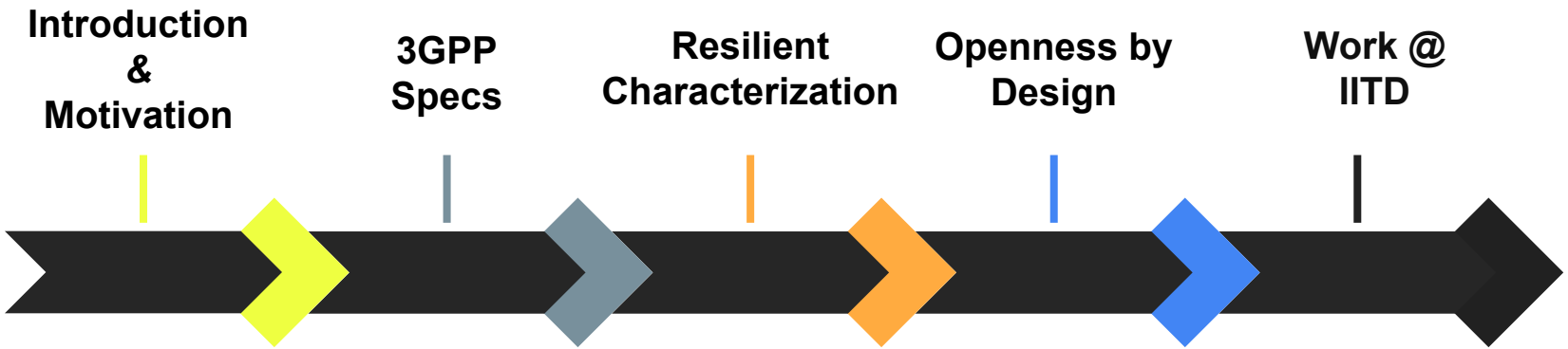
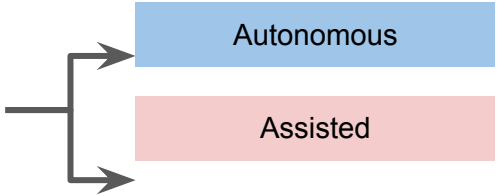
Outlook


Introduction & Motivation
3GPP Specs
Resilient Characterization
Openness by Design
Work @ IITD

Introduction

A robot's interaction with its surroundings can have different modes



Bilateral teleoperation

1. Human exists in the scenario as a **controller** (to provide assistive/ corrective steps).
2. Receives feedback (in some form) due to the the interaction of the robot.
3. To perform manipulation tasks **(grasping/ lifting/moving certain objects of interest)** in an incremental manner.
4. The controller and the robot are remotely connected.

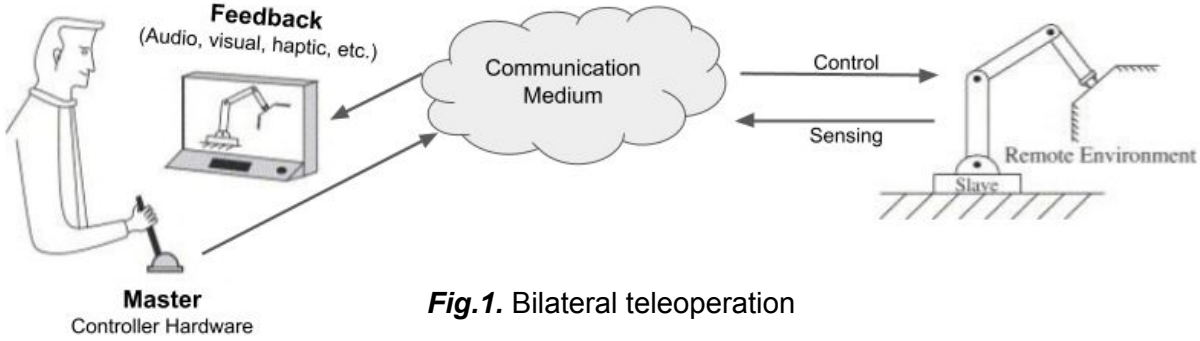


Fig.1. Bilateral teleoperation

5G Vision & Use Cases

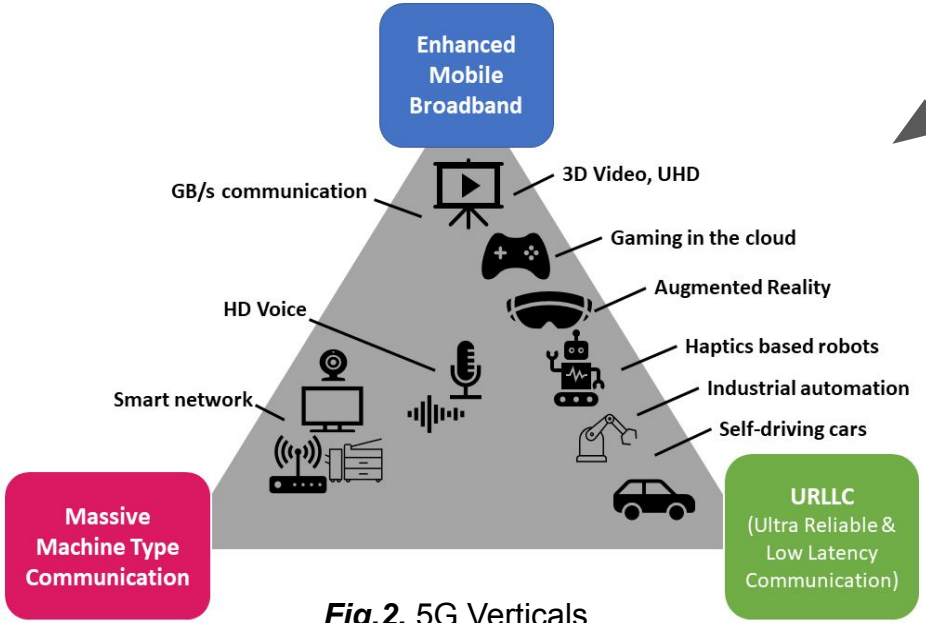


Fig.2. 5G Verticals

5G envisages to cater various applications

BUT, the reasons that…

1. *Some triggered unwanted events need special attention to cater!*
2. *Low latency to perform the actions.*
3. *Assistive steps rely on analyzing high-dimensional multimodal data (video, signals, etc).*

ENTAILS THAT…

***Vanilla URLLC paradigm might not be sufficient** to meet the specification of such an application!*

Introduction to Haptics

SCENARIO IN TRADITIONAL PARADIGM

1. The robot (interacting with the environment) is **remotely connected** to the human controller.
2. All the analytical computations are performed on the controller's side.
3. The control commands/ signals are sent from the controller side to the robot's side over a network.
4. The robot interacts with the environment and records the *data about the environment* **sent as feedback** to the controller. Data includes audio/video/haptics, etc.

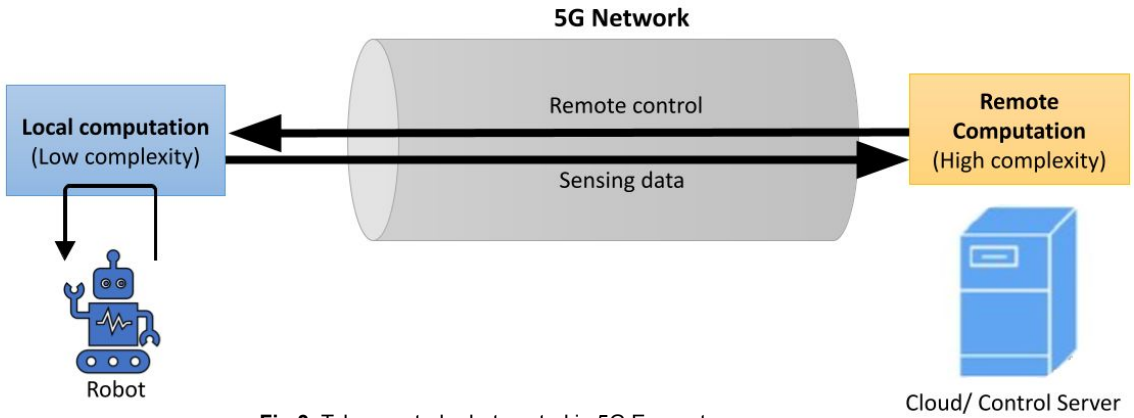


Fig.3. Teleoperated robot control in 5G Ecosystem

3GPP Specs for Haptics based use-cases

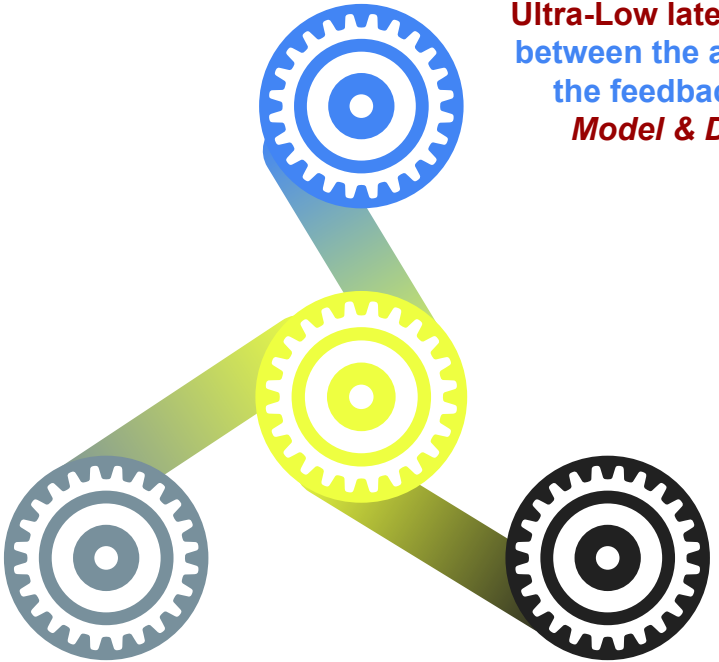
1. **Split control of AI/ML operation.**
   Some part during the control is put somewhere else

2. **Model and/or data distribution.**
   Parts of a single model is distributed on different places, or data required for the model is distributed

3. **Distributed /Federated Learning.**
   (During training) the parts of model are trained at different places.

Understanding ***Resilient*** by Design

Ultra-Low latency communication between the actuating signal and the feedback signal through ***Model & Data Distribution***



Precision in the calibration and motion between the local and remote apparatus through ***Distributed & Federated Learning***

Auto-corrective measures at the Edge for responding to loss in communication/ data through ***Split-control***

Resilient Haptics Use Case Design

SPLIT CONTROL PARADIGM

1. The robot (interacting with the environment) is **remotely connected** to the human controller.
2. Most the analytical computations are performed on the controller's side.
3. **Some part of the control is placed on the Edge Server** to process/analyze/control some special events! a.k.a The control is splitted from the human controller.

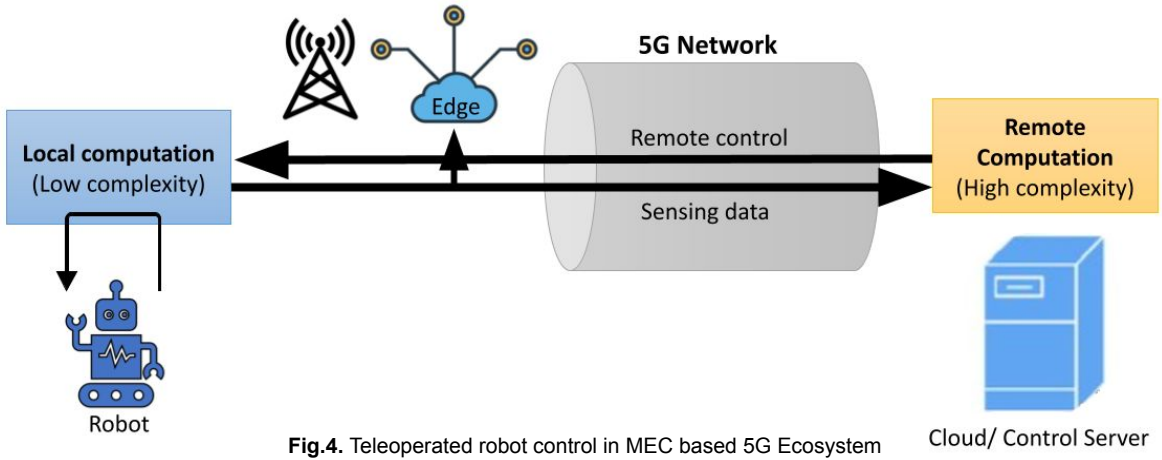


Fig.4. Teleoperated robot control in MEC based 5G Ecosystem

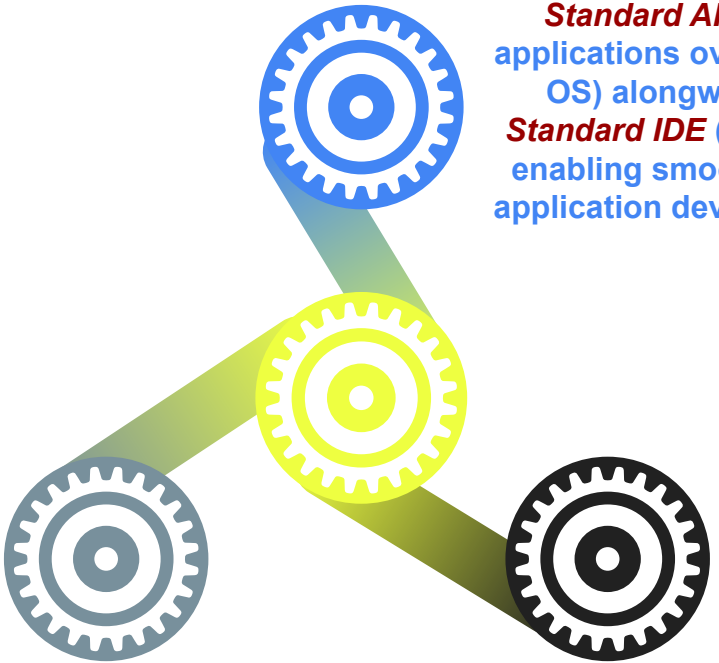
Motivation of leveraging MEC

- Guarantees <1ms> latency.
- Can detect a (feasible) event of interest and take action.

As a summary Haptics based applications need these:

Split control : some part of control stays somewhere else other than a human assistive controller
Quick takeover: In case an unwanted event happens, the control needs to be taken over to prevent that event
Higher Bandwidth: when multimodal data is involved.

Understanding ***Open*** by Design

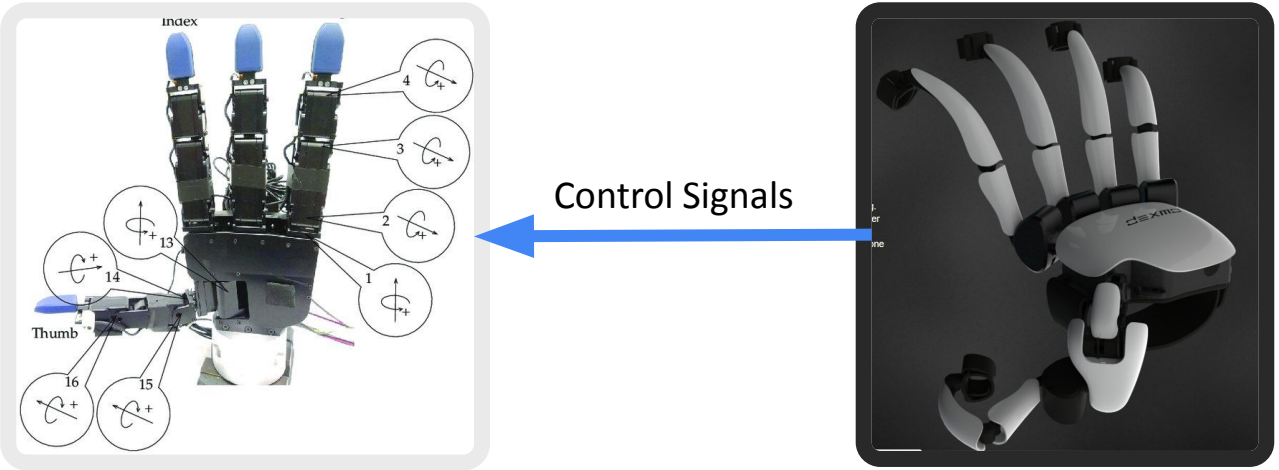


Standard APIs **for developing applications over ROS (like Android OS) alongwith support for an** ***Standard IDE*** **(like Android Studio) enabling smooth & inter-operable application development framework**

Support ***Encoding/Decoding Modalities*** **like Haptics in addition to Audio & Video in CPE like Mobile Phones, for enabling transmission of Haptic related information**

Handling the ***Varied DOF*** **across different models of Robotic Arm, Robotic Hand & Robotic Gloves like Allegro Hand has 16 DOF but Dexmo Haptic Glove has 11 DOF**

System Setup
(forward channel)

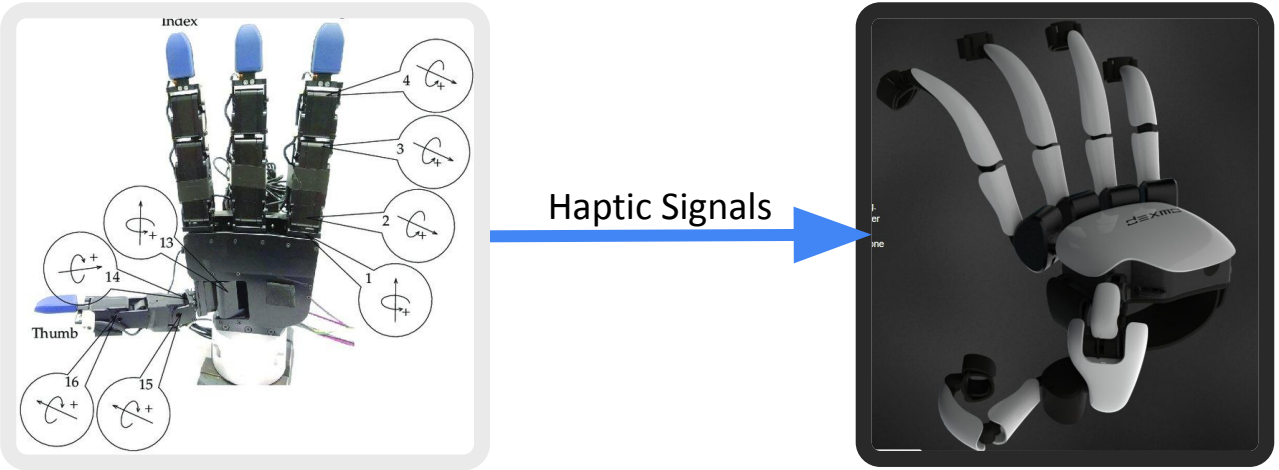


Allegro Robotic Hand (AH)
(16 DOF)

Dexmo Haptic Glove (HG)
(11 DOF)

Fig 12. Control signals from HG to AH

System Setup
(backward channel)



Allegro Robotic Hand
(16 DOF)

Dexmo Haptic Glove
(11 DOF)

Fig 13 . Haptic signals from AH to HG

System Setup

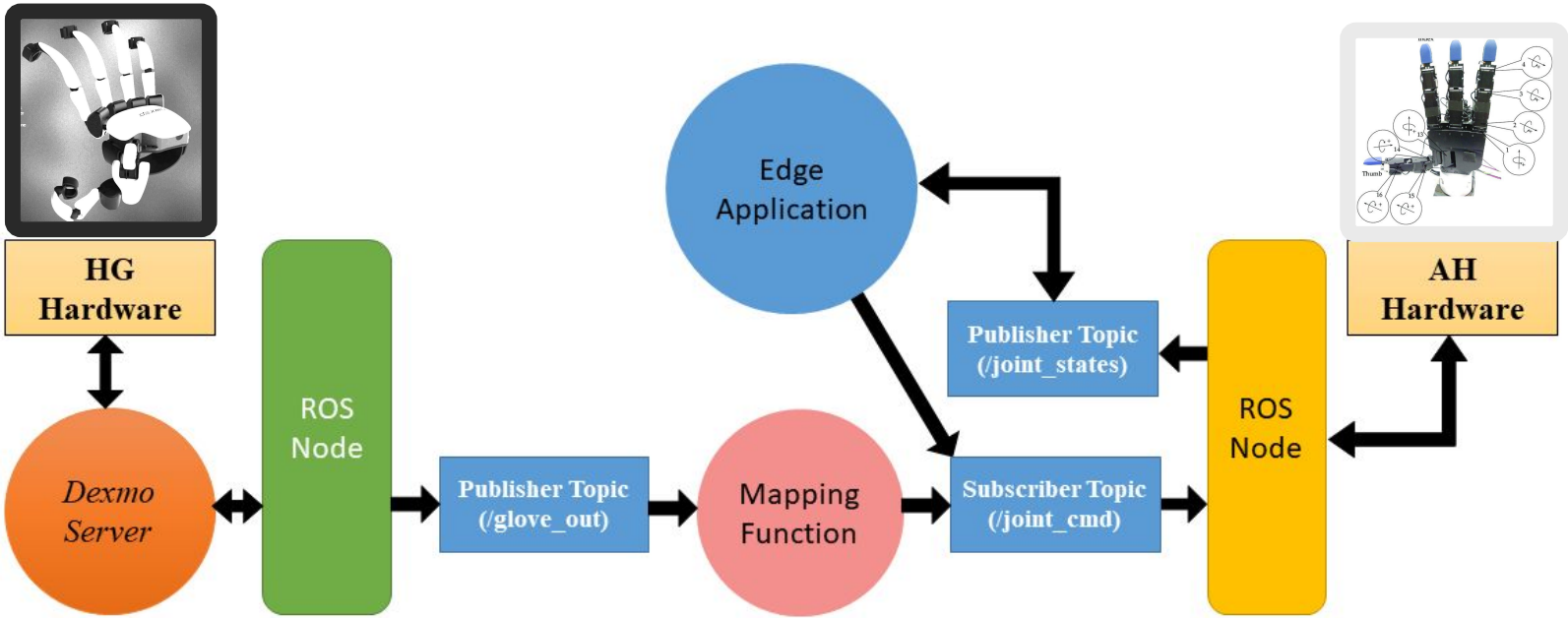


Fig 14. System Setup (High level) with ROS+ Edge

System Setup

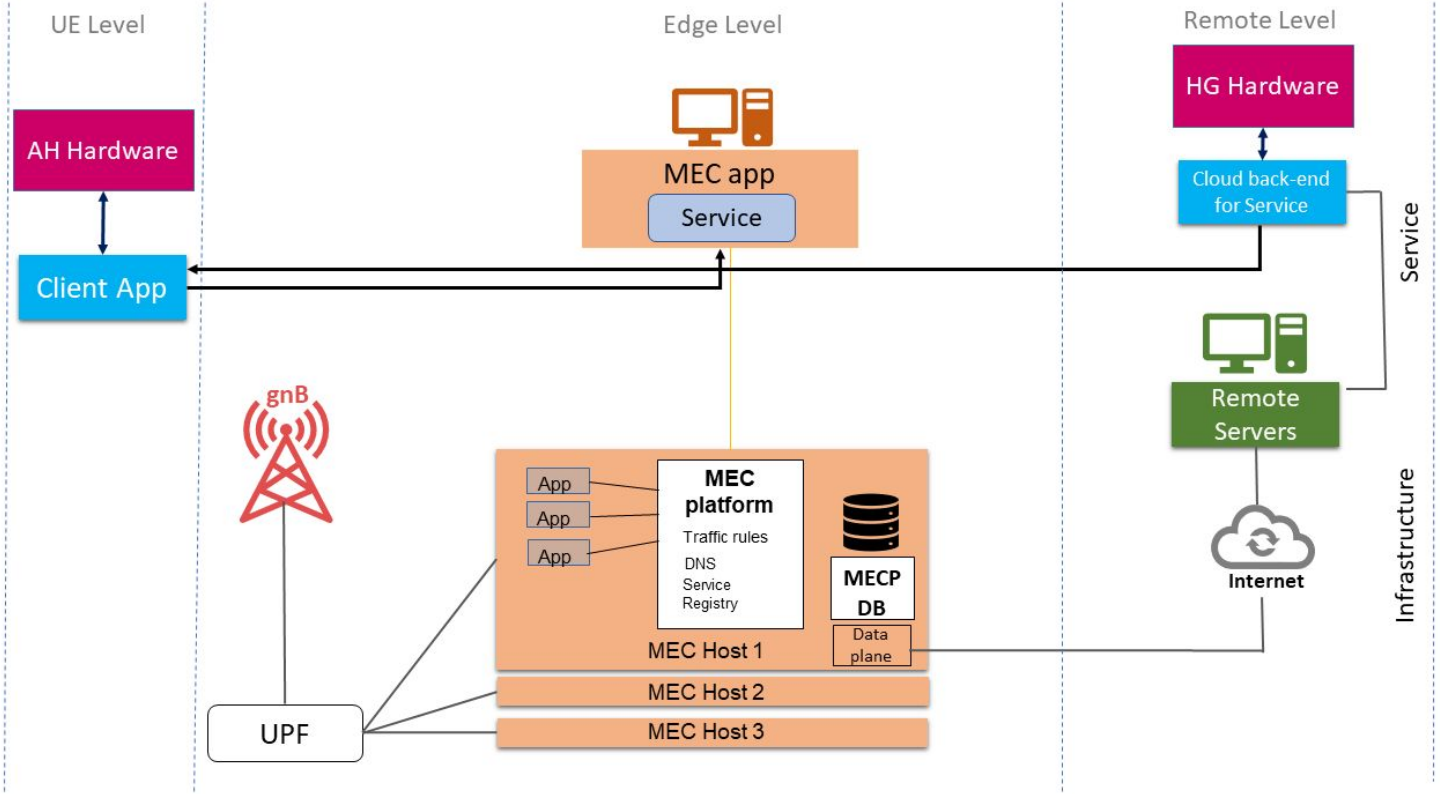
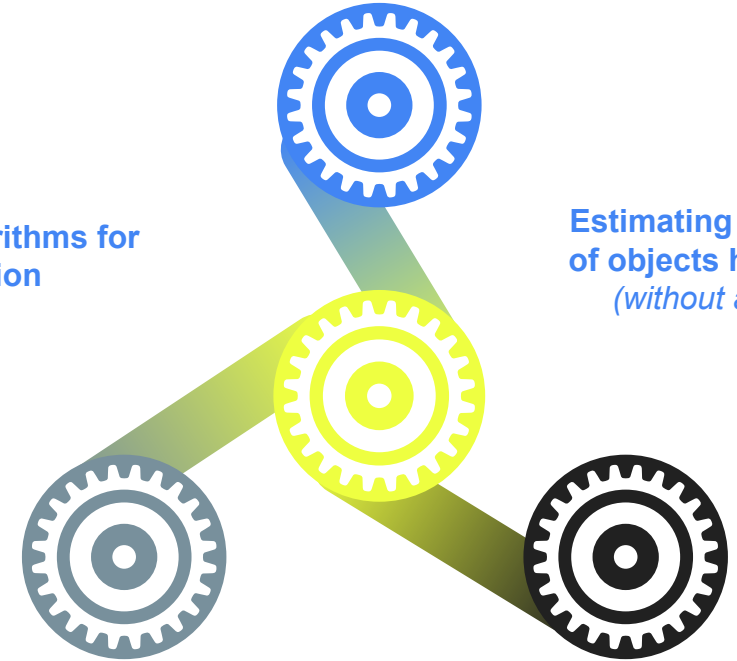


Fig 15. System Setup (MEC level integration)

Ongoing Work

Latency-aware algorithms for intent prediction



Estimating the geometry/shape of objects held with haptic data
(without augmenting vision)

THANK YOU