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Study on 5G System Support for a Network of Service Robots with Ambient Intelligence

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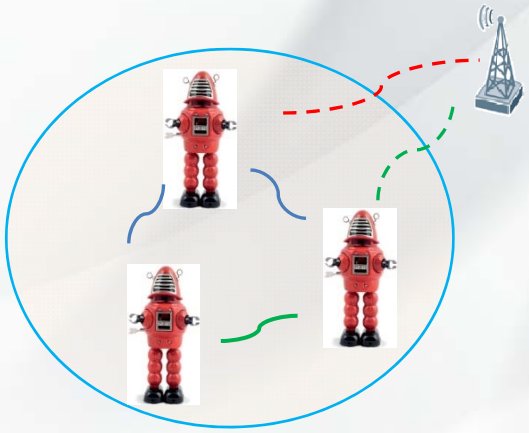
SOBOT Operational Models and Modes of Collaboration



Operational Models

1. Individual Operation Model
2. Group Operation Model (main interest)
   - a group/family of service robots *work together for a task*, often referred to as a multi-agent scenario/model

- **Uu, PC5, multihop**

Modes of Cooperation (e.g. according to communication service availability)

1. Competitive mode: zero-sum game
   a) Communication link is not good enough
   b) Share limited or no info (among multiple robots that work together)
2. Collaborative mode: positive-sum game
   a) Communication link is good enough
   b) Share full info

- **Handling Communication Interruption**

The Objectives

1. Enhanced support of on-demand priority communications that are necessary to help avoid or minimize disruptions of service robot operation

A. Exposure to application-layer information that becomes available to communications layer

B. Capability of communications layer to make necessary changes with high priority to help avoid or minimize disruptions that may be caused in the application layer

NOTEs

1. NOTE (1.A): Application-layer information includes: static information on sensor failure, validity of multi-sensory information (e.g., instead of deterministic trend information on failure, stochastic trend information on failure or validity, e.g., x% of failure is estimated).
2. NOTE (1.B): 5GS communication path needs to be re-configured very quickly (e.g., Uu to PC5, change PC5 link).

The Objectives *(cont.)*

2. Enhanced support of time bounded communication to help an event-triggered delivery of information/data between multiple service robots (including KPIs related to access delay)

NOTEs

1. NOTE: 3GPP system is expected to be enhanced to support such an event-triggered delivery of information/data in an ultra-timely manner when predictive information on critical communication interruption becomes available to communications layer.
2. NOTE: 5GS can be enhanced so that the communications layer can take ultra-responsive preparation to help delivery of information/data that service robots had collected which was not sent to others.
3. NOTE: In the group operation model where multiple service robots are cooperatively building up a single set of online fine-grained metadata (e.g., collaborative online high-definition 3D map building), it is necessary that the communications layer should provide in-time service (absolute difference) and a very high level of synchronization accuracy among those service robots working together.

The Objectives *(cont.)*

3. Support of service operations aspects, including avoiding or minimizing disruption of robot service operation due to employing new technology that serves multiple purposes using a common frequency band

- Usage scenarios of integrated communication and sensing service that can affect service disruption of cloud-based robot services, trade-off between temporary congestion for traffic and temporary degradation of surface sensing performance for service robots.

4. High level service scenarios that have security and privacy implications for resilient operations of a network of service robots

NOTE

1. Potential threat cause factors in the presence of advanced multi-sensory robot systems (e.g., social engineering attacks, misuse of overheard acoustic signals) will be considered for possible derivation of security/privacy guidelines and/or high-level security and privacy related requirements.

Appendix:

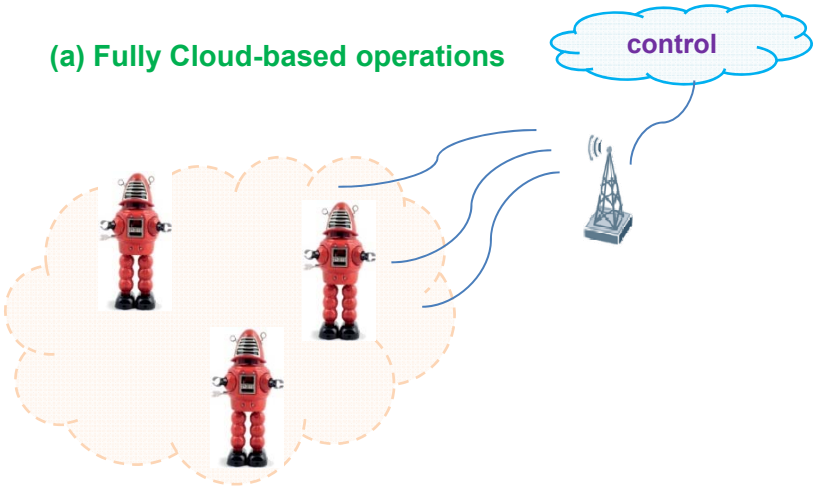
Use Case examples

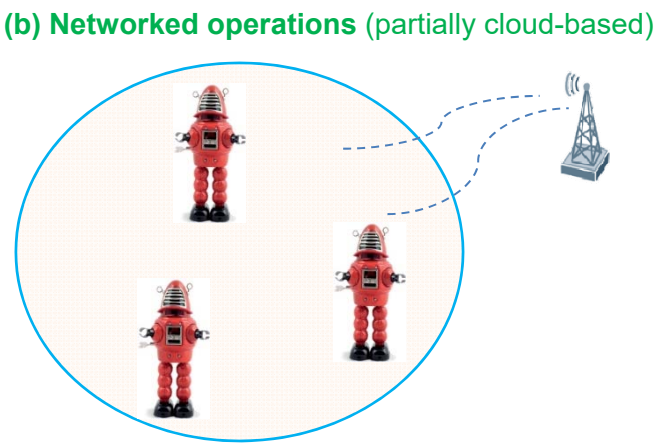
Business Aspects

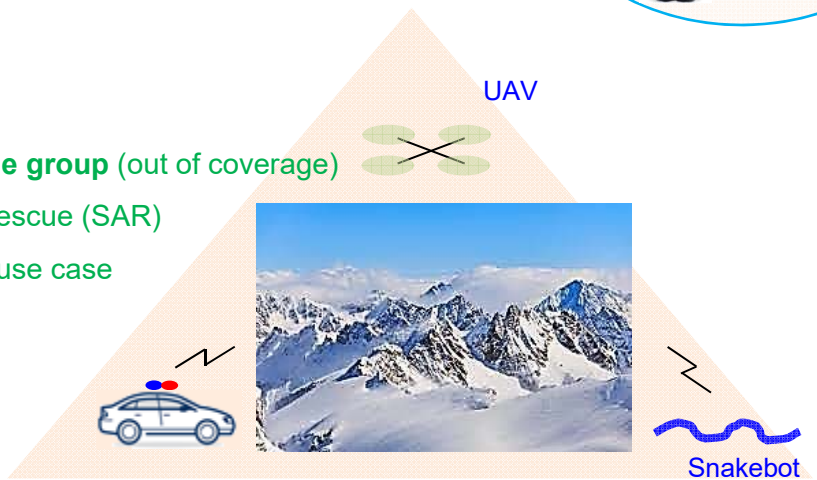
Cloud-based operations examples

Technical Challenges #1

- **#1:**
  -



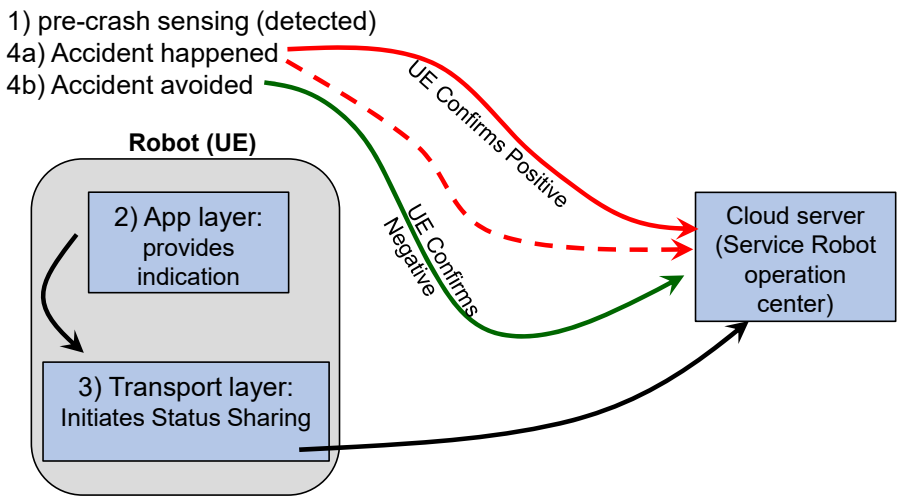


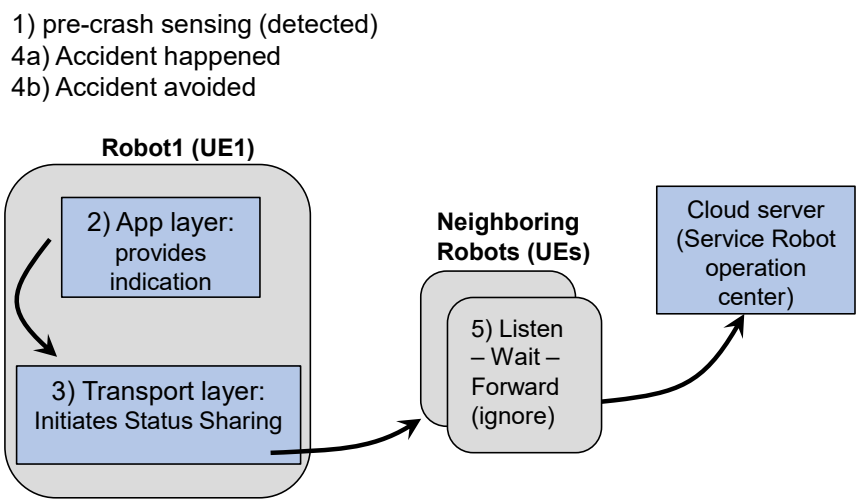


Technical Challenges #1 (cont.)

- **#1: Autonomic Networking:**
- **Network/service's capability to cope with unexpected events, including breakdown and functional failures, and precursory indications**
  - **[unknown] Timely Response to Unexpected Factors**
  - **[random] Random Factors: caused by human or by robots (e.g., failure, accident)**

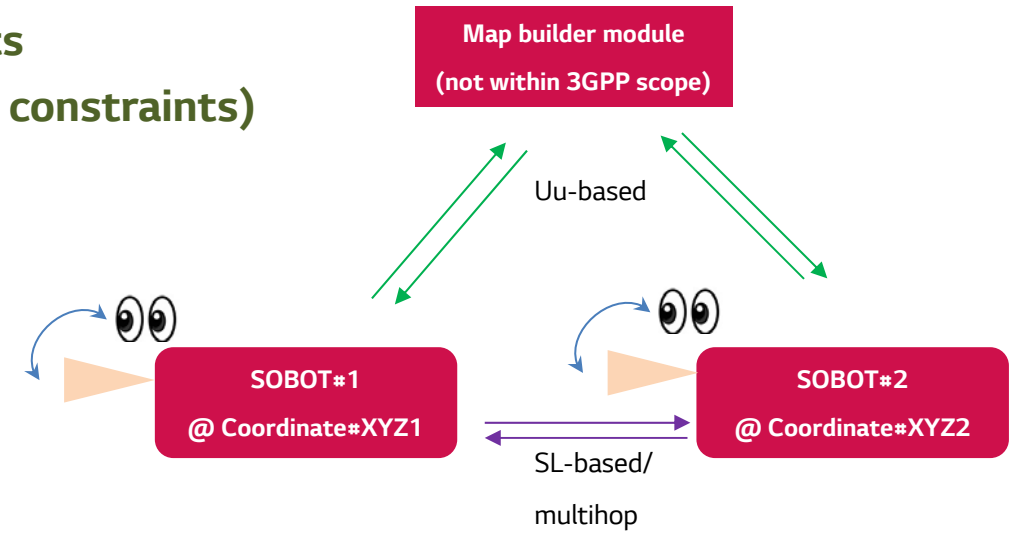
- **Basic Example: task information report (time-bounded communication)**
  - **post-accident response scenario, utilizing precursory indication**





Technical Challenges #2

- #2: Collaborative Online Fine-Grained Dataset Building Among a Group of Robots
- Usage scenarios
  - Indoor Service Robots
  - Local outdoor Service Robots
  - Firefighter robots (w/ visual constraints)



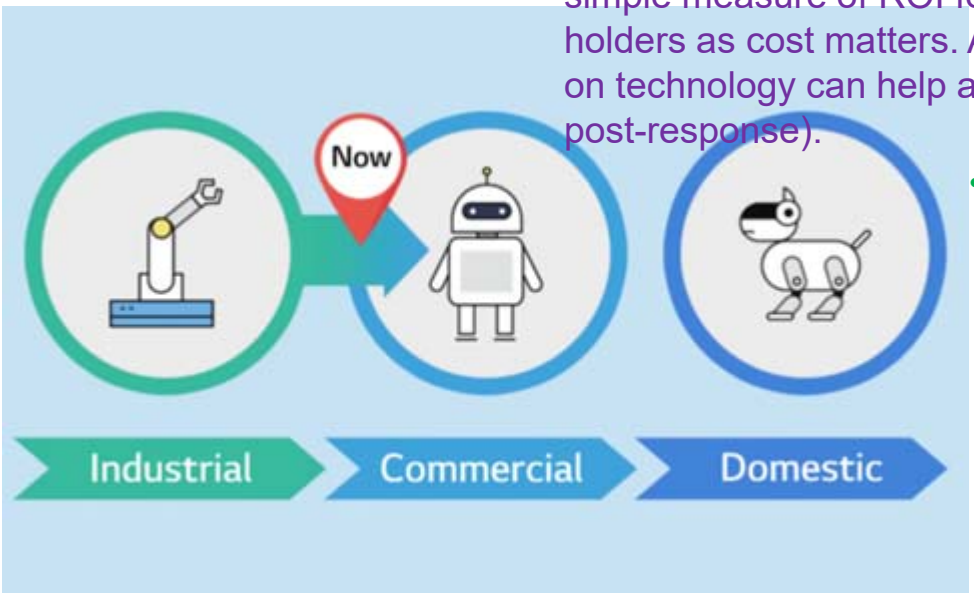
Requirements:

1) "Signal measurements" with time stamp of a very high accuracy level of clock sync [indoor: TBD; outdoor: TBD]
2) Clock sync: (a) IC/PC [deviation level detection] (b) OOC
3) KPIs

Business Aspects

Business opportunity

Today, robots are not so much ready to go outside. There are many more adv ance considerations/features that service robots should have for their automa ted maneuvering and decision-making. For them to have such capability, the simple measure of ROI for robot service provider and virtually the entire stake holders as cost matters. Along this line, it is very important how communicati on technology can help avoid and minimize service disruption (preventive or post-response).



- “Akin to how computers and automobiles were im plemented in industry and commerce before they made their way to consumers, service robots are f ollowing a similar path. Already widely found in ind ustries, service robots are now entering the comm ercial phase. When consumers will be able to purc hase a delivery robot of their own is still unknown but if LG has anything to say about it, it won’t be t oo far away.” (source: LG Group News)

Some domains of Service Robots that can be connected through 5G networking

Network of Service Robots

Cloud-based/Cloud-assisted Operation of Service Robots

- Indoor / Outdoor Delivery robots
- Disinfection robots with (almost) full autonomous maneuvering

- ***Porter Robots*** help customers get necessary inform ation and get "hands free" in shopping malls, hotels, an d senior-care facilities

- ***Care-Giving Robots***

- ***Disinfection Robots*** help environmentally f riendly disinfection to reduce labor and chemi cal costs;
- Required functionality: semi-/fully autonomo us maneuvering (e.g., SLAM, reflective intellig ent surface (RIS/sensing), inter-robot maneuv er sharing and collaboration), scalability to su pport a large network of robots, security

(2020 Dec) https://www.hotelbusiness.com/lg-developing-autonomous-robot-with-disinfecting-uv-light/

(2020 Dec) https://www.roboticsandinnovation.co.uk/news/cleaning-sanitation/lg-to-release-autonomous-disinfecting-uvc-robot.html

Cloud-based Operations –Examples

- Distributed network & Distributed computing
  - Dynamic creation and update of SOBOT subnetwork
  - Massive interactions among AI modules inside a SOBOT
  - Cooperation among SOBOTs

- Enhanced connectivity and coverage extension
  - Sobot Service availability, reliability

- Automatic & autonomic network
  - Real-time network configuration (update) to support adaptive interaction between SOBOTs and between SOBOT and human.

- Network supporting flexible service/application creation
  - Framework to provide easily the new SOBOT service creation (for both service providers and developers)

Cloud-based Operations –Examples

- Delivery use cases (autonomous maneuver)
  - Indoor delivery
  - Local outdoor delivery (more challenging) – the condition of pathway surface is different than general road surface used by ground motor vehicles
  - Related technology: surface sensing, object detection, record sharing (e.g., via DLT), communication path reconfiguration (Cooperation among SOBOTs)

- Disinfection (autonomous maneuver)
  - Related technology: mostly similar to technology required for "delivery use cases";
  - What's different? What evolutionary aspect are needed? E.g., "cow" (as workforce in the history of farming)

- Other use cases
  - Helping ordinary things / errands but with secure transaction and status records ensured
  - Cooking: Barista-bot
  - Shopping assistance: Porter-bot