3GPP SA1#96E
Nov 8th – 18th, 2021

S1-214062

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

- Cloud-based Robot Operations and their Networking Design Considerations – Part I

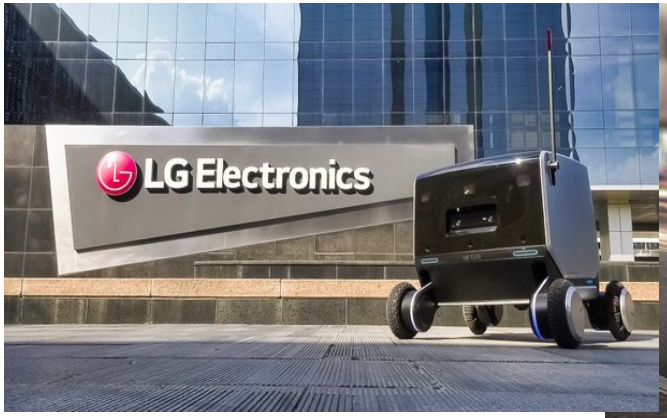
Ki-Dong Lee, Hyunsook Kim
(kidong (dot) lee@ lge (dot) com)

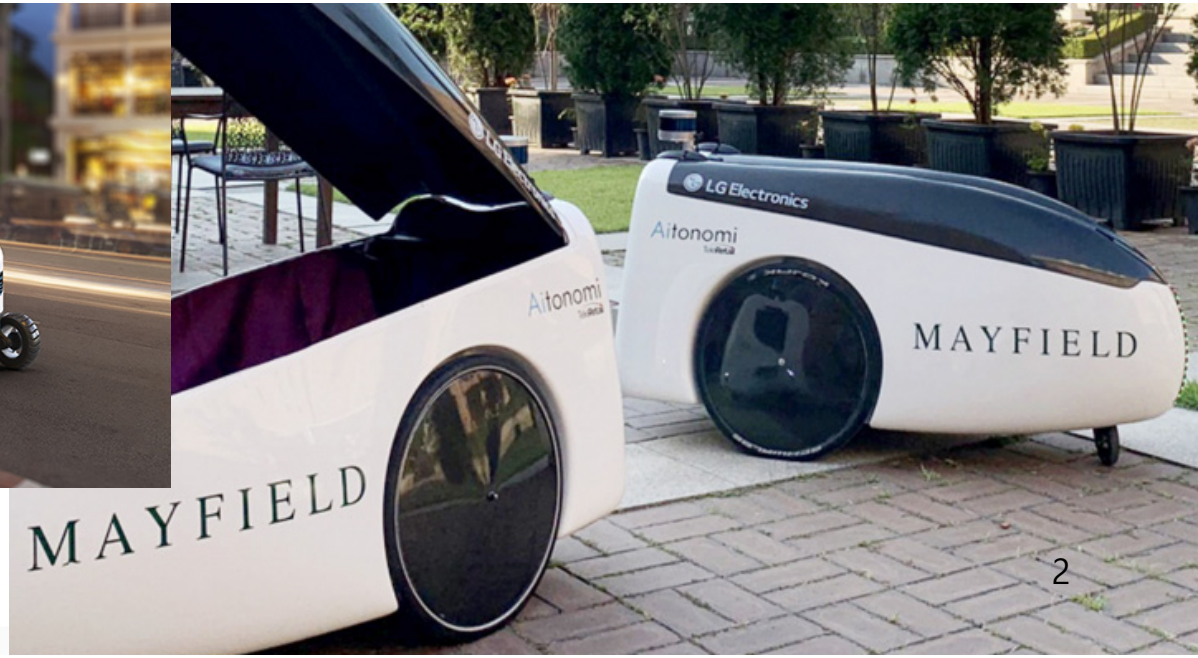
LG Electronics

Business Aspects

Categories of “Networked Robots” as per Intended Purposes

1. Industrial robot
   - [ISO] automatically controlled, reprogrammable, multipurpose manipulator, programmable in three or more axes, which can be either fixed in place or mobile for use in industrial automation applications
2. Service robot for ambient assistive living
   - [ISO] robot that performs useful tasks for humans or equipment excluding industrial automation applications
   - Delivery robots (e.g., restaurant, shopping mall, library, CCRC, hospital)

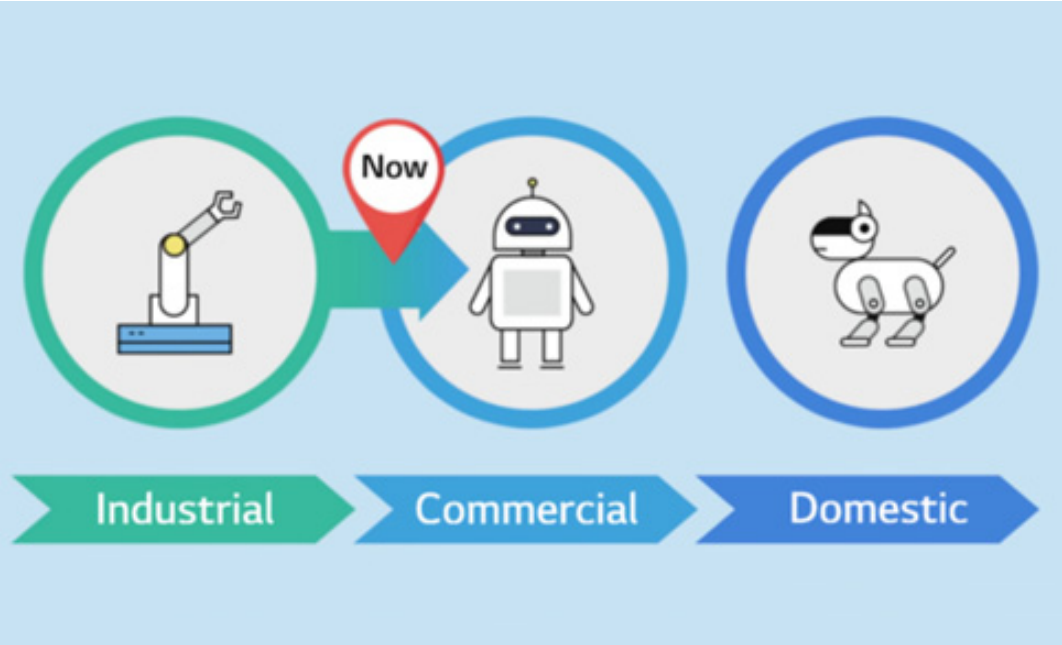




(sources: LGE, LG CNS, LG U+)

Business Aspects

Business opportunity



- “Akin to how computers and automobiles were imple mented in industry and commerce before they made t heir way to consumers, service robots are following a s imilar path. Already widely found in industries, service robots are now entering the commercial phase. When consumers will be able to purchase a delivery robot of their own is still unknown but if LG has anything to say about it, it won’t be too far away.” (source: LG Group N ews)

Business Aspects

- how SOBOTs help improve humans' living in the society

Table 1. Various Aspects of Service Robots that have Capability of Ambient Intelligence (usage scenarios associated with unstructured settings)

Aspects	Industry	Service features	Goals
Daily Living	Healthcare, Education, Logistics (indoor/local)	Preventive care/monitoring/therapy; education assistance; indoor deliver (food, medicine, cart); local delivery	Communication support of ultra-fast, reliable and effective interactions with human (gesture, language) with edge intelligence
Experience	Healthcare, Retail	Physical therapy assistance, physical motion training assistance (golf, aerobic, Pilates, etc.)	Congestion avoidance/management (ISAC) for True physical experience (digital replica)
Critical	Agriculture, Landscaping, light-duty constructions, search-and-rescue/public-safety	Smart and efficient harvest assistance, Local construction (skillset)	Network fabric-assisted environmental recognition and object detections, zero-touch network operation/management
Societal		Contributions to societal development goals, such as sustainability, the "aging population" (e.g., United Nations Report), etc.	

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

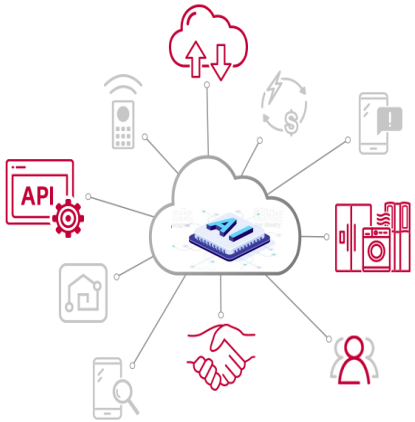
Cloud-based Operations –Examples

- 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

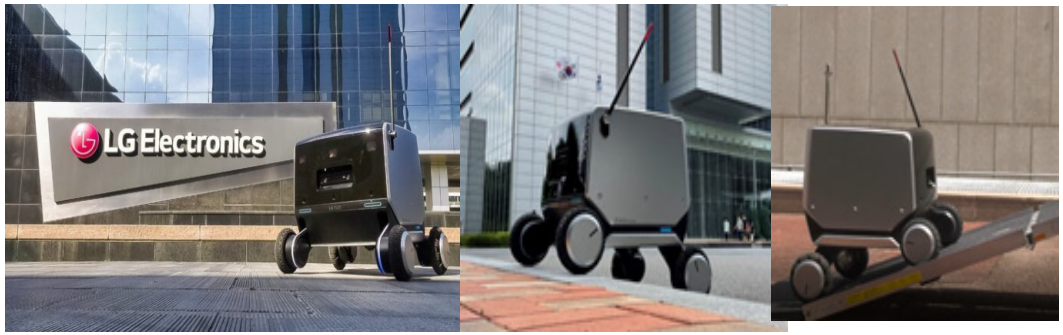
- Automatic & autonomic network
  - Real-time network configuration (update) to support adaptive interaction between SOBOTs and between SOBOT and human.

- 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)

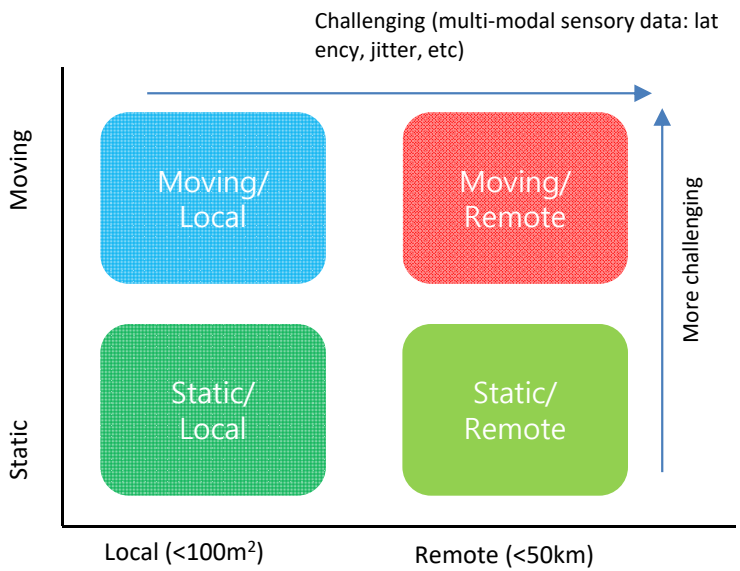


- Disinfection (autonomous maneuver)
  - Related technology: mostly similar to technology required for "delivery use cases";
  - What's different? What evolutionary aspect are needed? E.g., "cow" (as workforce in the history of farming)

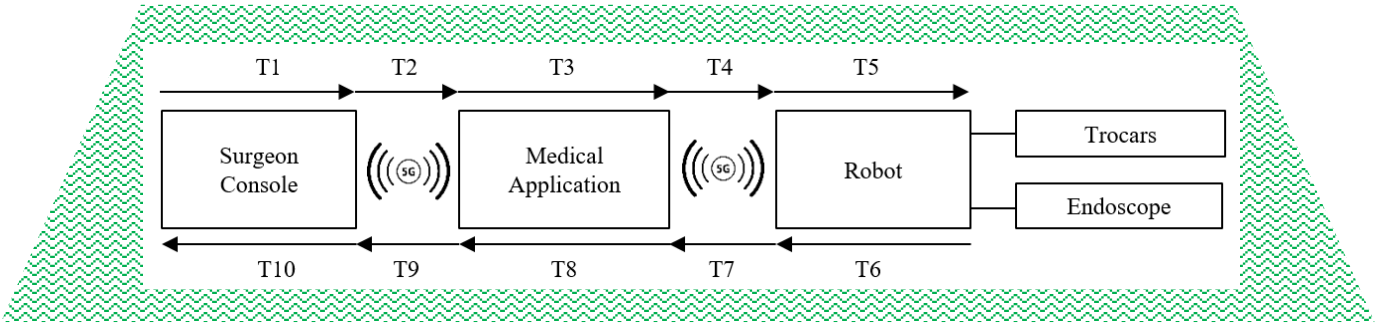
- Other use cases
  - Helping ordinary things / errands but with secure transaction and status records ensured
  - Cooking: Barista-bot
  - Shopping assistance: Porter-bot

Cloud-based Operations –Examples

- **Medical, Public-Safety and Commercial**
- Tele-surgery (CMED, 3GPP): Great advantage vs. Legal/Ethical duties
- **Difference: Surgeon robot is not actively moving** (typically the vehicle carrying the robot is moving)
- Robot control via 5G transport (possibly via the user plane)



Scenario		Latency	Bit rate
Static/local	control	< 2ms	16Mbits/s
	feedback	< 2ms	16Mbits/s
Static/remote	4K/60fps video	< 250ms	2Gbits/s
	feedback	< 20ms	16Mbits/s
Clock synchronization < 50 μs			
Connection re-establishment 20 ms			

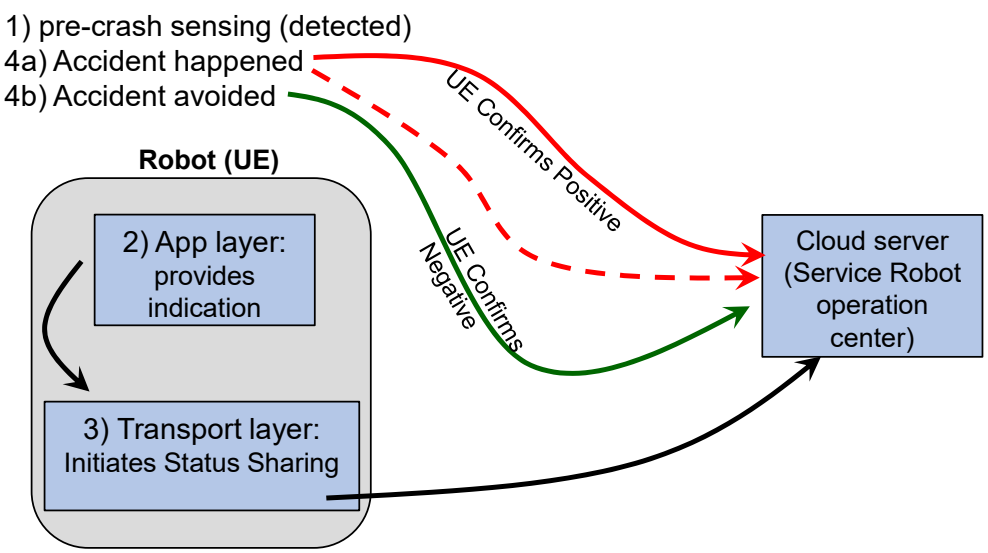


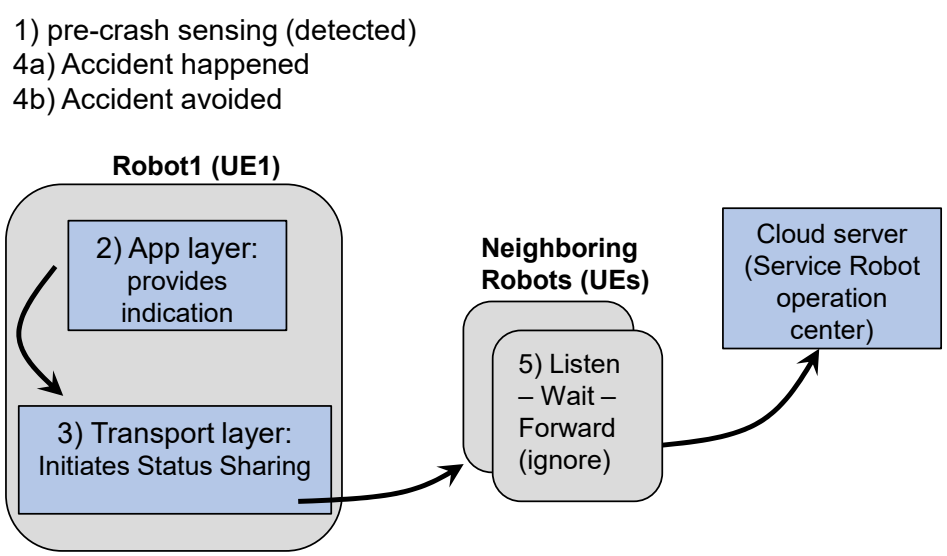
Latency factors in Robotic aided Tele-surgery

Technical Challenges #1

- #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: Support of SLAM using 3GPP Radio and Network
  - Centralized multi-agent mobile robots (e.g., semi-/fully autonomous maneuver)
  - Sensing of Objects including their peripherals (typically robot arms): not only the core object (e.g. main body of a participating robot) but also each of object's branches and peripherals (e.g. robot arm, etc.) should not collide each other

- Other aspects for considerations:
  - Difference b/w V2X Remote Driving
  - Difference b/w CMED tele-surgeon robot operations
  - Difference b/w Tactile Internet-based relatively short-range operations

- NOTE: due to the inherent nature of service robot operations and their related scenarios, the use of sensing and impact on communication disruptions/congestion may be described in service flow and descriptions during the study but if sensing specific requirements are identified, they will be eventually consolidated into Sensing Study outcome (in one place). Arranged b/w two companies.