3GPP SA WG1 Meeting #97e S1- 220149r1

Electronic Meeting, 14 Feb – 24 Feb 2022 (revision of S1-214244)

Source: LG Electronics, LG Uplus, OPPO, KRRI, China Unicom, Kyonggi University, Institute for Information Industry (III), Kontron Transportation France, CATT, Orange, SK Telecom, Xiaomi, Sharp, Hyundai Motors, Verizon UK Ltd, Futurewei, Tencent

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

Document for: Approval

Agenda Item: 4

3GPP™ Work Item Description

Information on Work Items can be found at <http://www.3gpp.org/Work-Items>   
See also the [3GPP Working Procedures](http://www.3gpp.org/specifications-groups/working-procedures), article 39 and the TSG Working Methods in [3GPP TR 21.900](http://www.3gpp.org/ftp/Specs/html-info/21900.htm)

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

Acronym: FS\_SOBOT

{Propose an acronym. Final acronym to be confirmed at the plenary. The sign "-" is a level separator between (Feature)-(Building Block)-(Work Task). The sign "\_" can be freely used. Studies have to start by "FS\_". Each acronym level has to be simple and short, 7 characters max recommended}

Unique identifier: tbd

{A number to be provided by MCC at the plenary}

Potential target Release: *{Rel-19}*

{Note that this field above indicates the proposed Release at the time of submission of the WID to TSG approval. It can later be changed without a need to revise the WID. The updated target Release is indicated in the Work Plan}

# 1 Impacts

{For Normative work, identify the anticipated impacts. For a Study, identify the scope of the study}

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Affects: | UICC apps | ME | AN | CN | Others (specify) |
| Yes |  | X | X | X |  |
| No |  |  |  |  |  |
| Don't know | X |  |  |  |  |

# 2 Classification of the Work Item and linked work items

## 2.1 Primary classification

### This work item is a …

{Tick one box. "**Feature** / **Building Block** / Work Task" form a hierarchical structure. E.g. no Building Block can be proposed without a corresponding parent Feature. The full structure of all existing Work Items is shown in the 3GPP Work Plan in <ftp://ftp.3gpp.org/Information/WORK_PLAN>}

|  |  |
| --- | --- |
|  | Feature |
|  | Building Block |
|  | Work Task |
| X | Study Item |

## 2.2 Parent Work Item

{"Parent" Work Item refers to the related, earlier-Stage, Work Item, e.g. the related Stage 1 Work Item shall be indicated here when a Stage 2 normative Work Item or Study Item is presented. "Parent" Work Item can also refer to the related preceding Study Item e.g. the related Study Item and the earlier-stage Work Item shall be indicated here when a normative-work Work Items is started. List here all parent Work Items of which requirements are either fully or partially covered by the proposed Item. }

{This section is mandatory to be filled out by the rapporteur. This section is to be filled with care: it indicates to the companies monitoring the parent Work Item that it will be addressed in this study/work item.}

For a brand-new topic, use “N/A” in the table below. Otherwise indicate the parent Work Item.

|  |  |  |  |
| --- | --- | --- | --- |
| Parent Work / Study Items | | | |
| Acronym | Working Group | Unique ID | Title (as in 3GPP Work Plan) |
|  |  |  |  |

### 2.3 Other related Work Items and dependencies

{List here other Work Items which relate to the proposed one, such as a Work Item in an earlier Release if further enhancing the feature from the previous Release)}

|  |  |  |
| --- | --- | --- |
| Other related Work /Study Items (if any) | | |
| Unique ID | Title | Nature of relationship |
| 800049 | 5G\_HYPOS | Normative work outcome summarized in 22.261 |
| 840041 | eCAV | Normative work outcome summarized in 22.261, 22.104 |
| 840039 | EAV | Normative work outcome on UAS in 22.125 |
| 840031 | VIAPA | Normative work outcome on CMED and A/V Service Production 22.263 |
| 860009 | FS\_AMMT | Ongoing study on AI/ML model transfer |
|  |  | {optional free text} |
|  |  | {optional free text} |

Dependency on non-3GPP (draft) specification:

{This section is to be typically used to identify the IETF dependencies. Delete the header "Dependency on non-3GPP (draft) specification:" if no such dependency}

# 3 Justification

The advancement of robotics application technology would bring more business opportunity in telecommunication market segments through interdisciplinary and cross-industry collaborations. Some critical communication aspect of industrial robots in the context of cyber-physical control systems has been studied so that important use cases, including those with human-machine interface (HMI), can properly be supported with a higher level of communication availability, reliability, clock synchronization and so on. As a result, the related requirements have been identified in three typical traffic classes or communication patterns in industrial environments (refer to 3GPP TS 22.104).

On the other hand, there is a growing demand in consumer electronics segments that expects a great deal of roles that service-oriented robots (or service robots) should play in order to improve the level/quality of a human user’s daily behaviours for, such as shopping, traveling and more to come upon us resulting from smart-living innovations. Some examples of service-oriented robots potentially include:

1. *serving robot* that is designed to deliver food and beverage to residents of Continuing Care Retirement Community (CCRC), guests of hotels and visitors to airport lounges quickly and efficiently;
2. *porter robot* that is designed to help minimize inconvenience for travellers by reducing slow service and long wait times. This robot can also facilitate express check-in and check-out service by handling payment and delivering luggage to a waiting vehicle in a fraction of the time;
3. *shopping cart robot* that is designed to help customers get necessary information and get “hands free” while shopping

The characteristics and required roles of service robots to play are, in general, different from those of industrial robots:

1. Application area: service robots are intended to assist humans in various settings (as described in ISO 8373:2012) whereas industrial robots are to replacing human workforce in structured settings, such as manufacturing
2. Interacting points: service robots have interactions with human, capable of understanding natural forms of human input (e.g., natural language, gestures, facial expressions) whereas industrial robots have more standardized and structured way of interactions with human workers in job site
3. Business opportunity: service robots are designed to play roles in such usage scenarios that are not properly assisted by the use of industrial robots, such as shopping assistance, care-giving, and indoor and local outdoor delivery
4. Technology readiness: apart from some basic roles that service robots can play, there exist challenging and promising areas that technology will need to catch up, in order to improve the service quality that service robots can provide, such as AI-native operation, zero-touch operation so that ideally human customers do not need to anything even when disruption happens in service robot operations

The operational models of service robot(s) include: (1) in an individual operation model, a single service robot is used for certain task (2) in a group operation model, a group/family of service robots work together for certain task, often referred to as a multi-agent scenario/model. The group operation model (or multi-agent model) is more advanced than the former model and thus has challenging requirements, which is the main focus of this study. Within the group operation model where a family of service robots work together, there are two modes of collaboration: (1) when the communication channel/link condition is not good enough and, as a result, some service robots out of the family/group cannot share the necessary information in time, they should make decisions with limited information, which is labelled as competitive mode. Each service robot in the group/family should go for a game-theoretic decision making process (typically, zero-sum game). (2) When the communication channel/link condition is good enough (not only at a certain epoch but continuously during their operation), the group/family of service robots can share necessary information fully and they could make a better coordination in strategy planning and can be more productive or efficient than in the previous case. Each service robot should go for a game-theoretic decision making process but, different from the previous case, the group/family can achieve better performance (typically, positive-sum game in this cooperative mode, namely, via the communication, their own individual decisions get better). Therefore, it is critically important to provide sufficient level of communication availability in the group operation model; if not (temporarily or not), it is critically important to provide a predictive means from communications layer suitable for the group operational model of service robots so that the group/family of service robots can maintain high level of performance/productivity/efficiency by avoiding or minimizing disruption of service robot operations. .

Example use case scenarios for cloud-based/cloud-assisted operations of service robots include, but is not limited to, indoor delivery robots, local outdoor delivery robots and disinfection robots via using edge clouds. Various scenarios and economic needs exist. Due to the nature of their roles of assisting human in some use case scenarios (e.g., delivery robots), some event-related information (e.g., accident, robot/sensor breakdown that have potential to contribute to or have contributed to service disruption, and information that has to rather be sent out of such a problematic situation that is predicted to happen or has already happened) needs to be share with the robot operator/server and/or with participating robots within certain time interval whenever such an event is predicted or any precursory indication becomes available (time-bounded communication).

Given the interesting scenarios and requirements involved, it is proposed to study potential new service requirements for the 3GPP 5G system to provide enhanced communication support for a group of service robots.

NOTE: Some definitions and/or terminology, which are considered necessary to properly describe the pre-condition, service flow and post-condition, will be aligned with ISO 8373:2012. However, an enhanced definition can also be considered if appropriate for 3GPP study and work.

Analysis of technical challenges/gaps:

Following 3GPP efforts in recent releases on the support of industry 4.0 that are focused on communications support for industrial robots, it is also gaining popularity in Europe, North America, and Asia to bring robotics applications into our everyday living environment as it’s important for each society to prepare for societal sustainability with the focus on workforce resources in the well-known global trend of population aging (Reference: The United Nations – “World Population Ageing”). However, it is not as simple as one can imagine to bring robotics applications (so-called “service robots”; Reference: ISO 8373:2012) into everyday living due to some of key challenges that are different from what are required by industrial robots in job sites.

1. Safety: Service robots are machines that have ambient intelligence, understanding natural forms of interaction with humans (e.g., natural language) and assisting humans while staying with humans in unstructured settings. Examples are care-giving robots, indoor/outdoor delivery robots, rescue robots, hazardous control robots, and the like. While performing certain task, service robots are required to perform “motion planning” and are strictly required to keep humans and themselves safe (e.g., no collision, no graze with humans, objects, etc.).
   1. Challenge: Disruption of robot operations – When a group of service robots use a common spectrum band (radio resources), it is necessary that radio resources are used in balance for their multiple different purposes even under congestions, i.e., communications and others such as surface sensing that is consistently necessary for safe robotic motions. While sensing itself is not part of this study, it is necessary to identify service requirement to achieve balance in the utilization of radio resources for robots’ operations, not degrading communication performance over the other and vice versa. Besides sensing, any other types of service that would use radio resources along with robots will also be considered against this challenge to identify service requirements.
2. Enhanced exposure and support of on-demand priority communications: Service robots are equipped with various advanced sensors for their intended purposes. When a disruption to service robot operation is predicted at the applications layer (via advanced sensors), this predicted information can be utilized for applications layer to indicate necessary changes in the communications layer in a very timely manner. This predicted information includes, e.g., 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). The types of necessary changes for the communications layer to make include: application-triggered path switching, path reconfiguration, and the like in a group operation model.
   1. Challenge: In order for 3GPP system to support the aforementioned feature when disruption of operation is predicted, the predicted information needs to be promptly shared with communications layer so that necessary changes can be made before actual problem happens. Once accident or breakdown has already happened, two types of problems can arise: communication itself is not available (temporarily or permanently); re-routing delay is expected. However, if predicted information is used for communications layer ahead of time, in order to prepare necessary changes, these types of problems can be avoided or minimized. Currently, this kind of support is not available in 3GPP and application enablement needs to be studied for some popular use cases.
3. Enhanced support for time-bounded communication for information/data sharing: 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 disruption becomes available to communications layer. Information/data may include robot task record, forensic data, other collected metadata and so on (that are just payload for 3GPP and is out of the scope of 3GPP). 5GS enhancement towards such a capability is aimed at enabling so-called zero-blackbox operation for group operation models of service robots even when critical and extreme situations happen, e.g., loss of physical entity of a robot in search and rescue, hazardous control, and online hijacking scenarios.
   1. Challenge: When critical disruption of operation is predicted, communications layer does not prepare to help applications layer unless applications layer uses the predicted information to provide indication to communications layer. Currently, there is no 3GPP support that can enable applications layer to prepare to use, or to prepare to continue to use communications layer. Note that such application enablement is not designed even in C-V2X although extended/advanced sensors are available. In addition, for KPIs, when the ongoing link is failed, it is required to re-establish connection in 20 ms (TS 22.263); however, when a robot is in idle mode, there is no justification studied and therefore no recommendation is available in stage-1.
4. Security and Privacy: Simple forms of UE’s, such as IoT, passive IoT, still need high-level study on security and privacy. Service robots are equipped with more advanced sensors than such simple forms of UE’s and are exposed to more privacy-sensitive environment. High-level security and privacy implications are
5. For the above-mentioned service scenarios, machine-type communications are likely to require dedicated media configurations for machine vision tasks such as object analysis. For example, the consumption of video signals by a robot does not follow the same quality constraints of human perception. This is currently addressed by the MPEG standardisation group under the Video Coding for Machine activity.

# 4 Objective

The scenarios that will be reviewed and studied to derive potential service and performance requirements include group operation models (or multi-agent models) where multiple service robots work together for a single task.

NOTE 1: Two modes of collaboration are considered to analyse the necessary enhancement of communications feature and performance: no or limited sharing of information among service robots due to limited network resources or bad network conditions (competitive mode) and maximum sharing of information (fully collaborative mode) that can differently affect the need of communication functional and performance requirements.

The objective of this study is to identify use cases and the related potential service and performance requirements for 5G system enhancement that can provide highly reliable, effective and efficient communications service for a group/family of service robots that act as a UE, Relay UE, or both.

* + Enhanced support of on-demand priority communications that are necessary to help avoid or minimize disruptions of service robot operation
    - Exposure to application-layer information that becomes available to communications layer
    - 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
  + 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)
  + Support of service operations aspects, including avoiding or minimizing service disruption due to employing new technology that serves multiple purposes using a common frequency band (e.g., usage scenarios of integrated communication and sensing service that can affect service disruption of cloud-based robot services, trade-off between temporary congestion and temporary performance degradation of any newly-employed technology for service robots).

NOTE 2: Due to the inherent nature of service robot operations and their related scenarios, the use of sensing and impact on communication disruptions/congestion might be described in service flow and descriptions during the study but this study is not intended to identify sensing specific requirements.

* + This study will consider high level service scenarios that have security and privacy implications for resilient operations of a network of service robots.

NOTE 3: Potential threat cause factors in the presence of advanced multi-sensory robot systems will be considered for possible derivation of security/privacy guidelines and/or high-level security and privacy related requirements.

Among various domains of service robots, this study will focus on the support for usage scenarios, such as how to improve the quality of ordinary living (e.g., care-giving) and quality of critical roles (e.g., smart local delivery, highly interactive controls under hazardous conditions) , that can be used against challenges that arise from aging population and/or pandemic situations.

Finally, this study will investigate potential service requirements on media aspects for optimizing the machine-type communications.

# 5 Expected Output and Time scale

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| New specifications {One line per specification. Create/delete lines as needed} | | | | | |
| Type | TS/TR number | Title | For info  at TSG# | For approval at TSG# | Rapporteur |
| "Internal TR" | 22.XXX | Study on 5G System Support for a Network of Service Robots with Ambient Intelligence | TSG#96  Dec. 2022 | TSG#97  Mar. 2023 | LEE, Ki-Dong (kidong.lee@lge.com), LG Electronics |
|  |  |  |  |  |  |

{Note 1: Only TSs may contain normative provisions. Study Items shall create or impact only TRs.  
"Internal TR" is intended for 3GPP internal use only whereas "External TR" may be transposed by OPs.}

{Note 2: The first listed Rapporteur is the specification primary Rapporteur. Secondary Rapporteur(s) are possible for particular aspect(s) of the TS/TR. In this case, their responsibility has to be provided as "Remarks".}

|  |  |  |  |
| --- | --- | --- | --- |
| Impacted existing TS/TR {One line per specification. Create/delete lines as needed} | | | |
| TS/TR No. | Description of change | Target completion plenary# | Remarks |
| {e.g. "22.281"} | {Possible values:  - either free text (e.g. “CS aspects to be removed")  - or “Specification to be withdrawn”} | {e.g. "TSG#89"} | {Free text} |
|  |  |  |  |

# 6 Work item Rapporteur(s)

LEE, Ki-Dong, kidong.lee@lge.com, LG Electronics

# 7 Work item leadership

SA1

# 8 Aspects that involve other WGs

# 9 Supporting Individual Members

|  |
| --- |
| Supporting IM name |
| LG Electronics |
| LG Uplus |
| OPPO |
| Korea Railroad Research Institute (KRRI) |
| China Unicom |
| Kyonggi University |
| Institute for Information Industry (III) |
| Kontron Transportation France |
| CATT |
| Orange |
| SK Telecom |
| Xiaomi |
| Sharp |
| Hyundai Motors |
| Verizon UK Ltd |
| Futurewei |
| KT [?] |
| Hansung University [?] |
| Tencent |
| Spreadtrum [?] |