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Standardization (final version)

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EXECUTIVE SUMMARY

The IntellIoT deliverable D6.10 is the final deliverable reporting the Standardization activities following by IntellIoT described in Task 6.4 between M13 to M40. The objective of this document is therefore to report on suitable standards investigated during that period.

It provides a brief overview of key Standards Development Organisations (SDOs), identify a subset, which closely match IntellIoT development and finally describes standardization events to which IntellIoT contributed.

The final version includes the descriptions of the latest specific contributions to SDOs and finally reports on standardization event participations.

The IntellIoT iKPI 2.1 "Influence standardization with at least 4 contributions" has been reached with 11 contributions.

1 INTRODUCTION

1.1 Objectives

The 'Standardization' Task 6.10 is part of the Impact, Dissemination and Standardization Work Package (WP6) of the IntellIoT project. Task 6.4 started on M13 and completed at the end of the project. The objective of T6.4 is to globally coordinate the standardization activities of the IntellIoT project. It will identify standards gaps and, when judged adequate propose contributions aimed to fill them. It will contribute to relevant Standard Development Organizations (SDO) bodies among the different IntellIoT WPs and tasks to provide a coherent impact of the IntellIoT project. Task 6.4 provides deliverables D6.4 and D6.10 (this document).

Starting T6.4 at M13 is mostly due to leave enough time for the IntellIoT WP2 activities (in particular D2.2 - Technology analysis & requirements specification) to specify the technological areas targeted by the project and the state-of-the-art contributions it will try to make. Based on this technology roadmap, T6.4 will try to identify the respective SDOs that IntellIoT needs to monitor and file proposals to advance or extend the standards they supervise.

As founding member of the OpenAirInterface Software Alliance (OSA)[1] and related Open 5G software platform, EURECOM closely follows 3GPP activities and whenever coherent, also contributes to it. Accordingly, EURECOM provided an overview of the 5G (rel.15 and rel.16) and 5G+ (rel.17-18) standards that are related to the IntellIoT platform, in particular the interaction between the 5G components and the other components such as AI/ML, TSN, IoT or Edge management.

EURECOM, SIEMENS and HSG followed W3C (the World Wide Web Consortium) in particular its Web-of-Things (WoT) activities, as WoT is central to the IntellIoT distributed edge orchestration and TTC followed IEEE activities related to TSN.

The rest of this document is organized as follows. Section 2 provides a rapid overview of SDOs related to IntellIoT activities. Section 3 focuses on specific SDOs identified where IntellIoT followed and contributed. Finally, Section 4 reports on SDO events to which IntellIoT T6.4 partners participated.

[1] https://openairinterface.org/

2 SDO OVERVIEW RELATED TO INTELLIOT

IntellIoT is envisioned as a reference architecture for next generation IoT. To achieve its full potential in that regard and drive adoption of its proposed technologies and concepts, it participated in standardization efforts both at the European area and globally. As such, IntellIoT partners have been actively contributing the project results to SDOs and have been engaged in a series of working groups related to existing and emerging standards. The next subsections highlight SDOs that IntellIoT targeted.

2.1 Alliance for IoT Innovation (AIOTI)

The AIOTI was launched by the European Commission and various key IoT players, such as SIEMENS, to give EU the lead in the IoT field by creating a European IoT ecosystem. The IoT Standardisation Working Group aims to address existing IoT standards, analyse gaps, and develop strategies and use cases for consolidation of architectural frameworks and (semantic) interoperability. The IntellIoT project has aligned its activities and contributed to the IoT Standardisation WG03 and Innovation Ecosystems WG02. Specifically, our goal has been to promote the HyperMAS and the associated semantic models for artefacts and things towards AIOTI.

Moreover, the three IntellIoT vertical use cases on agriculture, healthcare, and manufacturing have been aligned with "WG06 - Smart Farming and Food Security", "WG05 - Smart living for ageing well", and "WG11 – Smart Manufacturing" of AIOTI, respectively.

2.2 World Wide Web Consortium (W3C)

W3C is the international community that develops open standards to ensure the long-term growth of the Web. The W3C **Web of Things** Working Group (WoT WG) aims to accelerate the development of IoT applications by defining a description format for Things and APIs to interact with them. SIEMENS and EURECOM are founders of this group and have exploited the results on the Thing Description to flexibly integrate IoT devices into IoT applications defined through IntellIoT's MAS.

SIEMENS, EURECOM, and HSG contributed to the W3C WoT WG with work on the semantic models for things and artefacts and on interoperability challenges for physical, Web-connected, devices. HSG contributed to define a charter for a future standardization group on MAS and submitted key findings of IntellIoT as a W3C Member Submission.

2.3 3rd Generation Partnership Project (3GPP)

3GPP is the international standard development organisation for cellular technology. 3GPP leads the development of 5G over releases with the aim to provide a harmonized architecture for various verticals. The IntellIoT project closely interacted with the 3GPPP by monitoring the latest Work Items (WIs) in rel. 16, rel. 17, rel.18 and integrated selected features in EURECOM's OpenAirInterface 5G Platform. EURECOM contributed to the 5G smart factory, Wireless TSN V2X, extended relays WIs at 3GPPP. SIEMENS contributed with extended requirements from IntellIoT on Edge architectures.

2.4 European Telecommunications Standards Institute (ETSI)

ETSI is an independent non-profit standardization organization in the telecommunications industry in Europe. It shapes in its MEC-related standards an open environment, which allows the efficient and seamless integration of applications from different providers across multi-vendor Multi-access Edge Computing platforms. For IntellIoT, interoperability between MEC platforms and deployed IoT applications have been critical. Learning from IntellIoT's work on dynamic infrastructures for IoT environments, EURECOM contributed to defining capabilities of MEC platforms for direct communication to provide a localized IoT context between MEC and IoT devices.

2.5 IEEE Standardization Association

This organization within IEEE develops global standards in a broad range of industries. One of the IEEE standards that has been important for IntellIoT is the IEEE 802.1 Time-Sensitive Networking (TSN). This is the set of IEEE 802 Ethernet sub-standards defined by the IEEE TSN task group, where TTTech (parent of TTC) is a member. The standards describe mechanisms for improved or guaranteed real-time delivery of Ethernet traffic. TSN defines the first IEEE standard for time-triggered message forwarding in a switched Ethernet network, and therefore fully deterministic real-time communication. TTC/TTTech contributed towards integrating TSN into off-highway domains, i.e., relevant for the agriculture use case. SIEMENS provided project findings in the manufacturing use case to the TSN standardization and has observed IEEE P1918.1 (Tactile Internet).

2.6 Internet Engineering Task Force (IETF)

IETF is the organization standardizing Internet technologies. Within the IETF is the DETNET work group, which defines Layer 3 (IP) mechanisms supporting deterministic networks. DETNET currently builds from IEEE 802.1 TSN set of standards. EURECOM monitored DETNET to evaluate the extension architectures of OpenAirInterface toward L3 TSN.

2.7 OPC Foundation

OPC Foundation is an industry consortium, which creates and maintains standards for open connectivity of industrial automation devices and systems, such as industrial control systems and process control. The OPC standards specify the communication of industrial process data, alarms and events, historical data and batch process data between sensors, instruments, controllers, software systems and notification devices. TTTech (parent of TTC) and SIEMENS are members of the OPC Foundation and investigated opportunities to bring OPC to new domains, such as agriculture and contributed to the development of OPC (UA) in combination with deterministic communication (e.g., TSN) to improve reliability and timeliness of communication.

2.8 OPC Field Level Communication (FLC) Initiative

The Initiative has the goal to deliver an open, cohesive approach to implement OPC UA including TSN on field devices for all relevant industry automation use cases. The working groups in this initiative work on harmonizing and standardizing application profiles for IO, motion control, safety and system redundancy, information models for field level devices and mapping of OPC UA application profiles related to real-time operation on Ethernet networks (including TSN). SIEMENS and TTTech (parent of TTC) are partners in this initiative and contributed with IntellIoT findings to the profiles defined by the working groups.

2.9 5G Alliance for Connected Industries and Automation (ACIA)

5G ACIA is the central global forum for shaping 5G in the industrial domain. On one platform, various industries from all over the world jointly create a new ICT and OT ecosystem and set the frameworks for a highly attractive emerging market.

2.10 6G Industry Alliance (6GIA)

6G smart network and service industry alliance (6G-IA) is a recent alliance for 6G R&D regrouping a global industry community of telecom & digital actors. 6GIA major activities is to define the scope & objectives of Horizon Europe Smart Network & Services (SNS) calls, and accordingly has WI in various layers, such as Pre-standardization, CCAM or Spectrum.

3 CONTRIBUTIONS & STATUS OF SELECTED SDO

We list below the contributions or investigation of selected SDO, which either develop standards that IntellIoT needs to use, or where IntellIoT could contribute.

3.1 5G ACIA

SIEMENS and EURECOM contributed to the activities of the 5G ACIA standardization group with use cases for Edge computing in a 5G environment of a manufacturing shop floor as well as distributed AI.

3.2 W3C WoT WG

Integration with the W3C Web of Things Working Group has been an important consideration in the IntellIoT project from the project start, since the project set out to exploit the recently standardized W3C WoT Thing Description (WoT TD) for interoperability between decoupled services within the IntellIoT architecture, and specifically (in WP3) for enabling the simple programming of multiagent systems against services that provide W3C WoT TDs. The project's WPs, especially WP3, have made significant contributions to the validation of W3C WoT TDs in use cases, the creation of tooling and libraries around W3C WoT TDs, and the extension of W3C WoT TD.

The IntellIoT project integrated W3C WoT standards, in particular the W3C WoT Thing Description that was accepted as W3C Recommendation on April 9, 2020, and updated to Version 1.1 on January 19, 2023. Overall, IntellIoT's proposal to use W3C WoT TD within the project demonstrated that further tooling and *easy to access* guidelines for the use of W3C WoT TD by practitioners is required. While the original approach in the IntellIoT project has been that service providers also provide WoT TDs for their services (which is the intended approach put forward by W3C WoT), in practice we observed that service providers are (at most) familiar with human-oriented API descriptions such as OpenAPI. It was very hard for partners, especially in the use cases, to themselves design WoT TDs, and this led to the (unfortunate) situation that the partner most familiar with W3C WoT TD was creating most of these descriptions; based on this, we could hence not claim that W3C WoT TD *effectively* permitted the decoupling of services and their usage from an *organizational* standpoint. During the IntellIoT project, we also engaged in an exchange with the EU domOS project (Horizon 2020 Grant Agreement No. 894240), which reported similar organizational obstacles and which, curiously, treated W3C WoT TD documents as internal at first, perhaps indicating a misunderstanding about the purpose of these documents and reinforcing the requirement for easy to access guidelines. However, as expected, the usage of W3C WoT TD from a *technical* integration viewpoint proved effective once the appropriate tooling was available, which is what this project set out to create.

IntellIoT and HSG reported to the W3C WoT Working Group about the usage of, and extensions to, the W3C WoT that originate from the IntellIoT project on March 24, 2023, and included the findings from IntellIoT into the W3C WoT Use Cases and Requirements document[2]. At these occasions, HSG hence presented the IntellIoT Use Cases, focusing on UC1 and UC3 and on the ongoing integration with the EU domOS project. In addition, HSG reported on the following conceptual advancements of W3C WoT.

W3C WoT Thing Models for Late Binding in Edge Orchestration: As one outcome of the IntellIoT project, we proposed the usage of W3C WoT TD Templates (W3C WoT TD Version 1) and W3C WoT Thing Models (W3C WoT TD Version 1.1) for permitting late binding of edge-orchestrated services. We proposed that a service that is provided in an (industrial) IoT ecosystem may be hot-deployed only after the service's capabilities have been requested by a prospective client. This has advantages regarding resource usage, as undeployed services do not use resources. Furthermore, it brings benefits regarding the deployment management itself, as such services may be deployed to (edge) locations that are as close as possible (e.g., delay-wise) to the prospective client. In IntellIoT, this has been achieved through the Siemens

[2] https://www.w3.org/TR/2021/NOTE-wot-usecases-20210518/

Edge Orchestrator. The Edge Orchestrator emits W3C WoT Thing Models (i.e., Thing Descriptions without protocol binding) and clients – in the scope of WP3, Autonomous Agents within a Hypermedia MAS - are programmed against these models. At run time, an Agent requests a service (via its model) from the Edge Orchestrator and is, in turn, supplied with a protocol-bound W3C WoT TD that it can use to access the service. Since several IntellIoT services encapsulate machine-learning systems, members of the project proposed an extension to W3C WoT Thing Models (and TDs) with parameters that inform prospective clients about the machine-learning-related capabilities of the services.

W3C WoT TD-based Journaling of Interactions: Within the IntellIoT project, we proposed and implemented a prototype that demonstrates the journaling of W3C WoT TD-based interactions in a distributed ledger. This has advantages for the monitoring of an IoT system at run time, its auditing, and for root-cause analysis when encountering problems. Specifically, we proposed that both, clients of a W3C WoT TD-described interface as well as the service behind the interface, journal their interactions to enable these features. In this way, both the concrete exchanged messages (according to the TD-binding) and the service descriptions that were effective during run time are recorded. Specifically, in the IntellIoT project, this journaling has been implemented while using a distributed ledger via a DLT Client; however, any other (sufficiently trusted) journaling infrastructure may be used. We argue that it is a natural extension point for W3C WoT TD and have proposed that W3C WoT discusses the journaling of TD-based interactions.

Exposure of W3C WoT TDs via a Hypermedia MAS Infrastructure: The Hypermedia MAS Infrastructure supports the creation of Hypermedia MAS following the JaCaMo meta-model[3] and is an extension of the Yggdrasil[4] framework (see D3.5 for further details). The infrastructure supports the execution of computational artifacts, allows agents to instantiate artifacts, exposes HTTP interfaces for interacting with the artifacts, and generates W3C WoT TDs for the instantiated artifacts; these can be complemented by W3C WoT TDs for external devices or services. The resulting hypermedia environment is represented using the Resource Description Framework (RDF), which allows agents to query the environment at the knowledge level, and the infrastructure is compatible with a search engine[5] for the W3C WoT. We proposed that this concept be used as a blueprint for W3C WoT TD-based systems that would include Autonomous Agents. The concept and a largescale practical Hypermedia MAS have been presented in the AMAS 2024[6] event.

W3C WoT TD-based No-Code Development for Domain Experts: As part of IntellIoT, we developed a Web-based Agent IDE with a visual programming system that domain experts without programming experience can use to configure and deploy a Hypermedia MAS and that is based on W3C WoT TDs. Our Web-based Agent IDE (see D3.5 for further details) has been implemented as a Web application and let users program Autonomous Agents with a block language, which is based on the Blockly[7] library. The main aspect that is of relevance to the W3C WoT Working Group is that functional blocks in our language are automatically generated from W3C WoT TDs. Specifically, the Web-based IDE fetches the W3C WoT TDs of all registered services and then generates functional blocks from these TDs that are provided to domain experts as visual programming abstractions. When the domain expert has finished implementing a system using these blocks, the Web-based IDE is used to deploy the created Hypermedia MAS to the infrastructure. In this way, agent logic can be implemented against W3C WoT Interaction Affordances defined in a W3C WoT TD while resolving the protocol binding only at run time. This avoids compiling against bindings that might change at run time

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[3] https://mitpress.mit.edu/9780262044578/multi-agent-oriented-programming/
[4] https://link.springer.com/chapter/10.1007/978-3-030-25693-7_15
[5] https://dl.acm.org/doi/10.1145/3365871.3365901
[6] Danai Vachtsevanou, Bruno de Lima, Andrei Ciortea, Jomi Fred Hubner, Simon Mayer and Jérémy Lemée, Enabling BDI Agents to Reason on a Dynamic Action Repertoire in Hypermedia Environments, AAMAS 2024.
[7] https://developers.google.com/blockly?hl=de

and hence break the application, which extends one of the core approaches of W3C WoT TD to no-code environments. An initial report was published at the AAMAS 2023[8] conference and a larger implementation has been published in AAMAS 2024[9].

Investigation of Affordance Theory in the Context of W3C WoT TDs: IntellIoT has contributed to a deep investigation of ecological psychology and, specifically, of Affordance Theory, in the context of the guidance of interactions of autonomous hypermedia clients with affordances that they might exploit on the Web. In this research, which was published at AAMAS 2023[10], we have built on Affordance Theory concepts to support interaction efficiency in evolvable hypermedia environments such as in the IntellIoT use cases and we concretely introduced signifiers as a first-class abstraction in Web-based MAS. Specifically, we argued that we should differentiate between *signifiers* and *affordances*, where signifiers are designed with respect to the agent-environment context of their usage and enable agents with heterogeneous abilities to act and to reason about action, which we argued is more in-line with Affordance Theory than the current W3C WoT terminology. We further defined a formal model for the contextual exposure of signifiers in hypermedia environments and demonstrated our approach with a prototypical Web-based MAS whose scenario was created according to IntellIoT UC3 and where two agents with different reasoning abilities proactively discovered how to interact with their environment by perceiving only the signifiers that fit their abilities. We show that signifier exposure can be inherently managed based on the dynamic agent-environment context towards facilitating effective and efficient interactions on the Web.

Contribution to the Creation of a W3C Community group on Autonomous Agents on the Web: In addition to the above-mentioned contributions to a W3C standard, the IntellIoT project has contributed to the creation of W3C WoT Community Group on the topic of *Autonomous Agents on the Web*.[11] Led by another research project on Hypermedia Communities of People and Autonomous Agents (Swiss National Science Foundation Project #189474), we have contributed use cases and implemented artifacts from IntellIoT and have agreed on the creation of this group at a Dagstuhl Seminar on the topic of *Agents on the Web* in February 2023. The W3C WoT Community Group has been officially founded on March 21, 2023.

Overall, we evaluated the contributions of the IntellIoT project on the basis of W3C WoT as very timely and significant. We proposed our concepts to the W3C WoT Working Group and bootstrapped the W3C WoT Community Group on *Autonomous Agents on the Web* with significant thrust from the IntellIoT project.

3.3 3GPP

3GPP has completed its rel.16 5G NR specification and is actively working on its rel.17. In a nutshell, 3GPP rel.15 provided the specification of 5G NR, with minor support for services and functions required by IntellIoT. 3GPP rel.16 proposed extended functions of 5G NR, such a Vehicular-to-Everything (V2X) architecture, preliminary URLL mechanisms or architecture for Private 5G Networks. The project however had to wait for rel.17 and rel.18 to actually see functions that would be beneficial to IntellIoT either in its tight integration of AI, private network management or extended Device-to-Device support. Accordingly, EURECOM anticipated future 3GPP releases and proposed various extensions to 3GPP standards in anticipations to future compliances. EURECOM proposed a deterministic D2D scheduler, which APIs would only be compliant with expected future 3GPP release. Similarly, EURECOM's AIaaS platform, the IAKM

[8] Danai Vachtsevanou, Andrei Ciortea, Simon Mayer and Jérémy Lemée, Signifiers as a First-class Abstraction in Hypermedia Multi-Agent Systems, AAMAS 2023
[9] Danai Vachtsevanou, Bruno de Lima, Andrei Ciortea, Jomi Fred Hubner, Simon Mayer and Jérémy Lemée, Enabling BDI Agents to Reason on a Dynamic Action Repertoire in Hypermedia Environments, AAMAS 2024
[10] https://arxiv.org/abs/2302.06970
[11] https://www.w3.org/community/webagents/

component, has been initially developed outside the scope of 3GPP until 3GPP standardised its NetWork Data Analytics Function (NWDAF) architecture and framework for AI in rel.17. Once this standard has been published, EURECOM integrated the IAKM architecture with the NWDAF APIs to provide a 3GPP-compliant AIaaS architecture based on IntellIoT UC1 and UC3.

3.3.1 ULTRA-RELIABLE LOW LATENCY IN 5G RAN AND 5G CORE NETWORKS

5G system is supposed to be able to provide data transfer capability with strict performance requirements, e.g., very low latency and high reliability requirements, to fulfil the demands of vertical markets and applications.

Reaching URLL is not limited only to enhancing the 5G RAN but also to provide management functions to maintain it during 5G communications. This also requires extensions in the 5G Core Network, to support URLLC services within 5G system, in particular

-The support of the high reliability by redundant transmission in user plane

-The support of the low latency and low jitter during handover procedure

-The enhancement of Session Continuity during UE Mobility,

-The support of QoS monitoring to assist URLLC Services

Extensions are provided in 3GPP TS 23 501 TS 23 502 and TS 23 503 in rel.16 and beyond.

3.3.2 VEHICLE-TO-EVERYTHING EXTENSIONS

3GPP defined a first specification of 5G NR V2X in rel.16. Although multiple scheduling options (with or without network support) have been envisioned, 5G NR V2X rel.16 only support a basic LTB-SPS scheduler similar to LTE V2X.

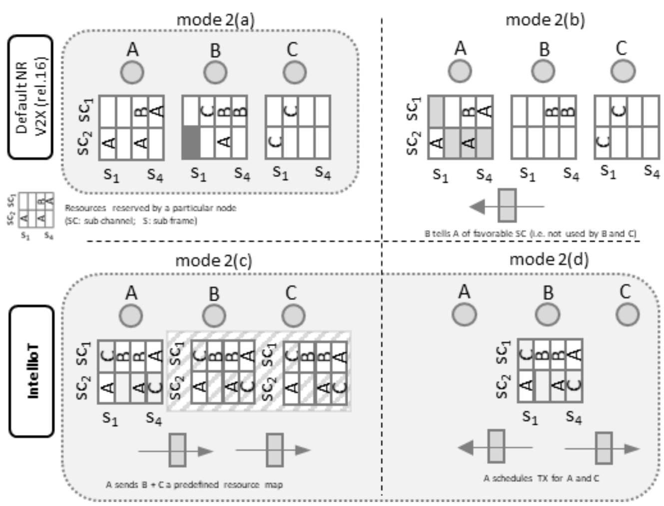

Figure 1 5G NR V2X scheduling paradigm for ad-hoc mode

Support for different scheduling paradigm (compared to the basic LBT-SPS imported from LTE V2X) is under study in rel. 17. As depicted in Figure 1, scheduling paradigms corresponding to mode 2(c) or 2(d) are promising candidates to reach URLL on the 5G NR Sidelink.

In addition, the 3GP LTE ProSe rel.12 specification has been integrated as 3PGG 5G NR Prose in Rel.17, providing a generalized description of D2D communication and services in 3GPP. This is a critical extension, as although 5G NR V2X provides significant innovations for sidelink communication, V2X remains the only supported service. 5G NR ProSe generalizes sidelink service and group management such that various robots or tractors would be able to join in non-interfering sidelink groups according to the offered Proximity Service.

Finally, 3GPP investigated functions for extended relay support in TR 22.866 rel.17 and TS 38.351 rel.18 as a way to support RAN-based relaying as well as multi-hop relaying. In particular, the Sidelink Relaying Adaptation Layer (SRAP) provides an important new feature to filter relaying packets according to radio bearers and accordingly to support QoS-based relaying or even multi-hop routing.

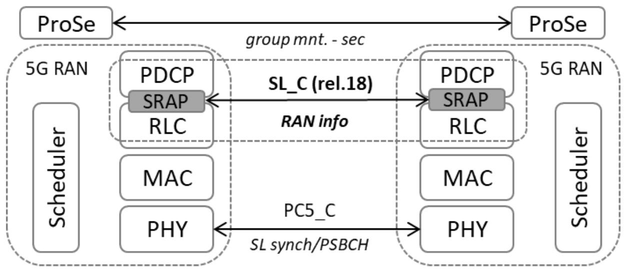

Figure 2 5G NR Sidelink Relaying Adaptation Layer (SRAP)

The 3GPP technical report related to extended relaying support for 5G NR Sidelink provides various potential use case descriptions, which could benefit from multi-hop 5G NR D2D communications. One of them is on Smart Factory. Considering potential radio obstacles and required energy saving requirements on mobile robotics or sensors, a multi-hop mesh topology is envisioned to maintain a robust connectivity between all devices and an edge gateway.

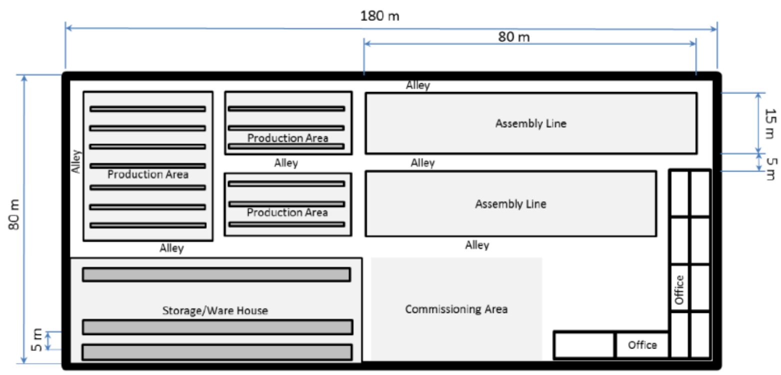

Figure 3 Smart Factory Topology and related radio obstacles

(source: 3GPP TR 22.866)

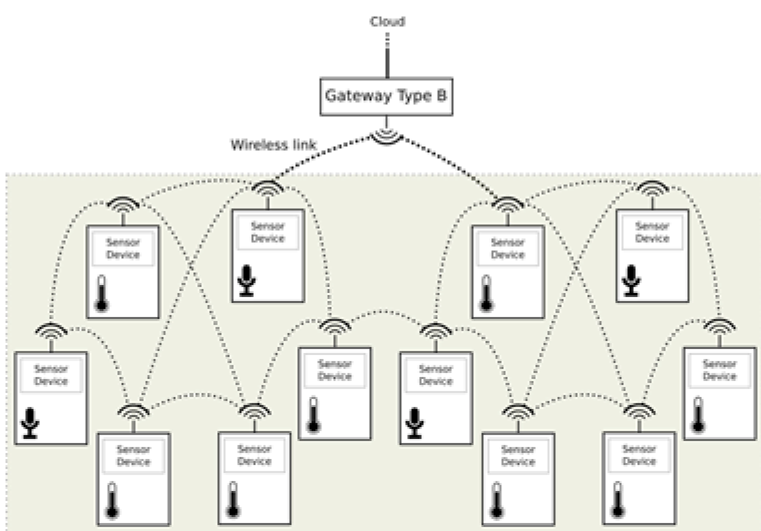

Figure 4 Smart Factory UEs forming a multi-hop mesh topology to an edge gateway

(source: 3GPP TR 22.866)

3.3.3 AI/ML INTEGRATION IN 5G SYSTEMS

3GPP rel. 18 extended the 5G Core System specification in TS 22.261 to provide requirements of the 5GC to integrate AI/ML service in future release. According to TS 22.261 rel.18, a 5G System should support the following AI/ML operations:

- AI/ML operation splitting between AI/ML endpoints - The intention is to offload the computation and energy intensive parts to network endpoints (edge devices), whereas leave the privacy and delay - sensitive parts at the end device.

- AI/ML model/data distribution and sharing over 5G system - Multi-functional mobile terminals might need to switch the AI/ML model in response to task and environment variations. The condition of adaptive model selection is that the models to be selected are available for the mobile device.

- Distributed/Federated Learning over 5G system - The cloud server trains a global model by aggregating local models partially-trained by each end device. Within each training iteration, a UE performs the training based on the model downloaded from the AI server using the local training data.

As it can be seen, these 5G extensions are perfectly in-line with what is targeted in IntellIoT, although IntellIoT demonstrated the three AI/ML functions separately from a 5GS. Following 3GPP suggestions, the IntellIoT AI/ML as well as IAKM components and functions have been integrated in the 5G System (as described in TR 23.700-80).

In addition, 3GPP IntellIoT has been in-line with this specification, as the AIKM provided the required services, which will have been integrated into a 5G Core new Networked AI Function (NWAIF). Various Work Items (WI) have been initiated either on how to exchange AI/ML on a 5G RAN interface or how to manage AI models.

For example, according to TS 23.288, the NetWork Data Analytics Function (NWDAF), initially designed to gather and exchange data analytics at the 5G Core system can be extended to discover and exchange AI/ML models. For example, NWDAF may be subject to a logical decomposition into two logical functions such as Model Training logical function (MTLF) and Analytics logical function (AnLF) (see Figure 5 (ii) or trained ML model sharing between multiple NWDAF instances (i.e. 5G core networks) as in Figure 5 (iii). UE (edge nodes) may also instantiate a NWDAF to request a particular AI/ML function (see Figure 5 (iv). However, 3GPP also indicated that it does not intent to standardize the format or process of sharing AI/ML across vendors. IntellIoT IAKM component precisely did this. The IAKM[12] has only been partially integrated in the NWDAF and at a final phase of the IntellIoT project, due to delayed specifications by 3GPP of the required standards.

[12] https://gitlab.eurecom.fr/public-intelliot/iakm-bot

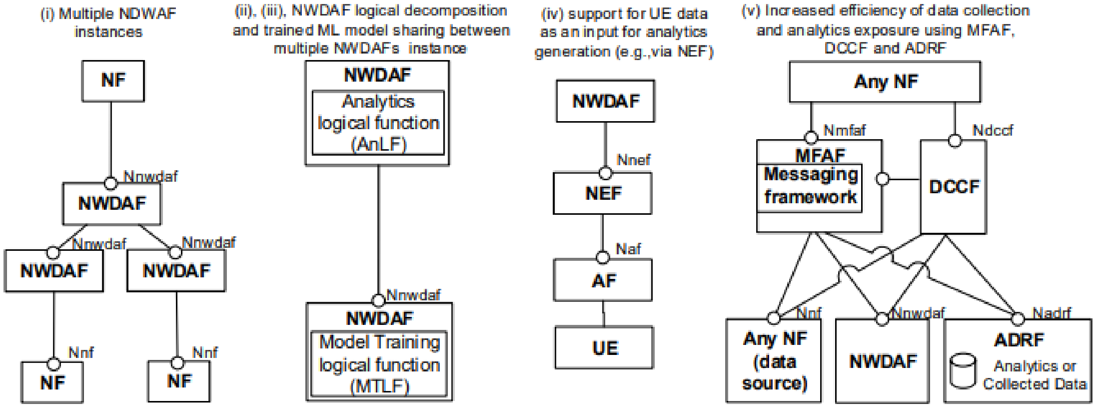

Figure 5 NWDAF extensions to support AI/ML in 5GS (source: Hexa-X, D5.1, Fig. 4-1)

3.3.4 INDUSTRIAL INTERNET-OF-THINGS (IIOT)

3GPP since rel.16 defined industrial IoT as a major application target and has been first discussing 3GPP use case requirements and KPIs in TR 23.700-20 and second extensions of the 5G RAN to support URLL in various Application Function (TS 38.473, TS 38.423, TS 38.463, TS 38.413).

A major function required is to enable the support of Time Sensitive Network (TSN) functions in a 5G system. EURECOM performed a technical analysis of the various approaches are proposed and the required extensions on the Private 5G component. The strategy followed by 3GPP and EURECOM has been to consider a 5G system as a TSN bridge as depicted in Fig. 8.

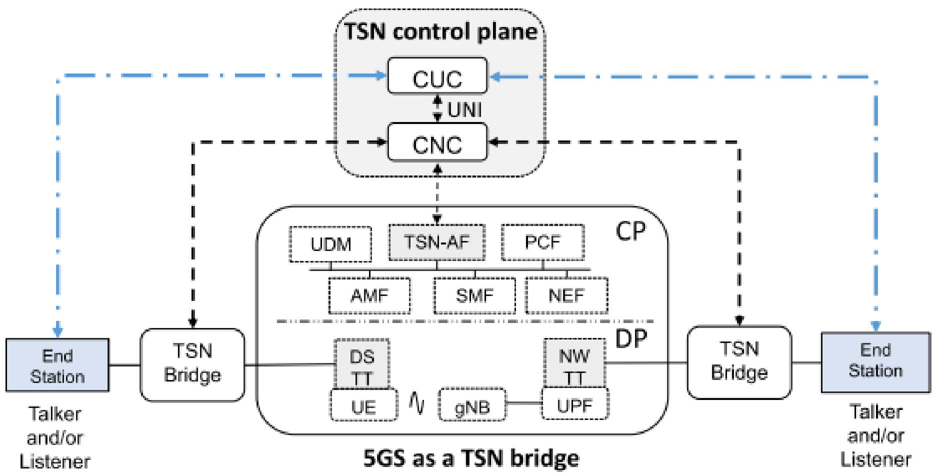

Figure 6 5G TSN architecture (5GS as a TSN bridge)

(source: S. Bhattacharjee et al, "Network Slicing for TSN-Based Transport Networks", IEEE Access)

Several challenges remained as discussed in TR 23.700-20, such as the dissemination of time synchronization between TSN devices in different TSN domains through a 5G system, which all required complex extensions of OpenAirInterface, notably to extend its support for L2 traffic. Providing a transparent TSN support of a 5G system is critical to Next Generation IoT solutions.

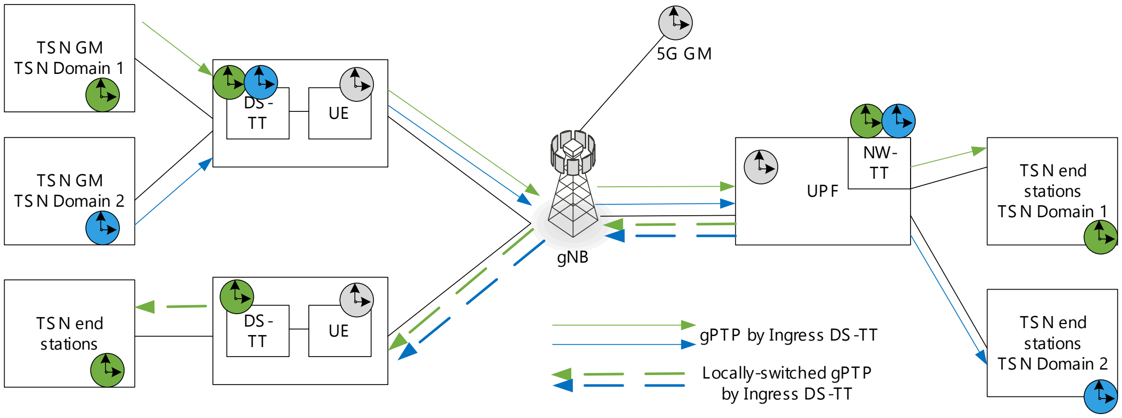

Figure 7 The distribution of UL Time Synchronization Information with the same User Plane Function (UPF)

EURECOM also conducted an analysis of another 3GPP domain related to Personal (or Private) IoT Networks, whose objective is to allow the hosting of the IoT management or bypassing the IoT backend management on a 5G system. In traditional IoT systems, data and applications are hosted at the IoT system provider, which opens critical questions related to data privacy or development of personal services based on personal IoT devices. 3GPP TR 22.859 describes extended functions, which will allow to consider IoT functions and IoT services at any other private 5G core network functions. Moreover, as described in Figure 8, 3GPP envisions a direct connection between a UE and a IoT PIN device (through a 5G Network) for edge provisioning and operation (case (a)). In addition, under the supervision of the private 5G Core network, a UE may directly connect to an IoT PIN device to extra data or control its actuation procedure.

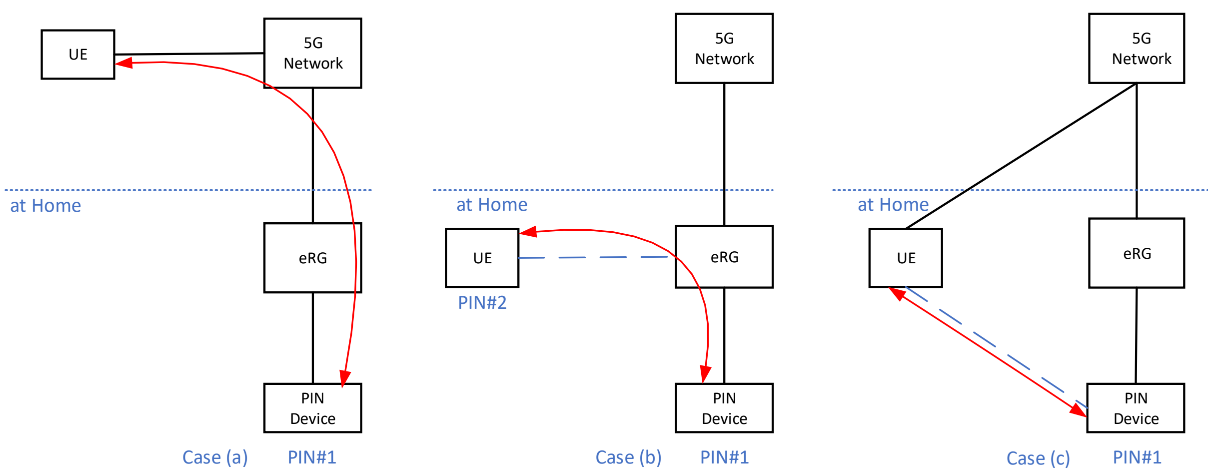

Figure 8 5G network support for a User/UE accessing services provided by in Home Devices

(source: TR 22.859 rel.18)

These new 3GPP functions showed to be particularly interesting for IntellIoT Smart Health use case (UC2), where medical wearable devices would not send data to a corporate IoT server, but rather to the private 5G Core function (NWDAF or NWAIF) or directly to a connected 5G UE.

3.4 Spectrum Aspects

3.4.1 PRIVATE 5G SPECTRUM

5G New Radio (NR) supports operation in a wide range of frequency bands, from 600 MHz to mmWave frequencies above 24 GHz. The majority of 5G deployments in Europe and the world utilize C-band spectrum in the 3.5 GHz range.

Private 5G Network are specific 5G deployment in campuses, in industrial entities or for industrial verticals, which would receive a localized exclusive license of usage. Commercial 5G operators, which need to provide a country-wide service continuity, and accordingly would need to use the same spectrum in the same country. Private 5G networks do not have such requirements and a more flexible spectrum reuse between the different deployment locations is envisioned.

If Private 5G spectra do not need to be harmonized country-wide (or even across country), hardware aspect would strongly favour to have similar private 5G spectrum bands throughout Europe. Unfortunately, private 5G spectrum allocations have not been harmonized at the UE level and each country decided which spectrum band would be allocated for private 5G usage. France allocated 3.8-4.0Ghz, whereas Germany allocated 3.7-3.8Ghz, or Switzerland recently allocated 3.4-3.5Ghz. Austria still needs to allocate private 5G Spectrum. These heterogeneous spectrum allocations are not expected to impact Private 5G Network deployments, with exceptions maybe of cross-border Private 5G sites (e.g. airports, custom, etc..). However, they will impact the 5G hardware, as a private 5G HW for France will not be compatible with a Private 5G HW for Germany, unless multi-bands Private 5G HW become available.

3.4.2 TIME DIVISION DUPLEX (TDD) NETWORKS

The majority of 5G deployments in Europe and the world utilize C-band spectrum in the 3.5 GHz range, and it is similar for the Private 5G spectra, in particular those used by IntellIoT. These frequency bands use a TDD scheme. In contrast to Frequency Division Duplex (FDD), where UL and DL data traffic use different frequency bands, TDD separates UL and DL traffic in time. This means that transmitter and receiver need to be synchronised and only transmit/receive in their respective time slots. In contrast to LTE, where there are seven distinct UL/DL patterns defined in the standards, 5G NR allows much more flexibility, and the pattern can be signalled by the network. To define a traffic pattern, individual slots can be assigned either to UL or DL traffic. In addition, there are so-called "special" slots which are inserted whenever the traffic switches from DL to UL. Special slots contain both DL and UL symbols as well as a guard period (GP) of empty symbols in between. Even the number of DL and UL symbols in these special slots can be configured. Two widely used patterns are DDDSUDDDSU and DDDSUUDDDD, with special slot configurations of 10:2:2 and 6:4:4 symbols assigned to DL, GP, and UL, respectively. An illustration of such configuration is depicted on Figure 9.

Figure 9 Two different DL optimized TDD configurations (source: 5GCroco D6.2)

Although 3GPP allows any type of TDD pattern, countries do not have similar ones. For example, France adopted a DDDSUUDDDD pattern to ensure coexistence with legacy LTE TDD networks. In Germany, on the other hand, a DDDSUDDDSU pattern is being used. These differences also apply to Private 5G, although the 'Private' aspect allows a better control on the TDD pattern.

TDD pattern have another issue: they are defined to favour a particular type of traffic. For instance, the patterns depicted on Figure 9 strongly favour DL traffic (i.e. from gNB to UE), which might be problematic if the required traffic is mostly UL (from UE to gNB). In commercial 5G NR deployment, traffic direction cannot be fully controlled and TDD patterns therefore need to be adapted to the traffic demand. Private 5G networks have one advantage is to be specialized to one or more use cases and as such traffic demand. Private 5G traffic does not stay static, but the Private 5G management has more control and predictability on the expected traffic at a given time. Finally, 5G NR Slicing adds also the possibility to alter the TDD configuration on various slices, which would allow for instance a DL-optimized TDD patterns for URLL and UL-optimized for eMBB slices respectively.

In IntellIoT, UC1 and UC3 have both traffic patterns strongly requiring UL traffic capacity. Large video-streams are transmitted UL either from the tractor cameras or from the HoloLens, whereas control commands to the tractor or instructions by the user to the HoloLens are transmitted DL. Accordingly, the default TDD configuration DDDSUDDDSU (i.e. 7:2) is not adapted. IntellIoT proposed a specific 1:1 TDD configuration corresponding equal number of UL and DL slots. This means that the IntellIoT Private 5G network provides equal UL/DL capacity. If an even stronger UL-preferred TDD configuration could better fit to the strong IntellIoT UL requirement, we opted for such configuration to also control the DL delay, as increasing UL slots would in turn impact the latency of DL traffic, which in IntellIoT must meet URLL requirements. In particular, we also adopted a 5ms TDD pattern.

3.5 AIOTI

IntellIoT use cases have been presented by EURECOM. Currently, contributions are being prepared to the AIOTI landscape maintenance & standardisation Task Force (TF). EURECOM contributed as input to the AIOTI survey Edge Computing OSS with its OpenAirInterface platform.

3.6 OASIS CACAO TC

A key enabler in the Trustworthiness pillar of IntellIoT is the SPHYNX Security Assurance Platform (SAP) which, in turn, integrates an Incident Response (IR) tool that offers security orchestration, automation, and response (SOAR) capabilities, supporting the prevention, detection, investigation, and response to cyber security attacks, as has been demonstrated in the relevant UC demos of the project.
At its core, the IR tool uses machine-processable & executable playbooks specified according to OASIS' Collaborative Automated Course of Action Operations (CACAO; see Figure 10) specification; it is in fact one of the first (if not the first), at the time of writing, commercial tool to do so.

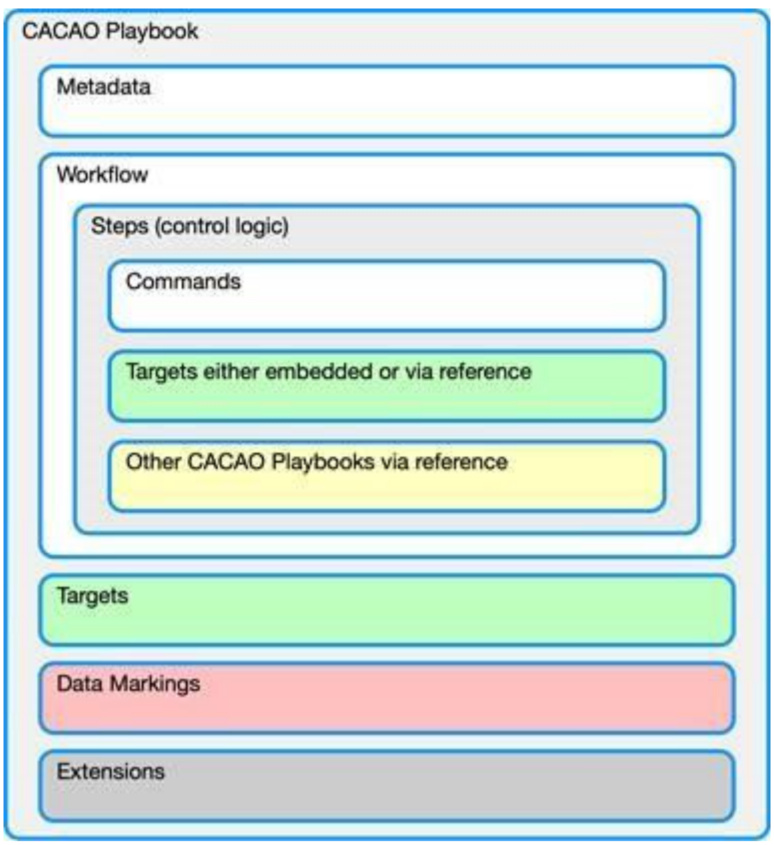

Figure 10 Overview of CACAO structure & objects (source: CACAO Security Playbooks Version 1.0 specification, OASIS)

As such, SPHYNX has been in continuous interaction with members of the OASIS Collaborative Automated Course of Action Operations (CACAO) for Cyber Security Technical Committee[6], providing its feedback & lessons learned from applying CACAO in practice within IntellIoT and its use cases. These recommendations have been considered for future versions of the CACAO specification, which is on its way to soon become a standard.

4 CONTRIBUTIONS TO EVENTS

4.1 EU-IoT Webinar

IntellIoT delivered a presentation in the H2020 EU-IoT project organised online workshop on "Next Generation IoT Architectures" on November 9th, 2021. Sphynx and EURECOM jointly disseminated IntellIoT's architectural vision in alignment with W3C WoT. The talk covered IntellIoT's vision and Next-Gen IoT, its architecture, and alignment with WoT components.

4.2 AIOTI

IntellIoT presented the objectives of the three use cases in the Standardization Task Force.

4.3 5G ACIA event

SIEMENS joined 5G ACIA plenary meetings between 21-23 of June 2021 for providing 5G requirements about "Augmented reality for remote operation" use case being developed in IntellIoT. This was part of WI058 (5G-ACIA_Req_5G_Devices_058) activity.

4.4 3GPP

EURECOM contributed to 3GPP RAN WI on 5G NR Sidelink (D2D) un unlicensed spectrum, as well as wakeup signals for low power 5G IoT devices. The former contribution is in line with the future extension of 5G NR D2D/V2X beyond the current ITS spectrum (5.9GHz), which needs to coexist with other technologies. The latter contribution aims at improving the energy efficiency of 5G low power devices with improved wake-up signals.

4.5 Mobile World Congress

From February 27th to March 2nd, 2023, EURECOM participated to the Mobile World Congress with a dedicated booth, where several innovative features and news where presented. The most important one is the announcement by the OAI general manager that the O-RAN alliance endorsed OpenAirInterface (OAI), as well as the full compliancy of the latest OAI 5G architecture with O-RAN. This has been a direct benefit from OAI's early adoption and integration of O-RAN standards, which impacted the implementation of the Private 5G components, notably by deprecating Flex-RAN and LL-MEC components and requiring to integrate O-RAN compatible replacements (Flex-RIC and Flex-CN).

From February 26th to February 29th, 2024, EURECOM participated to the Mobile World Congress along with one of its startups 'BubbleRAN' with a dedicated booth. At this event, BubbleRAN displayed a private 5G solution as a technology transfer from OpenAirInterface and EURECOM's components that were further developed as part of the IntellIoT framework. A mutual demo appearance at the Mobile World Congress 2024 will showcase this usage of private 5G for autonomous vehicles.

5 CONCLUSION

This document reported on activities of the IntellIoT standardization Task 6.4. It provided an overview of SDO related to IntellIoT activities and provided status and active or planned contributions in selected SDO consisting of 5G ACIA, W3C WoT, 3GPP and AIOTI. The iKPI 2.1 "Influence standardization with at least 4 contributions" has been reached, with contributions to W3C WoT, in particular the creation of a new working group specifically on an IntellIoT problematic, as well as 3GPP.

5.1 iKPI Aspect and Contributions to Standards

IntellIoT's iKPI 2.1 describes the expected achievements of T6.4. iKPI 2.1 requires T6.4 to influence standardization with at least 4 contributions. We describe below the contributions of T6.4 to standards, mostly linked to W3C and 3GPP:

Contributions & Proposal:

- W3C - Support the creation of a W3C WoT Community Group on the topic of "Autonomous Agents on the Web".
- W3C - Proposal to use W3C WoT TD Templates (W3C WoT TD Version 1) and W3C WoT Thing Models (W3C WoT TD Version 1.1) for permitting late binding of edge-orchestrated services.
- W3C - Proposal to W3C to add functions to support WoT TD-based Journaling of Interactions.
- W3C - Proposal to add exposure of W3C WoT TDs via a Hypermedia MAS Infrastructure as a blueprint for W3C WoT TD-based systems that may include Autonomous Agents.
- 3GPP - Contributions to 3GPP on 5G NR D2D in unlicensed spectrum.
- 3GPP - Contributions to 3GPP on 5G NR URLL slot configuration optimization.

Participations & Presentations:

- W3C - Presentation of IntellIoT Use Cases to the W3C WoT Community Group, with focus on W3C WoT Thing Description, and on the integration with the EU DomOS project.
- W3C - Presentation of IntellIoT Integration of Thing Description Templates (W3C WoT TD Version 1) and Thing Models (W3C WoT TD Version 1.1) via the Siemens Edge Orchestrator.
- W3C - Presentation of IntellIoT Journaling of TD-based Interactions in a distributed ledger.
- W3C - Presentation of IntellIoT No-Code Development Environment for Domain Experts.
- W3C - Presentation of extension proposals to TD and TD Ecosystems based on IntellIoT use cases.

Following these contributions, the iKPI 2.1 is reached.