Edge Computing Standard Framework Concepts

Release 1.0

AIOTI WG Standardisation

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Executive Summary

This deliverable introduces the landscapes of Standards Developing Organisation (SDO), Alliance and Open Source Software (OSS) initiatives that are currently focusing on edge computing.

The main objective of this deliverable is to briefly present the global dynamics and landscapes of edge computing SDO, Alliance and OSS initiatives, which can be used: 1) to leverage on existing edge computing standardization, industry promotion and implementation of standards and protocols, and 2) to provide input to edge computing standardisation gap analysis activities.

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1 Goal and motivation

The integration and synergy of IoT/IIoT and edge computing, including as well the applied federated learning solutions, can be considered to be a part of the paradigm shift from centralised solutions to decentralised and distributed computing architectures. In this paradigm, the information processing is located close to the edge, where “things” (e.g., sensors/actuators, devices, machines and humans) produce and utilise this information, knowledge and related experience. In particular, with the increased concentration of data value at the edge, edge computing has become a vital component of the processing layer of the IoT architecture: to advance the real-time processing of large scale IoT applications deploying edge computing units with storage, computational, connectivity and intelligence capabilities to implement newly decentralised IoT solutions.

The realization of the Edge Computing evolution and remaining challenges involve the development of standards and protocols and as well the industry promotion and implementation of these standards and protocols. This depends severely on the work and activities accomplished in SDO (Standards Developing Organization), Alliance and OSS (Open Source Software) initiatives. It is therefore important to understand the global dynamics and landscapes of Edge Computing SDO, Alliance and OSS initiatives, which can be used: 1) to leverage on existing edge computing standardization, industry promotion and implementation of standards and protocols, and 2) to provide input to edge computing standardisation gap analysis activities.

Currently there are several SDO, Alliance and Open Source initiatives that are active and competing in the Edge Computing technologies. This is a normal development considering that edge computing technology is still in the early phase of deployment. In this context, the landscape is complex, dynamic and challenging to grasp and visualize.

The method used to realise these edge computing landscapes is based on the method described in the AIOTI WG Standardisation – IoT Standardisation report "IoT LSP Standard Framework Concepts Release 2.9". In particular, this report gives several ways of visualising the landscape in order to simplify and facilitate the usage of the information in various application domains. AIOTI WG Standardisation has chosen three ways for this representation. First, the landscape is divided into four quadrants, where the horizontal axis represents the market type and the vertical axis represents the technology area covered by these initiatives; second the initiatives are classified based on the vertical and horizontal application domains.

2 Edge Computing SDO and Alliance Initiatives Landscape

This section briefly introduces main Edge Computing SDO and Alliance initiatives that have a worldwide visibility and applicability and provides the global landscapes associated with these SDO and Alliance initiatives.

Figure 1 shows the “Edge Computing SDOs and Alliances Landscape (Technology and Marketing Dimensions)”, where these initiatives are projected based on two dimensions. The horizontal

axis represents the market type and the vertical axis represents the technology/solution/knowledge area that these initiatives cover and focus. It should be understood that the most left part of the horizontal axis represents the customer (i.e., Business to Customer: B2C) market, while the most right part of the same axis represents the industrial internet (i.e., Business to Business: B2B) market. The top part of the vertical axis represents the technology areas that are related to services and applications, while the bottom part of the same axis represents the technology areas that are related to connectivity.

The projection of these initiatives on these two dimensions has been accomplished based on discussions among experts participating in both AIOTI WG Standardisation and relevant initiatives as well as on the collected information presented in Appendix 1 (Section 4).

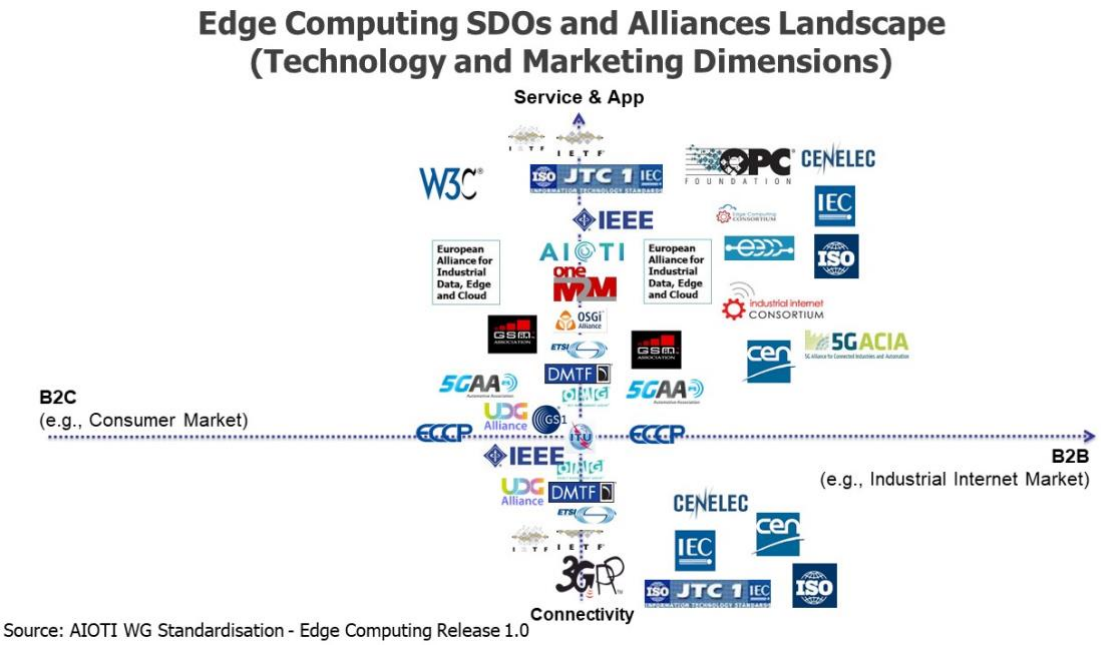


Figure 1: Edge Computing SDO and Alliances Landscape

In addition to the SDO and Alliance landscape shown in Figure 1 a projection of these initiatives into vertical industry domains is shown in Figure 2. The "Edge Computing SDOs and Alliances Landscape (Vertical and Horizontal Domains)" is a graphical representation aiming at highlighting the main activity (up to the day of generating this representation) of SDOs and Alliances with respect to the application domains represented as "verticals" and the Telecommunication Infrastructure domain represented as "Horizontal/Telecommunication".

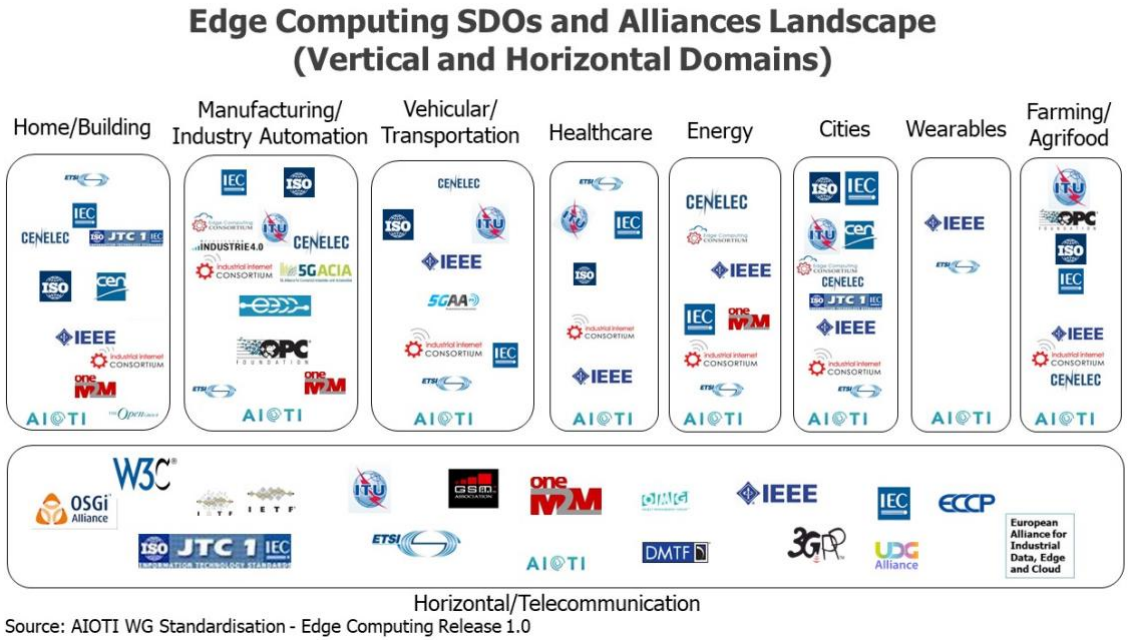


Figure 2: Edge Computing SDO and Alliance Initiatives Projection on Vertical and Horizontal Domains

The landscapes described in Figure 1 and Figure 2 show the current level of complexity of the activities related to the standardization of the Internet of Things from different perspectives.

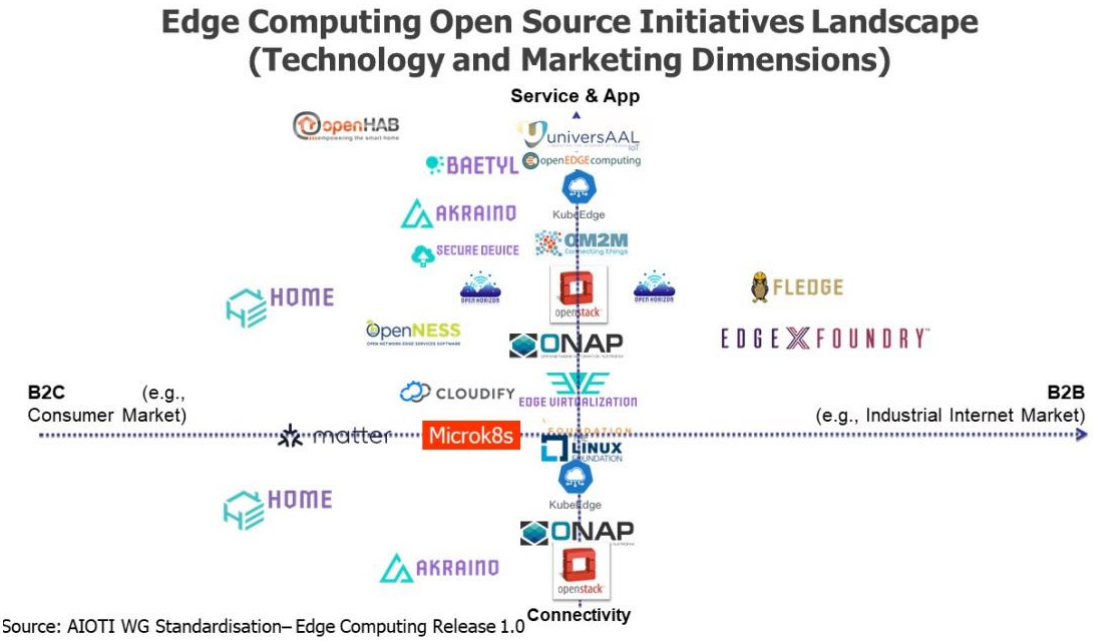
However, it has to be noted that there is a growing awareness in the market and in the standardization arena with respect to the need of Edge Computing standards convergence. Ongoing efforts in this perspective (e.g., recent actions to strengthen the collaboration among relevant SDOs involved in the horizontal/telecommunication dimension) are good premises of a simplification of this standards landscape in the medium term.

In this sense, in line with the goal and motivation of this deliverable, the experts participating in the AIOTI WG Standardisation expect this landscaping exercise will also contribute to the promotion of the Edge Computing standards convergence within the international community.

Appendix 1 (Section 4) provides the brief description of several SDO and Alliance initiatives shown in Figure 1 and Figure 2.

3 Edge Computing Open Source Software Initiatives Landscape

This section briefly introduces main Edge Computing Open Source Software (OSS) initiatives that have a worldwide visibility and applicability and provides the global landscapes associated with these OSS initiatives. The "Edge Computing Open Source Initiatives Landscape (Technology and Marketing Dimensions)" is a graphical representation that highlights the main activity (up to the day of generating this representation) of the open source initiatives in the area of IoT, according to the Business to Consumer (B2C) vs. Business to Business (B2B) (horizontal axis) and the Connectivity vs. Service & App (vertical axis) classifications. The dimensions of the landscape and the method used to project these OSS initiatives into the landscape shown in Figure 3 are the same ones as defined in Section 2.



Source: AIOTI WG Standardisation– Edge Computing Release 1.0

Figure 3: Edge Computing OSS Initiatives Landscape

It is important to be noticed that a projection of the OSS initiatives into vertical and horizontal industry domains, similar to the one shown in Figure 2, is not useful since the OSS initiatives are mainly focusing on the horizontal domain. Appendix 1 (Section 4) provides the brief description of several OSS initiatives shown in Figure 3.

4 Appendix 1: Edge Computing SDOs, Alliances and OSSs

This section provides a brief description of the SDO, Alliance and OSS initiatives shown in the landscapes figures included in Section 2.

This information has been provided by the AIOTI WG Standardisation members on a volunteering basis, generated by filling in the templates shown in Section 0. Official confirmation/verification coming from the relevant initiatives is expected to be realized in the future.

4.1 SDO, Alliance, and OSS Initiatives Template for Information Collection

If the SDO/Alliance/OSS is a large initiative, then the template should be applied for each of the Working Groups/Technical Committees that are focusing on IoT associated with each SDO/Alliance. Such large initiatives are ITU, IEEE, IEC, 3GPP, ETSI, IETF.

If the required information is not available, please fill in "Unable to find information"

- Description: main objective and focus of initiative
  Features: high level functionalities covered by the initiative

  Readiness: (for OSS, use Table 1: OSS Readiness Criteria and Options
- , for SDO/Alliances, use Table 2); **For each criterion please select one or more options**
- Interoperability level: identify the interoperability levels considered by the SDO/Alliance/OSS initiative, see Appendix A for details:
  - Syntactical interoperability
  - Technical interoperability
  - Semantic interoperability
  - Organisational interoperability
- Standards: standards and protocols proposed (SDO/Alliance) or supported (Alliance/OSS); Include details on whether an SDO/Alliance specified original protocols, or whether they are using and integrating standards and protocols developed by other SDOs
- Supporting organizations (mainly for Alliances/OSS): main organizations that back the initiative
- Domain: position the initiative, with respect to the four quadrants, see Figure 1 in Section 2, related to the market domain (consumer/industrial internet –horizontal axis) and the technical domain (connectivity, service & applications – vertical axis).
- Application area: whether the SDO/Alliance/OSS (or the WG/TC) initiative is focusing on integrated/complete solutions, i.e. horizontal industry, or whether it is focusing on a particular vertical industry (e.g., Smart City), when applicable, see Figure 2 in Section 2.
- IPR Policy Available: mention if there is any IPR policy available (e.g., FRAND); if available include a reference to the description of this IPR policy
- Specification Access: Describe whether and how SDO/Alliance/OSS members and non-members can get access to published and non-published (draft) specifications and/or software

Table 1: OSS Readiness Criteria and Options

1. Community

- Multiple individuals, no formal charter
- Mostly one single organization
- Multiple organizations
- Formal consortium

2. Commitment

- Mostly one committer
- Multiple volunteer committers
- Formally appointed committers from organizations
- Dedicated committers from organizations

3. Road map:

- Sporadic releases
- Frequent but non planned releases (release when ready)
- Planned releases
- Formal road map

4. Alignment of ongoing Standards

- Not aligned with SDO standards
- OSS output is aligned with SDO specifications

5. Licensing

- No license
- Type of license

6. Portability

- Only one target platform
- Multiple platforms are possible but no developed
- Multiple platforms are developed by project
- Platform independent

Table 2: SDO/Alliance Readiness Criteria and Options

1. Adoption (users base)

- No implementations
- Reference implementations
- Widely adopted in industry

2. Development Status

- Under development
- Approved with no planned revisions
- Approved with planned revisions

3. Compliance

- Not managed
- Having compliance testing process (include test suites, method, etc.)
- Formal certification process

4. Openness

- Very restrictive membership and closed to few entities
- Restrictive membership procedure
- Open by formal membership
- Open to public

5. Ratification process (how the standard is being approved?)

- Closed process done by members only with no consultation from external parties
- Done by members and open for consultation from external parties
- Open process for all parties interested in the ratification

More details on interoperability levels are provided below:

- **Technical Interoperability**: is usually associated with hardware/software components, systems and platforms that enable machine-to-machine communication to take place. This kind of interoperability is often centred on (communication) protocols and the infrastructure needed for those protocols to operate.
- **Syntactical Interoperability**: is usually associated with data formats. Certainly, the messages transferred by communication protocols need to have a well-defined syntax and encoding, even if it is only in the form of bit-tables. However, many protocols carry data or content, and this can be represented using high-level syntaxes such as HTML, XML or JSON.
- **Semantic Interoperability**: is usually associated with the meaning of content and concerns the human rather than machine interpretation of the content. Thus, interoperability on this level means that there is a common understanding between people of the meaning of the content (information) being exchanged.
- **Organizational Interoperability**, as the name implies, is the ability of organizations to effectively communicate and transfer (meaningful) data (information) even though they may be using a variety of different information systems over widely different infrastructures, possibly across different geographic regions and cultures. Organizational interoperability depends on successful technical, syntactical and semantic interoperability.

4.2 Edge Computing SDO/Alliance Initiatives

This section provides a brief description of the SDO and Alliance initiatives mentioned in Section 2. These brief descriptions are following and are based on the SDO and Alliance template described in Section 0.

The official URLs of each of these initiatives can be found via Table 3, Table 4 and Table 5.

Table 3: SDO/Alliance initiatives and their Official URLs: Part 1

Initiative	URL
3GPP (3rd Generation Partnership Project)	http://www.3gpp.org/
5GAA (5G Automotive Association)	http://www.5gaa.org/
5G-ACIA (5G Alliance for Connected Industries and Automation)	https://www.5g-acia.org/
AIOTI (Alliance for Internet of Things Innovation)	http://www.aioti.eu/
CEN (European Committee for Standardization)	https://www.cen.eu/
CENELEC (European Committee for Electrotechnical Standardization)	http://www.cenelec.eu/
DMTF (formerly known as the Distributed Management Task Force)	https://www.dmtf.org/
ECCP (European Centre for Certification and Privacy)	www.eccpcentre.org
EECC (European Edge Computing Consortium)	https://ecconsortium.eu/
ECC (Edge Computing Consortium)	http://en.ecconsortium.org/
ETSI (European Telecommunications Standards Institute)	http://www.etsi.org/

Table 4: SDO/Alliance initiatives and their Official URLs: Part 2

Initiative	URL
European Alliance for Industrial Data, Edge and Cloud	https://digital-strategy.ec.europa.eu/en/policies/cloud-alliance
GSMA	http://www.gsma.com/
GS1 (Global Standards 1)	http://www.gs1.org/
IEC (International Electrotechnical Commission)	http://www.iec.ch/
IEEE (Institute of Electrical and Electronics Engineers)	http://www.ieee.org/
IETF (Internet Engineering Task Force)	http://www.ietf.org/
IRTF (Internet Research Task Force)	https://irtf.org/
IIC (Industrial Internet Consortium)	http://www.industrialinternetconsortium.org/
ISO (International Organization for Standardization)	http://www.iso.org/
ISO/IEC JTC 1	http://www.iso.org/iso/jtc1_home.html
ITU (International Telecommunication Union)	http://www.itu.int/

Table 5: SDO/Alliance initiatives and their Official URLs: Part 3

Initiative	URL
OneM2M	http://www.onem2m.org/
OPC (Open Platform Communications) Foundation	https://opcfoundation.org/
OSGi Alliance	http://www.osgi.org/
UDG Alliance	www.udgalliance.org
W3C (World Wide Web Consortium)	http://www.w3.org/

4.2.1 3GPP (3rd Generation Partnership Project)

- Description:

  The below text is adapted /shortened from www.3gpp.org.

  The project covers cellular telecommunications network technologies, including radio access, the core transport network, and service capabilities including work on codecs, security, quality of service, providing complete system specifications. 3GPP specifications and studies are contribution-driven, by Member companies (originating from its Organizational Partners), in Working Groups and at the Technical Specification Group level.

  The Four Technical Specification Groups (TSG) in 3GPP are:

  - Radio Access Networks (RAN);
  - Service & Systems Aspects (SA),
  - Core Network & Terminals (CT);
  - GSM EDGE Radio Access Networks (GERAN).

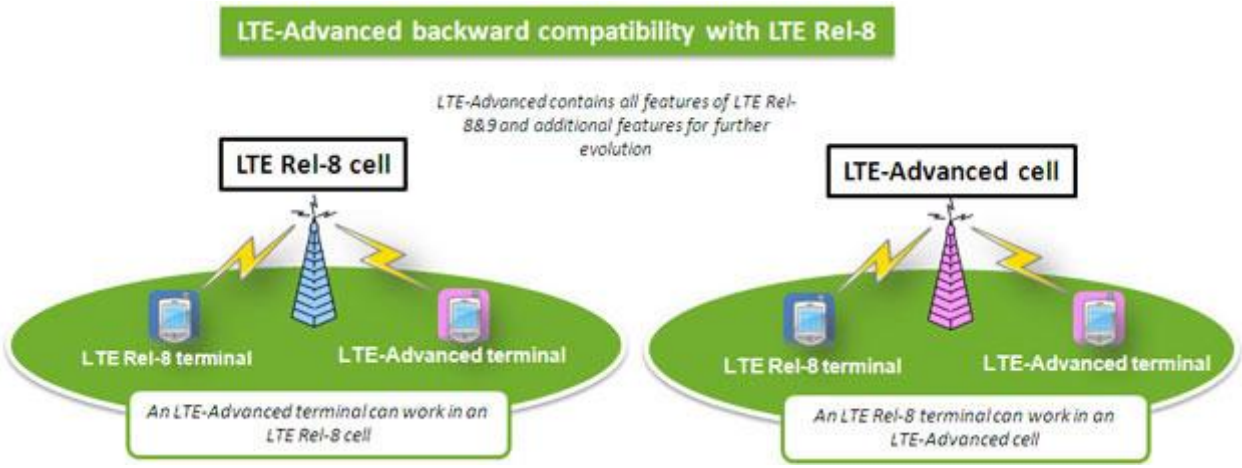
  The last meeting of a cycle of Plenary meetings is TSG SA, which also has responsibility for the overall coordination of work and for the monitoring of its progress.

  The 3GPP technologies from these groups are constantly evolving through Generations of commercial cellular / mobile systems. Since the completion of the first LTE and the Evolved Packet Core specifications, 3GPP has become the focal point for mobile systems beyond 3G.

  Backward Compatibility

  The major focus for all 3GPP Releases is to make the system backwards and forwards compatible where-ever possible, to ensure that the operation of user equipment is un-

interrupted. A good current example of this principle has been the priority placed in the working groups on backward compatibility between LTE and LTE-Advanced, so that an LTE-A terminal can work in an LTE cell and an LTE terminal works in the LTE-A cell.



- Readiness:

1. Adoption:
    - Widely adopted in industry.
2. Development Status:
    - Approved with planned revisions.
3. Compliance:
    - Having compliance testing process (include test suites, method, etc.).
    - Formal certification process.
4. Openness:
    - Open by formal membership.
    - Open to public.
5. Ratification process:
    - Done by members and open for consultation from external parties.

- Interoperability level:
    - Technical interoperability.
    - Organisational interoperability.

- Standards:

  As referred above 3GPP covers cellular telecommunications network technologies, including radio access, the core transport network, and service capabilities, including work on codecs, security and quality of service and providing complete system specifications.

  3GPP specifications also provide hooks for non-radio access to the core network, and for interworking with Wi-Fi networks.

  In particular, 3GPP specifications are taking into account IoT needs, namely know through a strong focus on the CIoT (Cellular IoT) and the support of Vehicular communications (LTE-Vx).

- Supporting organizations:

  The 3rd Generation Partnership Project (3GPP) unites seven telecommunications standard development organizations from Europe, China, India, Japan Korea and US (ARIB, ATIS, CCSA, ETSI, TSDSI, TTA, TTC), known as "Organizational Partners".

- Domain:
  - 3GPP provides network connectivity along the entire horizontal axis and mainly in vertical axis part under the horizontal axis.
- Application area:
  - 3GPP is not chartered to focus on a particular vertical industry. It provides standardized network layer technologies that are applicable to the various industry domains.
- IPR Policy Available:

  http://www.3gpp.org/about-3gpp/legal-matters
  http://www.3gpp.org/ftp/Information/Working_Procedures/3GPP_WP.htm#Article_55
  http://www.3gpp.org/ftp/Inbox/2008_web_files/3gppagre.pdf

- Specification Access:
  - Specification open 3GPP web site – free to access for all.

4.2.2 European Centre for Certification and Privacy (ECCP)

- Description:

  ECCP (www.eccpcentre.org) has been established to support the development and maintenance of standards related to data protection and ICT. One of its mission is to maintain the Europrivacy certification scheme (www.europrivacy.org) for certifying GDPR compliance. Europrivacy has been developed through the European research programme to be applicable to IoT deployments and emerging technologies such as artificial intelligence, smart grids, connected vehicles, eHealth, smart cities, distributed ledger technologies. ECCP is also working on ICT certification standards for IoT.

- Readiness:
  1. Adoption:
     - Europrivacy certification scheme has been endorsed by major certification bodies, consulting firms and law firms.
  2. Development Status:
     - Approved, with regular updates.
  3. Compliance
     - With ISO standards and the European General Data Protection Regulation (GDPR) as well as national regulations, including non-European regulations.
  4. Openness
     - Made available through free licensing to qualified companies.
  5. Ratification process:
     - Through consultation with data protection experts and supervisory authorities. Maintained and supervised by an international board of experts in data protection.

- Interoperability level:
  - Regulatory compliance with European and non-European regulations in data protection. Interoperable with ISO/IEC 17065 and 17021-1 certification processes, as well as with ISMS certification process such as ISO/IEC 27001 and 27701. Applicable to all IoT domains.

- Standards:
  - Europrivacy for data protection and GDPR compliance certification.

- Supporting organizations:
  - Universities, research centres, certification bodies, law firms, consulting firms, and close cooperation with the national supervisory authorities.

- Domain:
  - Applicable to all data processing, including consumer and industrial IoT.
  - Mainly focused on the application layer (data), but addresses also lower layers for security management.

- Application area:
    - ECCP is fully cross-domain, encompassing e-health, smart buildings, smart cities, smart factories, supply chains, smart agriculture, smart grid, etc.
- Scope:
    - Data protection, regulatory compliance (GDPR, NIS, ePrivacy, etc.) and certification.
- IPR Policy Available:
    - IPR is managed by ECCP and made available through free licensing to qualified service providers.
- Specification Access:
    - Accessible through the Europrivacy community website

4.2.3 European Edge Computing Consortium (EECC)

- Description:
- European Edge Computing Consortium (EECC) aims at supporting small, medium-sized and large enterprises in Europe and all around the world to adopt related technologies and in particular with a focus on the augmentation of Operational Technologies (OT) with Information and Communication Technologies (ICT). Its mission is to drive adoption of the Edge Computing paradigm within the manufacturing and other industrial markets. It will emphasize on utilizing and contributing to existing solutions, standards and initiatives to ensure that industrial needs and requirements are optimally addressed in member products.
- Therefore, goals of this initiative include the specification of a Reference Architecture Model for Edge Computing (EECC RAMEC), the development of reference technology stacks (EECC Edge Nodes), the identification of gaps and recommendation of best practices by evaluating approaches within multiple scenarios (EECC Pathfinders), and the synchronization with related initiatives/standardization organizations and the promotion of the results. The consortium welcomes collaboration with more partners who are engaged in the action of digitalization verticals.

- Readiness:
    1. Adoption:
    2. Development Status:
        - Early Preparatory (pre-standardization)
    3. Compliance
    4. Openness
    5. Ratification process:
- Interoperability level:
    - Technical
- Standards:

- Supporting organizations:

- Domain:
  - Industrial
- Application area:
  Smart Manufacturing
- Scope:
  - Support edge computing solutions for Smart Manufacturing
- IPR Policy Available:
- Specification Access:

4.2.4 ETSI (European Telecommunications Standards Institute)

This section provides a brief description of the ETSI SDO initiative and its IoT related Technical Committees (TCs) and Industry Specification Groups (ISGs).

ETSI initiative

- Description:

  ETSI (European Telecommunications Standards Institute) - a European Standards Organization with global impact (https://www.etsi.org/about/about-us)

  ETSI provides members with an open, inclusive and collaborative environment. This environment supports the timely development, ratification and testing of globally applicable standards for ICT-enabled systems, applications and services.

  ETSI is at the forefront of emerging technologies across all sectors of industry and society that make use of ICT. The ETSI 900+ member organizations are drawn from 64 countries and five continents.

Some of the benefits of the ETSI membership include:

- access to the most up-to-date information on global ICT standards
- direct participation in standards development
- competitive advantage through early standard adoption
- opportunities to network with industry leaders

ETSI operates on a not-for-profit basis and are one of only three bodies officially recognized by the EU as a European Standards Organization.

A EUROPEAN STANDARDS ORGANIZATION

ETSI is a European Standards Organization (ESO), being the recognized regional standards body dealing with telecommunications, broadcasting and other electronic communications networks and services.

ETSI has a special role in Europe. This includes supporting European regulations and legislation through the creation of Harmonised European Standards. Only standards developed by the three ESOs (CEN, CENELEC and ETSI) are recognized as European Standards (ENs).

ETSI GLOBAL IMPACT

ETSI was initially founded to serve European needs, but it has a global perspective. ETSI standards are now used the world over.

ETSI collaborates and works in partnership with different types of organizations around the world. This makes us well placed to support the ETSI members who operate in an increasingly international and competitive environment.

In addition, ETIS is a partner in the international Third Generation Partnership Project (3GPP™). Through this project, ETSI is helping to develop 4G and 5G mobile communications. ETSI also works with partners around the globe in the oneM2M partnership project to develop standards for machine-to-machine communications.

- Readiness:
  1. Adoption:

     Widely adopted in industry.

  2. Development Status:

     Depends on group and specification.

  3. Compliance:

  4. Openness:

     Results and work programme are public. Most technical groups are open to ETSI members some (ISGs) are also open to ETSI non-members.

  5. Ratification process:

     Done by members and open for consultation from external parties.

- Interoperability level:
  - Organisational interoperability.
- Standards:
  - Depends on specification.
- Supporting organizations:
- Domain:
  - Multiple domains.
- Application area:
  - Different specifications cover different areas.
- IPR Policy Available:
  - FRAND – ETSI IPR Policy - http://www.etsi.org/about/how-we-work/intellectual-property-rights-iprs.
- Specification Access:
  - Specifications available to the public for free from the ETSI web site https://www.etsi.org/standards#Pre-defined%20Collections.

ETSI TC CYBER

- Description:

Responsibility:

The main responsibilities of ETSI TC CYBER are:

- To act as the ETSI centre of expertise in the area of Cyber Security.
- Advise other ETSI TCs and ISGs with the development of Cyber Security requirements.
- To develop and maintain the Standards, Specifications and other deliverables to support the development and implementation of Cyber Security standardization within ETSI.
- To collect and specify Cyber Security requirements from relevant stakeholders.
- To identify gaps where existing standards do not fulfil the requirements and provide specifications and standards to fill these gaps, without duplication of work in other ETSI committees and partnership projects.
- To ensure that appropriate Standards are developed within ETSI in order to meet these requirements.
- To perform identified work as sub-contracted from ETSI Projects and ETSI Partnership Projects.
- To coordinate work in ETSI with external groups such as Cyber Security Coordination group in CEN CENELEC and ENISA.
- To answer to policy requests related to Cyber Security, and security in broad sense in the ICT sector.

Areas of activity

The activities of ETSI TC CYBER will be performed in close co-operation with relevant standards activities within and outside ETSI.

These activities include the following broad areas:

- Cyber Security.
- Security of infrastructures, devices, services and protocols.
- Security advice, guidance and operational security requirements to users, manufacturers and network and infrastructure operators.
- Security tools and techniques to ensure security.
- Creation of security specifications and alignment with work done in other TCs.

Organisation and working methods:

- ETSI TC CYBER shall work in accordance with the normal rules as given in the ETSI Directives and, in particular, the Technical Working Procedures.
- The tasks described above will require liaisons with relevant bodies within ETSI as well as outside ETSI according to the rules prescribed by the ETSI Directives.

Internal to ETSI:

- ETSI TCs that have a requirement for Security in their work. Examples are LI, SAGE, and SmartM2M. It is recognised that Security is a vertical activity and undertaken within groups, whilst TC CYBER may provide advice, guidance and horizontal coordination.
- ETSI ISGs that have a requirement for security in their work.

External to ETSI:

- ETSI TC CYBER is in coordination with European, National and International standards organisations, as well as other bodies such as ENISA, 3GPP, oneM2M, and Professional organisations etc.

Participation:

- Participation in ETSI TC CYBER is open to all ETSI members in accordance with the Technical Working Procedures. Observers and non-members may participate at the discretion of the Chairman in-line with clause 1.4 of the Technical Working Procedures.

- Readiness:

1. Adoption:

   Widely adopted in industry.

2. Development Status:

   Depends on specification, some published others under development.

3. Compliance:

4. Openness:

   Results are open to the public – TC Cyber participation is only for ETSI members.

5. Ratification process:

   Done by members and open for consultation from external parties.

- Interoperability level:
  - Organisational interoperability.
- Standards:
  - Depends on specification.
- Supporting organizations:
  - Not relevant.
- Domain:
  - Multiple domains.
- Application area:

- Different specifications cover different areas. Smart City focus in some specifications.

- IPR Policy Available:
  - FRAND – ETSI IPR Policy - http://www.etsi.org/about/how-we-work/intellectual-property-rights-iprs.
- Specification Access:
  - Specifications available to the public for free from the ETSI web site https://www.etsi.org/standards#Pre-defined%20Collections

ETSI TC MTS TST WG (Methods for Testing and Specification Testing WG)

- Description:

  Responsibility:

  The Testing WG („TST“) develops studies, guidelines, test catalogues and test specifications for specific ICT technologies that are not already covered by existing ETSI Technical Bodies.

  The WG will strongly make use of the well-established test development languages and methodologies developed inside and outside TC MTS as appropriate.

  Within the ETSI TC MTS, experts from industry and research in multiple domains are working together on the application of advanced testing methods and techniques.

  Due to the speed of new development and the public demand to provide a common approach for reliable quality criteria a working group within TC MTS is a fast and appropriate means to provide international reference documents for industrial quality test criteria. A common approach for the test specification of IoT test purposes will support the interoperability, quality and confidence into the IoT industry.

  Organisation and working method

  Following the advanced test methodology developed within MTS it has been discussed and decided to apply TDL-TO for the definition of test purposes. This new ETSI notation is part of the overall approach for test developments in the ICT domain. From our technical work in the past, we know that it is essential to define test scenarios in a formal way to avoid misinterpretation and to allow the application of utilities supporting e.g. formatting or maintenance.

- Readiness:
  - Adoption

    Reference implementations
  - Development Status

    The technical specifications from TC MTS WG TST working programme have been finished and confirmed by ETSI TC MTS. The documents are available for the public from May 2021.
  - Openness

    Open to public

- Ratification process
  Done by members and open for consultation from external parties

- Interoperability level:
  - Technical interoperability: addresses various IoT protocols and platforms (e.g. CoAP, MQTT, OPC-UA, LwM2M).
  - Syntactical interoperability: may be subject of future test catalogues

- Standards:
  Various SDO and consortia standards and protocols related to the protocols will be used and supported; sources will include IETF (CoAP), OASIS (MQTT), LoRa Alliance (LoRaWAN), IEC, etc.

- Supporting organizations:
  - Fraunhofer FOKUS
  - DEKRA Exam
  - Ericsson
  - AUDI
  - Iskratel
  - Spirent Communication
  - Sintesio Foundation
  - EasyGlobalMarket (EGM)
- Domain:
  - Initiative is related to multiple market domains (consumer/industrial internet) and the technical domain (connectivity, service&applications).

- Application area:
  - WG focus on horizontal industry, and do not exclude a particular vertical industry. Test types include, but are not limited to, conformance, security and performance.

- IPR Policy Available:

FRAND –http://www.etsi.org/about/how-we-work/intellectual-property-rights-iprs

Specification Access

- Published documents:
  https://www.etsi.org/standards/get-standards#page=1&search=&TB=860
- Work Item List:
  https://portal.etsi.org/tb.aspx?tbid=860&SubTB=860

ETSI TC Smart M2M

- Description:
  Responsibility:

ETSI TC Smart M2M will primarily provide specifications for M2M services and applications. Much of the work will focus on aspects of the Internet of Things (IoT) and Smart Cities. Furthermore, ETSI TC Smart will support European policy and regulatory requirements including mandates in the area of M2M and the Internet of Things. The ETSI TC

Smart M2M work includes the identification of EU policy and regulatory requirements on M2M services and applications to be developed by oneM2M, and the conversion of the oneM2M specifications into European Standards.

Areas of activity

The activities of TC Smart M2M will include the following:

- Be a centre of expertise in the area of M2M and Internet of Things (IoT) to support M2M services and applications;
- Maintain ETSI M2M published specifications;
- Produce specifications as needed for regulatory purposes;
- Transpose the output of oneM2M to ETSI TC Smart M2M.

ETSI TC Smart M2M will aim at referring to existing work done elsewhere, or encouraging existing groups to fulfil Smart M2M requirements. This TC will undertake necessary work that is not being provided for elsewhere.

- Readiness:
  1. Adoption:

     Widely adopted in industry.

  2. Development Status:

     Depends on specification, some published others under development.

  3. Compliance:

  4. Openness:

     Open to public – most groups some only open to members.

  5. Ratification process:

     Done by members and open for consultation from external parties.

- Interoperability level:
  - Organisational interoperability.
- Standards:
  - Depends on specification.
- Supporting organizations:
  - Work in close cooperation with the OneM2M partnership project.
- Domain:
  - Multiple domains.
- Application area:
  - Different specifications cover different areas. Smart City focus in some specifications.

- IPR Policy Available:
  - FRAND – ETSI IPR Policy - http://www.etsi.org/about/how-we-work/intellectual-property-rights-iprs.
- Specification Access:
  - Specification open ETSI web site – free to access for all.

ETSI ISG CIM (Context Information Management)

- Description

  The goal of ETSI ISG CIM is to develop technical specifications and reports to enable multiple organisations to develop interoperable software implementations of a cross-cutting Context Information Management (CIM) Layer. It is about bridging the gap between abstract standards and concrete implementations. The ISG CIM Layer enables applications to update, manage, and access context information from many different sources, as well as publishing that information through interoperable data publication platforms.

- Readiness
  1. Adoption (users base): not new specification yet but a related API (called NGSI) is in widespread use in many FIWARE projects.

     Several implementation of the API are available, such as:

     - Orion-LD
     - Stellio Context broker
     - Scorpio broker
     - Developers Catalogue - FIWARE
  2. Development Status is "under development", first release due in Q3 2017
     - Specification and reports (GS and GR) under development
  3. Compliance will not be managed, however it is hoped to encourage open-source interoperability events.
  4. Openness is excellent, for any "legal entity" which signs ETSI IPR policy i.e. not only ETSI members but also research institutes and fora.
     - Open to public.
  5. Ratification of specifications is done by members and participants; the ISG is proactive for consultation with external parties.
     - Done by members and open for consultation from external parties
- Interoperability level
  - The specifications aim at organisational interoperability, which includes Semantic, Technical, and Syntactical interoperability.
- Standards:
  - After considering the use cases and a gap analysis with respect to existing protocols, the ISG CIM will consider in what way existing standardised protocols need to be modified to be fit-for-purpose for flexible context information management. Additionally, a large number of SDO specifications and documents are being examined from many related fields in information management.
  - Depends on specification.

- Supporting organizations (mainly for Alliances/OSS)
    - Not relevant
- Domain
    - The operating domain of the specifications is in the consumer area, facilitating mass-market and eGovernment enhancement of data with metadata (context). Industrial IoT will be considered at the end of the standardization process, to check if additional changes in the protocol might make it fit-for-purpose in some Smart Factory application areas.

      There is also being applied over different domains under the initiative called Smart Data Models (https://www.fiware.org/developers/smart-data-models/) in which there are exposed the common data models to be included in context broker to represent IoT information. In the case of the water domain, these data models are being developed through an initiative of several EU funded projects.
- Application area
    - The work of ISG CIM is absolutely devoted to horizontal frameworks, for all kinds of vertical IoT domains, **however** to keep the work practical the initial use cases are considered for the SmartCity, vertical (expanding later to SmartAgriculture, Smart Water, SmartFactory, etc.).
- IPR Policy Available
    - ETSI IPR Policy (FRAND) is followed as set forth in Annex 6 of the ETSI Rules of Procedure, see http://www.etsi.org/about/how-we-work/intellectual-property-rights-iprs. Note that the ToR of ETSI ISG CIM expresses desire for 'collaboration with open source initiatives supporting the specifications'.
- Specification Access
    - Approved specifications will be published on the ETSI website, as for all TR and TS documents. Additionally, the ISG CIM has a policy to solicit public comment on draft specifications and has create an open area for publishing (after obtaining ETSI administrative support) specific documents: https://docbox.etsi.org/ISG/CIM/Open

ETSI ISG MEC (Multi-access-Edge Computing)

- Description:

  Mobile-access Edge Computing provides IT and cloud-computing capabilities within the RAN (Radio Access Network) in close proximity to mobile subscribers. Located at the base station or at the Radio Network Controller (RNC), MEC also provides access to real-time radio and network information (such as subscriber location, cell load, etc.) that can be exploited by applications and services to offer context related services; these services are capable of differentiating the mobile broadband experience. For application developers and content providers, the RAN edge offers a service environment with ultralow latency and high-bandwidth as well as direct access to real-time radio network information.

  Mobile edge computing allows content, services and applications to be accelerated, increasing responsiveness from the edge. The customer's experience can be proactively maintained through efficient network and service operations, based on insight into the radio and network conditions. Operators can open the radio network edge to third-party partners, allowing them to rapidly deploy innovative applications and services towards mobile subscribers, enterprises and other vertical segments. Proximity, context, agility and speed can be translated into value and can be exploited by mobile operators, service and content providers, Over the Top (OTT) players and Independent Software Vendors (ISVs), enabling them to play complementary and profitable roles within their respective business models and allowing them to monetize the mobile broadband experience.

  This environment can create a new value chain and an energized ecosystem comprising application developers, content providers, OTT players, network equipment vendors and mobile operators. Based on innovation and business value, this value chain will allow all players to benefit from greater cooperation.

  The intention is to foster dissemination of the deliverables produced by the ISG MEC in order to develop favourable market conditions which will create sustainable business for all players in the value chain, and to facilitate global market growth.

The goals of the ISG MEC are to:

- Create a standardized, open environment which will allow the efficient and seamless integration of third-party applications across multi-vendor Mobile-edge Computing platforms. This will ensure that the vast majority of the customers of a mobile operator can be served.
- Enable and accelerate the development of edge applications across the industry, increasing the market scale and improving the market economics.
- Address regulatory and legal requirements.

MEC can help accelerate and enhance smart city applications.

Example 1: Active device location tracking service:

- MEC tracks active devices (independent of GPS information) and provides real-time location information & location statistics of UEs located in coverage area of MEC server;
- Helps to understand how crowd is distributed;
- Crowd dynamics can help with smart transportation optimization as transportation systems require (anonymous) location information from a large population.
- Supports utility planning, etc..

Example 2: Intelligent video analytics at the edge:

- Distributed live video streams analytics at mobile edge and events are triggered automatically (e.g. movement, objects, crowd, etc.), enables fast detection and action triggering.

- Readiness:

1. Adoption:

Yes, several implementations are available; Open-source repository for APIs: https://forge.etsi.org/rep/mec

2. Development Status:

- Specification under development. (upgrades, corrections, inputs from other organisations).

3. Compliance:

- Robot test suite: https://hub.docker.com/r/etsiforge/mec-robot-hivetap-tt

4. Openness:

Open to public.

5. Ratification process:

Done by members and open for consultation from external parties.

- Interoperability level:
  - Organisational interoperability.
- Standards:
  - Latest APIs from the Multi-access Edge Computing ISG:
    - Application package lifecycle and operation granting API - GS 010-2
    - Multi-access Edge Platform Application Enablement API - GS 011
    - Radio Network Information API - GS 012
    - Location API - GS 013
    - UE Identity API - GS 014
    - Bandwidth Management API - GS 015
    - UE Application Interface API - GS 016
    - Application Mobility Service API – GS 021
    - MEC WLAN Information API - GS 028
    - Fixed Access Information API - GS 029
    - V2X Information Service API – GS 030
  - Abstract Test Suites from the Multi-access Edge Computing ISG at:
    - TTCN-3 Test Suite - GS 032 API Conformance Specification, Part 3
    - Robot Framework Test Suite - GS 032 API Conformance Specification, Part 3
- Supporting organizations:
  - Membership list: https://portal.etsi.org/TB-SiteMap/MEC/List-of-Members
- Domain:
  - Multiple domains.
- Application area:
  - Different specifications cover different areas. Smart City focuses in some specifications.
  - PoCs available: https://www.etsi.org/technologies/multi-access-edge-computing/mec-poc

- IPR Policy Available:
  - FRAND – ETSI IPR policy - http://www.etsi.org/about/how-we-work/intellectual-property-rights-iprs.
- Specification Access:
  - Specifications are open via the ETSI website – free to access for all.

ETSI ISG NFV (Network Functions Virtualisation)

- Description:

  The purpose of ISG NFV is to facilitate the industry transformation and the development of an open, interoperable, ecosystem enabling managing the lifecycle of virtualised network functions hosted on independently deployed and operated NFV infrastructure platforms, which can be distributed across various locations (e.g. centralised data centres, edge clouds, end user premises, etc.).

  The original target of ISG NFV consisted in providing a pre-standardisation study before considering later a broader standards proposal in a new or existing standardisation group. It was important at that stage to first clearly define, agree, and share the goals of virtualising network functions with the whole industry. This was addressed in the 2013-2014 time frame, and resulted in the publication of the first ISG NFV specifications release.

  In 2015 and 2016, the purpose of ISG NFV focused on producing the technical specifications for the NFV foundation technology. During the 2017-2020 period, the ISG focused on consolidating these technical specifications, defining a consistent operational integration with current network services, and addressing the additional requirements for NFV technologies brought by the evolution of telecommunications networks, especially in what relates to 5G, in close cooperation with global and regional initiatives.

  From 2021 onwards, ISG NFV will continue to further consolidate technical specifications and address new functional and operational requirements brought by new use cases (e.g. for industry verticals) and operational models, leveraging advances in network management, orchestration, virtualisation and Cloud technologies.

The ISG NFV will address technical challenges that include:

- Ensuring that virtualised network platforms will be able to support automated (and even autonomous) management of all application-independent aspects of virtualised services, ranging from the management of the virtualised resources they use to the management of the network functions they combine.
- Achieving high-performance virtualised network functions which are portable between different supporting platforms, which includes hardware, infrastructure software, and orchestration stacks.
- Achieving co-existence with legacy hardware-based network platforms whilst enabling an efficient migration path to fully virtualised network platforms.
- Catalysing the evolution of network management support systems to take full advantage of virtualisation and software-based operation techniques.
- Ensuring the security of virtualised network platform from attack and misconfiguration, and their compliance with national and international regulations on privacy and security matters.
- Maintaining network stability and service levels without degradation during any event in the functions lifecycle.
- Ensuring the appropriate level of resilience to hardware and software failures, operational errors, and other anomalous events.
- Exploring the necessary enabling technologies to support the new business models made possible by network virtualisation.
- Exploring technologies enabling cross-organizational continuous integration and continuous delivery practices in software-based virtualised environments.

The activities of ISG NFV include the following broad areas:

- Resource virtualization (storage, compute, network),
- Network Slicing,
- Hardware and software acceleration,
- Management and orchestration (of Virtualised Network Functions, of infrastructure resources, etc.),
- Performance, Reliability, Resiliency,
- Architecture (component and interface definition),
- Information and data modelling,
- Protocols, Application Programming Interface,
- Security, trust, attestation, regulation,
- Testing, benchmarking, continuous integration and development processes
- Readiness:

  1. Adoption:

     - Widely adopted in industry.

  2. Development Status:

- ISG NFV has developed over 100 different specifications and reports for the virtualization of network functions, with focus on the management and orchestration of virtualized resources.
- ISG NFV works on a number of Releases in parallel. The development status of the specifications depends on the Release they belong to.

    - Under development: Release 4, Release 5
    - Approved with no planned revisions: Release 1, Release 2
    - Approved with planned revisions: Release 3

3. Compliance:

- Having compliance testing process (include test suites, method, etc.)
    - Conformance test suites for Management and Orchestration APIs, including robot code:
        - https://forge.etsi.org/rep/nfv/api-tests
    - Conformance and Interoperability tests held regularly at ETSI Plugtests™ events.
        - https://www.etsi.org/technologies/nfv/nfv-plugtests-programme

4. Openness:

- Results and work programme are public.
- Participation is open to ETSI members as well as non-members having signed the participation agreement.

5. Ratification process:

- Done by members and open for consultation from external parties

- Interoperability level:
    - ISG NFV develops and maintains a full set of standards enabling an open ecosystem where Virtualized Network Functions (VNFs) can be interoperable with independently developed management and orchestration systems, and where the components of a management and orchestration system are themselves interoperable.
        - Syntactical interoperability.
        - Technical interoperability.
        - Semantic interoperability.
        - Organizational interoperability
- Standards:
    - ISG NFV has developed over 100 different specifications and reports for the virtualization of network functions, with focus on the management and orchestration of virtualized resources. This includes a set of Restful API specifications, the specifications of a packaging format for delivering VNFs to service providers, as well as TOSCA-based and YANG-based specification of the deployment templates packaged with the VNF software images to enable managing the lifecycle of VNFs.
    - The latest publications can be found here: https://www.etsi.org/committee/1427-nfv
    - and the associated code, here: https://forge.etsi.org/rep/nfv
- Supporting organizations

- 125 member or participant organizations from both the Telco and IT industry.
- Participation from academia is encouraged through the publication of a Research Agenda
  - https://docbox.etsi.org/ISG/NFV/Open/Other/NFV_Research_Agenda-202104.pdf
- List of member and participant organizations : https://portal.etsi.org/TB-SiteMap/NFV/NFV-List-members

- Domain:
  - Multiple domains on both axis.
- Application area:
  - ISG NFV develops a generic framework applicable to any kind of network function. ETSI GS NFV 001 describes typical use cases, including an IoT use case.
    - https://www.etsi.org/deliver/etsi_gr/NFV/001_099/001/01.03.01_60/gr_nfv001v010301p.pdf
- IPR Policy Available:
  - FRAND – ETSI IPR policy - http://www.etsi.org/about/how-we-work/intellectual-property-rights-iprs.
- Specification Access:
  - Find publicly available NFV specifications via the NFV committee page, and subscribe for alerts on updates of specifications (free to access for all).
    - https://www.etsi.org/committee/1427-nfv
  - The associated code can be found here
    - https://forge.etsi.org/rep/nfv
  - In addition to the published specifications, ISG NFV makes all of its drafts in progress publicly available for industry comment.
    - http://docbox.etsi.org/ISG/NFV/Open/Drafts/

4.2.5 GS1

- Description:

  GS1 is an international federation of not-for-profit organisations established in 114 countries with a total of more than one million member companies. GS1 manages a global identification system for items, parties, locations, assets, etc., a comprehensive set of automatic data capture standards using barcodes and RFID as well as standards for the electronic sharing of information.

  The large majority of GS1 standards fall under the IoT flag. The Auto-ID Center initiative at MIT in the early two thousands developed the EPC and other technical concepts and standards prevalent today in the global RFID industry. It coined the term Internet of Things which envisioned objects /things connected to object-specific data on the internet which could be accessed using the unique EPC on the tag attached to the object. As of 2003, GS1 took over the concept through its fully owned EPCglobal subsidiary. Formal standards were developed and the technology was brought to the market for implementation. EPCIS that is also published as ISO/IEC 19987 is a GS1 standard that defines a common data model for visibility

data and interfaces for capturing and sharing visibility data within an enterprise and across an open supply chain.

Today it is embarking on a global migration of optical data carriers to 2D, including connectivity to the Web.

- Readiness:
  1. Adoption:
     - Widely adopted in industry.
  2. Development Status:
     - Approved with planned revisions.
  3. Compliance:
     - Having compliance testing process.
  4. Openness:
     - Open by formal membership.
  5. Ratification process:
     - Done primarily by members but external parties may submit comments.
- Interoperability level:
  - The GS1 system architecture promotes interoperability. GS1 system components and any underlying processes that are developed strive to be interoperable in their design, development, and implementation to enable the widest adoption and usage by the User community. All GS1 standards are compliant with widely accepted technical standards from internationally recognised SDOs such as ISO, W3C, IETF and UN/CEFACT:
    1. Syntactical interoperability.
    2. Technical interoperability.
    3. Semantic interoperability.
    4. Organisational interoperability.
- Standards:
  - All GS1 standards are compliant with widely accepted technical standards from internationally recognised SDOs such as ISO, W3C, UN/CEFACT and IETF.
- Supporting organizations:
  - Large and small companies from various sectors including consumer goods, retail, healthcare, transport & logistics as well as solution providers. This broad support is well reflected in the diversity of the GS1 Management Board members, http://www.gs1.org/about/management-board.
- Domain:
  - The main scope of application of GS1 standards is in B2B processes. There are however more and requirements and therefore GS1 standards and services addressing the B2C area. GS1 focuses on services and applications rather than technical connectivity. It should thus be positioned in the upper right quadrant of the landscape.
- Application area:

    - The application area is mainly business to business supply chain processes. The main industry sectors using the GS1 system of standards are retail, healthcare and transport / logistics. There are however implementations in many other sectors.

- IPR Policy Available: Royalty fee or RAND, see http://www.gs1.org/ip.
- Specification Access: All specifications are available publicly and free of charge, see http://www.gs1.org/standards.

4.2.6 GSMA (GSM Association)

- Description:
  - http://www.gsma.com/aboutus/.
  - http://www.gsma.com/connectedliving/.

  The GSMA represents the interests of mobile operators worldwide, uniting nearly 800 operators with more than 250 companies in the broader mobile ecosystem, including handset and device makers, software companies, equipment providers and internet companies, as well as organisations in adjacent industry sectors. The GSMA also produces industry-leading events such as Mobile World Congress, Mobile World Congress Shanghai and the Mobile 360 Series conferences.

  The GSMA Connected Living programme (http://www.gsma.com/connectedliving/) is an initiative to help operators add value and accelerate the delivery of new connected devices and services in the Machine to Machine (M2M) market.

- Readiness:

  1. Adoption:
     - Widely adopted in industry.

  2. Development Status:
     - Approved with planned revisions.

  3. Compliance:
     - Not managed.

  4. Openness:
     - Open by formal membership.

  5. Ratification process:
     - Closed process done by members only with no consultation from external parties.

- Interoperability level:
  - Technical interoperability.
- Standards:
  - GSMA is mainly for public policy and spectrum policy lobby, mobile business development and mobile market promotion. The only one standard made by GSMA is eSIM.
- Supporting organizations
  - 3GPP.
  - There are also more than 250 vendors and more than 800 MNOs in the GSMA. The membership types consist of Full Membership, Associate Membership and

Rapporteur Membership. The full membership can be found http://www.gsma.com/membership/who-are-our-gsma-members .

- Domain:
  - GSMA make just one standard, eSIM. It locates in the connectivity domain, and can be used for both consumer and industrial market.
- Application area:
  - The GSMA is mainly for promotion of mobile industrial, which includes public policy and spectrum policy, management of mobile service, mobile API, mobile application in different vertical area of industry, and personal data.
- IPR Policy Available:
  Reference: http://www.gsma.com/newsroom/wp-content/uploads/2013/09/AA-32-v4-0.pdf
- Specification Access:
  GSMA published documents are available at: http://www.gsma.com/newsroom/gsmadocuments/ .

4.2.7 IEC (International Electrotechnical Commission)

This section provides a brief description of the International Electrotechnical Commission (IEC) initiative and its IoT related Technical Committees (TCs).

IEC covers all electrotechnical aspects from plugs, wires, voltage levels to automation, control and management.

Various protocols are supported, such as: IEC61850, IEC 61968/61970 (CIM), XMPP, DLMS/COSEM, OPC-UA, various field buses.

Various mature standards are available that are widely adopted in the industry.

The important committees & groups are:

- SC3D Product properties and classes and their identification;
- TC 8 Systems aspects for electrical energy supply;
- TC13 Electrical energy measurement and control;
- TC 57 Power systems management and associated information exchange;
- TC65 Industrial-process measurement, control and automation;
- SG8 Industry 4.0 - Smart Manufacturing;
- SG 9 Communication Technologies;
- SG10 Wearable Smart Devices;
- SyC Smart Energy;
- SyC Active Assisted Living;
- SEG1 Smart Cities;
- SEG5 Electrotechnology for mobility;
- SEG6 Non-traditional Distribution Networks / Microgrids.

Participation is open via the national committees. The followed IPR regime is (FRAND).

Moreover, the specifications are openly available for a fee.

IEC TC57

- Description:
  - To prepare international standards for power systems control equipment and systems including EMS (Energy Management Systems), SCADA (Supervisory Control And Data Acquisition), distribution automation, tele-protection, and associated information exchange for real-time and non-real-time information, used in the planning, operation and maintenance of power systems. Power systems management comprises control within control centres, substations and individual pieces of primary equipment including telecontrol and interfaces to equipment, systems and databases, which may be outside the scope of TC 57.
- Readiness:

1. Adoption:

   - Widely adopted in industry.

2. Compliance:

   - Not managed by IEC.

3. Openness:

   - Open to public.

4. Ratification process:

   - Done by members and open for consultation from external parties.

- Interoperability level:
    1. Syntactical interoperability.
    2. Technical interoperability.
    3. Semantic interoperability.
- Standards:
    - Some examples:
        - IEC/TR 62357 Reference Architecture.
        - IEC 61968 Application integration at electric utilities - System interfaces for distribution management.
        - IEC 61970 Energy management system application program interface.
        - IEC 62325 Framework for energy market communications.
        - IEC61850 Communication networks and systems for power utility automation.
        - IEC 62351 Power systems management and associated information exchange - Data and communications security.
        - IEC 62746 Systems Interface between Customer Energy Management System and the Power Management System.
- Supporting organizations:
    - Energy, Smart Grid, Smart Cities.
- Domain:
    - Industrial.
- Application area:
    - Smart Grid, Smart City.
- IPR Policy Available:
    - ITU / ISO / IEC code of practice.
    - FRAND.
- Specification Access:
    - Open to everyone with a fee.

IEC TC65

- Description:
  - IEC TC65, established in 1968, prepares basic standards for industrial automation as well as process industry specific standards. The Scopes of TC65 and its SCs are as follows:

    TC65: INDUSTRIAL PROCESS MEASUREMENT, CONTROL AND AUTOMATION:

    - To prepare international standards for systems and elements used for industrial process measurement, control and automation.
    - To coordinate standardization activities which affect integration of components and functions into such systems including safety and security aspects. This work of standardization is to be carried out in the international fields for equipment and systems.

    SC65A: SYSTEM ASPECTS:

    - To prepare international standards regarding the generic aspects of systems used in industrial process measurement, control and manufacturing automation: operational conditions (including EMC), methodology for the assessment of systems, functional safety, etc.
    - SC65A also has a safety pilot function to prepare standards dealing with functional safety of electrical/electronic/programmable electronic systems.

    SC65B: MEASUREMENT AND CONTROL DEVICES:

    - To prepare international standards in the field of specific aspects of devices (hardware and software) used in industrial process measurement and control, such as measurement devices, analysing equipment, actuators, and programmable logic controllers, and covering such aspects as interchangeability, performance evaluation, and functionality definition.

    SC65C: INDUSTRIAL NETWORKS:

    - To prepare international standards on wired, optical and wireless industrial networks for industrial-process measurement, control and manufacturing automation, as well as for instrumentation systems used for research, development and testing purposes. The scope includes cabling, interoperability, co-existence and performance evaluation.

    SC65E: DEVICES AND INTEGRATION IN ENTERPRISE SYSTEMS:

    To prepare international standards specifying:

    - Device integration with industrial automation systems. The models developed in these standards address device properties, classification, selection, configuration, commissioning, monitoring and basic diagnostics.
    - Industrial automation systems integration with enterprise systems. This includes transactions between business and manufacturing activities which may be jointly developed with ISO TC184.

- Readiness:
  1. Adoption:
     - Widely adopted in industry.
  2. Compliance:
     - Not managed by IEC.
  3. Openness:
     - Open to public.
  4. Ratification process:
     - Done by members and open for consultation from external parties.

- Interoperability level:
  - Syntactical interoperability.
  - Technical interoperability.
  - Semantic interoperability.
  - Organisational interoperability.

- Standards:

  Publication Examples:

  - IEC 60050-351 (IEV vocabulary);
  - IEC 61010 (Safety requirements for equipment);
  - IEC 62443 (Cyber security);
  - IEC 62708 (Documentation requirements);
  - IEC 61326 (EMC);
  - IEC 61508 Series (Functional Safety);
  - IEC 61511 (Functional Safety process industry sector);
  - IEC 61512 (Batch Control);
  - IEC 61131 (PLC);
  - IEC 61499 (Function Block);
  - IEC 60534 (Industrial-process control valves);
  - IEC 61207 (Expression of performance of gas analyzers);
  - IEC 61158 Series (Fieldbus);
  - IEC 61588 (Precision clock synchronization);
  - IEC 61784 (Industrial communication networks – Profiles);
  - IEC 61918 (Cabling);
  - IEC 62439 (High availability automation networks);
  - IEC 62591, IEC 62601, IEC 62734 (Wireless);
  - IEC 62657 (Wireless coexistence).

- Supporting organizations:
  - Manufacturing.
  - Industrial automation.

- Domain:
  - Industrial.

- Application area:
  - Smart manufacturing.

- IPR Policy Available:
  - ITU / ISO / IEC code of practice.
  - FRAND.

- Specification Access:
  - Open to everyone with a fee.

4.2.8 IEEE Standards Association

- Description:
  IEEE Standards Association mission is for advancing technology for the benefit of humanity by providing a globally open, inclusive and transparent environment for market relevant, voluntary consensus standardization. The objective of IOT Standardization is to establish reference framework and architecture for Internet of Things. The architectural framework defined in the IEEE 2413 standard will promote cross-domain interaction, aid system interoperability and functional compatibility across IOT systems. IEEE-SA also develops several other IOT standards across different verticals – Communications (IEEE 802 – wireless/wireline standards, IEEE 1901 on BPL), Transportation (IEEE 802.11p, IEEE 1609P), eHealth (11073), Smart Grid standards and Smart Energy Profile (IEEE 2030.5), and Sensor Standards (IEEE 1451, IEEE 2700) to name a few of the IEEE standards. For the full list of the IEEE-SA IOT Standards please see the attached word documents and powerpoint presentation on IEEE P2413 which was presented to the AIOTI WG3 on Standardization in Nov 2015.

- Interoperability level:
  - The various standards of the IEEE Standards Association address all the different levels of interoperability as mentioned below:
    - Syntactical interoperability.
    - Technical interoperability.
    - Semantic interoperability.
    - Organizational interoperability.

- Standards:
  - The standards activities of IEEE on IoT are numerous as is indicated on the IEEE Internet of Things initiative web site - http://standards.ieee.org/innovate/iot/stds.html.

- Supporting organizations:

- Domain:
  - Health
  - Smart City

- Application area:

- License (IPR regime):
  - The IEEE-SA Patent Policy is section 6 of the IEEE-SA Standards Board Bylaws (http://standards.ieee.org/develop/policies/bylaws/sect6-7.html). See also http://standards.ieee.org/about/sasb/patcom/materials.html.

- Availability:
  - IEEE-SA standards are available openly for the public. They can be obtained from IEEE (http://ieeexplore.ieee.org/Xplore/guesthome.jsp or http://www.techstreet.com/ieee). The IEEE-SA policies can be viewed at https://standards.ieee.org/develop/policies/

4.2.9 IEEE P2413: Standard for an Architectural Framework for the Internet of Things

- Description:
  - Defines an Architectural Framework for the IoT, including descriptions of various IoT domains, definitions of IoT domain abstractions, and identification of commonalities between different IoT domains.
- Readiness:

  1. Adoption:

     - Reference implementations

  2. Development Status:

     - Under development.

  3. Compliance:

     - Not managed.

  4. Openness:

     - Open by formal membership.

  5. Ratification process:

     - Done by members and open for consultation from external parties.
- Standards:
  - P2413 Standard for an Architectural Framework for the Internet of Things.

- Supporting organizations
  - Not relevant.
- Domain:
  - Market: consumer and industrial.
  - Technology: closer to service & applications.
- Application area:
  - Horizontal.
- Scope:
  - IoT Architecture knowledge area.
- IPR Policy Available:
  - FRAND, royalty free.
- Specification Access:
  - Open to everyone with a fee.

4.2.10 IEEE P2874 SPATIAL WEB Protocol, Architecture and Governance Working Group

- Description:

  IEEE P2874 Standard for Spatial Web Protocol, Architecture and Governance Working Group.

  This standard describes a Hyperspace Transaction Protocol (HSTP) that enables interoperable, semantically compatible connections between connected hardware (e.g. autonomous drones, sensors, smart devices, robots) and software (e.g. services, platforms, applications, artificial intelligence systems) and includes specifications for:

  1. a spatial range query format and response language for requesting data about objects within a dimensional range (spatial, temperature, pressure, motion) and their content.
  2. a semantic data ontology schema for describing objects, relations, and actions in a standardized way
  3. a verifiable credentialing and certification method for permissioning create, retrieve, update, and delete (CRUD) access to devices, locations, users, and data; and
  4. a human and machine-readable contracting language that enables the expression and automated execution of legal, financial and physical activities.

- Readiness:
    1. Adoption:
        - Reference implementations
    2. Development Status:
        - Under development.
    3. Compliance:
    4. Openness:
        - Open to public, based on IEEE rules
    5. Ratification process:
        - Following IEEE process, i.e., done by members and open for consultation from external parties.

- Standards:
    - This is a new standard that may include references to existing standards and specifications such as TCP/IP, http, html, W3C DID's and Verifiable Credentials.

- Supporting organizations
    - IEEE and Spatial Web Foundation (SWF), see: https://spatialwebfoundation.org/

- Domain:
    - The Standards are related to multiple market domains (consumer/industrial internet) and the technical domain (connectivity, service&applications).

- Application area:
    - WG focus on, i.e. horizontal industry, and do not exclude a particular vertical industry. Test types include, but are not limited to, conformance, security and performance.

- Scope:
    - IEEE P2874 Standard for Spatial Web Protocol, Architecture and Governance Working Group.

- IPR Policy Available:
    - IEEE copyright policy https://www.ieee.org/publications/rights/copyright-policy.html

- Specification Access:
  - https://sagroups.ieee.org/2874/

4.2.11 IETF (Internet Engineering Task Force)

This section provides a brief description of the IETF (Internet Engineering Task Force) initiative and its edge computing related Working Groups (WGs).

The mission of the IETF is to make the Internet work better by producing high quality, relevant technical documents that influence the way people design, use, and manage the Internet. The IETF Mission Statement is documented in RFC 3935.

Media OPerationS (mops)

- Description:
  The official website of IETF Media OPerationS (mops) is:

  https://datatracker.ietf.org/wg/mops/about/

  The focus of MOPS is on identifying areas where existing protocols and/or networks are challenged by updated requirements.

  MOPS will solicit input on media-related operational issues and practices; existing and proposed technologies related to the deployment, engineering, and operation of media streaming and manipulation protocols and procedures in the global Internet (inter-domain) and within-domain networking. In the context of this working group, media is considered to include the transport of video, audio, objects and any combination thereof, possibly non-sequentially.

  The scope is media and media protocols' interactions with the network, but not the technologies of control protocols or media formats. Where new protocols are needed, MOPS will help identify candidate venues for their development.

  The goals of MOPS include documenting existing protocol and operational issues with media on the Internet, and identifying requirements for potential IETF work.

With that in mind, MOPS will:

1. Solicit regular updates from other media technology developing consortia/standards bodies working with IETF-developed protocols.
2. Solicit input from network operators and users to identify operational issues with media delivery in and across networks, and determine solutions or workarounds to those issues.
3. Solicit discussion and documentation of the issues and opportunities in media acquisition and delivery, and of the resulting protocols and technologies developed outside the IETF.
4. Document operational requirements for media acquisition (for example, from cameras and recording devices) and delivery.
5. Develop operational information to aid in operation of media technologies in the global Internet.

These activities should document media operational experience, including global Internet, inter-domain and within-domain operations.

Media operational and deployment issues with specific protocols or technologies (such as Applications, Transport Protocols, Routing Protocols, DNS or Sub-IP

- Readiness:

1: Adoption:

- Working Group is active and RFC and Internet drafts are available.

2. Development Status:

Date	Milestone
1 Jul 2022	Last-call document on Society of Motion Picture and Television Engineers (SMPTE) protocol reliance on IETF protocols (including explicit outreach to SMPTE)
1 Jul 2022	Last-call document on Streaming Video Alliance (SVA) reliance on IETF protocols (including explicit outreach to SVA)
1 Nov 2021	IESG to decide whether continue, re-charter or close MOPS WG
1 Nov 2021	Last-call document on operational considerations for low latency streaming video applications
1 Nov 2021	Draft documenting Society of Motion Picture and Television Engineers (SMPTE) protocol reliance on IETF protocols
1 Jul 2021	Last-call document on edge network considerations for streaming media: https://datatracker.ietf.org/doc/draft-ietf-mops-ar-use-case/
1 Jul 2021	Revised draft operational considerations for low latency streaming video applications draft-ietf-mops-ar-use-case
1 Jul 2021	Draft documenting Streaming Video Alliance (SVA) reliance on IETF protocols

- 3. Compliance

- Not IETF responsibility.

4. Openness:

   - Open to public.

5. Ratification process:

   - Open process for all parties interested in the ratification.

- Interoperability level:
  - Syntactical interoperability.
  - Technical interoperability.
  - Semantic interoperability.
- Standards:
  - Media Operations Use Case for an Augmented Reality Application on Edge Computing Infrastructure, see: https://datatracker.ietf.org/doc/draft-ietf-mops-ar-use-case/
  - Operational Considerations for Streaming Media, see: https://datatracker.ietf.org/doc/draft-ietf-mops-streaming-opcons/
- Supporting organizations:
  - MOPS is an IETF WG.

- Domain:
  - Market domain: Located on the vertical axis, to show that it is equally used by the consumer and industrial internet market.
  - Technical domain: Closer to the service & applications edge of the vertical axis
- Application area:
  - MOPS WG is focusing on horizontal industry.
- IPR Policy Available:
  - The IETF intellectual property rights rules are defined in RFC8179, "Intellectual Property Rights in IETF Technology", see: https://www.ietf.org/rfc/rfc8179.txt
- Specification Access:
  - Access of published (RFCs) and non-published (Internet draft) specifications for members and non-members is open and free of payment.

Application-Layer Traffic Optimization (ALTO)

- Description:

  The official website of IETF Application-Layer Traffic Optimization (ALTO) is:

  https://datatracker.ietf.org/wg/alto/about/

  New approved charter:

  https://datatracker.ietf.org/doc/charter-ietf-alto/

  The ALTO working group was established in 2008 to devise a request/response protocol to allow a host to benefit from a server that is more cognizant of the network infrastructure than the host is.

  The working group has developed an HTTP-based protocol and recent work has reported proof-of-concepts of ALTO based solutions supporting applications such as content distribution networks (CDN).

  To support current and future deployments of ALTO, the working group is now chartered for the following activities:

  - Provide a place to collect implementation deployment and experience. It is hoped that ALTO practitioners will report their experiences on the mailing list, and the working group will track implementation and deployment reports on a wiki or in an Internet-Draft.
  - Perform protocol maintenance for the existing published protocol. It is anticipated that questions and issues will arise concerning the existing protocol specifications: The working group will develop and publish updates as necessary to resolve any interoperability, performance, operational, or security, or privacy problems that arise. The working group will also help resolve any errata reports that are raised. This work

item might be addressed by discussions and reviews, or might require additional RFCs.

- Develop operational support tools for the ALTO protocol. Based on experience from deployments, the advice in RFC 7971, and considering the latest opinions and techniques from the Operations and Management Area, the working group will develop tools to configure, operate, and manage the ALTO protocol and networks that use ALTO. This may include YANG models and OAM mechanisms. The working group may also update RFC 7971 in the light of new experience and protocol features that were added to ALTO after that RFC was published.
- Support for modern transport protocols. When work on ALTO began, the protocol was supported using HTTP version 1. Since then, the IETF has developed HTTP/2 and HTTP/3. The working group will develop any necessary protocol extensions and guidance to support the use of ALTO over HTTP/2 and HTTP/3.'

  Future use cases. The working group will provide a forum to discuss possible future use cases. The objective of this discussion will be to determine a small set of use cases that have strong support and a realistic chance of implementation and deployment. The working group will not develop protocol extensions for these use cases until it has been re-chartered specifically for that purpose.

- Readiness:

  1: Adoption:

  - Working Group is active and RFC and Internet drafts are available. At the moment is re-chartering, where edge computing will be one of the topics taken into considerations;

  2. Development Status:

  WG ALTO is re-chartering;

  Milestones and Deliverables:

  - Conduct a survey of working group participants and the wider community to discover ALTO implementation and deployment experience. Record the results in a publicly visible wiki.
  - Develop and standardize at least one OAM mechanism to support ALTO, including a YANG model for configuration and management of ALTO servers.
  - Analyze ALTO over HTTP/2 and HTTP/3 and publish a support document. Develop any necessary protocol modifications.
  - Report to the Area Director any use cases that have strong support and a realistic chance of implementation and deployment.

A relevant (Individual) Internet Draft in the edge computing area is: “Use of ALTO for Determining Service Edge”, see: https://datatracker.ietf.org/doc/draft-contreras-alto-service-edge/

- 3. Compliance
  - Not IETF responsibility.

4. Openness:

  - Open to public.

5. Ratification process:

  - Open process for all parties interested in the ratification.

- Interoperability level:
  - Syntactical interoperability.
  - Technical interoperability.
  - Semantic interoperability.
- Standards:
  - Application-Layer Traffic Optimization (ALTO) Deployment Considerations, RFC 7971, see: https://www.rfc-editor.org/info/rfc7971
- Supporting organizations:
  - ALTO is an IETF WG.
- Domain:
  - Market domain: Located on the vertical axis, to show that it is equally used by the consumer and industrial internet market.
  - Technical domain: Closer to the service & applications edge of the vertical axis
- Application area:
  - ALTO WG is focusing on horizontal industry.
- IPR Policy Available:
  - The IETF intellectual property rights rules are defined in RFC8179, "Intellectual Property Rights in IETF Technology", see: https://www.ietf.org/rfc/rfc8179.txt
- Specification Access:
  - Access of published (RFCs) and non-published (Internet draft) specifications for members and non-members is open and free of payment.

4.2.12 IRTF (Internet Research Task Force)

The Internet Research Task Force (IRTF) promotes research of importance to the evolution of the Internet protocols, applications, architecture and technology, see: https://irtf.org/.

The Internet Research Task Force (IRTF) focuses on longer term research issues related to the Internet while the parallel organization, the Internet Engineering Task Force (IETF), focuses on the shorter term issues of engineering and standards making.

The IRTF is comprised of a number of focused and long-term Research Groups. These groups work on topics related to Internet protocols, applications, architecture and technology. Research Groups have the stable long-term membership needed to promote the development of research collaboration and teamwork in exploring research issues. Participation is by individual contributors, rather than by representatives of organizations.

T2T (Thing to Thing) RG

- Description:
  The Thing-to-Thing Research Group (T2TRG) will investigate open research issues in turning a true "Internet of Things" into reality, an Internet where low-resource nodes ("things", "constrained nodes") can communicate among themselves and with the wider Internet, in order to partake in permissionless innovation. The focus of the T2TRG are on issues that touch opportunities for standardization in the IETF, i.e., it will start at the adaptation layer connecting devices to IP, and end at the application layer with architectures and APIs for communicating and making data and management functions (including security functions) available.
- Areas of Interest
  - Understanding the motivation for single-purpose silos and gateways; facilitating a move towards small pieces loosely joined (hence "thing-to-thing"); enabling scaling the number of applications in a single network
  - Deployment considerations; scaling considerations; cost of ownership
  - Management and operation of "things"
  - Lifecycle aspects (including, but not limited to, security considerations)
  - Cooperation with W3C, e.g., on data models, formats, and semantics
- More exploratory areas of interest include:
  - Operating "things" that have multiple masters/stakeholders (including understanding role definitions of devices, owners, operators, etc.)
  - Exploring the duality of state- and event-based approaches
  - Aspects of distribution (cf. "fog computing"); reliability and scalability considerations
  - Containerization and other forms of mobile code
- Readiness:

  1. Adoption:

     - Well adopted

  2. Development Status:

     - RFC published, see: "Internet of Things (IoT) Security: State of the Art and Challenges", RFC 8576, see: https://datatracker.ietf.org/doc/rfc8576/
     - On edge computing, there is an Internet draft being active: "IoT Edge Challenges and Functions", see: https://datatracker.ietf.org/doc/html/draft-irtf-t2trg-iot-edge-02

  3. Compliance:

4. Openness:

- Open to public.

5. Ratification process:

- Done by members and open for consultation from external parties.
- Open process for all parties interested in the ratification.

- Interoperability level:
  - Syntactical interoperability.
  - Technical interoperability.
  - Semantic interoperability.

- Standards:
  - The T2T RG is an IRTF Research Group that will be using and providing input mainly to IETF, but also to the IOT and edge computing research community. Produced one RFC: "Internet of Things (IoT) Security: State of the Art and Challenges", RFC 8576, see: https://datatracker.ietf.org/doc/rfc8576/

- Supporting organizations:
  - T2T RG is belonging to IRTF that is closely cooperating with the IETF and it represents the research activities of IETF.

- Domain:
  - Market domain: Located on the vertical axis, to show that it is equally used by the consumer and industrial internet market.
  - Technical domain: Closer to the service & applications edge of the vertical axis

- Application area:
  - IRTF T2T RG is focusing on horizontal industry.

- IPR Policy Available:
  - The IRTF follows the IETF Intellectual Property Rights (IPR) disclosure rules, see: https://irtf.org/ip. . This is a summary of these rules as they relate to IRTF research group discussions, mailing lists and Internet Drafts:
  - If you include your own or your employer's IPR in a contribution to an IRTF research group, then you must file an IPR disclosure with the IETF. If you recognize your own or your employer's IPR in someone else's contribution and you are participating in the discussions in the research group relating to that contribution, then you must file an IPR disclosure with the IETF. Even if you are not participating in the discussion, the IRTF still requests that you file an IPR disclosure with the IETF.
  - Finally, the IRTF requests that you file an IPR disclosure with the IETF if you recognize IPR owned by others in any IRTF contribution.

  The IRTF expects that you file IPR disclosures in a timely manner, i.e., in a period measured in days or weeks, not months. The IRTF prefers that the most liberal licensing terms possible are available for IRTF Stream documents, see RFC 5743. You may file an IPR disclosure here: https://www.ietf.org/ipr/file-disclosure
  See RFC 8179 (BCP 79) for definitions of "IPR" and "contribution" and for the detailed rules (substituting "IRTF" for "IETF", see: https://ietf.org/

- Specification Access:
  - Access of published (RFCs) and non-published (Internet draft) specifications for members and non-members is open and free of payment.

COIN (Computing in the Network) RG

- Description:

  The COIN proposed research group (COINRG) will explore existing research and foster investigation of "Compute In the Network" and resultant impacts to the data plane, see: https://datatracker.ietf.org/rg/coinrg/about/. The goal is to investigate how to harness and to benefit from this emerging disruption to the Internet architecture to improve network and application performance as well as user experience. COIN will encourage scrutiny of research solutions that comprehend the re-imagining of the network to be a place where routing, compute, and storage blend.

  COIN will address both controlled environments such as DCN and the ongoing shift from data center (DC) toward edge computing and will debate whether this shift can be viewed as a cloud continuum. COIN specifically will focus on the evolution necessary for networking to move beyond packet interception as the basis of network computation. While existing DCs employ rudimentary languages for programming switch, richer programmability is required to support emerging workloads, such as edge network analytics, machine learning and deep learn. Such applications not only need access to more general-purpose languages, but also need to operate in conjunction with local and remote caches, dynamic control points, and data stewardship.

  Orchestration of end-to-end resources between the DC network and the edge is another key topic to address in COIN. In particular, the RG will examine orchestration with increasingly heterogeneous distributed components and draw inspiration from current approaches (e.g., Kubernetes, Swarm) that are likely to need updating, extending, and/or simplifying in multi-domain network environments.

  Use-case-driven requirements, gathered from next-generation applications and services (e.g., video streaming, immersive AR/VR, autonomous/connected vehicles, industrial IoT), may lead to new architectures, which employ new ways to perform functional distribution and leverage co-design of layered approaches. In order to achieve its goals, COIN will expose and advance research on distributed, decentralized networks and resources required by DC, edge and ambient computing. COIN will investigate the implications of increased heterogeneity and limitations that arise if/when DC and edge computing employ a common architecture, programmable networks and API and interchangeable functionality in the Internet. An assumption will be that to improve Internet performance, the network, compute and storage resources must work jointly in close partnership throughout the network, while servicing data-intensive distributed applications.

  SCOPE of the COINRG:

  1. Research on solutions to use programmable network devices, languages and abstractions to implement network functions for improved Internet performance.
  2. Research on use case driven requirements analysis: the cloud continuum from the data center to edge networks and beyond including in-network computing using programmable switches. Identify potential benefits to these networks from in-network functionality, including but not limited to compute, cache, manage, control, etc.
  3. Research on novel architectures, data-plane abstractions and new network protocol designs to efficiently federate decentralized

computing resources, across the infrastructure regardless of where in the network the compute is placed (the DC, the core, the edge, and even in the end-user devices).

4. Research on potential new transport protocol, new privacy and security mechanisms required or enabled by in-network compute.

- Readiness:

1. Adoption:

- Well progressing

2. Development Status:

Date	Milestone
Nov 2020	Work toward defining a COIN scope appropriate for the IRTF, within which new architectures, mechanisms and protocols can be proposed
Apr 2020	Identify COIN network-related eco-system dependencies
Apr 2020	Target COIN case studies, from architecture, implementation and use case standpoints draft-montpetit-coin-xr draft-he-coin-managed-networks
Apr 2020	Discuss/catalog COIN requirements and implications for network elements (including network services, network SW stacks, network HW design, etc.) draft-mcbride-edge-data-discovery-overview draft-he-coin-managed-networks draft-kunze-coin-industrial-use-cases
Dec 2019	Articulate COIN challenges draft-liu-coinrg-requirement draft-kutscher-coinrg-dir
Dec 2019	Capture the SoTA of the COIN landscape draft-kutscher-coinrg-dir

3. Compliance:

4. Openness:

- Open to public.

5. Ratification process:

- Done by members and open for consultation from external parties.
- Open process for all parties interested in the ratification.

- Interoperability level:

1. Syntactical interoperability.

2. Technical interoperability.
3. Semantic interoperability.

- Standards:
  - The COIN RG is an IRTF Research Group that will be using and providing input mainly to IETF, but also to the edge computing research community.
- Supporting organizations:
  - COIN RG is belonging to IRTF that is closely cooperating with the IETF and it represents the research activities of IETF.
- Domain:
  - Market domain: Located on the vertical axis, to show that it is equally used by the consumer and industrial internet market.
  - Technical domain: Closer to the service & applications edge of the vertical axis
- Application area:
  - IRTF COIN RG is focusing on horizontal industry.
- IPR Policy Available:
  - The IRTF follows the IETF Intellectual Property Rights (IPR) disclosure rules, see: https://irtf.org/ip. . This is a summary of these rules as they relate to IRTF research group discussions, mailing lists and Internet Drafts:
  - If you include your own or your employer's IPR in a contribution to an IRTF research group, then you must file an IPR disclosure with the IETF. If you recognize your own or your employer's IPR in someone else's contribution and you are participating in the discussions in the research group relating to that contribution, then you must file an IPR disclosure with the IETF. Even if you are not participating in the discussion, the IRTF still requests that you file an IPR disclosure with the IETF.
  - Finally, the IRTF requests that you file an IPR disclosure with the IETF if you recognize IPR owned by others in any IRTF contribution.

  The IRTF expects that you file IPR disclosures in a timely manner, i.e., in a period measured in days or weeks, not months. The IRTF prefers that the most liberal licensing terms possible are available for IRTF Stream documents, see RFC 5743. You may file an IPR disclosure here: https://www.ietf.org/ipr/file-disclosure
  See RFC 8179 (BCP 79) for definitions of "IPR" and "contribution" and for the detailed rules (substituting "IRTF" for "IETF", see: https://ietf.org/
- Specification Access:
  - Access of published (RFCs) and non-published (Internet draft) specifications for members and non-members is open and free of payment.

4.2.13 International Telecommunication Union – Telecommunication Standardization Sector (ITU-T)

- Description:

The Study Groups of ITU-T assemble experts from around the world to develop international standards known as ITU-T Recommendations which act as defining elements in the global ICTs.

ITU-T Study Group 20 "Internet of things (IoT) and smart cities and communities (SC&C)", established in June 2015, is the central venue for IoT and

smart cities standardization activities within ITU-T. Note that activities related to edge computing for the IoT are as well addressed.

SG20 addresses the standardization requirements of Internet of Things (IoT) and smart cities and communities (SC&C).

SG20, via the Joint Coordination Activity on Internet of Things and Smart Cities & Communities whose supervision is ensured by SG20, maintains the coordination of IoT and smart cities & communities related studies across the various involved ITU-T Study Groups as well as with external SDOs, Alliances and Consortia.

Specific study items (a not exhaustive list) of SG20 include:

- Development of international standards to enable the coordinated development of IoT technologies, including machine-to-machine communications and ubiquitous sensor networks. A central part of this study is the standardization of requirements, capabilities and architectural frameworks across verticals, platforms, end-to-end architectures and protocols for IoT, mechanisms for the interoperability and interworking of IoT applications, networks and datasets employed by verticals.
- Development of international standards that leverage IoT technologies to address urban-development challenges, assess and evaluate smart cities and communities .
- IoT research and emerging technologies incl. - but not limited to - **Edge Computing**, Blockchain, Digital Twin, AI/ML, Big Data and Analytics **for IoT**.
- IoT trust, privacy and security.
- IoT identification.
- IoT semantics.
- IoT analytics, sharing, processing and management
- IoT accessibility

In terms of IoT and smart cities & communities, it has to be noted by the way that different ITU-T study groups have some related studies in the context of their specific areas of competence and also considering the current pervasive impact of digital transformation (largely enabled via the support of IoT related technologies) in all sectors of economy and society. Specific mention is deserved for ITU-T SG17 (general and vertical-specific security aspects of IoT and related technologies), ITU-T SG16 (multimedia aspects of IoT and related technologies), ITU-T SG13 and SG11 (network aspects of IoT and related technologies, including Edge Computing).

An ITU-T Focus Group which has been particularly relevant for IoT and smart cities & communities pre-standardization over the most recent years has been the Focus Group on Data Processing and Management to support IoT and Smart Cities & Communities (FG-DPM) [established 2017-03, terminated 2019-

07], most of its deliverables having been transferred and progressed by SG20 at the FG closure time.

A domain-specific international standardization coordination activity ensured by ITU-T is the **Collaboration on ITS Communication Standards (CITS)** (*https://www.itu.int/en/ITU-T/extcoop/cits/Pages/default.aspx*), whose intent is to provide a globally recognized forum for the coordination of an internationally accepted, globally harmonized set of Intelligent Transportation Systems (ITS) communication standards of the highest quality in the most expeditious manner possible to enable the rapid deployment of fully interoperable ITS communication-related products and services in the global marketplace.

It has also to be noted the UN initiative called **"United for Smart Sustainable Cities (U4SSC)"** *(https://www.itu.int/en/ITU-T/ssc/united/Pages/default.aspx)*, coordinated by ITU, UNECE and UN-Habitat, and supported by CBD, ECLAC, FAO, UNDP, UNECA, UNESCO, UNEP, UNEP-FI, UNFCCC, UNIDO, UNOP, UNU-EGOV, UN-Women and WMO. The U4SSC goal is to achieve Sustainable Development Goal 11: "Make cities and human settlements inclusive, safe, resilient and sustainable"

Note about ITU-T activities on IoT and smart cities & communities before October 2015

The IoT related specifications published before October 2015 by ITU-T, and the main IoT related activities of ITU-T till that time, involved Study Group 11, Study Group 13, Study Group 16 and Study Group 17:

- SG11 focused on the interoperability, protocol and testing aspects of IoT;
- SG13 mainly focused on the network aspects of IoT;
- SG16 mainly focused on the application aspects of IoT;
- SG17 focused on the security aspects of IoT.

Smart cities related activities were progressed before October 201within specific ITU-T Focus Groups which produced a set of technical reports and technical specifications, most of which were transformed into Supplements and ITU-T Recommendations (e.g. ITU-T L.1603 series: KPIs for Smart Sustainable Cities). The main Focus Groups involved in IoT and smart cities issues till October 2015 were: the Focus Group on M2M Service Layer, the Focus Group on Smart Water Management and the Focus Group on Smart Sustainable Cities.

Additional IoT activities were progressed within Study Group 15 (Smart Grid and Home Network aspects) and the Collaboration on ITS Communication Standards.

- Readiness:

1. Adoption:

    - No implementations/Reference implementations/Widely adopted in industry (according to the particular specification).

2. Development Status:

    - Under development/ Approved with no planned revisions/ Approved with planned revisions (according to the particular specification).

3. Compliance:

    - Not managed/Having compliance testing process (according to the particular specification). No process implemented yet for any IoT related specification.

4. Openness:

    - Open by formal membership.

5. Ratification process:

    - Closed process done by members only with no consultation from external parties

    NOTE – In some specific cases, it can be done by members and open for consultation from external parties, previous agreement with the external parties.

- Interoperability level:

    - Technical interoperability/Syntactical interoperability (according to the particular specification).
      NOTE – Some specific ongoing studies are considering Semantic interoperability aspects.

- Standards:
    - Various IoT and smart cities & communities standards have been proposed in published specifications (and others are considered in some ongoing studies).
    - Some published specifications on IoT and smart cities & communities use and integrate standards and protocols developed by other SDOs (and other SDOs' standards and protocols are considered in some ongoing studies). A specific mention to the transposition of various oneM2M specifications into ITU-T specifications (Recommendations, Supplements).
    - Published specifications and ongoing studies related to Edge Computing include:
        - Edge Computing for IoT (SG20)
            - ITU-T Y.4208 "IoT requirements for support of edge computing" (approval date: 1/2020)
            - Y.IoT-EC-GW "Capabilities and framework of edge computing-enabled gateway in the IoT" (ongoing, consent target date: 5/2021)
        - Edge Computing in general - network aspects (SG13)
            - ITU-T Y.3109 "QoS assurance-related requirements and framework for virtual reality delivery using mobile edge computing supported by IMT-2020" (approval date: 4/2021)
            - Y.ec-reqts "Edge computing - Overview and requirements" (ongoing)

- Y.IMT2020-CEFEC "Framework of capability exposure function in edge computing for IMT-2020 networks and beyond" (ongoing)
- Y.LSMEC "Local shunting for multi-access edge computing in IMT-2020 networks" (ongoing)
- Y. FMSC-MEC "Multi-access Edge Computing for fixed, mobile and satellite convergence in IMT-2020 networks and beyond" (ongoing)
- Y.FMC -AAEC-req "Use cases and Technical requirements for supporting application addressing in edge computing for future networks including IMT-2020 network" (ongoing)
- Y.FMC-EC "Unified edge computing for supporting fixed mobile convergence in IMT-2020 networks" (ongoing)

- Supporting organizations
  - Telecommunication Hardware and Software Providers.
  - Service Providers, Network Providers, Platform providers, Application Provider, Integrators, other vertical stakeholders.
  - Member State entities (Administration entities, Academies, Public Research).
  - National and Regional Regulation Authorities.
  - Other National and Regional Entities.

- Domain:
  - Most of the activities target the market without specific focus on consumer versus industrial internet.
  - Both sides of the technology domain are targeted, according to the particular specification.

- Application area:
  - Focus on integrated/complete IoT solutions, i.e. horizontal industry: numerous activities (in all involved Study Groups, including SG20);
  - Focus on numerous vertical industries: Home/Buildings/Civil Engineering (SG13, SG15, SG20), Vehicles/Transportation (SG16, SG20), Healthcare (SG16, SG20), Cities (SG20), Farming/Agrifood/Livestock (SG20), Manufacturing and Industrial Internet (SG13, SG16, SG20), Retail (SG20), Ports (SG20), others. NOTE – In principle, , SG20 is involved in all vertical industries.

- IPR Policy Available:
  - ITU / ISO / IEC code of practice.
    All details can be found at http://www.itu.int/en/ITU-T/ipr/Pages/default.aspx.

- Specification Access:
  - Published specifications: the vast majority is accessible to all free of charge once a final editing process is complete. Texts that are not free of charge include common ITU-T | ISO / IEC texts for which special arrangements exist.

- Non-published specifications: freely accessible to members only; not accessible to non-members.

4.2.14 ISO/IEC JTC1

- Description:
- ISO and IEC have a joint technical committee called JTC 1. JTC1 is a member based organization with the possibility of one member from each country. In 2015 JTC1 had 76 members. Standardization in JTC1 is builds on the WTO agreements on Technical Barriers to Trade.
- In 2012 ISO/IEC JTC 1 initiated preparatory work in the field of IoT. At the JTC1 meeting in November 2014 the IoT report was accepted as presented by all members of JTC1. As a consequence of the report and its acceptance, JTC1 decided to establish a working group on IoT with the mandate to develop foundational standards.

ISO/IEC JTC 1 ISO/IEC JTC 1 WG10 (IoT) / **SC 41**

The ISO/IEC JTC 1 WG10 (IoT) is denoted as ISO/IEC JTC 1/SC 41 since May 2017

- The ISO/IEC JTC 1 WG10 (IoT) has prepared a Strategic business plan but it will be confirmed at the upcoming JTC1 meeting in October 2012 in China. Until then the WG has the mandate to develop one standard which has got the following title and scope:
- The ISO/IEC JTC 1 WG10 (IoT) is denoted as ISO/IEC JTC 1/SC 41 since May 2017
  Title: Information technology – Internet of Things Reference Architecture (IoT RA)

  Scope of the proposed deliverable – This new work item specifies IoT Conceptual Model, conceptual reference model, and reference architecture from different architectural views, common entities, and interfaces between IoT domains.

- Business Impact:
  - All business will benefit from an international IoT standard provided from a conceptual to business specific IoT Architectures.

ISO/IEC JTC 1/SC 38 - Cloud computing and distributed platforms[1]

Standardization in the areas of Cloud Computing and Distributed Platforms including:

- Foundational concepts and technologies,
- Operational issues, and
- Interactions among Cloud Computing systems and with other distributed systems

SC 38 serves as the focus, proponent, and systems integration entity on Cloud Computing, Distributed Platforms, and the application of these technologies. SC 38 provides guidance to JTC 1, IEC, ISO and other entities developing standards in these areas.

[1] https://www.iso.org/committee/601355.html

- Readiness:

1. Adoption:

    - Developing use cases as considerations for Reference Architecture.
    - The ISO/IEC JTC 1 standard is expected to be widely adopted in industry.

2. Development Status:

    - In progress.

3. Compliance:

    - Through 13external and 11internal liaisons with other SDO's receiving input that balance with own work for selecting solutions to standards issues.

4. Openness:

    - Every standard document passes 6 stages to be realized as an international standard. National experts comment the documents at every stage for quality completeness etc. National bodies vote on the document on every stage to insure quality and acceptance.
    - Approved standards document are available through subscription or purchase

5. Ratification process:

    - Every formal step in developing of the standard is done by national experts.
    - The documents are casted and formally voted and commented on by national bodies. Comments and votes are being handled according to ISO/IEC Directives by the national body in charge of the secretariat.

- Interoperability level:
    - Syntactical interoperability.
    - Technical interoperability.

- Standards:
    - ISO SC41
        - Will include functions for technical as well as Syntactical interoperability.
        - It is also possibly that the standard will have opening for both semantic and pragmatic interoperability levels.
    - ISO SC38
        - ISO/IEC TR 23188:2020 Information technology — Cloud computing — Edge computing landscape
            - This document examines the concept of edge computing, its relationship to cloud computing and IoT, and the technologies that are key to the implementation of edge computing. This document explores the following topics with respect to edge computing:
                - concept of edge computing systems;
                - architectural foundation of edge computing;
                - edge computing terminology;

- software classifications in edge computing, e.g. firmware, services, applications;
- supporting technologies, e.g. containers, serverless computing, microservices;
- networking for edge systems, including virtual networks;
- data, e.g. data flow, data storage, data processing;
- management, of software, of data and of networks, resources, quality of service;
- virtual placement of software and data, and metadata;
- security and privacy;
- real time;
- mobile edge computing, mobile devices.

- Supporting organizations:
- Domain:
  - Market domain: ISO/IEC JTC 1 standards document will benefit horizontal axis.
  - Technical domain: ISO/IEC JTC 1 standards document will benefit all IoT – systems and integration on several interoperability levels.
- Application area:
  - The ISO/IEC JTC 1 standards document will benefit horizontal industries.
- IPR Policy Available:

  http://www.iso.org/iso/home/standards_development/resources-for-technical-work.htm

  https://connect.iso.org/display/ipr/Intellectual+Property.

- Specification Access:
  - JTC1 standards are publicly available for everyone. They can be bought thru the National Standardization Bodies or thrugh ISO.
  - Members of a National Standardization Body who are mirroring the WG10 work will have full access to all working documents and drafts in the development process thru a web platform. Please note that liaisons to WG10 will have access to the same web platform as WG10 experts.
  - Non-members: cannot get access to draft standards or other working documents but can get access to all published standards.

4.2.15 oneM2M

- Description:

  The text used in this section is based on: http://www.onem2m.org/about-onem2m/why-onem2m.

  oneM2M was launched in 2012. It is a global initiative (Partnership Project) that develops specifications to ensure the most efficient deployment of Machine-to-Machine (M2M) communications systems and the Internet of Things (IoT).

  oneM2M vision: A world of interoperable and secure IoT services where market adoption is easy and delivers benefits to society."

oneM2M mission: “We are the global community that develops IoT standards to enable interoperable, secure, and simple-to-deploy services for the IoT ecosystem. oneM2M standards are open, accessible and internationally recognized.”

The goal of oneM2M is to develop technical specifications for a common M2M and IoT service layer. This can be embedded within hardware and software to connect the wide range of devices worldwide with IoT and M2M application servers.

By bringing together more than 200 players from many diverse business domains, oneM2M ensures the global functionality of M2M and IoT and prevents the duplication of standardization effort.

Work in oneM2M is contribution driven, by members in working groups of the technical plenary.

oneM2M Technical Plenary:

- Requirements and Domain Models (RDM) Working Group
- System Design and Security (SDS) Working Group
- Testing and Developers Ecosystem (TDE) Working Group

oneM2M has been defining Technical Specifications and Technical Reports for:

- Use cases and requirements for a common set of Service Layer capabilities;
- Service Layer aspects with high level and detailed service architecture, in light of an access independent view of end-to-end services;
- Protocols/APIs/standard objects based on this architecture (open interfaces & protocols);
- Security and privacy aspects (authentication, encryption, integrity verification);
- Reachability and discovery of applications;
- Interoperability, including test and conformance specifications;
- Collection of data for charging records (to be used for billing and statistical purposes);
- Identification and naming of devices and applications;
- Information models and data management (including store and subscribe/notify functionality);
- Management aspects (including remote management of entities);
- Interworking towards other technologies standards in the subject area and legacy technologies, making it applicable for brownfield environments.
- Common use cases, terminal/module aspects, including Service Layer interfaces/APIs between:

- Application and Service Layers;
- Service Layer and communication functions.

- Readiness:

1. Adoption:

   - Reference implementations.
   - Widely adopted in industry.

2. Development Status:

   - Approved with planned revisions.

3. Compliance:

   - Having compliance testing process (include test suites, method, etc.):
     - oneM2M has developed a set of specifications for interoperability and compliance testing..
     - Since 2015 seven interop test events have been held, offering interoperability as well as conformance test sessions..
   - Formal certification process:
     - The aim of the oneM2M Certification program is to assure users that certified products and services meet oneM2M standard testing requirements that ensure interoperability. oneM2M Certification is a LOGO program, NOT a compulsory program.

     - The program was pioneered by the Telecommunication Technology Association (Korea), one of oneM2M's founding Partners. Since 2019, the program has been operated by the Global Certification Forum, which serves the mobile and IoT industry, with certification initiatives that verify the quality of the interoperability between mobile phones, wireless and IoT devices across different network elements and diverse vendor infrastructure.
       https://www.onem2m.org/harmonization-m2m/certifications
       https://www.globalcertificationforum.org/services/onem2m-standards-form2m-and-iot.html

4. Openness:

   - Open to public.

5. Ratification process:

   - Done by members and open for consultation from external parties.

- Interoperability level:
  - Syntactical interoperability.
  - Technical interoperability.
  - Semantic interoperability.

- Standards:

- Find and download the full set of oneM2M Technical Specifications and work program deliverables developed by oneM2M members from the earliest to the most recent Release cycle at: https://www.onem2m.org/technical

- Supporting organizations:
  oneM2M is a partnership project the current partners are:
  - Partner Type 1:
    - Alliance for Telecommunications Industry Solutions (ATIS);
    - Association of Radio Industries and Businesses (ARIB);
    - China Communications Standards Association (CCSA);
    - European Telecommunications Standards Institute (ETSI);
    - Telecommunications Industry Association (TIA);
    - Telecommunications Standards Development Society India (TSDSI);
    - Telecommunications Technology Association (TTA);
    - Telecommunications Technology Committee (TTC);
  - Partner Type 2:
    - GlobalPlatform;
  - Associate Members:
    - Ministry of Science, ICT and Future Planning (MSIP);
    - National Institute of Standards and Technology (NIST);
    - State Secretariat of Telecommunications and for the Information Society, Spain;
    - United States Department of Transportation;
  - ITU-T SG20 has transposed the oneM2M Specifications in its Y.4500.xseries
  - There are also more than 200 member companies/institutes supporting this work. See the full member list at: http://www.onem2m.org/membership/current-members.
- Domain:
  - oneM2M is positioned at the horizontal service domain (layer), which provides common service functionalities for IoT applications across vertical market domains.
  - As providing horizontal service layer technologies, oneM2M aims to cover a wide market range across both consumer and industrial domains.
- Application area:
    - oneM2M is not chartered to focus on a particular vertical industry. It shall provide standardized common service layer technologies that enables interoperability of applications across any domain
    - In order to enable a smooth standards based interworking with other domains Technical Specifications and Technical Reports have been developed for selected vertical domains (e.g. home, industrial, vehiclular, railway and smart cities) in detail to ensure the provided standard/technology fulfills the vertical requirements and interwork. More domains may be investigated in the future.
- IPR Policy Available:
  - http://www.onem2m.org/images/files/oneM2M_Partnership_Agreement.pdf.
- Specification Access:

- oneM2M published documents available at: http://www.onem2m.org/technical/published-documents
- oneM2M latest drafts available at: http://www.onem2m.org/technical/latest-drafts

4.2.16 OSGi Alliance

- Description:

  The OSGi Alliance is a worldwide consortium advancing a proven and mature process to create open specifications. These specifications enable dynamic end-to-end connectivity and facilitate the componentization of software and applications, thus increasing development productivity, reducing time to market and substantially decreasing the long term maintainability costs of the resulting modular solution. The technology also provides flexible remote management and interoperability for applications and services over a broad variety of devices. Member company industries include leading service and content providers, infrastructure/network operators, utilities, enterprise software vendors, software developers, gateway suppliers, consumer electronics/device suppliers (wired and wireless) and research institutions.

  Features: high level functionalities covered by the initiative

  - OSGi inherently responds to many requirements of the IoT. Its most important features can be listed as:
    - A Modular execution environment enabling functional reuse of components across diverse platforms.
    - A flexible Capabilities / Requirements model that enables environment-aware deployment and dependency management.
    - A dynamic environment allowing system components to be updated and/or reconfigured without restarting them.
    - Lifecycle aware components that are able to respond to changes in their environment, for example the addition/activation of a hardware device.
    - Support for dynamic deployment of native libraries based on the discovered system capabilities.
    - A defined security model for determining whether software modules are trusted and the actions they are permitted to perform.
    - Common API's for device connectivity using various underlying communication protocols.
    - A standardised common remote management interface using a variety of protocols including JMX and HTTP/REST.
    - Programming models for distributed environments using synchronous or asynchronous invocations. Suitable for use in edge or cloud environments.

- Readiness:
  - Adoption: Widely adopted in industry. Enterprise (most application servers, cloud backend software; cloud portal services); smart home: a broad variety of smart home solutions including DT QIVICON, devolo, AT&T Digital Life, Miele@Home etc.; telematics: various telematics solutions, including Groeneveld telematics solution for lorries, and MMLab telematics solutions for waste collection and cleaning services; adoption in AAL mainly in research projects (UniversAAL, sensiNact, etc.).
  - Development status: Release 6 Approved with planned revisions.
  - Compliance: Formal certification process, reference implementations and compliance tests.

- Openness: Open to public. Publicly available specifications with reference implementations and compliance tests. Various open source and commercial implementations exist and are adopted by the industry.
- Ratification process (how the standard is being approved?): Done by members and open for consultation from external parties.

- Interoperability level:
  - Syntactical interoperability:
    - Application modules deployed as Java code packaged in JAR files with additional metadata.
    - Deployment of native binaries using standard API.
    - Interaction with external devices through a unified abstraction layer.
  - Technical interoperability
    - Management via HTTP/REST.
    - Application modules deployed as Java code packaged in JAR files with additional metadata.
    - Runtime interoperability with any Java Virtual Machine language that has Java bindings (e.g. Java, Scala, EcmaScript), and native code via JNI.
  - Semantic interoperability
    - Possibility of expressing relevant semantics via OSGi's Requirements / Capabilities model.

- Standards:
  - The OSGi specifications provide a standardised service platform for interacting with services (both local and remote) using a variety of defined communication and messaging protocols, including UPnP, TR069, enOcean, OMA DM, HTTP/REST, JSON-RPC and many others built by the community

- Supporting organizations
  - The Strategic members of the OSGi Alliance include: Adobe, Deutsche Telekom, Huawei, IBM, Liferay, NTT, Oracle, Paremus, ProSyst Software, Salesforce.com and Software AG. Numerous other companies are active contributing members , such as Orange, Telecom Italia, Sagemcom, Schneider Electric, Hitachi, NEC and Eclipse Foundation.
  - OSGi Alliance liaises with various organizations. A collaboration between HGI, BBF, UPnP Forum and OSGi Alliance resulted in end-to-end service specifications for CPEs; Open Source communities such as Eclipse Foundation and Apache Foundation offer various reference implementations for OSGi specifications; EnOcean collaborates with the OSGi Alliance; other liaisons in IoT not be publicly announced yet, but very soon.

- Domain:
  - OSGi is being adopted in B2B and B2C product solutions, specifications are available for Smart Home, Enterprise, automotive, and mobile environments. An IoT Working Group has recently been established.

- Application area:
  - OSGi Alliance provides a horizontal platform with API's and device abstraction for specific vertical markets; it also provides specifications for enterprise solutions (app servers; cloud product solutions) and a framework for modular web application development.

- IPR Policy Available:
    - OSGi specifications are royalty free.
- Specification Access:
    - Publicly available specifications with reference implementations and compliance tests.
    - Various open source and commercial implementations exist and are adopted by the industry.

4.2.17 UDG Alliance

- Description:

  UDG Alliance (www.udgalliance.org) is an alliance developing a multi-protocol framework of IoT interoperability. It enables the integration and interoperability among over 40 IoT standards. It enables interoperability among various IP and non-IP based IoT standards and communication protocols.

- Readiness:

  1. Adoption:
     - Reference implementations; used by several European research projects and SMEs.
  2. Development Status:
     - Approved with planned revisions.
  3. Compliance
     - With over 50 IoT standards as well as with network virtualization.
  4. Openness
     - Reserved to the UDG Alliance members.
  5. Ratification process:
     - Closed process done by members only with no consultation from external parties.

- Interoperability level:
  - Technical interoperability/Syntactical interoperability/ Semantic interoperability. Portable on all sorts of networking technologies.

- Standards:
  - UDG Alliance has developed its own framework that has been designed to enable interoperability with all sorts of IoT standards developed by other SDOs.

- Supporting organizations:
  - University and European SMEs.

- Domain:
  - UDG Alliance encompasses both consumer and industrial Internet.
  - It encompasses bot connectivity and application layers, with a cross domain positioning.
- Application area:
  - UDG Alliance is fully cross-domain, encompassing smart buildings, smart cities, smart agriculture, smart grid, smart factory, etc.
- Scope:
  - Multi-protocol Integration/Interoperability knowledge area. Distributed intelligence and edge computing.

- IPR Policy Available:
  - Specific access rules defined by the Alliance.

- Specification Access:

- Non-published specifications: freely accessible to members only; not accessible to non-members.

4.2.18 World Wide Web Consortium (W3C)

W3C is an international member-funded organization focusing on standards and guidelines for web technologies, including web browsers, web data and metadata, as well as horizontal activities on accessibility, internationalization, privacy and security. W3C specifications are implementable under a royalty free patent policy and are available as free downloads.

Web applications execute on cloud servers, and at the network edge in web browsers. W3C's standards activities for the IoT and Edge Computing include the Web of Things, Decentralized Identifiers, WebNN for local and federated AI, WASM for speeding up applications at the edge, RDF and Linked Data, and early work on Cognitive AI.

Web of Things

The Web of Things is an abstraction layer for sensors and actuators where applications interact with digital twins independently of the protocols and data formats used to communicate with the IoT devices. This is based upon using RDF to describe digital twins in terms of their affordances (properties, actions and events), their associated data models and semantics, and the security and communications metadata for use by client platforms to connect to the IoT devices.

W3C released standards for Thing Descriptions in JSON -LD and the Web of Things Architecture as W3C Recommendations in April 2020, along with informative reports on a scripting API and security and privacy guidelines. Related work is addressing binding templates and discovery. For more details, see: https://www.w3.org/WoT/.

The Web of Things is applicable across many sectors, e.g., smart buildings, smart homes, smart cities and manufacturing.

Web Neural Network API

This is a low-level API for artificial neural networks with hardware acceleration, and can be used to execute pre-trained models as well as for local and federated machine learning. The Web Neural Network API is designed for execution at the network edge and can be applied to a wide range of applications. For more details, see: https://www.w3.org/groups/wg/webmachinelearning

Web Assembly

Web Assembly (Wasm) is designed as a portable target for compilation of high-level languages, enabling deployment on the Web for client and server applications. Web Assembly aims to execute at native speed, taking advantage of common hardware capabilities, and its binaries are much smaller than JavaScript files. This makes them faster to download, faster to decode and execute. It has been used for a wide range of applications, and can be used outside of the Web browser, e.g., for server-less computing. Compilers are available for C/C++, C#, Rust, Go, Kotlin, Swift and other languages. For more details, see: https://www.w3.org/wasm/

RDF and Linked Data

RDF is W3C's framework for graph data and metadata, and important for the IoT in respect to semantic interoperability whereby providers and consumers can agree on the meaning of data and metadata. There is a suite of existing standards including the OWL ontology language, the SPARQL query language and SHACL, the RDF shape constraints language. RDF defines an abstract model that can be serialised in a variety of formats including XML, Turtle and JSON-LD. RDF supports URIs for graph nodes and link predicates. URIs are globally unique identifiers and as such useful for standardising vocabulary terms as a basis for semantic interoperability. RDF URIs can be dereferenceable as a means to obtain further information. The Linked Data Platform (LDP) defines a set of rules for HTTP operations on web resources, some based upon RDF as an architecture for read-write Linked Data on the Web.

Cognitive AI

Classical AI is based on symbolic representations, search algorithms, rule languages and logical deduction. The dependence on manual knowledge engineering imposes a scaling bottleneck. By contrast, deep learning with artificial neural networks derive their power from machine learning using huge data sets.

Deep learning is good at deep statistical correlations, but has difficulties with salience and generalising beyond the training data. There is increasing awareness of the potential for hybrid approaches that combine symbolic and sub-symbolic statistical techniques. Cognitive AI seeks inspiration from the human brain as the only example of general intelligence we currently have.

Cognitive AI is still at an early stage. The W3C Cognitive AI Community Group is working on mimicking human perception, cognition, feelings and action. Chunks are based upon work in the cognitive sciences on human memory and the idea of chunking information to make it easier to recall. The chunks and rules specification describes chunk graphs and rules. It can be implemented on edge computers as a basis for combining the IoT with local or remote cognition. Chunks offer a simple way to reconcile Property Graphs and Semantic Graphs, and includes a mapping to RDF. For more details, see: https://www.w3.org/community/cogai/

Web Machine Learning Working Group

W3C is also working on standards for accelerating performance of web applications in the browser through lower level access to hardware, e.g. graphics accelerators and hardware acceleration of artificial neural networks, where we held a workshop and are now in the process of launching a new Web AI working group see: https://www.w3.org/groups/wg/webmachinelearning.

4.2.18.1 W3C Decentralized Identifier Working Group

- Description:

  Decentralized identifiers (DIDs) are a new type of identifier that enables verifiable, decentralized digital identity. A DID refers to any subject (e.g., a person, organization, thing, data model, abstract entity, etc.) as determined by the controller of the DID. In contrast to typical, federated identifiers, DIDs have been designed so that they may be decoupled from centralized registries, identity providers, and certificate authorities. Specifically, while other parties might be used to help enable the discovery of information related to a DID, the design enables the controller of a DID to prove control over it without requiring permission from any other party. DIDs are URIs that associate a DID subject with a DID document allowing trustable interactions associated with that subject.

  Each DID document can express cryptographic material, verification methods, or services, which provide a set of mechanisms enabling a DID controller to prove control of the DID. Services enable trusted interactions associated with the DID subject. A DID might provide the means to return the DID subject itself, if the DID subject is an information resource such as a data model.

  Decentralized identifiers v1.0 is a W3C Candidate Recommendation as of 27 June 2021, for more details, see https://www.w3.org/2019/did-wg/

  The mission of the W3C Decentralized Identifier Working Group is to standardize the DID URI scheme, the data model and syntax of DID Documents, which contain information related to DIDs that enable the aforementioned initial use cases, and the requirements for DID Method specifications.

  The W3C DID Working Group is closely allied with the groups and activities mentioned in the W3C introductions, such as:

  - Credential Community Group
  - The Web of Things
  - RDF and Linked data
  - Cognitive AI
  - Web Machine Learning Working Group

- Readiness:
  - Adoption:
    - Decentralized identifiers v1.0 is a W3C Candidate Recommendation as of 27 June 2021
  - Development status:
    - Decentralized identifiers v1.0 is a W3C Candidate Recommendation as of 27 June 2021
  - Compliance:

- Openness:
  - Open access via github
  - Ratification process (how the standard is being approved?):
- Interoperability level:
  - Syntactical interoperability (Yes)
  - Technical interoperability (Yes)
  - Semantic interoperability (Yes)
- Standards:
  - Decentralized Identifiers (DIDs) v1.0, Core architecture, data model, and representations (W3C Candidate Recommendation, May2021. Recommendation anticipated ca. September 2021).
- Supporting organizations:
- Domain:
  - IoT and edge computing
- Application area:
- IPR Policy Available:
  - W3C specifications are implementable under a royalty free patent policy and are available as free downloads.
- Specification Access:
  - Free download

4.3 Edge Computing OSS Initiatives

This section provides a brief description of the Edge Computing OSS initiatives mentioned in Section 3. These brief descriptions are following and are based on the OSS template described in Section 0.

The official URLs of each of these initiatives can be found via Table 6 and Table 7.

Table 6: OSS initiatives and their Official URLs: Part 1

Initiative	URL
AKRAINO	https://www.lfedge.org/projects/akraino/
Baetyl	https://www.lfedge.org/projects/baetyl/
Cloudify	https://cloudify.co/
Eclipse Foundation	https://www.eclipse.org/
Edge Virtualization Engine	https://www.lfedge.org/projects/eve/
EdgeX Foundry	https://www.edgexfoundry.org/
FLEDGE	https://www.lfedge.org/projects/fledge/
Home Edge	https://www.lfedge.org/projects/homeedge/
KubeEdge	https://kubeedge.io/en/
The Linux Foundation	https://linuxfoundation.org/
Matter	https://buildwithmatter.com/
Mikrok8s	https://microk8s.io/
Open Edge Computing	https://www.openedgecomputing.org/
openHAB	http://www.openhab.org/
Open Horizon	https://www.lfedge.org/projects/openhorizon/

Table 7: OSS initiatives and their Official URLs: Part 2

Initiative	URL
OpenStack	https://www.openstack.org/
OM2M	http://www.eclipse.org/om2m/
ONAP	https://www.onap.org/
Secure Device Onboard	https://www.lfedge.org/projects/securedeviceonboard/
universAAL	http://www.universaal.info/

4.3.1 Matter

- Description:
  This industry unifying standard is a promise of reliable, secure connectivity—a seal of approval that devices will work seamlessly together, today and tomorrow. Matter (https://buildwithmatter.com/) is creating more connections between more objects, simplifying development for manufacturers and increasing compatibility for consumers. This collaborative breakthrough is built on proven technologies and guided by the Connectivity Standards Alliance (formerly Zigbee Alliance), whose members come together from across industries to transform the future of connectivity.

  Matter is built around a shared belief that Smart home devices should be secure, reliable, and seamless to use. By building upon Internet Protocol (IP), Matter will enable communication across smart home devices, mobile app and cloud services and to define a specific set of IP-based networking technologies for device certification.

- Readiness:
  1. Community:

  - Formal consortium.

  2. Commitment:

  - Dedicated committers from organizations

  3. Road map:

  - Formal road map

  4. Alignment of ongoing Standards:

  - OSS output is aligned with SDO specifications

5. Licensing:

- Apache License version 2.0

6. Portability:

- Platform independent.

- Interoperability level:
  - Organizational interoperability
- Standards:
  - Matter, based on Internet Protocol (IP) and developed by the Connectivity Standards Alliance (formerly Zigbee Alliance)
- Supporting organizations:
  - Amazon, Apple, Google, Zigbee Alliance and others.
- Domain:
  - Matter is focused on Services and Applications for Consumer Market.
- Application area:
  - Matter makes it easier for device manufacturers to build devices that are compatible with smart home and voice services such as Amazon's Alexa, Apple's Siri, Google's Assistant, and others. The first specification release of the Matter protocol will run on Wi-Fi and Thread network layers and will use Bluetooth Low Energy for commissioning.
- IPR Policy Available:
  - https://zigbeealliance.org/about/governing-documents-ipr/
- Specification Access:
  - The Project's design and technical processes are intended to be open and transparent to the general public, including to Work Group non-members wherever possible. The availability of a GitHub repository and its source code under an Apache v2 license is an important and demonstrable step to achieving this commitment.
  - https://github.com/project-chip/connectedhomeip

4.3.2 OM2M (Open platform for M2M)

- Description:
  OM2M (Open platform for M2M) is an open source implementation of the SmartM2M standard and OneM2M standard diffused by Eclipse foundation. The project is initiated by LAAS-CNRS. It provides a horizontal M2M service platform for developing services independently of the underlying network, with the aim to facilitate the deployment of vertical applications and heterogeneous devices.
- Readiness:
  1. Community:
     - Multiple organizations.

2. Commitment:

- Multiple volunteer committers.

3. Road map:

- Frequent but non planned releases (small extension).
- Planned releases (synchronization with standard).

4. Alignment of ongoing Standards:

- SmartM2M (OM2M version 0.8).
- OneM2M (OM2M version 1.0).

5. Licensing:

- Eclipse Public License (ou EPL).

6. Portability:

- Platform independent.

- Interoperability level:
  - Syntactical interoperability.

- Standards:
  - OneM2M - OneM2M consortium.
  - SmartM2M – ETSI.

- Supporting organizations:
  - LAAS-CNRS.
  - Eclipse foundation.

- Domain:
  - OM2M creates horizontal service and allows to create applications. It concerns B2C and B2B.

- Application area:
  - OM2M creates a complete IoT solutions for horizontal industry. Several companies and research laboratories use OM2M in different domains: smart-building, transportation, healthcare, energy and smart cities.

- IPR Policy Available:
  - Eclipse Public License (ou EPL).

- Specification Access:
  - http://eclipse.org/om2m.

4.3.3 UniversAAL IoT

- Description:

  Objective: Overcome the intensified overhead of integrating the complex systems of systems of the digital era by providing open specifications for semantic interoperability to enable cross-domain constellations while minimizing integration and deployment costs; such specifications to be implemented by open source and free software resulting in global standards and commodotized infrastructure solutions and tools, altogether providing an open service platform around which an open and self-organizing ecosystem may emerge.

  Features:

  (1) A Framework for connectivity, communication and semantic interoperation between otherwise disparate Products, Services and Devices,
  (2) this way achieving interoperability across domains, vendors, devices, locations, and deployment strategies,
  (3) with support for the implementation of the Sensing-Reasoning-Acting pattern,
  (4) utilizing the cumulative potential of the sum total of capabilities within open distributed systems of systems,
  (5) as well as different deployment strategies (although the concept definitions back in 2007 were based on the paradigm of Edge Computing, it supports multi-tenant deployments as well as pure Could-based deployments)

  Unique characteristics:

  (1) implementation of semantic interoperability for SoA at the level of communication protocols that eliminates the need for domain-specific APIs by reducing syntactical dependencies to one single brokerage API,
  (2) Support for context-awareness with ontology-based data sharing, intuitive model with no dependency on domain-specific ontologies, distributed push & pull mechanisms, an associated RDF database supplemented with situation reasoning, extensible with further reasoners, and some good ontologies, especially the "physical world" ontology, and
  (3) Support for user interaction in smart environments (see IEC PAS 62883) based on the notion of "interaction channels" (ICs) and UI Handlers as IC managers, with situation-aware selection of UI Handlers for handling applications' UI requests, automatically making the applications multimodal, loss-less dynamic change of IC (e.g., automatic "follow me" or automatic switching between private and public ICs), and location-based notion of "sessions" with users

- Readiness:

  Certain parts of the platform have reached the technology readiness level TRL-9 with actual proof in operational environment running since 1.5 years seven days a week, 24 hours a day; some other parts of universAAL IoT completed the prototype demonstration phase (TRL-7). It is also clearer now what should be the next priorities in the maintenance and further development of universAAL IoT.

  1. Community: Multiple organizations from the European public sector

  The "Formal consortium" called "The universAAL IoT Coalition (uIC)" has been created 2018 as an open, non-profit, international association based in Brussels, but is not really active yet.

  2. Commitment: Multiple volunteer committers

  3. Road map: since 2018 only sporadic releases (due to the good level of maturity in real-life deployments on one side, and lack of dedicated budget on the other side)

4. Alignment of ongoing Standards: Not directly aligned with SDO standards but relies mostly on the Semantic Web specifications RDF, OWL and SPARQL

5. Licensing: Apache Software License 2.0

6. Portability: supported runtime environments are Java OSGi and Java Android with local Java APIs, but provides also a REST API for remote access from different heterogeneous runtime environments; communication between different runtime environments is based on plain text, with Turtle syntax (alternatively JSON-LD), so that there is no obstacle in supporting several heterogeneous runtime environments, by porting the API to such other runtime environments.

- Interoperability level:
  Syntactical interoperability: Turtle syntax/ JSON-LD based on RDF standard specifications
  Semantic interoperability: substitutes domain-specific APIs (syntactical dependencies between interoperable modules) by pluggable shared / compatible domain models (ontologies)
  Organisational interoperability: facilitates the creation of open distributed multi-vendor systems made from heterogeneous subsystems based on shared / compatible ontologies; not only data and information, but also functionality can be shared without any technical or syntactical dependency between the heterogeneous systems of different vendors

- Standards:
  several existing standards are being used and supported; the main set of standards used is the set produced by the Semantic Web community of the W3C. From universAAL IoT, there are several specifications that have the potential to become global standards, one of which has reached the status of an IEC PAS (Publically Available Specification); the community is looking for the right context to place its proven specifications as standardization candidates.

- Supporting organizations:
  www.igd.fraunhofer.de, www.sabien.upv.es, www.lst.tfo.upm.es, and www.isti.cnr.it

- Domain:
  equally relevant for both B2B and B2C, but the API is more relevant for "Service & App" rather than "Connectivity" (because for Connectivity, it is only providing a framework for bridging different connectivity solutions to the universAAL IoT ecosystem based on semantic communication and compatibility)

- Application area:
  universAAL IoT provides a horizontal service and application integration layer across all verticals so that it can be used for integrating arbitrary open distributed systems of systems but so far, all real-life deployments of universAAL IoT are related to smart living environments.

- IPR Policy Available:
  universAAL IoT is provided under the Apache Software License 2.0, which explicitly guarantees that there are no hidden patents and any possibly existing patent is included in the royalty-free distribution with unlimited usage rights, including commercialization by third parties.

- Specification Access:
  - all publicly available under https://github.com/universAAL/ Technical overview: universaal.info/site_files/6325/upload_files/universAAL-IoT_technical-overview.pdf

4.3.4 EdgeX Foundry

- Description:
  EdgeX Foundry is an open source, vendor neutral, flexible, interoperable, software platform at the edge of the network, that interacts with the physical world of devices, sensors, actuators, and other IoT objects. In simple terms, EdgeX is edge middleware - serving between physical sensing and actuating "things" and our information technology (IT) systems.
- Readiness:
  1. Community:
  2. Commitment:
  3. Road map:
  4. Alignment of ongoing Standards:
  5. Licensing:
  6. Portability:
- Standards:
- Supporting organizations:
- Domain:
  EdgeX Foundry Service Layers: EdgeX Foundry is a collection of open source micro services. These micro services are organized into 4 service layers, and 2 underlying augmenting system services. The Service Layers traverse from the edge of the physical realm (from the Device Services Layer), to the edge of the information realm (that of the Application Services Layer), with the Core and Supporting Services Layers at the center.
- Application area:
  Originally built to support industrial IoT needs, EdgeX today is used in a variety of use cases to include:
  - Building automation – helping to manage shared workspace facilities
  - Oil/gas – closed loop control of a gas supply valve
  - Retail – multi-sensor reconciliation for loss prevention at the point of sale
  - Water treatment – monitor and control chemical dosing
  - Consumer IoT – the open source HomeEdge project is using elements of EdgeX as part of its smart home platform
- Scope:
  Integration/Interoperability knowledge area:
  IoT Architecture knowledge area:
  - EdgeX Foundry Architectural Tenets
  - EdgeX Foundry must be platform agnostic
  - EdgeX Foundry must be extremely flexible
  - EdgeX Foundry should provide "reference implementation" services but encourages best of breed solutions
  - EdgeX Foundry must provide for store and forward capability
  - EdgeX Foundry must support and facilitate "intelligence" moving closer to the edge in order to address
  - EdgeX Foundry must be secure and easily managed
- Security and Privacy knowledge area:
- IPR Policy Available:
  EdgeX is distributed under Apache 2 License backed by the Apache Foundation. Apache 2 licensing is very friendly ("permissive") to open and commercial interests.
- Specification Access:
  https://docs.edgexfoundry.org/1.3/#project-release-cadence

Website: https://docs.edgexfoundry.org/1.3/

Annex I. Editor and Contributors to this Deliverable

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ABOUT AIOTI

AIOTI is the multi-stakeholder platform for stimulating IoT Innovation in Europe, bringing together small and large companies, start-ups and scale-ups, academia, policy makers and end-users and representatives of society in an end-to-end approach. We work with partners in a global context. We strive to leverage, share and promote best practices in the IoT ecosystems, be a one-stop point of information on all relevant aspects of IoT Innovation to its members while proactively addressing key issues and roadblocks for economic growth, acceptance and adoption of IoT Innovation in society.

AIOTI's contribution goes beyond technology and addresses horizontal elements across application domains, such as matchmaking and stimulating cooperation in IoT ecosystems, creating joint research roadmaps, driving convergence of standards and interoperability and defining policies. We also put them in practice in vertical application domains with societal and economic relevance.