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AIOTI

ALLIANCE FOR INTERNET OF THINGS INNOVATION

High Level Architecture (HLA)

Release 2.0

AIOTI WG03 – IoT Standardisation

2015

1. Highlights and recommendation

In the context of the AIOTI WG3 and by following the evolution on IoT Architectural aspects and available specifications, AIOTI WG3 has developed a High Level Architecture (HLA) for IoT that should be applicable to AIOTI Large Scale Pilots. The HLA takes into account existing SDOs and alliances architecture specifications. This document is an integral part of a set of deliverables from AIOTI WG3 that also cover IoT landscape and Semantic Interoperability aspects.

AIOTI WG3 recommends that the HLA be the basis for further discussion with the Large Scale Pilot (LSP) WGs in order to promote architectural convergence among the WGs. Further development of the HLA should be an incremental exercise taking into account the LSP WGs' feedback, however it should remain high level and not compete with established SDOs, alliances and open source projects.

2. Objectives of this document

This document provides an initial proposal for a high-level IoT architecture to serve as a basis for discussion within AIOTI, referred to as the AIOTI HLA (High-level architecture). The proposal results from discussions within the AIOTI WG3 and takes into account the work of SDOs, Consortia, and Alliances in the IoT space. Throughout the proposal, AIOTI WG3 has kept in mind the need to support instantiation for all Large Scale Pilot deployments.

This document:

- Introduces the use of ISO/IEC/IEEE 42010 by AIOTI WG3
- Presents a Domain Model and discusses the "thing" in IoT
- Presents a Functional Model
- Links this work with the AIOTI WG3 Semantic Interoperability work and the SDO Landscape work
- Provides mapping examples to some existing SDO/Alliances' architectural work related to functional models: ITU-T, oneM2M, IIC.

An annex describes work in progress, pertaining to the relationship of the HLA functional model with other models. The current version of this document contains some initial content related to the possible relationship with Big Data models, in particular the Big Data interoperability framework developed by NIST [2].

3. Use of ISO/IEC/IEEE 42010

A key recommendation from AIOTI WG3 is that architectures should be described using the ISO/IEC/IEEE 42010 standard. The standard motivates the terms and concepts used in describing an architecture and provides guidance on how architecture descriptions are captured and organized.

ISO/IEC/IEEE 42010 expresses architecture in terms of multiple views in which each view adheres to a viewpoint and comprises one or more architecture models. The ISO/IEC/IEEE 42010 standard specifies minimal requirements for architecture descriptions, architecture frameworks, architecture description languages and architecture viewpoints.

AIOTI WG3 recommends using ISO/IEC/IEEE 42010 to capture relevant views and supporting models.

The AIOTI HLA described in this document puts the “thing” (in the IoT) at the center of value creation. While the body of the proposal is consistent with ISO/IEC/IEEE 42010, AIOTI WG3 does not provide a complete architecture description for IoT which conforms to the standard. Figure 1 provides an overview of architectural models as described in ISO/IEC/IEEE 42010

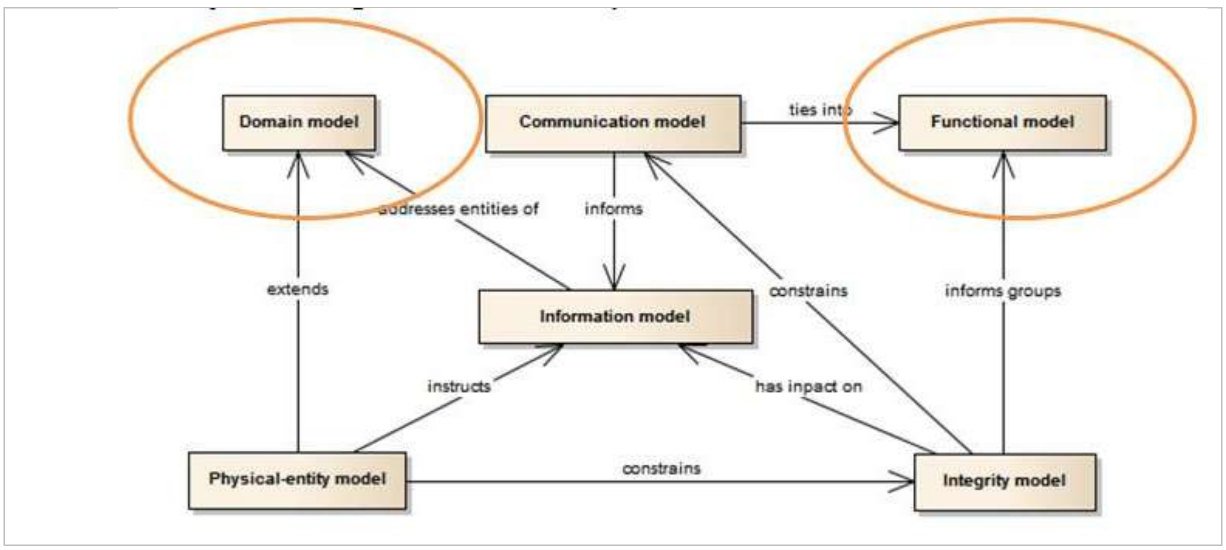


Figure 1: Architectural Models based on ISO/IEC/IEEE 42010

With respect to Figure 1, AIOTI WG3 focuses its recommendations on the Domain and Functional models:

- The Domain Model describes entities in the IoT domain and the relationships between them
- The Functional Model describes functions and interfaces (interactions) within the IoT domain

4. AIOTI Domain Model

The AIOTI Domain Model is derived from the IoT-A Domain Model [1]. A more detailed description of the IoT-A domain model is available in the companion slide-set.

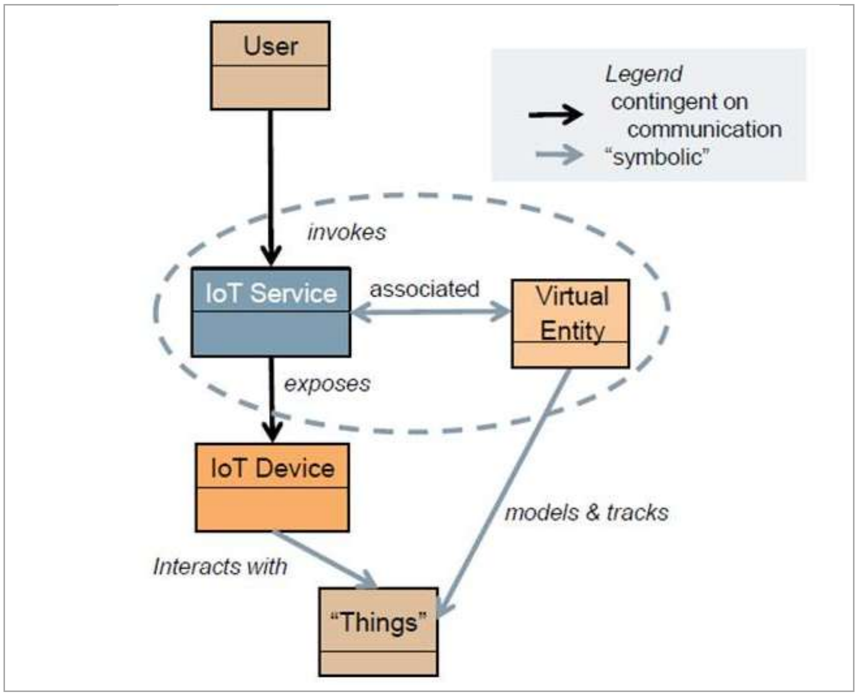


Figure 2: Domain Model

The domain model captures the main concepts and relationships in the domain at the highest level. The naming and identification of these concepts and relationships provide a common lexicon for the domain and are foundational for all other models and taxonomies.

In this model, a *User* (human or otherwise) interacts with a physical entity, a *Thing*. The interaction is mediated by an *IoT Service* which is associated with a *Virtual Entity*, a digital representation of the physical entity. The *IoT Service* then interacts with the *Thing* via an *IoT Device* which exposes the capabilities of the actual physical entity.

5. AIOTI Functional model

The AIOTI Functional Model describes functions and interfaces (interactions) within the domain.

Interactions outside of the domain are not excluded, e.g. for the purpose of using a big data functional model. Annex I provides initial ideas about the possible relationship between the AIOTI HLA functional model and the NIST big data interoperability reference architecture.

5.1.AIOTI layered approach

The functional model of AIOTI is composed of three layers as depicted in Figure 3:

- **The Application layer**: contains the communications and interface methods used in process-to-process communications

- **The IoT layer**: groups IoT specific functions, such as data storage and sharing, and exposes those to the application layer via interfaces commonly referred to as Application Programming Interfaces (APIs). The IoT Layer makes use of the Network layer's services.
- **The Network layer**: the services of the Network layer can be grouped into data plane services, providing short and long range connectivity and data forwarding between entities, and control plane services such as location, device triggering, QoS or determinism.

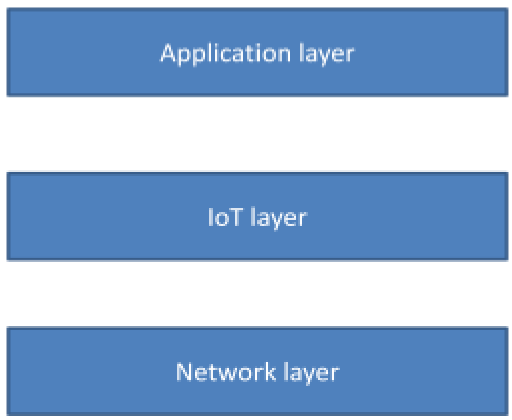


Figure 3: AIOTI three layer functional model.

Note: The term *layer* is used here in the software architecture sense. Each layer simply represents a grouping of modules that offers a cohesive set of services; no mappings to other layered models or interpretation of the term should be inferred.

5.2.AIOTI High level functional model

The AIOTI functional model describes functions and interfaces between functions of the IoT system. Functions do not mandate any specific implementation or deployment; therefore it should not be assumed that a function must correspond to a physical entity in an operational deployment. Grouping of multiple functions in a physical equipment remains possible in the instantiations of the functional model. Figure 4 provides a high level AIOTI functional model, referred to as the "AIOTI HLA functional model".

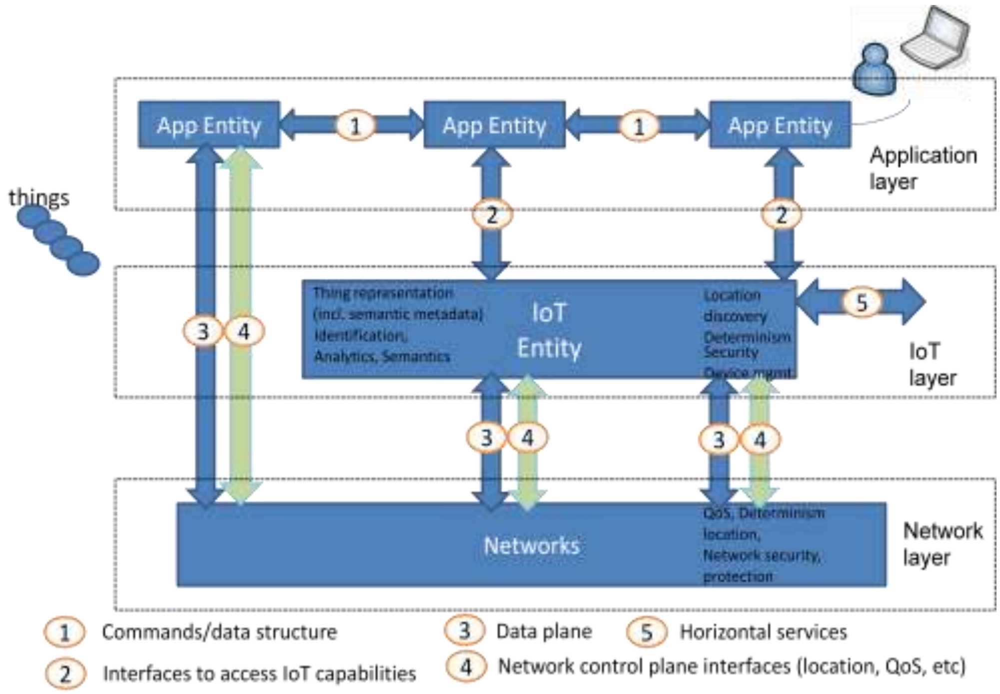


Figure 4: AIOTI HLA functional model

Functions depicted in Figure 4 are:

- **App Entity:** is an entity in the application layer that implements IoT application logic. An App Entity can reside in devices, gateways or servers. A centralized approach shall not be assumed. Examples of App Entities include a fleet tracking application entity, a remote blood sugar monitoring application entity, etc.
- **IoT Entity:** is an entity in the IoT layer that exposes IoT functions to App Entities via the interface **2** or to other IoT entities via interface **5**. Typical examples of IoT functions include: data storage, data sharing, subscription and notification, firmware upgrade of a device, access right management, location, analytics, semantic discovery etc. An IoT Entity makes use of the underlying Networks' data plane interfaces to send or receive data via interface **3.** Additionally interface **4** could be used to access control plane network services such as location or device triggering.
- **Networks:** may be realized via different network technologies (PAN, LAN, WAN, etc.) and consist of different interconnected administrative network domains. The Internet Protocol typically provides interconnections between heterogeneous networks. Depending on the App Entities needs, the network may offer best effort data forwarding or a premium service with QoS guarantees including deterministic guarantees.

According to this functional model a Device can contain an App Entity and a Network interface, in this case it could use a IoT Entity in the gateway for example. This is a typical example for a constrained device. Other devices can implement an App Entity, an IoT Entity and a Network interface.

Interfaces depicted in Figure 2 are:

- **1:** defines the structure of the data exchanged between App Entities (the connectivity for exchanged data on this interface is provided by the underlying Networks). Typical examples of the data exchanged across this interface are: authentication and authorization, commands, measurements, etc.
- **2:** this interface enables access to services exposed by an IoT Entity to e.g. register/subscribe for notifications, expose/consume data, etc.
- **3:** enables the sending/receiving of data across the Networks to other entities.
- **4:** enables the requesting of network control plane services such as: device triggering (similar to “wake on lan” in IEEE 802), location (including subscriptions) of a device, QoS bearers, deterministic delivery for a flow, etc.
- **5:** enables the exposing/requesting services to/from other IoT Entities. Examples of the usage of this interface are to allow a gateway to upload data to a cloud server, retrieve software image of a gateway or a device, etc.

The AIOTI HLA enables the digital representation of physical things in the IoT Entities. Such representations typically support discovery of things by App Entities and enable related services such as actuation or measurements. To achieve semantic interoperability, the representation of things typically contains data, such as measurements, as well as **metadata**. The metadata provide semantic descriptions of the things in line with the domain model and may be enhanced/extended with knowledge from specific vertical domains. The representation of the things in the IoT Entities is typically provided by App Entities or IoT Entities residing in devices, gateways or servers.

A one to one mapping between a physical thing and its representation shall not be assumed as there could be multiple representations depending on the user needs.
Figure 5 provides the relationships between the physical things, their representations and the link to semantic metadata which are an instantiation of the domain model described earlier in this document. Further information about AIOTI Semantic Interoperability is available from [6].

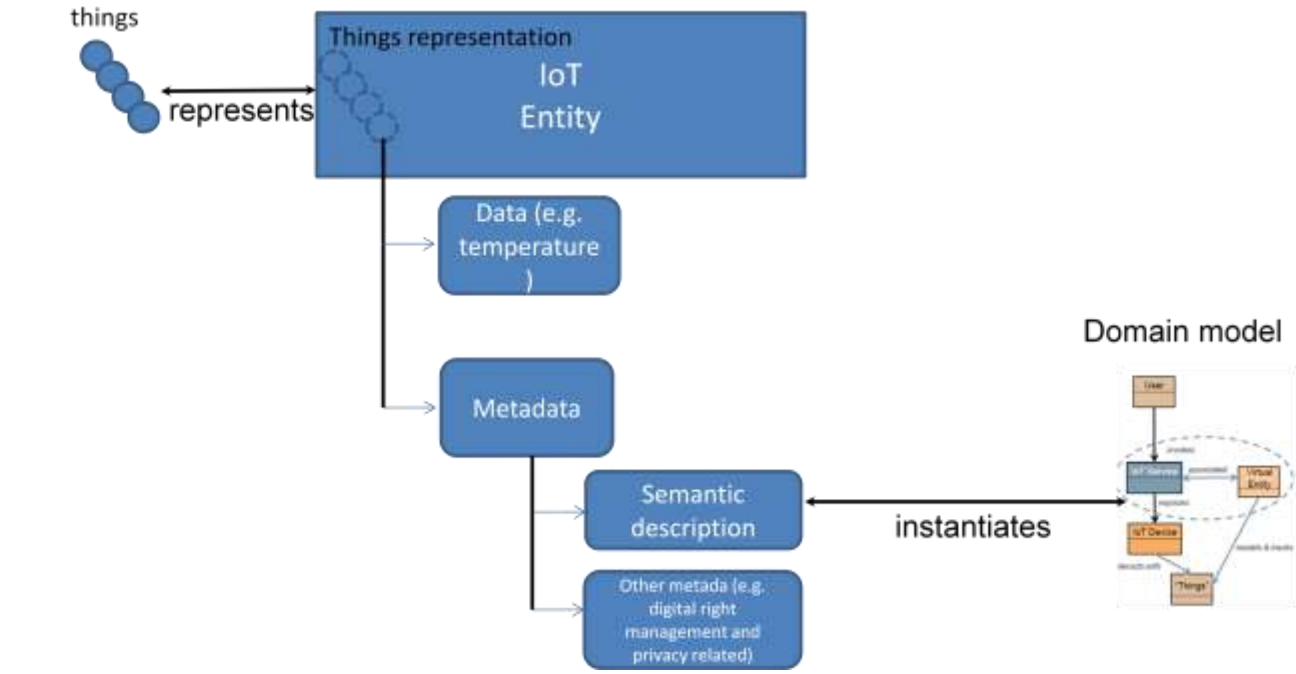


Figure 5: relationship between a thing, a thing representation and the domain model

5.3.HLA Security and Management considerations

Security and Management are fully recognized as important features in the AIOTI HLA. Some SDOs specify security and management as separate features, however in the AIOTI HLA security and management are intrinsic to interface specifications.
All the depicted interfaces shall support authentication, authorization and encryption at hop by hop level. End to end application level security could also be achieved via securing interface 1. It is fully recognized that there could be additional and diverse security needs for the different LSPs.

Note: AIOTI WG03 is in close cooperation with AIOTI WG4 that is addressing the policy issues for security and privacy.

As far as management is concerned, there are two aspects of interest:

- **Device and gateway management**, which are broadly defined as software/firmware upgrade as well as configuration/fault and performance management. Device management can be performed using interface **5** via known protocols e.g. BBF TR-069 and OMA LWM2M. Additionally Device and gateway management could also be exposed as features to cloud applications using interface **2**.

- **Infrastructure management** in terms of configuration, fault and performance is not handled in this version of the HLA but is fully recognized as important aspect for future study.

6. Mapping of SDOs' work to the AIOTI HLA functional model

The purpose of this section is to provide examples of mapping of existing SDO/alliances architectures to the AIOTI HLA functional model. The intent of this mapping exercise is three-fold:

- Demonstrate that AIOTI HLA is closely related to existing architectures and architectural frameworks
- Provide positioning of existing standards vis-à-vis the HLA
- Derive any possible important gaps in the HLA (even if the HLA aims to remain high-level)

This section does not intend to be exhaustive, other mappings can be added in future releases of this document.

6.1.ITU-T

In ITU-T Recommendation Y.2060 "Overview of the Internet of Things" [3], ITU-T has developed an IoT Reference Model which provides a high level capability view of an IoT infrastructure. As shown in figure 6, the model is composed of the following layers, providing corresponding sets of capabilities [Note - likewise for the AIOTI HLA, a layer represents here a grouping of modules offering a cohesive set of services]:

- Application Layer (Application capabilities)
- Service Support and Application Support Layer (SSAS capabilities - distinguished into Generic support capabilities and Specific support capabilities)
- Network Layer (Network capabilities - distinguished into Networking capabilities (Control plane level) and Transport capabilities (Data plane level))
- Device Layer (Device/Gateway capabilities)

The Security capabilities and Management capabilities - both distinguished into Generic Security (Management) capabilities and Specific Security (Management) capabilities – are cross-layer, i.e. they can be provided in support of different capability groupings.

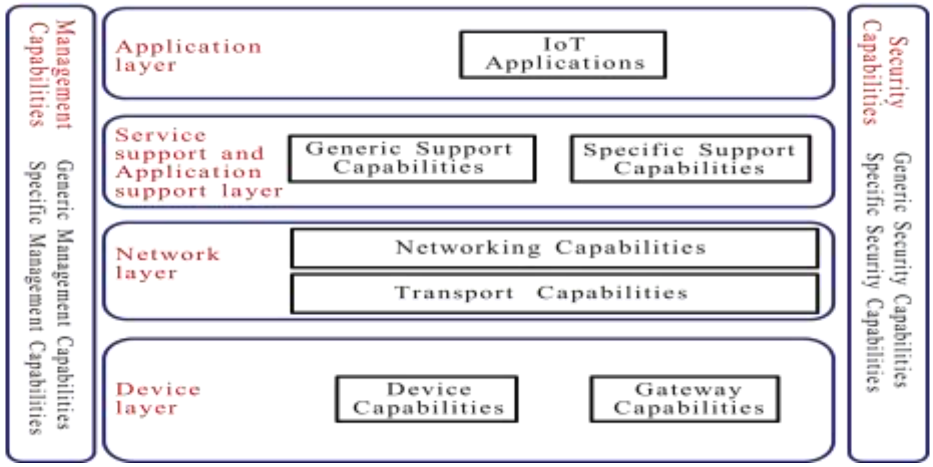


Figure 6: ITU-T Y.2060 IoT Reference Model

Figure 7 provides an initial high level mapping of the ITU-T Y.2060 IoT Reference model to AIOTI HLA functional model.

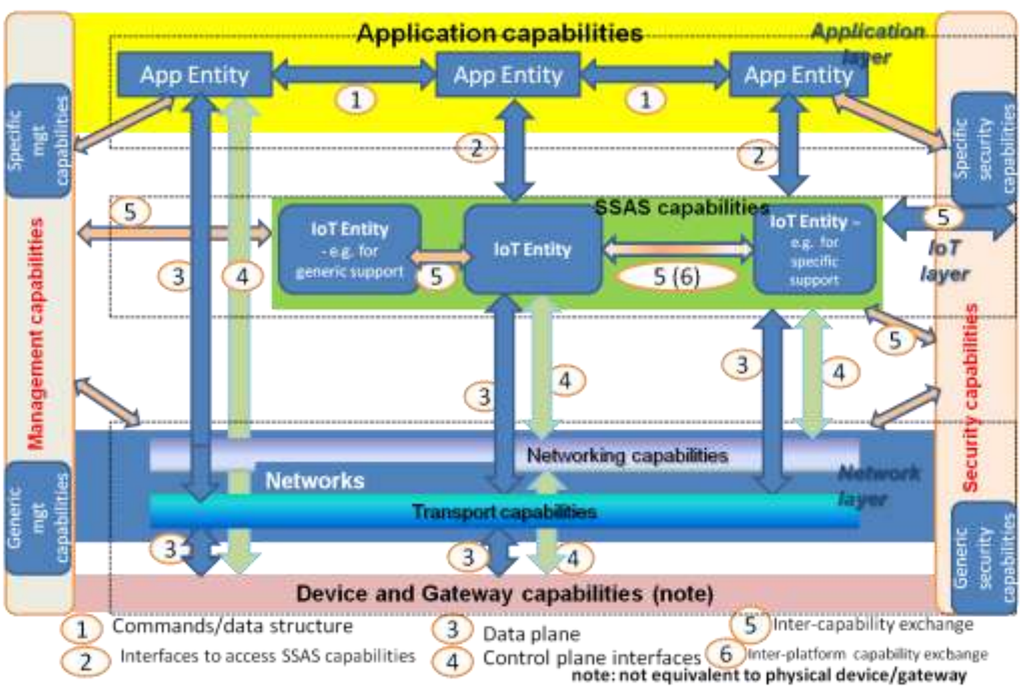
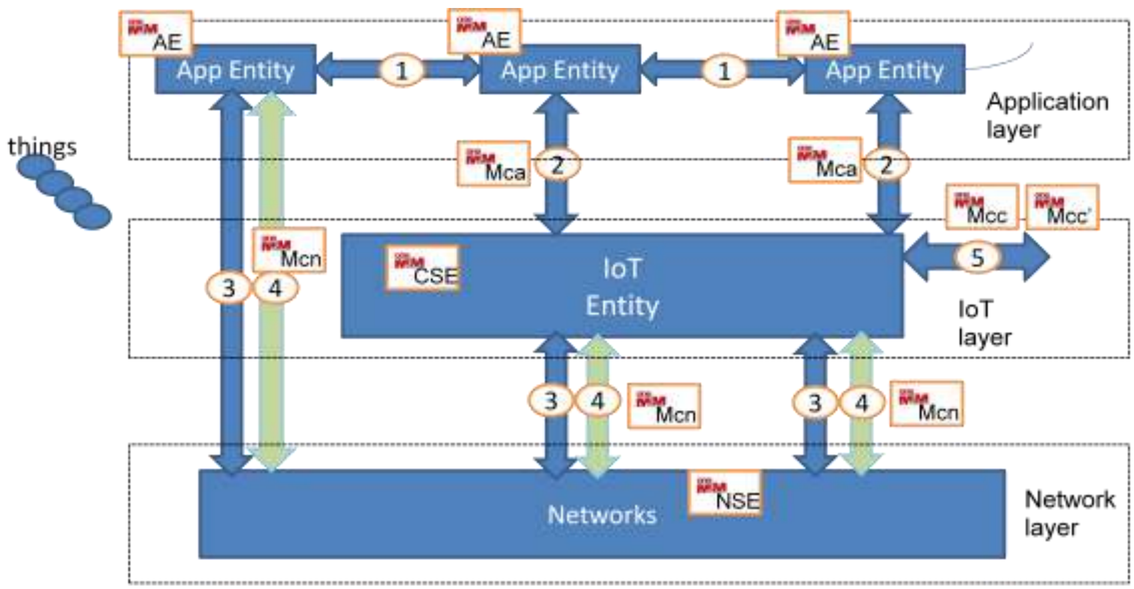


Figure 7: ITU-T IoT Reference Model mapping to AIOTI WG3's HLA functional model

Various detailed studies related to IoT functional framework and architectural aspects have been developed or are currently in progress within ITU-T; relevant ones include ITU-T Rec. Y.2068 ("Functional framework and capabilities of the Internet of things"), ITU-T draft Rec. F.M2M-RA ("Requirements and reference architecture of M2M service layer") and ITU-T draft Rec. Y.NGNe-IoT-Arch ("Architecture of the Internet of Things based on NGN evolution").

6.2.oneM2M

Figure 8 provides the mapping between oneM2M and the AIOTI HLA functional model. oneM2M specifies a Common Services Entities (CSE) which provide IoT functions to oneM2M AEs (Applications Entities) via APIs [4]. The CSEs also allows leveraging underlying network services (beyond data transport) which are explicitly specified in oneM2M and referred to as Network Services Entity (NSE).



CSE: Common Services Entity - **NSE**: Network Services Entity - **AE**: Application Entity
Mcn: reference point between a CSE and the Network Services Entity (NSE), enable a CSE to use network services such as location and QoS
Mcc/Mcc': reference point between a CSE and a CSE. It allows registration, security, data exchange, subscribe/notify, etc.
Mca: API to Application Entities that expose functions of the CSE.
oneM2M CSE functions include: device management, registration, discovery, group management, data management and repository, etc.

Figure 8: mapping oneM2M to AIOTI HLA

oneM2M has specified all interfaces depicted in Figure 8 to a level that allows for interoperability. Three protocols binding have been specified for Mcc and Mca reference points: CoAP, MQTT and HTTP. As regards the Mcn reference point, normative references have been made to interfaces specified by 3GPP and 3GPP2 in particular.
However oneM2M does not specify vertical specific data formats for exchange between App Entities according to AIOTI HLA interface 1. This can however be achieved by interworking with other technologies such as ZigBee, AllSeen, etc.

6.3. IIC

The Industrial Internet reference Architecture (IIRA) is a standard-based open architecture [5]. “The description and representation of the architecture are generic and at a high level of abstraction to support the requisite broad industry applicability.”, source IIC.
Figure 9 provides a three-tier architecture as specified in [5].

Figure 9: IIC three tier IIS architecture

The mapping of IIC to the AIOTI HLA is depicted in the following Figure.

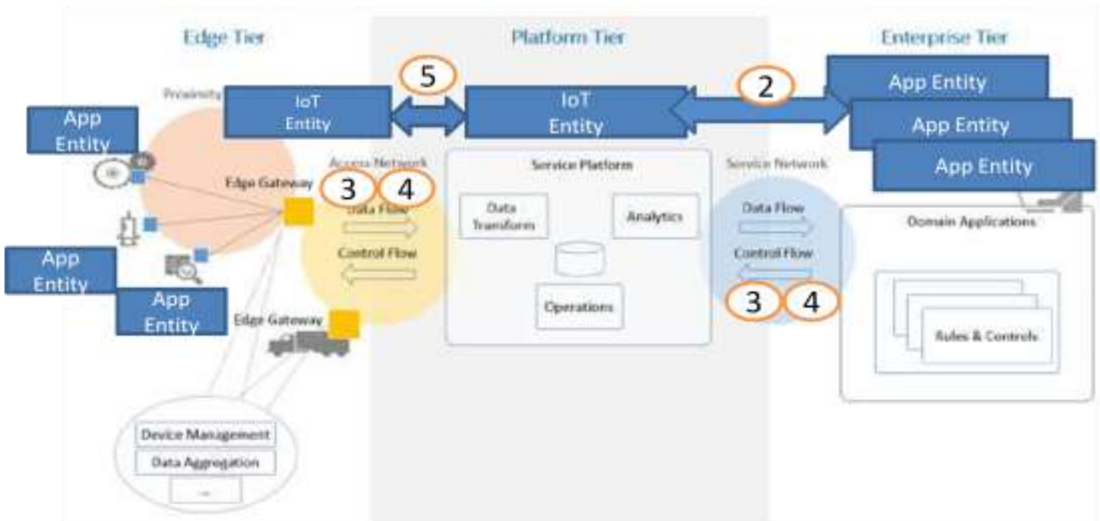


Figure 10: mapping HLA to IIC three tier IIS architecture

In Figure 10, devices in the IIC proximity domain would typically run App Entities according to the AIOTI HLA. The Edge gateways would in turn be mapped to IoT Entities, implementing as an example device management for proximity network devices.

Interactions with the network for the purpose of data exchange or other network services are depicted through the interface 3 and 4 from the AIOTI HLA. Finally the Application Domain in IIC would be equivalent to AIOTI App Entities running in the enterprise data centers.

7. Next steps

The next steps, as agreed by AIOTI WG3, are as follows:

- Continue to provide links to the AIOTI WG3 SDO landscape deliverable (an example is already provided in the companion powerpoint presentation)
- Provide instantiation examples to specific LSPs
- Ensure the AIOTI HLA is further discussed with other AIOTI WGs with the objective to collect feedback and improve the HLA incrementally (i.e. Integrate feedback from AIOTI WGs)
- Improve the link to Semantic Interoperability as documented in [6]
- Continue/refine the mapping exercise of existing SDOs’ architectures to the HLA

8. Annex - Relationship of HLA functional model to other models

Annex I – Relationship of HLA functional model with Big Data models

NOTE – This version of the document covers the Big Data interoperability framework developed by NIST.

The NIST Big Data interoperability framework has been described to a great extent in the following document [2]. Of particular interest to the scope of this deliverable is the NIST Big Data Reference architecture which is depicted in Figure I.1

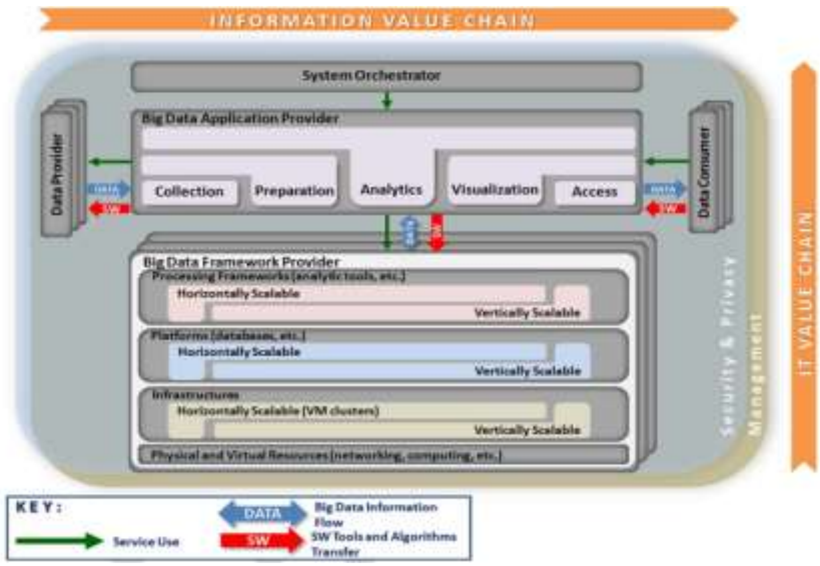


Figure I.1: NIST Big Data reference architecture

When considering the relationship between AIOTI HLA functional model and the NIST Big Data reference architecture, it is possible to consider a Data Provider as a HLA App Entity running in a Device or Gateway. The Big Data Application Provider could be an HLA IoT Entity or an App Entity running in a cloud server infrastructure, e.g. performing data aggregation. Finally a Data Consumer could be an App Entity running in a Utility back-end server. Figure I.2 depicts this mapping example.

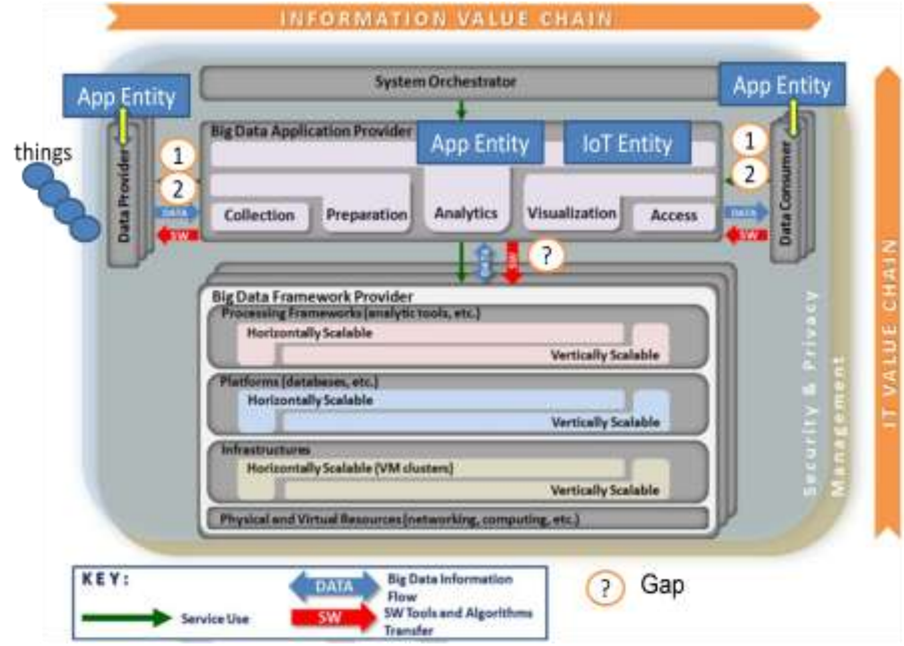


Figure I.2 Mapping AIOTI functional model entities to NIST big data reference architecture

In Figure I.2 the interface depicted with ("?") to a Big Data Framework Provider could be important in Large Scale Deployments of AIOTI. Further study is needed to figure-out current standardization developments related to this interface. A standardized interface may provide market benefits and remove dependency on a particular provider for the Big Data framework.

9. References:

[1] IoT-A project: http://www.iot-a.eu/public/public-documents
[2] NIST big data interoperability framework: http://bigdatawg.nist.gov/V1_output_docs.php
[3] ITU-T Y.2060 "Overview of the Internet of Things"
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http://www.etsi.org/deliver/etsi_ts/118100_118199/118101/01.00.00_60/ts_118101v010000p.pdf
[5] Industrial Internet Reference Architecture, http://www.iiconsortium.org/IIRA.htm
[6] AIOTI WG3 deliverable on Semantic Interoperability

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Editors:

HLA – Functional Model Editors:

Paul Murdock, Landis+Gyr, Switzerland
Omar Elloumi, Alcatel Lucent, France

HLA – Functional Model Contributors:

Omar Elloumi, Alcatel Lucent, France
Jean-Pierre Desbenoit, Schneider Electric, France
Patrick Wetterwald, Cisco, France
Georgios Karagiannis, Huawei, Greece
Juergen Heiles, Siemens, Germany
Paul Murdock, Landis+Gyr, Switzerland
Marco Carugi, NEC Europe, UK
Ovidiu Vermesan, Sintef, Norway
Martin Serrano, Insight Centre for Data Analytics, Ireland

Contributing Companies, Projects, Initiatives, SDOs:

Additional Contributing Experts:

Reviewers:

Patrick Guillemin, WG3 Chair, ETSI, France
Jean-Pierre Desbenoit, WG3 alternate Chair, Schneider Electric, France

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