CHARIOT – Taxonomy for IoT Services and Data

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Acronym	**Meaning**
OWL	Web Ontology Language
QoS	Quality of Service
IoT	Internet of Things
DSL	Domain-Specific Language
SCO	Smart City Object
DS	Directory Service

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1. Introduction

This document serves as a working draft document to identify and record a taxonomy for IoT services and data that fulfils the requirements of the CHARIOT project. This document has to be seen as in a working state until said otherwise; phrasing and structure may need a further revision.

To find a taxonomy that is of help to classify IoT services and data turns out to be very complex. Services and the produced data, even if we only take into account the use case of finding the most helpful service for a certain task, can be seen from different view angles: Next to the functional part there are many side aspects (context) that have to be considered. Therefore, a multi-dimensional taxonomy makes the most sense. In the next sections the different dimensions are discussed separately. The proposed multi-dimensional taxonomy is then a result of merging these individual taxonomies into a holistic solution.

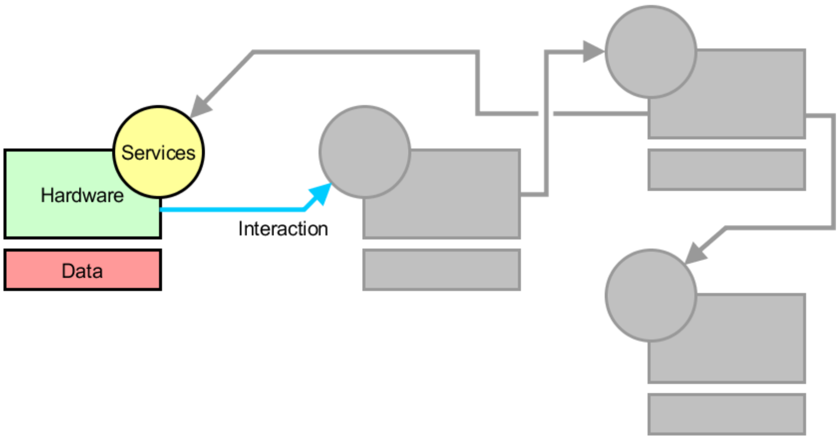

Figure 1: The four main parts that define IoT entities.

Looking at IoT entities from an abstract viewpoint, we can identify the following parts that play a role in such a system, where we define IoT entities as “heterogeneous physical devices that interact with each other using the advertised services” (see also Fig. 1):

1. The Hardware
2. The provided Service(s)
3. The managed Data
4. The Interaction

The Hardware and Services components can be derived from the specification language that has been described in another working package. The data component already comes from the title of this document; on the other hand, in a distributed system it turns out to be very important to classify data. The last part, the interaction, is important as it makes it possible to classify the relationship to other entities. We will discuss these four parts in the following. An important requirement of the individual parts is that each layer allows for a meaningful division, otherwise the relevant layer would be of no real use.

2. Hardware Taxonomies

2.1 Complexity

The complexity taxonomy really is an abstraction level for various categories that can be used to classify IoT entities [5]. A gradation with exact definition of the individual as in [3] would be possible, but we propose a simple approach that only differentiates between simple and complex devices:

- Simple
- Complex

2.1.1 Human Interaction

This dimension reflects if the IoT device, in order to work, needs any physical interaction with a human being. This could be a button that has to be pressed or a display that shows some results (which later needs to entered again in the system). The dimension is proposed to be simply nominal with two options (present / absent):

- Yes
- No

2.1.2 Energy Management

When speaking about the energy and the energy consumption, multiple possible measures come into one's mind. In [5] *energy source* and *energy management* are used. However, we propose a more condensed approach; the most important information related to the energy topic is how the device is behaving. Therefore, we foresee the following ordinal characteristics. Here Low power consumptions means that the device, maybe due to being equipped with a battery, has to economize its available energy:

1. Normally off
2. Low power consumption
3. Normally on

2.1.3 Mobile

This dimension is important for a planning component when it is searching for long-term compositions. A mobile device or service used in an orchestration requires a definitive partial re-planning in future uses; the dimension is simply stating whether the entity is mobile / movable:

- Yes
- No

2.2 Sensor & Actuator Types

Sensors measure certain (physical) information from their environment and make this information accessible in other electronics. The following table [1] gives a possible sensor type taxonomy:

Table 2: Sensor and Actuator Types

Type	**Motion**	**Position**	**Environment**	**Mass Measurement**	**Biosensor**
Subtype	Movement Velocity Inertia Vibration Acceleration Rotation	Orientation Inclination Proximity Presence Location	Temperature Humidity Luminance Acoustic Radiation Gas Magnetic Field Weather Chemical Electrical Color EMF	Volume Pressure Density Deformation Viscosity Flow Load Moisture Shock Contact Strain Corrosion Electrical Conductivity Oxygen	Blood Organ Mental Tissue

3. Service Taxonomies

3.1 Application Area

Regarding the service the IoT devices provide, a taxonomy of the application areas [2] makes sense. All the mentioned areas are linked with certain attributes like network size, connectivity, data management:

- Smart Home / Office
- Smart Retail
- Smart City
- Smart Agriculture / Forest
- Smart Water
- Smart Transportation

Another possible division of application areas comes from [3]:

- Industry
- Security
- Retail
- Society
- Healthcare
- Home
- Energy
- Mobility

A third approach, which consists of a 2-layer representation, is presented in [1]. It is related to IoT sensors, but since they are a/the main component of the IoT, this seems to be a good fit:

- Industrial
    - Agriculture
    - Logistic
    - Plant Floor

- Smart Cities
    - Transport
    - Buildings
    - Environment
- Healthcare
    - Monitoring
    - Management

3.2.1 Our Approach

To classify services into different application areas is the both clear & reasonable. A planning component will most likely know in which application area it operates. However, since for the overall goal of CHARIOT the specific application areas are not important and the focus of the CHARIOT taxonomy approach lies on finding the different dimensions, we refrain from further exploring the sub domains. We suggest the following application areas:

- Home
- Industry
    - Agriculture
- City (Society)
    - Water
    - Energy
    - Transportation & Mobility
    - Buildings
- Retail
- Healthcare
- Security

We support a 2-layer representation to highlight that we see some areas, which are sometimes used as top-level areas, as sub domains.

3.3 Service Types

Another possible classification, simple yet effective when filtering for potential communication partners, can be based on the abstract type of service:

- Utility Service
- Enduser
- Test

4. Data Taxonomies

4.1 Source

1. State
2. Context
3. Usage
4. Cloud

4.2 Abstraction Level

1. Raw
2. Fused
3. Analytical

5. Interaction Taxonomies

5.1 Partner

It seems logical to classify services in terms of for which interaction partner they are intended for [4]. Services may be used by other services or devices and have no real value for end-user applications. The proposed classification in [4] seems seasonable:

- User
- Business / Service Provider
- Thing

5.2 Direction

Since an interaction can be carried out as a monologue or as a dialog and implies very different approaches to using the service, a classification for this dimension is reasonable [4]. A unidirectional communication with a sensor is different to with an actuator:

- Unidirectional
- Bidirectional

5.3 Security

When talking about the IoT, the topic of security of the communication channels is indispensable. Again, the proposed taxonomies follow our main purpose, to help a requesting entity find the most suitable communication partner. Characteristics irrelevant to that are not covered; additionally, due to the need of fast grasping of the security aspects only the most relevant characteristics are taken into account in the following.

5.3.1 Authentication

While many different dimensions could be discussed, identification is essential. Since identification only makes sense in combination with authentication, we will subsume both terms in the taxonomy dimension "Authentication". This taxonomy could point to a sophisticated external taxonomy, which lists all possible forms of identification and authorization. However, we think that in order to find a suitable IoT device or service, it is sufficient to know how the identification and authentication is handled conceptually; details then can be specified in the technical endpoint description. Here we of course assume that e.g. a mutual identification enforces a mutual authentication. Therefore, we propose this criteria [5]:

- None
- One way
- Mutual

5.3.2 Encryption

- No
- Yes

5.3.3 Integrity

- No
- Simple
- Advanced

6. A Multi-Dimensional Taxonomy for IoT Services and Data

The multi-dimensional taxonomy given below assembles the parts discussed in the previous sections. Therefore, no explanation is given here, but can be looked up in the corresponding sections:

Table 3: Multi-Dimensional Taxonomy for IoT Services and Data

	Dimension	**Characteristics**	**Scale**
Service	Purpose	• End User • Utility • Actuator	*Nominal*

	Application Area	• Home
		• Industry
		  ○ Agriculture
		• City (Society)
		  ○ Water
		  ○ Energy
		  ○ Transportation & Mobility
		  ○ Buildings
		• Retail
		• Healthcare
		• Security
			Nominal

	Complexity	1. Atomic 2. Composite	*Ordinal*
Data	Source	5. State 6. Context 7. Usage 8. Cloud	*Ordinal*
	Abstraction Level	9. Raw 10. Fused 11. Analytical	*Ordinal*
Interaction	Partner	• User • Business • Thing	*Nominal*

	Direction	• Unidirectional • Bidirectional	*Nominal*
	Multiplicity	1. One-to-one 2. One-to-many 3. Many-to-many	*Ordinal*
	Authentication	Reference to a taxonomy of authentication types (see Security)	*Ordinal*
Hardware	Complexity	1. Simple 2. Complex	*Ordinal*
	Type	Reference to a taxonomy of hardware (see Sensor Types & Actuator Types)	*Nominal*

References

[1] V. Rozsa et al., “An application domain-based taxonomy for IoT sensors,” in Advances in Transdisciplinary Engineering, 2016, vol. 4, pp. 249–258.

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