ELASTIC

A Software Architecture for Extreme-ScaLe
Big-Data AnalyticS in Fog CompuTIng ECosystems

D1.5 Impact on standards and open initiatives - First analysis

Version 1.0

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Change Log

Version	Author	Description of Change
V0.1	TRT	Initial Draft
V0.2	BSC	Contribution on the analysis of OpenFog Initiative
V0.2	TRT	Contribution 61508 std, Railway std
V0.3	SIX	DMTF
V0.4	ISEP	FIWARE
V0.5	BSC	OpenFog
V0.6	THALIT	Contribution 61508 std, Railway std
V0.7	TRT	Final version, including revision
V0.8	SIX	Internal review
V1.0	BSC	Final adjustments. Version released to EC.

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1. Executive Summary

This document (D1.5) is the first analysis of the “Impact on standards and open initiatives” task. It covers the work done during the second phase of the project within WP1 “Smart Mobility Use-case”. It is built upon the work carried out in task T4.1. “Impact of ELASTIC on safety standards and open initiatives” to reach milestone MS2: First evaluation of standards and open initiatives considered.

During the second phase of the project, we have studied two sets of standards with different expectations on the ELASTIC architecture. The first set of standards is associated to the railway sector which mainly covers safety and security constraints on the development and exploitation of ELASTIC software architecture. In the other hand, the second set of standards is associated to the world of open initiatives, and aims into providing a standardized framework which supports the creation and reuses existing software building blocks in order to facilitate the development and interoperability of the ELASTIC software architecture.

This first document of task T4.1 allowed us to summarize and describe the main characteristics of the major standards that may impact or support the ELASTIC software architecture with the objective of providing recommendations in the final document (D1.6) to the standardization committees and the consortiums in charge of the open initiatives, to fully exploit the extreme-scale analytics.

2. Introduction

The objective of the ELASTIC project is to use all available computing resources deployed in a computing infrastructure under different use case scenarios (Smart city, transportation, etc.) to leverage and increase the efficiency of data analytics.

Task 1.4 will evaluate the impact of the ELASTIC architecture on the features of the railway standards and the open initiatives identified in Task 1.1.

This document (D1.5) is dedicated to investigate the safety railway standards which are going to impose safety and security requirements on the ELASTIC architecture because of the normative context of the railway domain (as defined in 61508 [1], 50126 [9], 50128 [10], 50129 [11]), and secondly to consider the case of OpenFog[23], DMTF [23] and FIWARE [19] to determine how they can effectively support the ELASTIC architecture.

This document will contribute to D1.6 which will evaluate what is the impact of ELASTIC on the safety standards and open initiatives, while providing recommendations.

2.1 Purpose and objectives

The purpose of this document is to describe the main Railway standards and the open initiatives (i.e., OpenFog, DMTF and FIWARE) that are relevant for the continuation of the project ELASTIC.

Objectives:

1) Identify and describe the main railways standard relevant to ELASTIC

2) Identify and describe the main set of relevant documents from the open initiatives

3) Evaluate if the standards support ELASTIC

2.2 Relationship with other WPs

Table 1: Relationship with other WPs

Deliverable	Task	Relation
D1.1	T1.1	Description of the use-cases and the related requirements.
D2.1	T2.1	Requirements of the data analytics platform.
D3.1	T3.1	Software Architecture.
D4.2	T4.1	The non-functional properties to cover the technical characteristics of the fog computing ecosystem.
D5.1	T5.1	Describe the General requirements of the fog architecture

2.3 Document structure

This document is organized in 6 sections:

- Section 1 provides an Executive Summary of the document
- Section 2 introduces gives the structure of the document
- Section 3 presents a short overview of the ELASTIC architecture
- Section 4 describes the main standards relevant applicable to ELASTIC project
- Section 5 describes the standard from the open initiative supporting ELASTIC
- Section 6 provides a summary and conclusion of the document

3. An overview of the ELASTIC architecture

ELASTIC is developing a software development ecosystem incorporating software components from multiple computing areas, including distributed data analytics, embedded computing, internet of things (IoT), cyber-physical systems (CPS), software engineering, high-performance computing (HPC), edge and cloud computing. Figure 1 shows the overall ELASTIC software architecture ecosystem including the main software components.

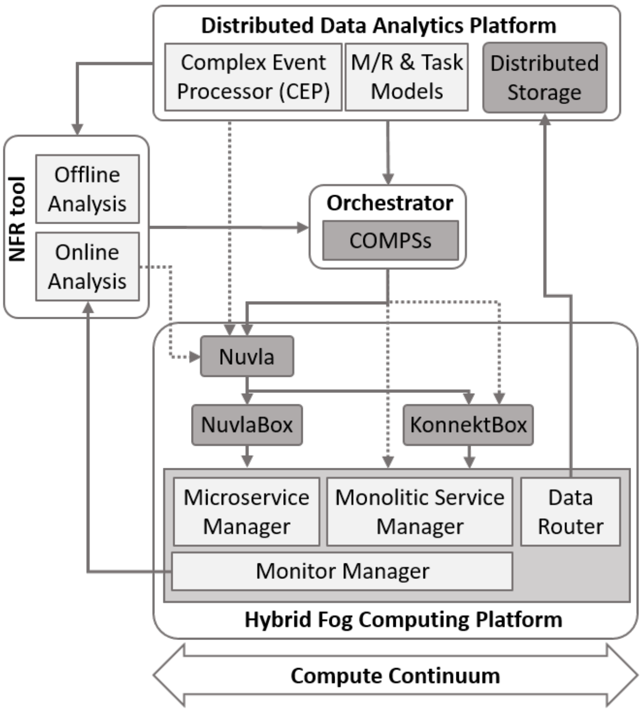

Figure 1: ELASTIC Software Architecture ecosystem

One of the key features of the ELASTIC ecosystem will be its capability to instantiate multiple software architecture configurations, incorporating different software components. This unique (and heterogeneous) combination of software components will enable to efficiently distribute extreme-scale big-data analytics across the compute continuum, from edge to cloud, and provide guarantees on the non-functional requirements of the system imposed by the cyber-physical interactions of the use case.

Further details on components that belong to specific WPs may be found in the respective design/requirement document of the WP for the first phase of the project, i.e., within ELASTIC deliverables D2.5 [29], D3.1 [30], D4.2 [31], and D5.1[32].

4. Railway safety standard

4.1 Principle of the 61508 Safety Standard

IEC 61508 [1] is the main European standard for functional safety. It provides a generic approach to all activities related to the safety lifecyle of safety-related Electrical/Electronic/Programmable Electronic (E/E/PE) systems that are used to perform safety functions. The standard is constructed so as to facilitate the development of international standards for products and industrial applications. IEC 61508 does not apply to those E/E/PE systems concerned with safety, in which the failure mode of each component is clearly defined, and for which the behaviour of the system can be fully determined in the event of a failure.

4.1.1 Functional safety

According to the IEC 61508 standard, functional safety [34] is the subset of the overall safety relating to equipment and its control system (component), which depends on the correct operation of the electrical safety related system (based on another technology) and the external risk reduction devices. Functional safety ensures that there are no unacceptable risks. The objective of functional safety is therefore to address the ability of safety-related systems to perform their safety functions as intended.

4.1.2 Objectives and application domain of the 61508 standard

IEC 61508 is a generic multi-domain standard whose scope includes all types of Electrical, Electronic and Programmable Electronic safety-related systems (E/E /PE). It was designed with a generic approach for systems which are composed of electrical and/or electronic and/or programmable electronic elements that are used to perform safety functions.

The first intention of the working group was to produce a generic standard to be used as the basis for drafting other product and application sector international standards. However, in practice, IEC 61508 is used directly by industries.

IEC 61508 standards were published between the period 1998/2000. The standard was updated and improved with a second version in 2011. The general objective of this standard is to permit the production of a design and development of E/E/PE safety related systems in accordance with the specification. For this, the standard proposes an operational approach to set up the E/E/PE safety-related system, starting from the study of the safety requirements and taking into account all stages of the system lifecycle.

4.1.3 General structure of the standard

In order to cover all aspects related to E/E/PE systems, the General Structure of standard 61508 is organized into 7 parts. The parts 1 [1], 2 [2], 3 [3] and 4 [4] are the normative part of the standard, while the parts 5 [5], 6 [6] and 7 [7] are only informative, offering advice and guidance to apply the normative parts. The contents of the different documents are described in the following table:

Functional safety of electrical/electronic/programmable electronic safety-related systems IEC 61508 Parts 1-7, First edition 12/1998, now in version 2011	
61508-P1[1]	**General requirements:** Part 1 sets the requirements for documentation and the way to be compliant with the standard. It defines also the technical requirements and the associated management and assessment for achieving safety throughout the entire lifecyle of the system.
61508-P2[2]	**Requirements for electrical/electronic/programmable electronic safety-related systems:** Covers the requirements for the development of E/E/PE hardware.
61508-P3[3]	**Software requirements :** Part 3 are specific to the software development
61508-P4[4]	**Definitions and abbreviations:** Provides the definitions used in the standard
61508-P5[5]	**Examples of methods for the determination of safety integrity levels:** Gives concrete examples of risk assessment resulting to the allocation of safety integrity levels
61508-P6[6]	**Guidelines on the application of IEC 61508-2 and IEC 61508-3:** Part 6 provides guidance about the application of the standard on hardware and software parts
61508-P7[7]	**Overview of techniques and measures:** Contains an overview of different techniques and relevant safety measures for the hardware and software parts of the standard

Table 2: IEC 61508 parts of the standard

IEC 61508 follows an industrial safety lifecycle model as shown in Figure 2 in order to structure requirements relating to specification, design, integration, operation, maintenance, modification and decommissioning of a safety-related system. The following figure shows the safety lifecycle model and indicates the role of each part of the standard in the achievement of functional safety for E/E/PE safety-related systems.

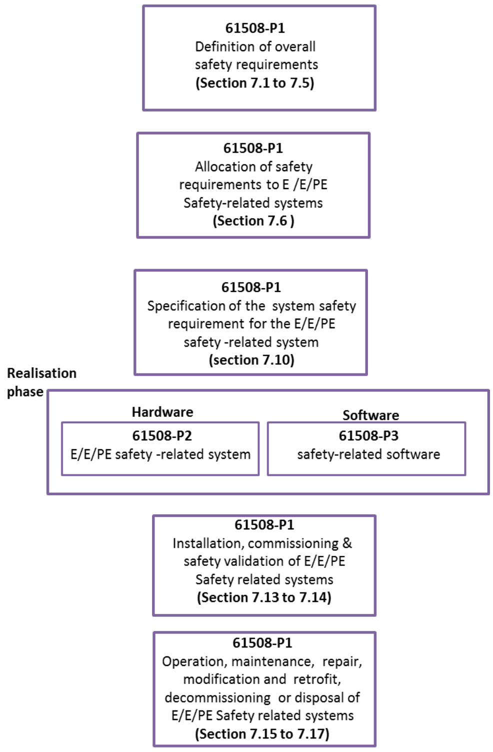

Figure 2: IEC 61508 safety life cycle model

4.1.4 Risk reduction

The Safety Integrity Level (SIL) [33] indicates a level of safety integrity. The SIL notion results directly from the IEC 61508 standard. The SIL may be defined as a measurement of operational safety that determines recommendations related to the integrity of the safety features to be assigned to E/E/PE systems. There are four SIL levels: SIL4 being the highest level of system security, SIL1 the lowest. This involves an average probability of failure on demand for a period of 10 years.

Thanks to significant expertise in formal calculation and operational safety, Thales Italy Engineering is qualified to conduct projects that require a SIL certification (SIL2, SIL3 or SIL4) pursuant to IEC 61508 standard.

If it is found during the hazard and risk analysis of the system functions that a particular aspect is too risky (we discuss below how this is determined), then the specific risk must be mitigated or eliminated. One way to do this is to redesign the system in such a way that the specific risky aspect is no longer present. Another way, emphasised by IEC 61508, is to provide additional functions whose purpose is to intervene to mitigate the identified risk so that it becomes acceptable. Such a function is called a safety function in the standard.

The entire assessment of safety in IEC 61508 occurs through risk assessment and risk reduction. In the hazard and risk analysis, hazardous events are identified and the necessary risk reduction for these events determined.

Apart from the definition of “risk” which we have discussed, IEC 61508 says that “risk is a measure of the probability and consequence of a specified hazardous event occurring” (Part 5, Annex A: Risk and safety integrity - general concepts, Paragraph A5. The definitions explicitly refer to Part 5, Annex A for “discussion”, so we may assume this is intended to be definitive). This suggests that the overall risk of using a system is not a concept to which IEC 61508 explicitly gives much credence.

4.1.5 IEC 61508 stand-alone standard

IEC 61508 stand-alone standard provides suppliers and users of safety equipment with a common framework for the design of products and systems for safety-related applications. All parts of IEC 61508 are suitable for direct use by industry as a stand-alone standard.

4.1.6 IEC 61508 a basis for other standards

IEC 61508 Parts 1 [1], 2 [2], 3 [3] and 4 [4] are the basic IEC publications in the field of functional safety. One of the responsibilities of IEC technical committees is to base, wherever possible, the drafting of their own industrial or product standards on these four parts whenever E/E/PE safety related systems are within their scope. IEC 61508 is for example the basis for other industry standards such as automation [12], railway [9] and automotive domains [18], as shown in Figure 3.

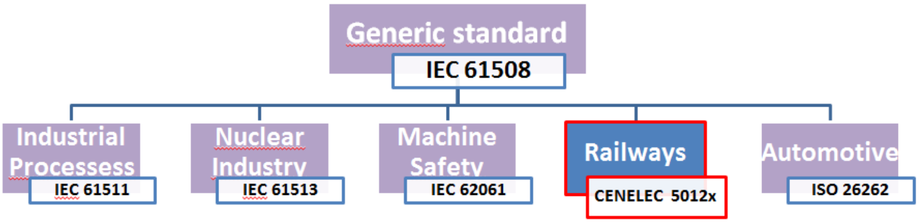

Figure 3: Industry standards based on IEC 61508

It has a strong impact on the development of E/E/PE systems and multi-sector products concerned with safety. However, it should be stressed that specific industry or product standards usually refer only to the specifications of the IEC 61508, therefore the users will always need to consult to IEC 61508.

4.1.7 Conclusion

The ELASTIC architecture has the ambition to manage critical systems and to provide confidence to the user of this new technology. Consequently, the future increases in maturity of the ELASTIC architecture will have to follow more and more the precepts used in the development of critical systems (or at least for some part of its architecture). The development of critical systems to operate safely involves reducing the risk as much as possible; this requires following a safety standard such as the IEC 61508 which is a generic multi-domain standard. The process of following a safety standard changes the usual engineering practices: in addition to considering the functional and non-functional requirements of the system, the safety requirements must also be taken into account, in order to ensure the correct and safe operation of the system functions. In particular, there are two safety components that must be considered: a functional component and a safety integrity component.

4.2 Overview and organisation of the set of railway standard

The CENELEC (50126 [9], 50128 [10] and 50129 [11]) are a set of European standards applicable to both heavy rail systems and light rail domain, but with restrictions linked to the scope of the standards 50128 and 50129, limited to signalling subsystems. Railway Standard 50126 follows a lifecyle model of industrial safety throughout the project. The 50128 Standard describes the actions to be performed in order to demonstrate software safety. Finally, the 50129 standard describes the actions to be performed in order to demonstrate the safety of the hardware. These standards are based on IEC 61508 [1] standards, and they provide normative reference to the railway industries an European Union. The three standards define and fulfil the objectives of Reliability, Availability, Maintainability and Safety (RAMS) required by the railway domain, and address the safety aspects of the system down to the hardware and software components.

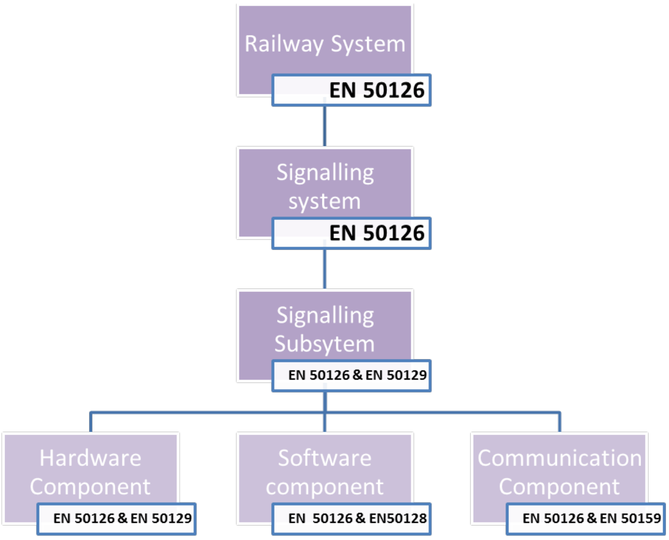

Figure 4: Railway signalling standard

These standards are complemented by a transmission standard CENELEC EN 50159 [8], which takes into account the Safety-related communication in closed and in open transmission systems. The EN 50159 [8] standard addresses some aspects of safety permitting to cover some part of the cyber-security and confidentiality. The railway standard does not specify requirements for ensuring system security, but some actors from the railway domain consider that in order to protect against cyber security threats, the IEC 62443[15][16][17] standard concerning "security" in the sector of industrial automation and control systems is a very interesting candidate. The major European Standards recommended for the railway Signalling are summarized in Table 3.

CENELEC and IEC standards for Railway Signalling	
EN 50126[9]	**System Level :** Describes the safety lifecycle throughout a project and establishes a method for the specification and demonstration of reliability, availability, maintainability and safety (RAMS), for the railway domain
EN 50129[11]	**Hardware Level :** Provides general guidance to demonstrate the safety of electronic systems and to construct the safety case for signaling railway application
EN 50128[10]	**Software Level:** Provides requirements for the software used in signaling railway application and describes the actions to be performed to demonstrate the safety of the software
EN 50159[8]	**Communication Level:** Safety-related communication in closed an open transmission systems
IEC 62443-3-3[15]	**System Level:** System security requirements and security levels
IEC 62443-4-1[16]	**Product Level:** Secure Product Development Lifecycle Requirements
IEC 62443-4-2[17]	**Product Level:** Technical security requirements for IACS components

Table 3: CENELEC and IEC standards for railway signalling

4.2.1 Railway standards and ELASTIC

In the scope of the ELASTIC project, special attention will be given to the analysis of the rules identified in the railway safety standards impacted during the project implementation phases.

In deliverables D1.5 (Impact on standards and open initiatives – First analysis) and D1.6 (Impact on standards and open initiatives – Final analysis), the link of the ELASTIC technology and the main principles of the railway standards IEC 61508 [1], EN 50126 [9], 50128 [10] and 50129 [11] will be evaluated.

Furthermore, in accordance with the objective of Task 1.4 “Impact of ELASTIC on safety standards and open initiatives”, if gaps are identified, the relevant findings will be communicated to the specific standardization bodies for information, and related changes will be proposed.

5. Open initiatives on the ELASTIC architecture

5.1 Distributed Management Task Force (DMTF)

The DMTF group [23], provides (amongst others) a cloud management standard called CIMI [24], that specifies a systematic and consistent way to define web service interfaces (REST). This approach facilitates interoperability and ensures that software services are modular and can easily be swapped, offering an open and extensible system. SIX's Nuvla software has been built with a comprehensive RESTful API server based on the CIMI specification.

Nowadays, however, Nuvla's API server has purposely started diverging from the CIMI specification, as an outcome of SIX's return on the experience from using the standard.

The decision to diverge was made in order to make Nuvla's API server simpler to use. In particular, the key reasons that lead SIX to that decision were:

- The need to simplify the resource naming conventions in order to have a single and consistent naming convention for each resource, according the system;
- The need to simplify the workflow for creating templated resources, by avoiding cross-resource referencing, which are a burden to regular users since they would need to infer the name of the template to be used in order to create their resource;
- The need to make the cloud-entry-point easier to discover and interpret;
- The need to move away from a Cloud-based standard. Since SIX is not a cloud provider, there's no reason to strictly stick to a cloud specification.

5.2 FIWARE

FIWARE [19] is an open initiative, initially driven by the European Commission for the development and deployment of applications and services in a variety of areas, including smart cities, sustainable transport, logistics, renewable energy, and environmental sustainability. FIWARE provides an open and royalty-free API specification to interface among users and system developers.

The FIWARE architecture is based on the concept of a Context Broker, a service which handles context information on a large scale, by implementing a standard RESTful API. Systems can be built through the addition of other FIWARE components (e.g. to process or analyse context information), as well as custom made components.

A FIWARE system can be deployed on top of the ELASTIC Software Architecture, with ELASTIC providing the required elasticity to FIWARE components.

5.3 An Introduction to the OpenFog Consortium

The OpenFog consortium promotes the fog computing paradigm by defining a horizontal, system-level architecture for the distribution of computing, storage and communication capabilities across the continuum, from edge to cloud. The fog computing paradigm intends to selectively move computation, control, and decision making closer to the edge, where data is being generated, in order to solve the limitations of the current infrastructure, hence enabling mission-critical, data-dense use cases. Fog computing can be seen as an extension of the traditional cloud-based computing model, retaining all the benefits of cloud computing, such as containerization, virtualization, orchestration, manageability, and efficiency. The computational, networking, storage and acceleration elements of this new model are known as *fog nodes*.

The **OpenFog Consortium** [21], in which BSC is a member, is an independently-run open membership ecosystem of industry, end users and universities in charge of the specification of the *OpenFog Reference Architecture (RA)*. The OpenFog RA provides interoperability, messaging, and interface standards to enable fog nodes to cooperate, with the objective of reducing latency, network bandwidth and availability constraints. OpenFog Applied to Smart Cities

Deliverable D1.1 [20] introduced the eight pillars upon which the OpenFog RA can benefit smart cities and connected vehicles: *security, scalability, open, autonomy, RASS (Reliability, Availability, and Serviceability/Safety), agility, hierarchy, programmability* (see Deliverable D1.1 for a description of each pillar).

During Phase 2, the following pillars were selected to be addressed by the ELASTIC Software Architecture ecosystem: *Security; Programmability; Scalability, Autonomy, Agility* and *Hierarchy; and Reliability, Availability, and Serviceability/Safety (RASS)*. Next, we explain about how these pillars are currently addressed by CLASS.

5.3.1 Security

In the ELASTIC project, security is addressed from two different angles:

- First, the ELASTIC software architecture includes a *secure deployment mechanism* through the Nuvla software component that ensures that the new computing elements introduced in the fog platform are trustable by means of a strong authentication mechanism. This prevents the use of unsecured or untrusted computing elements that can compromise the correct operation of the system (see Deliverable D5.2 [28] for further details).
- Second, the fog platform continuously monitors the deployed systems and applications to detect potential threats, apply security upgrades, and deploy updates to existing configurations. To do so, ELASTIC considers the Security Content Automation Protocol (SCAP) [22], a multi-purpose framework of specifications that supports automated configuration, vulnerability and patch

checking, technical control compliance activities and security measurements (see Deliverable D4.1 [27] for further details).

If a vulnerability is detected, the information is forwarded to the ELASTIC software architecture orchestrator that will prevent the usage of the unsecured computing resource/network/application.

5.3.2 Programmability

The ELASTIC software architecture includes two well-known programming models upon which the workflows implementing the different data analytics methods across the compute continuum are described, i.e., the map/reduce and the tasking execution models. These two models are complementary and exploit two different types of parallelism: the former exploits structured parallelism and the latter unstructured parallelism. With the objective of addressing this important pillar, ELASTIC integrates the two models into the same ecosystem. Concretely, we have extended COMPSs to support the map/reduce operations provided by Spark. Deliverable D2.1 [25] provides a detail description of this integration.

5.3.3 Scalability, autonomy, agility and hierarchy

These highly interconnected pillars refer to the capability of the system to distribute computing and storage nodes across the tram vehicles and the tram stops with decision-making capabilities. To do so, the core of the ELASTIC software architecture includes a *distributed data analytics platform (DDAP)*, described in Deliverable D2.1 [25], and an *advanced orchestrator component* described in Deliverable D3.3 [26] that, based on the information coming from the *Non-Functional Requirement (NFR) tool,* distributes the data analytics workflows. The NFR tool, described in Deliverable D4.2 [6], is responsible of constantly monitoring the status of the fog platform in terms of computing resources and network capabilities.

This feature is fundamental to guarantee the non-functional requirements such as real-time, thus ensuring the correct operation of the system. Deliverable D3.3 [26] provides an overall description of the ELASTIC software architecture operation.

If the scheduler component determines that the real-time requirements are not fulfilled, the system will be informed so counter-measurements can be applied (e.g., scale-up computing resources).

Overall, the ELASTIC software architecture addresses each of the pillars as follows:

1. *Scalability*. The ELASTIC software architecture is independent of the underlying fog platform. Our software architecture will be constantly monitoring the computing network, selecting the most convenient computing node to fulfil the non-functional requirements of the system.
2. *Autonomy*. The decisions taken by the architecture will be independent of the existing computing nodes.
3. *Agility*. The architecture will have the capability to adapt the workflow to the actual execution conditions and communicate to the system if the non-functional requirements will be fulfilled or not.

4. *Hierarchy*. The scheduling decisions will be taken in a hierarchical environment composed of distributed and heterogeneous computing and storage elements.

5.3.4 Reliability, Availability, and Serviceability/Safety (RASS)

The NuvlaBox and KonnektBox incorporate telemetry mechanisms used by the NFR tool to monitor the fulfilment of the non-functional requirements of the system. If the NFR tool detects a violation of a non-functional requirement, the ELASTIC orchestrator re-distributes the data analytics workflow to guarantee system requirements. By doing so, fog nodes are aware of each other and act as a community of nodes, checking on each other, requesting feedback, and getting the health status on local network connections (see deliverables D5.2 [28] and D4.1 [27] for further information.

6. Conclusion

In this document, we presented two sets of standards with different expectations on the ELASTIC architecture and we described the main characteristics of the major standards that may impact or support the ELASTIC software architecture.

The first set of standards presented are related to the railway domain 61508 [1], 50126 [9], 50128 [10], 50129 [11] and impose safety constraints on the development and exploitation ELASTIC in an operational railway use case. From a safety point of view, the higher the SIL level, the greater the constraints applied to system developments will be. As an example of constraints which could impact the development of the ELASTIC software architecture, we can mention the following cases from the software standard 50128 Annex A (normative)

- Table A.3 – Software Architecture
  - "Artificial Intelligence – Fault Correction" is not recommended for SIL1 to SIL4 application
  - "Dynamic Reconfiguration of software" is not recommended for SIL1 to SIL4 application
- Table A.12 – Coding Standards :
  - The use of dynamic objects is not recommended for SIL 3 / SIL 4 application

The second set of presented standards related to the open initiatives DMTF[23], FIWARE[19] and OpenFog[21] and provides a standardized framework which supports the creation and reuse of existing software building blocks, in order to facilitate the development and interoperability of the architecture.

This first document of task T4.1 allowed us to describe the main characteristics of the major standards that may impact or support the ELASTIC software architecture with the objective of providing recommendations in the final document (D1.6) to the standardization committees and the consortiums in charge of the open initiatives, to fully exploit the extreme-scale analytics.

7. Acronyms and Abbreviations

- API - Application Programming Interface
- CENELEC - Comité européen de normalisation en électronique et en électrotechnique
- DMTF - Distributed Management Task Force
- CPS - Cyber-Physical Systems
- E/E/PE - Electrical/Electronic/Programmable Electronic
- HPC - High-Performance Computing
- IEC - International Electrotechnical Commission (IEC)
- IoT - internet of things
- NFR - Non-Functional Requirement
- RAMS - Reliability, Availability, Maintainability and Safety
- RASS - Reliability, Availability, and Serviceability/Safety
- SCAP - Security Content Automation Protocol
- SIL - Safety Integrity Level

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