AsyncSLA: Towards a Service Level Agreement for Asynchronous Services

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ABSTRACT

Complex distributed systems increasingly involve physical components as part of cyber-physical systems or Internet of things initiatives. Communication with such subsystems is typically asynchronous. Several initiatives like *Web of Things* or *AsyncAPI* have emerged to standardize and facilitate the definition of such asynchronous communications. However, these initiatives do not cover standards to specify the quality of service or define service level agreements (SLAs) for these asynchronous interactions. To address this issue, this paper proposes both a comprehensive quality model for asynchronous services based on the ISO/IEC 25010 standard, and a domain specific language to specify SLAs for asynchronous services based on the *WS-Agreement* standard. To facilitate its adoption, our proposed solution has been expressed also as an extension for the AsyncAPI specification. Finally, we provide a tool support to define these SLAs by extending an existing toolkit.

KEYWORDS

AsyncAPI, Web of Things, Service Level Agreement.

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1 INTRODUCTION

Physical components are becoming more pervasive and are often equipped with sensors and actuators that allow them to interact with their environment and with each other in what is called the *Internet of things* (IoT). Systems mixing this kind of components are called cyber-physical systems (CPS). CPS are the key element of modern industrial environments, known as *Industry 4.0* [21], which are becoming widespread in several sectors, enabling smart cities, smart homes, and smart transportation [17].

These physical components communicate with each other through the set of services they expose. These services are typically asynchronous—e.g., a service may continuously provide context information obtained from the physical sensors of the underlying component. All these asynchronous communications have led to an architectural style known as *event-driven service-oriented architecture* [11]. In these architectures, the constituent services communicate through the notification of events following the publish-subscribe pattern: a service producer publishes some event into a service broker, which sends it to all the service consumers subscribed to that type of events. In this manner, the interaction between producers and consumers is highly decoupled, which facilitates its scalability, reduces dependencies, and improves fault tolerance [11].

Event-driven service-oriented architectures have surged in popularity because of its adequacy in the context of CPS. According to a 2021 industry survey conducted by Solace, 85% of organizations recognize the business value and are striving for event-driven SOA architectures [28]. However, a subsequent survey conducted by the same organization in 2022 found that the biggest technical challenge for adopting this architecture is its integration with existing applications [29].

Several initiatives have emerged to facilitate the integration of this type of IoT services. For instance, the *Web of Things* (WoT) proposal aims to reuse and extend standard web technologies to apply them to the IoT domain [26]. In the same direction, specifications like *AsyncAPI*—which is independent of the underlying technology and protocol, and as such, can describe services using web-based technologies like *WebSocket*—have emerged to provide machine-readable definitions of APIs of asynchronous services [5].

Although these initiatives provide a common framework that enables the definition, discoverability, and interoperability of IoT-based services, they do not provide standards to define the *quality of service* (QoS) that is expected or required from them. For example, latency, availability, or throughput are key QoS metrics that need to be guaranteed in order to ensure a proper operation of the system. Although several approaches have been proposed to define and specify the QoS in the fields of WoT and IoT, they are limited in the number and type of metrics they address. Moreover, the required QoS is usually formalized in the form of a *service level agreement* (SLA). SLAs are contracts that establish the QoS agreed between service providers and service consumers [24]. Several formal machine-readable languages have been proposed for specifying SLAs. The primary objective behind making them machine-readable is so that they can be processed by a computer and, for instance, automatically derive and instantiate monitors to measure the compliance of the conditions stablished in the SLA. Although some proposals for

SLAs for WoT and IoT exists, they have some limitations in their expressivity and lack alignment with current standards, such as WS-Agreement or the AsyncAPI specification (see Section 2 for an in-depth discussion).

To cover this gap, this paper proposes *(i)* a *quality model* that comprises and structures several quality dimensions for asynchronous services based on the ISO/IEC 25010 standard; *(ii)* a *domain specific language* (DSL) to specify SLAs for asynchronous services considering these dimensions, adapting the *WS-Agreement* standard and integrating it with the AsyncAPI specification; and *(iii)* a *tool* that supports the proposed language and quality model.

We argue that these contributions are a first step towards supporting automatic techniques that rely on machine-readable QoS in an IoT or asynchronous context, such as the automatic generation of monitors, SLA assessment, or the discoverability of WoT based on QoS.

The rest of the paper is organized as follows: Section 2 discusses the related work. Section 3 explores the quality of service for asynchronous services and introduces our proposed quality model. Section 4 details our proposed domain specific language to specify SLAs for asynchronous services. Section 5 describes the tool support we have developed. Finally, Section 6 concludes the paper.

2 RELATED WORK

Several languages have been proposed in the literature to specify SLAs for traditional synchronous web services. Some of the most well known are WSLA [16], SLAng [18], SLA* [15] and WS-Agreement [4], with the latter being the established standard endorsed by the Open Grid Forum. In comparison, SLA languages for IoT-based asynchronous services is rather limited. We have analyzed some of the most relevant SLA proposals in the literature for asynchronous services along with the characteristics of the most well known synchronous ones. In this analysis we have examined various general and technical characteristics of the SLA languages. The general characteristics that we have examined comprise the type of service, metrics supported, the level of the defined syntax model, and whether the proposal is derived from a standard. The technical characteristics that we have examined comprise if the SLA supports preconditions, complex conditions, different scopes and whether the proposal has tool support. Table 1 provides a summary of such analysis that we describe in detail below.

Type of service: The proposals analysed cover both synchronous and asynchronous services. Regarding the synchronous ones, some SLA languages are aligned to a particular web service specification: SLA4OAI [9] is aligned with the OpenAPI specification used in RESTful services, and WSLA [16] and SLAng [18] are aligned with the Web Service Description Language (WSDL), which is usually used for SOAP-based web services. Other proposals are generic and are not aligned with any particular language describing the web service specification [4, 15]. However, due to this generalizability, they do not provide a fully concrete syntax model. Regarding the asynchronous services, none of the proposals analysed are aligned with the AsyncAPI specification.

Metrics: Most of the proposals—both synchronous and asynchronous—offer support for an extensible set of custom metrics [3, 4, 9, 15, 16, 20]. However, it is worth noting that these metrics are often presented as illustrative examples without a standardized structure or clear definitions. Furthermore, a few proposals for asynchronous services are limited to just a few metrics related to availability and latency without providing extensibility capabilities [8, 23]. It is noteworthy that only SLAng [18] introduces a quality model that systematically organizes the metrics employed in the SLA. However, it is important to note that the quality model presented in SLAng has been defined without considering any standard as a reference.

Syntax model: Some proposals provide SLAs as simple examples without any formalism [8, 23]. Some of the proposals provide only an abstract representation, such those presenting a UML metamodel [20], or an abstract set of mathematical rules [15] without a concrete syntax specifying the grammar of the SLA. Only a few proposals provide a complete DSL consisting of an abstract and a concrete syntax for the language [3, 9, 16, 18]. And from these, only Alqahtani et al. [3] has been designed for asynchronous services. It is also important to remark that WS-Agreement [4] provides a concrete syntax, but only partially, as many elements have been not defined on purpose in favour of generalizability, leading to multiple WS-Agreement complaint (sub)languages.

Derived from a standard: Several of the proposals of SLA languages for synchronous services have become or are based on some standard: WSLA, developed by IBM, was one of the first languages considered a de-facto standard due to its popularity in the early 2000s. This was the case, until the irruption of WS-Agreement, which was endorsed by the OSGi group, and emerged as the new standard for synchronous services. Some of the SLA language proposals for synchronous services have been derived from one or both of these two languages [9, 15]. However, regarding asynchronous services, almost none of the proposals derive from a standard (including the standards established in the synchronous services domain). Only Li et al. [20] is based on the WS-Agreement standard and has been adapted for asynchronous services.

Support for preconditions: Some SLA languages for synchronous services provide support to define preconditions in their guarantee terms (i.e. a precondition that must be met for a guarantee to be enforced), either completely [4, 15] or partially (e.g. limited to the periods of time when the guarantee should be enforced) [16]. However, in the context of asynchronous services, only WIoT-SLA [20] provides such support.

Support for complex conditions: Some proposals for syncrhonous services support the definition of complex boolean expressions in the objectives to be met (e.g. a combination of nested AND/OR operators) [4, 15, 16]. However, none of the SLAs for asynchronous services provide this type of support, limiting the expressivity of the guarantees to simple conditions consisting of a metric, an operand and a value.

Support for different scopes: An objective may apply to a specific scope of a service, such as a service method in synchronous services or a channel in asynchronous ones. Although a few proposals do not support the definition of scopes in their SLA languages, most of them do [3, 4, 9, 15, 16, 20].

Tool support: With the exception of Mustafa et al. [23], all proposals have tool support for their proposed SLA language.

To conclude, although some solutions exists defining SLA languages for asynchronous services, their capabilities are not as powerful as those proposed for synchronous ones. To cover this gap,

Table 1: Analysis of the related work

	General characteristics			Technical characteristics				
Proposal	**Type of service**	**Metrics**	**Syntax model**	**Derived from standard**	**Support for preconditions**	**Support for complex conditions**	**Support for different scopes**	**Tool support**
WSLA [16]	Synchronous (WSDL)	Extensible, custom	Concrete	Yes*	Partially	Yes	Yes	Yes
SLAng [18]	Synchronous (WSDL)	Extensible, based on quality model	Concrete	No	No	No	No	Yes
SLA* [15]	Synchronous (generic)	Extensible, custom	Abstract	Yes	Yes	Yes	Yes	Yes
WS-Agreement [4]	Synchronous (generic)	Extensible, custom	Concrete (Partially)	Yes*	Yes	Yes	Yes	Yes
SLA4OAI [9]	Synchronous (OpenAPI)	Extensible, custom	Concrete	Yes	No	No	Yes	Yes
WIoT-SLA [20]	Asynchronous	Extensible, custom	Abstract	Yes	Yes	No	Yes	Yes
Ezzedine et al. [8]	Asynchronous	Limited, custom	Not formalized	No	No	No	No	Yes
Alqahtani et al. [3]	Asynchronous	Extensible, custom	Concrete	No	No	No	Yes	Yes
Mustafa et al. [23]	Asynchronous	Limited, custom	Not formalized	No	No	No	No	No
AsyncSLA	Asynchronous (AsyncAPI)	Extensible, based on quality model	Concrete	Yes	Yes	Yes	Yes	Yes

we propose an SLA language for asynchronous services aligned with the AsyncAPI specification and comprising an extensible set of metrics based on a quality model; with an abstract and concrete syntax model, derived from the WS-Agreement standard, including support for preconditions, complex conditions, multiple scopes, and tool support.

3 QUALITY OF SERVICE FOR ASYNCHRONOUS SERVICES

QoS is defined by the ISO/IEC 13236:1998 standard as “A set of qualities related to the provision of a service as perceived by a service-user” [13]. These qualities comprise many dimensions of the service—e.g., performance, security, reliability, etc. In this regard, the first question when proposing a QoS approach for asynchronous systems is: what are the quality dimensions we should be concerned about and what metrics can be used to measure them? For instance, time performance may be evaluated with the response time in synchronous services (i.e., the time it takes for the service client to receive the response since the request was sent). However, in the field of asynchronous services, the asynchronous interaction of the services requires other metrics to measure performance (e.g., the time it takes from the packet generation by the source node to the packet reception by the destination node).

To address this question, quality models have been proposed as the engineering artifacts to structure the concepts and definitions of the quality dimensions of a software system [12]. There exist many proposals of general-purpose quality models for software systems. They differ on the terminology that they use, the set of quality attributes they define, and the structure of the quality model. The most widely adopted one is the ISO/IEC 25010 standard [12], which classifies software quality into a structured set of high-level characteristics—*functional suitability*, *performance efficiency*, *compatibility*, *usability*, *reliability*, *security*, *maintainability* and *portability*—which are then decomposed into 31 sub-characteristics (see Figure 1). However, the ISO/IEC 25010 standard is not specifically tailored to the services domain. For instance, the sub-characteristic *Installability* is usually not applicable to web services because they are executed remotely at the server side. On the other hand, the ISO/IEC 25010 standard does not provide quantitative or qualitative measurable metrics to evaluate those dimensions.

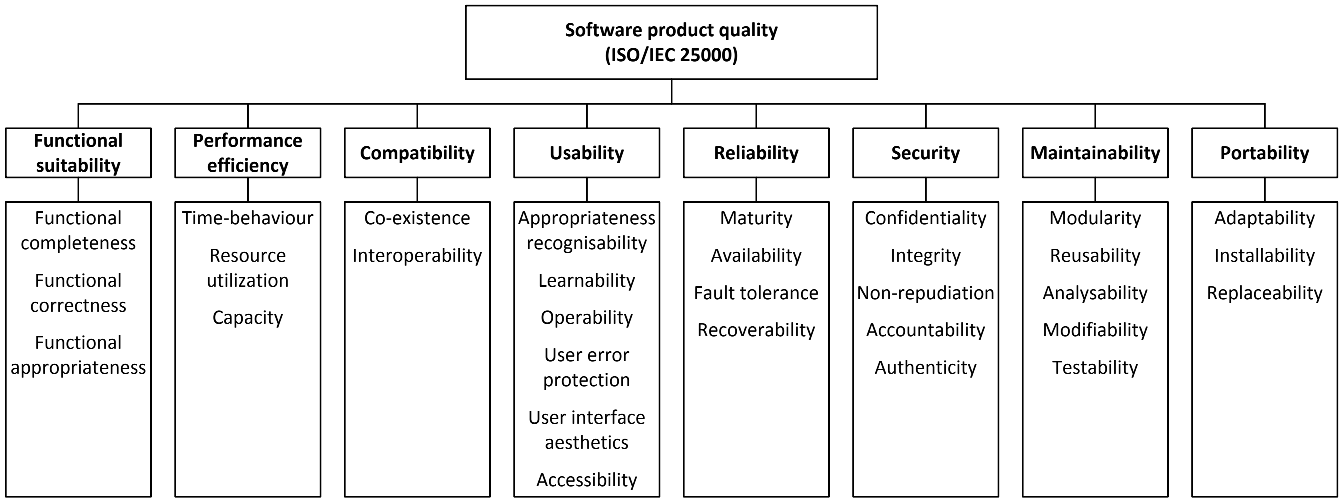


Figure 1: ISO/IEC 25010 quality model for software systems

While many quality models tailored for web services have been proposed [25], to the best of our knowledge, no comprehensive quality model specific for asynchronous services has been defined yet. As a result, most works involving QoS for asynchronous services usually use quality dimensions without a formal structure, as discussed in the related work.

To cover this gap, we propose a quality model for asynchronous services. To build this quality model, we gathered a variety of existing quality metrics and their definitions as proposed in the literature, both from services in general (i.e. they apply to both synchronous and asynchronous services) and asynchronous services in particular. Instead of building this quality model from scratch, we extended the quality model derived from a systematic study of quality models for services, which was developed as part of one of the authors' previous work [25]. This earlier study identified several quality metrics for services and categorized them to the subcharacteristics of the ISO/IEC 25010 standard.

In this work, we have identified the quality metrics that are applicable to asynchronous services from the quality model presented in [25] and, when needed, updated their definitions according to the results we found in the literature for asynchronous services, resulting in a quality model for asynchronous services aligned with the ISO/IEC 25010 standard.

For each metric, we provide its definition and a reference to the work that inspired it—if not, it is based on our expertise in the topic. We also group these metrics based on the most appropriate quality subcharacteristic from ISO/IEC 25010. Table 2 shows the core metrics we identified, mapped to its corresponding sub-characteristics of the ISO/IEC 25010 standard.

It is worth to mention, that the presented metrics are independent from the monitoring process, although their measurements might be affected by the monitoring infrastructure in place. For instance, latency is defined as the time it takes from the packet generation by the source node to the packet reception by the destination node. If the monitors are instrumented in both the service producer and service consumer, the latency measured is end-to-end. However, the monitors might be instrumented between the service producer and the service broker, measuring therefore the latency between these two entities. It is also worth noting that other type of metrics do not require to instrument both sides of the communication and can be measured by instrumenting just one side (e.g. Payload size). Finally, some metrics are rather static and do not require runtime monitoring (e.g. versioning).

4 A DOMAIN SPECIFIC LANGUAGE FOR SLAS OF ASYNCHRONOUS SERVICES

We propose a domain specific language (DSL) to define SLAs for asynchronous services, named AsyncSLA, by tailoring the structure and key concepts of the *WS-Agreement* standard, as this will help in the adoption and recognition of the SLA to all people familiar with this specification.

In addition to addressing the quality dimensions for asynchronous services outlined in the previous section, we have also specified our DSL to support the inherent characteristics of asynchronous services, that are distinct from the synchronous ones. These characteristics are:

- *Interactions are initiated by the service provider:* In contrast to synchronous services where the service client initiates the interaction—i.e., the service client sends a request to the service provider to obtain a response—in asynchronous services, it is the service producer who initiates the interaction—i.e., the service producer sends the information related to an event to the subscribed service consumers.
- *One-way interaction with service consumers:* Although the service consumer can acknowledge the reception of the information, there is no response that the service producer expects from its subscribed consumers.
- *Channel-based communication:* Instead of service methods or operations that are offered by synchronous services, asynchronous services are composed of *channels*, where the service producer publishes the information related to an event

Table 2: List of metrics mapped to ISO/IEC 25010 quality model

Quality Metric	Parent from ISO/IEC 25010	Definition
Probability of correctness	Functional suitability (correctness)	The probability that the content of the message accurately represents the corresponding real world situation [1]
Precision	Functional suitability (correctness)	How exactly the provided information in the message mirrors the reality. Precision is specified with bounds [1].
Up-to-dateness	Functional suitability (correctness)	How old is the information upon its receipt [1]
Latency	Performance (time behaviour)	The total time from the packet generation by the source node to the packet reception by the destination node [6]
Round Trip Time	Performance (time behaviour)	The time from the packet generation by the source node to the reception of the ACK [27]
Jitter	Performance (time behaviour)	Variation of Latency [1]
Throughput	Performance (time behaviour)	The amount of error-free bits transmitted in a given period of time [19]
Message frequency	Performance (time behaviour)	The amount of messages transmitted in a given period of time. It is the inverse of Time period
Time period	Performance (time behaviour)	The amount of time elapsed between two messages. It is the inverse of message frequency
Memory used	Performance (resource utilization)	The amount of memory used by the service
CPU used	Performance (resource utilization)	The amount of CPU used by the service
Bandwith	Performance (resource utilization)	The amount of bandwith used by the service
Payload size	Performance (resource utilization)	The size of the payload enclosed in the message sent by the service
Max. subscribers	Performance (capacity)	The maximum amount of subscribers the service is capable of handling
Max. throughput	Performance (capacity)	The maximum throughput the service is capable of providing
Load balancing	Performance (capacity)	To what extent the service has load balancing capabilities
CPU capacity	Performance (capacity)	The maximum CPU the service is capable of using
Memory Capacity	Performance (capacity)	The maximum memory the service is capable ofusing
Documentation	Usability (recognizability)	The extent to which a web service interface contains an adequate level of documentation [2]
Discoverability	Usability (recognizability)	The ease and accuracy of consumers' search for an individual service, based on the description of the service [14]
Expected failures	Reliability (maturity)	Expected number of failures over a time interval [7]
Type Consistency	Reliability (maturity)	The data flow is consistent with respect to definition of data types [1]
Time to Fail	Reliability (maturity)	Time the service runs before failing [7]
Availability	Reliability (availability)	The probability that a service is available at any given time [1]
Uptime	Reliability (availability)	The duration for which the service has been operational continuously without failure [22]
Packet loss	Reliability (availability)	Ratio of the number of undelivered packets to sent ones [7]
Disaster resiliance	Reliability (fault tolerance)	How well the service resists natural and human-made disasters [22]
Exception Handling	Reliability (fault tolerance)	Internal activities that are performed in the case of failures during the execution of the service. [1]
Time to Repair	Reliability (recoverability)	Time needed to repair and restore service after a failure [7]
Failover	Reliability (recoverability)	Whether the service employs failover resources, and how quickly [22]-
Versioning	Maintainability (Modifiability)	Whether the service implements versioning strategies to ensure backward compatibility

so that the service consumers subscribed to that channel can receive it.

- *Broadcast communication:* When an asynchronous service publishes a message, this is received by all the subscribed service consumers in the channel, leading to a 1–N relationship for a given event (i.e. one event has one service producer and *N* service consumers receiving it).

Fig. 2 depicts the metamodel—i.e., the modeling primitives and their relationships—of our DSL for asynchronous services SLAs, following the *WS-Agreement* structure. It is worth noting that the figure does not depict it as a conceptual model, but as an implementation model using the *Ecore* metamodeling language of the *Eclipse Modeling Framework* (EMF) [30]. We present this model for brevity, since we also cover the concrete notation of our DSL in Section 5.

SLA is the top-level class for the definition of an SLA, and it is composed of several *GuaranteeTerms*. A *GuaranteeTerm* is a WS-Agreement element that defines the terms that the service must meet regarding the QoS. It includes a set of *scopes*, a set of *qualifying conditions* and a set of *service level objectives* (*SLO*). While these components are inherent to the WS-Agreement standard, we've tailored them to suit asynchronous services. The *Scope* defines the scope where the *GuaranteeTerm* applies to. In our DSL, it includes an identifying *name*, and relates to the service *Channel* that is used as a scope—which is akin to the service methods in synchronous services. This granularity enables tailored QoS conditions for different service channels within the asynchronous service. For instance, one channel providing information related to critical events may impose stricter QoS conditions compared to another less critical channel. The *QualifyingCondition* defines the preconditions, expressed as a boolean expression (*BooleanExpression*), that must be met for a condition to be enforced. In its turn, the *SLO* defines the QoS condition that must be assessed—when the *QualiyingCondition* is met. An *SLO* is specified as a boolean expression of the condition that must be assessed for the goal to be fulfilled.

In our DSL, boolean expressions support the combination of *OrExpressions* and *AndExpressions* in a tree-structure form, leading to one or more *ComparisonExpressions*. A *ComparisonExpression* is an expression composed of a *QoSMetric*, an *Operator*, and a *value*. Based on our findings in different SLAs, we opted for a lightweight but powerful enough grammar to define boolean expressions, rather than using a more complex but cumbersome language—e.g., OCL.

QoSMetric defines the metric involved in the SLA/SLO evaluation. It has an identifying *name*, a *description*, a *QoSMetricType*, a *QoSMetricUnit*, and a *groupedByMessage* flag. The attribute *QoSMetricType* is used to link the defined metric to the type of metrics from the quality model. In this way, the SLA can be seamlessly integrated with any predefined quality model, allowing flexibility in linking the defined metric to specific metric types through the *QoSMetricType* attribute. The *groupedByMessage* flag determines whether the *QoSMetric* is calculated as the average result for the metric across all clients subscribed to a specific event when set to 'true,' or if distinct QoS metrics are calculated for each individual client when set to 'false.' For instance, if two clients are subscribed to the same channel and this attribute is set to 'false,' two values (one per client) would be produced. Conversely, if it's set to 'true,' a single value (the average of both clients' metrics) would be generated.

Finally, *DerivedQoSMetric* defines a derived QoS metric, i.e., the result of aggregating values—e.g., average, max, min—in an interval. Thus, it includes a window, a windowUnit, and an aggregationFunction.

5 A TOOL TO SPECIFY SLAS FOR ASYNCHRONOUS SERVICES

To show the feasibility of our approach, we have implemented a tool prototype that supports the definition of SLAs for asynchronous services using our AsyncSLA proposal.

To implement this tool, we have first defined a concrete syntax matching the metamodel described in the previous section. In particular, the concrete syntax is defined as an extension of the *AsyncAPI* specification as we believe this will facilitate its adoption. *AsyncAPI* is an initiative that, similar to what *OpenAPI* represents for the REST world, aims at providing a *single source of truth* in the definition of asynchronous and message-based services. *AsyncAPI*

Listing 1: Excerpt of an example of SLA integrated with the *AsyncAPI* specification

```
{
    "asyncapi": "2.0.0",
    ...
    "channels": {
        "smartylighting/.../lighting/measured": {...}
    }

    "components": {
        ...
        "x-qosMetrics": [
        {
            "name" : "availabilityPerEvent",
            "description" : "Availability per each event",
            "groupedByEvent" : true,
            "metricType" : "availability",
            "unit" : "null"
        },
        {
            "name" : "individualLatency",
            "description" : "Latency for each message and client",
            "groupedByEvent" : false,
            "metricType" : "latency",
            "unit" : "milliseconds",
        },
        {
            "name" : "medianLatency",
            "description" : "Median latency in 1h for each client",
            "groupedByEvent" : false,
            "metricType" : "latency",
            "unit" : "milliseconds",
            "derivedQoSMetricDefinition" : {
                "aggregationFunction":  "MEDIAN",
                "window" : "60",
                "windowUnit" : "minutes"
            }
        }]
    },
    "x-sla": {
        "guaranteeTerm" : {
            "scopes" : {
                "scope1" : "smartylighting/.../lighting/measured"
            },
            "slos" : {
                "slo1" : {
                    "qosMetric" :  "AvailabilityPerEvent",
                    "operator" : ">",
                    "value" : "0.9"
                },
                "slo2" : {
                    "qosMetric" :  "individualLatency",
                    "operator" : "<",
                    "value" : "3000"
                },
                "slo3" : {
                    "qosMetric" :  "medianLatency",
                    "operator" : "<",
                    "value" : "2000"
                }
            }
        }
    }
}
```

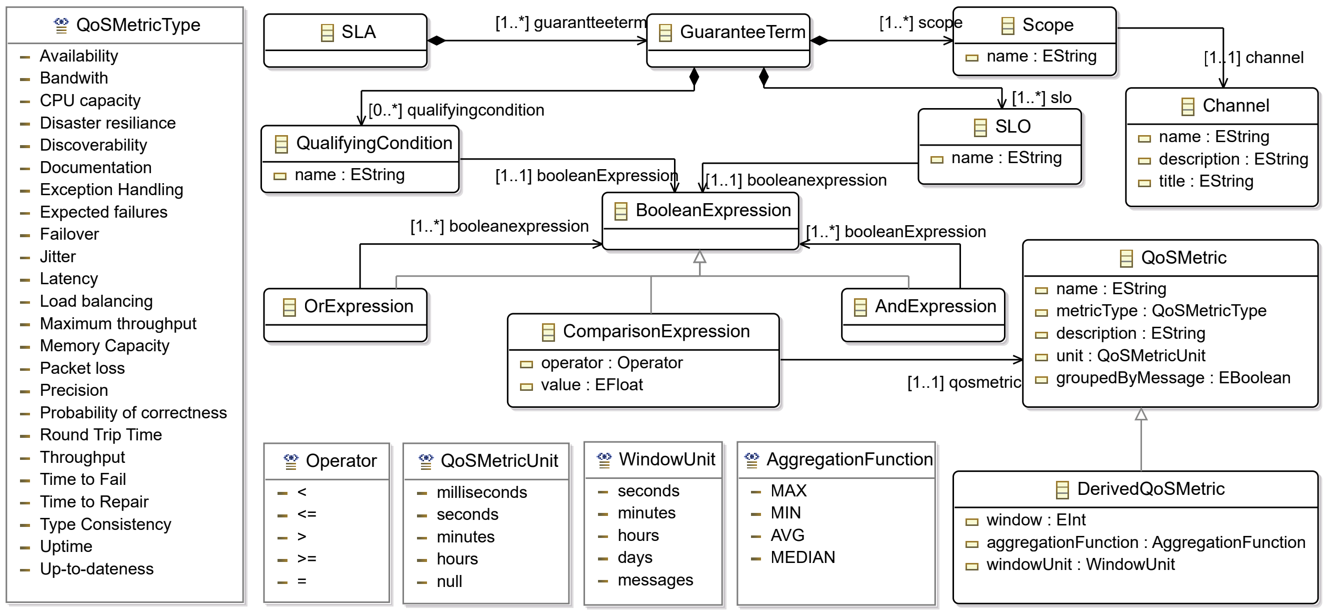


Figure 2: Metamodel of the proposed SLA

descriptions are expected to be both human and machine readable. To achieve this goal, files defining a message-driven API are represented as JSON objects and conform to the JSON standards. Such files allow describing, among other things, the message brokers of an architecture, the *topics*—i.e., channels—of interest, or the formats of the messages associated with each of the *topics*.

As part of our previous work, we developed the *AsyncAPI Toolkit*[1], an Eclipse-based tool that supports the development of *AsyncAPI* specifications and automatically generate code using model-driven engineering techniques. The *AsyncAPI Toolkit* defines both the concrete and abstract syntax for *AsyncAPI* specifications using Xtext[2].

We have now extended the *AsyncAPI Toolkit* to seamlessly integrate both *AsyncAPI* and the AsyncSLA specifications. This integration starts at the metamodel level, where we have linked the *AsyncAPI* metamodel presented in our previous work [10] with the AsyncSLA metamodel presented in Section 4. In the integration, we have fused the common elements such as *Channel*, and we have added the *SLA* object as a field of the root *AsyncAPI* object.

We have also defined a concrete syntax for the SLA-related elements—i.e., those that do not already belong to the *AsyncAPI* specification—in JSON. We indicate that such additions do not conform the official *AsyncAPI* specification by prefixing them with an `x-`. An example of an SLA using our concrete syntax integrated in the *AsyncAPI* specification is shown in Listing 1.

This example shows an SLA that defines 3 metrics:

- *availabilityPerEvent* is a metric of type *availability*. By setting the flag *groupedByEvent* to true, it measures to what extent the service producer is available to all subscribed consumers. For instance, if a service channel has 3 subscribed consumers and a message from a service producer is only received by two of these consumers, availabilityPerEvent would be 0.66;
- *individualLatency* is a metric of type *latency* and measures the latency for each message received by each client in milliseconds.
- *medianLatency* is a derived metric of type *latency* and computes the median latency of the messages received within one hour per each client.

[1]https://github.com/SOM-Research/asyncapi-toolkit
[2]https://www.eclipse.org/Xtext/

For simplicity, the provided SLA defines just one *guaranteeTerm* with one *scope* (i.e. the part of the system to which the SLOs apply). In this *guaranteeTerm*, 3 SLOs comprising the previously defined metrics are defined using simple boolean expressions.

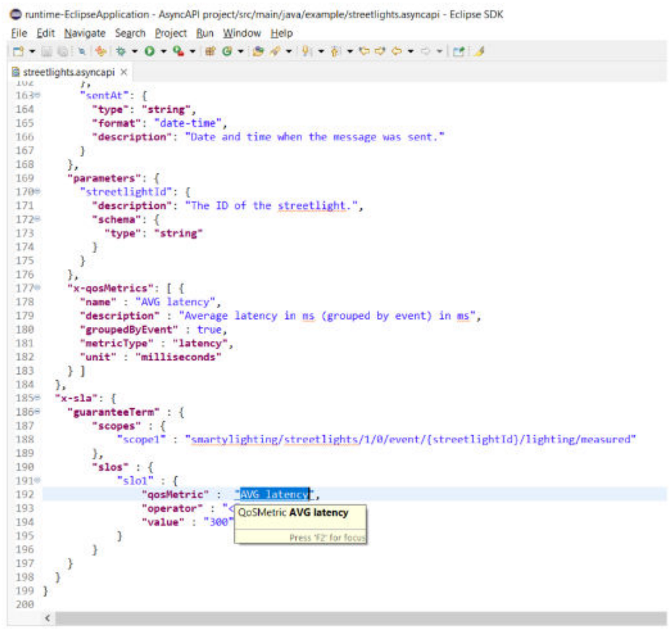
This concrete syntax has been implemented using the Xtext Framework. One of the key advantages of using Xtext is that it is capable of automatically providing all the necessary tooling to support the development of documents following the defined syntax.

As a result, the extended *AsyncAPI Toolkit* provides a content-assisted editor and parser to define SLAs along with the *AsyncAPI* specification. Figure 3 provides a screenshot of the tool.

The *AsyncAPI Toolkit* with SLA support is now officially available on GitHub (see footnote 1).

6 CONCLUSIONS

In this work we have presented a framework to specify service-level agreement documents for asynchronous services. Among its different assets, we have proposed *(i) a quality model* aligned with the ISO/IEC 25010 standard that defines several quality metrics for asynchronous services; *(ii) a metamodel and concrete syntax* to define SLAs for such services, named AsyncSLA, and aligned with the *WS-Agreement* and AsyncAPI specifications, that enables the


runtime-EclipseApplication - AsyncAPI project/src/main/java/example/streetlights.asyncapi - Eclipse SDK
File Edit Navigate Search Project Run Window Help
streetlights.asyncapi
QoSMetric AVG latency
Press 'F2' for focus

```
      },
      "sentAt": {
        "type": "string",
        "format": "date-time",
        "description": "Date and time when the message was sent."
      }
    },
    "parameters": {
      "streetlightId": {
        "description": "The ID of the streetlight.",
        "schema": {
          "type": "string"
        }
      }
    },
    "x-qosMetrics": [ {
      "name" : "AVG latency",
      "description" : "Average latency in ms (grouped by event) in ms",
      "groupedByEvent" : true,
      "metricType" : "latency",
      "unit" : "milliseconds"
    } ]
  },
  "x-sla": {
    "guaranteeTerm" : {
        "scopes" : {
            "scope1" : "smartylighting/streetlights/1/0/event/{streetlightId}/lighting/measured"
        },
        "slos" : {
            "slo1" : {
                "qosMetric" : "AVG latency",
                "operator" : "<
                "value" : "300"
            }
        }
    }
  }
}
```

Figure 3: Screenshot of the extended AsyncAPI Toolkit with content-assisted editor to define SLAs

definition of conditions of the previously identified quality metrics; and *(iii) a toolkit* to support this new DSL.

As future work, we plan to extend and validate our quality model and to implement additional features in the *AsyncAPI Toolkit* for the automation of SLA related activities, such as the automatic generation of monitors from the SLA. We also plan to analyze how to better integrate our proposed DSL to existing WoT standards and validate it through its deployment in a real-world company, serving as a comprehensive case study.

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