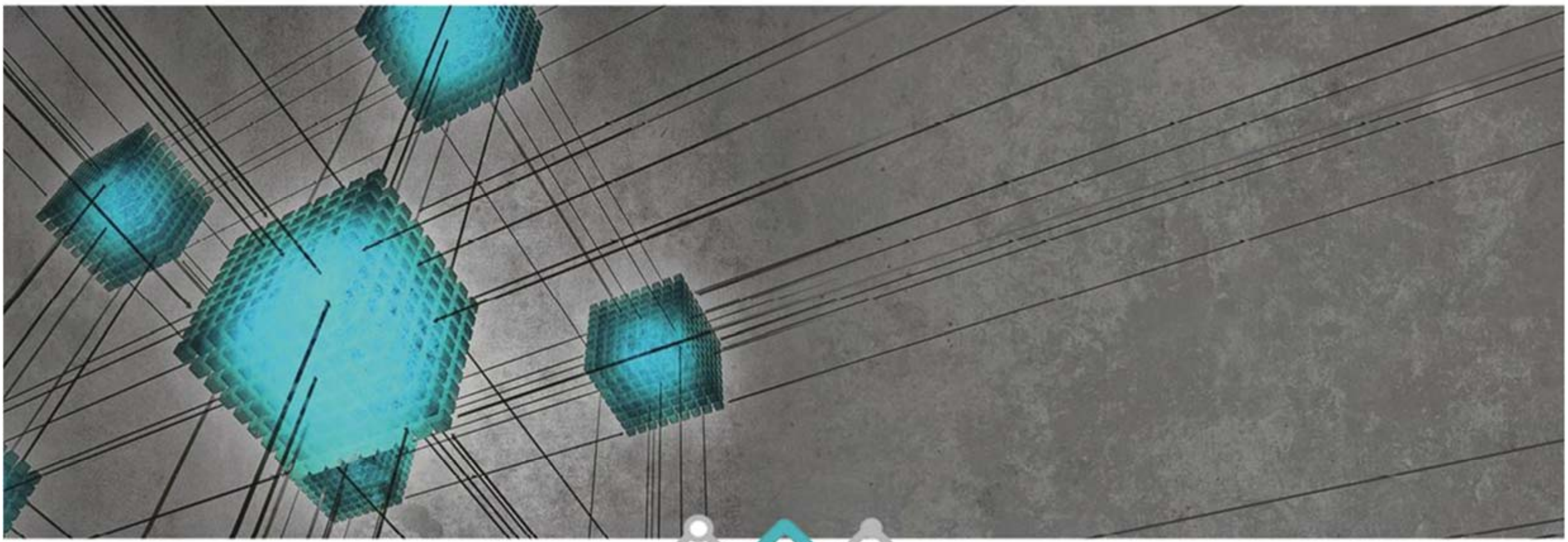
Ref. Ares(2018)4993321 - 28/09/2018



interiot

INTEROPERABILITY
OF HETEREOGENEUS
IOT PLATFORMS.

D7.2

Technical Evaluation and Assessment Report

September 2018

INTER-IoT

INTER-IoT aim is to design, implement and test interoperability tools, a framework and a methodology that will allow interoperability among different Internet of Things (IoT) platforms.

Most current existing IoT developments are based on “closed-loop” concepts, focusing on a specific purpose and being isolated from the rest of the world. Integration between heterogeneous elements is usually done at device or network level and is just limited to data gathering. Our belief is that a multi-layer approach to the integration of different IoT devices, networks, platforms, services and applications will allow a global continuum of data, infrastructures and services. Additionally, a reuse and integration of existing and future IoT systems will be facilitated, enabling the creation of a de facto global ecosystem of interoperable IoT platforms.

In the absence of global IoT standards, INTER-IoT results will allow any company to design and develop new IoT devices or services, leveraging on the existing ecosystem, and bringing them to market quickly.

INTER-IoT has been financed by the Horizon 2020 initiative of the European Commission, contract 687283.

INTER-IoT

Technical Evaluation and Assessment Report

Version: 1.0

Security: Public

September 2018

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Disclaimer

Executive Summary

The primary objective of this deliverable is to present the technical evaluation of the project. Work carried out as part of WP7 focused on the assessment of technical KPIs which give an insight into the technical maturity of INTER-IoT and its components. 45 of the 113 KPIs are covered in the document. This represents nearly all of the project's technical developments (apart from large scale pilots) which have been completed at this stage in the project.

A full review and update of the data collection, KPI subdivision and score calculation methodology is presented. The data collection methodology and/or scoring methodology have been updated for 12 of the KPIs. The changes represent improvements in the clarity of the methodology as well as addressing bias which could be introduced by outliers in individual KPI scores. By presenting the calculated KPI, field and dimension scores in 2 ways—as planned in D7.1 and with a maximum limit for any individual KPI score set to 100—a more complete understanding of the data is realized. The overall INTER-IoT score is 148 utilizing the methodology outlined in D7.1 and 94 for the adjusted methodology. Areas where the technology is performing well are highlighted as well as areas where additional work is needed.

Development and functional KPIs have performed particularly well with multiple individual KPIs far exceeding the goals set. Documentation for all aspects of the project is underway. Improving the coverage and quality of this important aspect of the project will show improvements in the associated KPIs in D7.3. Additionally, KPIs whose testing is tied to pilot activities are often lower than the target. D7.3 will show progress in these areas as well.

Overall, the report is very positive and reflects the work done as part of the INTER-IoT project consortium. Additional work will be done to complete the assessment of the remaining technical and non-technical KPIs during the final stage of the project with the final evaluations included in D7.3 delivered in M36 of the project.

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Change control datasheet

Version	Changes	Chapters	Pages
0.1	TOC, methodology selection	All	10
0.2	Methods updated, kpi score updates	2	15
0.3	Results and evaluation	2,3	30
0.4	Ethics and results update	3,4	36
0.5	Methodology and results	2, 3	37
0.6	Conclusion, introduction, results and evaluation section update	1, 3, 5	51
0.7	Review	All	50
1.0	Final changes added from review	All	55

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Acronyms

API	Application Programming Interface
AS2AS	Application services layer interoperability solution, result of INTER-IoT T3.4
ATA	Actual Time of Arrival
BMI	Body Mass Index
CASE	Computer-Aided Software Engineering
CREATE-IoT	H2020 project
D2D	Device layer interoperability solution, result of INTER-IoT T3.1
Dn.m	Deliverable number, as in D2.1 (deliverable 1 of work package 2)
DoW	INTER-IoT Description of Work
ETA	Estimated Time of Arrival
ETR	Estimated amount of Time of Resolution
FIWARE	An IoT platform for the development of smart applications
GIoTP	Generic Ontology for IoT Platforms
H2020	Horizon 2020 Programme for Research and Innovation
HTTP	Hypertext Transfer Protocol
HW	Hardware
ICT	Information and Communication Technologies
INTER-DOMAIN	INTER-IoT cross-domain pilot
INTER-FW	INTER-IoT IoT interoperability framework
INTER-Health	INTER-IoT eHealth pilot
INTER-IoT	Interoperability of Heterogeneous IoT Platforms
INTER-Layer	INTER-IoT layer interoperability
INTER-LogP	INTER-IoT transportation pilot
INTER-METH	INTER-IoT methodology for the integration of IoT platforms
INTER-MW	Middleware layer interoperability solution, result of INTER-IoT T3.3
IoT	Internet of Things
IPR	Intellectual Property Rights
IPSM	Inter-Platform Semantic Mediator
JSON-LD	JavaScript Object Notation for Linked Data
KPI	Key Performance Indicator
Mn	n^{th} month of the project (M1=January 2016)
N2N	Network layer interoperability solution, result of INTER-IoT T3.2
PWT	Professional Wen Tool
PU	Professional user
RDF	Resource Description Framework
REST	REpresentational State Transfer
Rn	n^{th} requirement
SDK	Software Development Kit
SDN	Software Defined Network
SSL	Secure Socket Layer
SME	Small or Medium-sized Enterprise
Tn,m	Task number, as in T2.1 task 1 of work package 2
W3C	World Wide Web Consortium
WP	Work Package

1 Introduction

Work package seven oversees the project's overall evaluation. This process begins with the definition of KPIs and the associated measurement methodologies to assess the success of individual facets of the project as well as summary markers. This report will present the assessment findings from a technical perspective covering integration, testing and trial activity KPIs that have been completed by project partners as of M33 of the project. The evaluation of some aspects of INTER-IoT is partially completed as the large-scale pilots are underway and some components continue to be developed during the pilots (WP6). Additionally, 3rd party partners who joined during the Open Call will provide technical KPIs in D7.3. In addition to results from the measured KPIs, updates to KPI measurement methodology are provided if they were thought necessary after M27 when D7.1 was submitted.

This deliverable is divided into five main section. In this first section, an overview of the entire deliverable is given including the presentation of the document's objectives. In the methodology, updates to the data collection methodology are presented as well as updates to the KPI score calculation methodology for some of the KPIs. The results section reports on the KPIs measured as part of the technical evaluation of the project and present the field and dimension scores for the current set of KPIs. The results are then discussed and specific objectives are highlighted as a result of the work done so far. A review of the ethical issues related to the collection and evaluation of project results is included in the next chapter. The final chapter will be reserved for conclusions.

1.1 Objectives

The primary objective of deliverable D7.2 is to present the technical evaluation of the project through M33. A full review and update of the data collection, KPI subdivision and score calculation methodology is presented. Results of the evaluation will be presented. Areas where the technology is performing well will be highlighted as well as areas where additional work is needed. A discussion of the results will also be provided so that the reader can gain a greater insight into the meaning of the work.

2 Methodology

The information presented in D7.2 gives the first insight into the technical evaluation of the project. KPIs have been selected for reporting based on their classification in D7.1. Technical KPIs are reported in D7.2. All additional KPIs will be reported in D7.3. KPIs from field 4.7 and 2.2 have also been included in this deliverable as they were ready for initial assessment and they address the technical readiness of WP5 and the INTER-Health pilot respectively. Updates will be made to these fields in D7.3. Table 1 below indicates the KPIs to be included in this deliverable and D7.3. Grey KPIs are only to be included in D7.3. KPI collection methodology is addressed in section 0. Clarification is offered to the methods reported in D7.1 if necessary. A brief review of the KPI score calculation methodology will follow in section 2.2. This section will include updates with respect to D7.1 to specific KPI score calculation methodologies. These updates were made to add depth and clarity to the KPIs used to evaluate the project. The section 2.3 will summarize the methods used in grouping the KPIs into dimensions and fields for summary analyses.

Table 1: KPI methodology update and reporting deliverable location

KPI id	Name	Data Collection Methodology Changed (section 2.1)	KPI Score Calculation Method Updated (section 2.2)	Reporting Deliverable
KPI.1.01	Stakeholders involved	N	N	7.3
KPI.1.02	Stakeholders analysed	N	N	7.3
KPI.1.03	Open Calls launched	N	N	7.3
KPI.1.04	Received proposals in Open Call	N	N	7.3
KPI.1.05	Accepted proposals in the Open Call	N	N	7.3
KPI.1.06	Business models proposed	N	N	7.3
KPI.1.07	Monetizable products	N	N	7.3
KPI.1.08	Private companies using INTER-IoT products (estimate)	N	N	7.3
KPI.1.09	Public institutions using INTER-IoT components (estimate)	N	N	7.3
KPI.1.10	Open-source readiness	N	N	7.3
KPI.1.11	Business model flexibility	N	N	7.3
KPI.1.12	Derived products	N	N	7.3
KPI.1.13	Existing products influenced by INTER-IoT developments	N	N	7.3
KPI.1.14	Spin-offs created	N	N	7.3
KPI.1.15	Time to go-to-market	N	N	7.3
KPI.1.16	Commercial presentations	N	N	7.3
KPI.1.17	Commercial leads	N	N	7.3
KPI.1.18	Commercial industrial events	N	N	7.3
KPI.1.19	Partners involved in joint exploitation	N	N	7.3
KPI.1.20	Openness in business models	N	N	7.3
KPI.1.21	External partnerships and collaborations	N	N	7.3
KPI.1.22	Channels selected	N	N	7.3
KPI.1.23	Effective business model design	N	N	7.3
KPI.1.24	Competitors	N	N	7.3
KPI.1.25	IPR	N	N	7.3
KPI.2.01	Use cases	N	N	7.3
KPI.2.02	Number of patients connected to INTER-Health	N	N	7.3
KPI.2.03	Number of objects connected to INTER-LogP	N	N	7.3
KPI.2.04	Accuracy ETA vs ATA	N	N	7.3
KPI.2.05	Activity detected in the railway area	N	N	7.3
KPI.2.06	Trucks detected by system	N	N	7.3
KPI.2.07	Global events detected by system	N	N	7.3
KPI.2.08	Average BMI improvement	N	N	7.3
KPI.2.09	Average waist circumference improvement	N	N	7.3
KPI.2.10	Chronic diseases risk reduction	N	N	7.3
KPI.2.11	Physical activity (steps) improvement	N	N	7.3
KPI.2.12	Physical activity (minutes of activity) improvement	N	N	7.3
KPI.2.13	Average eating habit improvement	N	N	7.3
KPI.2.14	Dropout rate	N	N	7.3
KPI.2.15	Performance of the Professional Web Tool	Y	N	7.2 and 7.3

KPI id	Name	Data Collection Methodology Changed (section 2.1)	KPI Score Calculation Method Updated (section 2.2)	Reporting Deliverable
KPI.2.16	Body Cloud mobile app usage	N	N	7.3
KPI.2.17	Professional Web Toll application usage	Y	N	7.2 and 7.3
KPI.3.01	Dissemination channels	N	N	7.3
KPI.3.02	Initiatives to support standardization	N	N	7.3
KPI.3.03	Verticals involved	N	N	7.3
KPI.3.04	Publication actions generated	N	N	7.3
KPI.3.05	Organisation of Scientific events	N	N	7.3
KPI.3.06	Academic impact (PhD and MSc Thesis)	N	N	7.3
KPI.3.07	Participation in industrial dissemination actions	N	N	7.3
KPI.3.08	Industrial demos development	N	N	7.3
KPI.3.09	Research projects identified for Cross Dissemination	N	N	7.3
KPI.3.10	Social network followers	N	N	7.3
KPI.3.11	Number of individual addressed through different communication channels	N	N	7.3
KPI.3.12	Business or commercial meetings to present the project	N	N	7.3
KPI.3.13	Participation in technological forums/discussions	N	N	7.3
KPI.3.14	Collaboration in Free and Open projects	N	N	7.3
KPI.4.01	APIs offered by INTER-IoT layer-specific solutions.	Y	N	7.2 and 7.3
KPI.4.02	Issue tracking	N	N	7.2 and 7.3
KPI.4.03	IoT platforms integrated on MW2MW layer	Y	N	7.2 and 7.3
KPI.4.04	IoT platforms integrated on AS2A layer	N	N	7.2 and 7.3
KPI.4.05	Syntactic translators between different data formats and RDF	N	N	7.2 and 7.3
KPI.4.06	Ontology alignments	N	N	7.2 and 7.3
KPI.4.07	IoT platforms assets integrated in INTER-AS2AS	N	N	7.2 and 7.3
KPI.4.08	Identified Patterns for Layer-oriented Integration	N	N	7.2 and 7.3
KPI.4.09	Methodology and guidelines for integrating a new platform into INTER-IoT ecosystem	Y	Y	7.2 and 7.3
KPI.4.10	Documented deployment and update procedures	N	N	7.2 and 7.3
KPI.4.11	Open source platforms integrated	N	Y	7.2 and 7.3
KPI.4.12	Software defined network frameworks integrated	N	N	7.2 and 7.3
KPI.4.13	Device to device protocol integration in gateway	N	N	7.2 and 7.3
KPI.4.14	Standards supported	N	N	7.2 and 7.3
KPI.4.15	Alignment with IoT architectures	N	N	7.2 and 7.3
KPI.4.16	Alignments between GIoTP and known standards	N	N	7.2 and 7.3
KPI.4.17	Semantic translation scalability	N	N	7.2 and 7.3
KPI.4.18	INTER-MW scalability	Y	N	7.2 and 7.3
KPI.4.19	D2D scalability	N	N	7.2 and 7.3
KPI.4.20	N2N scalability	N	N	7.2 and 7.3
KPI.4.21	AS2AS scalability	N	N	7.2 and 7.3
KPI.4.22	Availability of the configuration and administration tools	N	Y	7.2 and 7.3
KPI.4.23	Components supporting monitoring over the lifetime of IoT application deployment	Y	N	7.2 and 7.3
KPI.4.24	Failover mechanisms	Y	N	7.2 and 7.3
KPI.4.25	Security mechanism in place	N	N	7.2 and 7.3
KPI.4.26	Documentation availability	Y	N	7.2 and 7.3
KPI.4.27	Longevity/stability of INTER-METH	N	N	7.2 and 7.3
KPI.4.28	Usability of INTER-METH	N	N	7.2 and 7.3
KPI.4.29	Extensibility of INTER-METH	N	N	7.2 and 7.3
KPI.4.30	Generality of INTER-METH	N	N	7.2 and 7.3
KPI.4.31	Coverage/completeness of INTER-METH (per-layer)	N	N	7.2 and 7.3
KPI.4.32	Availability of CASE tool supporting the process of integration	N	N	7.2 and 7.3
KPI.4.33	User satisfaction with the CASE tool	N	N	7.2 and 7.3
KPI.4.34	Speed up/productivity increase when using CASE tool	N	N	7.2 and 7.3
KPI.4.35	Usability of CASE tool	N	N	7.2 and 7.3
KPI.4.36	Collaborative work support in CASE tool	N	N	7.2 and 7.3
KPI.4.37	Compliance of CASE tool to INTER-IoT approach	N	N	7.2 and 7.3
KPI.4.38	Extent of End User Involvement	N	N	7.2 and 7.3
KPI.4.39	Coverage, completeness and consistency (per-phase)	N	N	7.2 and 7.3
KPI.4.40	System uptime	N	N	7.2 and 7.3
KPI.4.41	INTER-MW Latency	Y	N	7.2 and 7.3
KPI.4.42	Loss rate	N	N	7.2 and 7.3
KPI.4.43	Standard open ontologies referred by GIoTP ontology	N	N	7.2 and 7.3
KPI.4.44	INTER-N2N Latency	N	N	7.2 and 7.3
KPI.5.01	Legalisation assessment	N	N	7.3
KPI.5.02	Human-centred innovations	N	N	7.3

KPI id	Name	Data Collection Methodology Changed (section 2.1)	KPI Score Calculation Method Updated (section 2.2)	Reporting Deliverable
KPI.5.03	Connections and trust	N	N	7.3
KPI.5.04	Worktime - Time Saving	N	N	7.3
KPI.5.05	Life - Social inclusion	N	N	7.3
KPI.5.06	Socially excluded groups Elderly / Disabled	N	N	7.3
KPI.5.07	Citizens' involvement	N	N	7.3
KPI.5.08	Number of identified regulations and public policies	N	N	7.3
KPI.5.09	Trusted, safe, secure IoT environment promotion	N	N	7.3
KPI.5.10	Threat on the labour demand	N	N	7.3
KPI.5.11	Help on disabled people's lives	N	N	7.3
KPI.5.12	Accessibility of INTER-IoT tech	N	N	7.3
KPI.5.13	Publicity of data for research	N	N	7.3

2.1 Data collection methodology updates

As KPI measurements have been carried out, additional information has been generated to add clarity to the methods used in the collection of all data. If changes were seen in relation to the methods outlined in D7.1, they are recorded below in full under the specific KPI.

KPI.2.15 Performance of the Professional Web Tool

This KPI measures the technical performance of the pilot system as perceived by professional users (PU). The responsiveness of the Professional Web Tool (PWT) will be measured indirectly through the analysis of system log files. Parameters such as speed of SQL queries execution or HTTP response times will be considered.

PWT has been developed following Model-View-Controller architectural pattern. PWT performance refers to the time that an action takes since a query is launched until the result is shown to the PU, then invested time is registered in the system.

PWT is divided into *controllers*. Each controller has defined different actions (methods). When an action is triggered, the controller executes a query in the database. Then a model is prepared based on the obtained result. Finally, the model is sent to the *view*, which generates the *html* code to show the result to the PU.

The list of actions taken into account are the following:

- Login. PU login into the PWT
- getPatientsList. PU accesses to the Patient list screen
- PatientsFolderGet. PU accesses to the folder of a specific patient
- AddCheckUpGet. PU creates a new check up for a patient
- AddCheckUpPost. PU saves the data added to a new patient's check up
- ViewCheckUp. PU consults the data of an existing check up
- EditCheckUpGet. PU edits the data of an existing check up
- EditCheckUpPost. PU saves the modifications done to an existing check up
- PrintCheckUp. PU prints the data of an existing check up
- viewQuestionnaires. PU consults historic data of questionnaires reported by a patient
- viewPreventionProgram. PU consults the prevention program defined for a patient
- viewWeightChart. PU consults historical weight data of a patient
- viewPhysicalActivityChart. PU consults historical physical activity data of a patient
- ViewBloodPressureChart. PU consults historical blood pressure data of a patient
- Logout. PU logout

The final KPI value is the average of the total time of actions divided into the number of actions.

KPI.2.17 Professional Web Tool application usage

As in the case of the patient, the time spent by the health professionals in the PWT is also important to measure the adherence to the tool. Time spent by a PU in a patient counselling session and without using INTER-Health solution is around 90 minutes.

Value of this KPI is obtained by addition of time spent in each screen of the app during the consultation. Measured in the app itself and per patient.

In INTER-Health, patients are split in experimental and control group. Patients in the experimental group are using BodyCloud mobile app with the medical sensors, which implies that every day the patients send data to the PWT and have counselling each six months. Instead, in the control group, the patients visit doctors every three months and do not have any associated app neither medical sensors.

The time of usage of the tool may vary depending on the group a patient belongs to. It is not the same when a PU is checking the profile of a patient or counseling her/him, either when the face-to-face visits are dilated in time or are the unique feedback from the patient.

It is easy to determine the time spent in the PWT, by using the list of actions described in KPI 2.15, when a PU is actively working. However, there are moments where the PU interviews the patient or introduces data that is not evident how to quantify this time. For that reason, we introduce Process Mining techniques to recognize the different procedures followed by PUs.

The KPI is understood as the time that a professional dedicates to a patient during a counseling session, where is not possible to do more than one counseling session per day and patient. A counseling is described as a face-to-face visit of a patient to the hospital, where the professional interviews and checks the progress of that patient.

Process Mining allows identifying workflows followed by PUs and inferring the total time spent. The final KPI value is the median of all value obtained.

KPI.4.01 APIs offered by INTER-IoT layer-specific solutions

For this KPI the number of exposed API collections, per layer, is counted. In principle, we expect to provide one REST API endpoint for each layer.

Several conditions should be met to make an API interface eligible for this KPI:

- API must be implemented according to a widely accepted standard (e.g. REST, Java interface);
- API must be well documented in accordance to conventions in use for that specific interface (e.g. Swagger for REST, Javadoc for Java interfaces);
- Versioning of provided APIs is in place.

Reliability, scalability and availability are not part of this measure, as these indicators are measured elsewhere in this section.

In addition to list all available APIs and verify that the documentation exists, tests will be performed to verify that the behaviour corresponds to the documentation provided.

This evaluation has been performed in parallel with the task of creation of a unified REST API interface for INTER-FW (T4.5, INTER-API).

D7.3 will include any updates made to the REST API and additional documentation of any additional APIs

KPI.4.03 IoT platforms integrated on INTER-MW layer

For this KPI the number of fully developed platform bridges is counted. A bridge to be eligible should have been successfully tested with at least one platform deployment, syntactic translator and semantic alignment.

The acceptance criteria is either through the existence of FAT/SAT documents (D6.2, D6.3) or testing reports performed by the evaluating partner. We expect to use FAT/SAT reporting for Open Calls and in-situ testing for bridges developed by INTER-IoT partners.

D7.2 will include the bridges developed by INTER-IoT partners. D7.3 will include bridges developed by Open Call partners and any updates to the bridges recorded in D7.2.

KPI.4.09 Methodology and guidelines for integrating a new platform into INTER-IoT ecosystem

Effectiveness of INTER-METH in driving the integration of new platforms into INTER-IoT ecosystem is measured through a set of KPIs mostly involving questionnaires and interviews with final-users and integrators. The users are given 3 options to address this KPI. They are

1. INTER-METH is scarcely effective in driving the integration process
2. INTER-METH is moderately effective in driving the integration process
3. INTER-METH is notably effective in driving the integration process

Each of the options is associated with a score of 1, 2, or 3 as labelled above.

KPI.4.18 INTER-MW scalability

Scalability of INTER-MW will be measured using both laboratory testing, as defined in D7.1. Additionally, we will also capture the performance during the execution of the INTER-LogP pilot, which will be to verify that the system behaves as set in the requirements phase.

For the lab testing, a deployment on a typical server HW with three platforms and one API client attached to INTER-MW. To minimise the influence of external factors, the following approach will be used:

1. Platform emulators will be used to generate several OBSERVATION messages with increasing frequency.
2. API clients will subscribe to those device readings and a call-back to consume messages (in D7.1 we proposed the "pull" method, but INTERMW has evolved since).
3. IPSM will be excluded and identity alignments used.
4. The number and frequency of messages will be verified through the client application.

The INTER-LogP test will evaluate a real-life scenario, where external factors, like the integration of IPSM, significantly influence the performance. The following approach will be used:

1. Platform bridges will be used to gather OBSERVATION messages with frequency as generated by sensors.
2. API clients will subscribe to those device readings and use a call-back to consume messages.
3. The number and frequency of messages will be verified through the client application.

The Lab tests described above will be reported in this deliverable. The INTER-LogP tests will be reported on in D7.3 along with other KPIs associated with the large-scale pilots.

KPI.4.23 Components supporting monitoring over the lifetime of IoT application deployment

Percentage of INTER-IoT components that can be monitored. Value of this KPI is computed from the INTER-IoT technical specification. Monitoring in this KPI will refer to checking a running component to know its status and performance related metrics.

KPI.4.24 Failover mechanisms

We understand Failover as a backup operational mode in which the functions of any INTER-IoT component are assisted by secondary system components when the primary one becomes unavailable due to failure or scheduled down time. This used to make the system more fault-tolerant and reliable. This procedure also involves the ability to restart the component itself when this unavailability occurs and restore the last known system state.

The mechanisms in the failover system may include the automatically offloading of tasks in a seamless manner, for that reason it may be needed component redundancy.

To meet the fulfilment of this KPI, the components of INTER-IoT in which is viable and convenient to add a failover mechanism, should implement it. If these mechanisms behave as expected and the result of its implementation is successful, the KPI is fully accomplished (YES).

KPI.4.26 Documentation availability

This KPI focuses on the availability and the quality of the documentation. As code itself is barely understandable, and without being supported by a comprehensive documentation is practically impossible to use, it’s necessary to produce a high-quality documentation to support it. The ways to measure the quality of the documentation are essentially two:

- The spectrum covered by the documentation (no function is left out),
- The easiness and completeness in the description (no further questions are needed).

The metric that can be used are therefore two: one more objective (number of functions documented / number of functions developed), which should be as close as possible to 1, and another more subjective (number of questions that are received concerning understanding of the proper behaviour of the functions).

The first metric comparing the number of functions documented to the number of functions developed will be reported in D7.2. The second metric will be reported in D7.3.

KPI.4.41 INTER-MW Latency

Average time between the moment when message is created in the bridge component and when it reaches the REST server, being queued.

This value will be obtained by subtracting message send time (as contained within the message’s metadata) from message receive time (when the message pushed to the REST client). Platform emulators will be used to generate several messages, and the computed average latency will be written in the log file.

Additionally, we will perform the same test for the INTER-LogP pilot, with observations generated by port and terminal IoT platforms.

The Lab tests described above will be reported in this deliverable. The INTER-LogP tests will be reported on in D7.3 along with other KPIs associated with the large-scale pilots.

2.2 KPI score and evaluation updates

The KPI score calculations have remained largely unchanged from D7.1. Changes from the previous methodology have been recorded below. These changes do not affect the spirit of the previous work but add depth and clarity to the KPIs where needed. Table 2 shows changes made to KPI scoring calculation reported in D7.2. This is followed by text addressing the primary motivation for the change for each individual KPI.

Table 2: Updates to the KPI scoring metrics

KPI id	Name	Metric	Target (T)	KPI score calculation (%)
KPI.4.09	Methodology and guidelines for integrating a new platform into INTER-IoT ecosystem	Number	3	KPI_score = KPI_value / T * 100
KPI.4.11	Open source platforms integrated	Number	4	KPI_score = KPI_value / T * 100
KPI.4.22	Availability of the configuration and administration tools	Number	8	KPI_score = KPI_value / No. of Layer entities * 100
KPI.4.26	Documentation availability	Number	1	KPI_score = Functions Documented / Functions developed; KPI_score = 0% if (1) 50% if (2) 100% if (3)

KPI.4.09 Methodology and guidelines for integrating a new platform into INTER-IoT ecosystem

In order allow for multiple users to address this KPI, the KPI score calculation methodology was update from a Yes/No to a scoring system as described above in section 0 KPI.4.09.

KPI.4.11 Open source platforms integrated

The number of potential open source platforms available for integration into INTER-IoT is continually growing so we made the decision to set a concrete target of 4 rather than the previously set 50% goal.

KPI.4.22 Availability of the configuration and administration tools

The previous KPI score calculation methodology did not allow the distinction between tool sets for different layers of INTER-IoT. Including this in the KPI score calculation adds depth to this KPI. Each layer which includes configuration and administration tools will contribute toward numerator. All layers will contribute to the denominator.

KPI.4.26 Documentation availability

The text of the KPI methodology explicitly states the duality of this KPI calculation. The additional KPI scoring formula has been added to the KPI score calculation column for completeness. The previous version only included the formula necessary for the calculation of the second aspect.

2.3 INTER-IoT, dimension and field score calculation update

In order to gain a better understand of the areas of success and those that need additional work, the KPIs have been grouped into dimensions and further subdivided into fields as shown in D7.1. The methodology utilized here is based on the CREATE-IoT[1] project. The validation work done in Deliverable 01.04 in the H2020 project aligned very well with the structure of INTER-IoT.

[1] https://european-iot-pilots.eu/wp-content/uploads/2017/10/D01_04_WP01_H2020_CREATE-IoT_Final.pdf

Selection

Table 3 and Table 4 below show the Fields to be reported on in this deliverable from the pilots and interoperability dimensions. These represent the technical KPIs which are able to be measured at this point in the project. Additional work will be carried out between now and project completion which will update the technical KPIs and report on all KPIs defined in D7.1.

Table 3: Fields and KPIs in the pilots' dimension

Field id	Field Name	KPI id	Name
Field 2.2	**IINTER-Health pilot**	KPI.2.15	Performance of the Professional Web Tool
		KPI.2.17	Professional Web Tool application usage

Table 4: Fields and KPIs in the interoperability dimension

Field id	Field Name	KPI id	Name
Field 4.1	**IoT devices and INTER-IoT modules**	KPI.4.01	APIs offered by INTER-IoT layer-specific solutions.
		KPI.4.02	Issue tracking
		KPI.4.25	Security mechanism in place
Field 4.2	**IoT platforms**	KPI.4.03	IoT platforms integrated on MW2MW layer
		KPI.4.04	IoT platforms integrated on AS2A layer
		KPI.4.05	Syntactic translators between different data formats and RDF
		KPI.4.06	Ontology alignments
		KPI.4.07	IoT platforms assets integrated in INTER-AS2AS
Field 4.3	**IoT system functional design**	KPI.4.08	Identified Patterns for Layer-oriented Integration
		KPI.4.09	Methodology and guidelines for integrating a new platform into INTER-IoT ecosystem
		KPI.4.10	Documented deployment and update procedures
		KPI.4.26	Documentation availability
Field 4.4	**Use of open technology devices and platforms**	KPI.4.11	Open source platforms integrated
		KPI.4.12	Software defined network frameworks integrated
		KPI.4.13	Device to device protocol integration in gateway
		KPI.4.43	Standard open ontologies referred by GIoTP ontology
Field 4.5	**Use of supported standards**	KPI.4.14	Standards supported
		KPI.4.15	Alignment with IoT architectures
		KPI.4.16	Alignments between GIoTP and known standards
Field 4.6	**Scalability**	KPI.4.17	Scalability of semantic translation
		KPI.4.18	Scalability of INTER-MW
		KPI.4.19	D2D scalability
		KPI.4.20	N2N scalability
		KPI.4.21	AS2AS scalability
Field 4.7	**Supportability**	KPI.4.27	Longevity/stability of INTER-METH
		KPI.4.28	Usability of INTER-METH
		KPI.4.29	Extensibility of INTER-METH
		KPI.4.30	Generality of INTER-METH
		KPI.4.31	Coverage/completeness of INTER-METH (per-layer)
		KPI.4.32	Availability of CASE tool supporting the process of integration
		KPI.4.33	User satisfaction with CASE tool

Field id	Field Name	KPI id	Name
		KPI.4.34	Speed up/productivity increase when using CASE tool
		KPI.4.35	Usability of CASE tool
		KPI.4.36	Collaborative work support in CASE tool
		KPI.4.37	Compliance of CASE tool to INTER-IoT approach
		KPI.4.38	Extent of End User Involvement
		KPI.4.39	Coverage, completeness and consistency (per-phase)
Field 4.8	Configuration and monitoring	KPI.4.22	Availability of the configuration and administration tools
		KPI.4.23	Components supporting monitoring over the lifetime of IoT application deployment
		KPI.4.24	Failover mechanisms
		KPI.4.40	System uptime
		KPI.4.41	INTER-MW Latency
		KPI.4.42	Loss rate
		KPI.4.44	INTER-N2N Latency

Calculation

Individual KPI score calculation methodology has been described a length in D7.1 and updated in section 2.2. After calculation of the individual scores, Field scores are calculated for all available measured KPIs. The method for Field score calculation is shown in Figure 1. This is followed by the calculation of the dimensional scores and the overall INTER-IoT score which are average values of each field and dimension respectively. Figure 2 shows the process of calculating each score.

$$FieldScore = \frac{\sum_{i=1...N} KPIscore_i}{N}$$

Figure 1: Formula for computation of the Field score

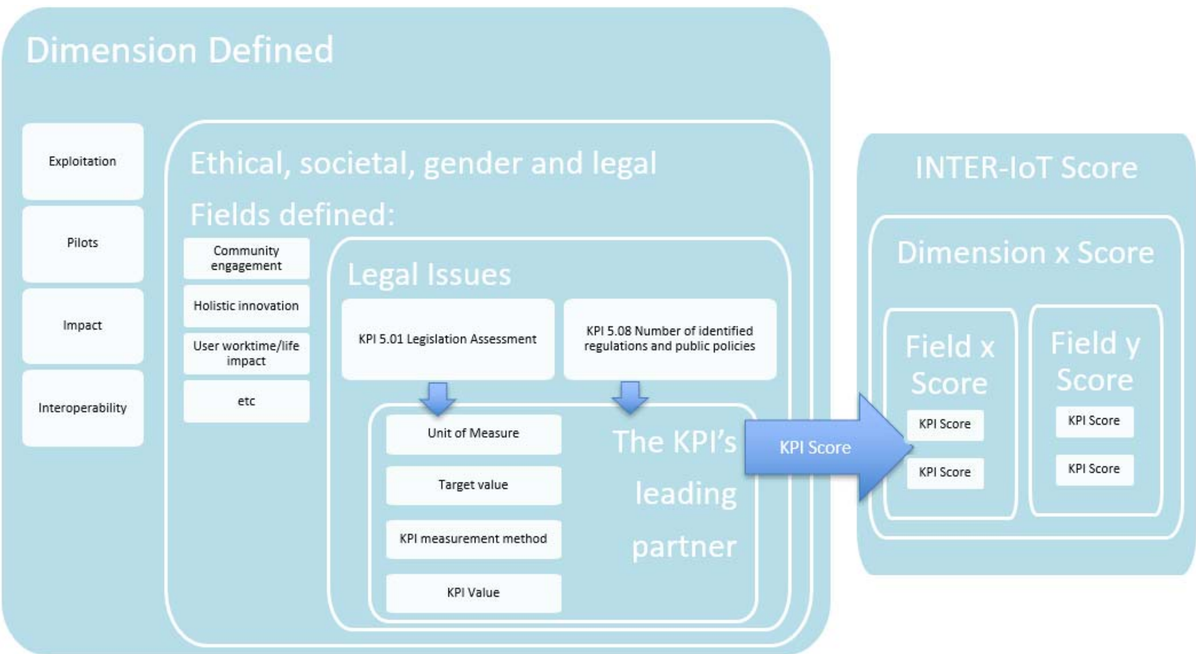


Figure 2: Calculation of INTER-IoT KPI, field, and dimension scores

One additional update is necessary due to the occurrence of outliers in the KPI scoring process. Previously we defined the following rules to show how a KPI value should be transformed into a KPI score:

a. KPI value = no achievement → KPI score = 0%
b. no achievement < KPI value < target → 0% < KPI score < 100%
c. KPI value = target → KPI score = 100%
d. KPI value > target → KPI score > 100%

If a KPI value and the associated rules for calculation of the KPI Score lead to an outlier capable of skewing the results of a field or even dimension, this could affect our ability to understand the overall quality of fields and dimensions In the results section, there are examples of some KPIs which have been surpassed significantly. For example, KPI.4.17 has a target of 10 messages translated per millisecond by the semantic component of INTER-IoT. The technical team were able to achieve 250. This leads to a KPI score of 2500% which is greater than the sum of a perfect score in all the KPIs in the scalability field in which this KPI resides. This could skew the overall interpretation of the field score as all other KPIs in this field could be zero but we would perceive this field as being fully addressed. In these cases, it is appropriate to report the Field, Dimensional and INTER-IoT scores in 2 ways. They will first be reported as in D7.1 and secondly, a maximum value for the individual KPI scores will be set to 100%. The results of both of these methods will be reported below in section 1.

3 Results and Evaluation

This section will report and discuss each of the technical KPIs for INTER-IoT. Some measures will be repeated in D7.3 as the technology development of INTER-IoT will continue.

3.1 KPI, Field, Dimension and INTER-IoT Score

This section will report on 45 of the 113 project KPIs. These KPIs, representing the primary technical measures for the project's success, will be updated during the final quarter of the project with results presented in D7.3. These results are also an indication of the projects internal maturity. Table 5: Project results below gives a full overview of the KPIs values, KPI scores, field scores, dimension scores, and the overall INTER-IoT Score for all technical KPIs gathered so far. KPIs which were not measured are scored as NA and are not included in the analysis.

The two dimensions addressed here are dimensions 2 and 4 from D7.1, pilots and interoperability respectively. The pilot dimension provides only 2 technical KPIs for this part of the evaluation process. They both come from the INTER-HEALTH field. An overall 100 score is a good indication that the technology being trialed within INTER-Health is performing well. Results for each individual KPI are covered in the section 3.2.

The interoperability dimension provides the remaining 43 KPIs grouped into 8 fields. They represent all the fields within this dimension. IoT devices and INTER-IoT modules field shows good progress with the addition of 2 extra APIs above the goal set of 5. The effect of this is seen in the field score of 100 using the standard methodology. Applying the secondary calculation methodology for the field score yields a result of 86. This decrease highlights the fact that some KPIs in the field are underperforming. This effect may have been overlooked without this additional methodology.

The IoT platforms field is well represented by scores of 102 and 92. Additional work in platform integration at the AS2AS level will be performed to improve results in this area. In the IoT system functional design field, work is ongoing to produce full documentation and update procedures for INTER-IoT components. While documentation is prepared and online for all modules of INTER-IoT, formal evaluation processes have not been completed so this KPI cannot be claimed as complete.

Fields 4.4 and 4.5 addressing the use of open technology devices and platforms as well as standards are well completed exceeding goals in almost all KPIs. The scalability field provided the primary motivation for rethinking the field score and dimension score methodology. The semantic translation rate target was eclipsed by 25 times the speed. This has led to field scores of 759 and 88. The adjusted score of 88 allows us to see that there are still areas for improvement in the field.

The supportability field focuses primarily on INTER-METH and the INTER-CASE tool. Preliminary results have been provided in this deliverable, but further development in this area is due and additional assessment will be undertaken in D7.3. The preliminary results show a positive to the material covered and the utility. Improvements can be made to the overall usability of INTER-METH and the CASE tool.

Configuration and monitoring are some of the last tasks to be undertaken during the project. The work completed and assessed so far has performed well. Full results in this field are will be presented in D7.3.

We are happy with the progress so far but know that certain areas must be improved during the coming months to insure INTER-IoT is fully ready for life after the project. D7.3 will provide the opportunity show the full picture of INTER-IoT.

Table 5: Project results

KPI, Field and Dimension		Metric	Target (T)	KPI Value	D7.1 Scoring Inter-IoT / Dimension / Field / KPI	Adjusted Scoring Inter-IoT / Dimension / Field / KPI
INTER-IoT					**148**	**94**
Dimension 2: Pilots					105	100
Field 2.2: INTER-Health pilot					105	100
KPI.2.15	Performance of the Professional Web Tool	seconds	5	0.07	100	100
KPI.2.17	Professional Web Toll application usage	Minutes	60	65.82	110	100
Dimension 4: Interoperability					190	88
Field 4.1: IoT devices and INTER-IoT modules					100	87
KPI.4.01	APIs offered by INTER-IoT layer-specific solutions.	Number	5	7	140	100
KPI.4.02	Issue tracking	Percentage	50%	0.3	60	60
KPI.4.25	Security mechanism in place	Number	3	3	100	100
Field 4.2: IoT platforms					102	92
KPI.4.03	IoT platforms integrated on MW2MW layer	Number	4	5	125	100
KPI.4.04	IoT platforms integrated on AS2A layer	Number	4	5	125	100
KPI.4.05	Syntactic translators between different data formats and RDF	Number	3	3	100	100
KPI.4.06	Ontology alignments	Number	10	10	100	100
KPI.4.07	IoT platforms assets integrated in INTER-AS2AS	Number	10	6	60	60
Field 4.3: IoT system functional design					93	73
KPI.4.08	Identified Patterns for Layer-oriented Integration	Number	10	18	180	100
KPI.4.09	Methodology and guidelines for integrating a new platform into INTER-IoT ecosystem	Number	3	3	100	100
KPI.4.10	Documented deployment and update procedures	Number	7	3	43	43
KPI.4.26	Documentation availability	Number	3	2	50	50
Field 4.4: Use of open technology devices and platforms					127	92
KPI.4.11	Open source platforms integrated	Percentage	4	4	100	100
KPI.4.12	Software defined network frameworks integrated	Number	3	2	67	67
KPI.4.13	Device to device protocol integration in gateway	Number	3	6	200	100
KPI.4.43	Standard open ontologies referred by GIoTP ontology	Number	25	35	140	100
Field 4.5: Use of supported standards					100	100
KPI.4.14	Standards supported	Number	3	TBC	NA	NA

KPI, Field and Dimension		Metric	Target (T)	KPI Value	D7.1 Scoring Inter-IoT / Dimension / Field / KPI	Adjusted Scoring Inter-IoT / Dimension / Field / KPI
KPI.4.15	Alignment with IoT architectures	Number	1	1	100	100
KPI.4.16	Alignments between GIoTP and known standards	Number	2	2	100	100
Field 4.6: Scalability					822	100
KPI.4.17	Semantic translation scalability	msg/ms	10	250	2500	100
KPI.4.18	INTER-MW scalability	msg/s	50	190	380	100
KPI.4.19	D2D scalability	Number	50	150	300	100
KPI.4.20	N2N scalability	msg/ms	100	107.02	107	100
Field 4.7: Supportability					79	79
KPI.4.27	Longevity/stability of INTER-METH	Number	3	2.25	75	75
KPI.4.28	Usability of INTER-METH	Number	3	1.5	50	50
KPI.4.29	Extensibility of INTER-METH	Number	3	1.75	58	58
KPI.4.30	Generality of INTER-METH	Number	3	3	100	100
KPI.4.31	Coverage/completeness of INTER-METH (per-layer)	Number	3	3	100	100
KPI.4.32	Availability of CASE tool supporting the process of integration	Number	3	3	100	100
KPI.4.33	User satisfaction with the CASE tool	Number	3	3	100	100
KPI.4.34	Speed up/productivity increase when using CASE tool	Number	3	2.25	75	75
KPI.4.35	Usability of CASE tool	Number	3	1.75	58	58
KPI.4.36	Collaborative work support in CASE tool	Number	3	1	33	33
KPI.4.37	Compliance of CASE tool to INTER-IoT approach	Number	3	3	100	100
KPI.4.38	Extent of End User Involvement	Number	3	2.25	75	75
KPI.4.39	Coverage, completeness and consistency (per-phase)	Number	3	3	100	100
Field 4.8: Configuration and monitoring					98	85
KPI.4.22	Availability of the configuration and administration tools	Number	8	12	150	100
KPI.4.23	Components supporting monitoring over the lifetime of IoT application deployment	Percentage	70%	TBC	NA	NA
KPI.4.24	Failover mechanisms	Number	5	2	40	40
KPI.4.40	System uptime	h	168	TBC	NA	NA
KPI.4.41	INTER-MW Latency	ms	100	100	100	100
KPI.4.42	Loss rate	Percentage	0	TBC	NA	NA
KPI.4.44	INTER-N2N Latency	ms	10	9.7	100	100

3.2 Key Performance indicators

Each individual KPI will be discussed in some detail below.

KPI.2.15 and KPI.2.17 Performance of the professional web tool and Professional web tool application usage

The most representative data is the different workflows identified in KPI 2.17. In the following pictures can be seen the most common path (red arrows) and where has been spent more time (red nodes). Nodes name correspond with the list of actions introduced in KPI 2.15.

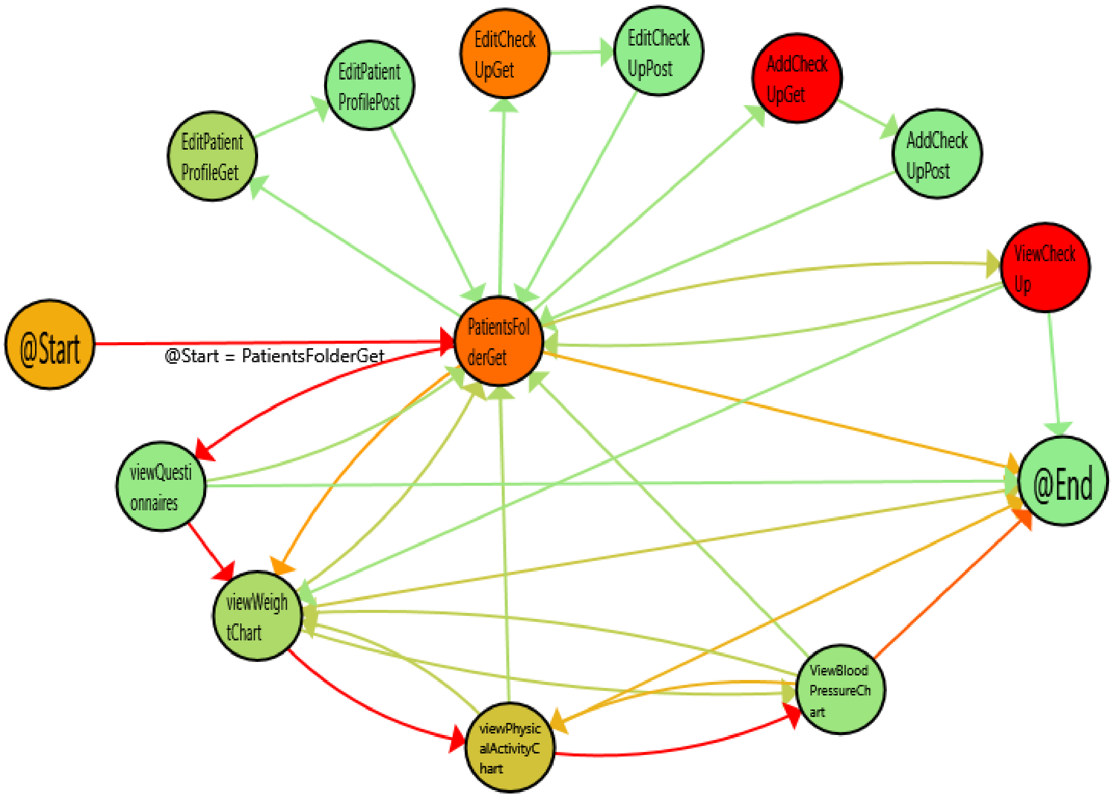


Figure 3: Actions done by a PU per patient

There are clear differences between counselling a patient or consult a patient profile. In the first case, PU is more focused on interviewing the patient and add a new checkup. Nonetheless, when it is not a counseling, the professional spends more time in progress data than in the checkups. Even though, the most common procedure is to check questionnaires, the evolution of the weight, physical activity and blood pressure and then add a new checkup.

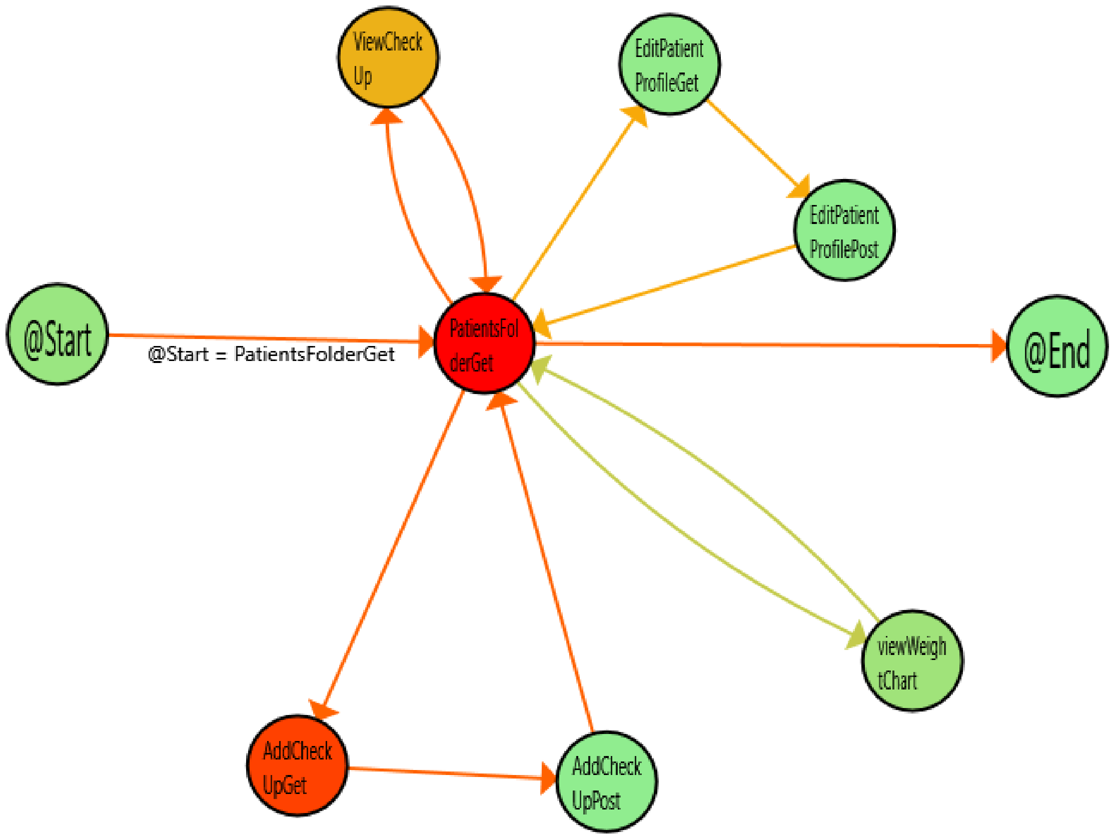


Figure X.

Figure 4: Actions done by a PU during a counselling

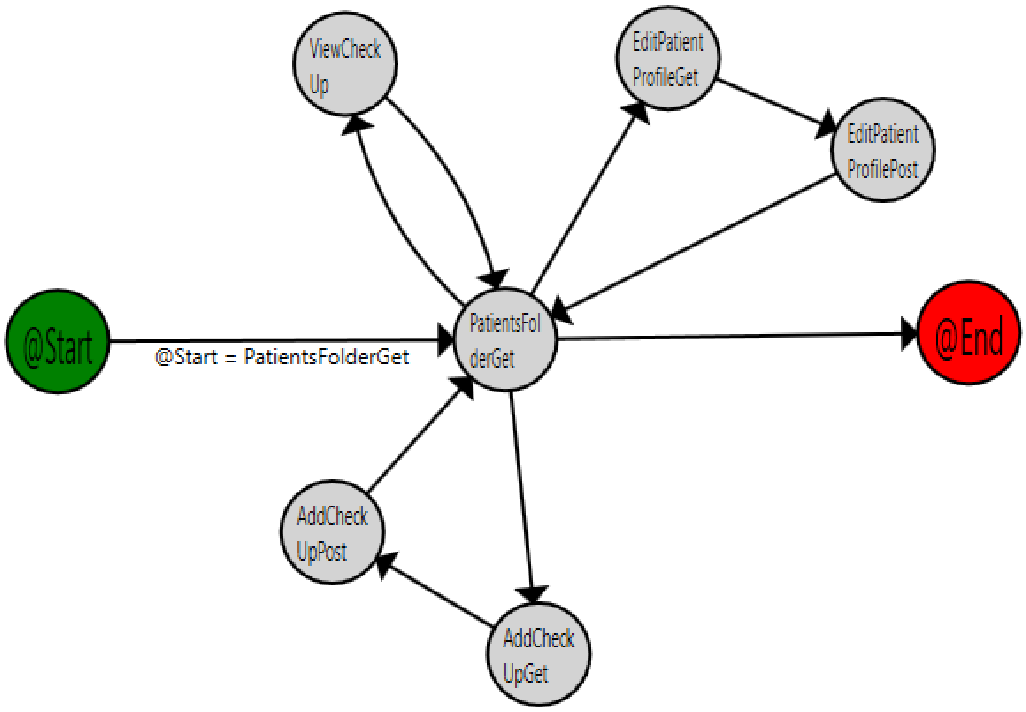


Figure 5: Actions done by the professional user during the first counselling

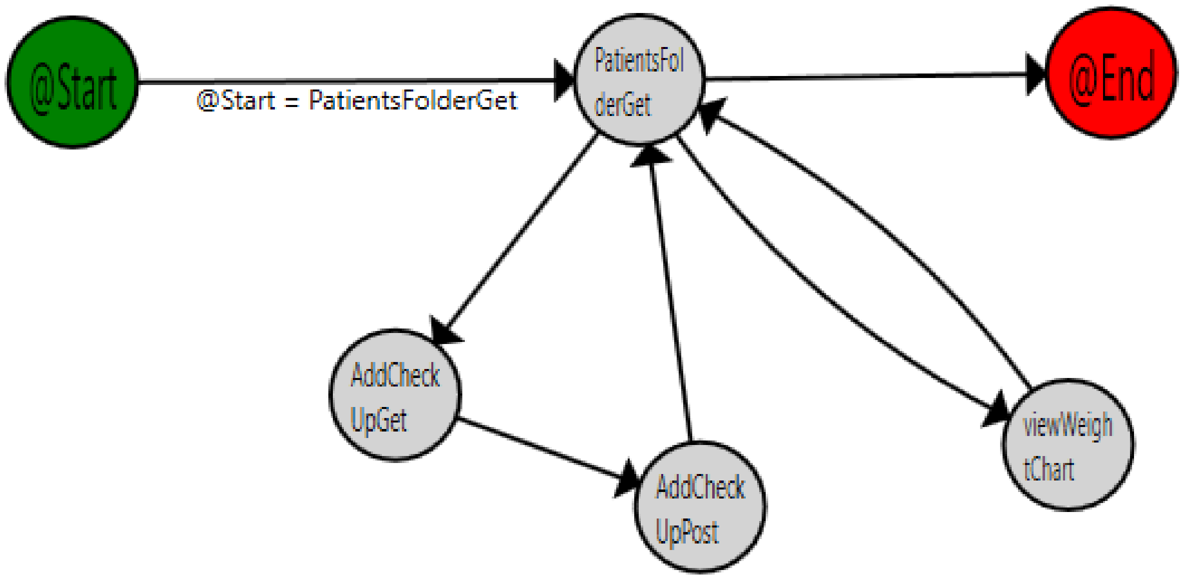


Figure 6: Actions done by the professional user during the second counselling

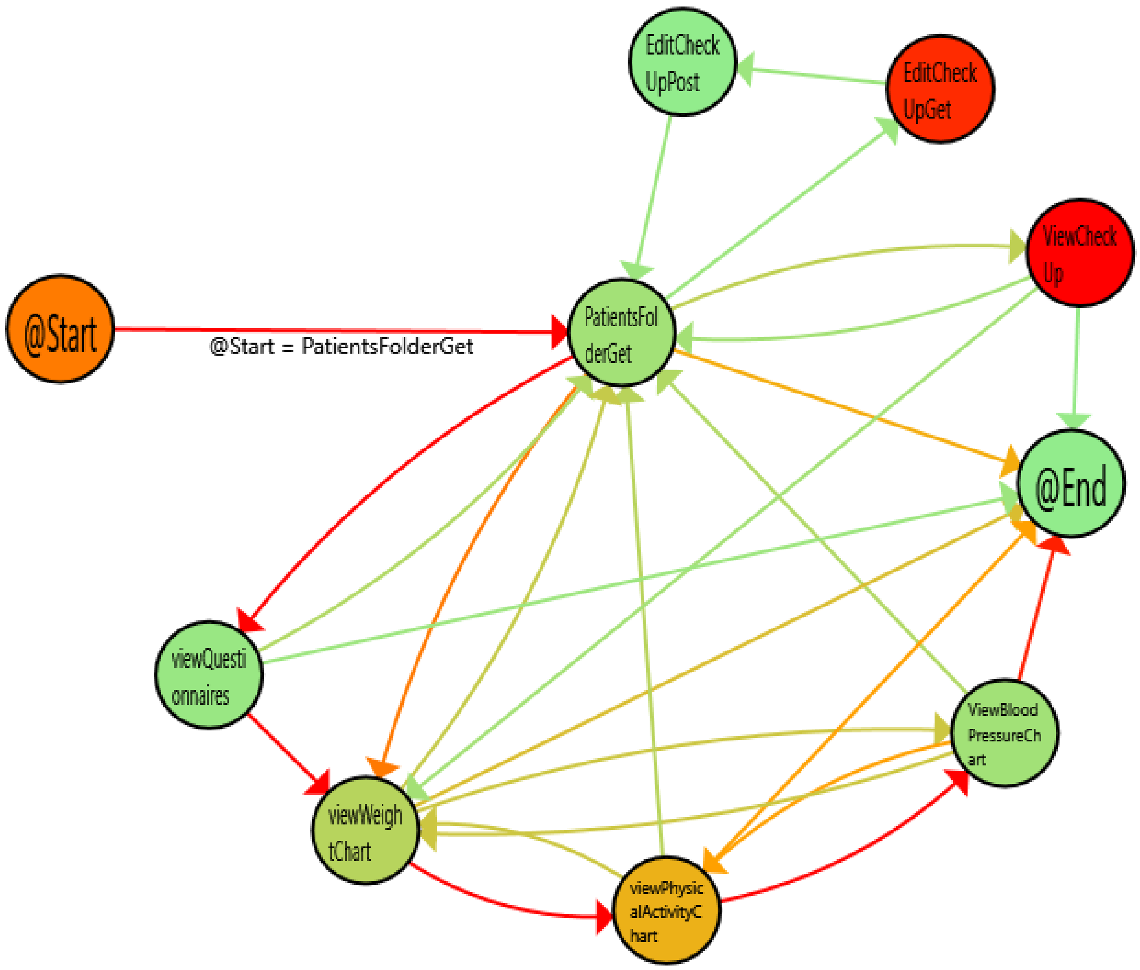


Figure 7: Actions done by a PU when consults a patient's profile

In summary, it is difficult to quantify KPI.2.17, to determine the common case, when there is activity or not, a professional user is consulting data or just went to grab a coffee. In addition, there are values that cannot be quantified because they could introduce delays that would distort the final values. There are also actions that cannot be quantified because they are generated automatically by the system, being watertight. Nevertheless, with Process Mining we can infer data and conclude with reliable values.

KPI.4.01 APIs offered by INTER-IoT layer-specific solutions

For this deliverable the evaluation of INTER-Layer REST API interfaces has been performed. All INTER-Layer components provide a REST API that is documented in respective OpenAPI definitions as shown in the table below.

Table 6: APIs for INTER-IoT

	INTER-Layer	Description	OpenAPI definition	Published documentation
1	d2d	Device to device API allows access to physical and virtual part of the gateway, as well as API extensions.	https://git.inter-iot.eu/Inter-IoT/layer_apis/src/master/gateway/swagger-v0.3.1-SNAPSHOT-20180426160853.json	https://docs2.inter-iot.eu/docs/interapi/latest/openapi/d2d/index.html
2	n2n	Network controller API.	https://git.inter-iot.eu/Inter-IoT/layer_apis/src/master/network/swagger-api.yaml	https://docs2.inter-iot.eu/docs/interapi/latest/openapi/n2n/index.html
3	mw2mw	INTER-IoT Middleware Layer Interoperability Components	https://git.inter-iot.eu/Inter-IoT/layer_apis/src/master/middleware/intermw-swagger.yaml	https://docs2.inter-iot.eu/docs/interapi/latest/openapi/mw2mw/index.html
4	as2as	Admin API methods for Application and Services interoperability.	https://git.inter-iot.eu/Inter-IoT/layer_apis/src/master/application/AS2AS.json	https://docs2.inter-iot.eu/docs/interapi/latest/openapi/as2as/index.html
5	ds2ds	Inter Platform Semantic Mediator API	https://git.inter-iot.eu/Inter-IoT/layer_apis/src/master/semantics/ipsm/swagger.json	https://docs2.inter-iot.eu/docs/interapi/latest/openapi/ds2ds/ipsm/index.html
6	ds2ds	Semantic Repository API	https://git.inter-iot.eu/Inter-IoT/layer_apis/src/master/semantics/semantic_repository/swagger.json	https://docs2.inter-iot.eu/docs/interapi/latest/openapi/ds2d2/repo/index.html
7	Unified API	INTER-IoT INTER-Layer unified API supports unified access to all INTER-Layer components.	https://git.inter-iot.eu/Inter-IoT/layer_apis/src/master/unified/unified-layers.yaml	https://docs2.inter-iot.eu/docs/interapi/latest/openapi/unified-layers/index.html

APIs of all INTER-Layer components are also exposed through the Unified INTER-IoT API (see deliverable D4.6). The API versioning is implemented through a unified REST API provided by the INTER-API components.

We can conclude, that the eligibility criteria set in the KPI definition has been met for **all seven** exposed APIs:

Table 7: Assessment of KPI.4.01

Criteria	Approach	number of APIs
API must be implemented according to a widely accepted standard	REST API	7
API must be well documented in accordance to conventions in use for that specific interface	OpenAPI + Swagger UI for a better user experience	7
Versioning of provided APIs is in place	OpenAPI definitions versioned in a GIT repository, while API versioning is performed through the API Manager implemented in T4.5.	7

In the second step, APIs 1 to 5 where tested through the unified API interface. In total, 59 API calls have been tested. Tests for the semantic repository have been performed separately.

Possible test outcomes are as follows:

- Working: API has been tested and is working correctly according to specification.
- Deprecated: API is working but has been deprecated and may be excluded from future INTER-API versions.
- Excluded from testing: Excluded from testing for technical reasons. In some cases, the system setup did not allow for testing specific calls or sets of parameters. However, we count the test as successful, as the test has been performed original component developers.
- Not REST compliant: The API in not REST compliant, thus needs revisioning.
- Not exposed: The API exists but has not been exposed.
- Not tested

Table 8: KPI.4.01 test results

Layer	method	Test Results	Endpoint	Comment
d2d	GET	Deprecated	/d2d	Successful operation
d2d	GET	Working	/d2d/devices/{deviceId}	Successful operation
d2d	POST	Working	/d2d/devices/{deviceId}	Successful operation
d2d	GET	Working	/d2d/gw/physical	successful operation
d2d	GET	Working	/d2d/gw/physical/devices	successful operation
d2d	GET	Working	/d2d/gw/virtual	successful operation
d2d	GET	Excluded from testing	/d2d/gw/virtual/extensions/{extensionID}/api	OpenAPI specification checked.
n2n	GET	Working	/n2n/switches	Switches ID list
n2n	GET	Working	/n2n/switches/{switchId}	Switch Info
n2n	GET	Working	/n2n/switches/{switchId}/tables/{tableId}/flows	Flow information
n2n	POST	Working	/n2n/switches/{switchId}/tables/{tableId}/flows	successful operation
n2n	PUT	Working	/n2n/switches/{switchId}/tables/{tableId}/flows/{flowId}	successful operation
n2n	DELETE	Not REST compliant	/n2n/switches/{switchId}/tables/{tableId}/flows/{flowId}	DELETE method is not REST compliant as it contains JSON information in the body payload.
n2n	GET	Working	/n2n/switches/{switchId}/tables	Table information
n2n	GET	Working	/n2n/switches/{switchId}/ports	Port information
n2n	GET	Working	/n2n/switches/{switchId}/ports/{portId}	All Ports information
n2n	PUT	Working	/n2n/switches/{switchId}/ports/{portId}	OK
n2n	GET	Working	/n2n/switches/{switchId}/queues	Queue status of the schema
n2n	POST	Working	/n2n/switches/{switchId}/port/{portId}/queues	Flow info
n2n	DELETE	Working	/n2n/switches/{switchId}/queues/{queueId}	
n2n	GET	Working	/n2n/switches/{switchId}/rules	Rule configuration
n2n	POST	Working	/n2n/switches/{switchId}/rules	OK. Qos ID generated

n2n	DELETE	Not REST compliant	/n2n/switches/{switchId}/rules/{ruleId}	DELETE method is not REST compliant as it contains JSON information in the body payload.
n2n	GET	Working	/n2n/switch/{switchId}/meters	Meter configuration
n2n	POST	Working	/n2n/switch/{switchId}/meters	OK
n2n	DELETE	Not REST compliant	/n2n/switch/{switchId}/meters/{meterId}	DELETE method is not REST compliant as it contains JSON information in the body payload.
mw2mw	POST	Working	/mw2mw/clients	successful operation
mw2mw	GET	Working	/mw2mw/clients/{clientId}	successful operation
mw2mw	GET	Working	/mw2mw/clients	successful operation
mw2mw	PUT	Working	/mw2mw/clients/{managedClientId}	successful operation
mw2mw	DELETE	Working	/mw2mw/clients/{managedClientId}	successful operation
mw2mw	GET	Working	/mw2mw/platforms	successful operation
mw2mw	POST	Working	/mw2mw/platforms	successful operation
mw2mw	DELETE	Working	/mw2mw/platforms/{platformId}	successful operation
mw2mw	GET	Working	/mw2mw/devices	successful operation
mw2mw	POST	Working	/mw2mw/devices	successful operation
mw2mw	PUT	Working	/mw2mw/devices	successful operation
mw2mw	DELETE	Working	/mw2mw/devices/{deviceId}	successful operation
mw2mw	GET	Working	/mw2mw/subscriptions	successful operation
mw2mw	POST	Working	/mw2mw/subscriptions	successful operation
mw2mw	DELETE	Working	/mw2mw/subscriptions/{conversationId}	successful operation
mw2mw	POST	Working	/mw2mw/responses	successful operation
mw2mw	POST	Working	/mw2mw/requests	successful operation
as2as	GET	Working	/as2as/auth/login	successful operation
as2as	POST	Not exposed	/as2as/auth/token	successful operation
as2as	POST	Not exposed	/as2as/auth/revoke	successful operation
as2as	GET	Working	/as2as/settings	successful operation
as2as	GET	Working	/as2as/flows	successful operation
as2as	POST	Excluded from testing	/as2as/flows	successful operation
ds2ds	GET	Working	/ds2ds/alignments	Available alignments info
ds2ds	POST	Working	/ds2ds/alignments	Alignment uploaded successfully
ds2ds	DELETE	Working	/ds2ds/alignments/{name}/{version}	Alignment deleted
ds2ds	GET	Working	/ds2ds/channels	Array of channel information records
ds2ds	POST	Working	/ds2ds/channels	Channel created successfully

ds2ds	DELETE	Working	/ds2ds/channels/{channelId}	Channel deleted
ds2ds	POST	Excluded from testing	/ds2ds/translation	Translation successful
ds2ds	GET	Working	/ds2ds/alignments/{name}/{version}	Alignment successfully returned
ds2ds	GET	Working	/ds2ds/logging	Current logging level successfully returned
ds2ds	POST	Working	/ds2ds/logging/{level}	Logging level set successfully

Except for the three non-compliant DELETE methods, all other REST calls performed as expected. The non-compliant methods are going to be fixed for the final INTER-API release before the end of the project.

We concluded that all existing REST APIs are well-documented and functional. We have reached the target already in this phase. We expect to increase this KPI even further in D7.3, when additional (non-REST) APIs will be evaluated.

KPI.4.02 Issue tracking

Work is ongoing to improve issue resolution within INTER-IoT. To measure this KPI, the included issue tracking of our self-hosted git service (Gogs) is used. For each ticket opened in a repository, the estimated amount of time of resolution (ETR) required by this issue is calculated. Once that issue is marked as solved (changes tag from “Opened” to “Closed”) the amount of time required to close the issue is measured.

At any point of time, this KPI can be calculated as the % of issues solved on time (resolution time below ETR). An update to this KPI will be given in D7.3

KPI.4.03 IoT platforms integrated on INTER-MW layer

In the table below a full list of INTER-MW platform bridges developed by either INTER-IoT project partners or 3rd parties are provided.

Table 9: INTER-MW platform bridges

Platform	Repository	Main authors	Status
Azure	https://git.inter-iot.eu/Inter-IoT/intermw_bridge_azure	Neways	In development as part of integration activities for the INTER-LogP pilot.
Sensinact	https://git.inter-iot.eu/Inter-IoT/intermw_bridge_sensinact	CEA (3rd party)	3rd party bridges will be evaluated in D7.3
SEAMS2	https://git.inter-iot.eu/Inter-IoT/intermw_bridge_seams2	Prodevelop	Functional as part of the INTER-LogP pilot.
universAAL	https://git.inter-iot.eu/Inter-IoT/intermw_bridge_universaal	UPV/Sabien	Functional as part of the INTER-Health pilot.
WSO2 port	https://git.inter-iot.eu/Inter-IoT/intermw_bridge_wso2port	VPF	Functional as part of the INTER-LogP pilot.
FIWARE	https://git.inter-iot.eu/Inter-IoT/intermw_bridge_fiware	Prodevelop	Functional.
OM2M	https://git.inter-iot.eu/Inter-IoT/intermw_bridge_om2m	VUB (3rd party)	3rd party bridges will be evaluated in D7.3
e3tcity	https://git.inter-iot.eu/Inter-IoT/intermw_bridge_e3city	E3TCity (3rd party)	3rd party bridges will be evaluated in D7.3

Semantic Middleware	https://git.inter-iot.eu/Inter-IoT/intermw_bridge_semantic_mw	ITIA-CNR (3rd party)	3rd party bridges will be evaluated in D7.3
BodyCloud	https://git.inter-iot.eu/Inter-IoT/intermw_bridge_bodycloud	UNICAL	Functional as part of the INTER-LogP pilot.

A total number of ten bridges is being developed as part of the INTER-IoT ecosystem. For this deliverable we provide the status of, six bridges are developed by INTER-IoT project partners. The Azure bridge is still under development, as the need has been identified during the implementation of the INTER-LogP pilot. for this reason, the evaluation of this bridge is going to be provided later in the deliverable D7.3.

The other five bridges (SEAMS2, universAAL, WSO2, FIWARE, BodyCloud) have been successfully used in at least one pilot or test scenario in order to conclude, that their evaluation has been successful.

We concluded five platforms are sufficiently integrated in the INTER-MW infrastructure in order to be eligible for this KPI. The Azure platform, for which the need emerged during INTER-LogP integration activities, will be evaluated in D7.3, together with bridges developed by Open Calls, as originally planned. We expect to increase this KPI even further in D7.3, when we include Open Calls in the evaluation process.

KPI.4.04 IoT platforms integrated on AS2AS layer

The expected number of platforms has been reached, but the total number of services desired has not yet been reached (KPI.4.07). The development of nodes was the focus during the first stages of the project, with additional focus given to the correct creation of nodes that can be used as an example to develop other nodes.

KPI.4.05 Syntactic translators between different data formats and RDF

So far syntactic translation has been implemented from XML, JSON and RDF format (change of serialization, named graphs). This KPI value is established by inspection of INTER-MW bridges implemented within INTER-IoT and Open Call projects. Continued work is planned here and will be reported in D7.3. Higher KPI values are to be expected with more usages of INTER-MW and IPSM.

KPI.4.06 Ontology alignments

So far alignments have been prepared for:

- INTER-LogP – 2 alignments
- INTER-Health – 2 alignments
- GIoTP and FIWARE Device Model – 2 alignments
- Central ontology based on GIoTP and UniversAAL ontologies to FIWARE – 1 alignment
- INTER-IoT-EWS (Open Call) – 1 alignment
- INTER-oneM2M (Open Call) – 2 alignments

Work is in progress for alignments for Semantic Middleware and SensinAct platforms (Open Call projects).

Further alignments will be prepared when INTER-IoT products are exploited outside the project. Improvements will be documented in D7.3.

KPI.4.07 IoT platforms assets integrated in INTER-AS2AS

The total number of services desired has not yet been reached (6 of 10). The development of nodes was the focus during the first stages of the project. Now, progress is being made more quickly in the development and testing of new nodes. Furthermore, the advanced state of the project, the collaborations of the Opencall partners and the pilots contribute to the acceleration in the creation of new nodes. Therefore, it is expected to reach the desired number of nodes.

KPI.4.08 Identified Patterns for Layer-oriented Integration

The INTER-IoT design patterns catalog has been published in deliverable D5.1 “Design Patterns for Interoperable IoT Systems”. It specifies 18 patterns assigned to specific layers, framework and cross-layer.

KPI.4.09 Methodology and guidelines for integrating a new platform into INTER-IoT ecosystem

Review of the data collection methodology was undertaken to allow this KPI to be more granular. An initial survey has included 15 subjects from UNICAL research groups, spinoffs and labs. Additional evaluation of this KPI is planned for the final quarter of the project and will be reported in D7.3

KPI.4.10 Documented deployment and update procedures

For D7.2 the following deployments have been evaluated: INTER-MW, IPSM and INTER-API. The table below summarises the deployment documentation for those components. The table also provides the status, which confirms the existence of sufficient information for deployment as well as the actual deployments that were performed.

Table 10: Deployment and update procedures

Component	Documentation	Status
INTERMW	https://docs.inter-iot.eu/docs/intermw/latest/user-guide/installation/	INTERMW has been deployed multiple times using the provided documentation: INTER-Health pilot (SABIEN), INTER-LogP pilot (XLAB, PRO, VPF), third party bridge developers (CNR and others).
IPSM	https://docs.inter-iot.eu/docs/ipsm/latest/Deployment/Docker-image/	All of the deployments of INTERMW included also a deployment of IPSM.
INTER-API	https://docs.inter-iot.eu/docs/interapi/latest/user-guide/installation/	Deployed as part of the INTER-Health pilot (SABIEN) and INTER-LogP (XLAB) pilots. PRO performed an additional deployment for internal testing.

We can conclude that the documentation of all three components under evaluation is sufficient to perform the installation and update of the respective component. This fact has also been confirmed by at least one party not involved in the original development of the component.

We successfully evaluated three INTER-IoT components as eligible for this KPI. With the performance of the full evaluation of the remaining parts of the framework in D7.3, we expect to reach this target as well.

KPI.4.11 Open source platforms integrated

The methodology for this KPI has been updated. The current open source platforms integrated are:

- FIWARE
- UniversAAL
- One M2M
- Sensinact

KPI.4.12 Software defined network frameworks integrated

Integration tests were carried out on the RYU, ODL, Floodlight, POX and Nox frameworks. The RYU framework and the ODL have been integrated into INTER-IoT. Additional work is being undertaken as part of WP6 and within the Open Call project teams. Progress will be reported in D7.3.

KPI.4.13 Device to device protocol integration in gateway

The following device to device protocols have been integrated in the gateway:

- firmata, inter-hare and panstamp over serial
- raw udp over ip packets
- modbus over serial
- miband bracelet over bluetooth

KPI.4.14 Standards supported

Work is ongoing to measure this KPI. KPI.4.16 partially reports on this, and in the IPSM progress meets the KPI of a minimum of 3 standards supported. The extent of support given by each module will be fully documented in D7.3.

KPI.4.15 Alignment with IoT architectures

The INTER-IoT architecture has been developed following existing established reference models and architectures. The IoT-A ARM (architectural reference model), oneM2M functional architecture, ITU-T Y2060 IoT Reference Model and IEEE P2413 IoT Architectural Framework have been utilized. The alignment of our architecture is explained in the deliverables D4.1 and D4.2 in great detail.

KPI.4.16 Alignments between GIoTP and known standards

The alignment between GIoTP and FIWARE Device Model has been prepared. In INTER-IoT-EWS Open Call GIoTP is aligned to part of SAREF ontology. In INTER-oneM2M Open Call alignment is prepared between data syntactically translated from OBIX standard.

The plan is to prepare alignments for oneM2M ontology and SAREF ontology (greater coverage that the alignment prepared within INTER-IoT-EWS). Additional work will be reported in D7.3.

KPI.4.17 Semantic translation scalability

The target for scalability measure was set to save value that is achievable by other approaches available on the market. The choice of approach and technologies in INTER-IoT allowed us to reach a much better result.

KPI.4.18 INTER-MW scalability and KPI.4.41 INTER-MW Latency

The test involved 3 platform emulators, each connected to its own bridge and each having one device. Each emulator provided observation messages in a constant interval. The subscribed client used server push method with call-backs, for obtaining messages from platforms. IPSM was excluded when measurements were taking place. Testing was done on 2 different devices, one was dedicated for testing only and one was developing environment, the specifications of both are shown below.

1. Dedicated server ("Server")
   - Gigabyte GA-H67MA-D2H-B3 Motherboard
   - Intel Core i5-2400S CPU @ 2.50GHz
   - 2x DDR3 4GB RAM
   - 120GB 2.5-inch SSD
   - Ubuntu Server 18.04.1 LTS OS
   - CORSAIR CMPSU-400CX 400W ATX12V V2.2 80 Power Supply Unit
2. NUC7i7BNH ("NUC")
   - Intel Core i7 7567U CPU @ 3.50GHz
   - Intel Optane Memory Series 16GB M.2 80mm
   - 500GB 2.5-inch SSD
   - Fedora Workstation release 27 OS

We executed a series of nine experiments on each device with increasing message creation frequency. The creation frequency ranged from 30 msg/s to 270 msg/sec with the increasing step of 30 msg/sec. The duration of each experiment was 300 seconds. With this approach we test the performance bot around the KPI target of 50 msg/sec and well above the target for more demanding use-cases. As part of this test, we also measure the latency in order to verify if we reach the target of 100 ms.

Table 11: Test results for INTER-WM scalability and latency

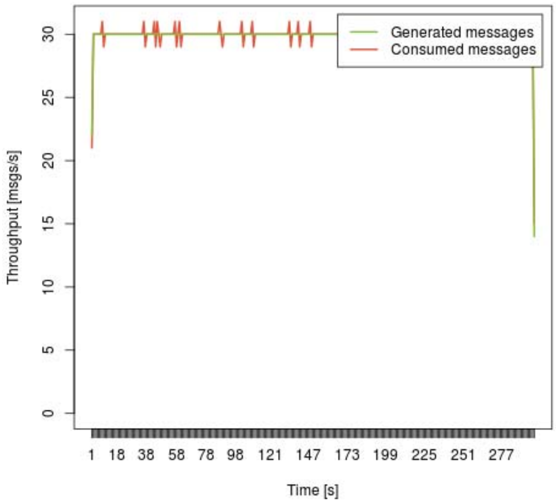
device	Experiment no.	Average message generation rate [msg/s]	Average message consumption rate [msg/s]	Total number of messages	Latency min [ms]	Latency max [ms]	Latency mean [ms]	Latency median [ms]
Server	1	29	29	8946	5	54	8,921753	9
Server	2	59	59	17888	5	62	8,742229	9
Server	3	90	90	27104	5	185	9,293831	9
Server	4	119	119	35777	4	578	12,63018	8
Server	5	149	149	44726	5	1475	36,14394	8
Server	6	186	186	55910	4	3379	108,3281	7
Server	7	213	213	63901	4	4863	228,9574	6
Server	8	248	248	74561	4	7507	537,104	6
Server	9	271	271	81326	4	8340	618,2957	6
NUC	1	29	29	8946	3	91	16,30986	18
NUC	2	59	59	17895	2	129	16,52378	18
NUC	3	90	90	27105	3	103	7,737613	6
NUC	4	119	119	35786	2	347	10,94509	7
NUC	5	149	149	44723	2	587	11,92829	5
NUC	6	186	186	55903	2	1794	42,13003	4

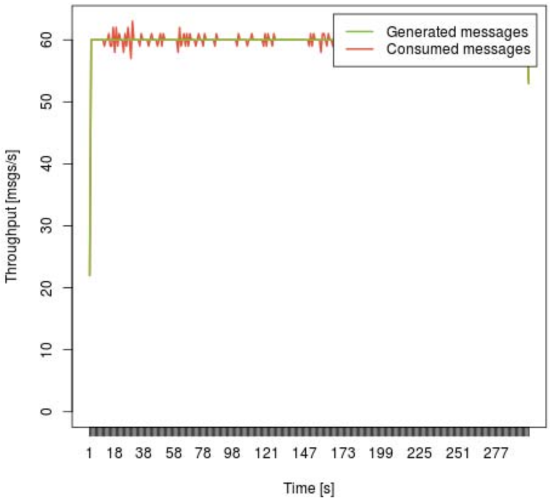
NUC	7	212	212	63889	2	3213	107,6513	4
NUC	8	248	248	74541	2	4907	207,0225	4
NUC	9	271	271	81323	2	5851	305,1608	5

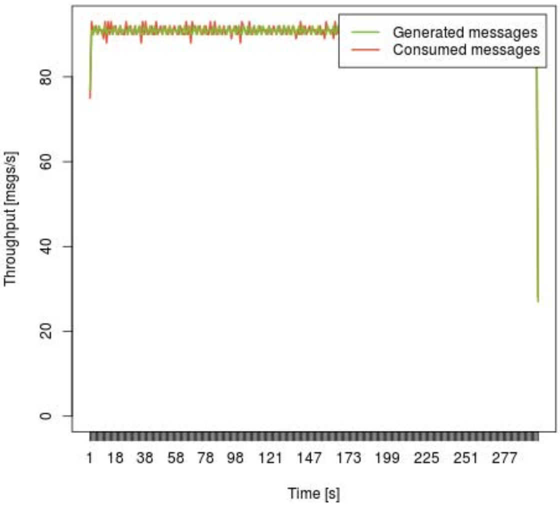
The immediate conclusion, by checking the values of the first and second experiments is, that at the message generation speed of around 50 msg/s we are reaching the target of latency under 100 ms.

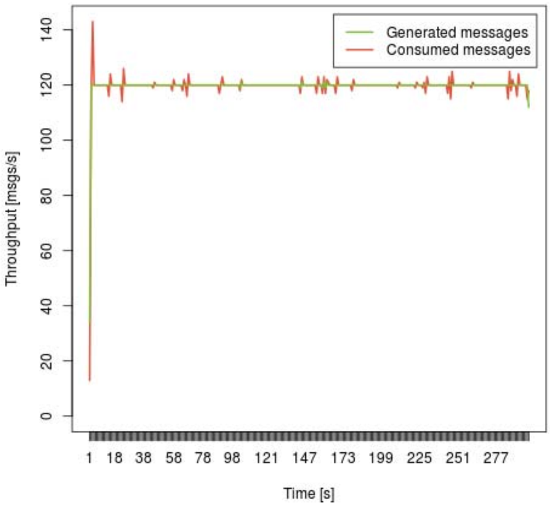
However, a more in-depth analysis shows several interesting features, capabilities as well as possible limitations of the system. As the results from both devices are fairly similar, we can also conclude that the experiment setup is relatively stable, and we managed to exclude most of external factors. For this reason, we proceed with in-depth analysis of just one set of results, namely from the NUC machine.

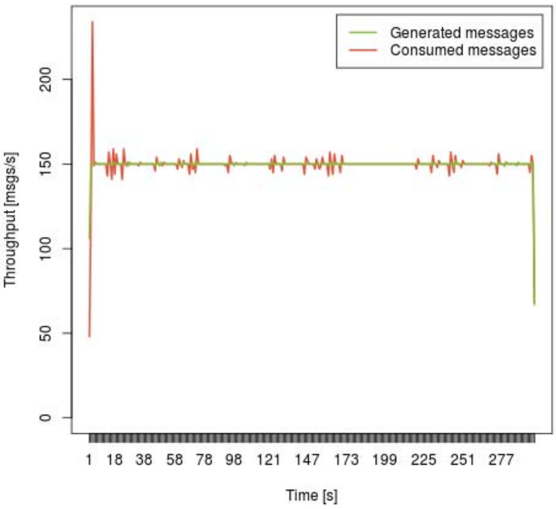
In the first set of graphs the generation speed vs. message consumption speed is shown. The x-axis shows time in seconds from the beginning of an experiment (typically, from one to 300 seconds). On the y-axis we show the throughput as number of messages per second (green - generated messages, orange - consumed messages).

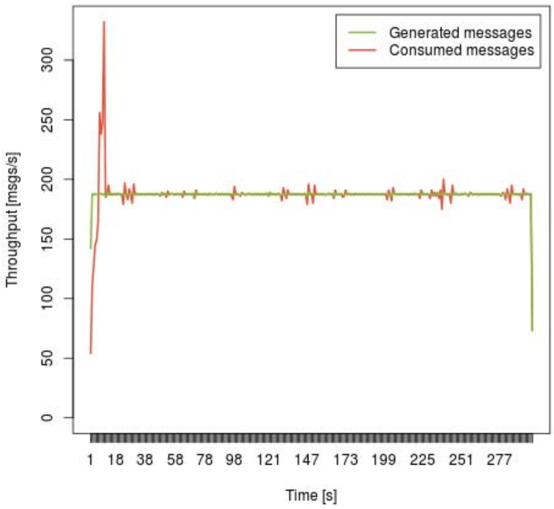

Generated messages
Consumed messages
Throughput [msgs/s]
Time [s]


Generated messages
Consumed messages
Throughput [msgs/s]
Time [s]


Generated messages
Consumed messages
Throughput [msgs/s]
Time [s]


Generated messages
Consumed messages
Throughput [msgs/s]
Time [s]


Generated messages
Consumed messages
Throughput [msgs/s]
Time [s]


Generated messages
Consumed messages
Throughput [msgs/s]
Time [s]

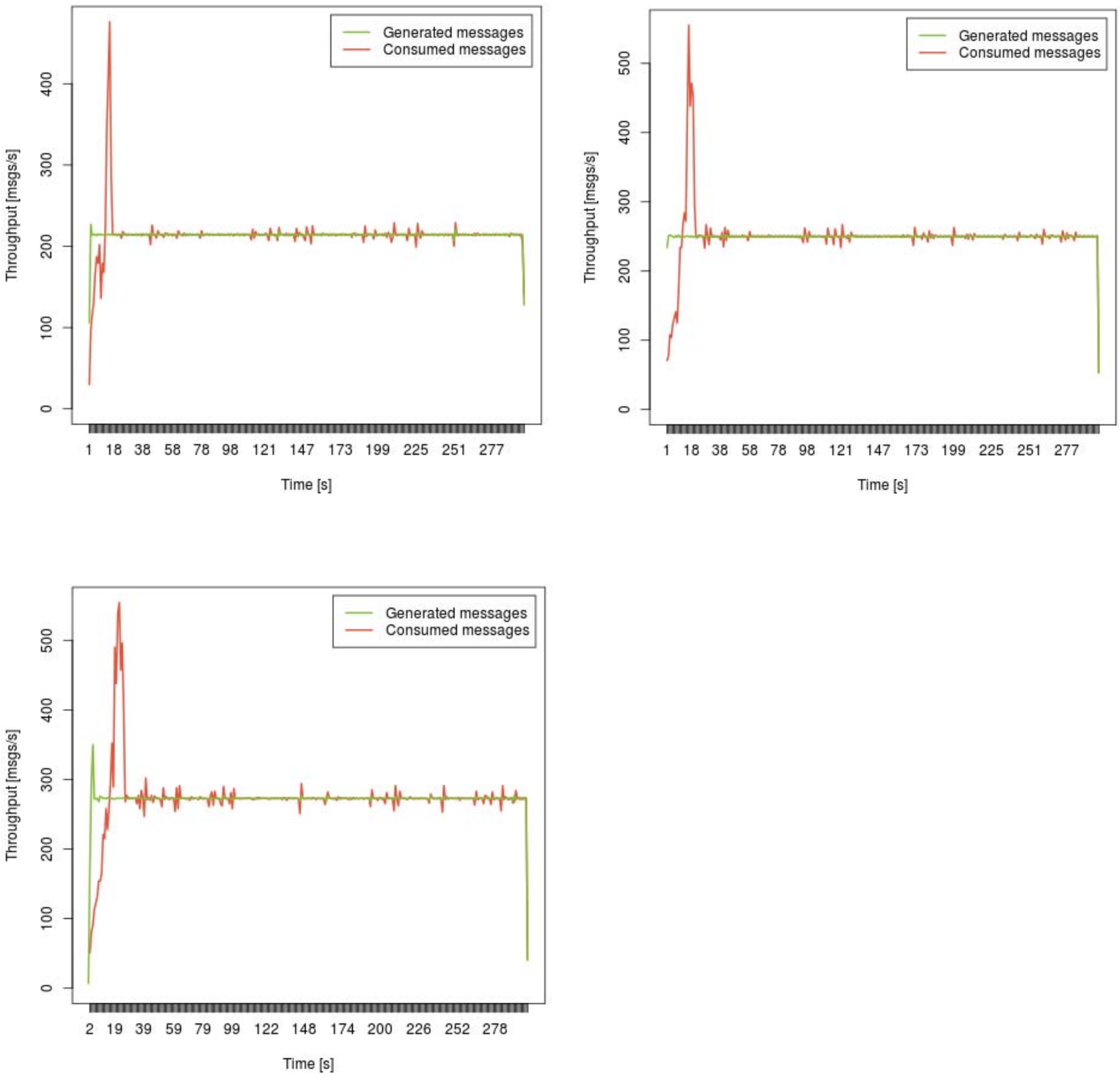
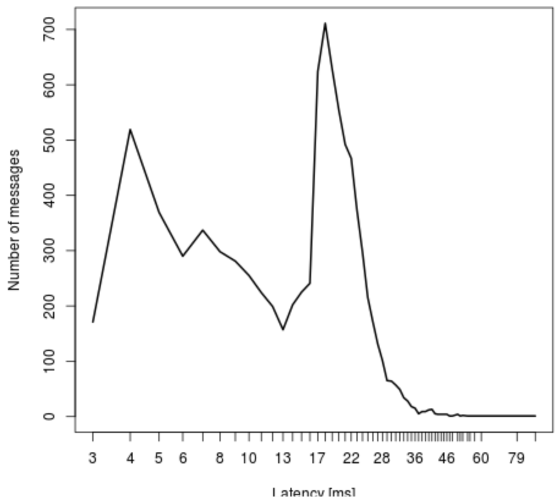
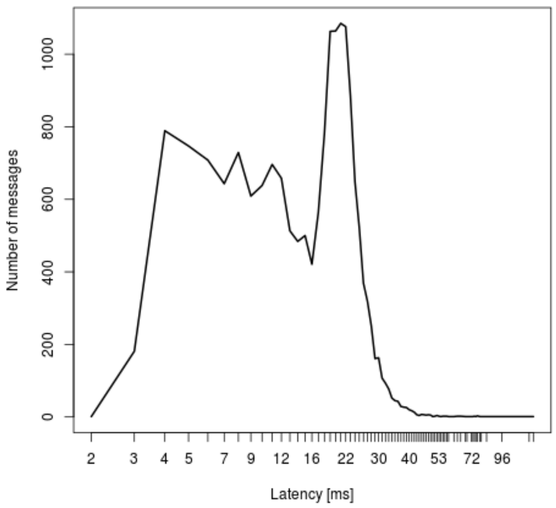


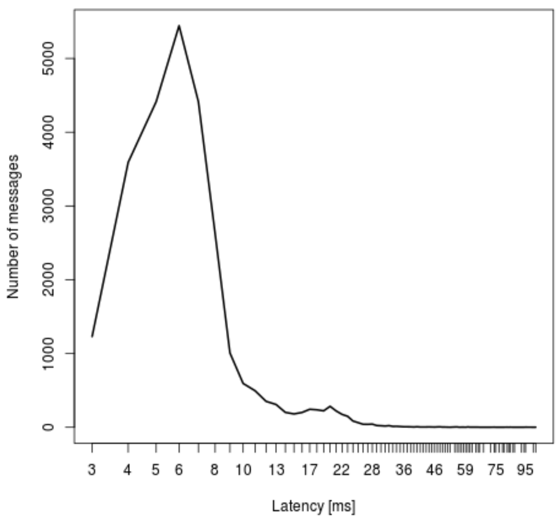
Figure 8: KPI 4.18 scalability assessment

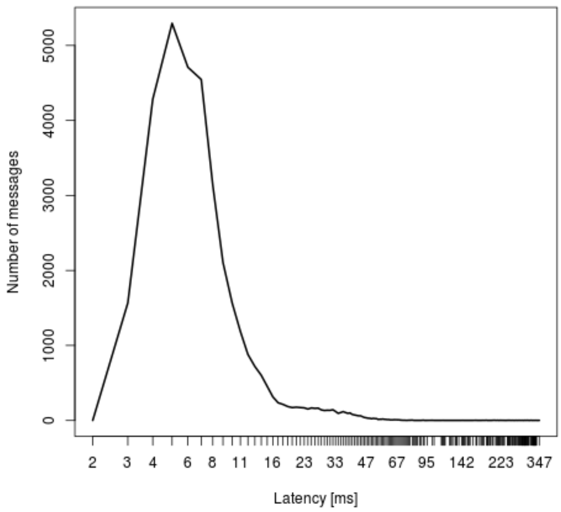
The graphs clearly show that during most of the duration of the experiment, regardless of the message generation frequency, the consumption speed “keeps-up” with the generation. In other words, the system does not get overloaded or saturated. The only unexpected behaviour is the lag during the first few seconds of each experiment, which becomes more obvious during with increasing generation frequency. The authors suspected that INTERMW start up procedures cause the initial delay, but even with delayed start of the experiment results are very similar. This behaviour would need more in-depth profiling in order to detect the cause of the anomaly.

In the second set of graphs the distribution of the latency is shown. The x-axis shows the latency in milliseconds (logarithmic scale). On the y-axis we show the number of messages (distribution).


Number of messages
Latency [ms]


Number of messages
Latency [ms]


Number of messages
Latency [ms]


Number of messages
Latency [ms]

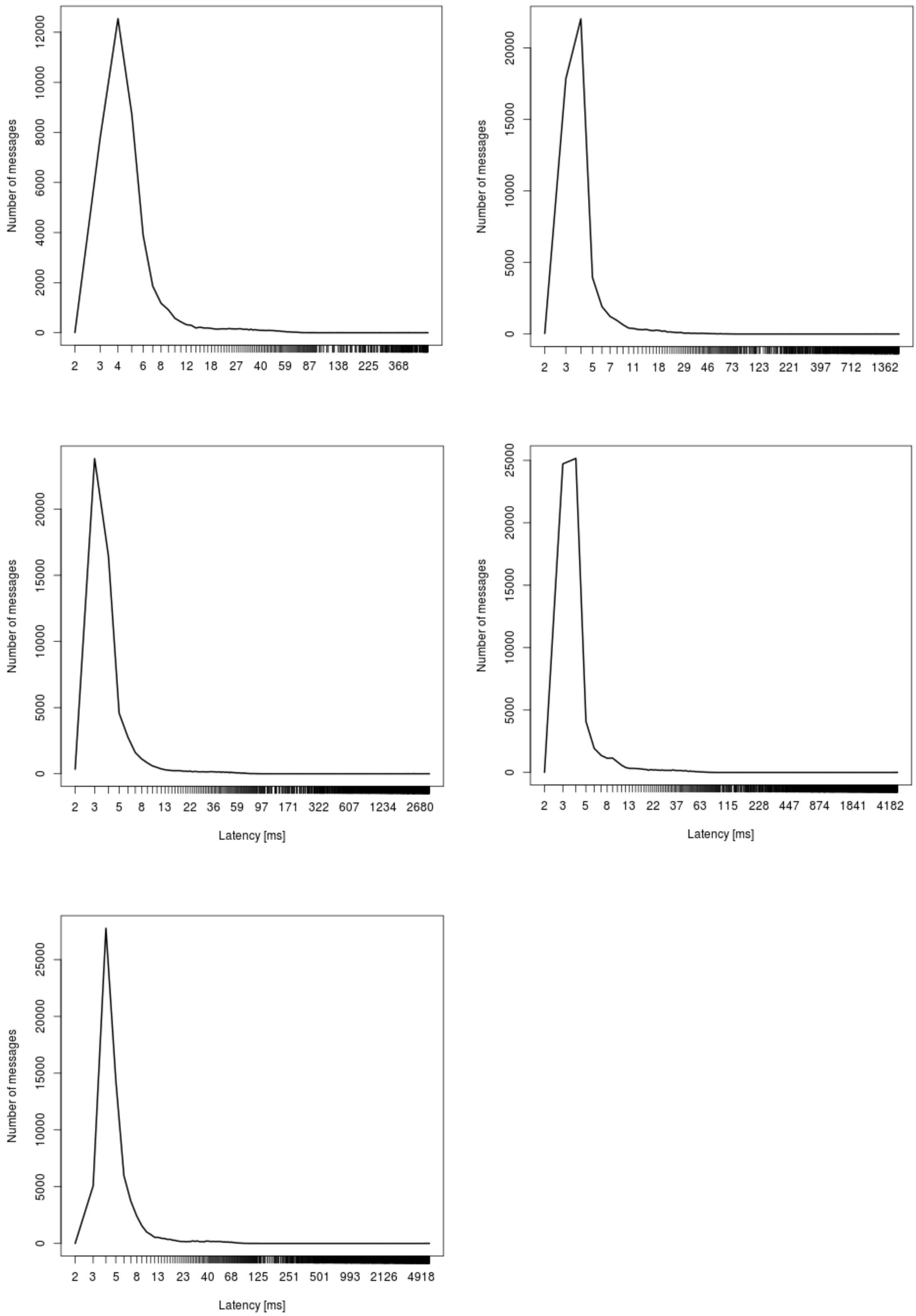
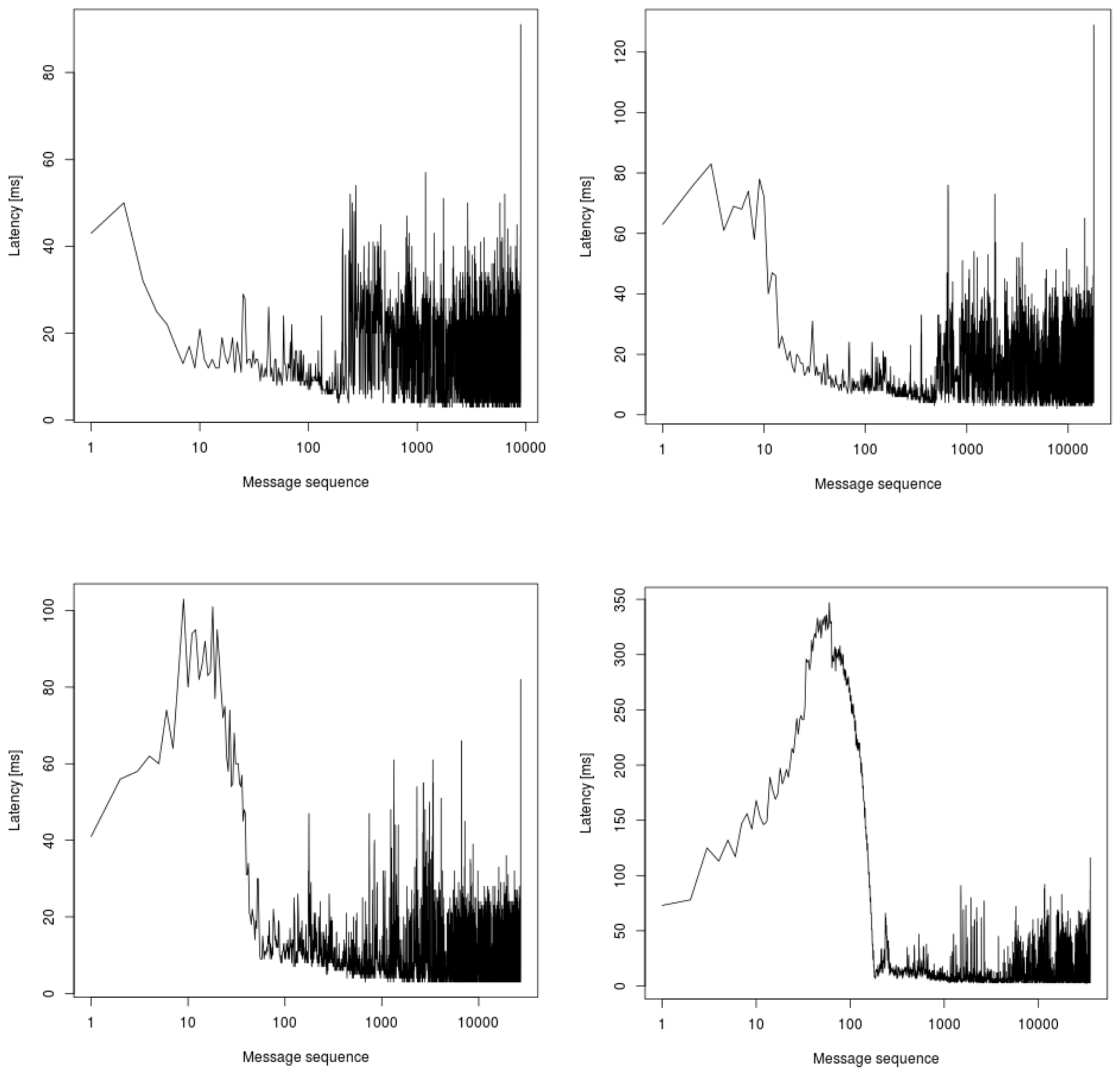


Figure 9: KPI 4.41 latency assessment

For all distributions we can conclude that most messages are well within acceptable limits. This conclusion is also supported by the median value provided in the summary table. Practically, we may have a long tail of high-value latencies, but the majority will always be within the desired bounds.

The third, and last set of graphs may help to provide us with more insight into the reason for a long tail of high-latency values. The x-axis shows, on the logarithmic scale, the sequence number of each message, while on the y-axis the latency of each message is provided.



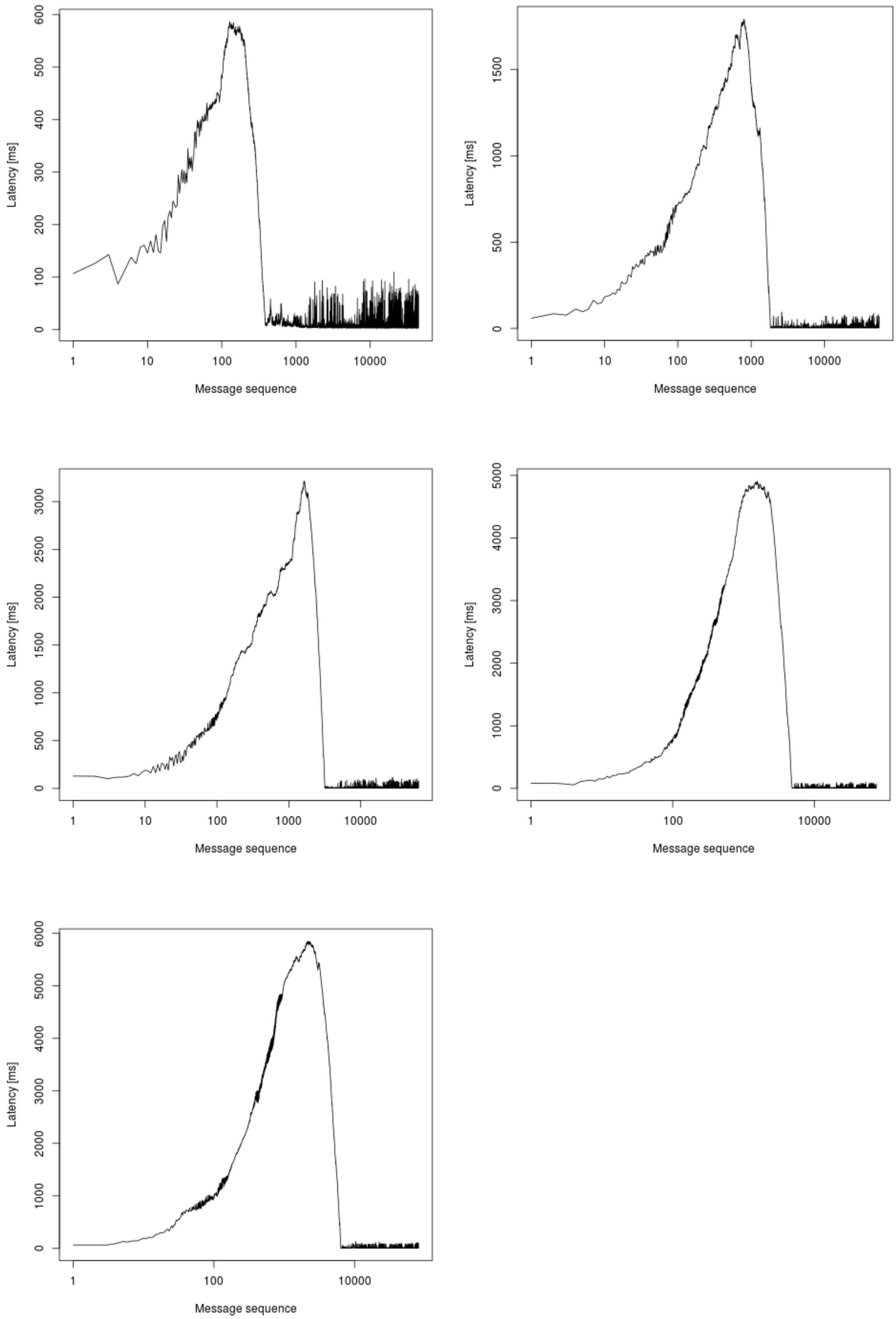


Figure 10: KPI 4.41 further latency assessment

From this third batch of graphs, we can clearly identify that the source of the unacceptable latency values is always from the very beginning of each experiment. At the beginning, for the first few percent of the messages, the latency increases, then again drops and maintains acceptable values until the end of experiment.

The system shows very good performance in laboratory environments; thus we conclude that the target value has been reached. In D7.3 a similar assessment will be performed for production environments.

KPI.4.19 D2D scalability

A variety of tests have been performed using difference connector technology and different deployments. Current testing has indicated that the system can handle 150 devices without dropping below the 5 second delay threshold set.

Connector Technology	Theoretical Number of Devices / Nodes	Devices to Waterbuoy GW Device Lora - GPRR gateway	Devices to Trashbin GW Device Panstamp - Raspberry Pi	Devices to Smart Office GW Device Panstamp - Raspberry Pi	Devices to Soil Moisture GW DevicePanstamp - Raspberry pi2	Devices to Soil Moisture GW DevicePanstamp - Raspberry pi3	Device to Present GW Device RFID USB - Raspberry pi	Devices to UPV
Total		25	58	58	58	58	0	150
Serial communication		0	6	6	6	6	0	150
Serial			1	1	1	1		150
USB			4	4	4	4		
Ethernet			1	1	1	1		
Wireless communication		25	52	52	52	52	0	0
Panstamp			50	50	50	50		
Bluetooth			1	1	1	1		
BLE								
Wifi			1	1	1	1		
Tread	200							
GPRS								
5G								
Lora		25						
Sixfox								
ZigBee	65000							
Z-Wave	232							
Neul								
NB-IoT								
LTE-M								
NFC								

Table 12: D2D Scalability

KPI.4.20 N2N scalability

To evaluate the N2N scalability, we measure in msg/ms the throughput at the node level in the network. The higher the throughput, the more scalable the network is, since it means we can add many devices without overloading the network nodes. The performance was measured several times with iperf[2], with two hosts exchanging 8KB TCP packets over an INTER-IoT switch.

The network deployment is left to the users of INTER-IoT, and thus, may vary a lot in between instantiations. The KPI value of 107% was obtained when measuring the scalability of a virtual SDN network deployed in the cloud. In this environment, it is expected to perform very well.

We exceed the target value by 7% meaning that scalability of N2N is well assured in a virtual network deployed in the cloud. However, this value may drop if the deployed SDN network is not only virtually hosted, or if the cloud hosts the network nodes on different locations.

KPI.4.21 AS2AS scalability

This KPI will be analysed when the pilots are finished, because they will offer more realistic information about the performance.

KPI.4.22 Availability of the configuration and administration tools

The following tools are currently available for configuration and administration purposes. Platform administration.

- Device administration.
- Virtual gateway administration.
- Service flow administration.
- SDN controller administration.
- Network topology administration.
- Ontology alignment administration.
- IPSM channel administration.
- IPSM translation administration.
- Security policy administration.
- User management.
- API management.

These tools address needs in all levels of INTER-LAYER, in INTER-FW and in INTER-METH.

KPI.4.23 Components supporting monitoring over the lifetime of IoT application deployment

The monitoring feature, as not part of the 'core' features for pilots and integration of platforms, is still in development as part of WP6. This is something that must be addressed in the last part of the project and will be reported on in D7.3.

KPI.4.24 Failover mechanisms

Two failover mechanisms have been verified at the time of this KPI assessment

- Inter-Health PWT employs a watchdog, a process running in background that checks that PWT is functioning. If the watchdog detects that PWT is down, it will restart it.

[2] https://iperf.fr/

- In AS2AS it can, optionally, be implemented redundant nodes and flows that will allow the layer service to perform correctly the tasks if the primary nodes and flows go down, minimizing the risk of failure.

Additional failover mechanisms will be assessed in the final quarter of INTER-IoT. An update to this KPI score will be provided in D7.3

KPI.4.25 Security mechanism in place

There are currently 3 security mechanisms in place. They are SSL, authentication mechanisms (via the use of an authentication server) and also individual permissions for each user and type of user (through an id server). These security mechanisms are common to all layer APIs.

Additional layer specific security mechanisms will be assessed during the final quarter and reported on in D7.3.

KPI.4.26 Documentation availability

The documentation server is live. https://docs.inter-iot.eu/ All project documentation is included. As work proceeds to support the Open Call partners and pilots, less than 100% of the code is fully documented. By D7.3, we believe that it will be finalized.

KPI.4.27 - KPI.4.39

An initial survey has included 15 subjects from UNICAL research groups, spinoffs and labs. Obtained results showed a good appreciation of the surveyed INTER-IoT products (i.e., INTER-METH and CASE-TOOL). In particular, both functional and not-functional KPIs have been mostly positively evaluated. Indeed, in analysing the obtained results, one should consider that (i) working with a methodology, especially one so articulated and full-fledged, is intrinsically complex, as well as with its related product (see KPIs 4.28-4.29-4.35); (ii) some aspects of CASE-TOOL are still (according to the project schedule) under development (e.g., collaborative work support, see KPI.4.36).

The results presented in Table 5.

KPI.4.40 System uptime

Full assessment of this KPI will come when the pilots are fully running in a way that this KPI can be measured. Results will be reported in D7.3.

KPI.4.41 INTER-MW Latency

Please se KPI.4.18 INTER-MW scalability and KPI.4.41 INTER-MW Latency above for information regarding KPI.4.41.

KPI.4.42 Loss rate

Full testing of this KPI is planned for completion in the last quarter of the project. We can see from KPI.4.23 that some aspects of the system monitoring were not yet completed in time for the measures necessary to complete this KPI.

KPI.4.43 Standard open ontologies referred by GIoTP ontology

The Inspected 35 ontologies are outlined in Deliverable 4.1. Some of them are referred directly by GIoTP ontology.

KPI.4.44 INTER-N2N Latency

Time stamp of a message of arrival at the destination - Time stamp of delivery to the N2N layer
The goal was <10ms (Generic)

Latency is defined as the time that takes for an IP packet of data to arrive from one specific point (source) to another (destination) and come back. In majority of cases this time is measured by sending a packet that is returned to the sender; the round-trip time (RTT) is considered the *latency*. *Latency* is a consequence of the limited velocity with which any data interaction can propagate.

For SDN deployments we can differentiate two types of latency. The latency of packets between nodes of the data plane and the controller (control plane) that configures them and the latency between the nodes that exist on the data plane.

Using different measurement tools such as tcpdum, iperf, *bmon*, and *netstat* we analysed both types of latency in a test deployment.

Control plane Latency

We perform testing against the SDN controller, creating several virtual switches that send numerous packets against the controller.

The channel created between these nodes uses OpenFlow protocol over TCP with a defined set of messages. An example of testing and a set of results can be seen in the following figures;

```
cbench: controller benchmarking tool
   running in mode 'latency'
   connecting to controller at localhost:6633
   faking 16 switches offset 1 :: 16 tests each; 1000 ms per test
   with 100000 unique source MACs per switch
   learning destination mac addresses before the test
   starting test with 0 ms delay after features_reply
   ignoring first 1 "warmup" and last 0 "cooldown" loops
   connection delay of 0ms per 1 switch(es)
   debugging info is off
12:45:46.571 16  switches: flows/sec:  187  169  161  155  147  143  143  143  143  141  141  141  141  141  141  141   total = 2.377156 per ms
12:45:47.671 16  switches: flows/sec:  230  194  180  168  162  158  156  158  158  156  158  156  158  156  158  158   total = 2.663995 per ms
12:45:48.771 16  switches: flows/sec:  218  198  174  164  162  160  160  160  160  160  160  160  160  160  160  160   total = 2.675995 per ms
12:45:49.872 16  switches: flows/sec:  208  184  170  160  156  156  156  156  156  156  156  156  156  156  156  156   total = 2.593997 per ms
12:45:50.974 16  switches: flows/sec:  230  186  170  166  158  160  158  158  158  156  156  156  156  156  158  156   total = 2.635328 per ms
12:45:52.074 16  switches: flows/sec:  202  190  174  156  156  156  156  154  152  152  152  152  152  152  152  152   total = 2.559997 per ms
12:45:53.174 16  switches: flows/sec:  218  198  180  170  166  158  158  158  158  158  158  158  158  158  158  158   total = 2.669992 per ms
12:45:54.274 16  switches: flows/sec:  212  192  182  168  162  158  156  156  154  154  154  154  154  154  154  154   total = 2.617997 per ms
12:45:55.375 16  switches: flows/sec:  214  186  174  168  160  160  160  158  160  160  160  160  160  160  158  160   total = 2.656369 per ms
12:45:56.476 16  switches: flows/sec:  222  192  176  168  166  164  164  164  162  162  162  162  162  162  162  162   total = 2.711995 per ms
12:45:57.577 16  switches: flows/sec:  238  206  192  168  164  164  162  164  162  162  162  162  162  162  162  162   total = 2.752379 per ms
12:45:58.679 16  switches: flows/sec:  224  204  186  164  160  154  154  154  154  154  154  154  154  154  154  154   total = 2.627717 per ms
12:45:59.779 16  switches: flows/sec:  220  194  182  160  158  156  156  158  156  158  158  158  156  156  156  156   total = 2.637997 per ms
12:46:00.879 16  switches: flows/sec:  214  188  168  158  154  150  150  150  150  150  150  150  150  150  150  150   total = 2.531997 per ms
12:46:01.980 16  switches: flows/sec:  216  190  168  168  162  158  158  158  158  158  158  158  158  160  158  158   total = 2.643995 per ms
12:46:03.080 16  switches: flows/sec:  206  188  174  164  160  158  158  156  156  156  156  156  156  156  156  156   total = 2.611997 per ms
RESULT: 16 switches 15 tests min/max/avg/stdev = 2532.00/2752.38/2639.45/53.22 responses/s
```

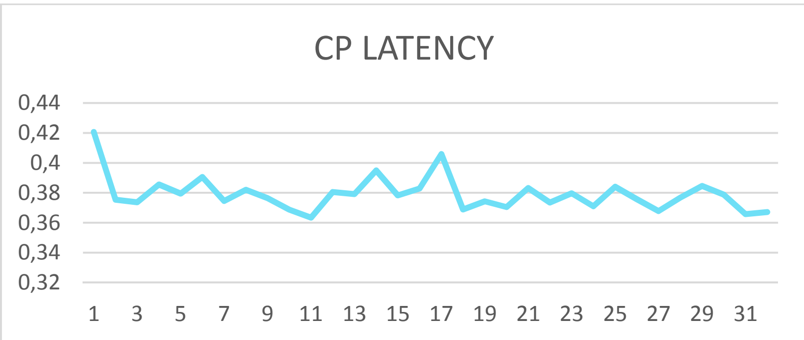


Figure 11: SDN Example latency testing and results

In the previous graph we observe the latency time in ms (Y axe) derived from the results of the test and the packet number (X axe). As the connection between switch and controller is previously set and there is no middle nodes in the path, the latency of the messages exchanged between them is minimum.

<u>Data plane Latency</u>

In this case we perform testing between different nodes of the data plane. These nodes can communicate following other transport protocols (TCP, UDP, MPTCP, etc.)

Using a simple mechanism as *ping* command between nodes we can observe the time that an ICMP packet takes to arrive from one host to another and come back (RTT) and so the latency.

In a simple linear topology of four nodes connected through three virtual switches we perform some testing as;

```
PING 10.0.0.2 (10.0.0.2) 56(84) bytes of data.
64 bytes from 10.0.0.2: icmp_seq=1 ttl=64 time=0.210 ms
64 bytes from 10.0.0.2: icmp_seq=2 ttl=64 time=0.036 ms
64 bytes from 10.0.0.2: icmp_seq=3 ttl=64 time=0.047 ms

--- 10.0.0.2 ping statistics ---
3 packets transmitted, 3 received, 0% packet loss, time 2000ms
rtt min/avg/max/mdev = 0.036/0.097/0.210/0.080 ms
```

Figure 12: SDN Node1 <--> Node2

```
PING 10.0.0.3 (10.0.0.3) 56(84) bytes of data.
64 bytes from 10.0.0.3: icmp_seq=1 ttl=64 time=0.188 ms
64 bytes from 10.0.0.3: icmp_seq=2 ttl=64 time=0.044 ms
64 bytes from 10.0.0.3: icmp_seq=3 ttl=64 time=0.041 ms

--- 10.0.0.3 ping statistics ---
3 packets transmitted, 3 received, 0% packet loss, time 1999ms
rtt min/avg/max/mdev = 0.041/0.091/0.188/0.068 ms
```

Figure 13: SDN Node1 <--> Node3

```
PING 10.0.0.4 (10.0.0.4) 56(84) bytes of data.
64 bytes from 10.0.0.4: icmp_seq=1 ttl=64 time=0.222 ms
64 bytes from 10.0.0.4: icmp_seq=2 ttl=64 time=0.031 ms
64 bytes from 10.0.0.4: icmp_seq=3 ttl=64 time=0.034 ms

--- 10.0.0.4 ping statistics ---
3 packets transmitted, 3 received, 0% packet loss, time 1999ms
rtt min/avg/max/mdev = 0.031/0.095/0.222/0.090 ms
```

Figure 14: Node1 <--> Node4

```
PING 10.0.0.4 (10.0.0.4) 56(84) bytes of data.
64 bytes from 10.0.0.4: icmp_seq=1 ttl=64 time=0.209 ms
64 bytes from 10.0.0.4: icmp_seq=2 ttl=64 time=0.064 ms
64 bytes from 10.0.0.4: icmp_seq=3 ttl=64 time=0.031 ms

--- 10.0.0.4 ping statistics ---
3 packets transmitted, 3 received, 0% packet loss, time 2000ms
rtt min/avg/max/mdev = 0.031/0.101/0.209/0.077 ms
```

Figure 15: Node2 <--> Node4

```
PING 10.0.0.3 (10.0.0.3) 56(84) bytes of data.
64 bytes from 10.0.0.3: icmp_seq=1 ttl=64 time=0.192 ms
64 bytes from 10.0.0.3: icmp_seq=2 ttl=64 time=0.029 ms
64 bytes from 10.0.0.3: icmp_seq=3 ttl=64 time=0.032 ms

--- 10.0.0.3 ping statistics ---
3 packets transmitted, 3 received, 0% packet loss, time 1998ms
rtt min/avg/max/mdev = 0.029/0.084/0.192/0.076 ms
```

Figure 16: Node2 <--> Node3

```
PING 10.0.0.4 (10.0.0.4) 56(84) bytes of data.
64 bytes from 10.0.0.4: icmp_seq=1 ttl=64 time=0.210 ms
64 bytes from 10.0.0.4: icmp_seq=2 ttl=64 time=0.037 ms
64 bytes from 10.0.0.4: icmp_seq=3 ttl=64 time=0.044 ms

--- 10.0.0.4 ping statistics ---
3 packets transmitted, 3 received, 0% packet loss, time 2000ms
rtt min/avg/max/mdev = 0.037/0.097/0.210/0.079 ms
```

Figure 17: Node3 <--> Node4

- Test with UDP

For further testing we use first UDP traffic between different nodes of the same virtual network

```
13:46:21.869572 IP 10.0.0.1.46154 > 10.0.0.3.3333: UDP, length 2048
13:46:21.869578 IP 10.0.0.1.46154 > 10.0.0.3.3333: UDP, length 2048
13:46:21.869584 IP 10.0.0.1.46154 > 10.0.0.3.3333: UDP, length 2048
13:46:21.869605 IP 10.0.0.1.46154 > 10.0.0.3.3333: UDP, length 2048
```

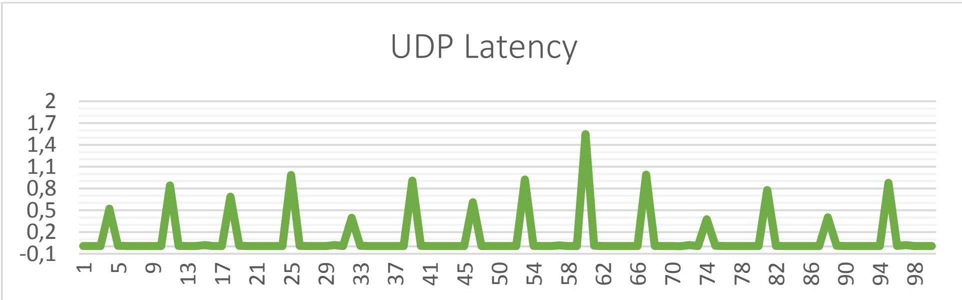


Figure 18: UDP Latency testing

In this case the latency is bigger than the case of control plane and the ICMP testing but still low enough.

- Test with TCP traffic

For this test we run an HTTP server on Node1 and perform request from another node (Node2 and 3) of the network. In the following figure an example of network sniff can be despite.

```
tcpdump: verbose output suppressed, use -v or -vv for full protocol decode
listening on h1-eth0, link-type EN10MB (Ethernet), capture size 262144 bytes
13:11:25.482942 IP 10.0.0.1.http > 10.0.0.2.38898: Flags [S.], seq 940601452, ack 2683378287, win 28960, opt
ions [mss 1460,sackOK,TS val 949904163 ecr 949904163,nop,wscale 9], length 0
13:11:25.483909 IP 10.0.0.1.http > 10.0.0.2.38898: Flags [.], ack 136, win 59, options [nop,nop,TS val 94990
4163 ecr 949904163], length 0
13:11:25.484478 IP 10.0.0.1.http > 10.0.0.2.38898: Flags [P.], seq 1:18, ack 136, win 59, options [nop,nop,T
S val 949904163 ecr 949904163], length 17: HTTP: HTTP/1.0 200 OK
13:11:25.484524 IP 10.0.0.1.http > 10.0.0.2.38898: Flags [P.], seq 18:56, ack 136, win 59, options [nop,nop,
TS val 949904163 ecr 949904163], length 38: HTTP
13:11:25.484923 IP 10.0.0.1.http > 10.0.0.2.38898: Flags [P.], seq 56:93, ack 136, win 59, options [nop,nop,
TS val 949904164 ecr 949904164], length 37: HTTP
13:11:25.484947 IP 10.0.0.1.http > 10.0.0.2.38898: Flags [P.], seq 93:142, ack 136, win 59, options [nop,nop
,TS val 949904164 ecr 949904164], length 49: HTTP
13:11:25.484961 IP 10.0.0.1.http > 10.0.0.2.38898: Flags [P.], seq 142:163, ack 136, win 59, options [nop,no
p,TS val 949904164 ecr 949904164], length 21: HTTP: Content-Length: 782
13:11:25.484974 IP 10.0.0.1.http > 10.0.0.2.38898: Flags [P.], seq 163:165, ack 136, win 59, options [nop,no
p,TS val 949904164 ecr 949904164], length 2: HTTP
13:11:25.485009 IP 10.0.0.1.http > 10.0.0.2.38898: Flags [P.], seq 165:947, ack 136, win 59, options [nop,no
p,TS val 949904164 ecr 949904164], length 782: HTTP
13:11:25.485040 IP 10.0.0.1.http > 10.0.0.2.38898: Flags [F.], seq 947, ack 136, win 59, options [nop,nop,TS
 val 949904164 ecr 949904164], length 0
13:11:25.492736 IP 10.0.0.1.http > 10.0.0.2.38898: Flags [.], ack 137, win 59, options [nop,nop,TS val 94990
4166 ecr 949904166], length 0
```

Figure 19: SDN Network sniff

In the following graphic the latency of each TCP/HTTP message is observed.

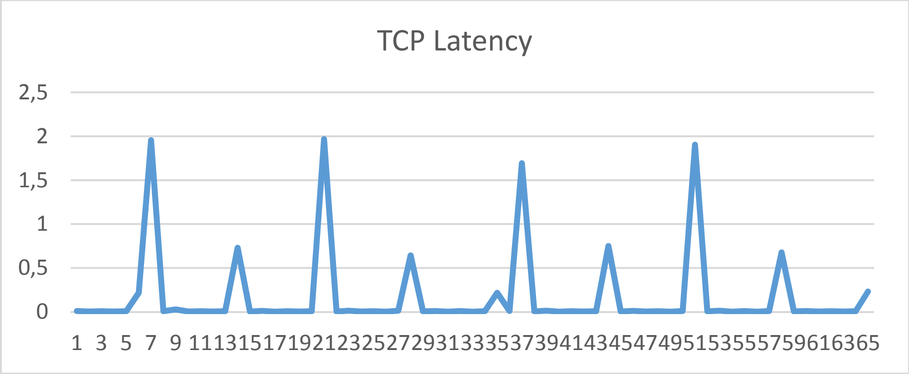


Figure 20: TCP Latency testing

However, to measure the whole HTTP request latency, since the request message is sent until the actual object of the request is received, we have to take the timestamp of the first and last packets of the HTTP request connection obtaining an approximated latency of;

$$(25.492736 - 25.482942) * 103 = 9{,}7\ ms$$

In this case, this is the maximum latency we obtain after performing the stack of test previously described.

In a classic deployment where two or more machines with enough computing resources connected over a gigabit network, the time spent in kernel and userspace on the destination machine is usually the most of total RTT, around 70% of the total RTT time. Thus, the actual time spent travelling through the SDN network is lower than the processing time spent within the machine responding the request received and turning the packet around.

Still some assumptions has to be done. Those include, the variable behaviour of the latency due to this is not constant and varies with Application, Protocol, Platform, Type of Operation, Rule priority, Switch Table Occupancy and Operations on place. A special mention must be declared regarding the Application variable as in some application the Latency is critical thus, QoS policies are implemented modifying the latency of the specific application and as an effect the latency of the other application traffic that travel through the same virtual switch-

As a conclusion, even though latency has been reduced in the data plane when simple traffic is managed there are many specific case to be analysed. In this case the KPI value is quite fulfilled taking in account the environment and different testing.

4 Ethics

INTER-IoT partners, both individually and as a consortium, are committed maintaining high ethical standards within this project and beyond it in all areas of work and life. As part of the project we have an internal ethical committee which meets regularly and has done so for the second half of the project to address new and existing ethical issues that become relevant as the project progresses. The evaluation of project results raises relevant ethical issues which were discussed in D7.1 and can be elaborating on here.

For any evaluation, there needs to be a clear plan which is open to review so that the quality and ethical nature of the evaluation able to be critiqued. D7.1 set out the INTER-IoT plan for evaluating the technology, use cases, and the processes involved in producing and using INTER-IoT technology and solutions. The United Nations Development Programme (UNDP) says that an evaluation should be independent, intentional, transparent, ethical, impartial, of high quality, timely and used. We believe that the plan put in place in D7.1 follows these guidelines and they will be expanded upon here.

Above we have documented changes to the plan set out in D7.1 to insure transparency of our methodology and provide the most descriptive evaluation of the project results as we can. The majority of the information gathered in the completion of D7.2 was gathered internally as this document focuses on technical developments. Interaction with external stakeholders will play a much more significant role during the final 3 months of the project where the wider impact of the project is assessed. In D7.3

Internally we have been vigilant to ensure that pressure from stakeholders is not influencing the findings prior to release. Following the predetermined methodology set out in D7.1 helps in this regard. Having pre-evaluation predictions about the results is near enough impossible to avoid but sticking to the methodology set out in D7.1, helps to avoid any undue influence of this bias. No findings in the project are being suppressed or ignored to the best of the knowledge of the consortium partners.

D7.1 being written before the evaluation process helps to address many of the ethical concerns involved in carrying out an evaluation.

Some updates to the KPI definitions and data collection and analysis methodology are included in this document. The vast majority are unchanged, but it is important to highlight these changes. We believe that no ethical boundaries have been crossed in making the above documented changes. The key steps taken to address ethical issues when carrying out the plan for D7.2 were documented in D7.1:

- The completion of this document where the process and KPIs are clearly defined and available to all partners for review prior to the start of the evaluation process
- Ensure transparency and honesty in reporting by involving multiple partners in the process. Specific partners involved in the development of each KPI and its measurement are documented so the results are fully auditable down to the people involved in the process.
- Review of process by the INTER-IoT ethical committee.
- The involvement of all project partners in the evaluation process.

5 Conclusions

The primary object of deliverable D7.2 was to present the technical evaluation of the project. Overall, the results of the analysis have been positive showing the maturity of the INTER-IoT technology. Updates to the data collection, KPI subdivision and score calculation methodology were presented. These changes in methodology represent a positive step for INTER-IoT in that the results reported are more complete and less likely to contain bias.

Areas where the technology is performing well have been highlighted. Field 4.6 which focused on scalability was particularly well completed as all KPIs met or exceeded the target values in 100% of cases. Progress across the whole technical gambit was positive as each field assessed contained KPIs with scores of 100+. Additionally, areas where improvements can be made have also been discussed. Particular focus will be given to improved system monitoring and documentation.

Additional development is planned in the last quarter of the project in line with the pilots and third parties which will improve the outcomes seen in some of the lower scoring KPIs and fields. The full analysis will be available of all INTER-IoT KPIs in D7.3 for M36.