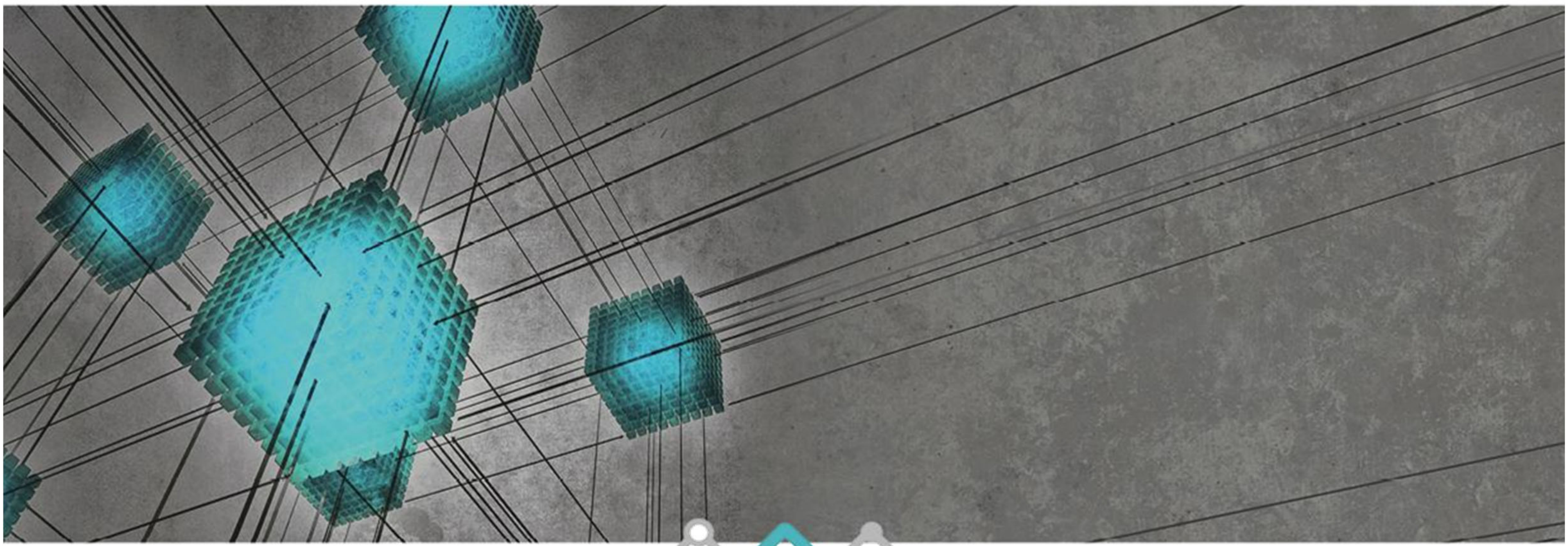

interiot

INTEROPERABILITY
OF HETEREOGENEUS
IOT PLATFORMS.

D7.3

Final Evaluation Report

December 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

Final Evaluation Report

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

Disclaimer

Executive Summary

The primary objective of this deliverable is to present the evaluation of the project. Work carried out as part of WP7 focused on the assessment of technical and non-technical KPIs which gives an insight into the maturity of INTER-IoT and its components as well as presenting assessing how it was received by end users and developers. All 113 KPIs are covered in the document. This represents all dimensions and fields including exploitation, pilots, impact, interoperability and ethical societal gender and legal aspects of 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 19 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 161 utilizing the methodology outlined in D7.1 and 92 for the adjusted methodology. Areas where the INTER-IoT 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 complete now. As indicated in D7.2, this was a goal of D7.3. Additionally, KPIs whose testing was tied to pilot activities have shown improvement. KPIs for impact and exploitation have exceeding the target in many cases. The pilots have been successful with both continuing in an operational sense beyond the end of the project. Ethical, societal, gender and legal aspects show potential for improvement with additional focus needed beyond the end of the project looking at the holistic nature of the innovation and community engagement.

Overall, the report is very positive and reflects the work done as part of the INTER-IoT project consortium. Feedback from stakeholders has been positive with areas for improvement highlighted.

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Change control datasheet

Version	Changes	Chapters	Pages
1.0	Update from D7.2	All	55
1.1	Addition of new methodology changes	2	58
1.2	Addition of new results	All	69
1.3	Full review and updates	All	69

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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 the whole of the INTER-IoT project exploitation, pilots, impact, interoperability and ethical societal, gender, and legal issues that have been completed by project partners as of M36 of the project. 3rd party partners who joined during the Open Call will also provide content in this deliverable. 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 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 D7.3 is to present the overall evaluation of the project through M36. 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 D7.3 gives an insight into the evaluation of the project and some ideas about how it can be improved beyond the completion of M36. Technical KPIs were reported in D7.2. This deliverable will address the remaining KPIs as well as updates to those presented in D7.2. KPI collection methodology is addressed in section 2.1. 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. This has been previously covered in D7.2 but has been included here as well as this document supersedes D7.2 for many of the KPIs. These updates have been made to add depth and clarity to the KPIs used to evaluate the project. Section 2.3 will review the methods used in grouping the KPIs into dimensions and fields for summary analyses.

2.1 Data collection methodology updates

2.1.1 Questionnaire for KPI evaluation

A survey of project partners, open call member and end users was undertaken to assess the projects success. This information has been used to steer future work and contributed directly to the KPI values of Dimension 5: ethical, societal, gender, and legal evaluation. Some KPIs were given multiple questions, while others were based on a single question. The survey was based in Google Forms. The survey ran from 1 November until 20 December 2018. 105 individuals participated in the survey. At least 1 member from each project partner and open call participant completed the survey. 65% of the completed surveys were from potential purchasers of solutions based on INTER-IoT. The remaining 35% were from universities and research institutions. The results of each KPI are recorded in Section 3.2 of this deliverable.

2.1.2 Specific KPI changes

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.2.09: Average waist circumference improvement

Waist circumference improvement detected during outpatient nutritional counselling, measured in cm. For this KPI we count the ratio of all patients that reached the waist circumference value that is less than 94 cm for males and less than 80 cm for females against the total number of patients involved in the pilot. The target will be calculated separately for the control and trial groups. Here we report the trial group results. Additionally, a comparison will be made to verify which group performed better. The waist circumference value states the risk of developing a cardiovascular disease.

KPI.2.13: Average eating habit improvement

Value collected through questionnaires filled by health operator during the outpatient nutritional counselling and questionnaires filled by subjects on the smartphone application. Those value are processed by the prevention program and by health care operators. During outpatient nutritional counselling a subjective assessment will be made to verify if eating habits of trial group patients have improved and assess if the use of questionnaires, filled on the smartphone application, could improve the motivation to follow a correct lifestyle. Here we report the trial group results. Additionally, a comparison will be made to verify which group performed better.

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).

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 were reported in D7.2. The INTER-LogP tests will be reported on below 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.4.28: Usability of INTER-METH

This KPI is an indication of the learning curve to start using the methodology. To collect the data for this KPI, interviewers with IoT system integrators will be held. The following options will be available to the integrator: Methodology is suitable only for experts; Methodology is suitable also for non-experts but requires a long training; Methodology is suitable also for non-experts and requires some reasonable training.

KPI.4.35: Usability of CASE tool

This KPI indicates how difficult it will be to learn and operate the CASE-tool. To collect the data for this KPI, interviews with end-users will be held. The following options will be available to end users: CASE-tool is suitable only for experts; CASE-tool is suitable also for non-experts but requires a long training; CASE-tool is suitable also for non-experts and requires some reasonable training.

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 1* 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.

KPI id	Name	Metric	Target (T)	KPI score calculation (%)
KPI.1.15	Time to go-to-market	Number	6	KPI_score = T / KPI_value * 100
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)

Table 1: Updates to the KPI scoring metrics

KPI.1.15 Time to go-to-market

This correction is to correct a mistake in the previous methodology which gave a higher score to a longer time to go to market. This new methodology favours a shorter time to market.

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 2.1 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.

2.3.1 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

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

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

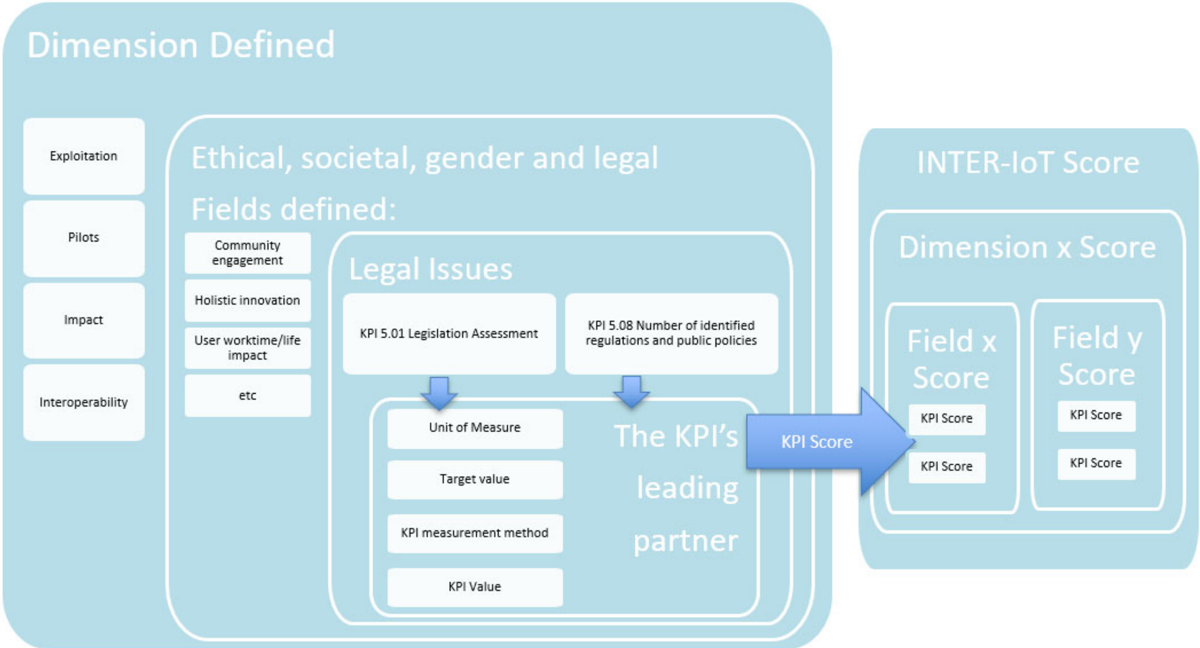


Figure 2: Calculation of INTER-IoT KPI, field, and dimension scores

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 3.

3 Results and Evaluation

This section will report and discuss each of the KPIs for INTER-IoT. Some measures will be repeated from D7.2 as updates have been made in the final quarter of the project.

3.1 KPI, Field, Dimension and INTER-IoT Score

This section will report on all of the 113 project KPIs. These KPIs represent the primary measures for the project's success. These results are also an indication of the projects internal maturity. *Table 2: 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 KPIs gathered in the project.

The dimensions addressed here are dimensions 1-5 from D7.1, exploitation, pilots, impact, interoperability and ethical, societal, gender and legal evaluations respectively. All KPIs from each dimension are assessed. Some have remained unchanged from D7.2. An overall 100 score is a good indication that the KPI being evaluated is to the level desired by the project. Within INTER-Health, KPI 1.24 is an exception as this KPI is more of a measure of the competitive landscape so a score of 100 indicates no competition and a score of 0 indicates infinite competition. Results for each individual KPI are covered in the section 3.2.

Exploitation KPIs showed positive results as nearly all fields exceeded expectations. The maturity of the products is summarized by an average time to market of 3 months reported by project partners. Additionally, partners are actively engaged with potential customers and their interest in the derived products has been demonstrated. Although many commercial presentations were given, this is one area we could have improved on.

The pilots have been successful with bother large scale pilots being continued beyond the end of the project the levels of scale of both the Health and Logistics pilot have been reflective of real-world scenarios and the reliability of the systems has been demonstrated. The full impact of them will be felt as they continue in the operational environment.

Overall impact has been good with a wide variety of dissemination channels identified and large number of project presentations given to a variety of audiences. Community engagement and online promotion could have been improved. The number of individuals address has exceeded our goals while primary being at in individual contact and event participation.

The technical maturity of the INTER-IoT solutions is demonstrated through the KPIs where the majority met or exceeded the targets set in D7.1. The supportability field associated with the CASE tool showed room for improvement. However, it was well received by the users as the targets set were very high. Additionally, the number of failover mechanisms was not reached but the use cases implemented have been addressed. Additional work beyond the end of the project may be needed if new use cases are to be implemented that are not covered by the current technology.

Dimension 5 showed the methods used in developing the INTER-IoT and the effects it would have on the public. Legal issues, trust, and life impact were widely assessed as being met. Holistic and community aspects show room for improvement. Further engagement with the wider public is advised as INTER-IoT progresses into 2019.

KPI, Field and Dimension		Metric	Target (T)	KPI Value	D7.1 Scoring	Adjusted Scoring
					Inter-IoT / Dimension / Field / KPI	Inter-IoT / Dimension / Field / KPI
INTER-IoT					**161**	**92**
Dimension 1: Exploitation					192	99
Field 1.1: Stakeholders' engagement					114	100
KPI.1.01	Stakeholders involved	Number	90	106	118	100
KPI.1.02	Stakeholders analysed	Number	0.75	98	123	100
KPI.1.19	Partners involved in joint exploitation	Number	12	100	100	100
Field 1.2: Impact on SMEs, start-ups and young entrepreneurs					107	100
KPI.1.03	Open Calls launched	Number	1	1	100	100
KPI.1.04	Received proposals in Open Call	Number	50	63	126	100
KPI.1.05	Accepted proposals in the Open Call	Number	12	12	100	100
KPI.1.14	Spin-offs created	Number	1	1	100	100
Field 1.3: Business Models					224	97
KPI.1.06	Business models proposed	Number	4	23	575	100
KPI.1.11	Business model flexibility	Number	3	4	133	100
KPI.1.20	Openness in business models	Number	15	13	87	87
KPI.1.22	Channels selected	Number/List	5	5	100	100
Field 1.4: Market readiness and monetization mechanisms					137	98
KPI.1.07	Monetizable products	Number	5	10	200	100
KPI.1.10	Open-source readiness	Number	4	7	175	100
KPI.1.15	Time to go-to-market	Number	6	3	100	100
KPI.1.16	Commercial presentations	Number	30	28	93	93
KPI.1.17	Commercial leads	Number	20	77	100	100
KPI.1.18	Commercial industrial events	Number	80	75	94	94
KPI.1.23	Effective business model design	Number	7	14	200	100
KPI.1.24	Competitors	Number/List	-	39	2.5	2.5
Field 1.5: Inclusiveness and participation of third parties					217	100
KPI.1.08	Private companies using INTER-IoT products (estimate)	Number	5	15	300	100
KPI.1.09	Public institutions using INTER-IoT components (estimate)	Number	4	10	250	100
KPI.1.21	External partnerships and collaborations	Number	3	3+	100	100

KPI, Field and Dimension		Metric	Target (T)	KPI Value	D7.1 Scoring Inter-IoT / Dimension / Field / KPI	Adjusted Scoring Inter-IoT / Dimension / Field / KPI
Field 1.6: Exploitation of products					353	100
KPI.1.12	Derived products	Number	3	25	833	100
KPI.1.13	Existing products influenced by INTER-IoT developments	Number	8	10	125	100
KPI.1.25	IPR	Number	13	13	100	100
Dimension 2: Pilots					185	96
Field 2.1: INTER-LogP pilot					101	100
KPI.2.03	Number of objects connected to INTER-LogP	Number	250	259	104	100
KPI.2.04	Accuracy ETA vs ATA	Minutes	5	<5	100	100
KPI.2.05	Activity detected in the railway area	%	80%	100%	100	100
KPI.2.06	Trucks detected by system	%	80%	100%	100	100
KPI.2.07	Global events detected by system	%	80%	100%	100	100
Field 2.2: INTER-Health pilot					104	87
KPI.2.02	Number of patients connected to INTER-Health	Number of patients	100	102	102	100
KPI.2.08	Average BMI improvement	% of Patients	60%	33%	55	55
KPI.2.09	Average waist circumference improvement	% of Patients	60%	NA	NA	NA
KPI.2.10	Chronic diseases risk reduction	% of Patients	100%	71%	71	71
KPI.2.11	Physical activity (steps) improvement	Number of steps	10000	70%	70	70
KPI.2.12	Physical activity (minutes of activity) improvement	Minutes	21	70%	70	70
KPI.2.13	Average eating habit improvement	% of Patients	70%	100%	143	100
KPI.2.14	Dropout rate	% of Patients (<25)	25%	12%	208	100
KPI.2.15	Performance of the Professional Web Tool	seconds (<5)	5	0.07	100	100
KPI.2.16	Body Cloud mobile app usage	Minutes (>10)	10	10.66	107	100
KPI.2.17	Professional Web Toll application usage	Minutes (>60)	60	68.82	115	100
Field 2.3: General					350	100
KPI.2.01	Use cases	Number	4	14	350	100
Dimension 3: Impact					174	100

KPI, Field and Dimension		Metric	Target (T)	KPI Value	D7.1 Scoring: Inter-IoT / Dimension / Field / KPI	Adjusted Scoring: Inter-IoT / Dimension / Field / KPI
Field 3.1: Business models					207	100
KPI.3.01	Dissemination channels	Number	20	60	300	100
KPI.3.03	Verticals involved	Number	3	4	133	100
KPI.3.12	Business or commercial meetings to present the project	Number	15	28	187	100
Field 3.2: Educational Effectiveness					120	95
KPI.3.04	Publication actions generated	Number	45	56	124	100
KPI.3.05	Organisation of Scientific events	Number	6	6	100	100
KPI.3.06	Academic impact (PhD and MSc Thesis)	Number	5	10	200	100
KPI.3.07	Participation in industrial dissemination actions	Number	8	8	100	100
KPI.3.08	Industrial demos development	Number	3	3	100	100
Field 3.3: Promotion of resources & Openness					100	100
KPI.3.02	Initiatives to support standardization	Number	4	4	100	100
KPI.3.09	Research projects identified for Cross Dissemination	Number	4	4	100	100
KPI.3.14	Collaboration in Free and Open projects	Number	2	2	100	100
Field 3.4: Community engagement					265	98
KPI.3.10	Social network followers	Number	1000	952	95	95
KPI.3.11	Number of individual addressed through different communication channels	Number	2000	12000	600	100
KPI.3.13	Participation in technological forums/discussions	Number	5	5	100	100
Dimension 4: Interoperability					175	87
Field 4.1: IoT devices and INTER-IoT modules					107	93
KPI.4.01	APIs offered by INTER-IoT layer-specific solutions.	Number	5	7	140	100
KPI.4.02	Issue tracking	Percentage	50%	0.4	80	80
KPI.4.25	Security mechanism in place	Number	3	3	100	100
Field 4.2: IoT platforms					131	94
KPI.4.03	IoT platforms integrated on MW2MW layer	Number	4	10	250	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	11	110	100

KPI, Field and Dimension		Metric	Target (T)	KPI Value	D7.1 Scoring	Adjusted Scoring
					Inter-IoT	Inter-IoT
					Dimension	Dimension
					Field	Field
					KPI	KPI
KPI.4.07	IoT platforms assets integrated in INTER-AS2AS	Number	10	7	70	70
Field 4.3: IoT system functional design					120	100
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	7	100	100
KPI.4.26	Documentation availability	Number	3	3	100	100
Field 4.4: Use of open technology devices and platforms					110	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	4	133	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	3	100	100
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					649	100
KPI.4.17	Semantic translation scalability	msg/ms	10	250	2500	100
KPI.4.18	INTER-MW scalability	msg/s	50	120	240	100
KPI.4.19	D2D scalability	Number	50	150	300	100
KPI.4.20	N2N scalability	msg/ms	100	107.02	107	100
KPI.4.21	AS2AS scalability	msg/s	50	50	100	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, Field and Dimension		Metric	Target (T)	KPI Value	D7.1 Scoring Inter-IoT	D7.1 Dimension	D7.1 Field	D7.1 KPI	Adjusted Scoring Inter-IoT	Adjusted Dimension	Adjusted Field	Adjusted KPI
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							108				90	
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%	100%				143				100
KPI.4.24	Failover mechanisms	Number	5	2				40				40
KPI.4.40	System uptime	h	168	192				114				100
KPI.4.41	INTER-MW Latency	ms	100	100				100				100
KPI.4.44	INTER-N2N Latency	ms	10	9.7				100				100
Dimension 5: Ethical, societal, gender and legal evaluation						79				79		
Field 5.1: Legal issues							92				92	
KPI.5.01	Legalisation assessment	Number	100 answers, positive results > 75%	91%				91				91
KPI.5.08	Number of identified regulations and public policies	Number	T1 >= 4 from at least T2 >=2 countries	T1=15 T2=7				100				100
KPI.5.13	Publicity of data for research	Number	100 answers, positive results > 75%	84				84				84
Field 5.2: Holistic innovation							74				74	
KPI.5.02	Human-centred innovations	Number	100 answers, positive results > 75%	59				59				59

KPI, Field and Dimension		Metric	Target (T)	KPI Value	D7.1 Scoring				Adjusted Scoring			
					Inter-IoT	Dimension	Field	KPI	Inter-IoT	Dimension	Field	KPI
KPI.5.03	Connections and trust	Number	100 answers, positive results > 75%	89				89				89
Field 5.3: User worktime / life impact							78				78	
KPI.5.04	Worktime - Time Saving	Number	100 answers, positive results > 75%	95				95				95
KPI.5.05	Life - Social inclusion	Number	100 answers, positive results > 75%	72				72				72
KPI.5.10	Threat on the labour demand	Number	100 answers, positive results > 75%	78				78				78
KPI.5.11	Help on disabled people's lives	Number	100 answers, positive results > 75%	65				65				65
Field 5.4: Targeted social groups							87				87	
KPI.5.06	Socially excluded groups Elderly / Disabled	Number	100 answers, positive results > 75%	80				80				80
KPI.5.12	Accessibility of INTER-IoT technology	Number	100 answers, positive results > 75%	94				94				94
Field 5.5: Trusted, safe, secure IoT environment promotion							81				81	
KPI.5.09	Trusted, safe, secure IoT environment promotion	Number	100 answers, positive results > 75%	81				81				81
Field 5.6: Community engagement							62				62	
KPI.5.07	Citizens' involvement	Number	100 answers, positive results > 75%	62				62				62

Table 2: Project results

3.2 Key Performance indicators

Each individual KPI will be addressed in detail below. KPIs are grouped into their respective dimensions and fields.

3.2.1 Exploitation

3.2.1.1 Stakeholder engagement

KPI.1.01: Stakeholders involved

WP2 undertook extensive work to identify stakeholders relevant to the project. 106 are identified and discussed in depth in D2.1.

KPI.1.02: Stakeholders analysed

Requirements gathered were managed in the JIRA system. Each requirement was tied to a stakeholder. Stakeholders who have highlighted requirements which have been addressed have been counted. 98 of the stakeholders have requirements that have been addressed in the project. This is higher than expected, but it is understandable as many stakeholders requesting overlapping requirements. For example, we did not implement a use-case addressing a ferry and patient monitoring system scenario, however, one of the requirements of this use-case was security of sensitive data. Security requirements were implemented in INTER-IoT, so we consider that we have addressed a requirement from this stakeholder. This may make this requirement seem artificially high.

KPI.1.19: Partners involved in joint exploitation

All partners have participated in the development of joint exploitation plans included in D8.7. Full details of the specific products and plans are available in D8.7 in annex B. Additionally many of the open-call third parties have also stated their intentions to explore joint exploitation of INTER-IoT components. These plans are included in annex D of D8.7.

3.2.1.2 Impact on SMEs, start-ups and young entrepreneurs

KPI.1.03-1.05

1 open call was successfully launched successfully during the project. We received 63 proposals in the Open Call. 12 proposals were accepted and the new third parties joined the project from this point forward. All of the third-party contributions have now been completed successfully. A full description of the open call process is included in D8.5 and D8.7b. Results of the open call projects are addressed in D6.2 and D6.3.

KPI.1.14: Spin-offs created

SRIPAS is planning to set up a spin-off company that will further extend and promote semantic solutions developed within the INTER-IoT project. At the moment, there are no official arrangements done, and next steps are to establish the objectives and business plan.

3.2.1.3 Exploitation: Business models

KPI.1.06: Business models proposed

Initial work to define business models was done in D2.2 early in the project. In order to further develop this work additional methodology was proposed in D8.7a to evolve the current work using the LLAVA methodology. The final version of D8.7 includes the updated business models set out by each partner. In total, 23 business models have been defined by partners and third parties. These are described in D8.7. Particular focus is given to those that utilize the selected products.

KPI.1.11: Business model flexibility

Many business models can be applied to multiple aspects of INTER-IoT. D8.7 specifically highlights the flexibility of 4 types of business models: traditional, IaaS, PaaS, and SaaS. These are addressed in chapter 3 when assessing business development per product layer.

KPI.1.20: Openness in business models

13 of the project partners and open call members have business models that involve reliance on open source software developed within INTER-IoT. In many cases, consulting services will be the primary income stream. In others, open source software will be used in conjunction with additional protected components. Additionally, many of the university partners will utilize open source software in course work forming the basis of degree programs. A few of the partners do not ever seek IP as part of their business allowing the clients to retain all IPR, so working open source is not often an option. Annex A and annex C in D8.7 outlines each partner's specific opensource vision.

KPI.1.22: Channels selected

Partners highlighted 5 key channels for moving forward with the promotion and sales of INTER-IoT products. They are partner traditional business and marketing operations, OSS channels, university channels, training agencies, and cloud services channels. They are further defined in D8.7.

3.2.1.4 Market readiness and monetization mechanisms

KPI.1.07: Monetizable products

D8.7 is the primary source for product related information. In section 3.5 the primary exploitable results are addressed. These are the versions of the selected products which were explored in greater detail by the partners. They include gateway, middleware, framework and mythology related products. There are 10 defined. Additional products are defined in D8.7. KPI.1.12 highlights these products.

KPI.1.10: Open-source readiness

D7.2 documented the readiness of INTER-MW, IPSM and INTER-API code and documentation. In this deliverable, we have evaluated the readiness of N2N, D2D, AS2AS, and INTER-FW. KPI.4.10 provides the location and the specifics of this activity. In total, 7 repositories of open-source code have been made available as part of the INTER-IoT project.

KPI.1.15: Time to go-to-market

D8.7, chapter 5, address partner specific go to market timings. The average time is 3 months from the project end with most partners planning to offer INTER-IoT related products in the first quarter of 2019. Some partners are already prepared, and others have left this as unconfirmed currently.

KPI.1.16: Commercial presentations

28 presentations were given as part of INTER-IoT. They are listed and detailed in D8.6.

KPI.1.17: Commercial leads

A survey of project partners and 3rd parties we carried out as part of the project evaluation. Partners identified a total of 77 commercial leads. This was a promising result as we had predicted about 20. As part of the follow-on for the project, these will be explored so the full commercial potential of INTER-IoT can realized by the companies involved.

KPI.1.18: Commercial industrial events

The partners from the consortium have in total attend 75 industrial events. Full details are included in D8.6.

KPI.1.23: Effective business model design

Each partner completed a LLAVA matrix as part of the exploitation and impact section of INTER-IoT. These are included in D8.7 annex F. This exercise proved very useful and will be carried forward by many partners beyond the scope of the project. This lead to 14 completed LLAVA matrixes.

KPI.1.24: Competitors

Rather than an indication of the project's success, this KPI highlights the competitiveness of the market. A score of 100 indicates that no competitors exist while a score of close to 0 indicates a high degree of competition. Partners identified 39 competitors leading to a score of 2.5. If no competitors had been identified, it is not necessarily a good thing as this may indicate there is no need for your solution. However, in this case, if you can show a good business case, then you can create a market. Additionally, if too many competitors are in the market, you must highlight your value proposition to differentiate yourself. A full list of the competitors is available in D8.7 along with associated arguments for how INTER-IoT products could be preferable. Consulting firms and universities could also be considered in this analysis.

3.2.1.5 Inclusiveness and participation of third parties

KPI.1.08: Private companies using INTER-IoT products (estimate)

The companies within the INTER-IoT consortium are all using products developed within INTER-IoT. Additionally, seven of the open-call partners are using products developed during the open call. For this KPI we have recorded 15 in line with the current usage. Partners have also estimated potential sales of INTER-IoT based products. Some partners have offered estimates of new clients based on INTER-IoT. Others have highlighted improvements to existing products already supplied which current customers are interested in purchasing. Hard number are difficult to estimate here. Annex A, B, C and D of D8.7 give further details in this area.

KPI.1.09: Public institutions using INTER-IoT components (estimate)

The public institutions within the INTER-IoT consortium are all using products developed within INTER-IoT. Additionally, public institutions of the open-call partners are using products developed during the open call. We have recorded 10 in line with the current usage.

KPI.1.21: External partnerships and collaborations

Consortium partners have established more than 3 external partnerships with entities outside of the project. These include hauler companies, government agencies, research groups and healthcare providers. Additionally, some partnerships are also protected by NDAs, so they are not possible to present. Overall there has been a lot of external interest in working with INTER-IoT partners to utilize the technology developed in the project.

3.2.1.6 Exploitation of products

KPI.1.12: Derived products

D8.7 fully addresses the products that have been derived from INTER-IoT modules. There are 25. A deeper exploration is done of seven of these including the full solutions deployed in the large-scale pilots. Additional details of these products are given in WP6 deliverables.

KPI.1.13: Existing products influenced by INTER-IoT developments

In addition to the INTER-IoT stand-alone products discussed extensively in D8.7, project partners and open call members have included parts of INTER-IoT in existing products. Below is the list of these products

- PRIME-IoT Gateway
- INTER-HARE
- MSC Enabler
- Senscape TM
- BodyCloud
- Posidonia Port Solution®
- INTER-NINC
- Nemergent Controlroom
- DocRAID
- DATAKORUM pole series light controller

KPI.1.25: IPR

There are three partners, SRIPAS, XLAB and PRODEVELOP, that are interested in doing commercial exploitation of their developments related to INTER-IoT. The rest of the partners, are exploiting know-how extracted from their own results achieved during the project.

3.2.2 Pilots

3.2.2.1 INTER-LogP pilot

KPI.2.03: Number of objects connected to INTER-LogP

this pilot there will be 235 objects directly connected to INTER-IoT in addition 2 of the open call partners are now participating in this pilot which has raised the number to 259. A full description of the INTER-LogP pilot is give in WP6 in D6.2 and D6.3.

KPI.2.04-2.07

The INTER-LogP pilot is running in the Port of Valencia. As this is a live environment currently utilizing the new INTER-IoT technology which plans to continue utilizing INTER-IoT's contribution to their infrastructure, updates to these KPIs are continuous and will continue beyond the end of the project. More importantly than the KPIs reported here is the demo which will take place in Valencia in late February where the reviewers will be able to observe the system in full operational mode.

The following results have been collected during pilot conditions. Additional results will be reported at the final review as more data is gathered. A high level of accuracy has been observed with respect to gate activity and this is reflected in KPI 2.04 where less than five minutes of difference is observed between ETA and ATA of monitored vehicles. Additionally, the lighting systems associated with KPIs 2.05 and 2.06 have shown good sensitivity to movement and activation of the associated lighting. KPI 2.07 has also exceeded expectations during the pilot. Operational results will be presented at the review so that progress of the system can be updated.

3.2.2.2 INTER-Health pilot

Compared the traditional nutritional counselling with the experimental nutritional counselling we have an innovative point of view available in the Inter Health system:

- Professional Web Tool (PWT) that allows the collection, uploading and consultation of health data collected during the nutritional counseling. The PWT is not a traditional nutritional folder but a dynamic online system in dialogue with devices equipped with a bluetooth wireless interface, which allows the transmission and recording of measurements taken with devices of the outpatient and received from the application installed on the smartphone of the subject in a decentralized way showing the progress of the activities carried out between the first visit and the subsequent check.
- a kit of electro-medical devices (a weight scale, a sphygmomanometer and a bracelet for the detection of physical activity) provided to the Experimental Group subjects throughout the study pilot, equipped with a bluetooth wireless interface to communicate with the smartphone with data connection (wifi / 2G / 3G) to transfer data collected with devices to the PWT database present in a central server installed in the ASL TO5 network.
- application installed on a smartphone that allows subjects to consult their activity progress and to fill in an online questionnaire on eating habits and the practice of physical activity, for a decentralized monitoring in their own homes and in mobility of their lifestyle.

The system described, compared to the proposals on the market, uses the Internet of Things technology so that both the health operators with their user credentials can access to the PWT database and can monitor the health progress of the subject and the subject itself can access, with its own credentials, to the application installed on smartphone, displaying its objective and subjective measures detected by the electro-medical devices and provided by the online questionnaire.

The decentralized monitoring allows the establishment of a less constrained subject / health operator relationship and the possibility to go to the outpatient in case of need, but more focused on the evaluation of the collected values in which the subject is himself the operator of his own health status.

It’s possible to highlight three areas of interest:

Scientific objectives

According to the medical standard protocols for the prevention and management of obesity to assess the health status (underweight, normo-weight, overweight, obesity) of a subject during a visit in the outpatient are collected objective measures (weight, height, BMI, blood pressure and waist circumference) and subjective ones (eating habits and physical activity practice). Among the objective measures, a key role for the diagnosis of overweight and obesity is the BMI value and the waist circumference value, directly related to the percentage of visceral adipose tissue (values of waist circumference higher than 94 cm for men and 80 cm for women are considered pathological). Physical activity, such as eating habits, is counted among the subjective measures and is normally detected in the outpatient by instruments such as frequency questionnaires. Today, technology provides the ability to measure objectively the physical activity practiced through the use of wearable mobile devices, objects that are part of the Internet of Things network (IoT).

Technological objectives

Creation of a "Inter health" tested health system to be offered to other private and public nutritional counseling outpatients. The criticality to be overcome in the technological field is the loss of data due to:

- No association of devices with the smartphone application due to lack of bluethooth association
- Physical errors of the user during association / monitoring phase

Economic / financial objectives

The need for the creation of a new IoT ecosystem in health care arises from the growth of number of subjects suffering from chronic diseases risk and from the increase in the senior class of the Society. Since the average life expectancy has increased, it is necessary to guarantee, with the same resources of the national health system, a more efficient and effective system for primary prevention from the main chronic-degenerative diseases. By comparing the different demands and offers of stakeholders (Public Institutions, Healthcare Operators, Research Institutes, Non-profit Organizations, etc.) in term of interoperability in the health care sector, the market will be favored, useful for the economic development of the Society as it allows a real savings on public and private healthcare costs.

The study ends with the hope that the Ministry, having seen and demonstrated all the benefits of the IoT in the field of prevention, and considering the current historical situation, is ready to invest in "new technologies."

Some developers propose to those who deal with proper lifestyles and in particular nutrition many applications or software for the management of the outpatient activity or for the registration of data collected during nutritional counselling.

At the same time, numerous smartphone applications are available for monitoring physical activity or for the possibility of compiling a virtual food diary.

The development of these applications is not always accompanied by the experience of professional figures who follow the subject in a possible path of lifestyles improvement, as in the same way many management proposals for the outpatient are not always designed ad hoc but they are not user friendly.

The market of new technologies in the healthcare sector should provide open devices with fast connections in order to overcome the problem of losing data.

It should also provide and develop (remote) assistance in the application field, in order to allow a homogeneous and randomized participation of end users, preserving classes that may be disadvantaged.

KPIs

After 1 year through the decentralized telemonitoring, we evaluated the following KPIs. Updated numbers will be available at the review in February as the study continues beyond the end of the project. Comparisons with test and control group will be available then.

KPI.2.02: Number of patients connected to INTER-Health

102 patients have been recruited to INTER-IoT. This is in line with the study protocol and has been reported by observing the number of patients registered in the health platform that actually use the mobile app.

KPI.2.08-2.14

Overall, INTER-Health Pilot is having a positive effect on the test population. The current patients BMI breakdown is now 32.5% normal weight, 43% overweight, and 24.5% obese. Additionally the rate of chronic disease is down to 29%. Physical activity monitoring is progressing well with increased step counts and overall time of activity. 44% of patients are now active for 30-60 minutes per day. Eating habits have improved in 100% of subjects. The drop-out rate is 12% which is less than we hoped for.

Patient specific outcomes will be addressed again in the final review as the clinical study is running beyond the end of the project.

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.

We can appreciate differences in ***Figure 3***. Now the health professionals are more focused on checkups, being the rest of tasks balanced on usage time. Current flow is similar to the one from D7.2. It is due to the fact that the PWT is designed using checkups as a center element and the rest of functionalities are complementary. It means that the tool meets the needs of the professionals and there is a clear better understanding of the tool.

Information extracted from D7.2 | Current information

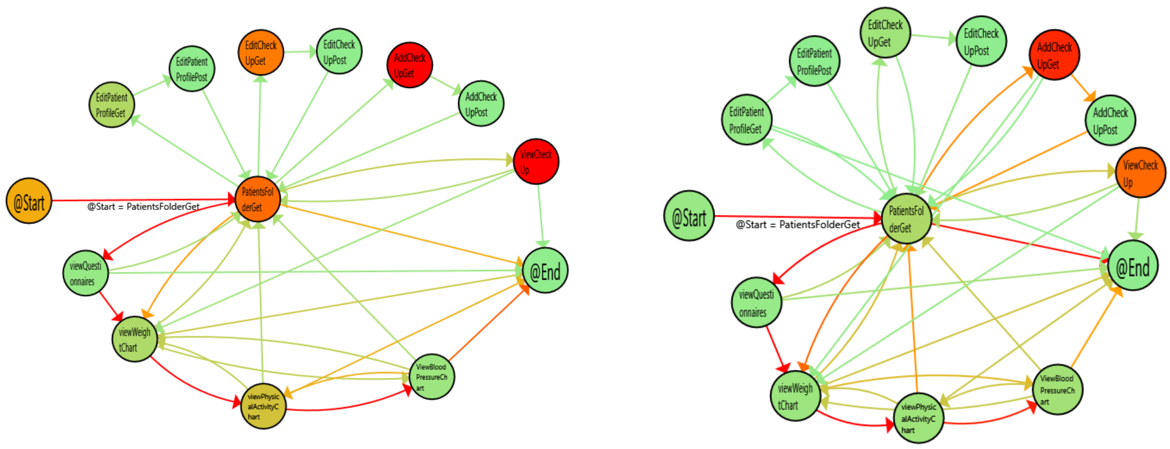


Figure 3: Actions done by a PU per patient

In this final stage of the project the usage of the tool is more normalized, since there are previous checkups and the professionals can compare among them.

Information extracted from D7.2 | Current information

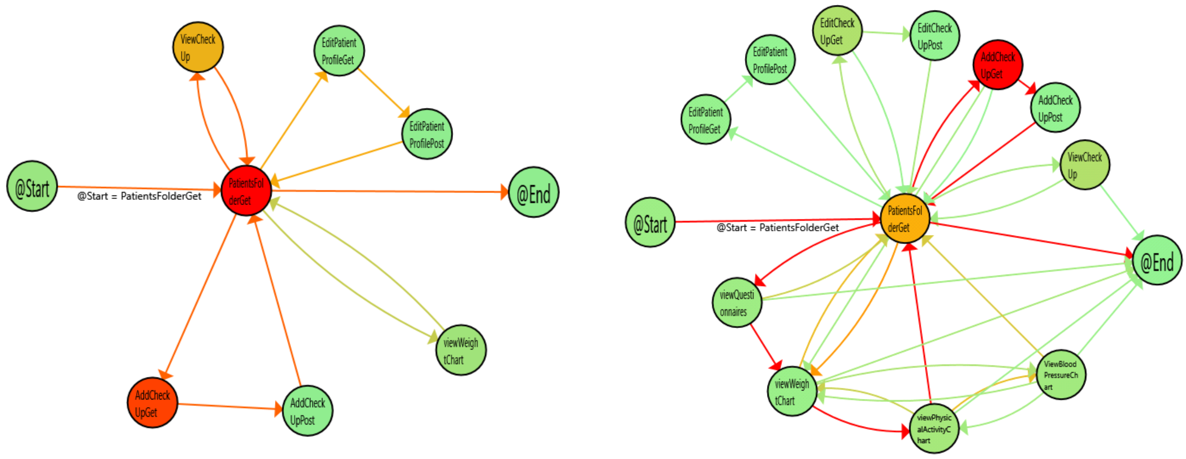


Figure 4: Actions done by a PU during a counselling

There is no relevant difference between the previous stage and the current one. In both cases behaviour is similar in the first counselling.

Information extracted from D7.2 | Current information

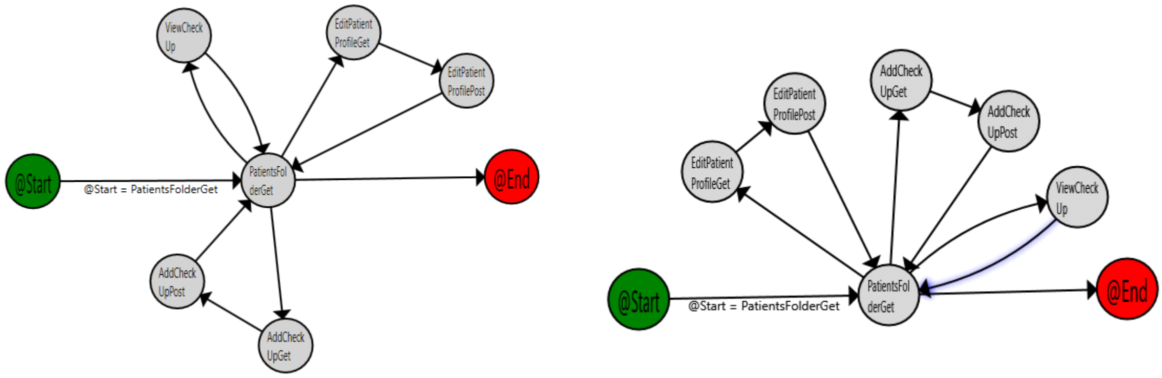


Figure 5: Actions done by the professional user during the first counselling

In the previous stage, described in D7.2, there were few cases in which a subject had more than one checkup. Due to it, only few features of the tool were used during a second counselling. Now, health professionals do a normal use of it, checking preceding checkups.

Information extracted from D7.2 | Current information

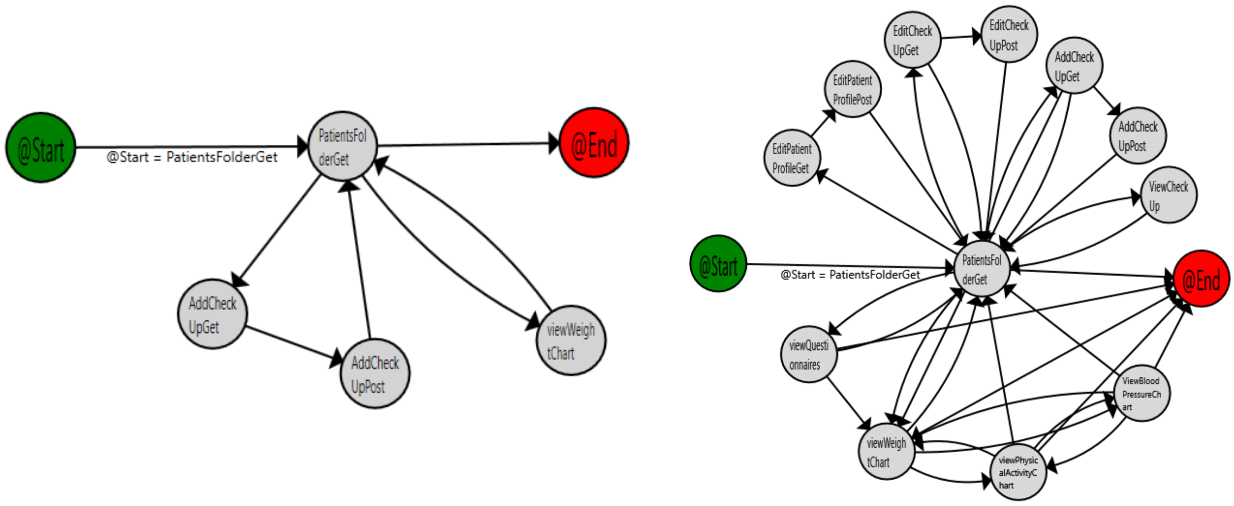


Figure 6: Actions done by the professional user during the second counselling

The third counselling is similar to the second one. They usually don’t edit previous information of the subject.

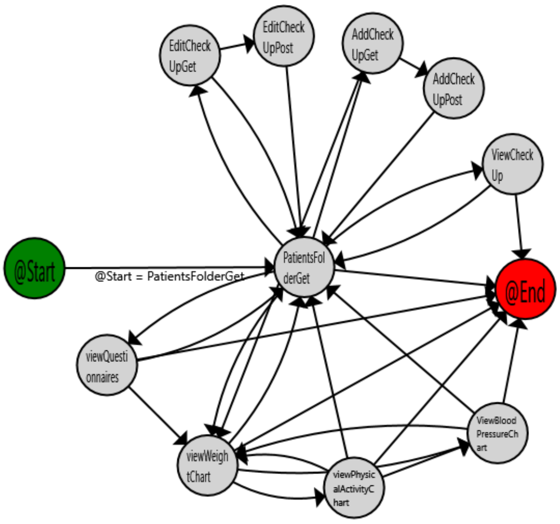


Figure 7: Actions done by the professional user during the third counselling

Both graphs are similar, being the most identifiable different the fact that in previous stages health professionals entered to edit previous checkups. It could be a consequence of not knowing properly the tool. In this last stage, it seems that the usage of the tool is appropriate according to the requirements specified.

Information extracted from D7.2 Current information

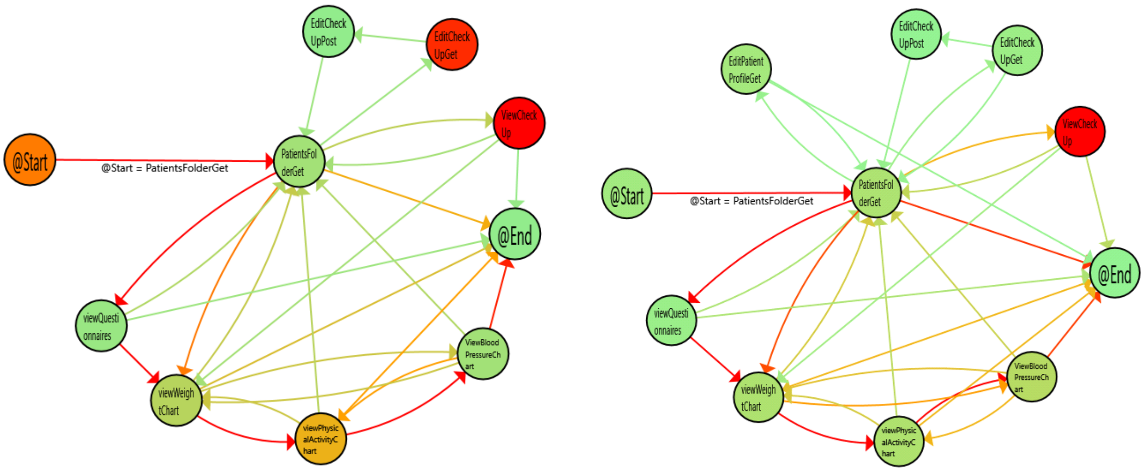


Figure 8: Actions done by a PU when consults a patient's profile

In summary, as it was stated in D7.2, it is difficult to quantify KPI.2.17 per se, 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.2.16 Body Cloud mobile app usage

An average of 10 minutes and 40 seconds was spent by the patients using the mobile app every day. This was observed by adding the time spent on each screen of the app together. This can be interpreted positively as a good indicator of participant commitment to the project. Alternatively, it could be considered as a negative reflection on the user experience as users may not be able to efficiently navigate when using the application.

3.2.2.3 General

KPI.2.01: Use cases

14 use cases have been addressed for INTER-Health and INTER-Domain. They are defined in detail in D2.4 and further developed in WP6 deliverables. A large of number of INTER-Domain use cases have been generated by the open call partners. This is the primary reason that we have exceeded the target of 4 set for this KPI.

3.2.3 Impact

3.2.3.1 Business models

KPI.3.01: Dissemination channels

The project utilized multiple dissemination channels. Partners utilized their own online presence and project specific websites and social media. Additionally, multiple events were used to promote the project. D8.6 has a full list. Overall, we exceeded the goal of 20.

KPI.3.03: Verticals involved

INTER-IoT is potentially useful for multiple verticals beyond what has been addressed in the project. To maintain focus and not try to accomplish too much, we address 4 primarily. The verticals addressed by the project are Transport & Logistics, Active & Healthy Ageing (AHA), e-Health, and 5G communications. Two of these are explicitly addressed in the pilots done as part of WP6.

KPI.3.12: Business or commercial meetings to present the project

INTER-IoT partners participated in 28 relevant meetings to present project demos and technology. Full description of these is provided in D8.6.

3.2.3.2 Educational Effectiveness

KPI.3.04: Publication actions generated

56 publications have been completed as part of the project to date. A full list and description is included in D8.6. This exceeds the goal set of 45 significantly.

KPI.3.05: Organisation of Scientific events

Full description of all events arranged is included in D8.6. Six were arranged in total. Below is a list of those arranged by INTER-IoT partners which featured INTER-IoT.

- -IEEE ICNCS 2017
- -InterIoT 2017
- -Globe-IoT (2016,2017,2018)
- -Data-Science center summit of Eindhoven Lecture by Giancarlo Fortino, Towards Interoperable, Cognitive and Autonomic IoT Ecosystems: an Agent-based Approach (2017)

KPI.3.06: Academic impact (PhD and MSc Thesis)

INTER-IoT has been the basis of 10 MSc and PhDs. This has exceeded our expectations as the original KPI goal was 5.

- 1 MsC (VPF)
- 1 MsC (SRIPAS)
- 1 MsC (UNICAL)
- 1 MsC (TUe)
- 1 PhD (SRIPAS)
- 1 PhD (UNICAL)
- 2 PhD (TUe)

KPI.3.07: Participation in industrial dissemination actions

INTER-IoT partners participated actively in numerous industrial events. D8.6 give full details of the event attendance, the role of INTER-IoT partners in the event and event details. The total number is not available as many of these occurred under NDA. We have exceeded the target of 8.

KPI.3.08: Industrial demos development

INTER-IoT partners prepared 3 demos that are given at multiple industrial events. D8.6 gives full details of the event attendance. The total number for this KPI is not available as many of these occurred under NDA. We have exceeded the target of 3 events where a demonstration was given.

3.2.3.3 Promotion of resources & Openness

KPI.3.02: Initiatives to support standardization

INTER-IoT has worked with 4 bodies which support standardization. These are AIOTI, the FIWARE foundation, IQRF group, and HL7. These relationships have been positive and productive.

KPI.3.09: Research projects identified for Cross Dissemination

INTER-IoT has identified 4 project where the work done can have a real impact and cross dissemination has been completed.

- chariot
- Activage
- Pixel
- 5genesis

KPI.3.14: Collaboration in Free and Open projects

INTER-IoT has contributed to two open source projects as part of the project. Node-red, and ITEA3 ESTABLISH. These contributions have helped to promote INTER-IoT in the opensource community. Additional work to engage the opensource community is underway and detailed in D8.7. The ultimate goal is to have parts of INTER-IoT integrated into established open source communities.

3.2.3.4 Community engagement

KPI.3.10: Social network followers

INTER-IoT has had a good presence on social media. We have 603 twitter followers, 276 linkedin connections, and 73 facebook likes. This is 952 total social media connections. Or target was 1000 so we nearly accomplished this.

KPI.3.11: Number of individuals addressed through different communication channels

Impact creation is addressed in detail in D8.6. When assessing the number of individuals addressed, we considered our online presences and our in-person contacts. Our online assessment included social media followers as defined in KPI.3.10, project and company web page views and youtube views. In person impact included event participation numbers and individual meetings. Most event numbers were not known exactly so an estimate has been given for these. In total approximately 12,000 individuals have been presented with information about INTER-IoT.

KPI.3.13: Participation in technological forums/discussions

Partners participated in multiple technology forums and discussions. This included task force telcos within IoT-EPI, where INTER-IoT partners were very present. Additionally, we have been involved with standards bodies discussion forum such as with HL7 where we specifically promoted the IPSM. Result of this collaboration is a joint paper, that is in preparation, that compares INTER-IoT approach for semantic interoperability with semantic translation approach proposed and tested by HL7.

3.2.4 Interoperability

3.2.4.1 IoT devices and INTER-IoT modules

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

A detailed evaluation of INTER-Layer REST API interfaces and of the Unified INTER-API has been performed in D7.2. Although the evaluation in D7.2 was successful, there were three non-compliant DELETE methods, all other REST calls performed as expected.

In this evaluation we successfully re-iterated the all tests performed in D7.2, including those methods from the n2n layer that failed previously (reported in the table below).

Layer	method	Test Results	Endpoint	Comment
n2n	DELETE	Working	/n2n/switches/{switchId}/tables/{tableId}/flows/{flowId}	Successful flow deletion
n2n	DELETE	Working	/n2n/switches/{switchId}/rules/{ruleId}	Successful rule deletion

Table 3: KPI.4.01 additional test results

KPI.4.02: Issue tracking

Improvement has been seen in this category as in D7.2 we were on 0.3 and we have now improved to 0.4. 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.

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.

3.2.4.2 IoT platforms

KPI.4.03: IoT platforms integrated on INTER-MW layer

In D7.2 successful evaluation of five bridges used in the LogP and eHealth pilots has been performed. In this deliverable an additional bridge was added to the LogP pilot (Azure) and four additional bridges developed by 3rd party open call projects. They have all been evaluated either through the LogP pilot or FAT/SAT documents provided during the Open Calls final evaluation meetings.

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

Platform	Repository	Main authors	Status
Azure	https://git.inter-iot.eu/Inter-IoT/intermw_bridge_azure	Neways	Functional as part of the INTER-LogP pilot.
Sensinact	https://git.inter-iot.eu/Inter-IoT/intermw_bridge_sensinact	CEA (3rd party)	FAT/SAT confirmed during the final Open Calls evaluation (Valencia, 24.10.2018 - 25.10.2018). Used in ACTIVAGE.
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 and ACTIVAGE..
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	PRO/UPV	Functional. Will be used in ACTIVAGE pilots from January 2019.
OM2M	https://git.inter-iot.eu/Inter-IoT/intermw_bridge_om2m	VUB (3rd party)	FAT/SAT confirmed during the final Open Call evaluation (Brussels, 29.11.2018).
e3tcity	https://git.inter-iot.eu/Inter-IoT/intermw_bridge_e3city	E3TCity (3rd party)	FAT/SAT confirmed during the final Open Calls evaluation (Valencia, 24.10.2018 - 25.10.2018). In addition,the bridge has been integrated in the LogP pilot.
Semantic Middleware	https://git.inter-iot.eu/ecaldarola/ViaggiaTreno_Platform https://git.inter-iot.eu/ecaldarola/OpenWeather_Platform https://git.inter-iot.eu/ecaldarola/CasAware_Platform https://git.inter-iot.eu/ecaldarola/CasAware_Dashboard	ITIA-CNR (3rd party)	FAT/SAT confirmed during the final Open Calls evaluation (Valencia, 24.10.2018 - 25.10.2018).
BodyCloud	https://git.inter-iot.eu/Inter-IoT/intermw_bridge_bodycloud	UNICAL	Functional as part of the INTER-LogP pilot.

Table 4: INTER-MW platform bridges

A total number of ten bridges has been developed and successfully evaluated as part of the INTER-IoT ecosystem. In addition the the bridges listed above, INTER-MW has been used by UPV and other partners in the ACTIVAGE EU research project (http://www.activageproject.eu/) with the following bridges: FIWARE, universAAL, SENIORSOME, OpenIoT, sensiNact, IoTivity and Sofia2.

KPI.4.04: IoT platforms integrated on AS2AS layer

The expected number of platforms has been reached. The 3 parties have contributed in this area demonstrating one of the benefits of the open call to the project success. 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

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. Higher KPI values are to be expected with more usages of INTER-MW and IPSM as the project progresses beyond the end of the project.

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
- Semantic Middleware and SensinAct platforms – 1 alignment

Further alignments will be prepared when INTER-IoT products are exploited outside the project.

KPI.4.07: IoT platforms assets integrated in INTER-AS2AS

The total number of services desired has nearly been reached (7 of 10). The development of nodes was the focus during the first stages of the project. Additional progress was made during the final months of the project, with the collaborations of the Opencall partners and the pilots contribute to the acceleration in the creation of new nodes.

3.2.4.3 IoT system functional design

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. A survey has been conducted of UNICAL research groups, spinoffs and labs to assess the utility of INTER-METH at driving the integration process. It was found that INTER-METH is notably effective in driving the integration process. This is associated with a score of 3.

KPI.4.10: Documented deployment and update procedures

For D7.2 the following deployments have been evaluated: INTER-MW, IPSM and INTER-API. In this deliverable, we have evaluated N2N, D2D, AS2AS, INTER-FW.

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.

Component	Documentation	Status
N2N	https://docs.inter-iot.eu/docs/n2n/latest/sdn-solution/user-guide/#installation	N2N has been deployed by the following project partners: UPV and TUe.
D2D	https://docs.inter-iot.eu/docs/gateway/latest/user-guide/getting-started/	D2D has been deployed by the following project partners: UPV, NEWAYS The following Open Calls also tested the deployment procedures: AUEB, IRIDEON, UPF.
S2AS	https://docs.inter-iot.eu/docs/as2as/latest/deployment-guide/howtodeploy/	AS2AS has been deployed by at least two project partners: UPV, VPF, PRO. The following Open Calls also tested the deployment procedures: INTER-HINC, SecurIoTy.
INTER-FW	https://git.inter-iot.eu/Inter-IoT/framework https://git.inter-iot.eu/Inter-IoT/wso2-sso	INTER-FW has been deployed by at least two project partners: PRO and UPV.

Table 5: Deployment and update procedures

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.

With the addition of previous evaluation, we have confirmed that all components have been successfully evaluated, thus assigning the value of 7 to this KPI.

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, 100% of the code is now fully documented.

3.2.4.4 Use of open technology devices and platforms

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. These frameworks have been found to address the current use cases in INTER-IoT.

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.4.43: 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.

3.2.4.5 Use of supported standards

KPI.4.14: Standards supported

Each component has made the limit of a minimum of 3 standards supported. After combining all the lists, the following standards are supported:

- FIWARE Device Model
- SAREF
- OBIX
- REST
- JSON
- OSGi
- WebSocket
- AMQP messaging
- APACHA Kafka messaging
- OWL RDF Turtle
- MQTT
- ModBUS
- XACML
- OAUTH
- SAML
- XML
- YAML
- JSON-LD
- NGSI from FIWARE
- Bluetooth 4.0

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.

Additional work has also been done to prepare alignments for oneM2M ontology and SAREF ontology (greater coverage that the alignment prepared within INTER-IoT-EWS).

3.2.4.6 Scalability

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 and KPI.4.41: INTER-MW scalability and Latency

In-depth INTER-MW evaluation involved three separate tests performed on Azure cloud VM deployments. They are all related to performance evaluation in a real-world scenario, related with the LogP pilot. We performed the following series of tests:

1. **T1:** This series of tests without IPSM has been the same as performed in D7.2 on physical machines at XLAB, but this time on Azure cloud. The duration of each test was between 5 and 20 minutes.

2. **T2:** The second series of tests is an extension of the previous, with inclusion of IPSM for message translation. For this test, the maximum frequency of observations generation has been limited to 10 msg/sec, in-line with IPSM specifications.
3. **T3:** The third test was performed on the production deployment of the LogP platform. The evaluation software module has been subscribed to all devices and received all observation messages for 24 hours. In this experiment we had no control over the type and frequency of generated messages.

T1 and T2 tests involved 3 (three) 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 in T1 and included in T2. Testing was done on a Standard_DS2_v2 Azure instance, see specification in the table below.

	Emulation tests ET1, ET2	**LogP test PT1**
Azure VM type	Standard_DS2_v2	Standard_DS11_v2
Server name	vmplsp02	vmbrkr01
vCPU	2	2
Memory: GiB	7	14
Temp storage (SSD) GiB	14	28
Max data disks	8	8
Max cached and temp storage throughput: IOPS / MBps (cache size in GiB)	8,000 / 64 (86)	8,000 / 64 (72)
Max uncached disk throughput: IOPS / MBps	6,400 / 96	6,400 / 96
Max NICs / Expected network bandwidth (Mbps)	2 / 1500	2 / 1500

Table 6: testing specification for Standard DS2 v2 Azure instance

T3 involved three platforms (wso2port, azureport, traxens) with the total number of 85 registered devices and 12 subscriptions. However, during the 24h testing period only gate opening sensors from the WSO2 platform sent observations.

T1 evaluation

We executed a series of six experiments with message creation frequency ranging from from 30 msg/s to 120 msg/sec. The duration of the first four experiments was 5 minutes. In order to verify the system stability, we repeated 90 msg/s and 120 msg/s experiments for a longer period of 20 minutes. With this approach we test the performance both 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 max. 100 ms at the message rate of around 50 msg/sec.

The overall results are provided in the tables below:

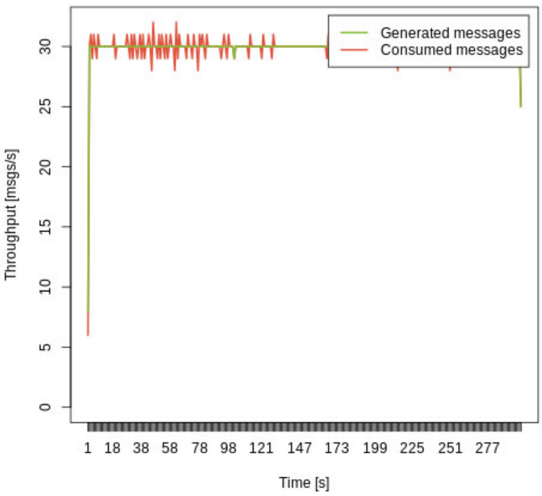
device	Experiment no.	Average message generation rate [msg/s]	Average message consumption rate [msg/s]	Total number of messages	Latency min [ms]	Latency max [ms]	Latency mean [ms]	Latency median [ms]	Duration [min]
vmplsp02	1	30	30	8972	7	88	10,373	9	5
vmplsp02	2	59	59	17943	7	113	11,143	10	5
vmplsp02	3	90	90	27049	8	2950	270,560	19	5
vmplsp02	4	119	119	35853	8	19117	4169,905	32	5
vmplsp02	5	90	90	81690	8	2500	69.751	17	15
vmplsp02	6	119	119	107842	7	20567	1714.714	20	15

Table 7: T1 evaluation results

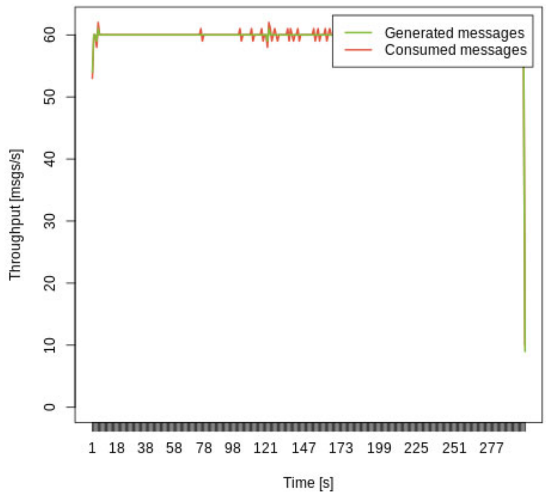
The immediate conclusion, by checking the values of the first and second experiments is, that at the message generation speed of around 50 msg/s we are reaching the target of latency under 100 ms.

However, a more in-depth analysis shows several interesting features, capabilities as well as possible limitations of the system.

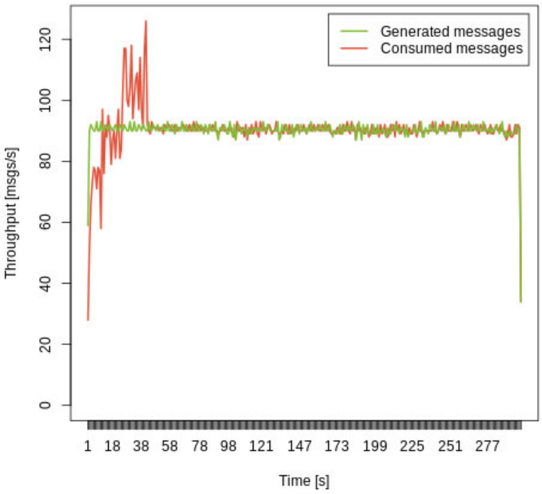
In the first set of graphs the generation speed vs. message consumption speed is shown. The x-axis shows time in seconds from the beginning of an experiment, typically, from one to 300 (5 min) or 900 (15 min) seconds. On the y-axis we show the throughput as number of messages per second (green - generated messages, orange - consumed messages).



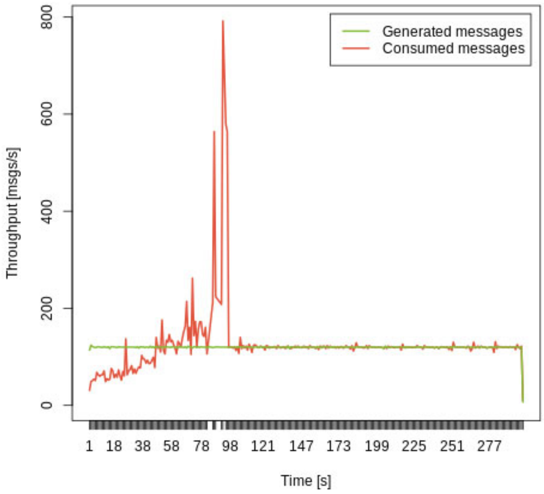
Message generation frequency 30 msg/s, experiment duration 5 minutes.



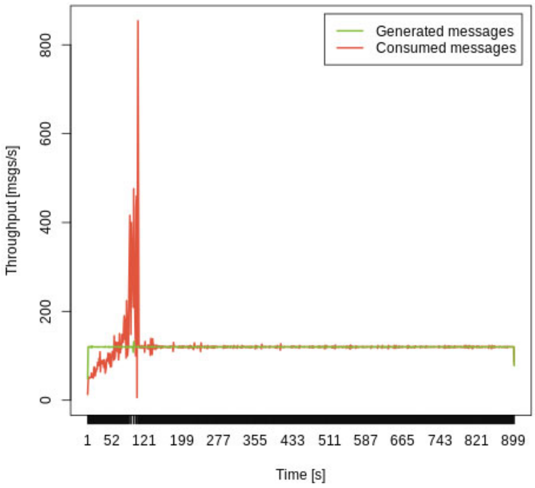
Message generation frequency 60 msg/s, experiment duration 5 minutes.



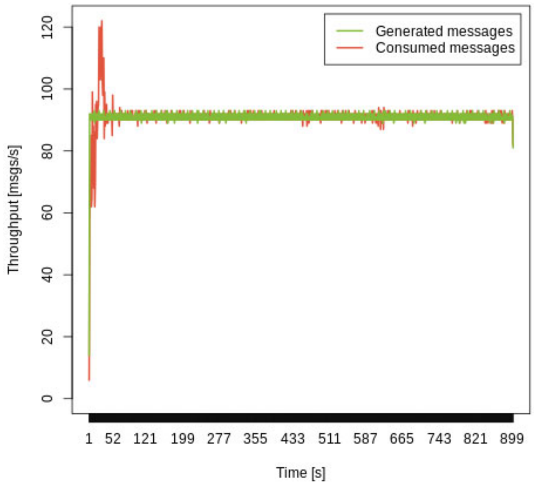
Message generation frequency 90 msg/s, experiment duration 5 minutes.



Message generation frequency 120 msg/s, experiment duration 5 minutes.



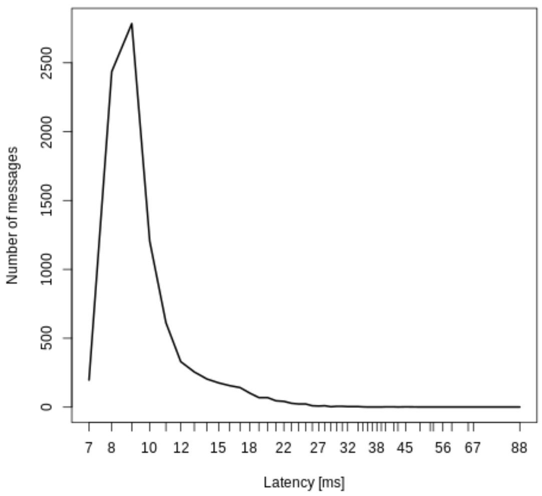
Message generation frequency 120 msg/s, experiment duration 15 minutes.



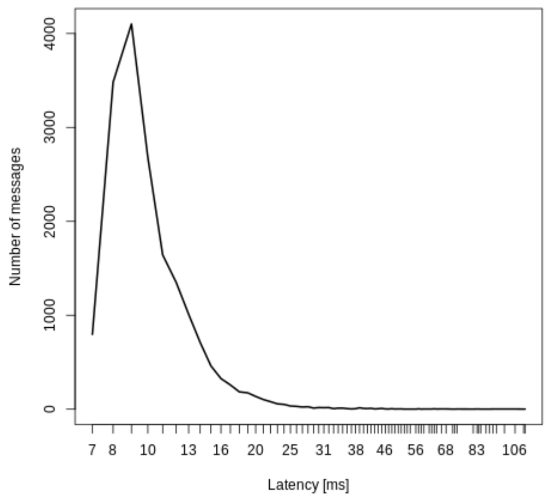
Message generation frequency 90 msg/s, experiment duration 15 minutes.

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 increasing generation frequency.

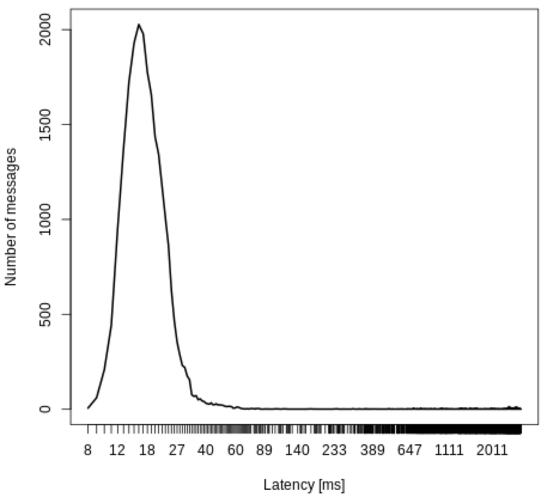
In the second set of graphs the distribution of the latency is shown. The x-axis shows the latency in milliseconds (logarithmic scale). On the y-axis we show the number of messages (distribution).



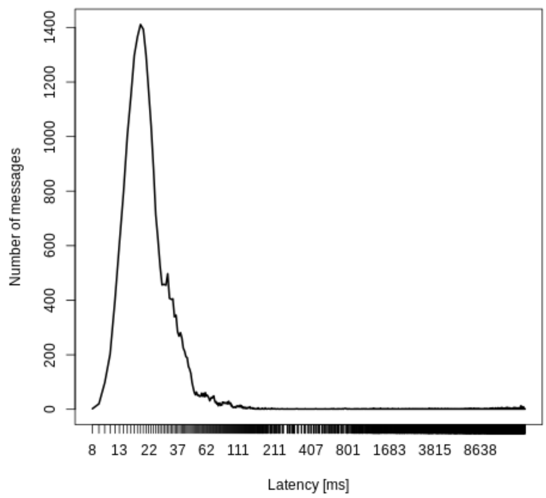
Message generation frequency 30 msg/s, experiment duration 5 minutes.



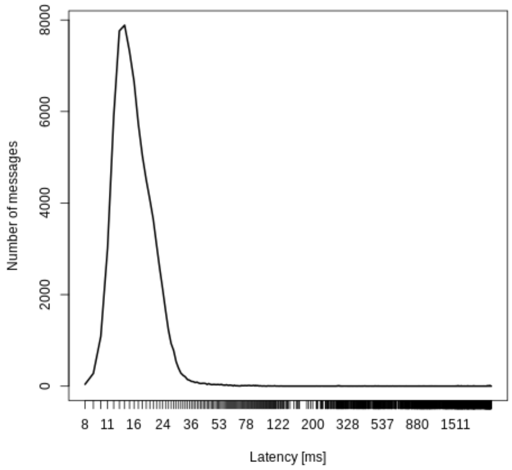
Message generation frequency 60 msg/s, experiment duration 5 minutes.



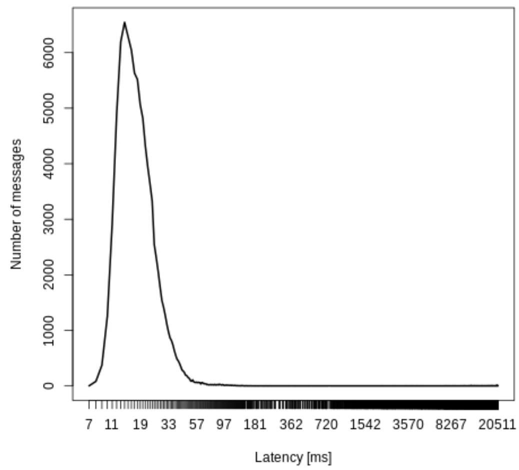
Message generation frequency 90 msg/s, experiment duration 5 minutes.



Message generation frequency 120 msg/s, experiment duration 5 minutes.



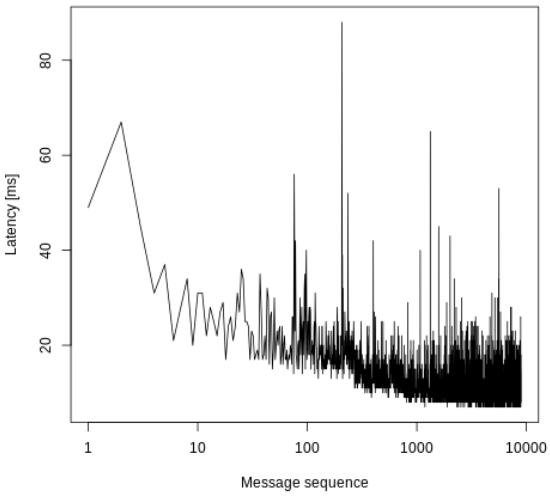
Message generation frequency 90 msg/s, experiment duration 15 minutes.



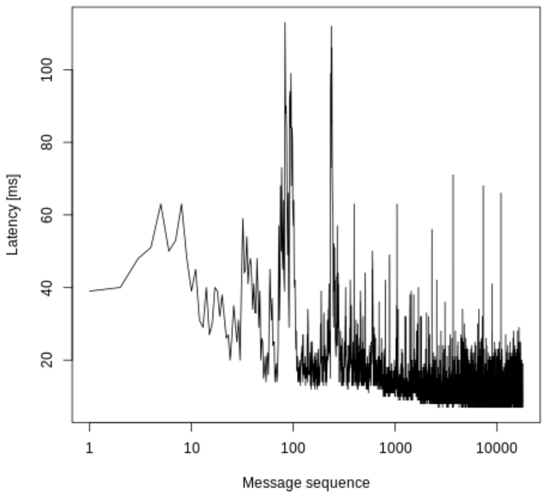
Message generation frequency 120 msg/s, experiment duration 15 minutes.

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.

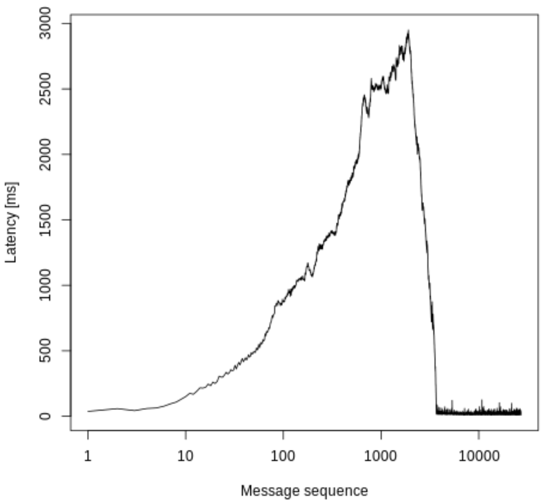
The third, and last set of graphs may help to provide us with more insight into the reason for a long tail of high-latency values. The x-axis shows, on the logarithmic scale, the sequence number of each message, while on the y-axis the latency of each message is provided.



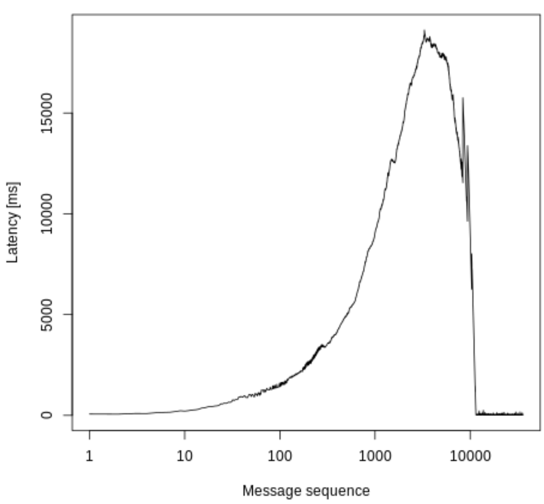
Message generation frequency 30 msg/s, experiment duration 5 minutes.



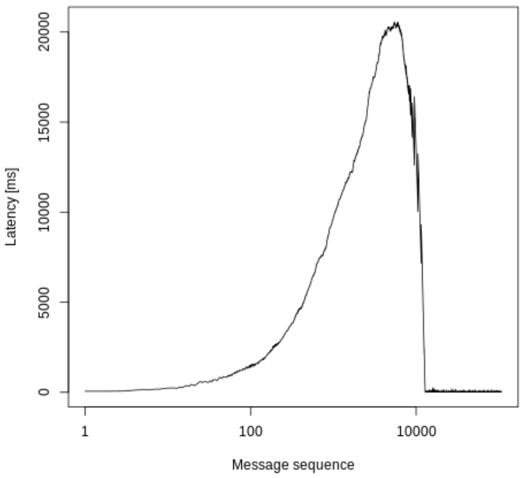
Message generation frequency 60 msg/s, experiment duration 5 minutes.



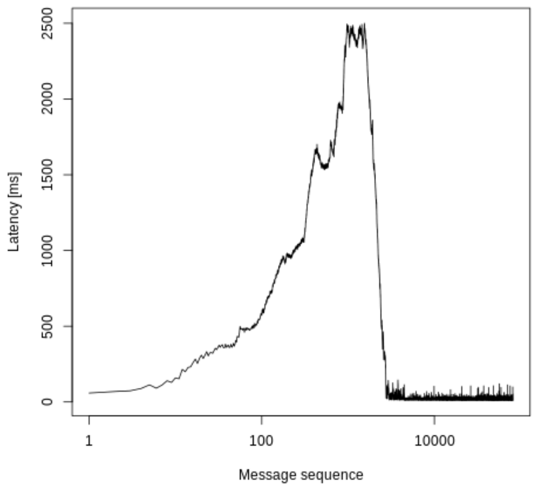
Message generation frequency 90 msg/s, experiment duration 5 minutes.



Message generation frequency 120 msg/s, experiment duration 5 minutes.



Message generation frequency 90 msg/s, experiment duration 15 minutes.



Message generation frequency 120 msg/s, experiment duration 15 minutes.

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. We further tested this behaviour in the two last experiments, which run for 15 minutes. After around the first 10k messages, the system is stable. This may either be related to the behaviour of Azure VMs, or the INTER-MW itself.

<u>T2 evaluation</u>

We executed a series of ten experiments, on each device with increasing message creation frequency. The creation frequency ranged from 1 msg/s to 10 msg/sec with the increasing step of 1 msg/sec. The duration of each experiment was 300 seconds. With this approach we test the performance around the IPSM KPI target of 10 msg/sec and we also measure the latency in order to verify if we reach the target of max. 100 ms.

The overall results are provided in the tables below:

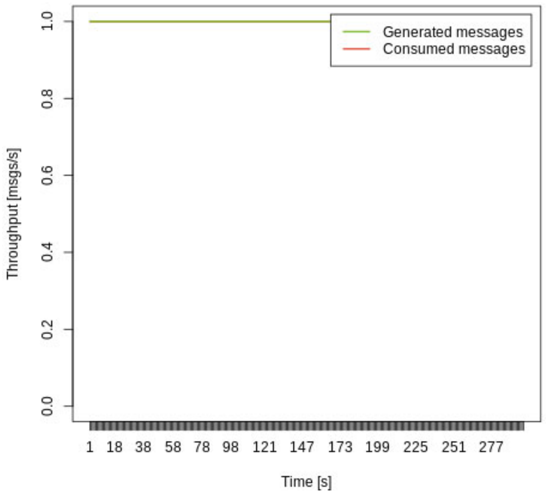
device	Experiment no.	Average message generation rate [msg/s]	Average message consumption rate [msg/s]	Total number of messages	Latency min [ms]	Latency max [ms]	Latency mean [ms]	Latency median [ms]
vmplsp02	1	1	1	299	19	110	53,515	50
vmplsp02	2	2	2	599	18	120	31,021	25
vmplsp02	3	3	3	898	17	107	55,275	55
vmplsp02	4	4	4	1197	17	99	23,923	22
vmplsp02	5	5	5	1495	17	165	54,189	53
vmplsp02	6	6	6	1802	16	138	50,982	49
vmplsp02	7	7	7	2106	16	1968	29,880	20
vmplsp02	8	8	8	2393	16	148	21.828	20
vmplsp02	9	9	9	2694	15	1944	29,423	20
vmplsp02	10	10	10	2990	16	228	21,429	20

Table 8: T2 evaluation results

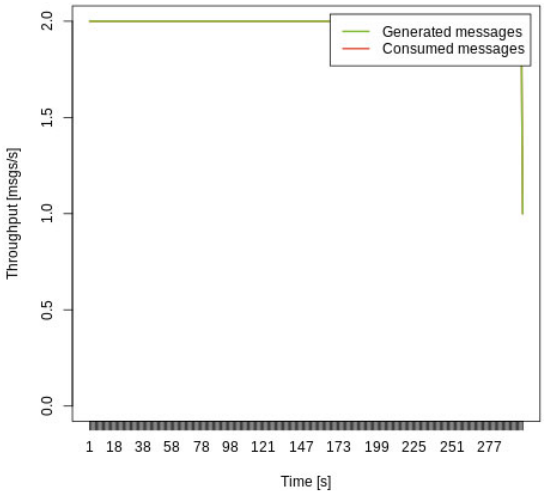
The immediate conclusion is, that at the message generation speed of around 10 msg/s we are reaching the target latency, with some occasional spikes.

A more in-depth analysis shows several interesting features, capabilities as well as possible limitations of the system.

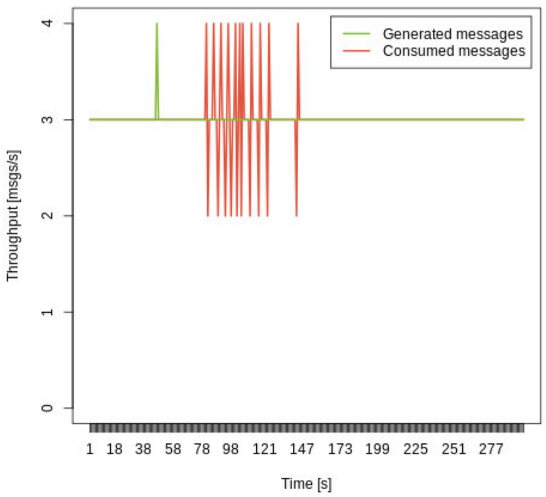
In the first set of graphs the generation speed vs. message consumption speed is shown. The x-axis shows time in seconds from the beginning of an experiment (typically, from one to 300 seconds). On the y-axis we show the throughput as number of messages per second (green - generated messages, orange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



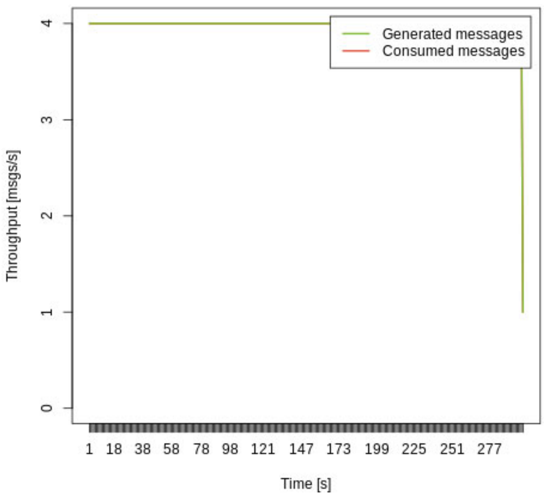
Message generation frequency 1 msg/s, experiment duration 5 minutes.



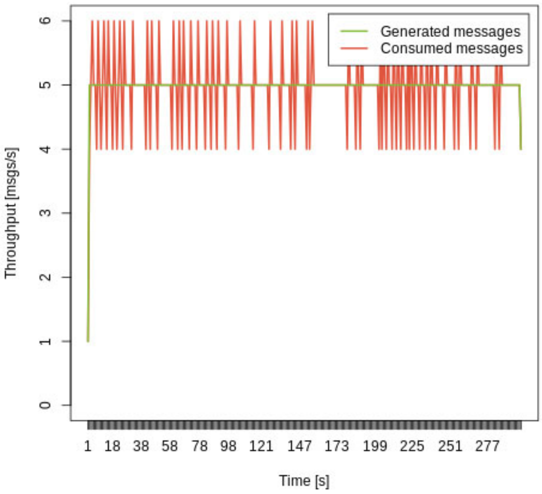
Message generation frequency 2 msg/s, experiment duration 5 minutes.



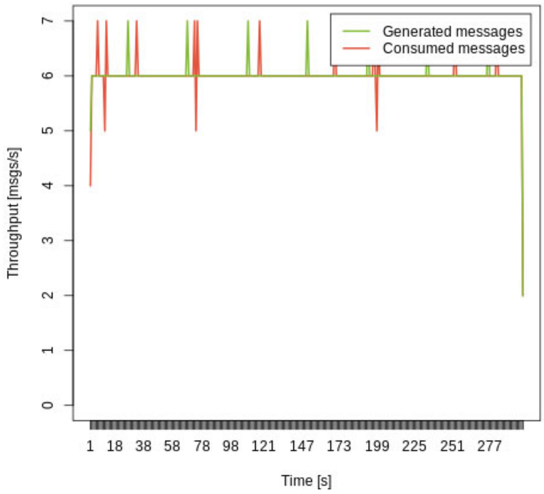
Message generation frequency 3 msg/s, experiment duration 5 minutes.



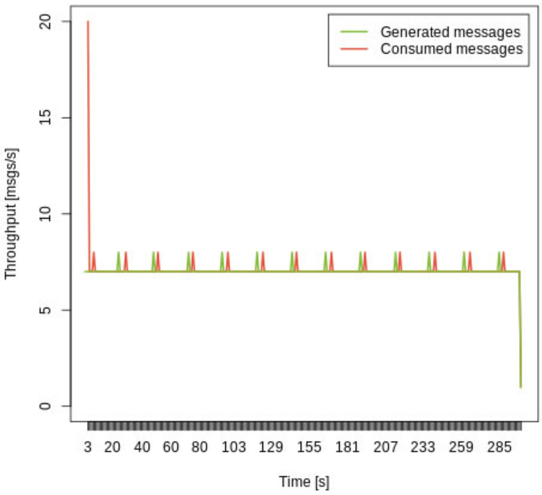
Message generation frequency 4 msg/s, experiment duration 5 minutes.



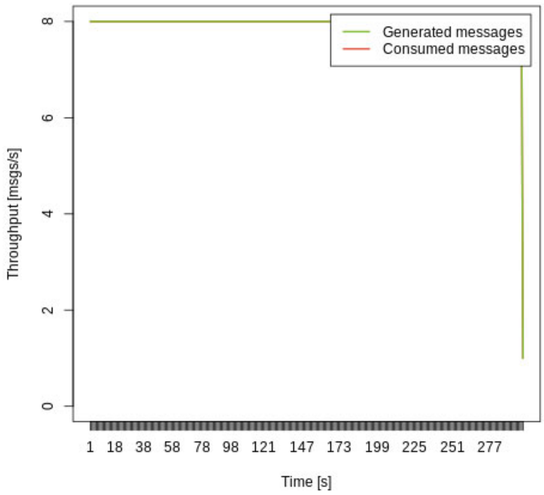
Message generation frequency 5 msg/s, experiment duration 5 minutes.



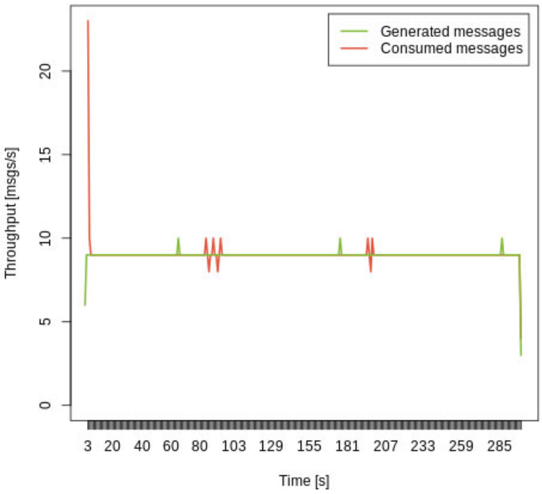
Message generation frequency 6 msg/s, experiment duration 5 minutes.



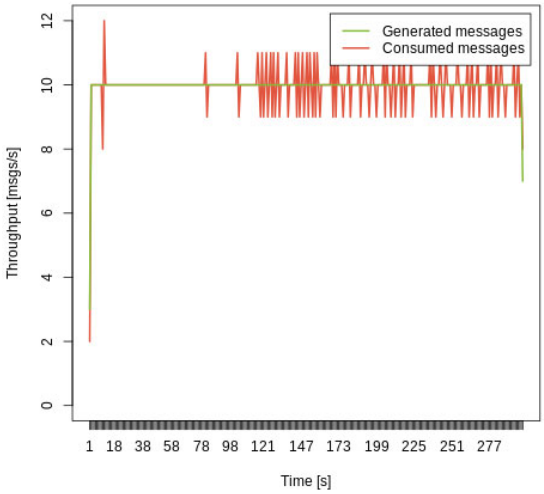
Message generation frequency 7 msg/s, experiment duration 5 minutes.



Message generation frequency 8 msg/s, experiment duration 5 minutes.



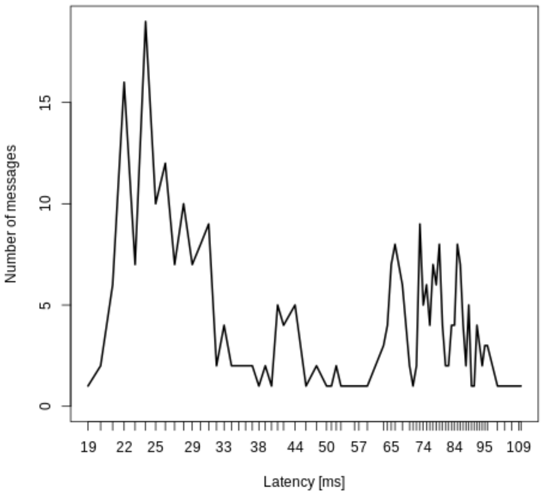
Message generation frequency 9 msg/s, experiment duration 5 minutes.



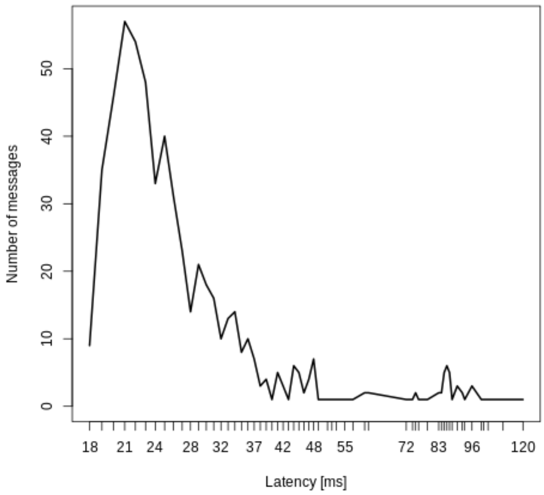
Message generation frequency 10 msg/s, experiment duration 5 minutes.

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.

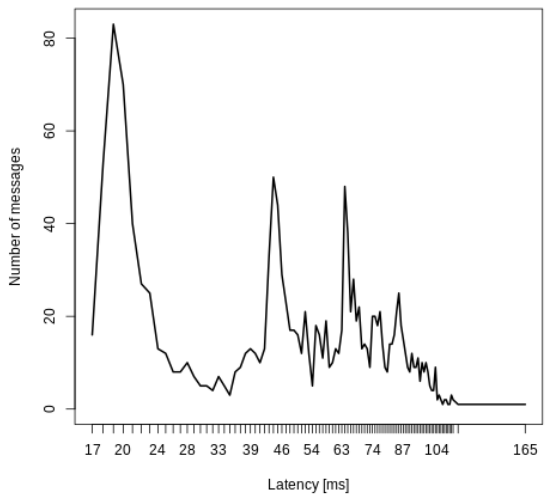
In the second set of graphs the distribution of the latency is shown. The x-axis shows the latency in milliseconds (logarithmic scale). On the y-axis we show the number of messages (distribution).



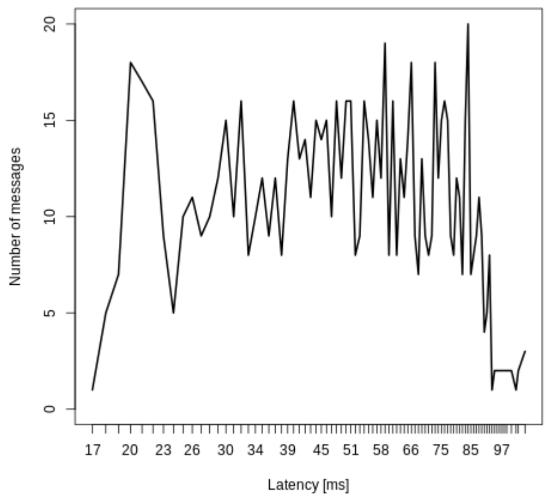
Message generation frequency 1 msg/s, experiment duration 5 minutes.



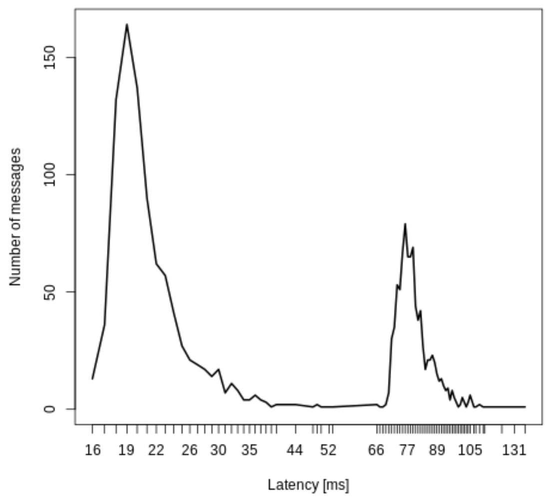
Message generation frequency 2 msg/s, experiment duration 5 minutes.



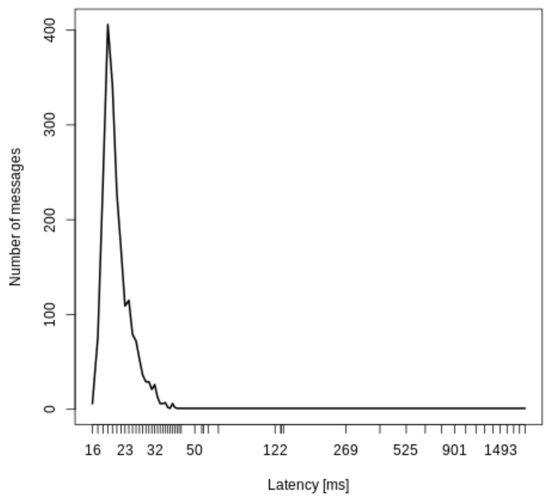
Message generation frequency 3 msg/s, experiment duration 5 minutes.



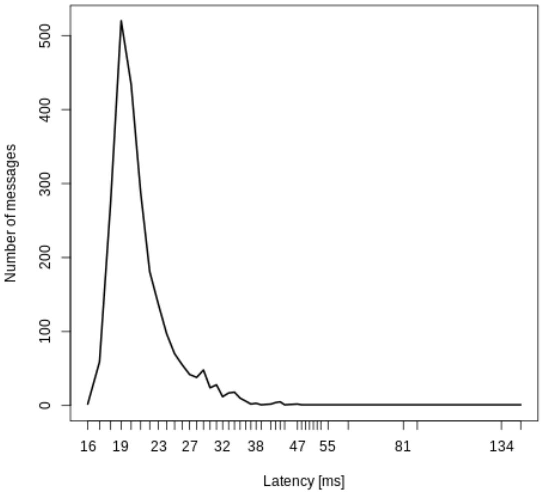
Message generation frequency 4 msg/s, experiment duration 5 minutes.



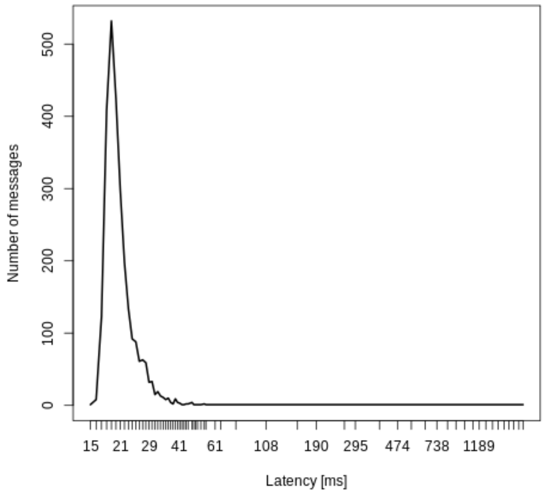
Message generation frequency 5 msg/s, experiment duration 5 minutes.



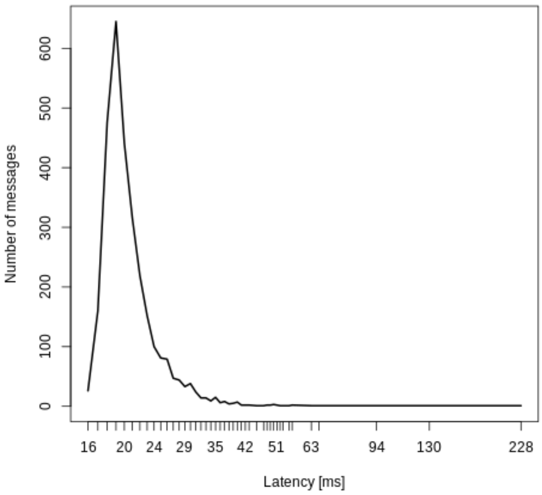
Message generation frequency 6 msg/s, experiment duration 5 minutes.



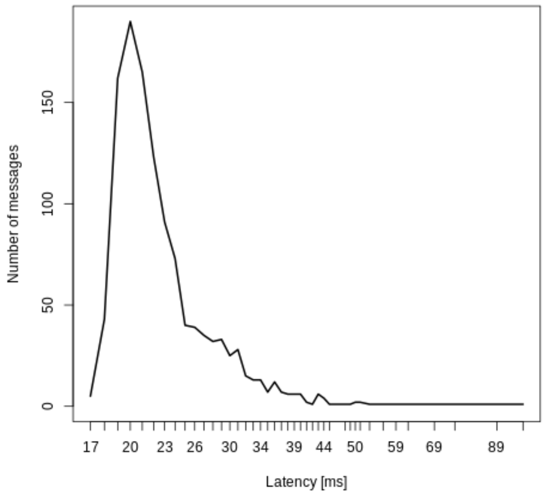
Message generation frequency 7 msg/s, experiment duration 5 minutes.



Message generation frequency 8 msg/s, experiment duration 5 minutes.



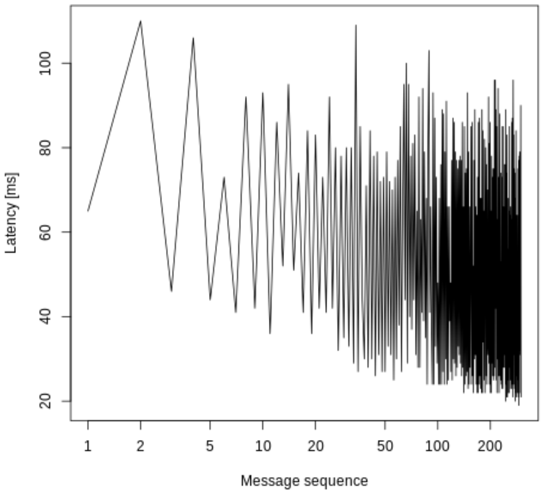
Message generation frequency 9 msg/s, experiment duration 5 minutes.



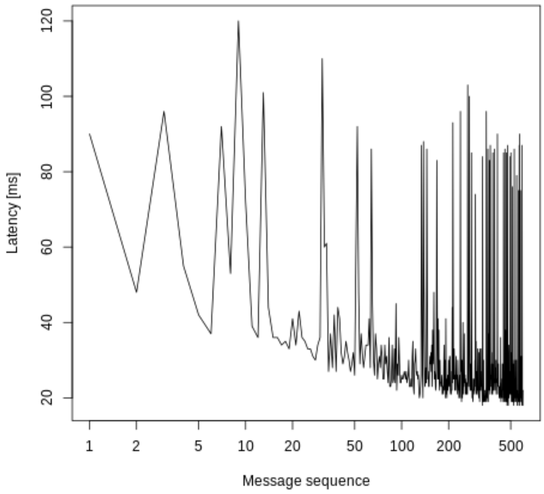
Message generation frequency 10 msg/s, experiment duration 5 minutes.

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.

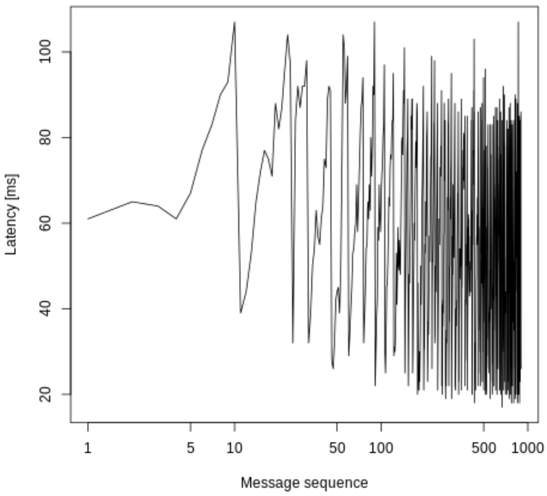
The third, and last set of graphs may help to provide us with more insight into the reason for a long tail of high-latency values. The x-axis shows, on the logarithmic scale, the sequence number of each message, while on the y-axis the latency of each message is provided.



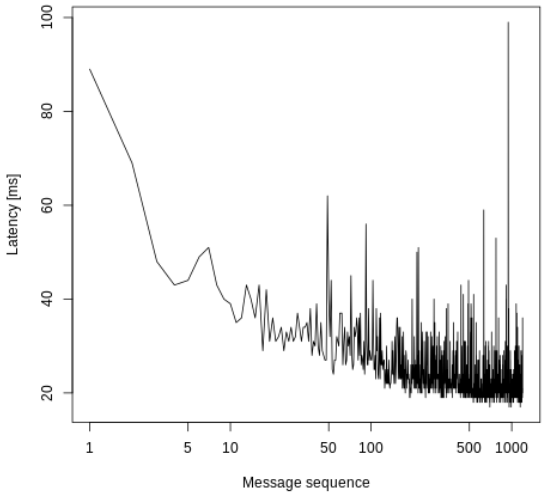
Message generation frequency 1 msg/s, experiment duration 5 minutes.



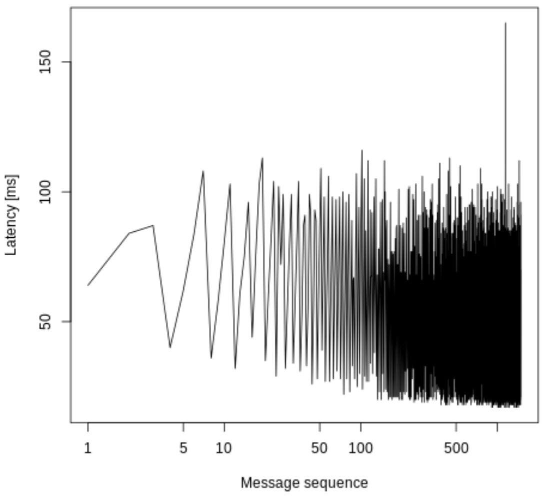
Message generation frequency 2 msg/s, experiment duration 5 minutes.



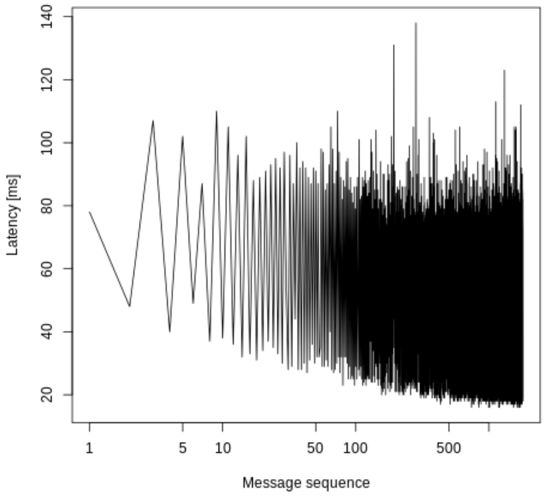
Message generation frequency 3 msg/s, experiment duration 5 minutes.



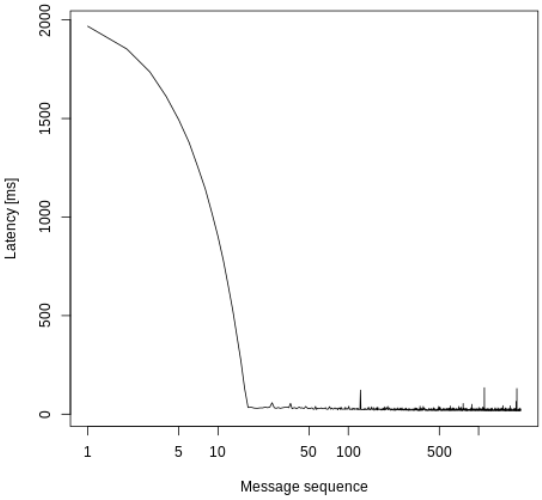
Message generation frequency 4 msg/s, experiment duration 5 minutes.



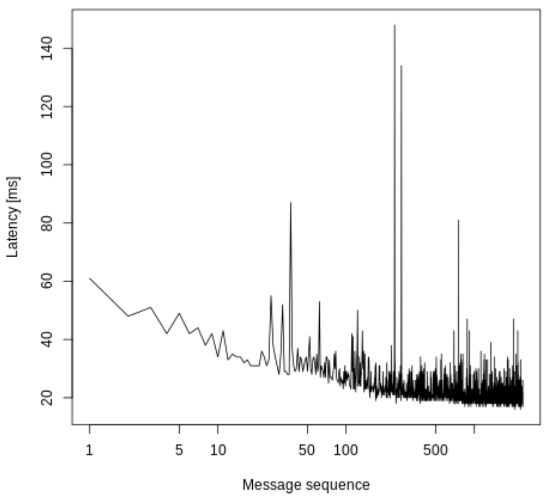
Message generation frequency 5 msg/s, experiment duration 5 minutes.



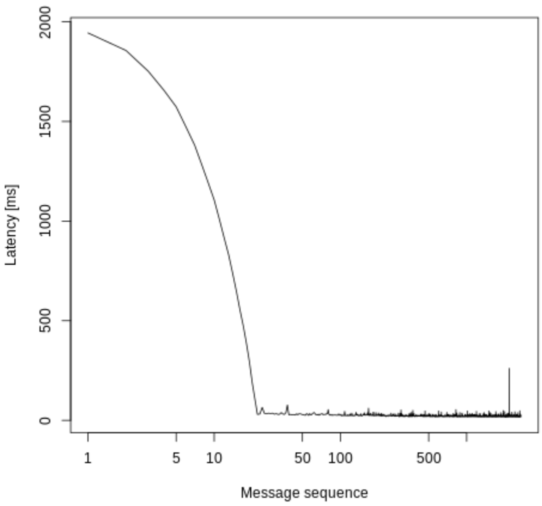
Message generation frequency 6 msg/s, experiment duration 5 minutes.



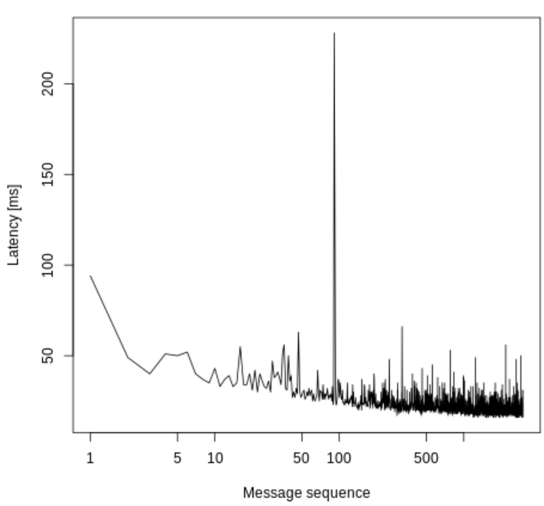
Message generation frequency 7 msg/s, experiment duration 5 minutes.



Message generation frequency 8 msg/s, experiment duration 5 minutes.



Message generation frequency 9 msg/s, experiment duration 5 minutes.



Message generation frequency 10 msg/s, experiment duration 5 minutes.

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.

T3 evaluation

For this evaluation step the LogP operational deployment has been used. A client application for performance testing has been subscribed to all registered devices. We thus dubled the load on the system as what regards number of message flows. As this is a live system, we had no control over type or frequency of observations received. We measured only the generation frequency for this test and the test run only once.

The test run for 24 hours and received 12444 observations in total.

Table 9: Number of received messages from different devices in 24 hours

Device ID	Total number of messages
http://www.inter-iot.eu/wso2port/gate/51	1000
http://www.inter-iot.eu/wso2port/gate/13	1179
http://www.inter-iot.eu/wso2port/gate/4	931
http://www.inter-iot.eu/wso2port/gate/6	494
http://www.inter-iot.eu/wso2port/gate/12	1432
http://www.inter-iot.eu/wso2port/gate/14	1052
http://www.inter-iot.eu/wso2port/gate/7	343
http://www.inter-iot.eu/wso2port/gate/53	498
http://www.inter-iot.eu/wso2port/gate/5	738

http://www.inter-iot.eu/wso2port/gate/52	81
http://www.inter-iot.eu/wso2port/gate/11	168
http://www.inter-iot.eu/wso2port/gate/15	550
http://www.inter-iot.eu/wso2port/gate/41	2943
http://www.inter-iot.eu/wso2port/gate/3	1035

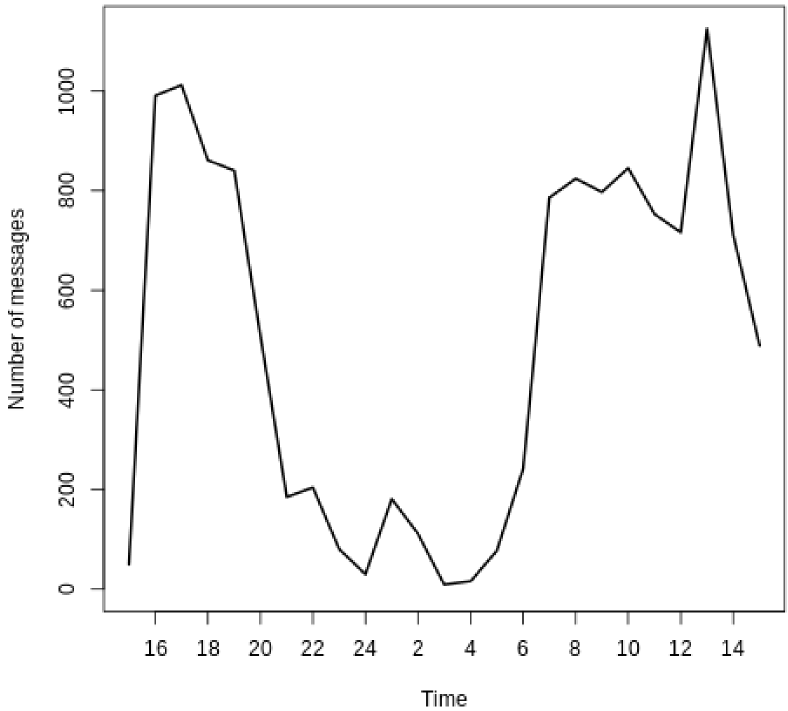


Figure 9: generation speed of messages. The x-axis shows the hour of day. On the y-axis we show the throughput as number of messages.

As can be observed from the graph, evaluation started in the afternoon around 16h. There was high activity at the gates until around 19h. The traffic started raising again around 6h in the morning and is constant during the day.

This third test closes the series of tests performed to evaluate INTER-MW in real world scenarios. INTER-MW performed accordingly to project requirements.

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 10: 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 was assessed following the completion of the pilots. The flows created and tested could handle 50 messages. This was the target set for the KPI.

3.2.4.7 Supportability

KPI.4.27 - KPI.4.39

A survey of multiple parties from UNICAL research groups, spinoffs and labs was undertaken to assess multiple aspects of INTER-METH and the CASE-Tool. 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 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). Reasonable training should be considered mandatory for many aspects of the tools. If this is undertaken, improvements could be seen in survey results.

The results presented in *Table 2*.

3.2.4.8 Configuration and monitoring

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.

[2] https://iperf.fr/

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

All component documentation is now complete. This documentation highlights that monitoring of each component is implemented. This documentation and the associated repositories are available for detailed review here https://docs.inter-iot.eu/.

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.
- 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.

KPI.4.40: System uptime

For this KPI, the two pilots have been evaluated. The initial goal of 168h has been met for each. 192h has been achieved for the health pilot and 208h for the transport and logistics pilot. We are hopeful that we will continue to improve the system reliability moving forward.

KPI.4.41: INTER-MW Latency

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

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
```

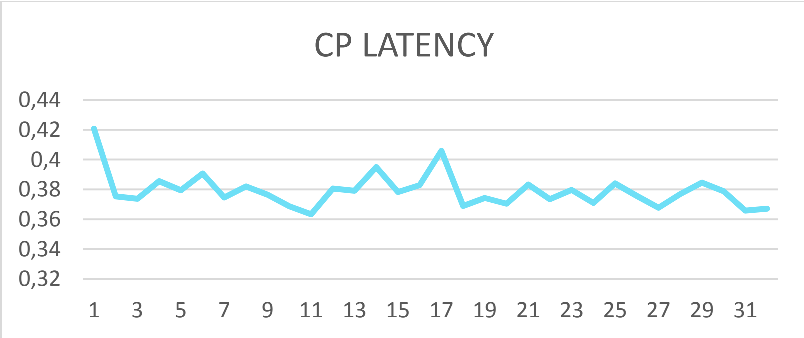


Figure 10: SDN Example latency testing and results

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 11: 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 12: 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 13: 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 14: 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 15: 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 16: 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
```

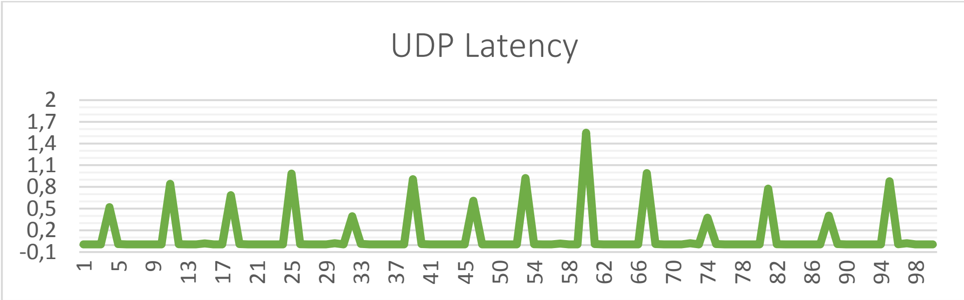


Figure 17: UDP Latency testing

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 hl-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 18: SDN Network sniff

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

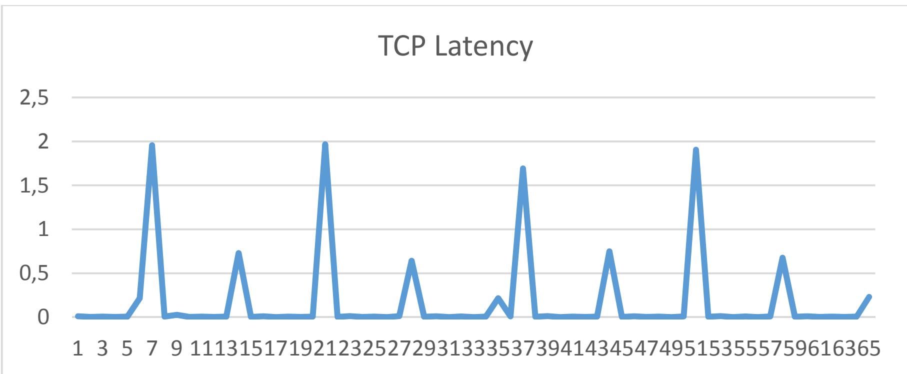


Figure 19: TCP Latency testing

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.

3.2.5 Ethical, societal, gender and legal evaluation

3.2.5.1 Legal issues

KPI.5.01: Legalisation assessment

Two questions were asked of consortium members, open call parties and end users: do you feel safe about the collected data and do you think Intellectual Property is properly managed? 91% of respondents answered positively to each question separately.

KPI.5.08: Number of identified regulations and public policies

Full details of this KPI can be found in D2.5. 15 European level pieces of legislation were identified. Their corresponding implementation was identified in seven European countries.

KPI.5.13: Publicity of data for research

For this KPI, the following questions were asked of consortium members, open call parties and end users: should the data collected in the INTER-IoT platform be accessible for research? 84% indicated that they thought that data collected by INTER-IoT should be accessible for research purposes.

3.2.5.2 Holistic innovation

KPI.5.02: Human-centred innovations

For this KPI, 2 questions were asked to consortium members, open call parties and end users: do you feel that the INTER-IoT project will improve people lives and will the project have an impact on people, more than companies? 97% responded positively to the first question. However only 22% of respondence believed there would be a larger impact on people rather than companies. Overall this

KPI has a value of 59%. The overall effect may be skewed downward due to the comparative nature of the second question.

KPI.5.03: Connections and trust

For this KPI, the following questions were asked of consortium members, open call parties and end users: do you think the connections between different IoT platforms are working well and do you feel safe in using solutions based on INTER-IoT? 83% of respondents thought the connections between different IoT platforms were working well. 95% felt safe about using INTER-IoT solutions. This led to an overall score of 89%. This shows that there is confidence and trust in INTER-IoT based products.

3.2.5.3 User worktime / life impact

KPI.5.04: Worktime - Time Saving

For this KPI, 2 questions were asked to consortium members, open call parties and end users: do you think that an INTER-IoT platform can be saving work time? Do you think that an INTER-IoT platform will improve business output? 95% responded positively to the both questions independently. This is a great point for future sales and highlights one of the value propositions set out in D8.7.

KPI.5.05: Life - Social inclusion

For this KPI, 2 questions were asked to consortium members, open call parties and end users: will the INTER-IoT system have an impact on your life (private or professional) and do you feel that the INTER-IoT platform will improve social inclusion? 87% responded positively to the first question. 56% responded positively to the second question. This led to an overall score of 72%. Additional thought should be given to how INTER-IoT can have a wider impact on social inclusion.

KPI.5.10: Threat on the labour demand

For this KPI, the following question was asked to consortium members, open call parties and end users: do you believe that the INTER-IoT platform can be a threat to the labour force, since it might replace some human intervention? 78% indicated that they thought INTER-IoT did not pose a threat in this way.

KPI.5.11: Help on disabled people's lives

For this KPI, the following question was asked to consortium members, open call parties and end users: do you feel like INTER-IoT will help in improving disabled persons lives? 65% indicated that they thought INTER-IoT could have an effect on disabled persons lives.

3.2.5.4 Targeted social groups

KPI.5.06: Socially excluded groups Elderly / Disabled

For this KPI, 2 questions were asked to consortium members, open call parties and end users: do you believe that INTER-IoT will help to prevent incidents (elderly, disabled people) and do you believe that INTER-IoT will help to preserve people's health? 78% responded positively to the first question and 83% responded positively to the second question. Overall 80% of responses were positive.

KPI.5.12: Accessibility of INTER-IoT tech

For this KPI, the following question was asked to consortium members, open call parties and end users: do you think the INTER-IoT platform will only provide benefit to people/companies considered as "rich"? 94% of respondence indicated that they did not think that INTER-IoT products would only benefit “rich” companies/people. This is a good indication that the technology is perceived as accessible to a larger portion of society.

3.2.5.5 Trusted, safe, secure IoT environment promotion

KPI.5.07: Citizens’ involvement

For this KPI, 2 questions were asked to consortium members, open call parties and end users: do you feel that citizens have sufficiently been involved in the project development and do you believe that citizens should be involved for further development? 49% of respondence indicated that citizens should have had more involvement with 75% indicating that they should be more involved in future development.

3.2.5.6 Community engagement

KPI.5.09: Trusted, safe, secure IoT environment promotion

For this KPI, the following question was asked to consortium members, open call parties and end users: do you feel like the promotion of trust, safeness and security has been done properly? 81% responded positively to this question indicating a good level of confidence in the work done within INTER-IoT.

4 Ethics

INTER-IoT partners, both individually and as a consortium, are committed to 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 it focused on technical developments. Interaction with external stakeholders played 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 we presented results of these interactions.

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 D7.3 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 D7.3 was to present the overall evaluation of the project. Overall, the results of the analysis have been positive showing the maturity of the INTER-IoT technology and the good acceptance by end users and potential customers of INTER-IoT. 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 project performed well have been highlighted. Involvement of stakeholders was highlighted as a strength whereas involvement of the general public was a weakness. Consideration of this in post project development and exploitation must be considered. The accessibility of INTER-IoT to SME and start-ups as well as non-“rich” companies and people was seen as a strength. The pilots have been a great success and both continue beyond the end of the project with the end users happy with the result and keen to utilize INTER-IoT in their operational environments. Implementation of additional failover mechanisms may be necessary if specific use cases are not covered by those currently implemented. Ethical societal gender and legal aspects of the project showed a desire for greater involvement of the public in projects of this nature and room for improvement in holistic impact and community involvement.

The INTER-IoT project has led to new products being made available, development of new business models and university courses which can benefit project partners and other potential users of the INTER-IoT opensource technology and tools. Overall there seems to have been a positive impact on all those involved in the work.