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D6.6: HEADS Project Roadmap

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Abstract / Executive summary:

This deliverable summarize the roadmap for the main technologies provided by HEADS. In particular:

- HEADS Design Language – ThingML
- HEADS Runtime Language – Kevoree
- HEADS Methodology and IDE
- Framework for Resource-constrained Devices and Networks
- Complex Event Processing
- Use case Safe@Home
- Use case SensingNews

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Version History

Version	Description	Date	Who
0.1	Initial structure	2017-03-06	Martin Skorsky
0.2	Roadmap for CEP	2017-03-30	Martin Skorsky
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1 Introduction

This deliverable describes the roadmap after the end of the HEADS project for the technologies developed in HEADS (project duration: October 2014 to March 2017). In particular:

- HEADS Design Language – ThingML
- HEADS Runtime Language – Kevoree
- HEADS Methodology and IDE
- Framework for Resource-constrained Devices and Networks
- Complex Event Processing
- Use case Safe@Home
- Use case SensingNews

The roadmap contains the status and public plans ahead for these technologies and use cases. Section 2 describes the roadmaps for the HEADS technologies and uses cases listed above. Section 3 provides a list of ongoing research and development projects where HEADS technologies will be evolved.

2 HEADS Technologies Roadmap

HEADS uses the modelling approach to develop Heterogeneous and Distributed services (HD-Services) and to deploy and monitor these services. With this approach we model IoT 'things' in the modelling language ThingML, and manage the deployment and runtime management with Kevoree.

The HEADS methodology and HEADS IDE is the integrated part of HEADS which combines the four technologies ThingML, Kevoree, Resource Constrained Devices (RCD) framework, and Complex Event Processing (CEP) into a development model for HD-Services. The two use cases of the HEADS project, Safe@Home and SensingNews are used to validate the methodology and HEADS IDE.

2.1 HEADS Design Language, ThingML

At design-time, HEADS IDE will provide the ThingML to provide different HEADS actors with modelling languages, editors and tools to engineer HD-services.

ThingML include a domain-specific modelling language which includes concepts to describe both software components, their behaviour and the communication protocols. The formalism used is a combination of architecture models, state machines and an imperative action language. They are build on similar to concepts found e.g., in UML2. ThingML also provides a set of compilers (currently targeting C and Java-based platforms) in order to produce fully executable code from the HEADS model specifications. HEADS supports the platform experts to define drivers and service developers to define business logic.

ThingML is the main achievement for SINTEF in HEADS, and SINTEF has already exploited early versions of ThingML in both research project and industry projects.

During the autumn 2016 Tellu and SINTEF started to discuss a closer cooperation around the technologies developed in HEADS, in particular ThingML. This initiated a process with TellU, SINTEF, and SINTEF Technology Transfer Office (TTO) that has resulted in attracting SINTEF TTO and Investinor (the Norwegian state venture capital company, a significant investment company in Norway (http://www.investinor.no/en/about-us/) to invest in TellU and ThingML. The investment is motivated both to do commercialisation of ThingML, making ThingML a strategic competitive advantage for TellU evolving TellUCloud and its offerings (including services originated in the Safe@Home use case). As part of the investment and commercialisation deal, the ThingML ownerships is transferred from SINTEF to TellU, currently it will continue to be maintained under the Apache open source license, seeking to grow the community around ThingML. The investors (SINTEF TTO and Investinor) are now active owners of TellU, and have seats in the new board of the company. Thus, ThingML has become a strategic technology component for Tellu and will be exploited as part of the longer term strategy of TellU to be a leading player in IoT within specific application domains such as eHealth, welfare and personnel security.

Further main points related to the roadmap for ThingML is:

- ThingML has been integrated into two Master-level courses at University of Oslo and University College of Halden given respectively by Dr Arne-Jørgen Berre and Prof Øystein Haugen. In particular, students need to implement a home-automation system in ThingML. These two courses are lectured annually, thus, ThingML will be thought to Master students in these institutions in the years to come. Moreover, SINTEF has hosted four master-level interns working with and contributing to ThingML, and will

host two more interns summer 2017, expecting to continue hosting students at this level in the years to come.

- Connected to the commercialisation of ThingML with Tellu SINTEF has acquired a significant portfolio of R&D projects related to ThingML and where also Tellu is a partner: STAMP (H2020 project), Productive4.0 (ECSEL project), DiversIoT (NRC project), with a total value of 2M € for SINTEF (and 1M € for Tellu). In addition SINTEF has acquired a bilateral project doing ThingML evolution with TellU. First phase is worth 50 000 € for SINTEF. This set of projects has already ensured funding for significant exploitation and evolution of ThingML the next three years. Moreover SINTEF and TellU has joined their forces submitting 7 joint R&D projects related to ThingML exploitation and evolution that are currently evaluated. Thus, the project portfolio around ThingML is expected to continue to grow.
- SINTEF has received an invitation from Springer to write a ThingML book. The invitation is accepted and currently we are in the process of proposing the outline of the book. It is already decided that the target readers are users of ThingML. The plan is also to apply this book in the Master-level courses at University of Oslo and University College of Halden.
- SINTEF recently got accepted a Gemini Centre on IoT together with University of Oslo and the Norwegian University of Science and Technology, for the next three years with option to continue the centre after this period if the evaluation of it is good. A Gemini centre is a centre of science excellence, and it couples both academics and industry. The Gemini Centre for IoT will couple to the IoTSec cluster (http://its-wiki.no/wiki/IoTSec:About), and Digital Norway Toppindustrisenteret (http://www.digitalnorway.com/english/). The Gemini Centre will be exploited to impact development and innovations in Norwegian industry and society as well as excellence in science. SINTEF is leading this centre. HEADS and ThingML has been an important project for SINTEF to get in the position to get and lead a Gemini-centre on IoT, and ThingML will be one of the assets to evolve in terms of demonstrating science excellence in this centre.
- SINTEF Digital strategic projects MASens is an internal strategic project building toolboxes of reusable components for applications in the unmanned vehicle domain and in the sensor systems. The HEADS design and runtime platforms are baseline for the formalisation and re-usability of both toolboxes. The funding is until end of 2017

2.2 HEADS Runtime Language Kevoree

At runtime, the HEADS platform will be composed of a set of components and protocols supporting the execution of HD-services. These are modelled with Kevoree as the modelling language. State machines are a common formalism to express reactive behaviour that needs to react on some events, correlate events, and produce some new events. A state machine-based programming language (ThingML in particular), is suited to implement Kevoree components and write the logic that orchestrates the different ports of these components. HEADS configuration and deployment model (Kevoree) provides a practical solution to handle the complexity of managing the configuration and reconfiguration of complex HD-services at runtime. It provides concrete solution to:

- Build reconfigurable apps and services.

- Orchestrate coherent and transactional reconfiguration of all cloud deployment scenarios.
- Unify virtualization mechanisms, system containers, and application container managements.
- Provide a flexible configuration model with built-in efficient model exploration capabilities. This feature allows to quickly build efficient reasoning engines, schedulers or autonomic manager.

Consequently configuration and deployment model allows service operators to configure or reconfigure their apps via an application manager available at editor.kevoree.org.

HEADS is not bound to a specific runtime platform. The platform expert is responsible for adding support to deploy code to a new platform. The roadmap for Kevoree is related to the following points:

- INRIA Rennes is a joint lab with the University of Rennes, allowing to directly include Kevoree breakthroughs to advance computer science and software engineering courses for Master or Doctoral students. In particular, three courses that integrates Kevoree technologies are already created. The last two years we have practiced the Kevoree and Heads tutorials for more than 150 students. We plan to continue to do this for more than 100 Master students per year for the coming years.
- Since INRIA is a partner of the b-com IRT[1], the plan is to transfer Kevoree results to the local industry in Brittany. The goal of IRT is to combine public and private partners to develop joint research programs, technology platforms and training to achieve excellence in the most competitive sectors and create the jobs of tomorrow. In this context, several presentations have already been done to demonstrate current results. In particular, the work on the use of Kevoree to drive a large set of docker.io containers seems to be promising.
- INRIA bought two Open Source Vehicle (https://docs.google.com/presentation/d/1p__PwyXGEB36CxzY9n4E24NbrOpVjtLvQfY2y7fHP6g/edit?usp=sharing, https://www.osvehicle.com/). OSV Vehicle projects provides the mechanical part and the power electric part of the vehicle but no open-source electronic neither open-source software is embedded. INRIA plans to become a leading place around this maker-fair open source project. In particular, INRIA plans to apply Kevoree and in general fully reuse the results of the HEADS project in this context.
- INRIA has acquired two bilateral projects with Orange Labs and Nokia respectively where Kevoree will be exploited and evolved. With Orange the task is to enable a software stack for producing single usage software. The idea is to specify the behaviour of a distributed system (using ThingML) and to introduce mutation in this model. Then, we use Kevoree to automatically deploy a new variant for each new usage of the same application. With Nokia, INRIA will extend Kevoree to integrate Network configuration and in particularly the deployment of Network Virtual Function.

2.3 Methodology and IDE

The HEADS methodology defines three roles: platform experts, service developers, and service operators. The methodology guides them step by step in order to use the HEADS IDE, which is the development environment that integrates the languages and tools of HEADS. The platform expert is responsible for writing plugins for the HEADS IDE in order to support different target

[1] http://b-com.com/en

platforms where the things are deployed. The service developer uses HEADS design language ThingML to define the components of the HD-Service and implement the logic of those components. The service operator uses HEADS runtime language Kevoree for the deployment and monitoring of the components.

The HEADS methodology is available at http://heads-project.github.io/methodology/ as a GitBook and the HEADS IDE source code is available in GitHub (https://github.com/HEADS-project). Thus, the different versions of the HEADS IDE and methodology have continuously been released, and is available in public open-source repositories. The main components of the HEADS IDE (ThingML and Kevoree) are developed as open-source in their own open-source repositories, and integrated together in the HEADS repository. We provide online tutorials for all the Heads modules (available on GitHub). HEADS IDE is based on Eclipse.

- As nearly all development tooling of the SAG Digital Business Platform is based on the Eclipse infrastructure Software AG is exploring exploitation of the HEADS IDE. The Eclipse plugins of the HEADS IDE work inside Software AG Designer, which is the development tool of the Software AG's Digital Business Platform. At this stage suitable plugins will be offered internally and externally as additions to the product via a suitable Eclipse installation. This will allow feedback of customers and consultancy on the applicability of the plugins within the suite. Moreover, HEADS methodology will be considered for integration into the corresponding methodologies of Software AG development services.
- Software AG has besides its licensed Software products also many public and internal materials to offer support and consulting services to SAG professional service organisation and directly to the customer in using SAG products. These include methodologies, best practices and use cases where HEADS methodology and HEADS IDE will be exploited.
- The HEADS methodology will be exploited for the integration into the relevant methodologies and best practices of Software AG consulting services. SAG expects to integrate several parts of the HEADS methodology by adopting it to the existing methodologies of Software AG
- HEADS methodology will be exploited and evolved related to the received invitation from Springer to write a ThingML book.
- Software AG increasingly builds up and fosters an ecosystem of SMEs and start-ups to extend Software AG's offerings for dedicated markets and to address smaller markets that demand in-depth domain knowledge. For this purpose, Software AG has established a so-called start-up program that gives start-ups and SMEs free access to Software AG's technologies to develop their specific solution on top of these and then address the markets with the combined results. These SMEs and start-ups are given access to the HEADS methodology and the CEP Recommender as well, depending on their needs.

In addition to main HEADS IDE components such as ThingML, Kevoree, the RCD framework and CEP we have a few more specific modules and components that are developed in HEADS and is applied as part of the HEADS IDE, in particular it is worth mentioning:

- Npmi, a NodeJS package that gives a simpler API to npm install. Npmi is developed in HEADS and has been particularly successful in terms of gaining interest and usage. It has had several thousand downloads every day for about 2 years. As an example, the status of the day of writing this deliverable the status is 4600 downloads the last day, 25770

downloads for the last week and 114 483 downloads for the last month. (see https://www.npmjs.com/package/npmi)

- Related to the HEADS WP4 results on testing and the provisioning of an infrastructure for testing non-functional properties of software modules, this work will be evolved in the H2020 STAMP project.

2.4 Framework for Resource-constrained Devices and Networks

HD-Services are composed of communicating software components on a distributed and heterogeneous set of hardware platforms. Communication protocols used in HD-Services will vary a lot in terms of bandwidth and complexity of use based on the purpose for the communication, e.g., sensor communication, communication with computers on Internet. HEADS IDE (Integrated Development Environment) will support the development of HD-Services by providing readymade components for dealing with heterogeneity and distribution.

Applying different kinds of target platforms/protocols puts a great burden on the developers who have to possess deep knowledge of the peculiarities of the specific platforms/protocols. To facilitate and simplify the development process, the HEADS IDE provides the developer with a set of supported target platforms and network plugins handling various communication protocols. The target platforms that HEADS IDE addresses are characterized in three different classes based on available data and program memory: tiny, small and large RCD (Resource Constrained Device). For each of the RCD classes we describe how we have supported different HEADS concepts like Complex Event Processing (CEP) and dynamic configuration.

Communication protocols are dealt with in HEADS IDE through the concept of network plugins. Network plugins can be implemented as either HEADS design components, code generator plugins or HEADS runtime components. A broad spectrum of communication protocols has been implemented as network plugins in the HEADS IDE to support the requirements from use-cases and other experiments.

The three main outputs related to the development of the HEADS RCD framework and networks are:

- HEADS Network plugin framework implemented with support for several protocols applied in use-cases and examples. This is a base functionality for the HEADS IDE.
- Tellu Fall detector system fully implemented with HEADS technology on the SINTEF body sensor based on Silicon Labs EFM32. SINTEF and Tellu are collaborating in order to extend the Tellu software platform to support a set of body sensor developed by SINTEF making up a fall detection system. TellU has submitted a patent application for the fall detection system that are currently in the stage two processing. Moreover, the use of the SINTEF sensors together with the HEADS approach opens new opportunities for creating services in the health domain. In particular, a feasibility study supported by the Norwegian Research Council was conducted related to the fall the detection system and it concluded a significant potential for it.
- Tellu Home GW, a Mediatek MT7621 platform with MIPS architecture, running HEADS runtime on Tellu's Smart Home Gateway is developed and will be deployed in a set of homes as the gateway for TellU eHealth services.

2.5 Complex Event Processing

Complex event processing (CEP) in HEADS focuses on distributed CEP. This means we have an event processing network with CEP engines on several devices which are connected to exchange events. We have to consider CEP inside HEADS design language as described in [2]

and CEP with Software AG's Apama, which is described in [4]. CEP inside the HEADS design language ThingML depends on the ReactiveX libraries and targets mainly RCDs.

One of the main contributions to HEADS by Software AG is the CEP Recommender, a tool to re-write CEP queries for central execution to CEP queries for distributed execution. Beside other technologies this plays an important role for distributed CEP. The current state at the end of HEADS for Apama is that distributed execution is supported in different ways. These include but are not limited to running as a Docker container, connecting to an enterprise service bus, using large in-memory caches for synchronization of states between distributed CEP engines. The support for heterogeneous platforms in Apama was enlarged during HEADS. The platforms include ARM 7 and Intel Atom processors and of course high-end processors like Intel Xeon E7 [7]. For RCDs which are not supported by Apama we have with HEADS the option to bridge from Apama's CEP language through ThingML to the target language of the device.

Future work will align Apama and other Software AG's products for the IoT market for CEP or broader Streaming Analytics. This includes IoT services in the cloud or on-premise and consulting to build IoT platforms. Interesting directions are IoT for healthcare as in the Safe@Home use case or IoT for journalism as in the SensingNews use case or IoT for production with predictive maintenance and location analytics.

Future research for distributed CEP will include CEP query re-writing as the CEP Recommender uses it. This is related to CEP operator placement which should be investigated in more detail. In addition other technologies for distributed CEP have to be considered.

In terms of further roadmap related to the CEP we have:

- Together ATC and Software AG consider integrating distributed CEP as investigated in the SensingNews use case into other products of ATC. In general, new start-ups and collaborations for new products or services are supported by Software AGs start-up program. This program allows using products and selling services or other products based on Software AG products with license revenue adapted to the growth phase of the business.
- The CEP Recommender feature will be discussed with product management in SAG how to add this as a product feature for Apama. The evaluation of the advantage of distributed query execution over central query execution will help for this.
- Software AG offers HEADS methodology and tools through consulting services for IoT projects. Apama and other products used for distributed CEP in IoT projects will be supported and improved over the next releases.
- INRIA and Université of Rennes 1 has joined the Perseus Project. The PERSEUS' project (Projet Etudiant de Recherche Spatiale Européen Universitaire et Scientifique/ University and Scientific European Student project of Space research) is an initiative of the Launch Directorate of CNES, the French Space Agency, to promote the emergence of innovative technical solutions of spatial projects with industrial and educational particularities, realized by students of higher education. INRIA mainly joined to contribute with expertise on Open Source low-cost hardware or software and our expertise in building software on top of these components. For those project, we plan to use HEADS technologies and in particular the CEP ThingML module.
- In June 2016 the Apama Community Edition was launched[2]. The community edition is a free edition of Apama. It is a fast approach to get started with Apama and to develop projects for Streaming Analytics. Documentation and tutorials for Apama are available on

[2] http://www.apamacommunity.com/

the website. For small devices like Raspberry Pi2/3, Apama is available at the Apama Community. The community edition can be upgraded to the commercial version by buying a license. For HEADS developers this improves the availability of a CEP engine on various platforms.

- Software AG is involved in a H2020 project in the health sector (RADAR-CNS) which among others uses IoT devices for remote patient monitoring. The suitability of the CEP recommender to facilitate distributed data steaming analysis will be investigated. We expect to gain valuable insights from this domain and its requirements.
- End of 2016, Software AG acquired the company Zementis[3] Their offering ADAPA has been combined with APAMA to enable the application of PMML models (e.g. explicitly built based on application models or derived from machine learning / deep learning) in the course of APAMA's data streaming analytics. Currently, however, such a model application cannot be distributed over multiple processing nodes / a processing hierarchy. We expect that an extension of the CEP recommender could allow for a decomposition of the model evaluation and leads to optimizations in throughput and latency of such applications.

2.6 Use Case Safe@Home

The industrial use-case from TellU implemented in HEADS is a smart-home system for helping elderly people to stay home as long as possible and have independence in their daily life. Safe@Home is built up as a set of HD-services for the deployment of personalized eHealth solutions for patient homes, elderly homes and elderly institutions. The system is based on the TellUCloud back-end system and composed by a set of services which can be combined in order to create fully customized systems for each customer.

The main purpose of the use-case, in addition to specify a system of industrial relevance, has been to assess the HEADS IDE capabilities of handling heterogeneous computing nodes, distribution of services, and scalability of the system. Thus, it has focused on specifying a broad range of computing nodes spanning from small and very constrained platforms (Arduino, Raspberry PI, Intel Edison) to cloud resources with virtually unlimited capacity. In terms of distribution the use case has also focused on deploying different communication technologies spanning from wired sensor communication (e.g. I2C), via wireless (e.g. ZWave, WiFi, BLE) to communication with Internet protocols (e.g. TCP/IP, HTTP, MQTT). Eventually, it managed to specify a set of sensors to be included in the use case. Through this use-case, the HEADS IDE demonstrated how the service developer and operator can work at an abstraction level that is convenient in terms of handling differences in the underlying platforms implementations and system distribution. Thus, the development and operation process will be facilitated and speed up.

The Safe@Home use case is incorporating a set of services that Tellu is providing to Nordic municipalities together with partners where Tellu supports a great variety of sensors and gateways in its device portfolio to provide an extensive offer in the eHealth and welfare domain. TellU have started to see that we get increased sales due to our new and unique approach to device integration and operation and a strong position in specific market segments.

Through the HEADS project, Tellu has familiarised with the HEADS IDE as well as several kinds of microcomputers and their applications. Because of this new knowledge, Tellu is now

[3] (http://www.softwareag.com/corporate/Press/pressreleases/20161202_Software_AG_Acquires_Company_Zementis.asp).

implementing a generic gateway for sensor data collection based on HEADS technology as this is a central piece in TellUs eHealth and welfare offerings. Today, Tellu is operating some hundred medical sensors like blood sugar, blood pressure meters and scales, but the current solution for sensor data collection and transmission will not be feasible in the future. As of today, Tellu has no generic microcomputer gateway in the device library. Such a gateway must support several communication interfaces like Bluetooth/BLE for medical sensor communication and WiFi/GSM communication for transferring information to TelluCloud services. Our experience with microcomputers like Raspberry PI and Intel Edison together with the HEADS tools, show us that applying the HEADS framework is the correct approach to achieving a generic and operational sensor gateway. The Tellu gateway development is starting early in 2017 and we are expecting to be able to deliver gateways to the marked before the summer 2017. Tellu has received concrete requests for such gateways from partners buying services from Tellu.

Through the Safe@Home use-case Tellu has worked with a novel concept for fall detection, medical gateway and home automation services. Tellu has applied for patent on the invention and are planning to exploit this opportunity to provide improved fall detection services to the marked. By the end of HEADS project, we have a pilot system based on HEADS results implemented. Tellu is collaborating with Service Providers delivering elderly care services to Norwegian municipalities, and they have showed great interest in the fall system. Norwegian health authorities anticipate as much as 120.000 elderly care alarms in Norway by 2020. However, they also say that due to new technology and possibilities, the number may be as high as 300.000. To demonstrate the technology Tellu has a permanent demonstration at Telenor Expo to demonstrate the setup of Safe@Home services.

Further, as part of the strategic acquirement of ThingML Tellu is incorporating the entire HEADS suite of tools and methodologies into development strategies for services in the IoT domain.

2.7 Use Case SensingNews

ATC develops services and application for the news and media industry, with the NewsAsset suite being one of its most prominent product lines. NewsAsset is an end-to-end multimedia cross-channel solution for news agencies, broadcasters and publishers. It allows simple editorial and issue planning, aggregation of content from multiple feeds (newswires, web, blogs, RSS), tools for editing or creating new content, archiving, and distributing it in the desired channels. It provides content adaptation for multiple channels, such as web and mobile, automatic pagination for printed output and broadcast program scheduling. NewsAsset currently runs on dedicated servers which have to be configured for receiving the different components of the application and its architecture remains centralized around a central database. To keep up with the demands of the news and media domain, the services provided by ATC need to constantly expand order to incorporate new data sources and new distribution channels.

The SensingNews use case is referring to the future computing continuum applied in the media domain. It is composed of a wide set of heterogeneous platforms (Java, JavaScript, .NET) and promises to be an environment that will definitely affect the media industry in terms of creating, managing and exploiting trustworthy media items. Nowadays, interesting media info is out there in the digital world and can be possessed and exploited by utilizing a variation of nodes and software engineering practices like network nodes, gateways, smart-phones, cloud computing and service-oriented methods, etc. ATC develops HD-services and application for the news and media industry, with the NewsAsset suite being one of its most prominent product lines. NewsAsset is an end-to-end multimedia cross-channel solution for news agencies, broadcasters and publishers. The challenge for NewsAsset platform as a complete media system is to catch

up with this evolution and provide services that can handle the developing new situation in the media industry. HEADS innovations are envisioned to offer this opportunity. HEADS IDE is offering the creation of a "HEADS news item" as the outcome of the analysis of data that are coming from different and heterogeneous resources. The nodes could be social networks, mobile devices, existing news wires and sensor networks. A Complex Event Processing (CEP) hosted in a cloud infrastructure is used to perform the analysis of the raw data. Alongside NewsAsset, the open source SocialSensor Platform that collects, processes, and aggregates big streams of social media data and multimedia to discover trends, events, influencers, and interesting media content is used. SocialSensor is tailored to utilise HEADS technology. The challenge in the media domain is that there is a big variation in the amount of data over time. When an event happens, there is a tremendous amount of data to analyse. Thus, in that case the system needs to automatically, quickly and efficiently scale up. The HEADS runtime platform Kevoree allows to monitor and to adjust this scaling in real time. Effective scaling can improve user experience and mitigate information overload when a sudden event happens.

It is planned to present SensingNews to ATC sales department and to a major customer (a Portuguese News Agency has already expressed its interest to the system). The ultimate goal is to provide a first version of the commercially optimized system and individual modules. ATC expects the adoption of HEADS solution into NewsAsset's framework and the deployment of an initial prototype. A continuous testing and code optimization process will be initiated. Furthermore, ATC is planning to present SensingNews to a market-oriented workshop/event in the media domain, International Journalism Festival (http://www.journalismfestival.com/), 5-9 April). Several existing or potential customers will be invited to participate.

ATC plans to provide the complete package of finished products plus training, consultancy and customization services. ATC expect the full operation of the HEADS solution into news business partners' product portfolio and the initiation or consolidation of intensive marketing, sales and after-sales support activities. It is also expected an expansion of ATC customer base. Finally, ATC plans the effective operation of the HEAD virtual network and the review of the initial market limits.

3 Project Portfolio Roadmap

This Section list the set of "follow-up" projects that have been gathered and that will exploit and evolve HEADS technologies. Most of these projects have to a large extent been gathered thanks to knowledge and technologies developed in HEADS. This project portfolio represent significant funding and is therefore an important brick to ensure sustainability and evolution of HEADS technologies. We expect the project portfolio that exploits and evolves HEADS technologies to increase. HEADS partners have more than 10 such projects currently under evaluation/review.

Project	Type of project, area/application domain and HEADS partners	Remark	Status
STAMP	H2020, DevOps and testing, INRIA, SINTEF and TellU are among the partners,	Exploitation and evolution of HEADS technologies.	Ongoing, until 2019
Arrowhead	ARTEMIS project Home – automation, SINTEF is among the partners	Exploitation and evolution of HEADS technologies in particular ThingML	Ongoing, until 2017
DiversIoT	Norwegian Research Council R&D project, Security, privacy and Trust in IoT systems, SINTEF and TellU are partners	Exploitation and evolution of HEADS technologies in particular ThingML	Ongoing, Until 2021
Bilateral project Orange-INRIA	Bilateral, specify the behavior using ThingML and to introduce mutation in this model, appy Kevoree to automatically deploy a new variant for each new usage. INRIA is partner	Exploitation and evolution of HEADS technologies in particular ThingML and Kevoree	Ongoing, until 2018
Bilateral project Nokia-INRIA	Bilateral, will extend Kevoree to integrate Network configuration and in particularly the deployment of Network Virtual Function. INRIA is partner	Exploitation and evolution of HEADS technologies in particular Kevoree	Ongoing, until 2018
TellU DevOps Bilateral project TellU-SINTEF	Bilateral, DevOps and testing, integration of ThingML in TellUCloud, Bilateral project TellU-SINTEF.	Exploitation and evolution of HEADS technologies, in particular ThingML	Ongoing, until 2017
INFRA JVM	French research council project Managing resources in virtualized environment, and perform testing, INRIA is partner	Exploitation and evolution of HEADS technologies, in particular testing of resource constrained devices	Ongoing, Until 2019
Ma-sense	Internal strategic project at SISNTEF, Apply ThingML to specify and manage navigation software on drones. SINTEF is the only partner.	Exploitation and evolution of HEADS technologies, in particular ThingML	Ongoing, Until 2017
Smart – Cloud router	Norwegian project, Dynamic adaptation of Home Gateways, TellU and SINTEF work together	Exploitation and evolution of HEADS technologies, in	Ongoing, until 2018

Project	Type of project, area/application domain and HEADS partners	Remark	Status
	with Telenor, Predictor medical, Celer Way, and Tieto-Enator	particular the framework for resource constrained devices and ThingML	
Productiv 4.0	ECSEL JU project, Industry 4.0 project, Smart manufacturing applying automation and distributed systems across cloud-edge and IoT spaces, SINTEF and TellU are partners	Exploitation and evolution of HEADS technologies, in particular ThingML and the framework for resource constrainted devices	Ongoing, until 2020
RADAR-CNS	H2020 project in the eHealth. SAG is partner	Exploitation and evolution of HEADS technologies, in particular CEP recommender to facilitate distributed data steaming analysis.	Ongoing, until 2019
Perseus Project	PERSEUS' project (Projet Etudiant de Recherche Spatiale Européen Universitaire et Scientifique/ University and Scientific European Student project of Space research) is an initiative of the Launch Directorate of CNES, the French Space Agency, to promote the emergence of innovative technical solutions of spatial projects with industrial and educational particularities, realized by students of higher education. INRIA is a parnter	Exploitation and evolution of HEADS technologies in particular Kevoree https://istic.univ-rennes1.fr/actualites/perseus	Long term
Front-VL	CELTIC project on eHealth, SINTEF and TellU are partners	CELTIC project	Ongoing, until 2017
Apama and CEP	Internal SAG R&D project, CEP/Streaming analytics and IoT. Product development by SAG	Experiment for Exploitation of HEADS technologies, in particular HEADS methodology and IDE	Continuous

4 Conclusion

Through the HEADS project the technologies to model HD-Services evolved significantly and the roadmap ensure the sustainability of these technologies:

- The HEADS design language ThingML has been acquired by TellU as part of an investment deal with SINTEF TTO and Investinor. ThingML is still available as open source.
- Kevoree as the HEADS runtime language is available as open source and has evolved to scale up for uses cases with large numbers of devices.
- The HEADS IDE and methodology is planned to be evolved and exploited in several contexts.
- The RCD framework is open source and is exploited to provide new products
- The CEP is partly open source, and CEP in general is a central piece in the SAG flagship product Apama

Both uses cases demonstrates the feasibility and usefulness of the HEADS IDE and methodology. The evolution of the TellU use case has already extended TellU offerings and ATC has been able with SensingNews to add new services to the NewsAsset platform.

A significant project portfolio is acquired ensuring sustainability of HEADS results as well as their exploitation and evolution.

5 References

The references list public deliverables of the HEADS project for a more detailed description.

[1] D1.7 Final evaluation and validation
[2] D2.3 Final modelling languages and transformation framework
[3] D3.3 Final framework for resource-constrained devices and networks
[4] D4.3 Final cloud-based platforms for testing and data management
[5] D5.5 Final release of the IDE for HD-services development
[6] D5.6 Methodologies for HD-service developers and platform experts
[7] http://www.b2b.com/blog/reality_check/index.php/uncategorized/software-ag-high-speed-streaming-analytics-producing-unprecedented-results-with-intels-new-xeon-processor/ (visited 2017-03-30)
[8] http://www.softwareag.com/corporate/Press/pressreleases/20170327_Software_AG_acquires_Cumulocity_to_Extend_IoT_Technology_Leadership.asp (visited 2017-03-31)
[9] http://www.softwareag.com/corporate/Press/pressreleases/20160615_Software_AG_to_the_Edge_and_Revolutionize_IoT_Architecture_page.asp (visited 2017-03-31)

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