Third-party Innovation Enablement in FI-WARE

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Lead editors: Juan José Hierro, Uwe Riss, Axel Fasse
e-mail: jhierro@tid.es, uwe.riss@sap.com, axel.fasse@sap.com

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The current document has been elaborated using a number of collaborative tools, with the participation of Working Package Leaders and Architects as well as those partners in their teams they have decided to involve.

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1 Introduction

1.1 About this document

During the design of the first Release of FI-WARE, the FI-WARE project has made choices that will affect the way FI-WARE can be used by 3rd parties. Some of these choices will allow and some will limit the possibilities that 3rd parties will get to innovate on top of the platform. It is expected that such choices relate to architectural design and/or to the business model of FI-WARE. This deliverable will document the key choices made and will analyse their effect on future 3rd party innovation. As such, it will provide a justification of these choices against the ultimate objective of enabling 3rd party innovation.

1.2 Intended audience

Decision makers within companies, who consider the adoption of FI-WARE technologies, investors in companies targeting implementation of FI-WARE technologies, market researchers and analysts trying to evaluate the potential of FI-WARE technologies.

2 Innovation-driven value chains powered by FI-WARE

The FI-WARE project intends to support the development of innovation-driven value chains around Applications and Services. These value chains are materialized by a number of actors playing various roles supported by FI-WARE technologies. The following table describes the different roles envisioned for the FI-WARE-enabled value chains.

Role	Description
Application Developer	Future Internet Application Developers are encouraged to develop smart applications targeting either mass markets or individual enterprises and organizations (which in turn may have a limited number of users or, again, the mass market as End Users). These applications should offer flexible means for deployment, provisioning and runtime operation "on the Cloud". Future Internet Applications are intended to be meaningful and stand-alone, implementing a number of functions they export "as a Service" to End Users through a number of user interfaces but also to 3rd party applications in some cases, through well-defined service APIs (Application Programming Interfaces). They typically rely on functions provided by a number of Enablers, which can be specific to the Application Domain or generic (meaning they are for general purpose).
Enabler Developer	Enabler Developers are encouraged to develop software components or more complex systems that can be instantiated to provide functions easing the development, provisioning and/or runtime operation of Future Internet Applications. Enablers are intended to be universal, that is, multiple applications can rely on the functions they implement. Those functions are exported "as a Service" either to Applications or 3rd party Enablers, through well-defined service APIs, or to End Users in some cases, through a number of user interfaces. Enabler Developers may integrate several lower-level Enablers to realize new and more powerful Enablers. Note that Applications and Enablers resemble each other in their architecture since both implement functions that they export as services. The central differentiator between them is the primary set of users to be addressed (End Users in the case of Applications, Applications or other Enablers in the case of Enablers). Note, however, that some products may qualify equally as Applications or Enablers. Enablers can run as stand-alone components and offer services to multiple Applications. Alternatively, they can be packaged and deployed together with the particular Applications they serve. We may distinguish between developers of: • **Generic Enablers (GEs)**, which are intended to be general purpose • **Domain-specific Common Enablers**, which are intended to cover needs that are common to applications linked to a concrete Application Domain (e.g., eHealth) FI-WARE Generic Enablers refer to Generic Enablers the specifications of which have been defined or adopted in the FI-WARE project as Open Specifications.

(Application / Enabler) Service Provider	Service Providers are in charge of deploying, provisioning and operating instances of Applications or Enablers. In the case of Applications, they use to be also referred as Application Providers for short. IoT Services Enablement Platform Providers and Data/Context Management Platform Providers are terms used to refer to Enabler Service Providers that deliver an integrated set of Enablers easing development of IoT-oriented Applications or applications that exploit data and context information, respectively. Stakeholders playing the Application/Enabler Developer role may also play this role. However, this is not always the case (e.g., a Public Administrator may be playing the Service Provider role with respect to applications developed by 3rd parties that the city procures and offers to its citizens)
(Application / Enabler) Service Hosting Provider	Service Hosting Providers provide and operate the hosting infrastructure on top of which Applications or Enablers can be deployed. They entwine themselves with the Service Providers to reduce the costs for service provision. Service Hosting Providers may provide cloud services for hosting Applications and Enablers. Note that, in this case, they can indeed be considered a concrete case of Enabler Service Provider (here, the Enabler is the cloud providing hosting services) so they may be also referred as "Cloud Hosting Provider". In many cases, an entity playing the Enabler Service Provider role also hosts the Enablers it provides, therefore also playing the Enabler Service Hosting Provider role. Providers of the BigData FI-WARE GE, for example, may host this GE rather than relying on a 3rd hosting provider. However, note that this is not strictly required (one may think about a Enabler Service Provider that provides a number of Enablers, all of them being deployed on Amazon hosting services).
(Application / Enabler) Service Aggregators	Service Aggregators select services from a broad variety of Service Providers and compose them to build new service offerings that address the specific requirements of niche End Users.
(Application / Enabler) Service Brokers	Service Brokers provide Marketplace and revenue-share functions. Marketplace functions bring together a multitude of services from diverse Providers and give access to them so that users can compare the published services, matching their requirements with the capabilities of the published services. They should exploit economies of scale and protect investments in the long run. Therefore, they have to support the combination of applications and services from different providers that exploit innovative revenue-share models across providers and potentially also customers (e.g. crowd-sourcing) that have to be adapted dynamically as market conditions change.
End Users	We may distinguish between two different types of End Users: End Consumers (individuals in the mass market) and enterprises and other organizations: • **End Consumers** want to gain access and easily consume applications that can effectively assist them in daily life situations (e.g., purchasing goods, managing bank accounts, or planning travels). Some of the underlying problems involved are the management of the ever-growing data and information (e.g. from their sensor-enabled environments) and the seamless access anywhere, anytime and from any device. They also ask for improved means for communication and collaboration within their social networks,

	families, neighbourhoods in real-time and while being mobile, meeting security and privacy requirements. Overall, these capabilities would transform communities, homes and cities into safer and better places to live and leverage the Internet as an additional societal utility. The Future Internet that aims at more fine-grained and individualized services has to respond to their requirements as a central issue of innovation. Even though these end consumers do not bring about innovation they nevertheless indirectly become the drivers of innovation because they ultimately decide about the success or failure of innovation. • **Enterprises and other organizations** on the other hand, wish to get closer to their customers in order to deliver an even more compelling user experience and better service. For this reason, they would like to exploit contextual user data which may lead to a more personalized interaction experience and service offering, and would like to realize a stronger participation of users in all phases of product and service lifecycles, thereby bringing the lessons of the Web 2.0 phenomena into the services space. In order to develop and operate their services, new methods, technologies and tools are needed to speed up the time to market, to establish value added services which may be better configured in partnership with others and to simplify access to relevant resources and capabilities, e.g., from the Internet of Things. Additional requirements on business services include reduced complexity of ICT provisioning, scaling, global availability and meeting security requirements from customers and legal authorities. An appropriate Future Internet platform would greatly contribute to meeting these demands from business customers. Enterprises and organizations possess the capacity to investigate consumer behaviour and drive development of innovative services and applications based on these investigations. Despite we are referring here to enterprise and organizations playing the End User role, they can partake in the Future Internet in different ways so that we will individually consider these roles in the following. They can appear as End Users as well as in any of the previously described roles. Relations between enterprises and organizations are often governed by long-term contract, which provides another area of possible innovation.

Products implementing FI-WARE GEs can be picked, instantiated and plugged together with product instances implementing complementary Enablers in order to build FI-WARE Instances, operated by so called FI-WARE Instance Providers. FI-WARE Instance Providers can play one or more of the roles described above:

- They can for sure be categorized as *Enabler Service Providers* with respect to the Enablers (both FI-WARE GEs and complementary Enablers) they provide and operate. *FI-WARE IoT Services Enablement Platform Providers* and *FI-WARE Data/Context Management Platform Providers* are terms used to refer to Enabler Service Providers that deliver FI-WARE IoT Services Enablement GEs or FI-WARE Data/Context Management GEs, respectively.
- They may also host the Enablers that conform the particular FI-WARE Instance they operate, in which case they also play the role of *Enabler Service Hosting Provider*. Note that this, as already mentioned in the description of roles, is not strictly required (one may think about a FI-WARE Instance Provider that provides a number of FI-WARE GEs, all of them conforming a particular FI-WARE Instance, but deployed on some 3rd-party hosting services). When they provide cloud hosting capabilities and they are based on FI-WARE Cloud Hosting GEs, they can be also referred as *FI-WARE Cloud Hosting Providers*.

- They can play the role of Service Aggregators. When playing this role based on FI-WARE GEs defined to support that role, they are referred as *FI-WARE Service Aggregators*.
- They can play the role of Service Brokers. When playing this role based on FI-WARE GEs defined to support that role, they are referred as *FI-WARE Service Brokers*.

The FI-WARE project will generate a FI-WARE Instance, hereunder referred to as **FI-WARE Testbed**, which will allow partner Use Case projects (including a number of Use Case projects that are part of the European FI PPP initiative) to run and test Future Internet Applications based on FI-WARE Generic Enablers. Note that the FI-WARE Testbed is different from FI-WARE Instances linked to execution of trials or commercial services (exploitation phase). Those are typically referred to as "FI-WARE Instances in production".

The FI-WARE Testbed is aimed to be complete, in the sense that it will comprise reference implementations of all Generic Enablers defined in the FI-WARE Architecture. The FI-WARE Testbed will not necessarily be centralized, but will be under central control and be accessible from a dedicated website. The FI-WARE project will work on setting up a **FI-WARE Open Innovation Lab** around the FI-WARE Testbed after the second release of FI-WARE. This Open Innovation Lab will support community involvement beyond the initial partner Use Case projects, offering a space where future innovations on top of the Generic Enablers provided by FI-WARE can be nurtured. Availability of the FI-WARE Testbed per se does not guarantee innovation as such, therefore the FI-WARE Open Innovation Lab will comprise all what is needed to stimulate awareness among target application providers and users so that they feel attracted to participate and build a community. In order to support this, it will also bring tools helping members of the community to share their experiences, needs, etc. Combined with FI-WARE Instances that will be setup to support trials in phase 2 of the FI-PPP, it will help potential FI-WARE Instance Providers to realize about the business opportunities that participation in FI-WARE –enabled value chains will bring for them.

Design decisions in FI-WARE are targeted to offer multiple pathways to innovation for 3rd parties playing any of the roles identified in value chains enabled by FI-WARE. Following chapters elaborate on these decisions. First, we will elaborate on key decisions taken at overall FI-WARE level. Then, afterwards, we will elaborate on specific decisions taken at each of the individual FI-WARE Technical Chapters. The FI-WARE Open Innovation Lab will bring an excellent opportunity to experiment all these pathways to innovation so lessons learned will ultimately help to define a successful exploitation and sustainability strategy,

3 Key choices at overall level enabling 3rd party innovation

3.1 Open, public and royalty-free nature of the FI-WARE Architecture and FI-WARE Open Specifications

One central decision made in the FI-WARE project was to provide a truly open, public and royalty-free Architecture and set of Open Specifications. FI-WARE Open Specifications will allow any 3rd party willing to play the FI-WARE GE Developer role to develop products that are compliant with the specifications while still be open to innovate. The GEs provided by the FI-WARE partners serve as reference implementations, which can demonstrate how future Enablers can be designed and technically realised. The FI-WARE Architecture on the other hand, yields the description of how products implementing FI-WARE GE Open Specifications can be integrated to build FI-WARE Instances by so called FI-WARE Instance Providers, still giving them enough freedom for innovation. Both the FI-WARE Architecture and the FI-WARE Open Specifications are available on the public wiki of the project[1].

We envision that the public and royalty-free nature of the FI-WARE Architecture and Open Specifications will foster innovation in a variety of ways, all contributing to the creation of a virtuous circle:

- FI-WARE GE Open Specifications focus on the specifications of APIs and interoperable protocols that FI-WARE GE developers/providers have to comply with. Compliance with published specifications is what makes a FI-WARE GE compliant product replaceable. However, this does not come at the price of preventing implementers of FI-WARE GEs to innovate. Actually, they can still differentiate from competitors who implement the same FI-WARE GE specifications because FI-WARE GE Open Specifications do not prescribe how any valid implementation is designed internally. In other words, it prescribes "what" features and APIs/protocols should be supported and offered to the application developer but not "how" those APIs/protocols are to be implemented, thus providing opportunities for differentiation through innovation. FI-WARE GE implementers may also extend FI-WARE GE Open Specifications in order to incorporate innovative functions and propose those extensions for future adoption in FI-WARE.
- The ability to replace a given FI-WARE GE-compliant product by another compliant product will also protect the investment of FI-WARE Instance Providers because FI-WARE Instance Providers will avoid to be locked in any particular FI-WARE GE Developer/Provider. This is quite relevant because the whole success of FI-WARE depends on the existence of parties who may be willing to play the role of FI-WARE Instance Provider. But besides this, FI-WARE Instance Providers will be able to innovate because they will be able to combine FI-WARE GE -compliant products with products implementing complementary Enablers that may provide differential value (see next section). Therefore, there will be a space for them to innovate.
- Application developers will benefit from the existence of alternative FI-WARE GE compliant products offering the same set of APIs, avoiding to get locked in any specific vendor, therefore protecting their investment. Actually, relying on FI-WARE GE API specifications, they should be able to change the FI-WARE GE instances that their applications use at runtime. Investment protection will become a catalyser for the creation of a wide and rich community of developers, thus fostering innovation. Besides, the GE concept helps application and service developers to build new services faster since they can concentrate on the core domain aspects. As the community

[1] https://forge.fi-ware.eu/plugins/mediawiki/wiki/fiware/index.php/FI-WARE_Architecture_and_Open_Specifications

of developers becomes wider, potential developers of FI-WARE GE compliant products will become attracted who will be called to differentiate among themselves through innovation about "how" FI-WARE GE specifications get implemented. This way, the referred virtuous circle gets closed.

3.2 The FI-WARE Instance concept

As explained previously, products implementing FI-WARE GEs can be picked, instantiated and plugged together with complementary product instances in order to build FI-WARE Instances operated by so called FI-WARE Instance Providers. This means that it is not the aim of the FI-WARE project to provide a single global FI-WARE Instance (like www.google.com) trying to become the single global platform for all Future Internet Applications.

On the other hand, a FI-WARE Instance does not have to comprise all FI-WARE GEs. It may just comprise those GEs linked to a particular chapter (e.g., Cloud Hosting Chapter) or several chapters. Even within a given chapter, it may comprise only part of the FI-WARE GEs (e.g., those in the Data/Context Management chapter dealing with discrete data).

Complementary products allow FI-WARE Instance Providers to differentiate among themselves by means of more efficient operations or the set of Enablers they provide. For example, one FI-WARE Instance Provider may decide to develop and/or integrate its own set of monitoring/management tools, because this will allow it to benefit from a better integration with the tools already used for the monitoring/managing of other services. This will increase the efficiency of operations significantly. Another FI-WARE Instance Provider, in turn, may go for complementing the set of FI-WARE GEs it provides with other Enablers developed on their own, exploiting cross-selling opportunities.

Besides, a given FI-WARE Instance Provider may rely on the GEs of the FI-WARE Instance operated by another FI-WARE Instance Provider. For example, a FI-WARE Instance Provider may provide GEs in the IoT and Data/Context Management chapter and deploy them based on services offered by some FI-WARE Cloud Hosting Provider (i.e., a FI-WARE Instance Provider running a FI-WARE Instance that just comprise cloud hosting capabilities based on FI-WARE Cloud GEs).

All of this will not restrict the way Application Developers ultimately develop their applications because they only have to take care of the APIs defined in FI-WARE. Application Providers, in turn, will just need to pick the FI-WARE GE Instances, associated to particular FI-WARE Instances, their Applications will use at runtime. Functionality of such FI-WARE GE Instances will be provided "as a Service", accessible from applications by means of invoking the corresponding FI-WARE GE APIs, and Application Providers may decide to change the configuration of their applications so that they stop using a particular FI-WARE GE Instance and start using an alternative instance of the same FI-WARE GE.

This model eases the advent of multiple FI-WARE Instance Providers since each of them will not have to provide all the FI-WARE GEs to go to market. Going for a "provide-all-or-nothing" approach had actually meant that the number of FI-WARE Instance Providers be limited to a small number of companies. With the adopted approach, FI-WARE Instance Providers can concentrate their bet on FI-WARE GEs for which they own the real expertise, so that they can make business out of them. The ability to combine services offered by GE instances located in multiple FI-WARE Instances will foster an ecosystem, in which only those FI-WARE Instance Providers bringing valuable and innovative offers will survive and where liaisons between complementary, best-of-the-breed, FI-WARE Instance Providers may happen.

4 Key choices at chapter level enabling 3rd party innovation

4.1 Applications & Services

The Application and Services Ecosystems delivery framework chapter in FI-WARE (Apps Chapter, for short) will provide the infrastructure that enables the provision, composition, and trading of services on the Future Internet. Both services and applications encompass technical, business and operational perspectives. In order to make a service tradable, all of the relevant aspects such as its general description, provided interfaces, terms and conditions, pricing, SLA conditions, should be described in an open and very generic format. For this purpose, we have decided to use Linked-open-Data USDL[2], which is flexible enough to fulfil these needs.

The Apps Chapter provides central GEs for **Repositories**, **Registries**, **Marketplaces**, **Stores**, **Business Models and Elements** (including revenue sharing and SLA management) as well as **Service Mediation** and **Service Composition**.

The delivered implementations of the Generic Enablers defined in the Apps Chapter provide ensembles of interacting services. These ensembles and their interaction can be seen as blueprints of the architecture that we envision for the Future Internet and that will act as catalyser of completely new, flexible and innovative service ecosystems. Through these blueprints it becomes clearer for 3rd parties to understand the intended interaction of GEs; this helps them to build their own applications and services in combination with those of other 3rd party providers and in compliance with the general FI-WARE architecture. The key feature in this respect is the capability to compose services coming from different parties and published on the Marketplace in order to build completely new innovative offerings.

This open and flexible framework supports 3rd party innovation at 5 different levels:

- The FI-WARE **composition and business framework** facilitates the introduction of simple service compositions by 3rd party providers without undue technical implementation efforts.
- Implicitly the FI-WARE Apps Chapter provides an **architecture blueprint** that describes how the fundamental Enablers such as Marketplace, Repository, and Service Composition interact with each other. Therefore, 3rd party providers can build on this core. They can introduce their own Services and Applications as extension of this core within the platform framework of GEs provided by FI-WARE.
- The chapter does not only drive technological innovation but also fosters innovative **business approaches** including novel business models, based on the combination of existing service business models. The business framework supports such combinations of business models respecting the existing revenue sharing and SLA management.
- Finally, the current FI-WARE project partners already form the core of **future service ecosystems** that are open for new 3rd party players to participate and to further develop this ecosystem with respect to new domains and technologies.

The Unified Service Description Language (USDL) enables the general description, beyond specification of technical interfaces, of instances of the different FI-WARE Generic Enablers. We expect USDL to realise universal exchangeability of information between services. Based on the use of USDL, we see the FI-PPP partners as the core of a future community of practice that exploits the full capacity of this language

[2] In the following we will use the shorter expression USDL instead of Linked-open-data USDL for the sake of better readability.

in various domains. In particular the Linked Open Data extension of USDL prevents adoption of USDL to become a bottleneck. Instead it rather invites partners from multiple domains to develop their own specific extensions. This approach enables 3rd parties to bring in their own specifics such as their domain knowledge to extend USDL towards their concrete needs while retaining the principle interoperability of Services and Applications.

3rd Party Roles

In the following, we elaborate on examples that illustrate how the FI-WARE design and architectural decisions in the Apps Chapter may lead to innovation introduced by 3rd parties. The roles, which are described here, correspond to the compilation given in Chapter 2:

- **Application/Enabler Service Developers and Providers**

  They provide new domain services that aim increasing the efficiency of service provision. For example, such increase can be realised by a simpler coordination and orchestration of services, which is supported by the FI-WARE platform that provides development tools and the core functionalities like hosting and security services. Here we want to point at specific aspects of the FI-WARE platform that support such service providers:

  - The Unified Service Description Language (USDL) provides a means for the specific description of Services in a general form:
    - it makes services searchable, which is a fundamental requirement for the definition of services marketplaces.
    - it realises a Linked-open-Data approach that helps to avoid time-consuming and error-prone data translations.
    - it follows a Linked-open-Data approach that allows for the description of all possible domain specific facets of data; this increases the efficiency of service provisioning and the service processing.
    - it is designed to be supplemented by aspect and domain specific vocabularies. Application Providers can extend the USDL descriptions according to the needs of innovative applications relying on adequate descriptions of arbitrary aspects on top of USDL. For instance, a logistics provider could introduce new USDL descriptions that support the handling of cold chains.
  - Making usage of Service Composition GEs, which will be delivered by the App Chapter, Application/Enabler Service Developers may build new services compositions on top of other innovative services provided by 3rd parties. Application/Enabler Providers may also take advantage because their Applications/Enablers may become more valuable to End Users when combined with others.
  - As part of the service platform, the FI-WARE Marketplace is available to all 3rd parties so that it will foster the competition between various service offerings. Thus, it works in favour of the most suitable and efficient available service, which can be chosen to build better and more innovative applications easily.
  - The Generic Enablers developed in the Apps Chapter use Web APIs that allow Application Developers to build innovative solutions for their target environments being part of the business framework.
  - Instruments and tools provided by the Apps Chapter support the development of new Business Elements & Business Models and help Application/Enabler Service Providers to cover the business aspects of new services more efficiently. An example for this is the GE for revenue sharing.

- **Service Broker**

  FI-WARE supports Service Brokers in innovation with respect to the following aspects:

  - USDL yields a formalized service description and thus enables a more efficient comparison of services including relevant business and operational aspects leading to increased competition. Hereby innovators with novel and more attractive service offerings are favored even though they might not yet be well established.
  - The web-scale distribution of service repositories, which gives higher flexibility for different kinds of instances of the business framework: This, in return, will help realize a wide range of innovative applications and business cases.
  - The marketplace that provides the general overview of existing services and means of expressing feedback from end consumers; this drives competition, which can be leveraged for innovative businesses.

- **Service Hosting Providers**

  The chapter supports specific aspects that help Service Hosting Providers:

  - By including hosting services, FI-WARE, as commercial service platform, provides opportunities for innovative hosting providers since the uniform description simplifies the exchange of GE-based hosting services, for example, changes to more innovative hosting providers. In this way the FI-WARE infrastructure avoids “lock-in” effects.
  - The same features support the provision of specialized hosting services and increase the competition between hosting providers; this fosters innovation as well.

- **Service Aggregators**

  - FI-WARE’s GE concept and USDL simplify the aggregation of services since they provide a generic umbrella including a description of various aspects for aggregation and composition. FI-WARE provides several composition environments for this purpose addressing different application scenarios. This shows the potential for the integration of new upcoming innovative composition and aggregation technologies. These environments diminish the effort of service aggregators considerably.
  - The marketplace makes it easier to find specific services, which are required for composition and specialized offerings, enabled by USDL.
  - The support of generic Business Elements & Business Models including revenue sharing and service level agreement (SLA) help supplement new service aggregations with a suitable business-oriented infrastructure. The Open Specifications hereby specify how to interact with the various GEs.
  - The basic point of Composition Environments is that they stimulate innovation through quick service creation. A list of available services can trigger new combinations or additional steps leading to service improvements.
  - For tailor-made services this approach allows new business opportunities with a clear long-tail perspective.

- **Channel Makers**

  The Apps Chapter supports innovation in this respect in various ways:

  - Multi-channel and multi-device features help to offer services through social and content platforms as well as operating systems and handsets of devices.
  - The I2ND Chapter provides a set of open and standardised interfaces to network and devices that supports these features.

- **End Users**

  In a long-term perspective the FI-WARE infrastructure can even support End Users in innovation, enabling them to adapt service to their personal needs.

  - The adaptability of Composition Editors to personal needs further encourages the personalized use of services offered on the FI-WARE platform.
  - Composition Environments target at a simplification of processes and communication, customization and bundling of services and tasks and thus change consumers' organisational habits. Services are essential for organisational tasks in private and business life. Indeed, we find a growing demand for individualized ICT services that are tailored to personal needs. They can help to essentially innovate the management of individual resources and communications.
  - Composition Environments enable enterprises and other organisations (especially SME) to explore new organizational processes by means of web, media and telco services. Allowing non-programmers to compose and evaluate situational technical solutions based on several enabling services drive flexible organizational processes for more efficiency, faster time-to-market and even new business processes with customers.

Generally we can say that the Apps Chapter diminishes the following **barriers** for 3rd party innovation:

- lack of guaranteed SLAs for compositions of service
- complexity in handling service compositions, taking into account compliance with business terms and conditions
- complexity during the integration of specialised services
- proprietary environments for services that are to be composed
- complexity of frameworks supporting monetization of services and service compositions

4.2 Cloud

The Cloud Hosting Chapter provides capabilities to host compute, storage and network resources required by Future Internet applications and services, so that they can be consumed "as a service", typically on a pay-per-use basis or some similar manner. This allows Application/Enabler Service Providers, even though they represent small companies, to deliver services without large initial capex while still being able keep opex still under control, so only the resources that are required to handle an increasing and variable amount of service requests, data or number of customers are allocated. Based on their specific needs, cloud consumers can choose between multiple abstraction levels of provisioned resources. These are provided by different core Generic Enablers. This includes individual virtual machines and associated resources (IaaS Resource Management GE), objects and associated metadata (Object Storage GE), application containers (PaaS Management GE) or cloud proxy appliances (Cloud Proxy GE), which can be deployed forming complex topologies of multiple resources, elastically allocated (IaaS Service Management).

Different stakeholders, who are involved in the life cycle of Future Internet applications and services, can use the various Cloud Hosting capabilities for different purposes. For example, *cloud providers* can use Cloud Hosting GEs to offer cloud capabilities to their customers. *Application developers* can use cloud hosting capabilities (provided by a cloud provider) during the development cycle, to develop and test their applications. Moreover, *service providers* can use cloud resources along the various phases of the service life cycle -- testing, migration, staging, 'production', disaster recovery, etc.

3rd Party Roles

Cloud Hosting GEs enable 3rd party innovation in a variety of ways depending on their level of abstraction. Here are some examples, elaborating on the specific mechanisms facilitating 3rd party innovation as applicable to 3rd party companies playing different roles in the FI-WARE ecosystem:

- **Application/Enabler Service Providers**
  - The IaaS DataCenter Resource Management GE provided by FI-WARE is open for deployment of arbitrary software stacks, installed on one of standard general-purpose operating systems (Windows, Linux, etc). This way 3rd parties can easily deploy and manage their applications on existing cloud infrastructure, and focus on innovation in their respective areas, without the need to spend effort on deployment and management of their own servers.
  - IaaS Service Management GE provided by FI-WARE can help designing complex virtual infrastructures, supporting applications spanning multiple virtual machines, with built-in capability to scale the application by adding more resource on demand, based on predefined policies and rules. Moreover, provisioning and life cycle of such services will be fully automated, reducing the burden of manual installation and administration of the corresponding virtual machines.
  - Object Storage GE provided by FI-WARE can be used by a service provider to easily store objects such as images and video clips, uploaded by users of their new social application, or storing medical records of patients -- all that without worrying about implementation of such a storage in a scalable and resilient way.
  - Capabilities provided by Cloud Proxy GE would enable service providers to develop applications that leverage resources located on gateway-like devices close to End Users, thus improving user experience, enhancing security, etc.
  - Management of the life cycle of complex Future Internet applications and services is a highly IT-intensive and labor-intensive effort, covering numerous activities such as hardening and testing, migration and staging, deployment and upgrade, rollout and disaster recovery. 3rd party service providers can greatly simplify these processes by hosting the applications/services in a cloud environment -- where these tasks can be automated using

capabilities of IaaS Data Center Resource Management and IaaS Service Management GEs. This will allow then investing in development of better, more innovative and hence competitive service offerings.

- One of the challenges of cloud computing is the lack of mature standards. By promoting and adopting standards-based open specifications, FI-WARE contributes to better portability and interoperability of cloud-based services, thus shifting the emphasis on functionality and innovation in core application capabilities. When open standards are in place, service providers have more flexibility in choosing cloud provider to host their applications, and can also move their application from one provider to another, without the need to redesign and/or rebuild their applications, avoiding lock-in, enabling cross-cloud application deployment, etc.

- **Application/Enabler Developers**
  - Application developers can use Cloud Hosting capabilities for rapid development and testing of their applications, by leveraging the capabilities to automate the life cycle of virtual machines provided by IaaS Data Center Resource Management GE (and collections of virtual machines, by IaaS Service Management GE), and to link it to the life cycle of the application providing higher-level abstraction to the users (adopting the emerging DevOps trend). Developers can invest their effort in developing the most appealing and competitive applications and services, without investing in their own IT infrastructure and labor.

- **Cloud Providers, Service Hosting Providers**
  - Cloud providers (also referred as service hosting providers) can build highly innovative cloud offerings using Cloud Hosting GEs provided by FI-WARE. By leveraging the state of the art capabilities encompassed in FI-WARE platform, they can put their effort on developing differentiating value-add capabilities, as well as new cloud service, new cloud-based business models, etc. For example, a cloud provider may leverage IaaS Service Management GE from FI-WARE, enhance it with a rich catalog of custom-built service templates (virtual appliances), and offer automated life cycle of those service templates as a premium service to their customers.
  - The foundation of the Cloud Hosting platform in FI-WARE is based on OpenStack, which is a leading, rapidly emerging open source project provided under Apache v2 license and widely adopted by the industrial and scientific communities. Leading IT companies are contributing intellectual property and effort to create a highly advanced open source cloud infrastructure. This phenomenon creates a unique opportunity for 3rd party companies to build innovative solutions and offerings on top of OpenStack, leveraging the momentum and the huge investment across the industry in the cloud infrastructure layer, without the need to build the foundation on their own. FI-WARE adds even more capabilities available to 3rd parties, boosting their ability to innovate even more. For example, FI-WARE implementation of IaaS Data Center Resource Management GE will provide premium resiliency and efficiency for workloads hosted in the cloud, allowing to offer better QoS and differentiated SLAs to cloud consumers.
  - Relying on capabilities of Cloud Proxies and the ability to manage them, Cloud/Hosting Providers may offer an innovative hosting service that expands the limits of traditional hosting, enabling to offer allocation of resources not just in centralized datacenters but also in nodes that are close to End Users.

Generally we can say that the Cloud Services reduce the following **barriers** for 3rd parties:

- The entrance threshold for new players on the market, especially if they provide applications and services for smaller consumer groups, is reduced since the support of the cloud enablement supersedes the investment into expensive infrastructure.
- On the other hand, a dynamic market for cloud services can provide a competitive environment that encourages the development of new kinds of hosting services for smaller groups of services providers with more specific needs.

4.3 Internet of Things (IoT) Services Enablement

The chapter for Internet of Things (IoT) Service Enablement (IoT Chapter, for short) aims at fostering innovation by supporting powerful, connective and generally applicable everyday Internet of Things use cases. For this purpose it offers a framework of suitable Generic Enablers that support such connection.

The envisaged architecture will support the connectivity for several families and standards of devices and smart objects, as well as the management of the huge amount of information that machines and people will exchange in a near future.

The FI-Ware IoT architecture is based on two fundamental ideas:

- Provide the right abstraction level to deliver the relevant functionalities that simplify the development of your own Internet of Things application. This is done by means of providing simple yet powerful APIs for management of IoT-related information as “context” information but also by providing means for composing services “on the fly”.
- Enable a physical infrastructure which will be able to provide the same access to different kind of sensors, actuators, devices based on their own standardized interfaces. This infrastructure includes gateways as smart things which bridge between several technologies but also host management features for things and information.

These two concepts foster Open Innovation not only by Application/Enabler Developers/Providers but also by End Users. Actually, each End User will be able to become service developer using connected things in his own environment and discovering other resources through secured networks capabilities.

The IoT Gateway Data Handling GE proposes collecting in real-time relevant information based on some local rules which in the further release will be associated to specific profiles and rights. All data are exchanged under the same model (defined in OMA NGSI) and managed as context information, without prescribing any particular data model, thus enabling adaptation to specific domains. This approach assumes a common interface with the IoT Things Management GE that manages a smart thing as an entity that possesses attributes the values of which map to data captured through a collection of existing sensors and IoT resources. The IoT Gateway Device Management GE includes some interfaces with dedicated existing protocols and standards as IETF Core CoaP and further releases will include more protocol adaptors as for Zigbee sensor or RFID tags. This set of Generic Enablers will provide for application and Enablers developers an uniform access to several type of sensors and object using the same model: OMA NGSI.

3rd Party Roles

During the design and architecture process key decisions were taken in order to foster innovation. In the following we present the different role perspectives:

- **Application/Enabler Developers and Providers**
  - The Generic Enablers provided by this chapter help Application/Enabler Developers (Providers) to develop (provide) new services using IoT resources. Their innovation will be

based on the relationships between different kinds of things and sensors to build cross-domain applications. Those applications will also enable interactions with the environment instead of just collecting some raw data and managing smart historical analysis. To be able to interact in real-time with a dedicated environment and all things or sensors, which will be in this environment maybe during only some minutes, is the key challenge that Service Providers will target, using IoT Service Enablement FI-WARE GEs. Applications will be enabled to identify in some seconds how many things are available in a building, in a street, around you and these applications will know the value of attributes linked to things since they will be available as context information. Using these characteristics, new information will be pushed to some other applications and for the best End Users services.

- The chapter identifies a meta-model which can federate a large variety of existing standards dedicated to vertical areas with their own constraints (e.g. Logistics, Environment, Utilities). This powerful interface with several families of sensors and actuators is based on the Open Mobile Alliance Next Generation Service Interface (OMA NGSI 10 description) which is not specifically related to Internet of Things but enable to exploit data coming from physical world as well as contextual data capturing End Users or applications behaviour. This approach would enhance cross vertical applications providing knowledge of what happen in some other environments,
- The architecture is split into different parts such as device, gateway and backend. At each level of the Internet of Things there are possibilities for innovation: a device vendor can integrate the new device no matter of what protocol the device supports, through protocol adaptation, into the gateway; a gateway vendor (hardware vendor) can deploy the gateway software on top of the new product and introduce additional proprietary features through connector components; a software component developer can integrate on top of the backend through the exposed, things and device management-level APIs,

- **Cloud Providers, Service Hosting Providers**

  Cloud Providers and Service Hosting Providers may add value to their offering by means of providing FI-WARE IoT Services Enablement GEs as built-in "libraries" available to hosted Applications. Hosted Applications will get automatic access to FI-WARE IoT Services Enablement GE APIs through well defined service end points. In the case of Cloud Providers, FI-WARE IoT Services Enablement GEs will be configured so that allocated computing, storage and network resources will adapt dynamically. Therefore the Cloud Provider will deal with the complexity of configuring the virtual hosting infrastructure on top of which each FI-WARE IoT Services Enablement GE would be deployed. Innovative offerings can be put in place so that usage (and therefore payment) of FI-WARE IoT Services Enablement GEs and Hosting Services can be bundled together.

- **IoT Services Enablement Platform Providers**

  Besides innovation capabilities shared with Application and other Enabler Service Providers (point above), IoT Services Enablement Platform Providers may benefit from the following features:

  - The most popular device and gateway level protocols will be supported either by default or through protocol adapters, while additional ones can be incorporated through the development of new protocol adapters. This integration of several protocols will provide new business opportunities for IoT Services Enablement Platform Providers who will be enabled to easily deliver new frameworks for enlarged Internet of Things worlds.
  - Default protocols and APIs at the backend and gateway level designed/chosen to support the widest range of possible Internet of Things scenarios, but also to be based on support from

industrial partners. This will become a pole of attraction for Application Developers/Providers.

- IoT Services Enablement Platform Providers may use instances of FI-WARE GEs defined in the IoT Chapter over a wide range of technologies. In particular, they may choose gateway technologies from a set of different possibilities such as commercial, off the shelf hardware, such as commodity PC-s, as well as mobile platforms (Android devices) and credit card sized gateways, IoT Servcies Enablement Platform Providers will create their own world of peer to peer Internet of Things services depending of dedicated rights things owners or users will delegate. Note that by the aid of Enablers from the Apps Chapter, IoT Services Enablement Platform Providers will be able to publish services they are able to share and innovate themselves creating innovative Business Models, e.g. offering services per event, some rights to access resources for a dedicated timeslot and so on.

- **Services Aggregators/Brokers**

  They get the opportunity to more easily connect existing services to physical objects, offering innovative solutions with more impact on everyday use. It is particularly the possibility to better integrate digital services and physical objects such as products, means of transportation and others that provides a wide range of innovation and foster future service economy.

- **End Users**

  They will be the most active and relevant actors of a Future Internet based on IoT Service Enablement FI-WARE GEs. They will actually be able to provide and publish capabilities and services linked to their own smart things. These things will provide their own services and contribute to other innovative services with dedicated interfaces. In particular they obtains the following advantages

  - End Users will be able to declare their smart things in AppStores and to describe them easily with some characteristics, the kind of data and information they should send and receive, but also associate and delegate some rights for typical applications. End Users will also publish that they are interested by typical context elements to enrich their Apps and to be active in the smart things world. Some of the Apps will provide administration and configuration facilities and End Users will be some primary developers using customization of their smart things.
  - End Users will be actors of the creation of the Internet of Things world being able to manage themselves access rights on data, events and information they will deliver and receive. New tools will appear to enhance application mash-up using Internet of Things resources and providing new user interfaces.

4.4 Data/Context Management

Nowadays, several well-known free Internet services are based on business models that exploit massive data provided by end users. This data is exploited in advertising or offered to 3rd parties so that they can build innovative applications. Twitter, Facebook, Amazon, Google and many others are examples of this.

The Data/Context Management FI-WARE chapter aims at providing outperforming and platform-like GEs that will ease development and provision of innovative applications that require management, processing and exploitation of context information as well as data streams in real-time and at massive scale. Combined with Enablers coming from the Apps Chapters, Application Providers will be able to build innovative business models such as the ones described above and beyond.

In a nutshell, FI-WARE Data/Context Management GEs will enable to:

- Record, subscribe for being notified about and query for context information coming from different sources.
- Model changes in context as events that can be processed to detect complex situations that will lead to generation of actions or the generation of new context information (therefore, also treatable as events).
- Processing large amounts of context information in an aggregated way, using map&reduce techniques, in order to generate knowledge that may also lead to execution of actions and/or creation of new context information.
- Process data streams (particularly, multimedia video streams) coming from different sources in order to generate new data streams as well as context information that can be further exploited.
- Process metadata that may be linked to context information, using standard semantic support technologies.
- Manage some context information, such Location information, in a standardized way.

The amount of context information being managed is huge and may relate to entities of the physical world (things) or any other kind of entities (end users, application processes, etc). Data streams may also come from different sources and be required to be delivered to multiple destinations. Both have to be treated in real-time or almost real-time.

It is difficult to anticipate how these GEs can be used to develop innovative applications. Many times, innovation occurs when one given party discovers how to exploit, using the capabilities above, context information provided by a 3rd party, thus leading to a truly innovative application. A good example would be that of a party that could discover the potential applicability of analysing mobile operators logging information (CDRs) using the BigData Analysis GE in order to detect crowds or individuals in certain locations in the cities and therefore be able to control, for instance, lighting systems.

3rd Party Roles

During the design and architecture process key decisions were taken in order to foster innovation. In the following we present the different role perspectives:

- **Application/Enabler Developers and Providers**
  - The FI-WARE Data/Context Management Chapter provides a set of enablers that solve very common problems but this doesn't mean they are simple to solve. Indeed, they are problems that are rather hard to solve because of their inherent complexity and can be even harder when trying to deal with large amount of data and/or close to real-time response is required. The investment required to build these components, just to be able to develop applications on top, would not be affordable by many SMEs which are the companies from which major innovative ideas in the application space will come from. Using FI-WARE Data/Context Management GEs, Application/Enabler Developers and Providers will be able to focus their investment in what really may be innovative and differential in their applications. Their investment would be protected as far as FI-WARE Data/Context Management GE APIs start to become adopted (something we expect to foster based on the open, public and royalty-free nature of FI-WARE Architecture and Open Specifications, as explained in chapter 2).
  - Modularity is a basic concept that has always been bear in mind in the design of the FI-WARE Data/Context Management Chapter. This means that each FI-WARE Data/Context Management GE has been ultimately designed to be able to work alone (no take-it-all-or-

nothing approach) but still can easily be integrated with GEs in the rest of the chapter[3]. Application/Enabler Developers will benefit from this because they will be able to use more sophisticated (while not more complex) functions without taking care of this integration themselves. Some examples about how this integration can be exploited follows:

  - The Publish/Subscribe Broker GE may connect with the Complex Event Processing (CEP) GE so that rules can be applied on context information to detect situations upon which some immediate action is required, essentially because updates on context can be treated as events that the CEP GE can process.
  - The Publish/Subscribe Broker GE may connect with the BigData Analysis GE so that map reduce analysis can be applied on context information to generate insights or even updated values on attributes of more abstract context information entities that can be also part of the context (i.e., so that generated values can be submitted to the Publish/Subscribe Broker GE as an update of context).
  - Context Producers updating context information on the Publish/Subscribe Broker GE can rely on the Location Platform GE to update value of attributes linked to location of physical objects or users.
  - Notifications derived from the Compressed Domain Video Analysis GE (formerly named as Multimedia Analysis GE) can be further processed by the CEP GE or lead to update on attributes of context entities through the Publish/Subscribe Broker GE

- One key design principle in the Chapter is that of enabling Applications/Enablers to rely on services being offered by single (therefore shared) instances of the FI-WARE Data/Context Management GEs. This will enable that context information updated by a given Application/Enabler be used by another Application/Enabler. A lot of opportunities for innovation can be derived from that, based on the creation of an innovation ecosystem where new Applications not only can leverage on services provided by 3rd Applications but also on data generated by those 3rd applications, accessible and exploitable using FI-WARE Data/Context Management GEs.

- **Data/Context Management Platform and IoT Service Enablement Providers**
  - Relying on implementation of FI-WARE Data/Context Management GEs, Data/Context Management Platform Providers may create a solid and unique offering. FI-WARE GE instances integrated in the provided platform would be offered "as a Service", being able to manage data from Applications (or other Enablers) in almost real-time and large scale. Innovative business models based on the ability to pay just for actual usage or charge for published data can be implemented.
  - IoT Service Enablement Providers may federate with Data/Context Management Platform Providers, or the same FI-WARE Instance Provider can play even both roles. This way, commercialization of services or data offered by one platform may take advantage of service and/or data that is published by the other.

- **Cloud Providers, Service Hosting Providers**
  - Cloud Providers and Service Hosting Providers may add value to their offering by means of providing FI-WARE Data/Context Management GEs as built-in "libraries" available to hosted

[3] Despite feasibility of integration has been bear in mind during the overall design of the FI-WARE Data/Context Management Chapter since the very first Release, integration is the major focus of the second Release.

Applications. Hosted Applications will get automatic access to FI-WARE Data/Context Management GE APIs through well-defined service end points. In the case of Cloud Providers, FI-WARE Data/Context Management GEs will be configured so that allocated computing, storage and network resources will adapt dynamically.

- Cloud Providers will deal with the complexity of configuring the virtual hosting infrastructure on top of which each FI-WARE Data/Context Management GE would be deployed. Therefore, Application/Enabler Developers and Providers can get rid of the complexity of deploying and configuring them. Innovative offerings can be put in place so that usage (and therefore payment) of FI-WARE Data/Context Management GE and Hosting Services can be bundled together.

- **Service Aggregators/Brokers**

  Service Aggregators/Brokers may add value to their offering by means of publishing services provided by a Data/Context Management Platform based on FI-WARE GEs on their marketplaces. This will allow 3rd parties to use them to compose new Services or Applications, potentially using composition tools. Service Brokers would share revenues with the Data/Context Management Platform Provider. Using enablers provided by Service Aggregators and Brokers, Applications may be able to commercialize data they generate, which may become a complementary source of revenues or even the main one.

- **End Users**

  - We can envision scenarios in which data generated from FI-WARE Data/Context Management GE instances running on a particular FI-WARE Instance can be mashed up with Applications and Services directly by End Users, using tools developed in the FI-WARE Apps Chapter. Mashup applications may be used by End Users in order to improve their productivity or to be provided to 3rd parties (End Users becoming prosumers)
  - We can also envision innovative scenarios in which the End User becomes a raw data/context source feeding Data/Context Management GEs and in turn they obtain some direct or side profit out of it.

4.5 I2ND

The focus of I2ND GEs inside the FI-WARE platform is to exploit functionalities from the connected devices, the network and the end termination towards the applications and services providers. Therefore it is possible to create an additional set of 3rd party applications incorporating the special functionalities of such Generic Enablers. Via special APIs, the 3rd party applications and/or services are able to retrieve network status information, set up application based QoS parameters, exploit functionalities of an end-terminal or from the network side and put processing power as well as storage capacity towards the network-cloud-edge. Four GEs are defined in the I2ND architecture:

- *CDI (Connected Device Interface)*: It is a GE which provides a set of runtime APIs available to application developers. The CDI GE provides two main types of API, on-device API which is available to Developers who create applications which execute on the device (like an installed application), and off-device API which is available to Developers who create cloud hosted (server hosted) applications, which need to interact with connected devices, similar to a network service API. The APIs provide access to device specific features, such as local hardware, and integrate with the network through which the devices are connected to provide advanced QoE (Quality of Experience) by monitoring user interactions and using that data to drive changes in any network dependant QoS (Quality of Service) configuration.

- *CE (Cloud Edge)*: This GE can be seen as a "super gateway". It is located at the edge of the home, in between the WAN (xDSL, cable ...) and the LAN (Ethernet, WiFi, home-automation networks etc., ...). It has the capacity to locally execute downloadable applications in virtual machines (or in containers), thus giving the 3rd party application developers an easy and wide access to all the features of a machine that is located at the user's premises (a Linux computer in fact).
- *NetIC (Network Information and Control)*: The API of this GE is intended to facilitate access to network information and network control features for a wide range of 3rd parties. This will facilitate the operation of a new class of services which require a tailored quality of service for optimum service delivery; on the other hand the network operators retain all network control needed to maintain safe operation of their networks.
- *S3C (Service, Capability, Connectivity and Control)*: The API of S3C is intended to facilitate the access to information and control of the services offered by a Future Internet network as well as to the means for managing the connectivity parameters. The new API enables the application platforms and the services to dynamically adapt their delivery parameters through the specific network while the control of the network is maintained in the operator exposing the API. The parameters that can be adapted and exposed through the specific API, address the telecom application adaptation, mediation and exposure, the device connectivity and remote management and the exposure of connectivity parameters such as location, resource reservations, subscription profiles and charging.

3rd Party Roles

The following compilation illustrates how innovation can be introduced by parties which play the roles described in the previous sections, through the exploitation of the FI-WARE design and architectural solutions provided by the I2ND chapter GEs.

- **Application Developers:**

  The I2ND GEs support 3rd party Application Developers by lowering the cost of application development, aiding innovation, and making it easier for developers to provide applications with excellent user experiences across multiple device types, functioning across multiple network infrastructures, and avoiding 'link bottlenecks' when operating at the boundary of a *cloud universe*. Application Developers can leverage more specifically:

  - The core functionalities provided by the CDI GE such as:
    - Application platform ubiquity: the cross platform development problem is addressed, and it aids developers by providing an single easily understood and familiar development environment based on web standards - first of all HTML and JavaScript - which can be supported by most of the key connected device categories;
    - Application connectivity and device management: new applications need to understand the capabilities of - and reach out the - end user's devices, this will lower the cost for 3rd party Application Developers by providing a framework which allows cloud hosted elements to query connected devices for their capability, and to reach out and connect to these devices via a remote device management functional block;
    - Advanced support for connected application development: API accessing key technologies like QoE and QoS will provide 3rd party Application Developers the means to instrument, measure and control the experiences their distributed applications deliver to end users.
  - The entry point of the home system computing and storage capabilities, which can be directly used and controlled by the cloud actors via the Cloud Edge GE functionality. Application Developers, as well as Cloud Operators, may download executable codes on the Cloud Proxy which will interact with their cloud-based applications.

- The NetIC API enablement for Network Operators allows Application/Enabler Developers for making their Applications/Enablers react flexibly on network status information and changes. Furthermore, the new API will also enable Application/Enabler Developers to customize the underlying network to the needs of their Applications/Enablers (within the limits given by e.g. network operators' security constraints). As the API is intended to provide an abstract view on the network, the Application/Enabler Developers can focus on the required network features and won't need to customize their Applications/Enablers to specific networks.
- The S3C layer, between access & core network and service platforms, which allows the Application Developers to have an interaction between the service operators, the network behavior and the end user's system. It helps the Developer to request network parameters for QoS, get information of the current core network and enhance the quality of experience of a specific service via obtaining additional service specific information from the network side. S3C provides different kind and levels of APIs that could be tailored to answer different needs. For example, the API mediation aims at managing HTTP based APIs, the OpenEPC is available through a Diameter interface and some S3C APIs comply with the OneAPI specification.

- **Enabler Developers:**

  The FI-WARE platform provides opportunities for Enabler Developers to participate in the FI-WARE value chain. More specifically, JavaScript Plugin Library Developers can create new plugins to extend the functionality originally provided by the CDI GE, and new services can be built upon the remove device management features, providing additional support for new methods of device management.

- **Service Providers, Service Hosting Providers, Service Aggregators:**
  - Having these enhanced Applications/Enablers at hand, provision of the new NetIC API by network operators will enable Application/Enabler Service Providers, Application/Enabler Service Aggregators up to Service Hosting Providers to flexibly exploit the features of the underlying networks for the sake of an optimal service provision to the Application End Users. The new API provided by NetIC GE might also *create new business in Future Internet*: Local network owners can cooperate with more global operating connectivity providers or Virtual Network Providers/Operators. In this case, the intended new API will allow control of different underlying local networks on an abstract level, thus reducing significantly the integration effort for the overlaying Network Provider. This might enable also local Network Operators to get their share of the network business as they can offer a common API to an integrating Virtual Network Operator
  - Cloud Operators, as well as Application Developers, will be able to use and control the capabilities to download code from cloud applications onto the Cloud Proxy, which shall be executed in isolated Linux containers. Such capabilities are offered by Cloud Edge Service Management API and will contribute to enhance security aspects.
  - The S3C layer enables the opportunity to create new service functionality with the inclusion of the current network situation, event notifications and additional core network functionality. The future services are able to use the wide bandwidth of telecommunication technologies towards an end user's terminal, including established technologies and services (e.g. SMS), seamless mobility via common and new radio and fixed access technologies, service enhancement via location information and network based identity management via SIP/IMS authentication.
  - Service Providers will be able to provide networks functionalities (such as the mentioned location based services and network identity management) *as a feature* for future services;

these additional network functionalities can help building an innovative service, but they can hardly be conceived as stand-alone services for market places, hence the possibility to be exploited by stakeholders as Service Aggregators.

- **Service Brokers:**
  - Via the OTT API, which connects to the OpenEPC Core Network Platform, billing end users will be made available by the S3C GE.
  - Application Store providers can offer End Users (and developers) a marketplace for showcasing and downloading CDI based applications.
  - Further Network functionalities such as Location and Identity Management can be exploited by Service Brokers by means of the APIs provided by S3C GE.

- **End Users:**

  Utilising services which integrate functionalities of the I2ND chapter will be profitable for end users (End Consumers and Enterprises) too:
  - With comprehensive network functionalities for Service Providers, End Users can get a better QoE/QoS from the application.
  - With the focus of enterprise customers, I2ND's core network can manage the network architecture with new and standard radio & fixed access technologies, seamless/uninterrupted connectivity over different access networks and provide QoS levels towards the employees over the connected access network, but will not provide (physical) infrastructure to the customer.
  - The application downloading capability enabled by the Cloud Edge GE allows a better experience of the offered services to the End User, as some "real time" features (such as the upload of content for example) can be intelligently "cached" by the local application.

In summary, the I2ND GEs address the needs of several 3rd party innovators targeted by the FI-WARE platform, Application Developers and Service Providers being the prevailing ones. New or enhanced services can benefit of the additional functionality from the network side to improve their existing services or even create completely new ones. On the Application Developer side, it is possible connecting via the CDI GE to a homogeneous Interface and obtain and set settings of the end user's device while interacting to a service which is simultaneously able to obtain the network status, request flow/application based QoS parameters, receive additional information from the network side and will therefore be capable to adapt the flow settings and content specifications of its application.

4.6 Security

The Security Chapter aims at answering the most prominent security needs on which each and every use case can agree. For that, the Security Chapter has designed a number of Security GEs for Security, Privacy and Trust, ranging from Security Monitoring to Context-based Security & Compliance, but also including Identity Management, Privacy and Data Handling.

Each of these GEs has been designed to deliver the key functionalities requested by FI-WARE stakeholders. Their design takes into account the most recent security standards but also aims at easing evolution of security functions, e.g., for the sake of flexibility and changeability.

In addition to that and to what these Security GEs can already offer to 3rd party innovation (e.g., Security By Design, Security by Default) the Security Chapter has extended this initial set of GEs by another set of Enablers, called Optional Security Enablers, in order to offer additional security services which may also be drivers of innovation for 3rd parties. This generic approach has been successfully demonstrated in the Security Chapter so that a number of optional security Enablers/services have already been provided and new ones are being planned.

The innovation resulting from the use of Security GEs by the stakeholders of the other Chapters (i.e. Cloud Hosting, Data/Context Management, …) is also an innovation factor 3rd parties will take advantage of. They will actually get rid of the burden derived from securing the solutions delivered in other FI-WARE Chapters. On the other hand, Security services advertised on FI-WARE Catalogue and uniformly described in USDL-SEC, will become an opportunity for 3rd parties who may adopt them to secure their own services. In this respect, we expect that innovation will be driven by contributions from 3rd parties implementing either FI-WARE GEs or their own Applications/Enablers, both being able to come up with novel security usage concepts based on Security GEs, individually or in combination with other services.

3rd Party Roles

The following compilation of examples illustrates how FI-WARE design and architectural decisions in the Security Chapter may lead to 3rd party innovation by actors playing the roles described in Chapter 2:

- **Application/Enabler Developers and Application Providers:**
  - The Attack Paths Engine, a component of the Security Monitoring GE, is Open Source. It adopts Datalog as the modeling language for the elements in the analysis (bug specification, configuration description, reasoning rules, operating-system permission and privilege model, etc.). It leverages existing vulnerability-database and scanning tools by expressing their output in Datalog and feeding it to the Attack Paths reasoning engine. Datalog is a widely used query and rule language for deductive databases and is currently implemented in Open Source software open to 3rd party contributors.

    The usage of Datalog, and consequently its expressive capabilities, combined with the fact that both Datalog and the Attack Paths engine can be employed freely (the Attack Paths engine is Open source), paves the way to potential innovation by 3rd parties.

    Future Application/ Enabler Developers may make use of the Application cyber-resilience design capabilities. Moreover, Datalog security reasoning rules can be adapted to reflect changes required by developers providing additional future contributions.
  - The Attack Paths Engine is compliant with the Open Vulnerability Analysis Language (OVAL). OVAL utilizes Standard Extensible Markup Language (XML) schemas that outline the necessary security-relevant configuration information. This strongly supports data interoperability solutions. In OVAL a single XML document encodes the precise details of specific issues. Moreover, it is an open alternative to closed, proprietary, and replicated efforts. Finally, and most importantly regarding the innovation from 3rd entities, OVAL is supported by a community of security experts, system administrators, and software developers.

    Application/ Enabler Developers can make use of OVAL in order to employ new vulnerability scanners more easily. The inclusion of new scanners has an important impact, since it dramatically improves the capability to detect more security breaches, and refine the vulnerability analysis output. This definitely increases the security of 3rd party investments.
  - The visualization framework in the Security Monitoring GE has been designed to facilitate the incorporation of new visualization means by 3rd parties. A flexibility point is introduced between the Data Broker component of the visualization framework, which is responsible for converting the various monitoring data sources into a common format, and the visualization

component, which renders the data available in the defined common format. Application/ Enabler Developers can also exploit this common data format when creating new visualizations, without having to provide interfaces to the pre-existing Security Monitoring data sources.

- The Context-based security and compliance GE will select between the security services already registered in FI-WARE marketplace, the most suitable one that fulfills the End User application security requirements. This feature will give security providers a powerful tool to publish and advertise their solutions that will be immediately accessible by applications at the very moment they have been registered into the FI-WARE Marketplace.

- **Enabler Service Providers:**
  - The Attack Paths Engine, a component of the Security Monitoring GE, uses the Common Vulnerability Scoring System (CVSS) an open framework for communicating the characteristics and impacts of IT vulnerabilities. Currently, IT management must identify, assess and prioritize these vulnerabilities and remediate those that pose the greatest risk. The CVSS addresses this issue.

    The Attack Paths Engine will allow Services providers to obtain innovative contributions in risk assessment and service cyber-resilience. In addition, the use of CVSS will allow making risk analysis-oriented business. It is a major innovation because at the moment, the CVSS does not take into account the business risk in the vulnerability scoring. It only into account only 3 metrics: the access vector (local, bluetooth.), the access complexity, and the number of times an attacker must authenticate to a target in order to exploit a vulnerability. Therefore, the FI-WARE Security Monitoring GE allows users to take the business risk in the vulnerability scoring into account.
  - To collect the vulnerabilities we use the proprietary Nessus Scanner. One of the reasons for choosing Nessus was the fact that it is one of the most widely used scanners (sectools.org reports that Nessus is the world's most popular vulnerability scanner). Nevertheless, Nessus is free of charge for personal use in a non-enterprise environment. FI-WARE Instance providers will also be capable of employing scanning functionalities from the service side.
  - The configuration management database (CMDB) will be available on the Cloud Hosting as a distributed service. Therefore, 3rd parties will not lack the presence of such a crucial module in future enhancements during the innovation process. The enrichment of the database with the identified vulnerabilities on software and hardware components will enable a better understanding of risk, a knowledge sharing by all stakeholders, a better control of the threat and indirectly the implementation of more effective countermeasures by the FI-WARE Instance Providers.
  - OSSIM is the basis of the Service Level SIEM (Security Information and Event Management). It is another component of the Security Monitoring GE. The choice of OSSIM as part of this GE was influenced by the fact that it is one of the most extended open-source SIEM solutions, with a huge community supporting it and using it, and it is the base of more than 30 security tools developed on top of this framework. OSSIM is in addition a result of the work of the open source community that has acted as a strong promoter of its use.

    This new Service Level SIEM will allow Service Providers to handle large volumes of information in a distributed manner avoiding performance problems others SIEM's currently have and providing elasticity for the event processing in order to minimize the used resources to the minimal.

    This will allow 3rd parties to offer new innovative solutions on top of it, mixing and adding new sources of security events (such as physical security). This will allow them to handle more complex security rules.

- The Identity Management GE acts as the identity provider; it provides federated identity for Web-SSO and attributes for an authenticated user; identity federation and single-sign-on support ease of use. Given the heterogeneity of the FI Core Platform, identities should be usable across trust domains. The identity management approach used in FI-WARE will combine established technologies and bridge them where possible, thus offering a flexible system being used by all Service Providers.

  Europe has taken a specific direction with respect to privacy protection. The rights regarding the respect for private and family life, home and correspondence are deeply rooted in the European Convention on Human Rights and have since been the foundation for extensive regulation on privacy and data protection. Privacy protection in Europe is geared towards protection of a right to respect and personal dignity as well as to data minimization and minimum disclosure as basic implementation principles on the infrastructural level. FI-WARE is providing Attribute Based Credential (ABC) mechanisms in order to enable trustworthy identity management and trust relations between users and service providers while respecting privacy.

  Service Providers can make use of ABC functionality so that they can comply with all privacy standards expected in the EU and elsewhere.

- The Context-based security and compliance GE selects, as a response of a security request from applications, the most suitable Security Enabler found in the FI-WARE marketplace that fulfills the application security requirements. This partition between security and applications will allow:
  - 3rd parties to abstract from security and to concentrate on the business logic of their applications, making in this way more innovative and specialized applications, but still secure.
  - Applications to be constantly up-to-date and adapted, in terms of security mechanisms, to the dynamic and unpredictable changes done in context and regulations.
  - Service Providers to offer an environment where the most suitable Security Enabler will be found according with the user specifications
  - Security service developers a way to publish and advertise their solutions that will be immediately accessible by user applications at the very moment it has been registered into the FI-WARE marketplace.

  These functionalities are possible because the decision taken in the choice of the USDL-SEC language to both describe security requirements and compare security features offered by optional Security Enablers.

  Service Providers involvement in USDL-SEC can be significant, due to its open design principles. USDL-SEC permits to complement USDL service descriptions with security-specific non-functional information, through the Linked-Open-Data paradigm. With the same paradigm, also USDL-SEC can be complemented, for example adding additional details regarding a particular technology; here 3rd parties can integrate their contributions to the specification, besides being able to describe the security features of their services.

- The interface of the Malware Detection Optional Security GE is simpler and it allows FI-WARE Instance Providers to easily interface with it and replace the malware detection engine and benefit from it, as well as allowing them to replace the malware detection engine.

4.7 Tools

The Developer Community and Tools chapter aims at offering a comprehensive environment that enable Future Internet Application Developers to use the FI-WARE outcomes (i.e. GE Implementations and FI-WARE Instances) in a more efficient, easy and effective way. This includes, for instance, tools that support 3rd party Application Developers to manage the development lifecycle for their applications. An example for such a tool is the FI-WARE environment for testing applications running on top of a core platform.

Some of the central features and architectural choices of this chapter are described in [2].

3rd Party Roles

The main focus of the tools provided by this chapter is the developers of new applications and services. One device that goes beyond this focus is the FI-WARE Catalogue. It does not only provide information about available GEs to Application/Enabler Developers but also to interested parties in other roles. The detailed description of the approach is described for the individual roles.

- **Application/Enabler Developers:**

  Particular aspects to foster innovation by any 3rd party regarding the support of development are:

  - One aspect is the proposal to use a widely adopted, environment (i.e. Eclipse) as reference implementation for the Integrated Development Environment (IDE). One IDE which could be easily customizable by 3rd party Application/Enabler Developers to build innovative applications based on the FI-WARE Generic Enablers to optimize the development of Future Internet applications based on existing Generic Enablers and develop new Generic Enablers based on the available Open Specifications, to facilitate development of higher quality applications through integrated testing/analysis and a direct interaction with Generic Enablers and, last but not least, enabling the creation of community of interest around Generic Enablers.

    Due to the general acceptance of Eclipse we can ensure that Application and Enabler Developers can work with well known environments. This diminishes the costs of 3rd parties for such developments since additional training expenses are not required.

  - Another aspect is the openness that enables the interaction with 3rd party components in a relatively easy way. For instance, the Mylyn plug-in enables developers to plug any forge within the Eclipse environment. The choice of the Eclipse IDE as basis for the FI-WARE IDE opens the way to the development\adoption of a notable set of plug-ins (native of from 3rd parties) that covers most of the common development aspect needs.

    Application and Enabler developers will find a dedicated environment that can be extended with their own favourite Eclipse plug-ins having, at the same time, facilities (e.g. a dedicated catalogue, clients, testing facilities) to interact with and use the existing Generic Enablers API specifications and instances available on the various FI-WARE Instances.

- **Application Enabler Service Providers/Hosters/Aggregators/Brokers/Channel Makers:**

  - The offered Catalogue of Generic Enablers will work as a “One Stop Shop” where all the PPP Stakeholders (and 3rd parties) can find information on the Generic Enablers, their Open Specifications, their instances and implementations and innovate using these. This catalogue will not be only accessible via web browser but it can be also embedded to the Eclipse environment, or any other solution, to find and select the needed Generic Enablers. The Catalogue will also list the dependencies and relationships among the different Generic Enablers in order to ease the selection and use of Generic Enablers;

By the aid of this Catalogue it becomes easier for these groups of 3rd party innovators to get an overview of the available GEs. The information provided there is particularly adapted to 3rd party needs.

- Application/Enabler Service Providers as they will have a configurable environment to deploy the Future Internet Applications on a cloud environment using well defined standard open APIs.
- Application / Enabler Service Aggregators as they will be able use solutions to monitor and analyze the performance of the aggregated services during design and runtime.

All the components are open source except the two Eclipse Plug-ins provided by SAP and IBM for the performance analysis (Software Performance Cockpit) and the runtime monitoring (TraceAnalyser) of the Future Internet Applications which are IP-protected.

In conclusion, differently from the other Generic Enablers Chapters, this Chapter is thought to provide 3rd Parties supporting tools and methods necessary to innovate developing Future Internet Applications using the available Generic Enablers instances as well as by developing new Generic Enablers referencing the available open specifications.

5 Conclusions

The success of FI-WARE will depend on the ability to answer a crucial question such as "Why and How FI-WARE is going to help me to innovate?". This question has to be answered for each of the central roles that actors may take in FI-WARE–enabled value chains, as defined in chapter 2 of this document. A number of design decisions has been taken in FI-WARE that aim at enabling innovation in each of these potential roles. To achieve this we had to answer the above question in a convincing way. We have summarized these answers in chapter 3 and 4 of this document. We assume that opportunities to innovate in the described roles will become a major pole of attraction of potential actors.

Two major concepts have emerged while we tried to come up with design decisions that enable innovation by 3rd parties (potential actors). The first was that technologies in FI-WARE must rather work as a **backbone** for Future Internet Applications. Equally important, they must be truly **open** in order to give enough freedom to innovative ideas.

To realise this backbone, FI-WARE will provide the following assets:

- A single set of APIs, each of which brings about concrete built-in innovation-enabling capacities (see chapter 4) and altogether allow Application Developers to focus on domain-specific innovation.
- A common language, USDL, that enables FI-WARE GEs to describe all relevant data of technical, operational and business aspects in a uniform way, easing the integration of different applications and services beyond a mere interoperability perspective.

At the same time openness is supported by the following aspects of the FI-WARE approach:

- The public and royalty-free nature of FI-WARE Open Specifications allows replacement of products instantiated to build FI-WARE Instances, or used from Applications. This way, both FI-WARE Instance Providers and Application Providers avoid to get locked in a concrete product vendor.
- FI-WARE Open Specifications do not prescribe more than what is strictly required to ensure the ability to replace compliant products without compromising functionality. This opens up opportunities for FI-WARE GE developers to drive innovation.
- FI-WARE Instance Providers can go for developing sustainable business models around FI-WARE Instances, which do not necessarily comprise the whole set of FI-WARE GEs. This fosters the appearance of FI-WARE Instance Providers who are specialised in concrete FI-WARE Chapters where they feel capable to bring innovative ideas that differentiate them from potential competitors. Application Providers, on the other hand, are able to decide which concrete FI-WARE GE Instances they will use out of the variety of available FI-WARE Instances. They might even be able to change their selection dynamically.
- FI-WARE Instance Providers can complement the FI-WARE GE Instances they build with other Enablers (e.g, Enablers providing access via API to services offered by a popular Social Web service or some mobile advertising platform they own) that may bring a differential value to target Application users.

We see this technical infrastructure as the basis on which FI-WARE Application Developers as well as FI-WARE Instance Providers can develop those innovative offerings that bring about completely new business opportunities and stimulate the service economy of the future.

The depicted design of FI-WARE as a backbone that at the same time offers the described degree of openness, will ultimately result in a number of business benefits for FI-WARE Application Developers and FI-WARE Instance Providers:

- For FI-WARE Application Developers we see the following benefits:
  - FI-WARE gives them opportunities that current platform technologies do not supply because they are usually based on different technologies, different standards, missing an overall usage model that describes how they can be used together:
    - The possibility to easily aggregate services and applications, saving efforts and costs; the adoption of a common aggregation model by the backbone reduces the complexity of this task;
    - The response to obvious market requirements regarding secure, stable and cost-efficient products; the definition of a common standard backbone covering most of the Generic Enablers, which are needed to develop Future Internet applications, 3rd parties are encouraged to integrate available FI-WARE services that disburden them from developing essential but expensive services on their own; this removes a significant barrier for new 3rd parties with limited financial resources;
    - The opportunity for Application Developers to focus their efforts on the actual differentiation of their products from those of their competitors; this means a particular chance for small and medium sized service providers to concentrate on what is crucial for their for business success.
  - FI-WARE addresses the specific currently existing requirements and business constraints in order to realise these business enabling factors:
    - FI-WARE offers royalty-free, open and standardized access points to essential services and technologies, developed in the different FI-WARE chapters, thus protecting the investment of Application Developers;
    - The architecture of FI-WARE ensures the general interoperability (interplay) between the different applications and services and, overall, the ability to combine offerings from different FI-WARE Instance Providers;
    - 3rd parties become part of the FI-WARE ecosystem as long as they follow the FI-WARE standards but without being forced to use all defined FI-WARE GEs.
- On the side of FI-WARE Instance Providers we find the following benefits:
  - They are free to do deal with all FI-WARE GEs that are interesting in the Instance Provider's offering;
  - This allows them to adapt, compile and aggregate existing FI-WARE applications and services in innovative way to address, for instance, the needs of niche markets, in the sense of a long-tail approach;
  - They become part of the FI-WARE ecosystem; this ecosystem will not only be characterized by competition between FI-WARE Instance Providers but, at the same time, also by synergies and complementarities, because FI-WARE Instance providers get the chance to choose different market approaches.

At the end of the day it will be these business arguments that determine whether 3rd parties will accept the FI-WARE infrastructure. Therefore technology and business innovation must go hand in hand.

It is to be emphasised that FI-WARE cannot anticipate and must not predefine in which way 3rd parties will use the FI-WARE GEs. However, 3rd parties interested in playing the role of FI-WARE Instance Providers must get an idea what the architecture of a FI-WARE Instance looks like and how they can integrate products that are compliant with FI-WARE GE Open Specifications. 3rd parties interested in playing the

Application Developer/Provider role, starting with UC projects in the first phase of the FI-PPP, must also get an idea on how an application making usage of FI-WARE GE can be built, deployed and offered to potential customers, and measure how all these processes can actually be speed up using FI-WARE. The FI-WARE Open Innovation Lab should bring an opportunity for both to answer their questions. Information about products implementing FI-WARE GE Open Specifications and instantiated as part of different FI-WARE Instances, including those that may come from 3rd parties that are not FI-WARE partners, will be available in the FI-WARE Catalogue. The first set of FI-WARE Instances available will be part of trials in phase 2 and 3 but this set should later be extended to include FI-WARE Instances on top of which commercial application and services could be deployed.

6 Glossary

ABC	Attribute Based Credential
API	Application Programme Interface
CAPEX	Capital Expenditure
CDI	Connected Devices Interfacing
CDR	Call Data Record
CE	Cloud Edge
CMDB	Configuration Management Data Base
CEP	Complex Event Processing
CVSS	Common Vulnerability Scoring System
ETSI	European Telecommunications Standards Institute
EU	European Union
GE	Generic Enabler
HGI	Home Gateway Initiative
HTML	HyperText Mark-up Language
I2ND	Interface to Networks and Devices
IaaS	Infrastructure as a Service
ICT	Information and Communication Technology
IDM	Identity Management
IETF	Internet Engineering Task Force
IoT	Internet of Things
IPR	Intellectual Property Rights
IT	Information Technology
LAN	Local Area Network
LTE	Long Term Evolution
LOD	Linked Open Data
M2M	Machine to Machine
NetIC	Network Information & Control
OCCI	Open Cloud Computing Interface
OMA	Open Mobile Alliance
OPEX	Operating Expenses
OSS	Open Source Software
OTT	Over The Top
OVAL	Open Vulnerability and Assessment Language
P2P	Peer to Peer

PaaS	Platform as a Service
PPP	Public Private Partnership
QoE	Quality of Experience
QoS	Quality of Service
RDF	Resource Description Framework
RFID	Radio Frequency IDentification
RTP	Real-Time Transport Protocol
S3C	Service Capability, Connectivity and Control
SDNP	Software Driven Network Protocol
SIEM	Security Information and Event Management
SIP	Session Initiation Protocol
SLA	Service Level Agreement
SME	Small and Medium-Sized Enterprise
UC	Uses Case
UCP	Uses Case Projects
UI	User Interface
USDL	Uniform Service Description Language
VM	Virtual Machine
XML	Extensible Mark-up Language