# Technical Infrastructure for a Pan-European Federation of Testbeds

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*Abstract* — **The Pan-European laboratory – Panlab – is based on federation of distributed testbeds that are interconnected, providing access to required platforms, networks and services for broad interoperability testing and enabling the trial and evaluation of service concepts, technologies, system solutions and business models. In this context a testbed federation is the interconnection of two or more independent testbeds for the temporary creation of a richer environment for testing and experimentation, and for the increased multilateral benefit of the users of the individual independent testbeds. The technical infrastructure that supports the federation is based on a web service through which available testing resources can be queried and requested. The available resources are stored in a repository, and a processing engine is able to identify, locate and provision the requested testing infrastructure, based on the testing users' requirements. The concept is implemented using a gateway approach at the border of each federated testbed. Each testbed is an independent administrative domain and implements a reference point specification in its gateway.**

***Keywords – Testing, Testbeds, Panlab, Testbed Federation, Teagle, Network Domain Federation***

## I. INTRODUCTION

Rapid development of Information and Communications Technologies (ICT) in the last decades has been ensured by significant efforts performed by the corresponding research community world-wide. Both theoretical research, e.g. based on mathematical analysis and simulations, and research based on experiments contributed significantly to the recent technological developments. Meanwhile, the complexity of ICT systems, for example networks, devices, applied methods and algorithms, has increased in order to ensure their proper operation. Therefore, to be able to develop and asses new concepts and achievements in complex environments, researchers and engineers are increasingly looking for opportunities to implement their concepts in testing systems and in this way obtain quickly the solutions that can be implemented in production systems. Thus, with the recent developments in the ICT area, the necessity for experimental research carried out in the form of large scale experiments and testing is significantly growing among the research and engineering communities. In the ICT area as the main driver of common global developments, there is a fundamental need for world-wide experiments and testing ensuring that developed solutions can be applied anywhere as well as empowering wider groups of researchers to have access to various experimental and testing facilities at a global scale.

In order to meet such requirements, enlarged experimental opportunities and remote testing, the Panlab concept [1] has been created in Europe to form a mechanism that enables early-phase testing and interoperability trials as widely and deeply through the layers and players of telecommunications, as possible. In order to boost European testing, we must have the means to dynamically provision testbeds according to customer requests. This can be achieved by means of a new functionality capable of composing, managing and refining testbed resources. This constitutes the primary objective of the pan-European laboratory for networks and services, which implements the Panlab concept [2].

Panlab is not a static organization but has to be rather dynamic and adaptive. It can be extended, adjusted and improved by any new available platform, service and system that can be offered by the interconnected testbeds and laboratories or new testbeds and laboratories joining the federation.

The entire mechanism, the rules and procedures of how to achieve the effective testing collaboration, have been developed in the Panlab project [1] at a high abstraction level. The considered mechanisms include legal and operational requirements on the Panlab concept as well as requirements on technical infrastructure to be established in order to realize the Panlab concept, as summarized in [3]. In this paper, we describe the technical infrastructure necessary for the realization of the Panlab concept and implementation of a future Pan-European Laboratory.

The paper is organized as follows: First, we present the Panlab concept and related work (section II), including an introduction of the Panlab roles and the integration of testbeds, as well as "Teagle" as the main collaboration tool. In section III, the Panlab federation infrastructure is presented. Section IV focuses on the seven operational stages of the Panlab concept, while the remainder of the document describes in section V important mechanisms for later stages of the Panlab concept implementation such as service composition. In Section VI, the conclusions of the paper are presented.

## II. General Panlab Concept and Related Initiatives

### *A. Related Work*

Currently, a number of research initiatives are addressing the need for large scale experimental facilities and the concept of federation on both a European and a worldwide scale.

The European FIRE initiative (Future Internet Research & Experimentation, [4], [5]) seeks to create a dynamic, sustainable, large scale European Experimental Facility, which is built by federating existing and new testbeds in order to boost European innovation and its competitive role in defining Future Internet concepts. Projects worth mentioning here that target the FIRE objective of building a federated experimental facility are Onelab [6] and Federica [7].

Onelab builds upon PlanetLab [8], [9] software but aims at extending PlanetLab into new environments beyond the traditional wired internet (wireless extension), deepen PlanetLab's monitoring capabilities and provide a European administration for PlanetLab nodes in Europe (federation). The Federica project aims at creating an infrastructure for Future Internet research, allowing disruptive experiments in a short time frame using virtualization. The infrastructure relies on the multi-domain European National Research and Education Networks (NRENs) and the GÉANT2 [10] backbone. In the approach followed by Federica, virtualization is used to create "slices" from a physical substrate according to the user's request. A slice is a set of virtual network and computing resources that can be created, allocated and used simultaneously for experiments.

Similar to the FIRE initiative in Europe, the US NSF-funded (United States National Science Foundation [11]) GENI initiative (Global Environment for Network Innovations [12]) seeks to enable network science and engineering experiments by providing an experimental suite of network infrastructure. Federation also plays a central role in the overall GENI architecture [14] to allow for large scale experiments in heterogeneous environments. Several GENI projects are currently under way, which are organized into five competing clusters that will implement the prototype GENI control plane. Most projects rely on already running software namely the Emulab software [13] and the PlanetLab software [8].

The name Emulab refers to the Emulab project, the facility (testbed) and the software. The Emulab project maintains the facility. The Emulab facility uses the software, which is also used by numerous other testbeds to control their infrastructure. The Emulab software is enhanced by GENI cluster A and C to derive a GENI architecture [14] compatible control framework. The PlanetLab software is used by GENI cluster B and C. Currently, the implementation of a wrapper module is under way to support the GENI-defined interfaces and make the software compatible with the overall GENI system architecture.

Further information on the GENI projects, their control framework and GENI spiral 1 achievements can be obtained in [15], [16] and [17].

In the following, we will describe the Panlab Testbed Federation architecture. The difference between our approach and the work described above is that Panlab does not only focus on network testbeds but also incorporates more or less closed environments where pre-commercial product testing, interoperability testing and benchmarking is carried out. This demands, apart from a sound technical concept, a legal and operational framework to establish the necessary trust relationships between the different test sites (Panlab Partners), test users (Panlab Customer) and the organization (Panlab Office) itself. The different roles and their interactions are explained in the following subsection.

### *B. Components and Roles Within the Panlab Concept*

The Panlab infrastructure has to ensure interconnection of different distributed testbeds to provide services to its customers, in order to do various kind of testing. Coordination of the testing activities, for example infrastructure provisioning, ensuring necessary interconnection of customers and testbeds, and the overall control and maintenance of the environment, is ensured by the so-called Panlab Office and tools offered and maintained by this office. Thus, we can outline the following main roles of the Panlab concept, as presented in Figure 1:

- Panlab Partner – an entity that participates in Panlab activities by providing infrastructural elements and services necessary to provide testing services. Panlab Partners are connected to the Panlab Office for offering functionality to the Panlab Customers and provide the basis for the entire federation concept.
- Panlab Customer – an entity that uses services provided by the Panlab Office and the Panlab Partners, typically to carry out research and development activities and to implement and evaluate new technologies, products, or services, benefiting from the Panlab testbed federation offerings.
- Panlab Office – an entity that realizes a brokering service for the test facilities, coordinating and supporting the Panlab organization. It is responsible for the provisioning of the testing infrastructure and services by using tools and interfaces at the partner testbeds. Furthermore, the Panlab Offices ensures and facilitates the communication between Panlab Partners and Panlab Customers.

In addition to the roles defined above, the Panlab architecture relies on several other architectural components that will be introduced in the course of the following sections. Among those are the Panlab search and composition engine "Teagle" and a Panlab repository that stores testbed descriptions and testing results.

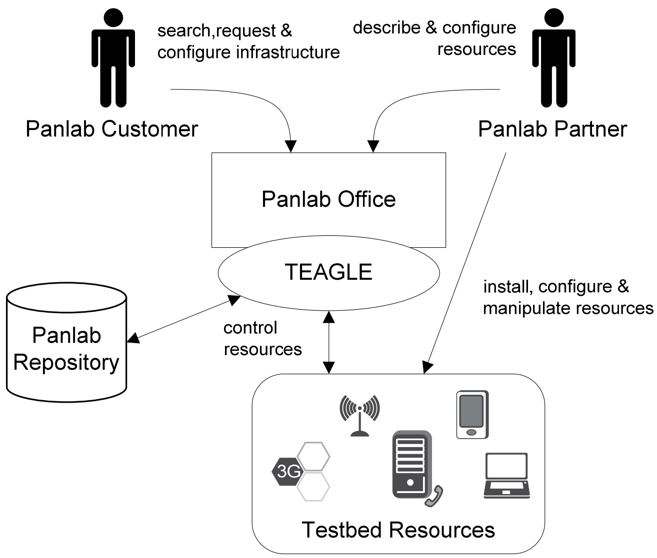


Figure 1. Panlab components and roles

In a first phase of Panlab operation, various operational steps, ensuring the creation and realization of testing projects, are executed manually by personnel of the Panlab Office and involved partners and customers. Thus, the testbed metadata held in the Panlab Repository is entered manually as well as testing configurations, etc. In order to achieve a near to full automation of all Panlab related processes, the so-called Teagle tool (Sub-sec. D) will be developed. Teagle shall for example offer (among other functionalities) an online form where the testbed representatives can enter the relevant data describing the testbed [18] and its resources. Panlab customers may search the Panlab Repository to find suitable resources needed for executing their tests.

## *C. Integration of Testbeds*

In a general use case applied to the Panlab architecture, two or more Panlab components have to be interconnected in order to ensure realization of a particular testing project (Figure 2). The established connection between the different testbeds must serve a specific objective, i.e. it must serve the interactions between (i) applications, (ii) signaling control and service support, or (iii) user data transport. Connections can be requested to serve one or more of these objectives. For establishing different requested connections, a service oriented approach should be used, where the connections are established by a set of service properties that can be managed at each testbed site by a gateway. Once the desired environment has been set up, it is ready to be used by the Panlab customer. This includes using the provisioned components as they are, fine tuning the entire environment or installing new software on selected components. A description of which types of operations are allowed for what type of resources is part of the testbed and resource description held in the Panlab repository for every testbed/resource. For example, the installation of new software on a component might be allowed for some resources, for others not.

One of the tasks of the gateways is to match property requirements to the connectivity service with the properties of the available connectivity. In many cases Virtual Overlay Network (VON) technologies can be used to connect resources and sites with a common set of connectivity properties. Especially Virtual Private Network (VPN) or Virtual LAN (VLAN) technologies are well established means to create a logically dedicated network for a specific purpose. From the federation point of view, a logical connectivity support function must be implemented, which is able to control the gateways, located at the edge of the individual testbeds, to establish the requested connections to the peer site or sites. Thus, interconnection of Panlab components is ensured by establishing connections among gateways of respective individual components representing separated administrative domains, where all other interconnection functions remain under control of these components.

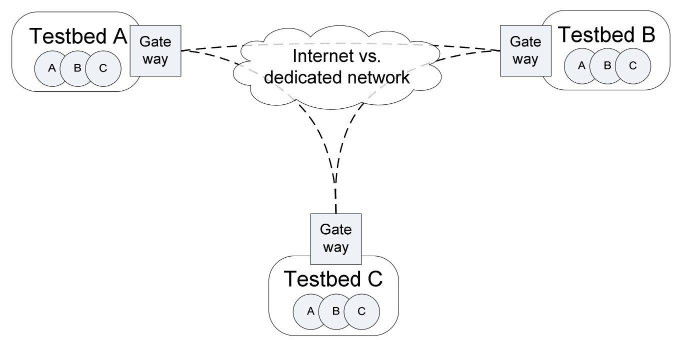


Figure 2. Gateway concept

## *D. Teagle Tool Providing Search & Match Functionality*

As mentioned before, the Panlab architecture relies on a tool called "Teagle" which is a web instance that provides the means for a customer to express the testing needs and get feedback on where, how and when testing can take place. Teagle enables finding a suitable site for one's testing needs within a database of partner testbeds (the Panlab repository). The objective of Teagle is to manage the complete set-up of a desired infrastructure. This includes necessary resource reservations and interconnection of elements to serve a specific testing need. Thus, by using Teagle, the customers can select desired technologies and features for a test configuration to be set up. Functionalities of Teagle tools are described in [3] and further specific details can be found in the documents available at [1].

# III. INFRASTRUCTURE FOR TESTBED FEDERATION

## *A. Generic Layered Structure*

Existing interconnected testbeds are built, focusing on a specific target testing subject and are pretty static in their configuration. This configuration can be horizontally oriented, for example in order to test the interoperability of systems which have been developed observing the same standards. This configuration can also be vertical, for example in order to test a specific delivery platform and services provided by this platform over a specific new transport network. The interest there is whether the APIs are consistently defined, but also performance and integrated management are of concern.

In contrast, the infrastructure described here introduces the elements of "dynamism" and exploits the concept of "federation" as motivated in the previous section. It relies on existing environments and builds the "glue" to describe, discover and interconnect testbeds and testing resources on demand. The infrastructure is open, meaning that any testbed can offer its services and interconnect through it as long as it obeys the Panlab federation framework. The infrastructure is generic, meaning that conceptually it is agnostic to specific technologies inside the testbeds that it federates, as long as these can be described by the Panlab service description techniques and can be brokered by Teagle.

"Dynamism" means that not all testbeds are interconnected all the time. A testbed configuration is only provisioned when requested and according to a customer's specification. A testbed configuration means all necessary resources (incl. network links, service platforms, application servers, etc.) and forms a testing configuration description that can be stored in a repository for future reference and reproducibility. "Federation" means that the testbeds are not under a centralized control. The infrastructure is ensuring the independence of its members. A testbed federation is the interconnection of two or more independent testbeds for the temporary creation of a richer environment for testing and experimentation, and for the increased multilateral benefit of the users of the individual independent testbeds.

The infrastructure supports network agnostic service provisioning by separating the testing service logic from the underlying networking infrastructure. It identifies and defines the necessary interfaces for resource negotiation at the technology and administrative domain borders. It defines the necessary messages at the federation level that are mapped via a Panlab Testbed Manager (PTM) to intra-testbed messages to automate provisioning (Figure 3). The messages defined at the federation level are standardized across the entire federation and might be based on or aligned with yet existing approaches such as the New Generation Operations Systems and Software (NGOSS) [19] framework. Reference Points (RP) mark an interface specification between Panlab entities and are more precisely defined in the following subsection.

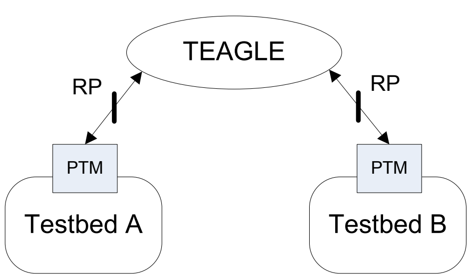


Figure 3. Gateway concept implementation – The PTM

Each participating testbed implements at its border the necessary functionality in the PTM, to be able to receive and interpret provisioning messages from the federation. The PTM is responsible for the clear separation between the mechanisms for services provisioning to its users, from the mechanisms needed to map these services onto the network infrastructure.

Furthermore, each participating testbed implements an Interworking Gateway (IWG) for the technologies it supports at the testing usage level (Figure 4). The IWG covers only the protocols and technologies that are meaningful in the context of usage of the components and resources within the respective testbed.

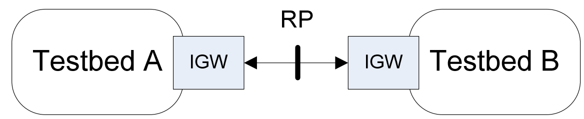


Figure 4. Gateway concept implementation – The IGW

### B. *Reference Points*

Each testbed forms its own administrative domain, and is connected to another administrative domain via a reference point, as illustrated in Figure 5.

In order to explain the concept of reference points we introduce the following definitions [20]:

- Administrative domain: An administrative domain is defined by the requirements of one or more business roles and is governed by a single business objective. This could be for example the Open SOA Telco Playground [21] governed by Fraunhofer FOKUS.
- Business relationship: An association between two business roles. For example Fraunhofer FOKUS and another stakeholder could establish this for IMS testing.
- Business role: The expected function performed by a stakeholder in a telecommunications business environment. In our example Fraunhofer FOKUS has a Panlab Partner (resource provider) role.
- Contract: A contract is the context defining constrains for one or more reference points to operate under.
- Stakeholder: A party that holds a business interest or concern in the telecommunications business. A stakeholder owns one or more administrative domains.

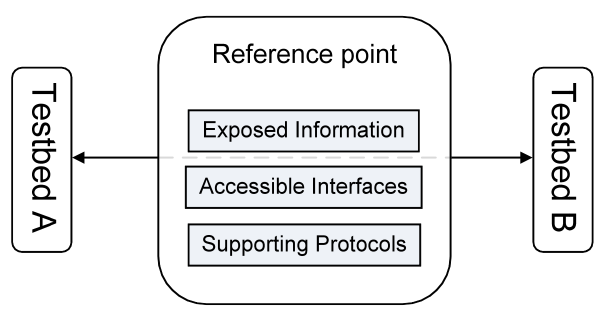


Figure 5. Reference point

This leads us to the definition of a Reference Point (RP). Each RP is the manifestation of a business relationship and consists of one or more related specifications governed by a contract. The contract describes the business constrains that apply on the RP. A RP may contain specifications in the following areas:

- Business: describes the scope, limitations, functional and non-functional requirements posed on the business relationship by the business roles. It is derived from the requirements of the business roles for their interaction. General business requirements describe the roles performed by the stakeholders involved in the reference point.
- Information: defines the information which is shared between the administrative domains. Exposed information is a specification of information that needs to be made visible between the administrative domains in order to fulfill the requirements for both engaged business roles in the business relationship. Examples are names, management information, etc. This information is specified in terms of an information model. Suitable candidate for such a model is the industry standard Shared Information Data (SID) [22] model developed by the TMF (TeleManagement Forum) [23].
- Computational: defines interfaces on computing assets to be made accessible to the other domain. To promote re-use and manageability the interfaces are grouped according to the use.
- Engineering: defines the separations of the supporting distributed infrastructure in nodes, signaling and control links, supporting operating systems and protocol stacks needed for interactions between the administrative domains. Specified supporting protocols are necessary for enabling the interaction over an accessible interface.
- Miscellaneous: defines other constraints, e.g. limitations on other specifications imported into a reference point specification, allowed limitations on compliance, etc.

## IV. Operational Stages of the Panlab Concept

This section aims at exemplifying key operational aspects as they emerge from the overall Panlab concept and use cases. To this end, we have identified seven operational stages, the purpose of which is to provide the context that specific operations are defined and executed in.

### *A. Customer Interaction*

This stage comprises the interactions between a customer requesting the provisioning of a testbed and the corresponding tests to be carried out when the testbed has been provisioned. This interaction takes place through the Teagle and may formally take the form of a Service Level Agreement (SLA). This SLA can then be used by Teagle to analyze customer requests and then to find the proper testbeds in the Panlab repository that match the customer request. Then this SLA becomes a binding contract.

### *B. Testbed Discovery*

This stage may well be seen as a precursor of the previous stage or as a distinct part of customer interaction. In the former case, a customer before interacting with Teagle may search on his own the testbed repository in order to find for himself what is available in Panlab. This means that proper Graphical User Interfaces (GUI) guide the customer through the Panlab offerings and/or provide examples of the available technologies. In the latter case, Teagle simply searches through the Testbed repository in order to find, with or without the customer's collaboration, suitable technologies.

### *C. Testbed Provisioning*

This is when the Panlab Customer and Panlab Office have both agreed on the SLA, and Teagle can now initiate the provisioning of the testbed environment before it is delivered for use to the Customer. This is an entirely Panlab Office responsibility. Provisioning is carried out through a number of interfaces implemented by the Panlab control architectural elements. As part of the testbed provisioning, we identify two distinct types of provisioning: infrastructure provisioning and capacity provisioning.

By infrastructure provisioning we mean plain technology that is needed - as a result of the SLA agreement - to be deployed, configured and interconnected. This involves equipment that implements protocol stacks and interface/standard specifications as well as gateways necessary to resolve any interoperability/interworking issues.

In contrast, by capacity provisioning we mean the overall resources (computational, communication, etc.) required by the testbed which are going to be consumed during its use and testing phases. We note here that we have used the term "capacity provisioning" as opposed to the overloaded term "resource provisioning" in order to distinguish from resource reservation mechanisms, namely QoS, which may be part of the provisioned testbed and as such relevant during the usage thereof.

One major aspect of testbed provisioning is the wide variety of configuration operations performed on testbed components - hardware or software - as they may range from dynamically setting up a VPN between two geographically distributed remote sites for providing testbed connectivity, to customization of functionality hosted in specific components for example adding new users to a Home Subscriber Server. However, configuration critically depends on control interfaces available in the testbed devices and they raise problems of interoperability for controlling these devices. Resolving them requires that the testbed components implement open or standard interfaces for their configuration. In case of proprietary control interfaces there must be functionality in place that performs mappings of configuration operations on to the proprietary control interfaces. This description gives rise to one of the main architectural components of the Panlab architecture, namely, the PTM. Finally, all these operations are performed in a secure environment.

### *D. Usage and Management of Testbed by the Customer*

When entering this stage, the testbed has been deployed and handed over to the Customer and his users or test suites for its actual use. This means that a number of management interfaces may be exported to the Customer so that he can further tune the testbed internal operations according to user needs or test requirements. At this stage the testbed operations pertaining to specified tests and users' requirements become the responsibility of the Panlab Customer whereas the overall welfare (security, fault tolerance, SLA conformance etc) remains at Panlab's office responsibility (see subsection G, Quality Assurance). Any additional operation that falls outside the scope of the contracted SLA must be re-negotiated and re-provisioned.

### *E. Monitoring and Collection of Test Data*

Monitoring services and collection of test data represent an important part of the overall Panlab services as it provides the means to process and analyze the behavior of the product (equipment, application, service, software, user behavior) for which the Customer has requested the testbed in the first place.

Monitoring in Panlab may be carried out either by the Panlab Customer by deploying monitoring mechanisms customized for his proprietary tests, e.g. logging facility in a server under test, or on behalf of the Panlab Customer when he needs common monitoring mechanisms e.g. packet traces, sampling etc. In the former case, we assume that monitoring functionality is part of the components contributed to the testbed by the customer whereas, in the latter case, the monitoring mechanisms form part of the testbed offerings (through testbed repository) and as such they also undergo deployment and/or configuration during the provisioning stage. The same mechanisms may also be used for other activities, e.g. Quality Assurance or SLA conformance, but special care must be applied so that the context they used for is clearly defined, as it has an impact on the design and configuration of these monitoring mechanisms. Finally, there are proper interfaces, protocols and resources (mainly storage), for the collection and transport of monitoring data to repositories either in the customer or Panlab premises, so that they may become available for further processing and analysis.

### *F. Processing and Accessing Test Data*

After completing the tests, data should be collected and stored in repositories for further processing by the Panlab Customer or on behalf of the Panlab Customer according to his needs. Access to these data may be controlled by certain policies. To this end, a customer may decide to make the collected data publicly available or keep them for his own purposes. In due course, we expect that the collected data will become a valuable asset of the Panlab Office and as such it is envisioned that these data should become available to other Panlab Customers even if they do not require the deployment of a testbed. This involves the definition of common formats to read the data as well as tools for carrying out analysis e.g. statistical, anomaly detection etc. Accordingly, the Panlab Office through Teagle may consider this stage as an additional service to testbed provisioning and a distinct service on its own.

### *G. Quality Assurance*

This stage comprises a series of Panlab functionalities running at the background of any testbed operations and aims at guaranteeing the welfare operation of the testbed infrastructures and conformance to contracts by both sides, namely, Panlab Customer and Panlab Office. Such functionality ranges from security to monitoring as well as proof of conformance to contract terms.

## V. Ressource Description, Service Exposure and Service Composition as Federation Enabler

For federating different testbeds residing in autonomous administrative domains and provide composite infrastructures using resources across the boundaries of the domains, three major blocks of functionality need to be provided:

- Resource Description
- Service Exposure
- Service Composition

### *A. Ressource Description*

Whatever is offered by a testbed towards the federation must be described according to a common information model in order to allow Teagle to understand the functionality of resources, offer them towards external users and provide compositions of distributed functionalities. This means that Panlab Partner resource offerings become services to be consumed by the costumer. The services need to be described uniformly to allow Teagle as a broker residing between the customer and the resource, to match requests to concrete functionalities. The TMF SID [22] provides a good starting point for a common information model that might need to be extended to meet the Panlab requirements and to deal with the high heterogeneity of Panlab Partner testbed resources.

### *B. Service Exposure*

The basic service exposure mechanism foreseen for the Panlab architecture is shown in Figure 6. A1 and A2 are functionalities that are offered by testbed A towards the federation. Examples for such functionality are hardware, software, a web service or even advanced setups such as an IP Multimedia Subsystem (IMS) signaling core.

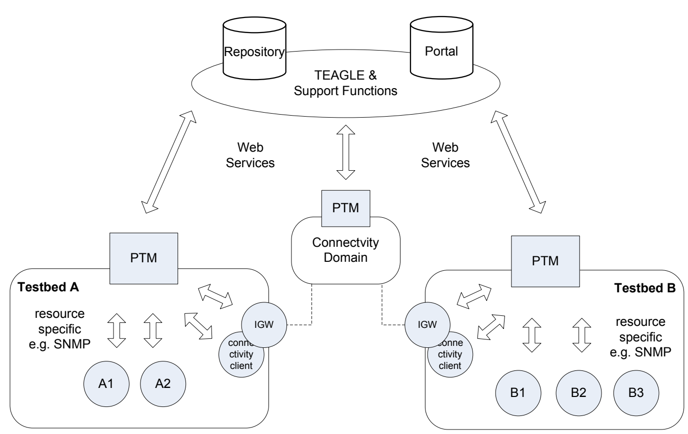


Figure 6. Service Exposure

As described in Sec. III, the PTM provides the mapping from federation level communication to resource specific commands and the IGW is responsible for providing connectivity to other administrative domains. The PTM exposes the configuration of A1 and A2 as provisioning services to the federation. As an example consider A1 to be an application server and A2 an IMS signaling core. The PTM would then expose configuration and management services that allow the set-up and configuration of A1 and A2. For example if a Panlab Customer would like to deploy a prototype application on the application server (A1) in order to test the application within a standard IMS environment, the IMS core (A2) would need to be connected to the application server and configured accordingly. This configuration shall be enabled remotely and in an automated fashion by using the Panlab mechanisms described here. This will speed up development cycles as desired environments can be provisioned in a short time.

The Panlab Partner testbeds shall capsulate functionality in more or less atomic building blocks that can then be used in a combinational manner across the entire federation. This means that functionalities offered by the individual testbeds are represented as atomic components that act as building blocks during the composition of a testbed. In this context, a testbed instance acts as a container of the selected building blocks. Accordingly, different combinations of building blocks may result in different testbed instances dictated by customer requests. This is in line with the general concept of Service Oriented Architectures (SOA) and shall ultimately lead to a service market. However, in contrast to open, "internet-style" service markets, the principle demonstrated here relies on centralized support functions and legal entities that ease the establishment of business relationships between multiple stakeholders. For example, the negotiation of Non-Disclosure Agreements (NDA) and contacts is simplified through agreed templates and a trusted relationship between the Panlab Partner and the Panlab Office.

### C. *Service Composition*

Teagle shall offer a service composition functionality that allows the orchestration of building blocks offered by different testbeds. In order to do so, as stated above, it requires a solid description on what is available. A repository shall hold descriptions of the available resources in the federation and instructions on how to invoke them. Teagle displays the content to the customer, provides user accounts and offers a search tool for browsing federation resources. Once the customer has looked up and identified interesting functionality to be provided by the federation, a composition tool shall provide a provisioning workflow that defines how to provision the desired virtual environment as a composition of building blocks from different testbeds. In this regard several aspects are important:

- Pre- and post-conditions of building blocks
- Timing across the entire workflow (which operation goes first, second, etc.)
- Dynamic probing of availability

The field of service orchestration is still subject to extensive research boosted by the success of Service Oriented Architectures. Panlab will make use of current state of the art technologies in this area and seeks to contribute with scientific results to this important field of research. However, first Panlab implementation stages are foreseen to rely on many manual processes while fully automated service composition remains the grand vision to be achieved in later concept implementation stages.

## VI. Conclusions

The work presented here is the fundament to prove that federation is a model for the establishment of a long-term sustainable large scale and diverse testing infrastructure for telecommunications technologies, services and applications in Europe. Beyond the demonstration of the technical feasibility of the service related mechanisms described in this paper, the future work includes research towards the fully automated provisioning of composite testbeds across the whole infrastructure.

Furthermore, a number of use scenarios imply that the provisioning of testing services has to be achieved in a network agnostic manned, in particular considering the issues that relate to roaming of testing users, and roaming of end-users within the federation. Especially in the context of mobile services, but also in the context of service continuity, issues with location awareness and network agnostic addressing must be addressed.

To support the long-term sustainability of the federation, future work will develop and elaborate on the mechanisms to combine and accommodate potential clean slate approaches. In particular the work is focused on the architectural requirements to facilitate the separation of the "provisioning platform" from the underlying infrastructure as a means to accommodate approaches based on different architectural mindsets.

Finally, Panlab foresees the inclusion of end-users as part of the testing environment. We call this concept "User Driven Innovation", which means that we aim to engage the intended end-users in the whole process of inventing and creating something new and relevant. By allowing end-users access to the testbeds, when possible, it is possible to observe their behavior and invite them to a dialogue on their needs, desires and habits of use of technology.

However, this latter objective introduces a new set of requirements, the foremost among them being the "Identity Management". As users are likely to "wander around" with various names and addresses, using several devices and requiring different authentication mechanisms for validation, existing approaches for managing user identities are bound to be inadequate and difficult to be extended. Accordingly, a novel approach for cross layer identity management is more than essential, especially when considering clean slate approaches in the context of Future Internet.

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