Creating a distributed mobile networking testbed environment – through the Living Labs approach.

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Abstract— **Today, new ways of constructing and delivering complex wireless and mobile services require more elaborate and distributed prototyping, testing, and validation facilities. Testbeds are becoming an important tool for integrating technology components into the complex environment of the wireless world and end-users in their daily life. However technology in itself is no longer valid – benefits and usefulness for people in their daily life must be proven before the technology or service can be said to be a success.**

Living Labs is a user-centred real-life approach to wireless and mobility service and technology design and development (as well as other service areas). The user-centred approach places special emphasis on the need to develop mobile services that are usable, i.e. effective, efficient and satisfying to use, and has full end user integration in the creation and validation processes, which is necessary for gauging market acceptance of the developed prototypes and solutions.

I. INTRODUCTION

Many research projects over the years, have ended in a report on a bookshelf. In some cases the market was not ready, in many others the results from the project were never validated under real-life conditions. Nor did it start from the very needs and preconditions of the intended user.

During recent years, the demands and criteria for getting a project funded has increased, both when it comes to the core idea of the project, but also when it comes to the dissemination of results and securing the relevance for society in general or industry in specific.

Creating a mobile networking testbed environment through the interconnection of international testbeds is an initiative to extend Europe's e-Infrastructure and innovation platform in a direct contribution to facilitate European approaches to communication research and development.

e-Infrastructures should be able to provide the most advanced fully integrated communication and information processing services to researchers in Europe. They should also provide transparent, easy, cheap and secure access to all types of distributed resources (computers, databases, heavy research instruments, etc)".

The need to include mobile and wireless resources for access by the R&D community is obvious. Europe has achieved a strong position in this field and it continues to be a key area for Europe's future growth. CEO's of Europe's top telecom companies have identified interoperability, testing and joint research as strategic areas for future development.

Placing wireless research into the daily life situations of society [1], enable researchers to interact with all stakeholders present in a specific scenario, situation or context is a well-suited method for accomplishing a high degree of relevance.

Research environments have been defined across the world as arenas for this kind of investigation. Different concepts of user involvement can be seen from examples of PlaceLab [2] at MIT, the Future Computing Environments [3] at Georgia Tech, and more closer to home in Europe, HomeLab at Eindhoven University of Technology [4]. These environments have the common characteristic of being in a single-context. This means that users take part in experiments with one single task that normally has nothing to do with the rest of their life.

The Living Labs Concept refers to an R&D methodology where innovations, such as new services, products or application enhancements, are **created** and **validated** in collaborative multi-contextual empirical real-world environments within individual regions.

The individual is in focus in the role of a citizen, user, consumer, or worker. The user experience focus ranges from user interface design and ergonomics as well as assessment of user acceptance and behavior, to user co-design process, finally leading to service or product creation. The benefits of deploying tests on distributed testbeds, for service development research is not only limited to analyzing end user requirements, but also analyzing the performance and capacity of networks to support service quality. This analysis is crucial towards service development as well as meeting the business goals.

Value is captured on an individual level as well on the organization level. Emerging value distribution and changes of existing value chains and business models are analyzed. Culture and site specific features are identified when innovative applications are transferred across borders to different diverse contexts and cultures. Mass customization models are planned in deployment and in European/global exploitation.

The challenge of the methodology lies in its design, including core local partners from user groups, public or civic sector participation parallel with private sector technology and service providers.

In order to conduct such R&D experiments as described above, an extensive technology platform (Testbed or eInfrastructure) must be made available. It is assumed that no such region or testbed can facilitate all emerging service platforms or technologies, so a networking approach must be considered in order to enable the most suitable technology to a specific experiment.

Augmenting these environments with a Multi-Agent Testbed [5] which is a virtualized mobile network, geographically distributed across international testbeds [6] is the core concept of our approach.

While attempting to facilitate and enable this in a seamless way, the distributed testbed can be mapped to many technological research areas – including the underlying communication systems, service platforms and applications supporting the individual at every unique situation needed. This is largely due to the increase in communications research development, where future wireless research cannot be focused on a specific component of the architecture, but rather the integrated architecture (e.g. core network and access networks combined). By providing integrated research through distributed wireless testbeds, we will be able to (1) assist less developed countries to be able to benefit from tests performed in real conditions in real test beds, (2) collaborate research areas in wireless networks between various institutions to expand research spectrum for both basic and applied research, and (3) to lower long term expenses of infrastructure funding on research test beds.

This approach has been extensively applied to the domain of software development. As a consequence there are many advanced human-computer interaction research methodologies and techniques available to support and guarantee a user-centricity throughout the design process [7].

This paper is organized as follows: Section II will present the main components of the proposed architecture, while section III will discuss the implementation. Section IV will present test scenario, and lastly section V will present the conclusion.

II. Main Components

A. Requirements

The Mobile Communications & Technology Platform [8] (the CEOs of 14 major companies involved in the mobile communications sector) identified key issues and major steps to be taken by both industry and government, with a view to assuring the success of 3G mobile broadband communications, and the sustainable health of the sector going forward. They have identified that

- For the EU to regain the lead that it has achieved in GSM technology, bodies such as ETSI and 3GPP must find effective ways to keep pace with technological evolution and to streamline mechanisms to achieve network/device interoperability.
- European industry should meet end user demand for interoperability by inter alia defining a ‘profile’ of functions needed.
- 3G mobile broadband marks a step change from GSM. It will increasingly become a complementary platform to fixed broadband access

The group has identified the need for large-scale demonstration platforms will arise that will permit to prototype and verify the interoperability of a multitude of applications, services and devices.

Given the existence of these requirements for a wireless and mobile extension to Europe’s e-Infrastructure, how do we go about making this e-Infrastructure available and usable for the entire R&D community?

B. Proposed Model

The Living Labs network approach is an attempt to supersede the existing prevalence of isolated private wireless test-beds with restricted access, with a model of providing open testing and validation support to any research project that has a wireless or mobility research component. The work carried out is complementary to Wireline (fixed) testbeds and removes the need for research projects to attempt to replicate testing environments for research results.

This vision is being brought into reality by the establishment of a number of wireless test beds in different countries, and interconnecting these through an IPv6 communication network such as GEÁNT. Provision of testing facilities is seamlessly integrated through security, quality of service and mobility management modules, with open access to R&D institutions and Research projects.

Participating test beds exist independently of this collaboration, leveraging additional national and test bed partner funds as well as the local partnership involving stakeholders from various parts of value chains. These environments will support the creation of new services and emerging mobile and wireless concepts.

In this environment the Living Lab will continually evolve and expand to satisfy changing wireless and service provisioning requirements and takes advantage of test bed advances and Next Generation Network developments.

Each interconnected test bed has Independent End Users, ordinary “people on the street” as test pilots as a critical research validation element in this trusted and secure environment.

The initiative significantly reduces infrastructure and testing costs for all by utilizing a complex and sophisticated network of existing wireless testbeds.

The initiative builds on and deploys existing and emerging research results (such as the SEINIT’s [9] security framework & OPIUM’s [10] Middleware for interoperability) to facilitate rapid deployment.

III. Implementation

This open test bed infrastructure, which we like to call the wireless playground, provides the basis for end user trials, 3G system component testing and interoperability events. Our wireless implementation is illustrated in Fig. 1. The architecture provides different research developers various capabilities to perform tests not limited to service creation, but also various networking protocols that support wireless networks. As shown in fig. 1., the wireless playground is organised in a hierarchical overlay architecture connecting distributed management plane that combines heterogeneous wireless testbeds that are geographically distributed at various locations.

Each test bed contains a profile that is located in a Directory Repository (DR), which contains information about the different access technologies, transport protocols, and service platforms Supported by the specific site. Fig. 1, shows an example of two management planes geographically located in different locations. In site A, the profile consists of Parlay X service platform supported by Mobile IPv6, IPv6 and SIP protocols while site B supports OSA Parlay service platform with DVB, IPv6 and v4 protocols. The profile also describes the different access networks for each test site (e.g. site A supports GPRS, WLAN whiles site B supports WMAN, Bluetooth, and UMTS). Partners are able to view various test bed profiles and capabilities of the different testbeds in order to select the most appropriate to perform testing. Once developers have selected the most appropriate test bed legacy code can be submitted to repositories (service repository -SR) and execute their code while monitoring their capabilities through the Monitoring Facilities (MF) remotely. As described in the introduction, developers are not limited to only analyzing performance of services executing on various service platforms but may also extend to reconfigure QoS infrastructures to analyze the network protocol support for the services (e.g. modifying Diffserv routers for different traffic class and analyzing performance of services under different class constraints).

This wireless playground consists of:

1) Multiple Access Technologies and End Systems

The testbed includes access technologies such as GSM/GPRS, UMTS, WLAN, W-MAN, Bluetooth, WLL and connect to core networks supporting IPv4, IPv6, MobileIP, and Digital Video Broadcasting (DVB) Terrestrial & Satellite protocols. This is by nature local in the coverage area of the specific access technology. It is assumed that these access technologies can be utilized so that end users can access services in their daily life.

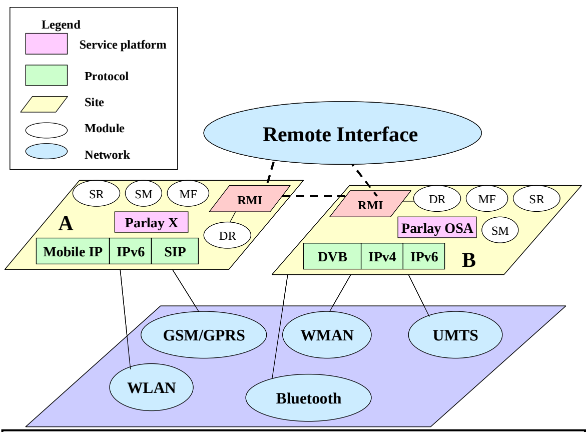

Figure 1 The Wireless Playground

2) Unified Communications Infrastructure

Each access technology has its own individual switching function manager (SM) which administers individual call legs of that technology, accommodating different media types, whether they are switched circuits or IP streams.

It is at this layer that a unified call state model which is presented to the Service platforms and middleware layer, independent of the media type used for carrying the voice or data.

3) Flexible Services Platform & Middleware

For maximum agility in service access and delivery capabilities, dynamic service aggregation, subscription handling, and services provisioning for the architecture, and underlying technologies the testbed uses SIP, IN/Camel, OSA Parlay, Parlay X, IMS, SIP AS, CTI, AAA, Push- to-talk on top of an all IP network infrastructure. The main idea is to be able to share these platform and middleware components within the network, as shown in Fig. 1. For example, if a developer needs to evaluate a particular service on both OSA Parlay and Parlay X, the service can be tested on both site A and B. For each of the tests, developers can analyze the performance through the Remote Monitoring Interface (RMI) during execution.

4) Effective Network Management and Control

System technologies for the Network Management environment are in place and focus on an innovative platform enabling different management distribution strategies and catering for effective co-operative management by multiple management systems. This is accessible through the Remote Management Interface which provides access from both individual users to monitor the current system or peer monitoring system performing co-operative management tasks.

5) Evaluation and co-creation by the real consumer, the End User

The test facility is enhanced by means of a human resource component - an end user community willing to participate in application testing. We call these people Test pilots and the centre has added a behavioral evaluation service related to those users. Through the co-creative approach, test pilots are involved early in the service creation phase in order to cater for their needs and preconditions for use. Together with the end users there is a need to make use of interdisciplinary competence in a wide spectrum of areas, like behavior of humans, economics, attitudes etc. In this respect the test beds often utilizes competence to be found on universities or research institutes.

6) Tools for Testing, validation and management

A rich set of evaluation methods are in place for technical testing measurement and human related evaluations of applications. Test bed validation includes the design and execution of systematic tests for conformance, interoperability, performance, and scalability. Test development tools are used to develop advanced test suites for selected target systems.

7) Service Development

In order to support the service development and experimentation, the test beds can support tools and SDK for the various platforms and components being made available at the facilities. As shown in Fig. 1, service developers are able to submit legacy services to service repository and execute the services while monitoring the results remotely during service execution.

8) Code Repository

The distributed testbed also supports software reuse to allow partners an opportunity to access pre-existing software to perform tests. This not only saves resources for developers but at the same time expands the research horizon and further open opportunities for collaborative research between different partners.

IV. SCENARIO

An initial example of the integrated wireless testbed can be seen through the EU IST project OPIUM [10]. The goal of the project was to support the accelerated rollout of commercial mobile services within Europe by addressing the key issues of interoperability, roaming and billing prior to the delivery of commercial services.

In this context the project set out to validate end-to-end service mobility, interoperability and roaming solutions through the interconnection of open middleware platforms based on OSA/Parlay.

The focus of the trial(s) within the project, was the provision of new applications specifically created to take advantage of the unique characteristics of the high-speed wireless networks. An example of a particular application trialled was Enago iMAPs, an enago service based on GeoPlaneta iMaps applications and offering mapping services based on information provided by the user (address, city,etc.) or based on the actual user location.

In order to carry out the trial, the OPIUM project developed an architecture for internationally interconnected trial sites.

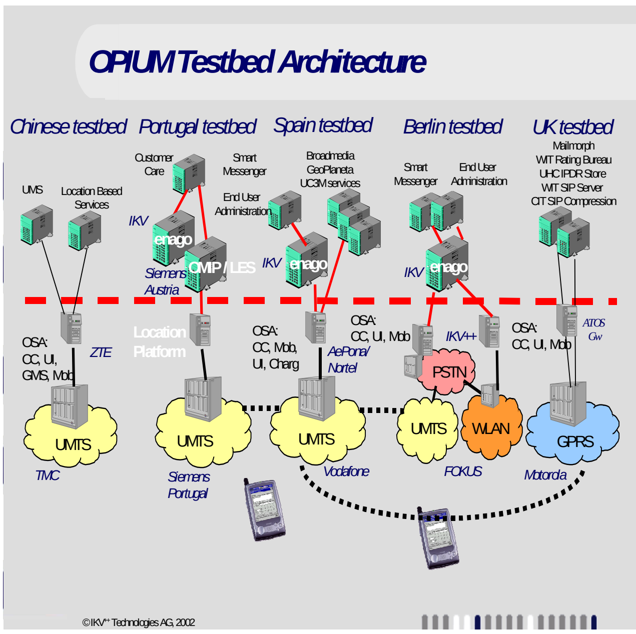

Figure 2 OPIUM Inter Trial Site Architecture

OPIUM consisted of five trial sites in five countries (Portugal, Germany, Spain, UK and China).

These trial site architecture covered the following layers:

- Multiple Access Technologies and End Systems
- Service Development
- Flexible Services Platform & Middleware

The trials were carried out in two phases. Phase I of the trial used separate trial islands where the trial site owner managed each trial. This meant that individual trial sites were set-up and tested, with the overall feasibility of 3G communication and service concepts demonstrated.

Phase II of the trial was more comprehensive and complex as it concentrated on the validation of end-to-end service mobility, interoperability and roaming solutions through the interconnection of open middleware platforms, focusing on a Pan-European trial.

In Phase II different possibilities for interworking between individual trial sites in various layers was demonstrated. Test Cases were prepared for the testbed connections and trialled with both OSA/Parlay application portability and 3G roaming. In doing so, it was found that roaming was transparent for the application providers, allowing the subscriber to use their applications while roaming as if they were attached to their home network.

In performing these trials across the Pan-European integrated testbed it was proved that Parlay was able to provide a flexible, standardised way of implementing services. Once ported these services could be used in many network environments.

Based on the trials, the OPIUM consortium made a number of recommendations, examples of which includes:

- All applications used by the roamer should request services and information from the Home Parlay gateway. The rationale behind is that the main profile of the user is at the HSS (always located at the Home network) and this profile can only be accessed by the Parlay gateway of the Home network. Any other business model would be very complex.
- If the application requires information that can only be obtained or gathered by the Visited network (e.g. location information), the Home network should be responsible to get such information and send it to the application through the Parlay gateway.
- Operators and application providers should work towards simple billing solutions and models which do not generate large amounts of data.

On the results of the project the Parlay group referenced OPIUM as an important demonstration of Parlay capability and used the results as part of the sales pitch to Operators and value added service providers. This was supplemented through the Phase II tests of various solutions on the integrated testbed. The integrated testbed has provided a swift solution towards the project's significance in removing key barriers to adoption and the uptake of Parlay, namely fears over portability, interoperability and roaming. Indeed it turns out that these fears would have been justified as when the project started these issues had not been sufficiently examined by Parlay vendors.

V. Conclusion

The objective of the Living Labs approach is to extend existing e-Infrastructures into the wireless dimension and to take a user-centered approach which places a special emphasis on the need to develop mobile services that are usable, i.e. effective, efficient and satisfying to use, and has full end user integration in the creation and validation process. This will result in a mobile research environment where:-

- Researchers have 'Open' access to a powerful, flexible, and evolving federated wireless test bed infrastructure interconnected by a fixed IPV6 backbone based on national wireless test bed hubs.
- The need has been removed for separate, duplicated wireless testbed investments to support R&D projects, European Industry, and Academia.
- Interoperability of services and service provision environments (including roaming across heterogeneous networks) are validated; research approaches are verified; and take-up is accelerated.
- Real End users participate actively in the validation of a complex wireless environment of mobile intelligent, adaptive and self-configuring services that demand seamlessly accessing anywhere, anytime and in any context in a trusted and secure environment.

Development of this mobile/wireless e-Infrastructure, interconnected and secured on a global level will result in an improved mobile/wireless research environment for the academic and commercial community, especially in the areas of communication Services & Applications development, existing wireless test-beds, Standards bodies, and Research Communication Networks such as GEÁNT.

It will form the technological base and make wireless technology for Living Labs in which a wide area of projects can be conducted. A world-class technology platform will enable the focus of projects to be moved to social, experience and value issues of service development.

It has and will continue to lead superior cooperation between research and industry, providing roadmaps and strategic guidance for future networks, speedier incorporation of technology & take up of wireless research.

The Living Labs approach will give SMEs an edge in the global market and reduces barriers to entry for innovative ICT solutions.

At the time of writing, Living Labs comprises of a nucleus of partners TSSG Waterford, CDT (Testbed Botnia), University of Bremen, Helsinki School of Economics and the Turku region, InfoPark and the Budapest region, the Freeband initiative in the Netherlands operated by Telematica Instituut among others. Associated partners also include ATOS Origin, IBM, Nokia and Ericsson.

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References

[1] L. Palen, M. Salzman, E. Youngs , “Discovery and Integration of Mobile Communications in Everyday Life”, Personal and Ubiquitous Computing , Volume 5 , Issue 2, July 2001, pp. 109 - 122

[2] S. Intille, K.Larson, J.S. Beaudin, J. Nawyn, E. Munguia Tapia, P. Kaushik, “A Living Laboratory for the Design and Evaluation of Ubiquitous Computing Technologies”, Conference on Human Factors in Computing Systems, CHI '05 extended abstracts on Human factors in computing systems 2005, Portland, OR, USA, April 02 - 07, 2005.

[3] G.D. Abowd, C.G. Atkeson, A.F. Bobick, I.A. Essa, B. MacIntyre, E.D. Mynatt and T.E. Starner, “Living Laboratories: The Future Computing Environments Group at the Georgia Institute of Technology”, Conference on Human Factors in Computing Systems (CHI 2000), The Hague, Netherlands, April 1-6, 2000.

[4] P. Markopoulos, “Towards a Living Lab research facility and a ubiquitous computing research programme”, Position Paper, for the CHI 2001 workshop: 'Distributed and Disappearing UI's in Ubiquitous Computing', CHI 2001 Conference on Human Factors in Computing Systems, Seattle, Washington, 31 March-5 April 2001.

[5] S. Abu-Hakima, R. Liscano, and R. Impey, “A Common Multi-Agent Testbed for Diverse Seamless Personal Information Networking Applications”, IEEE Communications Magazine, July 1998, pp. 68 – 74

[6] L. Peterson and T. Roscoe, “The Design Principles of PlanetLab”, PlanetLab Design Note 04-021, http://www.planet-lab.org/PDN/PDN-04-021/, June 2004.

[7] D.H. Sonnenwald, “Developing a theory to guide the process of designing information retrieval systems”, Annual ACM Conference on Research and Development in Information Retrieval, Copenhagen, Denmark, 1992.

[8] European Commission, “Mobile Communications & Technology Platform Final Report, Brussels, 8 January 2004.

[9] SEINIT, Security Expert Initiative, EU FP6 IST Project, www.seinit.org

[10] OPIUM, Open Platform for Integration of UMTS Middleware, EU FP5 IST Project, www.ist-opium.org