Simplicity:
a Key Feature of Modern Telecommunications Networks

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***Abstract*— As technology develops, and becomes more and more pervasive, people are using an ever broader and heterogeneous range of ICT devices and network-based services. The result is an enormous burden of complexity on the shoulders of users, service providers, network operators and manufacturers. In this framework, simplicity is not only a buzzword or a seemingly obvious requirement: it is a key feature that makes the difference between a market failure and a widespread uptake of a technology, or of a product. It should be the Leitmotiv in the design of networks and services.**

In this paper, we describe research paths and technical approaches devised to "integrate" simplicity in modern telecommunications networks. With reference to both results achieved in collaborative research projects and ideas still to be fully developed, we tackle aspects such as: i) personalization of services, ii) portability of services across heterogeneous terminals and devices; iii) autonomic adaptation of services to available networking, computing and service support technologies and capabilities; iv) tools easing the design and deployment of contextualized mobile services, exploitable even by non-experienced programmers; v) security and privacy capabilities, adapted to specific services and enforced in specific contexts in easily understandable way for the end-users; vi) definition of versatile digital items allowing user personalization, description of real world objects, inclusion of dynamic and user-generated contents; vii) handling of such digital items across different platforms; viii) server-less instances of the Internet, allowing communication between people and applications located within close proximity of each other.

I. Introduction

Nowadays, ICT users employ a variety of different terminals and devices to access a range of different "services" in the office, in the home, in buildings or in public spaces, for example, communications, computing capabilities, security support etc. Some services may be as simple as remote control of an entertainment device via a wireless link, or access control to a building. Others can be very complex and may require location awareness, QoS support, message exchanges with network databases, structured interaction with remote networking devices (e.g., media gateways), etc. The emergence of new research areas, such as pervasive computing, will further increase the diversity of the devices and services with which users have to deal.

But already today, users who attempt to exploit the services on offer have to deal with multiple procedures for configuring devices, multiple authentication mechanisms and passwords, multiple billing and payment procedures, multiple access technologies and protocols. This complexity is likely to limit the effective exploitation of the wide range of access, virtual reality, ambient intelligence and context-aware solutions currently under study and development. It will deepen the digital divide, making it difficult for non-technical users to benefit from new developments. And of course it will also create difficulties for network operators, who will be forced to manage the complexity of a multi-access networking environment.

In this scenario, it is always more important to "integrate" simplicity in modern telecommunications networks: from design to deployment, use, management, maintenance, evolution and even dismantling of networks. In this paper we will describe solutions and ideas that strive to bring easy of use in the life of ICT users, service providers, network operators and manufacturers.

We will briefly illustrate the main results of four collaborative research projects co-funded by the European Union and two ideas still to be fully developed.

II. The "Simplicity" project

The Simplicity project is a European Union program, which lasted 26 months (January 2004 - February 2006) [1][5]. The acronym, Simplicity, intends to convey the very aim of the project: design and deploy a brokerage level allowing i) easy personalization of services to match user preferences and needs, ii) seamless portability of services, applications and sessions across heterogeneous terminals and devices, and iii) smooth adaptation of services to available networking and service support technologies and capabilities.

The personalization concept is based on a user profile. In this view, each user will be provided with a personalized profile, giving access to different services, and using heterogeneous classes of terminals. The personalized user profile will allow automatic, transparent customization and configuration of terminals/devices and services, uniform mechanisms for recognizing, authenticating, locating and charging the user, policy-controlled selection of network interfaces and applications services. Thanks to the profile, users will also enjoy the automatic selection of services appropriate to specific locations (e.g. the home, buildings, public spaces), the automatic adaptation of information to specific terminal devices and user preferences, and the easy exploitation of different telecommunications paradigms and services.

The user profile will be stored in a so-called Simplicity Device (SD). Though it seems natural to think of the SD as a physical device, (e.g., an enhanced or generalized SIM card, a Java card, a USB stick, a sensor, etc.), the SD could also be implemented as a network location or a software agent. In some case the physical SD could store "pointers" to complete profile information, which resides in the network. If the SD is a physical device, users could personalize terminals and services by the simple act of plugging the SD into the chosen terminal.

The SD will provide all the information necessary to adapt services to the characteristics of the terminal, the nature of the environment and the user's personal preferences. Fig. 1 shows the overall picture of the Simplicity scenario, where the SD interacts with Terminals to configure and adapt Terminals, the Applications therein contained, the access to Networks and the access to Services. The project has developed four SD prototypes using devices very familiar to end-users:

- a Bluetooth phone SD (BTSD), which exploits the memory, connectivity and processing capabilities of J2ME and Bluetooth-enabled phones; the BTSD stores user data in the phone and/or in the SIM and communicates with the device to be personalized via Bluetooth;

- a Java Card SD, which implements the SD as an applet deployed on a JavaCard;
- a Flash Memory SD which uses memory sticks;
- a Virtual SD: a pure software implementation.

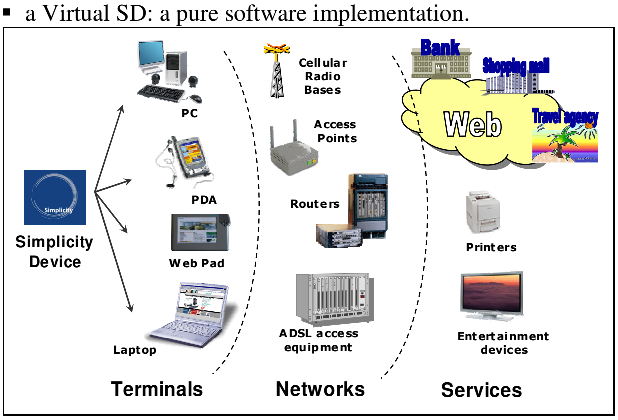

Fig. 1. Overall scenario

The Simplicity system also encompasses a Brokerage Framework. This brokerage level uses policy-based technologies (e.g. policies for mobility support, QoS, security, SW downloads) to orchestrate and adapt network capabilities, taking into account user preferences and terminal characteristics. The main components of the Simplicity system are the SD, the Terminal Brokers (TBs), the Simplicity Personal Assistant (SPA) and the Network Brokers (NBs). The Simplicity system can interact with existing ("legacy") application and services and with external applications which are designed to exploit the capability of the system (denoted as "Simplicity enabled 3rd party applications").

The role of the SD, as discussed above, is to store user's profiles, preferences and policies. It also stores and allows the enforcement of user-personalized mechanisms to exploit service fruition, to drive automatic adaptation to terminal capabilities, and to facilitate service adaptation to various network technologies and related capabilities.

The TB manages the interaction between the information stored in the SD and the terminal in which the SD is plugged in. The SD enables the TB to perform actions like adaptation to networking capabilities and to the ambient, service discovery and usage, adaptation of services to terminal features and capabilities. The TB caters also for the user interaction with the overall Simplicity system (including network technologies and capabilities).

The Simplicity Personal Assistant (SPA) represents the interface of the Simplicity systems towards the end-user. The SPA interacts with users via a convenient User Interface, assisting users in their tasks. Its look, behavior and actions are adapted to user preferences and needs. SPAs are meant to provide as much support as possible to the user. The SPA acts autonomously whenever it can, requiring only minimal input from the user. This entity also provides uniform access to the Simplicity System, and to the services it provides. More specifically the SPA is involved in many tasks, which include user authentication, management of user's preferences and also application-related functionalities like session management, service subscription, adaptation (personalization) and invocation.

The NB has the goal to provide support for service advertisement, discovery and adaptation. Moreover, it orchestrates service operation among distributed networked objects, taking into account issues related to the simultaneous access of several users to the same resources, services, and locations. Other functions of NBs include sharing/allocating available resources, and managing value-added networking functionality, such as service level differentiation and quality of service, location-context awareness, and mobility support.

3rd Party Applications run on the user terminal and on other network-side entities. 3rd Party Applications use features provided by the Simplicity system through a specific interface, called Simplicity Applications Interface (SAI). More details on architectural and functional issues, and related references, can be found in [1][5]. The relationships between all the Simplicity related entities are depicted in Fig. 2 below.

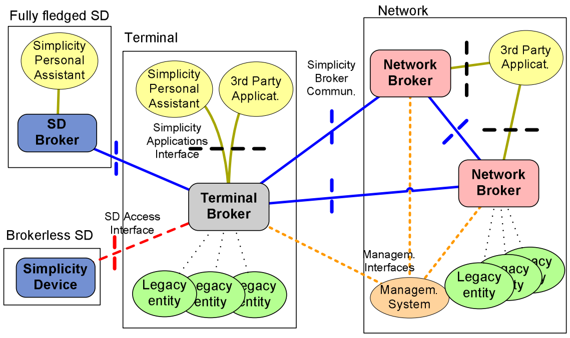

Fig. 2. System architecture: an overview

A. The demonstrator

A major project achievement was the implementation of the Simplicity Demonstrator. The Demonstrator was organized around 5 scenarios and 9 "Demonstration Services":

- A Simplicity Aware Service Environment for Mobile Workers, which provides a friendly, adaptive service environment for its target users. The scenario included the following Demonstration Services
  - My PC: a service supporting the needs of mobile workers moving frequently between different terminals and services (e.g. by allowing them to carry their 'bookmarks', 'address books' and application preferences with them).
  - I-Provisioning: a service allowing secure download and installation of software on the user terminal.
- A Media Streaming – Home Entertainment System (HES), in which Simplicity helps users in their interaction with a Web portal selling media content and automatically adapts media according to terminal capabilities. The HES comprised three "Demonstration Services".
  - A streaming service.
  - A "buy media service.
  - A "personal storage service".
- A Tour Guide System that shows how Simplicity can be used to personalize a context-aware Tour Guide system, including applications and services running on devices that are not owned by users. The Demonstration Service consists of a:
  - Tour Guide service for visitors to the city of Lancaster.
- A Campus Network where Simplicity exploits user preference information and network monitoring functions to manage network load. The Demonstration Service is a:
  - Dynamic allocation of users to Access Points.
- An Adaptive Multimedia Messaging Service, in which Simplicity supports a multi-media chat service which adapts

to different media (text, images and sound) and terminal capabilities. The Demonstration Service consists of a:

- Multimedia Messaging with automatic content adaptation

The majority of these Scenarios also show an additional Demonstration Service: an automatic form-filling tool, that stores its data in the Simplicity User Profile.

Summing up, the Simplicity project demonstrated a new service concept, facilitating access to services and networks and showing how few key innovative design principles can drastically ease the life of all players in the ICT world.

III. The "Simple Mobile Services" project

The work performed by the Simplicity project is continued in a follow-up project, named Simple Mobile Services (SMS). The SMS project, co-funded by the European Union, started in June 2006 and will last 30 months [2][6].

The rationale of the project is the following: a key factor in the success of the Web is that not only it is very easy to "use" it, but also it is rather simple to create a web page, in an open environment. This means that a very large base of people can create Web pages and that a vast amount of imagination, culture and ingenuity is at work every day to continuously expand contents and services available on the Web. This is not true for current mobile services. If mobile services are to repeat at least in part the success of the Web, they have to be simple to find, simple to use, simple to trust and simple to set up.

As a matter of fact, the World Wide Web offers a practically infinite range of universal services – accessible to any user at any time in any part of the world. But these services mainly target users working from fixed locations (the home, the office). With a few exceptions (like train timetables and flight schedules) they fail to address the specific needs of mobile users. Even when they do, many mobile users are unaware that they exist, find them hard to use and are unwilling to trust them. Providers do not invest in services for which there is little demand.

Current mobile services do not satisfy users' need for rapid results, in "minimal attention situations". To address this problem, SMS focuses on simplicity. Unlike current universal services, each Simple Mobile Service will have a scope: it will target specific environments of interest to specific classes of mobile user performing specific activities. This means that SMS will be simple to find. Instead of "Googling" for services, users will choose from a small set appropriate to the activities and environment that currently interest them. When services target specific physical locations, it will be possible to advertise their availability with posters, signs, leaflets and electronic displays. Precise targeting of services to specific users and environments will make SMS attractive for advertisers.

Another goal is to ensure that SMS will also be easy to use. Authentication and configuration will be automatic. User interfaces and content will be automatically adapted to the characteristics of the terminal. Services will maintain the same basic logic as users move between environments and networks, even though the resources (sub-services/content) used to provide the service are dynamically discovered and exploited. Like the services provided by the Web, SMS will provide technology and operator-independent end-to-end connectivity. SMS will be terminal and network independent, working with a broad range of mobile devices (e.g. PDAs, smartphones, Laptops) and network infrastructures (e.g. UMTS, Wi-Fi).

SMS will be trust-worthy, providing end-to-end standards-based mechanisms for positive user identification, authentication, and data encryption (both on terminals and during transmission). Security and privacy characteristics will be designed to take account of key provider and end-user requirements, including ease-of-use and the need to understand the implications of specific security options.

Last, but not least, SMS will be easy to set-up. The SMS project aims to develop and use standards and standards-based tools, which are no more complex than current Web authoring tools. As a result SMS will be an empowering technology: the methodology and tools developed by the project will allow individuals, SMEs, NGOs and local government departments to compete with larger organizations as providers of mobile services.

In technical terms, the goal of the SMS project is to implement a new class of mobile service and to create a set of tools allowing easy design, deployment and management of these services. The tools created by the project will be integrated in a service platform. The service platform will be independent of specific technologies (e.g. for indoor and outdoor location) but will provide a common interface, allowing the use of different technologies. SMS will implement a prototype of the platform, with a Web interface, and service authoring tools allowing small businesses and individuals to develop and roll out their own services.

The project is currently halfway in its final objective of creating mobile services that are simple to find, use, trust and develop, and making it easier for individuals and small businesses to become service providers.

IV. The "Discreet" project

The Discreet project, co-funded by the European Union, started in December 2005 and will last 27 months [3].

Security and privacy are two major issues whose importance is always more felt in the ICT community. In this case too, we argue that not only is important to provide these features as efficiently and as properly as possible, but also that these capabilities have to be adapted to specific services and enforced in specific contexts in easily understandable way for the end-users. The Discreet project is motivated by the following fundamental question: Is pervasive technology forcing users to waive their privacy rights? And how much of our privacy can be traded for security and/or new service opportunities?

In [7] the project is briefly presented: "pervasive environments provide impressive perspectives in terms of high personalization of services (e.g. context or location aware), automated control of the surrounding environment, and improved safety through advanced tracking and monitoring tools. However, always-on devices, pervasive RFID tags, surveillance and tracking systems, biometric technologies, as well as, in more generality, the deployment of means for using user profiles and preferences to adapt, control, and interact with smart sensor-rich environment, poses severe challenges to the privacy of the user and their "right to be forgotten": once personal data are spread in the information systems, they are permanently away from the control of the end-user, and only regulation provides the user with the trust that their data will be used in the "proper" manner. All this poses a serious risk on the user privacy rights. The collection of personal and contextual data, in particular when integrated over various information sources, and their disclosure to various infrastructure operators and service providers (not to mention malicious intruders), may turn out as a serious obstacle for the practical deployment of pervasive services. Whether the virtual world we are creating in these years will provide drawbacks in terms of a dramatic reduction of the user privacy rights depends only on how we will be able to properly design it. Anonymity and uncontrolled access is, of course, not a proper approach, as it would be immediate, for intruders and malicious users, to abuse of such strong data protection measures for inappropriate (or even criminal) purposes. On the other side, total delegation and control exerted by operators and service providers, although important to prevent abuses and guarantee an improved safety for the citizens, can become a threat when the operators themselves (or their employers) make an improper usage of the personal data gathered while providing services. In the Discreet project we want to contribute to break what we argue to be a false dichotomy, in which systems designers force their users to sacrifice some part of a fundamental right - their privacy - in order to gain some utility - the use of the application. A fundamental, and quite challenging, research task consists in designing tools and solutions that, in the same time, either provide advanced service opportunities and benefits to the end users, meanwhile not introducing threats on the users' fundamental privacy rights. This can be accomplished by designing technical solutions capable of minimize and control the amount, the type, and the way personalized information is made available to the equipments and/or entities involved in the service provision".

Summing up, the example of Discreet shows that even security and trust related functions need to be designed with easy of use in mind, since the beginning.

V. THE "E2R II" PROJECT

The E2R II project, co-funded by the European Union, started in January 2006 and will last 24 months [4].

The key objective of the E^2R project is "to devise, develop, trial and showcase architectural design of reconfigurable devices and supporting system functions to offer an extensive set of operational choices to the users, application and service providers, operators, and regulators in the context of heterogeneous systems. Innovative research, development and proof of concept are to be pursued from an end-to-end perspective, stretching from user device through all system levels. Furthermore reconfigurability support for intrinsic functionalities, such as management and control, download support, spectrum management, regulatory framework and business models complete the project scope".

E2R II is a big project with 32 partners and covers almost all facets of reconfigurability [8]. Here we focus on autonomic adaptation of services to available networking, computing and service support technologies and capabilities [9].

Today's reconfigurable radio systems have several interesting functionality: i) user terminals can access different Radio Access Technologies (RATs), without duplication of hardware ii) the software (SW) modules required to access different RATs can be downloaded on demand from the network; iii) end-users can choice among different RATs the one more fitted to their needs; iv) end-users can customize and personalize the RAT that they are using; v) end-users can customize and personalize features at all protocol layers, including application services.

These capabilities are ordered along a path that starts from traditional reconfigurable systems operating at the physical layer only (software radio), with very limited decision opportunities for the user, and arrives to a fully fledged reconfigurability. This path corresponds also to a shift from a terminal-centric approach to a user-centric one. The main characteristic of this evolution is the increasing importance of profile information, which is needed to configure, customize and personalize terminal capabilities and services. Obviously, the profile information is tied to an end-user; thus, it is very useful to have a unique way to identify users across different RATs, each of which has typically different means to recognize its users. In [9] we i) examine a possible choice for a unique user identifier; ii) propose a user profile; iii) design a distributed approach to retrieve user profile information that does not require the mandatory presence of a public network operator.

The points of contacts of the work performed in E2R II with that described in the previous sections are rather obvious. A comment is that this work further confirms that autonomic functions should be designed with a whole-system approach.

VI. THE "VERDI" IDEA

VERDI (VERsatile Digital Items) is a project idea (submitted for approval) based on the premise that file-based and stream-based approaches to information management are no longer adequate. Files are machine and operating system dependent; we have no uniform way of assembling them into larger "packages", identifying them, searching for them, copying them, backing them up, synchronizing multiple copies, or controlling access. Recent multimedia standards (e.g. MPEG standards) address many of these issues. But modern users of information need to handle a practically infinite variety of information including data on real world, people, locations and objects (i.e. not just multimedia). They have to check if this information is up to date, and request updates and to synchronize information across multiple digital devices. They are anxious to protect their privacy. And often they wish to assert forms of control not needed by multimedia providers (e.g. express legal consent to use of information, assert a limit date for its validity). To address these needs, VERDI proposes a new framework for information management, leveraging and extending current multimedia standards. More specifically, VERDI will: i) extend the "digital items", introduced in MPEG 21, developing the concept of a "Versatile Digital Item" (VDI); (ii) provide features allowing users to define and encapsulate new, personalized, dynamic classes of content, and related meta-information in VDIs; (iii) introduce special features for the management of references to Real World Objects (e.g. people, places, products); (iv) define standard operations on VDIs, including creation of VDIs, naming of VDIs, searching for VDIs, reading and writing the attributes and content of VDIs, copying and backing up VDIs, efficiently synchronizing VDIs between multiple machines, satisfying always more demanding requirements posed by Web 2.0 applications; (v) specify (and create reference implementations of) open source middleware supporting these operations; (vi) develop demonstrator applications for the solutions proposed; (vii) develop business model(s) for future exploitation.

The VERDI idea extends the simplicity feature to application layer functionality and to the object of the information transfer: the digital items.

VII. THE "NEARNET" IDEA

Nearnet is a project idea (submitted for approval), based on the following considerations. The Internet provides efficient seamless, distance-independent, end-to-end communication between users and applications in practically every corner of the globe. Yet paradoxically, when two experts in telecommunications meet in a conference room and want to exchange data they often use an USB stick or an e-mail. If they do not use networking technology, it is because using the USB pen is easier. A second reason is the hierarchical, server-based architecture of the Internet. Without servers we have no viable mapping of domain names to addresses, no routing, no dynamic assignment of addresses, no way of protecting and isolating private networks, no email, no directory services, no AAA, no wi-fi access points. Yet access to the servers we need is usually complicated, often expensive, at times impossible. In many scenarios (like the local exchange of data in a conference room) it would obviously be better to do without.

Today this is difficult. Current technology (Wi-Fi etc.) provides the physical media needed to transport information among peers without resort to servers. But it does not provide a substitute for the broad, tightly integrated range of services provided by the Internet. Until equivalent services available, effective communication within ad hoc groups will continue to be a problem. The strategic goal of the NearNet project is thus to fill this gap, enabling local, server-less communication between people and applications located within close proximity of each other, while at the same time, maintaining backward compatibility with existing Internet protocols, and supporting their ability to communicate with the broader Internet. User scenarios include communications in large scale manufacturing plants, communications within an informal group attending a meeting, sensor networks, ad hoc music sharing in an urban space, inter-vehicle communications, deployment of networks in third world countries, war zones, hotels and disaster zones. Additional advantages include the elimination of the single points of failure, and the associated privacy, security and reliability risks inherent in server based scenarios, and better scaling properties (as required by a important emerging user scenarios such as large-scale sensors networks, massive use of multimedia streaming).

Many of the elements required to meet user needs are already in place. In particular ad hoc networking and mesh technologies already provide efficient layer 2 communications between peer machines; mobileIP makes it possible to associate users with a routable address, even when they are roaming across different networks; proprietary solutions such as "The Children's machine", currently under development at MIT, or Ericsson's Terranet, are based on Mobile Adhoc Networks (MANets). What is missing at the time, is a coherent architecture, integrating these different contributions and "packaging them" in such a way as to make them transparent to users.

With Nearnet we are trying to bring simplicity in the outposts of the Internet, but maybe also to influence the future of the Internet itself.

VIII. Conclusions

The concept of autonomic communications, originally proposed by IBM, apply notions of feedback control, self-organisation, monitoring and reasoning to the construction and management of large systems [10]. Since then, the concept expanded to the design and implementation of stable, "self-*" algorithms as well as the overall design and analysis of adaptive properties and behaviour. The idea spread also in the telecommunications community and has been further promoted by initiatives funded by the European Union, such as the autonomic communication forum [11]. This forum "is founded on the belief that a radical paradigm shift towards a self-organising, self-managing and context-aware autonomous network, considered in a technological, social and economic context, is the only adequate response to the increasingly high complexity and demands now being placed on the Internet". In this framework, the ACCA project [12] made a significant contribution for the development of this paradigm and for rising awareness on this issue. Traditionally, autonomic communication was understood to be about self-management. The ACCA project [12] and other researchers, helped to highlight that it should encompass also other technologies, "all of which begin with the word "self". Among them are self-awareness, self-configuration, self-healing and self-implementation".

In this paper we tried to show the importance of designing communication and computing systems that are *inherently* simple to deploy, use, maintain, manage, change/upgrade and even dismantle. We tried to substantiate this claim through specific examples, obtained in a span of several years (the first draft of the Simplicity project is of October 2002) and to further expand the scope of autonomic systems.

We firmly believe that the features discussed in this paper should be embedded in ICT systems and not simply added on top.

We close by stressing another related requirement, that of easy transfer of information/commands among different devices/different applications of the same users and among different users. In fact easy cooperation among all applications and devices exploited by the same users and among applications and devices belonging to different users is becoming of paramount importance.

All in all, we can summarize this paper by saying that there are three requirements that should be met by any proposed new system: i) simplicity; ii) self-functioning; iii) easy cooperation among heterogeneous devices/applications.

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