SYSTEM SCENARIOS OF END-TO-END RECONFIGURABILITY

François Marx (France Telecom R&D, France); Steve Hope (Orange, UK),
Antoine Delautre (Thales Communications, France), Enrico Buracchini,
Paolo Goria, Alessandro Trogolo (TILAB, Italy), Makis Stamatelatos,
Nancy Alonistioti, Alex Kaloxylos (University of Athens, Greece), Guillaume Vivier,
Karim El-Khazen (Motorola Labs, France), Miguel Alvarez (Telefonica I+D, Spain)

ABSTRACT

This paper will present the System Scenarios that are developed within the European research project End-to-End Reconfigurability (E^2R) [1,2]. Following the presentation of the methodology that was used to identify and define system scenarios, the three families of E²R scenarios will be introduced: (1) Ubiquitous Access, (2) Pervasive Services and (3) Dynamic Resources Provisioning. The impact on the end-to-end system in providing communications and the requirements for supporting each family of scenarios will also be addressed. This is achieved with a particular focus on the various parts involved in the reconfiguration of the communication protocol in order to cover all the layers. An analysis was also carried out to identify the E²R actors involved in the scenarios and the detailed interactions of those actors. The practicalities of implementing such scenarios from the different actors will also be discussed.

1. INTRODUCTION

Today, numerous radio communication standards as GSM/GPRS, IS95, CDMA2000, UMTS, 802.11x, DxB, Bluetooth, etc co-exist; as the telecommunication industry mature, it is increasingly becoming possible to devise, develop and trial architectural design of reconfigurable devices enabling a transport seamless handover. This article presents both the systems E²R scenarios and their reconfiguration mechanisms.

2. SCENARIO ANALYSIS

2.1. Methodology

The purpose of this analysis is to define scenarios in order to illustrate E²R requirements and constraints reconfigurations and to derive scenarios that capture the key reconfigurability elements. As this paper is dedicated to the overall system analysis, instead of other E^2R technical papers dedicated to some parts of the systems (sub-systems), the methodology tries to avoid the choice of a technological solution.

The first objective is to identify the main technological areas and to derive scenarios that capture the key reconfigurability elements. The next step is to clearly identify the different actors involved and the relations between these actors. Scenarios will be supported by a story described firstly as a script. This story will be used to identify the actors of the system as well as main objects of the system (e.g. networks elements, application platform…) and mechanisms involved in the reconfigurability process.

2.2. The Actors

In order to identify who constitutes an Actor in the end-to-end scenarios, it has been proposed that a separate actor should be considered whenever the functions associated to it may be performed by an independent entity completely separated from the rest of entities in the system. Similarly, if different functions are always performed by the same entity it is proposed that those functions are grouped in one single actor. Based on this principle, the actors involved in the various E²R scenarios are identified: User, Subscriber, Reconfigurable Equipment, Equipment Manufacturer, Network Operator, (Value-added) Service Provider, Regulator, Pilot Channel Provider, Content Provider, Software Provider, Service Aggregator, Certification Entity, Spectrum Manager, Reconfiguration Manager, and Security Entity. In many cases some of these actors may be grouped in a single entity (e.g. a network operator that is also a service provider or an equipment manufacturer which also acts as a software provider).

A **User** is an entity, which uses services. Example: a person using a 3GPP mobile phone.

A **Subscriber** is an entity (associated with one or more users) that is engaged in a subscription with a service provider. The subscriber is allowed to subscribe and unsubscribe services, to register a user or a list of users authorized to enjoy the services, and also to set the limits relative to the use of these services by the associated users.

A **Reconfigurable Equipment** is a device used by the user/network operator to obtain/provide access to the communication services, and that can be modified with several kinds of reconfiguration processes. In case of an end-user reconfigurable equipment, it may be provided to the user by the service provider or the network operator, or directly acquired by the user. A reconfigurable equipment is autonomous and able to decide/act without any other actor intervention. Besides, it is aware of its context and self-aware (knowing its characteristics). Different classes of reconfigurable equipments will be considered.

The **Equipment Manufacturer** is responsible for the design and manufacturing of the equipment (such as mobile devices, access points or base stations…) used in the service provision, network and user domains.

A **Network Operator** provides radio resources, mobility management and fixed capabilities to switch, route and handle the traffic associated with the services offered to users. Network capabilities are provided on behalf of service providers. A network operator may use several radio access technologies to provide these services to end users.

A **(Value Added) Service Provider** is responsible for providing a service or a set of services to users associated with it. A service provider negotiates with network operators for network capabilities needed to provide services to its users. A VASP can be considered as a SP with which the user contracts specific services not offered by the home service provider.

A **Regulator** sets laws and guidelines that determine the operation of the whole system. This includes aspects such as the acceptable equipment behaviour (regarding frequencies, power…), the tests that must be passed to place an equipment on the market, and the allocation of spectrum.

If available, the **Pilot Channel Provider** coordinates the RAT discovery. It allows the terminal to discover the new radio interface to use and provides access to the software for the local systems.

A **Content Provider** creates and maintains multimedia repositories and makes them available to service providers or end-users though the service provider.

A **Software Provider** supplies the software to be downloaded and installed in network equipment or end-users terminals.

A **Service Aggregator** mediates between SPs/VASPs, operators and users. It keeps users aware of the available services, categorizes services depending on their content, localization, terminal capabilities and subscriber profile, by operating a software platform for service, reconfiguration management and provision. The service aggregator comes into business level agreements with network operators and VASPs.

The **Certification Entity** guarantees the conformance of the protocol implementation and integrity of the software and the authenticity of its origin. Under the supervision of a regulator, this actor will be responsible for issuing, revoking and managing security credentials and public keys for data encryption and signature. This role can also be undertaken by an operator or a manufacturer or a third party.

The **Spectrum Manager** is the entity responsible for approving and monitoring spectrum allocation to different entities and the transfer of spectrum between them (be it sharing or rental), so that operators comply with the rules set by the regulator.

The **Reconfiguration Manager** is responsible for the reconfiguration management, intra/inter domain reconfiguration policy and respective interactions between service aggregators, certification bodies, operators, manufacturers…

A **Security Entity** provides the security reconfiguration information and the security context for the system, in cooperation with the rest of the actors of the system.

3. SCENARIO #1: UBIQUITOUS ACCESS

3.1. Objectives of the Scenario

Ubiquitous Access scenario relates to the support of the user who switches on his device in a new wireless environment to which he has not been previously connected, e.g. when leaving an aircraft and seeking access to his services. Roaming is a particular example of this scenario, and the increase of roaming possibilities granted by the reconfigurability is highlighted. For example, a customer moves from Europe to the USA, Japan or to China, or vice versa, with an E²R reconfigurable equipment. Before departure, the E²R equipment is configured on a GSM/GPRS/EDGE mode or UTRA mode. Arriving at destination, this customer switches on the E²R reconfigurable equipment and the local new system has to be activated and/or downloaded and configured on it. For example, considering the USA, if is present an IS95 or CDMA 2000 coverage, at least one of these radio interfaces have to be activated and/or downloaded and ready to be executed for service. Considering China, Narrowband TDD has to be activated and/or downloaded and ready to be executed for service, etc.

3.2. Reconfigurability Issues Addressed through the Scenario

Mr. Rossi is leaving his home in Turin during a secure download of his new e-mail messages with his E^2R equipment. When he enters in his car, he starts (without interrupting the download) a conversation call with his colleagues at the office. During the journey to the airport, the download ends and the E^2R equipment begins reading the subject of each new e-mail message: Mr. Rossi, with a vocal command, may order the E^2R device to read the entire

message or not. When Mr. Rossi arrives close to the airport, the E²R device informs him that the car parking has free space at the fourth floor. After parking the car, Mr. Rossi moves inside the airport. Immediately, the E²R equipment informs Mr. Rossi that an automatic tele-check-in system is available. Therefore, Mr. Rossi downloads the tele-check-in client software and then performs the check-in operation with his E²R device, digitising his ticket-code on the E²R equipment and choosing his seat and his menu for the lunch. Moreover, Mr. Rossi personalises his "Personal Profile" in the tele-check-in system server to automatically choose that menu for the next times. During the wait for the boarding, Mr. Rossi downloads with his E²R device the new lesson of his Electronic Advanced English Course and starts learning the new subjects, using his E²R equipment. When Mr. Rossi enters the airplane, he switches off his E²R device.

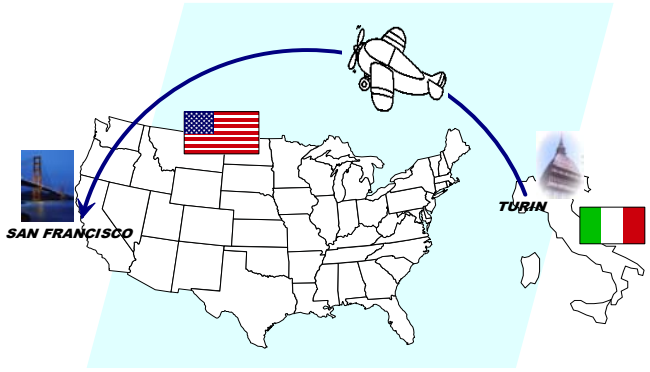

Figure 1: Ubiquitous Access: Mr. Rossi moves from Europe to USA with his E²R Device

Arriving at San Francisco, Mr. Rossi switches on the E²R device that starts seeking for a cellular system. Since in USA the local system is different from Europe, the E²R reconfigurable equipment automatically begins a download of the new standard using the pilot channel given by the Pilot Channel Provider covering San Francisco airport. The Pilot Channel Provider, before starting the download, performs a security check with the Reconfiguration Manager, in order to know if Mr. Rossi "User Profile" has the "Standard reconfiguration" option enabled. Other methods exist to download a new standard. After the download, the E²R reconfigurable equipment is able to manage all the services and applications supported by the new radio standard.

3.3. Potential Techniques – Reconfiguration Mechanisms

A way to activate and/or download the software in the E²R reconfigurable equipment has to be defined; for instance:

- Via Smart Card or SIM card: using a customised equipment that must be present in the airport,
- Though a point of sale: in the airport (or hotel or train station, etc..), a chain of point of sales has to be present in order to grant the software activation and/or download (e.g. via cable, IRDA, Bluetooth),
- Over-the-air (OTA): a radio channel has to be considered for the download procedure; this is the download method described in the story script,
- Activation of the system: a smart card or the terminal itself has in the memory several systems. The activation can be generated via network input or via auto detection.

Besides, some technical points must be underlined for this short-medium term scenario:

- The OTA download procedure (in-band or out-band) has different impacts on costumer and operator perspectives as well as on regulatory issues:
- Costumer latency and transparency: the download procedure has to be as much transparent, quick and cheap as possible in order to decrease the impact on the costumer,
- The size of the software has a strong impact on network dimensioning and user latency,
- Security: the procedure must be safe and controlled by operator (e.g. AAA via SIM card),
- Core network inter-working for profile and billing exchange.

4. SCENARIO #2: PERVASIVE SERVICES

4.1. Objectives of the Scenario

The purpose of this scenario is to stress the need for reconfigurability when several radio access technologies are present in the wireless environment. Indeed, to properly use these different access technologies, the reconfigurable equipment need many capabilities like system discovery, protocol reconfiguration and vertical handover. Besides, the reconfiguration of codecs, cipher algorithm is highlighted in this changing wireless environment.

Transport scenarios is a good example to illustrate the reconfigurability with numerous radio technologies; besides, the applications and services which can be offered in transportation underline the emergence of value-added service providers (VASPs) which provide services other than classical telecommunications services. In such a telecommunication environment, the customer can discover thanks to their E²R reconfigurable equipments, the different access technologies though their way (e.g. WLAN, GSM, UMTS…). The complex and continuously changing telecommunication environment may require vertical handovers, capability negotiation, situation-awareness and the possibility to adapt the services based on telecommunication system context parameters and restriction, as well as to reconfigure the reconfigurable

equipment with new protocols, codecs, and cipher algorithms for example. Multimedia location-based services related to tourist content and information on the visited areas are also available to the users through intelligent service provisioning of VASPs.

4.2. Reconfigurability Issues Addressed through the Scenario

In such a telecommunication environment, Ms Eve and other employees of a large company, after a working day, leave straight by train for another city. As soon as they embark on the train, they continue their meeting preparation work, using their company groupware software and have access to their Company Intranet using their E²R reconfigurable equipment. Private communication between Eve and her colleagues takes place thanks to a secure WLAN ad-hoc mode between corporate laptops. Moreover, Eve's equipment (e.g. laptop), the more powerful, becomes the gateway (and proxy) of her group towards the station's WLAN facility. During the journey, every passenger has the possibility to use the WLAN offered inside the train with an extra and rather expensive charging but also with the choice to get multimedia type information regarding the final or the mediate destinations and interesting points along the way (services provided by a VASP).

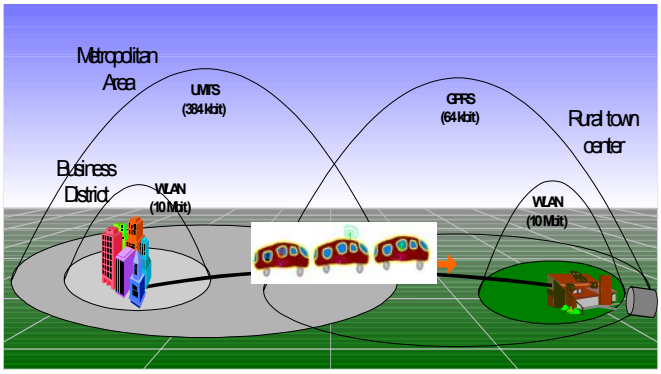

Figure 2: Pervasive Services: The Business Group in the Train

The multi-band reconfigurable equipment of Eve's is monitoring/interpreting context information continuously and is able to select a system to connect in a personalized way: the system selection may be carried out according to the various profiles (user/tariffing demands and terminal capabilities). For the system monitoring, new agents (mainly proprietary) may be discovered, downloaded/installed and executed. Protocol downloading and reconfiguration may take place in order to avoid frequent vertical handovers and also provide soft switching between access systems. When the WLAN connectivity breaks as the train leaves the station and speeds up, the Eve's equipment has already discovered an alternative radio access technology: UMTS. The handover takes place with information derived from Eve's profile regarding acceptable charging etc. In case this information is deficient, the software agent that manages her connection notifies Eve about the new charging and the estimated cost. The vertical handover results to protocol downloading, installing and execution or to a new protocol release update. Furthermore, different handover algorithms may be employed (standardized or proprietary) in order to minimize packet loss and handover delay and to ensure service continuity (avoid inter-system handover).

Eve and her boss at company headquarters are communicating through a videoconference (services provided by a VASP or directly by the network operator). When she was under WLAN coverage, she experiences an excellent Quality of Service. However, after seamless handover to UMTS, the quality was automatically decreased to black and white video, with a smaller image size. Nevertheless the quality of the transmission is still acceptable. This is enabled through reconfiguration of the codecs within Eve's equipment and activation of suitable transcoders placed in appropriate network nodes.

Finally, Eve and her boss close the discussion having agreed on the final version of the file. Due to the location, the high mobility and congestion, the network establishes 2 links, UMTS and GSM (respective reconfiguration is performed) in order to support the service requirements executed by the users for example when Eve shares the final document with her boss.

Eve arrives at her destination and while she is reading her e-mails, the corresponding VASP announces (through appropriate automated procedures) availability of a new version of the messaging application with additional location-awareness features. Eve receives the whole description of the messaging application (since it is currently executing the service), and also information about pricing and purchase conditions. Despite a higher price, she opts to stop execution of the older version and to immediately download and execute the new one. The equipment starts the authentication process with information extracted from Eve's security profile, but the WLAN service uses different cipher algorithm which the terminal is incapable of, so after setting up a secure configuration channel the new cipher algorithm is downloaded and installed and the new messaging application can be download. The downloading process is also based on Eve's security profile.

4.3. Potential Techniques – Reconfiguration Mechanisms

The following list illustrates aspects addressed through this medium-long scenario together with the corresponding techniques and reconfiguration mechanisms [3,4]:

- System discovery may be performed through new system discovery agents and may involve terminal/network monitoring and/or context information interpreting,
- Protocol flexibility may need the protocols to be re-designed in an object oriented way enabling their dynamic reconfiguration in a simple way,
- Private WLAN establishment with specific parameters,
- 3rd party Service Discovery may need negotiation in terms of user preferences and/or terminal/network capabilities (e.g. profile Specification),
- 3rd party Service Provision may need software download and installation and be performed either directly through the VASP that provides each service or via a middleware that supports the services and reconfiguration,
- Service adaptation and Reconfiguration may involve certain procedures such as adaptation negotiation software/protocol download and installation.
- Reconfiguration Management and Vertical Handover
- Personalization could use composite Capabilities/Preferences Profile, user Agent Profile or the Generic User Profile

5. SCENARIO #3: DYNAMIC RESOURCE MANAGEMENT

5.1. Objectives of the Scenario

The case of dynamic cells traffic areas (e.g. unusual events such as sporting event, accident, natural disaster…) has a particular significance to illustrate the concept of dynamic resource management. The goal of this scenario is to underline that a dynamic reconfiguration of the terminal and of network elements improves the bandwidth for the users thanks to better adapted radio interfaces, additional spectrum… In this case, the protocol stack must be updated in the terminal and in the network. The different communication systems covering such areas, which can move, must adapt to the load and services variations. To dynamically face theses changes of traffic and provide fast and cheap cells coverage to the reconfigurable equipment, the network operators would perform a spatial/temporal reconfiguration and/or redeployment of their networks capacities as well as a load balancing, based on different cooperation schemes.

5.2. Reconfigurability Issues Addressed through the Scenario

In summer 2008, the Olympic Marathon run will be held in Beijing. The route may encompass different kinds of areas: urban, sub-urban and rural areas, where a cellular infrastructure will be already deployed. However, this infrastructure is designed to handle classical traffic, corresponding to such areas and is unable to cope with the supplementary traffic generated by the marathon's followers. Moreover, this additional traffic is going to follow the run, e.g. requiring sporadic (in time) additional capacity on a given location. Such variation in traffic demand in space and time could be called “Dynamic cells”.

The reconfigurable networks equipments detect on their own the change in the traffic conditions, as well as the alternate radio access technology they could cooperate with on the same coverage. With the current network configuration the operator is not able to serve all the users. This does not necessarily means that the operator is not able to provide the service at all, but rather that the level of service does not match the one that may have been agreed, in a Service Level Agreement (SLA), between the operator and the user. So, in order to comply with the SLA, the network starts a reconfiguration process in the network infrastructure covering that area. As a result, the network has several possibilities:

- To reconfigure itself for tackling efficiently the incoming traffic demand by assigning more processing or spectrum resources in the base stations to certain radio technologies (such as 3G/HSDPA) which offer more bandwidth for data services, and therefore reducing the resources allocated to other technologies (such as GSM),
- To balance a part of its traffic into a cooperating network operator and/or radio technology (e.g. to use WLAN coverage when available, or balance traffic over GSM/EDGE/UMTS depending of the requested service),
- To ask for additional spectrum for tackling the traffic demand. The operator could rent some spectrum blocks offered by other operators which have free portions of spectrum according to Regulators rules.

In any of the previous cases, it may be necessary for the E2R equipment to reconfigure in order to adapt to the new radio technology or to the new network configuration. For instance, a GSM terminal should download the EDGE protocol stack before the network decides to switch from GSM to EDGE. In that case, the reconfiguration procedures encompass the radio access layer stacks. Reconfiguration could also be imagined in the core network to efficiently absorb the additional capacity brought by the enhancement of the radio interface.

While the run is on-going, thousands of spectators are waiting for the first runner to enter the Olympic Stadium. Some spectators may still be accessing the stadium. One of the possible ways in which they obtained their tickets could have been through their mobile phones. In this case they do not need a physical ticket to access the stadium; the information needed to gain access is already stored in the terminal. When the spectator gets near the entrance gate, a

communication is established between the terminal and the gate (through some short-range wireless technology such as Bluetooth), which checks if the terminal has a valid ticket stored.
In addition to DVB coverage (this again may require that some E2R equipments download the necessary software to be able to receive DVB), the stadium has been covered by WLAN type of connectivity which could be used to get side information not included in the DVB flow. For instance, people could choose to follow the situation of their favourite runner. People whose terminals do not have this capability could decide to download the appropriate pieces of software to enable the combination of information delivered from various radio access technologies. In this case, two radio links are opened: DVB and WLAN.
When the leading group of runner enters the stadium, a sudden lack of capacity is appearing. Indeed, in addition to the journalist fleet (still making real time video and comments), the thousands of people in the stadium are starting to share the end of the run with their family by either sending SMS, MMS, videos thanks to their video/camera equipments or by instant messaging means (push-to-talk, push-to-view). All the legacy wireless systems are fully loaded; the only way to get additional capacity is to get additional spectrum allocation. For that purpose, the Regulator is contacted (or any entity representing the regulator). It identifies free pieces in the spectrum (part of band, potentially after spectrum de-fragmentation). Once notified, operators and users begin to use the new allocated spectrum.

5.3. Public safety

Public Safety scenarios are another special but very important case that can be viewed as containing many elements in common with the Dynamic Resource Provisioning scenario described above. In case of an emergency or natural disaster all the public safety agencies will be able to perform their work more efficiently if it is possible for them to communicate seamlessly. Also it must be guaranteed that both citizens and public safety units have access to the necessary resources, so emergency services can be accessed and network congestion is avoided. These two features can be achieved using the same mechanisms described above, such as terminal and network reconfiguration or dynamic spectrum allocation. Besides, Public Safety operatives need also to use a number of different technologies in order to access their own information databases and potentially roaming to different technologies and networks not owned by the individual agencies. Thus there are key aspects that align them also with both Pervasive Services and Ubiquitous Access Scenario categories.

5.4. Potential Techniques – Reconfiguration Mechanisms

The techniques related to this high level medium-long term scenario could be summarized as follows:
- Dynamic Spectrum Allocation (DSA): spectrum sharing, spectrum trading, spectrum refarming,
- Systems monitoring,
- Self-tuning networks,
- Joint resource management, including load Balancing, complementing coverages (in space, time, technology),
- (Mass) software download.

6. CONCLUSION

The three families of scenarios derived in this paper represent a significant step forward in terms of identifying where reconfigurability can play a major role in the delivery of services to the user and also in the optimisation of the network resources to achieve the best results.
In addition, this analysis has highlighted potential new actors in the Communications Business Model such as the software provider and also raises the issue to identify a common method to download the software over an E²R reconfigurable device. An over-the-air approach, totally transparent to the user, could require a pilot channel available on a selected group of frequencies common in all the countries of the world. Otherwise, a kiosk model may be possible where software downloads can be obtained from a kiosk e.g. at airports, train stations… A mixed approach could be identified such as: a smart card or the terminal itself has in the memory several standards and the activation can be generated via network input or via auto detection. On the other hand, instead of download a whole new radio interface, the network operator or the user can simply upgrade the current radio interface in order to fix a bug or implement better algorithms in order to improve the network capacity. In some devices, it is not possible to reconfigure the lower layers, however new algorithms to improve the higher layers (cell selection...) can be downloaded. It is the network operator responsibility to choose a mass software upgrade or simply to notify the users who can choose to download these new functionalities or not.

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