The WSI[1] Reference Model for the Wireless World

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ABSTRACT

A reference model for the Wireless World is proposed. The model is composed of communication elements consisting of four basic building blocks and reference points between building blocks and communication elements. The Work of WSI on the model should be regarded as a starting point. Issues where further thought and work are still required are also described.
This reference model proposal has also been contributed to the Wireless World Research Forum (WWRF, http://www.wireless-world-research.org/), the global forum to develop and maintain a harmonised vision of the Wireless World. WWRF is an outcome of earlier WSI activities.

I. INTRODUCTION

The definition and development of complex systems requires structuring of different kinds, static system block structure, dynamic transaction behaviour, project organisation, and so on. Dividing such systems into different modules, which might be constructed of modules themselves is an approach often used. Such an approach allows the definition of reference points or interfaces between such blocks.
A mistake sometimes made in the past was to take reference models as "build plans" or system designs. This resulted in unwanted inefficiencies and distortions in products. As an example, the OSI layered model is probably the most important structuring scheme used in communication engineering, but only rare products are direct implementations of this model.
The Wireless Strategic Initiative proposes a structuring scheme for wireless communication, which is expected to be able to support the definition of complex mobile communication concepts and the structuring of the research work on the Wireless World.

A. The starting point

The Wireless Strategic Initiative developed a vision of the Wireless World by thorough assessments of usage scenarios. Their potential benefits for the end-user were evaluated and requirements on the network infrastructure were identified.
Based on these analyses a vision was developed, which reflects the key characteristics of the envisaged communication scenarios.
The main aspects of the vision are the recognition of an increased diversification of communication partners and the possibility to logically group them into spheres representing the relation of the communication partner to the end-user [2]. A graphical presentation of the sphere model is presented in Figure 1.

Figure 1: The WSI sphere model

B. From the vision of the wireless world to a reference model

The vision was used to derive a reference model supporting the definition and design of the wireless world infrastructure. The WW infrastructure in turn is supposed to realize the envisaged service scenarios. The services and communication scenarios as well as their characteristics are thus the input parameters, which determine the structure of the reference model.
The most influencing aspects derived from the WSI sphere model are:

- Increased number of devices interconnected and participating in the wireless world.
- Multiple, diverse access technologies.

[1] Wireless Strategic Initiative: IST Project Number 1999 - 12300

- Recursive structures of communication paths (connections routed via relay devices mainly situated in the spheres “Immediate Environment” and “Instant Partners”).
- Omni-present interconnectivity plane.
- Ubiquitous access to services.
- Gathering, transportation and utilization of ambient information for service personalization and adaptation.

In the following sections we present the reference model, as an outcome of the considerations on above-mentioned key aspects of the WW communication scenario.

II. THE REFERENCE MODEL

A. Design goals and Purpose

The specification of a reference model has been used as the means to structure the design and the work towards the specification of the targeted system, i.e. a future generation mobile system. This model does not make any technology choices nor restricts any implementation decision, but aims to guide research and development such that the envisaged system characteristics can become realized.

B. The basic element of the reference model

The vision of the wireless world is partly based on the assumption that the number of interconnected devices will increase and their characteristics and appearance will become more diverse than today. Still, it is assumed that all these devices can be described by a common structure. This structure, representing the physical devices, is the common denominator and is referred to as a Communication Element (CE), see Figure 2.

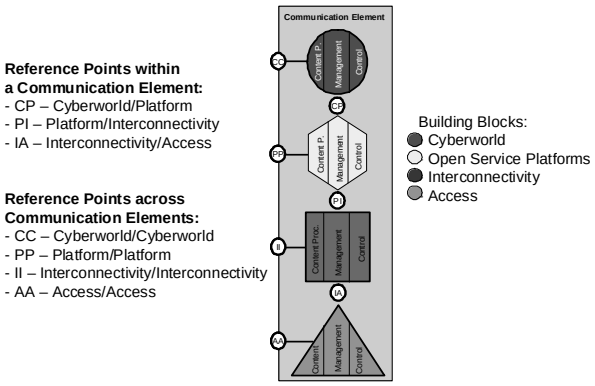

Figure 2: The Wireless World Communication Element and its Building Blocks

The functionalities integrated in the communication element are provided by different building blocks. Basic assumption is that the reference model should separate *Content processing*, *Control*, and *Management* functions into their own end-to-end planes and subsystems. The architecture specification does not allow a mixed use of these three functions. To facilitate this, the subdivision into these three functions is mirrored in all four building blocks of the communication element. The various functions include:

Content Processing Functions. They are dealing with the processing, transformation, adaptation and end-to-end delivery of application data.

Management Functions include those functions responsible for both horizontal and vertical communication management. The horizontal management takes care of functions inside one certain block of the communication element, while the vertical management coordinates the cooperation between the different building blocks.

Control Functions handle all signalling which is associated to the Content Processing Functions. They take care of negotiation and agreement of QoS parameters and need to span all building blocks in order to provide true end-to-end QoS for end users.

A wireless world communication element consists of 4 basic Building Blocks (as depicted in Figure 2):

- **Cyberworld** hosts all application-specific functionality. It relies on a generic service infrastructure provided by the “Open Service Platforms” and exploits these platforms to implement applications and services. Cyberworld implementations have to possess means to generically describe and explain their characteristics and requirements to ensure that the underlying infrastructure is used efficiently and the services are provided to the user’s satisfaction.
- **Open Service Platforms** is responsible for providing a flexible and generic service infrastructure to the CyberWorld. Implementations of this platform facilitate the creation of new services according to both user’s and operator’s needs. The restrictions imposed on the service creator have to be reduced to a minimum. This implies the use and provision of reusable generic service functions.
- **Interconnectivity** may also be referred to as the Networking part of the Wireless World reference model. The functions located in this building block take care of the logical links between CEs located within different spheres. Interconnectivity functions also maintain and manage these links even in cases when they are subject to change of network topologies or to changing access networks.
- **Access** implements all aspects of the physical connection(s) between different CEs. This includes radio or other types of physical connections. Due to the hierarchical structure of the reference model, a connection between two higher spheres could use multiple connections in underlying spheres, relying on the connection services provided by the “Interconnectivity” functional block.

C. Spheres

The aforementioned CEs (see Figure 2) define a common structure of all elements forming the WW. However, the physical appearance of a CE can be very different

depending on the type of sphere it (logically) belongs to. Elements of the personal or local sphere, corresponding to the spheres "Immediate Environment" and "Instant Partners" of the original sphere model (see Figure 1), may be single devices while CEs of the global sphere may represent complete networks or access systems.
For the latter case the recursive nature of a CE becomes important. A Communication Element may comprise a whole structure of interconnected CEs, i.e. complete networks. This makes it possible to specify networks or sub-networks in the same way as the complete wireless world infrastructure. The CE thereby represents the complete network and the actual details of the network structure and capabilities may be encapsulated and hidden in the CE description.

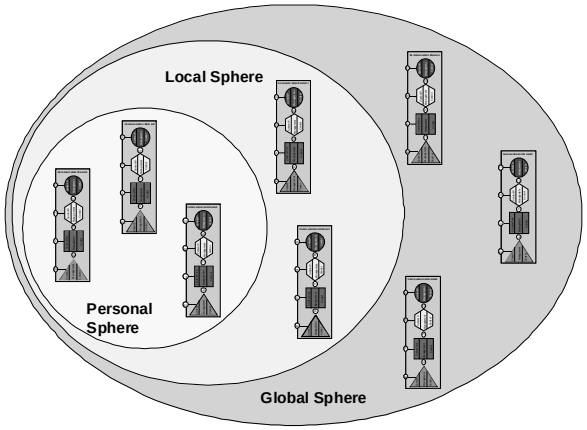

Figure 3: Logical grouping of Communication Elements according to communication spheres

D. The Building Blocks

A CE comprises a maximum of four building blocks, which structure it according to functional layers ranging from the physical connection means, providing the basis for connectivity, up to the level of services and applications. A Building Block relies on the presence of a Building Block located logically below it. A CE though does not need to include all four Building Blocks.
The four Building Blocks are described below in more detail:

Cyberworld

Today, the World Wide Web is chaotic. So much unstructured data exists that most people have hard time finding information relevant to the situation at hand. This problem is particularly acute for mobile users, who increasingly want to access web services while on the move. At the same time media are increasingly going digital, and more and more material is being made available every day. Digital imaging, desktop video, loop-based music software and web diaries are examples where both professionals and amateurs are producing content with computer-based tools.
The current non-mobile web offers little help for mobile contexts. The mobile user faces another kind of chaos in the form of information overload. As positioning systems and short-range communications are becoming commonplace, mobile terminals will be flooded with increasing amounts of on-the-spot information. Despite the added local aspect, there will be abundant data available, but relevant information will still be hard to find.
The aim of the wireless world will be to make the relevant information available to people in their daily lives. Considering the numerous possible contexts (not just location), it becomes evident that common descriptions for context information are needed. Similarly, mechanisms for managing and handling dynamic context information within the semantic web and devices on the move are also required. New kinds of mobile services based on virtualization of presence and digital augmented ambient environment are supported via advanced mechanisms of presence, identity and interaction.

Open Service Platforms

The introduction of new services, and convergence between networks, will create a highly diversified value network with new roles and key players (e.g. content providers, application providers, portal providers, mobile virtual network operators, etc.) in the area of network and service provisioning. Flexibility, in terms of supported business models, will reduce the time to market for new services. Standard open interfaces on top of generic service functions will foster the deployment of such service delivery chains.
Despite the underlying network complexity and heterogeneity, the service delivery will be, from the user perspective, simple, uniform and seamless. Advanced techniques for delivering mobility, service continuity, end-to-end security and QoS have to be provided.
The introduction, provision and management of numerous, probably highly complex services will be associated with factorization of key information, such as user knowledge and context awareness. A set of advanced key features, such as profiling, contextual information delivery, filtering, billing, user privacy guarantee, etc. will be provided by the Open Service Platforms.

Interconnectivity

The WW will offer seamless integration of all means of access as well as far reaching scalable support for the user's communication and information needs. A unified control space will make these resources usable and conveniently accessible. The Interconnectivity block is defined to support all capabilities of flexibly attaching and detaching terminal networks (e.g. PANs or BANs). Similarly, Interconnectivity provides support for the Open Service Platforms and assists those functions by providing generic functions for mobility, connectivity and delivery

(etc.). The functions of Interconnectivity are of particular importance in a mobile wireless world where the users may constantly change their point of access and even the actual network topology might change. New challenges are raised by networks moving within other networks (e.g. BANs/PANs, etc.) and also by reconfigurable co-operative network infrastructures.

Moving Networks within Networks: In future, communication systems will extend into the user domain, featuring both personal area networks (PAN) and privately owned and operated access networks. This will lead to private networks, which move within wider area public networks; such moving networks should be connected in a flexible, simple, secure and rich manner to public short range and wide area networks. Body area networks (BAN), PANs, car networks, and public hotspots, are precursors of this development and will need the capability to seamlessly access visited network infrastructure in a convenient and transparent way for the user.

Reconfigurable, co-operative network infrastructure: The WW assumes an increasingly diversified value chain with new key players and new roles in the area of network and service provision. This new paradigm requires a more flexible, reconfigurable and co-operative network environment. Networks have to provide the required flexibility to support different types of business models, and nodes within networks will need to be reconfigurable, to fully enable co-operation between fix and flexibly attached communication equipment.

To summarise, the "Interconnectivity" block acts as networking part of the Wireless World reference model and its functions take care of the logical linking of Communication Elements within different spheres. Interconnectivity establishes, maintains and manages these links even when the underlying network topologies or attachment to access networks are being changed.

Access

The goal aimed at by all WW-efforts is to facilitate easy, natural and intuitive communication for everybody & everywhere. "Access" will be a key issue in this context, because the future will witness a wide variety of different access technologies, employing a plethora of technical solutions, ranging from intelligent Medium Access Algorithms to Smart Antennas (a comprehensive set of envisaged technologies is described in [5]). The "Access" building block groups all functionality and technologies which are directly related to the transmission of content (data) via a physical medium, thereby paying respect to the wide range of requirements imposed by users, operators, services and the environment (incl. governmental regulation). To support the "multi-access-vision", special emphasis will have to be put on structures supporting the interworking of multiple access technologies. The "Access" block will have to provide a flexible interface towards "Interconnectivity" to facilitate easy negotiation for physical bearers and their characteristics.

The generic components, which cooperatively form the "Access" Block, and provide its functionalities based on the named goals, are identified as (also see [4]):

"Transceivers & Antennas": Aiming at providing small, and unobtrusive, cost-efficient solutions with a preferably low degree of complexity and low energy consumption while being reconfigurable and adaptive to a maximum extent.

"Transmission Schemes": Tailored to the scenarios in different spheres, but compatible to reduce development efforts. They further need to be inherently spectrum-efficient, support coexistence with other transmission schemes and provide high transmission quality.

"Medium Access": Strategies and related protocols, which aim at optimising the exploitation of the physical medium, and energy efficiency. They need to be QoS-aware and support the vision of ubiquitous medium availability.

E. Reference Points

The Building Blocks, which form CEs are connected by Reference Points. The early identification and specification of these reference points will enable more flexible communication systems than we will have with 3G systems. There are "vertical" and "horizontal" reference points. The vertical reference points are the interfaces between the building blocks of the communication elements. A connection can also take place between communication elements, which reside in different spheres using "horizontal" reference points.

The reference points between the building blocks are crucial elements for the precise technological description of the model. The functionalities which the different blocks have to provide at these reference points will have to be well-defined, complete, and generic, in order to assure the proper functioning of the model and to allow treating the building blocks as "Black Boxes" from the viewpoint of the adjacent blocks

The reference points represent well-specified points of contacts between the building blocks. This specification will cover so called "generic vertical functions" that have to be provided by all reference points to ensure a proper functioning of basic services of the wireless world. Vertical functions provide certain functionality through all the building blocks by addressing the dedicated problems and technologies of each building block. At the moment, the WSI project has identified nine different functions (see Figure 4) that have to be provided.

Note that the list of vertical issues is not claimed to be complete, since totally new services, probably unknown as of today, may raise totally new "vertical issues".

The service architectures for the Wireless World will have to cope with things like numerous service providers, always connected users, automatic service adaptation, context awareness and new IP devices. Aspects like dynamic service discovery and service provisioning in (for users) unknown environments and the personalised services usage require new mechanisms.

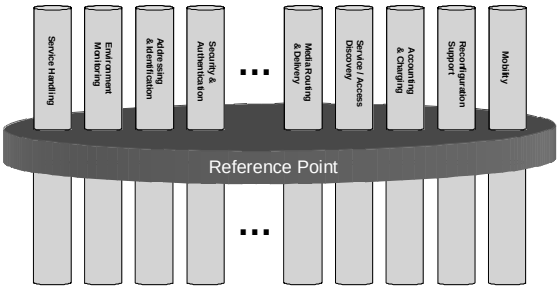

Figure 4: Generic Functions supported through the reference points

The generic functions will enable providers to make their products and services available in a flexible way. The same will make it possible for users to discover and use the desired service. Assembly and configuration of contexts composed of various service offers is needed to achieve the requirements stated explicitly or implicitly by the user.
The detailed definition of the reference points will be the work of future standardisation activities. Before such work can start, however, the principles of how communication works at reference points and how such communication is to be specified must be defined.
Definitions and assumptions made on reference points include:

- Communication among building blocks is established dynamically, i.e., in the normal case there are no pre-established configurations.
- Communication across reference points is asynchronous and uses messages exclusively.
- Function distribution among building blocks follows the principles of minimising message traffic and delay
- The first message to requesting a service and starting a new transaction normally carries no destination, but the destination is determined by a selector function included in each building block's control function. Further messages needed to conclude the transaction are directed to particular instances in the system.
- Communication across reference points is capable of supporting several protocols without requiring knowledge about the protocol's specifics.

III. BACKGROUND

The WSI project started in May 2000 as a joint activity of 4 large wireless equipment manufacturers (Alcatel, Ericsson, Nokia and Siemens) with the main objective to develop visions of the Wireless World (WW), a term given to the wireless communication systems that may follow third generation systems and that would become operational after 2012. The project decided to make the process to develop visions totally open and to invite everybody who wanted to contribute. The open approach resulted in a major success and the creation of the WWRF in 2001.
It became quickly apparent that structuring principles were needed to maintain momentum in the work of the forum and its working groups. It was therefore decided to devote the last year of the WSI project to the definition of a reference model, i.e. a structural framework for the definition and research on the Wireless World.
This paper describes the reference model and explains the background leading to its current structure.

IV. CONCLUSIONS

The paper describes an attempt at constructing a useful reference model for the Wireless World. The work is well advanced and based on a good understanding of the requirements and of the working of future communication systems.
There is, however, considerable research work remaining to be undertaken that exceeds the boundaries of this limited study. In addition to the static view presented here, the dynamic behaviour of the model needs to be addressed in more detail. Some further issues for future work include:

- A formal description of the semantics of the Reference Points
- A methodology to define communications via the Reference Points
- Definition of master-slave relationship between the building blocks of the model
- Dynamic representations of major transactions

V. ACKNOWLEDGEMENTS

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