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Design of a generic Protocol Stack for an Adaptive Terminal*

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Abstract — **The denotation *Software (Defined) Radio* (SDR) [1] comprises a multi-band radio capable of supporting multiple air interfaces and protocols [...] [2]. Unfortunately, most contributions to SDR focus on the radio aspects of different mobile communication systems and concentrate on finding respective solutions to be integrated in the SDR concept. However, one should not forget that systems do not only differ in the way of transmission, but also in the protocol stacks that come into operation. Therefore, the following paper will concentrate on the upper layers[1] of mobile communication systems. In this paper, a generic protocol stack that comprises the main characteristics of miscellaneous mobile radio systems will be introduced. This stack subsequently shall form the kernel of a so called *Adaptive Terminal* (AdapTer), a handset that is able to operate within different radio systems.**

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I. INTRODUCTION

Presently mobile communication systems of the third generation (3G) are under development and will be introduced into the market in the next few years. They will provide new services especially in the field of mobile data transfer which becomes more and more important due to the Internet. But the radio coverage of the third generation systems will not reach the quality of the established systems of the second generation in the first years. Hence, the customer who wants to maintain his mobility and make use of the new services has to obtain access to both systems. In order to maintain the same comfort to the customer there is a need of a mobile terminal which is able to provide the systems of both generations.

Next to the mobile communication systems the wired communication systems will still exist. They provide high accessibility, high data rates and low prices for communication. To combine the advantages of the mobile and wired communication systems without changing the hardware equipment the DECT-System (Digital Enhanced Cordless Telecommunication) should be integrated into an Adaptive Terminal next to the mobile communication systems UMTS as system of the third generation and GSM.

For the implementation a software solution was chosen which should contain a small and flexible protocol stack usable by all incorporated systems. To obtain this generic protocol stack the systems had to be investigated for possible analogies to be implemented as shared resources. Another advantage of a software protocol is the possibility of an easy extension of the existing protocols or the introduction of new services in a flexible manner.

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[1] referring to the ISO/OSI model

II. The Protocol Stack for an Adaptive Terminal

The Adaptive Terminal should be able to communicate with base stations, which are either DECT, GSM or UMTS compatible (Additional systems to be incorporated in this approach are thinkable). Different solutions are possible to fulfill this task. The easiest solution is to build three independent protocol stacks, which is rather inefficient as the three systems have some common parts. The second solution, which is presented in the paper, is based on the common parts of UMTS, DECT and GSM and results in the notion of the Adaptive Terminal. The Adaptive Terminal shares as much resources as possible. In the best case this would lead to one single protocol stack usable for all the three systems as shown in Figure 1.

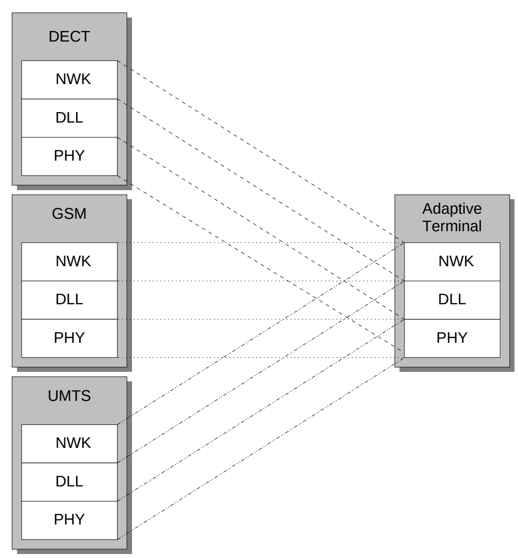

Figure 1: Protocol stack for an adaptive terminal in best case

However, since the three systems are too different another approach was chosen, where a stack-skeleton was built, which contains the common parts of the systems. This stack is adapted by the stack of each system and expanded with system specific functions. Therefore the different systems had been investigated layer by layer since the layered ISO/OSI model [12] is the basic common structural composition.

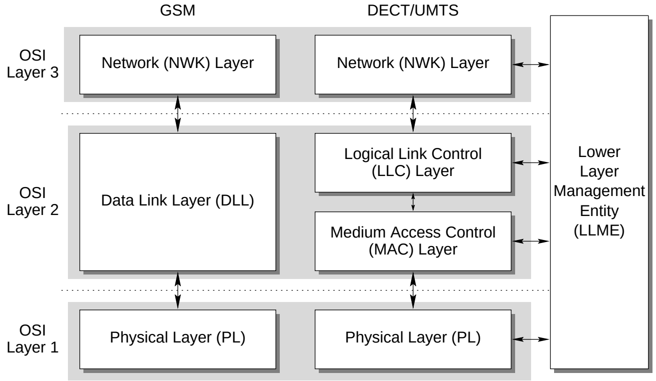

Figure 2: The layered structure of the mobile communication systems GSM (left) and DECT/UMTS (right)

Figure 2 pictures the respective layers more detailed than Figure 1, such it represents a kind of close-up. From this point of view the respective systems turn up first differences in their architecture. Although all systems are derived from the same model some differences already appear at this place. One reason for this differences might be the different age of the ISO/OSI reference model and GSM on the one hand and DECT and UMTS on the other hand. Progress has taken place in the newer systems like DECT and UMTS. Figure 2 shows that the newer mobile communication systems have split the Data Link Layer (DLL) into two layers, the Logical Link Control (LLC) and the Medium Access Control (MAC) layer. Another reason is that the ISO/OSI layer model was developed for communication systems with wired connections, while a mobile communication system has to deal with the mobility of its users. The much more sophisticated access to the medium led to the introduction of a new sublayer, which is called Medium Access Control layer. Beside the MAC, the Lower Layer Management Entity (LLME) has been introduced. The LLME has only administrative functions and allows communication between layers which are not adjacent. As the LLME does not exchange messages with a peer entity it is almost free in its implementation.

Nevertheless, certain similarities can obviously be discovered. In the following, especially layer three shall be examined.

Going more into the detail, Figure 3 shows a further close-up of the network layer, whereby referring to the fact that the network layer is only defined for the controlling procedures, only the Control-plane (C-plane) is considered. Here, one can see the structural composition of the respective service entities within the different systems, in this case DECT and GSM. Though the general architecture is slightly different since GSM defines certain sublayers, it is obvious that the same respective entities, e.g. Call Control (CC), Mobility Management (MM) or Message Services (MS), are present in both systems.

Further similarities can be found when examining the dedicated routing functions. Messages reach the network layer by Service Access Points (SAPs) and then are routed to their destinated entity by evaluating appropriate header information of the messages. In GSM, this evaluation is performed by special functions, located in the respective triangles of Figure 3. The same evaluation is done for DECT messages, too. The only difference is, that there is one central entity, the Link Control Entity, LCE, which is responsible for all aspects concerning routing of messages to the respective entities. In the adaptive solution, this principle was overtaken, which means that the spread routing functions of GSM were bunched within one central entity. In such a way, a generic network layer could be realized, which is able to serve routing requests from either system.

One central element of the network layer is the Call Control (CC) Entity. From a more abstract point of view, it can be described as a communicating finite state machine which exchanges messages across the radio interface and communicates internally with other protocol (sub)layers or entities. Each step in the establishment, maintenance or release of a call thereby can be represented by a well defined state. The transitions are only specified by incoming or outgoing trigger signals. Comparing the individual states of the different mobile communication systems opens a high conformity of these states as they are all derived from the Digital Subscriber Signaling System No. 1 (DSS1), which is described in the ITU-T Recommendations Q.930 [13] and Q.931 [14]. The DSS1 specifies the ISDN User-Network interface on layer 3 for basic call control. At the time of writing of this report the UMTS specification [15] is not fully completed yet and the CC entity is completely borrowed from the GSM specification.

Since all CCs are based on the DSS1, the Call Control (CC) entities of DECT, UMTS and GSM can be implemented in a very similar way. For the Adaptive Terminal this means, that the implementation can be performed in the generic part and subsequently only has to be overtaken (with slight changes) in the inherited system-specific parts.

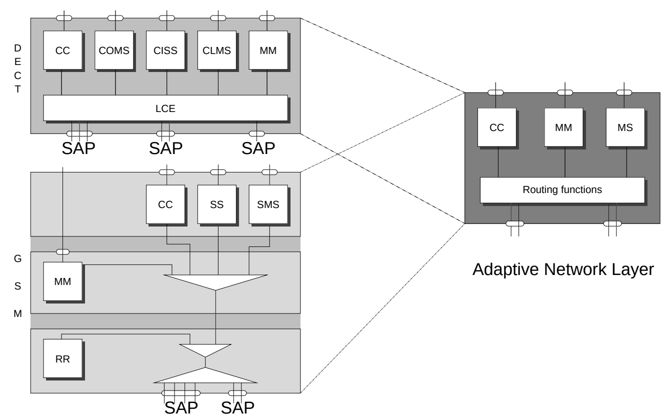

Figure 3: Generic Network Layer

III. IMPLEMENTATION

The implementation of the generic stack-skeleton was performed with the help of SDL (Specification and Description Language)[16][17]. SDL is an object orientated programming language that supports features like inheritance, information hiding and many others. Because of its graphical (besides an equivalent textual) presentation and an easily understood finite state machine basis, SDL became a quasi-standard in the specification of communication protocols. To obtain the portable source code from the SDL specifications , an automatic translation tool, called *SDL2SPEETCL* [18], was designed at ComNets. It takes the prose representation (SDL/PR), generated by the SDT-Analyzer [19] (thus syntactical and semantical errors are excluded), as input and maps the system behaviour to respective SPEETCL (SDL Performance Evaluation Tool Class Library) classes. The SPEETCL is a special C++ class library which was developed at ComNets. For a detailed description of an „Integration of Protocols specified in SDL into an event-driven Simulation Environment“ refer to [20].

The SDL implementation is composed of a hierarchical tree of SDL system types. Figure 4 shows the inheritance hierarchy for all system types (st) used in AdapTer. Each system inherits the members of its base type, redefines some of them and adds new ones. Members of the SDL systems are blocks, processes and procedures, which are connected by channels and signal routes, conveying defined signals. With this structure it is possible to implement all the common parts of a subtree in the top node of the subtree. The stDECT for instance includes all procedures and definitions that are common to the DECT base station unit and to the DECT mobile station unit. Only the specific parts of the base station and the mobile station are defined in the inherited system types stDECTBS and stDECTMS.

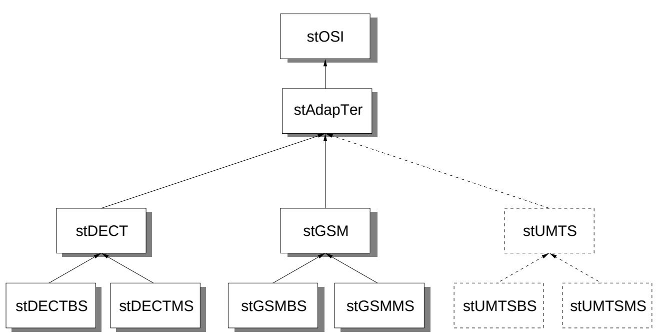

Figure 4: SDL inheritance tree

The advantage of this concept is the flexibility to alter or add some functionality to the whole system or a subtree, just by altering the topmost system type of that subtree. All changes will be automatically incorporated into the lower system types.

IV. TESTBED

In order to verify the implementation and to prove the feasibility of the generic principle, a testbed as shown in Figure 5 is currently under development. The whole project finally results in a demonstrator, whereby call-establishment -maintenance and -release according to the respective standards will be possible. Since this paper focuses on adaptivity of the upper layers, no explicit channel model is integrated. For each system (mobile and base station) one personal computer running under Linux is used. The communication between mobile and base station is accomplished over a simple TCP/IP connection. Such the air-interface is modeled in a black box. Thereby it is possible to simulate the random loss of messages/signals in order to test the correct system behaviour, e.g. the time out routines of the upper layers of the implementation.

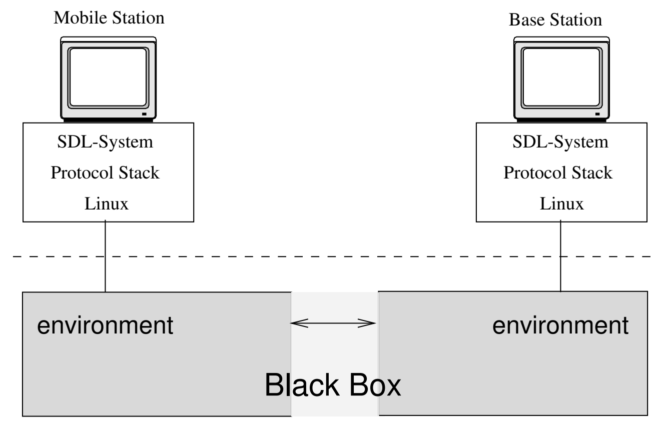

Figure 5: Testbed Architecture

Going back to the beginning of this paper, it was mentioned that most of the contributions to SDR focus on the radio aspects. Thus, they concentrate on the contents of the aforementioned black box. This paper is part of a project cooperation, whose aim is a merging of the results of software radio research of both, upper (this paper) and lower (black box) layers. For this purpose, a special interface to/from the black box was defined. Thus it is possible to incorporate adaptive layer 1 solutions in this research.

V. CONCLUSION

The Adaptive Terminal could be able to fill the hole in the development of software radio, which exists between the applications and the physical layer. Research in this area is concentrated on reconfigurable handsets and the ability of offering new services by means of downloading additional features (as the system specific functions in this example). AdapTer follows this idea in such a way, that the generic kernel provides basic features, and the system-specific attributes are simply added. This is how AdapTer can fulfill the task of network mobility.

VI. ACKNOWLEDGEMENT

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