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OBJECT-ORIENTED MODEL OF SDR LIBRARY FOR WIMAX/UMTS SYSTEM BASEBAND LEVEL

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ABSTRACT

Emerging standards in the area of mobile services, such as Worldwide Interoperability for Microwave Access (WiMAX) and Universal Mobile Telecommunication System (UMTS), require new capabilities from mobile devices. As a result, these devices should be aware of how to download and correctly install particular software. For this purpose, the Software Defined Radio (SDR) technology is used at present. SDR allows the co-existence of different independent standards, protocols, and services. This signal processing approach is broadly spreading because of the reprogramming and reconfiguring of mobile devices is of great importance. Due to the availability of SDR in the device architecture, a user can update and replace necessary services without changing the hardware. In this paper the object-oriented framework of model for SDR implementation are presented. The main accent was made on possibility to co-exist two types of standards and to describe it by high-level language software, which allows to simulate the complex systems. The base construction of proposed model was built. Furthermore this model shows that the SDR technique can be acceptable for the co-existence of WiMAX and UMTS structure independently from the physical layer.

I. INTRODUCTION

Most part of current research works in the wireless communication technologies focuses on providing many varied services and maintaining high bit rate [1]. The possibility to be reachable in any place and at anytime has also become much demanded. That is why the greatest companies try to find possible solutions to satisfy these requirements. To this end, there is a need to devise the structure which will be able to support the possibility to retune mobile terminals according to the signal reception [2]. Existing approaches assume that a user should purchase a detached device for each standard, because most of them have their own specification of frequencies range, types of modulation, coding scheme, and access to the environment. Therefore, the mobile operator has to provide support for all wireless systems separately. To resolve this problem, the Software Defined Radio (SDR) technology comes in handy [3].

Software Defined Radio is one of possibilities to realize the structure of device with a high mobility, flexibility, and reconfigurability [4]. This technology can provide the seamless shifting between existed air-interface standards. The base definition of SDR can be depicted as followings: SDR is a software system which can accomplish the connection between different hardware units, arranged in a radio node, and can govern the whole process by using software functions. This kind of control allows to widen perspectives of SDR systems development like a main part of mobile devices. Moreover, the chance to handle the system, which consisted of different radio-

functional units, by applying software commands only, can play the key role for the reconfiguration and reprogramming [5].

In the mobile communication area, many 2G standards such as Interim Standard 54 (IS-54), and IS-136, IS-95, Global System Mobile Communication (GSM) and Personal Digital Cellular (PDC) are widely used. At the same time the 3G standards such as: International Mobile Telecommunication-2000 (IMT-2000), CDMA2000 and Universal Mobile telecommunication System (UMTS) [6] increase the spreading everywhere in the world. Although mobile communication systems are improved its parameters of data transmission, e.g. the bit rate reaches up to 2 Mbps and the real-video format can be transmitted, the wireless systems such as various specifications of IEEE 802.11, Bluetooth and emerging specifications of IEEE 802.16 have become popular [7].

The present technologies oblige the user to buy a particular device for each type of communication standard, and the operators to prepare the base station for each system since they have its own parameters. However, the current needs are to have the chance to seamlessly hand the user equipment from one cellular standard to another one or from the cellular network to hotspot. In this case the emerging multi-standards, multi-bands, multi-modes [8], and multi-protocols systems have developed. The capability of the integration as much as possible diverse services into single terminals is extended. Therefore, SDR technique can serve as a base technology. SDR allows to make the reconfiguration and reprogramming of the system by using only software commands. These commands help to build the required architecture of the transceiver. Thus, SDR is the mechanism supporting rebuilding of the system according to the request. The work of SDR includes adaptability of the hardware by the software, downloading of the necessary software from the network and installation. All these steps do not require any skills and efforts from the user side.

The usage of new standards, such as WiMAX (IEEE 802.16e-2005) [9] for providing fast Internet connection with transmission of large data files, and UMTS in telephony family, are spreading everywhere [10]. Thereby examination of the possibility to realize at least two standards over one common element base, which will be handled and rebuilt by SDR [11], are become actual.

In our work, we propose a novel approach to handling the signal processing for two standards, more specifically, WiMAX and UMTS. The structural level of our development includes the baseband level of the transceiver architecture. We present the framework of SDR module which will be able to arrange the digital processing module. The framework representation will be realised in high-level language software as SystemC. In this paper we are going to describe the main principle of object-oriented model for baseband level of multi-standard system includes WiMAX and UMTS. The framework model of our structure will be defined. The general structure will be constructed by a number of modules for each particular component of UMTS and WiMAX signal processing chain, and also the modules for common units. The top-priority task was to show how the system works. The system can recognize the type of signal and select the exact way of its processing according to modulation type, code scheme and frequency range.

The rest of the paper is structured as follows. Section II describes realization probability of SDR technique with WiMAX/UMTS system. Section III sketches general object-oriented model for the SystemC modelling. Then, Section IV presents

the preliminary results obtained to the moment in context of software simulations. Finally, the conclusions and directions of the future work are drawn in Section V.

II. SDR FOR WiMAX /UMTS SYSTEM

The range of variable services in telecommunication is rapidly extended. Some can provide transmission of voice and short message services, and another ones handle high data rate transmission of real-time video and vast range of Internet services. The emerging standards of personal communication require a new capability of user equipment (UE). UE must satisfy different types of modulation, code schemes, and access to environment. Also UE has to retune frequency band, because in many cases different standards work on its own passband both for uplink signal and for downlink signal. And there is no overlap of frequency bands. Our choice of air-interface is based on WiMAX and UMTS standards.

WiMAX is the current broadband wireless connection for MAN, also concerned as IEEE 802.16 with specifications [12]. Accordingly the network organization requires less time to be built. The networks, realized on WiMAX base, present more flexible and simplest scaled structures. This new technology is aimed to realise followings:

- provide wideband access in that case when we can not apply DSL connection;
- like as variant for decision of Last mile problem;
- create connection for the large quantity of users at the same time;
- transmit audio-, video- and multimedia format files with a high bit rate, up to 75 Mbps;
- provide access “anywhere” and “anytime”;
- non-line-of-sight capability;
- roaming for mobile users;
- provide broadband wireless access for huge quantity of user for short time period (for example internet access during the conference in hotel).

The specification 802.16a and 802.16e are perspective directions for development of urban and rural area networks, especially in that case, when the signal has a lot of distortions and interferences during its propagation. One of the most important advantages is the supporting of non-line-of-sight that occurs since reducing of the frequency band below 11 GHz and using the Orthogonal Frequency Division Multiplexing (OFDM) or Orthogonal Frequency Division Multiplexing Access (OFDMA). This type of signal processing structure for baseband level is determined as the multi-carrier transmission technique and perfectly suitable for uplink and downlink transmissions. The main idea of using OFDM technique is the transmission of multiple carriers in parallel. The problem of interference can be avoided by the use of Fast Fourier Transform (FFT) [13].

Then for our work the general parameters of physical layer are critical. We have to be precise with regard to describing of all possible variation of the bit sequence transformation for each block of transceiver chain. The block diagram of baseband level for WiMAX transceiver is depicted in Fig. 1.

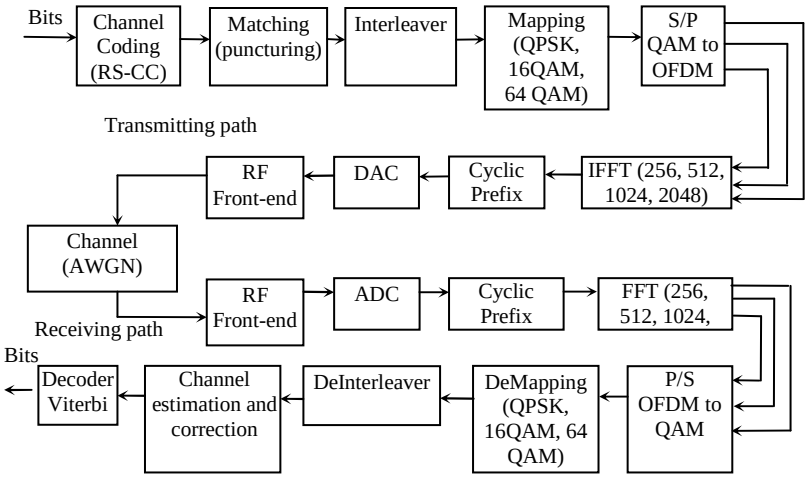

Fig. 1. The block scheme of WiMAX signal transmission from OFDM based transmitter to receiver.

In the filed of cellular mobile connection the stride was made, when the possibility to transmit real-time video is realized. UMTS is one of the third generation cellular technologies, which can support this service, and also number of other services such as voice call, video/audio broadcasting, mobile TV, web browsing, mobile office, services based on user location, maps and guidebooks, GPS, mobile e-commerce and payment of tickets. The general chain of UMTS signal at the sending and receiving directions is presented in Fig. 2.

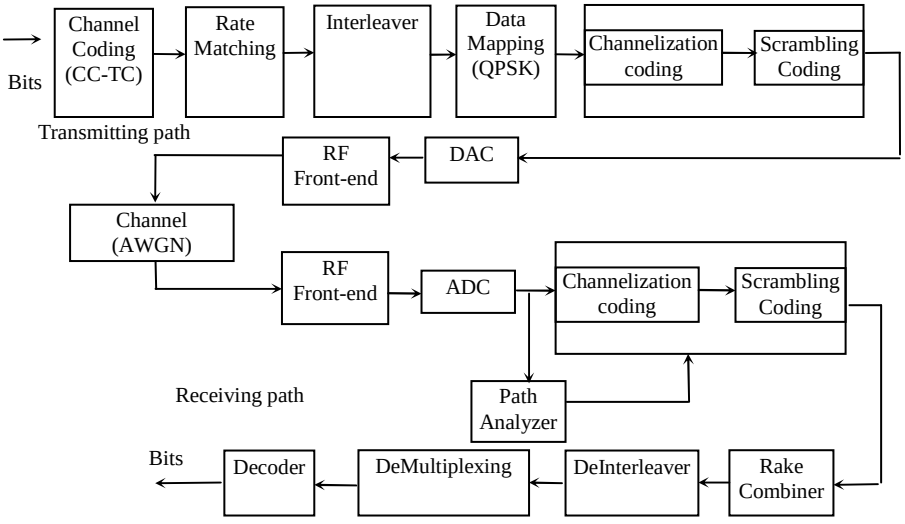

Fig. 2. . The block scheme of UMTS signal transmission from WCDMA based transmitter and receiver.

The wide range of applications can be achieved as result of adaptation the WCDMA (Wide-band Code Division Multiplexing) technology, which also supports the multi-user finding. The possibility of working with variable number of user leads to Inter-Symbol and Intra-Symbol Interferences. The reducing of channel intercrossing occurs at the expense of direct sequence spread spectrum mechanism, which implemented over 5 MHz band per carrier in UMTS case. Owing to the signal spreading by pseudo-noise sequence, each user is separated from another one by its own unique code. At the same time this method does not influence at data rate transmission. Moreover the high bit rate (960 kbps for uplink direction) can be achieved by the combination of the changeable spreading gain technique with fixed chip rate (3.84 Mcps). The high downlink rate can be obtained since using of QPSK and turbo coding. WCDMA technology is also predetermined for the multiple accesses for the same frequency band simultaneously.

Due to appearing of the new generation for the wireless connection such as WiMAX, which provides huge data transmission, and widening of phone capability, the co-existence both of them in the same device has become the stat-of-the-art direction in telecommunication area.

For realisation of seamless switching between different types of access environment the SDR technique is most suitable. This technology provides flexible system retuning. SDR method has known as the way of reconfiguration and reprogramming of platform, since the execution of control and handle software functions.

This technology allows running of different software modules, which located on generic hardware platform, for example DSP or FPGA. This hardware platform responds to radio function performances, arranged by integrated SDR module and can be implemented as the storage of components corresponding to software functions.

In order to achieve better performances for WiMAX as well as for UMTS, we propose the new design of the baseband physical layer for mobile devices based on commanding by the SDR control module. The block scheme of PHY for the signal processing is depicted on Fig. 3.

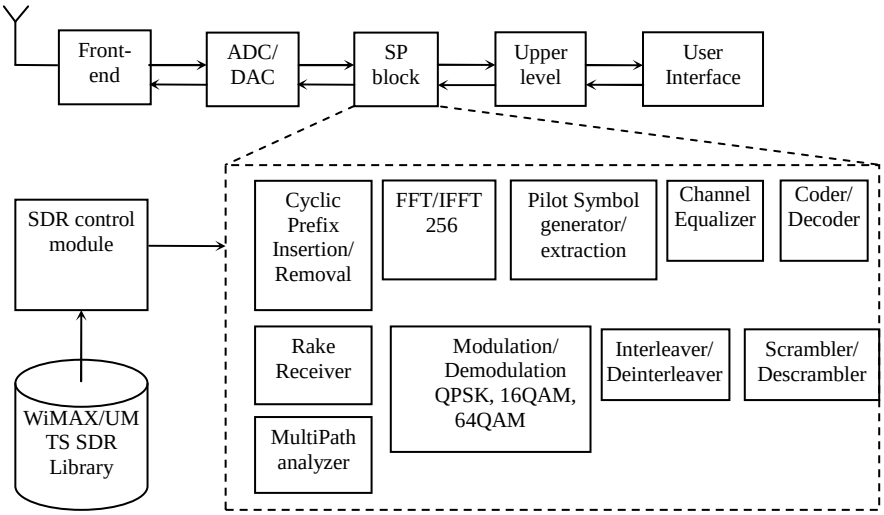

Fig. 3. The main block scheme for the transceiver based on SDR modules in the baseband level.

There are different schemes of the signal processing for WiMAX and UMTS at the baseband level. And we will apply the SDR technology reconfiguring and reprogramming the signal processing block. The special chains of processed blocks are built by the SDR modules which are included in the WiMAX/UMTS SDR library. Then, the SDR library is loaded into digital processing block. The main principle of the work of the SDR modules and the SDR library is illustrated in Fig. 4.

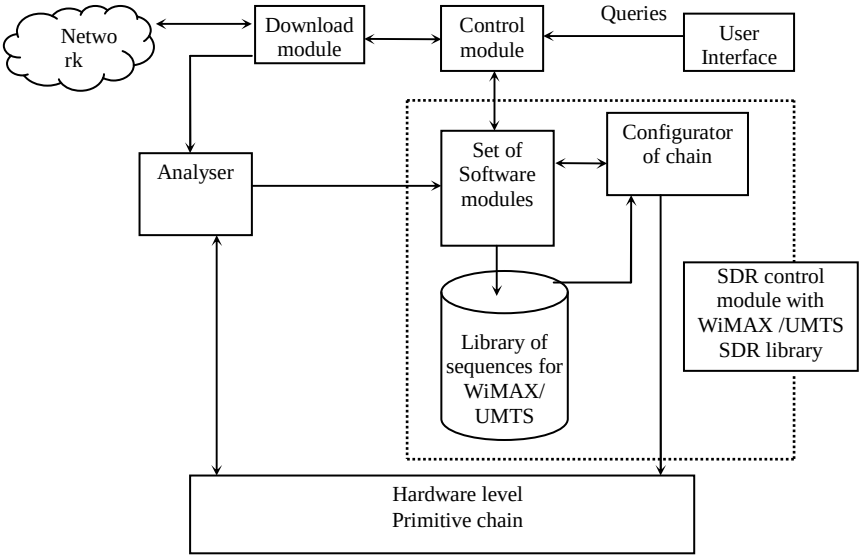

Fig. 4. The block scheme of detailed work of proposed SDR module and SDR library.

By the user's query, the Control module sends a simple request containing the application parameters to the Network and then receives the information about the design settings necessary to download these services. After Analyzer sends required parameters to the Set of Software modules, that connects with the Library of sequences. Inside of this library the commands, described main and particular functions of signal processing, are stored. Then some set of these functions is sent to Configurator of chain. It builds the correct order of the executed processing and to communicate to the hardware level, which provide the element base. And then the user terminal starts to work according to established parameters. This scheme is described by algorithms consisted of appointed functions.

III. Object-oriented Framework

The co-existence of two or more standards is based on two global components such as the hardware platform and the software platform. The representation of the hardware platform as an abstraction is described by an application program interface (API) [14]. The main API target is the displaying of applications in the hardware platform. The possibility to implement different components as the functional entities can be achieved by usage of one RISC processor and few coprocessors. The architecture of coprocessors is arranged for different types of entities: synchronization, demodulation, and input/output. Each processor is targeted to particular functional operations. They are separated from each other and can be connected through fixed buses. This approach was aimed to a receiver side of a transmission and includes the rigid structure of COFFEE RISC core, which operated with the limited length of commands. This limitation can be obstacle for an extension of the large parameter range in our case. Since the existence of WCDMA and OFDMA (IEEE 802.16e) methods involves the adaptive modulation mechanism, different size of FFT, and multipath technique; the structure of future system must include as much as possible functionality.

In order to make clearer our approach we can note main parameters for each subsystem, which presented in Table 1.

Table 1.

Main parameters for UMTS and WiMAX (IEEE 802.16e-2005)

Parameter	Coding	Mapping	Signal division
UMTS	CC, TC	QPSK	Spreading by OVSF and Pseudo Noise sequence code
WiMAX	RS-CC	QPSK, 16QAM, 64QAM	FFT: 265, 512, 1024, 2048

Thus we have to organize the structure which will be able to implement all these parameters simultaneously by calling the suitable function in software platform corresponding to component in the hardware platform. We plan to use the object-oriented language representation as an interface between two platforms.

The object-oriented designing of signal processing structure is widely developed in the telecommunication area. The model, configured in such system, can show the

main process of the interaction of separate modules and whole system as the one. It gives an opportunity to investigate disadvantages of the structure and improve it during the software implementation.

The using of high-level language allows to implement our approach in real-time model and to adopt it for the hardware process. Today there are existed many programming languages appropriated for description of object-oriented model in sense of hardware fulfilment, e.g. Verilog, C++, VHDL. Inasmuch as SystemC is exactly a high-level language software is used for the programming of hardware, we are going to build our model to corresponding with its architecture. This model then can be integrated to a signal processing module and checked in real-time conditions.

The proposed model consists of classes, library of sequences, and configurator of chain. For one's turn each of these parts includes particular modules, sequences of these modules with precise parameters of the definite signal processing. And at the end the configurator of chain collects all these data and must build the requisite string of receive/transmit signal.

In our case we have two big classes: UMTS and WiMAX. These classes subdivide into few general modules, for example, for UMTS are Scrambling/DeScrambling module, Spreading/DeSpreading module, Modulation/DeModulation module; and for WiMAX are FFT/IFFT module, Mapping/Demapping module. Also there should be the separation between receiving modules and transmitting modules. One chain constructs the correct form of signal and other one should reconstruct the signal with some distortions and errors, which were added in the channel, such as AWGN. At the same time we can determine common modules, which can fulfil the work for both classes, for example Interleaver/DeInterleaver module. Each module has to be defined by particular parameters, which then will be used in the library of sequences for the necessary case. Each module includes the functional description of its purpose. By the following procedures, it calls those functions in order to configure the correct chain of signal processing.

There are specific descriptions of each particular module in SystemC. This software builds the transmission process like real process. Thus we have to describe UMTS class module for transmitter and receiver sides and WiMAX class module for the same sides. The main structure of transmission chain is depicted at the Fig. 5.

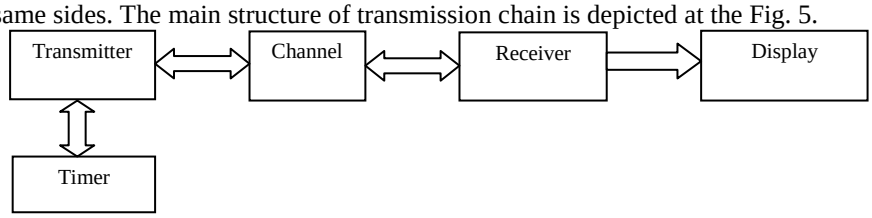

Fig. 5. Main structure of SystemC chain configuration.

In generally, transmitter block generates the packets by calling specify functions and then those packets are sent through channel block to receiver block.

For proposed model the blocks have to be configured according to chosen standards. Thereby from the WiMAX/UMTS system point of view it must be filled as presented in Table 1.

Table 2.

General description of SystemC module structure for WiMAX/UMTS system

Transmitter		Channel	Receiver		Display
Particular UMTS modules	Particular WiMAX modules	e.g. AWGN	Particular UMTS modules	Particular WiMAX modules	BER, SNR
Common modules			Common modules		

The idea is to split signal processing into the common and particular parts. Moreover, the describing of common modules should be concerned with both standard procedures. Each module includes ports, which are sensitive to signal, constructor elements, which identifies the process and initializes the variables used in the module, data and function members. The SystemC model goal is to track the behaviour of protocols, which can show the accuracy of the selected direction.

IV. Software Implementation and Simulation

We start to design the SDR architecture model as software prototype. The framework model was built in SystemC, to evaluate the work of SDR in software case implementation. This model allows to see the process of the packet interaction between transmitter and receiver and moreover the inter-packet interaction inside each module. The final model is complicated and at the present time the protocol implementation is in the early stage. The base of our model is a framework of the whole process, which then is constructed step by step and come up with the full software model, which can be integrated into the hardware platform. This implementation will then demonstrate the real-time results.

Transmitter and receiver blocks consist of two main parts such as UMTS and WiMAX. It means that for UMTS transmitter and receiver parts of system the process description has made and for WiMAX part as well. Also the generator of unipolar bit-signals was created. This generator produces the packets of fixed bit data length by random choice. This bit-generator file is called by the insertion of a suitable procedure in the main file. The main file collects all functional files and organizes the packet flow between corresponding components. The framework model described above is presented in Fig. 6.

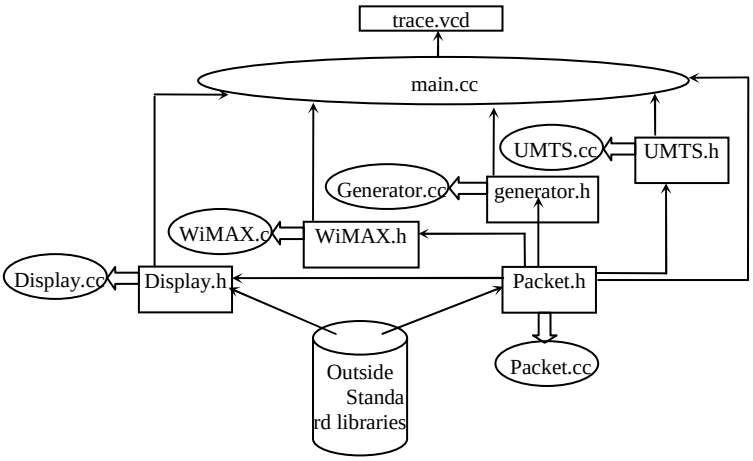

Fig. 6. Framework model of WiMAX/UMTS SDR architecture.

One of the main objects of the model is the packet file, since it includes procedures of the function description for every type of signal scenarios. The input of this framework includes the UMTS input packet and WiMAX input packet, although parameters of packets are determined in the description of packet file.

Outside standard libraries are included in standard set of functional libraries of SystemC. They already existed and we can just call them if necessary. Trace.vcd file provides the display image of current situation between modules. Its structure is existed in main file. This module catches the protocol flow in time domain and shows time diagrams. The time domain is assigned by start time in the body of the main module. Start time call the function to run the simulation kernel. By this existed structure we represented the framework architecture of WiMAX/UMTS system based on SDR handling.

Next developing step of proposed structure is the extension and the hierarchical ordering of more complex architecture. Thus the SDR model should be filled by required elements. The particular modules should be defined during this extension. And the hierarchical ordering will store the correct string of called procedures and function in modules.

The grouping of common and particular units into classes will provide the preparation of SDR library. This library is fundamental part of SDR process in our model and its creation will play the key role in the future development.

V. Conclusions and Future Work

The framework of WiMAX/UMTS system was described. This system is based on SDR implementation as a main handle structure. The SDR integration into the block of two different standards co-existence proves its necessity with respect to stat-of-the-art contributions. The base module was represented in SystemC software program. This program allows to transfer the existed modules into the hardware. The hardware implementation can be the confirmation of software simulations.

The future work can be related to detailed elaboration of main and particular parameters for each module separately. Proposed SDR library object-oriented model will describe all possible signal scenarios for UMTS and WiMAX standards. The description will be integrated into DSP system that will allow to make more particular analysis of such kind system. After precise testing and improvements of whole simulation work we will be able to implement our high-level language model for programming of real-time hardware platform, for example TMS320C6416T DSK. Thus we will receive the visual proofs of our model.

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