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Reconfigurable Radio Systems (RRS); Radio Equipment (RE) information models and protocols for generalized software reconfiguration architecture; Part 4: generalized Radio Programming Interface (gRPI)

Reference

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Foreword

This Technical Specification (TS) has been produced by ETSI Technical Committee Reconfigurable Radio Systems (RRS).

The present document is part 4 of a multi-part deliverable covering the Radio Equipment (RE) information models and protocols, as identified below:

Part 1: "generalized Multiradio Interface (gMURI)";

Part 2: "generalized Reconfigurable Radio Frequency Interface (gRRFI)";

Part 3: "generalized Unified Radio Application Interface (gURAI)";

Part 4: "generalized Radio Programming Interface (gRPI)".

Modal verbs terminology

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1 Scope

The scope of the present document is to define the generalized Radio Programming Interface (gRPI) for radio equipment reconfiguration. The work is based on the Use Cases defined in ETSI TR 103 585 [i.1], on the system requirements defined in ETSI TS 103 641 [1] and on the radio reconfiguration related architecture for radio equipment defined in ETSI TS 103 648 [i.2].

The present document will be based on ETSI EN 303 146-4 [i.4] and provide a generalized interface definition for the generalized Radio Programming Interface (gRPI).

2 References

2.1 Normative references

References are either specific (identified by date of publication and/or edition number or version number) or non-specific. For specific references, only the cited version applies. For non-specific references, the latest version of the referenced document (including any amendments) applies.

Referenced documents which are not found to be publicly available in the expected location might be found at https://docbox.etsi.org/Reference/.

NOTE: While any hyperlinks included in this clause were valid at the time of publication, ETSI cannot guarantee their long term validity.

[1] ETSI TS 103 641: "Reconfigurable Radio Systems (RRS); Radio Equipment (RE) reconfiguration requirements".

2.2 Informative references

References are either specific (identified by date of publication and/or edition number or version number) or non-specific. For specific references, only the cited version applies. For non-specific references, the latest version of the referenced document (including any amendments) applies.

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The following referenced documents are not necessary for the application of the present document but they assist the user with regard to a particular subject area.

[i.1] ETSI TR 103 585: "Reconfigurable Radio Systems (RRS); Radio Equipment (RE) reconfiguration use cases".

[i.2] ETSI TS 103 648: "Reconfigurable Radio Systems (RRS); Radio Equipment (RE) reconfiguration architecture".

[i.3] Directive 2014/53/EU of the European Parliament and of the Council of 16 April 2014 on the harmonisation of the laws of the Member States relating to the making available on the market of Radio Equipment and repealing Directive 1999/5/EC.

[i.4] ETSI EN 303 146-4: "Reconfigurable Radio Systems (RRS); Mobile Device (MD) information models and protocols; Part 4: Radio Programming Interface (RPI)".

[i.5] ETSI TS 103 681-1: "Reconfigurable Radio Systems (RRS); Radio Equipment (RE) information models and protocols for generalized software reconfiguration architecture; Part 1: generalized Multiradio Interface (gMURI)".

[i.6] ETSI TS 103 681-2: "Reconfigurable Radio Systems (RRS); Radio Equipment (RE) information models and protocols for generalized software reconfiguration architecture; Part 3: generalized Unified Radio Application Interface (gURAI)".

[i.7] ETSI TS 103 681-3: "Reconfigurable Radio Systems (RRS); adio Equipment (RE) information models and protocols for generalized software reconfiguration architecture; Part 3: generalized Unified Radio Application Interface (gURAI)".

3 Definition of terms, symbols and abbreviations

3.1 Terms

For the purposes of the present document, the following terms apply:

Abstract Processing Element (APE): abstracts computational resource that executes any computations downloaded from Radio Library

NOTE: APE is connected with input and output DOs. APE is reactive. Any computations are started if all input DOs are filled with real data.

basic operations: operations either provided by the Radio Library and/or UDFB Set to eRVM or by the Radio Library and/or RVM/eRVM Configcodes to RVM

NOTE: Each Basic Operation is mapped to a corresponding APE in the case of eRVM or mapped to a corresponding APE or RVM/eRVM in the case of RVM.

data flow chart: reactive data flow computational model consisting of data and operators where data are connected with operators

NOTE: Operators abstract computations. They are triggered by full data. Results of operator computations are written in connected output data if they are empty.

Data Object (DO): typeless token abstracting any type of data

NOTE: DO provides a container for storing data. It can be empty if no data in the container or it can be full if there is data in the container. DO is allocated in the infinite and flat memory. Any RVM has access to this memory. One or a few APEs from RVM can be connected with DO. DO acknowledges connected APEs about its status whether it empty or full.

dynamic operation: operation that is performed by allocating the computational resources during run-time for each APE required executing the given operation

NOTE 1: The resources are deallocated upon completion of the corresponding operation.

NOTE 2: Dynamic operation is available only in the case of RERC-7 defined in ETSI TS 103 641 [1]. In other words, dynamic operation is needed when RA requires the dynamic resource sharing.

native radio library: library providing platform-specific description of each SFB that represents the target platform hardware

port configuration: specification of the number of APEs inputs and outputs

Radio Equipment (RE): *"an electrical or electronic product, which intentionally emits and/or receives radio waves for the purpose of radio communication and/or radiodetermination, or an electrical or electronic product which must be completed with an accessory, such as antenna, so as to intentionally emit and/or receive radio waves for the purpose of radio communication and/or radiodetermination"*.

NOTE: The definition above is as defined in the Radio Equipment Directive, Article 2(1)(1) [i.3].

radio library authority: authority empowered to decide which components can be registered as new SFBs

NOTE: Any suitable organization can take the role of a Radio Library Authority. The choice of the organization is beyond the scope of the present document.

Radio Virtual Machine (RVM): abstract machine that supports reactive and concurrent executions

NOTE: A RVM may be implemented as a controlled execution environment that allows the selection of a trade-off between flexibility of base band code development and required (re-)certification efforts.

Radio Virtual Machine Runtime Environment (RVM RE): software that allows running Radio Applications that might be Configcodes or executable codes

reference radio library: library providing normative definition of each SFB

NOTE: There may be multiple such Reference Radio Libraries. For a given RA, a unique Reference Radio Library is used.

Software Intermediate Representation (SWIR): RA representation as data flow chart

NOTE: SWIR file contains information on all terminal objects, their parameters (cost, implement function, size, etc.) and connections (links, access type, source and destination).

terminal operation: operation that will always be executed without any other interruption

NOTE 1: Furthermore, terminal operation cannot be decomposed into smaller operations.

NOTE 2: "Terminal operations" are equivalent to "atomic operations", but additionally it indicates that a hierarchy is being used in which the "terminal operations" are on the lowest level of hierarchy and they can be part of another operation.

3.2 Symbols

Void.

3.3 Abbreviations

For the purposes of the present document, the following abbreviations apply:

AOT	Ahead-Of-Time
APE	Abstract Processing Element
ASF	Abstract Switch Fabric
CC	Configcodes Counter
CSL	Communication Services Layer
CU	Control Unit
DO	Data Object
eRVM	elementary RVM
eSFB	elementary SFB
FB	Functional Block
FBRI	FB Reusability Index
FFT	Fast Fourier Transform
gMURI	generalized Multiradio Interface
gRPI	generalized Radio Programming Interface
gRRFI	generalized Reconfigurable Radio Frequency Interface
gURAI	generalized Unified Radio Applications Interface
HD	Hardware Dimension
HW	Hardware
ID	IDentification
IFFT	Inverse Fast Fourier Transform
IR	Intermediate Representation
JIT	Just-In-Time
LCF	Last Configuration Flag
NAF	Next Address Flag
NAPE	Number of Abstract Processing Elements
NCAO	Next Configcode Address Offset
NDO	Number of Data Objects
NOP	No OPeration

RA	Radio Application
RAP	Radio Application Package
RAT	Radio Access Technology
RCF	Radio Control Framework
RE	Radio Equipment
RF	Radio Frequency
RLA	Radio Library Authority
ROS	Radio Operating System
RPI	Radio Programming Interface
RVM RE	RVM Runtime Environment
RVM	Radio Virtual Machine
SD	Software Dimension
SFB	Standard Functional Block
SWIR	SoftWare Intermediate Representation
UDFB	User Defined Functional Block
UML	Unified Modelling Language
URA	Unified Radio Applications
VDO	Virtual Data Object
VHDL	Very high speed integrated circuit Hardware Description Language
XML	eXtensible Markup Language
XOR	eXclusive OR

4 Introduction

A reconfigurable RE is capable of running multiple radios simultaneously, changing the set of radios by loading new Radio Application Packages (RAP) and setting their parameters. All Radio Applications (RAs) are called Unified Radio Applications (URAs) when they exhibit a common behaviour from the reconfigurable RE's point of view in ETSI TS 103 648 [i.2]. In order to run multiple URAs, the reconfigurable RE will include Communication Services Layer (CSL), Radio Control Frameworks (RCFs), Radio Platforms and 4 sets of interfaces for their interconnection.

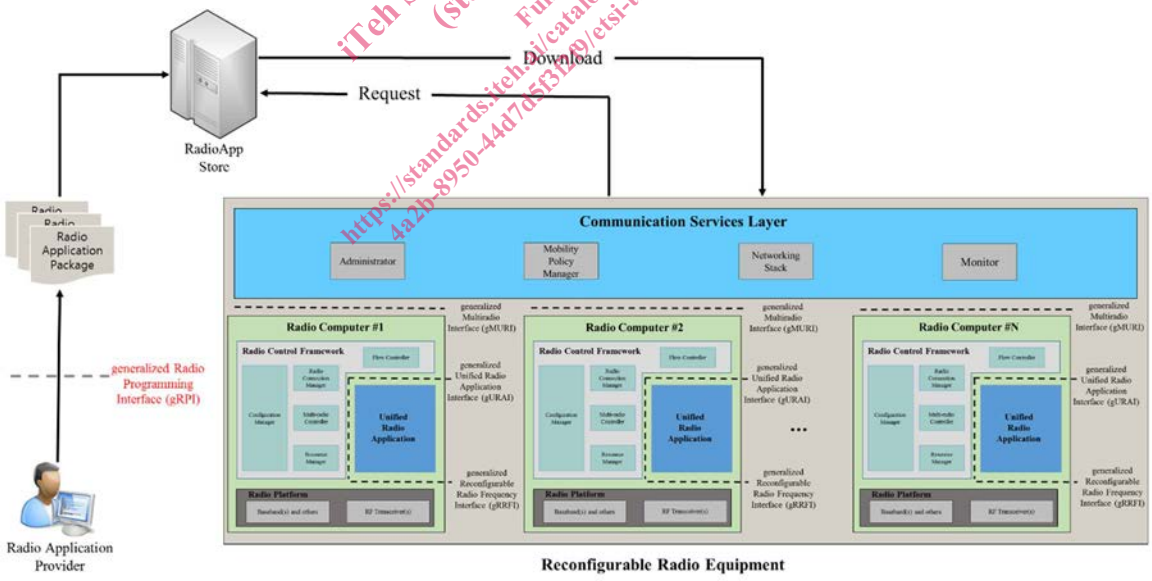

Figure 4.1: Four sets of interfaces for Reconfigurable RE

Figure 4.1 illustrates the Reconfigurable RE architecture with the 4 sets of interfaces, i.e.:

- gMURI for interfacing CSL and RCF (in ETSI TS 103 681-1 [i.5]);
- gRRFI for interfacing URA and RF Transceiver (in ETSI TS 103 681-2 [i.6]);
- gURAI for interfacing URA and RCF (in ETSI TS 103 681-3 [i.7]);
- gRPI for allowing an independent and uniform production of RAs which is the scope of the present document.

The present document defines gRPI.

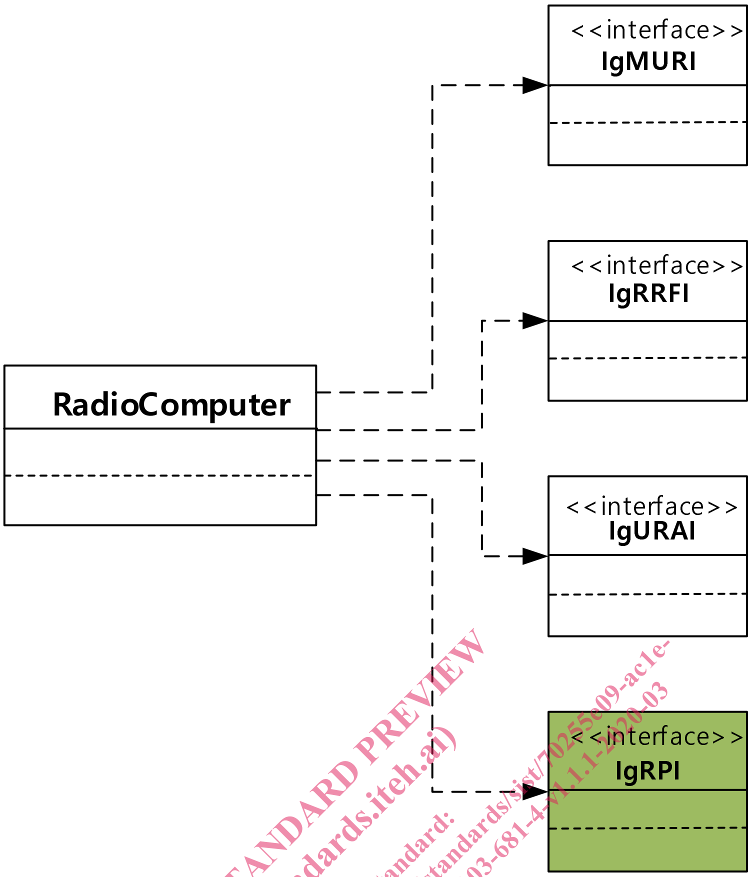

Figure 4.2: UML class diagram for Radio Computer interfaces

Figure 4.2 illustrates UML class diagram for Radio Computer interfaces. The reconfigurable RE may be seen as a set of multiple Radio Computers where individual URAs are engineered as software entities in ETSI TS 103 648 [i.2].

The present document is organized as follows:

- Clause 5 describes the system requirement mapping.
- Clause 6 describes the radio virtual machine specification.
- Clause 7 describes the Configcodes for RVM.
- Clause 8 describes the radio library structure.
- Clause 9 describes the loading, linking and initialization.
- Clause 10 describes the compiling for RVM.
- Annex A describes the mapping between Binary and XML.
- Annex B describes SFB Candidates.
- Annex C describes the replacement of selected components of an existing RAT.

While UML is used for defining the information model and protocol related to gRPI, other modelling languages could be used as well.

5 System Requirement Mapping

The Radio Programming Interface and its related components described in the present document shall support the system requirements shown in table 5.1 referring to clause 6 of ETSI TS 103 641 [1]. This is achieved by introducing the entities/components/units given in the 1st column of table 5.1.

Table 5.1: Mapping of Radio Programming Interface and its related components to the system requirements described in ETSI TS 103 641 [1]

Entity/Component/Unit	System Requirements [1]	Comments
Radio Programming Interface	R-FUNC-RER-04	The requirement shall be as described in clause 6.4.4 of [1].
Radio Virtual Machine	R-FUNC-RER-13	The requirement shall be as described in clause 6.4.13 of [1].
	R-FUNC-RER-14	The requirement shall be as described in clause 6.4.14 of [1].
	R-FUNC-RER-15	The requirement shall be as described in clause 6.4.15 of [1].
Radio Library	R-FUNC-FB-06	A library extension shall be supported. The requirement shall be as described in clause 6.3.6 of [1].

6 Radio Virtual Machine specification

6.1 Concept of RVM

As introduced in ETSI TS 103 648 [i.2], the Radio Virtual Machine (RVM) is an Abstract Machine which is capable of executing Configcodes and it is independent of the hardware. The implementation of a RVM is target Radio Computer specific and it shall have access to the Back-end Compiler (on the platform itself or externally as described in ETSI TS 103 648 [i.2], clause 4.4.1) for Just-in-Time (JIT) or Ahead-of-Time (AOT) compilation of Configcodes.

This clause describes the concept of RVM. As mentioned above, the RVM is an abstract machine, which executes a particular algorithm presented as a data flow chart. In other words, the RVM is the result of replacing all operators and tokens in the particular data flow chart with Abstract Processing Elements (APEs) and Data Objects (DOs), respectively. Each APE executes computations marked by the replaced operator identifier. These computations are taken from the Radio Library.

Figure 6.1 illustrates a conceptual view of RVM processing. This process requires APE, DO and Radio Library, of which the definitions are as follows:

- APE abstracts a computational resource corresponding to the operation in a particular data flow chart.
- DO abstracts a memory resource. In other words, DO is an abstracted memory for storing data used during the procedure of Radio processing.
- Reference/Native Radio Library includes normative definitions/native implementation of all Standard Functional Blocks (SFBs) [i.2] for front-end/back-end compilation. Note that the computations included in the Radio Library are represented in terms of normative definitions or native implementations of SFBs depending upon whether the Radio Library is used for front-end or back-end compilation, respectively.

NOTE 1: User Defined Functional Blocks (UDFBs) will be created through combination of SFBs and represented as a data flow chart to be executed in the RVM. Alternatively, a UDFB is implemented as a stand-alone module/function which can be mapped:

i) into one APE (i.e. this UDFB can be considered atomic); or

ii) into an eRVM/RVM (i.e. not atomic). UDFBs are not in general included into the Radio Library, but they are part of the Radio Application Package.

The RVM begins to work immediately after some DOs initialization. All APEs shall execute computations asynchronously and concurrently. An individual APE shall execute the allocated operator if all the corresponding input DOs are full. APEs shall access DOs with operations "read", "read-erase", or "write". After reading input data from DOs, the APE shall execute the allocated operator and, if output DOs are empty, then the APE shall write processed data. Any full output DO shall block the corresponding writing operation. The RVM shall execute computations until reaching the state when all APEs become inactive. In this state, there are not enough full DOs, which can activate the inactive operators. The result of computations are full DOs, which cannot activate the inactive operators.

NOTE 2: An Output DO can become an Input DO for a subsequent operator. Then, this input DO can activate the subsequent operator.

NOTE 3: The state or operation of a given APE is independent on the state of other APEs. I.e. each APE is atomic.

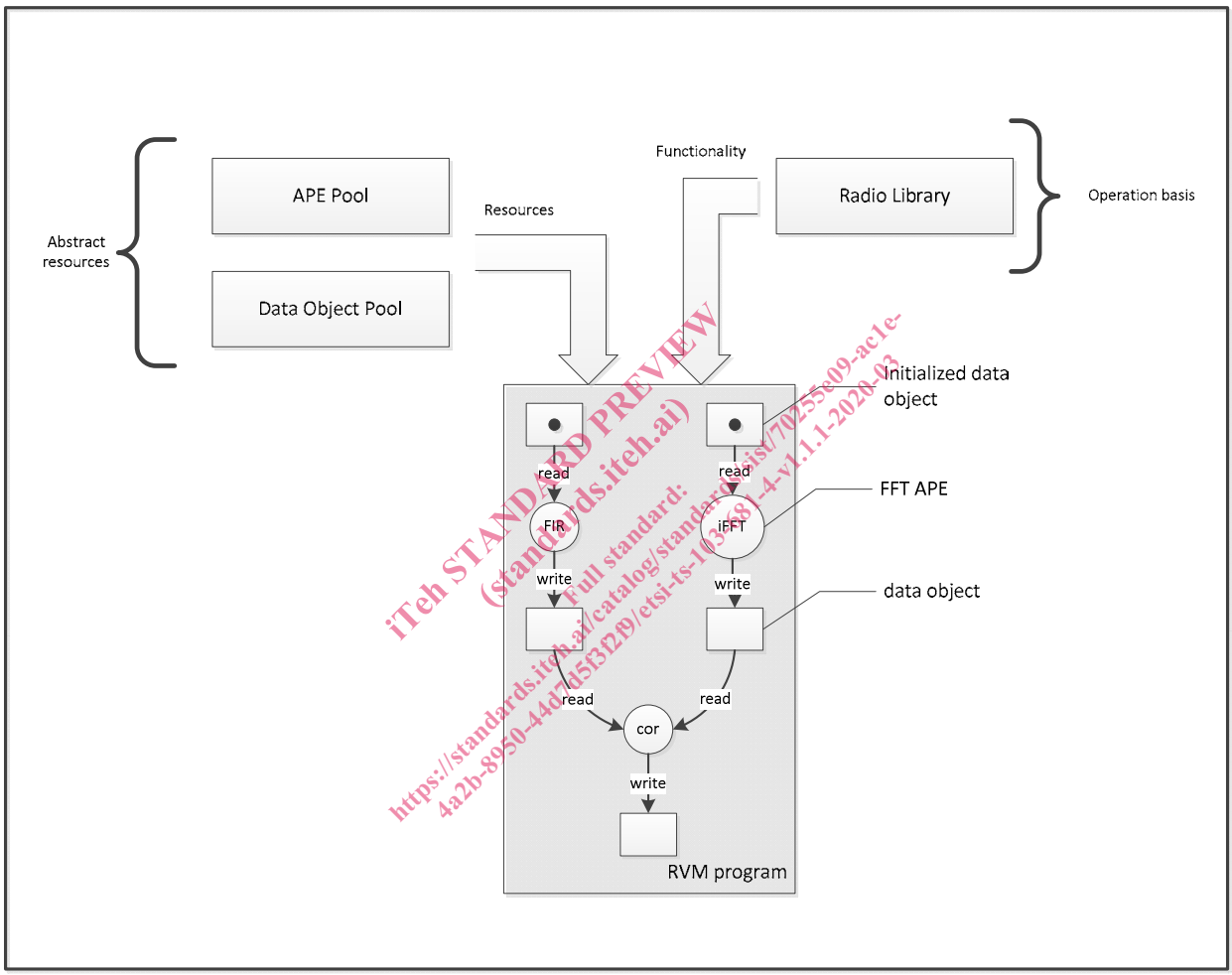

Figure 6.1: Conceptual Diagram of Radio Virtual Machine Processing

6.2 Elementary RVM (eRVM)

This clause describes the eRVM which shall consist of components of Basic Operations, Program memory, Control Unit (CU), Abstract Switch Fabric (ASF) as well as APEs and DOs, of which the definitions are as follows. eRVM shall not contain another eRVM or RVM.

- Basic Operations shall include operators either provided:

  i) from Radio Library as SFBs; and/or

  ii) from UDFB set as UDFBs, each of which is mapped onto one single APE.

NOTE 1: Since UDFBs might be implemented as a stand-alone module/function which can be mapped into one APE, in this case, Basic Operations include operators provided by UDFB Set as well as by Radio Library as SFBs. Note that those UDFBs are atomic.

NOTE 2: For a RVM, the SFB or UDFB can be mapped onto an APE or RVM or eRVM. In the eRVM case, the mapping to RVM or eRVM is not possible since it is the lowest level of hierarchy as it will be introduced in clause 6.3.

NOTE 3: From an execution perspective, there is no difference between SFBs and UDFBs.

- Program memory shall be provided with Configcodes which determine the eRVM configuration.
- CU shall generate Initialization and Set-up instructions for APEs, DOs and ASF based on decoding Configcodes stored in the Program memory.
- ASF shall connect APEs and DOs in accordance with CU signals. One DO can be connected with multiple APEs. One APE can be connected with multiple DOs. DO from other eRVMs can be connected with ASF through external data ports.

Figure 6.2 illustrates a block diagram of eRVM. Basic Operations in eRVM consist of operations provided by the Radio Library and/orUDFB Set.

NOTE 4: A target platform may or may not provide accelerators for some/all SFBs and/or UDFBs.

NOTE 5: Three cases can be considered:

i) RAP includes only SFBs;

ii) RAP includes only UDFBs;

iii) RAP includes SFBs and UDFBs.

NOTE 6: Furthermore, and independent of the upper note, Basic Operations may include:

i) SFBs only;

ii) UDFBs only; or

iii) SFBs and UDFBs.

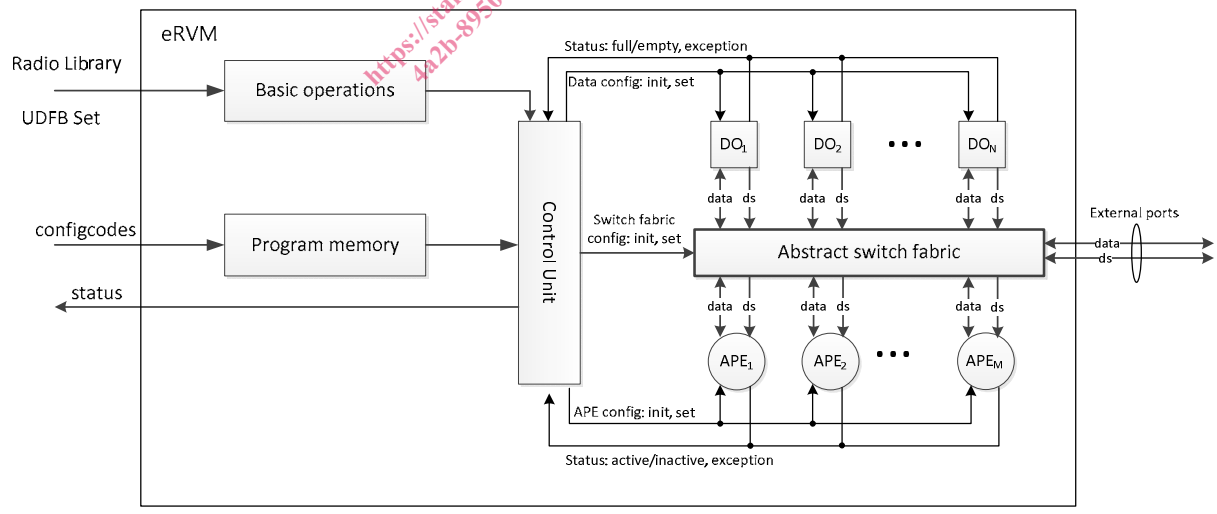

Figure 6.2: Elementary RVM