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Reconfigurable Radio Systems (RRS);
Feasibility study of a Radio Interface Engine (RIE)

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ETSI

650 Route des Lucioles
F-06921 Sophia Antipolis Cedex - FRANCE

Tel.: +33 4 92 94 42 00 Fax: +33 4 93 65 47 16

Siret N° 348 623 562 00017 - NAF 742 C
Association à but non lucratif enregistrée à la
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Foreword

This Technical Report (TR) has been produced by ETSI Technical Committee Reconfigurable Radio Systems (RRS).

Modal verbs terminology

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1 Scope

The present document addresses the efficient acquisition and management of context information and suitable equipment configuration in a heterogeneous radio environment. In particular, an eco-system within the equipment is defined in order to achieve this objective.

NOTE: An eco-system may comprise entities such as Context Information Acquisition Entity, Context Management Entity, Configuration Management Entity, Flexible Modulation Entity, and others. Context information may typically comprise information on the heterogeneous radio environment (e.g. which RATs are available), location information, etc., including information gathered from sensors.

2 References

2.1 Normative references

Normative references are not applicable in the present document.

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.

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

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 103 062 (V1.1.1): "Reconfigurable Radio Systems (RRS); Use Cases and Scenarios for Software Defined Radio (SDR) Reference Architecture for Mobile Device".

[i.2] 3GPP TR 22.891 (V14.2.0): "3rd Generation Partnership Project; Technical Specification Group Services and System Aspects; Feasibility Study on New Services and Markets Technology Enablers; Stage 1 (Release 14)".

[i.3] I. Siaud, A.M. Ulmer-Moll, H. Peng, S. Nanba and K. Moriwaki: "C/U-plane splitting architectures and Inter-RAT management for Radio Reconfigurable Systems", ETSI workshop on future radio technologies-air interfaces, January 2016.

[i.4] Giuseppe Bianchi, Pierluigi Gallo, Domenico Garlisi, Fabrizio Giuliano, Francesco Gringoli, Ilenia Tinnirello: "MAClets: active MAC protocols over hard-coded devices", in Proc. of the 8th international conference on Emerging networking experiments and technologies (CoNEXT '12), Pages 229-240, Nice, France. December 10 - 13, 2012.

[i.5] Dario Sabella, et al.: "Preliminary PoC evaluation in Flex5Gware", Deliverable D6.1 (section 10), H2020-ICT-2014-2 project Flex5Gware (Grant agreement no. 671563). June 2016.

NOTE: Available at http://www.flex5gware.eu/deliverables.

[i.6] Dario Sabella, et al.: "Preliminary PoC evaluation in Flex5Gware", Deliverable D6.1 (section 9), H2020-ICT-2014-2 project Flex5Gware (Grant agreement no. 671563). June 2016.

NOTE: Available at http://www.flex5gware.eu/deliverables.

[i.7] Ronald Raulefs, et al.: "The 5G Localization Waveform".

NOTE: Available at http://elib.dlr.de/102900/2/The_5G_Localization_Waveform_AuthorVersion.pdf.

[i.8] I. Siaud, A. M. Ulmer-Moll: "Green Oriented Multi-Techno Link Adaptation metrics for 5G Multi-Techno Heterogeneous Networks", Eurasip Journal, Special Issue on Evolution of Radio Access Network Technologies towards 5G, April 2016.

3 Definitions, symbols and abbreviations

3.1 Definitions

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

context information: any information that is used to describe:

- the characteristics of the radio signal at given circumstances such as time, frequency, location, and orientation by a measuring device;
- what impacts the characteristics of the radio signal by the measuring device at a given time, frequency, location, and orientation;
- the circumstances themselves, such as time frequency, location and orientation.

EXAMPLE 1: Received signal strength of the radio signal.

EXAMPLE 2: Awareness of a rain that hinders the radio signal reception under the potential circumstances.

correlated KPIs: performance indicators having correlation with each other

EXAMPLE: A high spectral efficiency results in a higher throughput of the system.

model based data set: statistical distribution describing a data set consisting of prior measurements e.g. by the mean and the variance.

EXAMPLE: Gaussian distribution $N(\mu, \sigma^2)$ with the mean μ and variance σ^2.

uncorrelated KPIs: performance indicators having no correlation with each other

EXAMPLE: The KPI delay of the transmission of a certain data package (latency) is uncorrelated with the KPI spectral efficiency of a dedicated waveform.

NOTE: The different KPIs could be correlated by considering constraints. Such constraints could be e.g. a certain SNR that may require repeated transmissions that will lead to a higher delay.

3.2 Symbols

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

BS_1 Base Station 1
MT_1 Mobile Terminal 1

3.3 Abbreviations

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

D2D	Device-to-Device
FEC	Forward Error Correction
FPGA	Field Programmable Gate Array
GPP	General Purpose Processors
HW	Hardware
KPI	Key Performance Indicator
LAN	Local Area Network
LOS	Line-of-Sight

LTE-U	Lone-Term Evolution-Unlicensed
MAC	Medium Access Control
MCS	Modulation and Coding Scheme
MD	Mobile Device
NLOS	Non-Line-of-Sight
OSI	Open Systems Interconnection
PHY	Physical Layer
PoC	Proof of Concept
QAM	Quadrature Amplitude Modulation
QoS	Quality of Service
RAT	Radio Access Technology
RIE	Radio Interface Engine
SDR	Software Defined Radio
SW	Software
UE	User Equipment
VLC	Visible Light Communications
WD	Wireless Device
WE	Wireless Equipment

4 Eco-System for a Radio Interface Engine (RIE)

4.0 General

The radio interface engine empowers a decision unit to operate in a heterogeneous environment. The unit can be either located at the mobile device or in the network. The decision relies on the eco-system that comprises multiple entities, as such as a context information acquisition entity, context management entity, configuration management entity, flexible modulation entity and others. The radio interface engine enables the efficient acquisition and management of context information and suitable equipment configuration in a heterogeneous radio environment.

4.1 General description and reference to past work

The present document will address the efficient acquisition and management of context information and suitable equipment configuration in a heterogeneous radio environment. In particular, an eco-system within the equipment will be defined in order to achieve this objective. Such an eco-system may comprise entities such as:

- Context Information Acquisition Entity.
- Context Management Entity.
- Configuration Management Entity.
- Flexible Modulation Entity.
- And others.

In [i.1] a set of four use cases is described together with actors and information flows for a proposed SDR Reference Architecture for MDs. In [i.2] several use cases are classified with potential requirements for future applications. In [i.3] and [i.8], radio link reliability key performance indicators are described as radio interface engine decision unit for flexible RAT management as well as flexible modulation entity.

4.2 Capabilities of a Radio Interface Engine

The purpose of the radio interface engine is to provide a defined method to interchange relevant context information to a decision unit. The Radio Interface Engine (RIE) provides a standard interface access to model based data that could represent historical data or relies on typical alternatively characterized scenarios. The predictive decision making relies on context information which serves as input to the RIE. The reliability of the data is improved by the RIE through iterative processing including a combination of multiple sources and KPI based decision making.

Figure 1 shows as an example to illustrate how an iterative process in a dynamic scenario using prior knowledge helps to improve various performance indicators. Assuming a UE moves from network A to network B, the performance of the vertical handover depends on an accurate location estimate. The location estimate itself relies on the chosen waveform, which consequently also defines the throughput in the given scenario. The overall throughput benefits from the current location estimate more than it loses by using a dedicated location waveform. The knowledge that the UE will remain in network A relieves the need on a precise location estimate and therefore a signal waveform can be chosen that is better for the communication throughput of a single link.

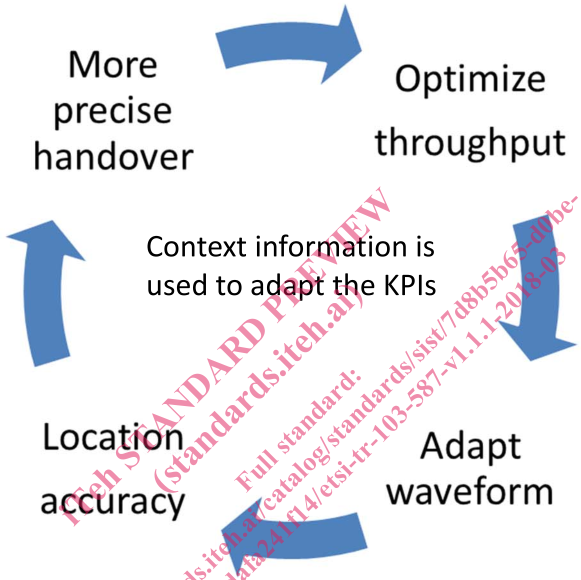

Figure 1: Example of an iterative procedure to improve various KPIs depending on the context information

NOTE: A decision unit can be internal and/or external to the RIE. The overall decision process comprises the internal and external decision units.

5 Key Scenarios

5.1 Overview

In the following key scenarios, identified in clauses 5.2 to 5.6, that will use the RIE are described. For each scenario, the following structure is used:

1) general scenario description;

2) usage example; and

3) role and usefulness of the engine.

The 1st proposed scenario relates to a mobile device and network centric decision making. This contribution is partly based on [i.1].

The 2nd proposed scenario is related to user circumstance context information management.

The 3rd scenario considers context information to download and install a different PHY/MAC protocol of wireless devices.

The 4th scenario studies the context to decide where the proper processing unit should be executed.

The 5th scenario relies on the available context information to adapt PHY and MAC to better estimate the position of the wireless devices. All the presented scenarios rely on context information, such as location information. In clause 5.6 the estimated location information as an input will be improved by adapting the wireless configuration and exploiting device-to-device exchanges between MDs themselves.

5.2 Scenario "Optimized Configuration selection in a Heterogeneous Radio Context"

5.2.1 General Scenario Description

A Mobile Device (MD) is able to operate in a heterogeneous wireless framework, typically consisting of Cellular systems, Wireless LAN, Wireless Personal Area Networks, mmWave systems, proprietary communications systems, etc. Some of these systems may be integrated into a common framework or they may be managed independently. Based on its reconfiguration capabilities, the MD is maintaining link(s) to a single RAT or a set of multiple RATs simultaneously (i.e. a data-stream may be optimally split across multiple links), depending on the context in order to optimize the operational conditions (e.g. optimization of power consumption, interference mitigation and carrier aggregation, etc.). The final configuration is typically identified subject to network constraints (e.g. ensuring an overall efficient network configuration) as well as user requirements (e.g. meeting a minimum Quality of Service level at the best possible power consumption, etc.).

The acquisition of context information will be exploited in order to identify the best possible network configuration.

End users: End Users' MDs accessing internet and other similar mobile data services. Additional stakeholders may be considered as appropriate.

5.2.2 Usage example

As illustrated in Figure 2, the acquired context information is exploited in order to identify the best possible working point for a concerned MD, typically taking network and user requirements into account. Depending on the choice of the decision making entity (e.g. Network centric decision making, MD centric decision making, hybrid decision making split between Network and MD), the context information needs to be transported (and accumulated from various sources) to the decision making entity.