ETSI TR 103 587 V1.2.1 (2023-02)

TECHNICAL REPORT

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

Reference

RTR/RRS-0155

Keywords

mobile, modulation, radio, system

ETSI

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Foreword

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

Modal verbs terminology

In the present document "**should**", "**should not**", "**may**", "**need not**", "**will**", "**will not**", "**can**" and "**cannot**" are to be interpreted as described in clause 3.2 of the ETSI Drafting Rules (Verbal forms for the expression of provisions).

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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.

[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.

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

[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.

[i.9] ECC Report 244 (2016): "Compatibility studies related to RLANs in the 5725-5925 MHz band".

[i.10] Commission Implementing Decision (EU) 2018/1538 of 11 October 2018 on the harmonisation of radio spectrum for use by short-range devices within the 874-876 and 915-921 MHz frequency bands.

[i.11] Commission Implementing Decision (EU) 2019/1345 of 2 August 2019 amending Decision 2006/771/EC updating harmonised technical conditions in the area of radio spectrum use for short-range devices (notified under document C(2019) 5660).

3 Definition of terms, symbols and abbreviations

3.1 Terms

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

3D	Three dimensional
API	Application Programming Interface
CDC	Country Determination Capability
CEPT	European Conference of Postal and Telecommunications administrations
D2D	Device-to-Device
DFS	Dynamic Frequency Selection
EC	European Commission
ECC	Electronic Commications Committee
EU	European Union
FEC	Forward Error Correction
FPGA	Field Programmable Gate Array
GNSS	Global Navigation Satellite Systems
GPP	General Purpose Processors
HW	Hardware
IP	Internet Protocol
KPI	Key Performance Indicator
LAN	Local Area Network
LB	Location-Based
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
RE	Radio Equipment
RIE	Radio Interface Engine
RLAN	Radio Local Area Network
SDR	Software Defined Radio
SNR	Signal-to-Noise Ratio
SW	Software
UE	User Equipment
VLC	Visible Light Communications
WAS	Wireless Access System
WD	Wireless Device
WE	Wireless Equipment
WiFi®	Wireless Fidelity

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 ETSI TR 103 062 [i.1] a set of four use cases is described together with actors and information flows for a proposed Software Defined Radio (SDR) Reference Architecture for Mobile Devices (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 Radio Access Technology (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.

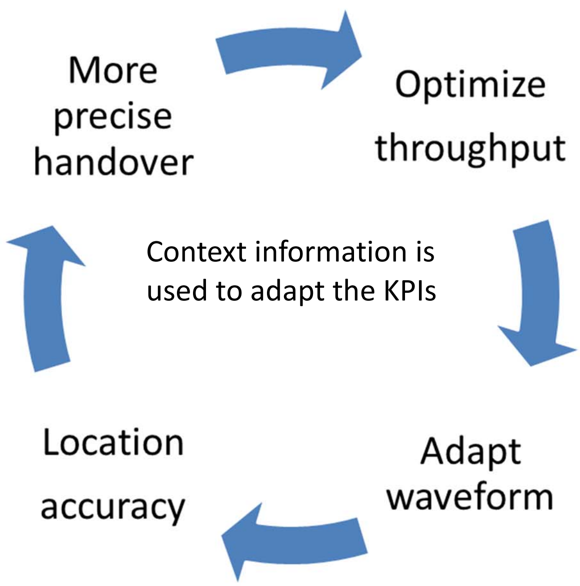

Figure 1: Example of an iterative procedure to improve various KPIs depending on the context information

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 ETSI TR 103 062 [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.

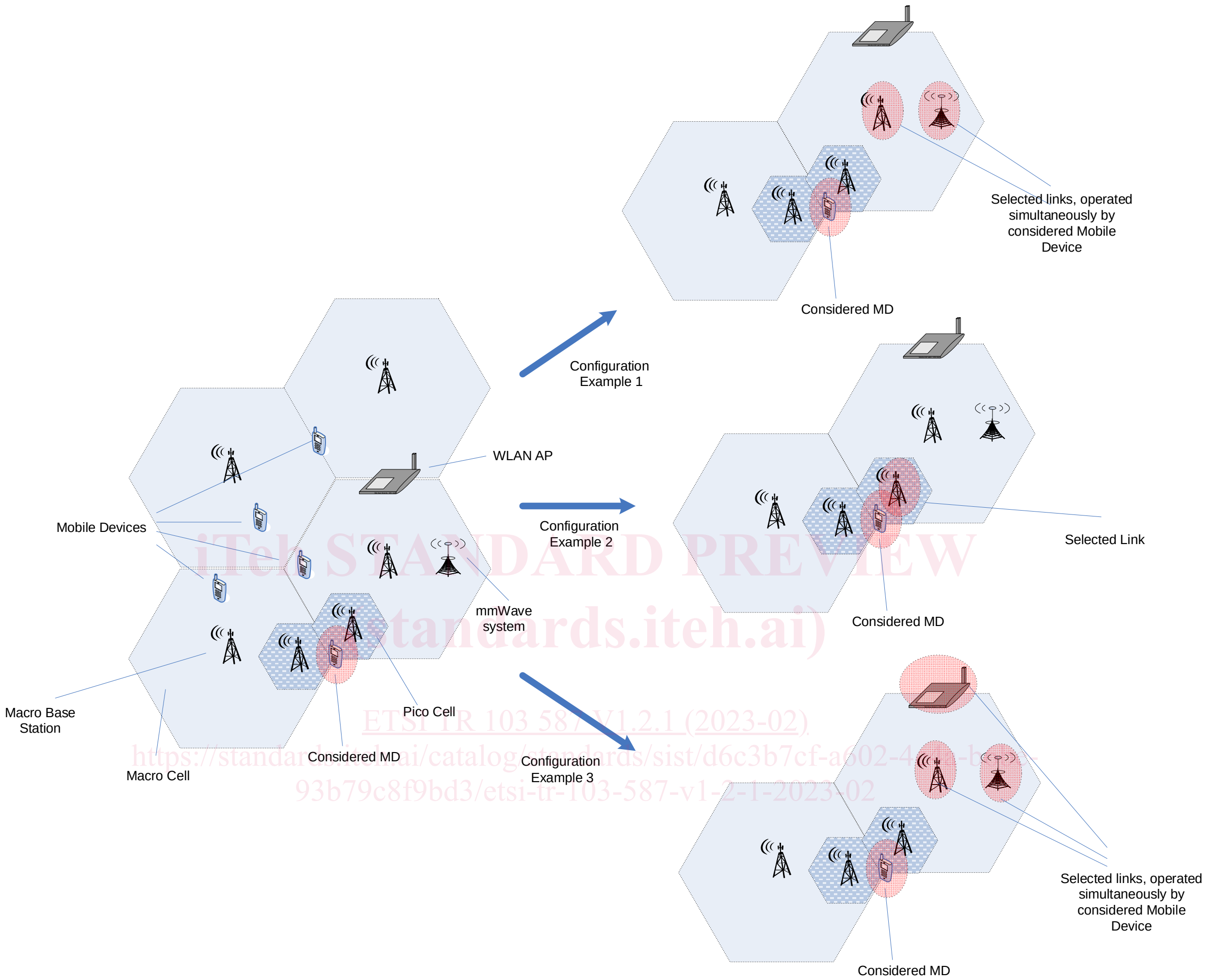

Figure 2: Scenario Illustration "Optimized Configuration selection in a Heterogeneous Radio Context" - the best combination is identified comprising of a single link or multiple links being operated simultaneously

While Figure 2 illustrates the configuration options from a MD perspective, a similar exercise can be performed for the network side. In particular, the most appropriate combination of Base Stations is identified for a target MD with multiple links possibly being operated simultaneously as illustrated in Figure 3. Signalling headers and mixed data and signalling information may be exploited to evaluate associated link reliability metrics (power consumption, QoS, link budget based key performance indicators) in order to make the decision on station selection and on the selection of single or multiple transmission links.

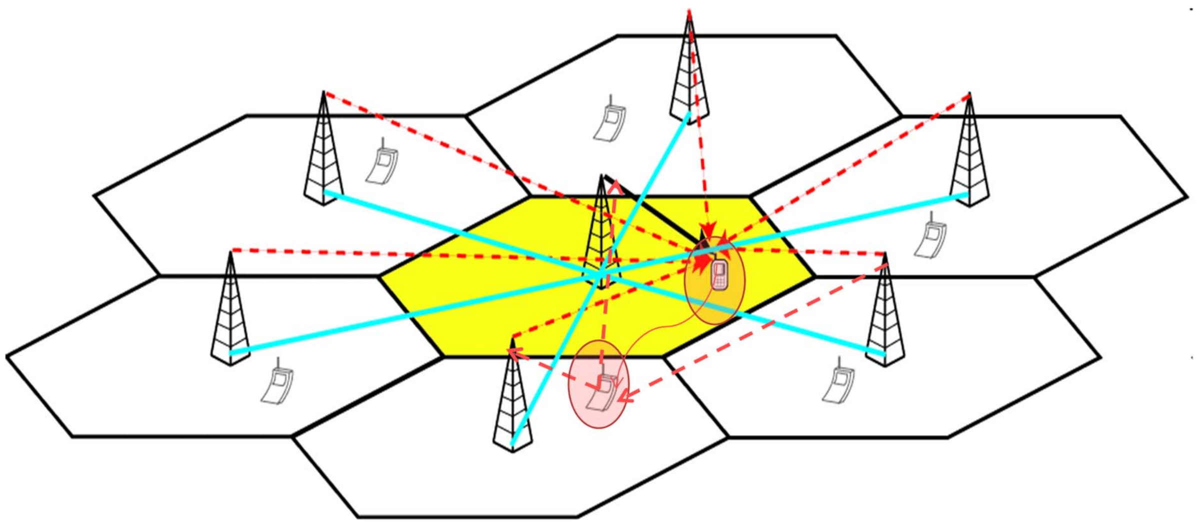

Figure 3: Selection of base station and radio link simultaneously in a time-variant and MD moving configuration

In this scenario, the most appropriate (combination of) base station(s)/access point(s) may be selected for a MD for establishing a link, depending on MD and base station locations and associated radio link reliability based on available transmission interfaces and dedicated link reliability metrics.

When Line-Of-Sight (LOS) and Non-Line-Of-Sight (NLOS) transitions affect the MD in a mobile environment, the access point switching may provide higher link reliability in connection with environment transitions. The selection is combined with transmission link and Modulation-and-Coding-Scheme (MCS) selection. As an example, MCS 16-QAM ¾ and 64-QAM ½ exhibit equivalent information data rate. In NLOS, the 64-QAM ½ is more performant than 16-QAM ¾ due to robust FEC coding rate. During the transitions, the MCS switching involves gains up to 3-4 dB on link budget. In LOS, the 16-QAM ¾ MCS provides better performance, following a lower modulation order compared to 64-QAM. Examples are detailed in [i.3], using a link budget based link reliability metric.

Furthermore, dynamic PHY/MAC processing and link selection may be applied for each RAT: by computing link reliability metrics, the MD may modify transmission link based on dynamic carrier/sub-carrier aggregation and Binary Interleaving Code Modulation process to limit power consumption. Dynamic carrier/sub carrier aggregation may be simply computed using several interleaving patterns to aggregate carriers in a logical channel.

5.2.3 Role and Usefulness of the Engine

The Radio Interface Engine is supporting the upper reconfiguration framework. In particular, the following features are provided by the Radio Interface Engine in a unified way:

- Standardized acquisition of context information, depending on the available sensors, such as location determination, characterization of radio links, interference environment, etc.
- Standardization distribution (and possibly aggregation) of context information provided by one (or multiple) sources. Provide (processed) context information to decision making entity.
- Link reliability metric definition.
- Procedure to compute link reliability metrics and station/MD location using available information to the MD and base station.
- HW accelerators for multiple link transmission solutions composed of different processing components.