



**SUB TASK D4 DELIVERABLE**

**LIAISONS, CONTRIBUTIONS TO 3GPP ETSI ON  
COLLABORATIVE RADIO/MIMO, ORI INTERFACE, ETC.**

**BY NGMN ALLIANCE**

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## 1 BACKGROUND AND OBJECTIVES

This document identifies the potential impact in standards from multi-vendor CRAN implementations. The starting point of this analysis is the set of requirements expressed in sub-task D2, along with the definition of the CRAN building blocks.

Some of these requirements mandate the possibility to build CRANs from building blocks designed by different vendors. These requirements impose open interfaces and interoperability between the relevant CRAN building blocks. Another set of requirements is purely design and implementation related, which is out of scope for this document.

Standards bodies such as 3GPP, being enablers of multi-vendor interoperability, have defined open interfaces between the functional elements of the UTRA and E-UTRA radio access networks as well as the core network. These interfaces were not originally designed to support CRAN, but fortunately most of them can support many physical implementations of the functional CRAN architecture. It is the objective of this document to establish if such functional interfaces are suitable for CRAN, and identify possible gaps that will preclude interoperability.

The methodology used in this document can be described as follows:

- Extraction of the requirements expressed in D2 relevant to open interfaces or interoperability
- Identification of the relevant standardization bodies (3GPP, ETSI/ORI)
- Mapping of the CRAN architecture on existing standardization reference models, and compliance statements
- Standards impact descriptions, importance and priorities
- (Suggestions for follow up)

C-RAN work is focused on RAN aspects. All requirements related to OAM will be studied in cooperation with another NGMN project (NGCOR), and are therefore not covered in this document.

## 2 REQUIREMENTS IN RELATION WITH STANDARDS

The D2 subtask identified a number of requirements. The requirements having potential standardization impacts are listed in the table below. All design related requirements have been eliminated from the D2 list.

Requirements		Relevance, interface
<b>Requirements on C-RAN architecture</b>		
A1	Separation of DU and RU and centralization of DUs as a form of DU clouds	DU-RU interface

A3	Compatibility between DU and RU from different vendors	DU-RU interface.  Note: this requirement is not specific to CRAN, it also applies to conventional DRANs
A4	Inter-operability of DUs or DU clouds between different vendors	DU-DU interface  Inter-DU cloud interface
<b>Requirements for flexibility and scalability</b>		
F4	Support of multi-band, multi-mode (TDD and FDD) RU with configurable band and power allocation	DU cloud-RU interface
F5	Low latency between DU and RU and interface itself (No impact on radio system performance)	DU-RU interface
F6	Multiple standards support in one DU-RU link simultaneously (e.g. GSM/LTE on the same DU-RU link)	DU-RU interface
F7	A standardized DU-RU interface which will provide IQ like sampling values from/to one or several antennas, with required time, frequency synchronization, and SON/OAM messaging	DU-RU interface, OAM interface
<b>For requirements for enhanced performance</b>		
P1	Capability to combine the signal or co-analyze user QoS transferred from different RUs, and support joint processing in the centralized DU pool (support of CoMP)	DU-DU interface  Inter-DU cloud interface
P2	Support of one common resource manager which will perform coordinated scheduling among multiple cells in a cloud DU for uplink and downlink (support of CoMP)	DU-DU interface  Inter-DU cloud interface
P5	Simple O&M functionality that can be monitored / managed as one stand alone node in central RAN O&M system.	OAM interface
P6	External interface from RU to connect external environment measurement or alarm system, and report this through the O&M in DU-RU link to central RAN O&M system.	RU-DU cloud interface, OAM interface
<b>For requirements for NW sharing</b>		
S1	Share DU resources, the fibre links and the RU sites with flexibility to manage its baseband and radio resources depending on the traffic load etc, and allow operators to share the surplus baseband capacity, spectrum and coverage with peers based on the policy definition inside DU (O&M)	O&M to cloud DU and RU interfaces  The analysis of this requirements is not covered by this document
S2	Share the DU resources with the possibility to maintain dedicated RU sites	O&M to cloud DU and RU interfaces  The analysis of this requirements is not covered by this document
S3	Share the RU sites with the possibility to maintain dedicated DU resources, while common language between the OAM of the corresponding shared network	

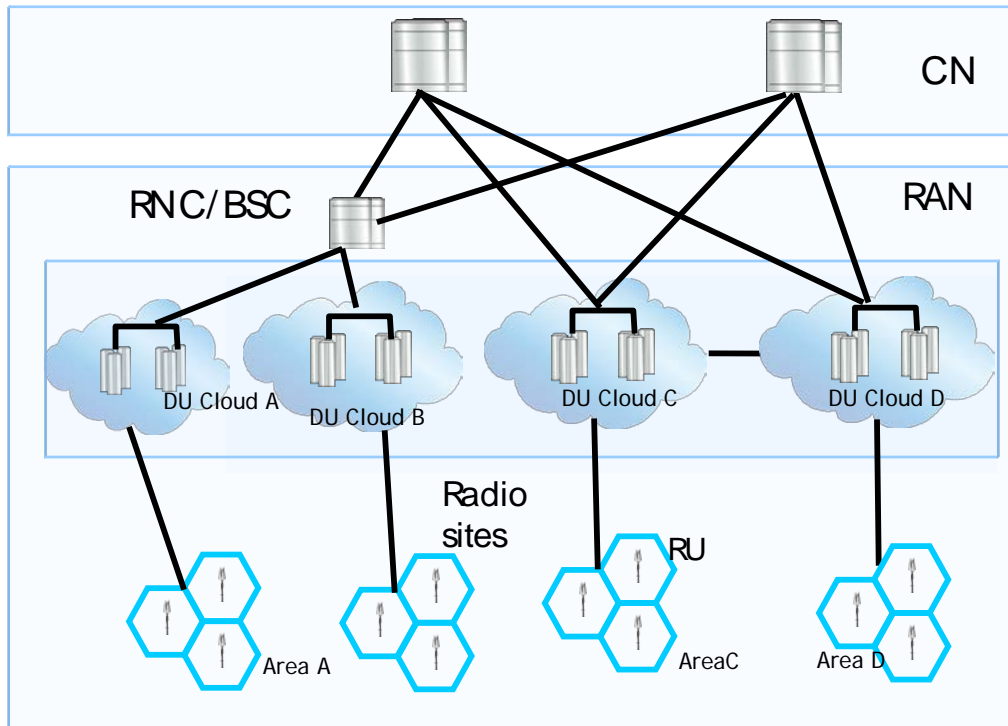
	need to supported to facilitate the NW sharing.	
S4	O&M or other entities inside the DU is required to allow joint radio planning between the RUs/Antenna from different operators inside the C-RAN architecture to optimize the network coverage	O&M to cloud DU and RU interfaces The analysis of this requirements is not covered by this document

### 3 CRAN BUILDING BLOCKS

Figure 1 shows a generic C-RAN architecture. Interfaces between the CN, RAN and radio and within these elements are not detailed in this figure since they are specific to each Radio Access Technology (RAT). One objective of this document is to indicate how CRAN can be mapped to the reference models that have been defined for each RAT. This task is essential in view of maximizing the reuse of the existing interfaces standards, and consequently, minimize the standardization impacts

This mapping is detailed in dedicated sections for the following RATs:

- GSM
- UTRA
- E-UTRA



## 4 MAPPING THE CRAN ARCHITECTURE TO THE REFERENCE MODELS

C-RAN is an implementation approach that consists, basically, in a different way of grouping functions, and has therefore no direct relevance to the standardization work conducted in the 3GPP. The 3GPP interfaces are defined at the functional level, and should naturally be exploited in CRAN. It is nevertheless useful to determine how the CRAN architectures can be mapped to the reference models defined for 2G, 3G and 4G. This analysis helps identifying the interfaces of the DU-clouds with the external world, and the degree of interoperability offered. For example the lub interface, even if defined by the 3GPP is not natively an interface allowing multi-vendor interoperability. Another aspect of the analysis is to determine if there are needs to define additional interfaces to support the physical level of interoperability (similarly to what is being done in ORI)

### 4.1 E-UTRAN model

Figure 2 shows the LTE reference model.

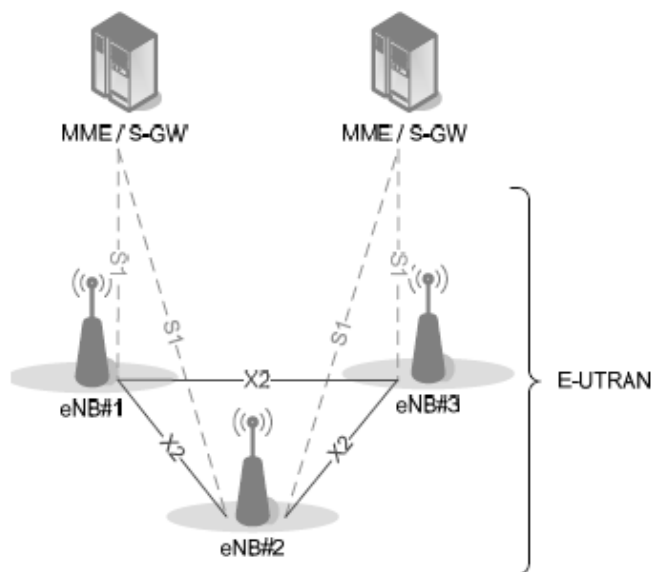


Figure 2: LTE reference model

3GPP has defined open interfaces between:

- eNB and MME/S-GW. This is the S1 interface.
- eNB and eNB. This is the X2 interface in charge of:
  - Mobility (HO)



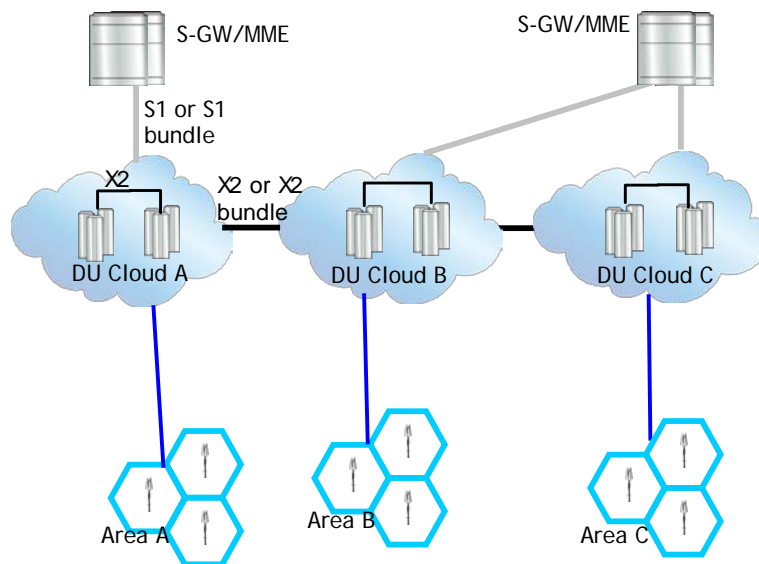
- Load control
- Interference control
- CoMP control exchanges (in Rel-11, under definition)

One eNB can serve up to 256 cells; a cell is defined as one carrier in one sector. A site comprises up to 3 to 6 cells (assumption taken: 3 sectors with 2 carriers aggregated). An eNodeB can therefore serve up to 42 to 85 sites.

As long as the DU cloud does not exceed 256 cells, it can be mapped to a DU cloud. Doing that, the interfaces between the clouds are simply the X2 interfaces.

Alternatively, in case of multi-vendor DU-clouds, it is possible to map each DU to an eNodeB. In this case, the interfaces between the DUs are X2 interfaces, and the interfaces are between the DU-clouds become bundles of X2. In case the DU clouds exceed 256 cells, this cloud can be subdivided into several eNodeBs, interconnected with X2.

In all the situations, described above, there is no need to define specific inter DU or inter DU clouds interfaces. Multi-vendor operation is possible using X2, at least for a basic configuration. CRAN mapping to the LTE reference model is depicted in Figure 3

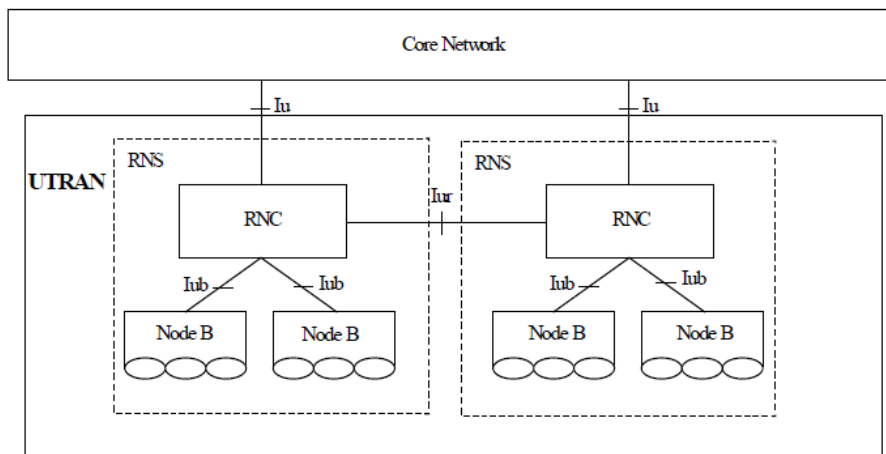


**Figure 3: Mapping CRAN to the LTE reference model**

As far as the S1 interface is concerned, the same reasoning can be used. Depending on the need to split or not each DU cloud into smaller entities, the S1 interface can become bundles of S1.

## 4.2 UTRA model

For UTRA, the same principles will apply to the E-UTRA model albeit with some differences introduced by the distributed nature of the UTRAN. For UTRAN reference model is shown in Figure 3, two centralization options can be envisioned.



**Figure 4: UTRAN reference model**

### 4.2.1 DUs/DU cloud & RUs is the RAN

In this option, the functions of the Node-B and RNC are combined making the Iub interface an internal virtual interface. The Iur will connect the DUs and undertake well know mobility procedures as in today's standards. Note that more than one RNCs may be centralized in one DU. In this case the corresponding Iur interfaces may be virtualised as well.

### 4.2.2 DUs/DU cloud & RUs is a group of Node-Bs

In this option, only the functions of the Node-B are incorporated into the DU. This scenario is appropriate for small clouds such as in coverage of stadiums or transport hubs where the exposed Iub interface continues to support a limited number of C-Ids (less than 256). There is no transport network virtualization in this scenario. Since the Iub is not fully open, this approach does not offer multi-vendor interoperability natively.

## 4.3 GSM model

GSM reference model is shown in the figure below, which is very similar to UTRAN's case in Figure 4. One Base Station Controller (BSS) in GSM is able to in charge of hundreds of base stations (BTS) and usually to provide services to a city does not require many BSS (usually less than 100). Therefore, from the centralization point of

view, we suggest only to incorporating BTS into DU. In other words, a DU Cloud will consist of a number of BTS and the interface between DU Cloud and BSC remains the same. Virtualization may be realized within a DU.

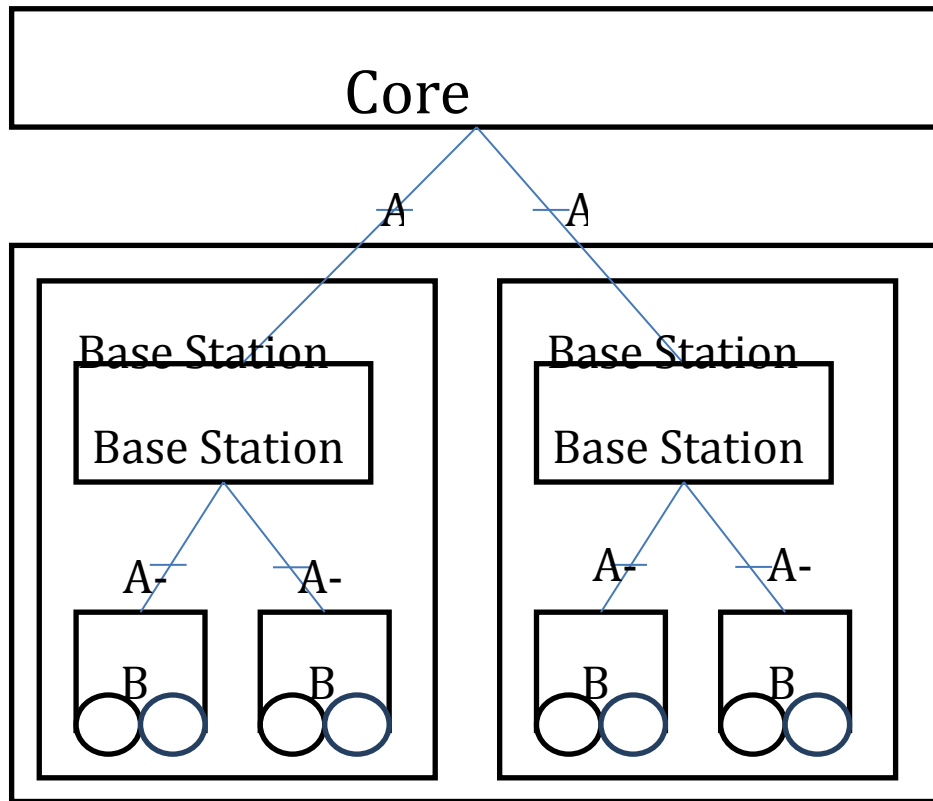


Figure 5: GSM Reference Model

## 5 DU-DU INTERFACE

The methods to interface DU or DU clouds from different vendors have been discussed in section 4. It turns out that the existing standardized interface (X2 for E-UTRA, Iur for flat UTRA) provides the required support at functional level, including mobility management, and load control.

However, there might be a need to define interface supporting the physical level, similarly to what is being done by ORI for the DU-RU interface. This Open DU-cloud Interface (ODI) would be used to support the following functions:

- Control plane (non exhaustive list)
  - Negotiation and decision of physical resources for load balancing
  - Recovery mechanisms in case of partial or full DU-cloud failure (e.g. in case of disaster)
  - Health status report
- User plane (non exhaustive list)

- User data transfer (to support load balancing). The user data format may take the form of I/Q samples or softbits (log-likelihood ratios)
- Interface between Cell Scheduler and Remote User processor in the cloud (needed for traffic load balancing)
- Transfer of S1 data via ODI to the Remote DU location (transparent to MME/SGW)
- Support of CoMP. Note that this functionality is not specific to CRAN, as 3GPP may include user plane for CoMP in future releases.

It is recognized within the CRAN project that defining an open standard for this interface would be complex. Additionally, ODI targets functionalities that might not be required in short to medium term deployments.

Additional studies are needed to further define this interface.

Besides DU-DU interfaces, it should be noted that an open interface raises a number of other points that are not exposed in details in this document:

- Reparenting capability of a DU-cloud to another S-GW/MME in view of supporting failover mechanisms (in case a DU cloud fails, the S1 interface needs to be rerouted to another DU cloud)
- In light of overall network resources optimization and Network Sharing capability, interoperability between DUs from different vendors should be required on OAM plane.

## 6 DU-RU INTERFACE

### 6.1 Open Radio interface

The Open Radio Interface (ORI) is a candidate for making the DU-RU interface fully interoperable. ORI is built on top of the Common Public Radio Interface (CPRI) for the lower layers. However, options are removed and functions are added with the objective of making the interface fully interoperable.

ORI ETSI ISG is an Industry Specification Groups (ISG) within the ETSI organization. An Industry Specification Group, is an activity organized around a set of ETSI work items addressing a specific technology area. ISGs offer a very quick and easy alternative to the creation of industry fora, and are focused on a very specific activity.

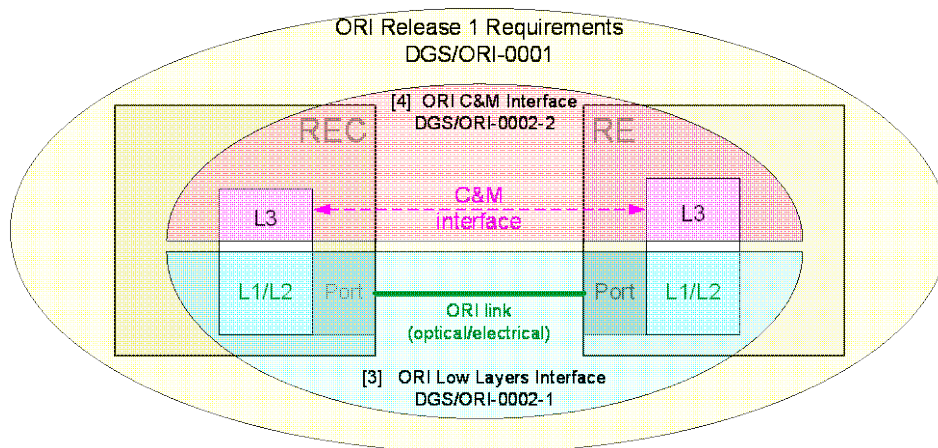
#### 6.1.1 Background on ORI

ORI ETSI ISG is specifying an open interoperable interface primarily focusing distributed RAN architecture.

ORI is about a digitised radio base station interface that establishes a connection between '**Radio Equipment Control**' (REC) and '**Radio Equipment**' (RE). The current definition assumes a conventional distributed RAN architecture. Centralized RAN is not part of the requirements, and the group does not have plans to develop evolutions of the interface for centralized RAN.

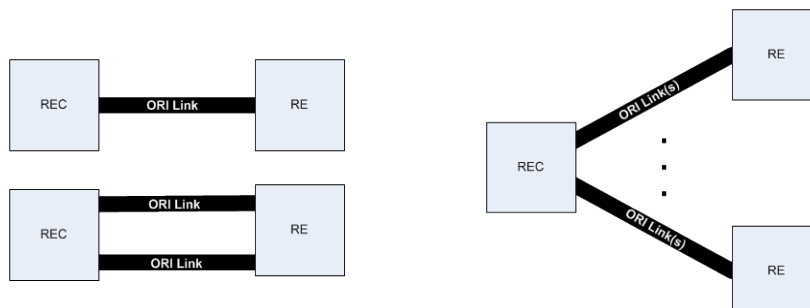
ORI specifications consist of 3 documents:

- Requirements specification. Approved in September 2011
- Lower Layer specification. Approved in September 2011
- C&M plane specification. Draft specification in April 2012



ORI Release 1 supports the following topologies:

- Single point-to-point link between one REC and one RE
- Multiple point-to-point links between one REC and one RE
- Multiple point-to-point links between one REC and several REs



**Figure 6: Topologies supported in ORI**

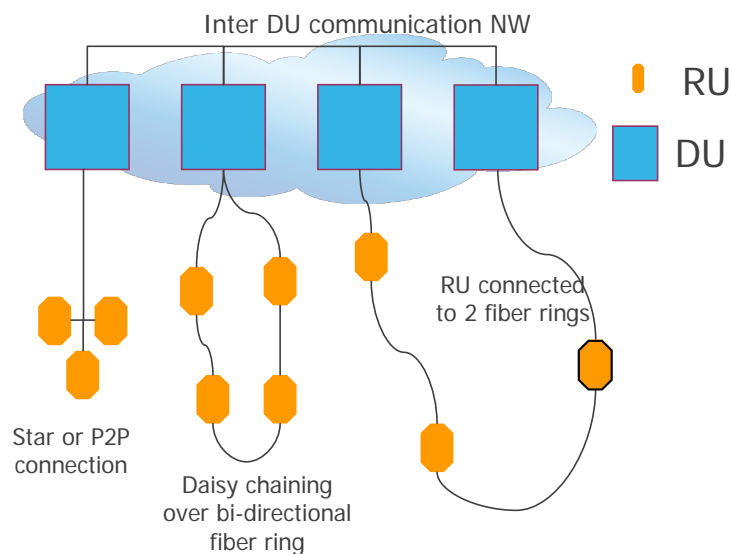
Daisy chaining is offered in CPRI, and will be part of the ORI release 2 specification. Note that the topology where one RE/RU is controlled by several REC/DUs is not supported in the specification. ORI release 1 will support: UTRA-FDD, E-UTRA-FDD, E-UTRA-TDD. GSM is not in the list of the radio standards to be supported for ORI release 1. GSM support is planned for CPRI R5. The multiplexing between UTRA-FDD and E-UTRA-FDD on a link is also a requirement for ORI.

## 6.2 Aspects specific to C-RAN architectures

This section identifies the standardized DU-RU interface gaps based on 2 reference CRAN architectures. These figures aim at representing what might be specific to DU-RU interconnection aspects, and are not expected to represent all physical implementation options. Figure 7 represents a first architecture where the RUs are directly connected to the DU. Several interconnection methods are illustrated:

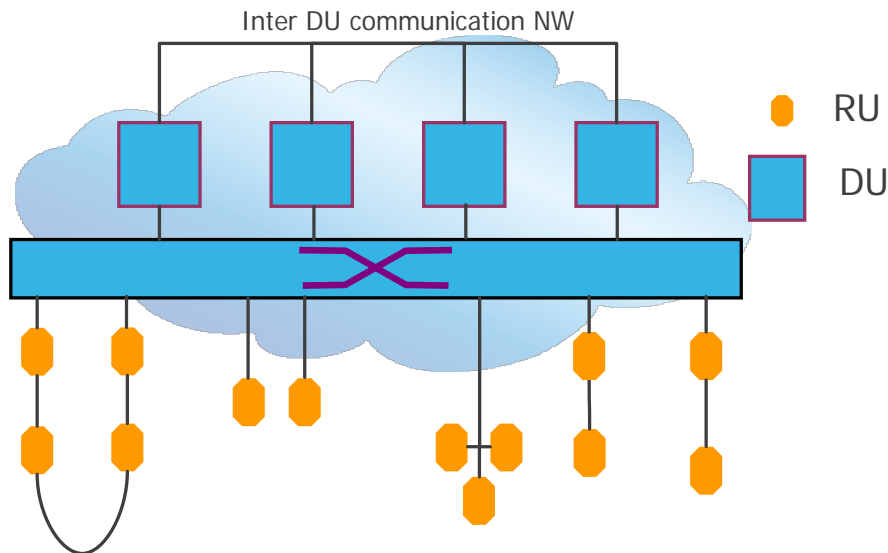
1. Point to point or star connection
2. Bi-directional ring
3. Ring with two different DUs (potential requirement)

Connection mode 3 provides failover mechanisms that are currently not part of the ORI specification.



**Figure 7: Architecture 1: direct connection of DU with RU**

Figure 8 shows an alternate architecture where a switch is inserted between the DUs and the RUs. This switch allows semi-static or dynamic association of RUs and DUs. Note that, in real implementations the switch can be distributed.



**Figure 8: Architecture 2: CPRI switch interconnects DU and RUs**

This architecture brings the following advantages on top of the first architecture using direct connections:

- Additional failover mechanism and possibility of HW change for repair or upgrade without service interruption. If redundant DUs are installed, self healing mechanisms can be supported.
- Pooling benefits by exploiting the time and spatial traffic distribution characteristics. A reduction of the number of DU is possible by statistical pooling effect, exploiting the cell load variations and redistribution over the day. This capability is subject to DU HW capability to handle a variable number of cells.

The CPRI switch is not identified as a functional element of any reference architecture (3GPP, ORI, CPRI ...). Therefore no open interfaces, either with DU or RU are defined or planned in the relevant standardization bodies.

Two possibilities are offered:

- Consider the switch as an internal implementation option, and therefore keep the interface of this switch with DUs proprietary, and terminate the ORI at the switch connector. This approach minimizes the impacts on the ORI specification. Its main limitation is that it does not allow connecting DUs from different vendors to the same switch.
- Define the switch as a functional element of the reference architecture, open the interfaces with the switch, include routing capability in ORI, and include the management of the switch.

The CRAN project recommends the first approach for the short medium term. For the longer term, when directions taken by the industry will be clearer, it will be easier to establish the requirements on interface that would enable multi-vendor operation.

### 6.3 Vendor Differentiation

Most vendor product offers include solutions with digital transport between BS and Radio equipment. But most of these interfaces are vendor specific. The reasons for such a situation are:

- Optimized management of radio equipment, generally vendor specific
- Compression algorithm to reduce front haul throughput, and enable combinations of more RATs over the same transport medium
- Redefinition of the distribution of functions between DUs and RUs. Several possibilities to split the modem functions between the DU and RU are possible in view of reducing throughput requirements.
- Capability of packet (Ethernet/IP) transmission for dynamic routing

So far, neither CPRI nor ORI fulfills these requirements. The relocation and/or splitting of the modem functions between RUs and DUs would require the highest amount of specification work.

## 7 SPECIFIC O&M REQUIREMENTS

This topic should be covered in the NGCOR phase II project (whose confirmation is still under discussion at the time this document is written). It will therefore not be covered in this document.

## 8 STANDARD IMPACTS SYNTHESIS

This section summarizes the gaps according to the requirements expressed in D2

Requirements		Gap
<b>Requirements on C-RAN architecture</b>		
A1	Separation of DU and RU and centralization of DUs as a form of DU clouds	No gap
A3	Compatibility between DU and RU from different vendors	ORI provides the functionality. Future versions should remove the current limitations  Gap : Evolutions required to support other topologies, and advanced RU features
A4	Inter-operability of DUs or DU clouds between different vendors	Further study needed to identify potential gaps  3GPP provide interoperability at functional level, but potential need for physical interface (ODI), but remains to be confirmed, and is anyway not blocking



<b>Requirements for flexibility and scalability</b>		
F4	Support of multi-band, multi-mode (TDD and FDD) RU with configurable band and power allocation	No gap  ORI release 1 shall supports: UTRA-FDD, E-UTRA-FDD, E-UTRA-TDD  GSM is not in the list of the radio standards to be supported for ORI release 1. (planned for CPRI R5)  The multiplexing between UTRA-FDD and E-UTRA-FDD on a link is also a requirement for ORI.
F5	Low latency between DU and RU and interface itself (No impact on radio system performance)	No gap: ORI, is developed in this aim
F6	Multiple standards support in one DU-RU link simultaneously (e.g. GSM/LTE on the same DU-RU link)	No gap, see F4
F7	A standardized DU-RU interface which will provide IQ like sampling values from/to one or several antennas, with required time, frequency synchronization, and SON/OAM messaging	No gap: ORI is developed in this aim  OAM is limited to C&M, SON is not specific to CRAN
<b>For requirements for enhanced performance</b>		
P1	Capability to combine the signal or co-analyze user QoS transferred from different RUs, and support joint processing in the centralized DU pool (support of CoMP)	Not specific to CRAN.  3GPP does not offer the possibility of multi-vendor CoMP in R11. should be brought in R12  ODI could be a possibility, but not for the short-medium term
P2	Support of one common resource manager which will perform coordinated scheduling among multiple cells in a cloud DU for uplink and downlink (support of CoMP)	No gap, since no specific to CRAN. Messaging to support coordinated scheduling to be defined by the 3GPP
P5	Simple O&M functionality that can be monitored / managed as one stand alone node in central RAN O&M system.	OAM interface
P6	External interface from RU to connect external environment measurement or alarm system, and report this through the O&M in DU-RU link to central RAN O&M system.	Gap  Not covered by ORI.
<b>For requirements for NW sharing</b>		
S1	Share DU resources, the fibre links and the RU sites with flexibility to manage its baseband and radio resources depending on the traffic load etc, and allow operators to share the surplus baseband capacity, spectrum and coverage with peers based on the policy definition inside DU (O&M)	O&M to cloud DU and RU interfaces  The analysis of this requirement is not covered by this document
S2	Share the DU resources with the possibility to maintain dedicated RU sites	O&M to cloud DU and RU interfaces  The analysis of this requirement is not covered by this document

S3	Share the RU sites with the possibility to maintain dedicated DU resources, while common language between the OAM of the corresponding shared network need to supported to facilitate the NW sharing.	The analysis of this requirement is not covered by this document
S4	O&M or other entities inside the DU is required to allow joint radio planning between the RUs/Antenna from different operators inside the C-RAN architecture to optimize the network coverage	O&M to cloud DU and RU interfaces The analysis of this requirement is not covered by this document

## 9 CONCLUSION

### Interface between DUs and between DU clouds

CRAN is primarily an implementation approach, and the functional interfaces defined by the 3GPP constitute the best choice in CRAN to support all conventional mechanisms for mobility, management of radio resources, and interference coordination in LTE. It has to be noted that there are some limitations for multi-vendor deployment since some interfaces (e.g. lub) are not fully open, but these limitations are also met in conventional DRAN architectures.

However, these interfaces do not support the physical level (e.g. I/Q data transfer between clouds or physical resource negotiation and allocation). To provide interoperability at this level the development of an additional interface (ODI) would be required, similarly to what has been done for the DU-RU interface. Additional study would be needed to determine if such an interface needs to be defined.

The unavailability of this interface is nevertheless not a blocking point for the deployment of multi-vendor DU-clouds. Additional studies are needed to define this interface. In between, proprietary mechanisms can be used to support the ODI functions, if needed.

### Interface between DUs and RUs

ORI shall be considered as the reference interface supported by most operators. The P-CRAN project has identified some limitations of the current specification, but these limitations should disappear in the future releases if appropriate efforts are done to drive the specification in the directions that are needed to support evolved CRAN. These evolutions concern the support of additional topologies, routing, and more advanced C&M.

It has to be noted that DU-RU interface standardization is a topic on its own, since it is also a relevant problematic for conventional DRAN architectures. The limitations of the ORI interface shall therefore not be considered as a blocking point for C-RAN deployments.



It is expected that a number of changes will occur in the future RAN architectures, impacting macro-cell based networks to heterogeneous NW. There are a number of aspects still unknown precisely on the way architectures will evolve. It is important to ensure a smooth, coordinated standardization and industry effort for DU-RU and DU-DU interfaces to ensure a rapid development of the necessary functionalities so that time to market is not impacted.

We expect that the outcome from the NGMN P-CRAN project will constitute a valuable guidance for the open radio standardization work in ETSI

## APPENDIX

None

## GLOSSARY OF DEFINITIONS AND TERMS

- DU : Data Unit
- RU : Radio Unit
- ORI : Open Radio Interface
- ODI : Open DU cloud Interface
- RE : Radio Equipment
- REC : Radio Equipment Control
- C&M : Configuration and Management
- RAT : Radio Access Technology
- CRAN : Centralized RAN
- RNC : Radio Network Control
- MME/S-GW : Mobility Management Entity / Serving GateWay