Optical-Wireless Cooperative Control with eCTI toward Beyond 5G and 6G

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NTT Access Network Service Systems Laboratories

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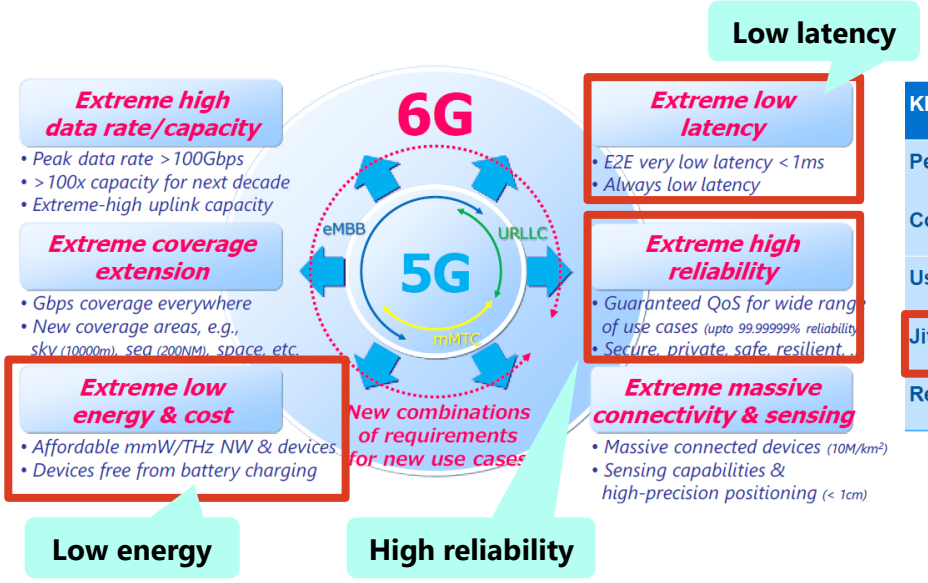
Requirements for Beyond 5G and 6G

NTT

Requirements for 6G wireless technology



NTT DOCOMO, "White Paper 5G Evolution and 6G"

Expected 6G's KPI vs. 5G Baseline

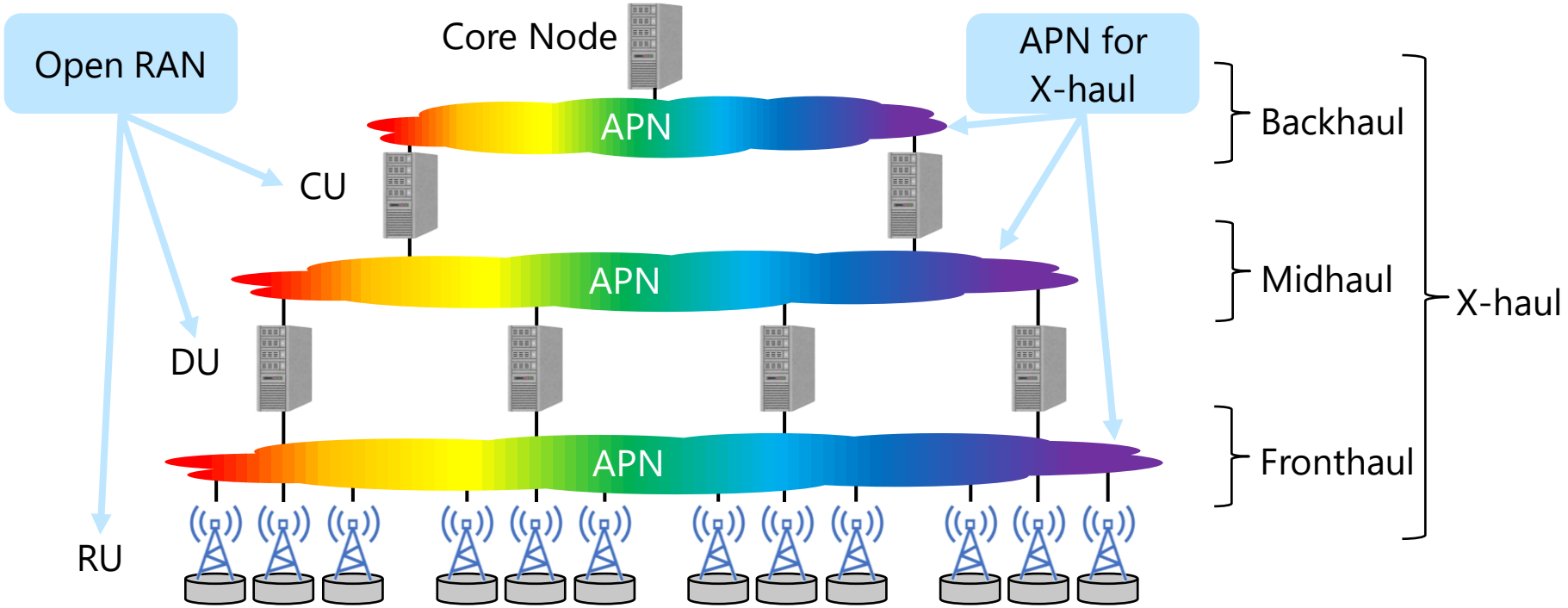
KPI	5G	6G	Improvement Factor
Peak Data Rate (Gbps)	10	100-1000	10-100
Connection Density	1/ m^2	10-100/ m^3	10-100
User Plane Latency (msec)	1	0.1	10
Jitter (msec)		0.0001-1	N/A
Reliability	Five 9s	Seven 9s to nine 9s	100 - 10000

Low jitter

IOWN Global Forum, "Technical Outlook for Mobile Networks Using IOWN Technology"

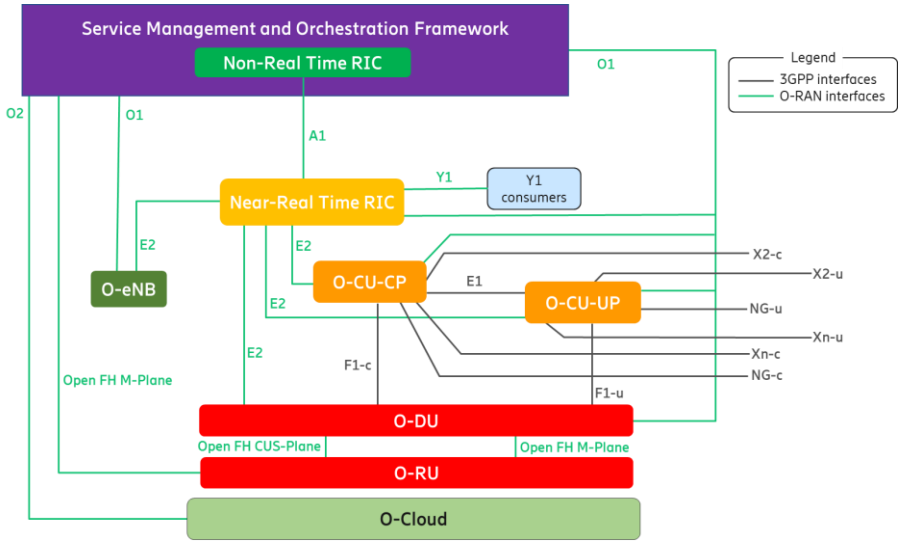
Various Requirements that must be met
in E2E across optical and wireless networks

Target Network Vision



Applying IOWN All-Photonic Network (APN)
to X-haul of Open RAN (O-RAN)

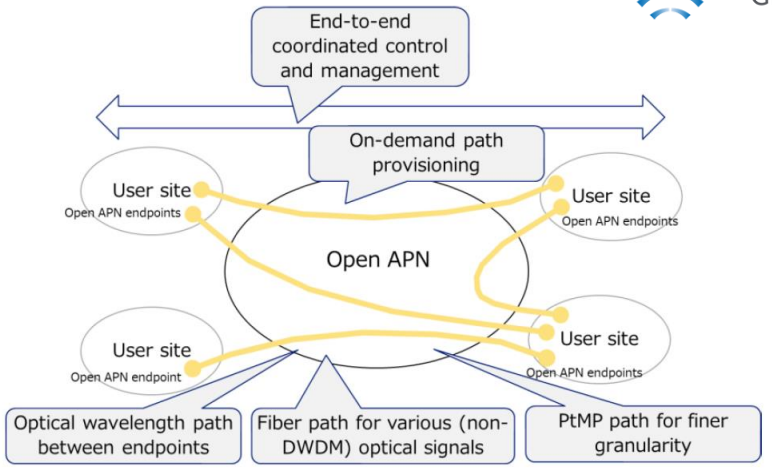
Open RAN



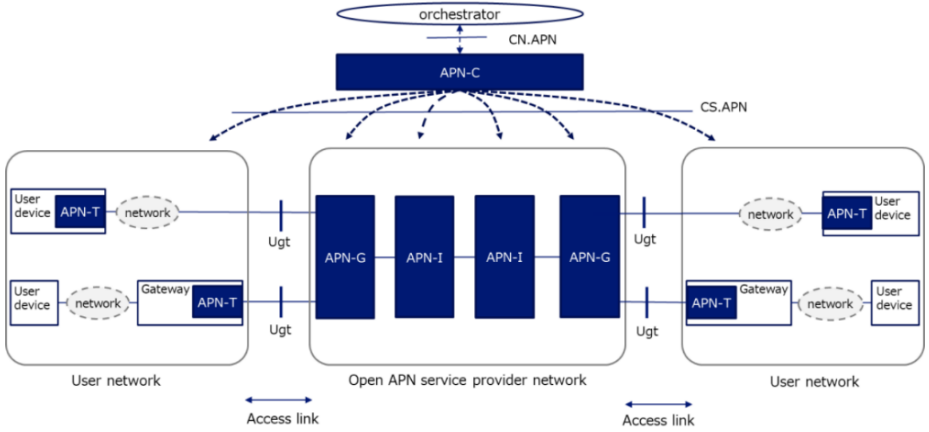
O-RAN architecture
(Figure 5.2-1 of "O-RAN.WG1.OAD-R003-v11.00")

O-RAN Alliance has been specifying
RAN architecture including CU/DU/RU

IOWN APN



Summary of APN services
(Figure 2-1 of "Open APN Functional Architecture-v2.0")



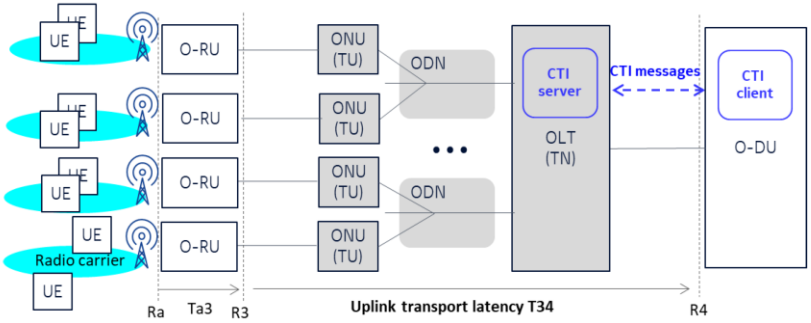
APN architecture
(Figure 3.1-7 of "Open APN Functional Architecture-v2.0")

IOWN global forum (IGF) has been specifying APN services and architectures including APN-G/I/T(ROADM and Tranceiver)

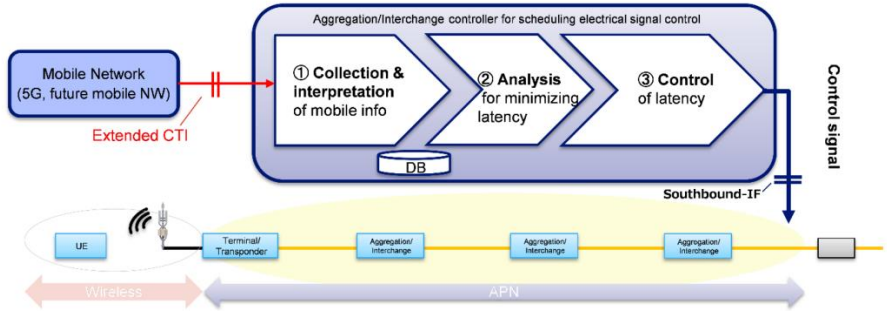
Optical-wireless cooperative control

- **Optical-wireless cooperative control** achieves coordination between RAN and optical access network to meet requirements of beyond 5G and 6G.
- **CTI/eCTI (Cooperative Transport Interface/extended CTI)** is an interface used for optical-wireless cooperative control.

Optical-wireless cooperative control using CTI
-Application areas in RAN: MFH
-Assumed optical access system: PON
-Target requirement: Mainly low latency



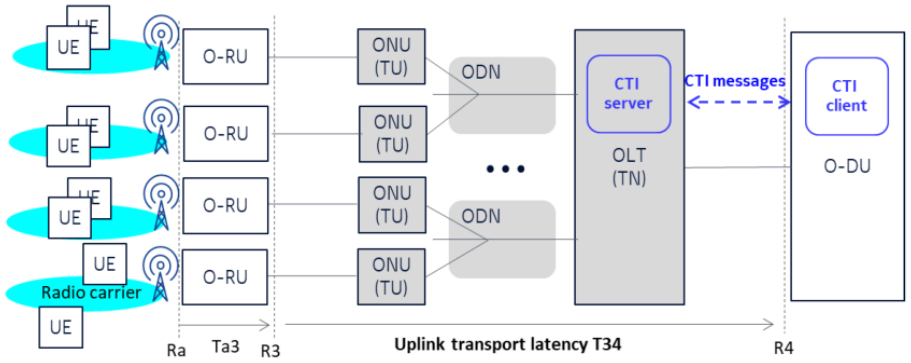
Optical-wireless cooperative control using eCTI
-Application areas in RAN: MFH, MMH, MBH
-Assumed optical access system: APN, packet NW (Not only PON)
-Target requirement:
Low latency, low jitter, low energy, high reliability, etc.



CTI specification in O-RAN WG4

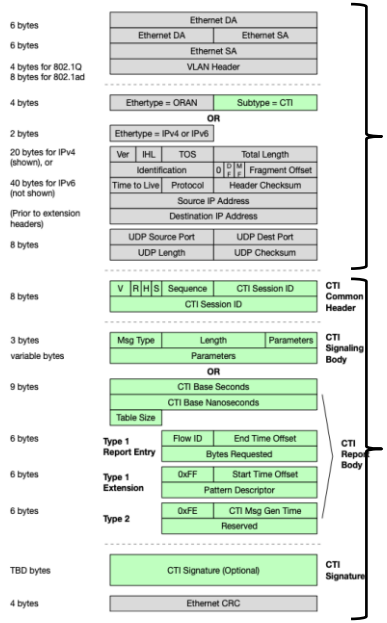
- CTI has been already specified in O-RAN WG4 (Working Group 4).

MFH applying PON and CTI



O-RAN.WG4.CTI-TCP.0-R003-v04.00 Figure 4.2

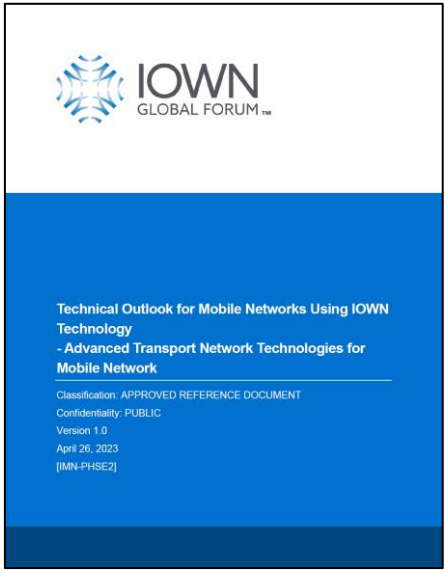
Frame structure of CTI message



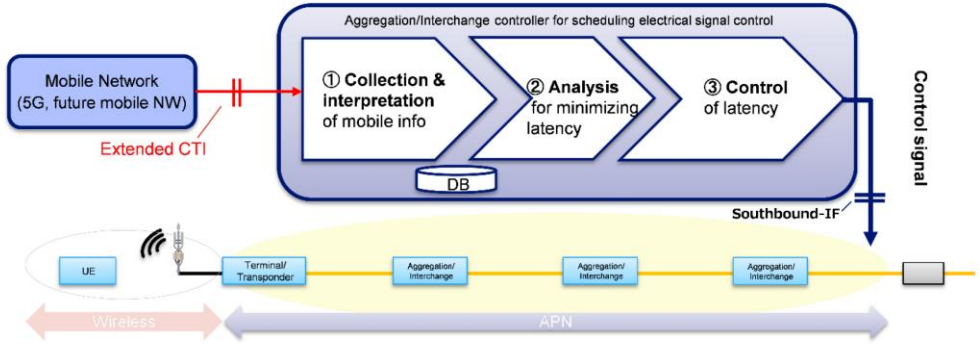
O-RAN.WG4.CTI-TCP.0-R003-v04.00 Figure5.3

eCTI discussions in IOWN global forum

- We are discussing eCTI and optical-wireless cooperative control for RAN applying APN in IMN-TF (IOWN for Mobile Network Taskforce) of IOWN global forum.
- Technical document including eCTI related topics has been published in Apr. 2023.

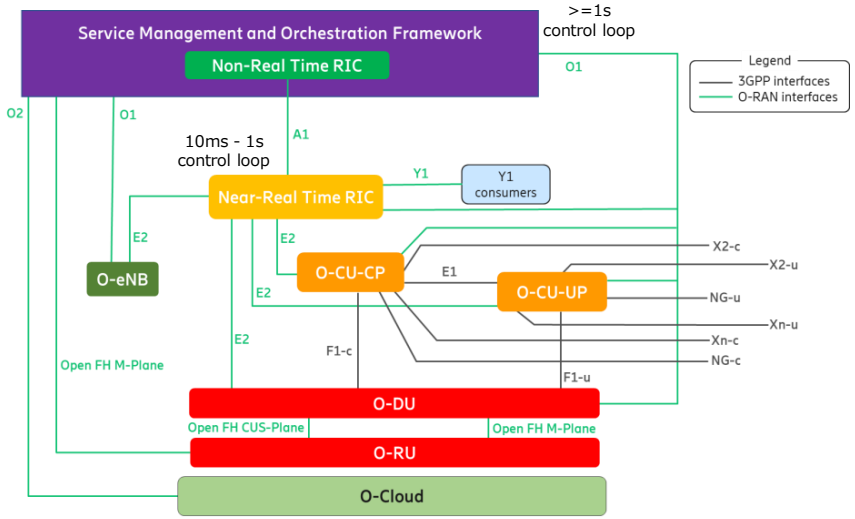


https://iowngf.org/wp-content/uploads/formidable/21/IOWN-GF-RD-IMN-PHSE2-1.0.pdf



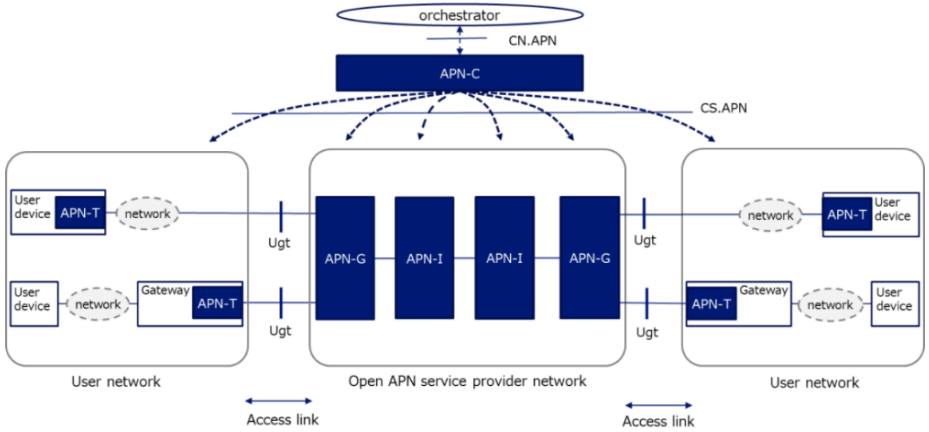
Currently discussed topic: RIC/APN-C

- O-RAN and IGF currently define controllers in each of RAN and APN.
  - Non-Real Time RIC/SMO and Near-Real Time RIC in O-RAN architecture
  - APN-C in APN architecture
- We need to discuss cooperation between RAN and APN based on these architectures.



O-RAN architecture

(Figure 5.2-1 of "O-RAN.WG1.OAD-R003-v11.00")

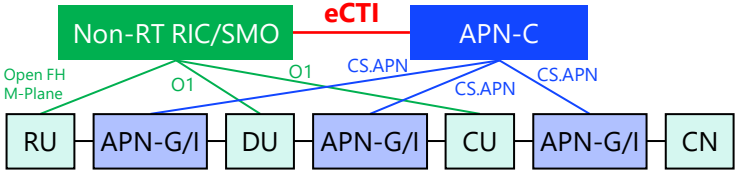
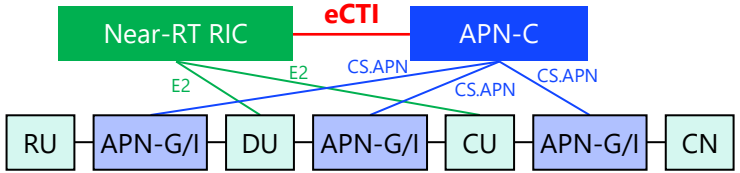
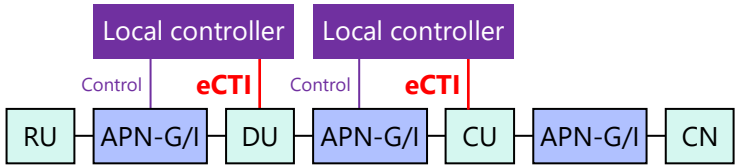


APN architecture

(Figure 3.1-7 of "Open APN Functional Architecture-v2.0")

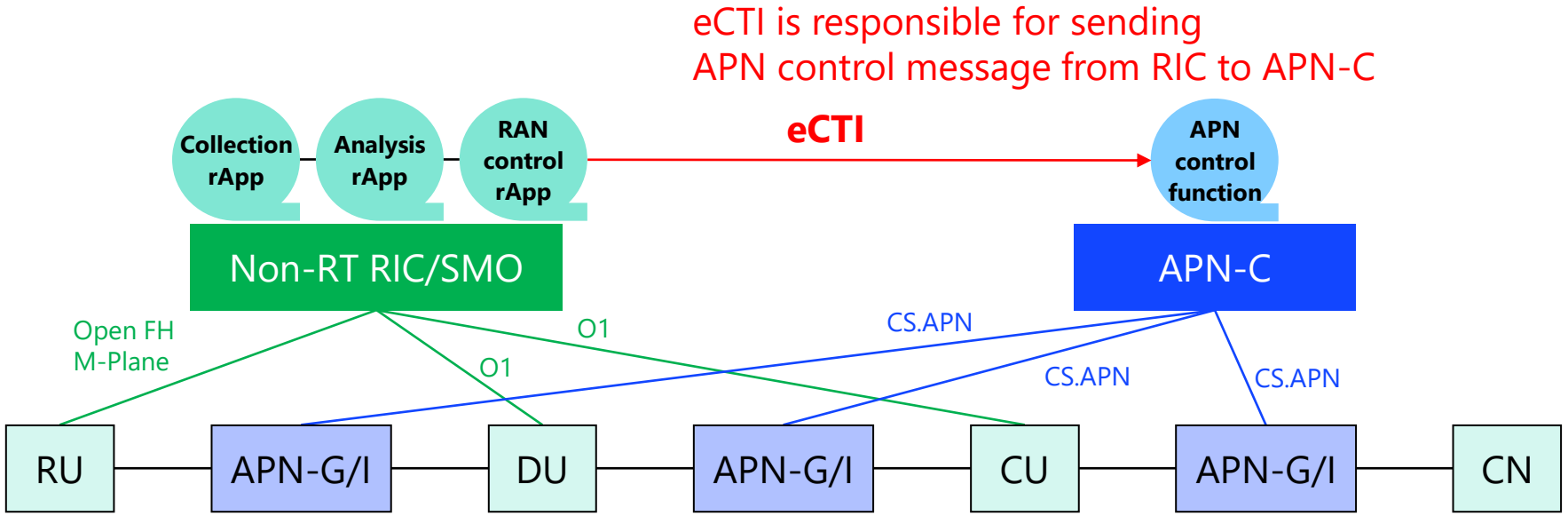
Cooperation between RIC and APN-C

- We proposed the architecture of optical-wireless cooperative control with eCTI between RIC and APN-C (or using Local controller)

What is connected via eCTI	eCTI connection architecture	Real-time requirement	Description
Non-RT RIC/SMO and APN-C		Low	• eCTI between Non-RT RIC/SMO and APN-C is the case of direct optical-wireless cooperation. • Indirect cooperation by E2E orchestrator is an alternative way.
Near-RT RIC and APN-C		Middle	• In this near-real time control case, eCTI may be the only way to optical-wireless cooperation and indirect cooperation by E2E orchestrator may be difficult.
CU/DU and Local controller		High	• This case uses local controller which is not clearly specified both in O-RAN and IGF. • Local controller has the functions of both RAN and APN controllers.

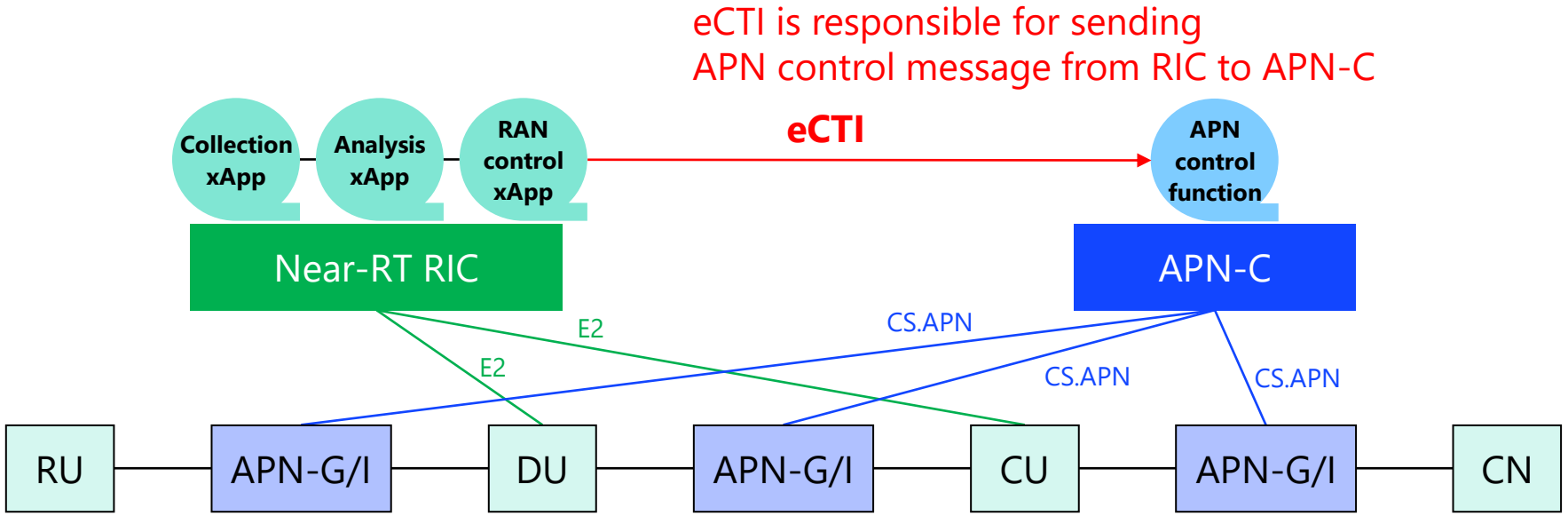
How to cooperate : Non-RT RIC case

- Non-RT RIC functions are implemented as applications called “rApp.”
- Non-RT RIC collects KPIs from CU/DU/RU, analyzes them, and control RAN.
  At the same time, it sends message to APN-C via eCTI for APN control.



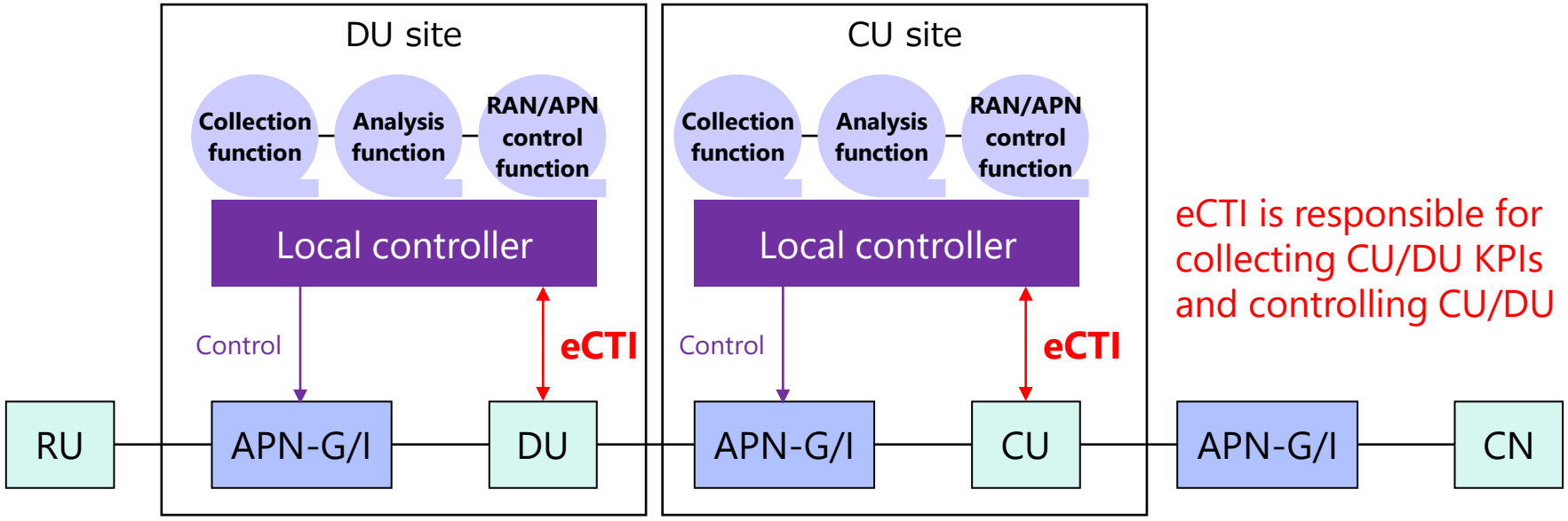
How to cooperate : Near-RT RIC case

- Near-RT RIC functions are implemented as applications called “xApp.”
- As with the case of Non-RT RIC, Near-RT RIC collects and analyzes KPIs from CU/DU, and control RAN while sending message to APN-C via eCTI for APN control.



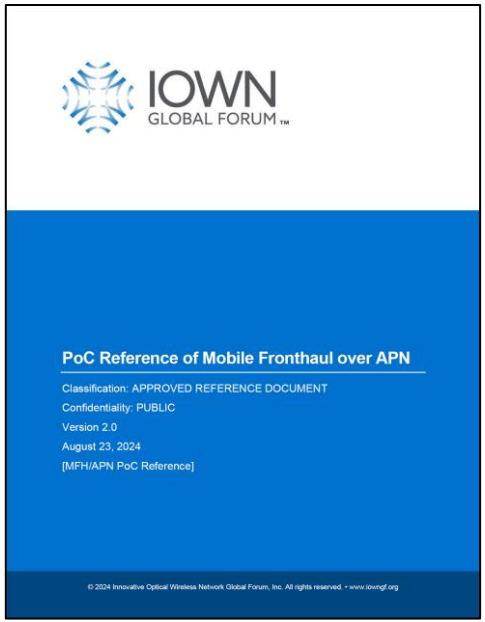
How to cooperate : Local controller case

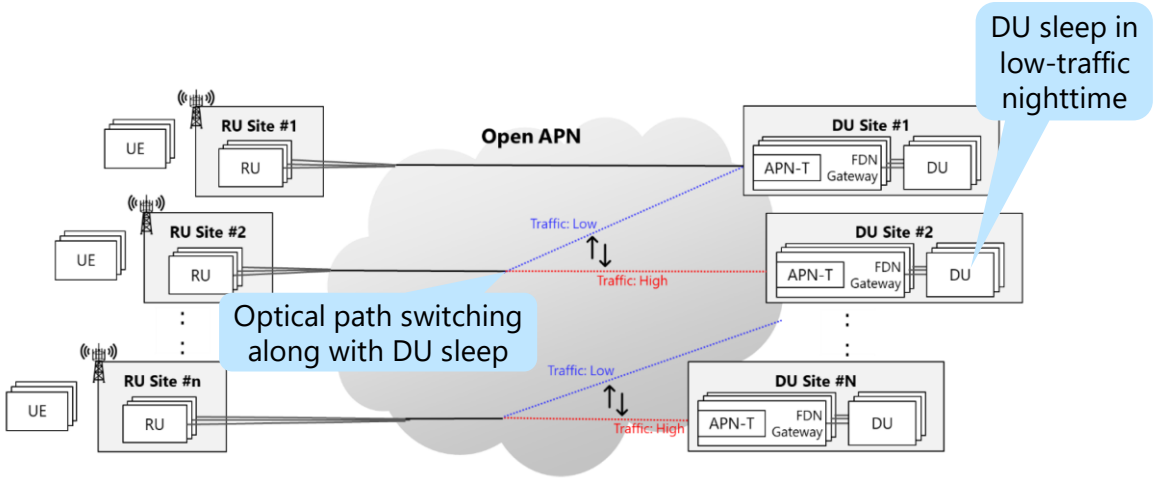
- Local controller is assumed to be located together with CU/DU and APN-G/I in CU or DU site.
- Local controller collects KPIs from CU/DU, analyzes them, and control both RAN and APN.
- eCTI is used to not only collect KPIs from CU/DU but also control CU/DU.



Example use case: Elastic load balancing

- DU sleep for Elastic load balancing in RAN is an example use case.
- DU sleeps in low-traffic nighttime and optical path is switched along with this DU sleep
- We currently conducting proof of concept (PoC) for this use case.

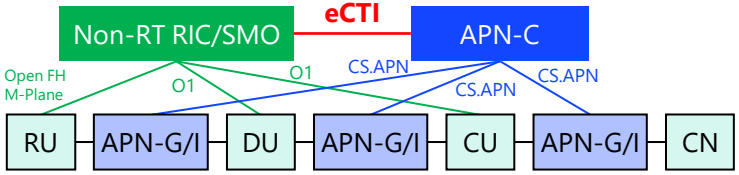
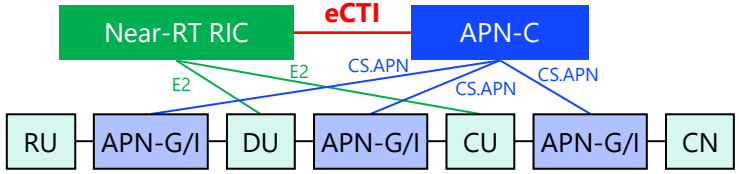
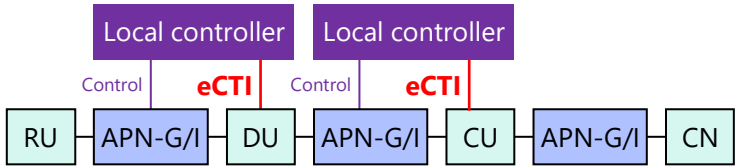




DU sleep scenario of elastic load balancing
(Figure 3 of "PoC Reference of Mobile Fronthaul over APN")

https://iowngf.org/wp-content/uploads/formidable/21/IOWN-GF-RD-PoC_Reference_of_MFH_over_APN-2.0.pdf

Summary

What is connected via eCTI	eCTI connection architecture	Real-time requirement
Non-RT RIC/SMO and APN-C		Low
Near-RT RIC and APN-C		Middle
CU/DU and Local controller		High

- Introduce optical-wireless cooperative control with eCTI for beyond 5G and 6G
- Explain cooperation architecture between RIC and APN-C as a currently discussed topic