A-RoF Based Mobile Fronthaul
- Sustainable Solution toward Beyond-5G Era -

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Net-Centric 2020
[F2-3]

Agenda

- Background
- Functional Split
- A-RoF Based MFH
- Sustainability toward Beyond-5G Era
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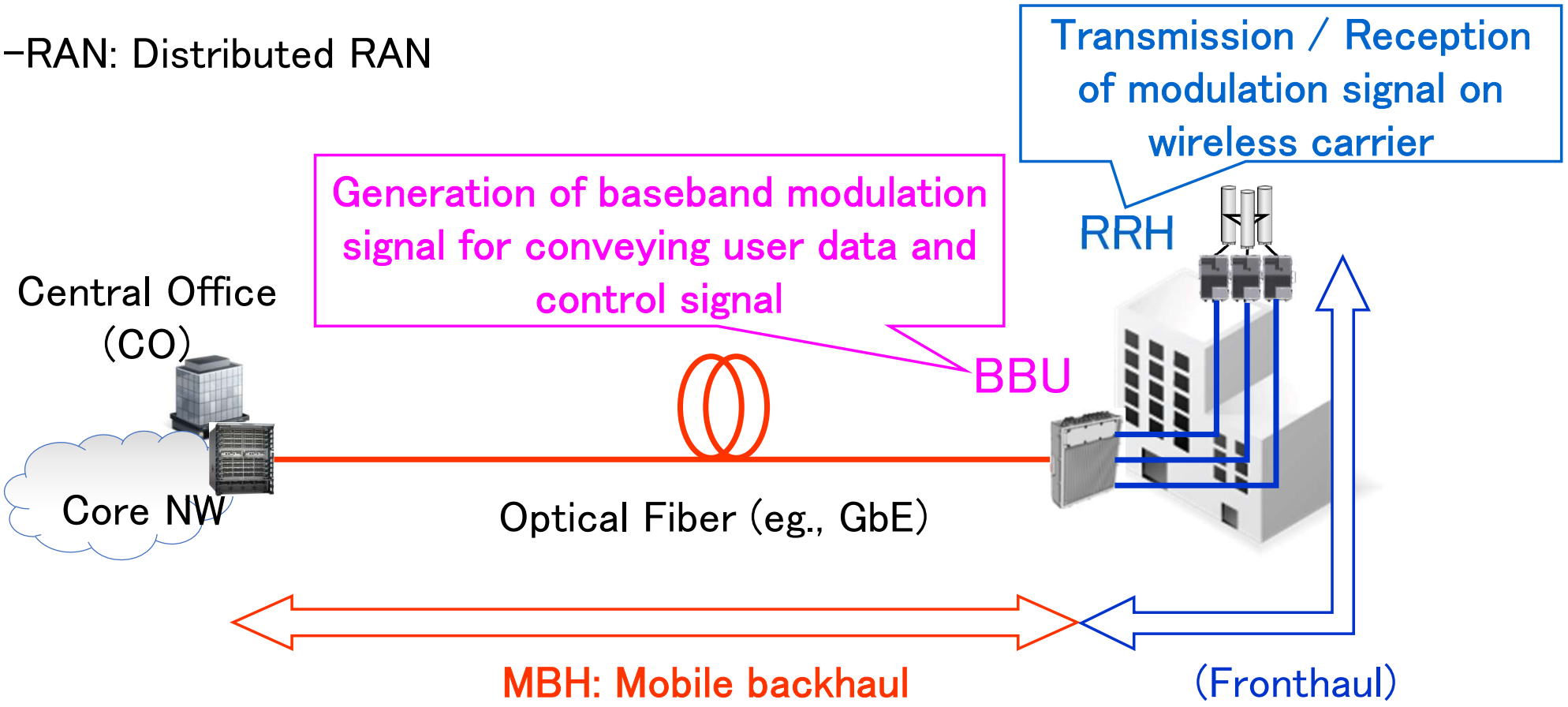
D-RAN Architecture

D-RAN: Distributed RAN

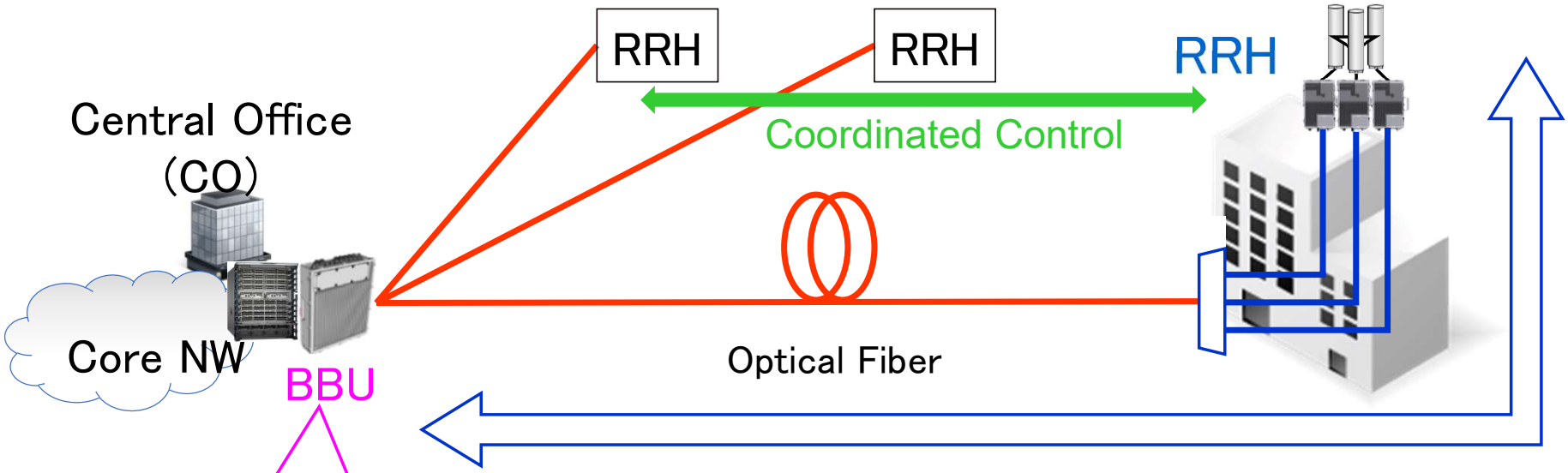


BBU: Baseband Unit RRH: Remote Radio Head

C-RAN Architecture

C-RAN: Centralized RAN

Maximum user throughput in C-RAN = Total capacity of RRH's controlled by single BBU pool



BBU pool for controlling multiple RRH's

Digital Radio-over-Fiber: D-RoF
(CPRI or OBSAI)

MFH: Mobile Fronthaul

CPRI: Common Public Radio Interface

OBSAI: Open Base Station Architecture Initiative

Example of Link Speed Required for D-RoF MFH (CPRI)

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Assumptions for LTE System

- 20 MHz Bandwidth
  → 64 QAM: Max. Freq. Utilization Efficiency 3.75 bps/Hz＝User data rate 75 Mbps

CPRI Specification for ADC

- Sampling Freq.: 30.72 MHz
- Quantization Bits: 15 bits

16.4 times !!

Required Link Speed

$30.72 \times (15 + 15) \times (16/15) \times (10/8) = 1228.8$ Mbps (CPRI Option 2)

- Sampling freq.
- Quant. bits I-ch + Q-ch
- Addition of 1 byte control word with 15 byte payload
- 8B/10B encoding

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Required Specs to 5G Mobile System

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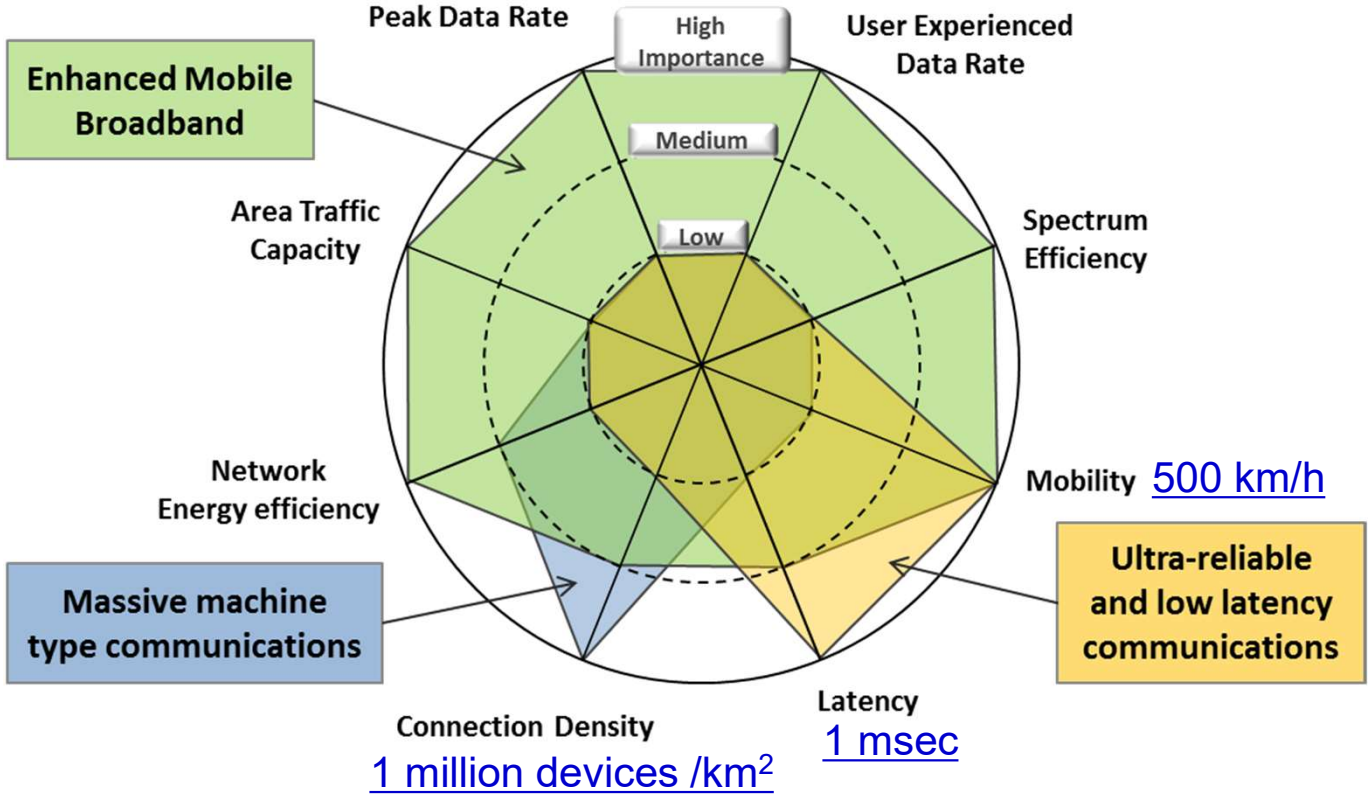
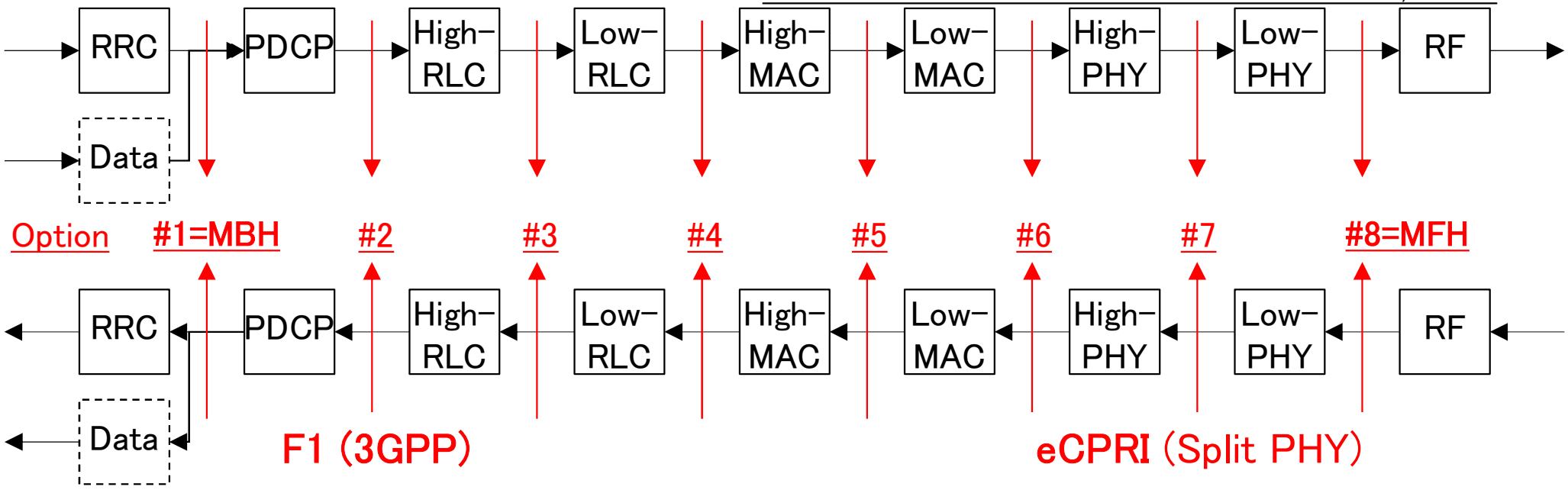
Downlink (DL): 20 Gbps, Uplink (UL): 10 Gbps



Source: ITU-R Rec. M.2083-0, “Framework and overall objectives of the future development of IMT for 2020 and beyond”, Sept. 2015

Functional Split: Definition of Options in 3GPP TS

source: 3GPP TR 38.801 v2.0.0 Release 14, 2017.



Small — Required MFH link speed — Large

trade-off

Power consumption and size of antenna site equipment (easiness of installation)

Low — Performance of coordination control of multiple antennas — High

Example of Link Speeds for Various Options

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Assumptions

Specifications		Options
Bandwidth	100 MHz	All Options
QAM	256 QAM	
MIMO layer	8	
Quantization Bits	2*(7～16) bit	Option 7a～7c
	2*16 bit	Option 8
Number of Antenna Ports	32	Option 7b, 8

Not yet scalable toward final phase of 5G and beyond

Calculation Results

Option	Link speed for Dwonlink MFH (Gbps)	Acceptable Latency	
1	4	10 ms	MBH
2	4.016	1.5～10 ms	F1
3	～4	～100 μs	
4	4	Several hundreds μs	
5	4	250 μs	
6	4.133	250 μs	
7a	10.1～22.2	250 μs	eCPRI
7b	37.8～86.1	250 μs	
7c	10.12～22.2	250 μs	
8	157.3	250 μs	CPRI

source: [1] 3GPP TR 38.801 v2.0.0 Release 14, 2017, Table A-1., [2] eCPRI Specification V1.0 (2017-08-22), Fig.5.

Sliced RAN's with Virtual MFH with Different Functional Split

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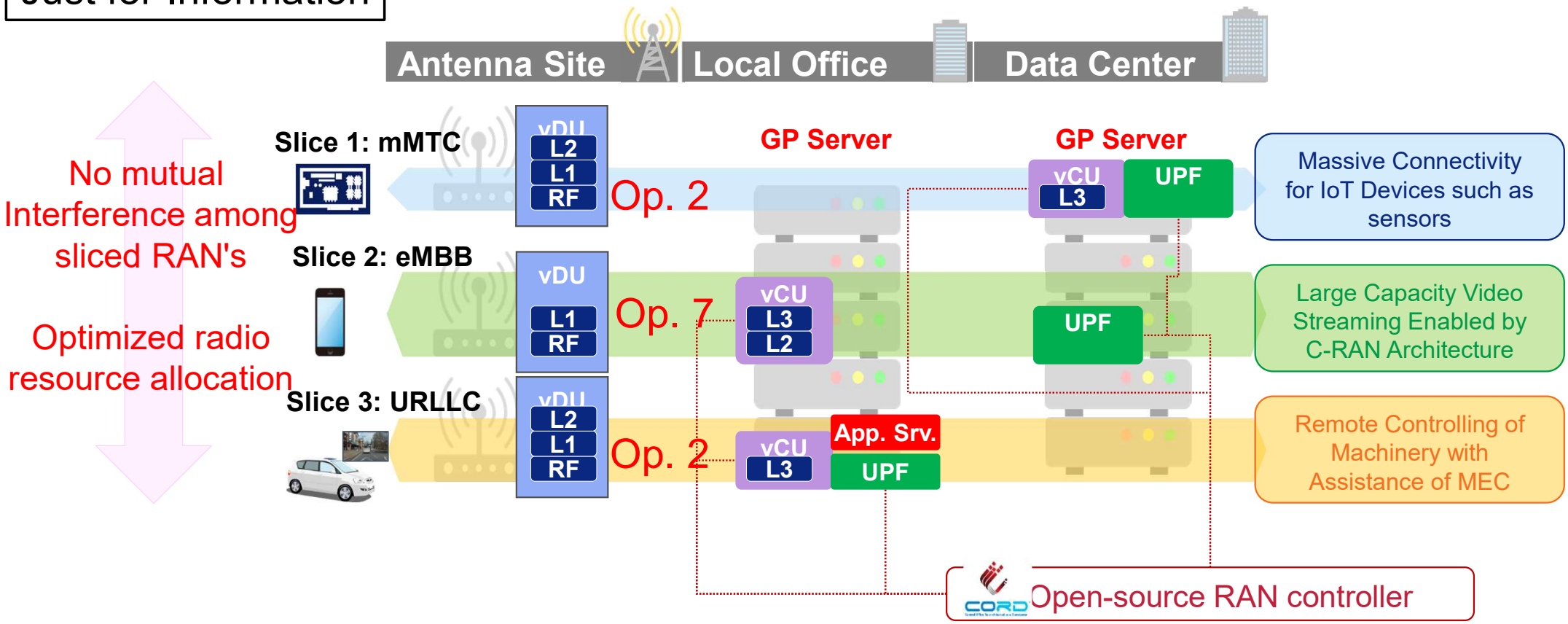
Just for Information



※CORD is the trade mark registered by Open Networking Foundation
URL: https://www.opennetworking.org/solutions/m-cord/

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Target toward Final Phase of 5G

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Downlink (DL): 20 Gbps, Uplink (UL): 10 Gbps

Establishment of technologies for constructing MFH capable to accommodate max. 5G DL throughput with **a high transmission efficiency.**

400 MHz/channel bandwidth and 64 QAM 5G NR signal
-> 1.5 Gbit/s channel -> 21 Gbit/s with 14 channel

1 million devices /km²

Source: ITU-R Rec. M.2083-0, “Framework and overall objectives of the future development of IMT for 2020 and beyond”, Sept. 2015

Fundamental Concept of A-RoF: Analog Radio-over-Fiber

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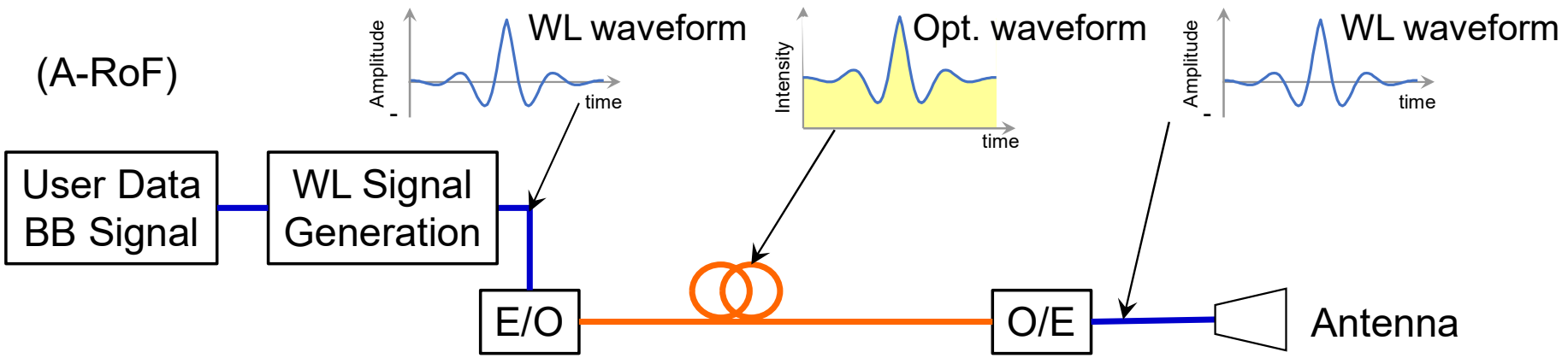
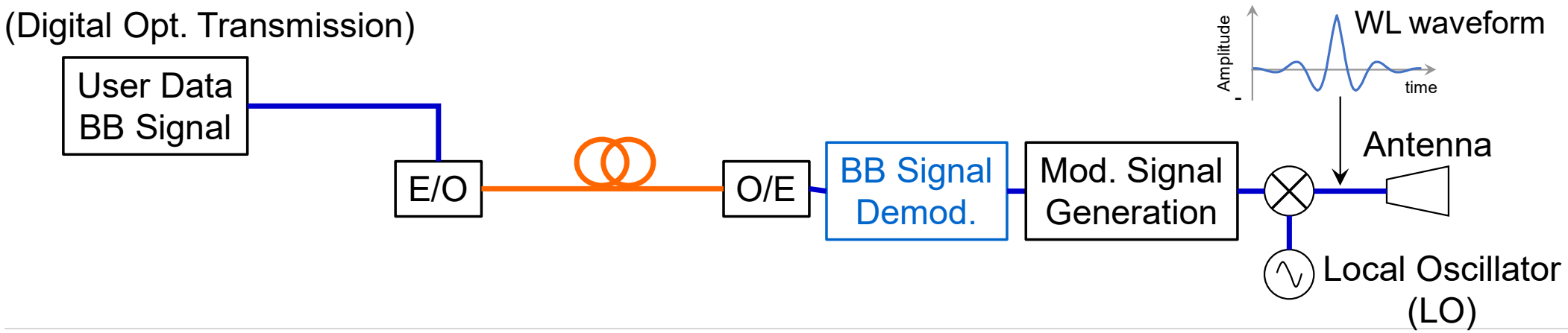
Waveform of wireless (WL) signal is conveyed as it is, no demodulation of baseband (BB) signal.





Merits of A-RoF MFH

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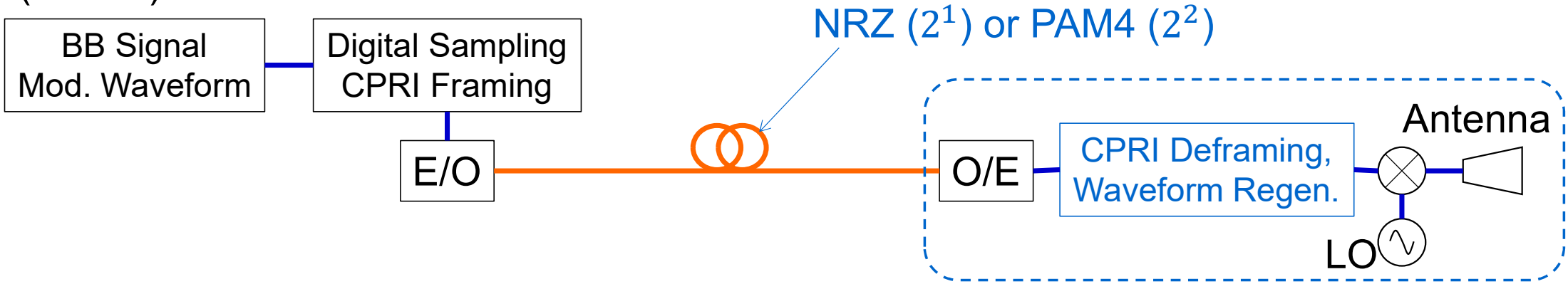
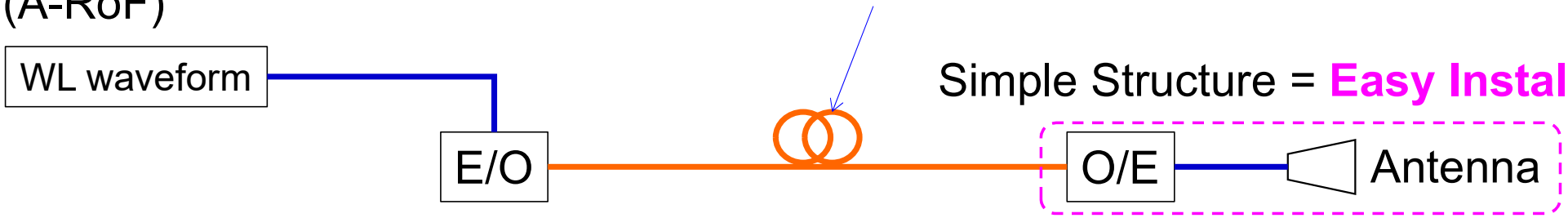
(D-RoF)



High Freq. Utilization Efficiency (64QAM = 2^6, 256 QAM = 2^8)
by **IM-DD-Like Simple Architecture** in Optical Transmission Part

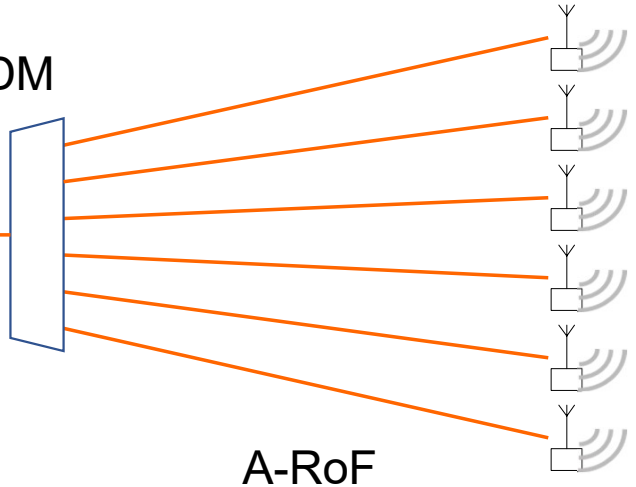
(A-RoF)



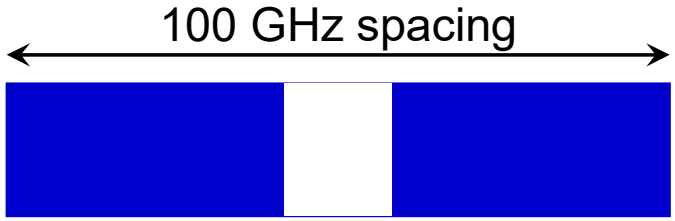
Coordination Control Ability Compatible to D-RoF with **Low Latency**

Simple WDM?

Yes, we can, but...

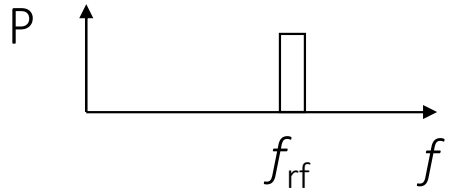


eg. (400 MHz^{W} 5G NR + 100 GHz DWDM) X $N\lambda$



400 MHz^{W} Channel XN channels

A-RoF

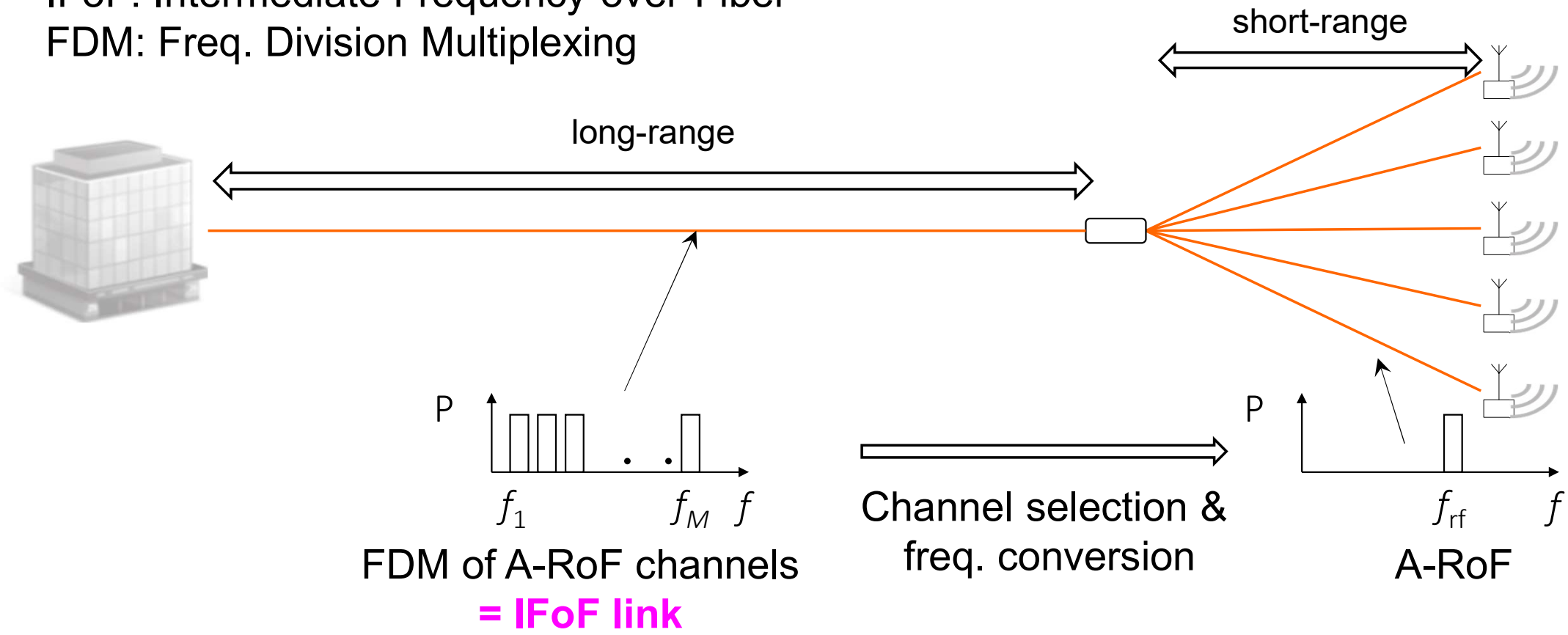


Low transmission efficiency comparing with potential bandwidth of a single optical carrier

-> Widening of signal bandwidth for higher transmission efficiency

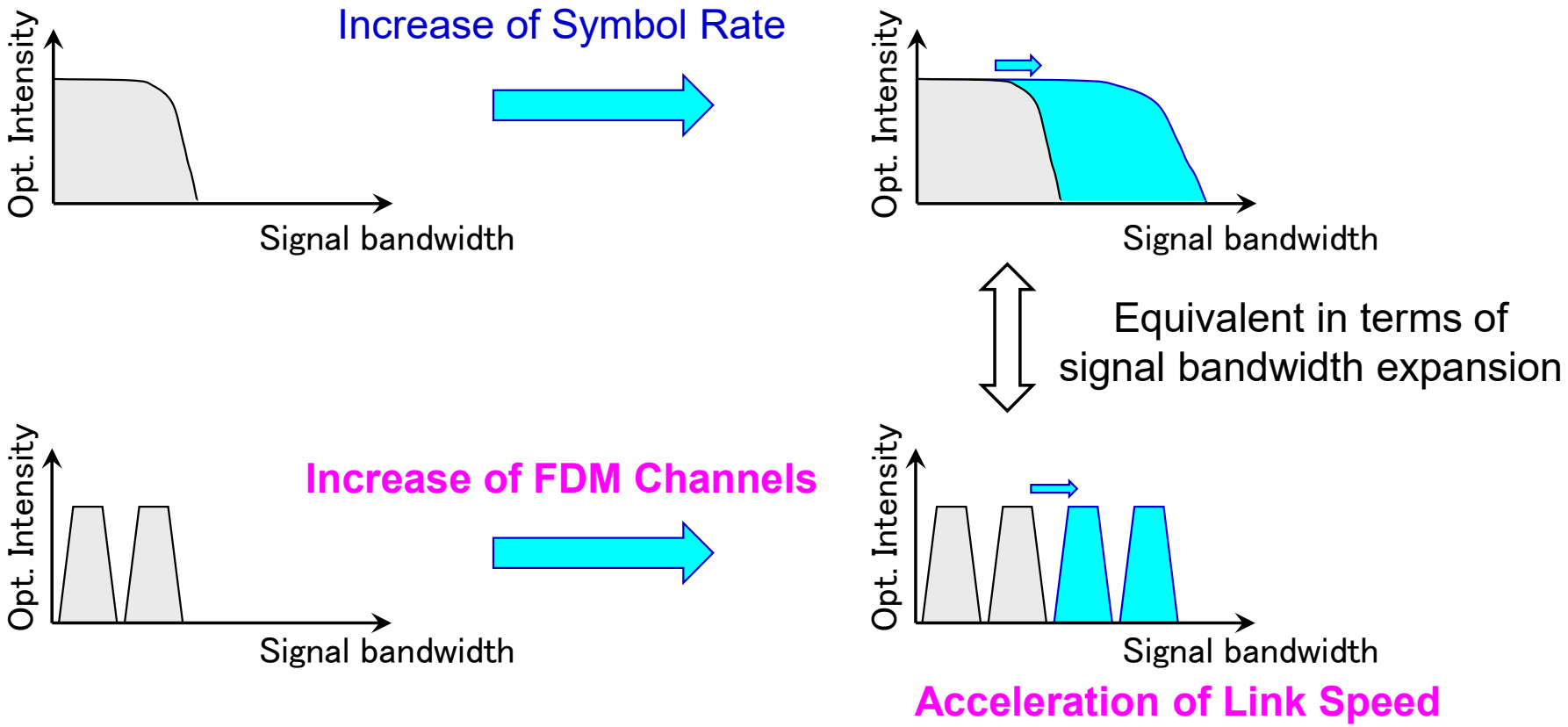
Introduction of IFoF: FDM of A-RoF Channels

IFoF: Intermediate Frequency-over-Fiber
FDM: Freq. Division Multiplexing



IFoF: Acceleration of Link Speed

Digital Opt. Transmission = TDM (Time Division Multiplexing) of Symbols



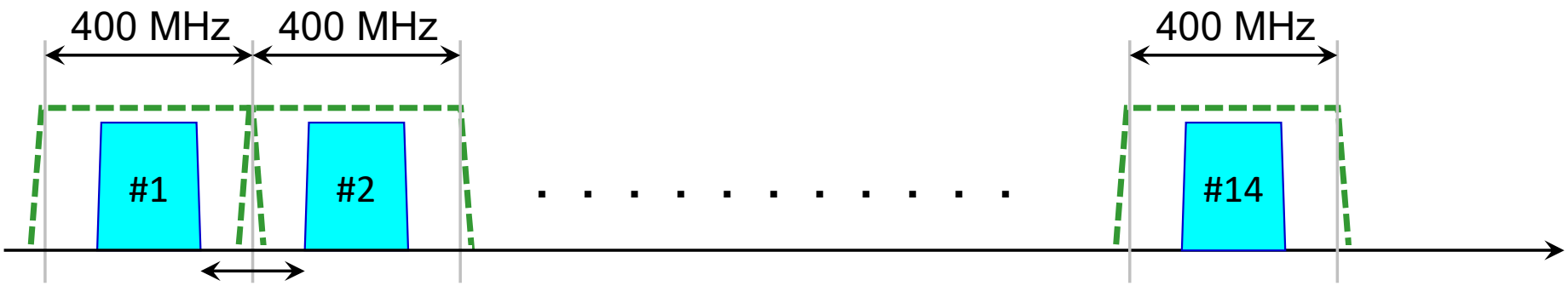
Key Numbers

Assumption: 5G NR signal having 400 MHz bandwidth and 64 QAM format (3.75 bit/s/Hz)

-> 1.5 Gbps per channel

-> **14 channels** = 21 Gbit/s -> enough for 5G DL

"Nominally 400 MHz wide"
5G NR signal

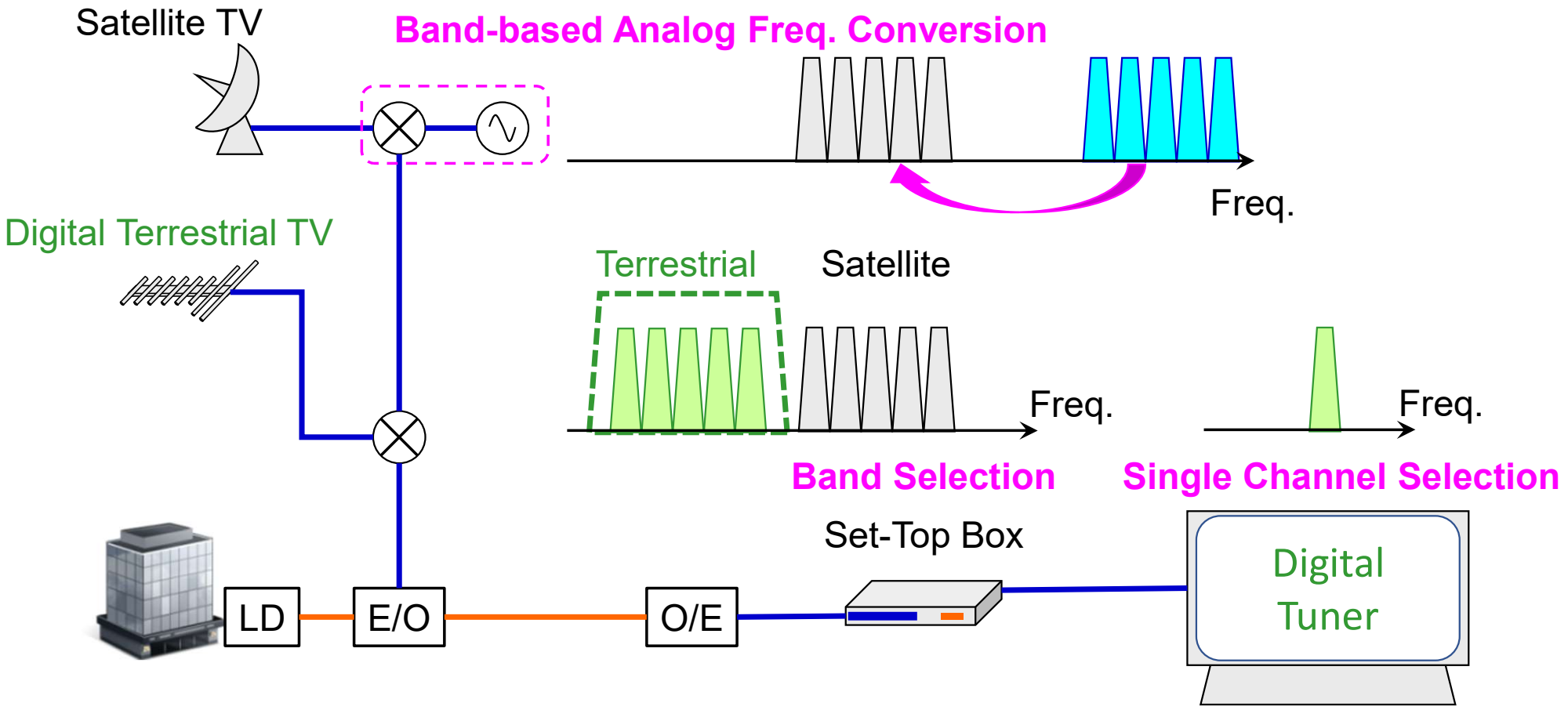


Wide enough for **"digital filtering"**

14 channels = **5.6 GHz**

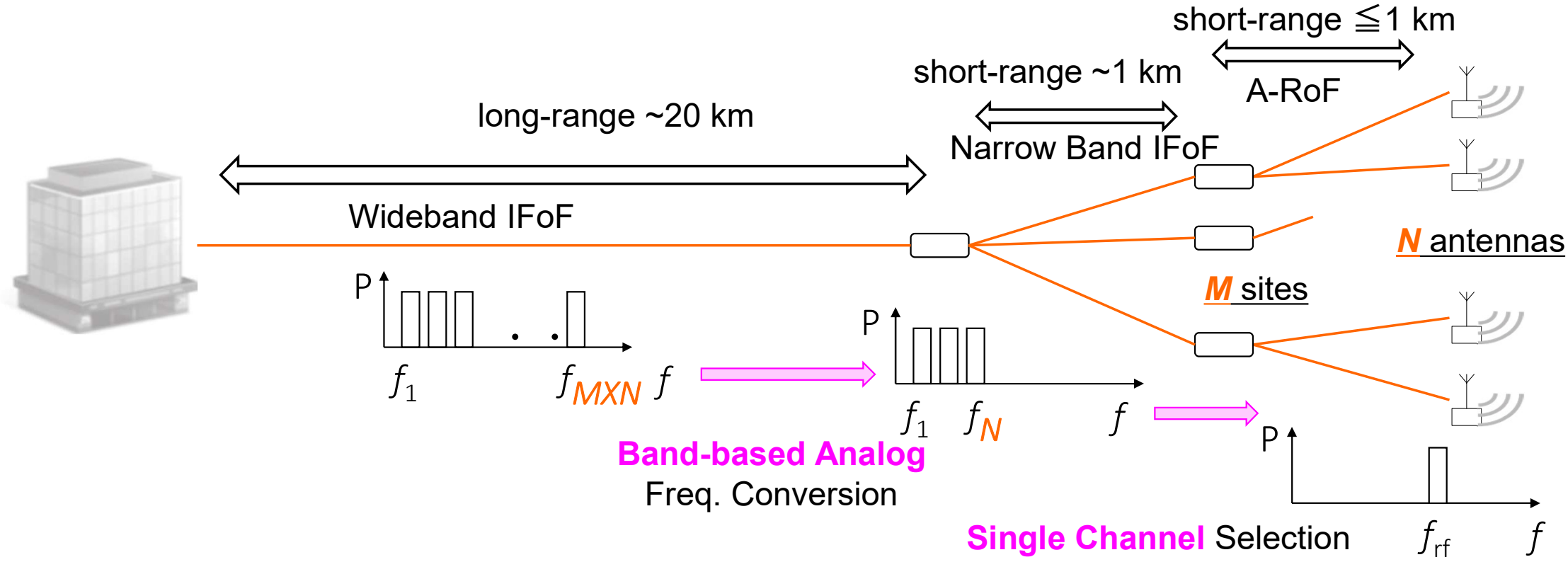
5.6 GHz bandwidth is **"too wide"** for ADC
on commercially available FPGA board
-> Constraint of Current Technology Level

Suggestion from CATV System



Band-based Analog Processing + Channel by Channel Digital Processing

Proposed MFH Architecture Exploiting IFoF and A-RoF



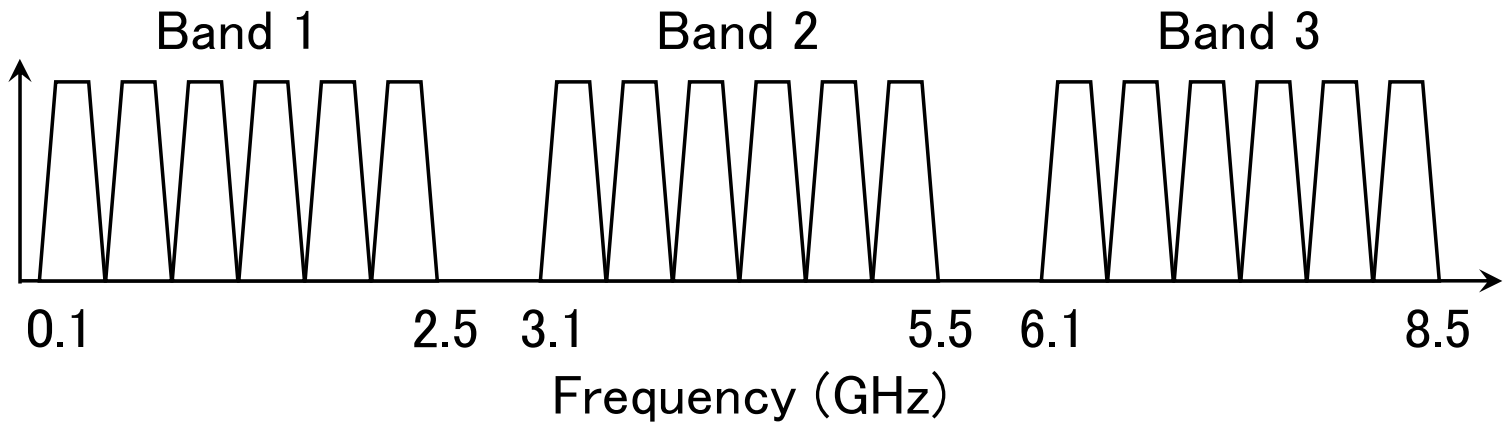
Requirement from Max. 5G DL User Throughput

M bands X *N* antennas ≧ 14 channels

Channel Allocation

Requirement from Max. 5G DL User Throughput (400 MHz bandwidth, 64 QAM)

M bands X *N* antennas ≧ 14 channels

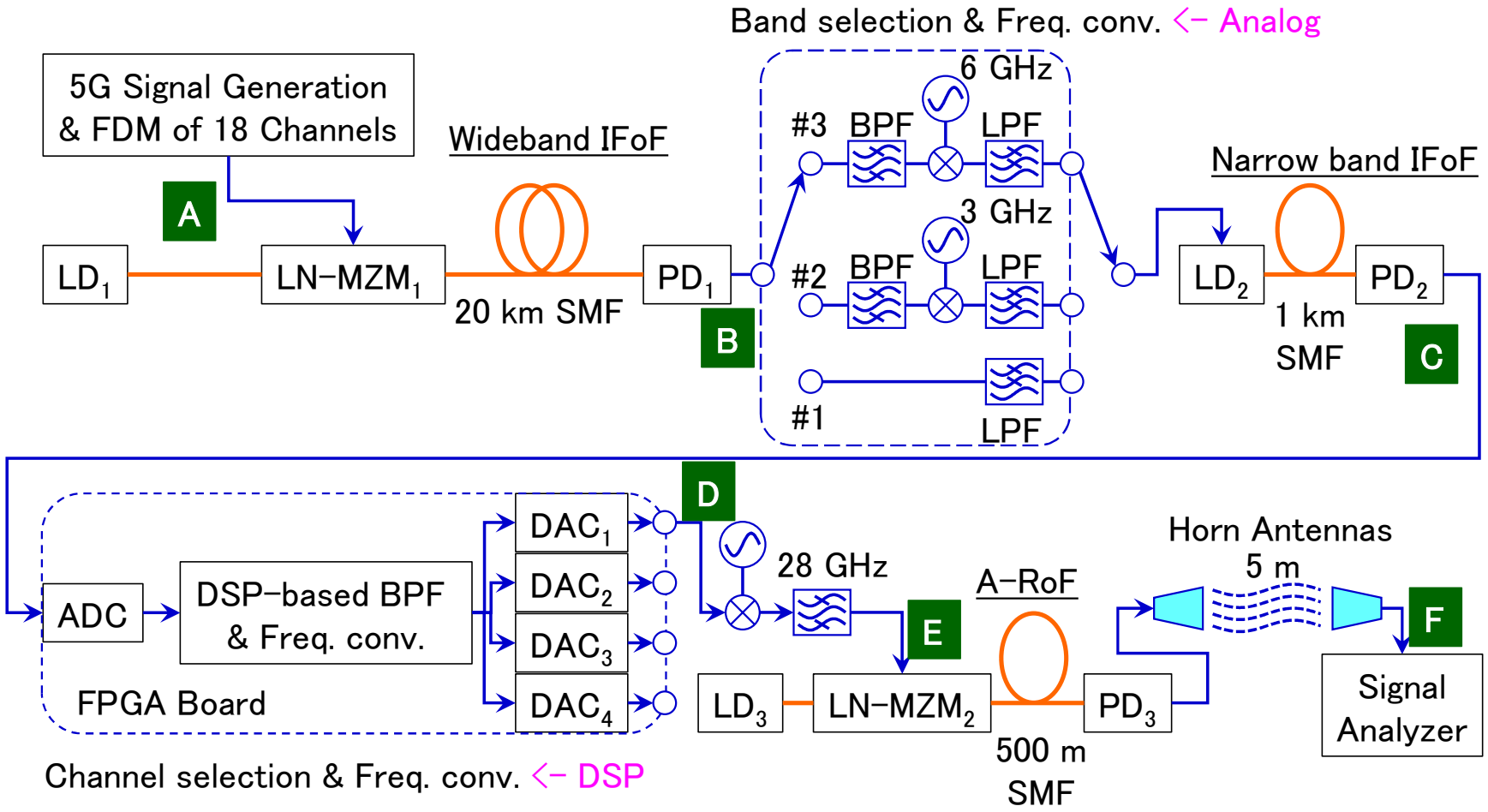


6 channels / band X 3 bands = 18 channels

-> 27 Gbit/s User Throughput in 8.5 GHz total bandwidth

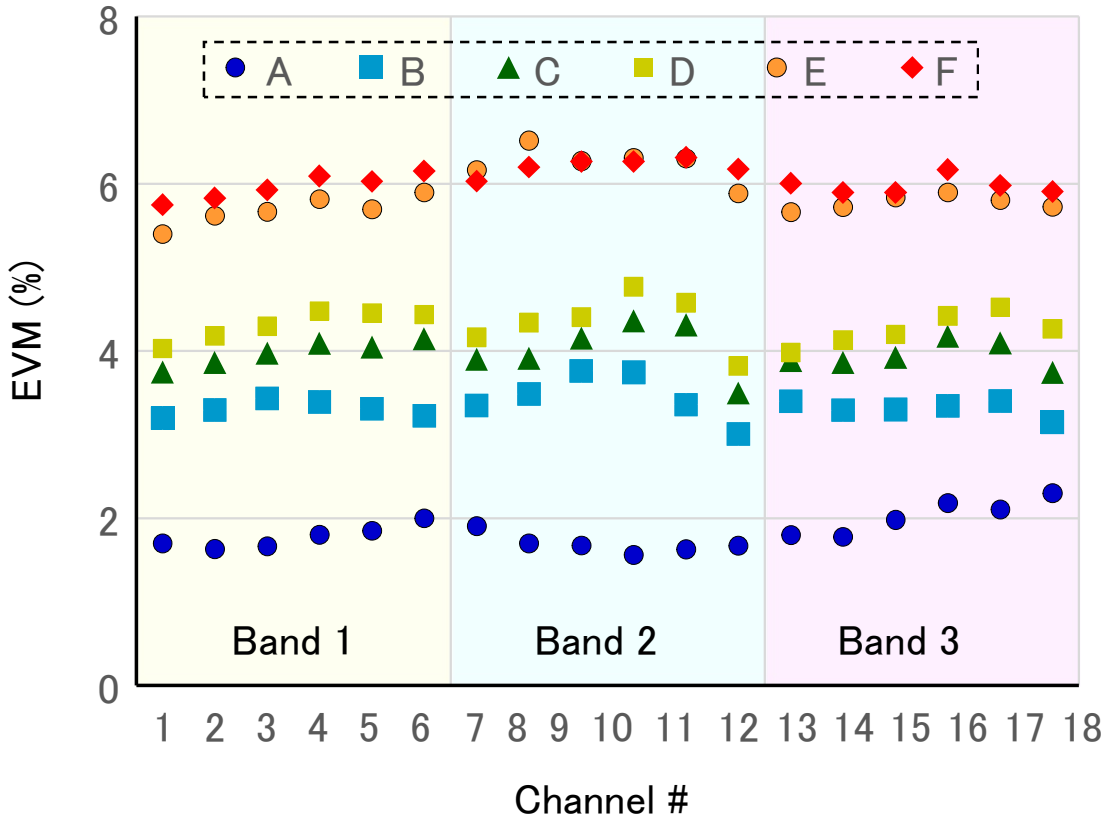
∴ 3.18 bit/s/Hz

Experimental Setup



Most of the components are commercially available and designed for digital optical transmission.

Experimental Results



All channels satisfy the criteria of signal quality defined in 3GPP specifications: EVM ≦ 8%.

Further details will be reported in Paper Tu1G-5 in ECOC 2020 (Dec 8th, 2020, Tue, 9:00 AM.).

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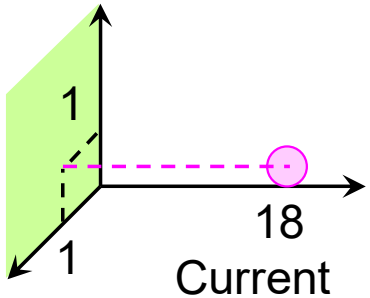
Extension of Capacity

Current: 27 Gbit/s user throughput without optical multiplexing (i.e., single lane)

SDM (Space division multiplexing)
= Number of cores in multi-core fiber

Product
= number of lanes



WDM =
= Number of wavelengths

Current

FDM = Number of channels
(equivalent to symbol rate in TDM)

Number of lanes can be increased **without additional developments.**

40 lanes (1.08 Tbit/s) can be realized by only DWDM or by combination of CWDM and SDM.

∴ Sustainably extendable toward Beyond 5G era.

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Summary

- C-RAN architecture, introduced in 4G, will be still essential for capacity expansion toward final phase of 5G and beyond
- Functional split will be introduced for "initial stage" of 5G, but it is not scalable toward "final stage" of 5G and beyond
- IFoF･A-RoF hybrid MFH for DL is verified to have enough capacity for accommodating max. 5G user throughput of 20 Gbit/s
- IFoF･A-RoF hybrid MFH has sustainability toward Beyond-5G Era

Acknowlegement

Part of the research results has been achieved by the R&D contract **"Wired-and-Wireless Converged Radio Access Network for Massive IoT Traffic (JPJ000254)"** with **the Ministry of Internal Affairs and Communications, Japan**, for radio resource enhancement,

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Thank you for your attentions!!