Proposal of an Efficient Multiplexing Scheme based on OFDMA and Massive MIMO Beamforming

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This research is supported by the Ministry of Internal Affairs and Communications in Japan.

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Research Background

- Our Assumption on the "5G Advanced" Environment
  - mmWave is one of the key components for 5G Adv.
  - Various Services Require Combinations of 5G key features, such as Very High Speed, Large Capacity, Very Low Latency, Low Error Rate.
  - 5G Adv. Network, where various services are connected, is assumed to have Dynamically Changing Traffics in time and locations.
    - Additionally, traffic amount itself could be 5 times more than now.

Research Background

- To Realize Highly Reliable 5G Adv. Network under the environment above, we started a R&D project as follows.
  - A Network Control Technology, which predicts shadowing considering changes of circumstances and provides various services continuously. (Theme-1)
  - A Wireless Access Technology, which provides highly reliable communication services, making the most of high-density mmWave base stations. (Theme-2)
  - An Adaptive Control Technology for the entire RAN in order to enable high-accuracy accommodation, assuming high-density base station deployment. (Theme-3)
  - A Base station Function Placement Technology applying RAN virtualization technology, that is expected to become popular in the future, in order to ensure high reliability while realizing flexible adaptive control. (Theme-4)

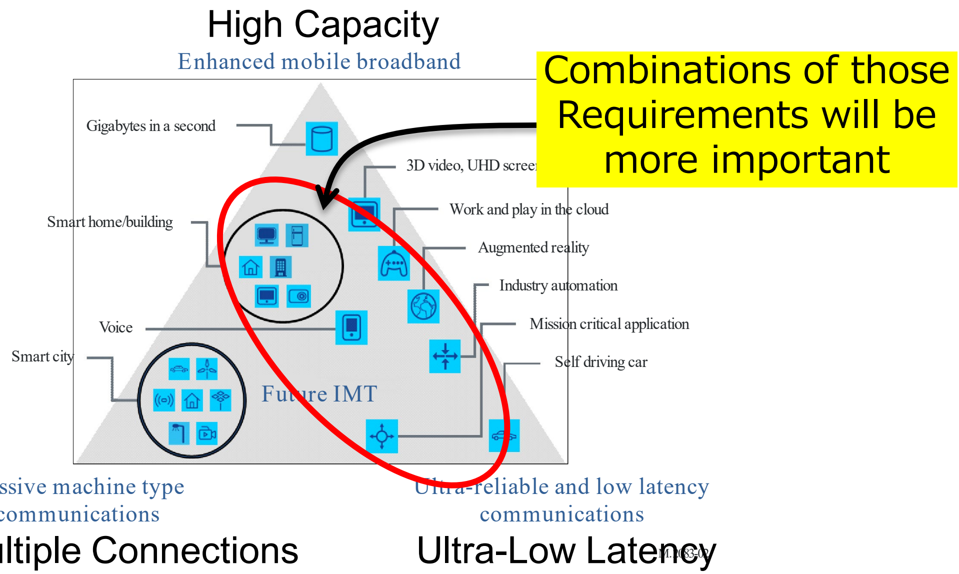
Assumptions

- In the period around 2025, where 5G has already been spread, it is important not only to improve communication performance, but also **to realize highly reliable communication services that combine high capacity, ultra-low latency, and super-multiple connections.**

  Background: Spread of Highly Autonomous Mobility (i.e. Robot), AR, MR and IOT, etc.
  - Divergence of communication quality requirements and it dynamically fluctuates.
  - To improve connectivity, one thing may have more than one communication terminal.

Usage scenarios of IMT for 2020 and beyond

(from ITU-R M.2083 Figure.2)

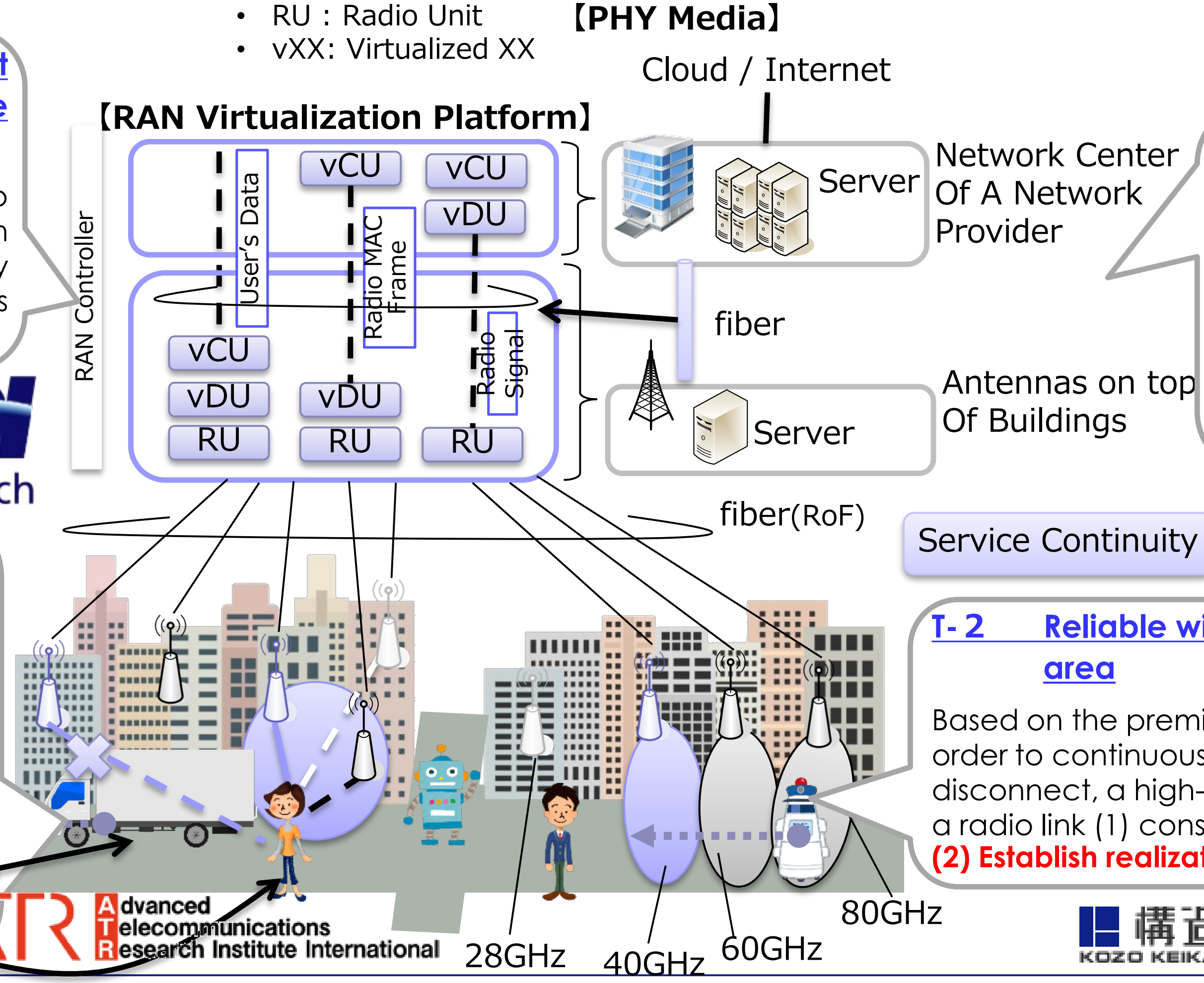


Our Assumptions about Reliability Requirements.

Items	IMT-2020 (Definitions on ITU-R M.2410)	Our Assumptions
Area traffic capacity	10 Mbit/s/m^2 (in-door)	50 Mbit/s/m^2 (in-door/out-door)
Connection density	1,000,000 devices/km^2 = 1 device/m^2	100 device/m^2 (Where the terminals concentrate locally)
Reliablity	1-10^{-5} (Edge of URLLC services in urban area)	Same level as IMT-2020. But the requirement may expand to other than URLLC.
Mobilty interruption time	10 ms (eMBB & URLLC)	Same level as IMT-2020. But the requirement may expand to other than URLLC.

Research Subjects and Major Contributions to High Reliability

- CU：Centralized Unit
- DU：Distributed Unit
- RU：Radio Unit
- vXX: Virtualized XX



QoS and Traffic Capacity

T- 4 Base station function placement technology to realize adaptive RAN

Apply RAN virtualization technology to provide more diverse services with high reliability and flexibility, and adaptively deploy RAN base station functions according to communication requirements

Service Continuity and QoS

KDDI Research

T- 1 Highly Riliable Network Control Technology Supporting Nano Area

To realize stable and continuous provision of services even when the shielding situation changes due to changes in the surrounding environment, the following is realized.

A) Pre-prediction technology for shadowing effects
B) Network control method that can maintain service quality

ATR Advanced Telecommunications Research Institute International

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Panasonic

東北大学 TOHOKU UNIVERSITY

Traffic Capacity and QoS

T- 3 T-3 Wireless integrated control technology to realize adaptive RAN

Realizes the next wireless integrated control technology for the entire RAN, which can adaptively respond to dynamic traffic fluctuations and volume increases, and contribute to the reliable provision of services.

Service Continuity

UEC TOKYO 国立大学法人 電気通信大学 AWCC Advanced Wireless and Communication Research Center

T- 2 Reliable wireless access technology for nano area

Based on the premise of using the millimeter wave band, in order to continuously secure a radio link that is easy to disconnect, a high-density base station can be used to secure a radio link (1) construction of a radio communication system, **(2) Establish realization technology**

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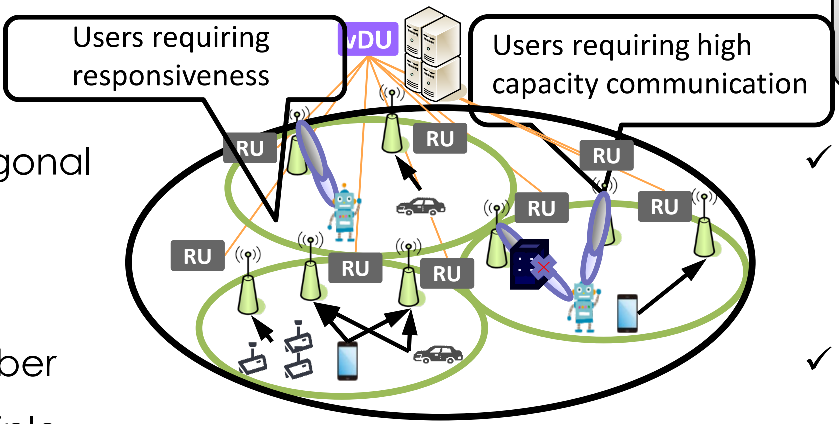
Wireless Access Methods “PHLEXIBLE”

PHY layer technology for nano area BSs (PHLEXIBLE)

- Densely installed base stations (= RU) operate with a common vDU
  - ✓ Divided users into (1) quick response and high reliability, and (2) high speed and high reliability, and PHY layer technologies (PHLEX1, PHLEX2) suitable for each are allocated to Resource Block (RB).
  - ✓ Once you join the Nano Area BS, all the controls are closed on the data plane.

PHLEX1)
Realization of **Quick and Reliable links**

- ✓ New method combining non-orthogonal random access method and compressed sensing
- ✓ Each base station uses a large number of antennas and realizes quick multiple access using a compressed sensing framework called MMVR



PHLEX2)
Realization of **High-Capacity and High-Reliability links**

- ✓ Overcome overhead until communication start by low-computation and high-accuracy channel estimation
- ✓ Highly reliable links are realized by forming beams by multiple base stations in consideration of unexpected interruption and other disturbances.

Theory and the Implementation

	PHLEX1	PHLEX2
Theory (UEC)	Research of **Grant Free NOMA** access method to realize low latency and highly reliable access link for IoT type applications.	Research of **Inter Base-Stations Cooperative Beamforming** method to realize large capacity and highly reliable access link.
Realization (KKE)	• Implementation of GF-NOMA access method on 5G NR OFDM wireless interface.	• Realize Dramatic Improvement of Beamforming Resolution and Accuracy with Full-Digital Beamforming Method.
	• Realization of Fast (Real-Time) Radio Channel Estimation. • Propose mmWave mMIMO SDR Platform Supporting Flexible Switch of Multiple Wireless Access Methods according to the Application's Request, as well as adaptability of RAN virtualization.	

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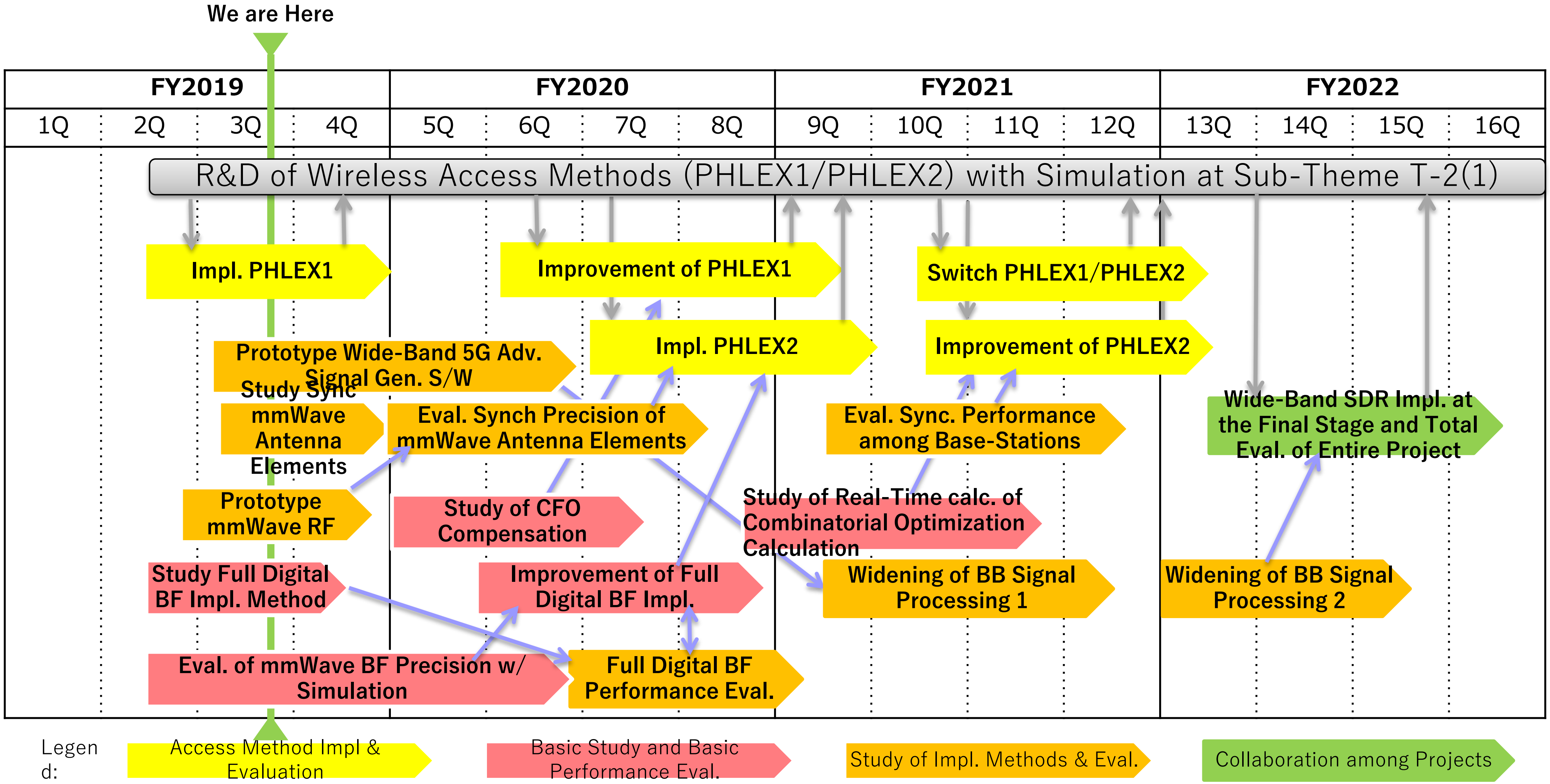
Implementation Challenges

- SDR Implementation Challenges of PHLEX1, PHLEX2

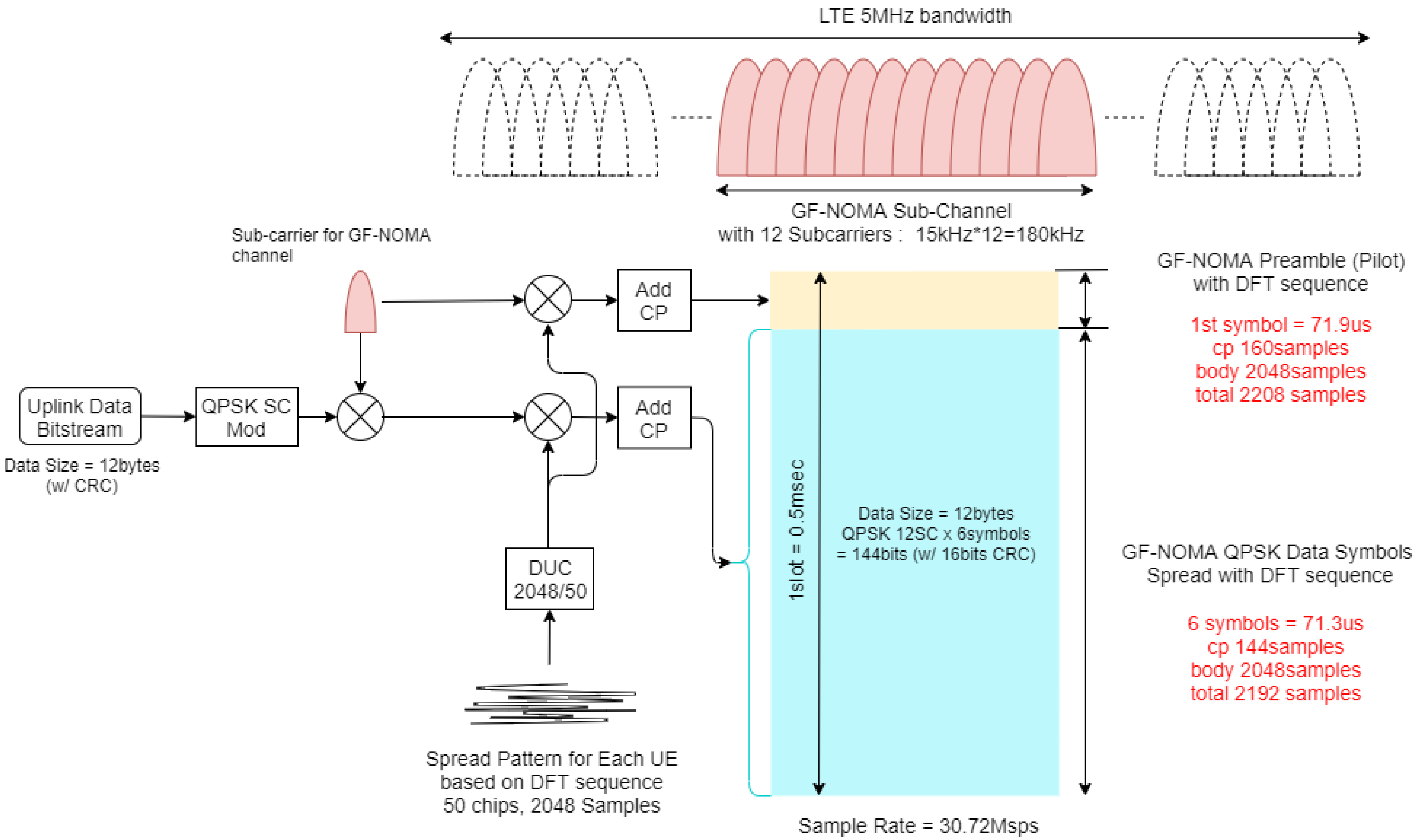
Items	Traditional SDR Platform	Our SDR Platform	Implementation Challenges
Frequency	< 6GHz	up to mmWave	(1) Compensation of **larger Carrier Frequency Offset (CFO)**
Signal Band Width	20 ~ 100MHz	100MHz～	(2) **Virtualizable Real-Time Signal Processing** of wider bandwidth baseband signal
massive MIMO	Digital BF(2～8ch) + Analog BF	Hybrid / Full-Digital BF (16ch～32ch)	(3) **Full-Digital BF** Implementation under the limitation of **FPGA circuit size and low power consumption** at RU (4) **High Precision Timing Synchronization method** among mmWave antenna elements.
Beam Resolution	>10deg	< 1deg	
Combinatorial Optimization Calculation	-	Real-Time Combinatorial Optimization Engine	(5) **Real-Time calculation of Combinatorial Optimization Problems**, required to realize 5G Adv. wireless access method, such as wireless channel estimation, beam forming, e.t.c.
I/F for RAN Virtualization	-	Virtualizable DU	(6) Establishment of standard I/F among DU and multiple RUs to support **full-digital BF and cooperative BF**. Contributes to **International Standardization.**

※ BF: Beamforming

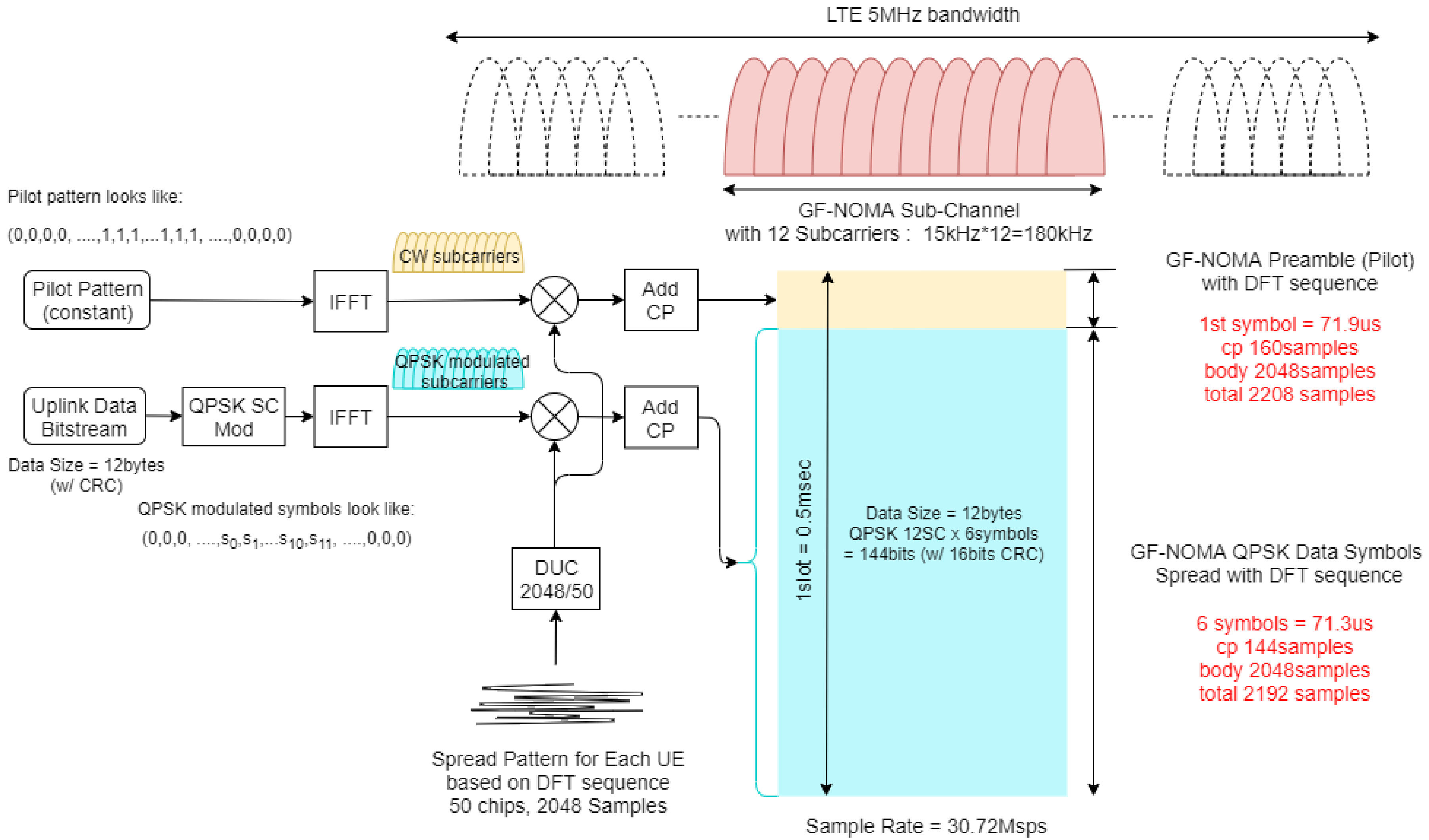
R&D Schedule


We are Here
FY2019
FY2020
FY2021
FY2022
1Q
2Q
3Q
4Q
5Q
6Q
7Q
8Q
9Q
10Q
11Q
12Q
13Q
14Q
15Q
16Q
R&D of Wireless Access Methods (PHLEX1/PHLEX2) with Simulation at Sub-Theme T-2(1)
Impl. PHLEX1
Improvement of PHLEX1
Switch PHLEX1/PHLEX2
Impl. PHLEX2
Improvement of PHLEX2
Prototype Wide-Band 5G Adv. Signal Gen. S/W
Study Sync mmWave Antenna Elements
Eval. Synch Precision of mmWave Antenna Elements
Eval. Sync. Performance among Base-Stations
Wide-Band SDR Impl. at the Final Stage and Total Eval. of Entire Project
Prototype mmWave RF
Study of CFO Compensation
Study of Real-Time calc. of Combinatorial Optimization Calculation
Study Full Digital BF Impl. Method
Improvement of Full Digital BF Impl.
Widening of BB Signal Processing 1
Widening of BB Signal Processing 2
Eval. of mmWave BF Precision w/ Simulation
Full Digital BF Performance Eval.
Legend:
Access Method Impl & Evaluation
Basic Study and Basic Performance Eval.
Study of Impl. Methods & Eval.
Collaboration among Projects

Single Carrier PHLEX1 on LTE



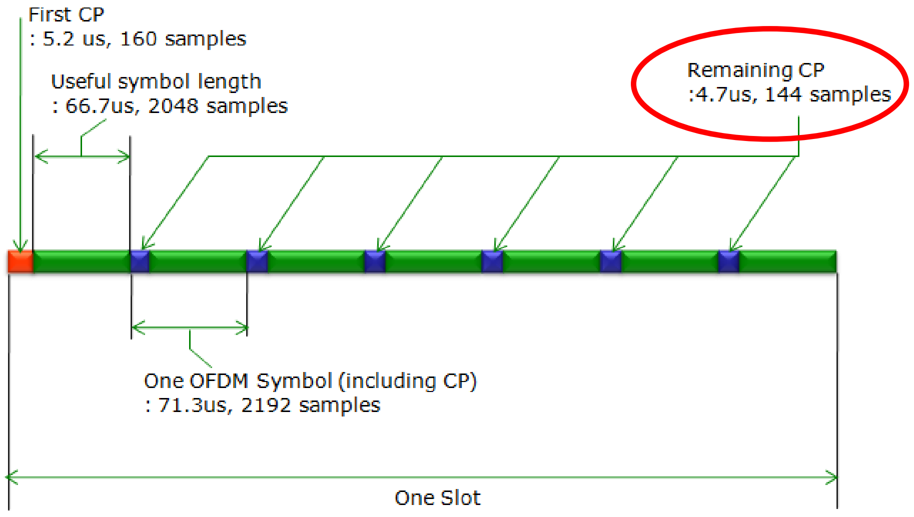
OFDM version of PHLEX1 on LTE

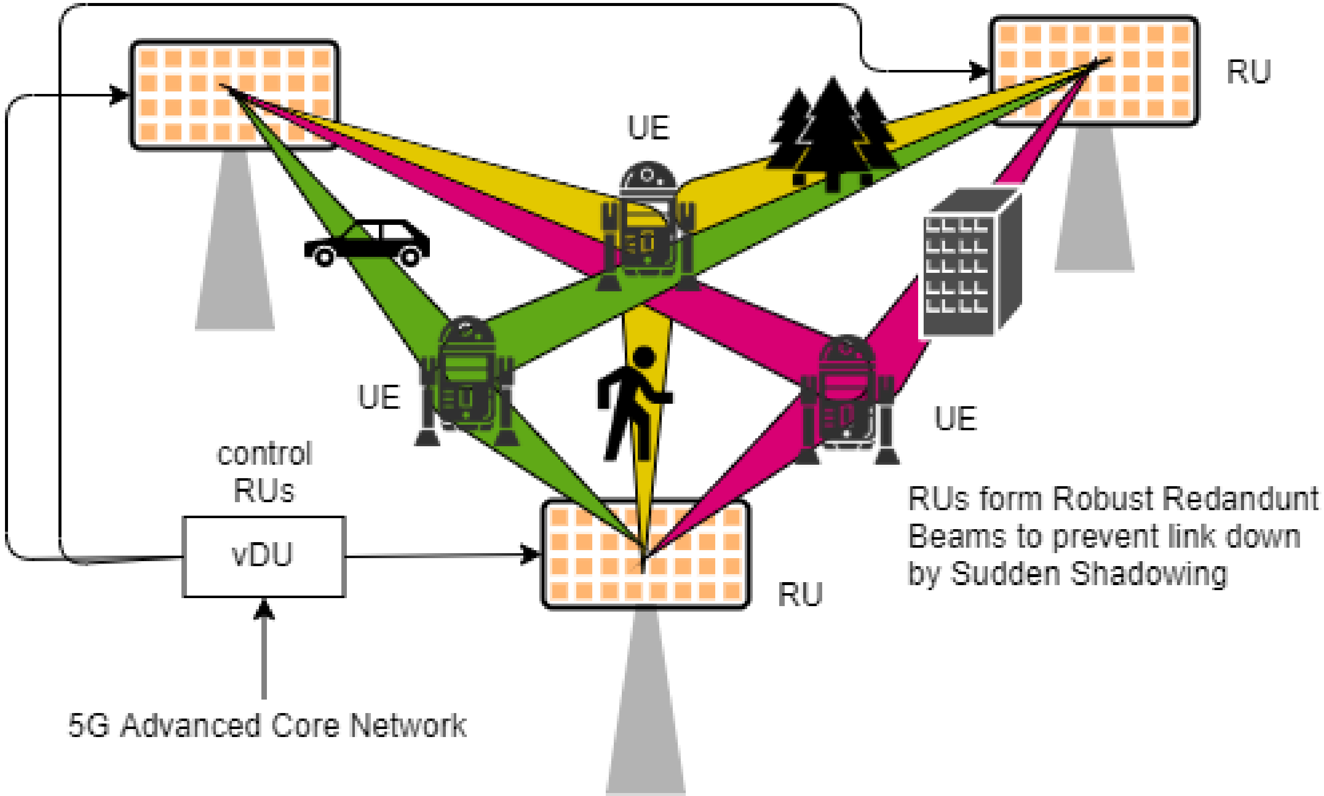


Cooperative Digital Beamforming w/ Multiple RUs for PHLEX2

- Challenges
  - **Precision Synchronization among RUs**

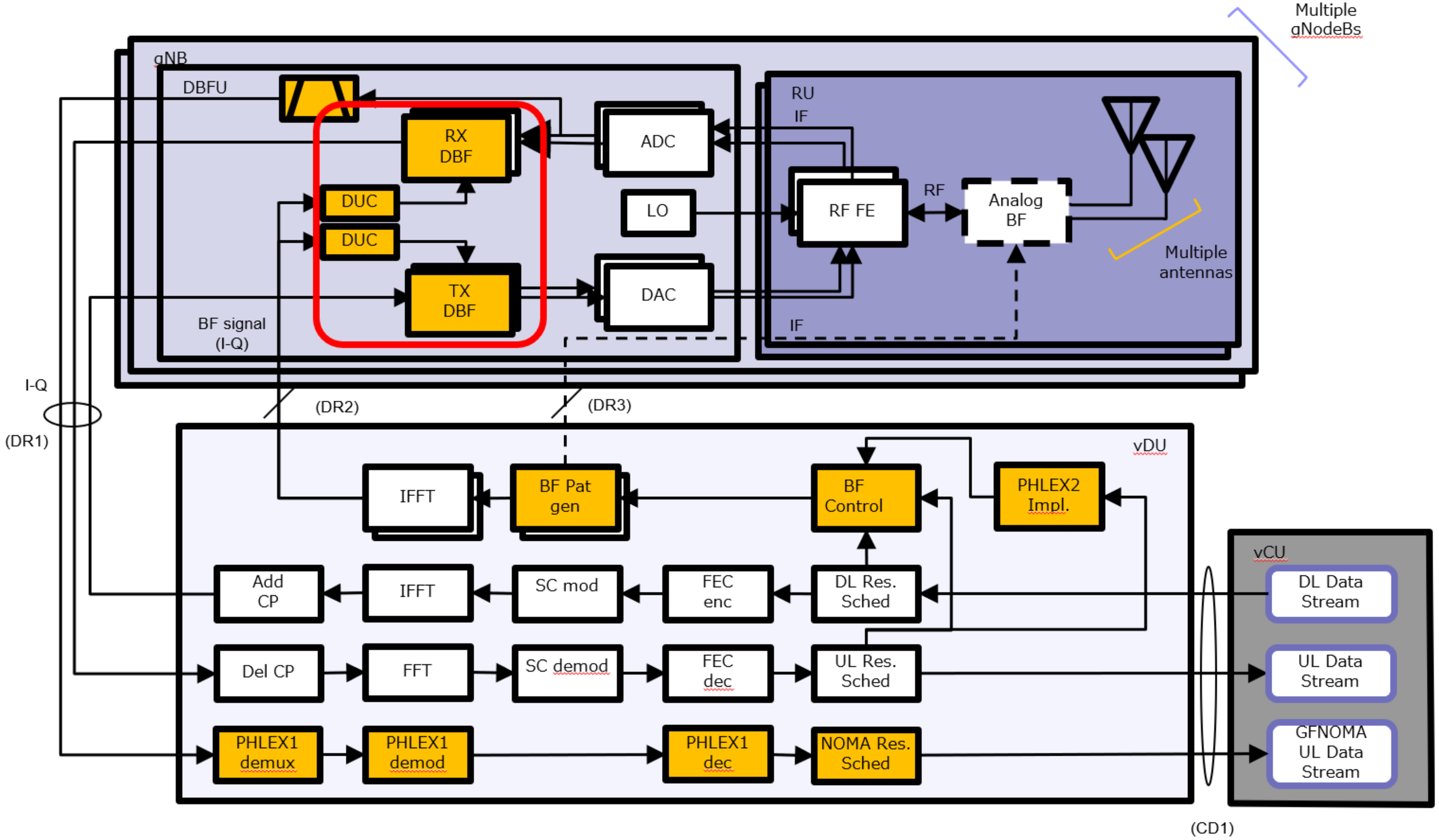
    $< 0.07 * t_{OFDMsym} \fallingdotseq 4.7\mu sec$
    - OFDM Symbol = 2048 samples
    - CP = 144 samples
  - **Higher Beam Resolution** to Support Thousands of UEs in the area.





https://www.sharetechnote.com/html/FrameStructure_DL.html

Base Station Architecture for PHLEX1/PHLEX2



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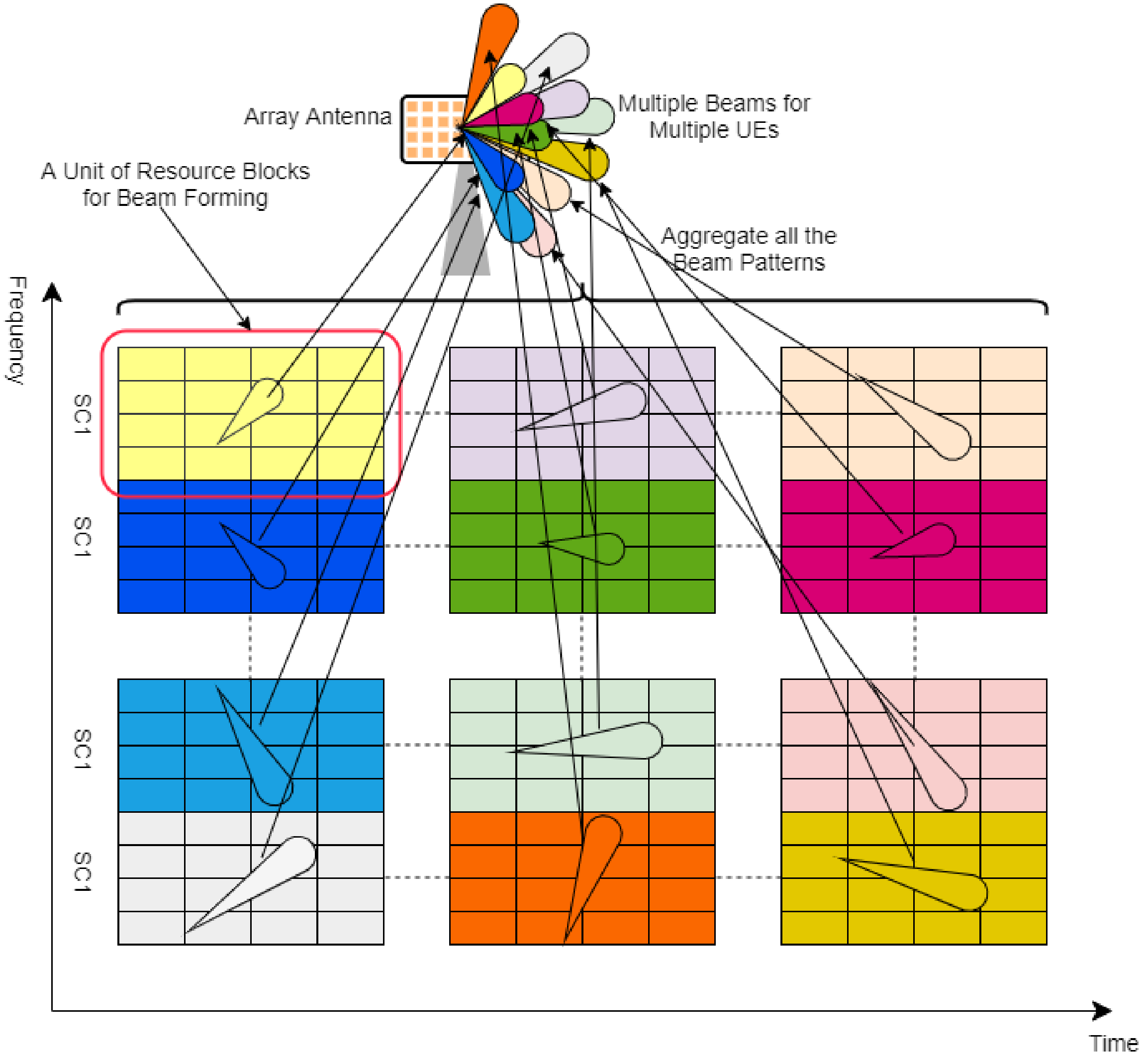
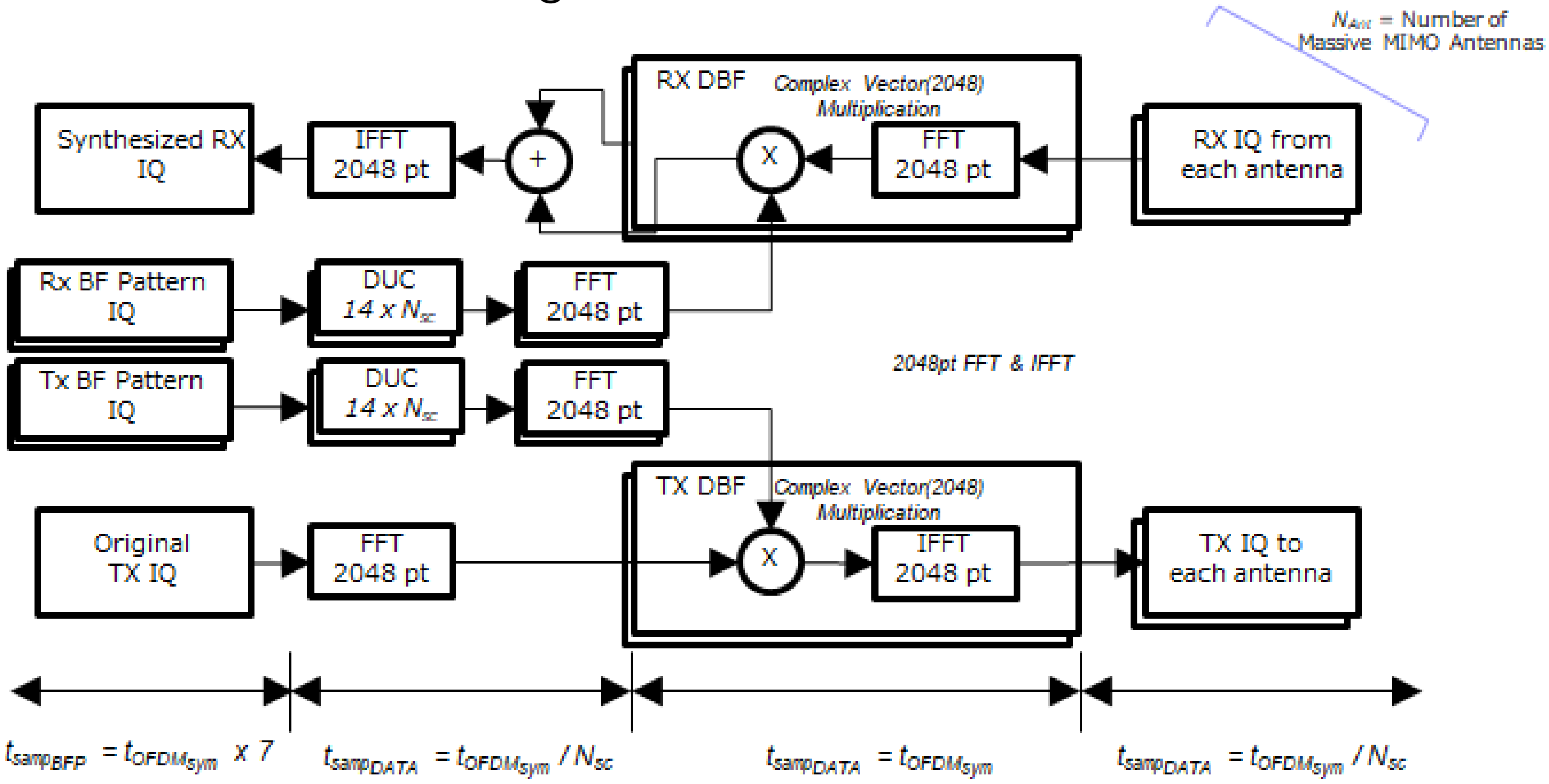
Micro Beamforming for OFDMA Waveform

- LTE/5G NR Resource Blocks (RBs) are assigned to different UEs.
- It is efficient if each RB could be steered to a specific UE spatially.
- Micro Beamforming enables the following properties.
  - Time Resolution : 7 OFDM Symbols(1 slot)
  - Freq. Resolution : 1 Subchannel (=12 Sub-carriers)
  - Spatial Resolution: Depends on antenna elements, …



Full-Digital Beamforming DSP Blocks

- Challenges
  - Limited FPGA Size and Power Consumption at RU
  - No Standard I/F between DU-RU for Digital BF



Conclusion and Further Work

- Goal of 5G Advanced wireless technology is to realize various traffic requirements
  - (1) Traffic requires combination of **High Reliability** and **Responsiveness**
  - (2) Traffic requires combination of **High Reliability** and **Large Capacity**
- For "nano-area" mmWave wireless link
  - **PHLEX1** is for requirements (1)
  - **PHLEX2** is for requirements (2)
  - Both access methods are provided by UEC AWCC
- Our goal is to implement **PHLEX1** and **PHLEX2** as real wireless access network
  - Using flexible SDR technology
  - mmWave and massive MIMO
  - Full digital beam forming to support large amount of UEs at a time
  - RAN virtualizable implementation
- We just started design of the implementation and basic evaluations and simulations
  - Next year, we'll evaluate real performance using prototype gNBs and UEs