RWS-150051

5G Vision for 2020 and Beyond

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Network/Communication Society in 2020 and Beyond

Everything connected by wireless

Monitor/collect information & control devices

Multiple personal devices

Interaction across multiple devices

Transportation (Car/Bus/Train)

Entertainment, Navigation
Traffic information

Consumer electronics

Remote operation using personal terminal

Watch/jewelry/cloths

Human interface (HI) and healthcare sensors

House

Remote control of facilities
House security

Sensors

Smart power grid
Agriculture and farming
Factory automation
Weather/Environment

Cloud computing

ドコモクラウド

All kinds of services supported by the mobile personal cloud

Extension/enrichment of wireless services

Deliver rich content in real-time & ensure safety

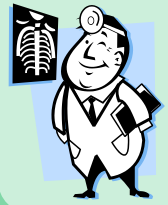
Video streaming

4K/8K video resolutions
Video on newspapers
Background video

New types of terminal/HI

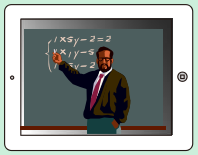
Glasses/Touch Internet

Healthcare



Remote health check & counseling

Education



Distance (remote) learning
Any lesson anywhere/anytime

Safety and lifeline system

Prevention of accidents
Robustness to disasters

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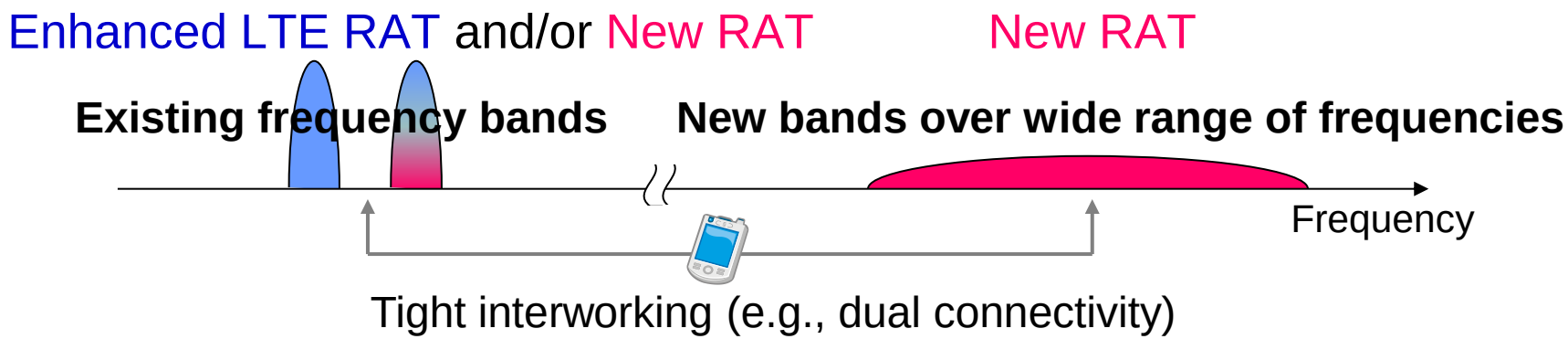
DOCOMO's 5G Concept

5G Radio Access = Enhanced LTE RAT + New RAT



Optimization for wide range of frequency bands

5G Technologies

New technologies for new bands

- ✓ *Can be non-backward compatible for further improvement*

Frequency agnostic new technologies

- ✓ *Backward compatibility is preferable for existing frequency bands*

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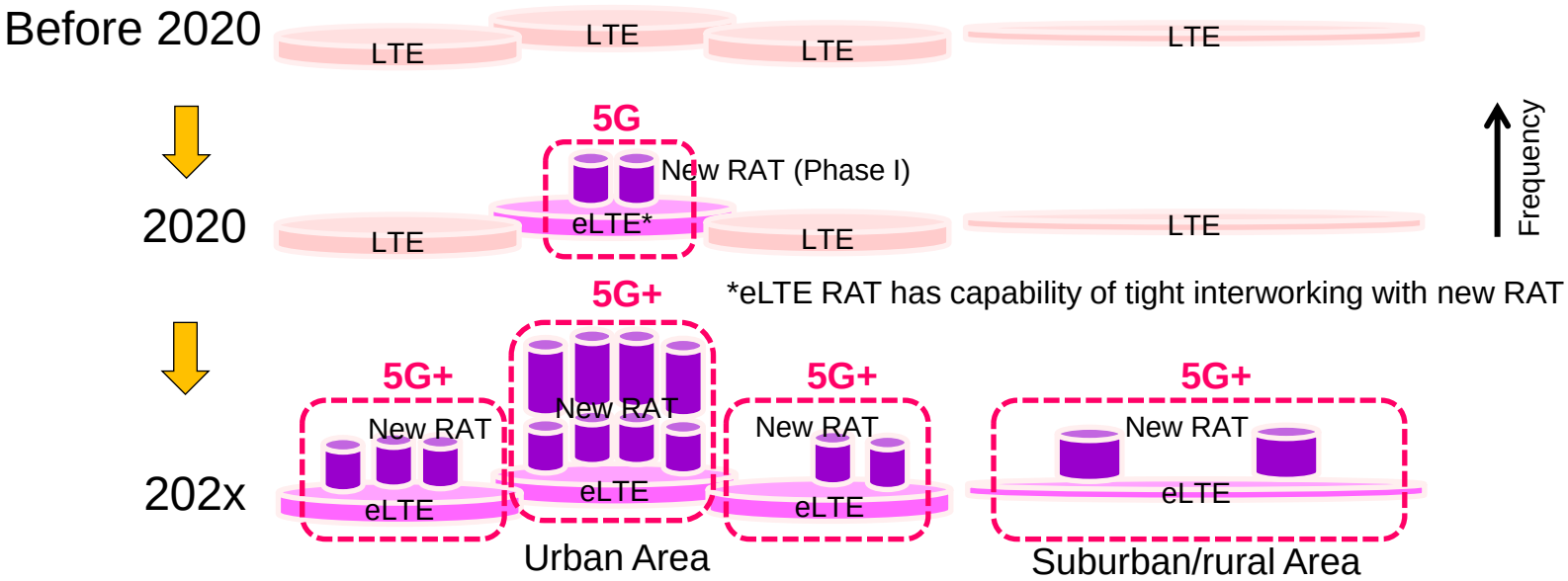
Deployment/Migration Scenarios

- **In 2020, 5G will be launched** initially from areas, where higher performance is required, e.g., dense urban area
  - New RAT (Phase I) and enhanced LTE (eLTE) RAT are introduced to realize tight interworking between lower and higher frequency bands
- **In beyond 2020, deployment areas for 5G are gradually expanded** while introducing additional technologies and frequency bands (= **5G+**)
  - LTE (or LTE-A) cell can be continuously used as eLTE cell for a long-time
    - Stand-alone new RAT might be deployed in the future



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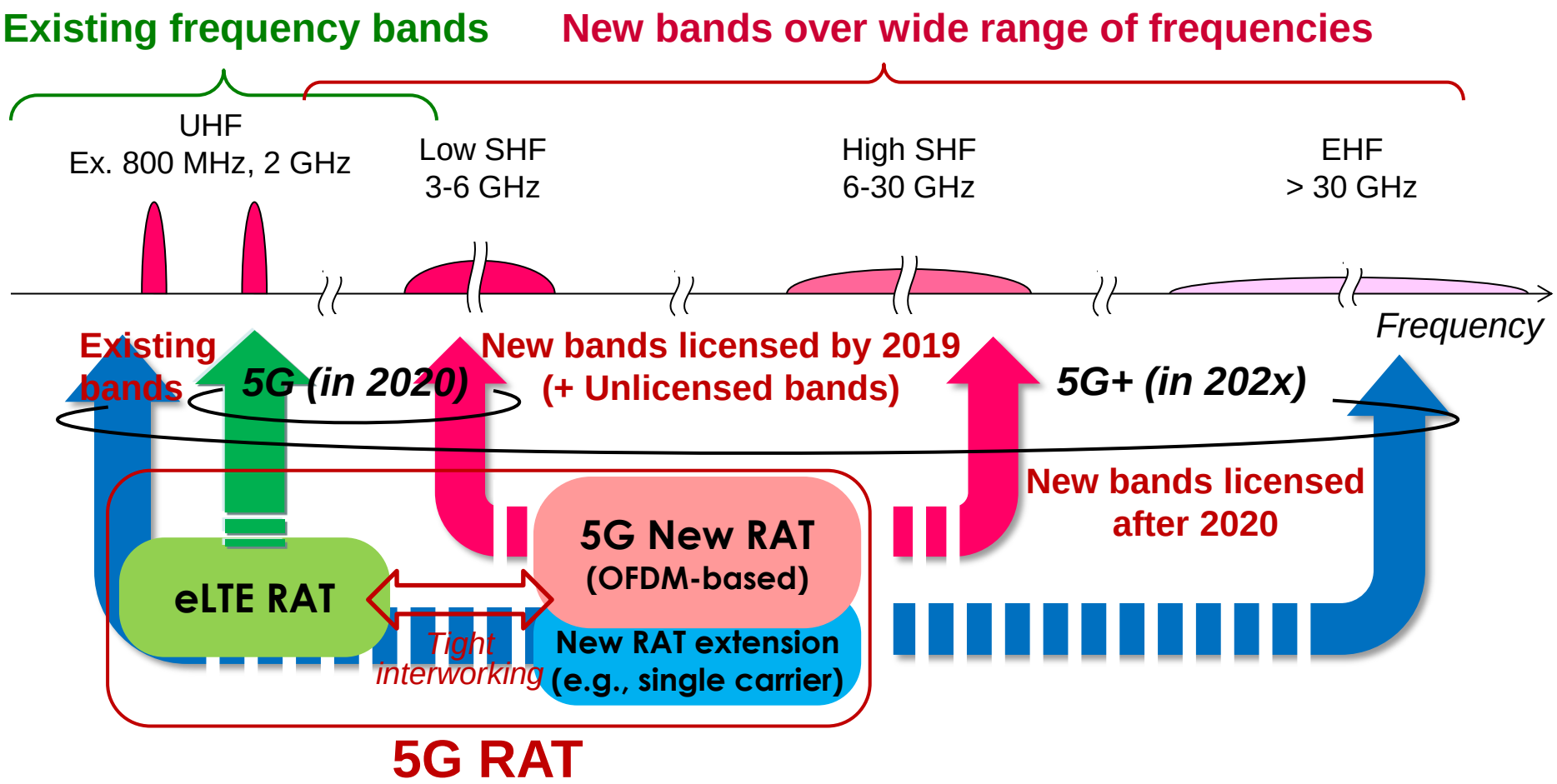
5G Phased Realization (PHY)

- Phased approach for 5G standardization and commercialization
  - ***5G (in 2020)*** : eLTE + New RAT Phase I (up to ~30 GHz)
  - ***5G+ (in 202x)*** : 5G extension for all range of spectrum (up to 100 GHz)



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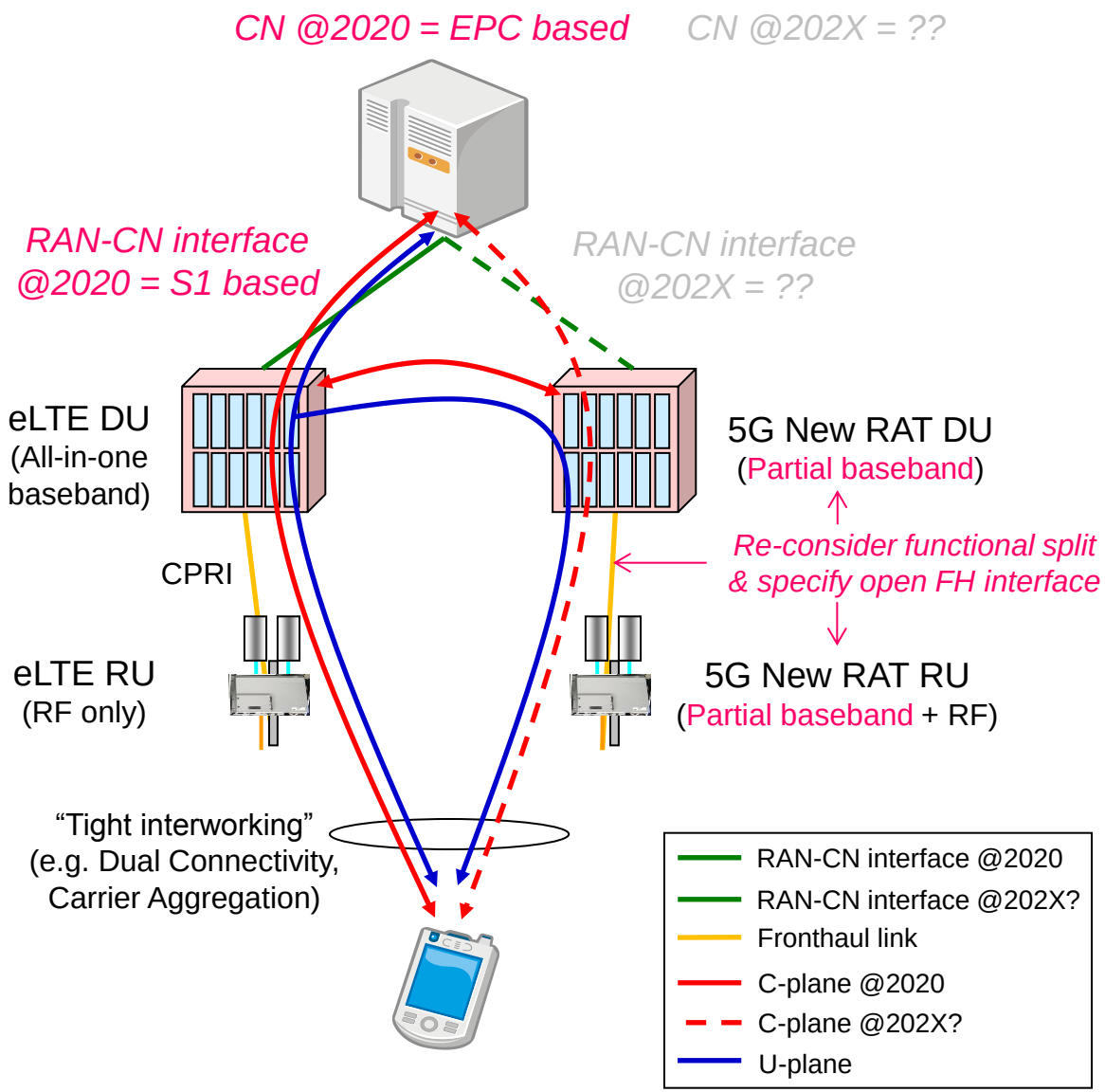
5G RAN C/U-plane and Architecture

- Early introduction of 5G New RAT @2020
  - *New RAT for U-plane*
  - *C-plane over eLTE*
  - *eLTE + 5G New RAT hosted by EPC via S1*
- Fronthaul interface
  - *Re-consider DU-RU functional split*
    - ➔ *Relax fronthaul BW requirement for 5G*
  - *Specify open fronthaul interface in 3GPP*
    - ➔ *Multi-vendor DU-RU*



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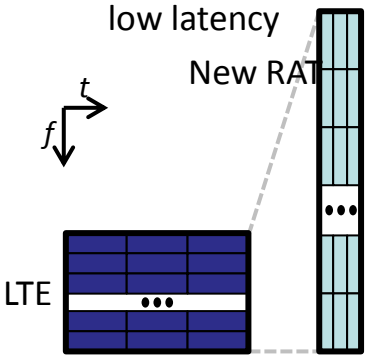
Technology Candidates for 5G in 2020

New RAT (Phase I)

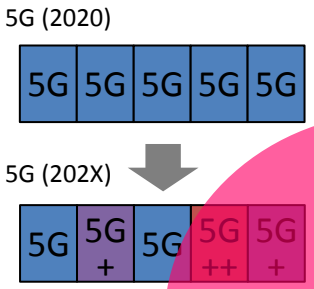
New numerology with shorter TTI

Wider bandwidth and low latency



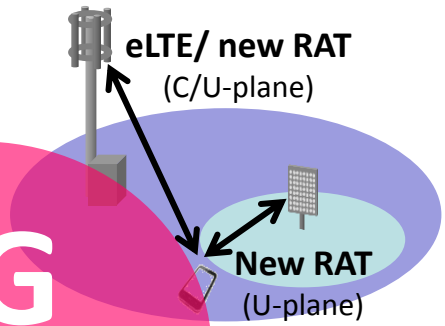
Lean radio frame

Less inter-cell interference, energy saving, good forward compatibility



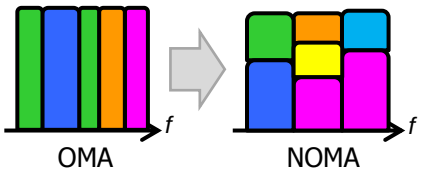
Tight LTE integration

C/U-plane split (dual connectivity, CA)



NOMA on LTE

Further cellular enhancement with massive connectivity

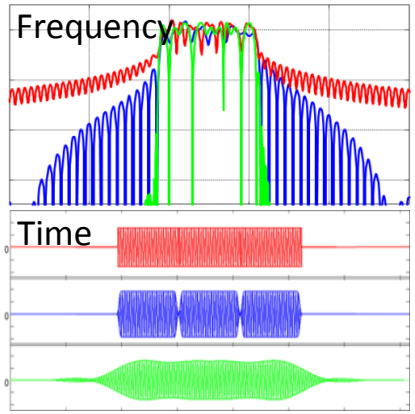


Intentional non-orthogonality

5G

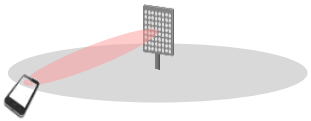
eMBB & IoT for 2020

Well localized waveform



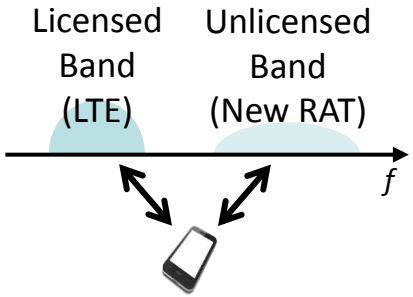
Massive MIMO/ beamforming

Cell range extension



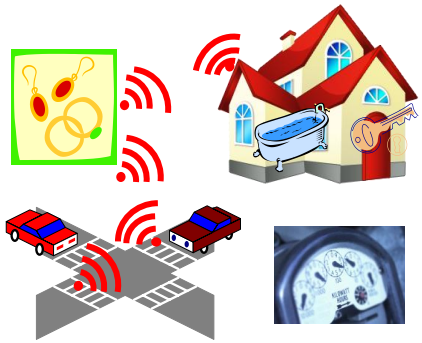
Improved spectral efficiency

Flexible duplex with unlicensed spectrum (e.g. LTE-assisted access)



IoT related LTE enhancements

Low cost / Long battery life devices



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Back Up

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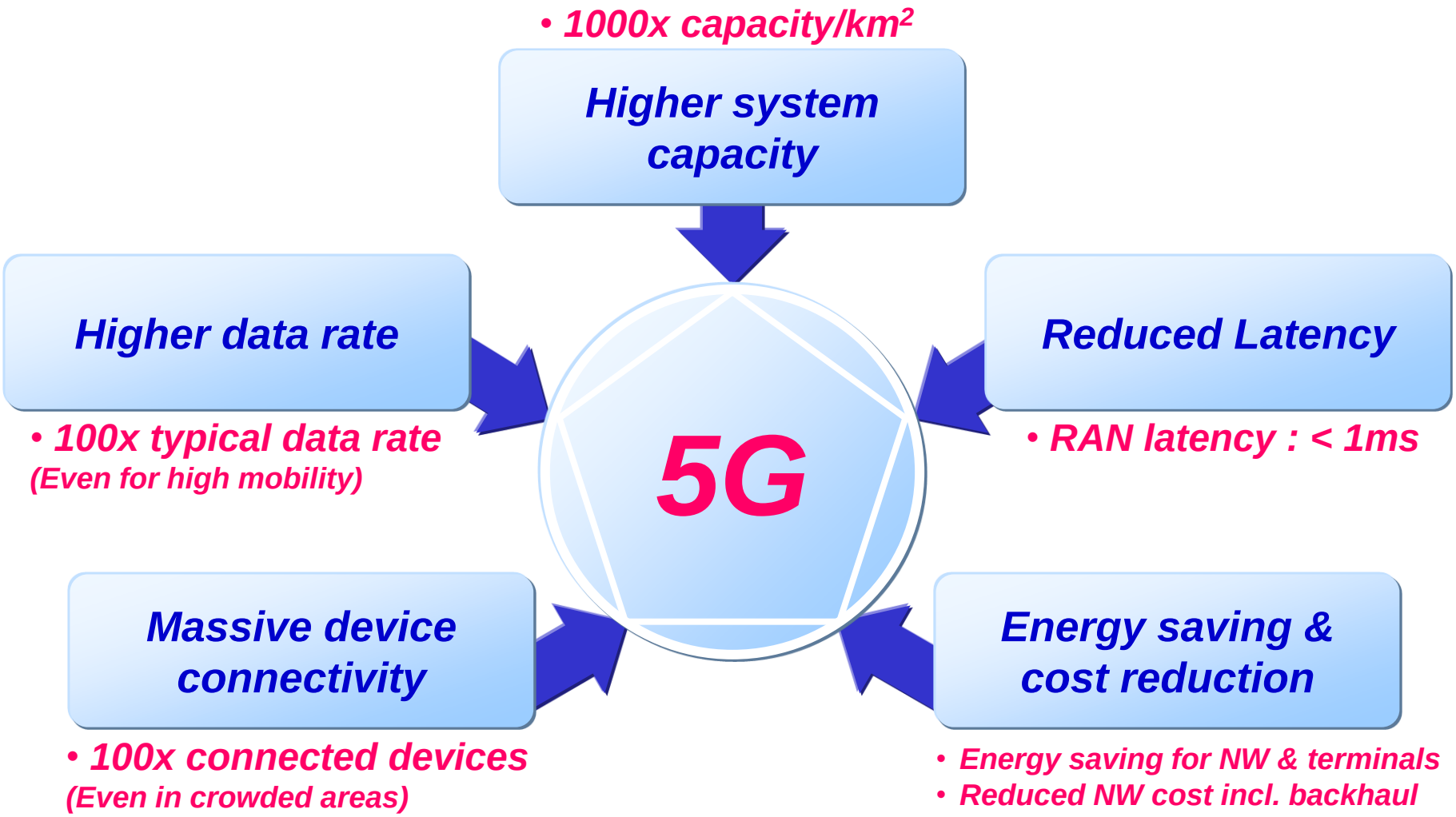
5G Requirements

5G radio access will provide a total solution to satisfy wider range of requirements for 2020 and beyond



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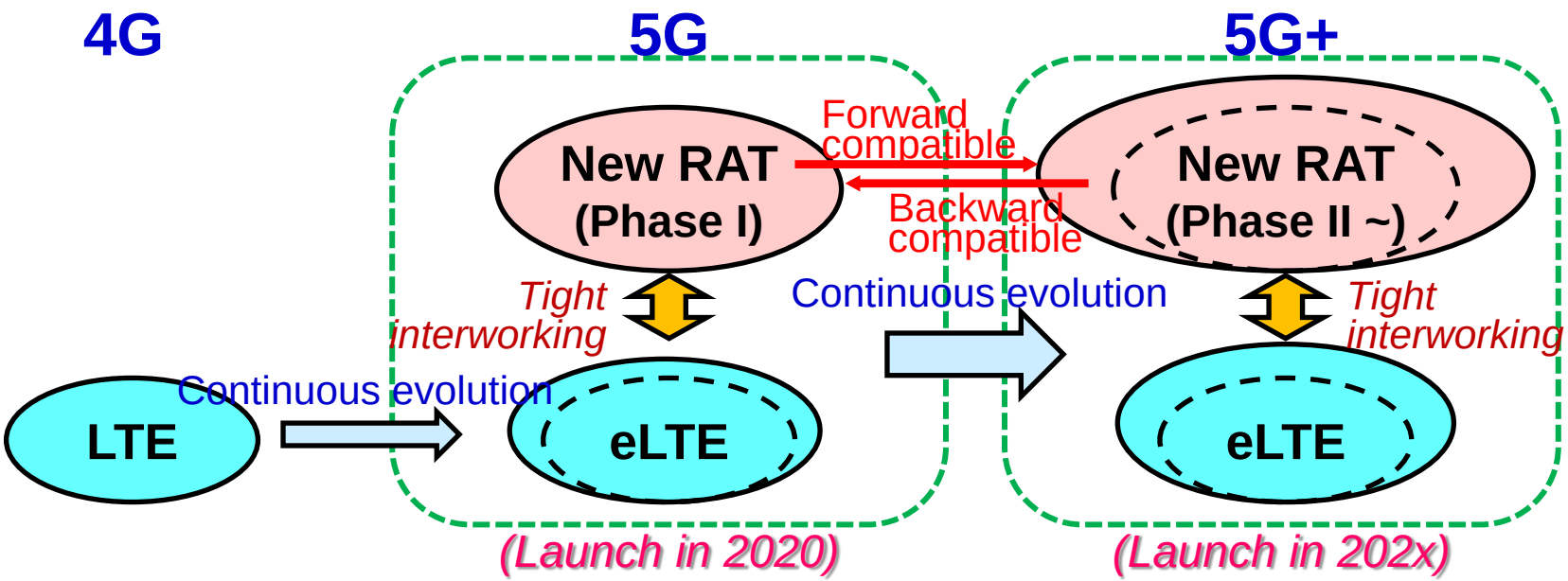
5G Forward/Backward Compatibility

- It is important to make sure 5G continuous evolutions and 5G forward/backward compatibility considering:
  - Unclear spectrum allocation plan especially for mmW
  - Difference in 5G launch timing between countries/regions
- 5G in 2020 should include forward compatible capability
- 5G+ in 202x should be backward compatible with 5G in 2020
  - For smooth migration from 5G to 5G+
  - To avoid technology fragmentation and ensure 5G eco-systems



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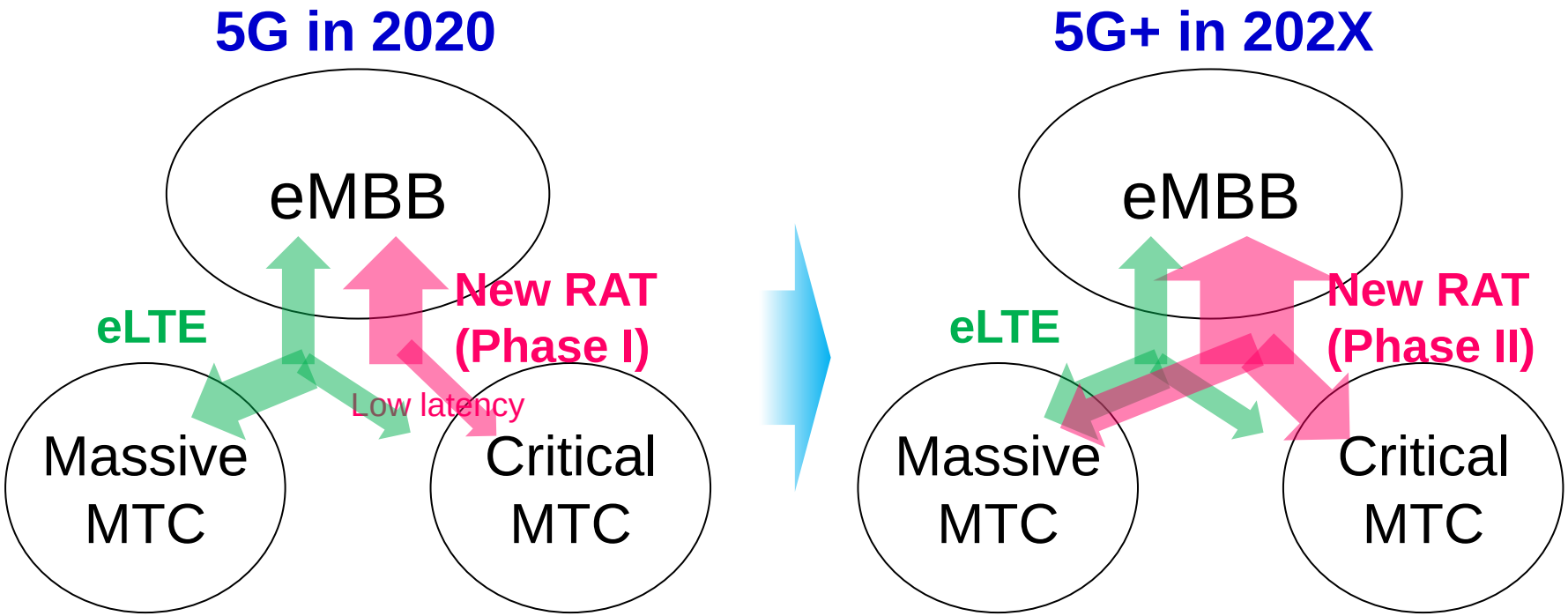
MBB and New Use Cases

- 5G will support both eMBB and MTC use cases together with LTE evolution



Phase I of the new RAT will focus on eMBB

Phase II of the new RAT will be enhanced for all use cases

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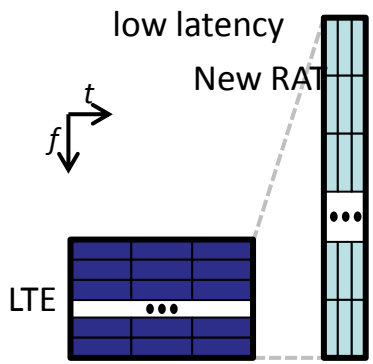
Phase I of The New RAT

- New RAT (Phase I) should include fundamental aspects of 5G physical layer to ensure forward compatibility, e.g.,
  - Numerology for wider range of spectrum bands
    - RF performance specs should be developed at proper timing according to practical spectrum allocation time plan
  - Shorter TTI for fundamental latency reduction for 5G era
  - Lean radio frame and well localized waveform design for easy introduction of new technologies
  - Massive MIMO as key technology to provide fundamental gain in 5G mobile broadband

New numerology with shorter TTI

Wider bandwidth and low latency



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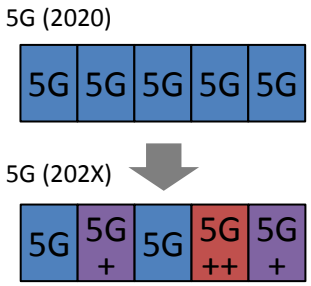
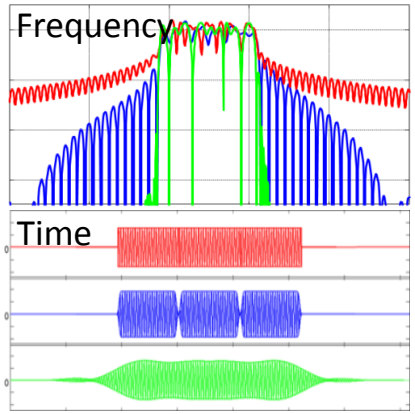
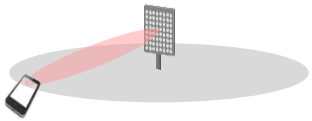


Well localized waveform



Massive MIMO/ beamforming

Cell range extension



Improved spectral efficiency

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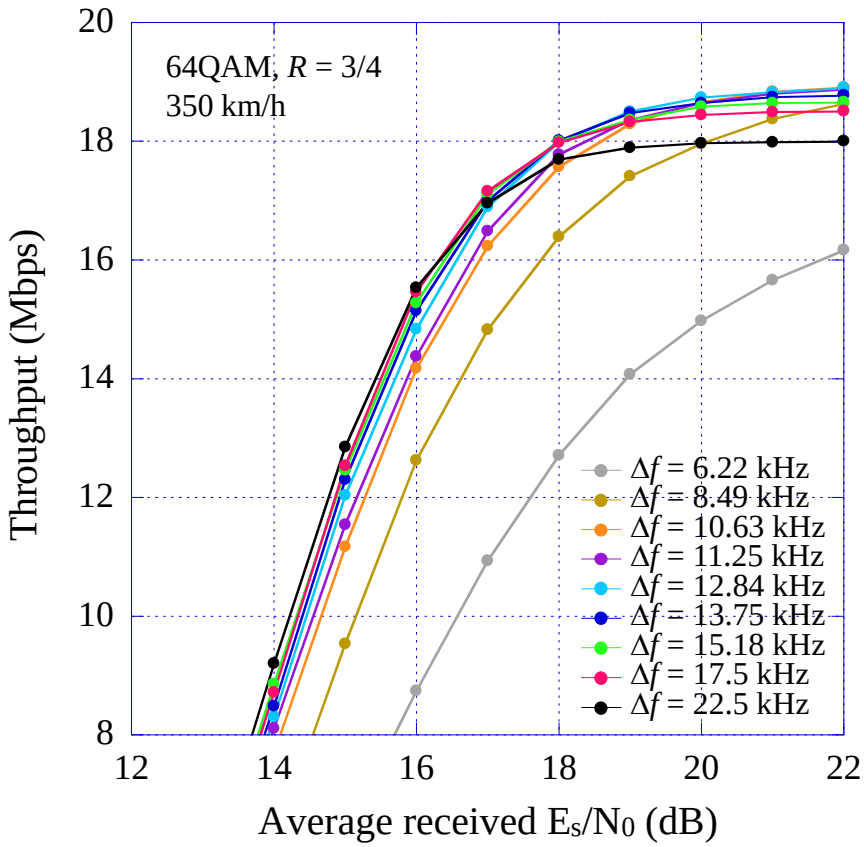
Numerology (LTE was…)

- LTE sub-carrier spacing
  - Optimized to support Doppler frequencies corresponding to UE speed up to 350 km/h for 2GHz carrier frequency
  - Sub-carrier spacing of **11-15 kHz** was recommended in R1-050386



R1-050386, NTT DoCoMo, Ericsson, Fujitsu, Mitsubishi Electric, NEC, Nortel, Panasonic, Texas Instruments, "Views on OFDM Parameter Set for Evolved UTRA Downlink," May, 2005.

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Numerology (5G will be…)

- New RAT sub-carrier spacing

Minimized number of options for Phase I

  - Will be designed to support higher mobility up to 500 km/h and wider range of carrier frequencies, e.g., up to 30-40GHz for Phase I
  - Sub-carrier spacing of **45-75 kHz** will be major candidate since it can support 500 km/h @6GHz and 100 km/h @30GHz with the same level of performance as in LTE worst case (350 km/h @2GHz)
    - Note: Further study considering phase noise needed
  - Sub-carrier spacing of approximately **240 kHz** is required to support UE speed of 500 km/h @30GHz, but it may not be needed in Phase I (?)

Calculation of $f_D/\Delta f$ for variable carrier frequencies and UE speeds

		LTE	5G New RAT																			
Carrier frequency (GHz)		2	3	3	3	3	3	6	6	6	6	6	10	10	10	10	10	30	30	30	30	30
UE speed (km/h)		350	3	60	100	350	500	3	60	100	350	500	3	60	100	350	500	3	60	100	350	500
f_D (kHz)		0.65	0.01	0.17	0.28	0.97	1.39	0.02	0.33	0.56	1.95	2.78	0.03	0.56	0.93	3.24	4.63	0.08	1.67	2.78	9.73	13.9
⊿f (kHz)	11	0.06	0	0.02	0.03	0.09	0.13	0	0.03	0.05	0.18	0.25	0	0.05	0.08	0.29	0.42	0.01	0.15	0.25	0.88	1.26
	15	0.04	0	0.01	0.02	0.06	0.09	0	0.02	0.04	0.13	0.19	0	0.04	0.06	0.22	0.31	0.01	0.11	0.19	0.65	0.93
	30		0	0.01	0.01	0.03	0.05	0	0.01	0.02	0.06	0.09	0	0.02	0.03	0.11	0.15	0	0.06	0.09	0.32	0.46
	45		0	0	0.01	0.02	0.03	0	0.01	0.01	0.04	0.06	0	0.01	0.02	0.07	0.1	0	0.04	0.06	0.22	0.31
	60		0	0	0	0.02	0.02	0	0.01	0.01	0.03	0.05	0	0.01	0.02	0.05	0.08	0	0.03	0.05	0.16	0.23
	75		0	0	0	0.01	0.02	0	0	0.01	0.03	0.04	0	0.01	0.01	0.04	0.06	0	0.02	0.04	0.13	0.19
	90		0	0	0	0.01	0.02	0	0	0.01	0.02	0.03	0	0.01	0.01	0.04	0.05	0	0.02	0.03	0.11	0.15
	120		0	0	0	0.01	0.01	0	0	0	0.02	0.02	0	0	0.01	0.03	0.04	0	0.01	0.02	0.08	0.12
	180		0	0	0	0.01	0.01	0	0	0	0.01	0.02	0	0	0.01	0.02	0.03	0	0.01	0.02	0.05	0.08
	240		0	0	0	0	0.01	0	0	0	0.01	0.01	0	0	0	0.01	0.02	0	0.01	0.01	0.04	0.06

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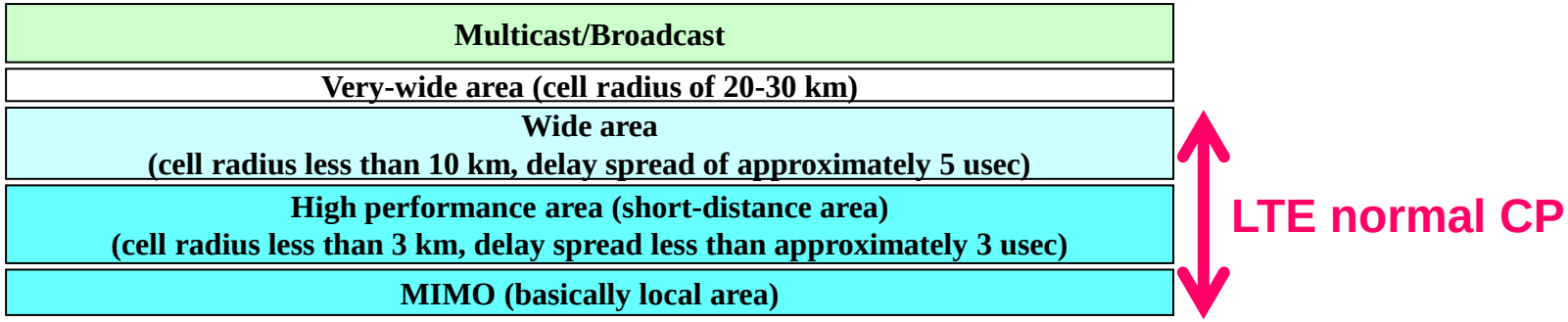
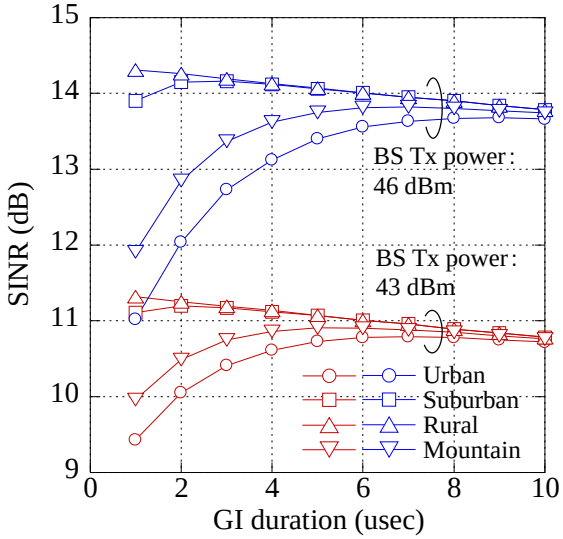
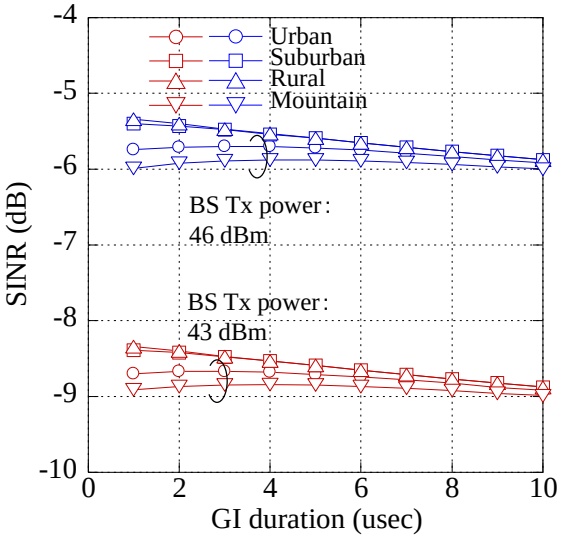
Numerology (LTE was…)

- LTE CP length
  - Normal CP (~ 4.7 us) was optimized to support wide area macro-cell coverage, i.e., cell radius up to 10 km, assuming **urban, suburban, rural, and mountain scenarios** (R1-050386)





(a) Cell radius, d = 3 km



(c) Cell radius, d = 10 km

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Numerology (5G will be…)

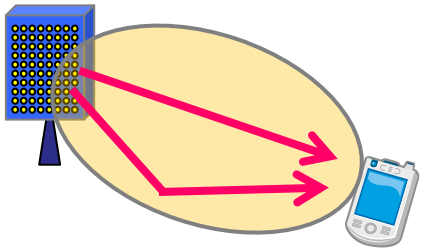
Minimized number of options for Phase I

- New RAT CP length
  - New RAT CP(s) will be optimized to support deployment scenarios of Urban Micro & Urban Macro, i.e., cell radius up to 1 km in Phase I

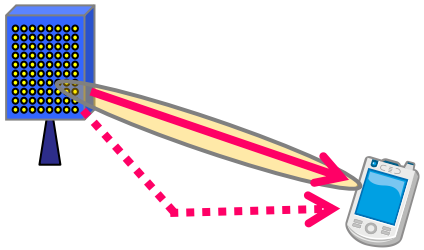
Multicast/Broadcast
Very-wide area (cell radius of 20-30 km)
Wide area (cell radius less than 10 km, delay spread of approximately 5 usec)
High performance area (short-distance area) (cell radius less than 3 km, delay spread less than approximately 3 usec)
MIMO (basically local area)

New RAT CP(s) for Phase I

  - New RAT CP(s) will be optimized considering beamforming effect and relevant channel models
    - Longer cell radius including rural and mountain scenarios may be supported keeping the same CP length with the beamforming effect (FFS)



Longer CP for wider beam transmission



Shorter CP for narrower beam transmission

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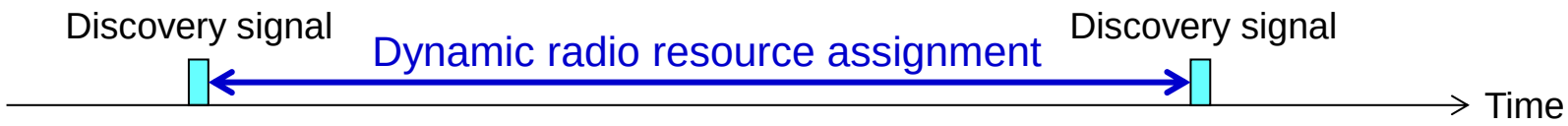
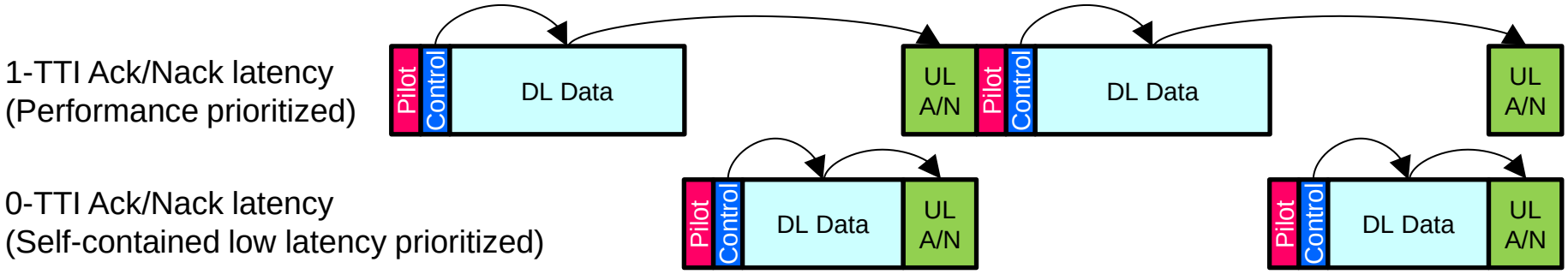
New Radio Frame Design

- **Lean radio frame supporting new RAT discovery mechanism**
  - Minimized overhead channels for LTE-assisted discovery



- **Flexible radio frame with shorter TTI to optimize tradeoff between performance and latency**
  - E.g. flexible HARQ round trip delay (RTD) to allow:
    - Ultra low latency with self-contained TDD radio frame structure
    - Advanced receiver with some decoding latency

(Note: Radio frame structure is an example)



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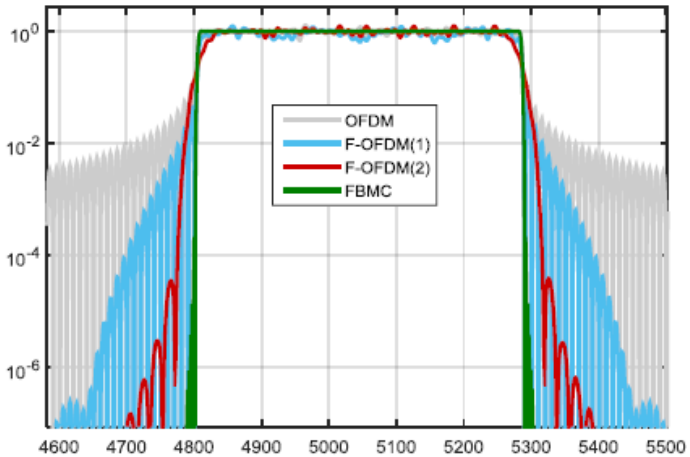
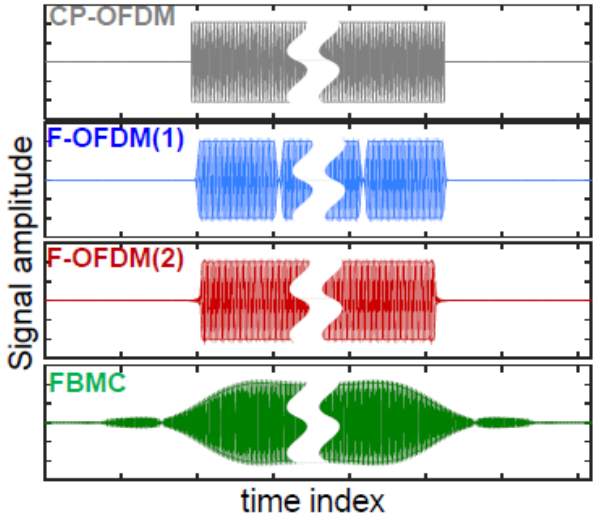
New RAT Waveform(s)

- OFDM-based waveform for both DL and UL
  - Higher spectrum efficiency for cellular eMBB
  - FFS: filtering/windowing for good frequency localization
    - Future compatibility for introducing new technologies
    - Allowing in-band different numerologies
    - Allowing in-band asynchronous transmissions
      - » e.g. UL grant-free transmission





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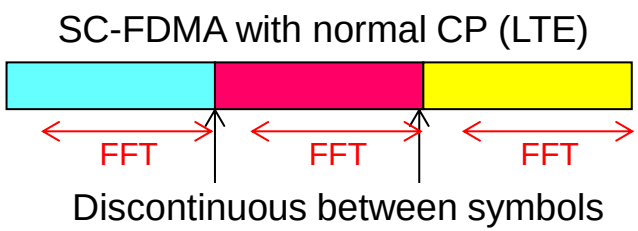
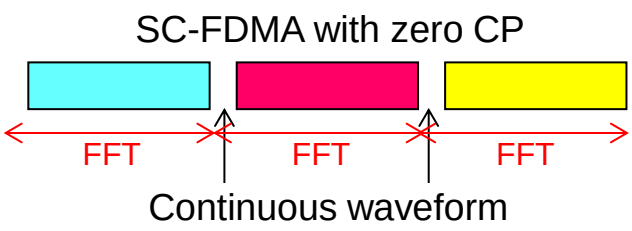
New RAT Waveform(s)

- Additional single carrier waveform (FFS in Phase II)
  - Possible application scenarios
    - mmW (> 30 GHz)
    - Coverage critical use cases, e.g., massive IoT
  - Will be specified if sufficient gain is identified compared with baseline OFDM-based waveform
    - DFT precoding to baseline OFDM is a promising way
  - Key benefits
    - Better coverage with lower PAPR
    - Good frequency localization by applying advanced CP
      - » Zero CP or Pilot CP can make continuous waveform





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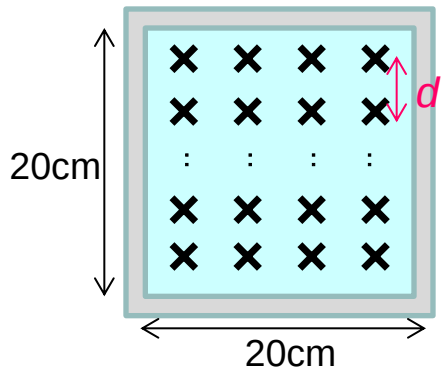
Massive MIMO

- **"Massive MIMO"** – Beamforming using massive antenna elements in higher frequency bands
  - *Essential key technology for* *both below & above 6GHz*

Example 2D antenna configuration



Antenna element spacing (d)	3.5 GHz (λ = 8.6 cm)	6 GHz (λ = 5 cm)	10 GHz (λ = 3 cm)	20 GHz (λ = 1.5 cm)
0.5 λ	16	64	169	676
0.7 λ	9	25	81	361

→ Improved spectrum efficiency and effective cell coverage

Improved spectrum efficiency with multi-user beamforming

Cell range extension by beamforming gain

To be supported by unified radio interface

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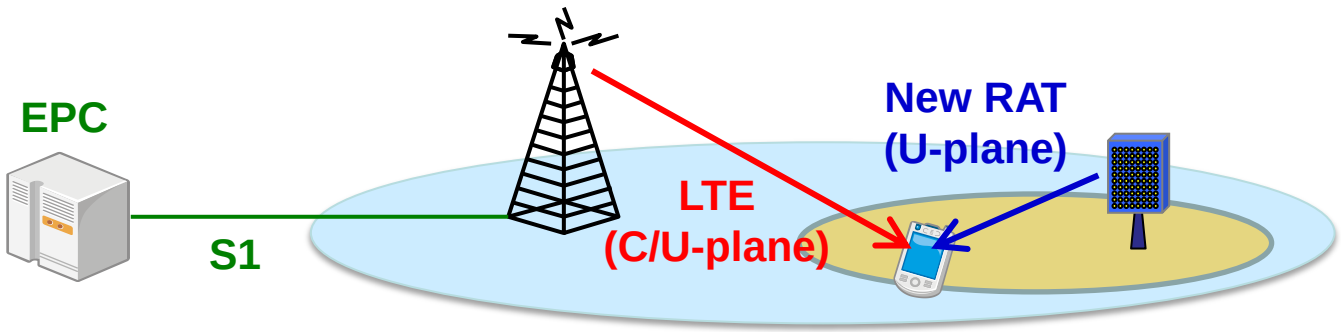
5G Phased Realization (Higher Layer)

- 5G in 2020 (Phase I) ➔ LTE-assisted access
  - New RAT for U-plane (data rate, latency) enhancement
  - Basic Idle mode and Connectivity (C-plane) provided by eLTE
  - 5G RAN (eLTE + New RAT) hosted by EPC via S1
  - ➔ U-plane benefits of New RAT can be enjoyed at an early timing



"Tight interworking" (e.g. Dual Connectivity, Carrier Aggregation)

- Architectural evolutions and C-plane over New RAT
  - To be considered for 5G+ in 202x (Phase II)
  - ➔ Enough time to be allocated for future-proof architecture / C-plane design

- Migration aspects need to be addressed in study phase
  - Phase I UE handling in Phase II NW needs care
  - Phase II should build onto Phase I and avoid duplicate development

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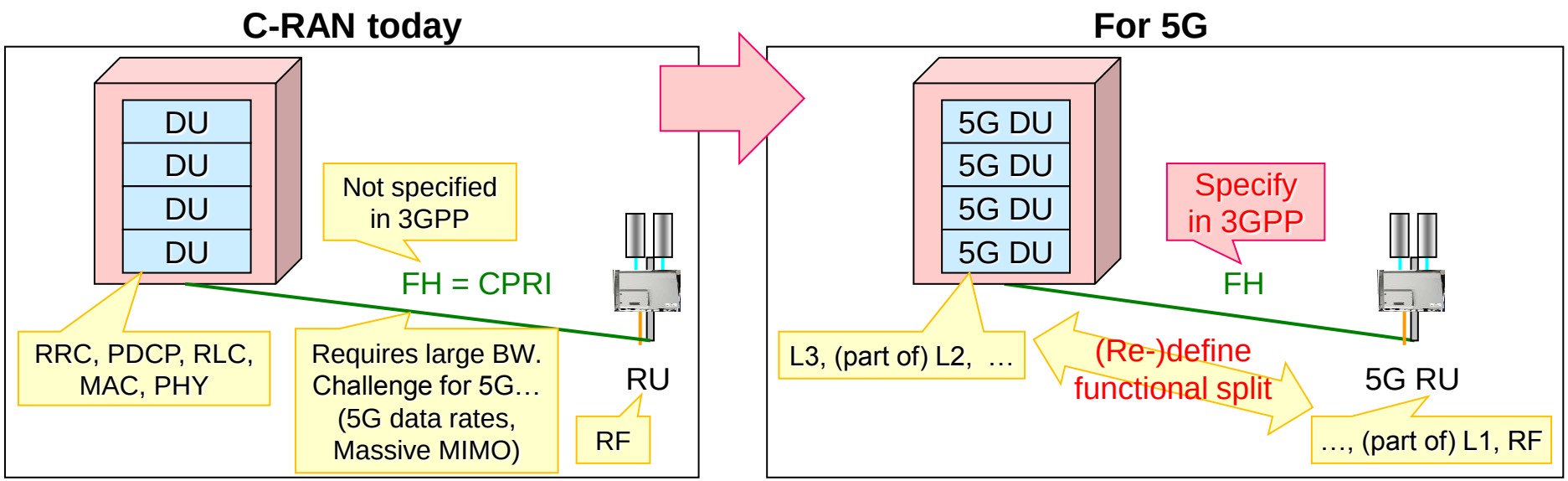
5G RAN Architecture and Fronthaul

- Development and deployment of “C-RAN” is gaining momentum in the recent years for its performance and cost benefits
  - Baseband processing units (DU) pooled at central location
  - Remote radio units (RU) distributed at cells sites
  - CPRI as the fronthaul (FH) link between DUs and RUs (defacto standard)
- “C-RAN” is believed to be a promising architecture also in the 5G era, but CPRI may not scale considering 5G data rates and massive MIMO
- It is proposed for 3GPP to (re-)define DU-RU functional split for 5G, and to specify an open interface for the fronthaul link between them



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