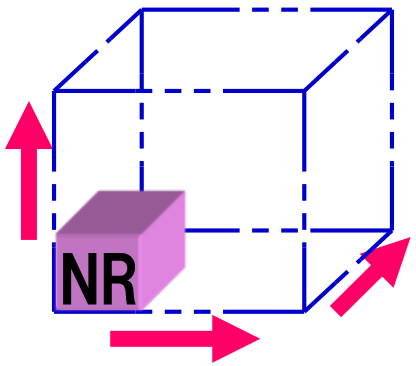
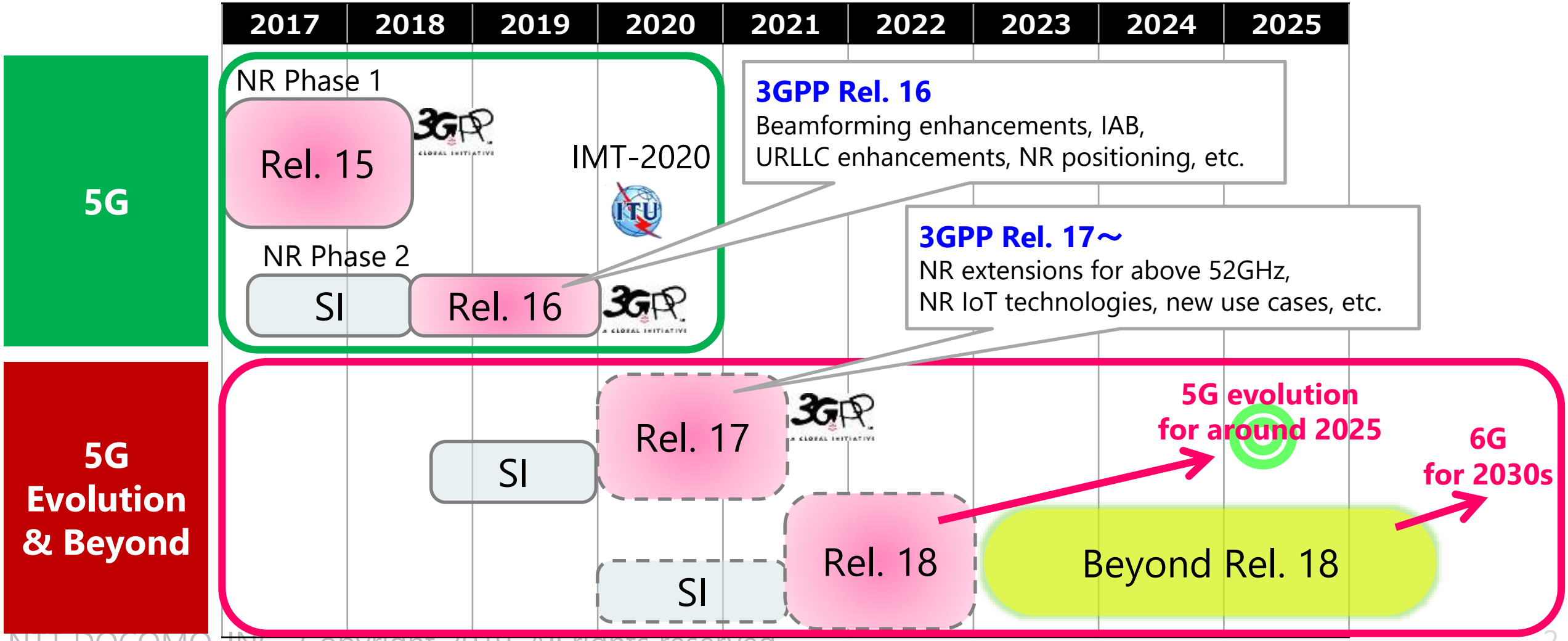
5G Evolution and Beyond
- Real & Future -



5G Laboratories
NTT DOCOMO, INC.

5G Evolution and Beyond

- 5G is now in commercial development phase, and researchers should focus on future wireless technologies for around 2025 and beyond



Real and Future

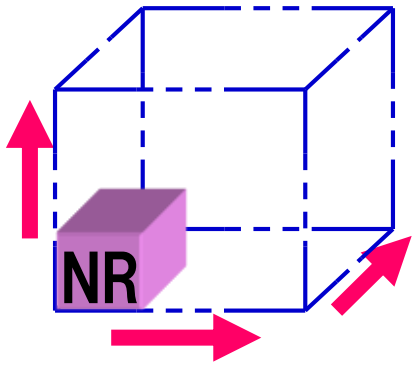
Problems from Real

&

Dreams for Future

5G Evolution and Beyond

for **any** use-cases, **any** requirements, and **any** consumer/industry markets



Performance

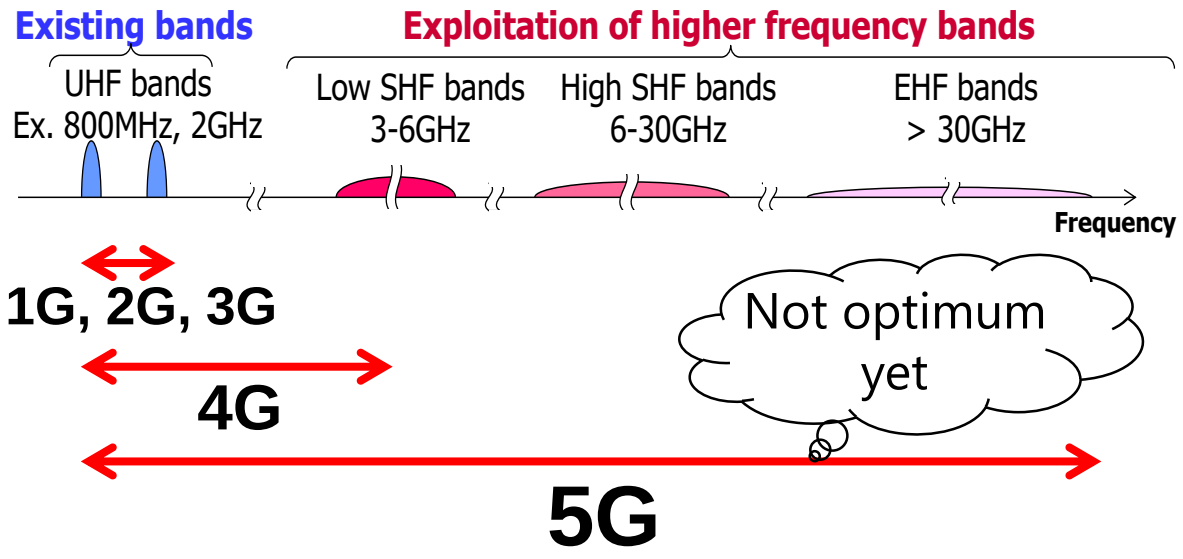
Flexibility

Efficiency

The Real
for 5G Evolution

Observations from 5G Real Issues

First generation using mmW



High interests from industries

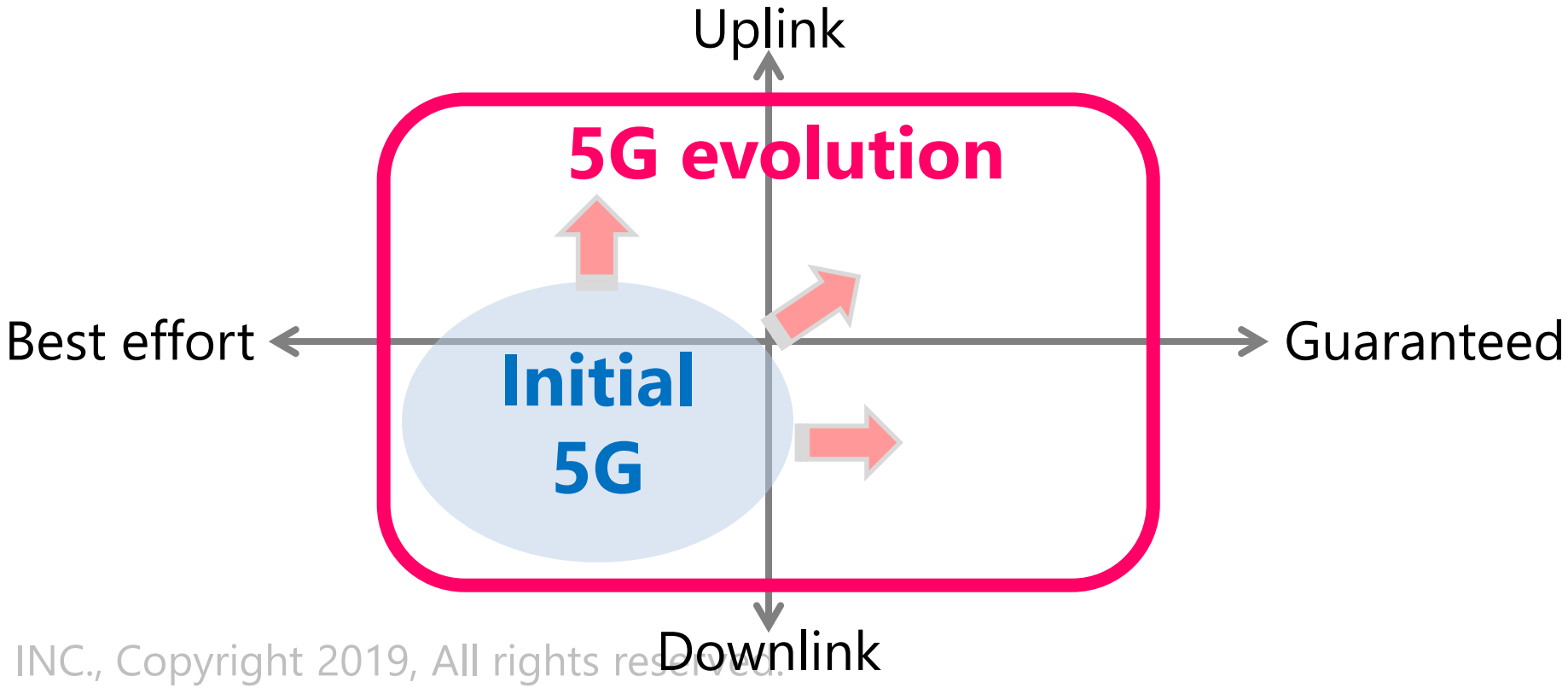
Very high performances

Key technical issues

- mmW coverage/mobility improvement
- Uplink performance enhancement
- High requirements for industry use cases

Evolution Required from 5G Real Issues

- Enhancement in "Uplink" performances
  - » Uplink is critical on mmW coverage
  - » High uplink performance is required in many industry use cases
- Support of "Guaranteed" performance in addition to legacy "Best effort"
  - » High demand from industry use cases - URLLC is only an example



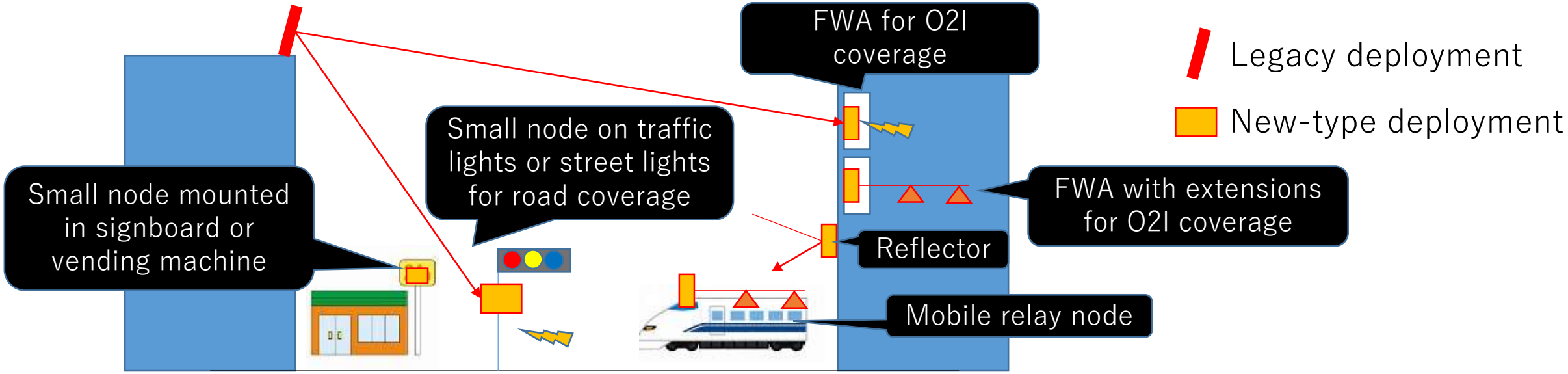
New-type Deployment for mmW Coverage

- Mixture of legacy and new-type deployments, e.g., IAB, with following desired features
  - Small size and light weight
  - Cost and energy efficient
  - Plug-and-Play and wireless
  - Invisibility

On-glass antenna

mmW reflector

(Example deployment image)



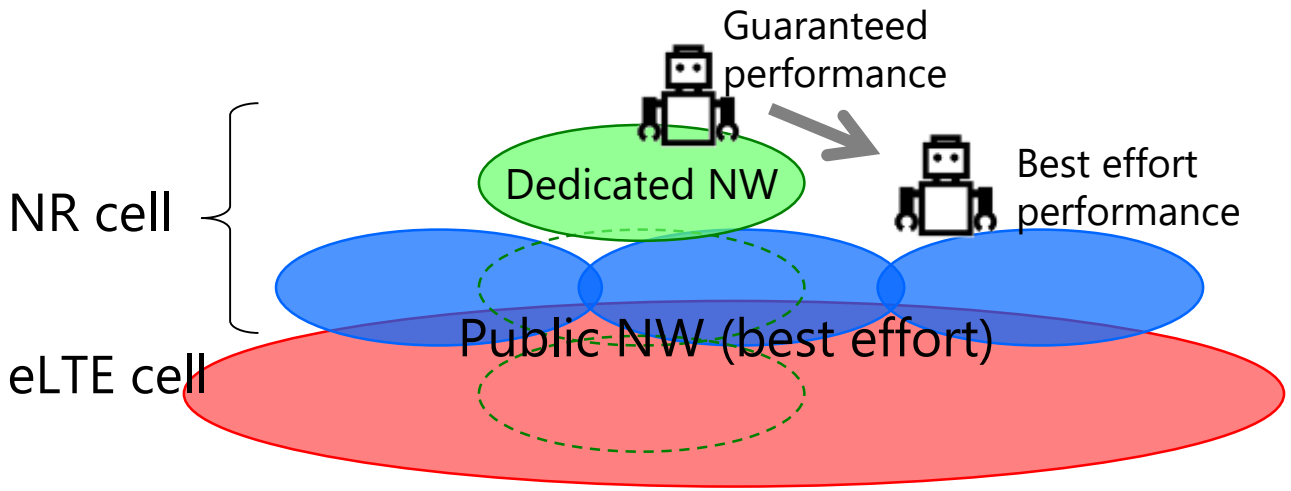
➔ Technical study considering such new-type mmW deployment will be needed

Industry Dedicated 5G Network

- High demand of industry network to provide specific and high performances, e.g.;
  - Relatively high minimum data rate (sometimes for many devices, sometimes uplink heavy)
  - High reliability to keep service quality
  - Low end-to-end latency
  - Easy temporary network deployment for events, construction sites, etc.

➔ Dedicated 5G network is a promising solution to address such requirements

- A technical issue – public/industry overlay deployment

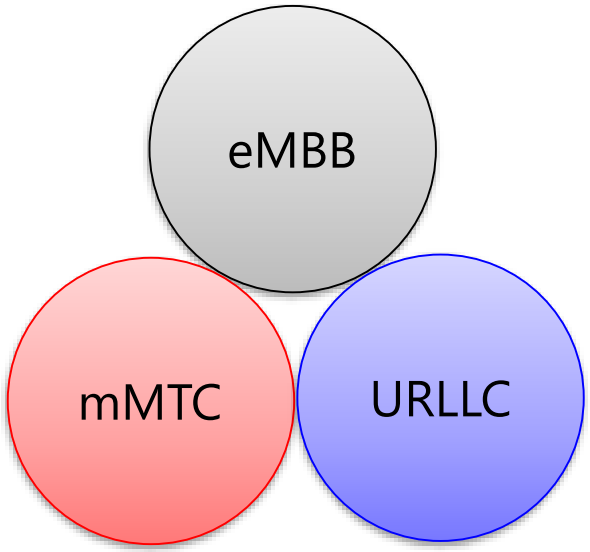


✓Spectrum
✓Interference coordination
✓Interworking
✓SA vs. NSA

The Future

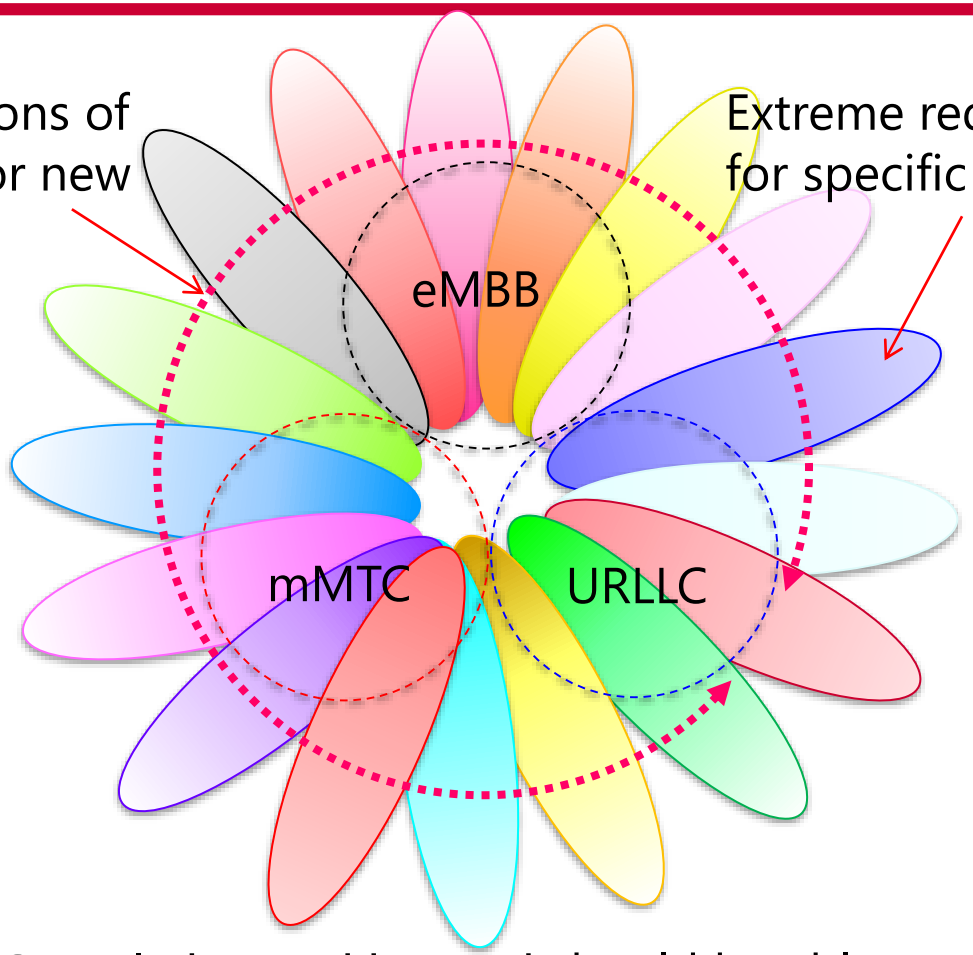
for 5G Evolution and Beyond

5G Evolution and Beyond – Fireworks



New combinations of requirements for new use cases

Extreme requirement for specific use cases



- 5G is able to satisfy various requirements for various use-cases

- 5G evolution and beyond should be able to reach further varieties of markets
- Available freedom is only in {time, frequency, space}
- Need to consider what should be achieved at the cost of what

Extreme Targets for Future Challenge

5G evolution & beyond

Extreme high data rate/capacity

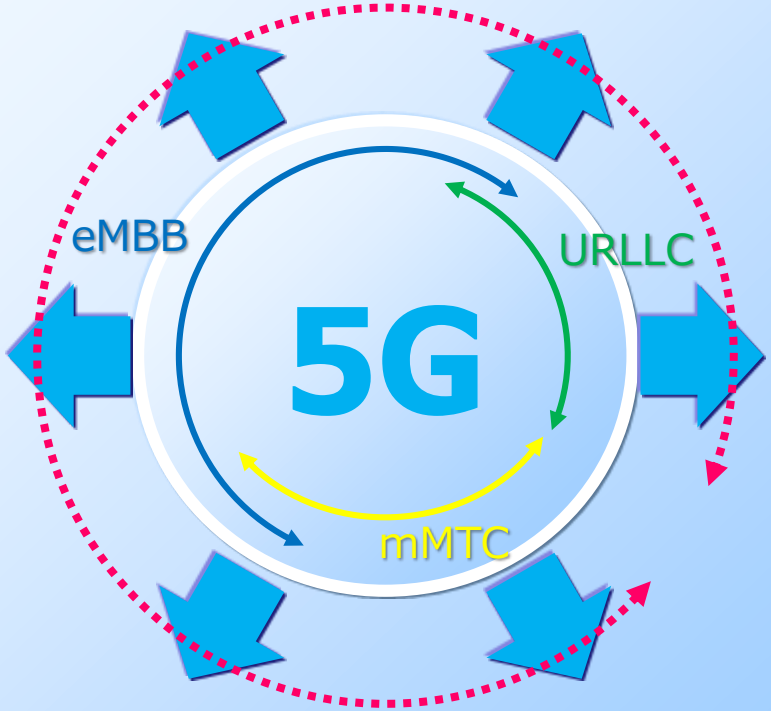
- *Peak data rate >100Gbps exploiting new spectrum bands*
- *>100x capacity for next decade*

Extreme coverage

- *Gbps coverage everywhere*
- *New coverage areas, e.g., sky, sea, space, etc.*

Extreme low energy & cost

- *Devices free from battery charging*
- *Affordable mmW devices*



New combinations of requirements for new use cases

Extreme low latency

- *E2E very low latency*
- *Always low latency*

Extreme high reliability

- *Guaranteed QoS for wide range of industry use cases*

Extreme massive connectivity

- *Massive AI devices*
- *High-precision positioning*

Future Use Cases – Examples

Super high-quality & real-time VR/AR

Extreme high data rate/capacity ***Extreme low latency***

Broadband/URLLC for flying mobility

Extreme coverage ***Extreme high reliability***

Massive IoT for anything & anywhere

Extreme coverage ***Extreme massive connectivity***

Device cluster free from buttery charging

Extreme low energy & cost ***Extreme massive connectivity***

New Spectrum – Potential Candidates (10-300GHz)

Frequency range (GHz)		Bandwidth (GHz)	Relative BW (%)
10.7	11.7	1	8.93
14.4	15.25	0.85	5.73
27	29.5	2.5	8.85
31.5	33.4	1.9	5.86
39.5	41	1.5	3.73
45.3	47	1.7	3.68
47.2	50.2	3	6.16
51.2	52.6	1.4	2.70
66	71	5	7.30
71	76	5	6.80
81	86	5	5.99
92	102	10	10.31
102	105	3	2.90
136	148.5	12.5	8.79
151.5	164	12.5	7.92
167	182	15	8.60
185	200	15	7.79
209	226	17	7.82
231.5	248	16.5	6.88
above 252		infinity	

10-20 GHz → Technically attractive, but heavily used by other systems…

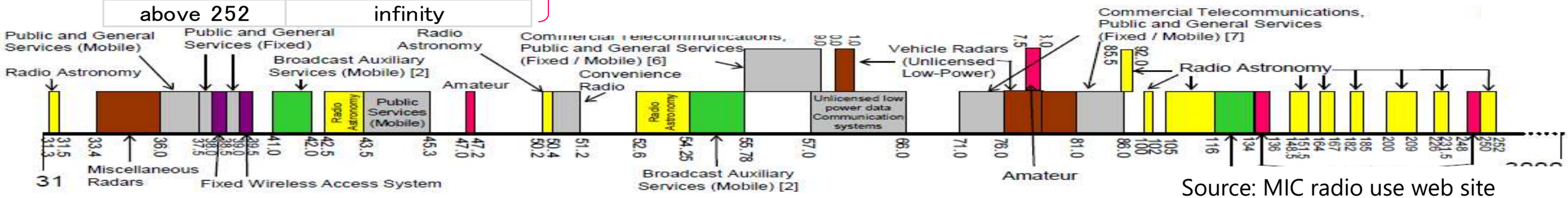
5G band in Japan (four 400-MHz blocks will be initially assigned)

Potential candidates for near future 5G band in Japan (depends on WRC-19 outcome)
- 39.5-41.0GHz (1.5GHz)
- 47.2-50.2GHz (3GHz)

*Close to the US 5G bands, i.e., 37-40 GHz and 47.2-48.2 GHz

Potential candidates for future 5G band above 52GHz (depends on WRC-19 outcome)
- 66-71GHz (5GHz) Not heavily used in Japan, unlicensed in other countries
- 71-76GHz (5GHz) E-band, high speed wireless communications
- 81-86GHz (5GHz) E-band, high speed wireless communications

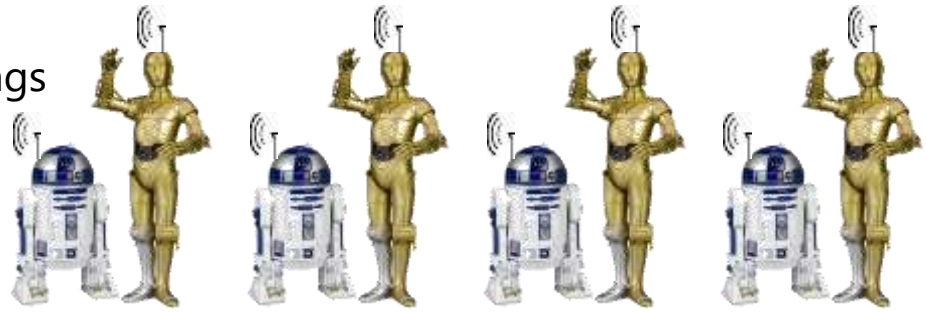
Not heavily used in Japan
Potential bands for long-term future study (above 100GHz)



Source: MIC radio use web site

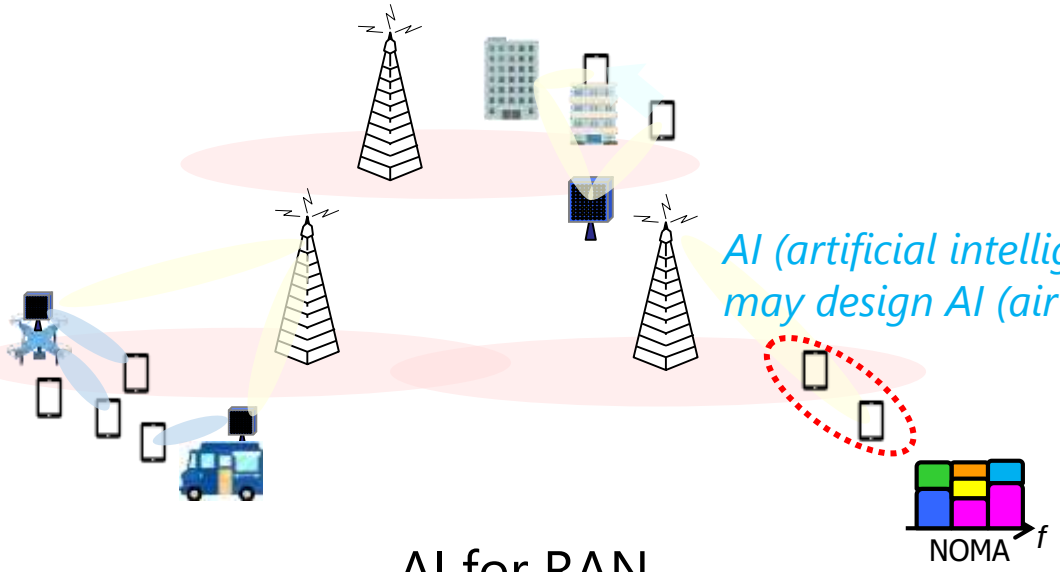
Evolutions Triggered by AI Technologies

- Evolutions triggered by AI will happen in 5G era and beyond
  - AI for RAN - Super intelligent RAN
  - Massive AI devices
    - » D2D and UE cooperation will be more important
    - » Potential high requirements for them, with abilities beyond human beings

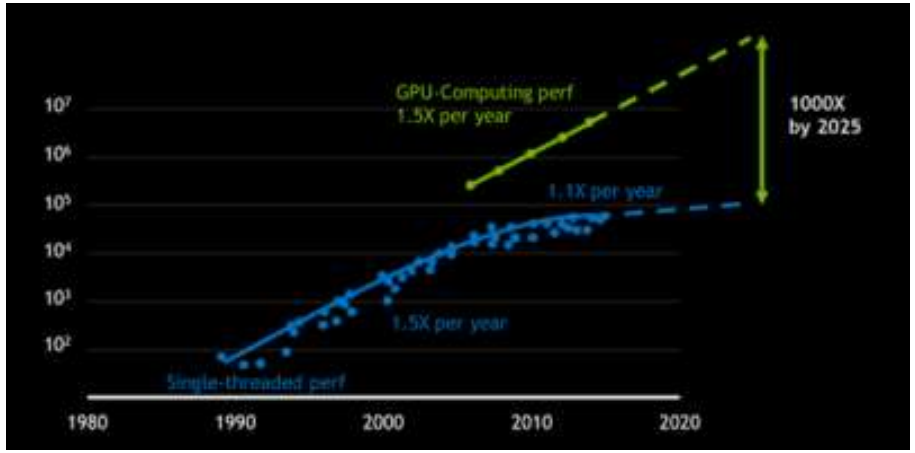


Massive AI devices

Cell design, parameter optimization, estimation and controls, etc.



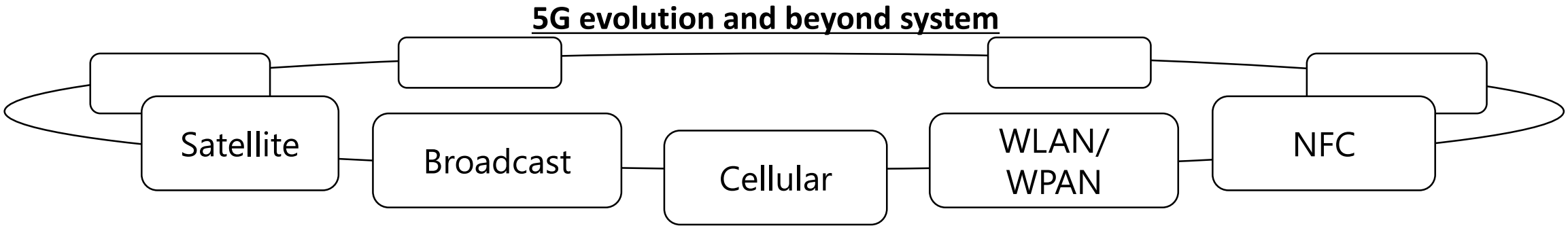
AI for RAN



Rise of GPU computing
(Source: Presentation by NVIDIA)

Integration of Non-Cellular/Wireless Technologies

- **Integration of non-cellular technologies into 5G evolution and beyond system**
  - Broadcast/Satellite systems e.g., for multi-cast service, emergency backhaul, etc.
  - Secondary use of spectrum and unlicensed spectrum use based on inter-RAT coordination



- **Integration of non-wireless communication technologies into 5G evolution and beyond system**
  - Sensor/camera information
  - Wireless charging/energy harvesting

➔ NR expansion for larger-scale ecosystem, global spectrum optimization, etc.

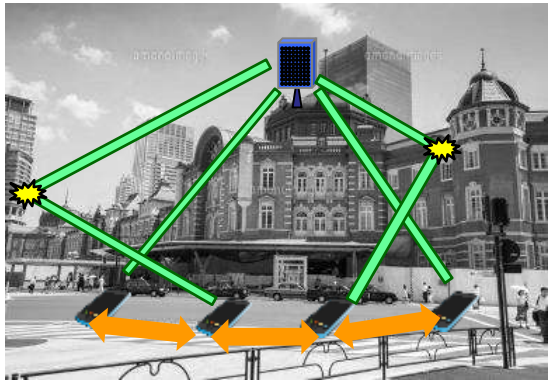
Future Radio Technologies – Examples

Super long-range broadband

to exploit new coverage areas

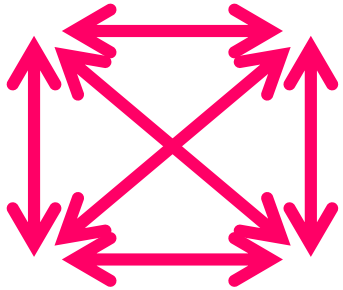
Massive MIMO enhancements

to improve data rate & capacity



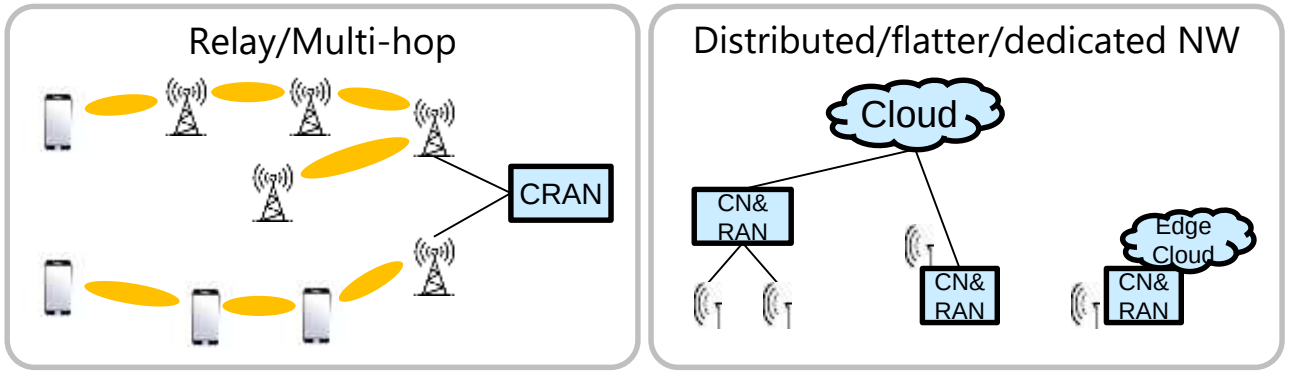
Advanced spatial multiplexing and diversity

Synergy of combinations



New network topologies

including device cooperation

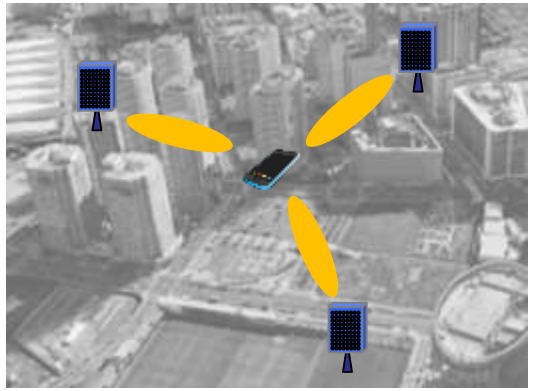


to improve coverage & capacity

to cope with variety of use cases

High-precision 3D positioning

to cope with variety of use cases



0.1 m-order accuracy in local environment

Summary

Real and Future for 5G Evolution and Beyond

Performance

Broadband for everything

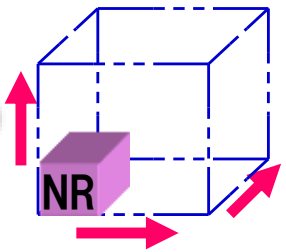
Super long-range

Gbps everywhere

Exploiting higher spectrum

Massive AI

AI for RAN



Uplink enhancement

Guaranteed performance

E2E low latency

Extreme use cases

High-precision positioning

Efficiency

New-type deployment

New spectrum use

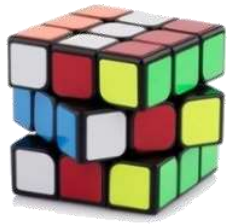
NR

Free from battery charging

Flexibility

Industry dedicated network

New coverage area



New combination of requirements