Future Radio Access for 5G

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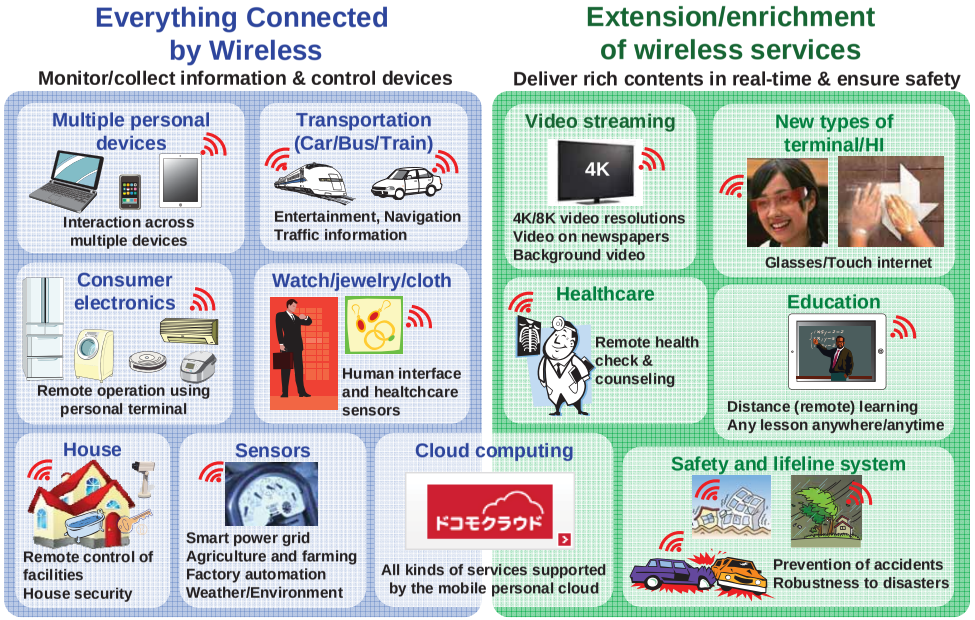
Outline

- High-level Vision
  - Phantom cell concept
- Key Technologies
  - Small cell enhancements
  - Massive MIMO
  - Non-orthogonal multiple access (NOMA)
- 5G Simulator Demo

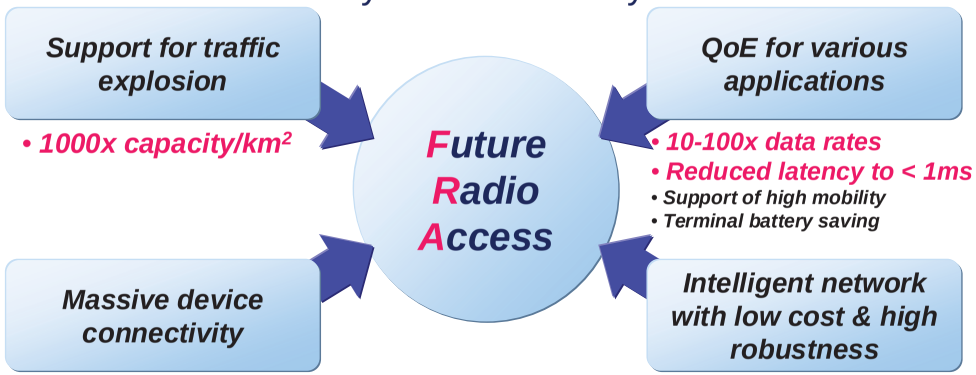
High-level Vision

Network/Communication Society in 2020 and Beyond



FRA concept and requirements

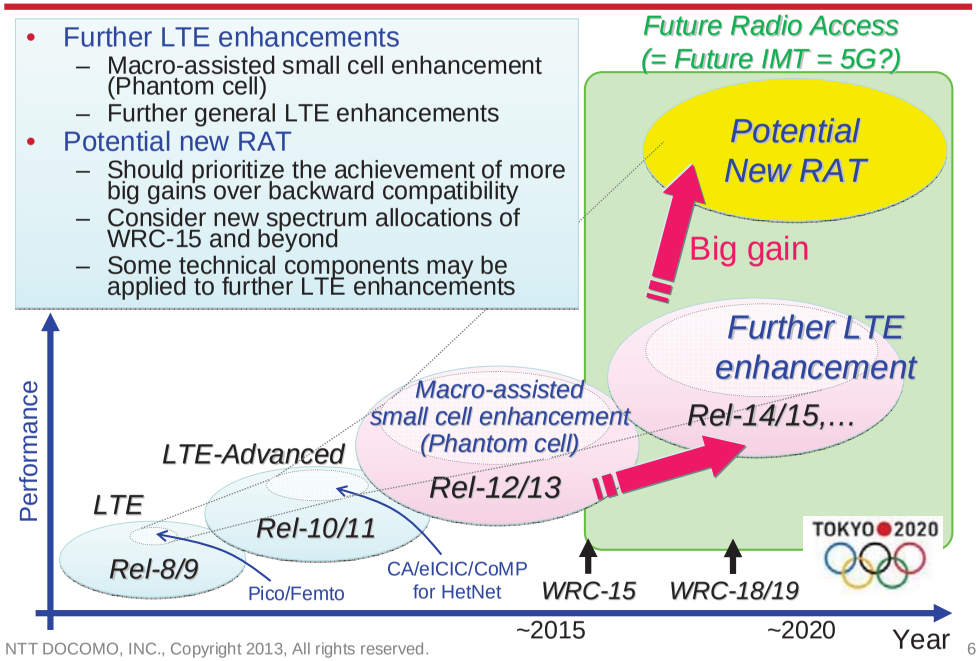
Various requirements for network/communication society in 2020 and beyond



FRA will provide a total solution to satisfy the requirements

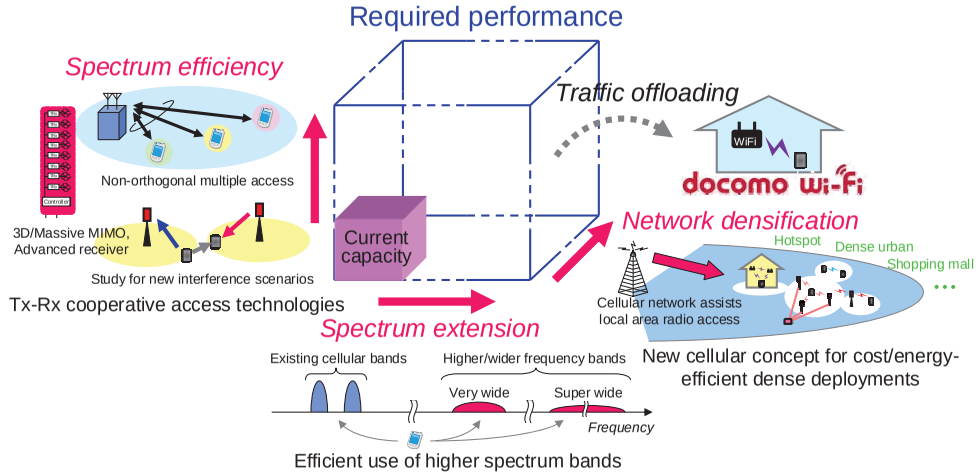
Evolution paths for FRA

- Further LTE enhancements
  - Macro-assisted small cell enhancement (Phantom cell)
  - Further general LTE enhancements
- Potential new RAT
  - Should prioritize the achievement of more big gains over backward compatibility
  - Consider new spectrum allocations of WRC-15 and beyond
  - Some technical components may be applied to further LTE enhancements



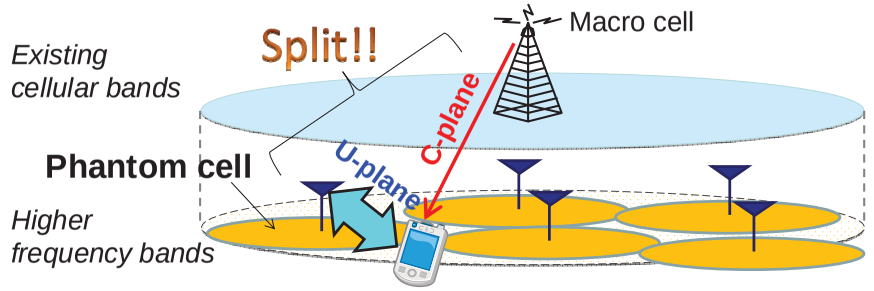
Directions of evolution: "The Cube"

A set of radio access technologies is required to satisfy future requirements



Phantom Cell

- *Proposed architecture to utilize higher frequency bands*
  "Phantom cell" – **Split of C-plane & U-plane** between macro and small cells in different frequency bands [1, 2]



[1] NTT DOCOMO, 3GPP RWS-120010, June 2012.
[2] H. Ishii et al., IEEE Globecom 2012 Workshop, Dec. 2012.

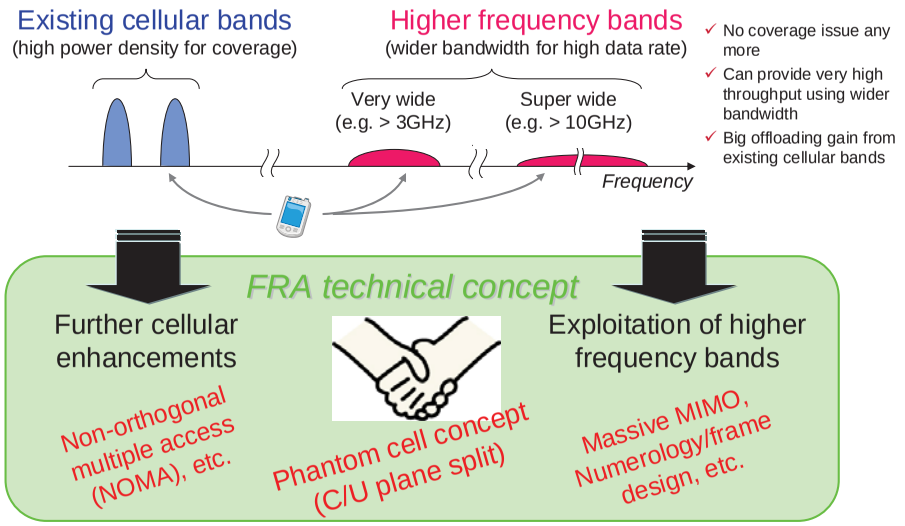
C-plane: Macro cell maintains good connectivity and mobility using lower frequency bands

U-plane: Small cell provides higher throughput and more flexible/cost-energy efficient operations using higher/wider frequency bands

FRA technical concept

Combined usage of lower and higher frequency bands

→ ***Higher frequency bands become useful and beneficial!***

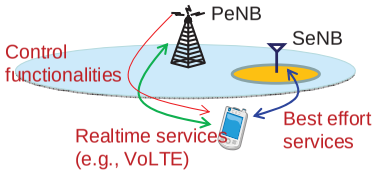


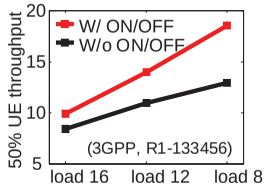
Key Technologies

Proposals for Small Cell Enhancements

Proposals for LTE Rel-12 SCE

- "Dual connectivity"
  - **C/U-plane architecture** and related physical layer aspects
  - **FDD/TDD joint operation** with carrier aggregation and/or dual connectivity
- Efficient small cell operation
  - **Small cell ON/OFF** for energy saving and interference reduction
  - **Efficient small cell Discovery**
  - Interference coordination and load balancing

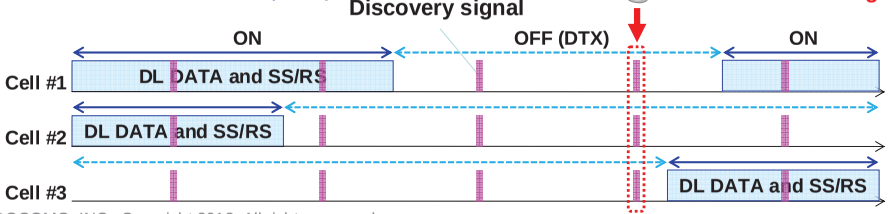




→ Proposed macro-assisted discovery

- UE can detect OFF (DTX)-state small cells

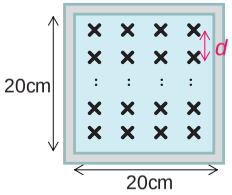
Macro-assisted measurement timing



Massive MIMO in higher frequency

- **Massive MIMO** – Beamforming using massive antenna elements in higher frequency bands
  - *Essential technology to extend effective cell range*

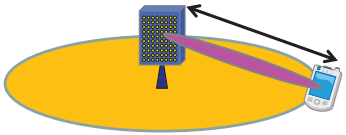
Example 2D antenna configuration



	LTE 3D-MIMO	Massive MIMO	
Antenna element spacing (d)	3.5 GHz (λ = 8.6 cm)	10 GHz (λ = 3 cm)	20 GHz (λ = 1.5 cm)
0.5 λ	16	169	676
0.7 λ	9	81	361

→ Compensation of increased path loss & Improved spectrum efficiency

Cell range extension by beamforming gain

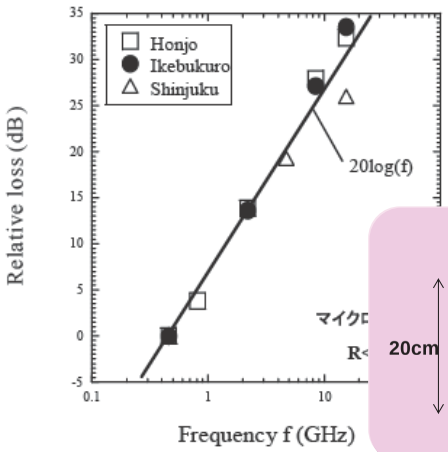


Improved spectrum efficiency with (multi-user) spatial multiplexing

Beamforming Gain vs. Path loss

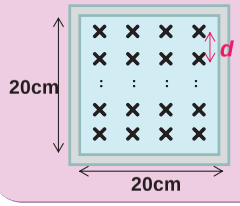
- Problem: In higher frequency bands, path-loss scales with **20log(f)** [1]

[1] Oda et al., IEEE VTC2001-Spring



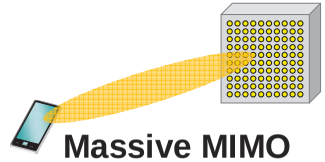
One digit increase of carrier frequency (e.g., 2GHz → 20GHz) is approximately equivalent to **20dB power loss**

Beamforming gain vs. path loss



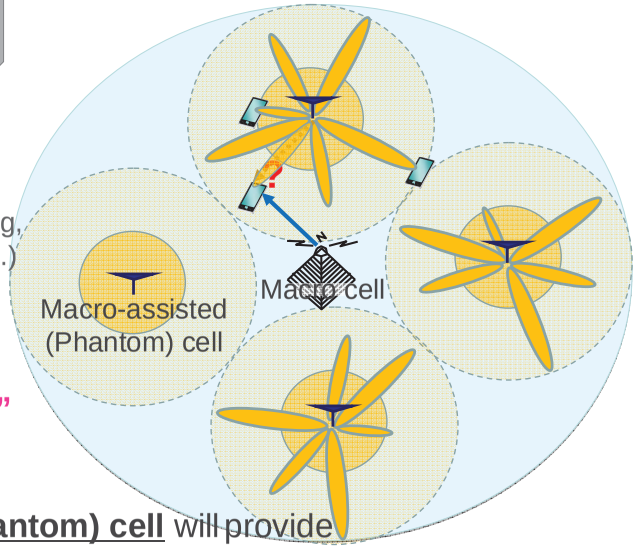
Number of antenna elements grows proportionally in square for a fixed surface
➔ **100x (20dB) BF gain**

Macro-assisted Massive MIMO



Massive MIMO

Key issue – Coverage for common channels (system information, paging, synchronization signal, etc.)



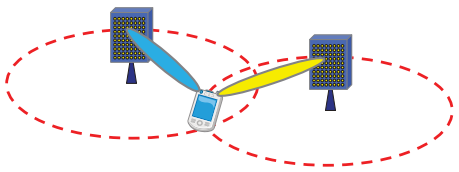
"an excellent feature"

The combination of **Massive MIMO** and **Macro-assisted (Phantom) cell** will provide adequate cell coverage even with higher frequency bands.

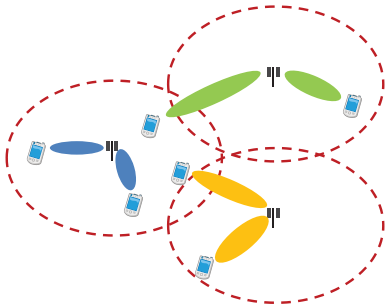
Macro-assisted discovery for Massive MIMO

- Discovery function is a key to achieve advanced multi-site operations for Massive MIMO
  - Multi-site cooperative beamforming
  - Beamforming for load balancing among cells

➔ Macro-assisted discovery is an effective approach

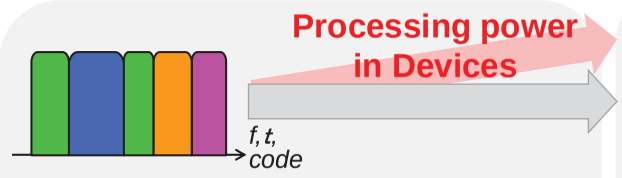


Cooperative beamforming



Beamforming for load balancing

Non-Orthogonal Multiple Access (NOMA)



Effort for Orthogonality

FDMA,TDMA, CDMA, OFDMA

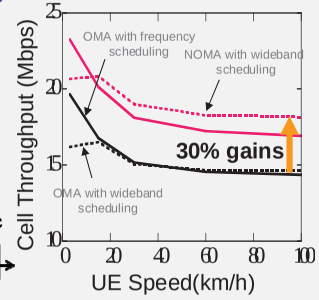
Effort for Interference Mitigation

Equalizer, Canceller

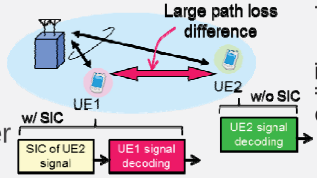
MIMO

Intentional Non-orthogonality

NOMA

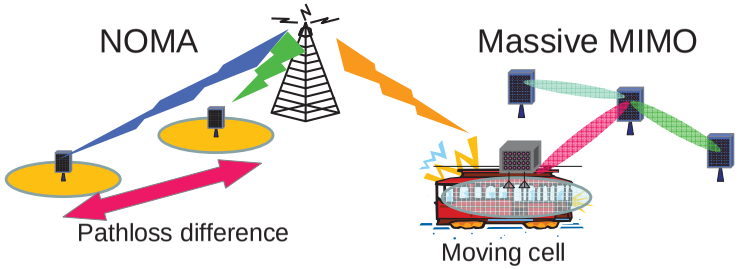


Exploitation of power-domain, path loss difference among users, and UE processing power



Application to wireless backhaul

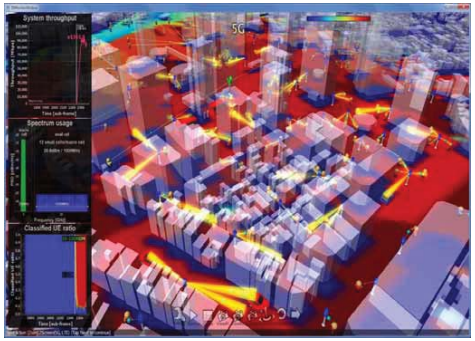
- Flexible support for access & backhaul links
  - Support for moving cell as well
- Massive MIMO and NOMA will be effective also for increasing capacity of wireless backhaul



5G Simulator Demo

Real-time Simulator of 5G World

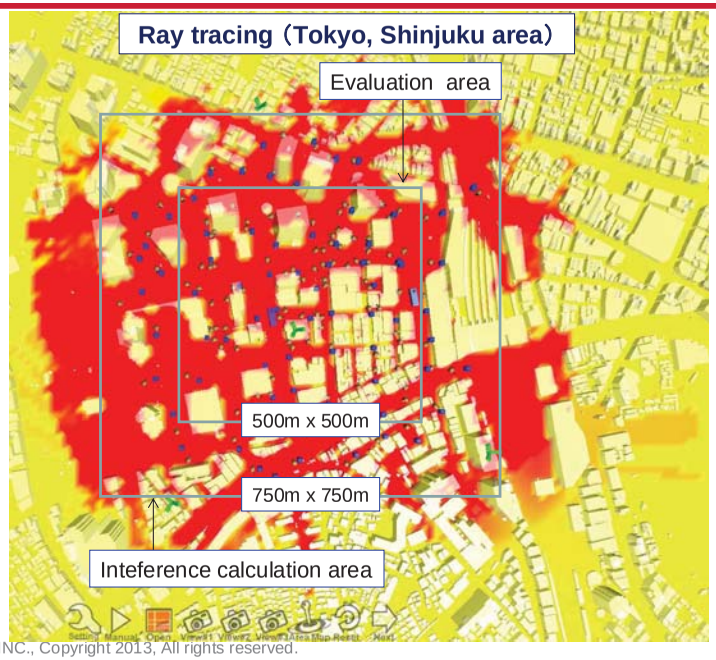
Simulator of high capacity and high data rate 5G world



CEATEC AWARD 2013

- Real-time evaluation of system performance and demonstration of download & play of high resolution movie (4K)
- Confirmation of DOCOMO candidate 5G technologies in real propagation environment (Shinjuku area)

Evaluation & Interference Calculation Area



Summary

- We presented our views on vision, requirements and potential key technologies for *Future Radio Access (FRA):*
  - Macro-assisted small cell, i.e., Phantom cell, and Massive MIMO are promising in the long-term future for higher/wider frequency bands
  - Non-orthogonal multiple access (NOMA) is a promising technology for future cellular enhancements
  - Other technologies, e.g. new numerology/frame structure, new waveform, contention based UL and flexible NW need to be further studied