Radio Interface and Radio Access Techniques for LTE-Advanced

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- **Targets for IMT-Advanced**
- **Requirements for LTE-Advanced**
- **Radio access techniques for LTE-Advanced**

Targets for IMT-Advanced

Targets for IMT-Advanced

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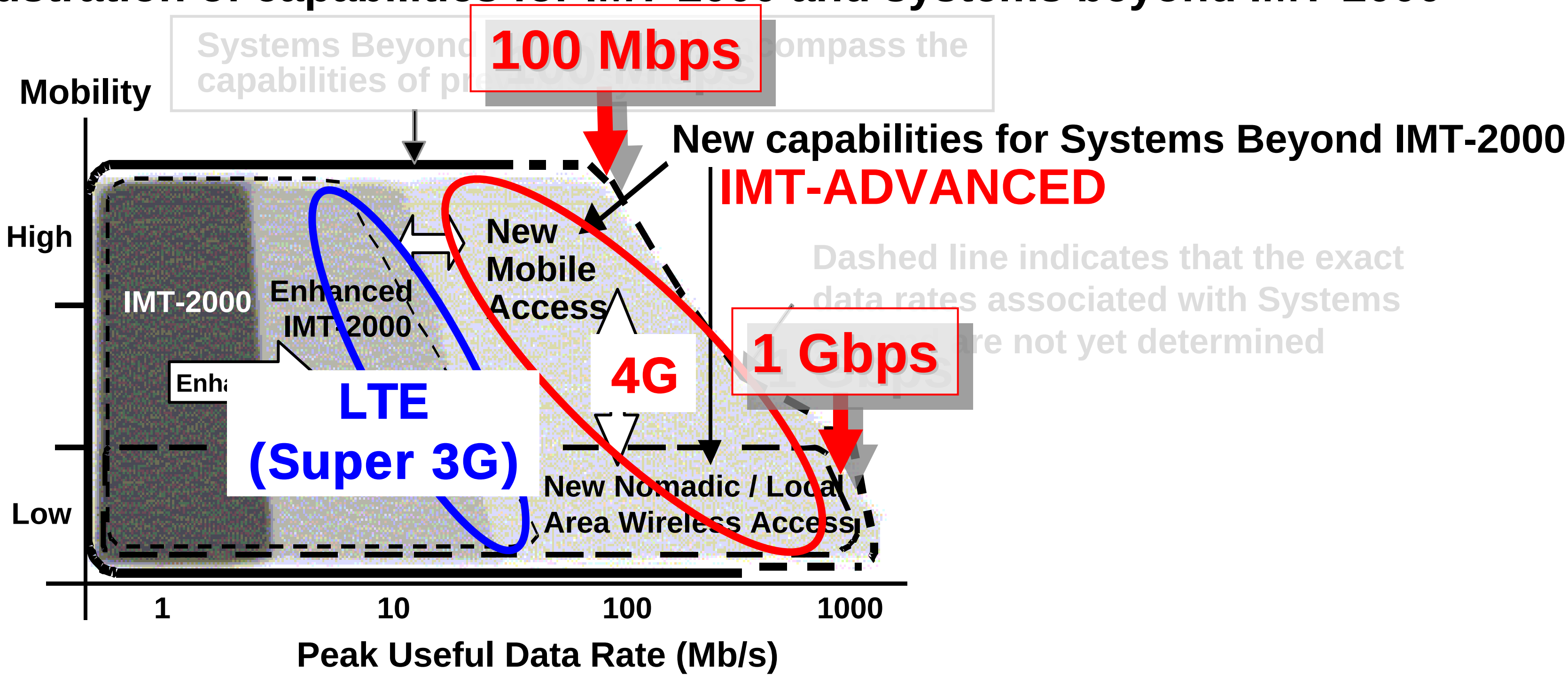
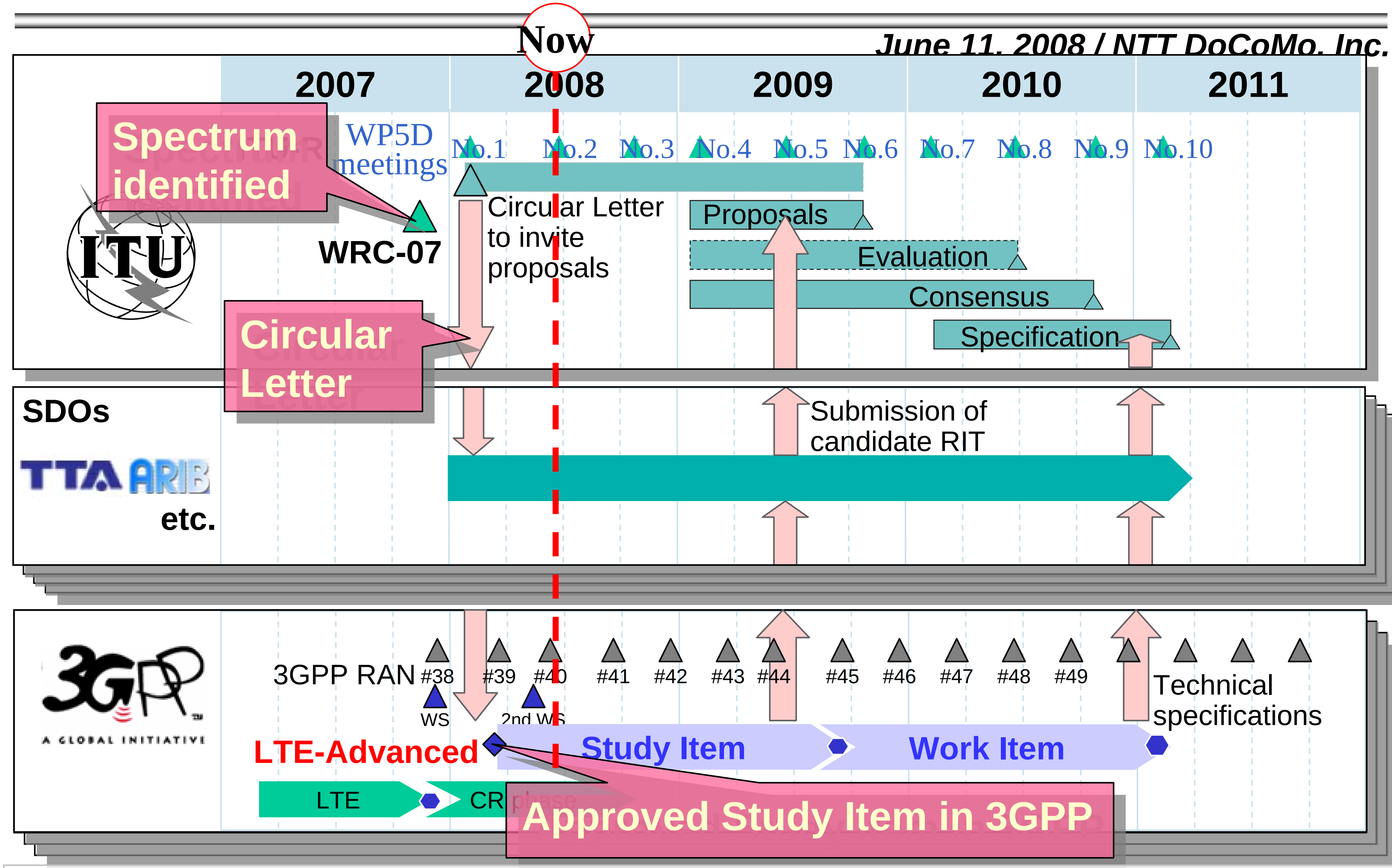
◆ **Recommendation ITU-R M.1645**

Framework and overall objectives for the future development of IMT-2000 and systems beyond IMT-2000

Illustration of capabilities for IMT-2000 and systems beyond IMT-2000



Schedule for IMT-Advanced



- In 3GPP, LTE-Advanced is regarded as IMT-Advanced
- DoCoMo continues to contribute to IMT-Advanced

Requirements for LTE-Advanced

High-Level Requirements for LTE-Advanced

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- **LTE-Advanced should be real broadband wireless networks that provide peak data rates equal to or greater than those for wired networks, i.e., FTTH (Fiber To The Home), while maintaining equivalent QoS**
- **Complete backward compatibility, i.e., full support of Rel-8 LTE and its enhancement is necessary in LTE-Advanced**
- **High-level requirements**
  - **Reduced network cost (cost per bit)**
  - **Better service provisioning**
  - **Compatibility with 3GPP systems**

- **Minimum requirement for LTE-Advanced is to meet or exceed IMT-Advanced requirements within ITU-R time plan**
- **Furthermore, LTE-Advanced targets performance higher than that for LTE in order to satisfy future user demand and to be a competitive mobile communications system**

Radio Access Requirements

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- **Full support of Rel-8 LTE and its enhancement within the same spectrum**
  - ➔ **Basically same radio parameters and multi-access schemes**
- **Lower latencies in C-plane and U-plane compared to those in Rel-8 LTE**
- **Improve system performance**
  - **Peak spectrum efficiency**
  - **Capacity (average spectrum efficiency)**
  - **Cell edge user throughput**
  - **VoIP capacity ➔ Higher capacity than in Rel-8 LTE**
  - **Mobility ➔ Improve system performance in low mobility up to 10 km/h**
  - **Coverage ➔ Equal or wider coverage than in Rel-8 LTE**

Performance Requirements (1)

■ Peak data rate

- Need higher peak data rates in LTE-Advanced than those for LTE in order to satisfy future traffic demands

	LTE (Rel-8)		LTE-Advanced
DL	300 Mbps	x3.3	1 Gbps
UL	75 Mbps	x6.6	500 Mbps

- Wider transmission bandwidth
- Higher-order MIMO

■ Peak spectrum efficiency

- Must reduce bit cost per Hertz and improve user throughput particularly in local areas
- Higher peak spectrum efficiency is beneficial to achieving higher peak data rate with limited available transmission bandwidth

	LTE (Rel-8)		LTE-Advanced
DL	15 bps/Hz (4 streams)	x2.0	30 bps/Hz (8 streams)
UL	3.75 bps/Hz (1 stream)	x4.0	15 bps/Hz (4 streams)

- Higher-order MIMO

Performance Requirements (2)

Capacity (Average spectrum efficiency)

- Need higher capacity to reduce further network cost per bit

	LTE (Rel-8)		LTE-Advanced
DL	1.69 bps/Hz/cell (2-by-2 MIMO)	x2.2	3.7 bps/Hz/cell (4-by-4 MIMO)
UL	0.735 bps/Hz/cell (1-by-2 SIMO)	x2.7	2.0 bps/Hz/cell (2-by-4 MIMO)

- Wider transmission bandwidth
- OFDM in uplink
- Higher-order MIMO
- Multi-cell transmission/reception
- Advanced receiver

Cell edge user throughput

- Need higher cell edge user throughput compared to that for LTE to provide better services

	LTE (Rel-8)		LTE-Advanced
DL	0.05 bps/Hz/cell (2-by-2 MIMO)	x2.4	0.12 bps/Hz/cell (4-by-4 MIMO)
UL	0.028 bps/Hz/cell (1-by-2 SIMO)	x2.5	0.07 bps/Hz/cell (2-by-4 MIMO)

- Higher-order MIMO
- Multi-cell transmission/reception
- Advanced receiver

* Target values are for Case 1 scenario in 3GPP, which is similar to Base Coverage Urban scenario in IMT.EVAL

Expect to satisfy these target values by

- increase number of Rx antennas (approximately 1.5 times)
- increase number of Tx antennas (approximately 1.1 times)
- employ other new/enhanced techniques (approximately 1.4 – 1.6 times)

Radio Access Techniques for LTE-Advanced

Proposed Techniques for LTE-Advanced

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- **Proposed radio access techniques for LTE-Advanced**

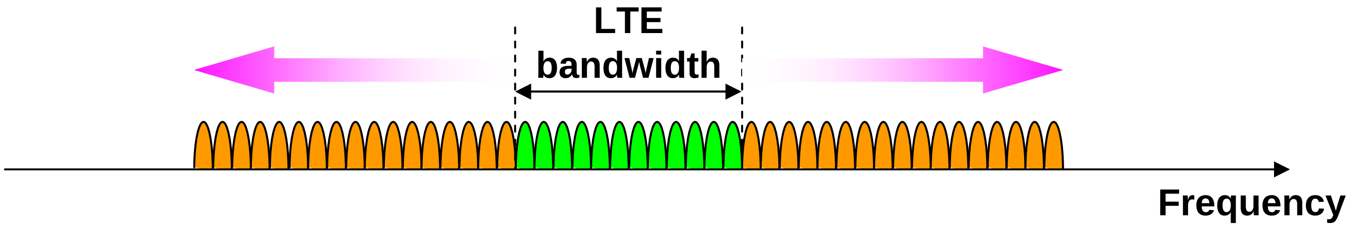
1. **Asymmetric wider transmission bandwidth**
2. **Layered OFDMA multi-access**
3. **Advanced multi-cell transmission/reception techniques**
4. **Enhanced multi-antenna transmission techniques**
5. **Efficient modulation/detection and channel coding**
6. **Enhanced techniques to extend coverage area**

Asymmetric Wider Transmission Bandwidth

Support of Wider Bandwidth

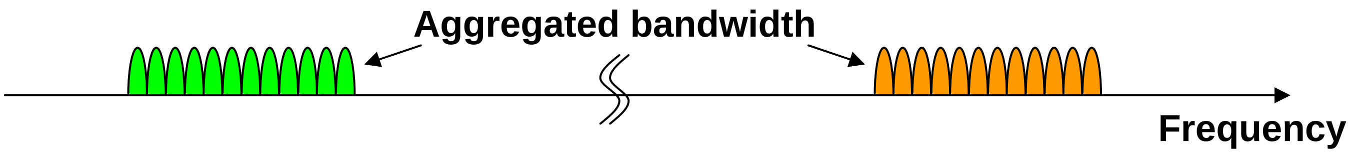
- Need wider bandwidth such as approximately 100 MHz to reduce bit cost per Hertz and to achieve peak data rate higher than 1 Gbps
- Continuous spectrum allocation should be prioritized, although both continuous and discontinuous usages are to be investigated

- Continuous spectrum usage



  - ✓ Better to simplify eNB and UE configurations than to employ discontinuous usage
  - ✓ Possible frequency allocation in new band, e.g., 3.4 – 3.8 GHz band

- Discontinuous spectrum usage ➔ Requires spectrum aggregation



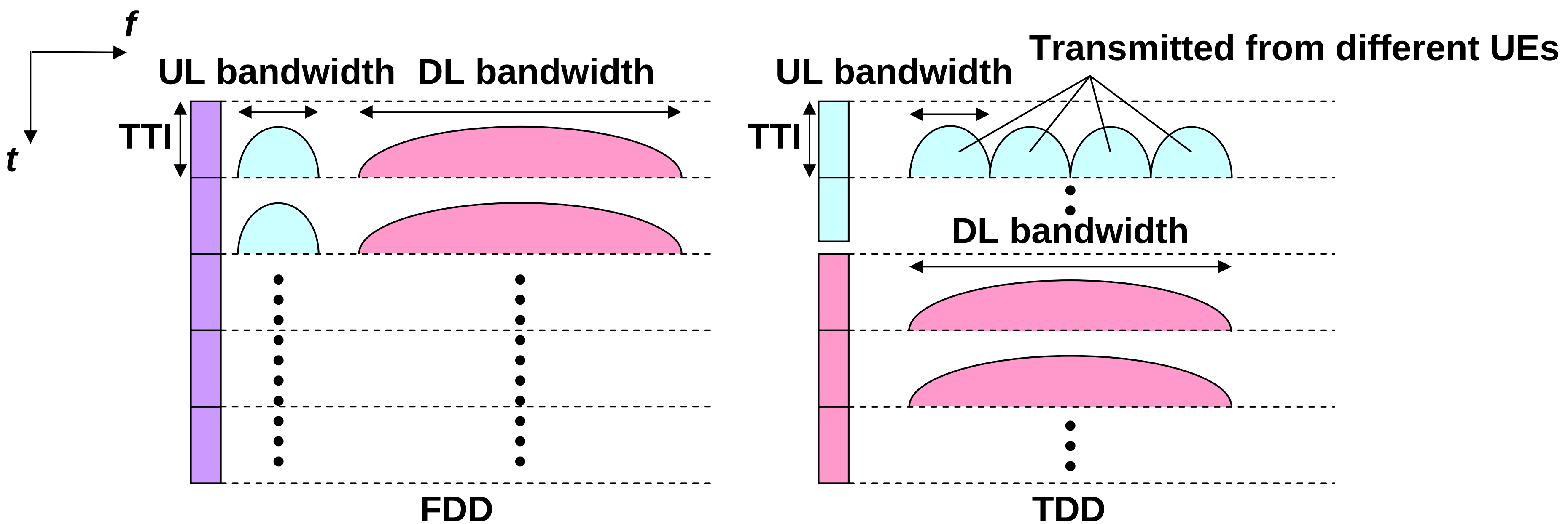
  - ✓ UE capability for supportable spectrum aggregation should be specified so that increases in UE size, cost, and power consumption are minimized

Asymmetric Transmission Bandwidth

■ Asymmetric transmission bandwidth

- **Required bandwidth in uplink will be much narrower than that in downlink considering current and future traffic demands in cellular networks**
- **In FDD, asymmetric transmission bandwidth eases pair band assignment**
- **In TDD, narrower transmission bandwidth is beneficial in uplink, since an excessively wider transmission bandwidth degrades channel estimation and CQI estimation**

➔ Propose asymmetric transmission bandwidth in both FDD and TDD



Layered OFDMA Multi-access

Layered OFDMA

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■ Requirements for multi-access scheme

- **Support of transmission bandwidth wider** than 20 MHz, i.e., near 100 MHz, to achieve peak data rate requirements, e.g., higher than 1 Gbps
- **Coexist with Rel-8 LTE in the same system bandwidth as LTE-Advanced**
- **Optimize tradeoff between achievable performance and control signaling overhead**
  - ✓ Obtain sufficient frequency diversity gain when transmission bandwidth is approximately 20 MHz
  - ✓ Control signaling overhead increases according to increase in transmission bandwidth
- **Efficient support of scalable bandwidth** to accommodate various spectrum allocations

■ Propose Layered OFDMA radio access scheme in LTE-Advanced

- ✓ Layered transmission bandwidth
- ✓ Support of layered environments
- ✓ Layered control signal formats

Layered Transmission Bandwidth (1)

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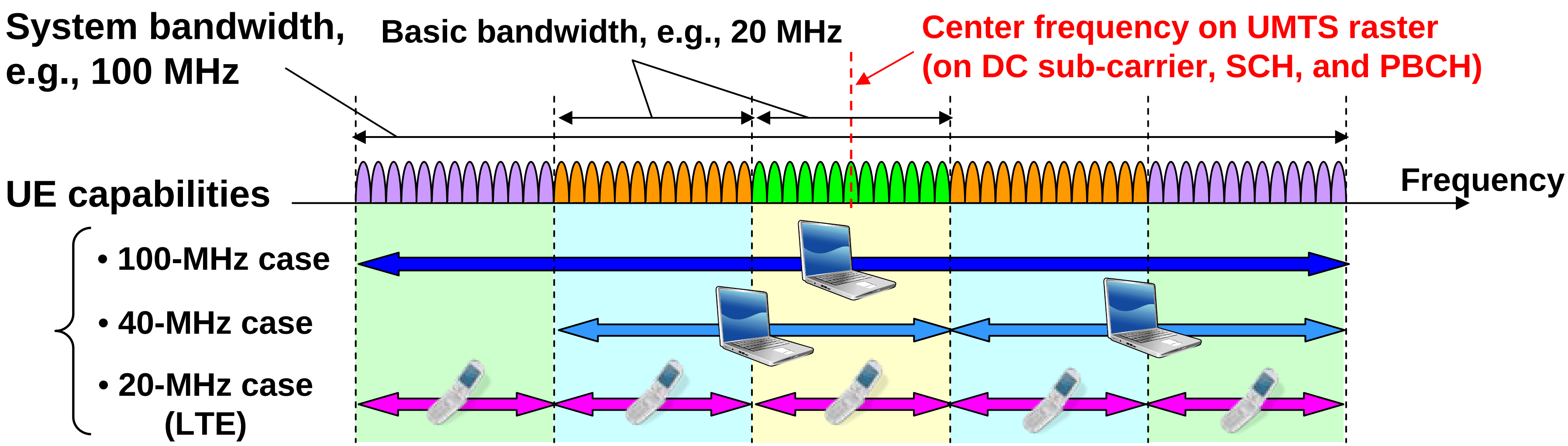
■ **Layered transmission bandwidths**

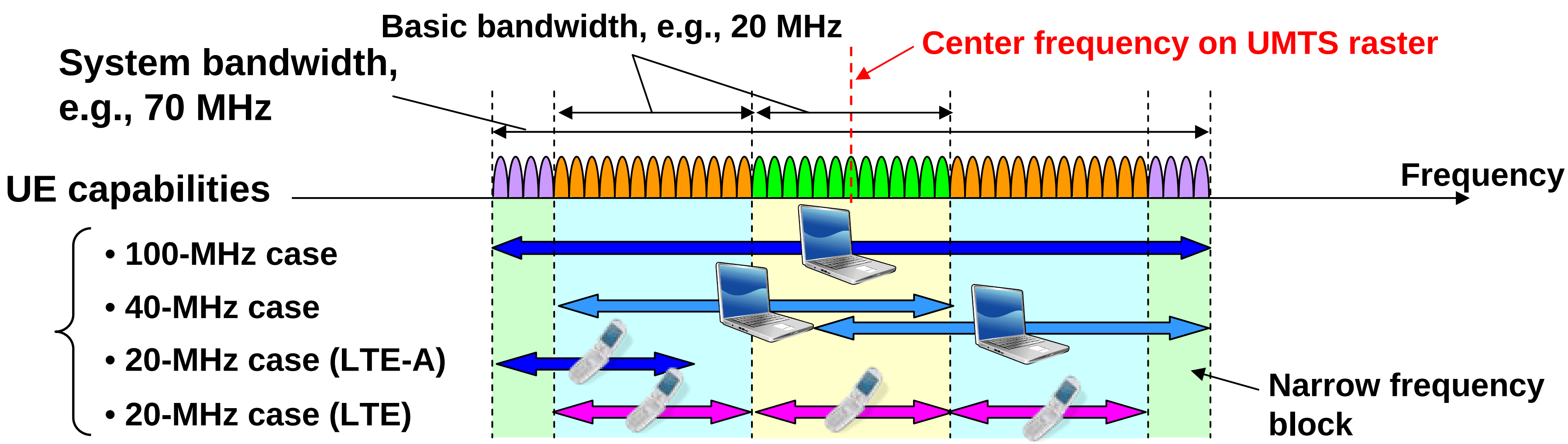
- **Layered structure comprising multiple basic frequency blocks**
  - ✓ **Entire system bandwidth comprises multiple basic frequency blocks**
  - ✓ **Bandwidth of basic frequency block is, e.g., 15 – 20 MHz**
- **Synchronization Channel (SCH) and Physical Broadcast Channel (PBCH) transmissions**
  - ✓ **At minimum, SCH and PBCH must be transmitted from the central basic frequency block**
  - ✓ **SCH and PBCH belonging to the central basic frequency block are located on UMTS raster**
  - ✓ **Transmission of SCH and PBCH from other basic frequency blocks is FFS**
- **Principle of UE access method**
  - ✓ **Both LTE-A-UE with different capability and LTE-UE can camp at any basic frequency block(s) including narrow frequency block at both ends**

Layered Transmission Bandwidth (2)

◆ Example when allocating continuous wider bandwidth, e.g., 100 MHz



◆ Example when allocating continuous wider bandwidth, e.g., 70 MHz



Support of Layered Environments

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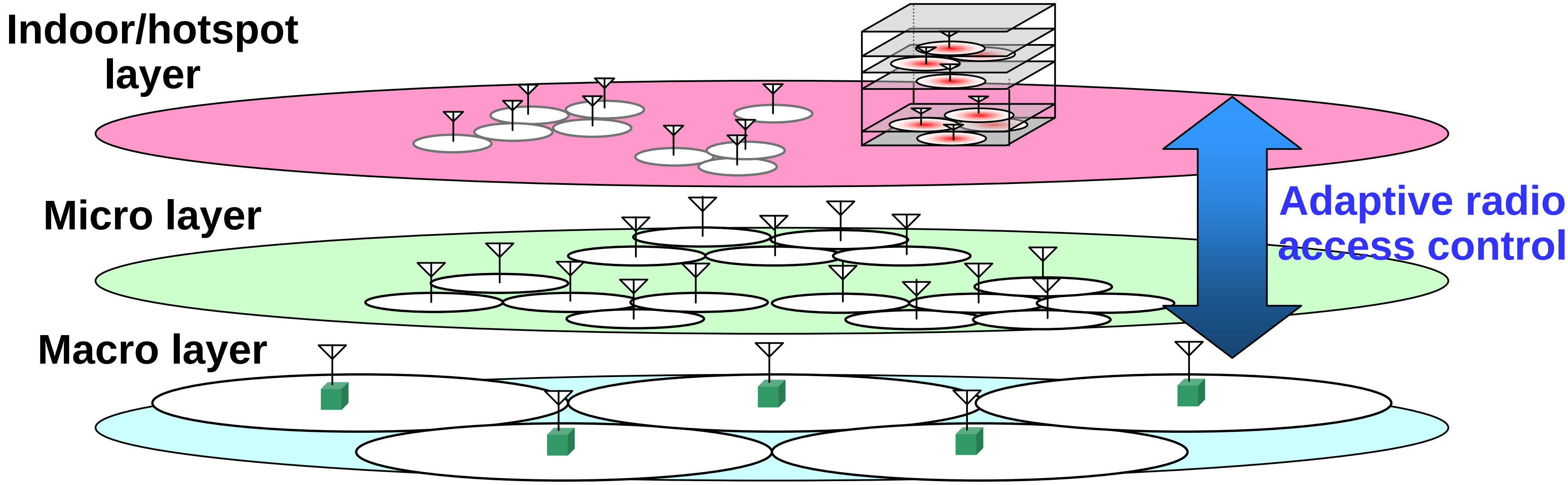
■ **Support of layered environments**

- **Achieves the highest data rate (user throughput) or widest coverage according to radio environment such as macro, micro, indoor, and hotspot cells and required QoS**
- **Adaptive radio access control according to radio environment**
- **MIMO channel transmission with high gain should be used particularly in local areas**



Proposals for Uplink Radio Access

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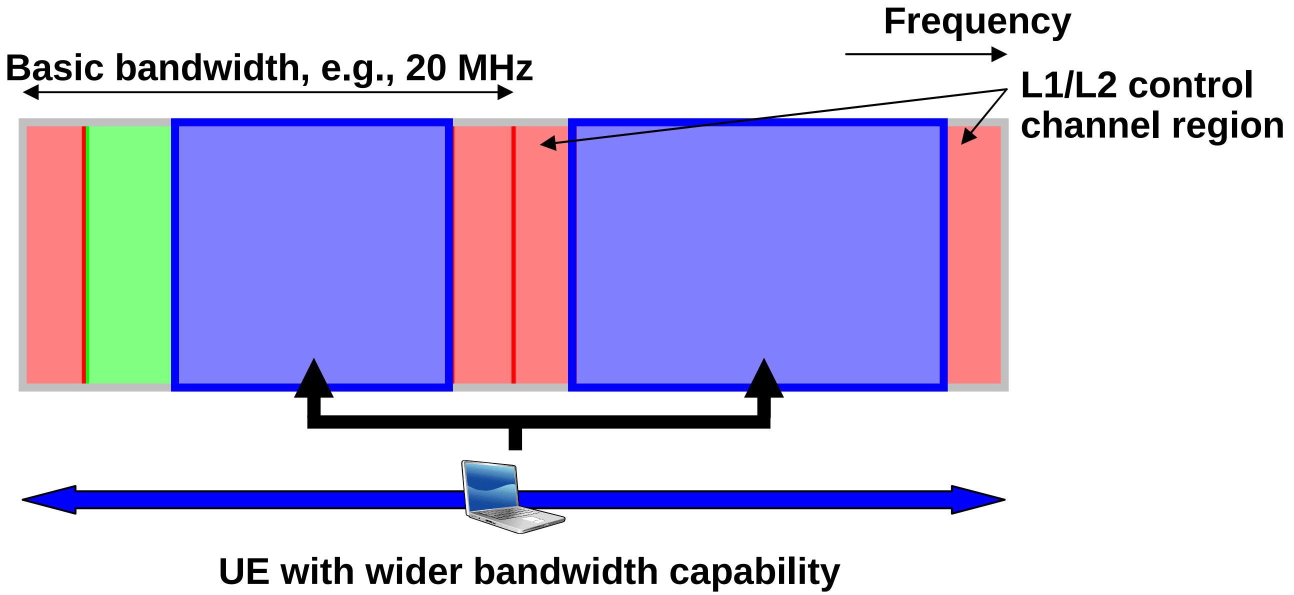
- **Purpose: Achieve high gain in SU-MIMO and MU-MIMO by mitigating the influence of multipaths**

➔ **Propose SC/MC hybrid radio access**

- **Purpose: Achieve SC based transmission with low PAPR for UE with wider bandwidth capability when PUCCH is transmitted in the middle of the transmission bandwidth**

➔ **Support application of clustered DFT-Spread OFDM transmission (e.g., REV-080022 (NEC))**



OFDM Benefits for MIMO Transmission

- **In LTE-Advanced UL, need much higher user throughput and capacity than those for LTE are necessary particularly in local areas**
  ➔ Should adopt UL radio access with high affinity to MIMO transmission

- **Maximum Likelihood Detection (MLD) based signal detection is more advantageous than LTE working assumptions such as Linear Minimum Mean Squared Error (LMMSE) or Serial Interference Canceller (SIC) for reducing the required received SNR**
  ➔ We propose supporting the radio access scheme so that the MLD based signal detection as well as LMMSE and SIC is applicable

  - **Reason why OFDM has high affinity to MIMO using MLD**
  - ✓ **In OFDM, only symbol replica at each subcarrier is necessary to perform MLD because multipaths are mitigated due to long symbol duration and insertion of cyclic prefix**
  - ✓ **Meanwhile, in SC-FDMA, symbol replicas for respective resolved paths at each subcarrier are required, bringing about significant increase in complexity**

SC/MC Hybrid Radio Access

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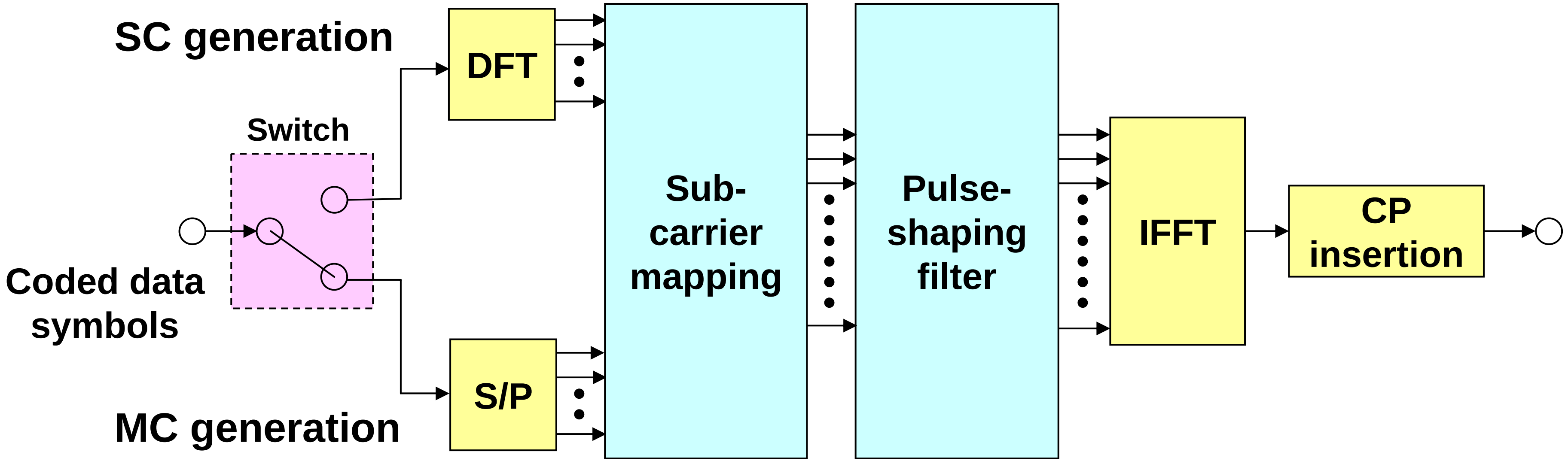
◆ **Adaptive radio access using MC/SC hybrid to support layered environments**

- **Universal switching of MC/SC based access using frequency domain multiplexing/de-multiplexing**
- **Optimization of PAPR (coverage) and achievable peak data rate according to inter-site distance, cell structure, and QoS requirements**
- **High affinity to UL MIMO transmission**



Layered Control Signal Formats

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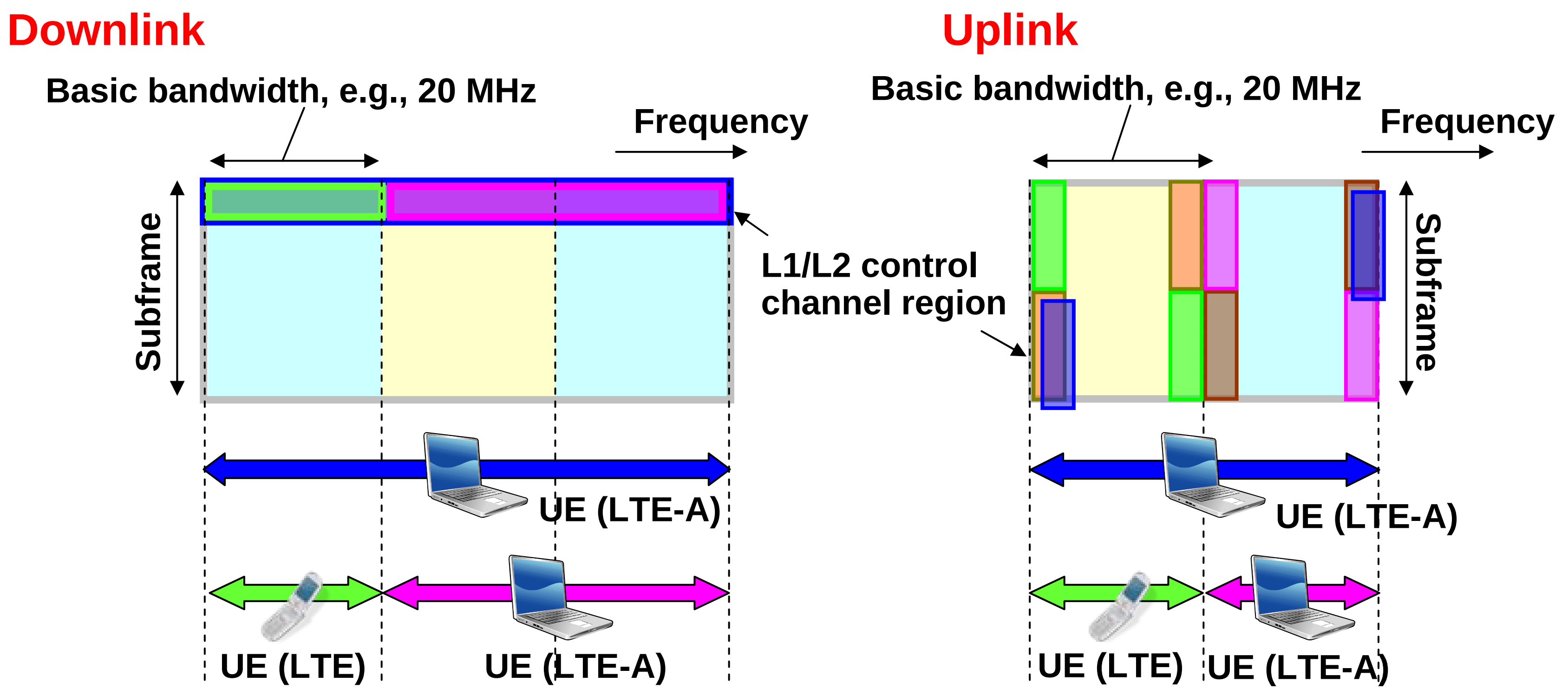
- **Layered L1/L2 control signal formats**
- Achieve high commonality with control signal formats in LTE
- Use layered L1/L2 control signal formats according to assigned transmission bandwidth to achieve efficient control signal transmission

Examples of layered multiplexing of L1/L2 control signals



Advanced Multi-cell Transmission/Reception Techniques

Advanced Multi-cell Transmission/Reception Techniques

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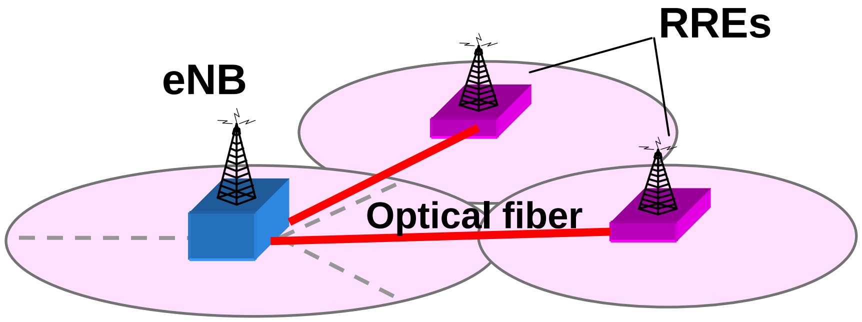
- **Use of advanced multi-cell transmission/reception techniques**
  - Advanced multi-cell transmission/reception, i.e., coordinated multipoint transmission/reception, is to be used to increase frequency efficiency and cell edge user throughput
  - Proposed techniques –
    - ✓ Fast radio resource management (i.e., inter-cell interference coordination (ICIC)) aiming at inter-cell orthogonalization
    - ✓ Fast handover at different cell sites

- **Use cell structure employing remote radio equipments (RREs) more actively in addition to cell structure employing independent eNB**
  - RREs are beneficial to both ICIC and fast handover



Inter-cell Orthogonalization

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One-cell frequency reuse

- Baseline is one-cell frequency reuse to achieve high system capacity

Intra-cell orthogonalization

- Achieves intra-cell orthogonal multi-access (multiplexing) in both links as well as in LTE

Inter-cell orthogonalization

- Although ICIC is adopted in LTE, it only introduces fractional frequency reuse at cell edge with slow control speed using control signals via backhaul
- Thus, inter-cell orthogonality will be established in LTE-Advanced to achieve high frequency efficiency and high data rate at cell edge

		W-CDMA	LTE (Rel-8)	LTE-Advanced
Intra-cell	DL	(Partially) orthogonal	Orthogonal	Orthogonal
	UL	Non-orthogonal	Orthogonal	Orthogonal
Inter-cell	DL	Non-orthogonal	Non-orthogonal	(Quasi)-orthogonal
	UL	Non-orthogonal	Non-orthogonal	(Quasi)-orthogonal

Fast Radio Resource Management for Inter-cell Orthogonalization

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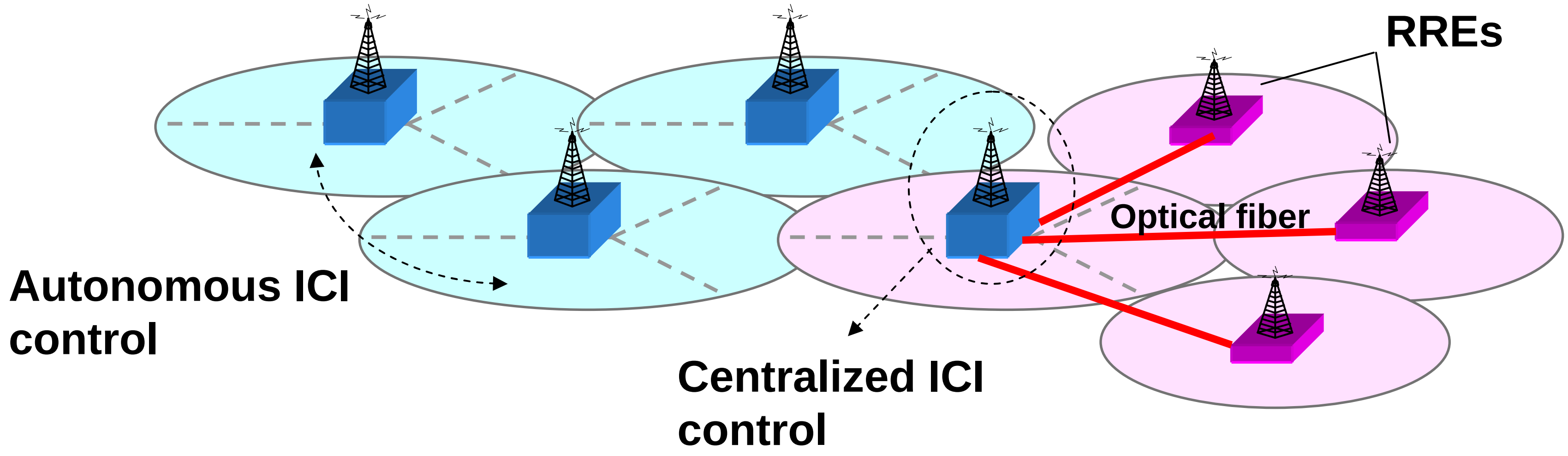
- **Achieve inter-cell orthogonality through fast inter-cell interference (ICI) management**
- **Centralized control:** ICI management among **RRE cells** using scheduling at central eNB
  ➔ Achieves complete inter-cell orthogonality
- **Autonomous control (similar to LTE method):** ICIC among independent eNBs using control signals via backhaul and/or air
  ➔ Achieves inter-cell quasi-orthogonality through faster control compared to LTE to achieve fractional frequency reuse at the cell edge



Fast Handover at Different Cell Sites

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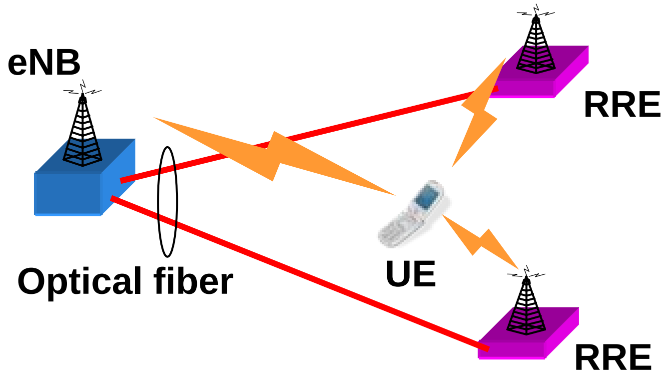
Cells using RREs

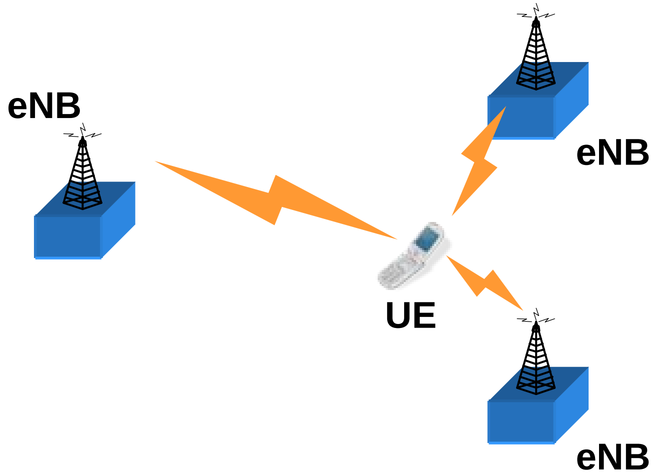
- **DL**: Fast cell selection (FCS) in L1 using bicast in L2/L3
- **UL**: MRC reception at the central eNB

Independent eNBs

- **DL**: Faster cell selection compared to LTE, i.e., as fast as possible, in L1 using bicast/forwarding in L2/L3
- **UL**: Simultaneous reception at multiple cells (or faster cell selection than that for LTE)



(a) Cells using RREs



(b) Independent eNBs

Enhanced Multi-antenna Transmission Techniques

Benefits of Higher-Order MIMO

■ Necessity of higher-order MIMO channel transmissions

Traffic demand in the era of LTE-Advanced

- **Requires higher peak frequency efficiency than that for LTE to satisfy the increased traffic demand in the era of LTE-Advanced**
  - **➔ Increased number of antennas directly contributes to achieving higher peak spectrum efficiency**

Local area optimization

- **Since LTE-Advanced will focus on local area, higher peak frequency efficiency also contributes to increase in average frequency efficiency**
- **Higher-order MIMO is more practical in local areas**

Number of Antennas Considered for LTE-Advanced

- User throughput is significantly improved according to the increase in the number of transmitter and receiver antennas, i.e., more effective than increasing modulation level
- Proposals for the number of supported antennas

	LTE (Rel-8)	LTE-Advanced
DL	Baseline: 2-by-2 MIMO Max: 4-by-4 MIMO	Baselines: 2-by-2, 4-by-2, and 4-by-4 according to UE categories and eNB types (optimization condition is FFS) Max: 8-by-8 MIMO
UL	Baseline: 1-by-2 SIMO	Baselines: 2-by-2 and 2-by-4 according to eNB types Max: 4-by-4(8) MIMO

- All LTE MIMO channel techniques should be enhanced and applied to LTE-Advanced
  - MIMO transmission mode control according to different requirements/targets
  - Adaptive rank control according to channel conditions
  - Adaptive rate control through modulation and coding rates
  - Codebook based precoding

Efficient Modulation/Detection and Channel Coding

Efficient Modulation/Detection and Coding

- **Must further reduce required received SNR and increase frequency efficiency**

- **Applicable techniques:**
  - **Higher-order modulation scheme (FFS)**
  - **Application of maximum likelihood detection (MLD) based demodulation and signal detection**
  - **Efficient channel coding and decoding for data and control channels**
    - ✓ **Investigate LDPC code to achieve data rates higher than 1 Gbps with reasonable decoding complexity, although backward compatibility should be considered**

Enhanced Techniques to Extend Coverage Area

Enhanced Techniques to Extend Coverage (1)

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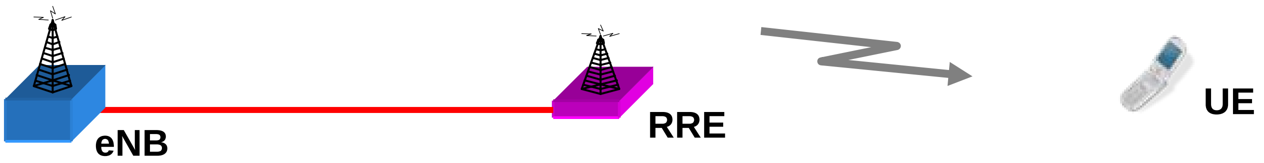
■ **RREs using optical fiber ("sector" belonging to the same eNB)**

- **Should be used in LTE-Advanced as effective technique to extend cell coverage**



Enhanced Techniques to Extend Coverage (2)

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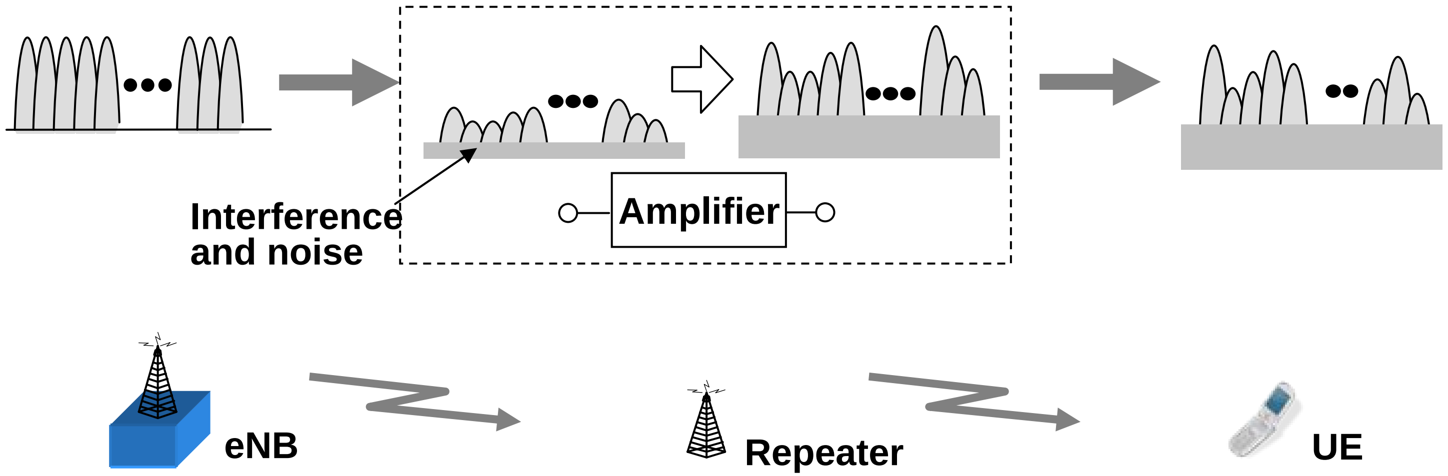
■ **Relays using radio**

- **L1 relays with non-regenerative transmission, i.e., repeaters**
  - ✓ **Since delay is shorter than cyclic prefix duration, no additional change to radio interface is necessary**
  - ✓ **Repeaters are effective in improving coverage in existing cells**
  - ✓ **Should be used as well as in 2G/3G networks**

- **Use the same (or different) frequency/time resources**
- **Short processing delay**



Enhanced Techniques to Extend Coverage (3)

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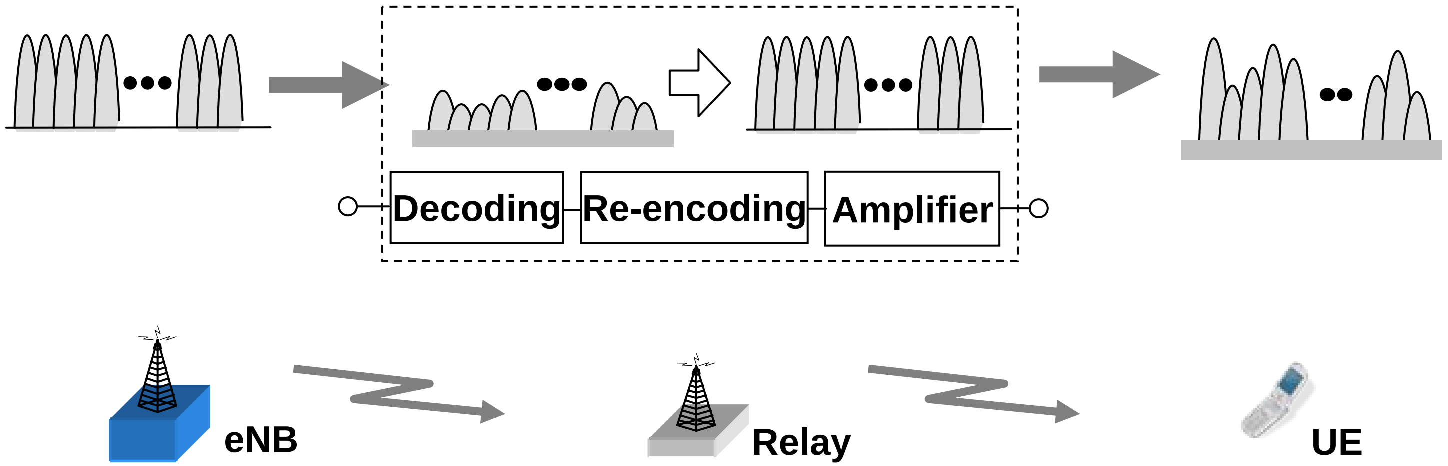
■ Relays using radio

- L2 and L3 relays
  - ✓ L2 and L3 relays can achieve wide coverage extension via increase in SNR
  - ✓ Problems to be solved are efficient radio resource assignment to signals to/from relay station, delay due to relay, etc.

• Use different frequency/time resources
• Long processing delay
• Radio resource management at relays (L2 and L3 relays)



Conclusion

■ Targets for LTE-Advanced

- Minimum requirement is to meet or exceed ITU-R requirements within ITU-R time plan
- LTE-Advanced targets higher performance than that for LTE

■ Proposed radio access techniques for LTE-Advanced

- **Asymmetric wider transmission bandwidth** to reduce network cost per bit and to achieve required peak data rate
- **Layered OFDMA** using layered physical channel structure with adaptive multi-access control to support layered environments and to achieve high commonality with LTE
- **Advanced multi-cell transmission/reception techniques** with inter-cell orthogonalization and fast handover
- **Enhanced multi-antenna transmission techniques** including higher-order MIMO channel transmission using larger number of antennas
- **Efficient modulation/detection and coding techniques**
- **Enhanced techniques to extend coverage area** such as RREs and relays using radio including repeaters