Beyond 3G
: 3GPP Long Term Evolution and 3GPP2 Ultra Mobile Broadband

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- Introduction and Background
- 3GPP Long Term Evolution (LTE)
- FLASH-OFDM® (pre-UMB)
- 3GPP2 Ultra Mobile Broadband (UMB)
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Introduction and Background

3GPP LTE

FLASH-OFDM

3GPP2 UMB

Summary and References

Beyond 3G

- International Mobile Telecommunications (IMT)-2000 introduced global standard for 3G.
- Systems beyond IMT-2000 (IMT-Advanced) is set to introduce evolutionary path beyond 3G.
  - Mobile class targets 100 Mbps with high mobility and nomadic/ local area class targets 1 Gbps with low mobility.
- 3GPP and 3GPP2 are currently developing evolutionary/ revolutionary systems beyond 3G.
  - 3GPP Long Term Evolution (LTE)
  - 3GPP2 Ultra Mobile Broadband (UMB)

3GPP Evolution

- Release 99 (Mar. 2000): UMTS/WCDMA
- Rel-5 (Mar. 2002): HSDPA
- Rel-6 (Mar. 2005): HSUPA
- Rel-7 (2007): DL MIMO, IMS (IP Multimedia Subsystem), optimized real-time services (VoIP, gaming, push-to-talk).
- Long Term Evolution (LTE)
  - 3GPP work on the Evolution of the 3G Mobile System started in November 2004.
  - Currently, standardization in progress in the form of Rel-8.
  - Spec scheduled to be finalized by the end of 2007/early 2008.
  - Target deployment in 2010.

3GPP2 Evolution

- CDMA2000 1X (1999)
- CDMA2000 1xEV-DO (2000)
- EV-DO Rev. A (2004): VoIP
- EV-DO Rev. B (2006): Multi-carrier
- Ultra Mobile Broadband (UMB), f.k.a. EV-DO Rev. C
  - Based on EV-DO, IEEE 802.20, and FLASH-OFDM
  - Spec by Apr. 2007.
  - Commercially available in early 2009.

Introduction and Background

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Summary and References

Requirements of LTE

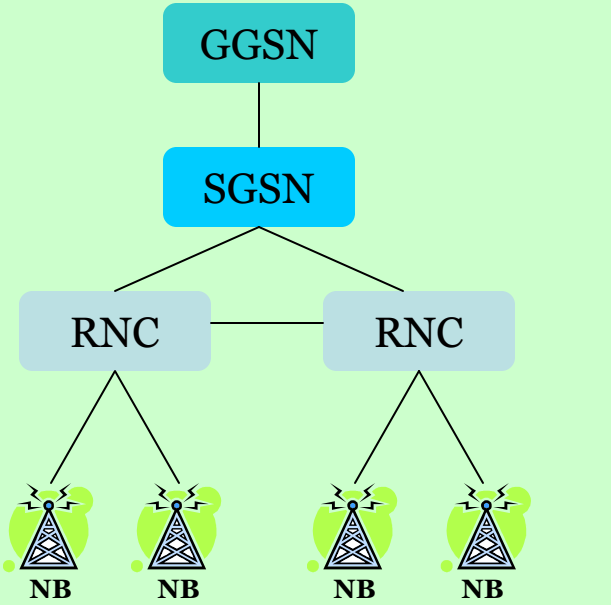
- Peak data rate
  - 100 Mbps DL/ 50 Mbps UL within 20 MHz bandwidth.
- Up to 200 active users in a cell (5 MHz)
- Less than 5 ms user-plane latency
- Mobility
  - Optimized for 0 ~ 15 km/h.
  - 15 ~ 120 km/h supported with high performance.
  - Supported up to 350 km/h or even up to 500 km/h.
- Enhanced multimedia broadcast multicast service (E-MBMS)
- Spectrum flexibility: 1.25 ~ 20 MHz
- Enhanced support for end-to-end QoS

Key Features of LTE

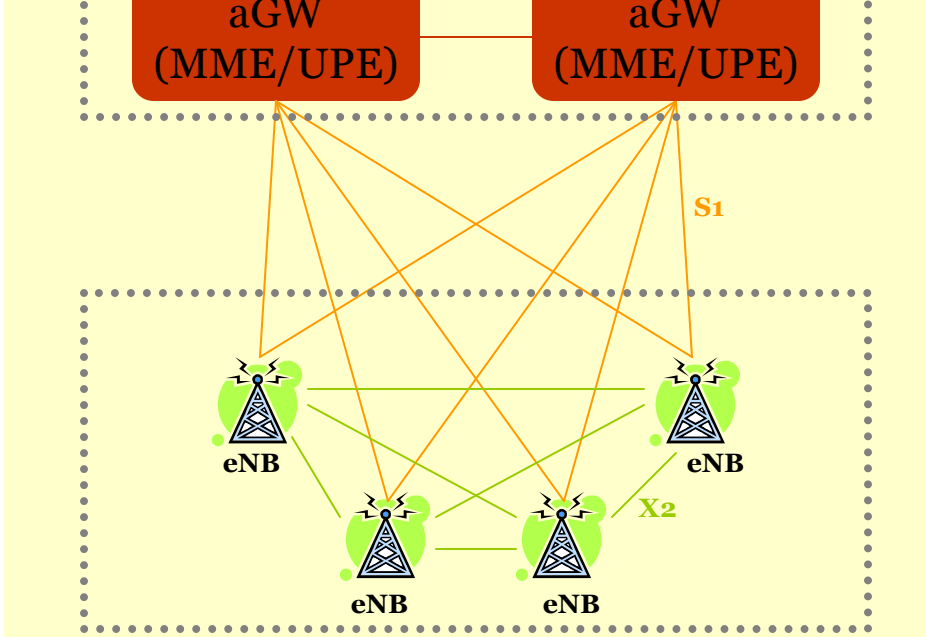
- Multiple access scheme
  - DL: OFDMA with CP.
  - UL: Single Carrier FDMA (SC-FDMA) with CP.
- Adaptive modulation and coding
  - DL/UL modulations: QPSK, 16QAM, and 64QAM
  - Convolutional code and Rel-6 turbo code
- Advanced MIMO spatial multiplexing techniques
  - (2 or 4)x(2 or 4) downlink and uplink supported.
  - Multi-user MIMO also supported.
- Support for both FDD and TDD
- H-ARQ, mobility support, rate control, security, and etc.

LTE Network Architecture

- E-UTRAN (Evolved Universal Terrestrial Radio Access Network)



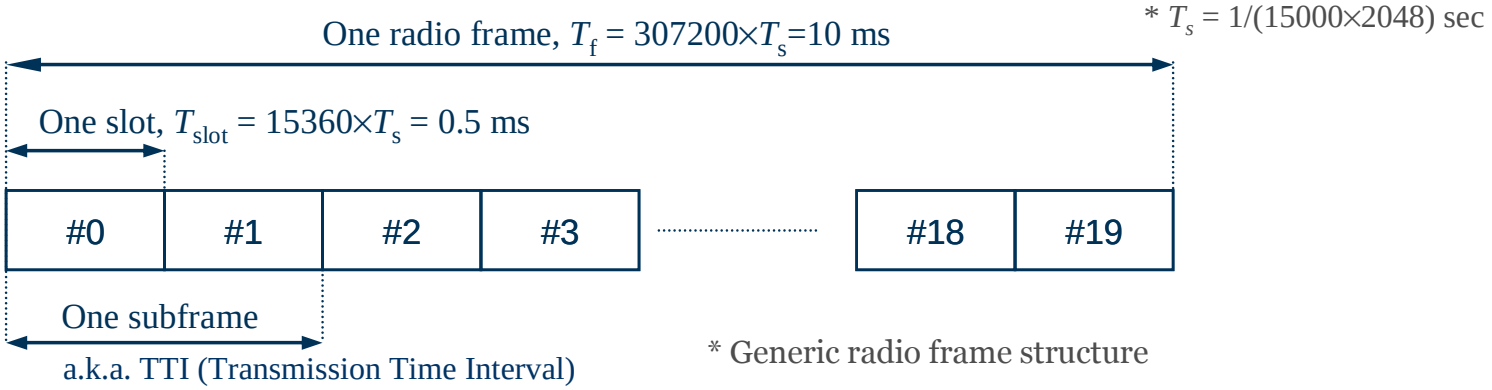
NB: NodeB (base station)
RNC: Radio Network Controller
SGSN: Serving GPRS Support Node
GGSN: Gateway GPRS Support Node



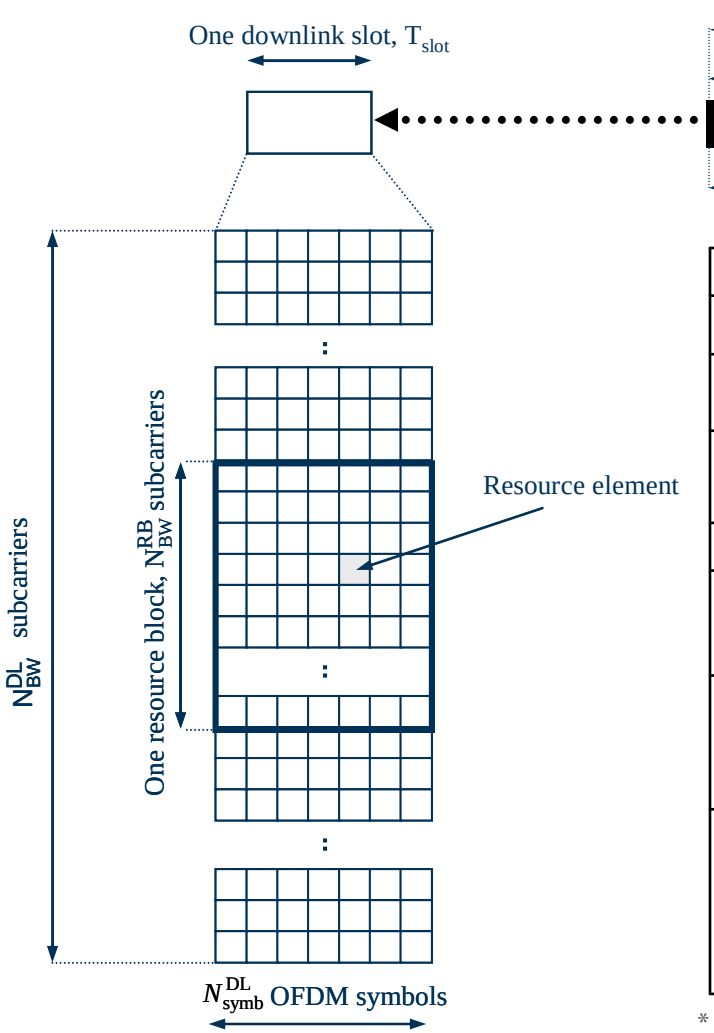
eNB: E-UTRAN NodeB
aGW: Access Gateway
MME: Mobility Management Entity
UPE: User Plane Entity

LTE Frame Structure

- Two radio frame structures defined.
  - Generic frame structure: FDD and TDD.
  - Alternative frame structure: TDD only.
- Generic radio frame has duration of 10 ms. It consists of 20 slots. A slot has a duration of 0.5 ms. 2 slots comprise a subframe.
- A resource block (RB) spans 12 subcarriers over a slot duration of 0.5 ms. One subcarrier has bandwidth of 15 kHz.



LTE DL Slot Structure



Transmission BW		1.25 MHz	2.5 MHz	5 MHz	10 MHz	15 MHz	20 MHz
Slot duration		0.5 ms					
Sub-carrier spacing		15 kHz					
Sampling frequency		1.92 MHz (1/2 × 3.84 MHz)	3.84 MHz	7.68 MHz (2 × 3.84 MHz)	15.36 MHz (4 × 3.84 MHz)	23.04 MHz (6 × 3.84 MHz)	30.72 MHz (8 × 3.84 MHz)
FFT size		128	256	512	1024	1536	2048
Number of occupied sub-carriers		76	151	301	601	901	1201
Number of OFDM symbols per sub frame (Short/Long CP)		7/6					
CP length (μs/samples)	Short	(4.69/9) × 6, (5.21/10) × 1*	(4.69/18) × 6, (5.21/20) × 1	(4.69/36) × 6, (5.21/40) × 1	(4.69/72) × 6, (5.21/80) × 1	(4.69/108) × 6, (5.21/120) × 1	(4.69/144) × 6, (5.21/160) ×1
	Long	(16.67/32)	(16.67/64)	(16.67/128)	(16.67/256)	(16.67/384)	(16.67/512)

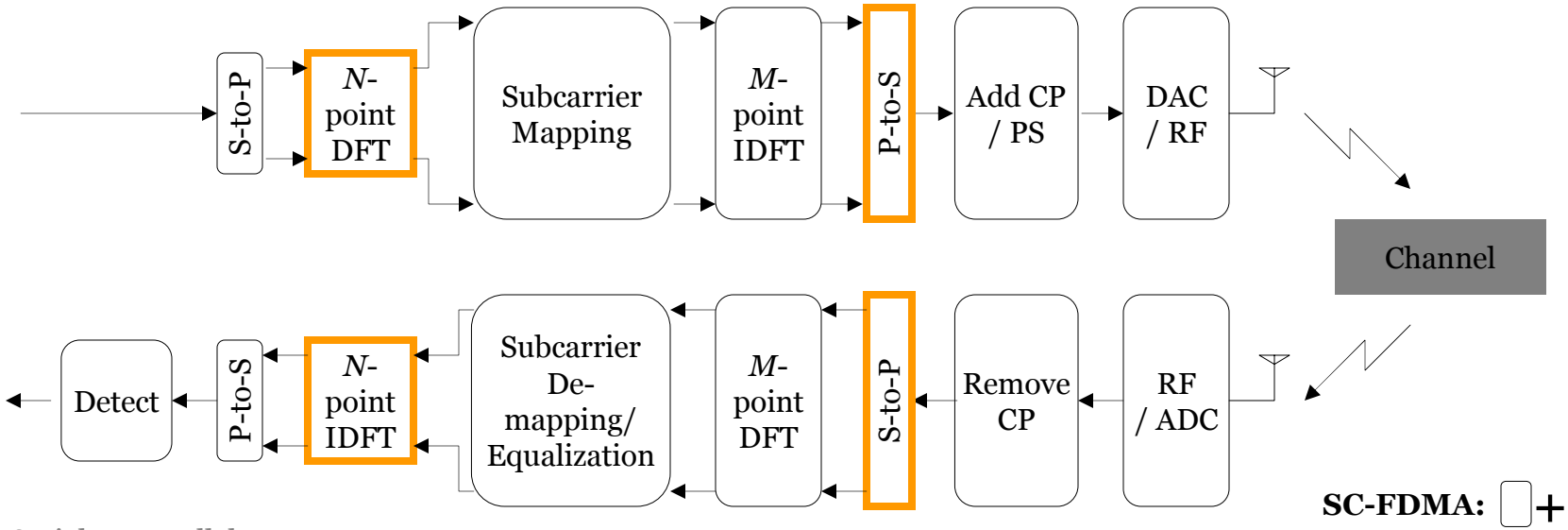
* 3GPP TR 25.814

LTE DL MIMO

- Support up to 4x4 configuration.
- Support for both spatial multiplexing (SM) and Tx diversity (TxD).
  - SM
    - Unitary precoding based scheme with codebook based feedback from user.
    - Multiple codewords
  - TxD: SFBC/STBC, switched TxD, CDD (Cyclic Delay Diversity) considered.
- MU-MIMO supported.

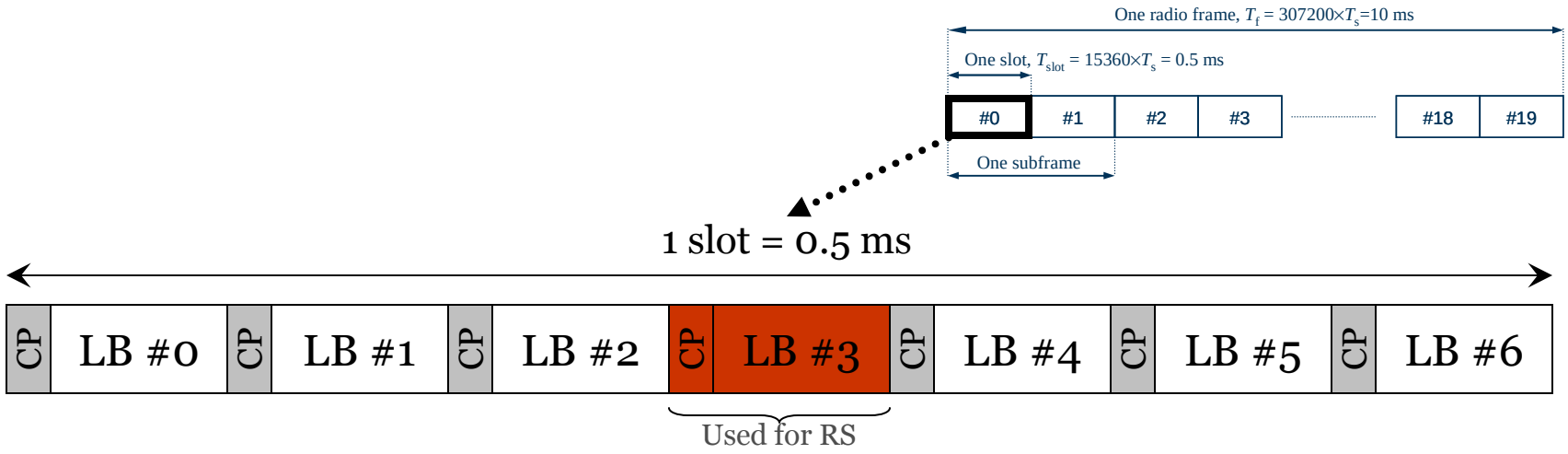
LTE UL: Single Carrier FDMA

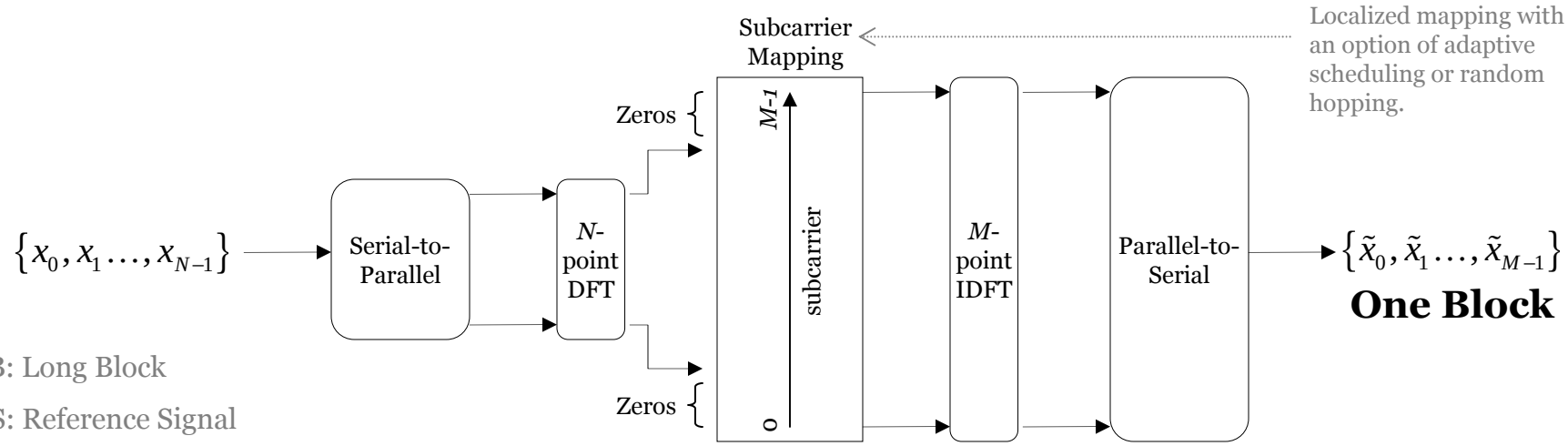
- What is Single Carrier FDMA (SC-FDMA)?
  - Single carrier modulation and frequency domain equalization.
  - Similar performance and essentially the same overall structure as those of OFDMA system. ⇒ *DFT-spread* OFDMA.
  - Low PAPR.



*$N < M$
* S-to-P: Serial-to-Parellel
* P-to-S: Parallel-to-Serial

LTE UL Slot Structure

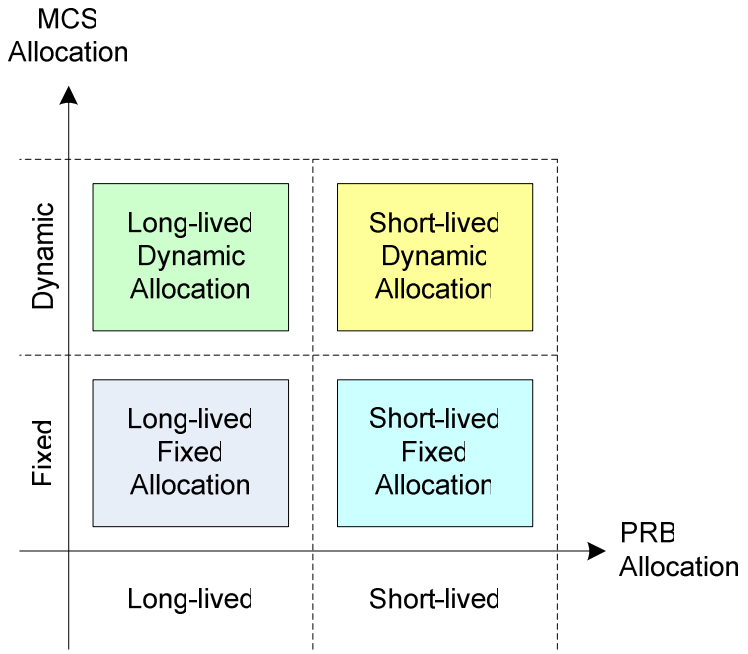




* LB: Long Block
* RS: Reference Signal

Resource Scheduling of Shared Channels

- Dynamic resource scheduler resides in eNB on MAC layer.
- Radio resource assignment based on radio condition, traffic volume, and QoS requirements.
- Radio resource assignment consists of:
  - Physical Resource Block (PRB)
  - Modulation and Coding Scheme (MCS)



Radio Resource Management

- Radio bearer control (RBC)
- Radio admission control (RAC)
- Connection mobility control (CMC)
- Dynamic resource allocation (DRA) or packet scheduling (PS)
- Inter-cell interference coordination (ICIC)
- Load balancing (LB)

Introduction and Background

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Summary and References

FLASH-OFDM®

- Fast Low-latency Access with Seamless Handoff-OFDM
- OFDM-based flat all-IP system developed by Flarion Technologies.
  - System concept in 1998.
  - Market trials in 2004.
  - Commercial launch in 2005.
- Positioned as a pre-UMB system

Key Features

- Packet-based flat all-IP system
- 1.25 MHz FDD with peak rates of 4.7 Mbps DL and 1.6 Mbps UL
- Fast tone hopping OFDM
- Full mobility support
- Efficient and fair scheduling through multiuser diversity, link adaptation, and joint user/power/rate/bandwidth allocation
- LDPC coding
- Low latency: < 30 ms ping RTT
- Tightly integrated PHY and MAC

Basic System Parameters

Channel bandwidth	1.25 MHz (FDD)
FFT size	128 samples (~88.8 μs)
Tones used	113 samples
Cyclic prefix	16 samples (~11.1 μs)
Tone spacing	11.25 kHz

PHY Features

- Fast tone-hopping OFDM-based multiple access
  - Intra-cell orthogonality and inter-cell interference averaging.
- Adaptive coding and modulation using LDPC coding
  - Codewords are long enough to obtain high coding gain but short enough to keep latency low.
  - Rates adaptively adjusted based on DL channel condition and power allocation.
- Fine granularity for allocating system resources
  - Rapid transmission of short (control) messages.
  - Efficient sharing of channel resources among mobiles.

MAC Features

- Fine granular channel structure based on OFDM PHY
- Optimized to support large number of users
  - Multiple states: ON, HOLD, Sleep
  - Fast transitions between states with QoS constraint.
- Low latency and fast ARQ
- Facilitates multiple scheduling options based on fairness constr aints and QoS

Other Features

- Flexband technology
  - Fractional frequency reuse scheme.
  - Carrier powers are scaled to create inner, middle, and outer coverage cells. Adjacent sectors are power scaled to fill in the coverage.
  - More technical details in *X. Wu et al., "Fractional Power Reuse in Cellular Networks," 44th Annual Allerton Conference, Sep. 2006*.
- BeaconTone technology
  - Every carrier transmits a beacon signal at full power. The mobile constantly measures all available beacon signals and evaluate which is the most optimal carrier in order to ensure the highest data throughput.
  - Enables fast acquisition and handoff.

FLASH-OFDM and UMB: Commonality

- Packet-based all-IP architecture
- Tone-hopping OFDMA
- OFDMA control signalling
- Low latency
- BeaconTone technology
- Fractional frequency reuse (Flexband) technique
- LDPC coding
- Efficient resource management

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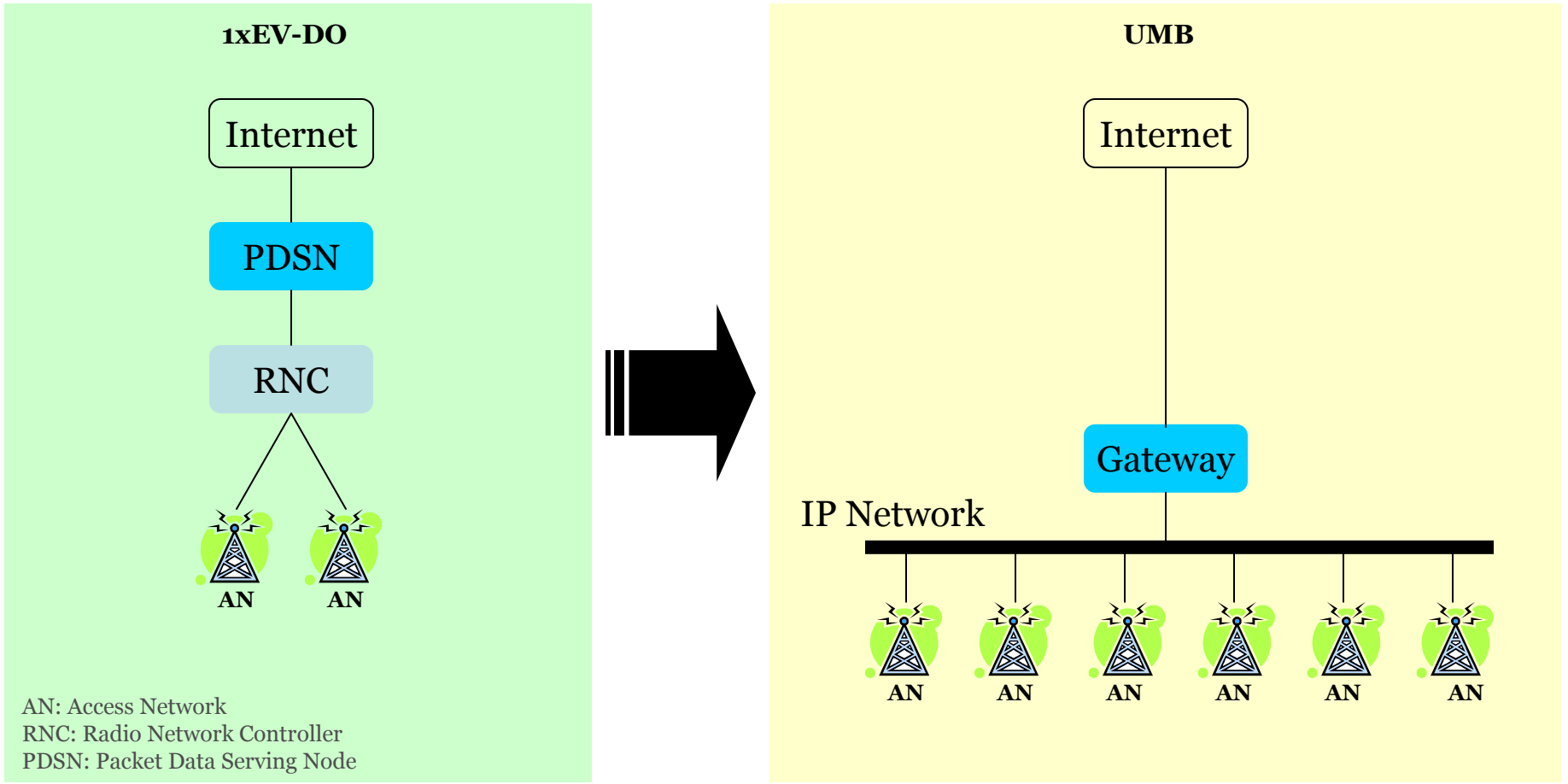
Summary and References

Key Aspects

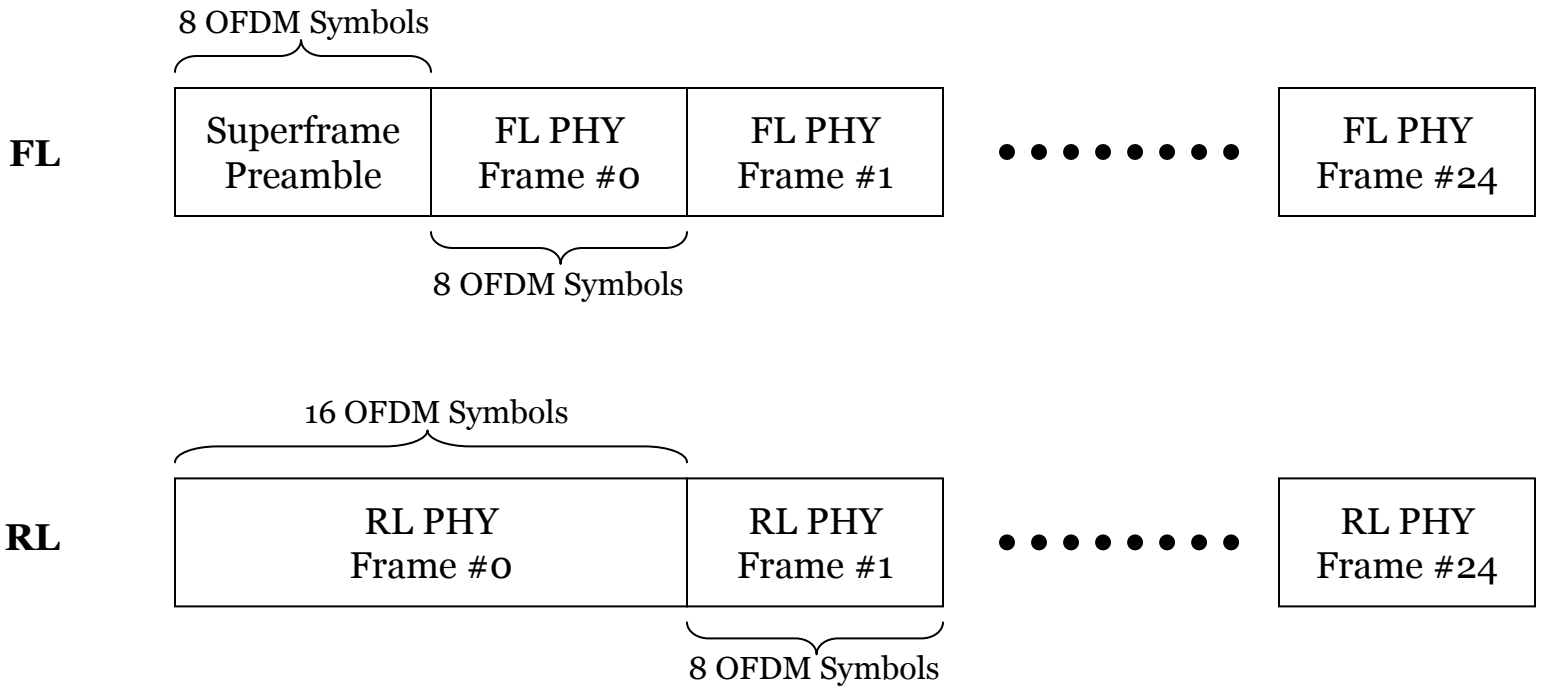
- Multiples access schemes
  - Forward link (FL): OFDMA
  - Reverse link (RL): OFDMA & CDMA
- Peak data rate
  - Up to 280 Mbps in FL and up to 68Mbps in RL.
- Advanced MIMO and SDMA
- Low latency
- Improved interference management techniques
- Scalable IP-based flat or hierarchical architecture and flexible spectrum allocations
  - Bandwidth allocations of 1.25 MHz, 5 MHz, 10 MHz and 20 MHz
  - Support for both FDD and TDD

UMB Network Architecture



UMB Frame Structure

- Transmission is divided into units of superframe.



Superframe Structure

Features

- Channel coding
  - Convolutional code for block lengths ≤ 128 and turbo code for block lengths > 128
  - LDPC coding optional
- Advanced MIMO, SDMA, and beamforming techniques for higher rates/capacity and improved cell-edge performance
  - SCW & MCW Precoding MIMO with rate and rank adaptation.
- Adaptive interference management
  - Dynamic fractional frequency reuse (FFR) scheme.
  - Dynamic RL power control.
- Synchronous H-ARQ on both FL and RL

Features - *cont.*

- Beacon technique for fast acquisition and handoff
- Centralized resource allocation for both FL and RL
  - "Sticky" assignment for delay sensitive applications (VoIP).
  - "Non-sticky" assignment for best effort applications.
- Power savings optimization
  - Quick paging.
  - Semi-connected state.

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Summary

	3GPP LTE	3GPP2 UMB
Channel bandwidth	1.25, 2.5, 5, 10, 15, and 20 MHz	1.25, 2.5, 5, 10, and 20 MHz
DL (FL) multiple access	OFDMA	OFDMA
UL (RL) multiple access	SC-FDMA	OFDMA & CDMA
Subcarrier (tone) mapping	Localized (block)	Distributed & block
Subcarrier hopping	Yes	Yes
Data modulation	QPSK, 16-QAM, and 64-QAM	QPSK, 8-PSK, 16-QAM, and 64-QAM
Subcarrier spacing	15 kHz	9.6 kHz
FFT size / usable subcarriers†	512 / 301 samples	512 / 256~480‡ samples
Channel coding	Convolutional coding & turbo coding	Convolutional coding, turbo coding, & LDPC coding
MIMO	SCW & MCW Precoding, SFBC/STBC, Switched TxD, & CDD	SCW & MCW Precoding, STTD, SDMA, & Beamforming

† For 5 MHz bandwidth in OFDMA.
‡ Number of usable subcarriers is variable.

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References and Resources - *cont.*

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  - CTIA Wireless 2007 Special Interest Seminar on UMB *available at* http://www.cdg.org/news/events/CDMASeminar/070327_UMB/index.asp
  - CDG Evolution Path *available at* http://www.cdg.org/news/events/webcast/061213_webcast/CDG%20Charts%20for%20Roadmap%20Webcast_13DEC2006F.pdf
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Questions? Thank you!

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