# LTE and LTE-Advanced: An Introduction

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# The history

- 1G (Early 1980s)
  - Analog speech communications.
  - Ex: AMPS
- 2G (Early 1990s)
  - Digital modulation of speech communications.
  - Advanced security and roaming.
  - TDMA and narrowband CDMA.
  - Ex: GSM
- 3G (Late 1990s)
  - Global harmonization and roaming.
  - Wideband CDMA
  - Ex: UMTS

# Beyond 3G

- Evolutionary path beyond 3G
  - Mobile class targets 100 Mbps with high mobility
  - Local area class targets 1 Gbps with low mobility
- 3GPP is currently developing evolutionary/ revolutionary systems beyond 3G
  - 3GPP Long Term Evolution (LTE)
- IEEE 802.16-based WiMAX is also evolving towards 4G through 802.16m

# 3GPP Evolution

- Release 99 (Mar. 2000): UMTS/WCDMA
- Rel-5 (Mar. 2002): HSDPA
- Rel-6 (Mar. 2005): HSUPA
- Rel-7 (2007): DL MIMO, optimized real-time services (VoIP, gaming, …)
- Long Term Evolution (LTE)
  - 3GPP work on the Evolution of the 3G Mobile System started in November 2004.
  - Standardized in the form of Rel-8.
  - Spec finalized and approved in January 2008.
- LTE-Advanced study phase in progress.

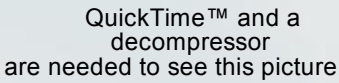
# Requirements for LTE

- Peak data rate
  - 100 Mbps DL/ 50 Mbps UL within 20 MHz bandwidth.
  - Up to 200 active users in a cell (5 MHz)
- 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.
- Spectrum flexibility: 1.25 ~ 20 MHz
- Enhanced support for end-to-end QoS

# LTE Enabling Technologies

- Two main technologies
  1. Orthogonal Frequency Division Multiplexing (OFDM)
  2. Multiple-Input Multiple-Output (MIMO)

# OFDM:
# A bandwidth efficient technique



# OFDM (continue)

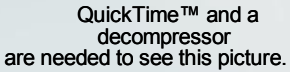
- Multi-carrier transmission offers various **advantages** over traditional single carrier approaches

  - Highly scalable
  - Simplified equalizer design in the frequency domain, also in cases of large delay spread
  - High spectrum density
  - Simplifies the usage of MIMO
  - Good granularity to control user data rates
  - Robustness against timing errors

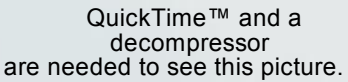
# Multiple-Input Multiple-Output (MIMO)

- Future wireless services require high data rates and high signal quality
- The wireless resources such as the bandwidth are scarce
- Wireless channels have a lot of impairments such as fading, shadowing, and multiuser interference
- One solution is the use of Diversity achieving schemes
- Spatial diversity is of special interest!

# MIMO (continue)



# Goals of LTE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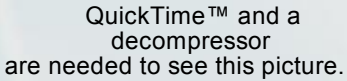
# MIMO Techniques

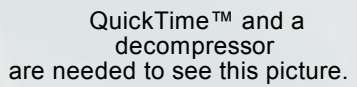
1. **Spatial Multiplexing**
   - § Goal is to maximize data rate
   - § Send as much independent data as possible over different antennas
   - § Works only if number of receiver antennas is greater or equal to number of transmit antennas(i.e. less suitable for DL)

2. **Space-Time Coding**
   - § Goal is to enhance the signal quality
   - § Achieves spatial diversity by introducing redundancy
   - § Alamouti Scheme is the most popular STC (for a 2xN system)

# Multi-User MIMO (MU-MIMO)



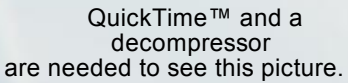
# Downlink (DL) Beamforming



# Requirements for LTE-Advanced (LTE-A)

- LTE-A shall have same or better performance than LTE
- Peak data rate (peak spectrum efficiency)
  - Downlink: 1 Gbps, Uplink: 500 Mbps
- Peak spectrum efficiency
  - Downlink: 30 bps/Hz, Uplink: 15 bps/Hz
- Same requirements as LTE for mobility, coverage, synchronization, spectrum flexibility etc

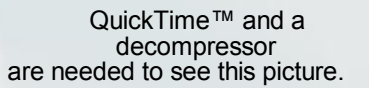
# LTE-A Proposed Enhancements



# LTE-A Technology Proposals

- MIMO enhancements
- Cooperative multi-site transmission
- Repeaters and relays

# MIMO Enhancements for LTE-A



# Coordinated Multi-Point Transmission (CoMP)

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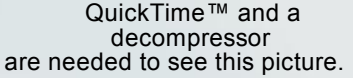
# Relaying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# Questions