All-IP Wireless Networks and Performance Issues

Dumisa W. Ngwenya

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Outline

- Evolution of wireless networks
- Technologies for improving data rates
- 3G evolution – WCDMA and other
- Long-Term Evolution (4G and beyond)

Keyword:

- OFDM, LTE, Modulation schemes – BPSK, QPSK, QAM
- 3G/IMT-2000/ all pre 4G technologies
- 4G/LTE/IMT-advanced

4G and beyond

- Spectral efficiency (bits/s/Hz)
- High network capacity – more users per cell
- Data rate of 100 Mbit/s at high speed; 1 Gbit/s when stationery
- Smoth handof across heterogeneous networks
- Seamless connectivity and global roaming
- High QoS
- (Interoperability with existing systems)
- All-IP, packet switched network

Wireless System Evolution

- 1G – early 80s
  - analogue systems targeting voice - e.g. NMT and AMPS
- 2G – late 80s
  - Digital and narrowband - e.g. GSM
- 2.5G/2.75G – mid to late 90s
  - GPRS, EDGE/EGPRS
- 3G/3.5G (IMT-2000)
  - WCDMS/UMTS, CDMA2000, WiMax
  - HSDPA, HSUPA and HSPA+
- 4G (IMT-Advanced)
  - Flash-OFDM, 3GPP LTE

Technologies for improving data rates

Data rate limiting factors

$$R \leq C = BW \cdot log_2\left(1 + \frac{S}{N}\right)$$

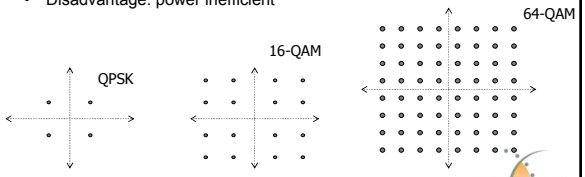
– Data rates limited by the BW signal-to-noise ratio

– Low bandwidth utilisation results in power limited operation

– High bandwidth utilisation results in bandwidth-limited operation

Higher-order modulation and channel coding

- Provides possibility for higher bandwidth utilisation
- QPSK – 1st release of 3G standards (WCDMA and cdma2000)
- 16-QAM, 64-QAM, etc
- Disadvantage: power inefficient

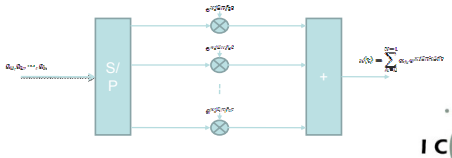


Wider bandwidth and multi-carrier transmission

- Good coverage and higher data rates require wider transmission bandwidth, but …
  - spectrum is scarce and expensive
  - Equipment complexity
- Multi-carrier transmission increases overall transmission bandwidth without increased signal corruption, also …
  - Smooth evolution in terms of radio equipment and spectrum
  - Suitable for base-station transmission (downlink)
- Special single-carrier transmission schemes, designed for efficiency while allowing low-complexity equalisation
  - Suitable for uplink (mobile-terminal transmission)

OFDM

- Large number of narrowband sub-carriers
- Simple rectangular pulse shaping (sinc-square-shaped per-sub-carrier)
- Tight frequency-domain packing of the sub-carriers
- Can be used as user-multiplexing and multiple-access scheme
- Can be use in statistical multiplexing – e.g. using CSMA
- Can be used also for broadcast/multicast



Wider band 'single-carrier' transmission

- There are techniques dealing with frequency domain equalisation
- Possibility of uplink FDMA with flexible bandwidth assignment
- DFT-spread OFDM

Multi-antenna techniques

- Provide additional diversity against radio channel fading
- Can be used for beam-forming
- MIMO – allows high bandwidth utilisation without reduction in power efficiency
  - Improved system performance
  - Improved coverage

Scheduling, link adaptation and hybrid ARQ

- Channel-dependent scheduling – efficient resource utilization
- Link adaptation – transmission parameters
- Hybrid ARQ – combination of FEC coding and ARQ
  - allows to measure variations
  - Allows advanced retransmission schemes

WCDMA Evolution

WCDMA architecture

- Core network – connected to PSTN and internet
- Radio network controller
  - Call setup, QoS handling, management of radio resources, ARQ protocols, etc
- NodeBs – handing transmissions in one or more cells

WCDMA physical layer

- Error protection strategy
- Modulation
  - QPSK used for downlink
  - BPSK used for uplink
- Modulation symbols to a physical channel corresponding to a spreading code

High-speed downlink packet access (HSDPA) – WCDMA release 5 and 6

- Allow shared-channel transmission using HS-DSCH
- Allows channel-dependent scheduling
- Release 6 allows power control
- Supports 16QAM for downlink

High-speed Uplink packet access (HSUPA) – WCDMA release 6

- Introduces Enhanced Dedicated Channel (E-DCH)
- Faster scheduling
  - Scheduler located in NodeB
  - Buffer status located in UEs
  - Signalling to convey buffer status

Multimedia broadcast multicast services (MBMS) – release 6

- For broadcast – e.g. mobile TV
- Allow resource savings
- Choice between point-to-point or point-to-multipoint - optimization
- Introduces new node – Broadcast Multicast Service Center (BM-SC)
  - Responsible for authorisation and authentication of the content provider, charging and overall configuration

HSPA Evolution – release 7

- Introduction of MIMO
- Higher order modulation

Modulation Scheme	Downlink peak rate (Mbit/s)	Uplink peak rate (Mbit/s)
16-QAM	14	
64-QAM	21	
64-QAM and MIMO	42	
BPSK/QPSK		5.7
16QAM		11

WCDMA evolution summary

- HSPA – improved packet support in downlink and uplink
  - Adaptation of transmission parameters to variations in radio-channel quality and traffic variations – using channel-dependent scheduling, rate adaptation, hybrid ARQ
- Broadcast performance of WCDMA through MBMS
- MIMO at both NodeB and EU

This is WCDMA evolution …

The ultimate goal is Long Term Evolution – 4G and beyong (IMT-advanced)

Other 3G/ IMT-2000 technology eveolution

CDMA2000

- 1x and 3x
  - Single carrier (1x) and multi-carrier (3x)
- 1x EV-DO Rev 0
  - Shared-channel transmission, Channel-dependent scheduling, Rate control, 16QAM for downlink, Hybrid ARQ
- 1x EV-DO Rev A
  - QPSK and 8PSK for uplink
- 1x EV-DO Rev B
  - Aggregation of multiple carriers
- 1x EV-DO Rev C (UMB)
  - Smart-antenna technologies, OFDMA downlink and uplink (optional), higher-order modulation

Evolved GSM/EDGE RAN

- Dual antenna
- Multi-carrier EDGE
- Reduce TTI and fast feedback
- Improved modulation and coding
  - 16-QAM giving 80 to 96 kbps per time slot
  - 32-QAM giving 120kbps per time slot

WiMAX

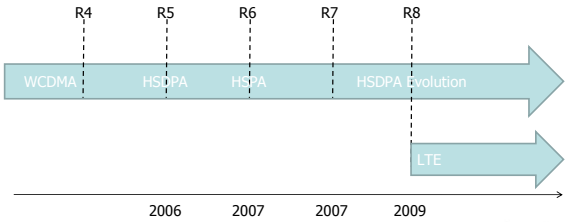
- OFDM and Scalable OFDMA
- TDD and FDD
- Range of bandwidth supported (1.25 – 28 MHz)
- QPSK, 16QAM and 64QAM combined with FEC coding
- Hybrid ARQ
- Adaptive antenna system and MIMO

DVB-T/H

- MPEG-2/4 source coding (lossy compression)
- FEC coding techniques
- 64QAM
- Base on OFDM
- DVB-H - allowing IP datacast

Long-Term Evolution

(4G and beyond/ IMT-Advanced)



LTE design targets

- Downlink and uplink 100 Mbits/s and 50 Mbits/s respectively at 20MHz spectrum allocation (5bits/s/Hz and 2.5 bits/s/Hz)
- High user throughput, spectrum efficiency, mobility, coverage, enhanced MBMS

LTE radio access overview

- Transmission schemes
  - Downlink OFDM
    - Frequency domain allowing additional degree of freedom to channel-dependent scheduler compared HSPA
    - Flexible bandwidth allocation
    - Broadcast/multicast easier with OFDM
  - Uplink SC-FDMA based on DFTS-OFDM
    - For lower PAR
- Channel-dependent scheduling and data adaptation
  - Shared-channel transmission
  - Access to frequency domain in addition to time domain
- Hybrid ARQ – advanced retransmission schemes

LTE radio access overview cont …

- Multiple antenna support
  - Receive and transmit diversity and different types of beam-forming
  - Spatial multiplexing (MIMO)
- Multicast and broadcast support
  - Highly efficient multi-cell broadcast
- Spectrum flexibility
  - Different duplex arrangements, frequency-bands-of-operation, different sizes of the available

Evolutionary path – proposed by UMTS forum