Lec27

Monday, March 23, 2020 3:51 PM

Extensions of GSM: GPRS/EDGE

- Generalized Packet Radio Service (GPRS) is an enhancement of GSM
- GPRS provides packet-switched data services at 5K-100Kbps by reusing the existing **narrow-band** GSM channels/infrastructure for circuit-switched services such as voice telephony.

- Enhanced Data Rates for GSM Evolution (EDGE) uses adaptive modulation techniques and can produce 384Kbps maximum transmission.
- Both GPRS and EDGE aim not to replace the current infrastructure, but to co-exist with it.

- To achieve Mbps bit rates will require using more sophisticated physical layer as well as resource & radio management.

Wideband CDMA

In March 1999, the final decision was made to select wideband CDMA as the access scheme for 3G, with three optional modes:

- W-CDMA (or UMTS): CDMA Direct Spread. 5MHz channel. Frequency Division Duplex(FDD).Based on Europe (ETSI) and Japan (ARIB)'s FDD proposal.

- CDMA-2000: CDMA Multi-carrier. Can use multiple 1.25Mhz channels. Based on US (TIA)'s proposal.

- TD-SCDMA:CDMA TDD (time division duplex). Can use multiple time slots. Based on China's proposal.

How to get high data rates - 10min

Tuesday, April 08, 2008 12:11 AM

To get high data rates, need to

- use multiple frequency bands
  - e.g.: cdma2000 3X 1.25MHz bands
  - also known as multiple-carrier CDMA (MC-CDMA)
- or use multiple slots: EDGE
- increase data rate together with chip rate
  - W-CDMA : 3.84Mcps
  - increase bandwidth requirement (5MHz)

} take more resources

- increase data rate while keeping the chip rate the same
  - W-CDMA & cdma2000
  - variable spreading gain CDMA
  - restricted by SINR, power assignment
- Increase modulation constellation
  - W-CDMA & CDMA2000
  - QPSK, 4QAM → 64QAM

} allow opportunistic scheduling

- use multiple codes in parallel
  - require multiple RAKE receiver
  - not the best way to use spectrum.
  - IS-95B & W-CDMA

20

Table 10.4 *Forward traffic channel parameters, cdma2000 1×EV–DV: high rate packet data system*

(from cdma, 2001; Table 9.3.1.3.1.1-1)

Data rate (kbps)	Packet length (bits)	Slots/packet	Code rate	Modulation type
38.4	1024	16	1/5	QPSK
76.8	1024	8	1/5	QPSK
153.6	1024	4	1/5	QPSK
307.2	1024	2	1/5	QPSK
614.4	1024	1	1/3	QPSK
307.2	2048	4	1/3	QPSK
614.4	2048	2	1/3	QPSK
1228.8	2048	1	1/3	QPSK
921.6	3072	2	1/3	8-PSK
1843.2	3072	1	1/3	8-PSK
1228.8	4096	2	1/3	16-QAM
2457.6	4096	1	1/3	16-QAM

LTE Overview

Friday, February 23, 2018 9:43 AM

- LTE stands for Long Term Evolution
- It is the standard developed by 3GPP (3rd Generation Partnership Project)
- Prior to LTE, 3GPP has developed many enhancements to 3G UMTS systems. While these enhancements are considered "short-term", LTE is proposed to ensure "long-term" competitiveness for a decade or more
- Competing standard is WiMax. However, LTE eventually dominates the market.
- Release 8 & 9 define LTE
  Release 10 and beyond define LTE-Advanced

Overall Architecture

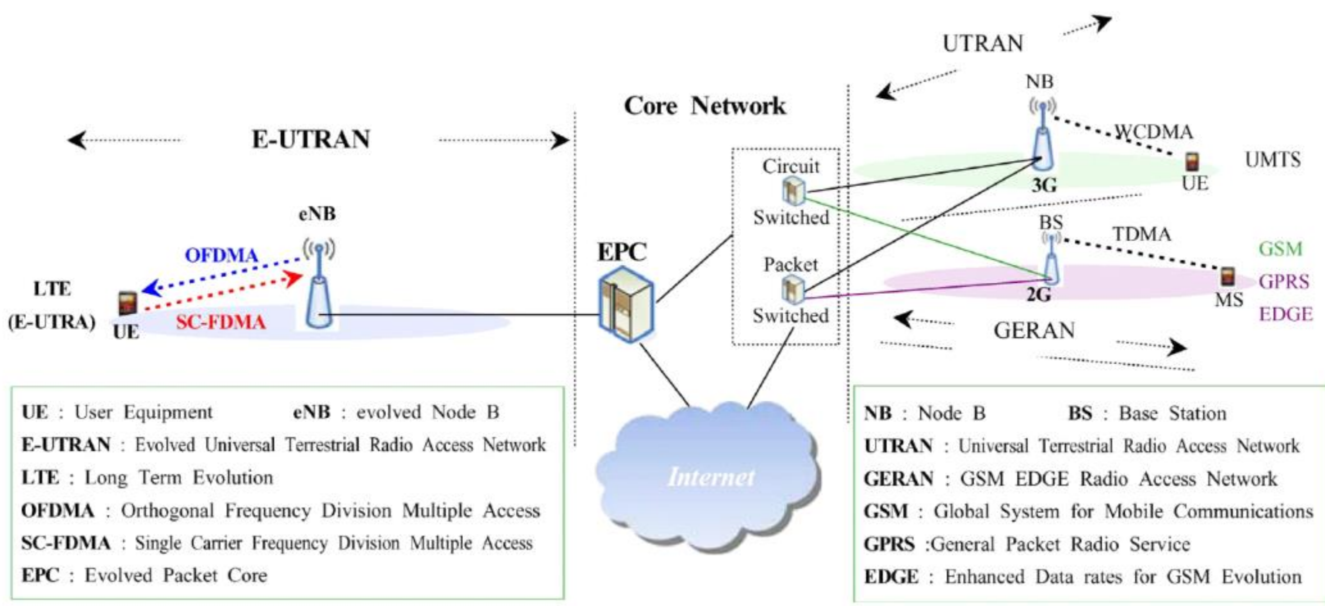


Fig. 1. Overall Architecture of E-UTRAN and EPC.

- EPC: packet based all IP network (AIPN)
  - lower cost / complexity compared to circuit switching
  - interface is defined with traditional MSC
  - Handles higher-level control: handoff, roaming, authentication, packet routing, filtering, etc.
- eNodeB:
  - Lower level radio resource management: scheduling, channel measurement, etc.
- UE: mobile phones

Primary design consideration of LTE

- higher data rate: 100Mbps downlink / 50Mbps uplink
- reduced latency: below 10ms with the use of shortened TTI (transmission timing interval).
- Improvement in capacity and coverage with OFDM/MIMO
- scalable bandwidth (1.4 MHz to 20MHz)

Some of the key features

Some of the key features

- OFDM: time-freq resource grid.
- MIMO (referred to as "layers")
  - DL: up to 4 in LTE, up to 8 in LTE-A
  - UL: up to 4 in LTE-A
- Carrier aggregation
- CoMP (coordinated multipoint): up to 5 cells to communicate with a single mobile. improved coverage, cell-edge throughput.

Will use the book

- S. Sesia, I. Toufik, and M. Baker, "LTE-the UMTS long term evolution: from theory to practice," John Wiley & Sons, 2011. (available online from Purdue library.)

OFDM - 15min

Monday, March 03, 2008 9:56 PM

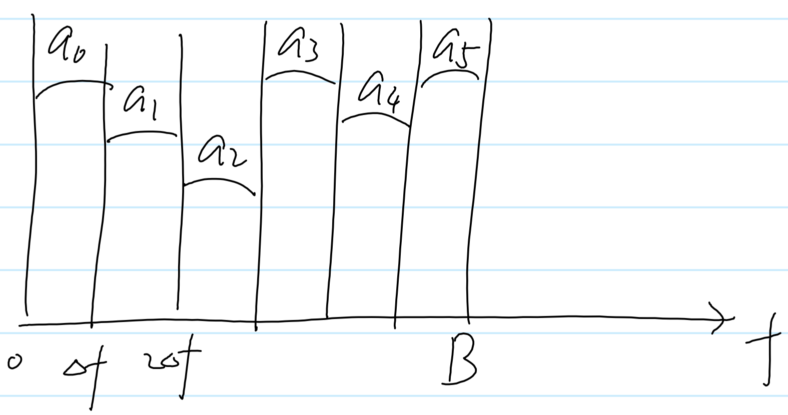
What to do if high data rate is required

- large bw with high SINR

At very large bandwidth, frequency-selective fading distorts the signal.

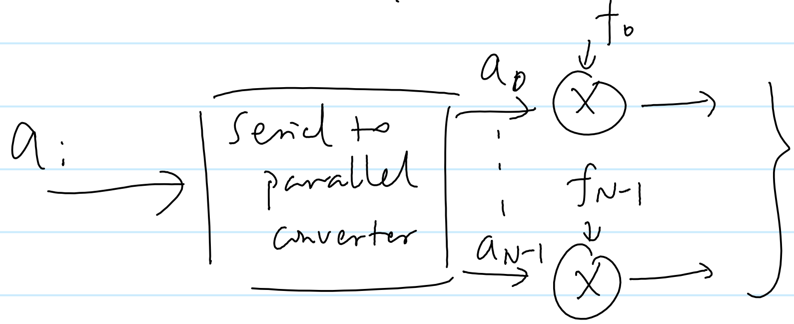
- one of the important schemes is OFDM (Orthogonal Frequency division multiplexing)
- WLAN, WiMAX,

OFDM divides a large bw into a number of narrowband subcarriers, such that flat-fading occurs at each sub-carrier.



① Let a_k be the symbol on sub-carrier k
The aggregate signal is then

$$s(t) = \sum_{k=0}^{N-1} a_k e^{j2\pi k \cdot \Delta f \cdot t} \quad (\cdot e^{j\omega_c t})$$



transmit N carriers in parallel

② We want the subcarriers to be orthogonal to each other (so that we can decode each a_k at receiver).

$$\int_0^{T_s} e^{j2\pi k \cdot \Delta f t} \cdot e^{j2\pi m \cdot \Delta f t} \, dt = 0$$

A sufficient condition is

$$\Delta f = 1/T_s$$

The total bandwidth is

$$\Delta f \cdot N = N/T_s$$

DFT/IDFT - 10min

Monday, March 17, 2008 10:15 PM

In OFDM, modulation/demodulation carried over multiple carriers in parallel

Can be simplified into DFT/IDFT

$$s(t) = \sum_{k=0}^{N-1} a_k e^{j2\pi k \cdot \Delta f \cdot t}$$

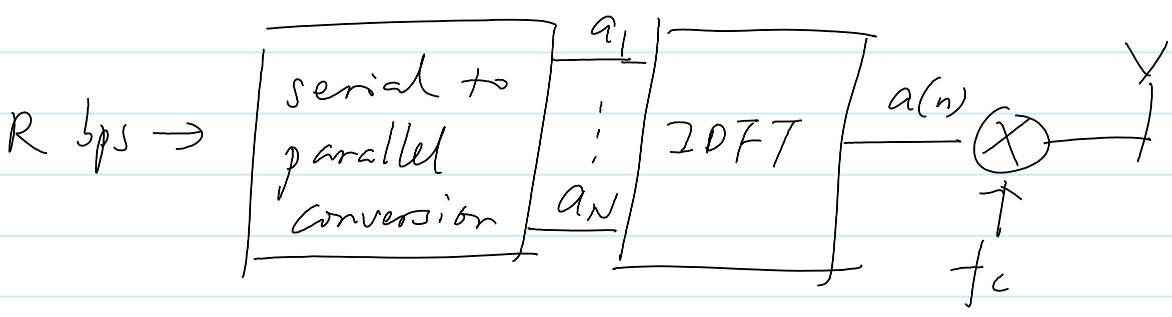
(3) If we sample $s(t)$ at T_s/N time apart

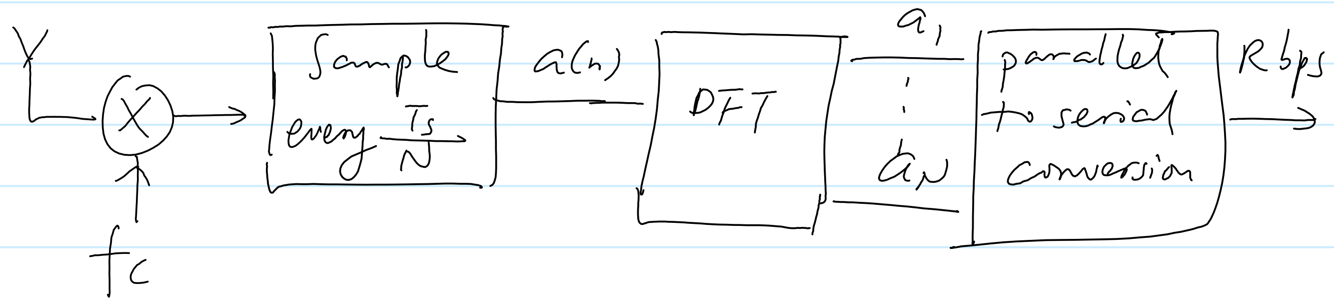
$$a(n) = \sum_{k=0}^{N-1} a_k \cdot e^{j2\pi k \cdot \Delta f \cdot \frac{T_s}{N} \cdot n}$$

$$= \sum_{k=0}^{N-1} a_k \cdot e^{j2\pi k \, n/N} \quad n = 0, 1, \cdots, N-1$$

This is precisely the inverse discrete Fourier transform.

Indeed, the modulation of various subcarriers can also be treated as if a single DFT/IDFT efficiently




Sample every $\frac{T_s}{N}$
$a(n)$
DFT
a_1
a_N
parallel to serial conversion
R bps
f_c

(20)

Downlink and Uplink

Friday, February 23, 2018 10:22 AM

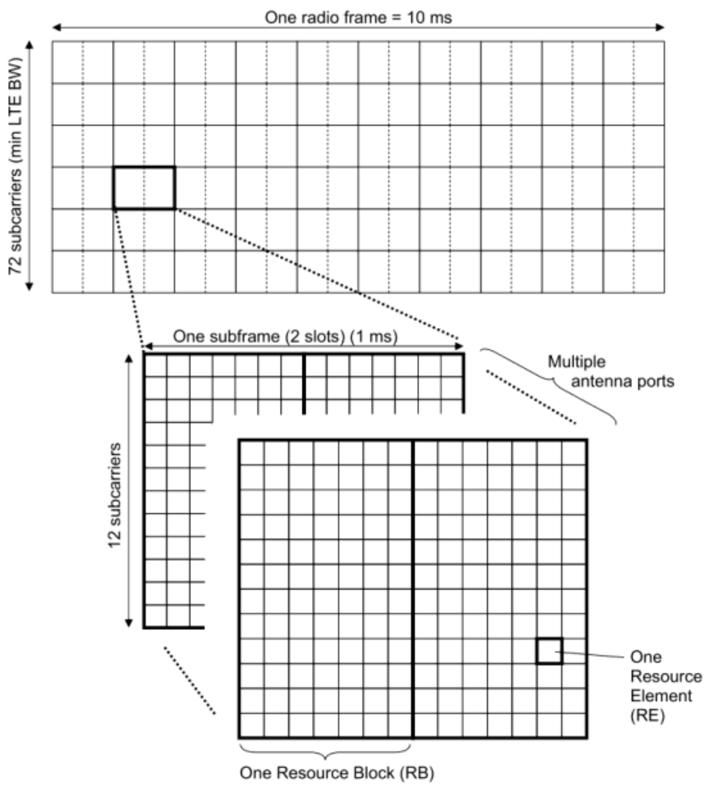


Figure 6.1: Basic time-frequency resource structure of LTE (normal cyclic prefix case).

Screen clipping taken: 3/25/2020 4:31 PM

- In time, each frame is 10ms,
  - 10 1ms sub-frame
  - TTI : 1ms
  - each subframe is further divided into two 0.5ms slots.
- Recall that

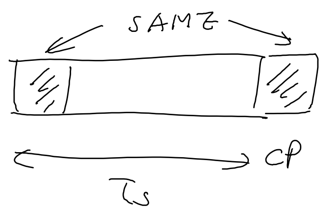
$$\Delta f = \frac{1}{T_s}$$

- When $\Delta f = 15$ kHz

  $T_s = 0.066$ ms

- In order to overcome inter-symbol interference, some spacing is needed between symbols

  - CP: cyclic prefix



  - CP needs to be larger than the delay spread.

  - Two possible values defined in LTE

    - CP = 16.667 μs "extended" CP
    - CP = 5.2083 μs "normal" CP

  - Recall Typical values for delay-spread:
    0.2 ~ 0.5 μsec in suburban areas
    3 ~ 8 μsec in urban areas

  - As a result, a 0.5 ms slot can accommodate either

$$\frac{0.5}{0.0667 + 0.0167} \simeq 6 \quad \text{symbols}$$

or

$$\frac{0.5}{0.0667 + 0.0052} \simeq 7 \quad \text{symbols}$$

- Coherent time and coherent bandwidth

- At 3GHz, speed of 360 km/h, doppler spread is about

$$\frac{v}{\lambda} = \frac{360 \times 10^3}{60 \times 60} \times \frac{3 \times 10^9}{3 \times 10^8} = 10^3 \text{ Hz}$$

- coherence time is about 1ms > slot duration

- At delay spread of 16.667μs, coherent bw is

$$\frac{2\pi}{16.667\mu s} \approx 360 \text{ kHz}$$

- A resource block is defined as 12 of the 15kHz subcarriers

$$12 \times 15 \text{kHz} = 180 \text{kHz}$$

- Together, this leads to the resource grid shown above

With OFDMA in the downlink

- inside cell: each user gets orthogonal time-freq resources

- across cell: inter-cell interference is suppressed by additional spreading with orthogonal cell-specific identity codes for different UEs.

- However, OFDM has high peak to average power ratio (PAPR): high requirement on linear amplifiers

- Uplink: use a modification called SC-FDMA

- single carrier FDMA
- lower PAPR
- can be viewed as a modulation on a contiguous set of sub-carriers

- Two modes of duplexing
  - FDD : our focus
  - TDD

Reference:
Chapter 5.2, Chapter 5.4, Chapter 6.2, Chapter 14.1, S. Sesia, I. Toufik, and M. Baker, "LTE-the UMTS long term evolution: from theory to practice," John Wiley & Sons, 2011. (available online from Purdue library.)

Difference from GSM

Thursday, March 1, 2018 10:57 AM

Although this time-freq grid may look similar to GSM, the difference in service dictating very different design:

- GSM is a circuit-switched voice system
  - Focus is on how to assign voice calls to dedicated to time-frequency
  - Traffic is mostly symmetric
- 4G LTE is for packet-switched systems
  - Traffic is much bursty
  - Traffic is asymmetric
  - Does not assign dedicated resource to users
  - Instead, each packet needs to be scheduled, and acknowledged
- Further, opportunistic scheduling and MIMO requires timely channel measurements to be successful

Hence, below our focus will be on:

- How channel measurement, scheduling, and acknowledgement is carried out in LTE?
- Tradeoff between efficiency, overhead, and energy consumptions