EE6143: Advanced Topics in Communications
Assignment 4
LTE Overview

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LTE (Long-term evolution) is a standard for cellular communication managed by *3GPP (Third-generation partnership project)* [1]. This was first instituted in Rel 8 in 2009.

1 Basic features of LTE

LTE has the following salient features:

- Ability to perform both FDD and TDD (frequency-division duplexing and time-division duplexing)
- OFDM (orthogonal frequency-division multiplexing)-based transmission
- Variable bandwidth, starting from ∼1 MHz to 20 MHz
- 40 frequency bands
- Support for reduced latency and greater mobility
- Multiple-input Multiple-output (MIMO)
- Cell-specific Reference Signals
- Carrier Aggregation

Some of these features are further elaborated the subsections below.

1.1 TDD and FDD

One important aspect of 4G is the ability to perform both TDD (time-division duplexing) and FDD (frequency-division duplexing). TDD utilizes *unpaired* spectrum and the packets are sent at different instants of time. FDD on the contrary uses designated parts of the spectrum called the *paired* spectrum, and the uplink and downlink transmissions occur at different frequencies. FDD requires a duplex filter with a sharp roll-off to remove UL / DL component which we do not need. To perform TDD, every `eNB` needs to transmit at the same time and every `eNB` needs to stay silent when the `UE`s are transmitting: this requires coordinated UL/DL transmission among base-stations.

1.2 Orthogonal frequency-division multiplexing (OFDM)

Orthogonal frequency-division multiplexing (OFDM) is the *cornerstone* of 4G systems. In OFDM, the frequency band is divided into a number of smaller *subcarriers*, each of which carry information.

- In the time domain, the OFDM consists of frames (10 ms). Each frame is further subdivided into subframes (1ms) each. A subframe is the smallest schedulable unit in LTE OFDM. A subframe itself consists of 2 slots, each consisting of 14 OFDM symbols.
- In the frequency domain, the OFDM consists of subcarriers of 15 kHz each. There are 1200 such subcarriers in a 20 MHz band.

One Resource element consists of 1 subcarrier and 1 OFDM frame. One Resource block consists of 7 subcarrier and 12 OFDM frames (i.e. 84 resource elements).

The primary advantage of OFDM is as follows: if the Bandwidth is large, the channel appears to be frequency selective. However, if the bandwidth is small enough, the channel appears frequency-flat, and a single-tap equalizer is enough to recover the original signal. Even though the bandwidth itself is large, each subcarrier is only 15kHz, and hence the channel appears frequency flat for each of the subcarriers.

1.2.1 Cyclic Prefix

To prevent Inter-symbol interference (ISI), OFDM contains a cyclic prefix of 4.7μs. This prevents ISI and converts a linear convolution of the input by the channel into circular convolution, which makes recovering the original signal much easier.

There are also facilities for having a longer extended cyclic prefix in case of worse channel conditions.

1.3 Multiple-input Multiple Output (MIMO)

Multiple-input Multiple Output (MIMO) is an important feature of 4G. In this, a number of *layers* are mapped to up to 4 antennae. In initial releases, up to 4 layers were allowed in the downlink, while uplink transmission allows only one layer. Performing spatial multiplexing takes advantage of Antenna diversity to reduce outage probability.

LTE Advanced (Rel 10) allows up to 8 layers in the DL and 4 layers in the UL, while LTE Advanced Pro (Rel 13) allows the same number of layers as LTE Advanced.

Note: This is further elaborated in the report on MIMO.

1.4 Cell-specific Reference Signals

The `eNB` transmits some reference signals continuously in each of the layers. Every third subcarrier out of 4 subcarriers is a reference signal, say for 2 x 2 MIMO. This is needed for:

1. Downlink channel estimation
2. Channel state reporting for scheduling
3. Correction of device side frequency errors
4. Initial access, i.e. random access
5. Mobility measurements

1.5 Carrier Aggregation

One significant feature of LTE is carrier aggregation: multiple carriers can be used to transmit information jointly. The Bandwidth is at most 20 MHz per band, and at most 5 carriers can be aggregated, leading to a maximum bandwidth of 100 MHz. The carrier components aggregated need not be continuous (inter-band aggregation).

There are different types of Carrier Aggregation, as in the figure 1 from [1].

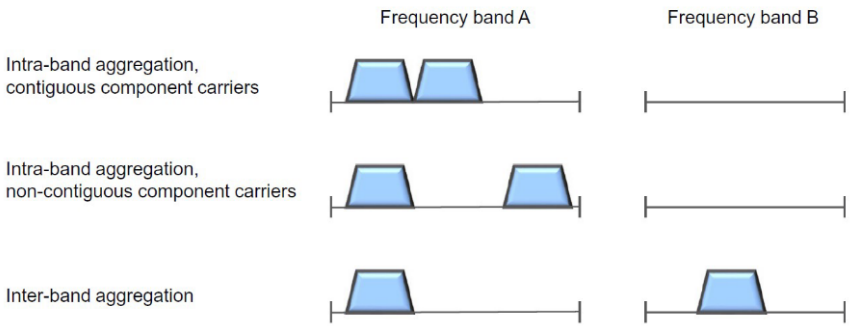

Figure 1: Schematic of Carrier Aggregation from [1]

It is noted here that Intra-band aggregation with contiguous component carriers is the easiest to implement, while Inter-band aggregation is the hardest to implement.

Rel 13 changed the limit from 5 carriers to up to 32 carriers, thus a maximum bandwidth of 640 MHz can be achieved!

2 Later Releases

2.1 Coordinated Multipoint Transmission (CoMP)

This involves two aspects:

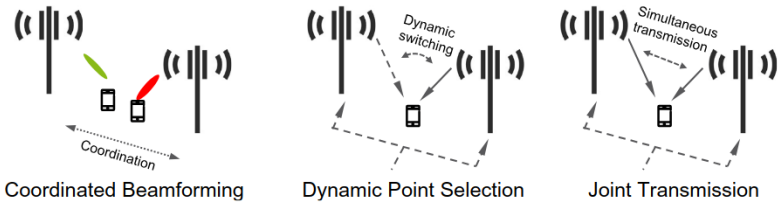

Figure 2: Coordinated Multi-point Transmission from [1]

- **Multi-point coordination (Coordinated Beamforming):** Transmission to a device is carried out from one specific transmission point but where scheduling and link adaptation are coordinated between the transmission points,
- **Multi-point transmission:** Transmission to a device can be carried out from multiple transmission points either in such a way that that transmission can switch dynamically between different transmission points (Dynamic Point Selection) or be carried out jointly from multiple transmission points (Joint Transmission).

2.2 License-assisted access

The licensed spectrum is purchased by operators and only the operator is allowed to transmit in that range. In contrast, the unlicensed spectrum is free for anyone to use. The advantage is that it's free and mostly available, the disadvantage is that it might be used by other operators also.

4G allows control information along with QoS (quality-of-service) flows to happen along the licensed spectrum (called the primary carrier), while most of the data goes through the unlicensed spectrum (called the secondary carrier) in a best-effort service. This is called license assisted access and was brought about in Rel 13.

2.3 Relaying and Heterogenous Deployments

In relaying, the UE communicates with the network via a relay node, which is in turn connected using a donor cell. The donor-cell to relay node link is also a wireless link called backhaul link.

In heterogeneous deployments, a macrocell might be augmented using pico-cells which have much lower transmit power and range. This might lead to multilayer interference, but this is taken care of by the CoMP techniques discussed in section 2.1

References

[1] Erik Dahlman, Stefan Parkvall, and Johan Sköld. Chapter 4 - lte—an overview. In Erik Dahlman, Stefan Parkvall, and Johan Sköld, editors, *5G NR: the Next Generation Wireless Access Technology*, pages 39–55. Academic Press, 2018.