Nomor 3GPP Newsletter – November 2007

Overview LTE TDD

Authors: Volker Pauli, Eiko Seidel

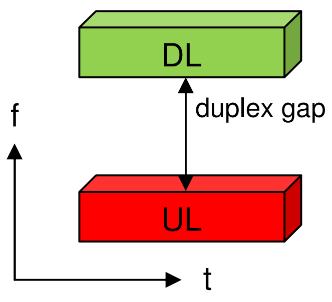
Introduction

While our past newsletters focused on frequency-division duplex (FDD), which appears to be the more promising approach for future LTE systems, a time-division duplex (TDD) mode for LTE is being standardized, as well. Contrary to 3GPP Release 99 this is to be implemented using the same radio access technology. Due to the great effort that is put into creating commonalities between the FDD and TDD modes, differences between the two are limited to the physical and only minor ones in higher layers.
Therefore, the objective of this newsletter is to provide you with a summary of how TDD is envisioned in LTE, what differences it introduces compared to FDD, and what the advantages and possible difficulties inherent to a TDD-based LTE system are.

Duplex Modes

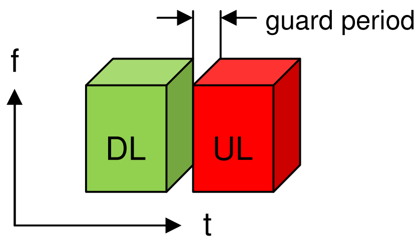
FDD

- Usage of paired spectra for UL and DL, separated by duplex gap to avoid near-end cross talk (NEXT).
- Duplex gap may be used (partially) by other systems.
- Duplex distance might be different for different frequency bands



TDD

- Same spectral resources are alternately used for UL and DL transmission, separated by guard period to avoid NEXT.



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Specified LTE Frequency Bands

E-UTRA Band	Uplink (UL) eNode B receive UE transmit	Downlink (DL) eNode B transmit UE receive	UL-DL Band gap	Duplex Mode
	F_{UL_low} - F_{UL_high}	F_{DL_low} - F_{DL_high}	F_{DL_ow} - F_{UL_high}	
1	1920 MHz - 1980 MHz	2110 MHz - 2170 MHz	130 MHz	FDD
2	1850 MHz - 1910 MHz	1930 MHz - 1990 MHz	20 MHz	FDD
3	1710 MHz - 1785 MHz	1805 MHz - 1880 MHz	20 MHz	FDD
4	1710 MHz - 1755 MHz	2110 MHz - 2155 MHz	355 MHz	FDD
5	824 MHz - 849 MHz	869 MHz - 894MHz	20 MHz	FDD
6	830 MHz - 840 MHz	875 MHz - 885 MHz	35 MHz	FDD
7	2500 MHz - 2570 MHz	2620 MHz - 2690 MHz	50 MHz	FDD
8	880 MHz - 915 MHz	925 MHz - 960 MHz	10 MHz	FDD
9	1749.9 MHz - 1784.9 MHz	1844.9 MHz - 1879.9 MHz	60 MHz	FDD
10	1710 MHz - 1770 MHz	2110 MHz - 2170 MHz	340 MHz	FDD
11	1427.9 MHz - 1452.9 MHz	1475.9 MHz - 1500.9 MHz	23 MHz	FDD
12	[TBD] - [TBD]	[TBD] - [TBD]	[TBD]	FDD
13	[TBD] - [TBD]	[TBD] - [TBD]	[TBD]	FDD
...				
33	1900 MHz - 1920 MHz	1900 MHz - 1920 MHz	N/A	TDD
34	2010 MHz - 2025 MHz	2010 MHz - 2025 MHz	N/A	TDD
35	1850 MHz - 1910 MHz	1850 MHz - 1910 MHz	N/A	TDD
36	1930 MHz - 1990 MHz	1930 MHz - 1990 MHz	N/A	TDD
37	1910 MHz 1930 MHz	1910 MHz 1930 MHz	N/A	TDD
38	2570 MHz - 2620 MHz	2570 MHz - 2620 MHz	N/A	TDD
39	1880 MHz - 1920 MHz	1880 MHz - 1920 MHz	N/A	TDD
40	2300 MHz - 2400 MHz	2300 MHz - 2400 MHz	N/A	TDD

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Frame Structures

Until recently, two frame structures, a "generic" (or "Type 1", cf. Figure 1) and an "alternative" (or "Type 2") frame structure had been foreseen for the TDD-mode in LTE. While the first was preferred e.g. in Europe due to its compatibility with UMTS and the fact that it is the same as the one used for the FDD-mode of LTE, the second was preferred especially in China due to its compatibility with TD-SCDMA (=LCR-TDD).

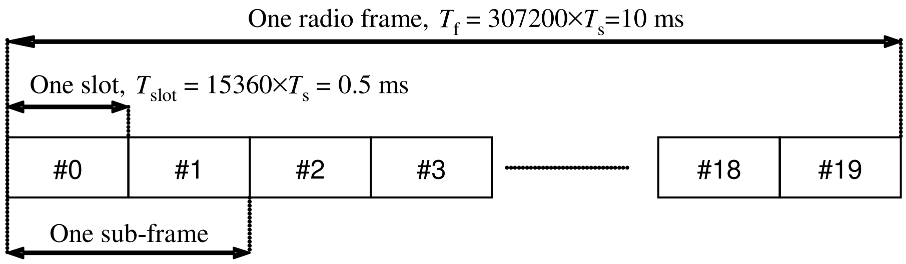

Figure 1: "Type 1" ("generic") frame structure ($T_s = 1/2048\ \Delta f$) for FDD.

At RAN WG Meeting #37, it was agreed that a single frame structure to be used for TDD should be determined, optimized with respect to

- Coexistence with TD-SCDMA and TD-CDMA
- UL coverage
- DL-UL guard flexibility
- RACH reliability
- Overhead reduction
- Simplification for dual-mode FDD/TDD equipment

Especially, with respect to the last issue the old Type-2 frame structure did not seem attractive. As further alternative, a large group of influential companies proposed a further frame structure for TDD mode at TSG RAN WG1 Meeting #51 in November 2007 (cf. Figure 2).

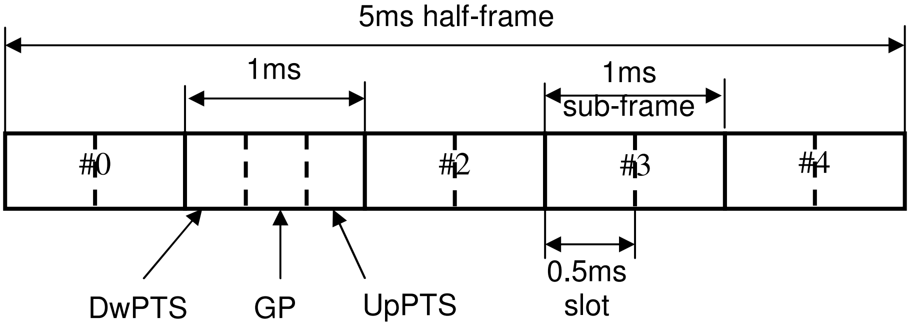

Figure 2: New Type 2 frame structure for TDD.

This new TDD frame structure was immediately introduced into the preliminary standardization document TS36.211 and the substantial changes to this document were agreed upon at

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RAN WG1 Meeting #51. Frame structure "Type 1" formerly also known as "generic frame structure" shall henceforth only apply to FDD mode, while for the TDD mode solely the new frame structure ("Type 2") is to be used. Compared to the old "Type 2" frame structure, it is advantageous especially due to a higher degree of commonality with the "Type 1" frame structure, thereby simplifying dual-mode equipment as higher layers are practically unaffected by switching between FDD and TDD mode. This change is subject to (very likely) agreement within the plenary, and hence both the old and the new version are illustrated in the following.

Configuration	Δf	Cyclic prefix length $N_{CP,l}$
Normal cyclic prefix	15 kHz	160 for $l = 0$ 144 for $l = 1,2,...,6$
Extended cyclic prefix	15 kHz	512 for $l = 0,1,...,5$
	7.5 kHz	1024 for $l = 0,1,2$

Table 1: Cyclic prefix length in subcarriers.

- Same number of (DFTS-)OFDM symbols per slot as for frame structure Type 1, i.e. 7 OFDM symbols per slot with normal cyclic prefix and 6 OFDM symbols per slot with extended cyclic prefix.
- The cyclic prefix lengths of frame structure Type 1 (cf.

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Table 1: Cyclic prefix length in subcarriers.

-) are adopted.
- Split of special 1ms interval into special fields DwPTS, guard period (GP) and UpPTS is configurable.
    - DwPTS**:**
        - Minimum length: 1 OFDM symbol (1st OFDM symbol shall carry primary synchronization signal)
        - Remainder (if any) can be used to transmit data, reference or control signals.
    - UpPTS**:**
        - Can be used to transmit short RACH preamble (2 OFDM symbols). Long RACH preamble is to be transmitted in a regular 1ms UL subframe.
        - The remainder (if any) can be used for data, and demodulation / sounding reference signals, but not for PUCCH.
    - Maximum guard period (no short-preamble RACH): ca. 0.92ms
- For PUCCH transmission, the same coding is used as for frame structure Type 1.

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- The assignment of demodulation reference signals for PUSCH and PUCCH is harmonized with that for FS Type 1.
- Apart from the four RACH preamble formats adopted from the specification for FS Type 1, a 5th preamble format has been defined: Its duration is $4096 \cdot T_S$ and it starts (without cyclic prefix) $5120 \cdot T_S$ before the end of UpPTS, i.e. directly after the DL UL switching guard period.
- The resource-element assignments for the PBCH, cell-specific reference signals and MBSFN reference signals have been harmonized with FS Type 1.

Switching between UL and DL (New Type 2 Frame Structure)

- Both 5ms and 10ms switching-point periodicity shall be supported, i.e. with a single pair of UL/DL and DL/UL switching points per 5ms or 10ms interval occurring at fixed time intervals of 5ms and 10ms, respectively.
- Only a single fixed DL UL switching point per 5ms half-frame is specified: between DwPTS and UpPTS.
- In case of 10ms switching periodicity:
    - UpPTS and GP exist only in the first half-frame within each frame where the DL UL switch occurs.
    - The duration of DwPTS in the half-frame, where GP and UpPTS do not exist, is 1ms.
    - Sub-frames #2…#4 of the second half-frame are reserved for DL transmission.
- Further restrictions:
    - Sub-frame #0 and DwPTS of each half-frame is always used for DL transmission, because synchronization signals are transmitted here with 5ms periodicity.
    - UpPTS and the following sub-frame are always reserved for UL.
- The configuration is signaled using BCCH.

Guard Periods

Guard periods between UL and DL transmission are required to avoid near-end cross talk (NEXT), i.e. own transmission interfering with own reception, and to allow for the terminal to switch from transmission to reception mode.

- DL UL: As mentioned above, the guard period for DL UL switching is configurable.

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- UL DL: As for the old Type-2 frame structure, there is no mentioning of UL DL switching in the proposal. Supposedly guard periods as originally planned for Type-1 frame structure (cf. Table 2) should be used for UL DL switching. Guard periods at switching points are generated by not transmitting during the N_{GP} last (DFTS-)OFDM symbols of the last sub-frame preceding the DL/UL switching point.

  However, strangely this table has been removed in the agreed-upon change request for TS36.211.

Configuration	**Sub-frame #0**	**Sub-frame #5**	**All other sub-frames**
Normal cyclic prefix	0, 1, 2, 3, 4, 5	0, 1, 2, 3, 4, 5	0, 1, 2, 3, 4, 5, 12
Extended cyclic prefix	0, 1, 2, 3	0, 1, 2, 3, 4	0, 1, 2, 3, 4, 10

Table 2: Supported guard periods in (DFTS-)OFDM symbols (N_{GP}).

Pros and Cons of TDD vs. FDD

<u>Pros:</u>

- **No requirement for paired spectrum**

  Ł Easier and more flexible spectrum allocation

- **Higher frequency diversity**

  The entire system bandwidth is used for both UL and DL.

- **Hardware cost**

  Only single oscillator per terminal, no duplexer required, instead: expensive switch

- **Reciprocity of channel**
  - **Theory:**
    - § Coherent channel knowledge is available at transmitter without explicit feedback.

      Ł Less delay of CSI at least during first slots of each transmission phase (better for high mobility!)

      Ł Advanced signal processing at transmitter:

      Example: simple pre-distortion in DL for multi-user MIMO (MU-MIMO)

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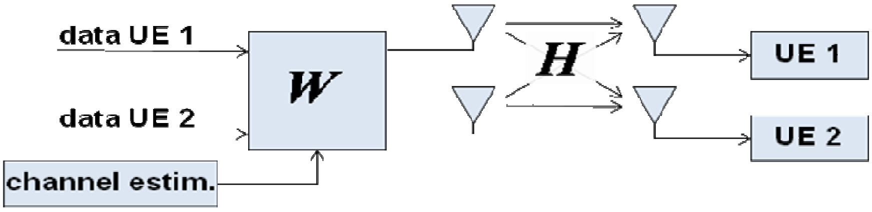

Figure 3: MU-MIMO in DL.

- Both UEs are scheduled in the same radio resources.
- Pre-distortion at transmitter with $W = H^H (HH^H)^{-1}$
  - No interference between the two data streams
  - No noise enhancement
  - No additional processing at the UEs

- **Reality:**
  - § While UL and DL channels may be reciprocal, this does typically not hold for the RF chains at transmitter and receiver side.
    - Ł At least some calibration may be required.
  - § Interference levels in UL and DL are usually different.
    - Ł Still CQI feedback required for channel-dependent scheduling.

- **Adaptation to asymmetry in UL-/DL-traffic**
  - **Theory:** Flexible shifting of UL/DL switching points to adapt to asymmetry of traffic load in UL and DL.
  - **Reality:** Switching points must be the same in neighboring cells to avoid “cross-slot interference”.

    Ł Only very slow adaptation feasible (if any)

    Ł ”Buffer cells” can be introduced between cells, where sub-frames are assigned to different transmission phases. Here, these sub-frames are used neither for DL nor for UL transmission.

Cons:

- **Guard periods between UL and DL required**

- High rate of UL/DL switches leads to waste of radio resources, but would be required for accurate channel state information in high-mobility scenarios.
- Better apt for local-area / single-cell scenarios (WLAN, DECT)

- **Discontinuous transmission**
  - Degradation of RF efficiency
  - Problems with delay-sensitive applications (amplified by (H)ARQ)
- **Higher sampling rate at receiver**
- **"Cross-slot interference"**

  BSs need to be synchronized with respect to timing and UL/DL assignment, otherwise interference between neighboring cells occurs. Particularly problematic: BS-to-BS interference.

- **"Inter-operator interference" (="adjacent-channel interference")**

  In general different operators neither coordinate their network planning nor synchronize their frames and traffic asymmetry. Particularly problematic: BS-to-BS interference.

The next newsletter ...

The next 3GPP newsletter will provide you the information on the latest progress in the different working groups concerning Long Term Evolution and High Speed Packet Access Evolution.

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