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TD-LTE and FDD-LTE

A Basic Comparison

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Contents

1 List of Acronyms

Term or Acronym	Definition
3GPP	Third Generation Partnership Project
ACK	Positive Acknowledgement
CDMA	Code Division Multiple Access
DL	Downlink
EDGE	Enhanced Data Rates for GSM Evolution
FDD	Frequency Division Duplexing
GSM	Global System for Mobile Communication
GPRS	General Packet Radio Service
HARQ	Hybrid Automatic Repeat Request
HSCSD	High Speed Circuit Switch Data
HSDPA	High Speed Downlink Packet Access
HSPA	High Speed Packet Access
HSUPA	High Speed Uplink Packet Access
IS-95-B	Interim Standard 95 Revision B
LTE	Long Term Evolution
MIMO	Multiple Input Multiple Output
NACK	Negative Acknowledgement
PUCCH	Physical Uplink Control Channel
R99	WCDMA Release 99
RB	Resource Block
RBS	Radio Base Station
RE	Resource Element
TDD	Time Division Duplexing
TD-LTE	Time Division Duplexing LTE
TD-SCDMA	Time Division Synchronous CDMA
QAM	Quadrature Amplitude Modulation
QPSK	Quadrature Phase Shift Keying
UE	User Equipment
UL	Uplink
WCDMA	Wideband CDMA

2 Definition of TDD and FDD

In communication systems, a user needs to exchange data with one or more parties through a shared resource – a common channel. Depending on whether the data is transmitted/received simultaneously, the following transmission techniques exist:

1. **Simplex** – One party transmits data and the other party receives data. No simultaneous transmission is possible – the communication is one-way and only one frequency (channel) is used. Examples of simplex communication are traditional (non-interactive) radio and television.
2. **Half Duplex** – Each party can receive and transmit data, but not at the same time. The communication is two-way and only one frequency (channel) is used. Examples of half duplex communication are walkie-talkies or other two-way radio systems.
3. **Full Duplex** – Each party can transmit and receive data simultaneously. The communication is two-way and two frequencies (channels) are used – one for transmitting and one for receiving.

In the case of cellular networks, a limited shared resource (spectrum) needs to be shared with all users so full duplex communication is possible (Note that full duplex service, like regular phone conversation, can be carried over a half duplex channel). The two main methods used are:

1. **Time Division Duplexing (TDD)** – The communication is done using one frequency, but the time for transmitting and receiving is different. This method emulates full duplex communication using a half duplex link.
2. **Frequency Division Duplexing (FDD)** – The communication is done using two frequencies and the transmitting and receiving of data is simultaneous.

The advantages of TDD are typically observed in situations where the uplink and downlink data transmissions are not symmetrical. Also, since the transmitting and receiving is done using one frequency, the channel estimations for beamforming (and other smart antenna techniques) apply for both the uplink and the downlink. A typical disadvantage of TDD is the need to use guard periods between the downlink and uplink transmissions.

The advantages of FDD are typically observed in situations where the uplink and downlink data transmissions are symmetrical (which is not usually the case when using wireless phones). More importantly, when using FDD, the interference between neighboring Radio Base Stations (RBSs) is lower than when using TDD. Also, the spectral efficiency (which is a function of how well a given spectrum is used by certain access technology) of FDD is greater than TDD.

3 Differences between FDD-LTE and TD-LTE

The two versions of LTE are very similar. In fact, they differ only in the physical layer and, as a result, the version implemented is transparent to the higher layers. This means that UEs will be able to support both TD-LTE and FDD-LTE with one chipset with only minor modifications required. All major chipset vendors – ST-Ericsson (M700/M710 chipsets), Altair Semiconductor (FourGee-6150 chipset), and Qualcomm (MDM9200/ MDM9600 chipsets) have already released chipsets that support both LTE flavors. UEs based on those chipsets are (or will soon be) available from Sony Ericsson, Huawei, Samsung, Nokia, and others.

The following features are unique to TD-LTE:

1. **Frame structure** – 3GPP has specified a special subframe that allows switching between downlink and uplink transmission.
2. **Random access** – Several additional random access formats exist in certain subframes. Also, several random access channels exist in every subframe.
3. **Scheduling** – The scheduling for the uplink is multi-frame.
4. **HARQ** – The number of HARQ processes depends on the uplink/downlink resource allocation.
5. **ACK/NACK** – Multiple acknowledgements and negative acknowledgements are combined on the uplink control channels. This ultimately leads to increased control signaling and lower spectrum/resource utilization.
6. **Guard periods** – These are used in the center of special subframes. They allow for the advance of the uplink transmission timing.

Another difference between FDD-LTE and TD-LTE is that in FDD-LTE every downlink subframe can be associated with an uplink subframe. In TD-LTE the number of downlink and uplink subframes is different and such association is not possible.

Additionally, the uplink coverage with respect to a specific data rate in TD-LTE is generally worse than FDD-LTE due to the fact that the uplink transmission is not continuous. The percentage of coverage for control and data channels is, however, very similar to that of FDD-LTE.

In terms of spectrum efficiency, the performances of TD-LTE and FDD-LTE are similar for non-delay sensitive traffic. The lower performance of TD-LTE is due to the guard periods mentioned above.

Finally, TD-LTE and TD-SCDMA work together with minimum interference issues, even if both technologies are deployed in the same frequency band (assuming that the TD-LTE UL:DL configurations are chosen correctly and both systems are synchronized to the same time source).

4 Frequency Bands for FDD-LTE and TD-LTE

The frequency bands listed in Table 1 are currently defined by 3GPP for TD-LTE and FDD-LTE.

Table 1 LTE Frequency Bands

LTE Operating Band	Uplink, MHz	Downlink , MHz	Duplex Separation, MHz	Duplex Mode
	$F_{UL\_low} – F_{UL\_high}$	$F_{DL\_low} – F_{DL\_high}$		
1	1920 – 1980	2110 – 2170	190	FDD
2	1850 – 1910	1930 – 1990	80	FDD
3	1710 - 1785	1805 – 1880	95	FDD
4	1710 – 1755	2110 – 2155	400	FDD
5	824 – 849	869 – 894	45	FDD
6	830 – 840	875 – 885	45	FDD
7	2500 – 2570	2620 – 2690	120	FDD
8	880 – 915	925 – 960	45	FDD
9	1749.9 – 1784.9	1844.9 – 1879.9	95	FDD
10	1710 – 1770	2110 – 2170	400	FDD
11	1427.9 – 1447.9	1475.9 – 1495.9	48	FDD
12	698 – 716	728 – 746	30	FDD
13	777 – 787	746 – 756	31	FDD
14	788 – 798	758 – 768	30	FDD
17	704 – 716	734 – 746	30	FDD
33	1900 – 1920	1900 – 1920	N/A	TDD
34	2010 – 2025	2010 – 2025	N/A	TDD
35	1850 – 1910	1850 – 1910	N/A	TDD
36	1930 – 1990	1930 – 1990	N/A	TDD
37	1910 – 1930	1910 – 1930	N/A	TDD
38	2570 – 2620	2570 – 2620	N/A	TDD
39	1880 – 1920	1880 – 1920	N/A	TDD
40	2300 – 2400	2300 – 2400	N/A	TDD

Typically, a wireless operator will be allowed to operate a LTE network in a certain band and its bandwidth will be allocated in terms of Resource Blocks (RBs), as listed in Table 2.

Table 2 LTE Channel Bandwidth

Channel bandwidth, MHz	1.4	3	5	10	15	20
Number of Resource Blocks	6	15	25	50	75	100

5 Peak Downlink and Uplink Data Rates

The peak data rates for various channel bandwidths and antenna options for both FDD-LTE and TD-LTE are shown in Tables 3 and 4.

Table 3 Peak Downlink Data Rates for FDD-LTE & TD-LTE (frame structure type 1)

Channel bandwidth, MHz		1.4	3	5	10	15	20
Number of Resource Blocks		6	15	25	50	75	100
Modulation	MIMO	Data Rate[1], Mb/s					
QPSK	Not Used	1.728	4.32	7.2	14.4	21.6	28.8
16 QAM	Not Used	3.456	8.64	14.4	28.8	43.2	57.6
64 QAM	Not Used	5.184	12.96	21.6	43.2	64.8	86.4
64 QAM	2x2	10.368	25.92	43.2	86.4	129.6	172.8
64 QAM	4x4	20.736	51.84	86.4	172.8	259.2	345.6

Table 4 Peak Uplink Data Rates for FDD-LTE & TD-LTE (frame structure type 1)

Channel bandwidth, MHz		1.4	3	5	10	15	20
Number of Resource Blocks		6	15	25	50	75	100
Modulation	MIMO	Data Rate[2], Mb/s					
QPSK	Not Used	1.8	4.5	7.5	15	22.5	30
16 QAM	Not Used	3.45	8.64	14.4	28.8	43.2	57.6
64 QAM	Not Used	5.184	12.96	21.6	43.2	64.8	86.4

[1] Assumes no coding and 12 RE per RB for control channels and reference signals
[2] Assumes no coding and 12 RE per RB for reference signals (PUCCH will reduce the rate slightly)

Table 5 contains a comparison between the downlink and uplink data rates for the currently active wireless standards:

Table 5 DL and UL Data Rates for various wireless technologies

Standard	DL Data Rate, Mb/s	UL Data Rate, Mb/s
GSM	0.0096	0.0096
GPRS[3]	0.08	0.02
HSCSD[4]	0.0432	0.0144
EDGE[5]	0.2368	0.0592
EDGE Evolution[6]	1.89	1.42
WCDMA R99	0.384	0.384
HSPA	14.4	5.76
HSPA+[7]	84.4	23
CDMA (IS-95)[8]	0.1152	0.0096
CDMA2000[9]	4.9xN	1.8xN
TD-SCDMA[10]	8.4	5
LTE[11]	345.6	86.4

[3] Assumes allocation of 4 timeslots in the DL and 1 in the UL
[4] Assumes allocation of 3 timeslots in the DL and 1 in the UL
[5] Assumes allocation of 4 timeslots in the DL and 1 in the UL
[6] Assumes allocation of 8 timeslots in the DL and 6 in the UL
[7] Assumes Dual Cell HSDPA (10 MHz) with 64 QAM and 2x2 MIMO
[8] Assumes the use of IS-95-B
[9] Assumes EVDO Rev B. N is the number of 1.25 MHz carriers that are used. 64 QAM is used in the DL
[10] Assumes single carrier TD-SCDMA HSPA+ and 64 QAM
[11] Assumes 20 MHz of bandwidth, 64 QAM and 4x4 MIMO in the DL

6 Operators' Challenges

Wireless operators are constantly looking for ways to reduce their operational expenses while increasing their revenue. In recent years, the focus has been on introducing and/or identifying data applications that are attractive to consumers while being inexpensive to implement and support. Additionally, operators such as China Mobile are searching for a next-generation technology that will overcome the limitations of TD-SCDMA (limited/expensive handsets available only in the domestic market; multiple mode handsets needed for global roaming). Finally, a technology that will address the continuously growing data traffic is needed. LTE seems to address all these challenges.

Even though many operators around the world have committed to deploying LTE as their next-generation wireless network, the possibility of using TD-LTE has not been generally considered. Recently, however, more and more operators (including Aircel (India), China Mobile (China), Aero2 (Poland), and Infotel (RIL India), vividwireless (Australia)) have expressed their support for TD-LTE, which is a clear indication that the technology will become widely accepted.

The main reasons for that sudden interest are the following:

1. The differences between FDD-LTE and TD-LTE are minimal, and single devices can support both technologies with one chipset – device availability will not be an issue.
2. The TDD spectrum is less expensive.
3. Both offer similar performance/spectral efficiency.
4. Handovers can be performed between FDD-LTE, WCDMA, TD-SCDMA, GSM, and CDMA.
5. Some of the frequency bands for TD-LTE overlap with WiMax bands, making it an attractive evolution path for WiMax operators.
6. TD-LTE is suitable for M2M (machine to machine) applications (such as Point of Sale, Fleet Management, Health Care Monitoring, etc.) due to its adaptable UL and DL configuration.

Finally, according to recent estimates of LTE rollout scenarios[12] a medium size tier one operator will need to invest about $8 Billion USD CAPEX to deploy LTE in the first 3 to 5 years. Similarly, the OPEX expenses could increase the operators' current OPEX costs by roughly 30%.

Overall, TD-LTE offers operators a great alternative to FDD. Its natural suitability for asymmetric applications, low latency, high throughput, and security make it a flexible and cost-effective solution for the next generation wireless networks.

[12] See http://www.aircominternational.com for more information