Technical Evaluation of TD-LTE for Low-band Spectrum

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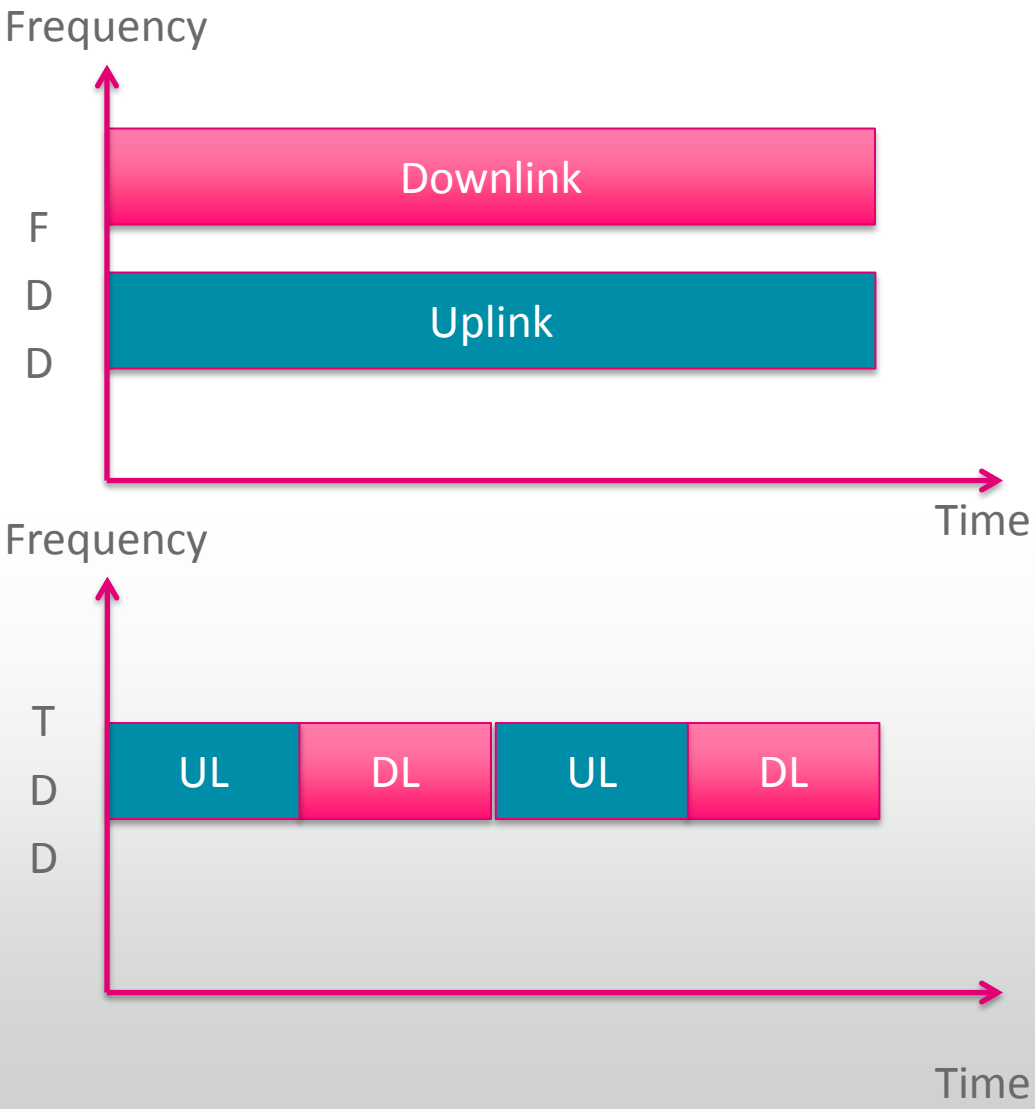
Introduction

- Deploying TD-LTE at 600 MHz will result in efficiency losses and operational deficiencies
  - Manufacturers and regulatory authorities throughout the world have focused on deploying TD-LTE in higher-frequency bands where the performance challenges associated with TD-LTE are fewer and less pronounced – a development T-Mobile supports.
  - In high-frequency bands the market and technology for TD-LTE continues to progress, but in low-frequency bands the tradeoffs associated with TD-LTE compared to FDD LTE remain significant and have limited both development and deployment of TD-LTE.
- Some of the notable drawbacks of TD-LTE in low-frequency spectrum include link budget deficits compared to FDD LTE, performance constraints compared to FDD LTE, and real-world limitations on the feasibility of variable downlink-uplink configurations

Defining FDD and TDD



- Separate UL and DL frequencies
- Both UL and DL frequencies in use at the same time
- UL and DL Symmetrical, same bandwidth

- UL and DL on same frequency
- Alternating UL and DL transmissions
- UL and DL can be symmetrical or asymmetrical

Characteristics of TD-LTE in the 600 MHz band

TD-LTE:		*But:*
Supports flexible uplink/downlink (UL/DL) configurations	→	UL/DL configurations cannot vary within the network and real-world conditions limit or eliminate flexibility among networks
Accommodates different cell sizes	→	Link budget will have a significant adverse effect on coverage
Can achieve nearly the spectral efficiency as FDD	→	Due to TDD's UL/DL switching, FDD is always more efficient than TDD
Can provide similar user experience as FDD	→	Achieving a similar user experience requires TDD to forfeit uplink capacity that is important to competition and anticipated consumer uses

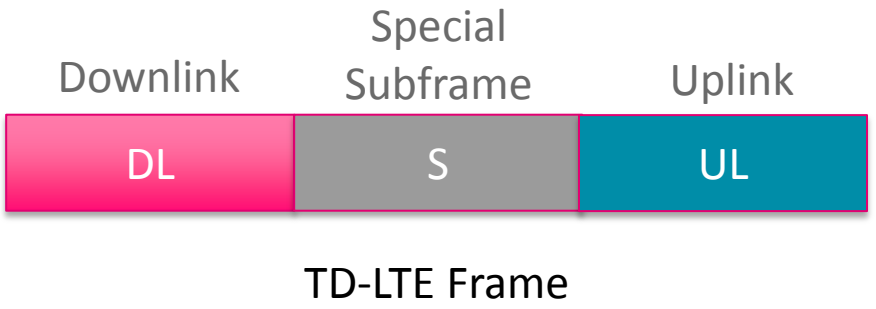
Downlink – Uplink Switching in TD-LTE

Special Subframe separates DL and UL

- Every transmission needs to wait for the time period allocated for the opposite link direction
- Special Subframe includes a guard period for switching between DL and UL transmissions
- GP is variable length to accommodate for different device distances from the BTS
  - Part of Special Subframe that is not dedicated for GP can carry user data in addition to control data

Why is Guard Period needed?

- All UL signals need to arrive at the BTS within the UL subframe
  - To avoid collisions and ensure synchronized receiving
- Due to different distances to BTS, devices need to start UL transmissions at different times
  - BTS informs devices when to transmit based on Timing Advance (TA)
- Duration of GP is configured by cell size

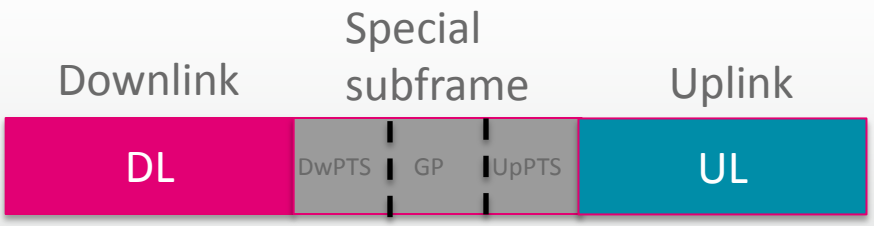


TD-LTE Frame

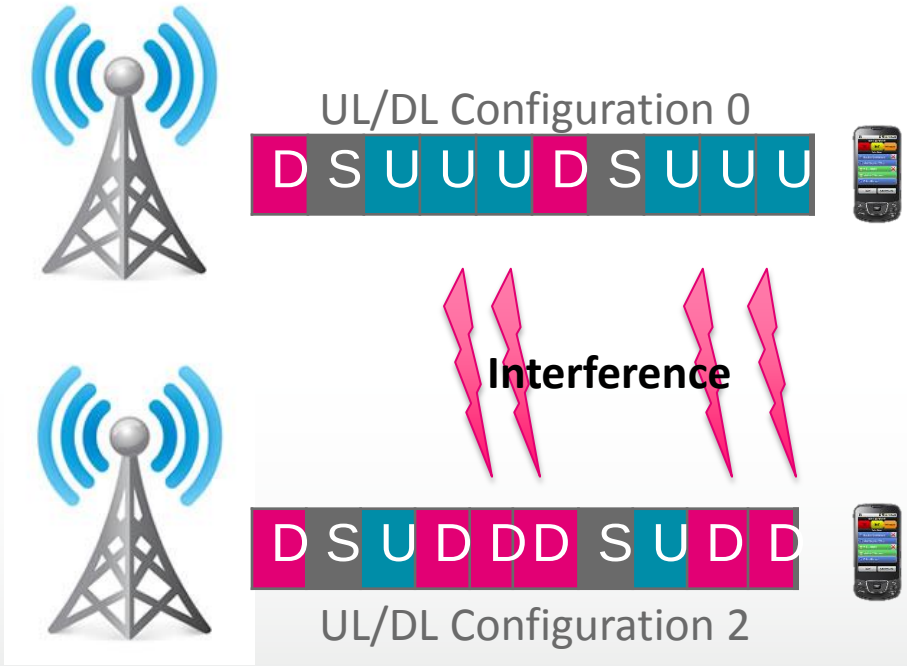
TD-LTE Flexible Use of Spectrum

- 7 different UL/DL configurations
- Typically configurations are not changed
  - 2:2 and 3:1 are common configurations
- The Special Subframe that separates Downlink and Uplink includes the Guard Period (GP) as well as Downlink and Uplink Pilot Timeslots
  - In addition to control information. Downlink Pilot Time Slot (DwPTS) can carry data
  - The smaller the GP, the higher the DL capacity

UL/DL configuration	Switch-point periodicity	DL/UL Ratio	Subframe number									
			0	1	2	3	4	5	6	7	8	9
0	5 ms	1:2	D	S	U	U	U	D	S	U	U	U
1	5 ms	2:2	D	S	U	U	D	D	S	U	U	D
2	5 ms	3:1	D	S	U	D	D	D	S	U	D	D
3	10 ms	6:3	D	S	U	U	U	D	D	D	D	D
4	10 ms	7:2	D	S	U	U	D	D	D	D	D	D
5	10 ms	8:1	D	S	U	D	D	D	D	D	D	D
6	5 ms	3:5	D	S	U	U	U	D	S	U	U	D



TD-LTE Requires Single UL/DL Configuration



UL and DL transmissions need to be synchronized

- **Same UL/DL configuration** in all cells across the network
- Networks on adjacent frequency blocks needs to be synchronized to avoid interference

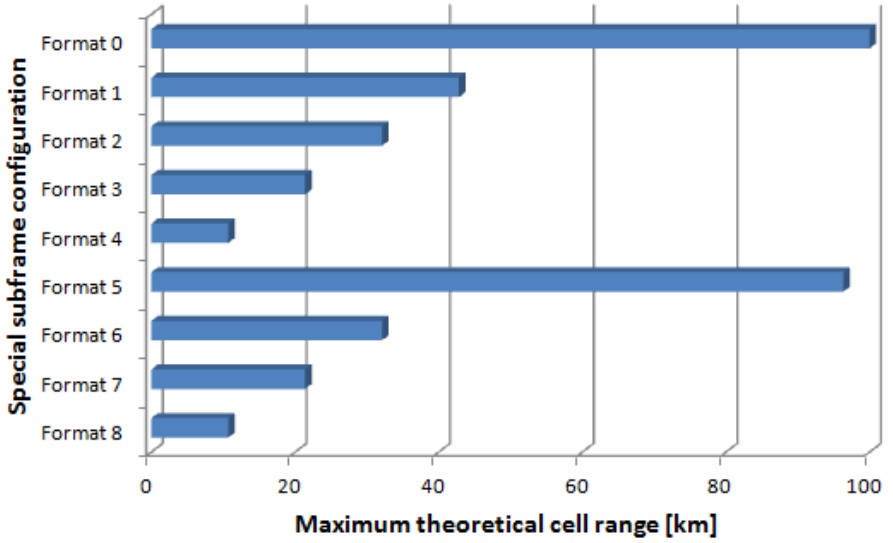
→ Reduced flexibility to accommodate different user segments and use cases between networks

→ UL/DL configuration is difficult to change, especially in large networks

TD-LTE cell sizes in the 600 MHz band

3GPP Specification 36.211:

Format	Normal CP (DL and UL)			Extended CP (DL and UL)		
	DwPTS	GP	UpPTS	DwPTS	GP	UpPTS
0	3	10	1	3	8	1
1	9	4		8	3	
2	10	3		9	2	
3	11	2		10	1	
4	12	1		3	7	2
5	3	9	2	8	2	
6	9	3		9	1	
7	10	2		-	-	-
8	11	1		-	-	-



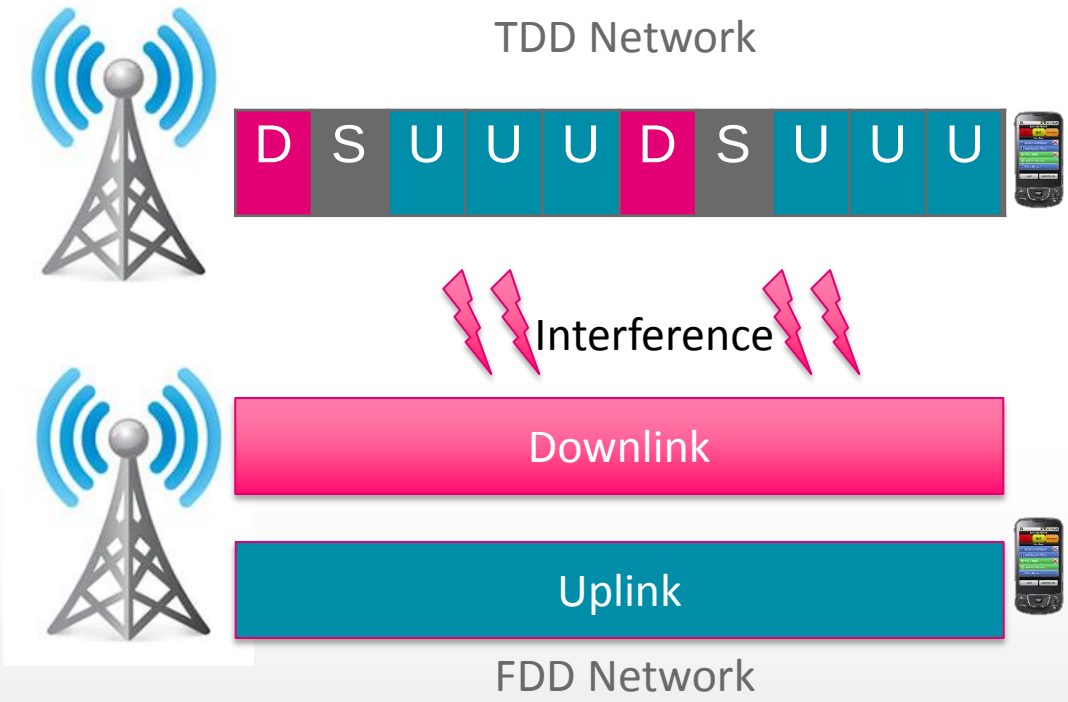
** assuming Normal CP*

TD-LTE in large cells must be configured **with largest Guard Period deployed in the network**:

→ This condition **consumes resources** that cannot be allocated for user data (or any other type of data) and **makes the system less efficient**

→ Low bands and large cells will have **reduced performance** due to the larger Guard Period

TD-LTE coexistence with FDD LTE requires a guard band



TDD UL and DL transmissions will interfere with an adjacent FDD network

→TD-LTE networks require a **guard band** between TD-LTE and FDD LTE networks

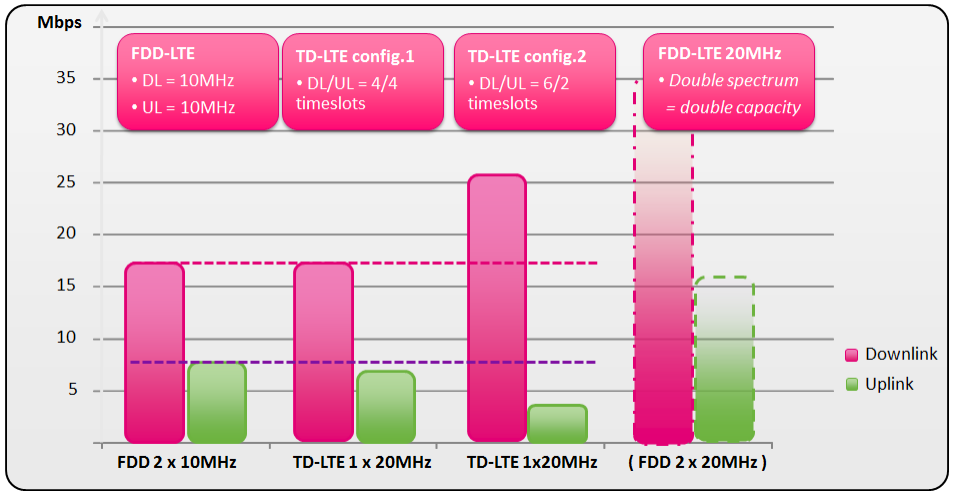
→Typically at least **8-9 MHz is recommended**

UL transmissions near Channel 37 pose a greater interference concern to Wireless Medical Telemetry services

→ TD-LTE will require a guard band on both sides of Ch.37

Spectral Efficiency

- Majority of Physical Layer and Radio Resource Management design is common for FDD and TD-LTE
  - Therefore on the link layer the spectral efficiency of both systems is the same

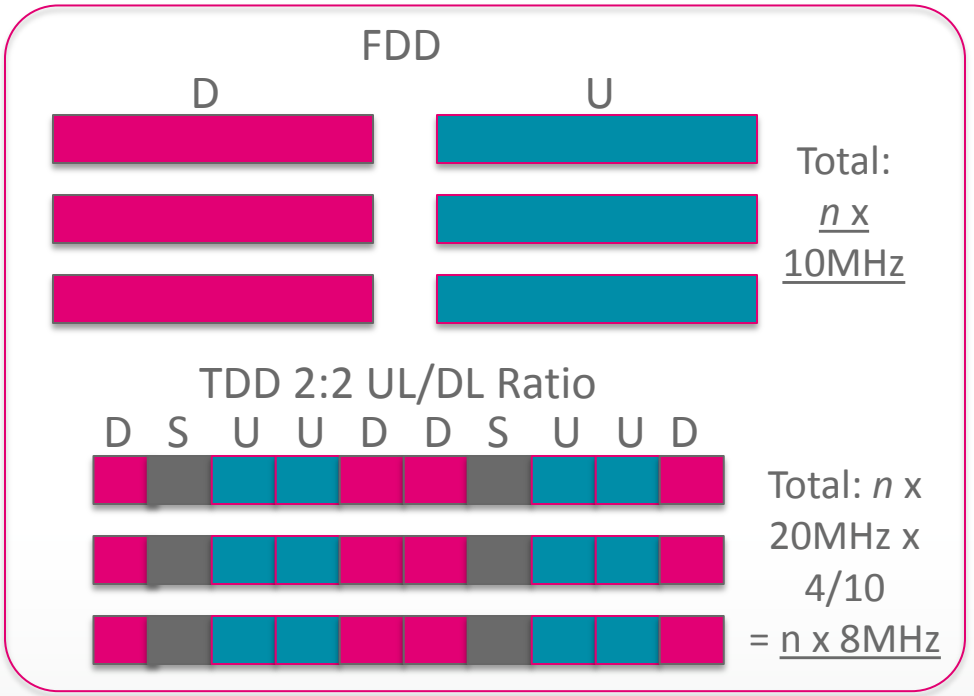


- Unlike FDD LTE, however, TD-LTE must share the resources in time and allocate some of them for Guard Periods for switching purposes
  - This resource commitment limits not only maximum data rates, but also average cell throughput

- Large cells need large Guard Periods resulting in further reduction of TD-LTE efficiency. Hence, **to maximize efficiency TD-LTE is best suited for capacity-constrained deployments in high bands where coverage is not the main driver**

TD-LTE Link Budget

- LTE coverage is limited in UL and even highly asymmetric transfers require sustaining both links
- To make a fair comparison one should assume same transmission period and same data volume to be transferred in both systems (FDD and TD-LTE)
  - same data rate for cell-edge criterion (link budget)



- To provide equivalent data rates on both sides (FDD and TD-LTE) TD-LTE needs to transmit more user bits per TTI
  - Resulting in increased coding rate in TD-LTE and less coverage at cell-edge
  - Effect is even stronger for DL dominant asymmetric frame configuration

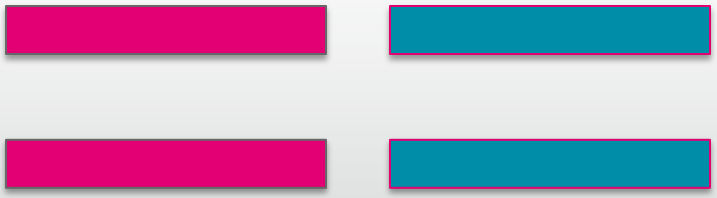
From an UL coverage perspective, FDD-based systems have an advantage over TDD system due to the continuous transmission.

Link Budget Example for Low Band Spectrum

- TD-LTE must share its spectrum in time thus uplink is on only for a certain period of time resulting in lower UL power density (4-7 dB loss)
  - Additionally TD-LTE eNodeB has 0.8 dB lower sensitivity due to the circulator and switch

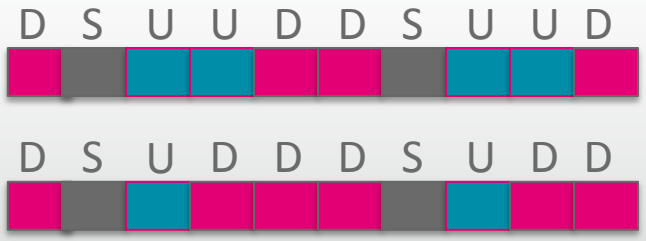
- Consequently TD-LTE 600 MHz link budget is significantly worse than FDD LTE link budget for 600 MHz for equivalent cell edge performance

FDD



Total 10+10MHz, 100% for Uplink

TDD



TDD Config 1: 10MHz, 40% for UL
TDD Config 2: 10MHz, 20% for UL

Sample 600 MHz Link Budget Study

FDD-LTE 600 MHz	TD-LTE 600 MHz (DL:UL= 2:2)	TD-LTE 600 MHz (DL:UL= 3:1)	Vs. Currrent FDD-LTE on AWS band
Maximum Allowed Path Loss (131 dB)	-4.8 dB	-7.8 dB	-4.5 dB
Site Area (6.2 sq km)	-46%	-64%	-46%
Sites required (#)	+87%	+186%	+86%
Inter-Site Distance (2.66 km)	-27%	-40%	-26%

In this common deployment model, a TD-LTE deployment on 600 MHz requires roughly the same number of sites as FDD-LTE on the 1.7 GHz AWS band, effectively eliminating one of the important propagation performance advantages of the 600 MHz band relative to higher-frequency spectrum

Summary

- For national mobile broadband deployments FDD LTE has important advantages over TD-LTE especially at low-frequency bands:
  - Higher spectral efficiency – allows carriers to wrest more use and value from the radiofrequency resource
  - Lower site count – reduces carrier costs and takes full advantage of low-band propagation characteristics
  - Higher maximum data rates – allows consumers to enjoy a better end-user experience for both uplink and downlink use cases

- TD-LTE involves challenges at any frequency, but at lower frequencies these challenges are more complicated and are accompanied by numerous additional drawbacks and performance limitations not found or less pronounced than in higher bands

- TD-LTE remains a good option for unpaired spectrum in higher-frequency spectrum where coverage is less important than capacity

Thank you

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