

# Investigation of Coexistence of TDD Systems in Indoor Environment

Soni Koul, Petri Patronen, Wang Daqing  
Nokia

e-mail: soni.koul@nokia.com; petri.patronen@nokia.com;  
wang.daqing@nokia.com

## ABSTRACT

This paper investigates the impact of Adjacent Channel Interference between the two TDD operators operating in Indoor environment. The impact of adjacent channel interference is studied in various scenarios and deployment configurations. Evaluation of TDD/TDD system coexistence is studied with system simulations using a static simulator. The selected system scenario is such that two TDD systems are operating in an indoor environment. Intersystem interference impacts to system capacity under various synchronization conditions, Base Station locations and power conditions are studied.

## 1 INTRODUCTION

WCDMA (Wideband Code Division Multiple Access) air interface has been specified by 3GPP (3<sup>rd</sup> Generation Partnership Project) standardization forum [1]. The WCDMA air interface consists of two modes, UTRA (UMTS Terrestrial radio access) FDD and UTRA TDD, for operating with paired and unpaired bands respectively. The possibility to operate in either FDD or TDD mode allows for efficient utilization of the available spectrum according to the frequency allocation in different regions.

UTRA TDD Tx /Rx 1900 MHz	UTRA FDD UL 1920 MHz -1980MHz	UTRA TDD DL 1980-2010MHz
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Figure 1: UTRA Spectrum Allocation in Europe

1900-1920MHz and 2010-2025 MHz are reserved for TDD operation. The advantage of using UTRA TDD for mobile radio communication is shown to be related to its ability to handle asymmetric data and benefits resulting from the reciprocal nature of the channel. But synchronization difficulties and the associated interference problems are seen as some limitations.

In this paper, one of the possible system deployment is discussed. The deployment scenario is such that the two TDD individual systems are operating in indoor environment and the spectrum allocation is such that the carrier separation between the two systems is 5MHz.

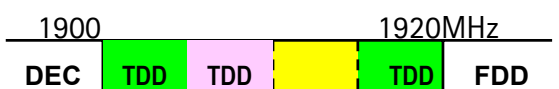


Figure 2: TDD Spectrum Allocation

Critical Adjacent Channel interface points from interference point of view are illustrated in Figure 2 (between TDD 1 and TDD2, TDD2 and TDD3, TDD3 and TDD4). The investigation of 10 MHz carrier separation between the two TDD operators is beyond the scope of this document.

The paper is organized in various sections Interference paths experienced in TDD-TDD system co-existence are discussed in section II. Section III outlines the methodology for the evaluation of TDD-TDD system co-existence. Impact of Adjacent channel interference is studied in section IV. Section V concludes the findings of this article.

## 2 INTERFERENCE PATHS

Figure 3 illustrates the interfering paths between two TDD systems belonging to two TDD operators. In this figure it is assumed that Cell 1 belongs to operator 1 and Cell 2 belongs to operator 2.

The interference experienced by each system can be segregated into two components "Intra" and "Inter" system interference.

Intra system interference " $I_{Intra}$ " is the interference experienced within an operators network.

Inter system interference " $I_{Inter}$ " is the interference experienced originating from the neighboring operator/operators. Hence total interference " $I_{Total}$ " can be illustrated as

In the calculation of intersystem interference, the RF characteristics of transmitter and receiver are taken into account by weighting adjacent system signal with a parameter ACIR. The definition of ACIR and other related radio parameters is explained in [3].

$$I_{total} = ACIR (I_{Inter}) + I_{Intra} \quad (1)$$

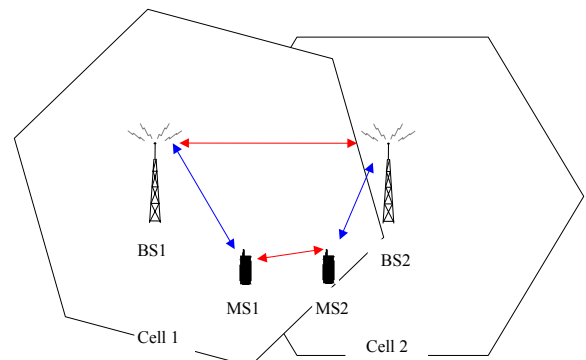


Figure 3: Interference Paths in asynchronous case

Unlike UTRA FDD, the uplink and downlink signals in the UTRA TDD mode are transmitted using the same carrier frequency.

In UTRA FDD, uplink and downlink signals are transmitted using different carrier frequencies. This is explained in Figure 4, Freq1 & Freq2 indicate the UTRA FDD operation whereas Freq\_T indicates the TDD operation.

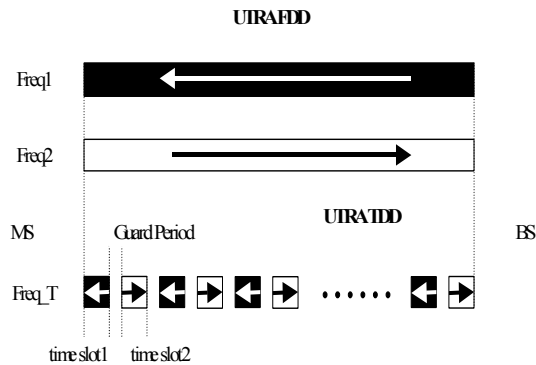


Figure 4: TDD and FDD mode of operation

The extent of the intra system interference experienced by the operator will depend upon the frame structure or "asymmetry". For a single TDD operator the interfering paths for same asymmetry and different asymmetry within the operators system are described below:

**Interfering Paths:**

- TDD Intraoperator (Same asymmetry)
  - TDD BS interferes with neighboring TDD UE's in DL.
  - TDD MS interferes with neighboring TDD BS's in UL.
- TDD Intraoperator (Different asymmetry)
  - TDD BS interferes with neighboring TDD BS's in DL.
  - TDD MS interferes with neighboring TDD MS's in UL.

In this article it is assumed that there is same asymmetry within an operator. For interoperator case, there is a possibility that the frames are not synchronized and possess a different asymmetry. In such scenario, dominant interference paths are described as follows:

**Interfering Paths:**

- TDD Intraoperator (Synchronized and Same asymmetry)

TDD BS interferes with neighboring TDD UE's in DL.

TDD MS interferes with neighboring TDD BS's in UL.

- TDD Intraoperator (Not synchronized)

TDD BS interferes with neighboring TDD BS's in DL.

TDD MS interferes with neighboring TDD MS's in UL.

For two operators, operating in adjacent bands with their frames synchronized interference paths for UL and DL with same asymmetry are as shown in Figure 5.

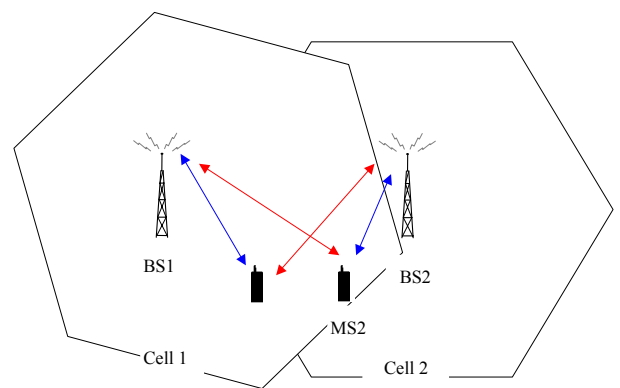


Figure 5: Interference Paths in synchronous case

For two operators, operating in adjacent bands with their frames not synchronized interference paths for UL and DL with different asymmetry are as shown in Figure 6.

In simulator, the imperfect frame synchronization or different asymmetry between two cells is modeled by considering that the time slots have an arbitrary time offset depicted in equation 2.

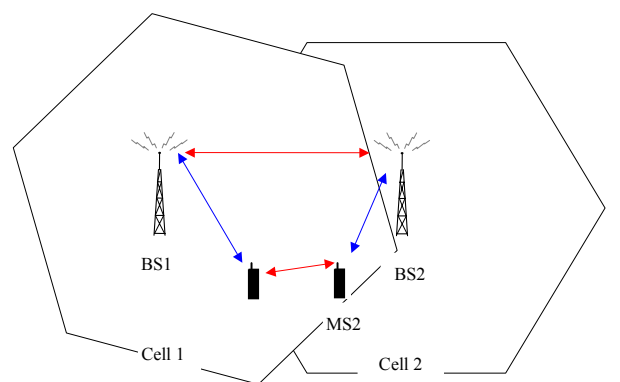


Figure 6: Interference Paths in asynchronous case

Different degrees of synchronization are possible to model synchronization between the two systems. Here, " $\alpha$ " depicts the degree of synchronization between the two systems and is defined as:

$$\alpha = \frac{t_{\text{off}}}{t_{\text{slot}}} \quad (2)$$

where  $t_{\text{slot}}$  is length of the time slot;  $t_{\text{off}}$  is timing difference between the time slots.

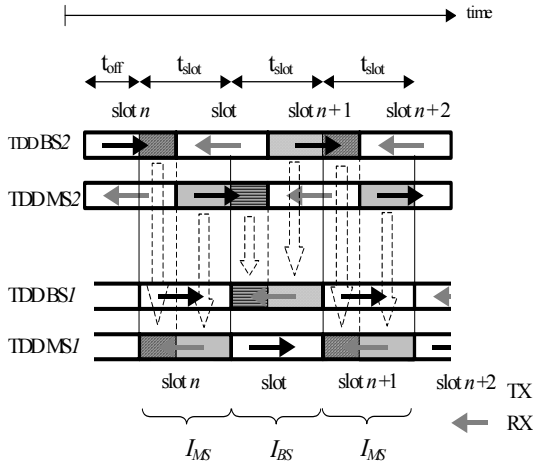


Figure 7: TDD-TDD Interference

### 3 METHODOLOGY FOR THE EVALUATION OF TDD-TDD SYSTEM CO-EXISTENCE

#### 3.1 Methodology for coexistence study

Interactions between two TDD systems operating in adjacent bands have been studied using a system simulator. The procedure adopted is such that performance of isolated TDD system is investigated. "Satisfied Capacity of the System" quantifies the performance of the TDD system. Then adjacent system is included in the system model and the "Satisfied Capacity of the System" is re-investigated. The comparative analysis of these two sets of system statistics evaluates the impact on the performance of the system in terms of capacity loss.

The system simulator used for this purpose is a static snapshot simulator. A simulation step or snapshot consists of placement of mobiles randomly, pathloss calculations, handover modeling, power control iterations and statistics collection. The simulation execution involves following steps:

- Base Station generation - as per the selected scenario
- Random distribution of MS's for each BS
- Path loss calculation between each MS and the BS - Gain Matrix Calculation
- Power control iterations to attain the desired quality
- Statistics collection for the individual systems

The power control used in these simulations is SIR based power control. Perfect power control is assumed, i.e., PC error is assumed equal to 0%, and PC delay assumed to be 0 s.

The outage criteria used in these simulations is the amount of satisfied users. MSs whose SIR at the end of snapshot is lower than the target are considered to be in outage and MSs whose SIR is higher (or equal) than the target are considered to be satisfied users. The relative difference in satisfied rate is based on differences between the satisfied rate determined under ideal condition (isolated system) and non-ideal condition (interfere in the adjacent band). The TDD/TDD Pico-Pico system scenario will be introduced in the following subsection.

#### 3.1.1 System Scenario TDD Pico-TDD Pico

The scenarios for this study is such that there are two TDD indoors systems operating inside the building. The indoor models are adopted from [3].

Figure 8, represents the cell deployment used in the indoor environment simulations. This deployment scenario describes conditions relevant to the operation of a UMTS system that might be found in the indoor office test environment [3]. For this indoor deployment scenario a model office environment has been specified that consists of a large office building with an open floor plan layout. Office cubicles are separated by moveable partitions. These partitions create a large degree in signal variation as is born out in the lognormal standard deviation. In this scenario, users in elevators and stairwells are not considered though realistically they would have to be accounted for. The specific assumptions about the indoor physical deployment environment are summarized in Table 1 below.

Table1: Indoor Office deployment model physical environment [3]

Area per floor (m <sup>2</sup> )	5000
Number of floors	3
Room dimension	10 x 10 x 3 m (room) 100 x 5 x 3 m (corridor)
Log-Normal Standard Deviation (dB)	12

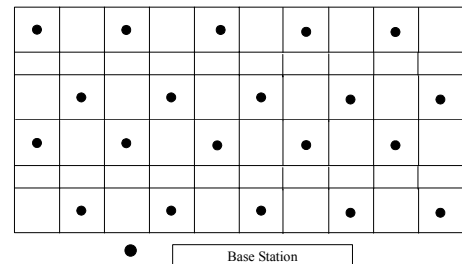


Figure 8: Indoor Deployment Model

The Base Station of the two TDD indoor operators are placed in various configurations ( as the case may be) viz. "Cosited", "Non-Cosited Corner" and "Non-Cosited Different Rooms". Figure 9-Figure 11 describe these configurations.

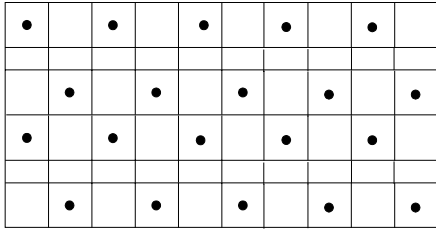


Figure 9: Co-sited Model

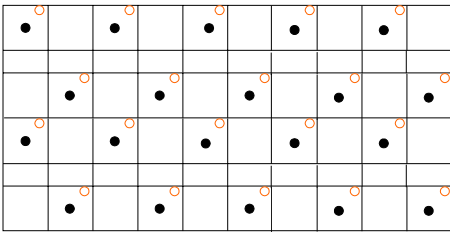


Figure 10: Non-Co-sited Corner

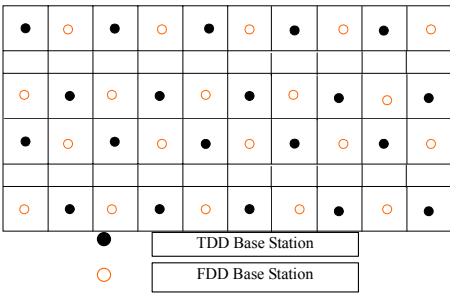


Figure 11: Non-Co-sited Different Rooms

### 3.1.2 Propagation Models

The propagation model used is indoor path loss model obtained from [3]. The indoor path loss model is represented in Equation 3.

$$L = 37 + 30\log_{10}(r) + 18.3n^{((n+2)/(n+1)-0.46)} \quad (3)$$

where  $r$  is the transmitter-receiver separation in meters and  $n$  is the number of floors in the path.

This same propagation model is valid in all directions (MS-MS, MS-BS, BS-BS) in indoor environment. Based on this propagation model, the coupling loss table for different configurations described in Figure 9-11 can be derived.

Table 2: Minimum Coupling Loss

Scenario/Coupling Loss	MCL (dB)
Cosited	37dB
Not-Cosited	62.4dB

Corner	
Not-Cosited	67dB
Different rooms	

## 4 INTERFERENCE IMPACTS TO SYSTEM PERFORMANCE

### 4.1 Simulation Parameters

Main system parameters used with TDD/FDD coexistence simulations are shown in Table 2. Radio parameters are selected according to 3GPP specs [4,5].

Table 3: Simulation Parameters

Parameter	TDD UL	TDD DL
Service parameters		
Bit rate (speech)	8kbps	8kbps
Eb/No target [dB]	3.7	6.1
Processing gain [dB]	13.9	13.9
SIR target [dB]	-10.2	-7.8
Radio parameters		
Max Tx power [dBm]	21	33
Power cntrl. range [dB]	65	30
Frequency [MHz]	1920	1920
ACS [dB]	45 (BS)	33 (MS)
ACLR [dB]	33 (MS)	45 (BS)
Other parameters		
Radio environment	pico	pico
BS MUD	off	-
Channel orthogonality	non-	0.06

### 4.2 Simulation Results for Isolated TDD System

In this section, the performance of the single TDD system is investigated. Figure 12 indicates the impact on "TDD UL Satisfied Rate" as a function of load for various instances of UE Tx power. This figure depicts uplink capacity per slot.

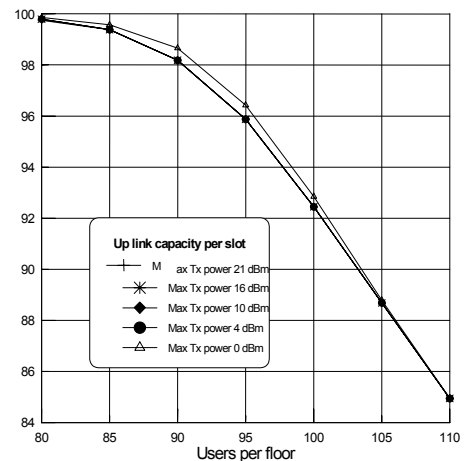


Figure 12: Uplink Satisfied Rate for TDD Single operator (X Axis: Users per floor; Y-Axis: Satisfied Capacity)

$$\text{Average users per BS/Slot} = \frac{\text{Number of users per floor}}{\text{Number of BS's per floor}}$$

Figure 13 indicates the impact on "TDD DL Satisfied Rate" as a function of load for various instances of BS Tx power.

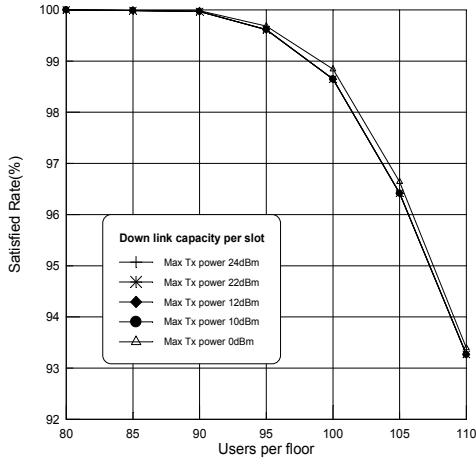


Figure 13: Downlink Satisfied Rate for TDD Single operator

From Figure 12, Figure 13 and equation 4 it can be concluded that the average number of users/BS /time slot for UL and DL are 4.8 and 5.3 respectively in this case. Also it can be concluded that in a single operator case low TDD BS and TDD UE power (~0-4dBm) are adequate. Reducing the BS and UE powers further below 0dBm resulted in severe capacity losses. Further, the number of Base Stations per floor was varied and impact on average number of satisfied users/BS /time slot was investigated. Table 4 lists the satisfied users /BS/slot for UL and DL @ 95% satisfied rate.

Table 4: Impact of increasing number of BS's in TDD systems on system capacity

Number of BS's per floor	UL satisfied users/BS/slot	DL satisfied users/BS/slot
1	9.3	25.8
6	6.2	9.4
20	4.8	5.3

From Table 4 it is quite evident that intra system interference increases as the number of the BS increases and hence the number of the satisfied users decreases.

#### 4.3 Simulation Results with Two TDD Systems Operating in Indoor Environment

In this section the interaction of two TDD system is studied based on the "degree of synchronization" described in equation 2.

##### 3.1.1 Cosited Configuration

Table 5: Impact of synchronization on system capacity

Degree of Synchronization " $\alpha$ "	UL satisfied users/BS/slot	DL satisfied users/BS/slot
0.0	4.8	5.3
0.5	4.5	5.3
0.9	4.25	5.3

0.0	4.8	5.3
0.5	4.5	5.3
0.9	4.25	5.3

##### 3.1.2 Non-Cosited, Corner Configuration

If the Base Stations of the two TDD operators are located as described in Figure 10 then the number of satisfied users/Base Station/Time slot @ 95% satisfied rate in for different " degrees of synchronization" are illustrated in Table 6.

Table 6: Impact of synchronization on system capacity

Degree of Synchronization " $\alpha$ "	UL satisfied users/BS/slot	DL satisfied users/BS/slot
0.0	4.6	5.0
0.5	4.5	5.0
0.9	4.4	5.0

##### 3.1.3 Non-Cosited Different room Configuration

If the Base Stations of the two TDD operators are located as described in Figure 11 then the number of satisfied users/Base Station/Time slot @ 95% satisfied rate in for different " degrees of synchronization" are illustrated in Table 7.

Table 7: Impact of synchronization on system capacity

Degree of Synchronization " $\alpha$ "	UL satisfied users/BS/slot	DL satisfied users/BS/slot
0.0	4.8	5.3
0.5	4.8	5.3
0.9	4.75	5.3

## 5 REMARKS AND CONCLUSIONS

Comparing Table 4 (20 BS's case) with Table 5-Table 7 the reduction in satisfied rate due to interoperator interference for various degrees of synchronzation can be concluded. This is illustrated in Table 8.

Table 8 depicts that a synchronization offset of one-time slot results in severe capacity losses (~11%) for TDD UL if the two systems are co-sited.

Table 8 : Impact on TDD systems in terms of decrease in satisfied rate due adjacent channel interference

Interferer/Victim TDD/TDD	Reduction in Satisfied Rate (%) UL		Reduction in Satisfied Rate (%) DL	
	$\alpha=0.0$	$\alpha=0.9$	$\alpha=0.0$	$\alpha=0.9$
Co -sited	<1	<11	<1	<1
Non-Cosited-Corner	<4	<8	<6	<6
Non-Cosited -Different Rooms	<1	<1	<1	<1

It should be noted that in Non-Co-sited -Corner configuration the capacity losses mostly originate from near and far effects as in this scenario the BS of one operator is located at the cell edge.

It is quite evident that if the BS-BS coupling loss between the two operators Base Stations is maintained  $\geq 70$  dB then the problems arising due to adjacent channel interference can be avoided.

However, these capacity losses can be mitigated by network planning techniques, RRM and Frame Synchronisation.

Hence the following can be concluded:

-If base stations are co-sited they must be synchronized and approximately the same asymmetry must be used.

-If synchronization is not possible, in indoors about 70 dB for coupling loss (3-13 m) between BSs is needed for satisfactory performance;

-in practice two unsynchronized operator can build full coverage to the same area.

With larger carrier separations (e.g. 10 MHz) adjacent channel interference will reduce due to larger ACLR and receiver selectivity. Further studies are ongoing to verify that TDD/TDD coexistence in adjacent frequency bands is feasible with other possible system deployments.

## REFERENCES

- [1] <http://www.3GPP.org>
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