TD-LTE and WiMAX
coexistence and migration

White paper
Innovation is happening right now at Nokia.

Many of the innovations from previous years described in this document are still relevant today and have been developed to support the optimization of mobile broadband networks and services.

Looking ahead, Nokia will continue to focus on innovation and we will be updating this document to reflect the latest developments.
Introduction

One important question on a lot of operator minds is: How to deploy TD-LTE next to WiMAX and then migrate WiMAX to TD-LTE?

The answer to this question is as varied as the many different operator business models. The one constant, however, is that interference mitigation can be very costly and involve a complex set of issues. If not properly addressed, interference can wreak havoc on a network resulting in smaller bits of useable spectrum, less capacity to handle heavy data usage and subscriber growth, and ultimately dissatisfied customers. In this increasingly competitive marketplace where the cost of acquiring spectrum is a major debt burden that operators may carry for years, it is crucial to resolve interference issues quickly and optimize network performance right from the start.

In this white paper, we discuss the interference scenarios between a WiMAX system and a TD-LTE system in adjacent spectrum blocks, recommendations and specific solutions for WiMAX/TD-LTE coexistence.

Interference scenarios in WiMAX-TD-LTE coexistence

When WiMAX and TD-LTE are deployed in adjacent spectrum blocks, several interference scenarios could occur. Please see Figure 1.

![Potential interference scenarios for WiMAX and TD-LTE coexistence](image)

Figure 1: Potential interference scenarios for WiMAX and TD-LTE coexistence

However, the severity of the interference will depend on overlap of the WiMAX DL/UL frame with the TD-LTE DL/UL frame as shown in Figure 2.

Among these different interference scenarios, it is noted that the BTS-to-BTS and UE-to-UE interference are typically the most problematic interference scenarios. This is mainly because the BTS-to-BTS interference could impact the performance of the whole sector. BTS-to-BTS interference can be mitigated to some extent by using filters with sharp roll-off characteristics.

For the UE-to-UE worst case interference scenario, the interfering UE could be transmitting at a high power in close proximity to the victim UE which is itself receiving a poor desired signal from its own BTS – causing very unpleasant user experience. Such scenarios could occur in areas where users congregate such as in a conference room, an airport, or a stadium.
For UEs, the transition bands of filters tend to be much wider which requires large guard bands to protect the worst case UE-to-UE interference scenarios mentioned above. However, UE-to-UE interference is probabilistic in nature and depends on many factors including transmit power and distance between UEs. So, protecting against worst case UE-to-UE interference scenarios could result in some aggressive guard band requirements as discussed in the next section.

The BTS-to-UE and UE-to-BTS interference are typically less severe and could be mitigated by co-locating the BTS of the two systems.

For detailed UE-to-UE interference analysis, please refer to Appendix A.

![Diagram](image)

**Figure 2:** WiMAX/TD-LTE coexistence as a function of DL/UL overlaps of the two systems

**Recommendations for unsynchronized / non-aligned DL/UL splits for WiMAX/TD-LTE coexistence**

Our recommendations for unsynchronized/non-aligned DL/UL splits for WiMAX/ TD-LTE systems are as follows:

**BTS to UE and UE to BTS interference**
- Usually analyzed by Monte Carlo simulation and expected to be less critical than BTS-to-BTS and UE-to-UE based interference.
- Could be mitigated by co-locating the BTS of the two systems.

**BTS to BTS interference**
- Deterministic de-sense analysis is usually used for BTS-to-BTS interference analysis.
- Very selective filter providing stringent transmit out-of-band emission of -45dBm/1MHz EIRP allows protection for co-located BTS deployments with 50dB antenna port to antenna port isolation or non- co-located BTSs with 100m separation distance. If coexistence under more severe conditions is expected, then other solutions would need to be explored.
• Receiver blocking could be an issue if based on current 3GPP blocking specification. Actual product performance could be better. Very selective filter would be needed on receive. In the case of TD-LTE, the transmit and receive filters are the same.

• Potentially, at least a 5MHz guard band is needed to meet the stringent transmit emission and receiver blocking requirements for coexistence.

• Operator coordination/agreement and good site planning is encouraged.

**UE to UE interference**

• Is a probability function depending on:
  - Channel bandwidth and band plan.
  - Geographical separation between UEs.
  - UE transmit power.
  - Maximum transmit power is worst case.
  - Average or 95% CDF taking into account power control might be more realistic.
  - UE receive characteristics.
  - Interference criteria (stringent vs. less stringent).
  - 1dB increase in noise floor as strict criterion.
  - More relaxed 3dB increase in noise floor can also be used.

• Could happen when the interfering UE is very close to the victim UE in a high user density area where the physical separation to provide enough isolation is very limited.

• Worst case protection with the interfering UE transmitting at maximum power and within 1m of victim UE which is itself receiving a poor signal would require >10MHz guard band if we rely only on the UE filter to mitigate the interference. This corresponds to the transition band of the UE filter which takes into account temperature and other variations.

• If less stringent interference criteria are allowed, i.e. operators are willing to accept a higher level of interference, then 5MHz of guard band could be needed (similar to what is needed to mitigate interference between BTS) based on a 3dB de-sense criterion, 5m separation and lower transmit power due to power control.

• Network control solution to further reduce out-of-band emission for coexistence with at least 5MHz guard band is also possible. This measure takes advantage of the fact that a TD-LTE UE out-of-band emission is a function of the number and location of the resource blocks within the channel and the power.
  - Schedule high power users away from channel border.
  - Restrict the transmit power, sub-carrier allocation for users assigned in the region close to the channel border.
  - PUCCH solutions needed.
  - Requires action in 3GPP.
  - WiMAX solutions to be explored.
• Explore other potential advanced interference cancelation schemes.
• Explore alternate wireless topology solutions (e.g. indoor pico-cells).

Specific solution for WiMAX/TD-LTE coexistence: Synchronizing and aligning DL/UL splits

The previous section addresses the case where WiMAX and TD-LTE are not synchronized and have different DL/UL splits. In that case, at least 5MHz of guard band along with selective BTS filters, smart scheduling, restriction on resource blocks and site engineering measures are potentially needed to mitigate the critical BTS-to-BTS and UE-to-UE interference. Therefore, to reduce or even eliminate the need for these costly measures, one potential solution would consist of:

• Frame synchronization and aligning DL/UL splits to eliminate the BTS-to-BTS and UE-to-UE problem (e.g. via GPS).
• Co-location of WiMAX and TD-LTE BTSs to avoid the classic BTS/UE near-far problems.

However, this solution implies the use of specific DL/UL splits in the WiMAX and TD-LTE systems which are not always possible because of the impact to the business plans of the operators and the services they want to provide (e.g. a broadcast system would be mostly downlink and hard to align with a system that has a 50:50 DL/UL splits for example). If it is the same operator controlling both systems, as in the case of a WiMAX to TD-LTE migration scenario, then it would be easier to synchronize and align the DL/UL splits of both systems. The operators need to evaluate if such measures are reasonable and outweigh the impact of BTS-to-BTS and UE-to-UE interference on their system performance and the additional costs needed to mitigate the interference.

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<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
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<td>5ms</td>
<td>D</td>
<td>S</td>
<td>U</td>
<td>U</td>
<td>U</td>
<td>D</td>
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<td>3</td>
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<td>S</td>
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**Figure 3:** TD-LTE sub-frame configurations

In order to time-align TD-LTE with WiMAX, the TD-LTE system must use a similar 5ms switching period as well as a similar downlink and uplink transmission period.

Referring to Figure 3, TD-LTE supports four configurations with a 5ms switching period, configuration 0, 1, 2 and 6. Of these, only the first three have identical downlink/ uplink
transmission sequences in the first 5 and second 5 sub-frames of the 10ms TD-LTE frame. The identical transmissions are necessary to make the 10ms TD-LTE frame compatible with the 5ms WiMAX frame.

**Synchronizing with a WiMAX 29:18 frame configuration**

TD-LTE frame configuration 1 has similar transmission periods to the typical WiMAX DL: UL ratio of 29:18. Figure 4 illustrates the compatible TD-LTE and WiMAX frame structures. For illustration purposes, special sub-frame format 4 is used to provide an approximate match to the WiMAX 29:18 frame with only a 2% overlap between BTS and MS transmission periods. Note that the TD-LTE radio frame starts 1ms later than the WiMAX frame.

Note that while special sub-frame format 4 is used for illustration purposes, other special sub-frame format configurations like 7 or 5 can also be allowed to align with the WiMAX frame.

Two options may be employed to eliminate the remaining overlap in downlink transmission period of WiMAX and the uplink transmission period of TD-LTE:

- WiMAX downlink symbols may be dropped to eliminate the overlap. If the WiMAX downlink period is reduced by 2 symbols there will be no overlap between the WiMAX downlink and TD-LTE uplink. WiMAX would then be 27 DL:18 UL instead of 29 DL:18 UL. This results in a maximum throughput reduction of 7% (=2/29) to the WiMAX downlink with no loss to the TD-LTE system.

- TD-LTE UpPTS may be dropped to eliminate the overlap. This results in no degradation to the downlink or uplink data throughput to WiMAX. Dropping of the UpPTS reduces the TD-LTE SRS and PRACH resources and hence there is minimal impact to the throughput.

**Figure 4:** Compatibility of TD-LTE and 29:18 WiMAX sub-frames

**Synchronizing with a WiMAX 35:12 frame configuration**

TD-LTE frame configuration 2 has downlink/uplink transmission periods that are similar to the 35:12 WiMAX frame structure. Figure 5 illustrates the compatible TD-LTE and WiMAX frame structures. TD-LTE special sub-frame format configurations 5 and 6 are both fully compatible with the 35:12 WiMAX frame structure, and support a cell radius of at least 15km (assuming WiMAX and TD-LTE co-location). Due to significant overlap between TD-LTE downlink transmission and WiMAX uplink when using special sub-frame formats 4 or 7, these special sub-frame format configurations are not compatible with a 35:12 WiMAX frame. Also note that the TD-LTE radio frame starts 2ms later than the WiMAX frame for this TD-LTE configuration.
Figure 5: Compatibility of TD-LTE and 35:12 WiMAX sub-frames

Summary

TD-LTE and WiMAX coexistence requires study of various interference scenarios. Nokia offers a high-level set of recommendations and solutions. These recommendations can help operators increase capacity, reduce churn and ultimately realize higher margins from delighted customers anxious to take advantage of the exciting new benefits of 4G.

At Nokia Networks, we offer the technology, the knowledge and the experience to help operator and spectrum owners take immediate advantage of the escalating demand for mobile broadband data service and applications.

If you have questions about the coexistence of WiMAX and TD-LTE talk with your Nokia representative.

Abbreviations

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
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<tr>
<td>BTS</td>
<td>Base station</td>
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<tr>
<td>CDF</td>
<td>Cumulative Distribution Function</td>
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<tr>
<td>DL</td>
<td>Downlink</td>
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<tr>
<td>DwPTS</td>
<td>Downlink Pilot Time Slot</td>
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<tr>
<td>FDD</td>
<td>Frequency Division Duplexing</td>
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<tr>
<td>PRACH</td>
<td>Physical Random Access Channel</td>
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<tr>
<td>PUCCH</td>
<td>Physical Uplink Control Channel</td>
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<tr>
<td>SRS</td>
<td>Sounding Reference Signals</td>
</tr>
<tr>
<td>TDD</td>
<td>Time Division Duplexing</td>
</tr>
<tr>
<td>UE</td>
<td>User Equipment</td>
</tr>
<tr>
<td>UL</td>
<td>Uplink</td>
</tr>
<tr>
<td>UpPTS</td>
<td>Uplink Pilot Time Slot</td>
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</table>
Appendix A: Detailed UE-to-UE interference analysis

The deterministic worst case methodology for UE-to-UE interference analysis with most conservative model can be represented as:

- The interfering UE is assumed to operate at maximum transmit power
- The probability factor that the two mobiles do not come in close proximity of each other.

As a result of such worst case assumptions, the amount of guard band required for harmonious coexistence based on the deterministic methodology can be quite prohibitive. In reality, power control is usually in effect so that the mobile scales down its transmit power due to its channel conditions and there is a chance of probability that two UEs come into close distance to cause interference.

On the other hand, there have been some practices to evaluate the UE-to-UE interference using the traditional Monte Carlo simulation assuming uniform user distribution within a cell. These studies often give more optimistic results as the probability of two UEs coming close to each other under the uniform distribution assumption is very low, resulting in often negligible performance degradation in terms of capacity loss. In addition, this approach does not take into account some real concerns of the operators – the "hot-spot" phenomenon, i.e. high user density areas such as a coffee shop or a sports stadium.

One potential way forward is to develop a more accurate statistical modelling for evaluating the UE-to-UE interference under Monte Carlo simulation. Some of our previous studies have developed a hotspot based Monte Carlo simulation with non-uniform user distribution to address these issues and try to strike a balance between the deterministic worst case analysis and Monte Carlo simulation with uniform user distribution. Inputs from operators are needed to better characterize these high user density spots.