Introduction to Shortened TTI And Processing Time for LTE

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Background
**TTI in LTE**

- Short for **Transmission Time Interval**

- But it can mean different things, e.g., TTI for PBCH is 40 ms

- Here it refers to the smallest scheduling unit in the time domain
  - One subframe $\leftrightarrow$ 1 ms
• Like TTI, it does not have a precise definition

• Here it refers to the standardized time delay for UE/eNB to report HARQ-A/N for DL/UL data transmissions
  • FDD: 4m
  • TDD: defined in a table
Motivation to Reduce Latency

- Reduce packet data latency
  - Directly affect perceived responsiveness; video conferencing/driving/real-time gaming/VR
  - Indirectly determine throughput
  - Improve resource efficiency
  - Improve error rate given delay requirement
  - Lower buffer requirement

- Advancements in hardware and processing capability
Reduce Latency by Shortening TTI

- Directly shorten the time unit for data scheduling
- Has various impacts on the physical control channel (PDCCH) and physical data channel (PDSCH)
Reduce Latency by Shortening Processing Time

- Reduce latency for normal TTI too
- Easier to multiplex with legacy UEs’ data
Don’t We Already Have A Shorter Processing Time?

• For the actual time spent on processing data, yes

• But the catch is that UE can’t just report HARQ-A/N to or received from eNB earlier even if the HARQ-A/N is ready
HARQ Timeline in LTE

• This allows both sides to agree on a schedule (where to expect data, where to expect HARQ-A/N)
  • Lower complexity, facilitate resource scheduling

• Also affects the soft buffer management at the UE side
Design Considerations
So, Just Shorten The TTI?

- Might not be that straightforward because
  - Boundary alignment
  - Control channel (PDCCH)
  - HARQ timing does not proportionally scale
  - Limited UE tx power (UL coverage)
  - Increased overhead of control signals
Boundary Alignment

• For ease of scheduling and multiplexing with legacy UE data, aligning sTTI at subframe boundary is desirable

• Can sTTI length change within a subframe?
  • More flexibility
  • Higher complexity/signaling overhead
PDCCH in LTE

- Inform UE there is a DL data scheduled for it and where/how to receive the data

- For efficiency, PDCCH is designed in a somewhat convoluted way
  - Variable length
  - Blind decoding
  - E-PDCCH
sPDCCH for sTTI

- Reuse PDCCH for sTTI?
- Contradicts the intention to have a lower latency (more granular scheduling decision)
- A new (shortened) PDCCH has to be designed and placed within each sTTI
sPDCCH for sTTI

- Span how many symbols?
  - Unified or separate design for different sTTI lengths?
- Same number of blind decoding in every sPDCCH?
- Can the first sTTI be scheduled by the legacy PDCCH?
HARQ Timing

• HARQ timing is 4 ms in legacy LTE systems

• Processing capability
  • Its advancement is what motivated this feature

• Timing advance
  • Determined by the supported cell size
HARQ Timing

- TA is determined by distance (cell size), and does not scale with the length of TTI.
Asymmetric DL/UL sTTI

- UL coverage is limited by UE tx power
  - TTI bundling is supported in LTE

- Allow combinations of a longer UL sTTI than DL sTTI?
  - Complicates system design and HARQ
Multi-layer Transmission

- 8-layer MIMO transmission is supported in LTE-A
  - Extra control information
  - More reference signal (RS)

- The added control information and RS overhead eats into the available time frequency resource for data transmission
Specification
sTTI Arrangement

- No sTTI spans over subframe boundary

- Support DL/UL sTTI combinations
  \{2,2\} {7,7} {2,7}
sPDCCH

- Configurable bandwidth
- 1~2 OFDM symbols (configurable) in each sTTI
- sDCI2 is still under discussion
HARQ Timing

• For DL/UL sTTI 7 OFDM symbols, n+4 assuming a max TA of 0.33 ms is supported

• For DL/UL sTTI 2 OFDM symbols, support
  • n+6 assuming a maximum TA of 0.33 ms
  • n+4 assuming a maximum TA of 0.067 ms

• For 1 ms TTI, n+3 assuming a maximum TA of 0.33 ms is supported
Multi-layer Transmission

- 4-layer MIMO transmission with single codeword is supported for sTTI 2 OFDM symbols
- 4-layer MIMO transmission with single codeword is supported for sTTI 7 OFDM symbols
Concluding Remarks

• Packet data latency, along with data rate, are the most important performance metrics

• Before 3GPP Rel-14, enhancements on LTE/LTE-A systems are mostly on increasing data rates (300 Mbps -> 4 Gbps -> 25 Gbps)

• Support of sTTI can potentially reduce latency to around $1/7^{th}$
  The specification of sTTI is still in progress.

• The support of different TTI values is also more aligned with the design principle of 5G NR systems.
thank you
References

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