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Analysis of Stakeholder Comment Regarding Loading and Overhead assumptions

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Overview: Loading and Overheads

- This study considers the following points raised by a stakeholder on Ofcom's modelling assumptions for LTE network loading and overheads
  a) Is 85% cell loading too high to give a decent user experience?
  b) Is 20% an appropriate level of overhead, especially given the number of symbols needed in PDCCH in heavily loaded cells?
- Study Overview:
  a) Explanation of issues:
     - How does loading relate to user experience? Need to explain that latency is related to loading, but impact depends entirely on burstiness of traffic and the tolerance of the user/application to the latency
     - Where do overheads come from and how do they vary?
  b) Look at sources of calculation of overhead from the open literature and previous Real Wireless studies.
  c) Look at how other studies treat loading levels, including 3GPP, books, papers and vendor presentations.
  d) Draw conclusions

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Stakeholder comments on loading and overheads

- A stakeholder questions whether 85% loading is suitable for evaluation of a coverage obligation and states that 20% loading has been agreed elsewhere and in previous studies
  - Initial analysis: There is a difference between the maximum number of Resource Blocks (RBs) assigned to a user in a cell (cell load) and the proportion of cells in the network simultaneously active (network load). It is reasonable to assume in a lightly loaded network (20% network load), that 1 in 4 cells has an active user, and in that cell most resource blocks are utilised serving a user (85% cell load).
  - Therefore the 85% cell load used is in line with what we understand to be a 20% network load suggested by the respondent. The issue behind this comment may therefore be that it needs to be more clearly stated that 85% is a cell load and this leads to a 20% network load.
  - We also understand (since completing this study) that the specific reference was made in the context of the coverage obligation rather than the competition assessment.
- A stakeholder questions the assumption of a 20% overhead, given that at high loads 3 symbols of PDCCH would result in a 30% overhead
  - Initial analysis: One element of overhead is the number of symbols of PDCCH (Physical Downlink Control Channel) per 14 symbol subframe, which can between L=1 and L=3 symbols
  - The number of PDCCH symbols relates to signalling load and number of connections, not necessarily the same as traffic load

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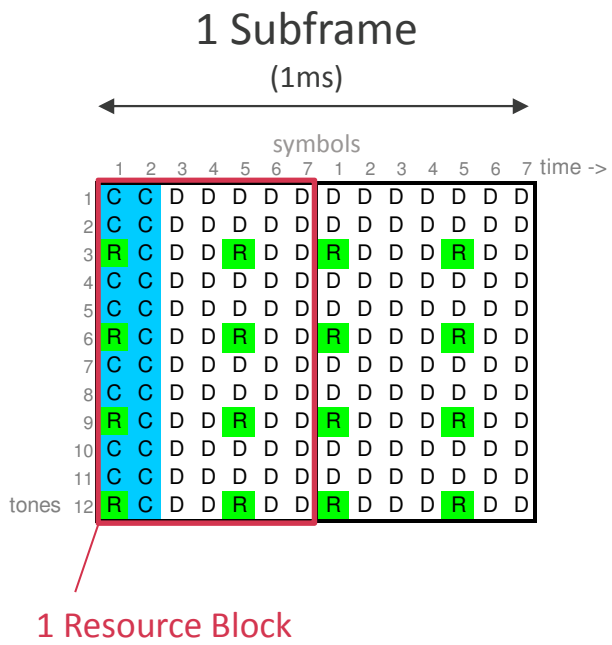
Data and Control Loading are independent



Key Types of Resource Element on the Downlink:

D — PDSCH = Data. Relates to traffic demands of user(s). Ofcom assumed 85% of RBs are used for this and control channels.

C — PDCCH = Control. L=1,2 or 3 symbols. Related to number of active connections. Ofcom assumed a 'mid' case L=2.

R — Reference signals for demodulation. Related to number of transmit antennas (MIMO Layers). 2 transmit antennas assumed by Ofcom.

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Resource Element Mapping and Overheads

2tx DL, L=2 Symbols of PDCCH

tones	1	2	3	4	5	6	7	1	2	3	4	5	6	7 time ->
1	C	C	D	D	D	D	D	D	D	D	D	D	D	D
2	C	C	D	D	D	D	D	D	D	D	D	D	D	D
3	R	C	D	D	R	D	D	R	D	D	D	R	D	D
4	C	C	D	D	D	D	D	D	D	D	D	D	D	D
5	C	C	D	D	D	D	D	D	D	D	D	D	D	D
6	R	C	D	D	R	D	D	R	D	D	D	R	D	D
7	C	C	D	D	D	D	D	D	D	D	D	D	D	D
8	C	C	D	D	D	D	D	D	D	D	D	D	D	D
9	R	C	D	D	R	D	D	R	D	D	D	R	D	D
10	C	C	D	D	D	D	D	D	D	D	D	D	D	D
11	C	C	D	D	D	D	D	D	D	D	D	D	D	D
12	R	C	D	D	R	D	D	R	D	D	D	R	D	D

															totals			
RSs	R	4	0	0	0	4	0	0	4	0	0	0	4	0	0	16	9.5%	} 21.4%
Control	C	8	12	0	0	0	0	0	0	0	0	0	0	0	0	20	11.9%	
Data	D	0	0	12	12	8	12	12	8	12	12	12	8	12	12	132	78.6%	
																168		

Shows 2 resource blocks comprising many resource elements:

R = Reference Signals for OFDM demodulation
C = PDCCH L1/L2 Control
D = PDSCH (Data Traffic)

2tx DL, L=3 Symbols of PDCCH

tones	1	2	3	4	5	6	7	1	2	3	4	5	6	7 time ->
1	C	C	C	D	D	D	D	D	D	D	D	D	D	D
2	C	C	C	D	D	D	D	D	D	D	D	D	D	D
3	R	C	C	D	R	D	D	R	D	D	D	R	D	D
4	C	C	C	D	D	D	D	D	D	D	D	D	D	D
5	C	C	C	D	D	D	D	D	D	D	D	D	D	D
6	R	C	C	D	R	D	D	R	D	D	D	R	D	D
7	C	C	C	D	D	D	D	D	D	D	D	D	D	D
8	C	C	C	D	D	D	D	D	D	D	D	D	D	D
9	R	C	C	D	R	D	D	R	D	D	D	R	D	D
10	C	C	C	D	D	D	D	D	D	D	D	D	D	D
11	C	C	C	D	D	D	D	D	D	D	D	D	D	D
12	R	C	C	D	R	D	D	R	D	D	D	R	D	D

															totals			
RSs	R	4	0	0	0	4	0	0	4	0	0	0	4	0	0	16	9.5%	} 28.6%
Control	C	8	12	12	0	0	0	0	0	0	0	0	0	0	0	32	19.0%	
Data	D	0	0	0	12	8	12	12	8	12	12	12	8	12	12	120	71.4%	
																168		

Source: TS 36.311, section 6.10.1.2 Mapping to resource elements, http://www.3gpp.org/ftp/Specs/html-info/36211.htm

- L=2 symbols of PDCCH gives 21.4% overhead per subframe. L=3 gives 28.6%
  - Primary and secondary Synchronisation channels increase the overheads to 21.8% for L=2 and 28.9% for L=3 per 10ms Radio Frame (assuming a 10MHz channel bandwidth).

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Considerations on PDCCH overhead

- 3GPP LTE Performance [1] evaluations assumed L=3:
  - "*Baseline control channel overhead in downlink spans the <u>three first OFDM symbols</u> of each sub-frame. Pilot positions in remaining OFDM symbols are to be considered in addition*". [1]
- Control channel overhead can be 1,2 or 3 symbols and scales with the number of active connections.
  - Large numbers of connections e.g. voice or M2M would likely need L=3.
  - 3GPP evaluations also assume L=3.
  - The L=2 case might represent a case with a smaller number of high data rate users.

[1] "*LTE physical layer framework for performance verification*", Orange, China Mobile, KPN, NTT DoCoMo, Sprint, T-Mobile, Vodafone, Telecom Italia, 3GPP tdoc R1-070674, February 2007.

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Ofcom Justification for Traffic Loading of 85%

- *"We assume that the user can access 85% of the resources of the serving cell (this reflects our assumption that a practical upper loading limit on any particular cell is on average approximately 85%."*
  - *'Second consultation on assessment of future mobile competition and proposals for the award of 800Mhz and 2.6GHz spectrum and related issues'*, Ofcom, 2012
- **Analysis**
  - The 85% is considered to represent 'fully' loaded and a practical upper loading limit.
  - No further justification can be found as to why this is not 100% as assumed by 3GPP(next slide).
  - A network operated at 100% load might result in delay variations due to queuing and poor QoE for users. It is assumed that 85% loading represents an operator controlled 'backoff' from fully loaded to reduce the probability of queuing for multiple users with bursty traffic profiles.
  - In the WCDMA uplink loading can be traded for stability. 3GPP simulations assume 75% loading (6dB power back off from 'pole capacity' [3GPP TR 25.942 'UMTS RF System Scenarios, v10.0.0 (2011-05)]
  - QoS mechanisms are implemented in LTE to ensure delay sensitive traffic is prioritised during congestion. However non QoS enabled users will not benefit from this and may experience some performance degradation. The appropriateness of the loading assumption depends on the importance of such degradations for such users.
  - It does not seem that the loading assumed is excessively high.

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3GPP Assume 100% of RBs can be loaded

- [1] shows that for LTE with two layer transmission, a downlink peak rate of 172.8Mbps is possible.
- This takes into account overheads for reference symbols and L1/L2 control (PDCCH)
- The analysis on the right arrives at same peak data rate if it is assumed that 100 out of 100RBs are used for PDSCH traffic (i.e. 100% loading)

[1] 'Summary of Downlink Performance Evaluation', Ericsson, 3GPP R1-072578, May 2007

tones	1	2	3	4	5	6	7	1	2	3	4	5	6	7 (time ->)
1	C	D	D	D	D	D	D	D	D	D	D	D	D	D
2	C	D	D	D	D	D	D	D	D	D	D	D	D	D
3	R	D	D	D	R	D	D	R	D	D	D	R	D	D
4	C	D	D	D	D	D	D	D	D	D	D	D	D	D
5	C	D	D	D	D	D	D	D	D	D	D	D	D	D
6	R	D	D	D	R	D	D	R	D	D	D	R	D	D
7	C	D	D	D	D	D	D	D	D	D	D	D	D	D
8	C	D	D	D	D	D	D	D	D	D	D	D	D	D
9	R	D	D	D	R	D	D	R	D	D	D	R	D	D
10	C	D	D	D	D	D	D	D	D	D	D	D	D	D
11	C	D	D	D	D	D	D	D	D	D	D	D	D	D
12	R	D	D	D	R	D	D	R	D	D	D	R	D	D

															totals		
RSs	R	4	0	0	0	4	0	0	4	0	0	0	4	0	0	16	9.5% } 14.3%
Control	C	8	0	0	0	0	0	0	0	0	0	0	0	0	0	8	4.8%
Data	D	0	12	12	12	8	12	12	8	12	12	12	8	12	12	144	85.7%
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Max bits per Resource Element	6	bits/RE
Code Rate	1	
Number of RBs for carrying Traffic	100	RBs
Subframe duration	1	ms
Parallel MIMO Steams	2	
Data bits over the air	**172.8**	**Mbits/sec**

Source: Real Wireless analysis

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3GPP Methodology in 36.942 assumes maximal loading

- 3GPP TR 36.942 defines the simulation assumptions used by 3GPP RAN4 (RF performance) for their simulations.
- This document states 'Maximal loading' shall be assumed to represent the full 24RBs in the 10MHz bandwidth configuration.
- We note from the document that this refers to the 'old' larger sized resource blocks from the study item, where there were 12, 24 and 48 RBs in total for 5, 10 and 20MHz bandwidths respectively.
- 3GPP's 'Maximal loading' represents 100% RBs used in a cell.

- Source: 3GPP TR 36.942 "*Evolved Universal Terrestrial Radio Access (E-UTRA); Radio Frequency (RF) system scenarios; (Release 8)*", 3GPP document TR 36.942 8.3.0, 2010-10-01

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Comments on Traffic loading of 85%

- One Stakeholder comment relates to a user having 85% of a cell's resources to meet coverage obligation requirements, when 20% is an agreed *network* load level for coverage analysis
  - It seems reasonable to assume that in a coverage limited network, only 1 cell in 4 has an active data transfer at any one time, and that the cell is full loaded in doing so. With 85% resources used in the active cell, the network load would be 21%
- Another comment is whether 85% represents enough 'backoff' to ensure bursty traffic profiles can be accommodated with sufficient QoE for users, or whether a lower number should be used, which may reduce data rates.
  - The 3GPP evaluation methodology (36.942) assumes 100% network load in its analysis, so if anything the Ofcom assumed 85% is cautious and higher data rates may be achievable.

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Comments on PDCCH Overhead of 20%

- The stakeholder states that the PDCCH overhead should be L=3, not L=2 symbols of PDCCH per sub frame.
- The number of PDCCH symbols relates to the number of active connections, which is not *necessarily* linked to the traffic load. For peak rate evaluations 3GPP assumed L=1 with 100% traffic load.
- A higher overhead of L=3 symbols would be representative of a large number of low rate connections such as a VoIP or M2M scenario. 3GPP spectral efficiency evaluations assume L=3.
- Ofcom's assumed L=2 does not seem unreasonable for a smaller number of higher rate users, even with high traffic loads
- Implication of scaling current L=2 results to represent L=3:
  - L=3 results in 29.5% overhead. L=2 results in 22.0%.
  - Data rates would be scaled by a factor of 0.904

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Conclusions

a) **Is 85% loading too high to give a decent user experience?**

- While there is a link between loading and user experience it is less than in 3G systems: 3GPP simulation assumptions are 75% loading for the UMTS UL, and 100% for LTE UL and DL
- 85% loading of the serving cell's resources appears reasonably consistent with 20% *network* loading assumption in the coverage obligation, since not all cells are simultaneously active
- On this basis 85% does not seem too high
- However at the time of our study the actual variation of performance with respect to loading had not been evaluated by Ofcom, and the stakeholder had not provided any specific evidence of the level of performance degradation which would be encountered.

b) **Is 20% an appropriate level of overhead, especially given number of symbols needed in PDCCH in heavily loaded cells?**

- 20% is consistent with L=2 PDCCH symbols
- If L = 3, 30% would be a more appropriate value
- The choice of L is not directly a function of loading but of the number of users, which could still be small in a heavily loaded cell.
- Nevertheless both could be relevant cases in some scenarios and a 3GPP source for LTE spectrum efficiency evaluation has assumed L=3.

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