教育部「5G行動寬頻人才培育跨校教學聯盟計畫」
5G行動網路協定與核網技術聯盟中心

課程: 5G系統層模擬技術

第十六週：效能評比準則及校準程序

國立中正大學
National Chung Cheng University

Outline

- 效能評比
  - Report ITU-R M.2412-0
    - Connection density
    - Reliability
    - Spectral efficiency
  - TR 37.910
- 校準程序
  - 校準的用意及好處
  - 校準程序、K圖
  - RP-180524
  - METIS Simulation Guidelines

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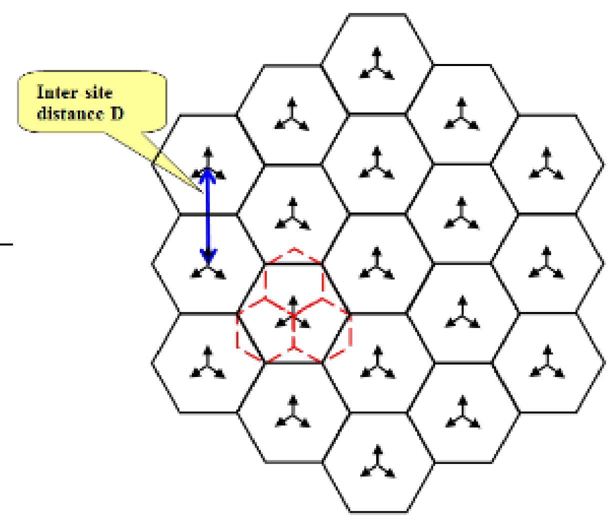
Report ITU-R M.2412-0

- [1]Guidelines for evaluation of radio interface technologies for IMT-2020
- 此文件有針對connection density、reliability、spectral efficiency、mobility，的計算流程、方式做詳細的介紹，本章節只會針對connection density、reliability、spectral efficiency做簡單的介紹，欲了解詳細的流程，請參閱ITU-R M.2412-0。

Connection density

- Connection density的定義為，每平方公里有幾個裝置可以連線
- Two evaluation methods:
  - Non-full buffer connection density
  - Full-buffer connection density
- 以下將針對Non-full buffer connection density 做介紹

5.2.4.3.9 Connection density (devices/km^2) *(4.8)*	mMTC	Urban Macro – mMTC	Uplink	1 000 000



Non-Full Buffer Connection Density

Step 1: Set system user number per TRxP as *N.*

Step 2: Generate the user packet according to the traffic model.

Step 3: Run non-full buffer system-level simulation to obtain the packet outage rate.

- outage rate: the ratio of packets that failed to be delivered to the destination receiver within a transmission delay of less than or equal to 10s to the total number of packets generated in *Step 2*.

Step 4: Change the value of *N* and repeat *Step 2-3* to obtain the system user number per TRxP *N'* satisfying the packet outage rate of 1%.

Step 5: Calculate connection density by equation $C = N' / A$

- TRxP area A = ISD^2 × sqrt(3)/6
- ISD is the inter-site distance.

- Reference:

Reliability

- *Step 1:* Run downlink or uplink full buffer system-level simulations using the evaluation parameters of Urban Macro-URLLC test environment, and collect overall statistics for downlink or uplink *SINR* values, and construct CDF over these values.
- *Step 2*: Run corresponding link-level simulations for either NLOS or LOS channel conditions, to obtain success probability, which equals to (1-*Pe*), where *Pe* is the residual packet error ratio within maximum delay time as a function of *SINR* taking into account retransmission.
- *Step 3:* The proposal fulfils the reliability requirement if at the 5th percentile downlink or uplink *SINR* value and within the required delay, the success probability derived in *Step 2* is larger than or equal to the required success probability. It is sufficient to fulfil the requirement in either downlink or uplink, using either NLOS or LOS channel conditions.

Spectral efficiency

- 因5G其中之一的賣點為高傳輸速率，且現行的頻段價格不斐，所以頻譜的使用率格外的重要，各家公司通常都以spectral efficiency，做效能的評估以及比對
- Spectral efficiency(bit/s/Hz)，為在某一時段頻段下，平均每秒每Hz能夠傳輸多少的bit
- 以下將對兩種Spectral efficiency作介紹
  1. Average spectral efficiency
  2. Cell edge spectral efficiency

Average Spectral Efficiency

- Average spectral efficiency is given by :

$$\mathrm{SE}_{avg} = \frac{\sum_{j=1}^{N_{drop}} R^{(j)}(T)}{N_{drop} * T * W * M} = \frac{\sum_{j=1}^{N_{drop}} \sum_{i=1}^{N} R_i^{(j)}(T)}{N_{drop} * T * W * M}$$

- $R_i^{(j)}(T)$ is the received bits by user i in j-th drop
- M is the number of the TRP
- W is the channel bandwidth, and T is the time

Cell Edge Spectral efficiency

- Cell edge spectral efficiency 5th percentile point of the cumulative distribution function (CDF) of the normalized user throughput.
- $r_i^{(j)}$ is the spectral efficiency of user i in drop j :

$$r_i^{(j)} = \frac{R_i^{(j)}(T)}{T_i * W}$$

- The lowest 5th percentile point of $N * N_{drop}$ is the cell edge spectral efficiency.

Spectral Efficiency評比準則

- 會影響spectral efficiency的因素有很多，包含：MCS table、天線個數、傳輸功率…，都會影響spectral efficiency，甚至連如何排程都會影響spectral efficiency。
- 因此，在與其他公司做比較之前，必須先確保各參數皆一致，才能確保比較結果的公正性

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TR 37.910(1/2)

- TR 37.910[2]提供了各家公司的參數設定及其模擬結果，包含：connection density、mobility、reliability、user data rate以及eMBB spectral efficiency
- 以eMBB_SE為例，eMBB_SE內包含了三種場景的spectral efficiency以及參數可供參考

InH - eMBB Technical configuration Parameters	Reference value	Huawei		Intel	
		NR FDD	NR TDD	NR FDD	NR TDD
Multiple access	OFDMA	Aligned with reference	Aligned with reference	Aligned with reference	Aligned with reference
Duplexing		FDD	TDD	FDD	TDD
Network synchronization	Synchronized	Aligned with reference	Aligned with reference	Aligned with reference	Aligned with reference
Modulation	Up to 256 QAM	Aligned with reference	Aligned with reference	Aligned with reference	Aligned with reference
Coding on PDSCH	LDPC Max code-block size=8448bit [with BP decoding]	Aligned with reference	Aligned with reference	Aligned with reference	Aligned with reference
Numerology	15 kHz / 30 kHz, 14 OFDM symbol slot	15 kHz SCS, 14 OFDM symbol slot	15/30 kHz SCS, 14 OFDM symbol slot	15 kHz SCS, 14 OFDM symbol slot	15 kHz SCS, 14 OFDM symbol slot
Guard band ratio on simulation bandwidth	FDD: 6.4% (for 10 MHz bandwidth) TDD: 8.2% (51 RB for 30kHz SCS and 20 MHz bandwidth) TDD: 4.6% (106 RB for 15kHz SCS and 20 MHz	Aligned with reference	Aligned with reference	Aligned with reference	Aligned with reference
Simulation bandwdith	FDD: 10 MHz TDD: 20 MHz	10 MHz	20 MHz	10 MHz	20 MHz
Frame structure		FDD: Full downlink	DDDSU	FDD: Full downlink	DSUUD
Transmission scheme	closed SU/MU-MIMO adaptation	closed SU/MU-MIMO adaptation	closed SU/MU-MIMO adaptation	closed SU/MU-MIMO adaptation	closed SU/MU-MIMO adaptation
DL CSI measurement		Non-precoded CSI-RS based	Non-precoded CSI-RS based	Non-precoded CSI-RS based	Non-precoded CSI-RS based
DL codebook		Type II codebook; 4 beams, WB+SB amplitude quantization, 8 PSK phase quantization	Type II codebook; 4 beams, WB+SB amplitude quantization, 8 PSK phase quantization	Type II codebook; 4 beams, WB+SB amplitude quantization, 8 PSK phase quantization	Type II codebook; 4 beams, WB+SB amplitude quantization, 8 PSK phase quantization
PRB bundling		4 PRBs	4 PRBs	4 PRBs	4 PRBs
MU dimension		Up to 12 layers	Up to 12 layers	Up to 12 layers	Up to 12 layers
SU dimension		For 4Rx: Up to 4 layers	For 4Rx: Up to 4 layers	For 4Rx: Up to 4 layers	For 4Rx: Up to 4 layers
Codeword (CW)-to-layer mapping	For 1~4 layers, CW1; For 5 layers or more, two CWs	Aligned with reference	Aligned with reference	Aligned with reference	Aligned with reference
SRS transmission	Companies to Report: • Precoded or non-precoded SRS transmission; • SRS switch or not for 1T4R/2T4R/1T2R • SRS bandwidth • Number of OFDM symbols within 1 slot for SRS transmission per UE	N/A	For UE 4 Tx ports: Non-precoded SRS, 4 SRS ports (with 4 SRS resources) 2 symbols per 5 slots for 30kHz SCS; 4 symbols per 5 slots for 15kHz SCS;	N/A	N/A
CSI feedback		PMI, CQI: every 5 slot; RI: every 5 slot; Subband based	CQI: every 5 slot; RI: every 5 slot, CRI: every 5 slot Subband based	PMI, CQI: every 5 slot; RI: every 5 slot; Subband based	CQI: every 5 slot; RI: every 5 slot, every 5 slot Subband based
Interference measurement		SU-CQI; CSI-IM for inter-cell interference measurement	SU-CQI; CSI-IM for inter-cell interference measurement	SU-CQI; CSI-IM for inter-cell interference measurement	SU-CQI; CSI-IM for inter-cell interference measurement
CBG	1	Aligned with reference	Aligned with reference	Aligned with reference	Aligned with reference
ACK/NACK delay		The next available UL slot	The next available UL slot	The next available UL slot	The next available UL slot

Revision comments | DL_Para_4GHz | UL_Para_4GHz | DL_Para_30GHz | UL_Para_30GHz | DL_OH_Para | UL_ ...

各公司參數設置

TR 37.910(2/2)

- InH eMBB 4GHz 12TRxP spectral efficiency

Channel model A	RIT	Antenna and TXRU mapping	Antenna config & Tx scheme	Numerology	Frame structure	Req.		Huawei	Intel	Mediatek	Motorola Mobility /	CATT	NTT DOCOMO	LGE	NEC	ITRI
	FDD															
DL Spectral efficiency	NR	gNB: (M,N,P,Mg,Ng; Mp,Np) = (4,4,2,1,1;4,4)	32x4 MU-MIMO Type II Codebook	15 kHz SCS		Average [bit/s/Hz/TRxP]	9	11.287	10.627	11.120	9.180	12.925		11.450		8.208
						5th percentile [bit/s/Hz]	0.3	0.356	0.398	0.330	0.400	0.491		0.339		0.343
	NR	gNB: (M,N,P,Mg,Ng; Mp,Np) = (4,4,2,1,1;4,4)	32x4 MU-MIMO Type I Codebook	15 kHz SCS		Average [bit/s/Hz/TRxP]	9								11.500	
						5th percentile [bit/s/Hz]	0.3								0.310	
	NR	gNB: (M,N,P,Mg,Ng; Mp,Np) = (4,4,2,1,1;4,4)	32x4 MU-MIMO Ideal CSI feedback	15 kHz SCS		Average [bit/s/Hz/TRxP]	9									
						5th percentile [bit/s/Hz]	0.3									
	NR	gNB: (M,N,P,Mg,Ng; Mp,Np) = (4,4,2,1,1;4,4)	32x8 MU-MIMO Type II Codebook	15 kHz SCS		Average [bit/s/Hz/TRxP]	9									
						5th percentile [bit/s/Hz]	0.3									

各公司模擬結果

參數設定

Requirement

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校準(Calibration)的用意及好處

- 校準是用於保持準確性的主要過程之一，有了各家公司、廠商的數據、樣本，我們可以明確的知道模擬的結果是否可靠。如果沒有經過校準的程序，就沒有個依據來證明模擬結果是正確的，也無法得知模擬結果有誤，進而對程式做修正。

校準程序、K圖

- 因各家廠商、公司，在估計(選擇)RI、MCS、PMI的策略不同，所以模擬出的spectral efficiency也會有所不同，故不會以spectral efficiency作為校準的依據。
- 通常採用coupling gain以及DL geometry來進行校準
- 校準程序：
  1. 先確保各參數皆一致
  2. 模擬出coupling gain以及DL geometry並個別劃出CDF圖
  3. 與各家廠商、公司做比較
- Coupling gain(or coupling loss): BS端的transmit power與UE端的receive power之差值
- DL geometry: Pre-processing UE DL SINR

RP-180524(1/2)

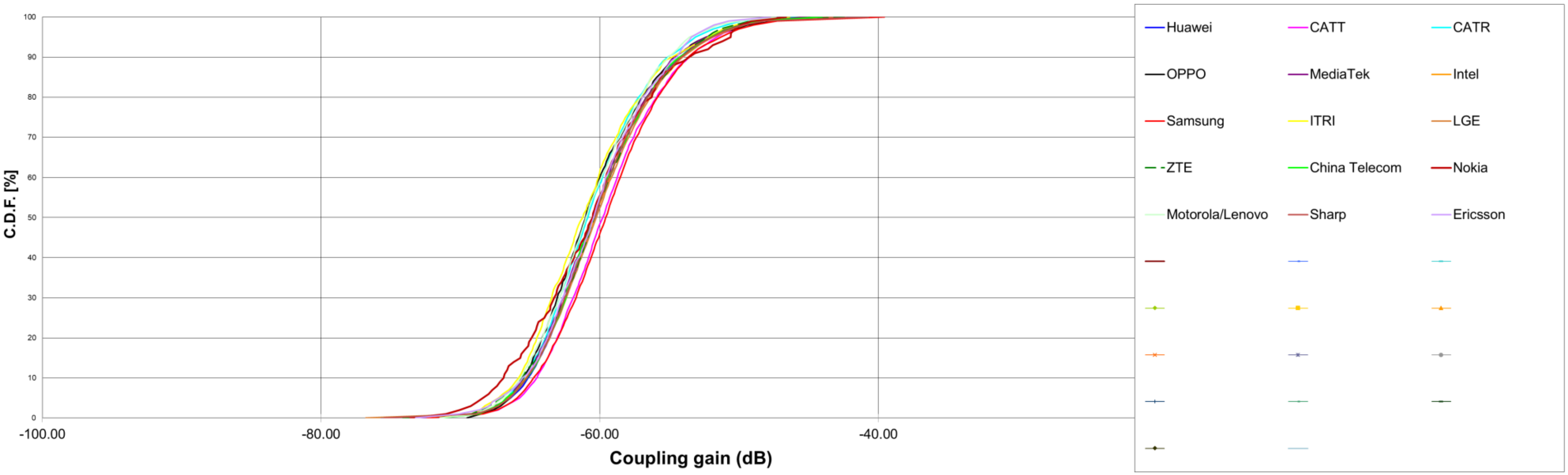
- RP-180524[3]有針對Coupling gain以及DL geometry做校準
- 包含數個場景以及其參數設定

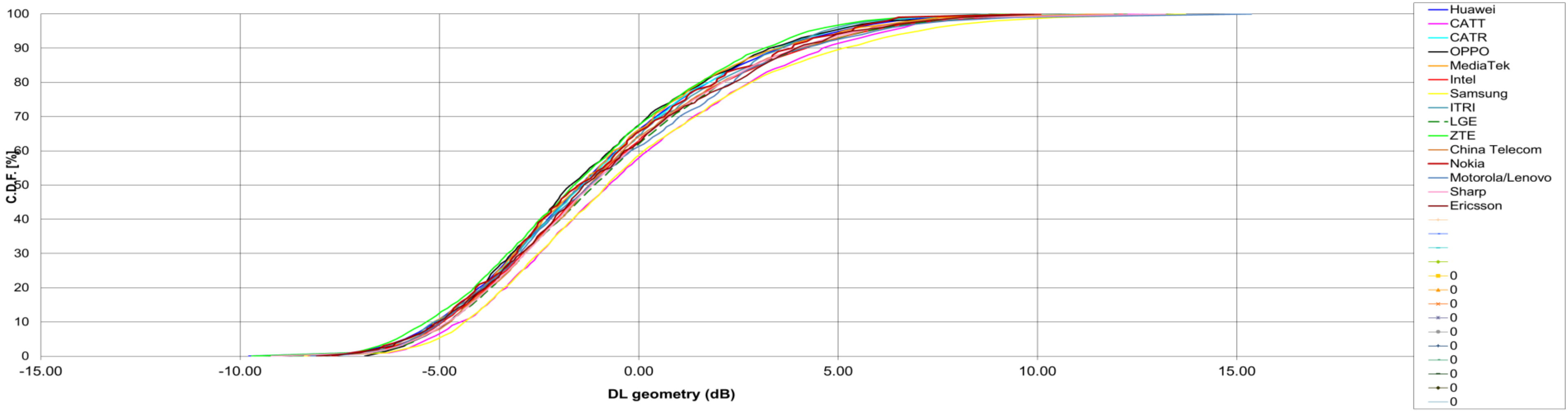
- 01.IndoorHotspot-eMBB_CouplingGain_and_DLgeometry_v18
- 02.DenseUrban-eMBB_CouplingGain_and_DLgeometry_v22
- 03 Rural-eMBB_CouplingGain_and_DLgeometry_v24
- 04.UrbanMacro-mMTC_CouplingGain_and_DLgeometry_v19
- 05.UrbanMacro-URLLC_CouplingGain_and_DLgeometry_v20

Indoor Hotspot - eMBB	Config. A	Config. B	Config. C
Carrier frequency for evaluation	4 GHz	30GHz	70GHz
BS antenna height	3 m	3 m	3 m
Total transmit power per TRxP	Baseline: 21 dBm for 10MHz bandwdith	Baseline: 20 dBm for 40 MHz bandwdith	Baseline: 18 dBm for 40 MHz bandwdith
UE power class	23 dBm	23 dBm	21 dBm
Inter-site distance	20m	20 m	20 m
Number of antenna elements per TRxP	32Tx/Rx, (M,N,P,Mg,Ng) = (4,4,2,1,1), (dH,dV) = (0.5, 0.5)λ +45°, -45° polarization	64Tx/Rx, (M,N,P,Mg,Ng) = (4,8,2,1,1), (dH,dV) = (0.5, 0.5)λ +45°, -45° polarization	256Tx/Rx, (M,N,P,Mg,Ng) = (8,16,2,1,1), (dH,dV) = (0.5, 0.5)λ +45°, -45° polarization
Number of TXRU per TRxP	32TXRU, (Mp,Np,P,Mg,Ng) = (4,4,2,1,1) (1-to-1 mapping)	8TXRU, (Mp,Np,P,Mg,Ng) =(2,2,2,1,1)	8TXRU, (Mp,Np,P,Mg,Ng)=(2,2,2,1,1)
Number of UE antenna elements	4Tx/Rx, (M,N,P,Mg,Ng) = (1,2,2,1,1), (dH,dV) = (0.5, N/A)λ 0°,90° polarization	32Tx/Rx, (M,N,P,Mg,Ng) = (2,4 ,2,1,2), (dH,dV) = (0.5, 0.5)λ (dg,V,dg,H) = (0, 0)λ. Θmg,ng=90; Ω0,1=Ω0,0+180; 0°,90° polarization	32Tx/Rx, (M,N,P,Mg,Ng) = (2,4 ,2,1,2), (dH,dV) = (0.5, 0.5)λ (dg,V,dg,H) = (0, 0)λ. Θmg,ng=90; Ω0,1=Ω0,0+180; 0°,90° polarization
Number of TXRU per UE	4TXRU, (Mp,Np,P,Mg,Ng) = (1,2,2,1,1) (1-to-1 mapping)	4TXRU, (Mp,Np,P,Mg,Ng)=(1,1,2,1,2)	4TXRU, (Mp,Np,P,Mg,Ng)=(1,1,2,1,2)
Device deployment	100% indoor Randomly and uniformly distributed over the area	100% indoor Randomly and uniformly distributed over the area	100% indoor Randomly and uniformly distributed over the area

RP-180524(2/2)

- InH_4GHz_36TRxP_ModelA





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METIS Simulation Guidelines[4]

- METIS在此文件有針對LTE的3種case做calibration，分別為：
  - Calibration case 1 - LTE with basic deployment
  - Calibration case 2 - LTE-Advanced with basic deployment
  - Calibration case 3 - LTE-Advanced with ultra-dense deployment
- 從比較簡單的case到複雜case，都提供大家一個參考的指標，其提供的結果包含：
  - Cell-spectral efficiency
  - Cell-edge user spectral efficiency
  - Cumulative distribution function of the normalized user throughput
  - Cumulative distribution function of the SINR

Calibration case 1 - LTE with basic deployment

- 模擬參數

Table 3.1: Simulated cases for calibration case 1

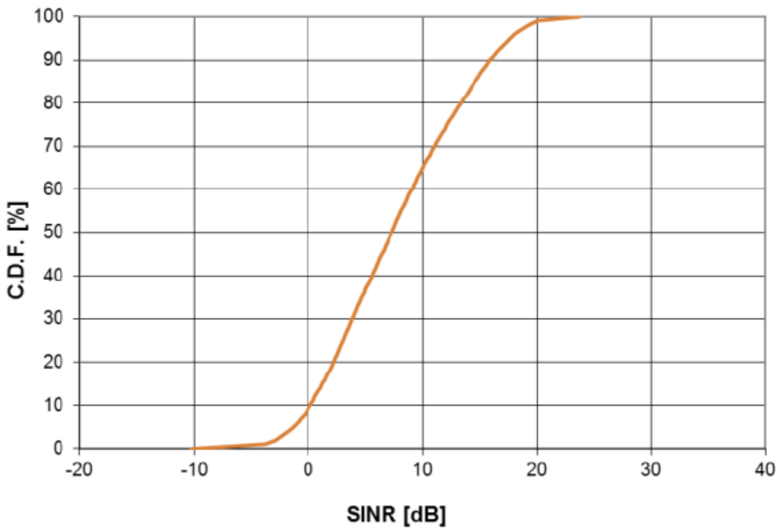
Case	Carrier [GHz]	ISD [m]	Tilt [º]	Bandwidth [MHz]
Urban micro-cell scenario	2.5	200	12	FDD:10+10

Table 3.2: Other simulation assumptions for calibration case 1

Issue	Assumption	Additional Information
MIMO	1x2	Receiver diversity
Scheduling	Round Robin	
Cell selection	1 dB HO margin	
Traffic Model	Full Buffer	
Interference Model	Explicit	
CSI feedback	Realistic	5 ms period (5 RBs) Follow standard
SINR estimation	Perfect	
Feeder loss	2 dB	
Duplex	FDD	
Links	DL	
L2S Modelling	MIESM	
Control overhead	3 OFDM symbols	
Receiver Type	MMSE	

Calibration case 1 - LTE with basic deployment

- 模擬結果



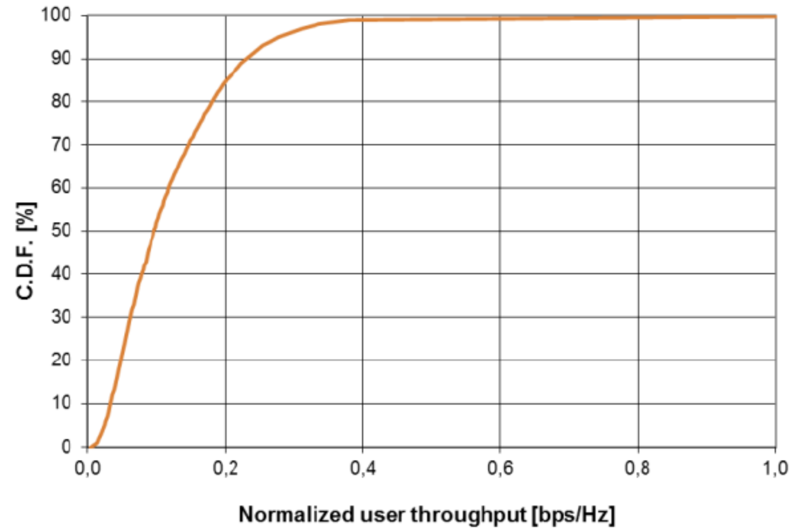


Figure 3.2: SINR and normalized user throughput distribution for calibration case 1

Table 3.3: Results obtained for the calibration case 1

Parameter	UPVLC	E///	NSN	ALUD	Nokia	Average
Cell spectral efficiency [bps/Hz/cell]	1.2077	1.1735	1.1744	1.1861	1.19525	1.187
Cell edge user spectral efficiency [bps/Hz]	0.0267	0.0231	0.0267	0.0232	0.0151	0.023

Calibration case 2 - LTE-Advanced with basic deployment

- 模擬參數

Table 3.4: Simulated cases for calibration case 2

Case	Carrier [GHz]	ISD [m]	Tilt [º]	Bandwidth [MHz]
Urban micro-cell scenario	2.5	200	12	FDD:10+10

Table 3.5: Other simulation assumptions for calibration case 2

Issue	Assumption	Additional Information
MIMO	4x2	SU-MIMO scheme
Scheduling	Proportional Fair	5 users per subframe (at most) Priority to retransmissions Weight factor = 0.001
Cell selection	1 dB HO margin	
Traffic Model	Full Buffer	Other traffic models in a second round
Interference Model	Explicit	
CSI feedback	Realistic	5 ms period (5 RBs)
SINR estimation	Perfect with synthetic error	error → lognormal 1 dB std
Feeder loss	2 dB	
Duplex	FDD	
Links	DL	
L2S Modelling	MIESM	
Control overhead	3 OFDM symbols	
Receiver Type	MMSE	With intercell interference suppression capabilities

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Calibration case 2 - LTE-Advanced with basic deployment

- 模擬結果

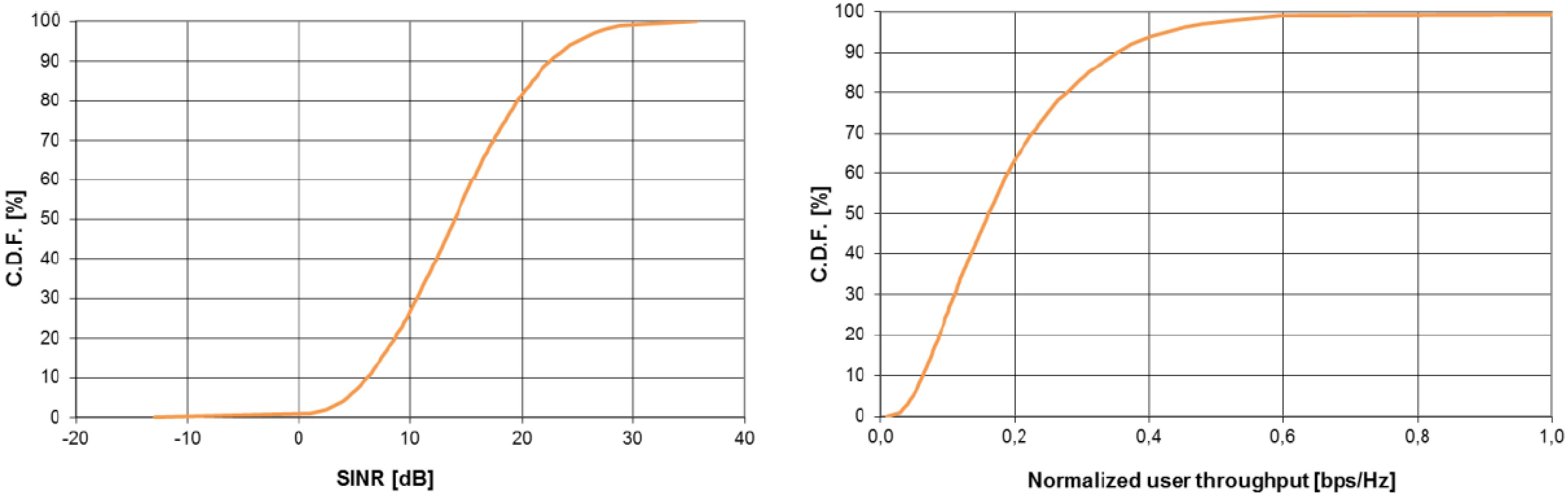

Figure 3.3: SINR and normalized user throughput distribution for calibration case 2

Table 3.6: Results obtained in the calibration process

Parameter	UPVLC	E///	Nokia	DCM	ALUD	Average
Cell spectral efficiency [bps/Hz/cell]	1.8458	1.8762	1.9469	1.9305	1.712	1.8623
Cell edge user spectral efficiency [bps/Hz]	0.0618	0.0446	0.0426	0.0424	0.0392	0.0461

參考資料

[1]Report ITU-R M.2412-0, "Guidelines for evaluation of radio interface technologies for IMT-2020", October 2017.

[2] 3GPP TR 37.910 V1.1.0 (2018-12), 3rd Generation Partnership Project; Technical Specification Group Radio Access Network; Study on Self Evaluation towards IMT-2020 Submission (Release 16)

[3] 3GPP TSG RAN Meeting #79, RP-180524, Chennai, India, 19 – 22 March 2018

[4] METIS Deliverable D6.1 Simulation guidelines, October 2013