3GPP TSG-RAN 4 #46 R4-080329
Sorrento, Italy, February 11 – 15, 2008

Agenda item: 7.1

Source: Qualcomm Europe

Title: 3GPP Home NodeB Interference Analysis

Document for: Discussion and Decision

Outline

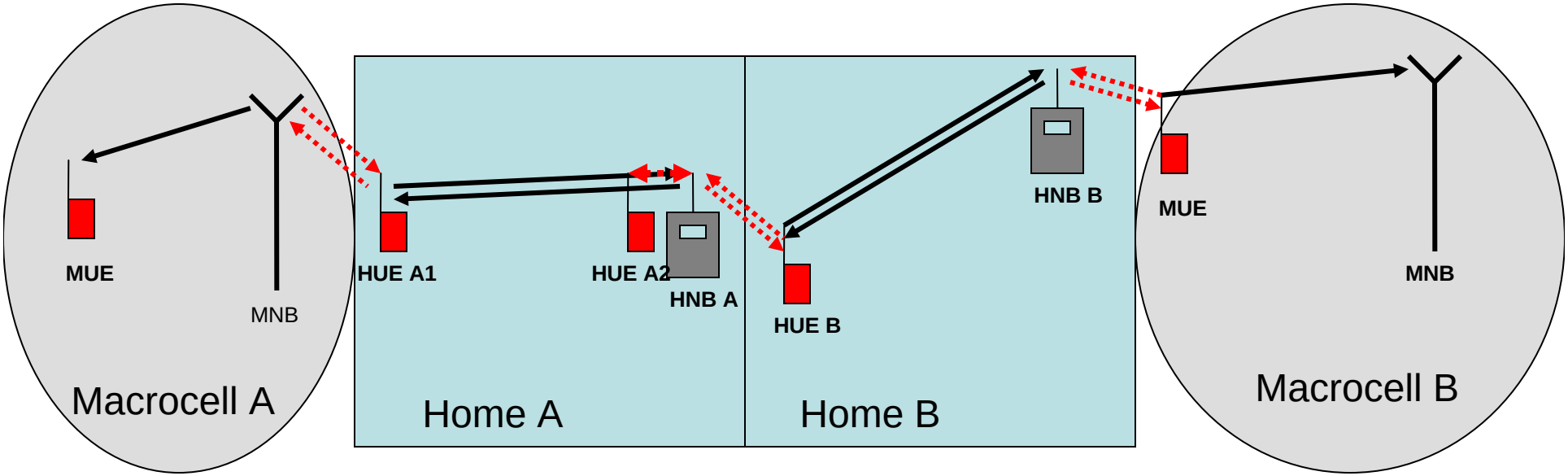
- Sources of interference issues in femtocells
  - Closed subscriber group
  - Unplanned deployment
  - Low isolation between apartments

- Above interference issues
  - Generally do not exist for macrocells or picocells
  - Can result in significant outage and jamming conditions for Home NodeB deployments with default parameters

- Previous contributions [1,2] showed system level simulation results for different deployment scenarios (e.g., dense apartment co-channel deployments, femto-macro co-channel and adjacent channel deployments)
  - Femto-femto interference issues
  - Femto-macro interference issues

- This presentation focuses on simple models to clearly identify different interference issues

Interference Issues



- Interference issues exist both on FL and RL:
  - Inter-femto interference (Model1)
  - Femto-macro interference (Model 2, 3)
  - Intra-femto desensitization

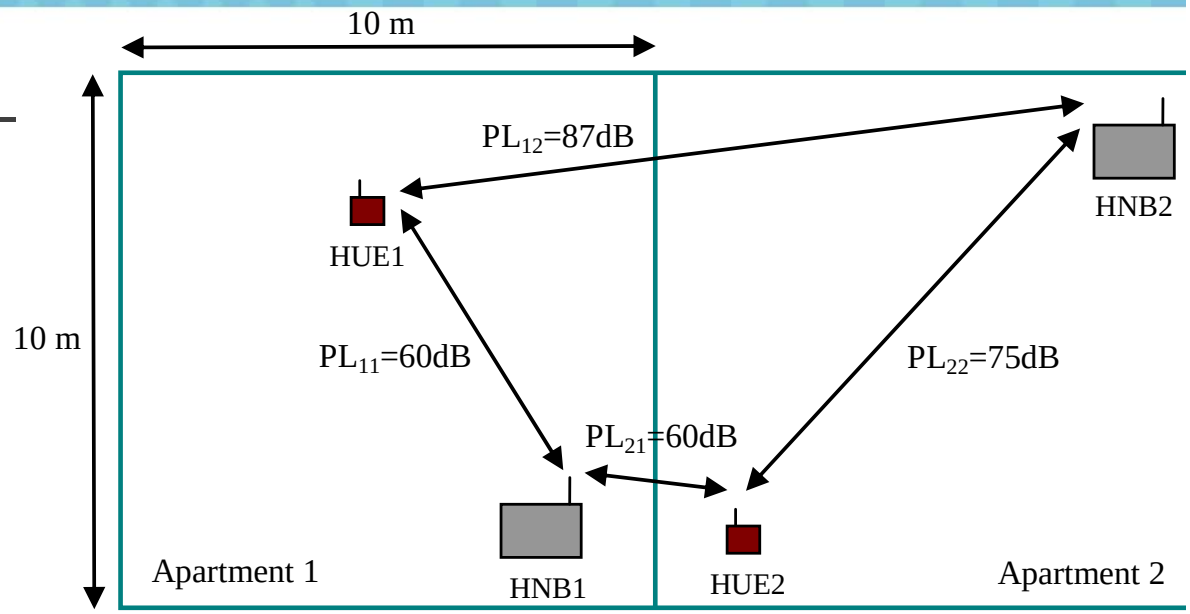
- Notation:
  - Home NodeB (HNB)
  - Macrocell NodeB (MNB)
  - UE served by Home NodeB (HUE)
  - UE served by Macrocell NodeB (MUE)

Summary of Interference Models

- Model 1 addresses femto-femto interference issues on DL and UL
  - Degraded UE UL performance due to high noise rise from neighbor UE
  - Degraded Home UE DL performance due to large interference from neighbor Home Node B
- Model 2 and Model 3 address femto-macro interference issues on DL and UL
  - Degraded Home UE UL performance due to high noise rise from macro UE
  - Degraded Home UE or Macro UE DL performance depending on Home Node B location and transmit power

Model 1

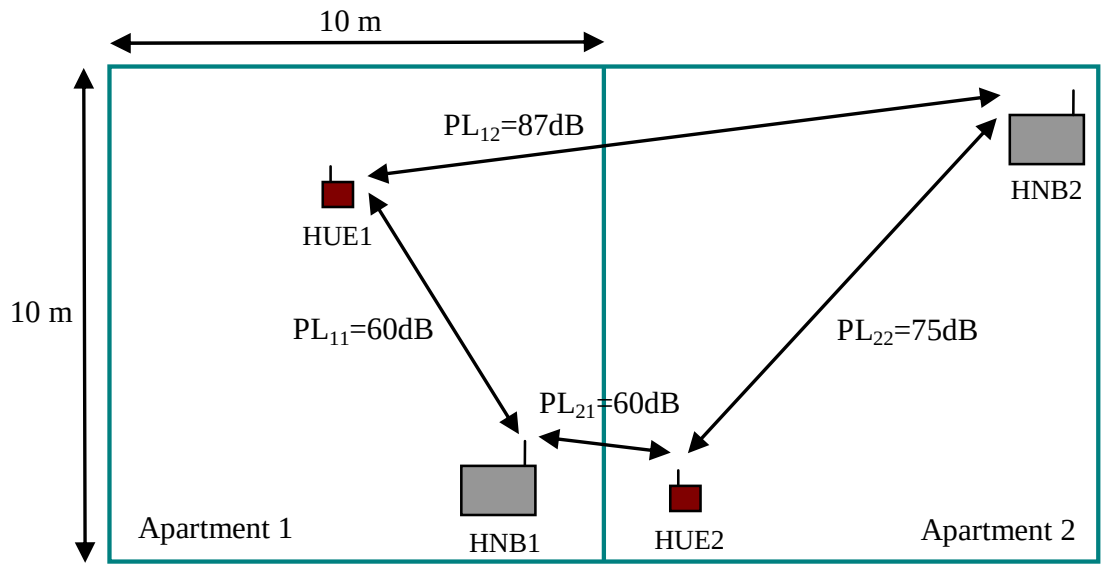
- System model for inter-femto interference simulations
  - E.g., two neighboring apartments with femtocells



- Path loss model:
  - PL=38.46+20log(*d*)+*qW*
  - *d*: distance [m]
  - *q*: number of walls
  - *W*: Wall separation (5dB)

PL (dB)	d (m)	q
60	3.8	2
60	6.7	1
75	11.9	3
87	15.0	5

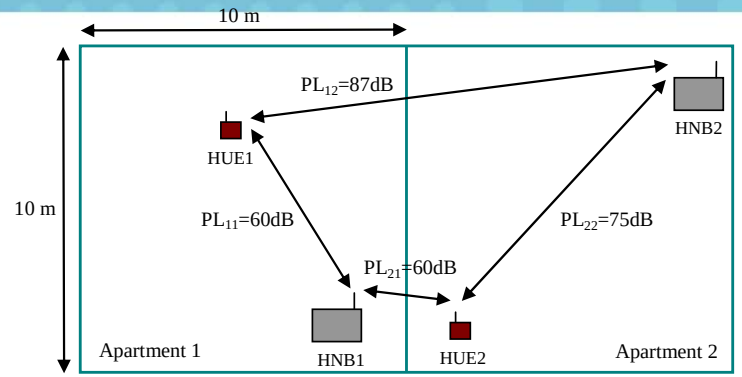
Model 1 UL Performance



		HUE1	HUE2
UL Performance for Baseline 1 (HNB NRT=5dB, HNB NF=5dB)	**Throughput [kbps]** **Avg Noise Rise [dB]** **Avg Tx Power [dBm]**	**25** **10.4** **-49.9**	**1319** **1.1** **-33.0**
UL Performance for Baseline 2 (HNB NRT=10dB, HNB NF=20dB)	**Throughput [kbps]** **Avg Noise Rise [dB]** **Avg Tx Power [dBm]**	**293** **10.6** **-29.4**	**1320** **1.1** **-18.0**

HUE1 has poor UL performance due to high noise rise created by HUE2

Model 1 DL Performance



Best Effort		HUE 1	HUE 2
Default Performance	Throughput (Kbps)	15512.2	42.5

HTTP		HUE 1	HUE 2
Default Performance, OCNS = 0	Page Delay (sec)	0.16	2.85
Default Performance, OCNS = 1	Page Delay (sec)	0.16	8.00

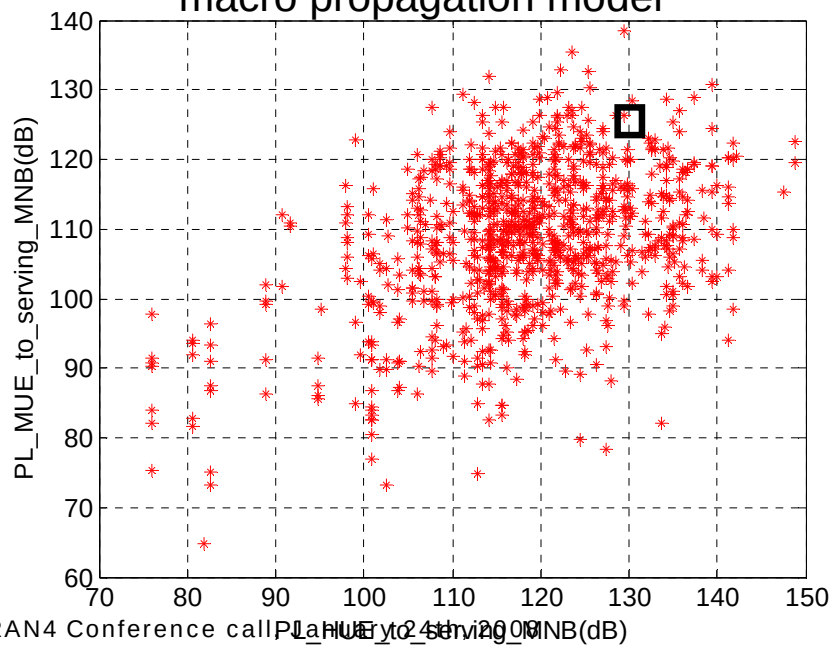
Release 99 Voice		HUE 1	HUE 2
OCNS = 0	PER	0.009	0.009
OCNS = 1	PER	0.009	0.015
Rel 99 DPCH (for voice user)		HUE 1	HUE 2
OCNS = 0	Tx Ec Ior (dB)	-56.01	-14.557
OCNS = 1	Tx Ec Ior (dB)	-51.434	-8.509

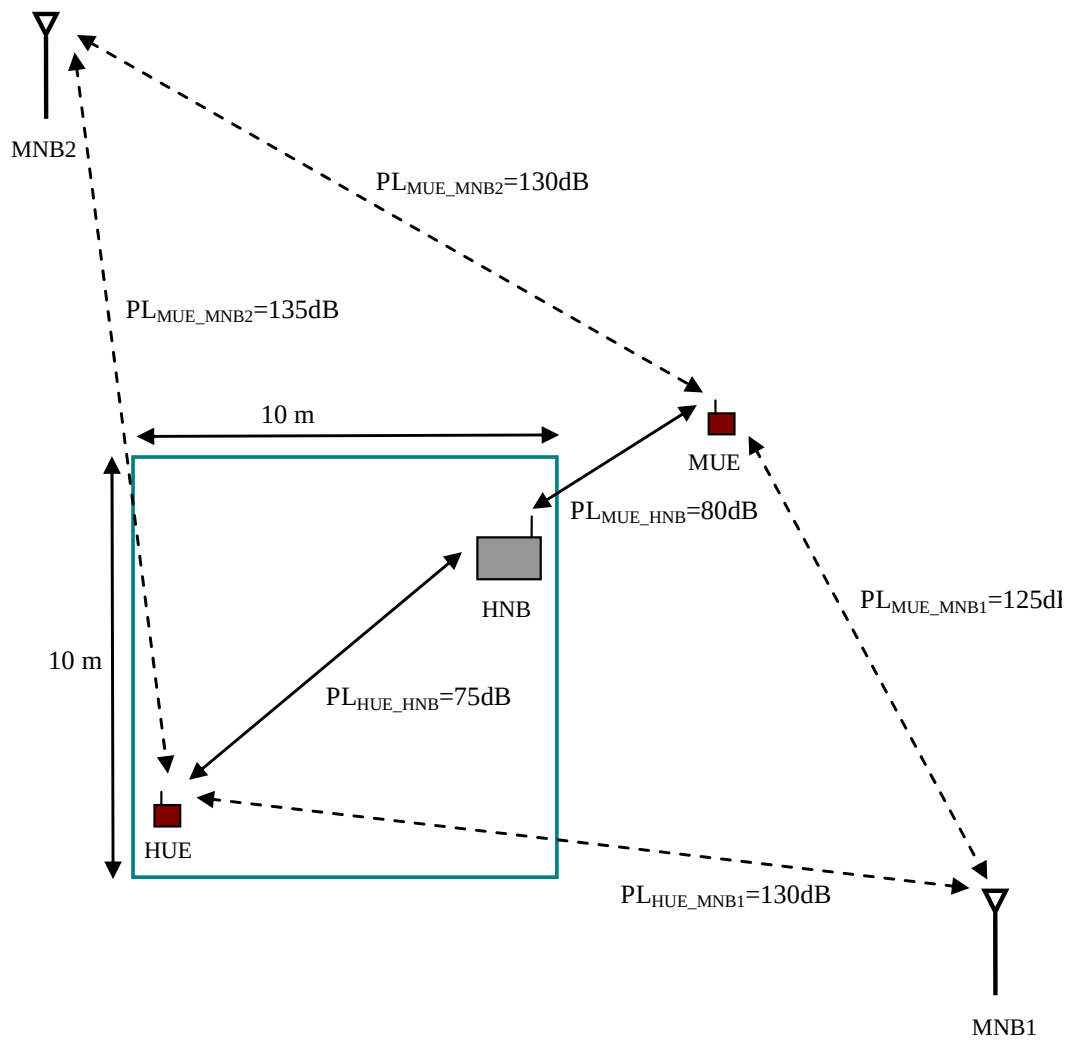
HUE2 has poor DL performance due to high interference created by HNB1

Model 2

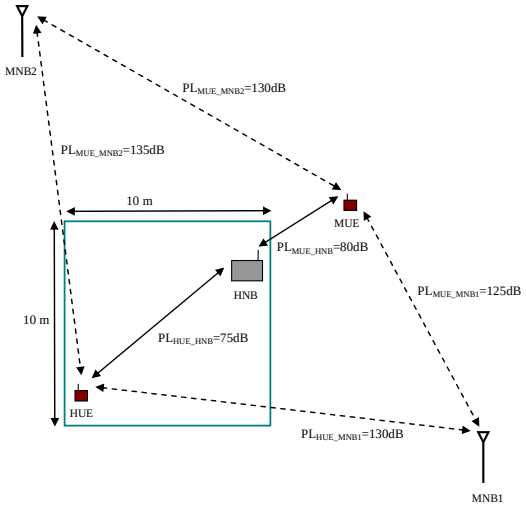
- System model for femto-macro interference simulations:
  - One sample point picked from actual system level simulation results as shown as small square below:

Path-loss scatter plot based on femto-macro propagation model





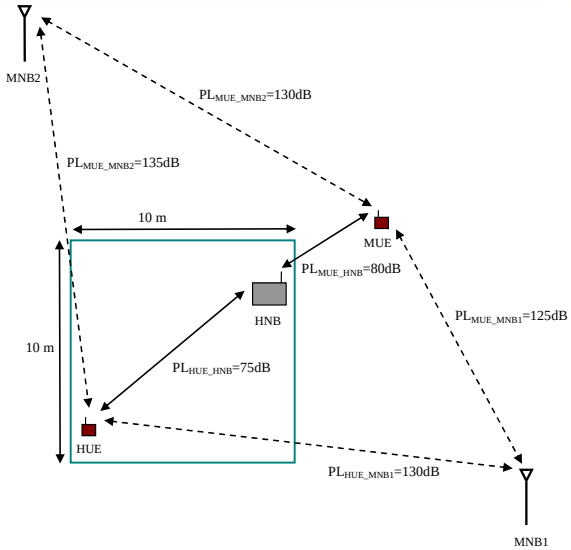
Model 2 UL Performance



			Home	Macro
ACIR=0dB	UL Performance for Baseline 1 (HNB NRT=5dB, HNB NF=5dB)	Throughput [kbps] Avg Noise Rise [dB] Avg Tx Power [dBm]	20 40.2 -5.8	1321 1.1 17.2
	UL Performance for Baseline 2 (HNB NRT=10dB, HNB NF=20dB)	Throughput [kbps] Avg Noise Rise [dB] Avg Tx Power [dBm]	20 25.2 -5.8	1321 1.1 17.2
ACIR=33dB	UL Performance for Baseline 1 (HNB NRT=5dB, HNB NF=5dB)	Throughput [kbps] Avg Noise Rise [dB] Avg Tx Power [dBm]	29 7.9 -37.9	1315 1.1 17.1
	UL Performance for Baseline 2 (HNB NRT=10dB, HNB NF=20dB)	Throughput [kbps] Avg Noise Rise [dB] Avg Tx Power [dBm]	1333 1.8 -17.3	1315 1.1 17.1

HUE has poor UL performance due to high noise rise created by MUE both in co-channel and adjacent channel deployment

Model 2 DL Performance



		Macro	Home
ACIR = 0dB	**Node B Tx**	43 dBm	20 dBm
	UE Throughput	0 Kbps	15512 Kbps
	UE Ecp/Nt	-32 dB	11.5 dB
	Node B Tx	43 dBm	0 dBm
	UE Throughput	531 Kbps	6137 Kbps
	UE Ecp/Nt	-12.9 dB	0.3 dB
	Node B Tx	43 dBm	-20 dBm
	UE Throughput	2869 Kbps	66 Kbps
	UE Ecp/Nt	-5.5 dB	-19.4 dB

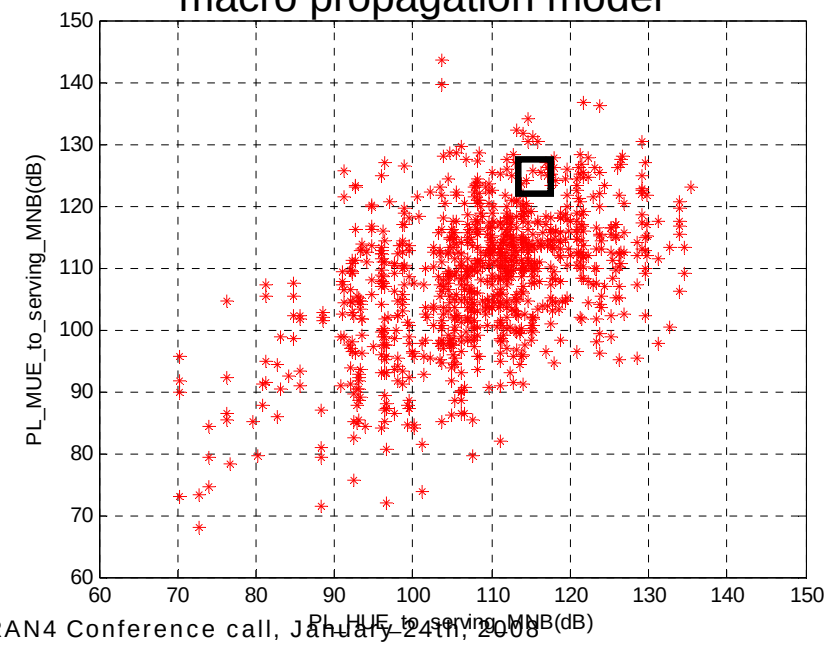
		Macro	Home
ACIR = 33dB	**Node B Tx**	43 dBm	20 dBm
	UE Throughput	2559 Kbps	15512 Kbps
	UE Ecp/Nt	-6.3 dB	11.9 dB
	Node B Tx	43 dBm	0 dBm
	UE Throughput	2965 Kbps	15325 Kbps
	UE Ecp/Nt	-5.4 dB	9.8 dB
	Node B Tx	43 dBm	-20 dBm
	UE Throughput	2955 Kbps	2536 Kbps
	UE Ecp/Nt	-5.3 dB	-6.1 dB

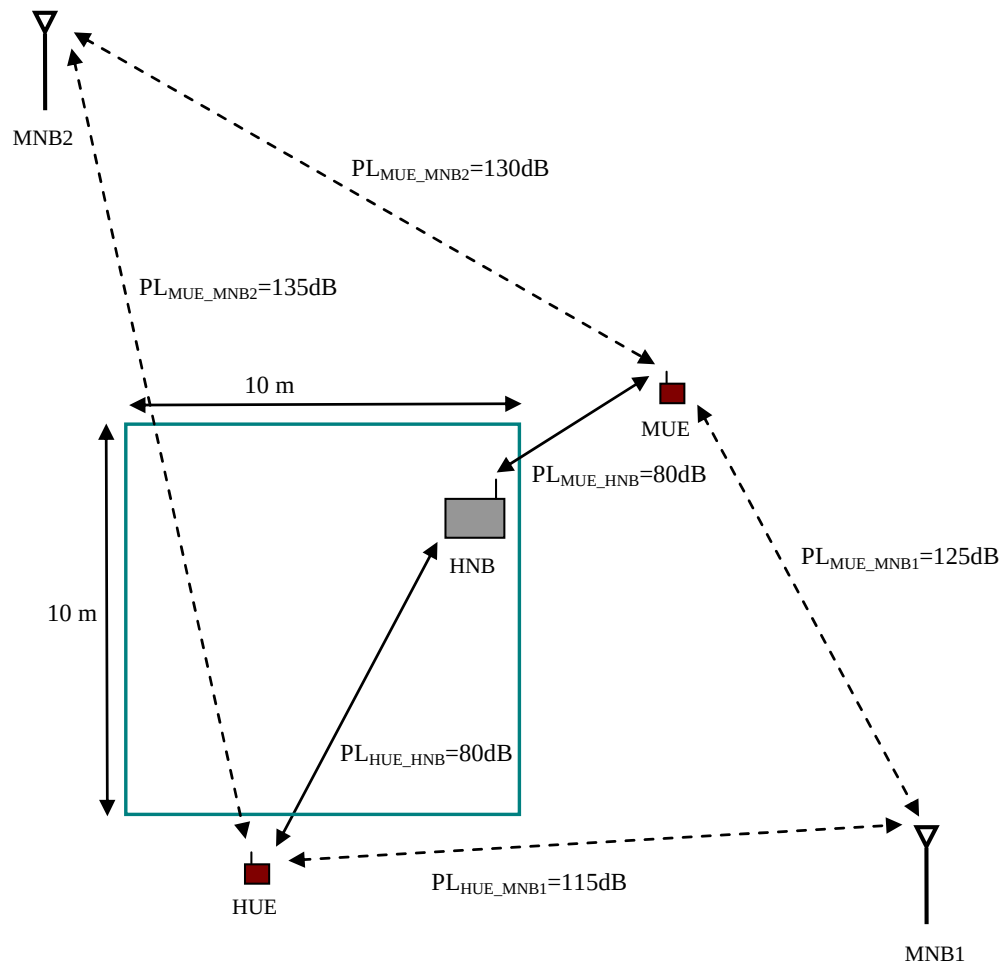
HNB Tx power needs to be adjusted to have the right tradeoff between MUE performance and HUE performance on the DL (both for co-channel and adjacent channel deployment)

Model 3

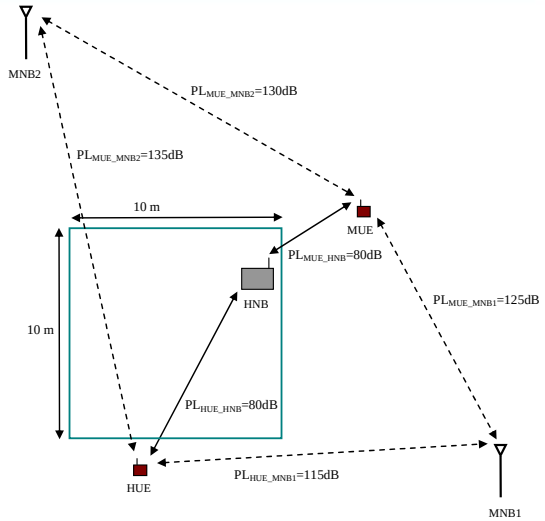
- System model for femto-macro interference simulations:
  - Another sample point picked from system level simulation results as shown as small square below:

Path-loss scatter plot based on femto-macro propagation model





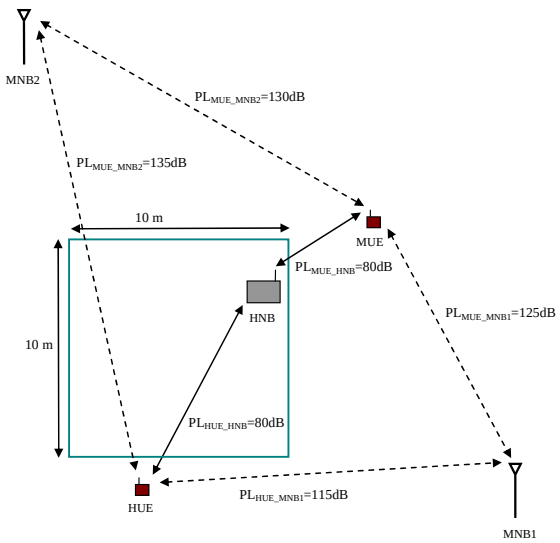
Model 3 UL Performance



			Home	Macro
ACIR=0dB	UL Performance for Baseline 1 (HNB NRT=5dB, HNB NF=5dB)	Throughput [kbps] Avg Noise Rise [dB] Avg Tx Power [dBm]	20 40.4 -1.0	1332 1.4 17.4
	UL Performance for Baseline 2 (HNB NRT=10dB, HNB NF=20dB)	Throughput [kbps] Avg Noise Rise [dB] Avg Tx Power [dBm]	20 25.3 -0.7	1306 1.3 17.2
	UL Performance with HNB NRT=10dB, HNB NF=45dB	Throughput [kbps] Avg Noise Rise [dB] Avg Tx Power [dBm]	1585 4.3 15.6	444 5.6 17.1

- HUE has poor UL performance due to high noise rise created by MUE
- When Noise Figure at HNB is increased to 45dB (from 5dB)
  - HUE performance improves due to desensitized HNB
  - MUE performance degrades due to additional noise rise created by HUE to the MNB

Model 3 DL Performance



		Macro	Home
ACIR = 0dB	Node B Tx	43 dBm	20 dBm
	UE Throughput	0 Kbps	7201 Kbps
	UE Ecp/Nt	-32 dB	1.5 dB
	Node B Tx	43 dBm	0 dBm
	UE Throughput	531 Kbps	87 Kbps
	UE Ecp/Nt	-12.9 dB	-18 dB
	Node B Tx	43 dBm	-20 dBm
	UE Throughput	2869 Kbps	0 Kbps
	UE Ecp/Nt	-5.5 dB	-38 dB

		Macro	Home
ACIR = 33dB	Node B Tx	43 dBm	20 dBm
	UE Throughput	2559 Kbps	15512 Kbps
	UE Ecp/Nt	-6.3 dB	11.9 dB
	Node B Tx	43 dBm	0 dBm
	UE Throughput	2965 Kbps	11568 Kbps
	UE Ecp/Nt	-5.4 dB	6.5 dB
	Node B Tx	43 dBm	-20 dBm
	UE Throughput	2955 Kbps	647 Kbps
	UE Ecp/Nt	-5.3 dB	-12 dB

HNB Tx power needs to be adjusted to have the right tradeoff between MUE performance and HUE performance on the DL (both for co-channel and adjacent channel deployment)

Performance Improvement

- Results with default system operation show poor performance both on the DL and UL
- Example methods to enhance femto performance:
  - UL: adaptive noise figure
  - DL: time re-use
- Improved performance results with above methods are shown in appendix
- Other methods can be utilized to improve performance as well

Conclusions

- Simple test cases are defined to analyze interference issues for Home NodeBs
- Potential interference issues exist for Home NodeB deployments
  - On the UL and DL
  - For dedicated and shared channel deployments
- Enhancements are possible to improve the system performance
- Further work is required to analyze system performance and define minimum performance specifications

Reference

[1] R4-071618, "Home Node B HSDPA Performance Analysis", Qualcomm Europe

[2] R4-071619, "Analysis of Uplink Performance under Co-channel Home NodeB-Macro Deployment", Qualcomm Europe

Appendix

General Simulation Assumptions

- Full Queue (BE) simulations
  - Full buffer traffic modeled
  - UE is modeled with type 3 receiver
- HTTP Simulations
  - HTTP implementation is based on 3GPP2 methodology
  - UE is modeled with type 3 receiver
- Release 99 Voice Simulations
  - AMR 12.2 speech, Markov Voice Model
  - Different UE receiver types are modeled (Rake receiver, single and dual receive antennas)
  - Dedicated channel is power controlled at 1% BLER
- Carrier allocation
  - Interfemto:
    - All femtocells are assumed to be on the same carrier
  - Femto-macro:
    - Co-channel (ACIR=0dB) and adjacent channel (ACIR=33dB) deployments considered for femtocells and macrocells

Uplink Simulation Assumptions

- Channel: normalized stationary channel
  - Rician K factor of 10 dB
  - Doppler of 1.5 Hz
- Min UE transmit power = -50dBm
- Max UE transmit power = 24dBm
- TTI=2ms
- Max Num of HARQ transmissions = 4
- For MNB
  - Scheduler noise rise threshold (NRT) is 5dB and noise figure (NF) is 5dB
- For HNB
  - Baseline 1: NRT=5dB, NF=5dB
  - Baseline 2: NRT=10dB, NF=20dB
- Minimum scheduler grant=128 bits

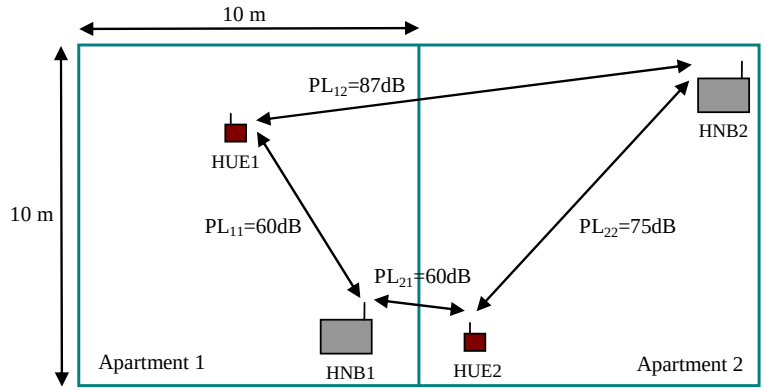
Downlink Simulation Assumptions

- Channel: normalized stationary channel
  - Rician K factor of 10 dB
  - Doppler of 1.5 Hz
- Maximum modulation is 64 QAM
- Number of HS-PDSCH codes is 15
- Maximum coding rate is 0.8 corresponding to maximum application layer throughput of 15.5 Mbps
- CPICH power ratio -10 dB
- Total overhead power ratio (CPICH, PCCCH, SCCCH etc.) -5.229 dB (30%)
- HNB has one omni-transmit antenna with antenna gain 0 dBi
- Simulations run with OCNS=0 and OCNS=1 (100% tx power)
- System acquisition and synchronization are not modeled yet
  - UE is assumed to be in CELL_DCH state

Adaptive Noise Figure for UL Performance Enhancement

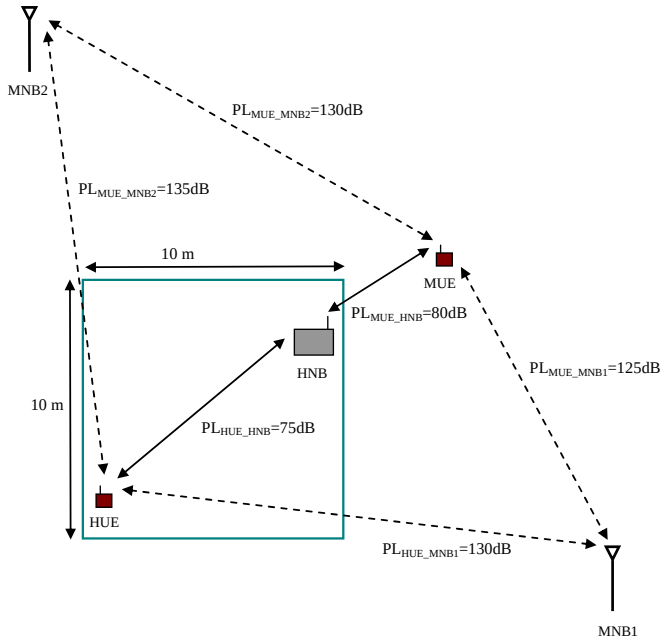
- Increasing UL attenuation or noise figure (NF) results in:
  - Reduced interference level from the non-associated UEs
  - Reduced received signal strength from associated UEs
    - Closed loop power control increases the associated UE tx power level to maintain the require UL SIR
    - Higher interference created by the associated UE to other femtocells and macrocells
- Thus adapt UL attenuation or noise figure (NF) only when needed to control the in-cell and out-of-cell received signal power within target values

Model 1 UL Performance with Enhancements



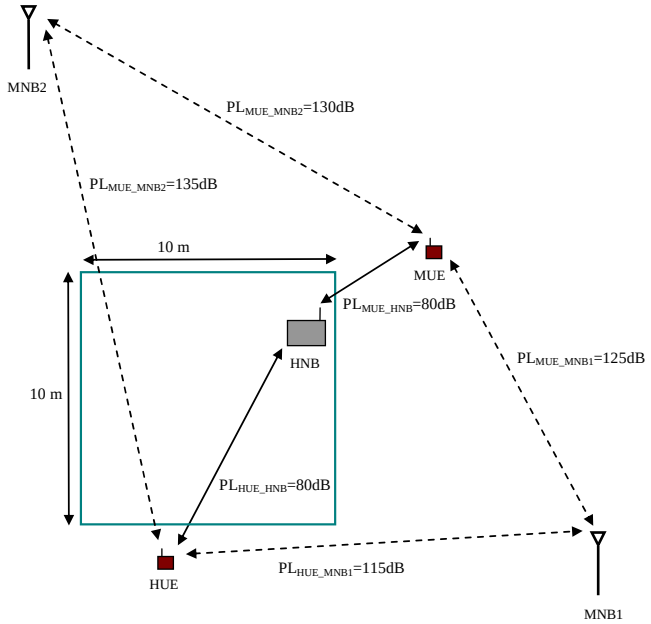
		HUE1	HUE2
UL Performance for Baseline 1 (HNB NRT=5dB, HNB NF=5dB)	**Throughput [kbps]** **Avg Noise Rise [dB]** **Avg Tx Power [dBm]**	**25** **10.4** **-49.9**	**1319** **1.1** **-33.0**
UL Performance for Baseline 2 (HNB NRT=10dB, HNB NF=20dB)	**Throughput [kbps]** **Avg Noise Rise [dB]** **Avg Tx Power [dBm]**	**293** **10.6** **-29.4**	**1320** **1.1** **-18.0**
UL Performance with Enhancements	**Throughput [kbps]** **Avg Noise Rise [dB]** **Avg Tx Power [dBm]**	**1475** **6.4** **-35.6**	**1334** **1.2** **-32.3**

Model 2 UL Performance with Enhancements



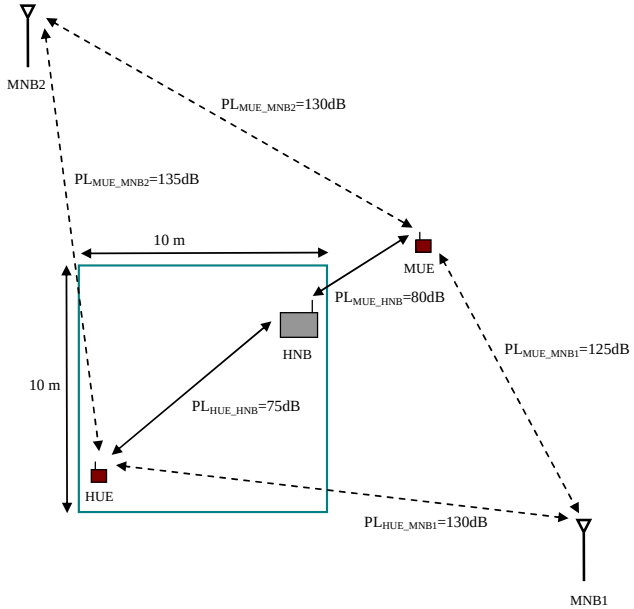
			Home	Macro
ACIR=0dB	UL Performance for Baseline 1 (HNB NRT=5dB, HNB NF=5dB)	Throughput [kbps] Avg Noise Rise [dB] Avg Tx Power [dBm]	20 40.2 -5.8	1321 1.1 17.2
	UL Performance for Baseline 2 (HNB NRT=10dB, HNB NF=20dB)	Throughput [kbps] Avg Noise Rise [dB] Avg Tx Power [dBm]	20 25.2 -5.8	1321 1.1 17.2
	UL Performance with Enhancements	Throughput [kbps] Avg Noise Rise [dB] Avg Tx Power [dBm]	1451 6.6 9.2	1328 1.2 17.3
ACIR=33dB	UL Performance for Baseline 1 (HNB NRT=5dB, HNB NF=5dB)	Throughput [kbps] Avg Noise Rise [dB] Avg Tx Power [dBm]	29 7.9 -37.9	1315 1.1 17.1
	UL Performance for Baseline 2 (HNB NRT=10dB, HNB NF=20dB)	Throughput [kbps] Avg Noise Rise [dB] Avg Tx Power [dBm]	1333 1.8 -17.3	1315 1.1 17.1
	UL Performance with Enhancements	Throughput [kbps] Avg Noise Rise [dB] Avg Tx Power [dBm]	1440 6.7 -24.1	1315 1.1 17.1

Model 3 UL Performance with Enhancements



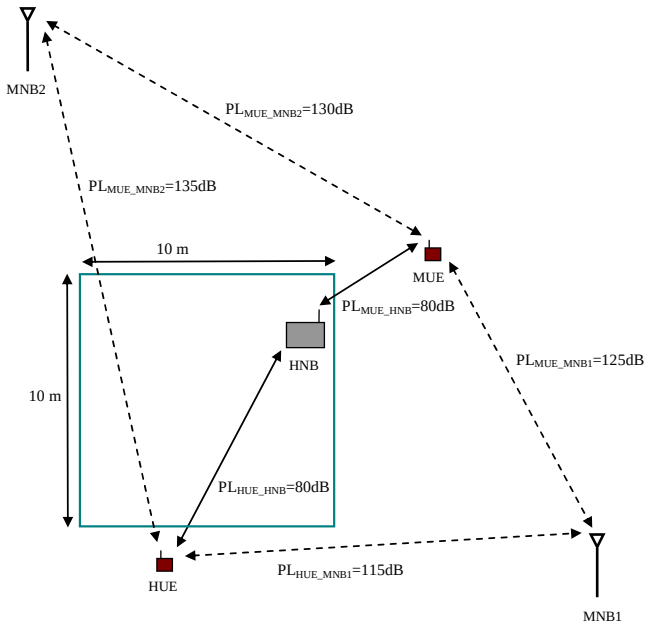
			Home	Macro
ACIR=0dB	UL Performance for Baseline 1 (HNB NRT=5dB, HNB NF=5dB)	Throughput [kbps] Avg Noise Rise [dB] Avg Tx Power [dBm]	20 40.4 -1.0	1332 1.4 17.4
	UL Performance for Baseline 2 (HNB NRT=10dB, HNB NF=20dB)	Throughput [kbps] Avg Noise Rise [dB] Avg Tx Power [dBm]	20 25.3 -0.7	1306 1.3 17.2
	UL Performance with Enhancements	Throughput [kbps] Avg Noise Rise [dB] Avg Tx Power [dBm]	1707 5.6 15.6	510 5.6 17.5
ACIR=33dB	UL Performance for Baseline 1 (HNB NRT=5dB, HNB NF=5dB)	Throughput [kbps] Avg Noise Rise [dB] Avg Tx Power [dBm]	29 7.9 -37.9	1315 1.1 17.1
	UL Performance for Baseline 2 (HNB NRT=10dB, HNB NF=20dB)	Throughput [kbps] Avg Noise Rise [dB] Avg Tx Power [dBm]	1327 1.8 -12.3	1339 1.1 17.2
	UL Performance with Enhancements	Throughput [kbps] Avg Noise Rise [dB] Avg Tx Power [dBm]	1435 6.6 -18.9	1339 1.1 17.2

Model 2 & 3 DL Performance with Enhancements



- Model 2

		Macro	Home
ACIR = 0 dB	**Node B Tx** **UE Throughput** **UE Ecp/Nt**	43 dBm 426 Kbps -13.5 dB	0.8 dBm 6692 Kbps 1.01 dB
ACIR = 33dB	**Node B Tx** **UE Throughput** **UE Ecp/Nt**	43 dBm 426 Kbps -13.5 dB	33.8 dBm 15512 Kbps 12 dB



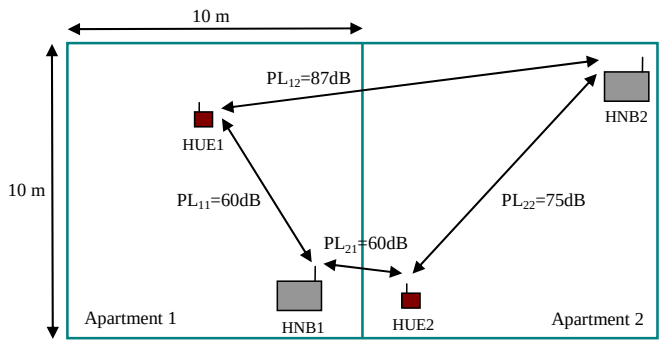
- Model 3

		Macro	Home
ACIR = 0 dB	**Node B Tx** **UE Throughput** **UE Ecp/Nt**	43 dBm 426 Kbps -13.5 dB	0.8 dBm 102 Kbps -17.3 dB
ACIR = 33dB	**Node B Tx** **UE Throughput** **UE Ecp/Nt**	43 dBm 426 Kbps -13.5 dB	33.8 dBm 15512 Kbps 12 dB

Time Reuse Method for DL Performance Enhancement

- Idea:
  - Reduce DL tx power during certain time periods
  - Create isolation and high SINR for neighboring femtocells
- Given a certain time reuse pattern femtocells can pick “best” time offset
  - E.g., by sensing the time offset used by neighbor femtocells
- Transmit power patterns (duty cycle)
  - Tradeoff between reducing outage and reducing peak rate
  - Maximum efficiency is achieved with orthogonal time re-use patterns
- Certain residual overhead (RoV) may be required to be transmitted continuously

Model 1 DL Performance with Enhancements



BE Throughput (Kbps)	HUE 1	HUE 2
Default Performance	15512.2	42.5
Time Reuse, 3 Groups, ROV = 0%	5172.2	5170.0
Time Reuse, 3 Groups, ROV = 5%	5172.2	385.3
Time Reuse, 3 Groups, ROV = 10%	5172.2	172.4

HTTP Page Delay (sec)	HUE 1	HUE 2
Default Performance, OCNS = 0	0.16	2.85
Default Performance, OCNS = 1	0.16	8.00
OCNS=1,TR, 3 Groups, ROV = 0%	0.21	0.22
OCNS=1,TR, 3 Groups, ROV = 5%	0.21	1.39
OCNS=1,TR, 3 Groups, ROV = 10%	0.21	2.59