Handover parameter adaptation based on SINR reduction rate for 5G heterogeneous networks

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WInnComm – 2015

24-26 March 2015, San Diego, California

Introduction

More devices

Network-connected wireless devices ~ 1000x the world's population by 2017 [1]

Higher data rate

~ 2/3 of mobile traffic will be video by 2017 [2]

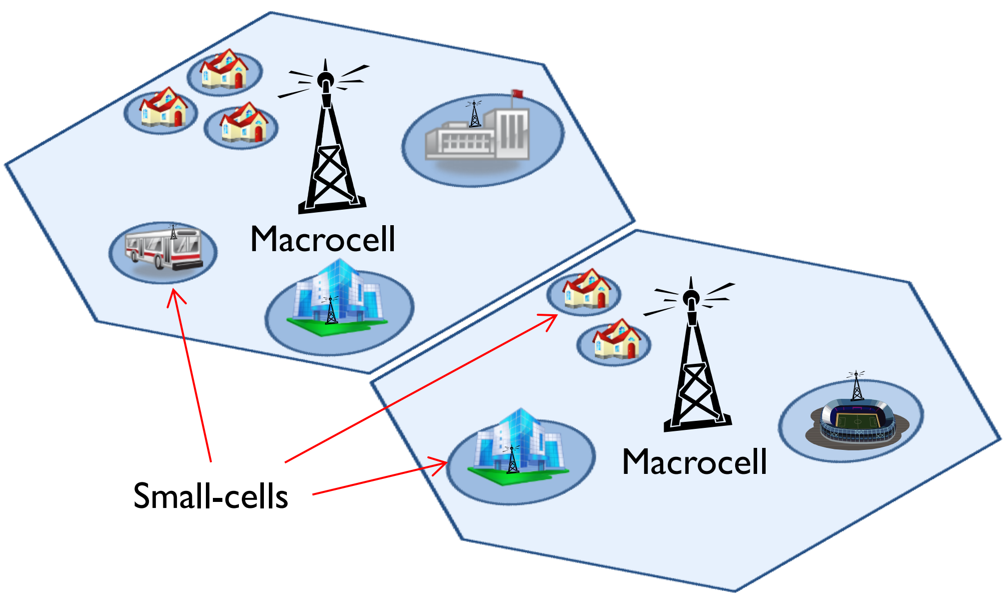
Need to increase network area capacity

in bits/s per area unit

One of the main drivers behind the future development of 5G communication systems

Introduction

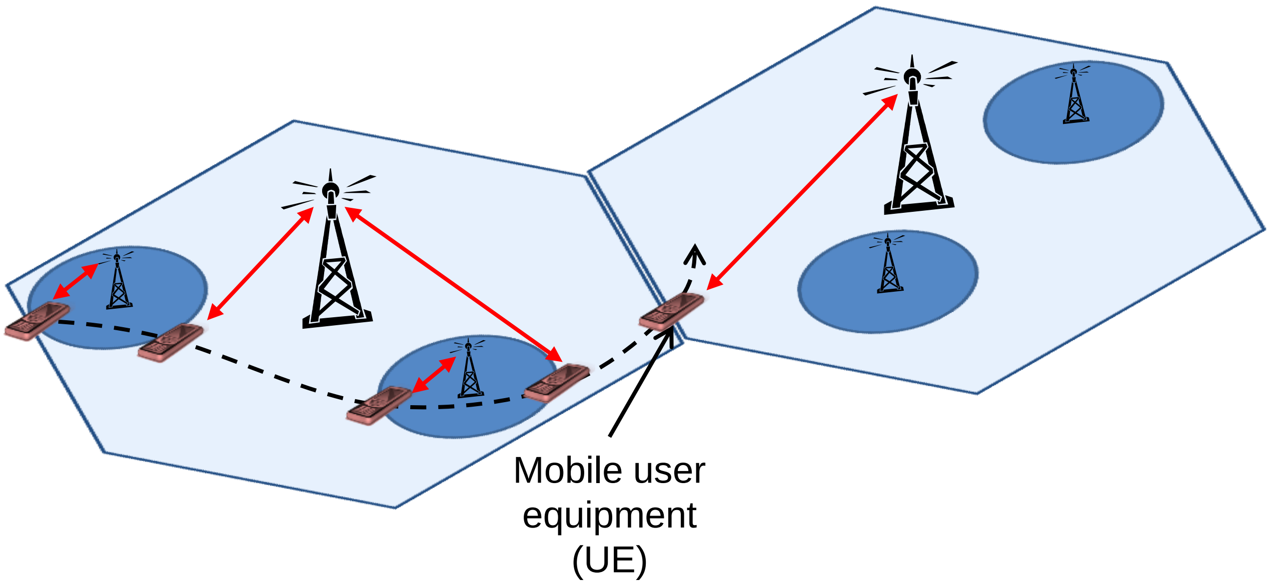
More small-cells → Higher frequency reuse → Higher network area capacity



Heterogeneous Network (HetNet)

5G networks may become progressively denser and heterogeneous with more small-cells per area unit [3]

Problem statement

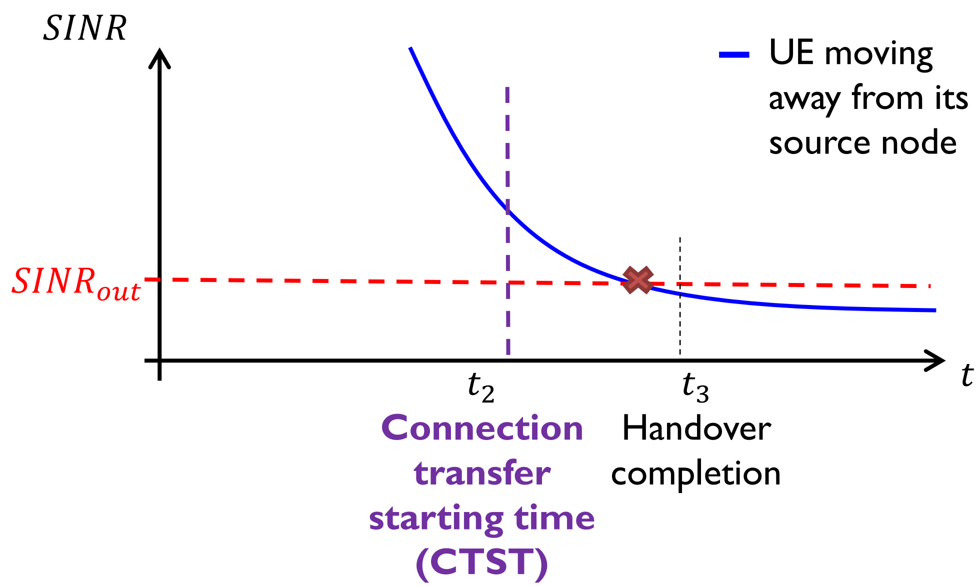


The **handover** is the UE's connection transfer, from a source node to a target node, in order to maintain communication with a specific quality of service [4]

Problem statement

Handover failure

- Occurs if during handover the SINR falls below a needed threshold to maintain communication [5]



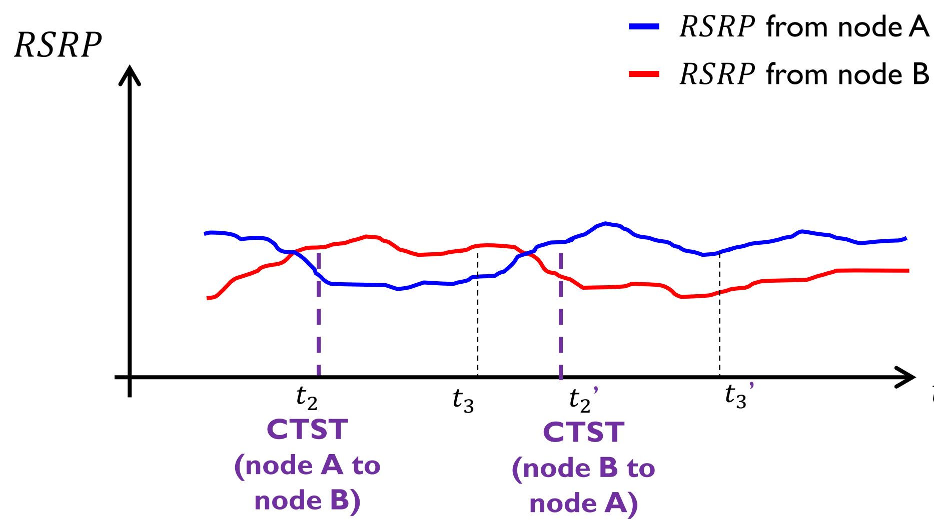
Advance of the connection transfer starting time → Less likely that $SINR$ falls bellow $SINR_{out}$ → Reduction of handover failure rate

- The opposite happens with a delay of the connection transfer starting time

Problem statement

Handover ping-pong

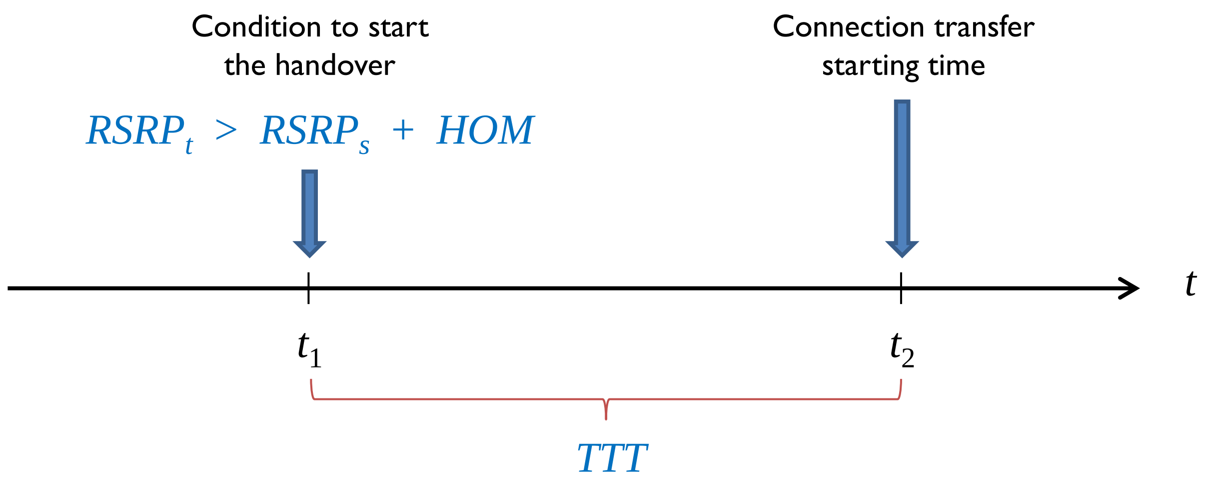
- Occurs if a UE connects to a new node, and shortly completes a handover back to the former source node [5]
- May be produced by temporal fading of the received power



Delay of the connection transfer starting time → Allows the network to avoid handover if power variations are caused by temporal fading → Reduction of handover ping-pong rate

- The opposite happens with an advance of the connection transfer starting time

Connection transfer starting time



- The connection transfer starting time depends on the HOM and TTT values

$RSRP_s$: reference signal received power from source node

$RSRP_t$: reference signal received power from target node

HOM: handover margin

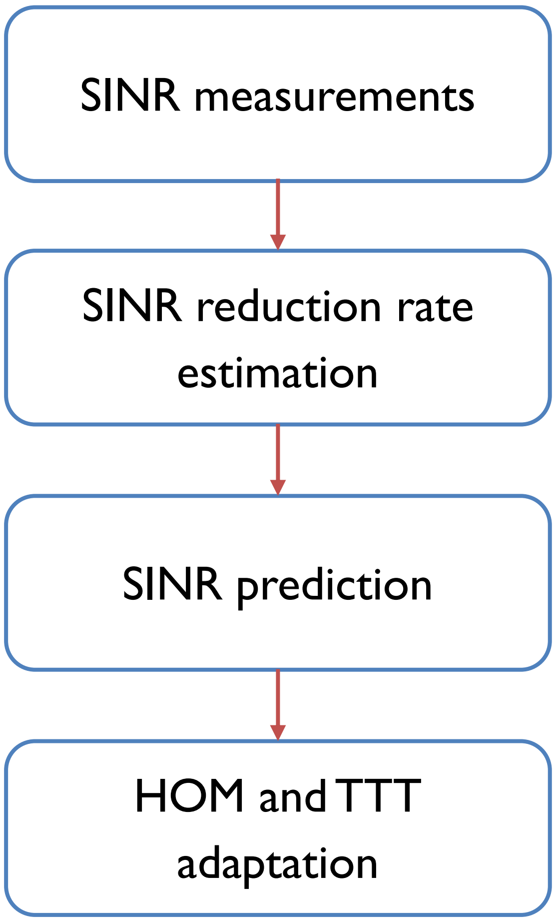
TTT: time to trigger

Effect of handover margin and time to trigger

HOM and TTT	Connection transfer starting time	Handover failure rate	Handover ping-pong rate
Small values	Advances	Reduces	Increases
Large values	Delays	Increases	Reduces

- Mobile communication specifications use constant values of HOM and TTT
- It is pertinet to adapt HOM and TTT due to changing conditions of the propagation environment

Adaptable handover parameters (AHP)



- UEs of mobile communications system already estimate SINR
- Knowledge of the SINR reduction rate allows to predict the SINR at a later time
- The AHP method is designed to adapt:
  - Small values of HOM and TTT for high SINR reduction rates
  - Large values of HOM and TTT for low SINR reduction rates

HOM and TTT adaptation

- SINR prediction model (truncated Taylor's series) [6]

$$\widehat{SINR}_s(t_3) \approx SINR_s(t_0) + [SINR_s{}'(t_0)](t_3 - t_0) \quad (1)$$

- HOM and TTT adaptation

$$TTT = \frac{1}{TR+1}\left[\frac{SINR_{des} - SINR_s(t_0)}{\frac{d[SINR_s(t_0)]}{dt}} - T_{HOp}\right] \quad (2)$$

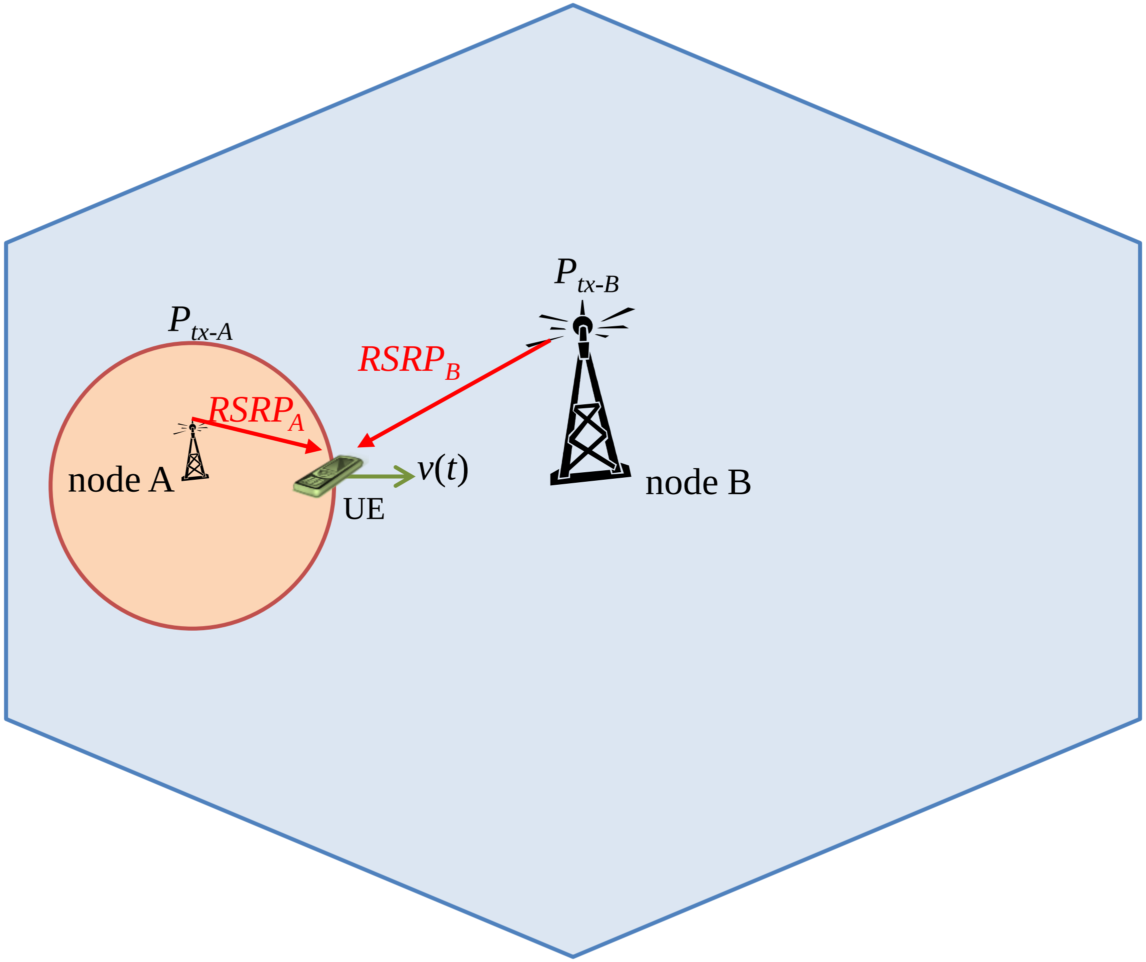
$$HOM = TTT \cdot TR\left(\frac{d[RSRP_t(t_0)]}{dt} - \frac{d[RSRP_s(t_0)]}{dt}\right) \quad (3)$$

t_3: time at handover completion

$SINR_{des}$: SINR desired at handover completion

T_{HOp}: handover preparation time

Evaluation scenario



- Simulation of mobile UEs
  - Straight trajectory
  - Constant speed
  - Path loss model with log-normal shadow fading
- Counted
  - Started handovers
  - Completed handovers
  - Handover failures
  - Handovers ping-pong

Simulation settings

Table 1: Simulation settings

Parameter	**Value**
Path loss model	Urban macro-cellular LOS
Fading model	Log-normal shadow fading
Fading standard deviation (σ)	4 (dB)
Fading correlation distance (d_{corr})	25 (m)
Source eNB to target eNB distance (D)	200 (m)
UE velocity [$v(t)$]	[3,10,30,60,100,120] (km/h)
eNB-A transmission power (P_{tx-A})	30 (dBm)
eNB-B transmission power (P_{tx-B})	46 (dBm)
Frequency (f_c)	2 (GHz)
UE measurement period	10 (ms)
Minimum time of stay (MTS)	2 (s)
RLF threshold ($SINR_{out}$)	-8 (dB)
RLF timer ($T310$)	1 (s)
$SINR_s(t_0)$	$\sim U[-3, 0]$ (dB)
Handover preparation time (T_{HO_p})	50 (ms)
Handover execution time (T_{HO_e})	40 (ms)
Time ratio (TR)	1
Time to trigger (TTT)	[40, 240, 440, 640] (ms)
Handover margin (HOM)	[1, 2, 3, 4] (dB)

Analysis of results

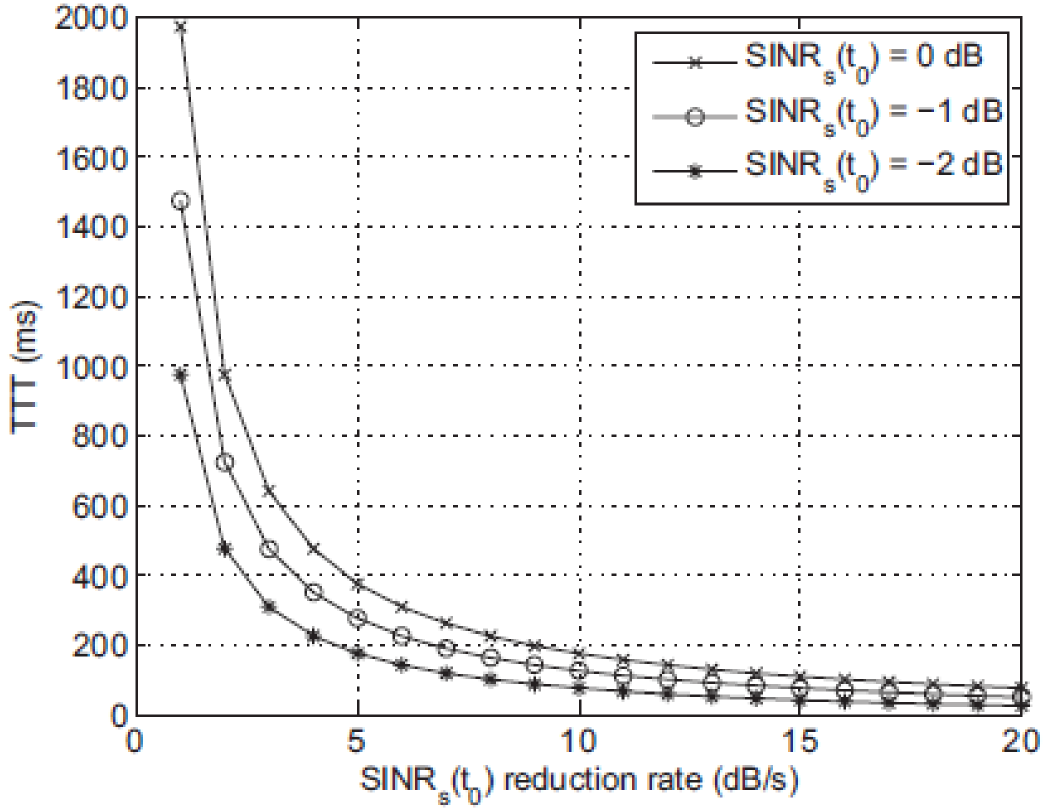


Figure 5: Adapted TTT.

- The AHP method adapted:
  - Large values of TTT for low SINR reduction rates
  - Small values of TTT for high SINR reduction rates

Analysis of results

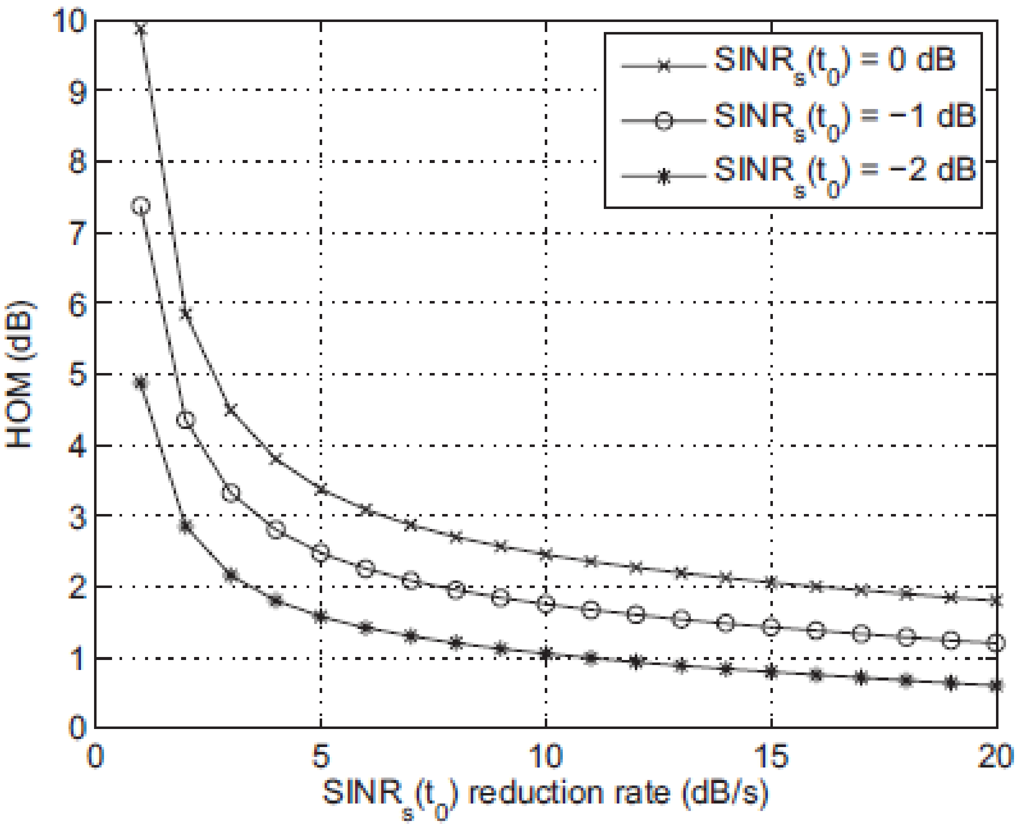


Figure 6: Adapted HOM.

- The AHP method adapted:
  - Large values of HOM for low SINR reduction rates
  - Small values of HOM for high SINR reduction rates

Analysis of results

Table 2: HOFR (%) and 95% CI

HOM(dB)	TTT(ms) 40	240	440	640
1	4.11 4.00-4.22	12.81 12.52-13.10	22.02 21.59-22.46	28.97 28.60-29.33
2	6.49 6.38-6.60	18.52 18.27-18.77	28.07 27.82-28.33	35.18 35.04-35.32
3	10.09 9.84-10.33	25.14 24.63-25.66	34.66 34.36-34.96	41.04 40.56-41.53
4	15.74 15.41-16.06	32.47 32.18-32.76	41.77 41.49-42.05	47.59 46.89-48.28

- Results for constant values of HOM and TTT confirm the tradeoff between handover failure rate (HOFR) and handover ping-pong rate (HOPR)

Table 3: HOPR (%) and 95% CI

HOM(dB)	TTT(ms) 40	240	440	640
1	27.75 26.90-28.60	6.46 6.13-6.81	2.34 2.20-2.49	1.10 0.96-1.24
2	9.34 9.00-9.68	1.24 1.14-1.34	0.31 0.23-0.39	0.10 0.07-0.14
3	2.68 2.39-2.96	0.24 0.18-0.30	0.03 0.00-0.07	0.01 0.00-0.02
4	0.67 0.58-0.76	0.04 0.02-0.06	0.00 0.00-0.01	0.00 0.00-0.00

Table 4: HOFR, HOPR, and 95% CI for the AHP method.

HOFR(%)	5.89 5.66-6.12
HOPR(%)	5.99 5.84-6.15

Conclusions

- We proposed a method that adapts the handover margin and the time to trigger parameters to reduce the HOFR and HOPR
- (HOFR+HOPR) for AHP method is 6.95% smaller than the best case of (HOFR+HOPR) with constant HOM and TTT
- For similar HOFRs, HOPR is 35% smaller in the AHP method
- For similar HOPRs, HOFR is 54% smaller in the AHP method
- Future work could consider an alternative SINR prediction model to improve results even further

References

[1] W. Cheng-Xiang, et. al., "*Cellular architecture and key technologies for 5G wireless communication networks*," Communications Magazine, IEEE, vol. 52, no. 2, pp. 122–130, February 2014.

[2] Qualcomm, "*Qualcomm's 5G vision*", November 2014, available online: https://www.qualcomm.com/invention/technologies/5g

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[4] D. Lopez-Perez, et. al., "*Mobility management challenges in 3GPP heterogeneous networks*." Communications Magazine, IEEE, 50(12):70–78, 2012.

[5] 3GPP, "*Mobility Enhancements in Heterogeneous Networks,*" 3GPP, Technical Report TS 36.839 v11.1.0, December 2012.

[6] S. Chapra, and R. Canale, "*Numerical methods for engineers*". McGraw-Hill, 6th ed., 2009.