An Analysis of Handover Performance in Heterogeneous LTE Networks

Nicholas Wooster
ntwooste@sfu.ca

Simon Fraser University | School of Engineering Science
ENSC894-G100: Communication Networks
Prof. Ljiljana Trajkovic

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OUTLINE

- Motivation
- Literature Review
- Overview of Relevant LTE Components
  - E-UTRAN Architecture
  - Elements of the Handover Process
- Simulation Methodology
- Results
- Discussion
- Future Work
- References

E-UTRAN: Evolved Universal Terrestrial Radio Access Network

MOTIVATION

- The integration of small-cell network nodes within a conventional cellular network provides a promising solution to increase overall network capacity.
- Offloading users from the macro-cell tier to the small-cell tier frees bandwidth on the macro-cell tier for other more mobile users.
- Handover is a key component of guaranteeing the expected quality of service while effectively managing resources within these heterogeneous networks.

LITERATURE REVIEW

- Significant research and commercial interest in deployment of small-cells and optimization of handover algorithms.
- Multitude of proposed handover algorithms exist.
  - Majority rely on weighting functions to alter behaviour of conventional received signal –based algorithms.
- Drivers are:
  - Self Organizing Networks [1, 2]
  - Load / traffic management [3, 4]
- Challenges are:
  - Unpredictability of small-cell deployment [3, 5]
  - Integration with existing networks [5, 6]

E-UTRAN ARCHITECTURE

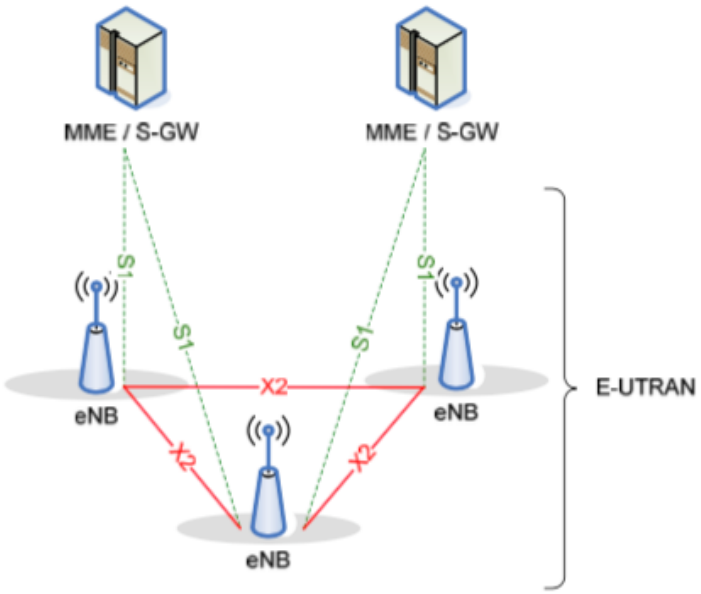


Figure courtesy of ETSI TS 136 300 V9.4.0

- eNBs are interconnected via X2 interface.
- eNBs connect to EPC via the MME and S-GW over S1 interface.
- LTE supports both S1 and X2 interface –based handover.

E-UTRAN: Evolved Universal Terrestrial Radio Access Network
eNB: E-UTRAN NodeB
EPC: Evolved Packet Core

MME: Mobility Management Entity
S-GW: Serving Gateway

ELEMENTS OF THE HANDOVER PROCESS

1. Channel Measurement
   - UE measures RSRP and RSSI (at least).
   - RSRQ can be derived from reported RSRP and RSSI: $RSRQ = (N_{RB} * RSRP) / RSSI$

2. Handover Decision
   - UE will report a measurement event to the serving eNB if the appropriate conditions are met.

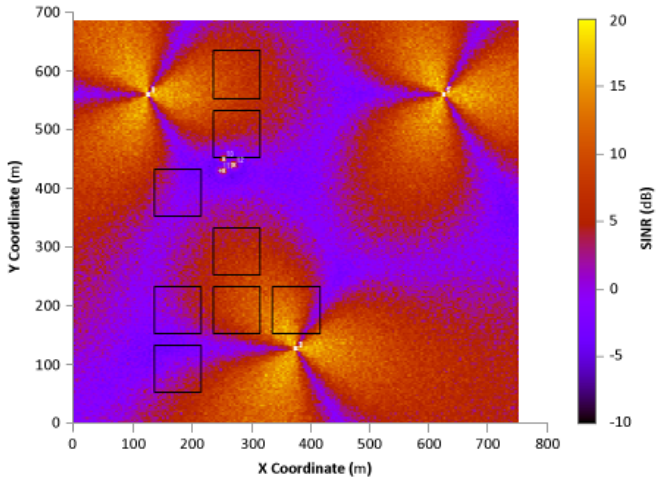
Selected Measurement Events	
Event A2	Serving cell's RSRQ becomes worse than *threshold.*
Event A3	Neighbouring cell's RSRP becomes *offset* better than serving cell.
Event A4	Neighbouring cell's RSRQ becomes better than *threshold.*

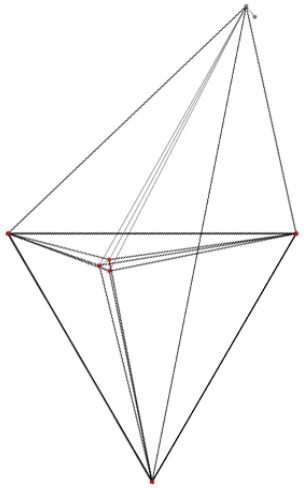
3. Handover Preparation, Execution & Completion
   - Tunneling of packets from source to target eNB.
   - Target eNB connection setup, source eNB connection teardown.

eNB: E-UTRAN NodeB
UE: User Equipment
RB: Resource Block
RSRP: Reference Signal Received Power
RSRQ: Reference Signal Received Quality
RSSI: Reference Signal Strength Indicator

SIMULATION METHODOLOGY

- Use ns-3 LTE Module developed by LENA Project.
- Install a localized small-cell network within a macro-cell hexagonal grid topology.
- All eNBs are connected via an X2 interface, and are connected to the EPC through an S1 interface.





eNB: E-UTRAN NodeB
EPC: Evolved Packet Core
SINR: Signal to Interference+Noise Ratio

SIMULATION METHODOLOGY
(continued)

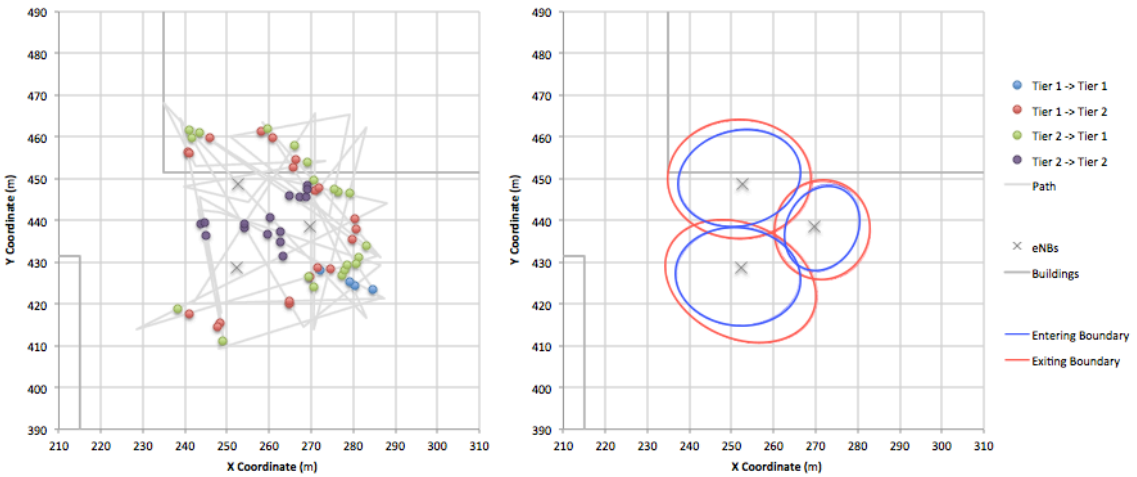
- Employ RSRP measurement and RSRQ measurement –based handover algorithms.
- Analyze the efficiency of both algorithms at offloading traffic from the macro-cell tier while ensuring acceptable quality of service.
- Analyze effective cell radii and coverage.

RSRP: Reference Signal Received Power
RSRQ: Reference Signal Received Quality

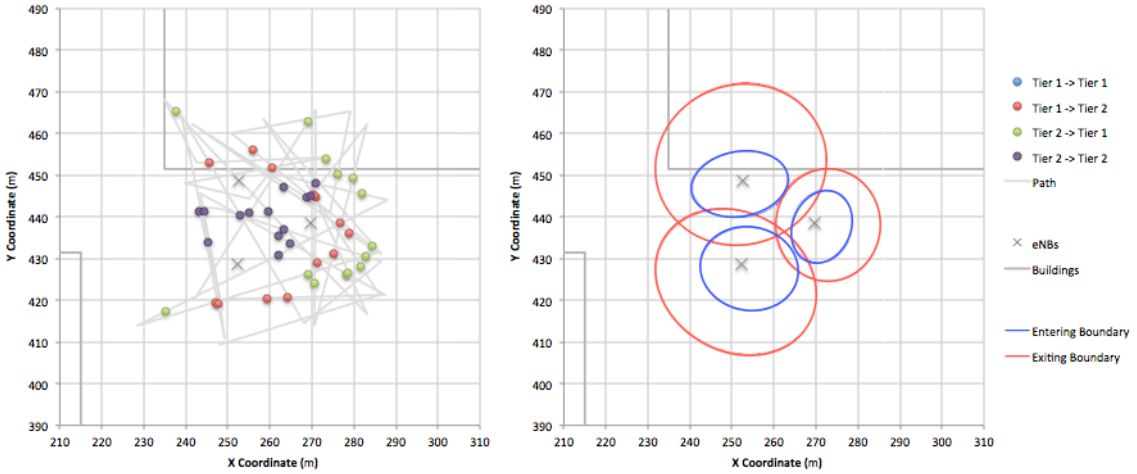
RESULTS

- A2 / A4 measurement event –based handover algorithm.

High *threshold*



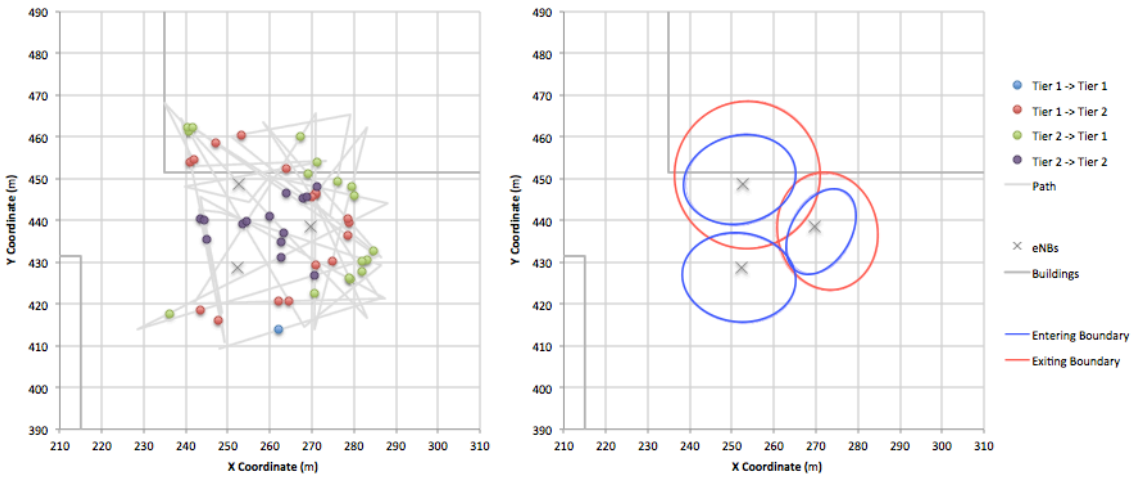
Low *threshold*



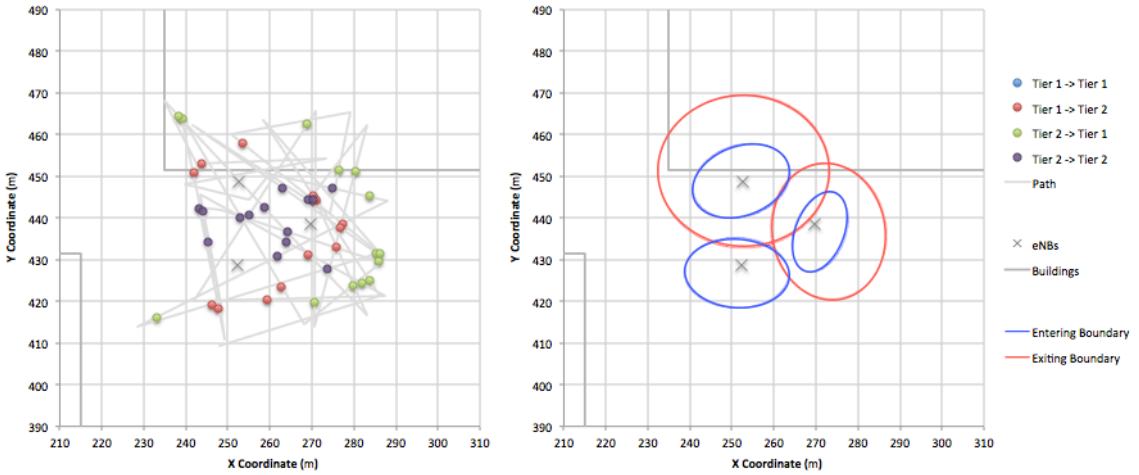
RESULTS
(continued)

- A3 measurement event –based handover algorithm.

Low
offset
Short
time-to-trigger



High
offset
Long
time-to-trigger



RESULTS
(continued)

	Network Tier	Link	Avg. Delay (ms)	Avg. Throughput (Mbps)	Packet Loss	Time as Serving Tier	Coverage Area
A2 / A4 High	Small-cell	UL	5.63	8.43	0.03%	62.02%	~ 47%
		DL	35.54	8.27	1.84%		
	Macro-cell	UL	5.66	8.42	0.09%	37.98%	
		DL	81.68	8.19	2.83%		
A2 / A4 Low	Small-cell	UL	5.67	8.43	0.03%	59.18%	~ 51%
		DL	42.49	8.18	3.01%		
	Macro-cell	UL	5.72	8.42	0.07%	40.82%	
		DL	95.43	8.02	4.85%		
A3 Low / Short	Small-cell	UL	5.66	8.43	0.03%	61.77%	~ 35%
		DL	50.21	7.99	2.67%		
	Macro-cell	UL	5.70	8.42	0.12%	38.23%	
		DL	92.38	8.04	3.66%		
A3 High / Long	Small-cell	UL	5.80	8.42	0.07%	62.52%	~ 55%
		DL	50.21	7.99	5.19%		
	Macro-cell	UL	5.73	8.42	0.08%	37.48%	
		DL	92.38	8.04	4.70%		

Time as Serving Tier is defined as the cumulative time the UE was connected to the associated network tier, expressed as a percentage of the total simulation time.

Coverage Area is defined as the sum over all small-cell nodes of the area bounded by an ellipse fit to all entering and exiting handovers for a given node as a percentage of the allowed range of UE mobility.

DISCUSSION

- High A2 / A4 threshold scheme shows best (by a small margin) small-cell and macro-cell downlink performance. Also shows smallest coverage area.
- High A3 offset, long time-to-trigger scheme shows worst (by a small margin) small-cell uplink performance. Also shows largest coverage area.
- High A2 / A4 threshold and high A3 offset, long time-to-trigger schemes show most effective at offloading users from macro-cell tier.

FUTURE WORK

- Examine the effects on handover performance of RSRP and RSRQ –based algorithms by increasing UE and small-cell density.
- Examine the performance of frequency reuse schemes on RSRP and RSRQ –based handover in heterogeneous networks.
- Examine the performance of weighting handover algorithms with factors derived from additional measurements.

RSRP	Reference Signal Received Power
RSRQ	Reference Signal Received Quality

REFERENCES

[1] M. Song, S. Moon and S. Han, "Self-optimization of handover parameters for dynamic small-cell networks," *Wireless Communications and Mobile Computing*, vol. 15, no. 11, pp. 1497-1517, Aug. 2015.

[2] O. Østerbø, O. Grøndalen, "Benefits of Self-Organizing Networks (SON) for Mobile Operators," *Journal of Computer Networks and Communications*, vol. 2012, Sept. 2015.

[3] Y. Li, B. Cao and C. Wang, "Handover Schemes in Heterogeneous LTE Networks: Challenges and Opportunities," *IEEE Wireless Communications*, vol. 23, iss. 2, pp. 112-117, May 2016.

[4] J. Ruiz Avilés, M. Toril and S. Luna-Ramírez, "A Femtocell location strategy for improving adaptive traffic sharing in heterogeneous LTE networks," *Journal on Wireless Communications and Networking*, vol. 15, no. 38, Dec. 2015.

[5] G. Gódor et al., "A survey of handover management in LTE-based multi-tier femtocell networks: Requirements, challenges and solutions," *Computer Networks*, vol. 76, pp. 17-41, Jan. 2015.

[6] D. Xenakis et al., "Mobility Management for Femtocells in LTE-Advanced: Key Aspects and Survey of Handover Decision Algorithms," *IEEE Communications Surveys & Tutorials*, vol. 16, pp. 64-91, Jul. 2013.