Load Balancing in Downlink LTE Self-Optimizing Networks

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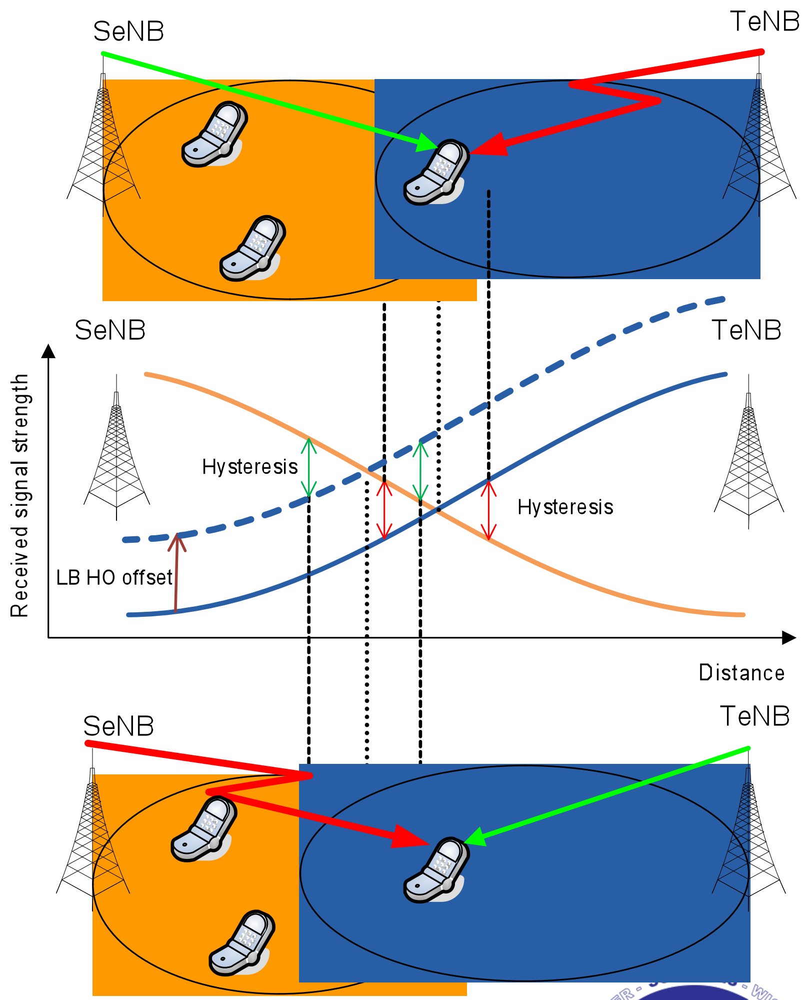
Introduction

- SOCRATES project
  – Self optimizing (HO optimization, Scheduling optimisation, Load Balancing ...)
  – Self healing (Cell outage detection, Cell outage compensation)
  – Self organizing (Automatic generation of initial default parameters)
- Load imbalance is a common problem in communication networks
  – non-uniform user deployment distribution,
  – heavily loaded cells may be in neighbourhood to lightly loaded cells.
  – Typicaly solved manually
- Load balancing use case group aims at developing methods and algorithms for automatically adjusting network parameters offload the excess traffic
- In this document is presented:
  – Load balancing algorithm based on network load status information which is able to automatically indicate optimal adjustments for network parameters,
  – comparison of results for different simulation setups: for a basic, regular network setup, a non-regular grid with different cell sizes and also for a realistic scenario based on measurements and realistic traffic setup

Load Balancing in general

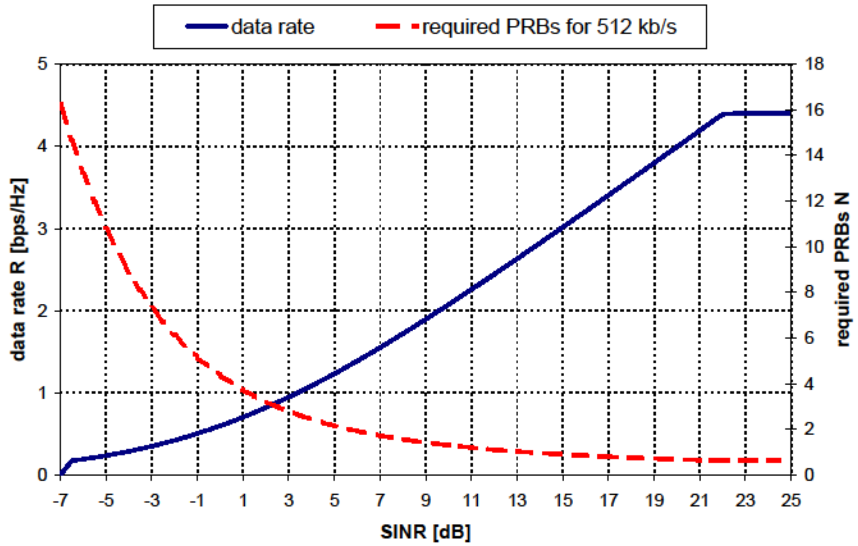
- Problem
  - Unequally load distribution cause overload
  - Users can not be served with required quality level due to lack of resources
- Main Idea
  - Reallocate part of users from overloaded cell to less loaded neighbour cell
  - SeNB adjust LB HO offset to TeNB and force users to HO to TeNB
- Result
  - TeNB increase overlapped area and take over part of users previously served by SeNB
  - LB operation set free resources at SeNB



Definitions: load (per user)

- Throughput mapping base on the concept of a truncated Shannon mapping curve

$$R(SINR_u) = \log_2\left(1 + SINR_u\right)$$



- Load generated by single user is the necessary number of PRBs N_u for the required throughput D_u and the transmission bandwidth of one PRB BW = 180 kHz

$$N_u = \frac{D_u}{R(SINR_u) \cdot BW}$$

  – D_u is an average data rate requirement per user u

Definitions: Virtual load

- The overload situation occurs when the total required number of PRBs N_u may exceed the amount of the total available resources in one cell M_{PRB}
- Virtual cell load can be expressed as the sum of the required resources N of all users *u* connected to cell *c* by connection function *X(u)* which gives the serving cell *c* for user *u.*

$$\hat{\rho}_c = \frac{1}{M_{PRB}} \cdot \sum_{u|X(u)=c} N_u$$

  - M_{PRB} is a number of available PRBs (depend on operating bandwidth)
  - All users in a cell are satisfied as long as $\hat{\rho}_c \leq 1$. In a cell with $\hat{\rho}_c > 1$ we will have a fraction of $\frac{1}{\hat{\rho}_c}$ satisfied users

Definitions: unsatisfied users

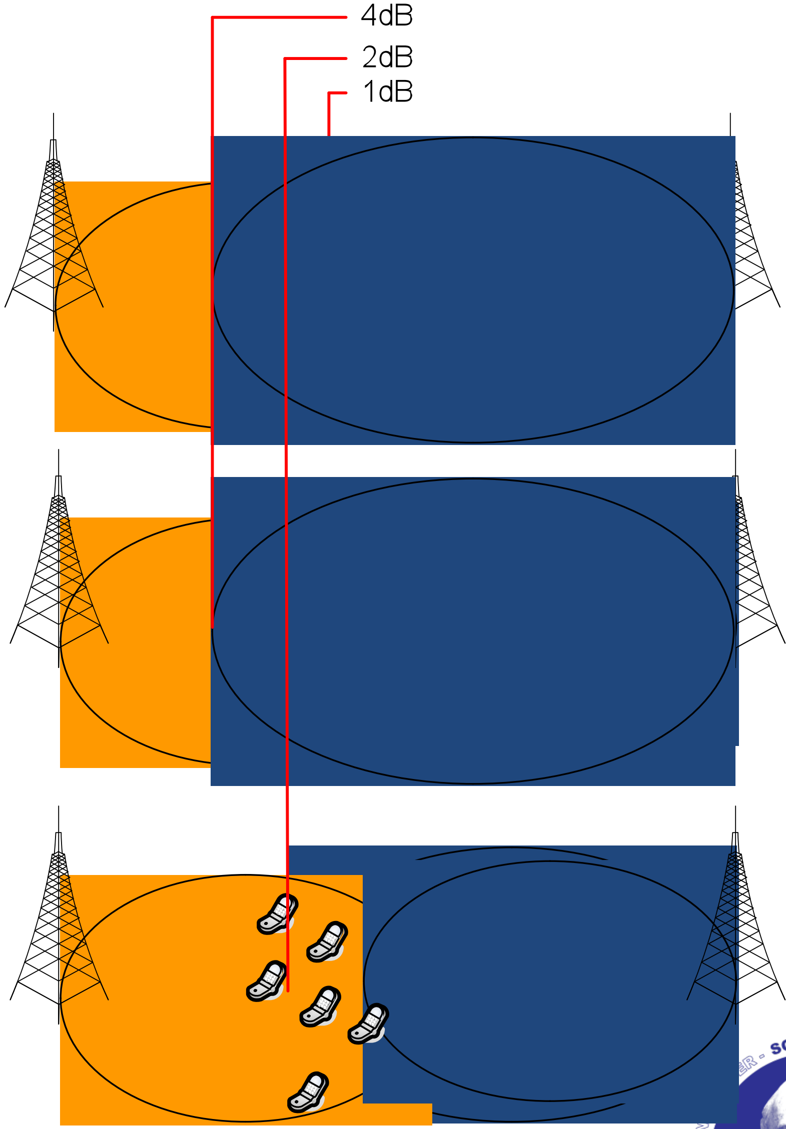
- Unsatisfied users due to resources limitation
- The total number of unsatisfied users in the whole network (which is the sum of unsatisfied users per cell, where number of users in cell *c* is represented by *Mc*)

$$z = \sum_{\forall c} \max\left(0, M_c \cdot \left(1 - \frac{1}{\hat{\rho}_c}\right)\right)$$

- LB performance evaluation by ‘z’ metric

How to adjust optimum HO offset

- Increasing HO offset by HO step value in few iteration
  - Time consuming
  - Load after HO may exceed available resources
- Increasing HO offset in one iteration (history)
  - Load after HO may exceed available resources
- Increasing HO offset by one accurate value in one iteration
  - Load estimation after HO required



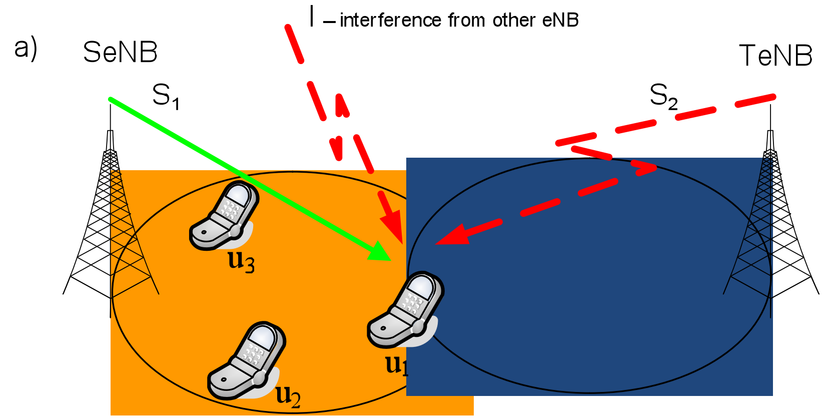
Load estimation DL

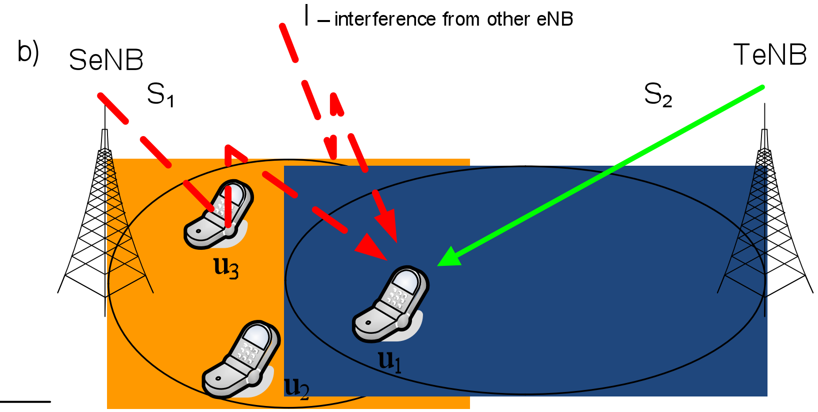
- Prediction method for load required at TeNB
  - Base on SINR estimation after LB HO
  - Utilise UE measurements RSRP, RSSI
- Before HO
  - The RSRP signal from TeNB is a component of total interference as well as signals originated from other eNBs (represented by I)

$$I_{u_1} = S_2 + \sum I \qquad SINR_{u_1,SeNB} = \frac{S_1}{N + S_2 + \sum I}$$

- After HO
  - received signal S_1 now contributes to the interference signal at u_1 whereas signal S_2 from TeNB is the wanted signal

$$SINR_{u_1,TeNB} = \frac{S_2}{\frac{S_1}{SINR_{u_1,SeNB}} + S_1 - S_2}$$





LB algorithm

- Inputs
  - List of potential Target eNB
  - Available resources at each TeNB
  - Collect measurements from users
- Adjusting optimum HO offsets
  - Estimate load after HO
  - Sort users regarding to the required HO offset
  - Calculate estimated load at TeNB for first group of users and compare with available space
  - If exceed available resources take next cell from list
  - If SeNB is still overloaded increase HO offset
- Algorithm works until
  - load at SeNB is higher than accepted level
  - HO offset is below max
  - Neighbours are able to accommodate more load

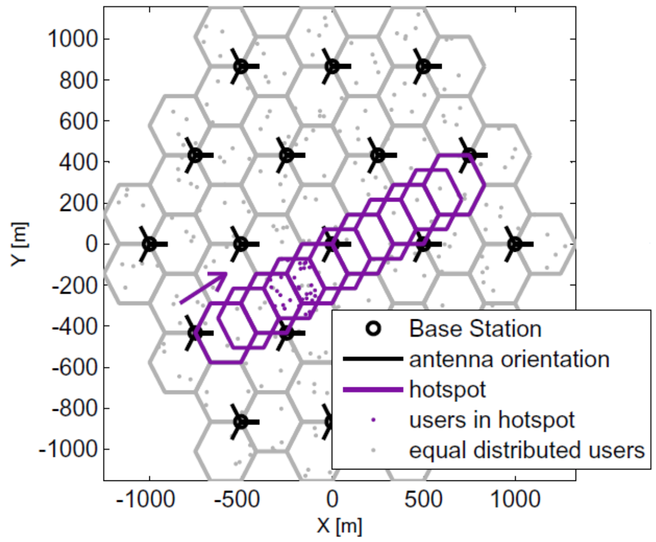
Algorithm 1 HO offset based LB algorithm

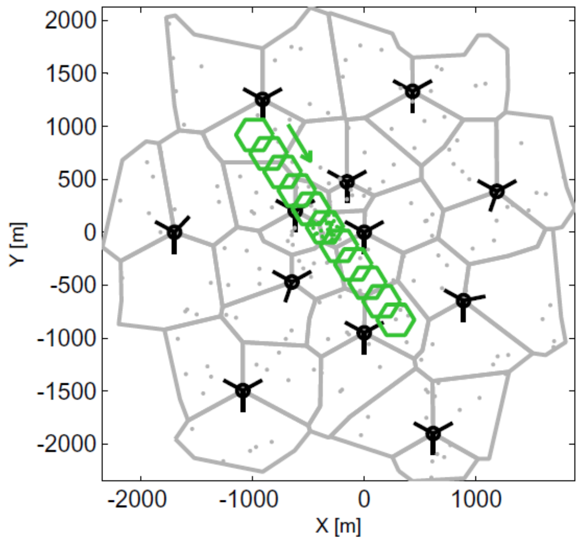
Require: List L of potential Target eNB (TeNB) for LB HO

1. collect measurements from user:; RSRP to potential TeNB,
2. group users corresponding to the best TeNB for LB HO (criterion is the difference between SeNB and TeNB measured signal quality),
3. obtain information from TeNB on available resources,
4. estimate a number of required PRBs after LB HO for each user in the LB HO group,
5. $T \Leftarrow 0$
6. **while** $\rho_{SeNB} > \rho_{Thld,SeNB} \wedge T < T_{max}$ **do**
7. $i \Leftarrow 1$
8. $T \Leftarrow T + step$
9. $L \Leftarrow sort$ (TeNB according to number of users allowed to LB HO with given T, descending order)
10.   **while** $\rho_{SeNB} > \rho_{Thld,SeNB} \wedge i \leq size(L)$ **do**
11. $C \Leftarrow L(i)$ {take next cell from list}
12.   estimate $\widehat{\rho}_c$ after HO for given T
13.   **if** $\widehat{\rho}_c < \rho_{Thld,C}$ **then**
14. $\rho_{SeNB} \Leftarrow \rho_{SeNB} - \rho_{SeNB,T}$ {update load in overloaded cell by substract handed over load}
15. $T_{C,u} \Leftarrow T$
16.   **end if**
17. $i \Leftarrow i + 1$
18.   **end while**
19. **end while**
20. adjust HO offsets T_C

Artificial scenarios

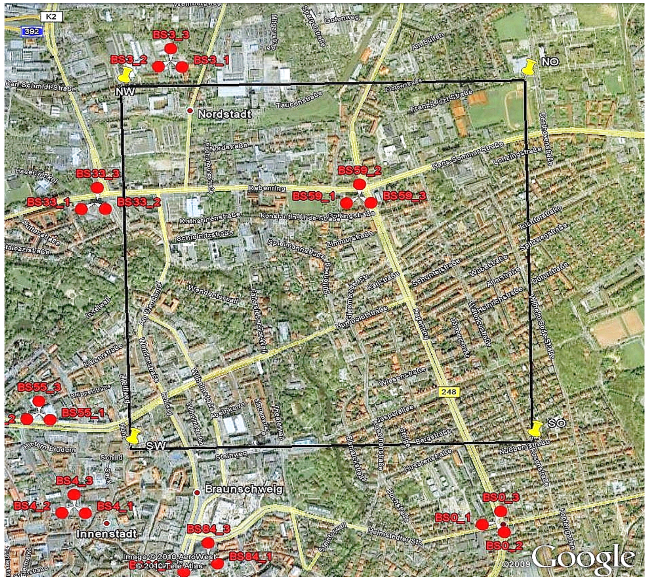
- Regular network grid
  - 19 sites
  - 3 sectors per site (57 cells)
- Non regular network grid
  - 12 sites
  - 3 sectors per site (36 cells)
  - real network effects:
    - different cell sizes,
    - number of neighbour cells,
    - interference situations.
- Background users equally dropped (both scenarios)

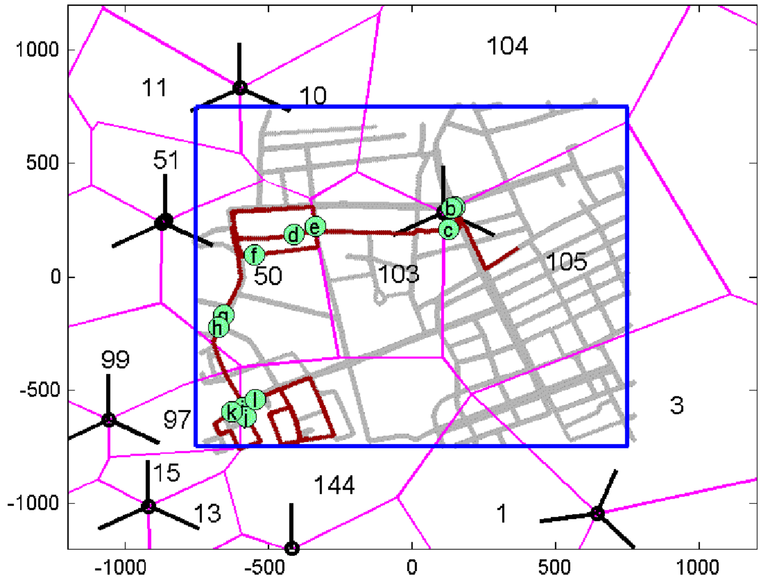




Realistic scenario - bus

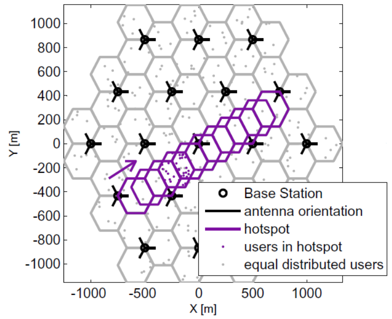
- Real layout of the existing 2G and 3G macro networks
- Cover area of 72 km x 37 km
  - 103 sites, 3 sectors per site (309 cells)
- Area of 1.5 km x 1.5 km (Braunschweig downtown) with the users mobility model (SUMO)
- Bus is moving with the variable speed (Brawn line –bus route)
- user data: new position every 100 ms, Rx power of 30 strongest signals from surrounding BSs

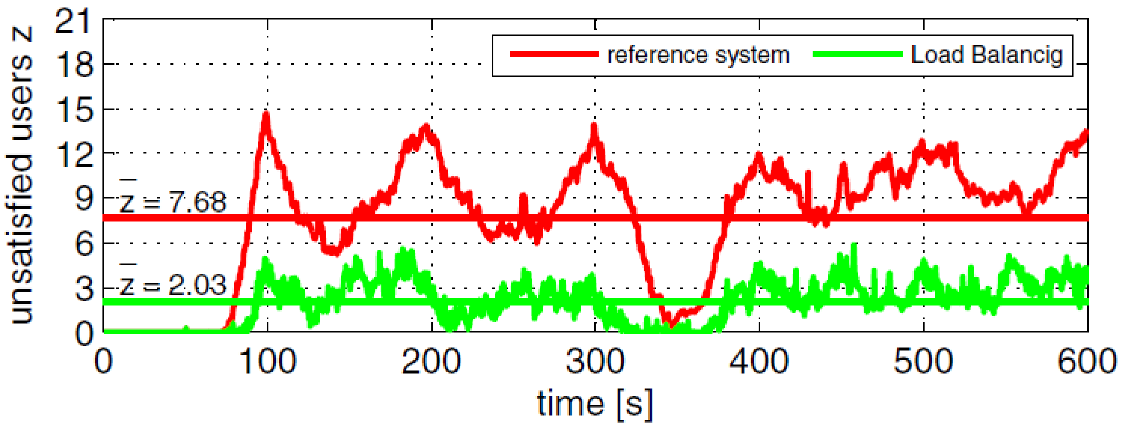




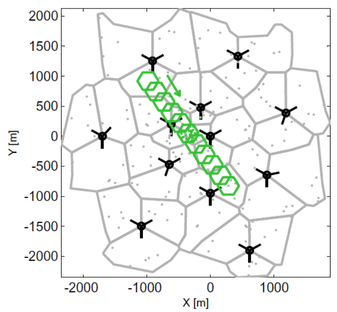
Simulation result, artificial scenario

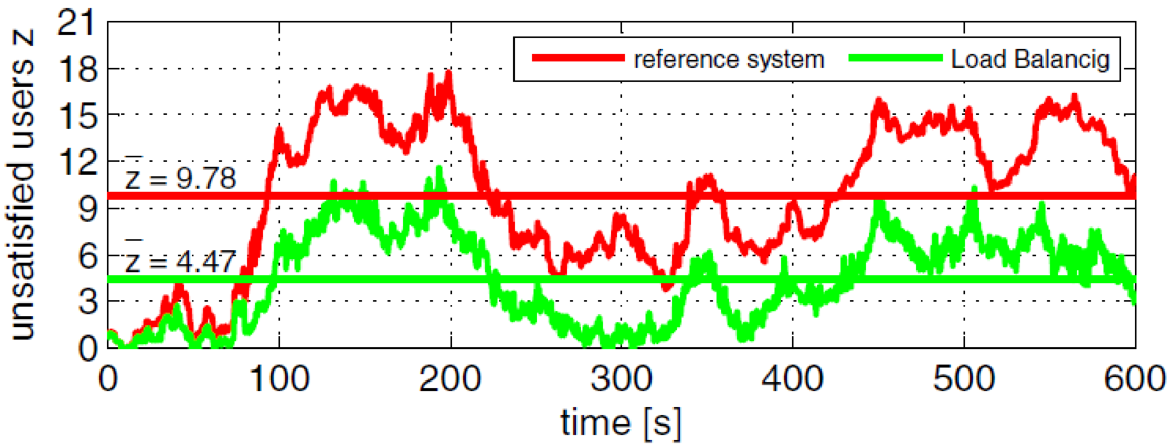
Regular (40 users in hot spot, 5 users per cell in background)



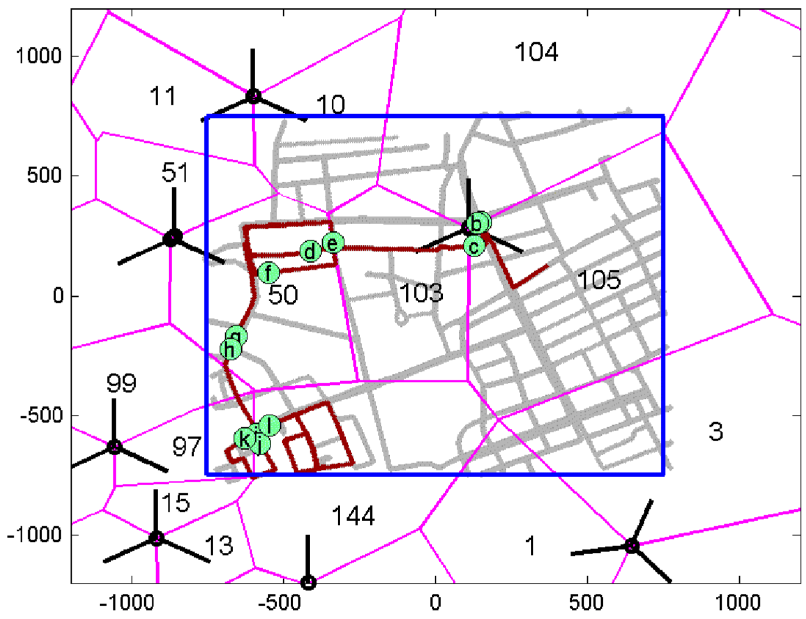


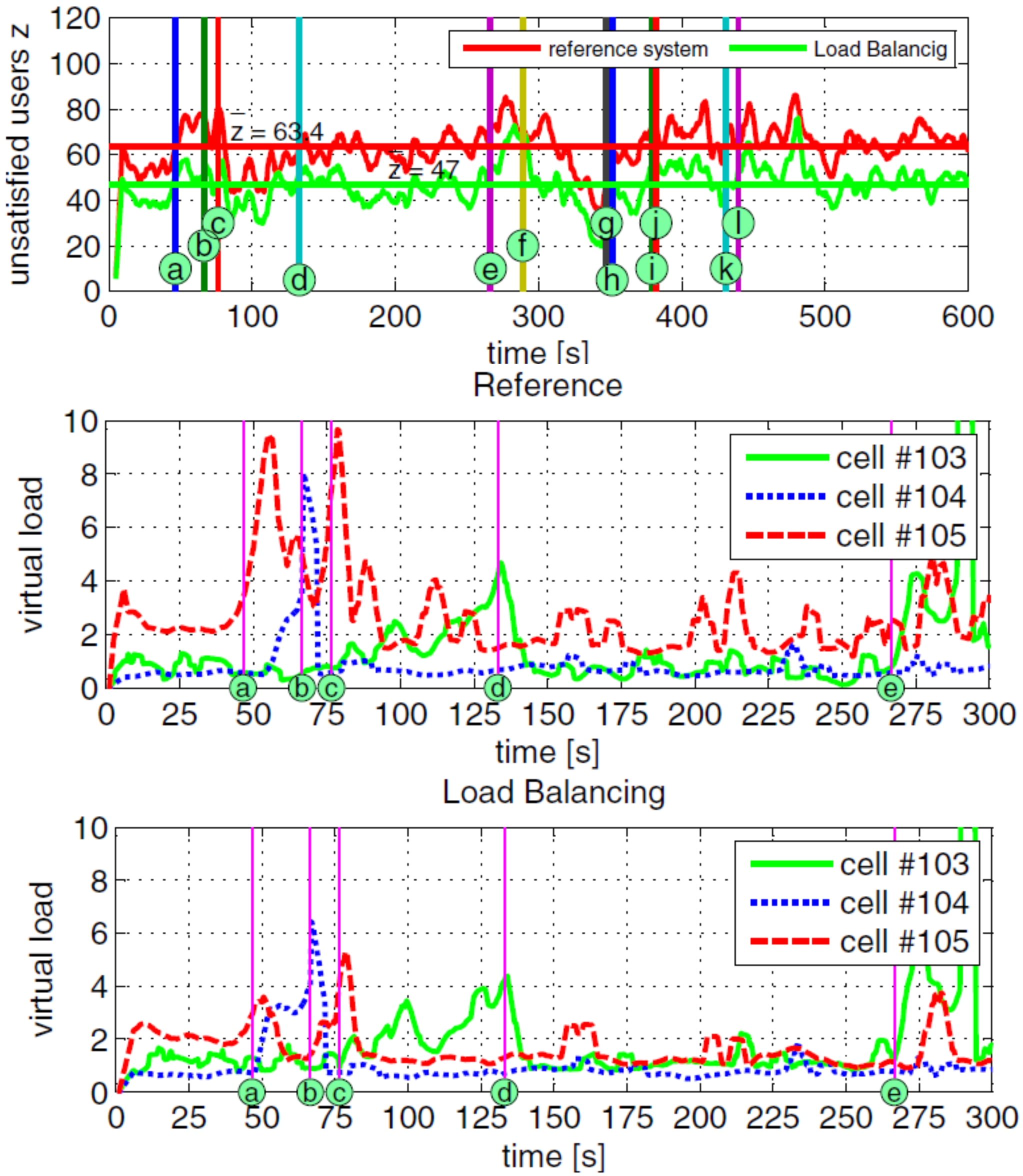
Non regular (40 users in hot spot, 5 users per cell in background)





Simulation result, real scenario





a → 104; b → 105; c → 103;

d → 50; e → 103; f → 50;

g → 99; h → 50; i → 15;

j → 97; k → 15; l → 144

Simulation results – different operating points

Users in hot spot, bus	Average number of unsatisfied users					
	regular		non regular		realistic	
	Ref	LB	Ref	LB	Ref	LB
20	-	-	-	-	47.0	30.6
30	2.8	0.3	3.2	0.7	53.8	37.8
40	7.7	2.0	9.8	4.5	63.4	47.0
50	13.6	6.4	16.8	10.6	74.3	58.8
60	22.0	15.5	23.1	17.4	86.6	68.2

Conclusions

- General conclusion: the average number of satisfied users can be improved with load-balancing.
- LB algorithm:
  - works on the measurements, information elements and control parameters defined by 3GPP for LTE Release9
  - deals with the overload in a suitable way and reduces the overload significantly.
  - Utilised method of load estimation after HO, which is based on SINR prediction is efficient
- Improve network performance in simulations, with synthetic data in regular and non regular network types and also simulations of realistic data
- Gain depends on the local load situation and the available capacity

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Thank you