Load Balancing in Downlink LTE Self-Optimizing Networks

TD (10)10071

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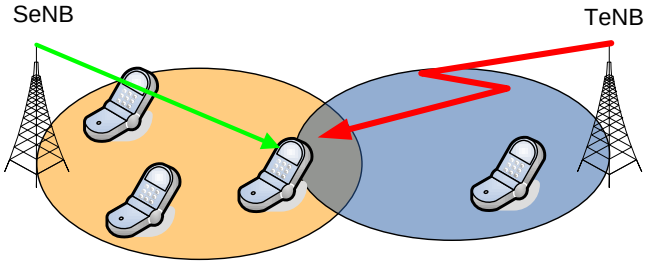
NSN, Wroclaw, Poland
NSN, Munich, Germany
TUBS, Braunschweig, Germany
IBBT, Ghent, Belgium

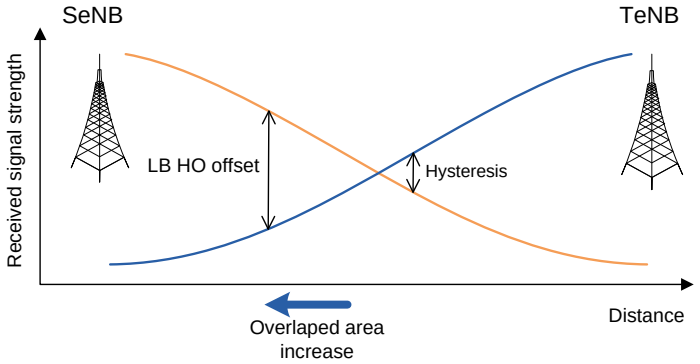
Outline

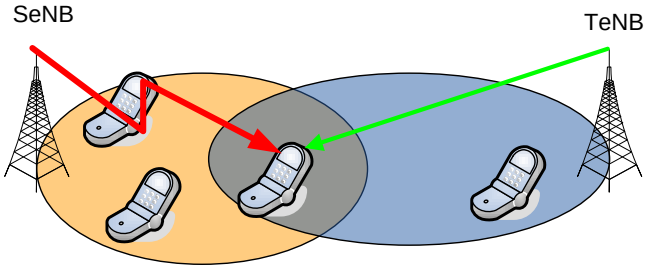
1. Introduction
2. Simulation metrics
3. Load balancing algorithm
4. Load estimation for the target eNodeB
5. Simulation scenarios
6. Simulation results
7. Conclusion

Introduction

- Problem
  - Users concentrate in the area served by one cell
  - Unequal load distribution causes an overload
  - Users can not be served with required quality level due to lack of resources
- Main Idea
  - Reallocate some users from the overloaded cell to less loaded neighbour cell(s)
  - Overloaded (SeNB) cell must find neighbour cell(s) (TeNB) which may accommodate additional load
  - SeNB adjusts the HO offset of the TeNB and forces users to HO to the TeNB
- Result
  - TeNB increases the overlapping area and takes over some users previously served by SeNB
  - LB operation sets free resources at SeNB
  - SeNB is able to serve remaining users with the required QoS







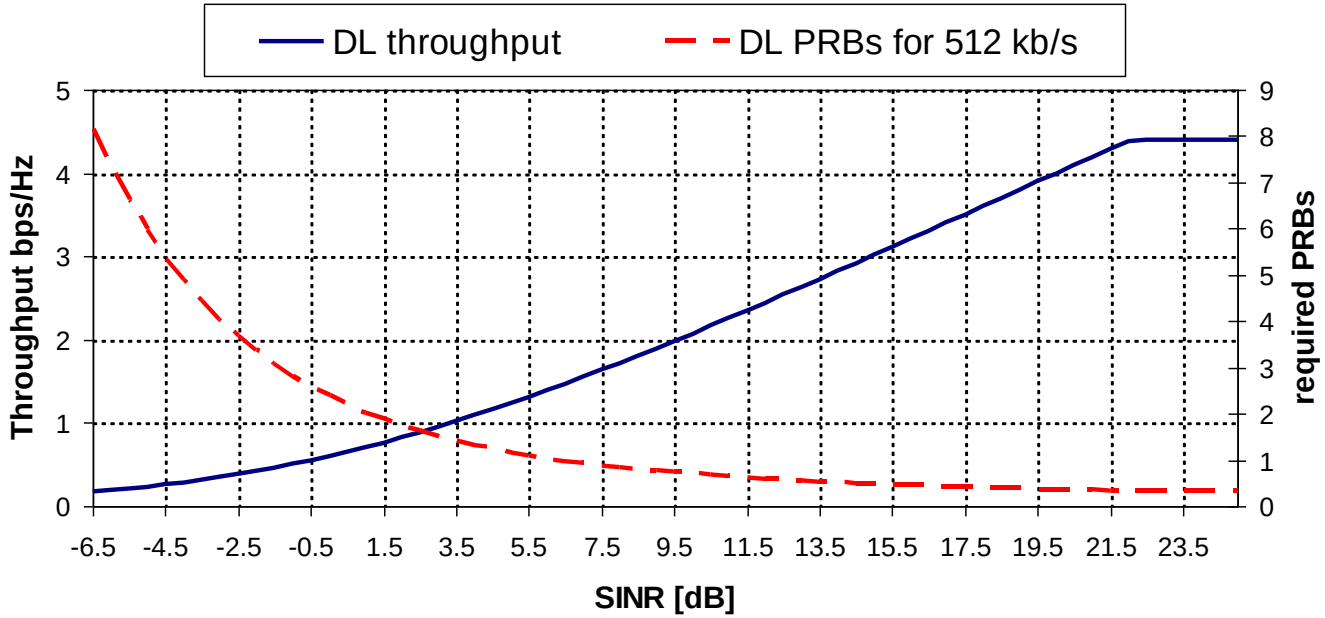
Virtual load

Virtual cell load can be expressed as the sum of the required resources of all users *u* connected to cell *c* by connection function *X(u)* which gives the serving cell *c* for user *u.*

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

- *Du* is the average data rate requirement per user *u*
- *R*(*SINRu*) is the average throughput data rate per physical resource block (PRB) for user u
- M_{PRB} is the number of available PRBs
- 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

Throughput mapping



- Throughput mapping bases on the concept of a truncated Shannon-Gap mapping curve

$$Thr(SINR) = \log_2 (+ SINR)$$

- The necessary number of PRBs for the required throughput Du and the transmission bandwidth of one PRB BW = 180 kHz can be obtained from the following equation

$$N_{PRB} = \frac{D_u}{Thr(SINR) \cdot BW}$$

LB performance evaluation z metric

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

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

- Unsatisfied users due to power limitation (applies to UL transmission) z_{power}

$$z_{power} = \sum_{\forall c} \sum_{\forall u | X_u = c} \begin{cases} 0 & for \quad M_{\max,u} <= \dfrac{D_u}{R(SINR_u)} \\ 1 & for \quad M_{\max,u} > \dfrac{D_u}{R(SINR_u)} \end{cases}$$

  - Where Mmax,u denotes the maximum number of PRBs that can be granted to user *u*

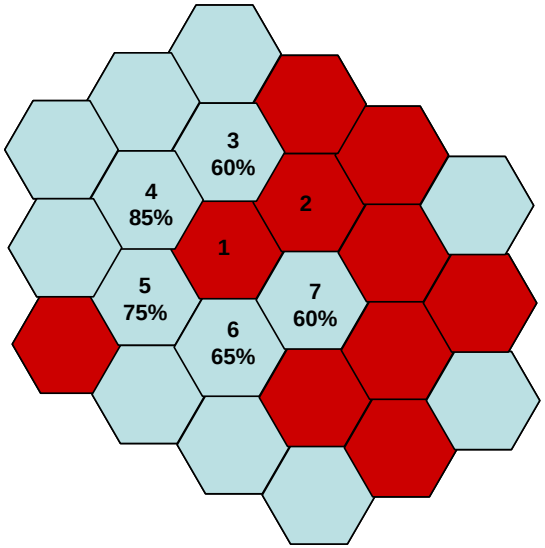
LB algorithm

- The load level of all cells is permanently monitored
- If the load level exceeds a certain threshold the load balancing is initiated

1. Sort all users by their SINR
2. Split the users in groups (according to the best suited target eNodeB)
3. Decide on the users to be handed over to other cells (based on the remaining cell load target for the source eNodeB)
4. Assure that the target eNodeBs are not overloaded after the load balancing activity
5. Modify the HO thresholds of the target eNodeBs
6. Send HO command to the selected users

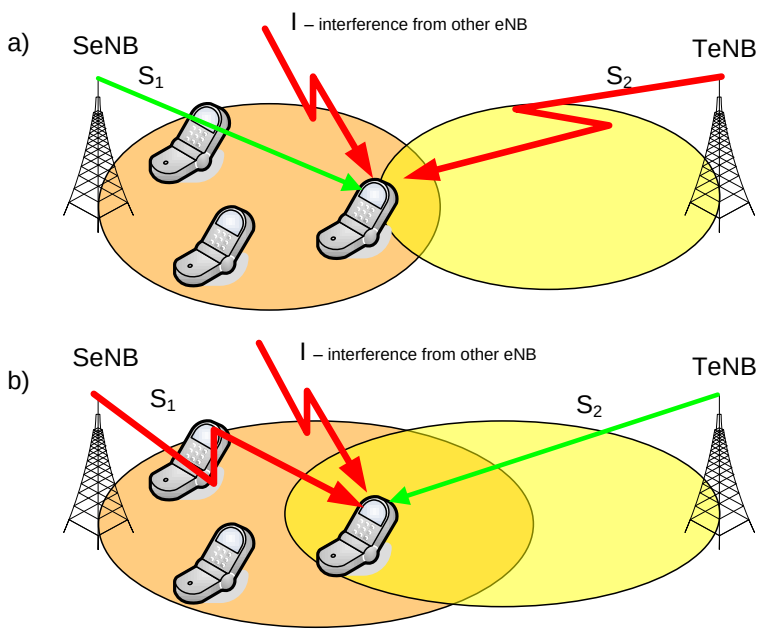
List of target eNodeBs for load balancing

- We propose a decentralised load balancing solution
  - all neighbouring eNodeBs are potential targets for load balancing
  - the decision depends on the reported load situation from all eNodeBs
- An decision made by one individual eNodeB cannot take the larger network environment into account (e.g. the neighbour of the neighbouring eNodeB of the overloaded cell may be also be overloaded)
  - the central load balancing entity can report the cell load of the 2nd neighbours
- The central entity provides guidelines on LB priorities
  - cell 1 can obtain information about its neighbour cells over X2
  - best target cells for cell #1 seem to be cells # 3 and # 7
  - based on the overall load distribution available in the central SON entity we generate a priority list for the load balancing event:
    - 4
    - 5, 6
    - 3
  - Cell # 7 is not on the list (LB to this cell is not allowed)
  - Cell #3 has the lowest priority due to the load situation in cell # 2
- The central entity has been presented by NSN in the SA5 meeting in Vancouver (pseudo CR for TS 32.521)

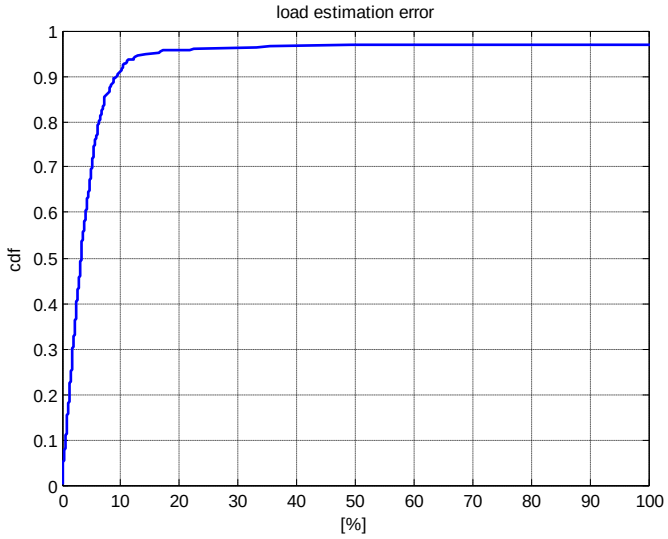


Load estimation in the downlink

- The load estimation at the TeNB has to be computed before the LB
- It is based on a SINR estimation for the time after the LB
  - Required UE measurements RSRP
  - We assume that the UE does not change its position during the LB operation

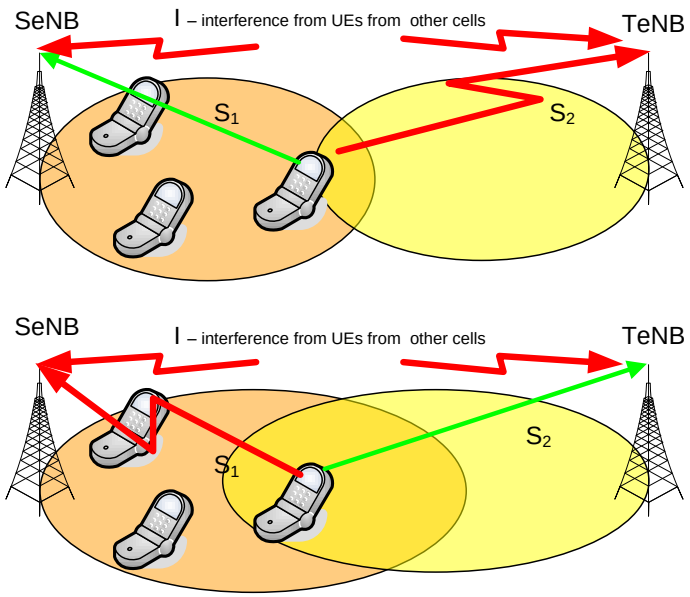


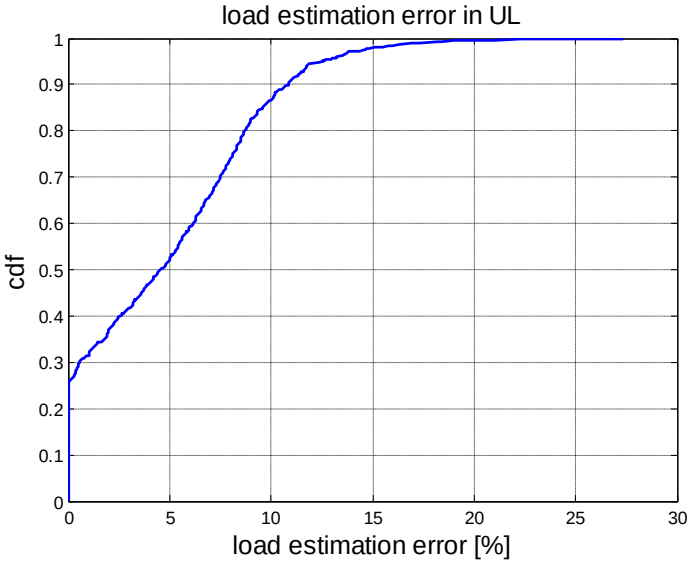
$$SINR_{TeNB} = \frac{S_2}{\frac{S_1}{SINR_{SeNB}} + S_1 - S_2}$$



- Load estimation error measured for moving hotspot
- Accuracy of load estimation could be higheer if users are fixed

Load estimation in the uplink





$$SINR_{TeNB} = SINR_{SeNB} + \Delta S + \Delta IoT$$

This equation is valid for users not limited in power

- Load estimation error measured for a moving hotspot
- Accuracy of the load estimation could be higher if users would be static
- IoT cannot be predicted, we assumed small changes during the LB

Scenarios for evaluation studies

Study 1: Impact of environment

Scenario proposal: In a network setting with multiple cells consider different site to-site distances and cell types

- Hexagonal network grid ISD 500m
- Hexagonal network grid ISD 1700m
- Nonregular network grid

Study 2: Impact of service type

Scenario proposal: Consider scenarios with a high and/or low rate of broadband service users. The load situation in the surrounding cells should also be varied for this study for the sake of service type or link direction.

- Like VoIP service, UL/DL 30 kbps
- Like video service, DL 512kbps, UL 256 kbps

Study 3: Impact of user mobility

Scenario proposal: The speed of the users should be varied to create scenarios with high/low user mobility

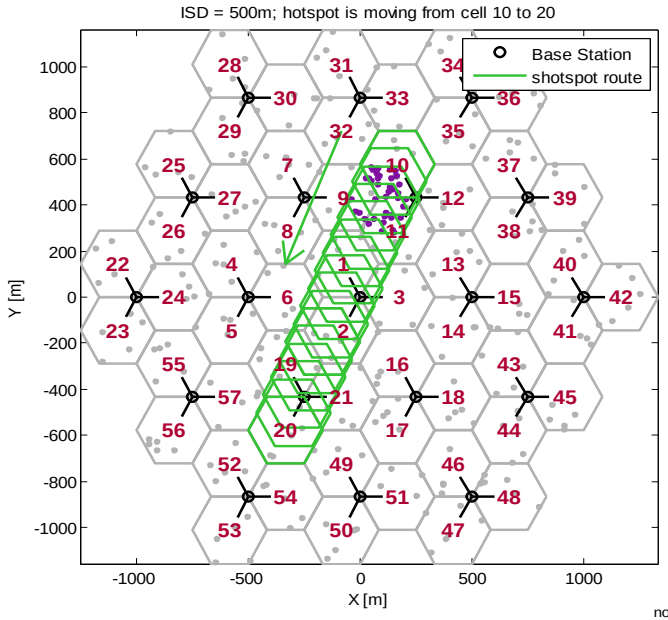
- User mobility speed 3 km/h
- User mobility speed 30 km/h

Study 4: Impact of traffic load

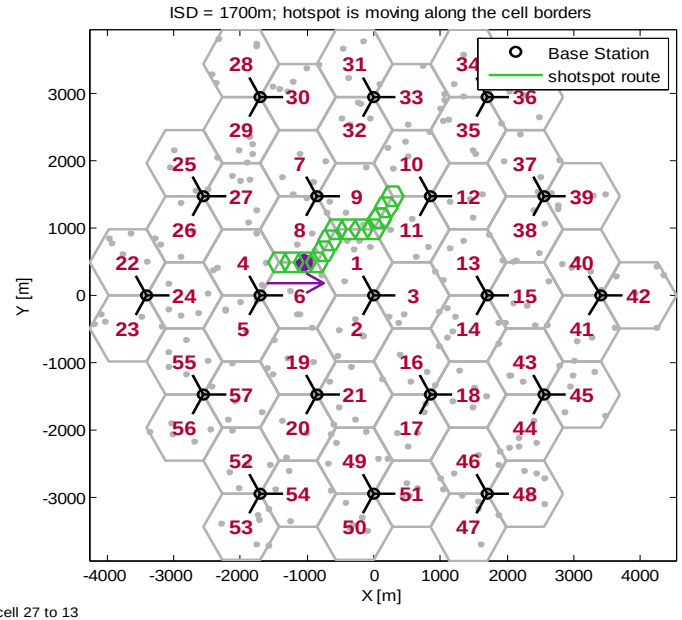
Scenario proposal: The amount of traffic load, load balance, size and shape of the overloaded area and location of the overloaded area should be varied in the scenarios.

- Users move through cells
- Users move along the cell borders

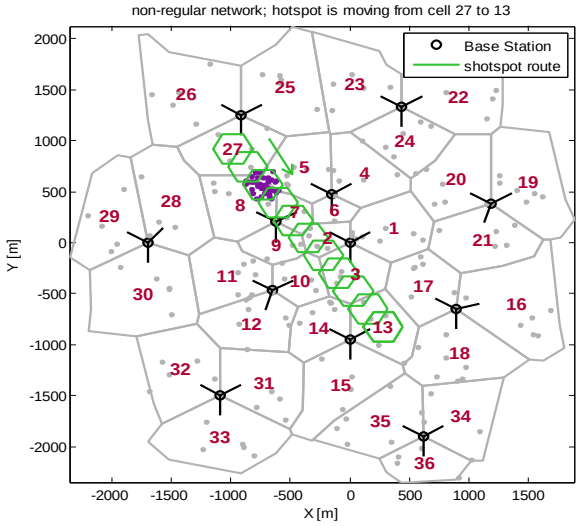
Network layouts and hotspot routes



1) Regular network layout, hotspot moving through the cells



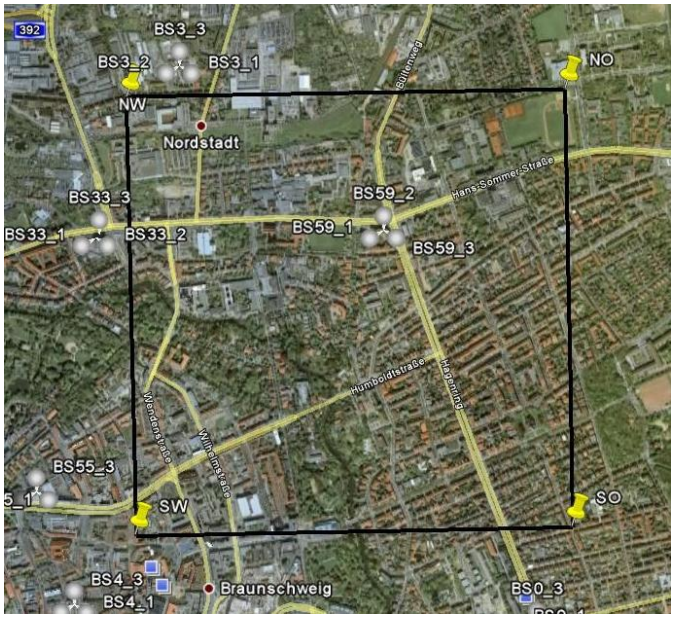
2) Regular network layout, hotspot moving along the cell borders

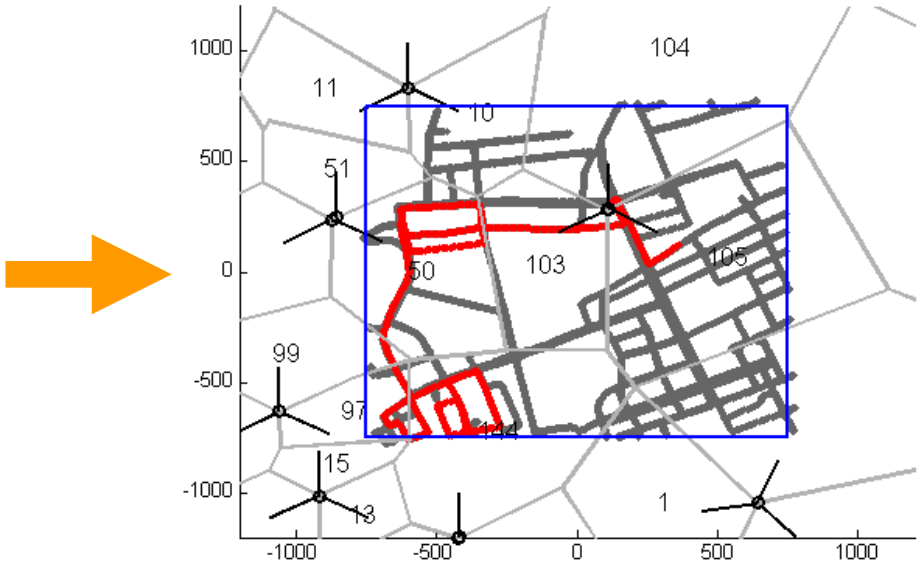


3) Non regular network layout, hotspot moving through the cells

Realistic SOCRATES scenario – Bus scenario

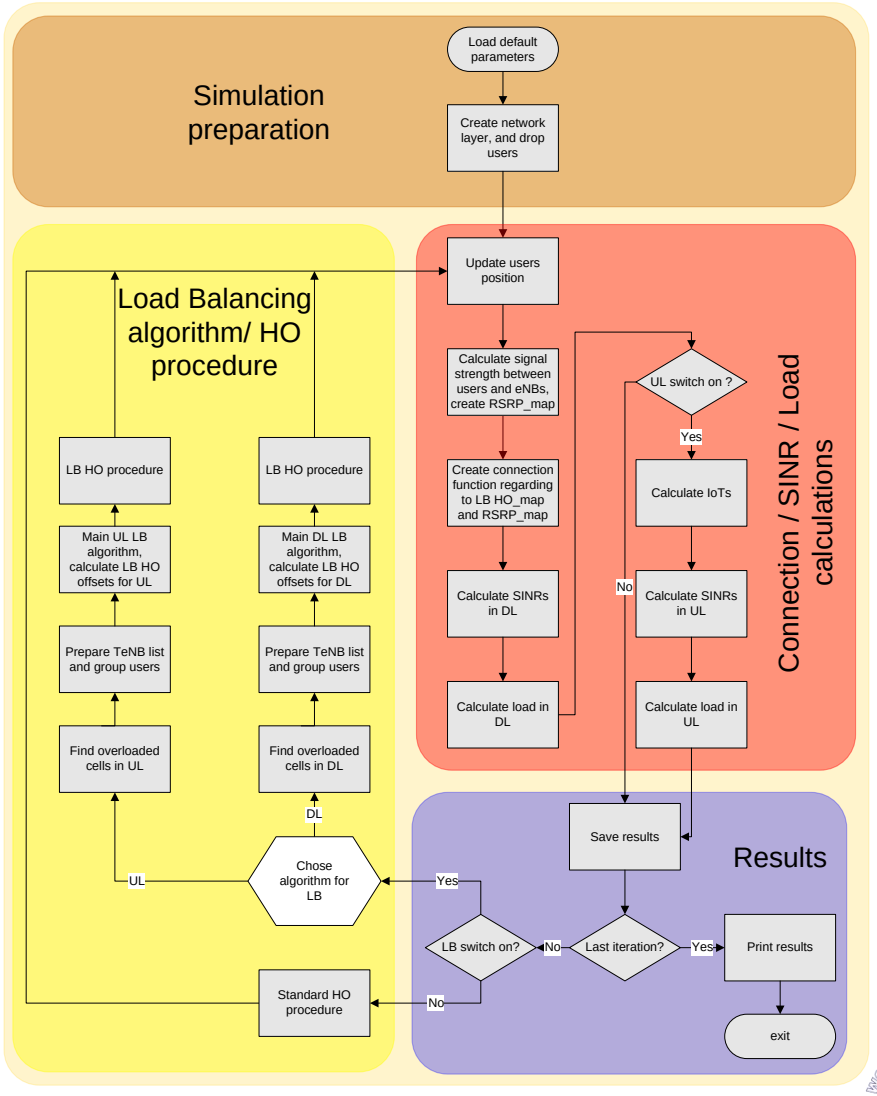
- Background users: static users in buildings and dynamic users moving along the streets
- Bus is moving with variable speed of 0 – 50 km/h (Red line – bus route)
- Grey lines indicate the theoretical cell borders (without shadowing)





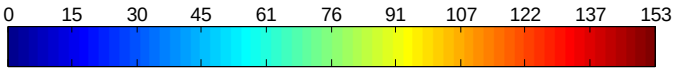
Simulation tool

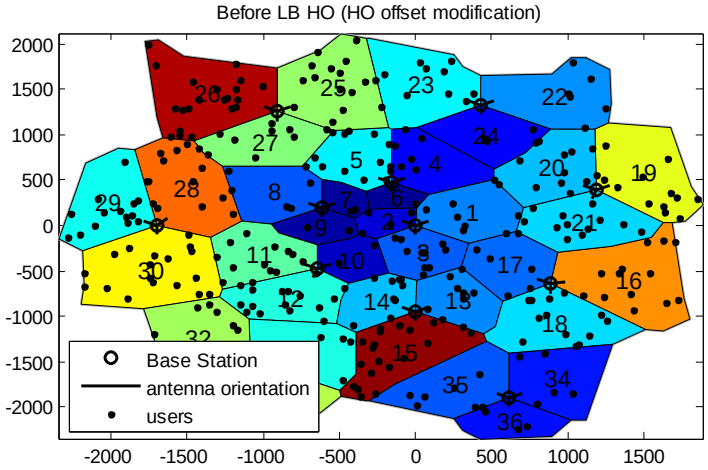
- Matlab based simulator
- Almost real time simulations ☺
- Modular structure
- Dynamic simulations
- DL and UL implemented
- Different network layouts

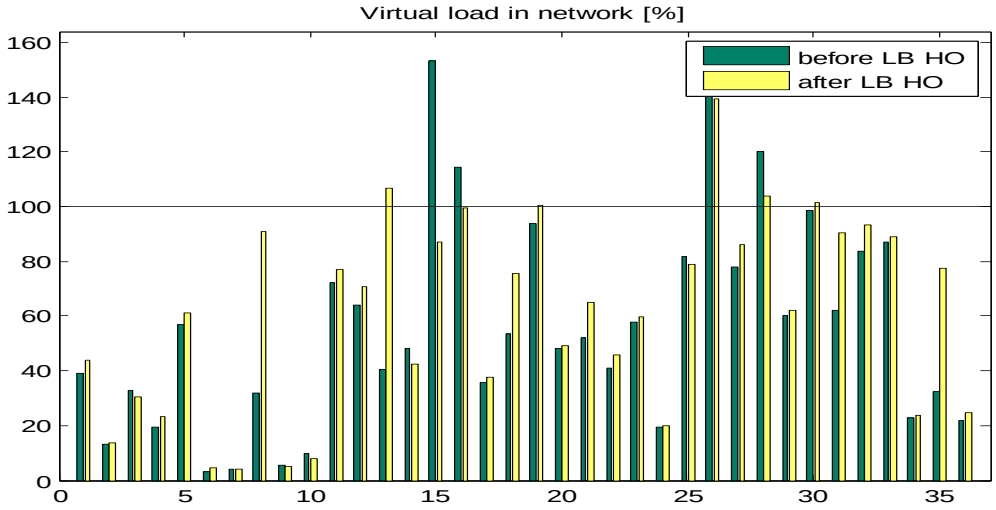


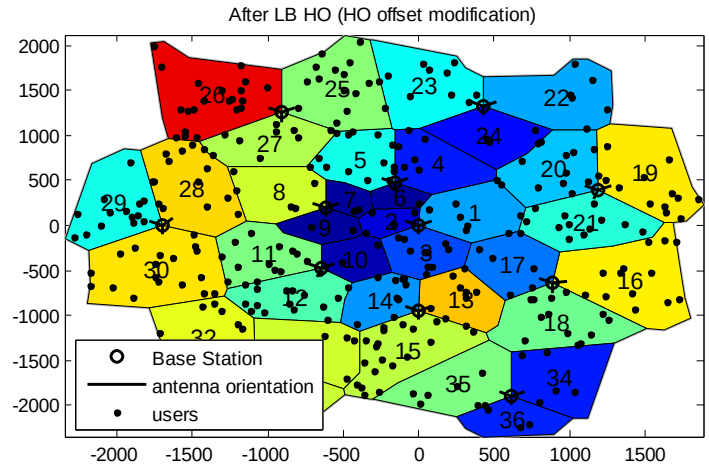
First results without load estimation

- LB algorithm base on HO offset
- During LB operations TeNB can be overloaded (lack of admission control mechanism)
- Important load estimation at TeNB after LB HO

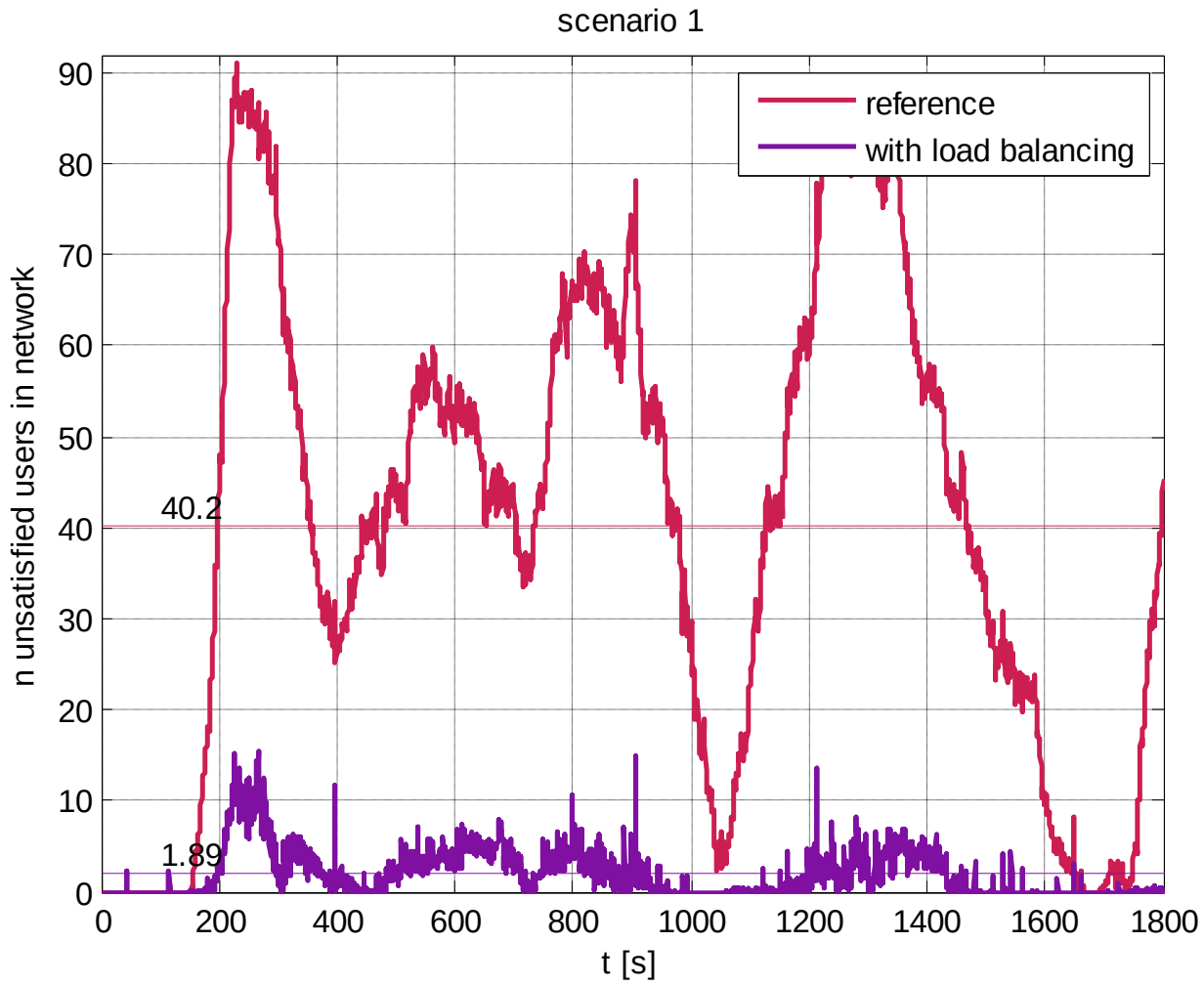






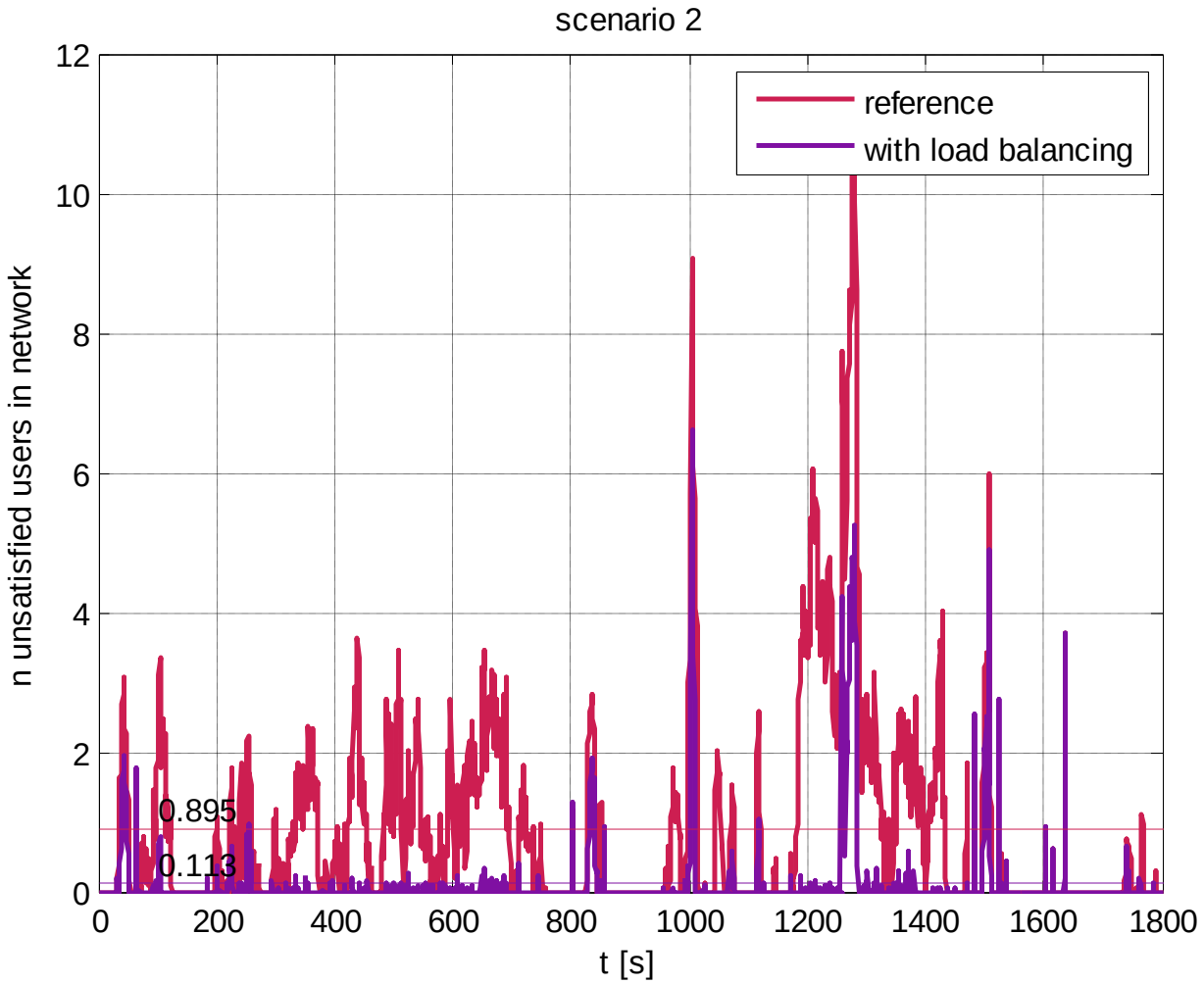


Downlink simulation results



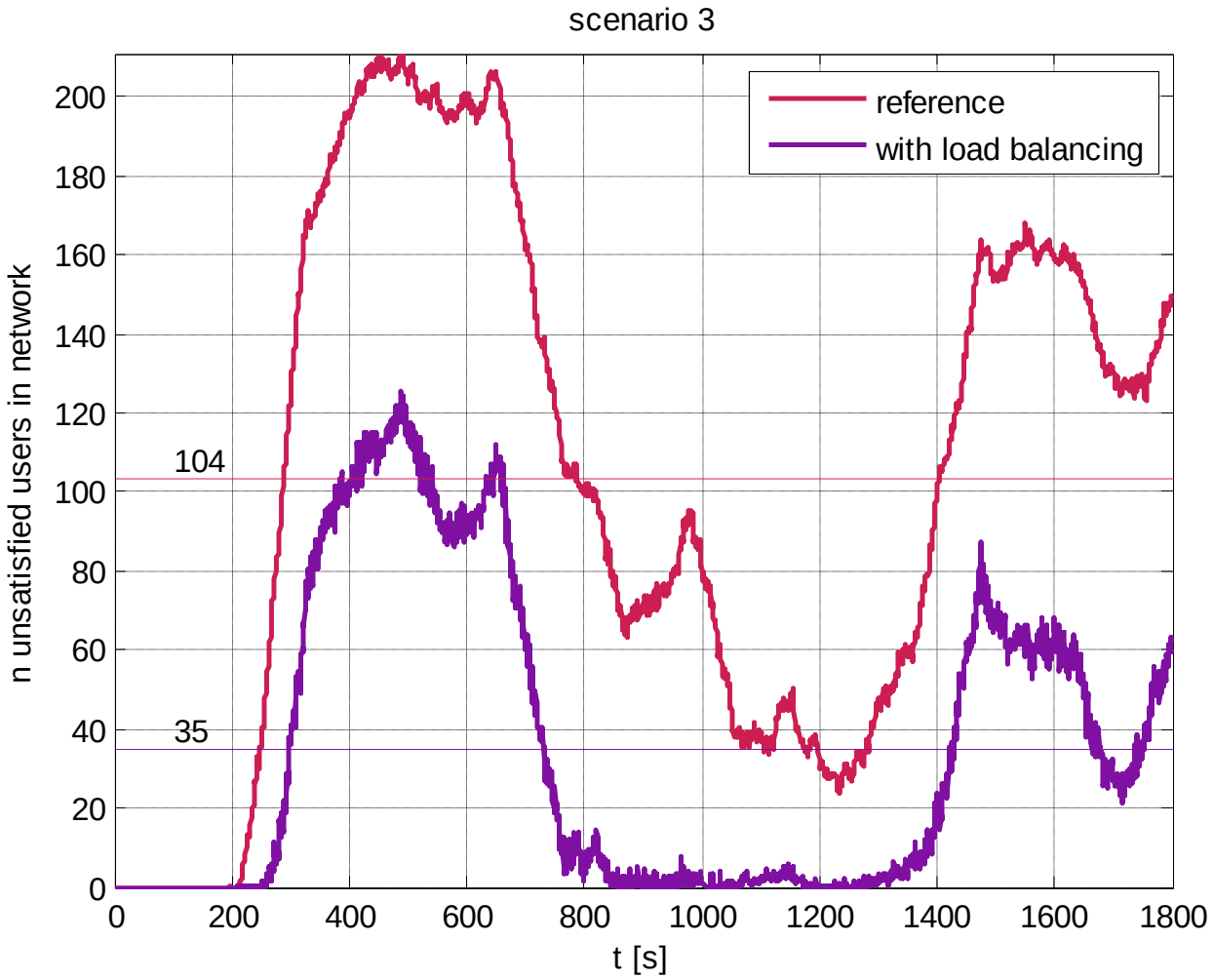
1) Regular network ISD = 500m

Downlink simulation results



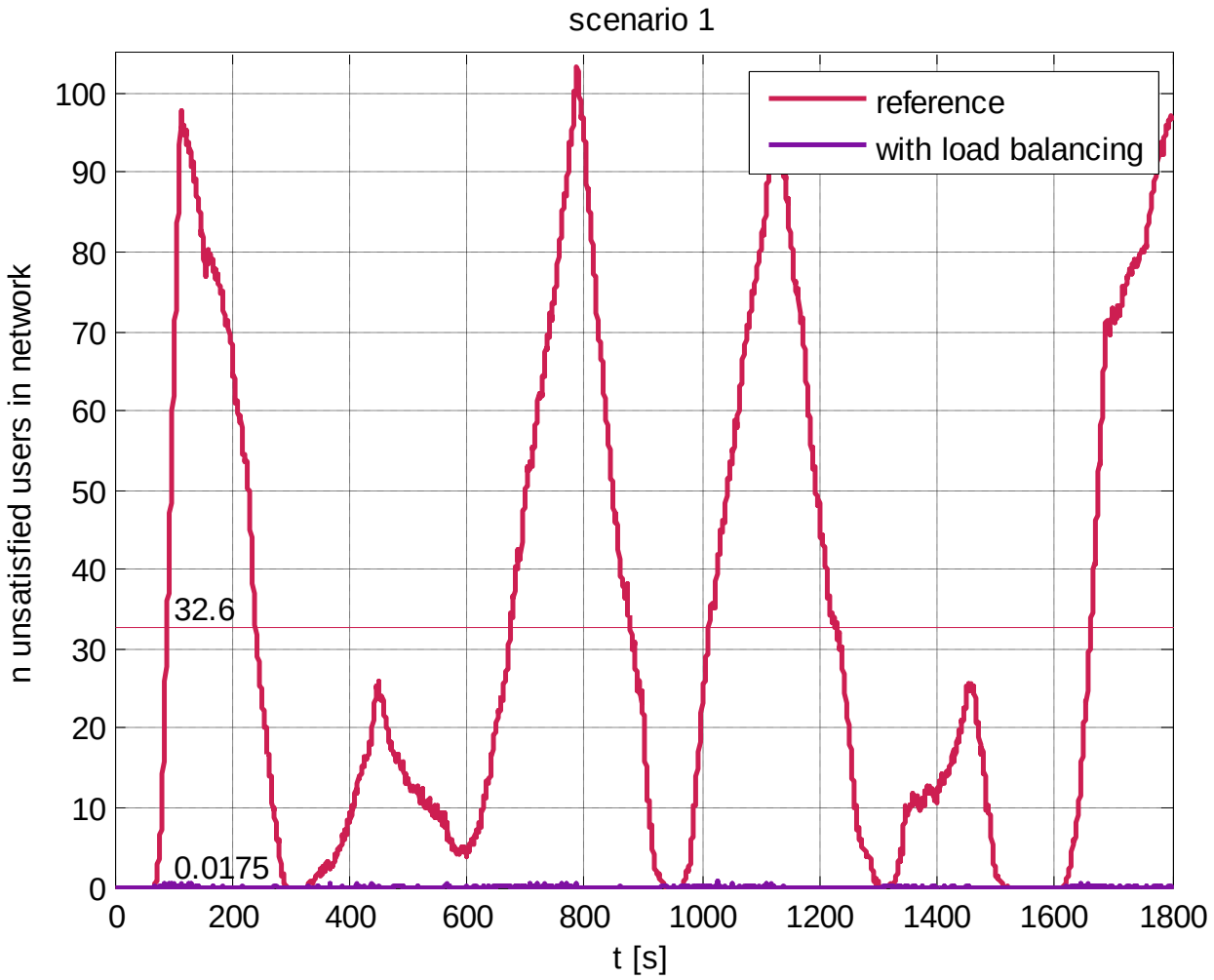
2) Regular network ISD = 1700m

Downlink simulation results



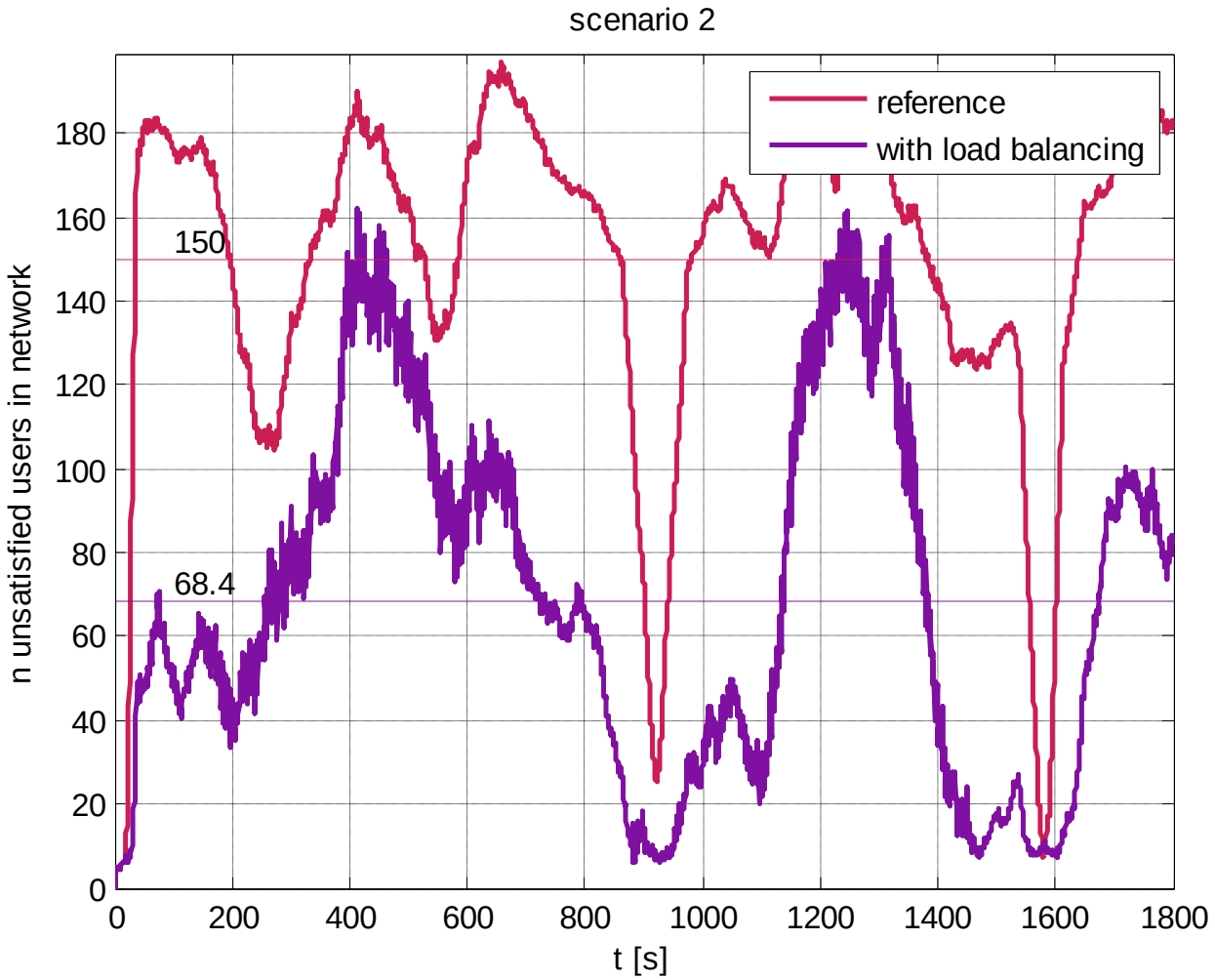
3) Non regular network

Uplink simulation results



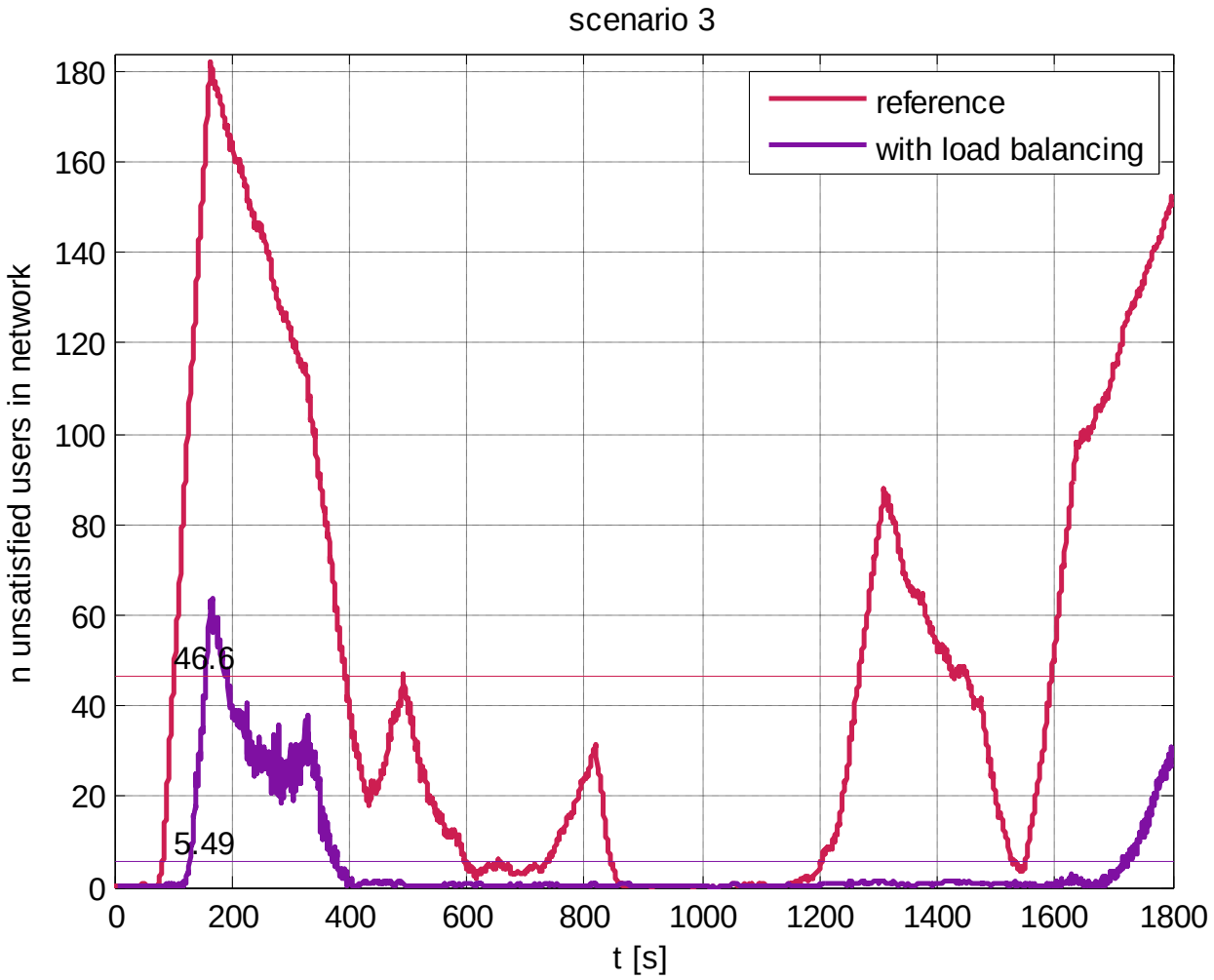
1) Regular network ISD = 500m

Uplink simulation results



2) Regular network ISD = 1700m

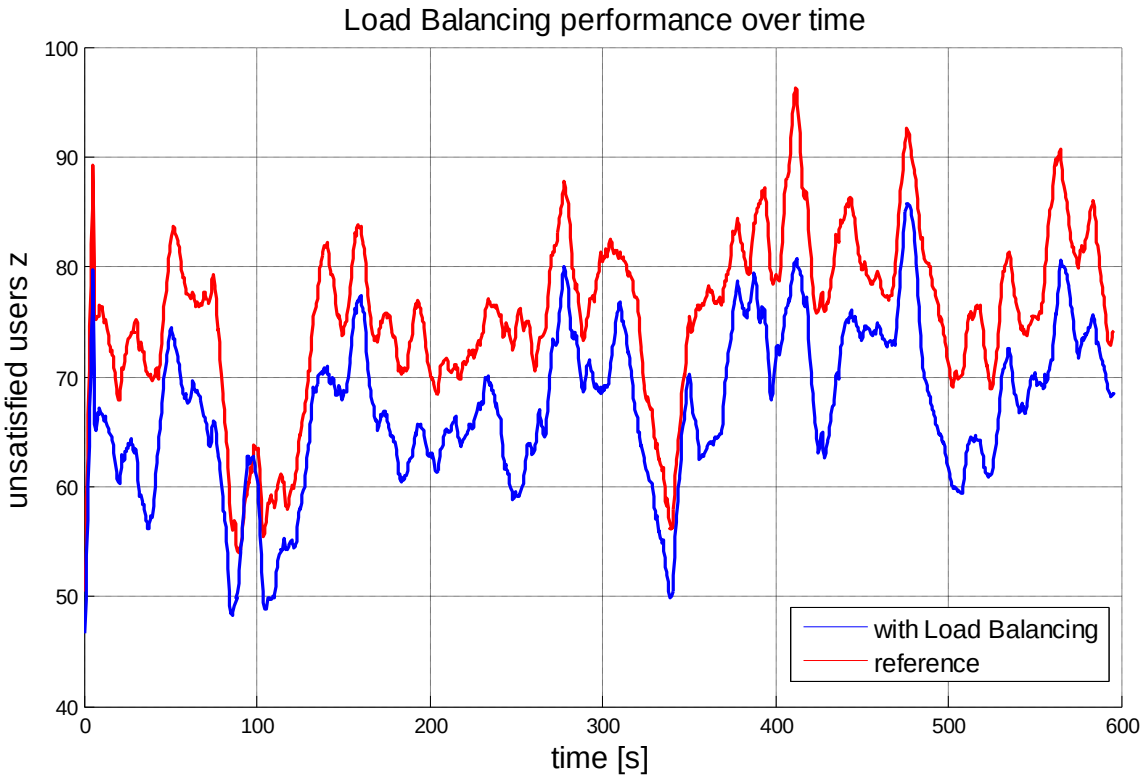
Uplink simulation results



3) Non regular network

Simulation results using the realistic SOCRATES scenario

- Simulation time 10 min
- 100 static background users
- 100 dynamic background users
- 40 users in the bus
- Reference case
  - 75.7 unsatisfied users
- Load Balancing
  - 67.3 unsatisfied users



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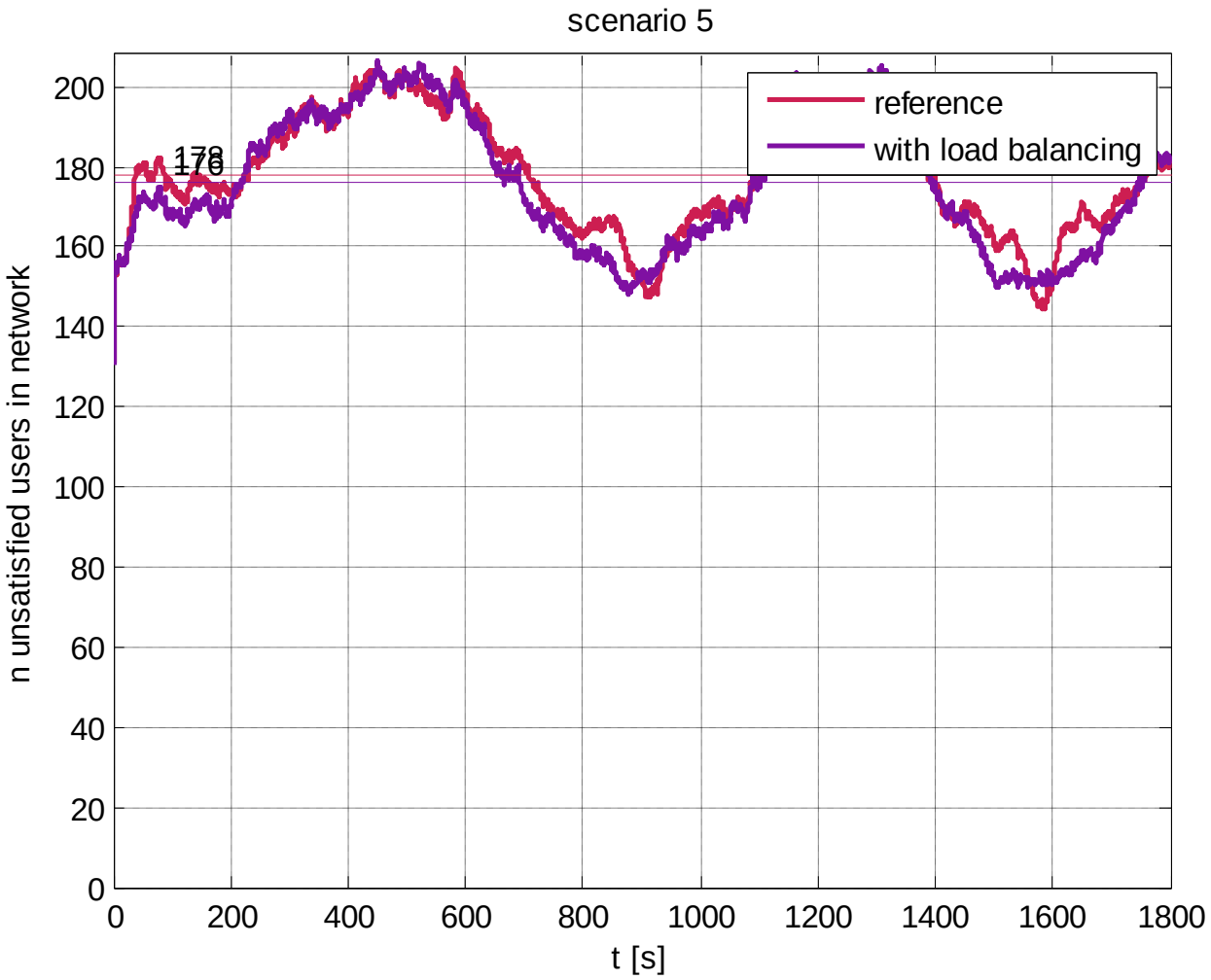

3) Regular network ISD = 500m

Conclusions

- The proposed algorithm reduces the overload significantly of the cells and increases the number of satisfied users
- Several simulation scenarios have been considered
- In almost every case the algorithm increased the system performance
- The algorithm works on the measurements, information elements and control parameters defined in 3GPP for LTE Release9
- UL power limitation is the most limiting factor for load balancing activities

Thank you very much for your attention