TECHNICAL UNIVERSITY OF KENYA

Education and Training for the Real World

THE USE OF CELL-SPECIFIC OFFSETS FOR LOAD BALANCING IN HETEROGENEOUS LTE-A NETWORKS

Ronoh Kennedy

kenronoh@gmail.com

The Technical University of Kenya

Department of Computer Science

Outline

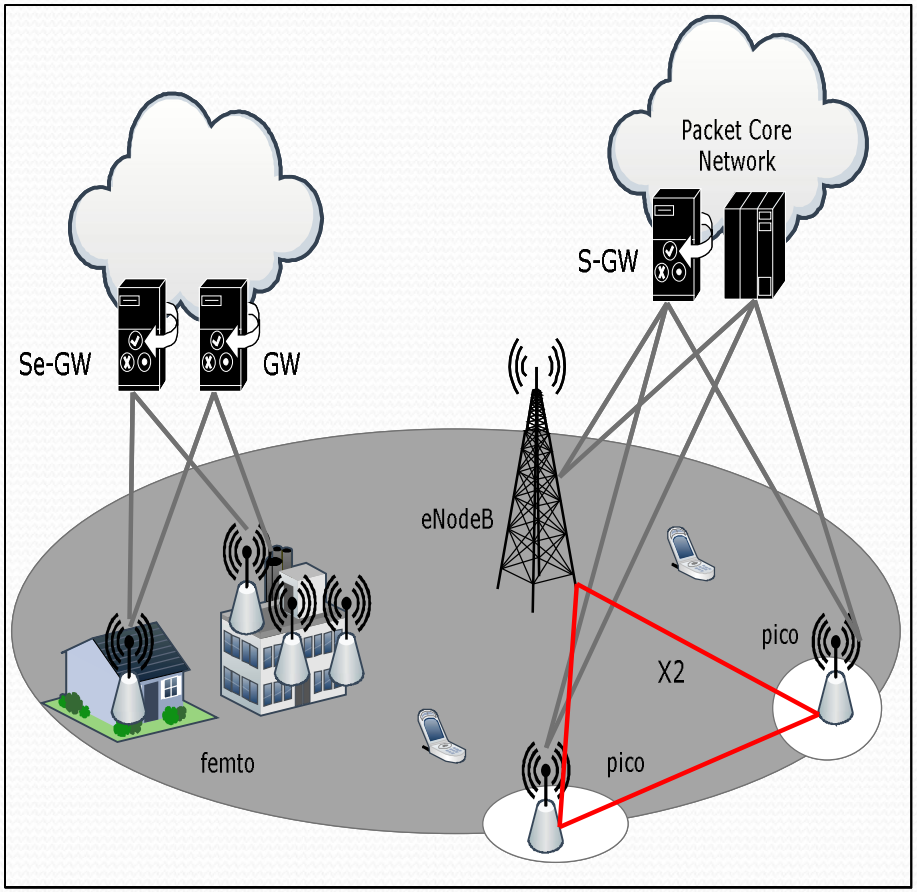
- Introduction
- LTE-A
- Heterogeneous LTE-A networks
- Load balancing in heterogeneous LTE-A
- Network configuration
- Results
- Conclusion

LTE-A

- LTE has a flat, all-IP architecture and all services in the system are IP-based
- Backward compatible with UMTS and GSM
- High data rates
- High capacity and spectral efficiency
- LTE-A supports heterogeneous networks **(HetNets)**

LTE-A HetNets

- Macro-cells (~5W – 40 W) overlaid with layers of LPNs like femto,and pico base stations.
- LPNs are equipped with omnidirectional antennas
- LPNs are smaller in size, cost less and have lower transmission power (0.1 W – 2 W)
- LPNs easier to deploy because they cause less interference and also due to their small size. Site acquisition also easier.



Benefits of HetNets

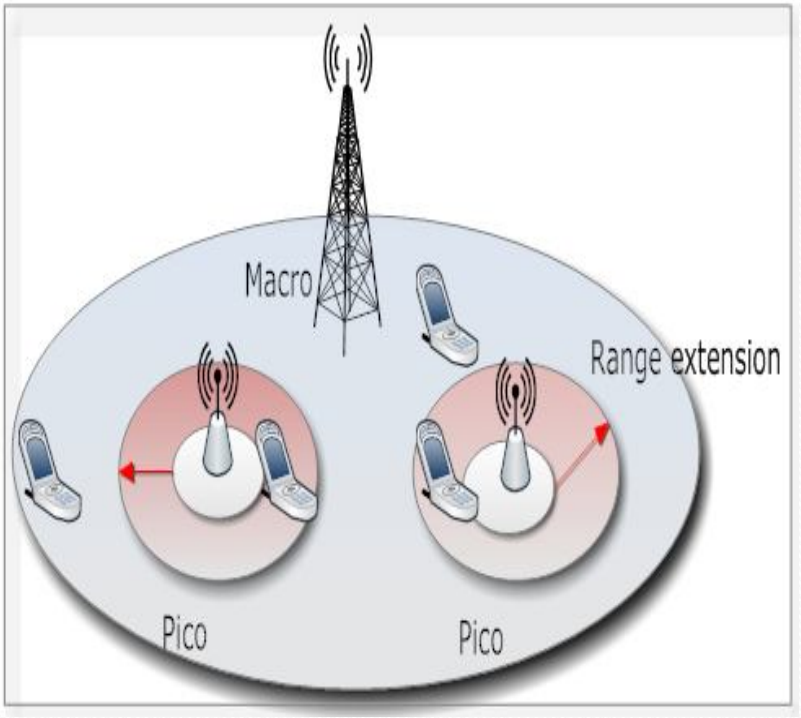
- Increase capacity especially in hotspots
- Improve coverage and spectral efficiency

Load balancing in LTE-A HeNets

- Under conventional cell selection scheme, a user equipment (UE) will select the cell with strongest received signal reference power (RSRP).
- Small number of users get attached to LPNs due to their low transmit power while macro-cells will have high number of users attached.
- Disadvantages of load imbalance:
  - Cell splitting gains will not be realized
  - There will be load imbalance
    - Macro-cells will have many users attached and may not have enough resources to serve all users
    - LPNs will have few users attached and will have their resources underutilized
    - There will be unfair distribution of user experiences in the HetNet
- The purpose of load balancing is to deal with unequal distribution of load over multiple cells.

Cell Range Extension (CRE)

- CRE used to solve the problem of load imbalance
- CRE done virtually through the use of offsets
- In virtual CRE, an offset is added to LPN cells during cell selection. UE connects to a cell with the highest (RSRP + Offset).
- More UEs will be associated with LPNs when CRE is used.
- CRE will result in an increase in coverage area (range) of LPNs



RSRP – Received Signal Reference Power

CRE using Uniform Offsets

- Uniform offsets has usually been used to offload users from macro-cells to LPNs so as to achieve load balancing in a HetNet.
- High offset will lead to overload of LPNs and low offset value will lead to insufficient offload
- Necessary to select optimal uniform offset that will result in load balancing in a HetNet.

Cell Load Coupling

- Cell load depends on the user demands, channel conditions and the level of interference from other cells. The last factor couples the elements in the load vector.
- The load of a cell is determined by SINR and data rates within that cell and these two factors depend on the load values in other cells.
- Therefore loads of cells in a network are coupled.
- To find the load of one cell, a set of non-linear equations has to be solved $\rho = f(\rho)$

CRE using Cell-specific Offsets

- Load balancing in a HetNet can be improved by using cell-specific offsets
- Cell specific offsets are necessary because:
  - User distribution in hotspots are different
  - Different propagation conditions
  - LPNs closer to macro eNodeBs require higher offsets and vice versa

Cell Load in LTE-A

$$Cell\ \ load = \frac{Total\ \ number\ of\ \ \text{scheduled}\ resource\ blocks}{Total\ \ number\ of\ \ resource\ blocks\ \ available\ in\ \ a\ cell}$$

- Cell load is between [0 ,1] under normal circumstances
- Cell loads close to 1 will indicate congestion and a possibility of service outage
- If cell load is greater than 1 it means that the cell does not have enough resources to serve all users ⟹ the cell is overloaded.

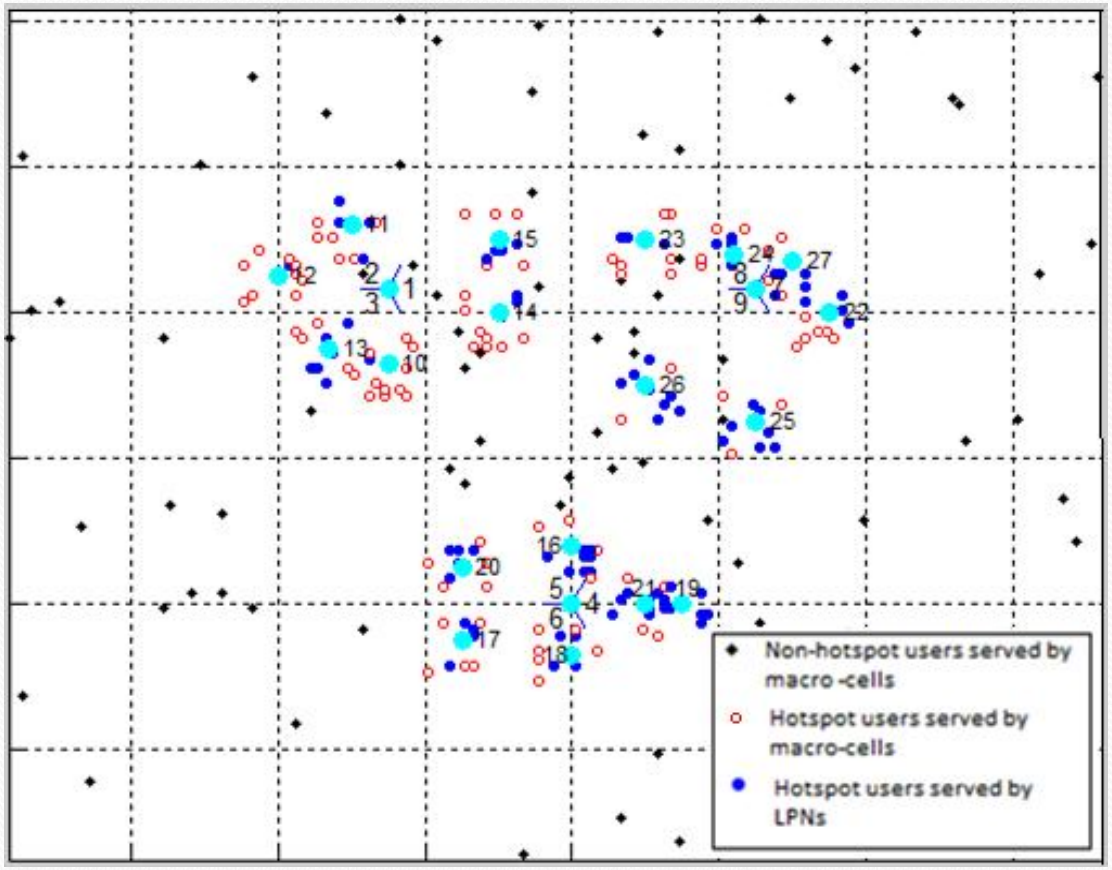
Jain's Fairness Index

- Jain's fairness criterion is used to measure the degree of load balancing among cells.
  - Less than 1 shows there is load imbalance
  - 1 means all cells have equal loads
- The goal of the load balancing algorithm is to maximize this index value .

Load balancing algorithm

1. First step is to to get optimal network-wide uniform offset
2. Second step is to deal with overloaded cells
   - Offset to be reduced only if fairness index increases
   - Offsets adjusted in steps of 1 dB
3. Third step is to deal with underloaded cells.
   - Offset to be increased only if fairness index increases after each offset adjustment.
   - Offsets adjusted in steps of 1 dB

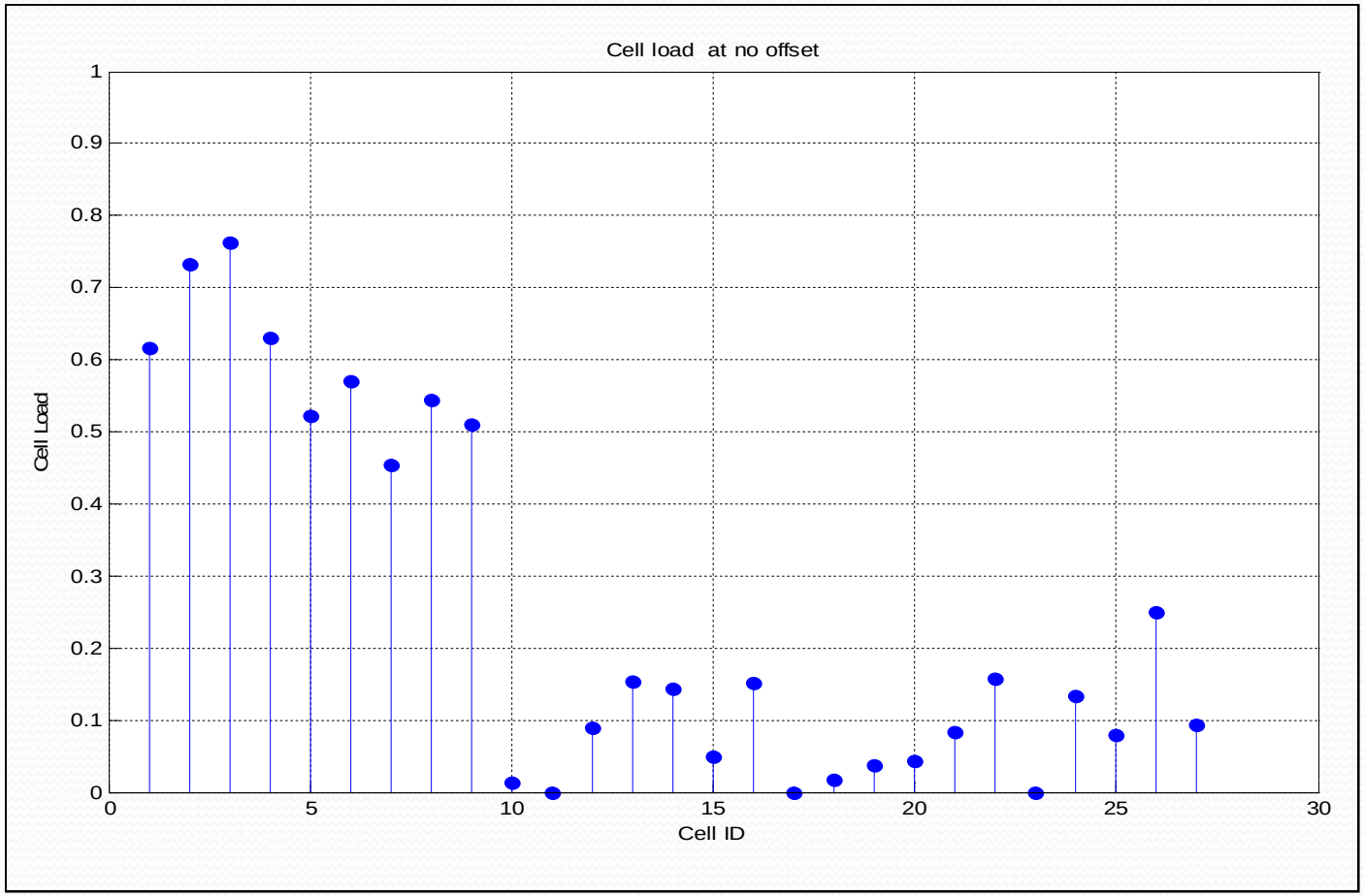
Network Configuration



- Network configuration according to 3GPP requirements
- 30 users in each macro-cell area
- 2/3 in hotpspots
- Hospot: 10 users distributed within 40 m radius of LPN
- Okomura Hata propagation model
- Shadow fading

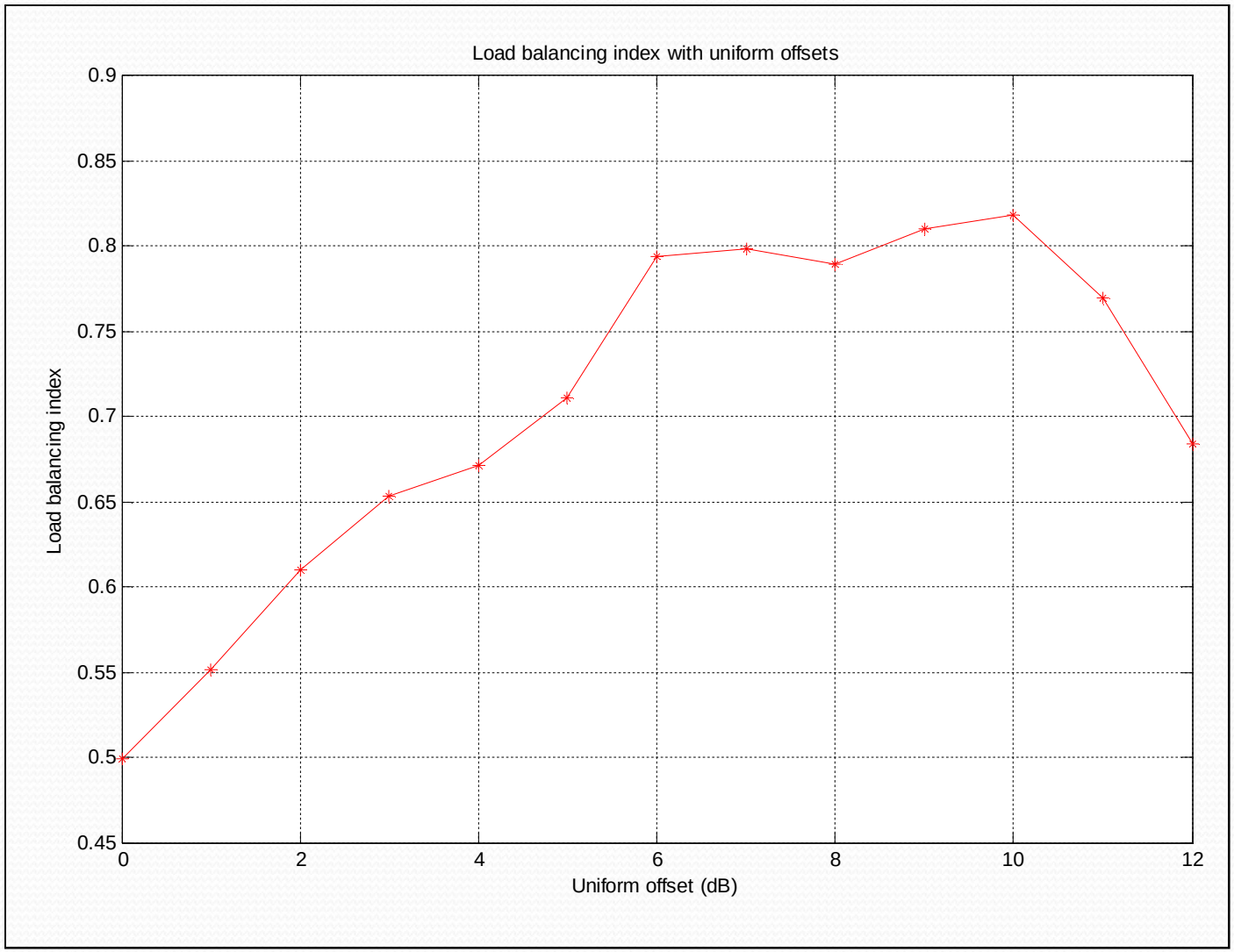
Results

Cell loads at 0 dB offset



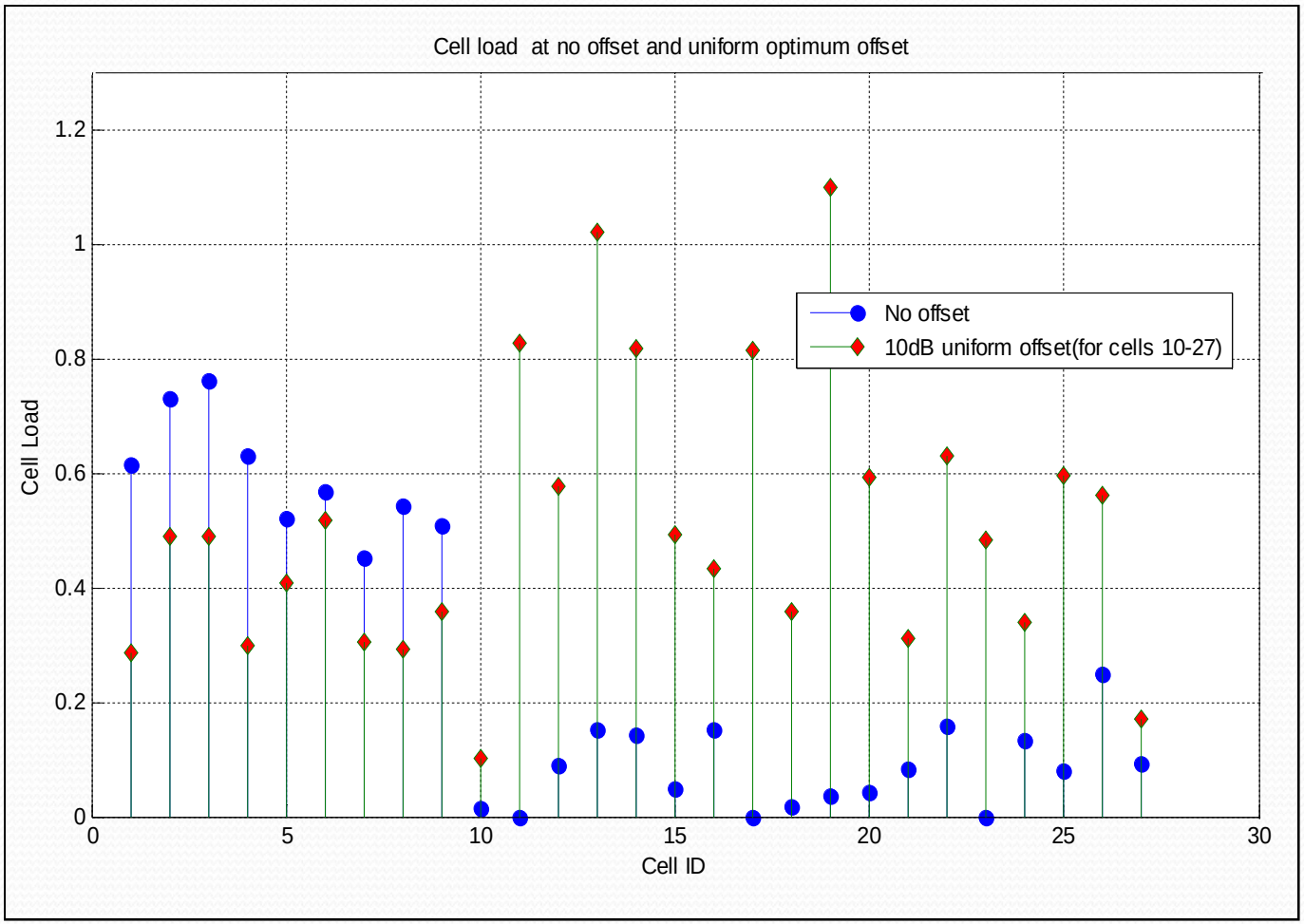
- Cell loads computed by solving 27 non-linear equations
- Most LPNs have low load values
- 10, 12 and 23 have zero load

Finding Optimal Uniform Offset



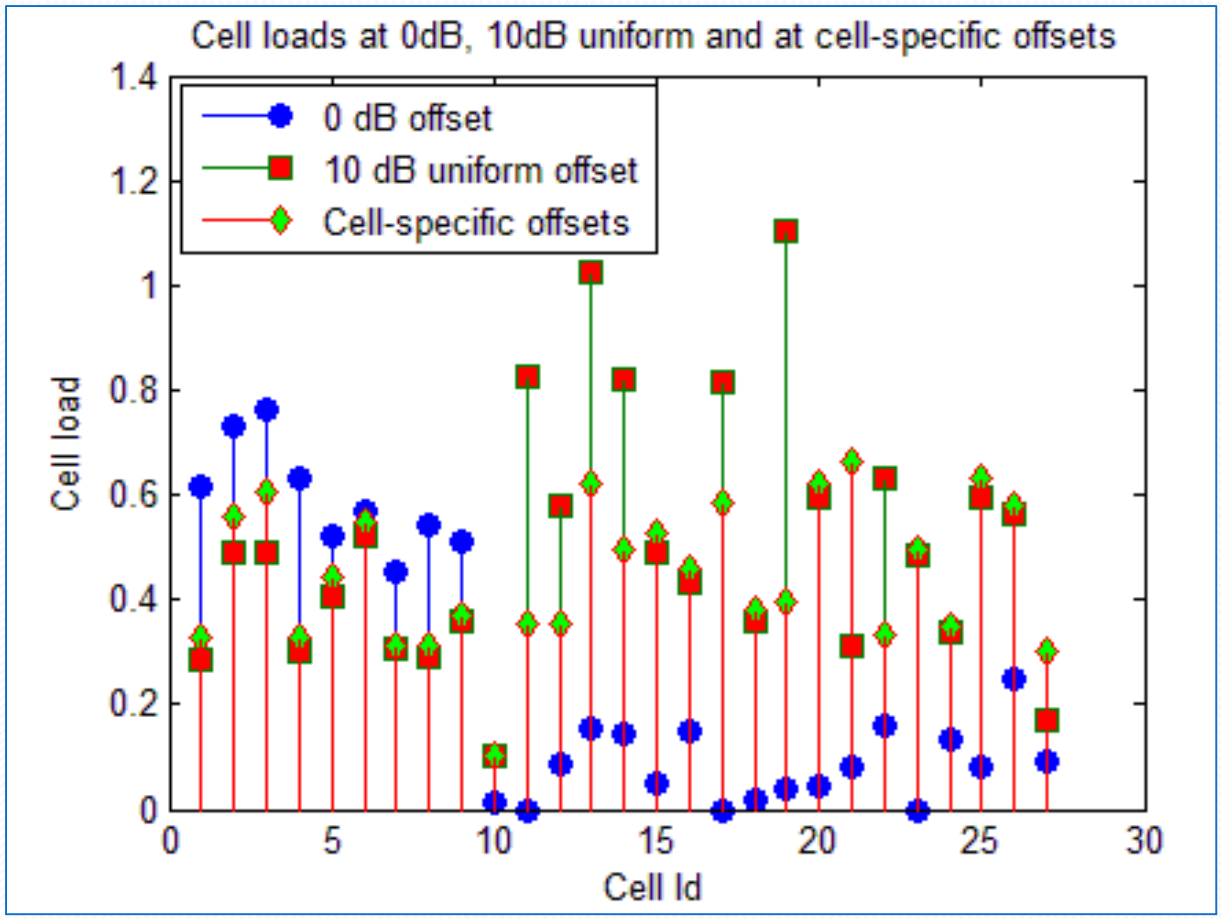
- Offsets to be assigned to LPNs according to algorithm
- First step is to find optimal uniform offset value
- Evaluated 0 – 12 dB
- 10 dB is the uniform offset

Cell Loads at Uniform Optimal Offset



- There is still load imbalance when optimal uniform offset is used
- Cell-specific offsets necessary

Cell Loads with Cell-specific Offsets



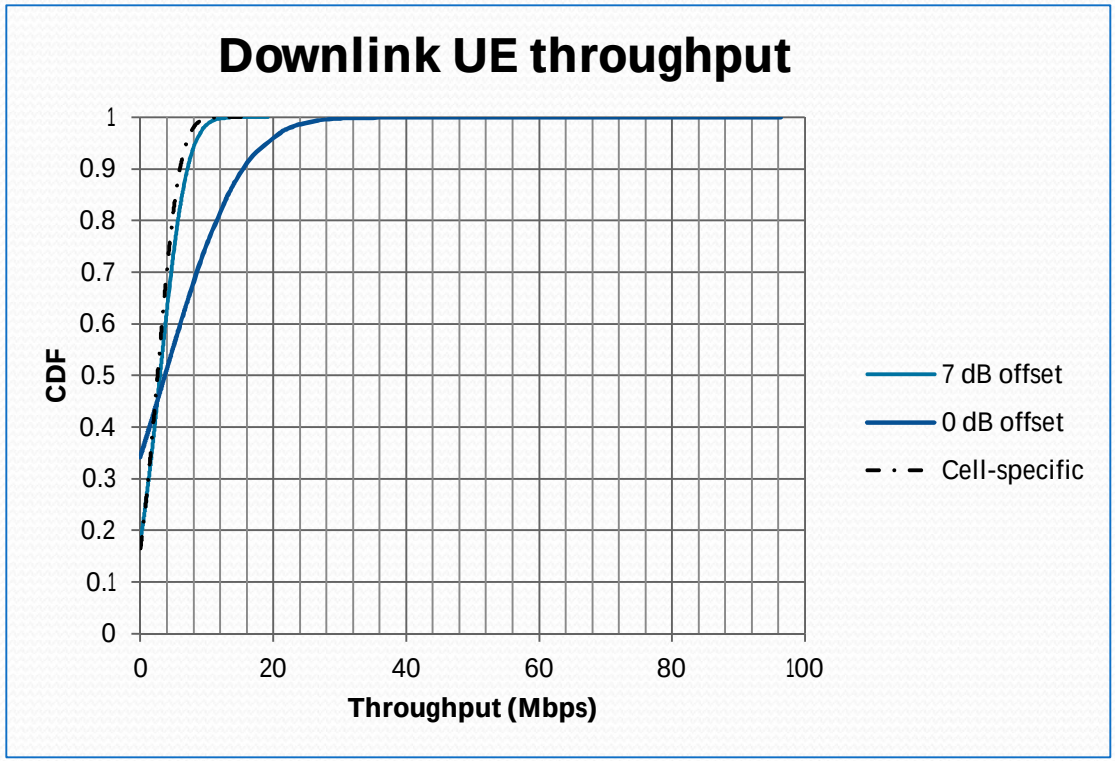
- More balanced cell loads
- Maximum offset set to 12 dB
- Fairness index rises to 0.91 from 0.86
- Offsets assigned according to algorithm
- 25 and 26 have lower offsets
- 10 and 12 have higher offsets

Performance Evaluation

Jain's Fairness Index

Offset	**0 dB**	**10dB uniform (optimal)**	**Cell-specific**
Jain's fairness index	0.5	0.82	0.92

Throughput



- High variation in throughput at o dB offset.
- Less variation in throughput when offsets are used
- Less variation when cell-specific offsets are used.
- More even user experiences

Offset	0 dB	10 dB uniform	Cell-specific
Standard deviation of throughput	9.16	3.22	2.65

Conclusion

- Cell-specific offsets improves degree of load balancing in a HetNet
- More even UE experiences when cell loads are balanced.

Thank you!