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Agenda Item: 11.5

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A system simulation study of downlink L2 relay network

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Views on Relay

- To be effective, relay node needs to have
  - Enough transmit power to improve the coverage
  - Enough antenna gain for connections both to eNB and to UEs
- Location of a relay node should
  - Consider over-the-rooftop antenna installation to attain better relay-eNB link
  - Be optimized for best connection to eNB and to covered UEs
- Relay node should be significantly cheaper than eNB
  - Cannot have too many L2/L3 functions
  - Lower transmit power compared to eNB's
  - Allow in-band link between eNB and relay node to save spectrum
- Limited number of relay nodes in a cell, to
  - Save the deployment cost and consumed power
  - Avoid significant interference introduced by relay nodes
- Time frequency resource needed by the multi-hops will have impact on the overall channel rate

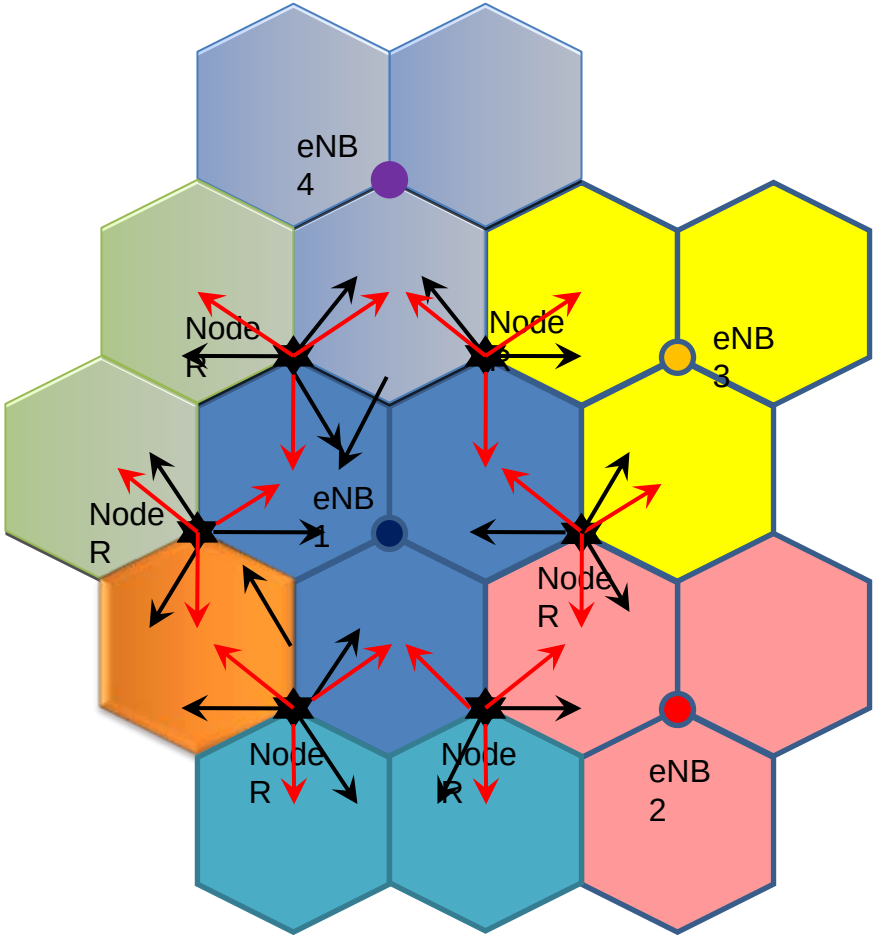
Relay Setup and Capabilities

- Relay node (NodeR) set up:
  - Clover-leaf site: 3 cells/site
  - Each cell has two NodeRs located at the conjuncture of 3 neighboring cells
  - Each NodeR has three sectors, each serving UEs in one cell
    - Directional antenna covering individual sector to reduce NodeR induced interference
  - Good channel quality of eNB-NodeR connection
    - Very slow Rician with strong line-of-sight (LOS) component
    - NodeR outdoor installed, no building penetration loss
    - Directional antenna at NodeR pointing to its serving eNB
- NodeR capabilities ("Layer 1.5"):
  - L2 decoding + re-encoding
  - Pass scheduling information from eNB to UEs
  - Transmit its own reference signal for NodeR-UE CQI reporting and PDSCH demod
  - Transmission time aligned (within cyclic prefix) with OFDM symbol timing of eNB to avoid NodeR induced intra-cell interference
  - In-band communication with eNB using PDSCH resource, directed by PDCCH
  - Support multiple UEs in time and frequency

Relay Setup and Capabilities (continued)

- New capabilities of eNB:
  - Interpret CQI of NodeR-UE connection
  - Resource scheduling for eNB-NodeR, NodeR-UE and eNB-UE connections, ensure proper time-frequency alignment for NodeR-UE and eNB-UE connections
  - NodeR-UE pairing
  - Relay mode selection, including whether a UE should be served by NodeRs
- New capabilities of UE (DL example):
  - CQI reporting of NodeR-UE connection, via NodeR reference signal
  - Estimation of combined channel of NodeR-UE and eNB-UE
  - Decode the scheduling information sent (not originated) from NodeR

Locations and Antennas of NodeRs

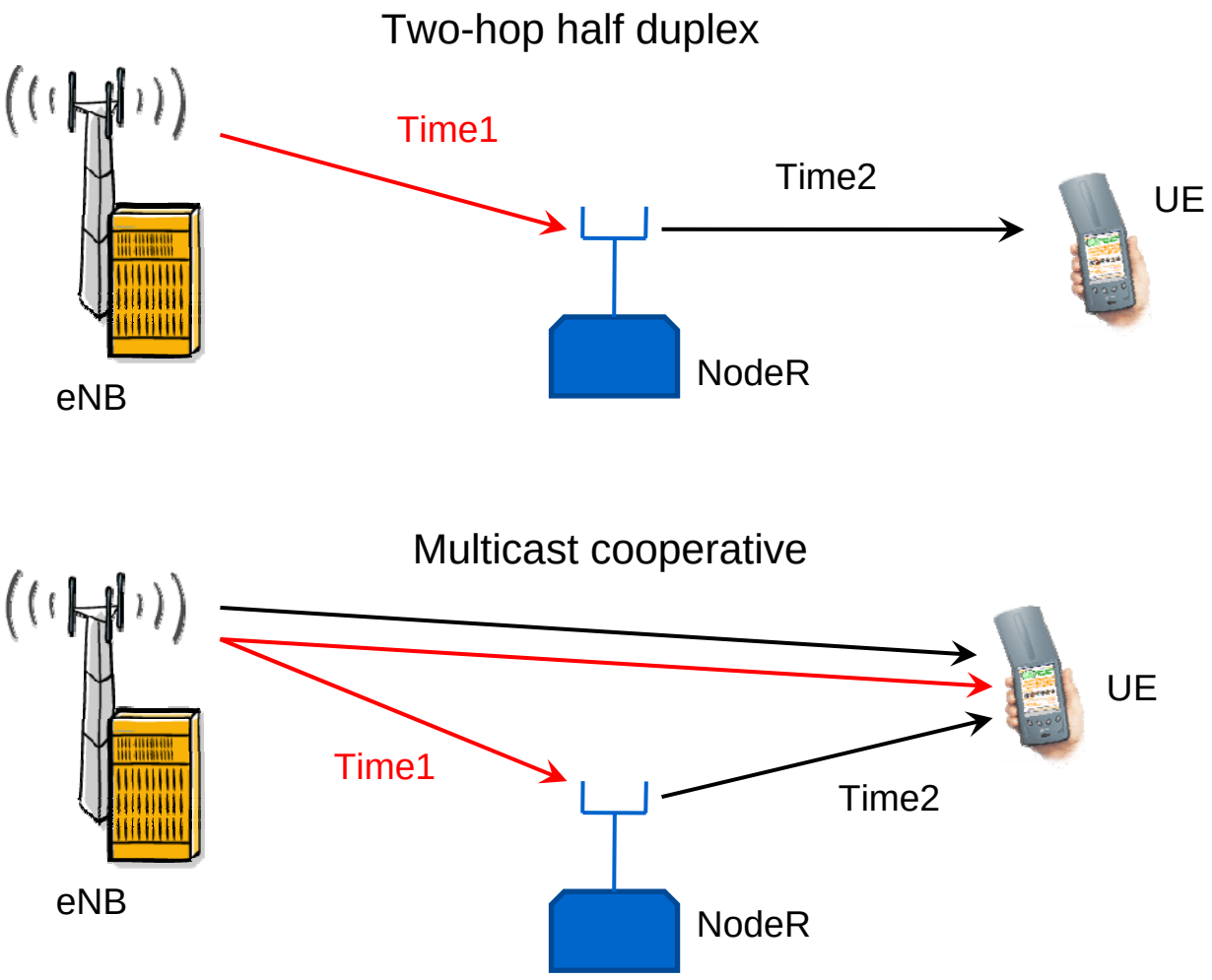


NodeR antenna directions:

NodeR - UEs

NodeR - eNB

Two Transmission Modes Considered



Pro and Con of Half Duplex vs. Multicast Cooperative

- Two-hop half duplex:
  - Pro:
    - Simpler processing at UE, not need to estimate the combined channel
    - eNB is idle in Time 2 for assigned PRBs, less processing
    - Less interference to other cells eNB
    - Relieve eNB of serving the poor geometry UE
  - Con:
    - Overall channel rate is likely low
- Multicast cooperative
  - Pro:
    - Higher overall channel rate is likely
  - Con
    - More processing at UE, need to estimate the combined channel
    - eNB transmits in both Time 1 and Time 2
    - Little advantage for very poor geometry UEs

Simulation Parameters

Parameters		Values
Inter-site distance		500 m, 1732 m
Distance-dependent path loss		eNB-UE: $L=128.1 + 37.6 \log_{10}(R)$ eNB-NodeR: $L=103.2 + 37.6 \log_{10}(R)$ NodeR-UE: $L=132.3 + 39.6 \log_{10}(R)$, R in kilometers
Shadowing standard deviation		8 dB (UE), 4 dB (NodeR)
Shadowing correlation	Between cells	0.5
	Between NodeB and NodeR	0.4
Building penetration Loss		20 dB (eNB/NodeR-UE), 0 dB (eNB-NodeR)
NodeR antenna beamwidth (horizontal), gain		60 degree for Node-UE connection, 15 dBi 35 degree for NodeR-eNB connection, 17 dBi
Carrier Frequency		2 GHz
Channel model		eNB/NodeR-UE: Typical Urban (TU), 3kmph eNB-NodeR: AWGN
Total power (Ptotal) – operating bandwidth		46dBm - 10MHz
Inter-cell interference modeling		Explicit modeling else cell power = Ptotal
Average number of UEs per cell		20 (UEs dropped uniformly in entire network)
Transmit power of NodeR		34 dBm, 40 dBm
NodeR antenna height		1/2 of eNB antenna height

Cell Throughput Results

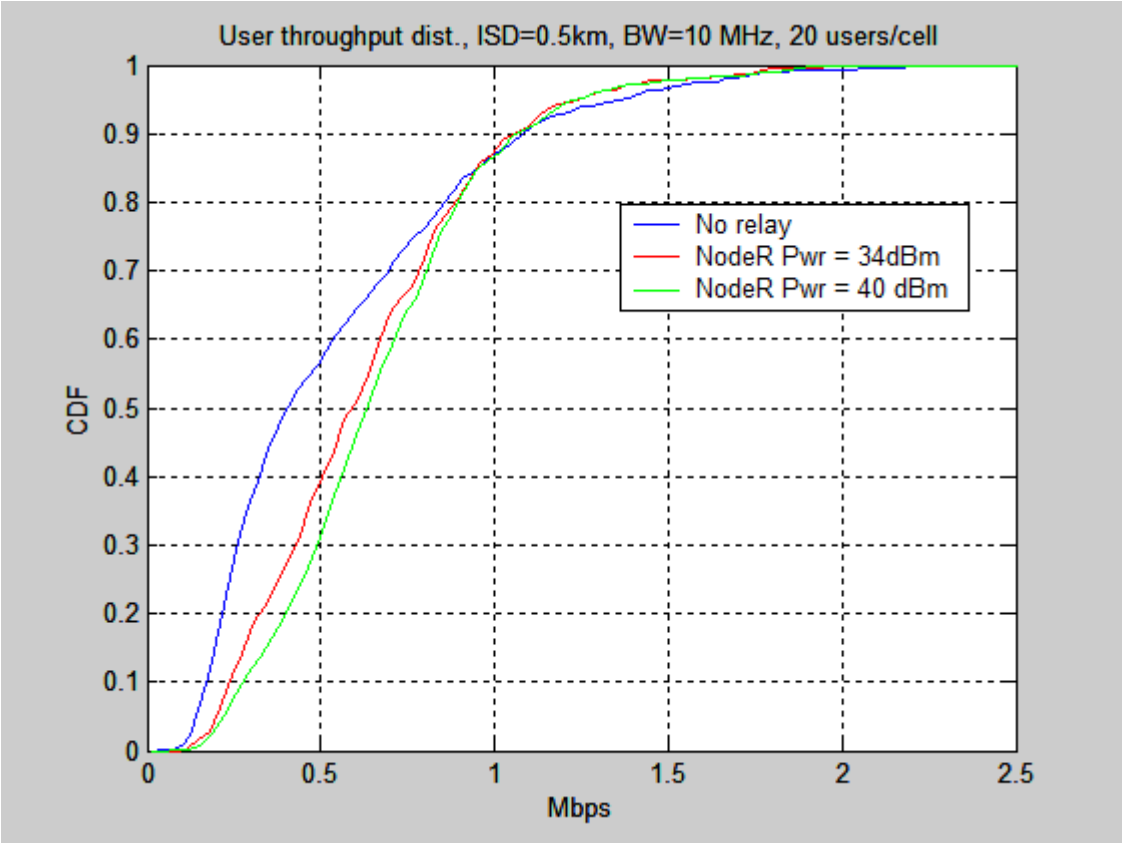
Data rate (Mbps)	ISD=0.5 km	ISD=1.73km
No relay	11.2	10.5
34 dBm	13.0	11.9
40 dBm	13.8	12.7

Cell throughput gain:

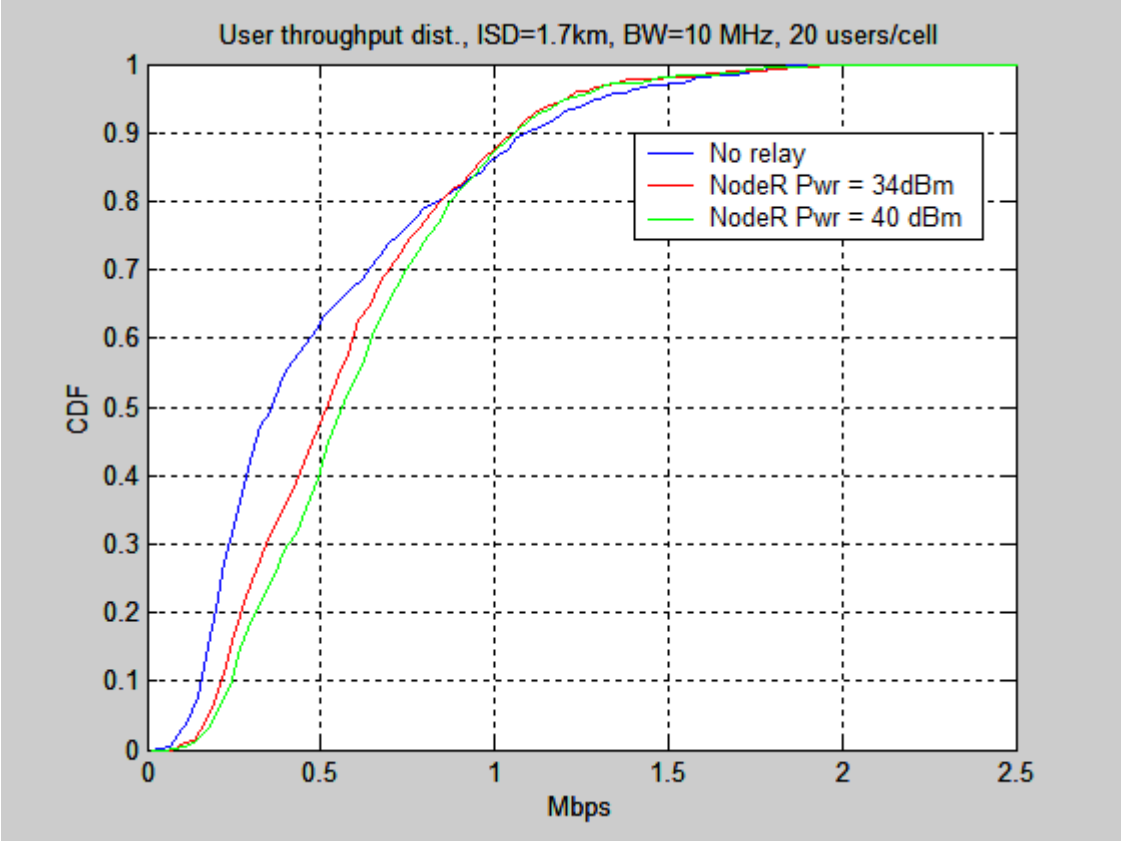
•13%~16% for 34 dBm,

•21%~23% for 40 dBm

User Throughput CDFs (ISD=500 m)

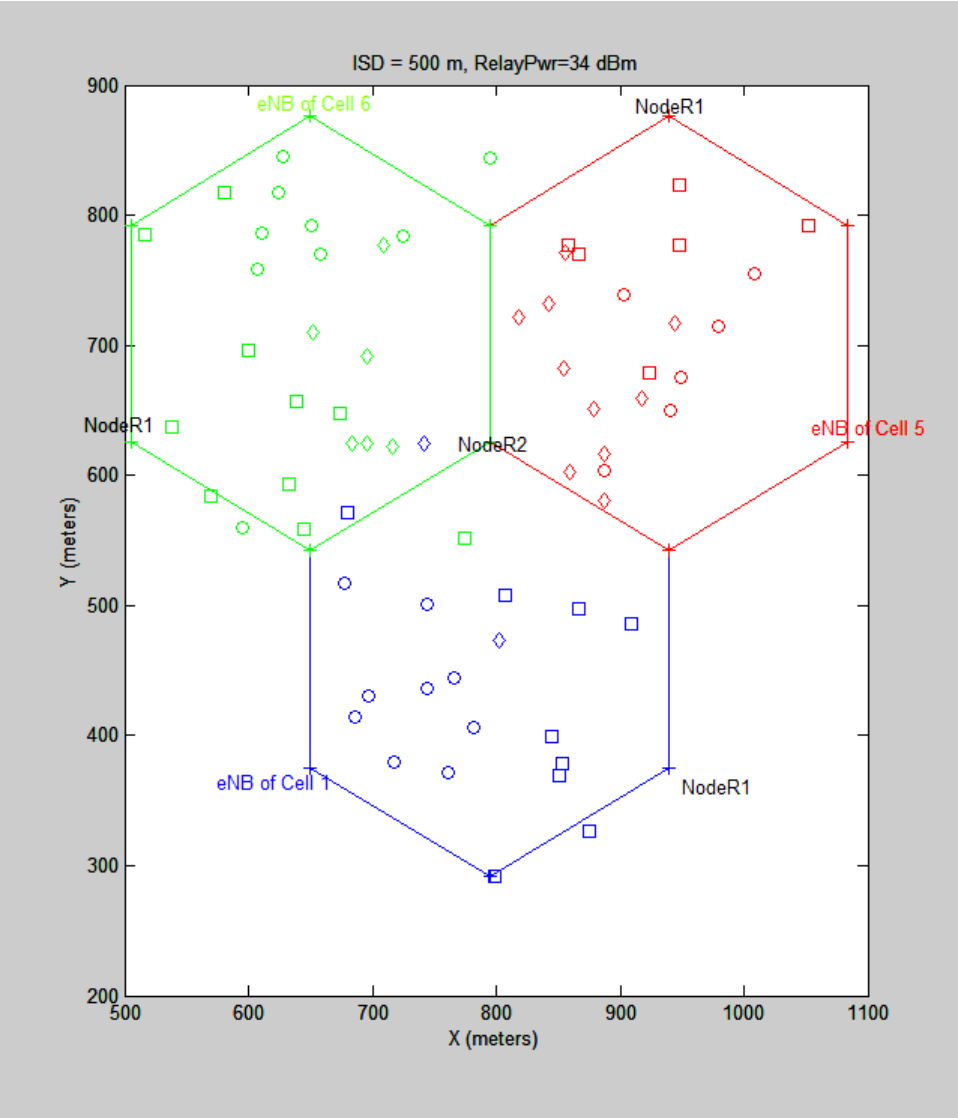


User Throughput CDFs (ISD=1732 m)



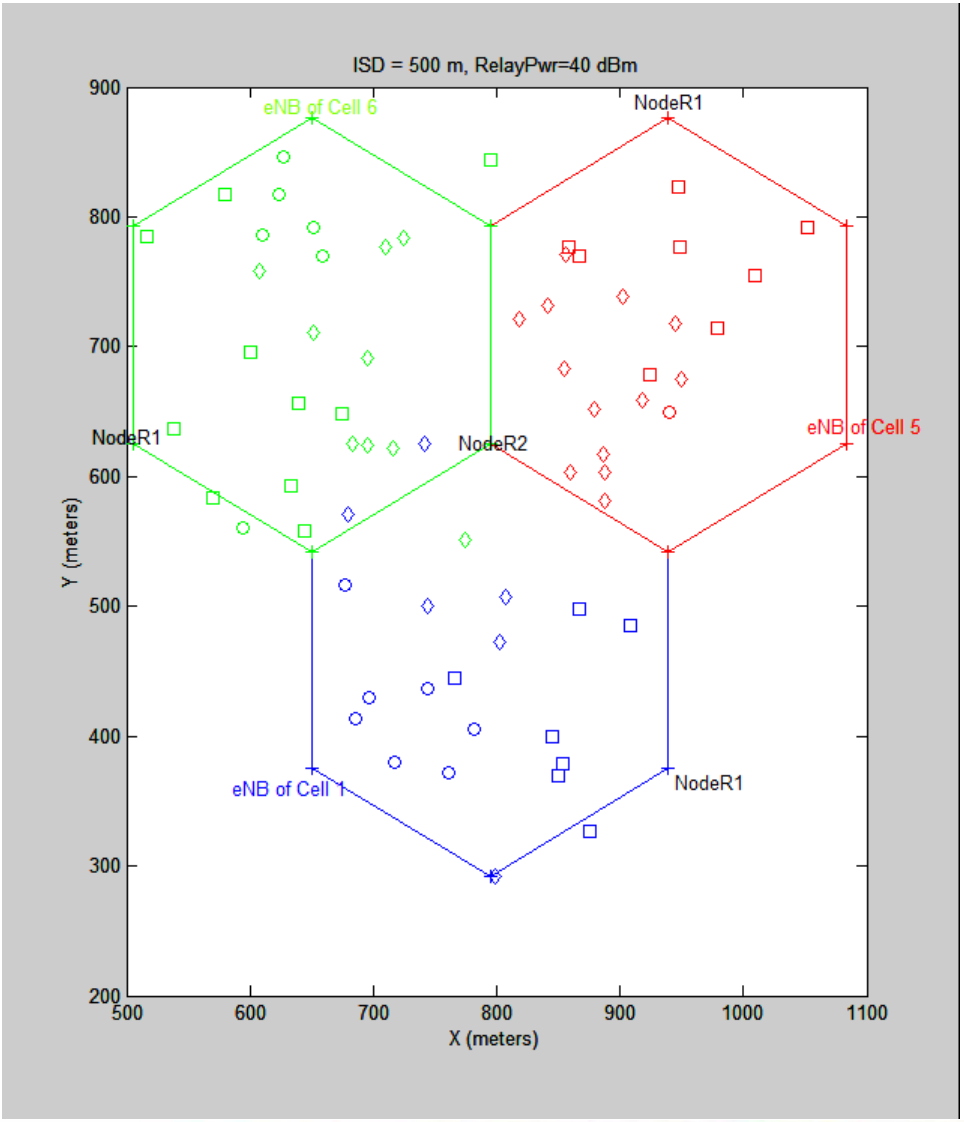
Throughput of low to medium geometry users is significantly improved, i.e. system is more fair

UEs in a Subset of the Network (ISD=500 m, 34 dBm)



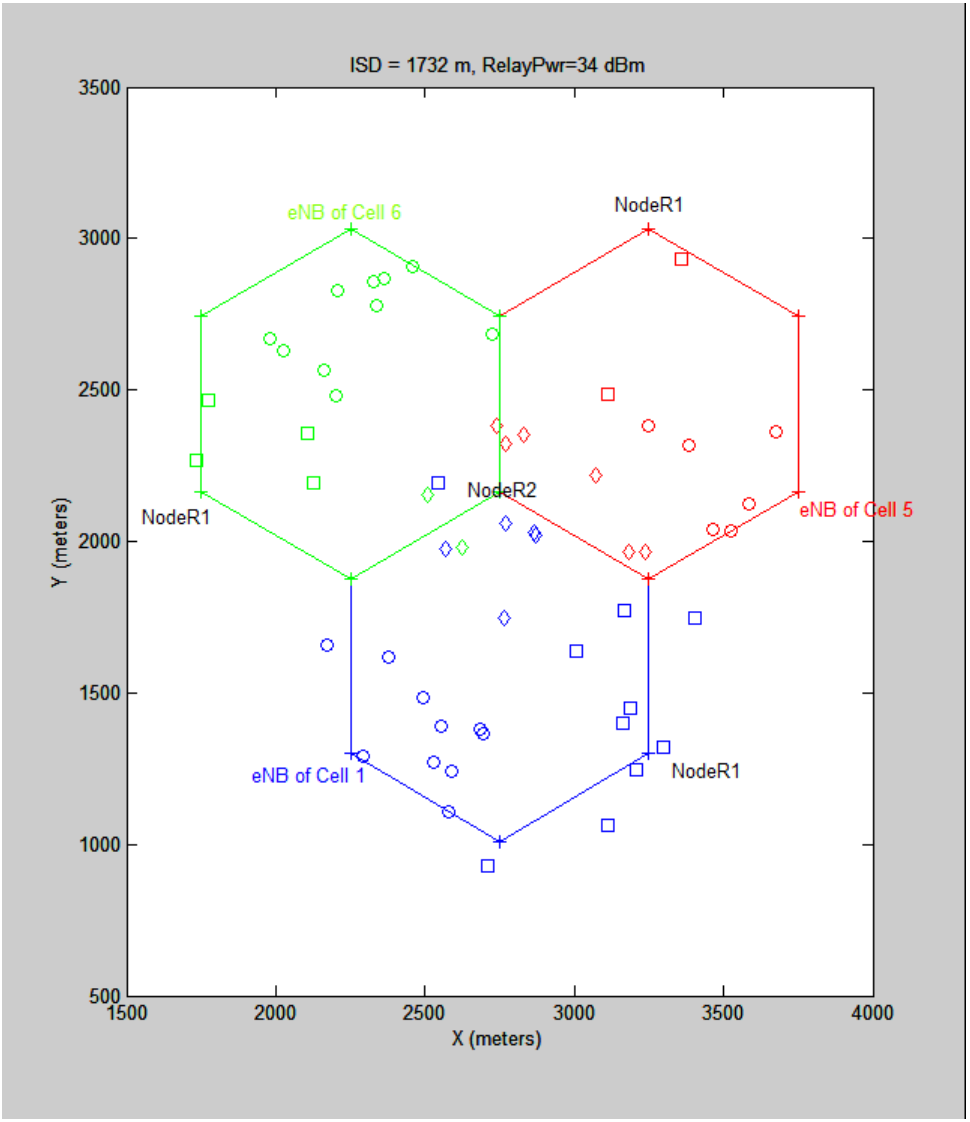
- Circles: not served by NodeRs
- Squares: served by NodeR1
- Diamonds: served by NodeR2
- Over the entire network, 64% UEs served by relay nodes

UEs in a Subset of the Network (ISD=500 m, 40 dBm)



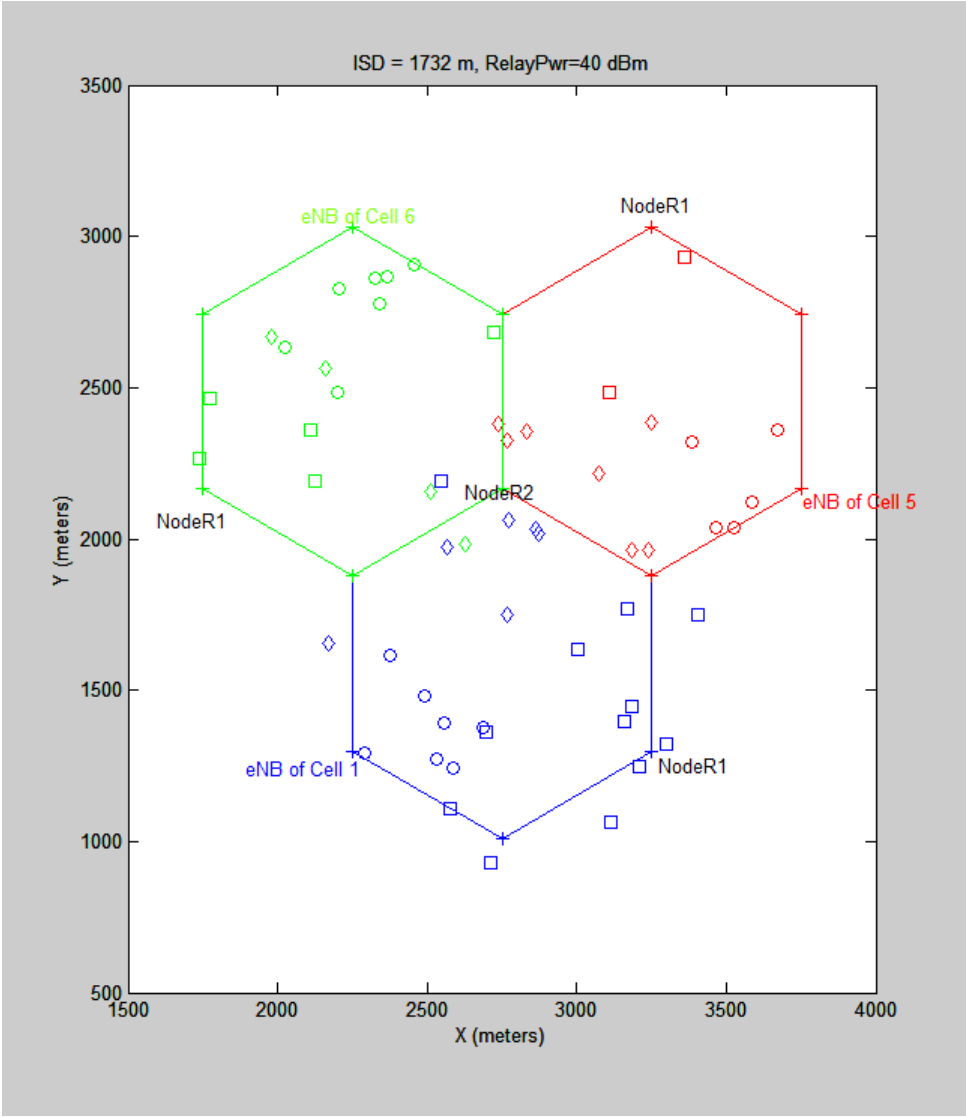
- Circles: not served by NodeRs
- Squares: served by NodeR1
- Diamonds: served by NodeR2
- Over the entire network, 73% UEs served by relay nodes

UEs in a Subset of the Network (ISD=1732 m, 34 dBm)



- Circles: not served by NodeRs
- Squares: served by NodeR1
- Diamonds: served by NodeR2
- Over the entire network, 63% UEs served by relay nodes

UEs in a Subset of the Network (ISD=1732 m, 40 dBm)



- Circles: not served by NodeRs
- Squares: served by NodeR1
- Diamonds: served by NodeR2
- Over the entire network, 70% UEs served by relay nodes

Conclusions

Studied:

- A cost-effective relay scenario with two L1.5 relay nodes per each cell

Observed:

- Significant gain in cell throughput
- Improved system fairness in terms of user throughput

References

[1] R1-082975 “Application scenarios for LTE-Advanced relay”, China Mobile (CMCC), Vodafone, Huawei

[2] R1-084017 “Text proposal for evaluation methodology”

[3] R1-083205 “Application of L2 Relay in an Interference Limited Environment for LTE-A”, InterDigital

[4] R1-083778 “System simulation evaluation for link from eNode-B to RN”, Fujitsu

[5] R1-083533 “Decode and forward relays for E-UTRA enhancements”, Texas Instruments

Thanks

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