Resource Allocation Strategies Based on the Signal-to-Leakage-plus-Noise Ratio in LTE-A CoMP Systems

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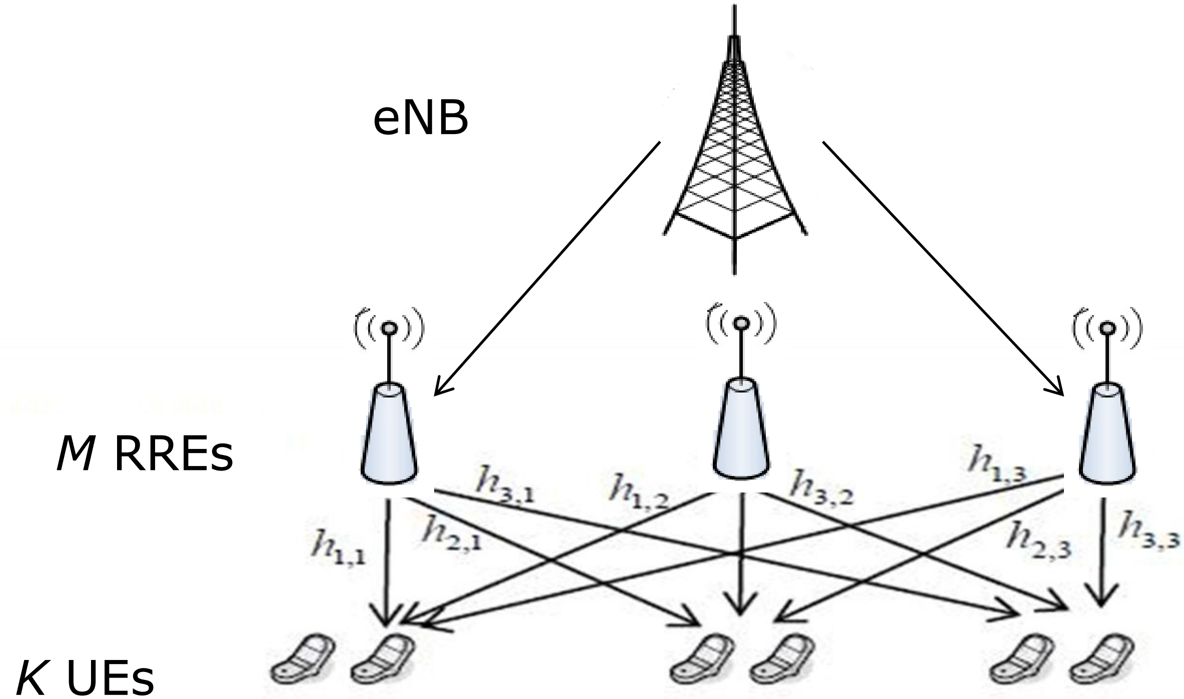
Motivation

- The bandwidth is becoming a more scarce resource.
- The capacity of wireless cellular networks is nowadays mainly restricted by interference.
- Resource Allocation (RA) can definitely play an essential role in better utilizing the available bandwidth.
- The main objectives of Coordinated multi-point (CoMP) are to mitigate the interference thus providing high spectral efficiency over the entire cell area, and increasing the overall throughput.

We present two novel RA strategies based on the Signal-to-Leakage-plus-Noise-Ratio (SLNR) for CoMP systems.

System Model



- N RBs are available in the system.
- Equal power allocation over RBs is assumed.
- Both Coordinated Scheduling (CS) and Joint Processing (JP) CoMP systems are considered.

Signal-to-Leakage-plus-Noise Ratio (SLNR)

- In the downlink, SLNR is the ratio between the power intended to a UE and the power leaked from the RRE towards other UEs sharing the same RB.

Signal power received by *k*th UE from all RREs

SLNR at *k*th UE on an arbitrary RB →

$$\beta_k = \frac{P_n \left|\underline{\mathbf{h}}_k \underline{\mathbf{w}}_k\right|^2}{\sum_{k' \neq k}^{K} P_n \left|\underline{\mathbf{h}}_{k'} \underline{\mathbf{w}}_k\right|^2 + |\eta_k|^2}$$

Signal power leaked from RREs towards other UEs

- The structure of the weighting vectors will differ between CS and JP cases.

Resource Allocation Strategies

- For each RB, a set of UEs will be selected by means of scheduling to share the same RB such that the overall throughput is not degraded.
- The RA allocation strategies thus includes two steps: first, the weighting vectors should be selected, then which UEs should share the same RB follows.

Selection of Weighting Vectors

- Weighting vectors determine which RRE(s) should serve each UE.
- The weighting vector will be set in order to maximize the SLNR.
- Coordinated Scheduling (CS) scheme:
  - Each UE is served by only one RRE.
  - The weighting vector will be a vector with all elements equal to zero except only one element will be unity.
- Joint Processing (JP) scheme:
  - Each UE is served by all RREs jointly.
  - In this case, the weighting vector is not as simple as in the CS scheme. The weighting vector will be:

$$\underline{\mathbf{w}}_k = \max \text{eig. vec.}\left(\left(|\eta_k|^2 \mathbf{I}_M + \widehat{\mathbf{H}}_k^* \widehat{\mathbf{H}}_k \right)^{-1} \underline{\mathbf{h}}_k^* \underline{\mathbf{h}}_k \right)$$

Grouping Algorithm

- The following steps will be repeated for every available RB:
  1. Choose the UE with the maximum SLNR and set it to be the first item in the set.

     $$k' = \text{argmax}_k(\beta_k),\ S = \{ k' \}$$

  2. Compute the leakage value vector from set in the direction of the rest of UEs.

     $$L_{s,s'} = \left| \underline{\mathbf{h}}_{s'} \underline{\mathbf{w}}_s \right|^2, \forall s' \in S', S' \not\subset S$$

  3. Add the UE with the least amount of leakage.

     $$S = S \cup \text{argmin}_{s'}\left(L_{s,s'}\right)$$

  4. Repeat steps 2-3 until the stopping condition is satisfied

Stopping Criterion (1)

- Leakage Threshold
  - The relationship between the leakage threshold and the number of UEs per cell is assumed to be linear.

$$\lambda = aK + b$$

  - Leakage threshold assures stopping when achieving nearly the highest throughput per RB.
  - It leads to high throughput gains
  - It is highly dependent on the channel parameters and propagation scenarios.
  - It is used as a benchmark for comparison with other proposed stopping criteria.

Stopping Criterion (2)

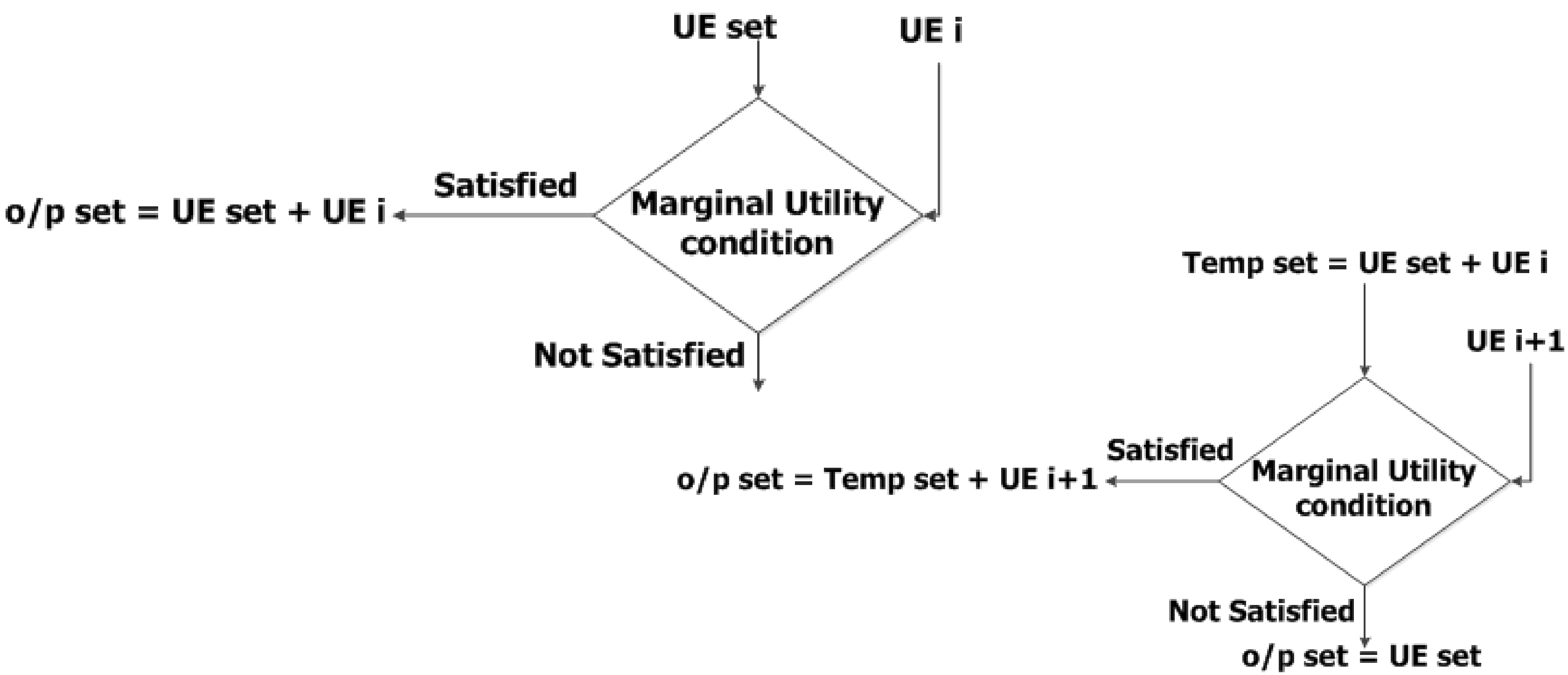
- Marginal Utility
  - A condition that is function of a utility function (U) is used in order to allow grouping.

$$U_{s_{new}} + U_{UE_{new}} \geq U_{s_{old}}$$

  - Efficient and provides high overall throughput gains.
  - But it might terminate before reaching the highest achievable throughput.

Stopping Criterion (3)

- Marginal Utility With Look-Ahead
  - If the marginal utility condition is not fulfilled, there is an extra possibility to add the UE to the set.



Complexity Comparison

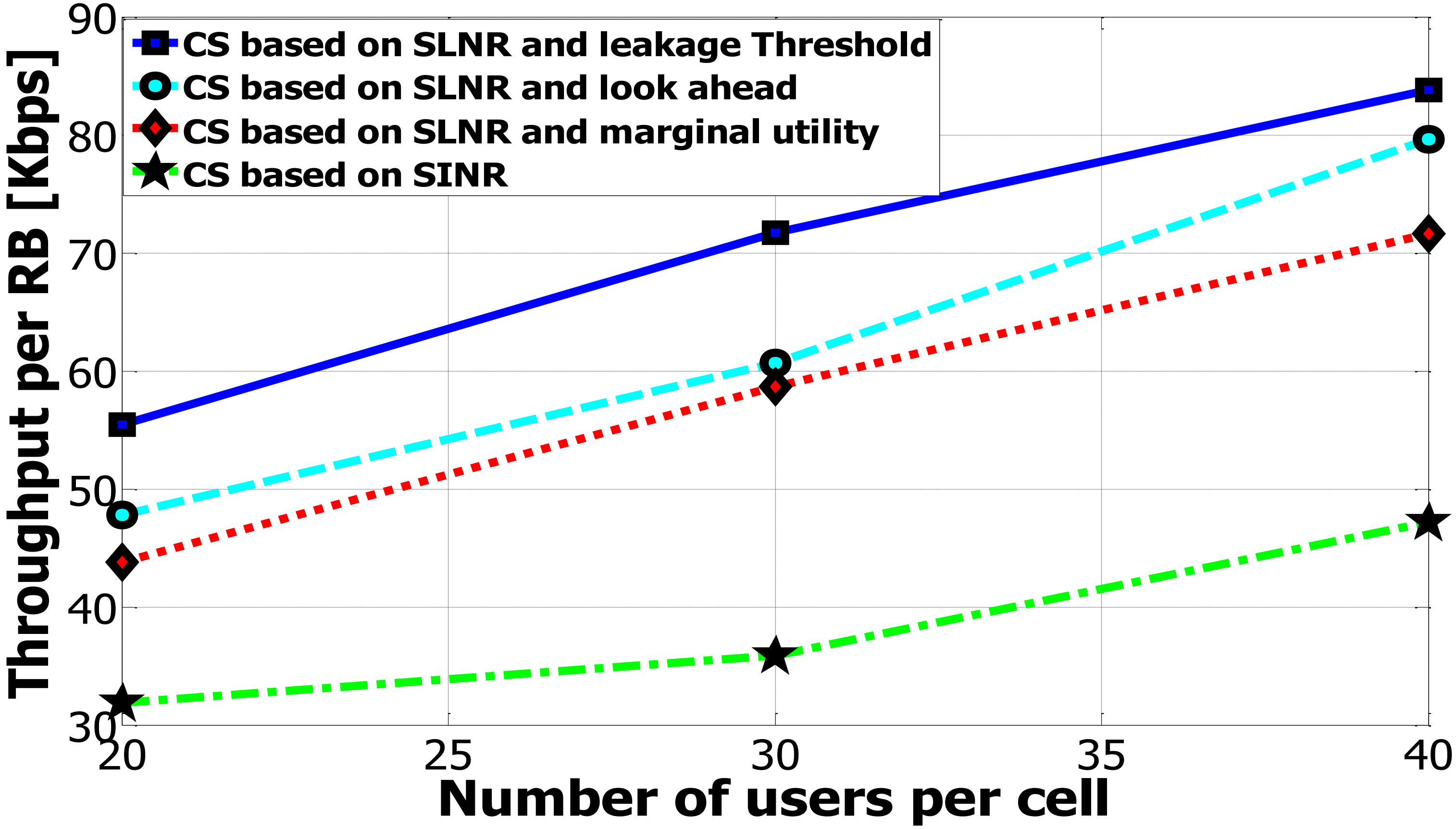
- Computational complexity is greatly reduced by considering the SLNR instead of the SINR as the main metric.
- The complexity order of maximizing the SINR metric for each UE assuming CS strategy is as follows:

Number of computations in SINR-based RA	$\begin{cases} \dfrac{M!}{(M-K)!}, & M > K \\ M * \dfrac{(K-1)!}{(K-M)!}, & \text{otherwise} \end{cases}$
Number of computations in SLNR-based RA	M

Simulation Parameters

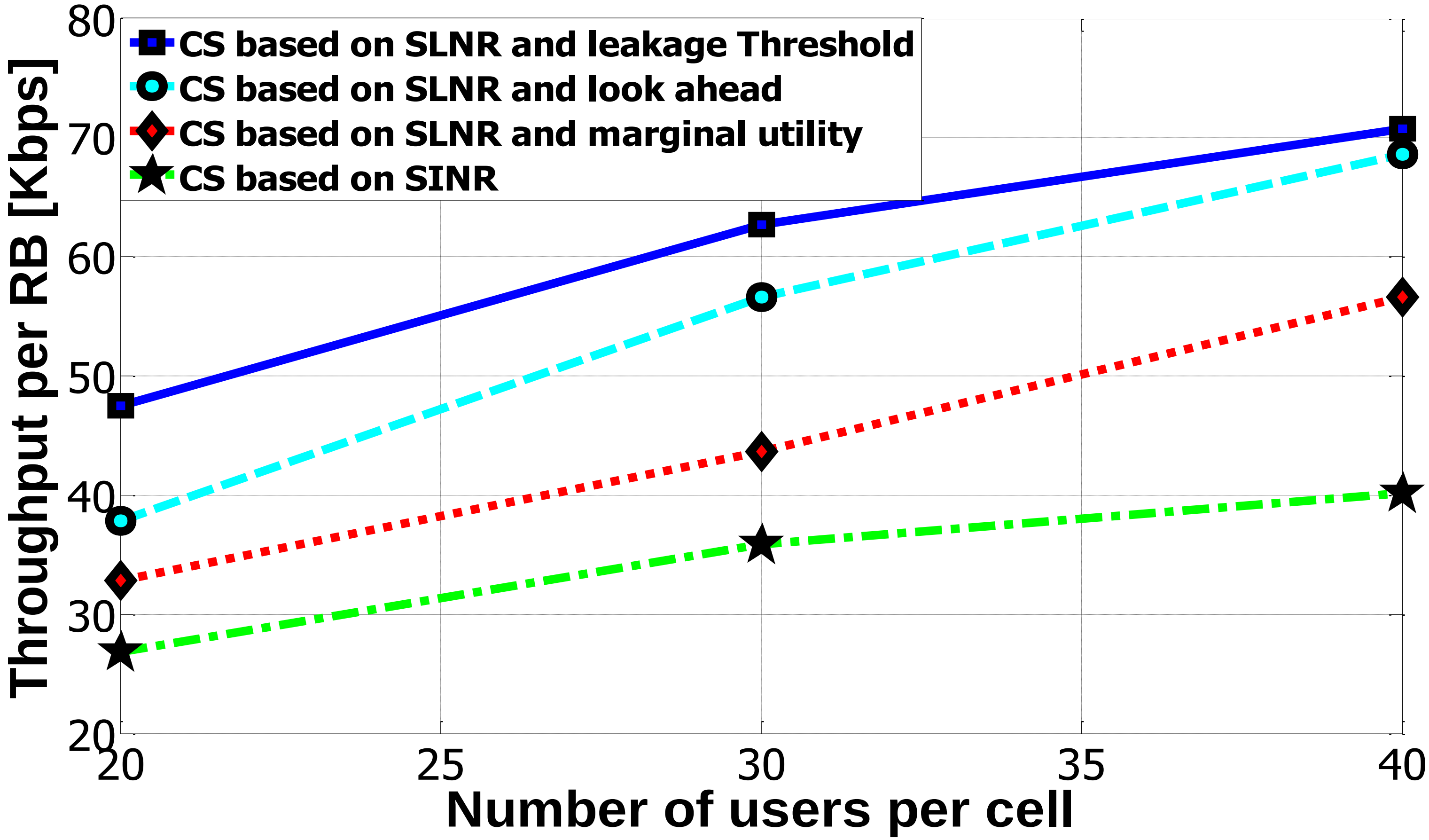
Parameter	Value
Number of RREs per cell	6
Number of UEs (k)	20, 30, 40
Carrier Center Frequency (GHz)	2
Subcarrier spacing (KHz)	15
Number of RBs (N)	100
Number of subcarriers per RB	12
System bandwidth (MHz)	20
Propagation Scenarios	Typical urban macro-cell and Bad urban macro-cell
Number of antennas per UE	One
Number of antennas per RRE	One
Power distribution among RBs	Uniform
UEs distribution among cell area	Uniform
Scheduling algorithms	CS, JP
Used modulation schemes	QPSK, 16-QAM, 64-QAM

Performance Results - CS



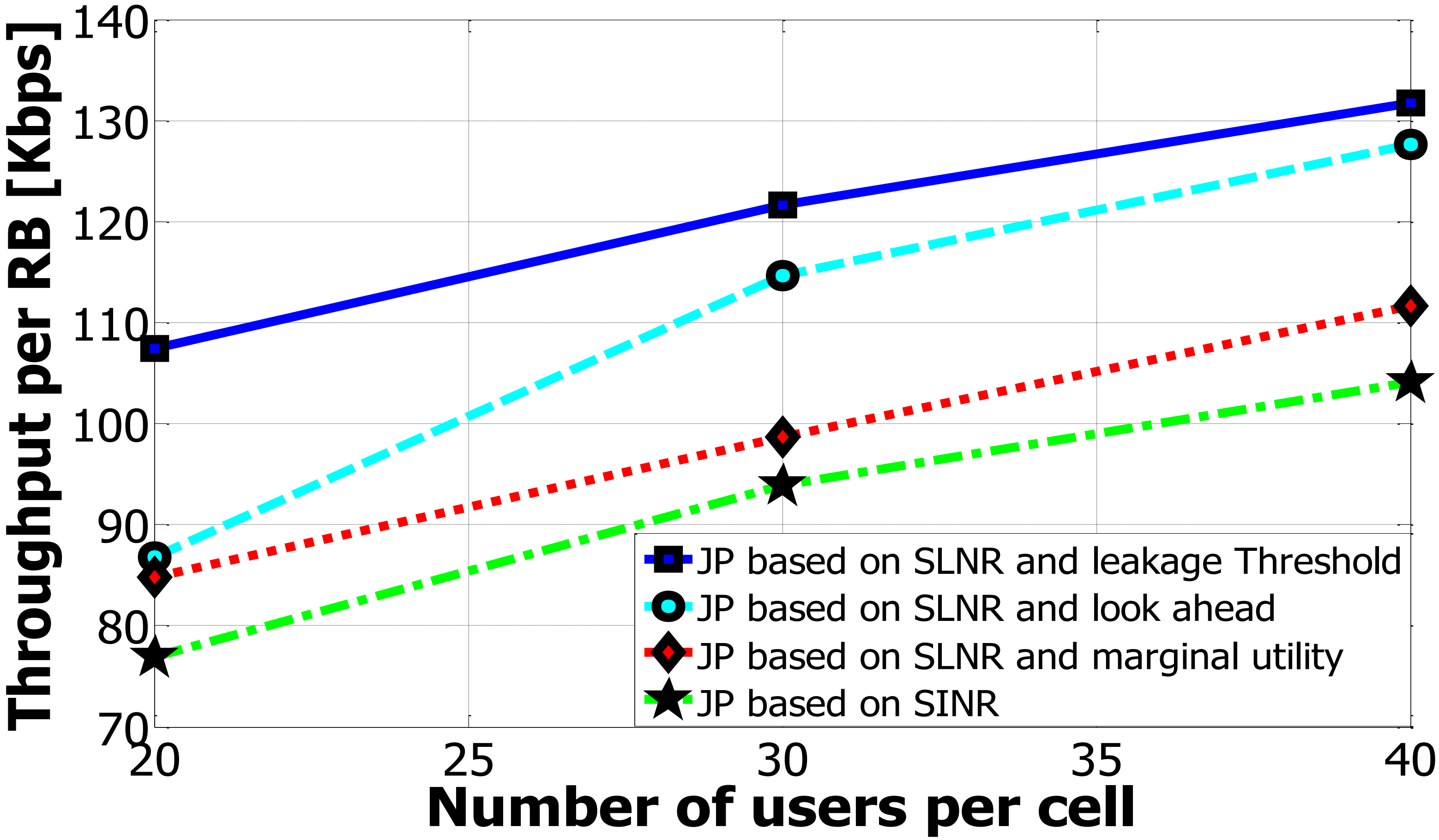
Throughput of the CS strategies in urban macro-cell scenario

Performance Results - CS



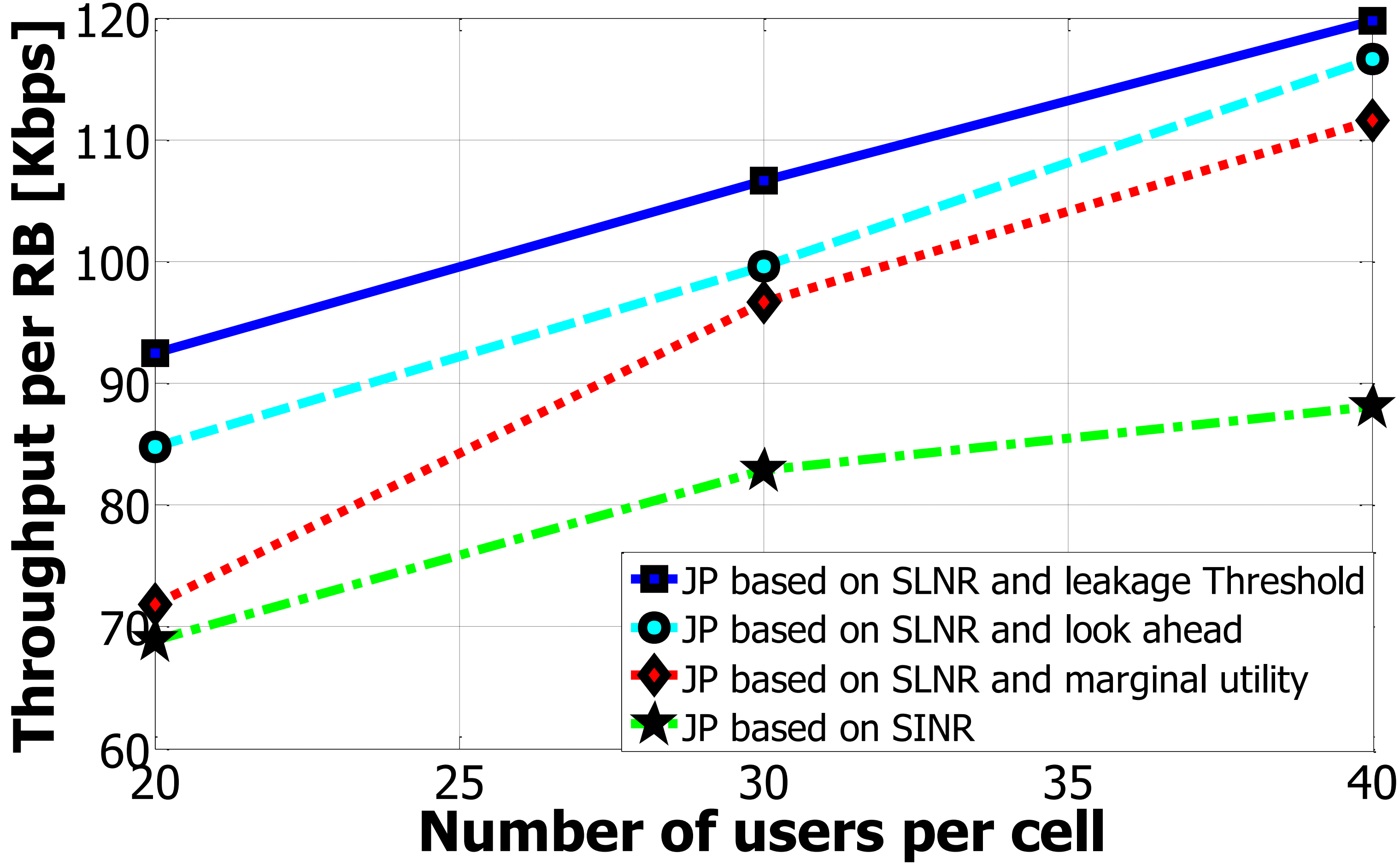
Throughput of the CS strategies in bad urban macro-cell scenario

Performance Results - JP



Throughput of the JP strategies in urban macro-cell scenario

Performance Results - JP



Throughput of the JP strategies in bad urban macro-cell scenario

Performance Results

- The proposed CS and JP strategies provide up to 80% throughput gains compared to the strategies that are based on the SINR.
- That is basically due to:
  - The accurate choice of the stopping condition.
  - The choice of the weighting vectors that are determined more accurately so as to maximize the SLNR metric for all UEs.

SLNR-based RA is shown to provide significant gains in the overall system throughput

Summary and Conclusion

- We presented two novel RA strategies based on SLNR metric. Those strategies achieve considerable throughput gains.
- The proposed RA strategies reduce the computational complexity as compared to the more classical RA strategy based on SINR.
- We investigated many stopping methods, the leakage threshold method achieves high throughput gains but needs pre-processing.
- We showed that the marginal utility with look-ahead criterion is efficient and achieves high throughput gains.

Thank you!