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Carrier Components Assignment Method for LTE and LTE-A Systems Based on User Profile and Application

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Communication Speed Over Generation

Definition	Analog
Throughput	14 kbps
Technology	AMPS, NMT, TACS,..

1G

Definition	Digital, Narrowband, Circuit Data
Throughput	14.4 kbps
Technology	CDMA, TDMA, GSM

2G

Definition	Digital, Broadband, Packet data
Throughput	3Mbps (D ↓), 700kbps(U ↑)
Technology	CDMA2000, UMTS, EDGE

3G

Definition	Digital, Broadband, Packet data, All IP
Throughput	300Mbps (D ↓), 5Mbps (U ↑)
Technology	WiMAX, LTE, Wi-Fi

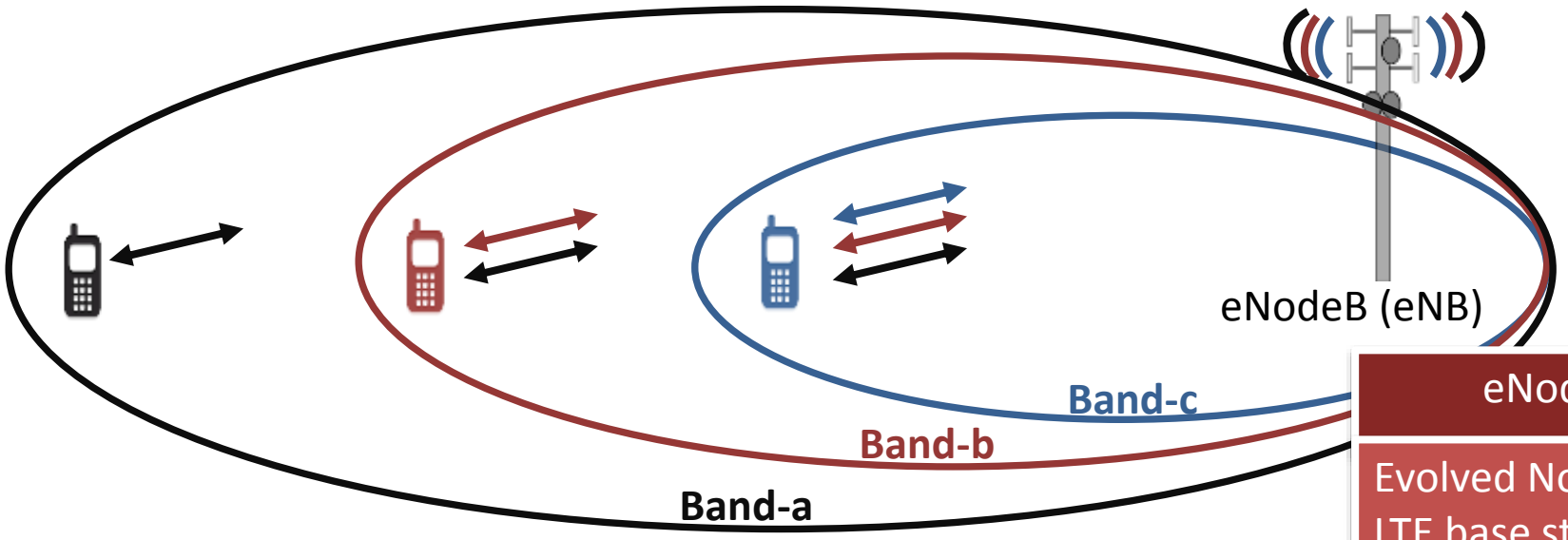
4G

LTE

LTE and LTE-A

	LTE	LTE-A
Theoretical Throughput	300Mbps (D ↓) - 75Mbps (U ↑)	3Gbps (D ↓) - 1.5Gbps (U ↑)
Experienced Throughput	13Mbps (D ↓) crowded area	
Technology	OFDMA (D ↓), SC-FDMA (U ↑)	OFDMA, CA, RN

Carrier Aggregation (CA)

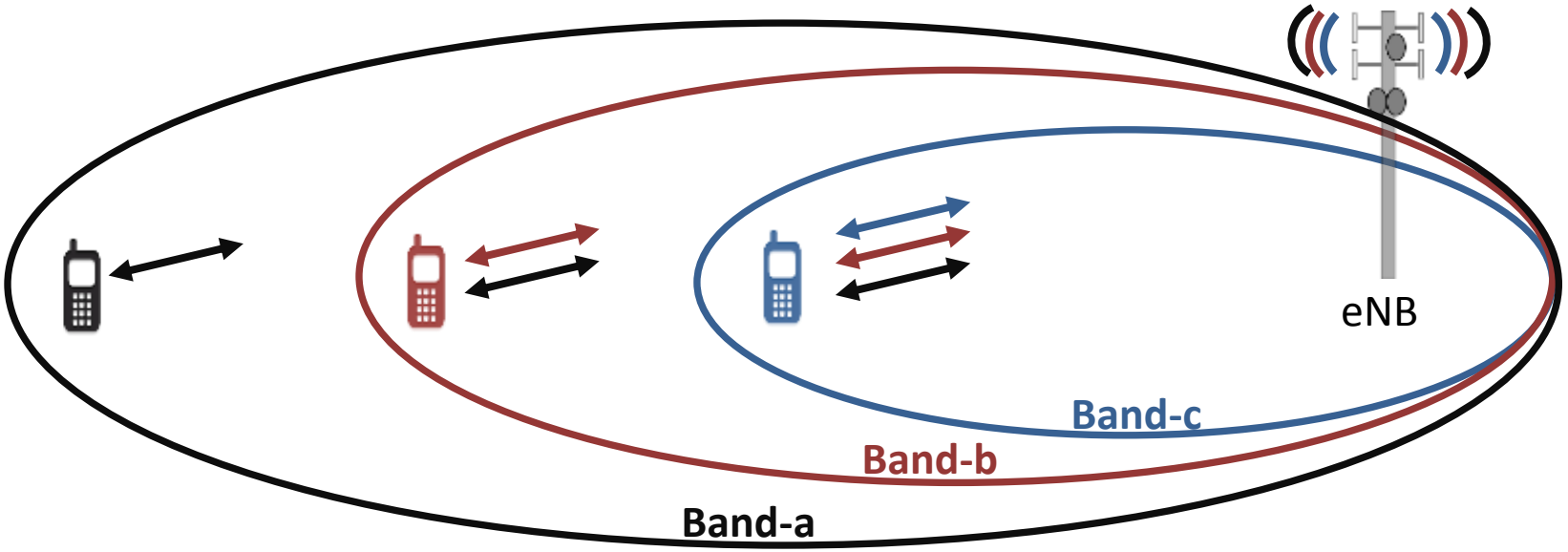


eNodeB

Evolved Node B:
LTE base station

Upto 5 Carrier Components (CC) for downlink and uplink

Carrier Assignment

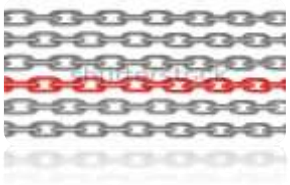


Problems:

1. Which band should eNB assign to each user?
2. How many CCs should be assigned to each user?

Current Solutions for Carrier Assignment

- Carrier Assignments
  - Randomly select band for each user (R)
    - Not utilize and balance bands in short term and No QoS
  - Methods based on Load Balancing
    - Selecting Least Loaded band for each user (LL)
    - Well utilizing and balancing bands and can provide QoS
  - Methods based on Channel Quality Indicator (CQI)
    - Assigning channel based on channel quality and can provide QoS.
- Number of Required CCs
  - How many CCs is required?
    - All of CCs can be used but increasing energy consumption of devices



Why need another Carrier Assignment Method?

- More advance Carrier Assignment Method is required to satisfy users
  - Increasing bandwidth demand
  - Limitation of resources (battery of devices and bandwidth)
  - Traffic management (real time and non-real time traffic)

- Determining the number of required Carrier Components

Why User Profile

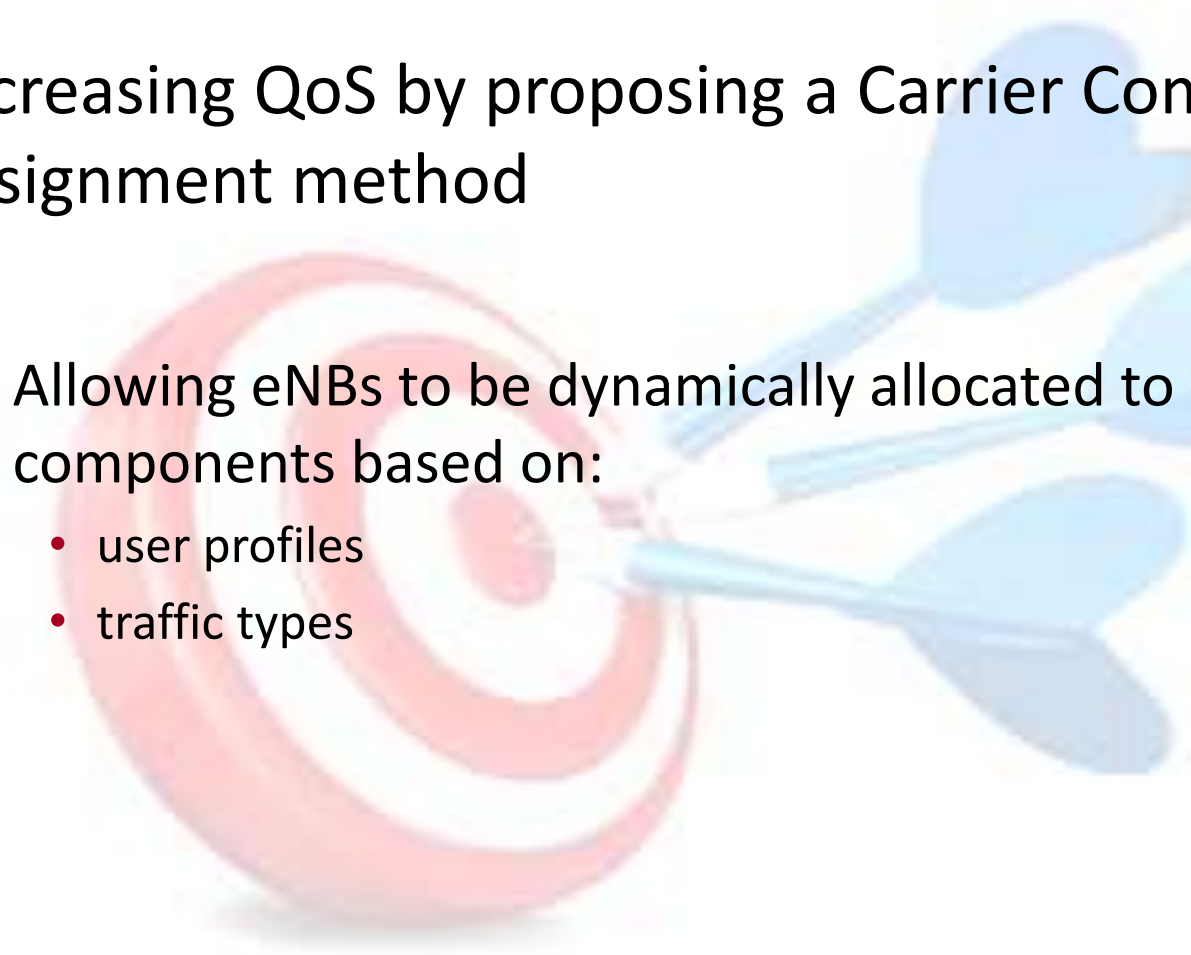
- User profile of each user for each eNB
  - Application type
    - What type of applications are used by users? (such as game, mail, video, talking..)
  - Data consumption
    - How much data do users use? (such as 100MB non-real time, 1GB real time)
  - Time
    - When do users mostly consume data during the day? (such as 10:00 am – 11:00 am)
  - Location
    - Where do users spend the most time during the day? (such as school, work, road …)
  - Users' device type
    - LTE (Only 1 CC), LTE-A full (Upto 5 CCs), LTE-A low (Only 1 CC)

Why Carrier Assignment Based on User Profile

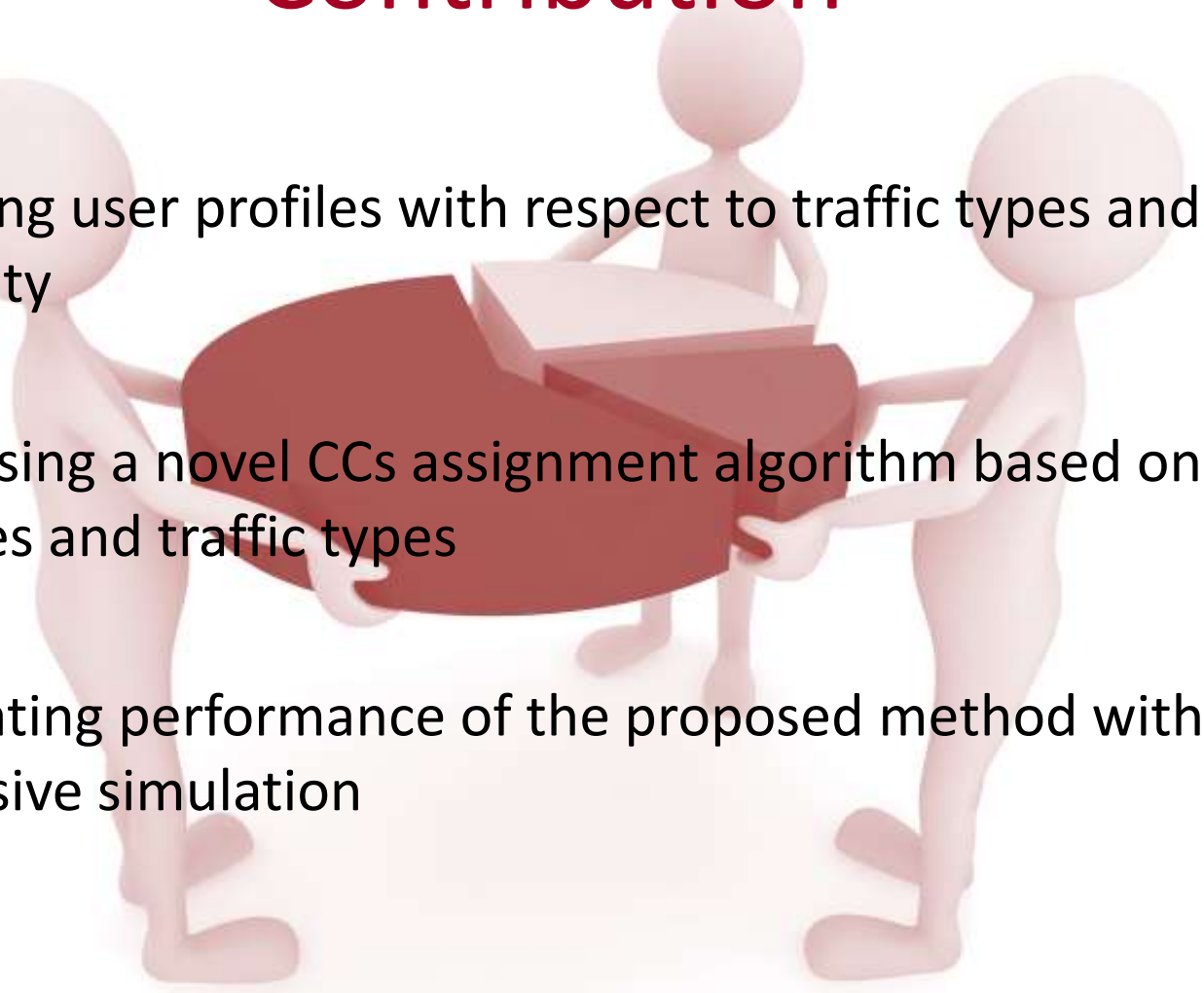
- Make users happy
  - Satisfy users based on the behaviors

Objective

- Increasing QoS by proposing a Carrier Components assignment method
  - Allowing eNBs to be dynamically allocated to users to carrier components based on:
    - user profiles
    - traffic types



Contribution



- Defining user profiles with respect to traffic types and mobility
- Proposing a novel CCs assignment algorithm based on user profiles and traffic types
- Evaluating performance of the proposed method with extensive simulation

User Profile Examples

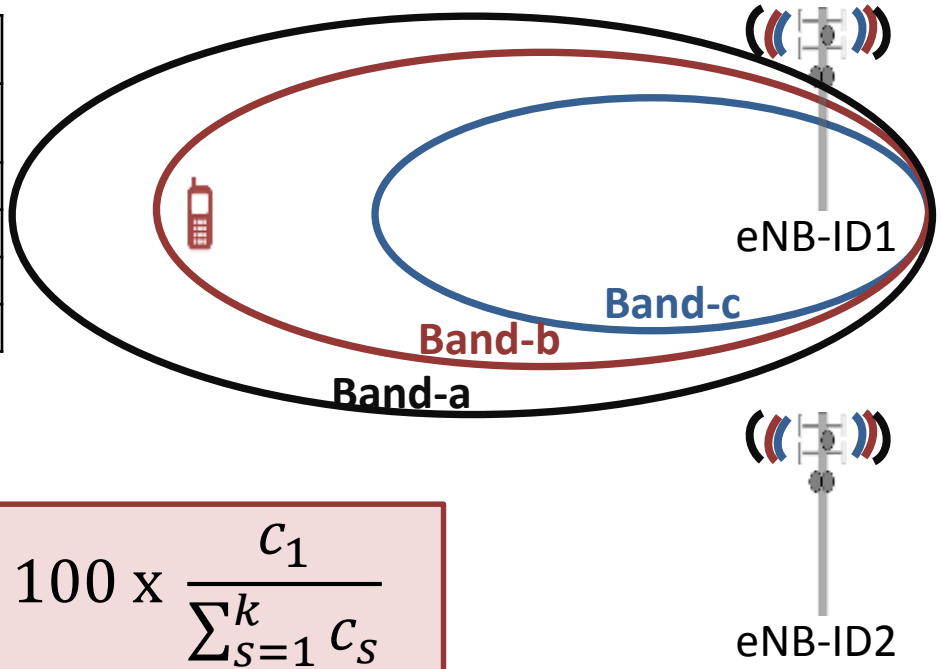
			User Profile				
			Teenager	**House wife**	**Businessman**	**Graduate Student**	**Grand Parent**
Traffic Types	**RT**	**Video**	Very High	Middle	Low	Medium	Low
		Online game	Very High	Low	Low	Medium	Low
		Movie	Very High	Very High	Low	Medium	Low
		Talk	Low	Medium	High	Medium	Very High
	NRT	**Web**	High	Low	Very High	Medium	Low
		Mail	High	Low	Very High	Medium	Low
		SMS	Very High	Medium	Low	Medium	Low
		Mobility	Low	Medium	Very High	Low	Low
		Location	Low	Medium	High	Medium	Low





User Profile Detection

	Band-a/Band-b/Band-c			RT Services		NRT Services	
eNB-ID	Times	Connection Time	Idle Time	Video	Game	Web	Mail
ID1	f1	c1	t1	v1	g1	w1	m1
ID2	f2	c2	t2	v2	g2	w2	m2
ID3	f3	c3	t3	v3	g3	w3	m3
ID4	f4	c4	t4	v4	g4	w4	m4



Statistical examples:

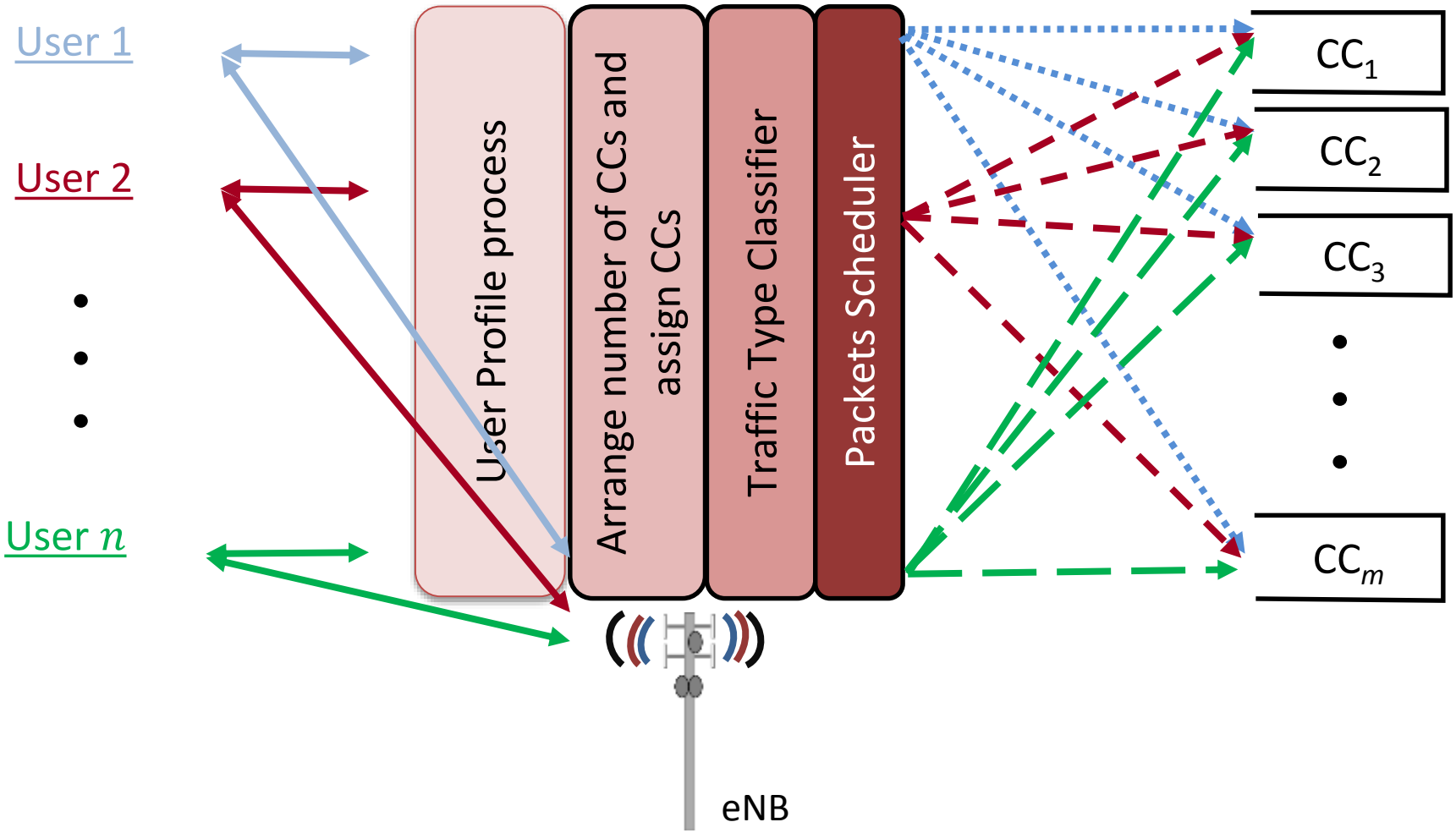
$$\Delta T_j^i = 100 \text{ x } \frac{f_1}{\sum_{s=1}^{k} f_s}$$

$$\Delta C_j^i = 100 \text{ x } \frac{c_1}{\sum_{s=1}^{k} c_s}$$

Examples

- Case1: Higher ΔC and lower ΔT → User spends more time around eNB
- Case2: Lower ΔC and higher ΔT → user temporarily request service from eNB such as driving to home/work.

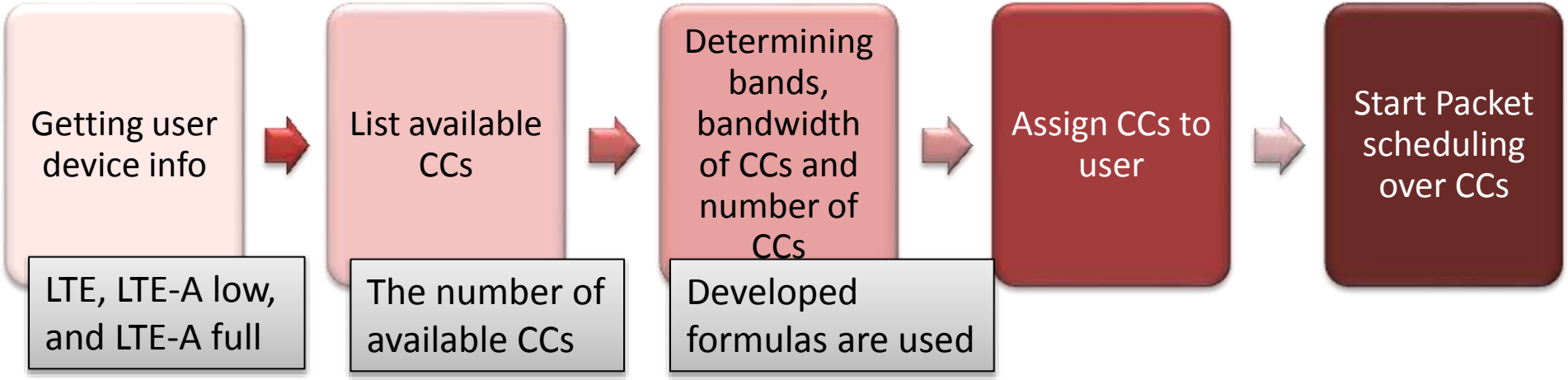
Carrier Assignment Based on User Profile Model



Estimating number of CCs

- **Required number of CCs** is estimated based on data usage and mobility of UEs (user profiles).
- Estimating RT and NRT data usage for a UE helps an eNB **arrange the number of CCs** and their **bandwidth sizes.**
- Estimating mobility of a UE reduces **handover overheads** and **risk of connection loss**.

Carrier Assignment Based on User Profile



Band is determined from active number of users and their data usage

$$\alpha = \frac{average\ real\ time\ data\ usage\ in\ this\ eNB}{Sum\ of\ average\ real\ time\ data\ usage\ in\ all\ eNBs}$$

$$\beta = \frac{average\ non-real\ time\ data\ usage\ in\ this\ eNB}{Sum\ of\ non-real\ time\ average\ data\ usage\ in\ all\ eNBs}$$

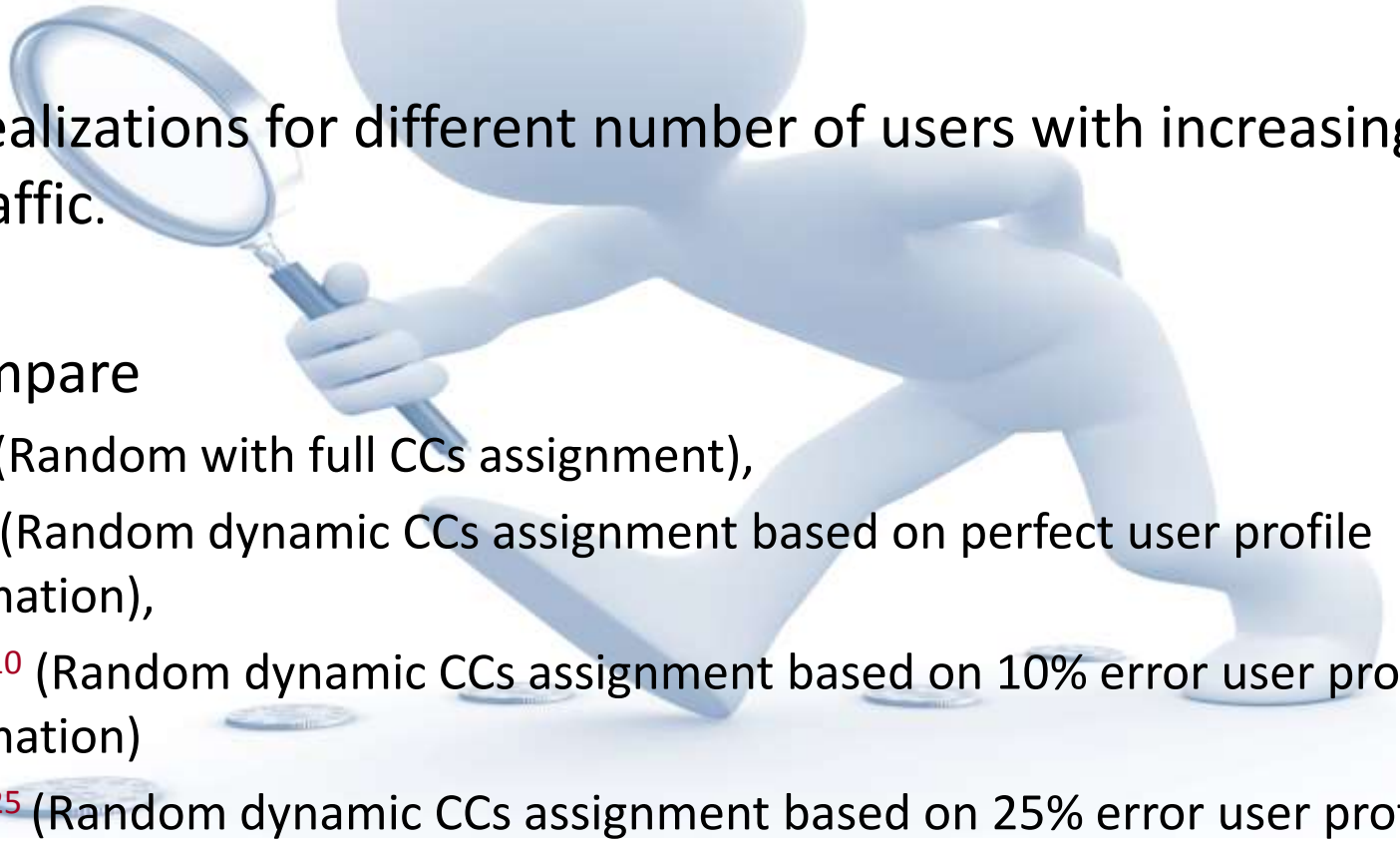
$$\eta RT = \begin{cases} 1xCC & if\ \frac{\alpha}{\xi} \leq 1 \\ \frac{\alpha}{\xi} xCC & if\ \frac{\alpha}{\xi} \geq 1\ and\ \frac{\alpha}{\xi} + \frac{\beta}{\xi} \leq 5 \end{cases}$$

Data rate which can be carried by a CC

Required number of CCs for real time traffic

Results

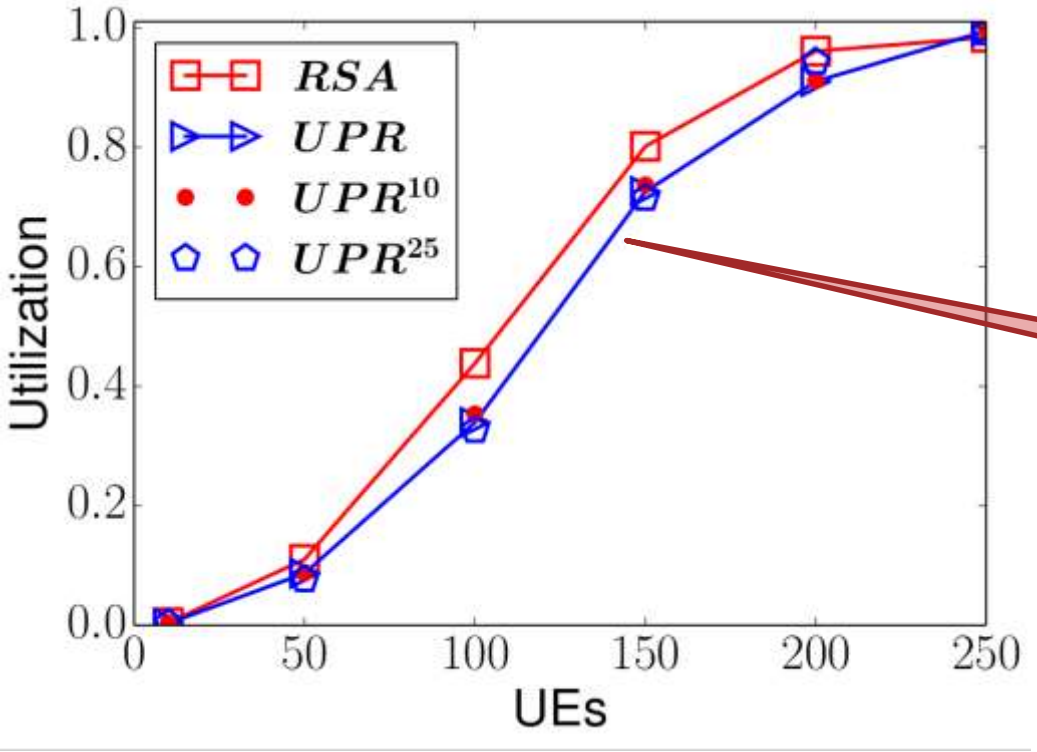
- Discrete event simulation by following $M/M_i/N$ and proposed carrier assignment.
- 1000 realizations for different number of users with increasing data traffic.
- We compare
  - RSA (Random with full CCs assignment),
  - UPR (Random dynamic CCs assignment based on perfect user profile estimation),
  - UPR^{10} (Random dynamic CCs assignment based on 10% error user profile estimation)
  - UPR^{25} (Random dynamic CCs assignment based on 25% error user profile estimation)



RSA vs UPRs (Band-a)

RSA is random with 4 CCs.

UPRs is proposed assignment with errors and at most 4 CCs.



Objective

Observing effects of number of users on utilization of Band-a.

Band-a utilization of RSA is higher than UPRs' ones.

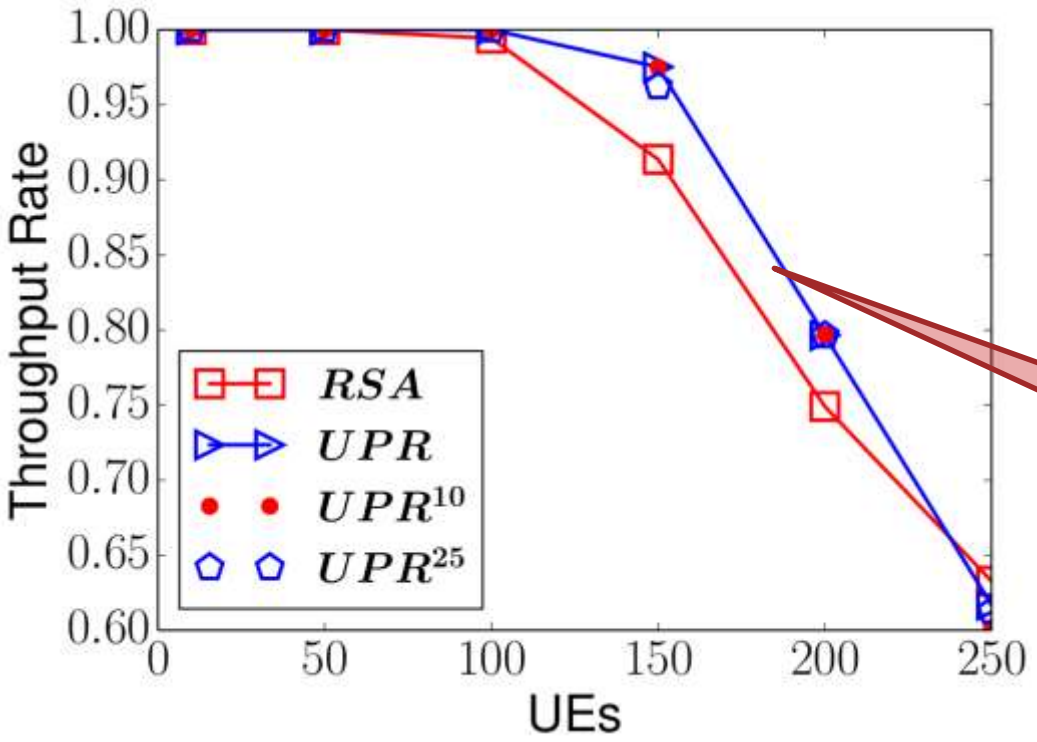
RSA = Random Carrier Component Assignment with static number of Carrier Components.
UPR = Random CCs assignment with dynamic number of CCs based on perfect user profile estimation.

Although overall average utilization of the four cases are similar, the utilization of each band is different.

RSA vs UPRs (nRT)

RSA is random with 4 CCs.

UPRs is proposed assignment with errors and at most 4 CCs.



Objective

Observing effects of number of users on non-real time traffic throughput.

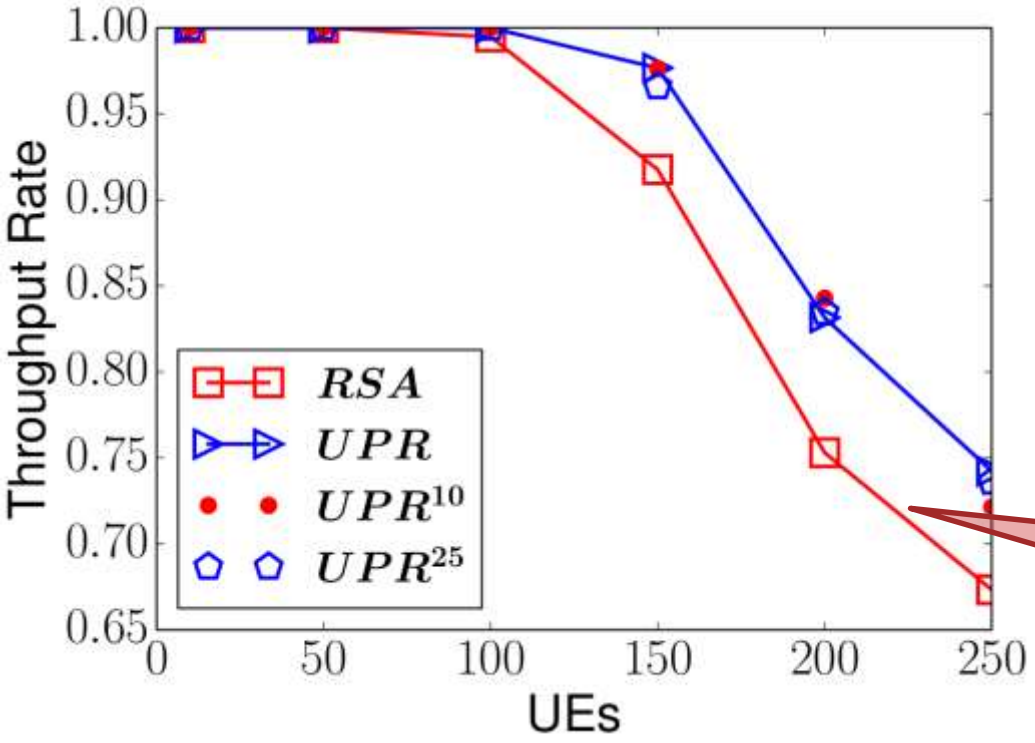
Non-real time throughput of RSA is generally lower than UPRs'.

UPRs are better than RSA in terms of non-real time traffic throughput until the number of users is 200.

RSA vs UPRs (RT)

RSA is random with 4 CCs.

UPRs is proposed assignment with errors and at most 4 CCs.



Objective

Observing effects of number of users on non-real time traffic throughput

Real time throughput of RSA is lower than UPRs'

UPRs are better than RSA in terms of real time traffic throughput.

Summary of Results

Improving throughput comparing to RSA.

UPRs

Performance of UPRs is not much affected by error in profile estimation upto 25%.

Conclusions

Thank You

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