Design and Implementation of efficient Cloud-based 5G management protocol

(Ph.D. thesis defense)

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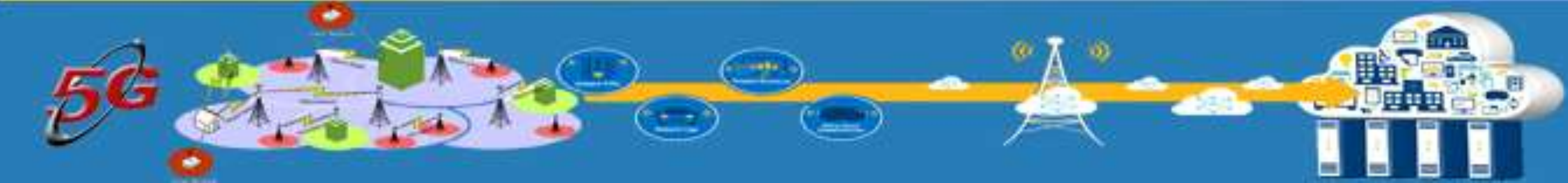

AGENDA

- 5G Overview
- Cloud Computing
- Cloud/5G Integration
- EUFS Algorithm
- LANCDC Algorithm
- Conclusion & Future Work
- References

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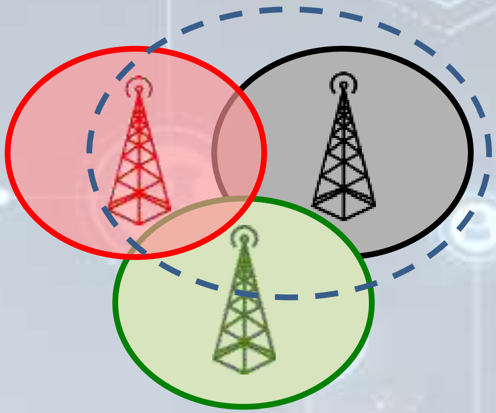
Introduction

- **Why cellular generations evolving?** [1-3]
  - Increase Capacity.
  - Increase Throughput.
- ***In 4G*** *(*the Long Term Evolution "**LTE**"*)*, increasing capacity / throughput done by:
  - Adding more cells [1-2],



- *This results in growing **inter-cell interference** levels and **high costs**.*

Introduction

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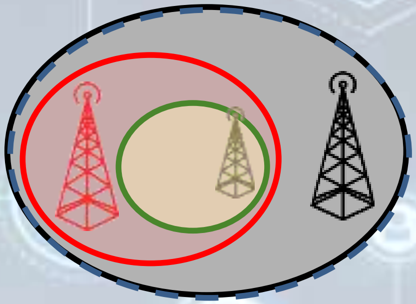
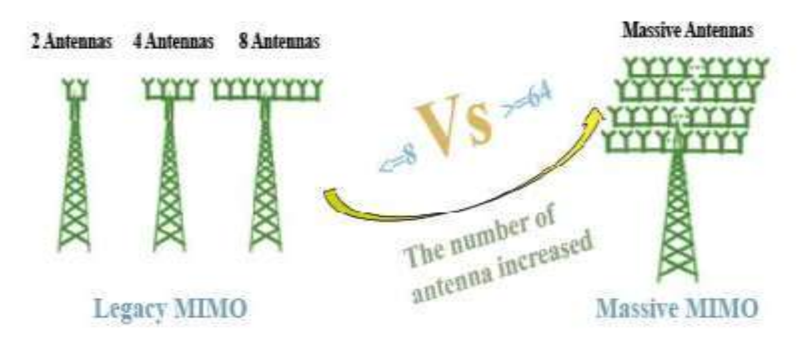
  - Increase (**HetNet**s) [4],



- *This results in growing **inter-cell interference** levels and **high costs**.*

Introduction (cont.)

- **Why cellular generations evolving?** [1-3]
  - Increase Capacity.
  - Increase Throughput.
- *In 4G (*the Long Term Evolution "**LTE**"*)*, increasing capacity / throughput done by:
  - Adding more cells [1-2],
  - Increase (**HetNets**) [4],
  - Implementing (**MIMO**) & **Massive MIMO** [5].



[5]

- *This results in growing **inter-cell interference** levels and **high costs**.*

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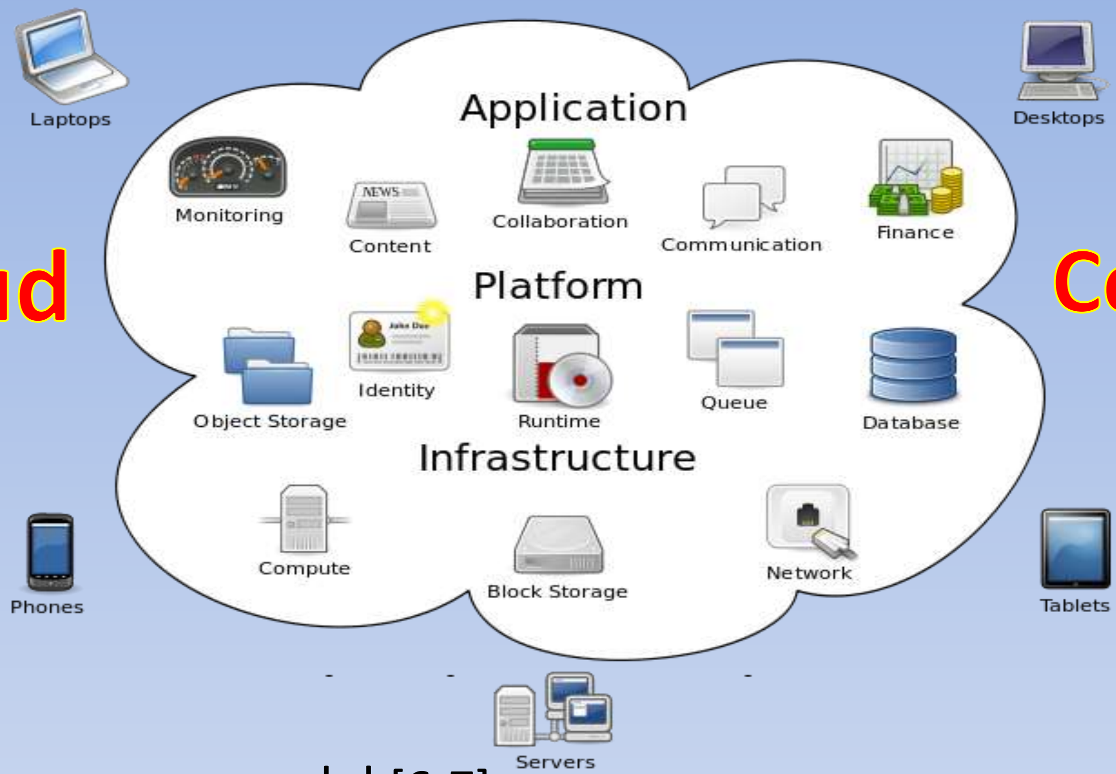
Cloud Computing



- A **pay-per-use** model [6-7].
- Enable convenient, on-demand network access to a shared pool of configurable and reliable *computing resources* (e.g., networks, servers, storage, applications, services) [6-7].
- Resources can be rapidly *provisioned* and *released* with minimal consumer management effort or service provider interaction [6-7].

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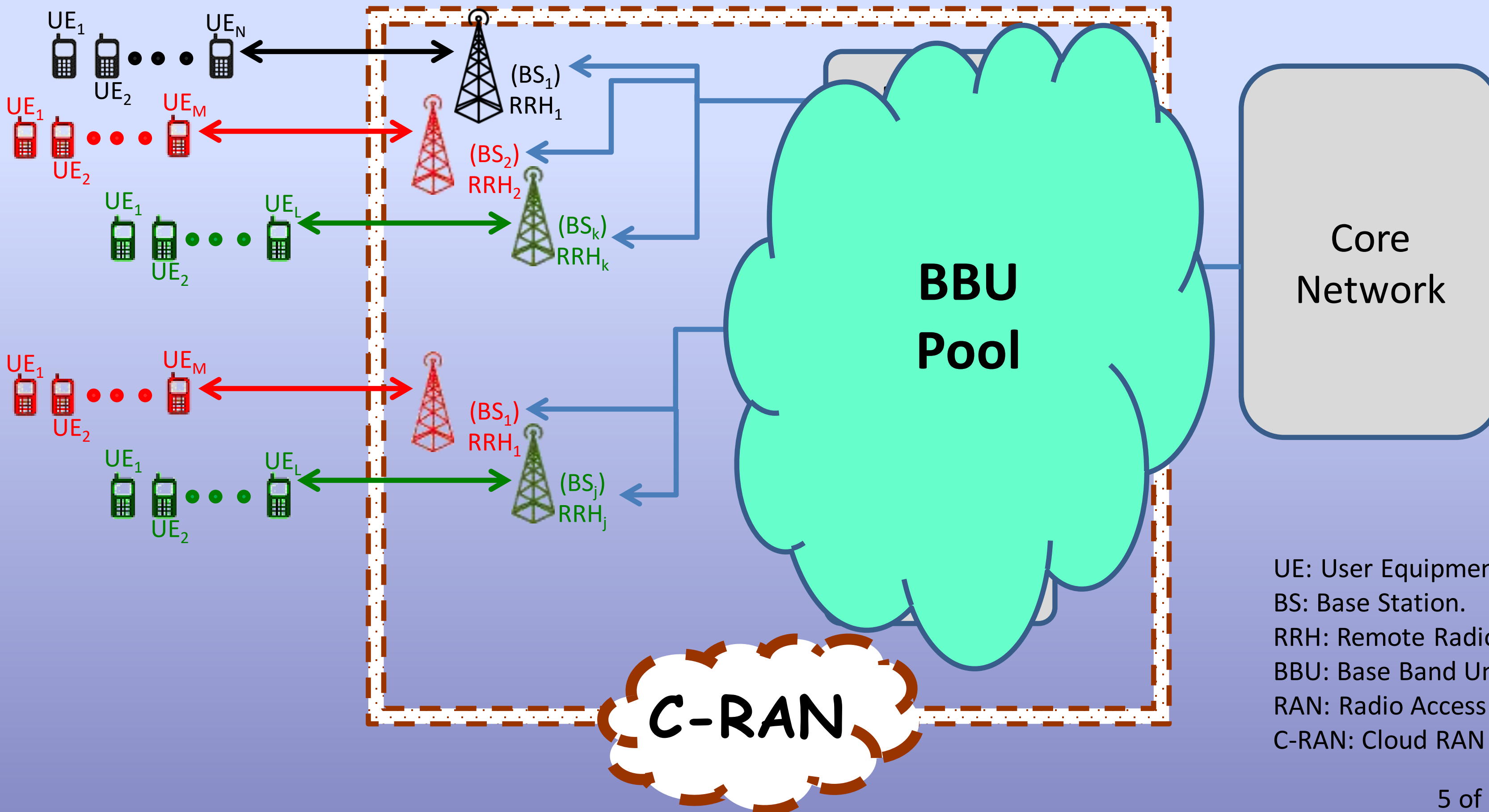
Cloud/5G Integration

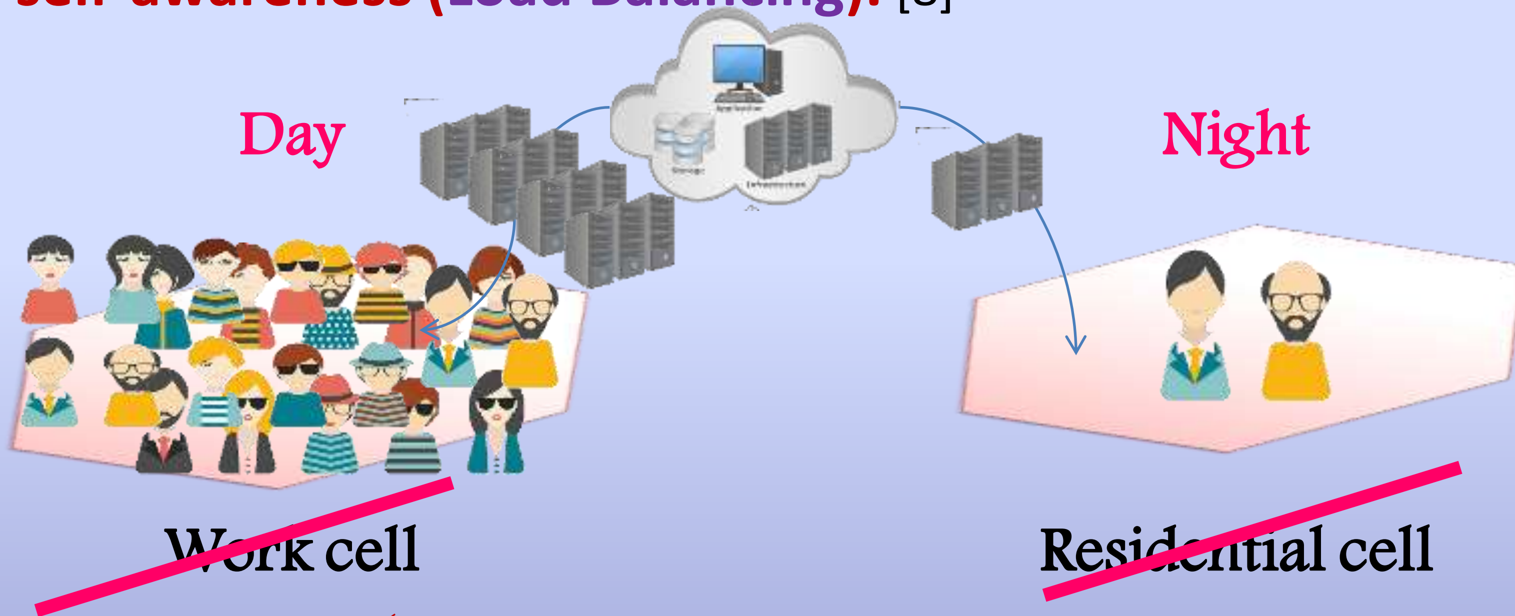
- Cloud-based (5G) network architecture
- Conventional (4G) network architecture



UE: User Equipment.
BS: Base Station.
RRH: Remote Radio Head.
BBU: Base Band Unit.
RAN: Radio Access Network
C-RAN: Cloud RAN

CRAN Features

- **Adaptability to dynamic traffic, scalability, availability and self-awareness (Load Balancing).** [8]



✓ Resource allocation and sharing

✓Higher efficiency and lower cost (i.e., reduced CAPEX/OPEX)

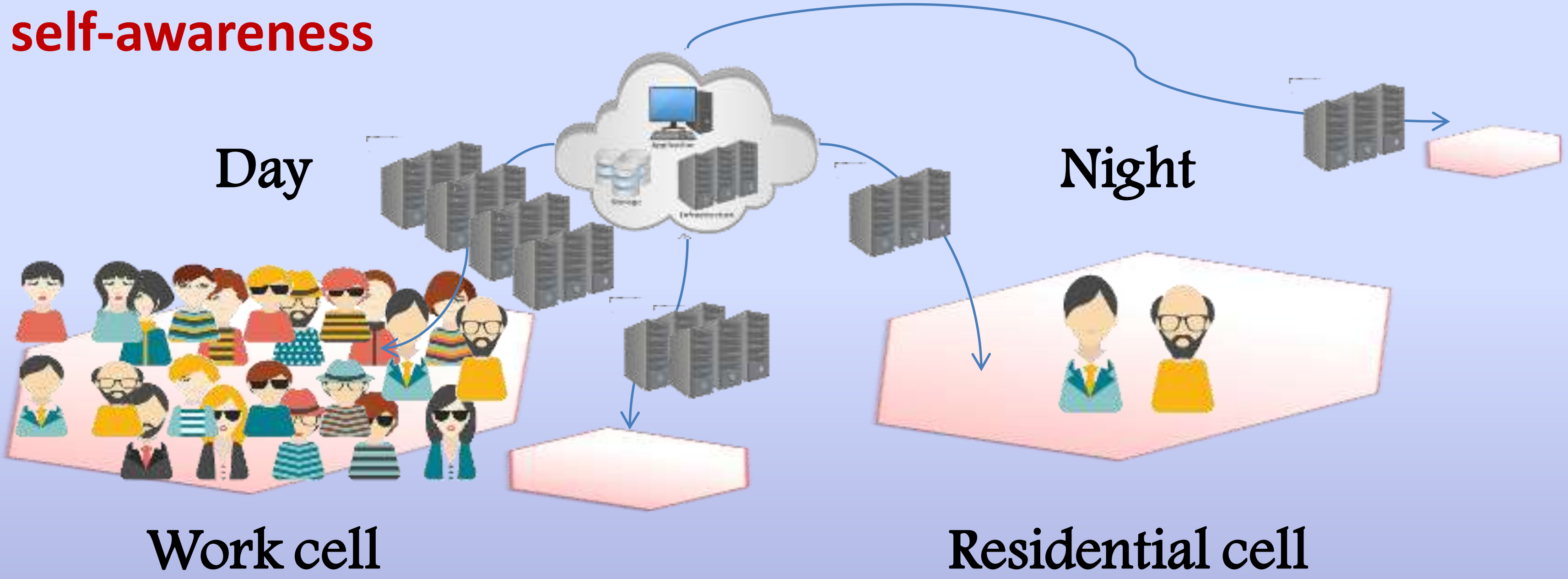
✓Centralized management, monitoring, configuration, optimization, maintenance and mobility control.

✓Joint processing approaches.

✓Virtualization.

CRAN Features

- **Adaptability to dynamic traffic, scalability, availability and self-awareness**



✓ Increased throughput

✓ Energy and power savings

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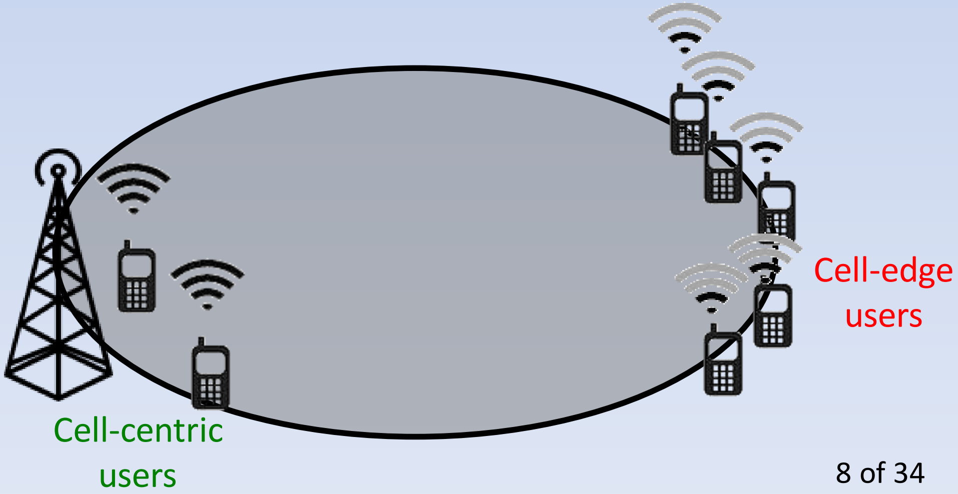
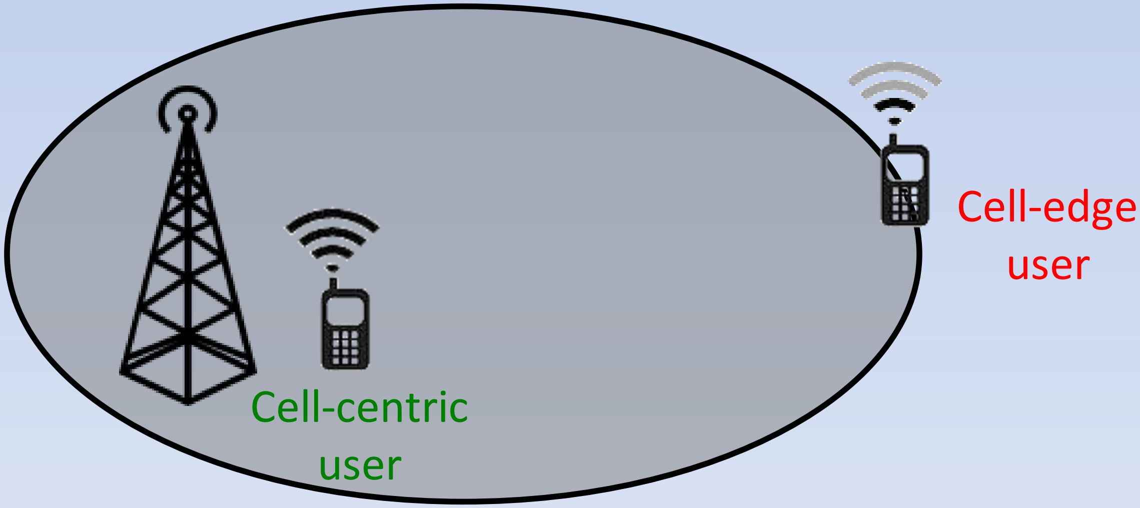
Algorithm-1 Introduction

- ***Ways to improve cell-edge throughput***
  - ***Resource Scheduling*** *[9-11]*
  - ***CoMP*** *[12-13]*
  - ***Power Control*** *[1]*
  - ***Load Balancing*** *[11]*

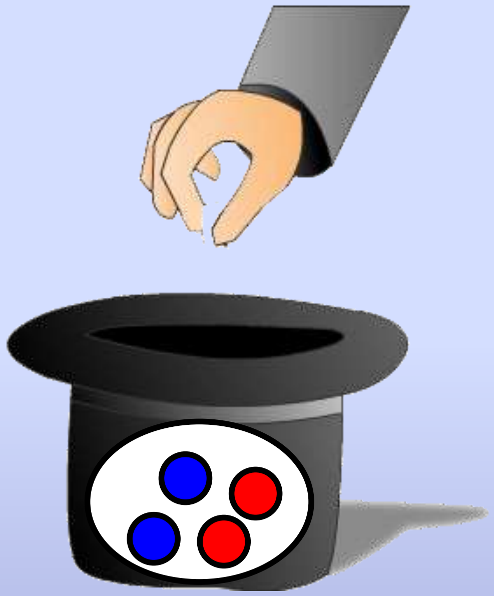


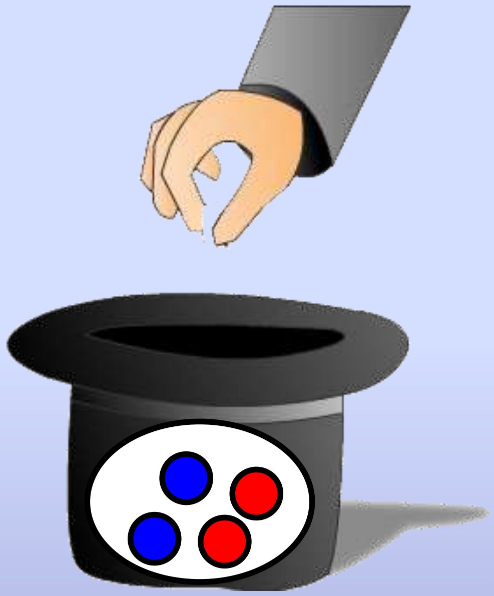
Problem-1 Statement

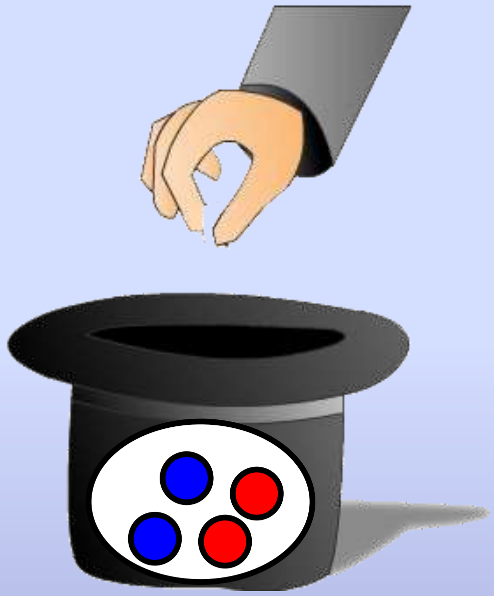
- ***Cell-edge problem***



Sampling with replacement [14]







Sample #1

P(red) = 1/2

P(blue) = 1/2

Sample #2

P(red) = 1/2

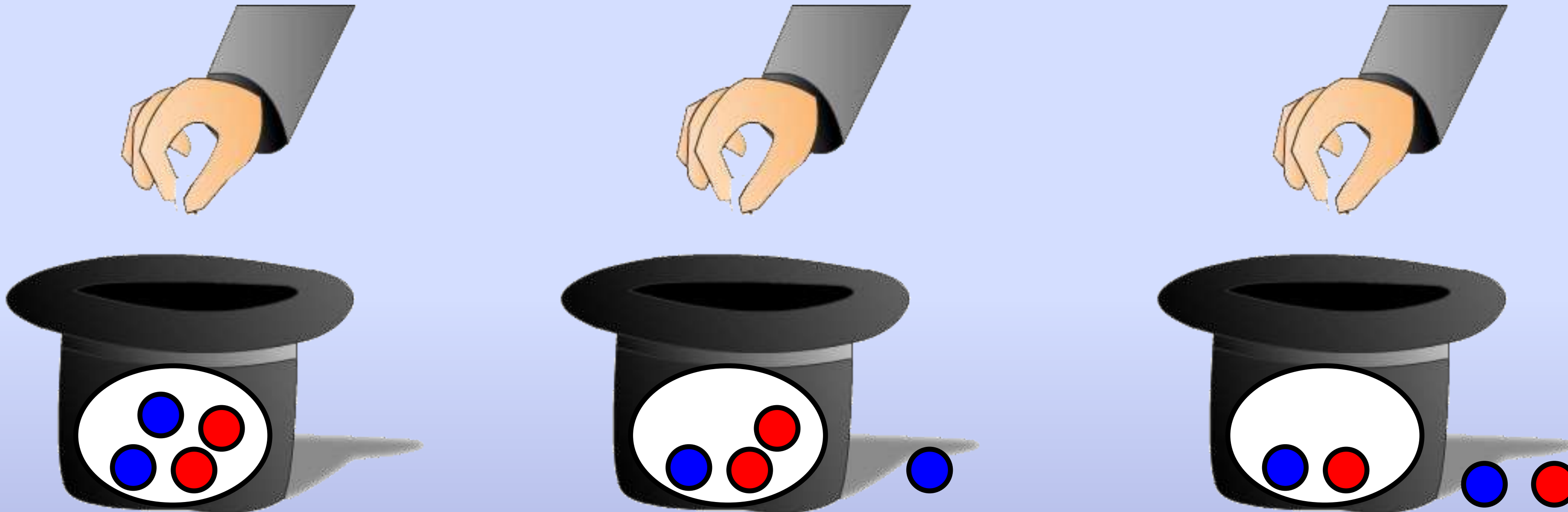
P(blue) = 1/2

Sample #3

P(red) = 1/2

P(blue) = 1/2

Sampling without replacement [14]



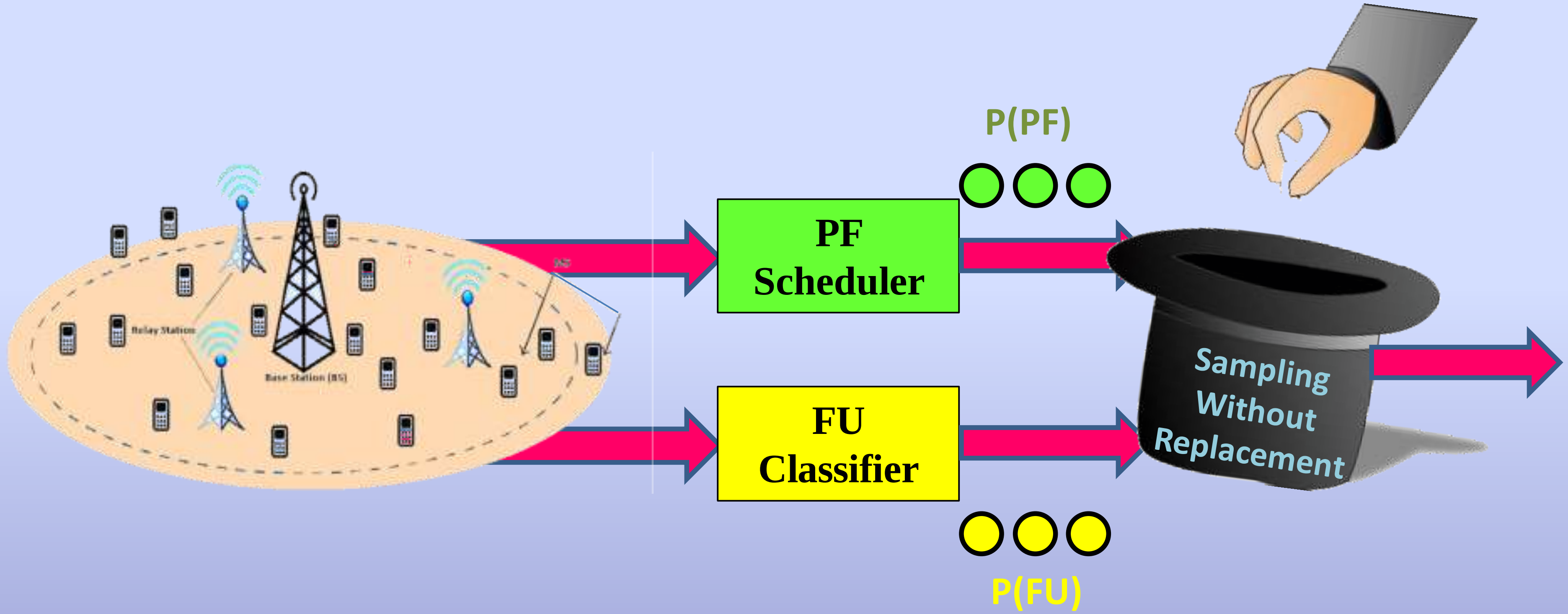
Sample #1	Sample #2	Sample #3
P(red) = 1/2	P(red) = 2/3	P(red) = 1/2
P(blue) = 1/2	P(blue) = 1/3	P(blue) = 1/2

Related Work

- ***State-of-the-art Scheduling Techniques***

    1. Proportional Fair (PF) [15]
    2. Dynamic PF Scheduler (D-PF) [16]
    3. Weighted Signal-to-Noise-Ratio (W-SNR) [17]

EUFS Abstracted Flowchart



Experimental Setup

Platform: Vienna LTE system-level simulator [18], runs on MATLAB.

Parameter	Value	Notes
System Bandwidth	20MHz	*Supported in 3GPP for maximum RBs [19]*
Carrier Frequency	2.14 GHz	*Corresponds to the used system BW [19]*
Channel Model	Fast Fading	*To approach reality [19]*
Total No. of RBs per TTI	100	*Corresponds to the used system BW [19]*
Antenna per RRH	3	*Supported in 3GPP [20]*
eNodeB Transmit Power	40W	*Supported in 3GPP [20]*
No. of eNodeBs	7	*Assumption*
User Mobility	No Mobility	*Neglected to focus on the EUFS effect*
No. of Cells	21	*Assumption*
No. of TTIs	100	*Assumption*

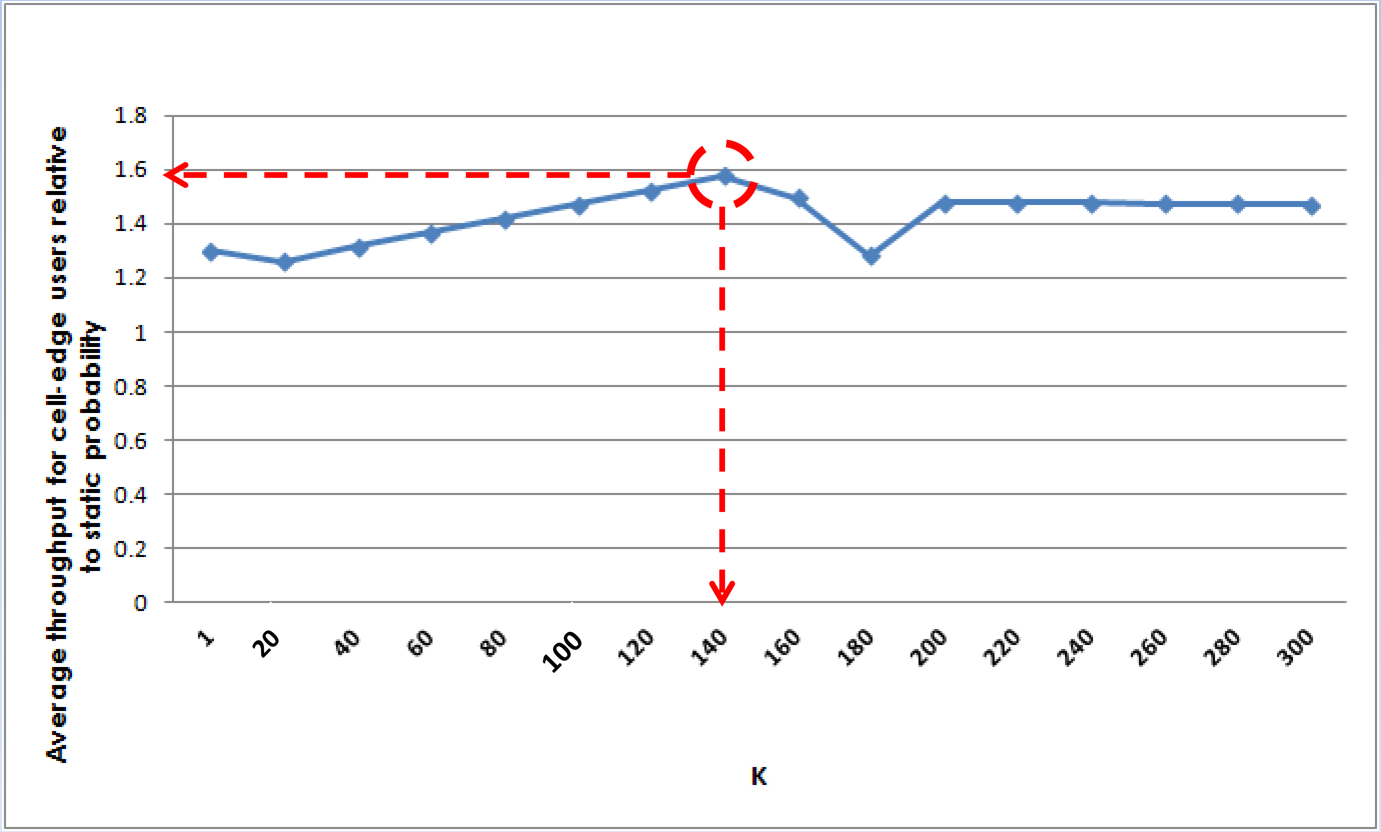
Results & Analysis

- ***Assessing the Initial Scaling Factor***

For K> N_RBs:

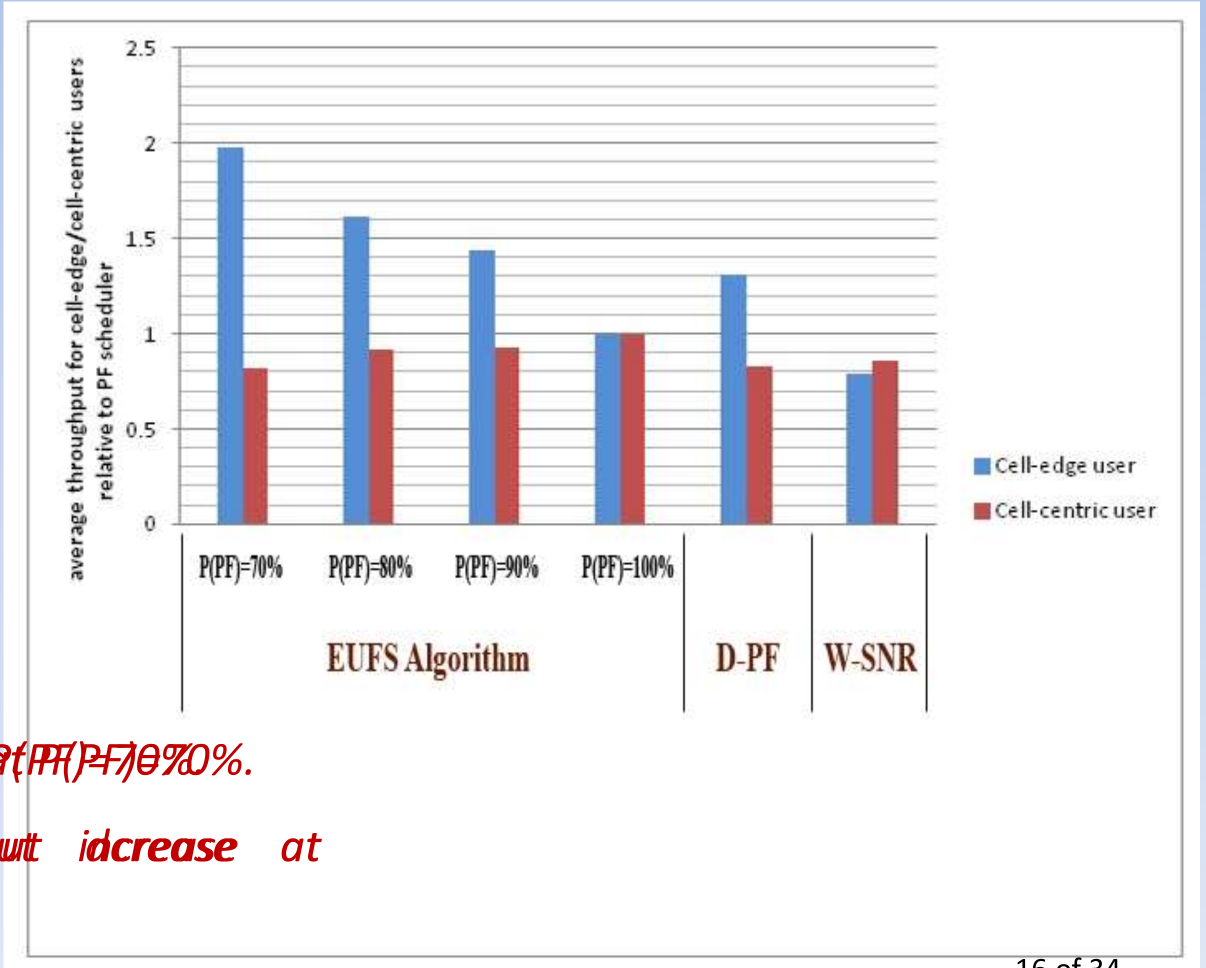
Two opposing factors:

- EUFS still approaching an adaptive RB assignment to the users
- Assigning redundant initial chances to the users occurs.



Results & Analysis (cont.)

- ***Assessing the Throughput***

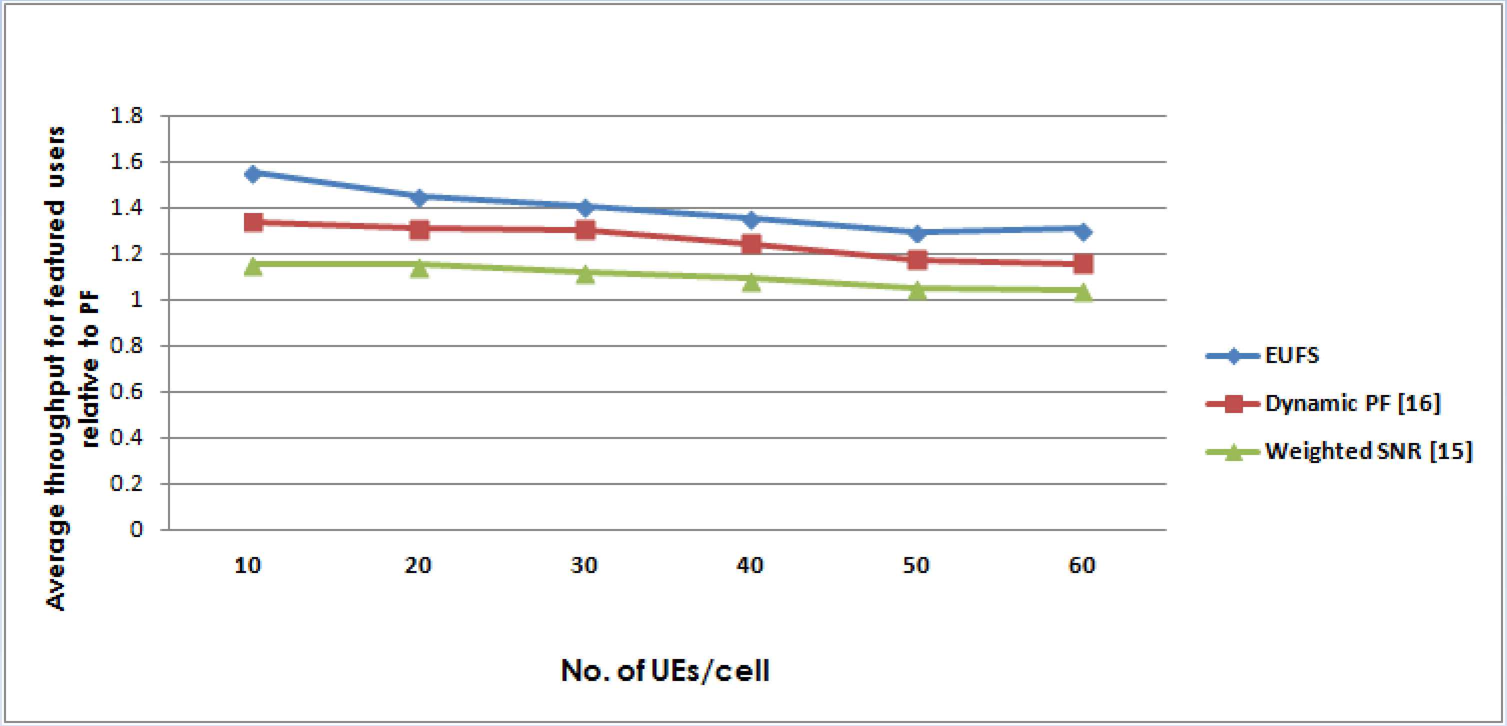


For cell-edge users: / **For cell-centric users:**

- *2x throughput increase at P(PF)=70%.* / *20% Throughput decrease at P(PF)=70%.*
- *10% **(approx.)** Throughput **increase** at P(PF)= 80% ~ 90%.* / *15% **(approx.)** Throughput **decrease** at P(PF)= 80% ~ 90%.*

Results & Analysis (cont.)

- ***Assessing the Throughput***



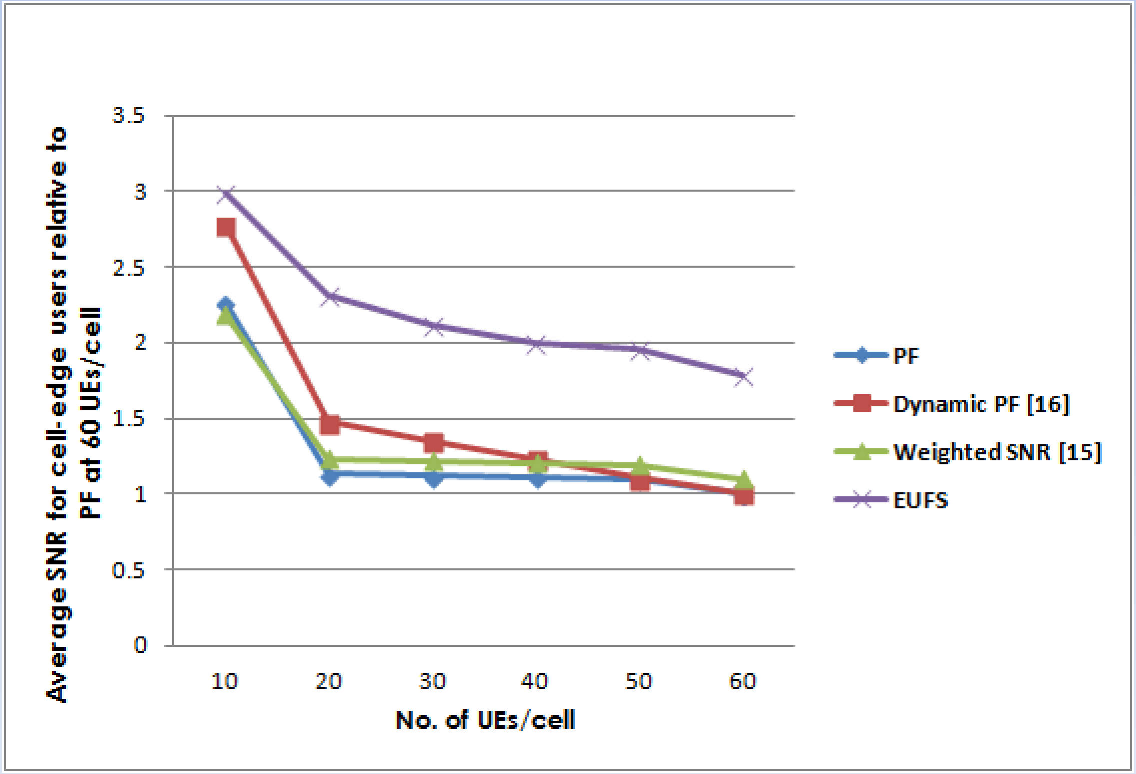
EUFS algorithm always outperforms other scheduling algorithms

Results & Analysis

- ***Assessing the Signal to Noise Ratio (SNR)***

For Cell-edge users:

For EUFS, cell-edge UEs gain 80% increase in SNR relative to PF at 60 UEs/cell, compared to only 45% reduction in the SNR for cell-centric users relative to PF at 60 UEs/cell.

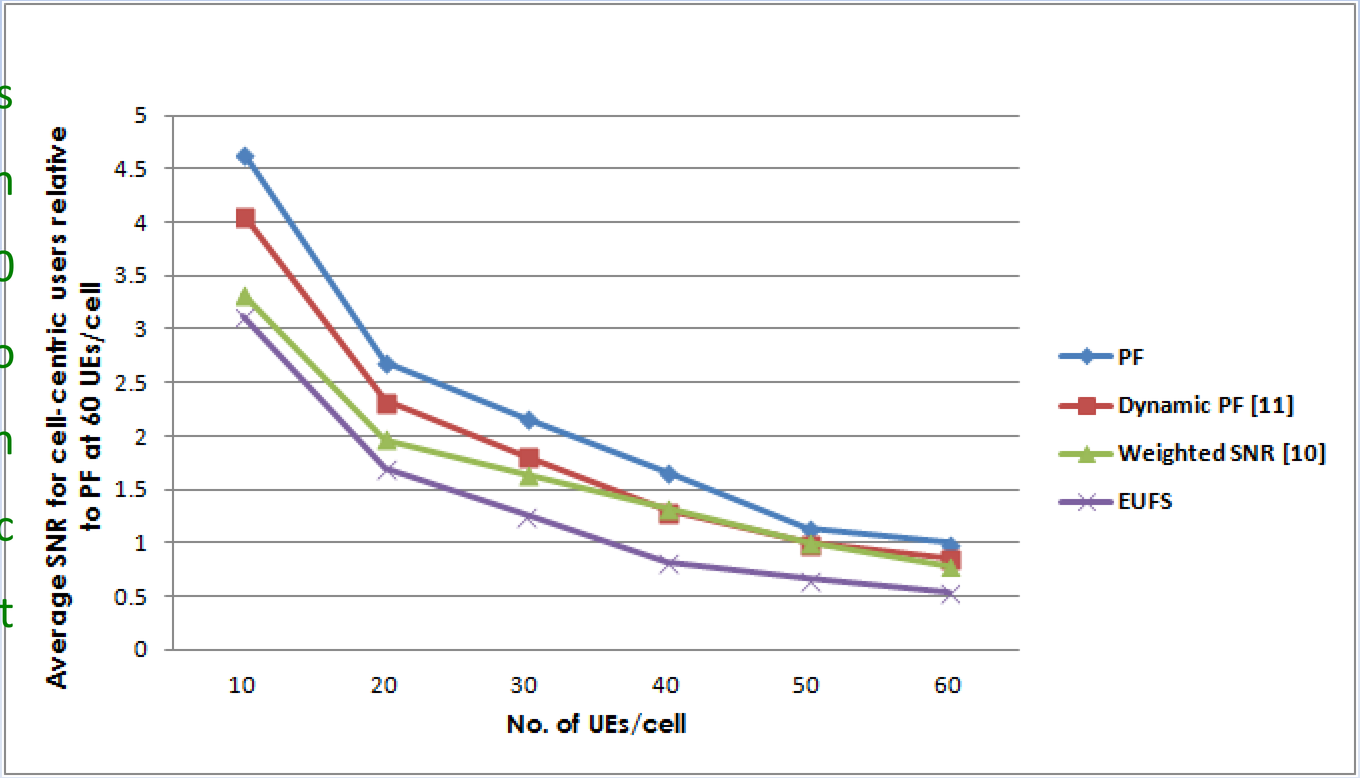


Results & Analysis (cont.)

- ***Assessing the Signal to Noise Ratio (SNR)***

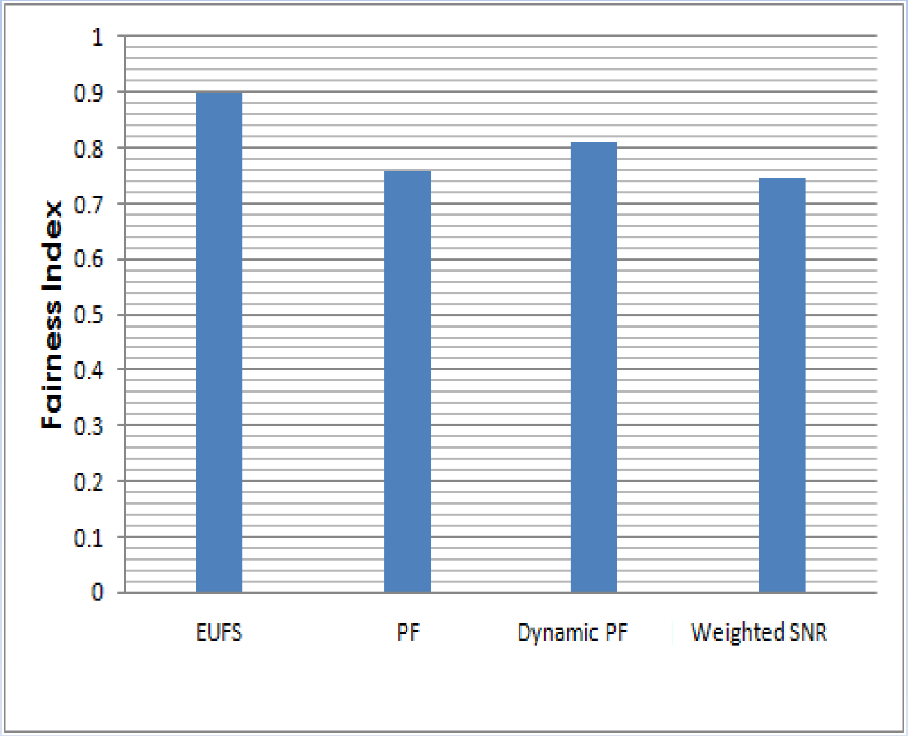
For Cell-centric users:

For EUFS, cell-edge UEs gain 80% increase in SNR relative to PF at 60 UEs/cell, compared to only 45% reduction in the SNR for cell-centric users relative to PF at 60 UEs/cell.

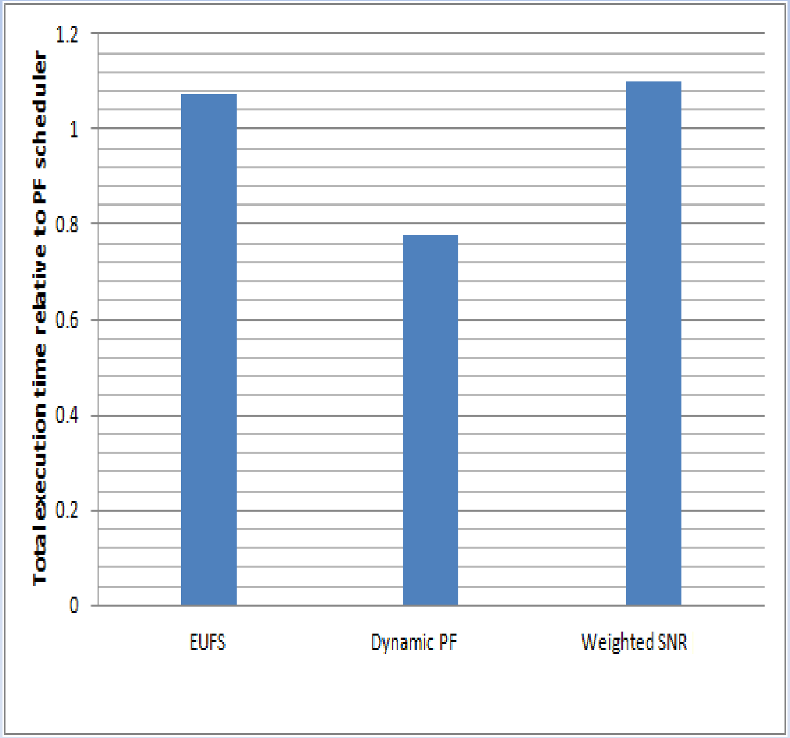


Results & Analysis (cont.)

- ***Assessing the Fairness***



- ***Assessing the Execution Time***



- Only 7.5% time increase from total PF execution time.

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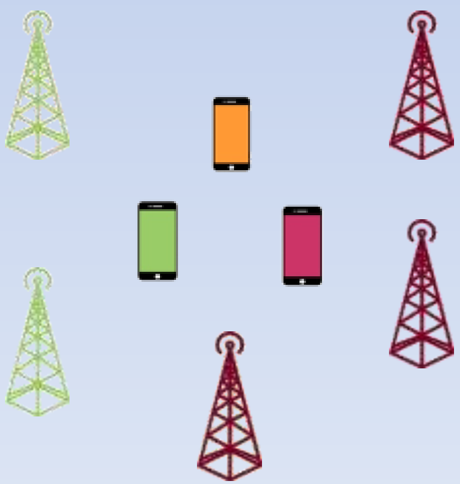
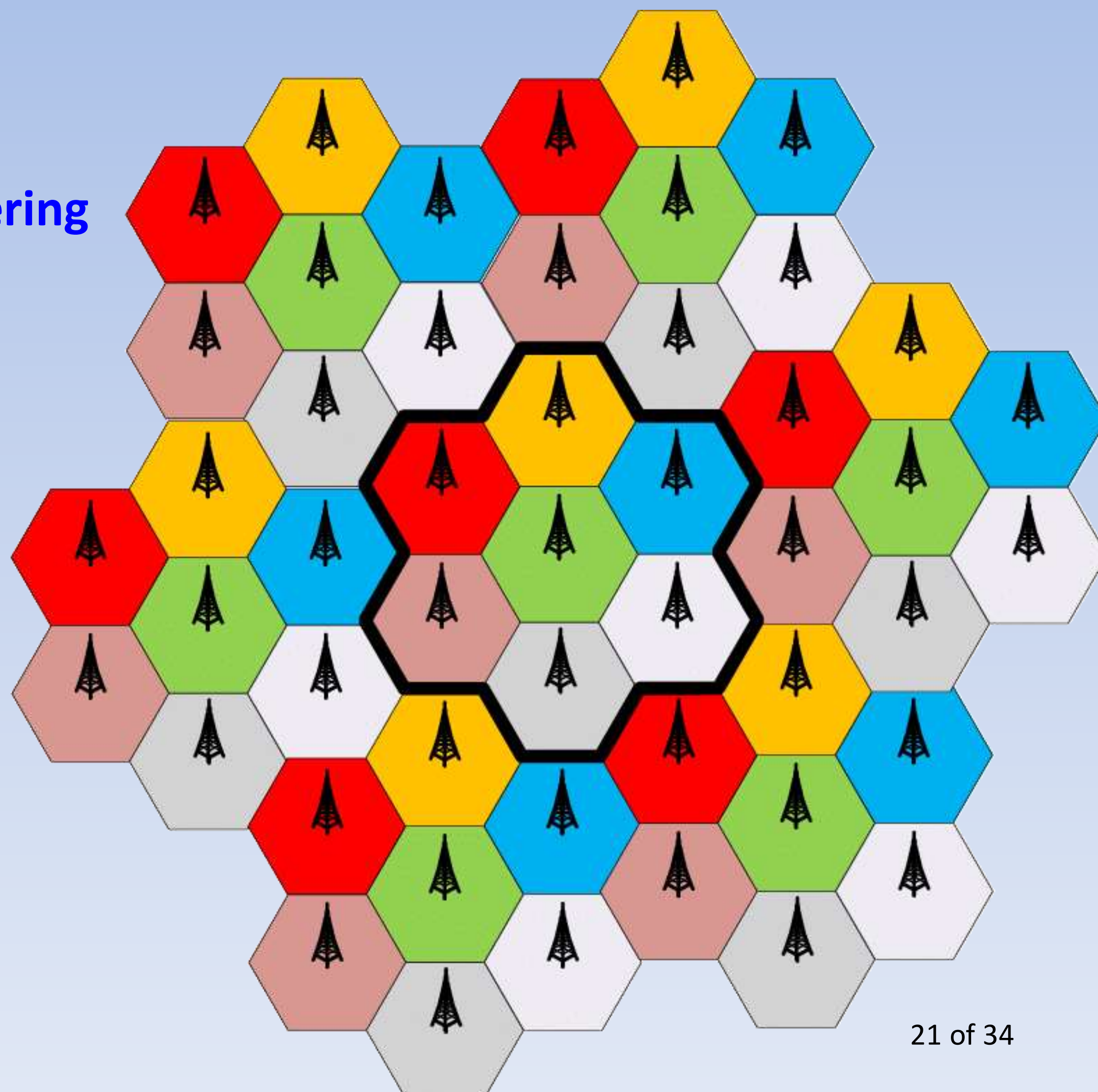
Algorithm-2 Introduction

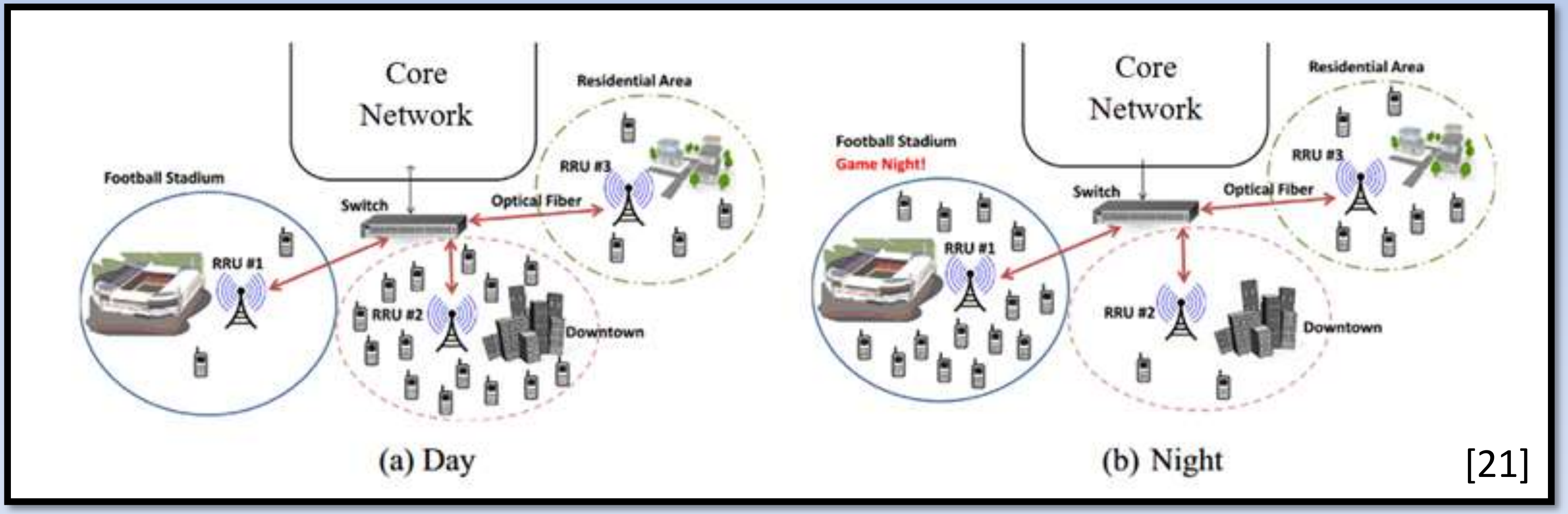
- ***Clustering***
  - **Network-Centric Clustering**
  - **User-Centric Clustering**





Problem-2 Statement

- ***Tidal Effect***



Related Work

- ***State-of-the-art Techniques***

1. Load-Aware, User-Centric, Dynamic Clustering Algorithm "LAUCDC" [22]
2. Smart Access for CoMP "SAC" [23]

LANCDC Algorithm

- ***Load Aware (LA)***

  → **Tidal Effect**

- ***Network-Centric (NC)***

  → **More control with Cloud Computing**

- ***Dynamic Clustering (DC)***

  → **Automation**

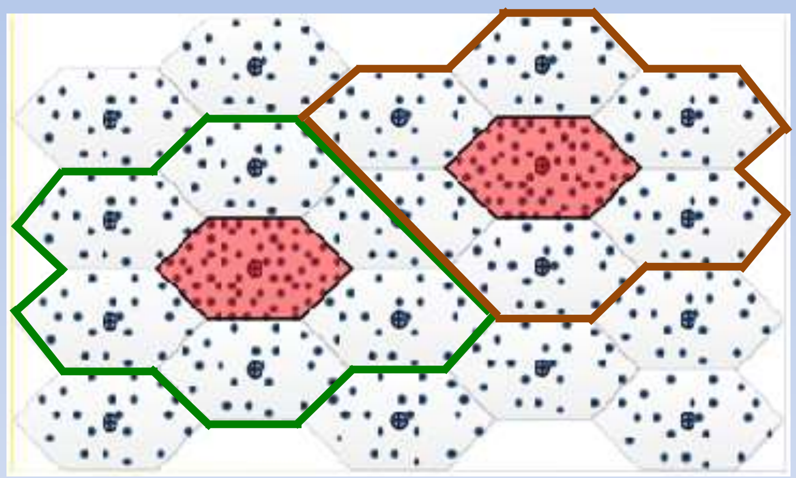
Experimental Setup

Platform: Vienna LTE system-level simulator [18], runs on MATLAB.

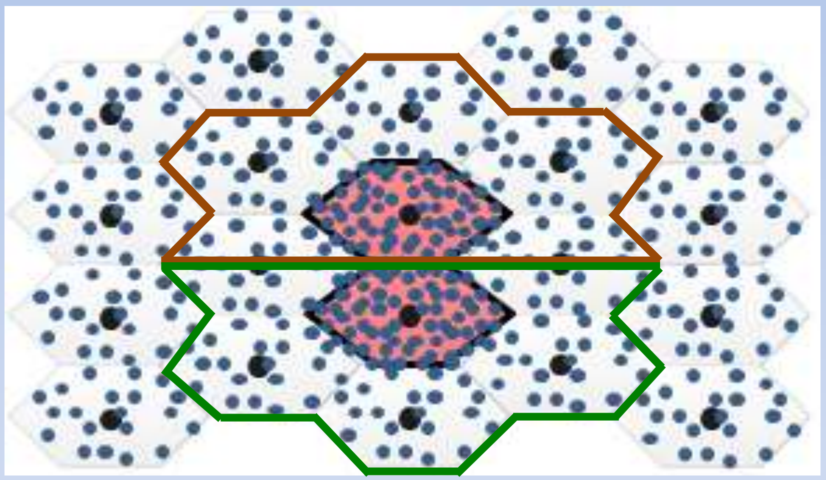
Parameter	Value	Notes
System Bandwidth	20MHz	*Supported in 3GPP for maximum RBs [19]*
Carrier Frequency	2.14 GHz	*Corresponds to the used system BW [19]*
Channel Model	Fast Fading	*To approach reality [19]*
Total No. of RBs per TTI	100	*Corresponds to the used system BW [19]*
eNodeB Transmit Power	40W	*Supported in 3GPP [20]*
No. of eNodeBs	20	*Assumption*
Total No. of Active UEs	480	*Assumption*
User Application	Multimedia Services (Around 10 Mb/s)	*To approach reality [20]*
No. of Cells	20	*Assumption*
No. of TTIs	100	*Assumption*

LANCDC In-Operation

Simulated Network Topology at Day and Night



Day



Night

Results & Analysis

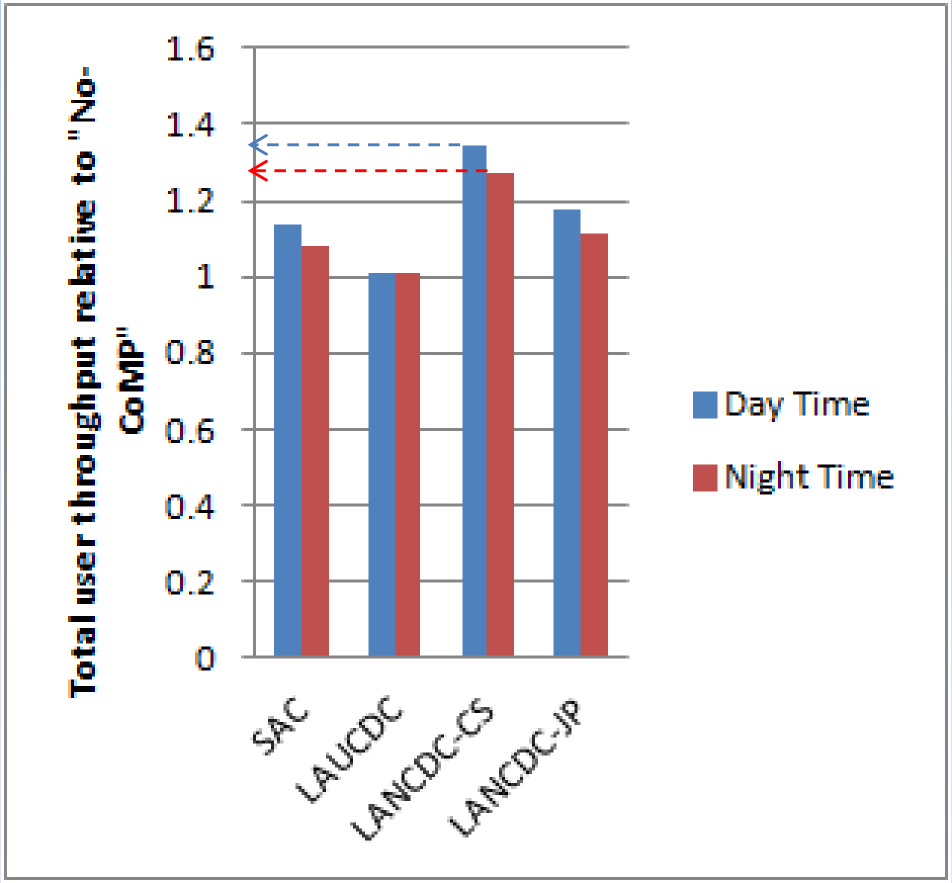
- ***Assessing the User Connectivity Status***

Algorithm	Day Time		Night Time	
	No. of Connected UEs	No. of Not-Connected UEs	No. of Connected UEs	No. of Not-Connected UEs
No-CoMP	380	100	378	102
LAUCDC	406	74	404	76
SAC	392	88	390	90
LANCDC-CS	390	90	386	94
LANCDC-JP	380	100	378	102

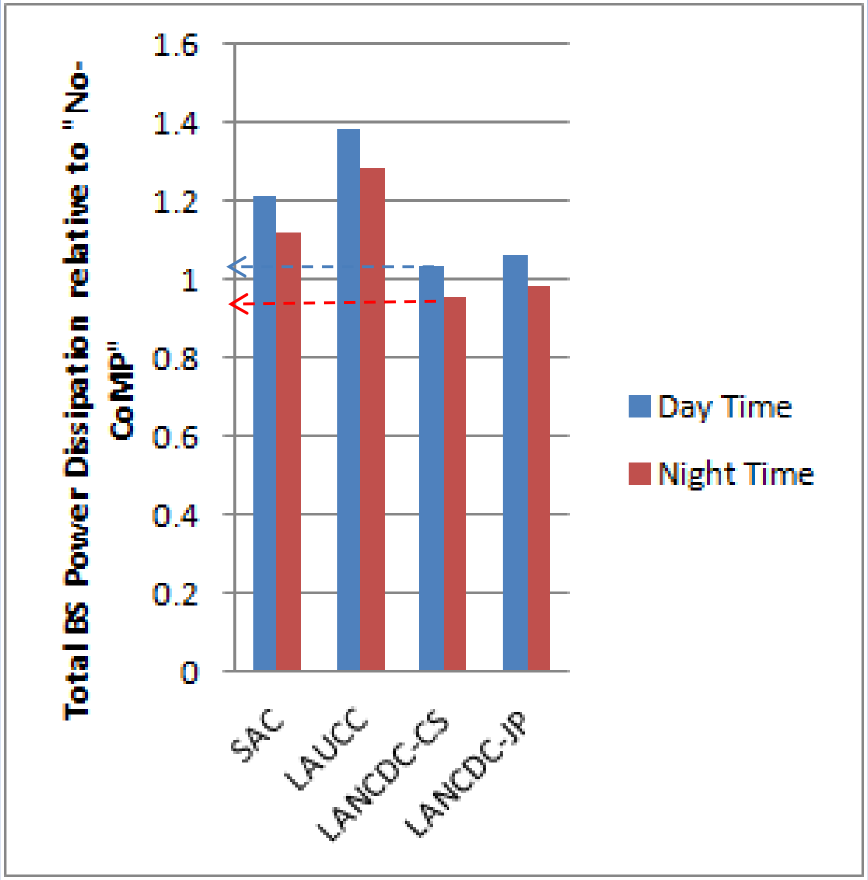
➢ User-centric algorithms guarantee that each user in the network has its own cluster.

Results & Analysis

- ***Assessing the Throughput***



- ***Assessing the Total BS Power Dissipation***



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Conclusions

- Cloud Computing leverages 5G RAN (C-RAN) by introducing novel features (e.g., centralization, pooled resources, virtualization, joint processing ...etc).
- Two Cloud-based 5G algorithms are developed to boost user performance especially in loaded and cell-edge areas.
- The first algorithm (i.e., EUFS) is devolved to increase the user throughput in cell-edge area. EUFS has proven to outperform other state-of-the-art algorithms in terms of cell-edge user throughput, SNR and fairness.
- The best trade-off for EUFS is to assign probabilities to PF candidates from 80% to 90%. This increases the average throughput for cell-edge users to about 150%, while reducing the average throughput for cell-centric users by only about 10%.

Conclusions (cont.)

- The second algorithm (i.e., LANCDC) is the first network-centric, dynamic clustering algorithm that adapts to user-density variations, to provide the best throughput with no significant change in power consumption compared to user-centric algorithms.
- LANCDC has proven to outperform other state-of-the-art algorithms in terms of user throughput, while the overhead of power dissipation is very limited.
- LANCDC algorithm scores 35% increase in overall user throughput relative to no clustering state. LANCDC exceeds LAUCDC and SAC throughput scores by 33% and 20%, respectively. LANCDC consumes only 3% additional BS power as compared to the no clustering case, which strongly outperforms LAUCDC and SAC that consume 40% and 20% additional BS power, respectively.

Future Work

- Recheck most-recent simulators (e.g., 5G LENA [24]) to validate the used simulator (i.e., Vienna LTE Simulator).
- Communicate with industrial cellular operators in the market to cooperate in implementing and testing the performance of our proposed algorithms (i.e., EUFS and LANCDC) in their real cellular networks.
- Other 5G techniques (e.g., CA) could be invoked beside both of our proposed algorithms (i.e., EUFS and LANCDC) to achieve the most possible peak performance, by compiling the benefits of all in one packed solution.
- Enhancements in scheduling and clustering techniques will be needed to meet new 6G's [25] KPIs.
- Fog [26] and Edge [27] Computing is the future of the Cloud Radio Access network in 5G/IoT world.

Publications

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2. Wael S. Afifi, Ali A. El-Moursy, Mohamed Saad, Salwa M. Nassar and Hadia M. El-hennawy; "A Dynamic Clustering Approach for Increasing User Throughput in 5G Wireless Networks"; The 32nd IEEE/IFIP Network Operations and Management Symposium (NOMS 2020), 20-24 April 2020, Budapest, Hungary.
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Thank you