Energy Efficiency Analysis of Base Station in Centralized Radio Access Networks

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Outline

- Introduction
- BS Energy Consumption Model
- BS Sleeping Schemes
- Simulation Results
- Conclusion

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- **Introduction**
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- **Conclusion**

Introduction (1)

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➢Mobile cellular networks face the issue of exponential growth of traffic demand from users, which leads to a serious energy consumption problem.

- The CO_2 emissions of the mobile network will exceed the fixed network to be the largest emitter of the ICT industry by 2020 [1].
- Vodafone uses more than 1 million gallons of diesel per day to power their network [2].
- The BSs' share of overall RAN energy consumption is about 60% to 80% [1, 3].

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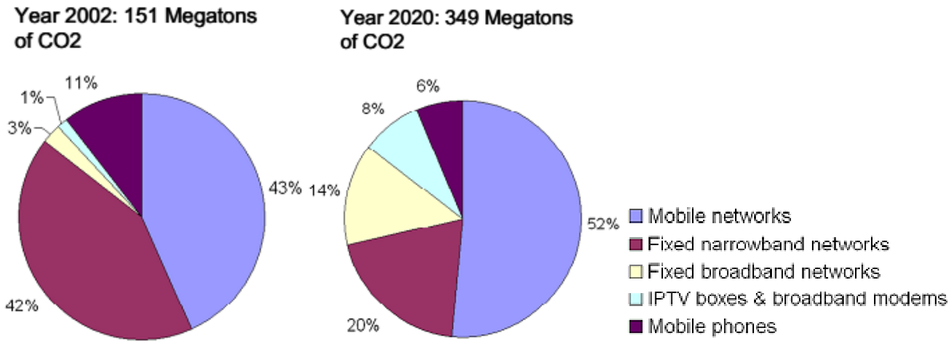

Fig. 1 Contribution of mobile communications to the CO2footprint of telecommunication industry in 2002 and estimated for 2020 [1]

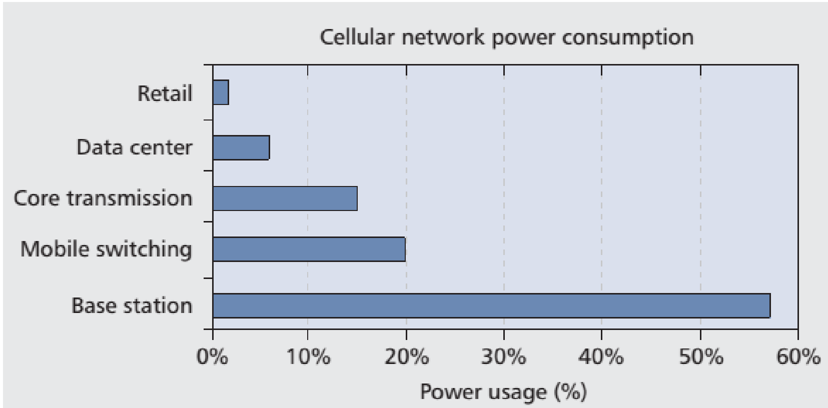

Fig. 2 Power consumption of a typical wireless cellular network (sources: Vodafone) [2]

Introduction (2)

➢ One promising approach is using BSs or RRHs sleeping technology to improve energy efficiency [10].

- The frequently movement of subscribers shows a very strong time-geometry pattern [4], which leads to a waste of resources.
    - ✓ Research [8] shows that, even in peak hours, 90% of the data traffic is carried by only 40% of the cells.
- The main idea of BS/RRH sleeping technology is dynamically switching off the cell with low traffic, and the cell will be taken care by its neighbors.

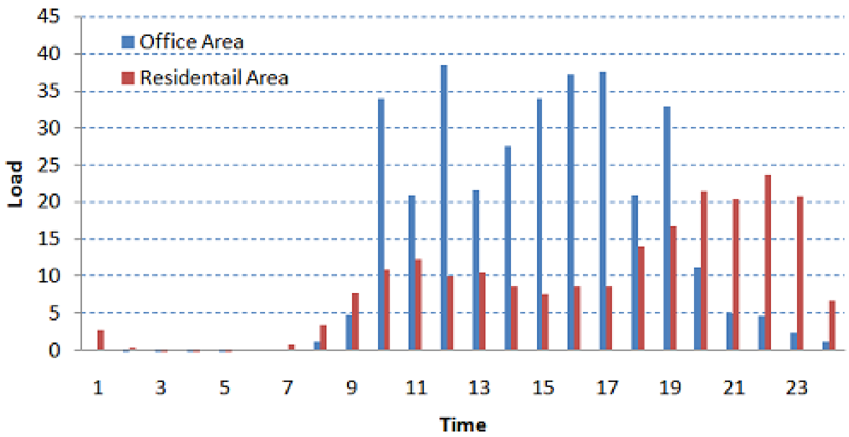

Fig. 3 Mobile network load in daytime [4]

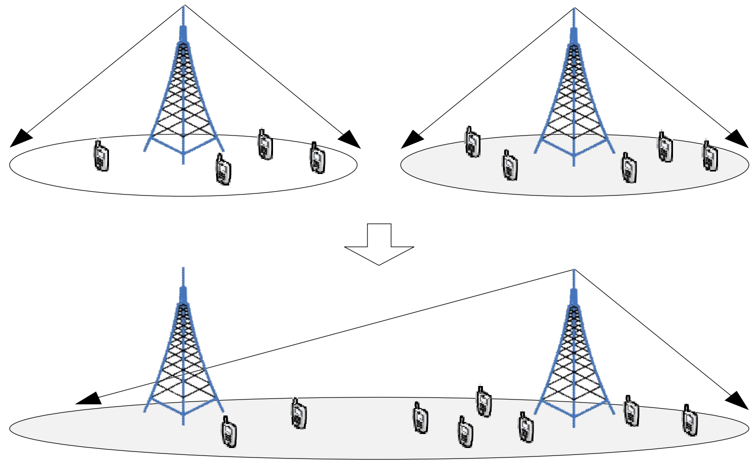

Fig. 4 The way of BS sleeping

Introduction (3)

➢ Meanwhile, researches suggest to develop centralized RANs instead of the conventional distributed RANs [4], which facilitates the implementation for sleeping technology.

- The distributed RANs are difficult to implement BS sleeping
  - ✓ Low efficiency management.
  - ✓ Resources are tightly coupled.
- The centralized RANs provide a more flexible & sustainable platform
  - ✓ Moving BBUs of distributed BSs to be a centralized BBU pool.
  - ✓ Leaving RRHs in the front end.
  - ✓ Open IT platforms.

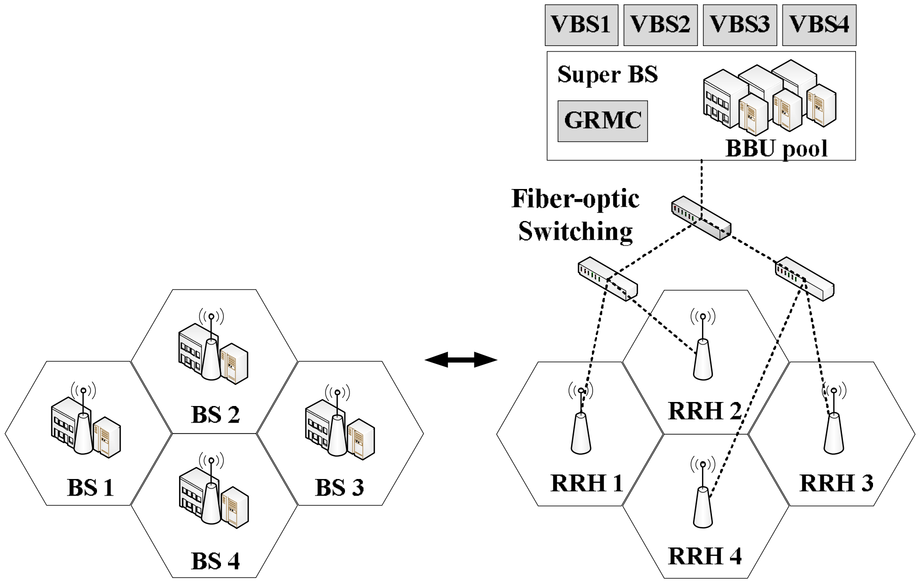

Fig. 5 The difference between centralized and distributed RANs [7]

- By now, several centralized RANs infrastructures are proposed, e.g., C-RAN [4], WNC [5], CONCERT [6], Super BS [7, 8], etc.

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BS Energy Consumption Model (1)

- Generally, a typical BS is composed of a *PA*, *RF module*, *BBUs*, *power supply module* and *active cooling system* [11, 12, 13].
  - Research [11] proposes two typical BS energy consumption model
    - ✓ The Maximum Load Model (MLM)

$$P_{in} = \frac{P_{out}/\eta_{PA} \cdot (1-\sigma_{feed}) + P_{RF} + P_{BB}}{(1-\sigma_{DC})(1-\sigma_{MS})(1-\sigma_{cool})}$$

    - ✓ The Linear Sleeping Model (LSM)

$$P_{in} = \begin{cases} N_{TRX} \cdot P_0 + \Delta_P \cdot P_{out}, & 0 < P_{out} \le P_{max} \\ N_{TRX} \cdot P_{sleep}, & P_{out} = 0 \end{cases}$$

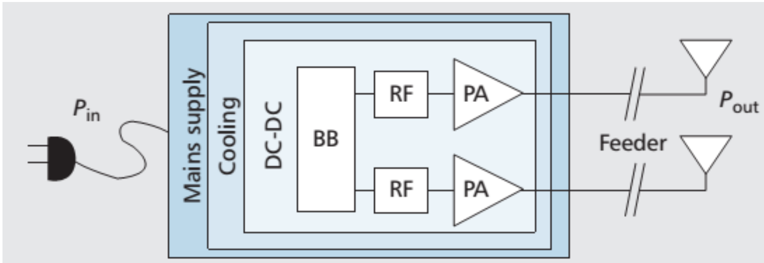

Fig. 6 Block diagram of a BS in distributed RANs [11]

- In centralized RANs, the mentioned models are no longer matching
  - Feeder loss and cooling is changed.
  - The MLM can not embody sleeping tech.
  - In the LSM, BBU/RRH/BBU+RRH sleeping schemes are not fully considered.

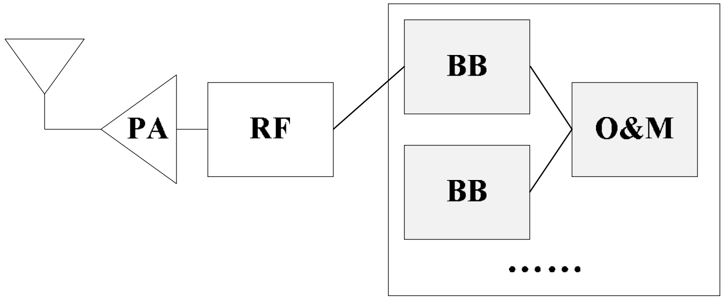

Fig. 7 Block diagram of a BS in centralized RANs

BS Energy Consumption Model (2)

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- In our research, we propose a energy consumption model based on Super BS infrastructure, which takes a sufficient consideration of
  - Changes of feeder loss and active cooling.
  - Various combinations of different resources.
- Super BS Model (SBSM)

$$P_{in} = \frac{P_{PAsum} + P_{RFsum} + \frac{P_{BBsum}}{(1-\sigma_{cool})}}{(1-\sigma_{power})}$$

Parameter	Value	Parameter	Value
P_{in}	Total power consumption	η_{PA}	PA efficiency
P_{PA}	Power of PA	c	Coefficient for static part
P_{RF}	Power of RF	ρ	Multiplexing coefficient
P_{BB}	Power of BB	μ	Coefficient for serving UE
σ_{power}	Loss factor of power	N_{ON}	Awake RRHs
σ_{cool}	Loss factor of cooling	N_{RRH}	Amount of RRHs

where

$$P_{PAsum} = \frac{P_{out}}{\eta_{PA}} + N_{RRH} \cdot c \cdot P_{PAmax}$$

$$P_{RFsum} = N_{RRH} \cdot P_{RF}$$

RRH sleep modeling →

$$P_{PAsum} = \frac{P_{out}}{\eta_{PA}} + N_{ON} \cdot c \cdot P_{PAmax}$$

$$P_{RFsum} = N_{ON} \cdot P_{RF}$$

$$P_{BBsum} = \rho \cdot N_{RRH} \cdot P_{BB}$$

BBU sleep modeling →

$$P_{BBsum} = \mu \cdot \rho \cdot N_{RRH} \cdot P_{BB}$$

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BS Sleeping Schemes Overview

- Generally, the BS sleeping schemes are composed of two steps
  - The first step is the trigger procedure, which can be further classified as
    - ✓ The Semi-static & dynamic schemes.
    - ✓ The Centralized & distributed schemes.
  - The second step is the decision and operation procedure, which includes
    - ✓ The Random partner & fixed partner schemes.
    - ✓ The Single-factor & multi-factor schemes.

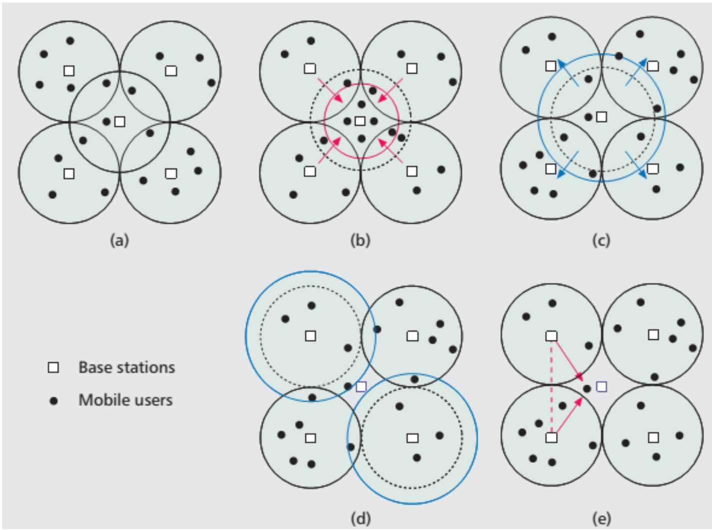

Fig. 8 Cell zooming for cellular networks [10]

BS Sleeping Schemes (1)

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- Semi-static & dynamic schemes: the trigger timing is different [14].
  - The semi-static scheme is predefined and usually long, e.g., one hour, half a day, etc.
  → low complexity but low energy efficiency.
  - The dynamic scheme triggers when some constraints are break, i.e., traffic load, QoS, etc.
  → high energy efficiency but high complexity.

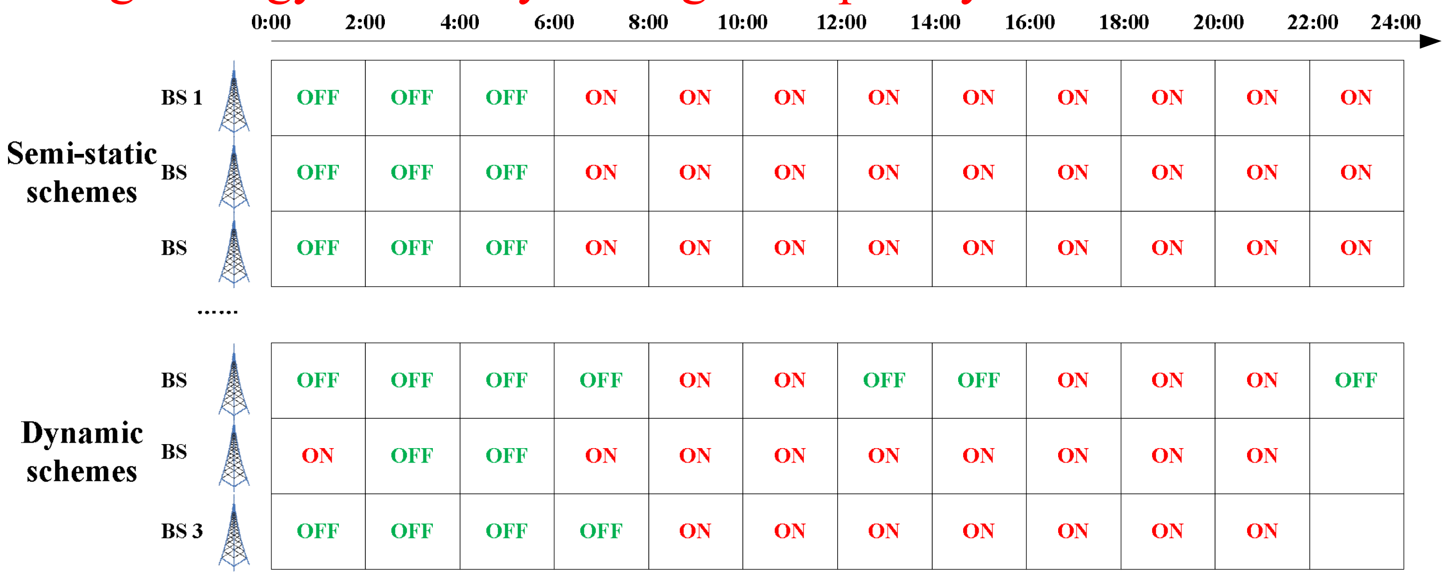

Fig. 9 Difference between semi-static and dynamic schemes

BS Sleeping Schemes (2)

- Centralized & distributed schemes: the management of them is a whole different way [10].
  - The centralized controller collects information and decides sleep deployment from a holistic point of view.
  → approach global optimal results but high complexity.
  - The manager of distributed schemes , e.g. a BS, is always from a local point of view.
  → approach local optimal results but low complexity.

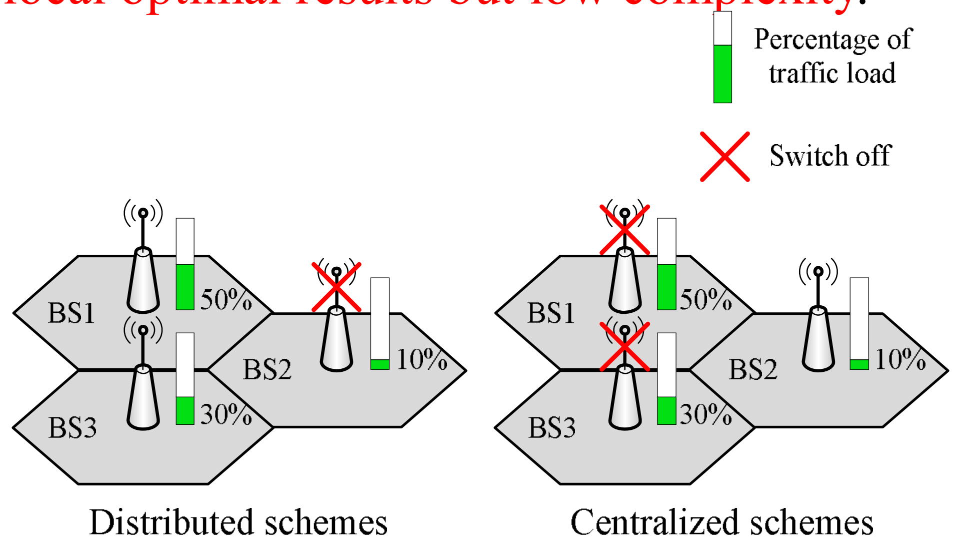

Fig. 10 Difference between centralized and distributed schemes

BS Sleeping Schemes (3)

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➢ Random partner & fixed partner schemes: the sleep-expansion associations of them are different [15].

•The random partner scheme allows BSs which request to sleep choosing the compensation BSs from all its neighbors.

→ high energy efficiency but low success ratio.

• In the fixed partner scheme, the sleep-expansion associations are already predefined.

→ high success ratio but low energy efficiency.

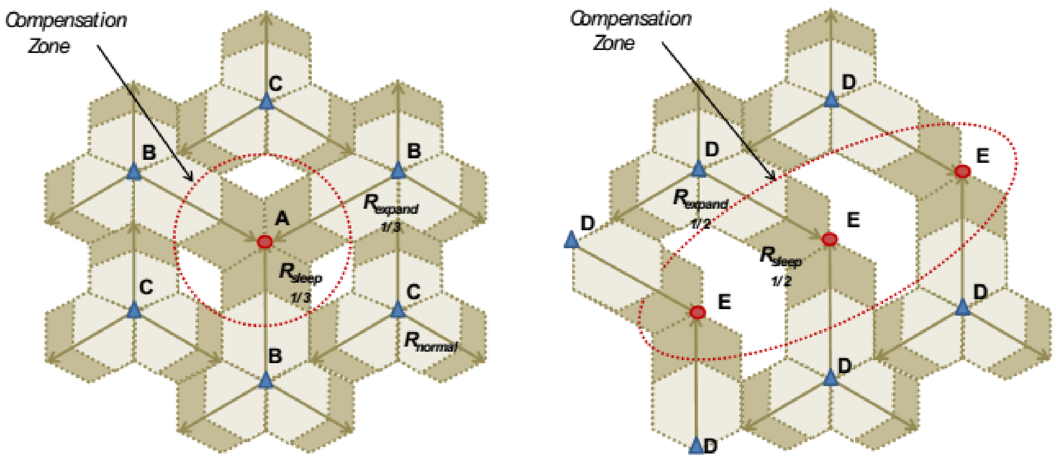

Fig. 11 1/2 and 1/3 fixed partner schemes [15]

BS Sleeping Schemes (4)

- Single-factor & multi-factor schemes: the optimal object is different.
  - The single-factor schemes only consider to reduce energy consumption when they make BS sleeping decisions [16].
    → approach best energy efficiency.
  - The multi-factor schemes take several factors into consideration such as energy and delay [10], QoS guarantee and energy saving [17].
    → approach a more comprehensive BS sleeping deployment.

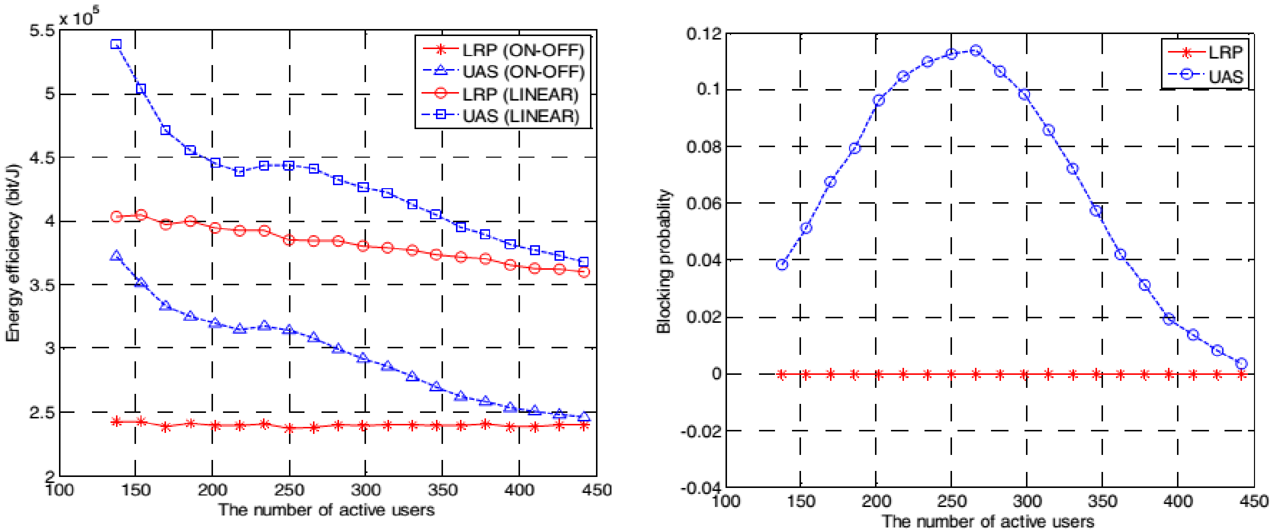

Fig. 12 The difference between single-factor (UAS) and multi-factor (LRP) schemes [17]

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Performance Evaluation (1)

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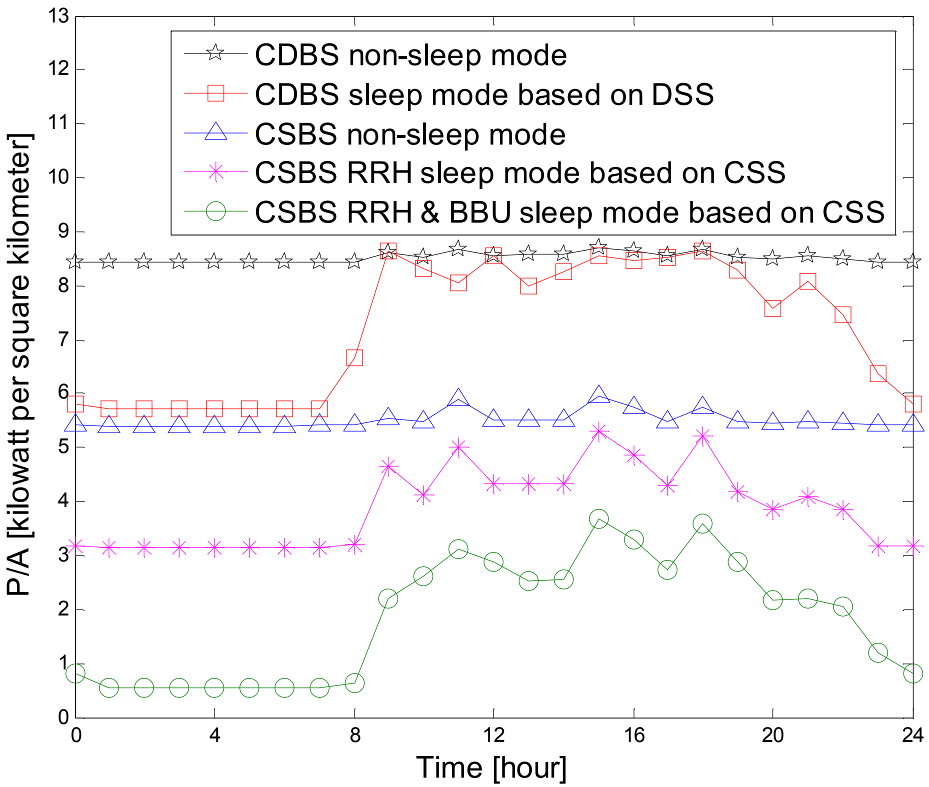
➢Parameters Setting

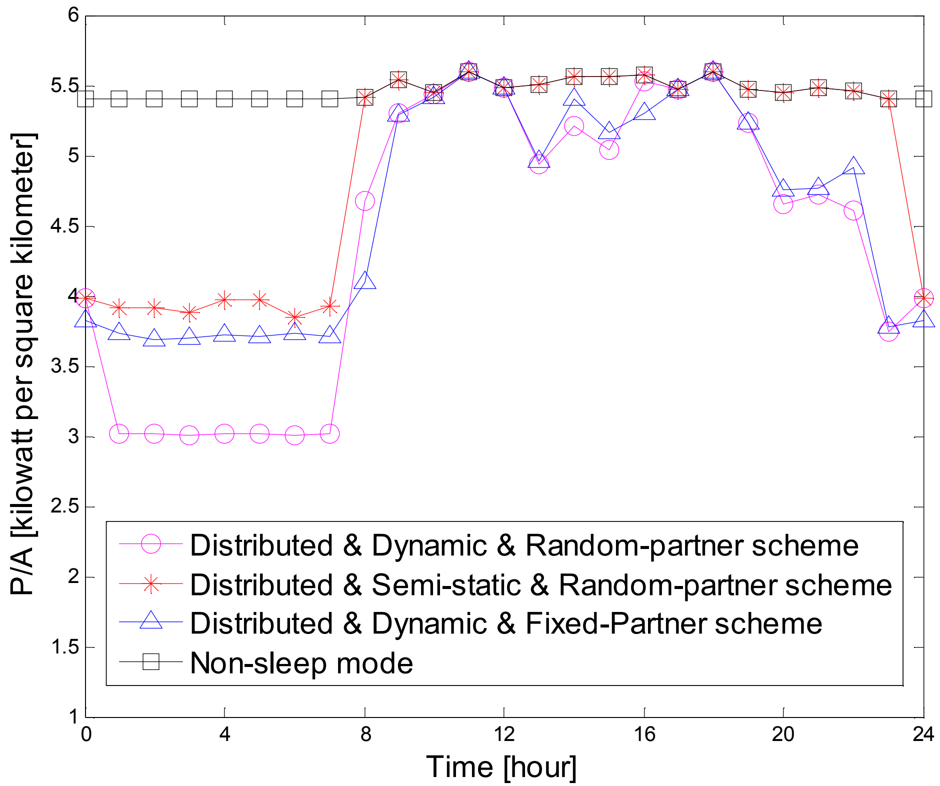
Parameter	Value
N_{RRH} (scale of CSBS)	21
N_{BA} (number of business area)	10
N_{RA} (number of residential area)	11
W (system bandwidth)	10 (Mhz)
B (user bandwidth)	W/(user number)
ε (data requirement for each UE)	100 (kbps)
c (percentage of PA for static part)	40%
ρ (percentage of multiplexing coefficient)	100%
R (cell radius)	0.2 (km)
TI (time interval)	60 (min)
σ^2 (noise power)	-174 (dB/Hz)
K_S (distributed sleeping threshold)	15%
$PL(d)$ (path loss)	$137.5+35.2 \cdot \log_{10}(d)$
N_G (group number in the fixed-partner scheme)	8

Performance Evaluation (2)



- Centralized RANs infrastructure approach more energy efficiency than the distributed ones;
- RRH+BBU sleep schemes are better than BBU sleep schemes in the performance of energy saving.

Performance Evaluation (3)



- Dynamic schemes are better than the semi-static schemes in the performance of energy saving;
- Random-partner saves more than fixed-partner schemes.

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- An energy consumption model for centralized radio access networks infrastructure (Super BS) is proposed in this paper.
- Simulation result shows that centralized radio access networks infrastructure saves more energy than the distributed ones.
- Kinds of different BS sleeping schemes are estimated and classified in this paper.

Reference (1)

- [1] Gruber M, Blume O, Ferling D, et al. EARTH - Energy Aware Radio and Network Technologies.[J]. IEEE International Symposium on Personal, Indoor & Mobile Radio Communications, 2009:1 - 5.
- [2] Han C, Harrold T, Armour S, et al. Green radio: radio techniques to enable energy-efficient wireless networks[J]. Communications Magazine, IEEE, 2011, 49(6): 46-54.
- [3] G. Auer, V. Giannini, C. Desset, I. Godor, P. Skillermark, M. Olsson, M. A. Imran, D. Sabella, M. J. Gonzalez, O. Blume et al.. How much energy is needed to run a wireless network? IEEE Wireless Communications, vol. 18, no. 5, pp. 40- 49, Oct. 2011.
- [4] China Mobile Research Institute. C-RAN: The road towards green RAN. White Paper, Oct. 2011, version 2.5.
- [5] Lin Y, Shao L, Zhu Z, et al. Wireless network cloud: Architecture and system requirements[J]. IBM Journal of Research and Development, 2010, 54(1): 4: 1-4: 12.
- [6] Liu J, Zhao T, Zhou S, et al. CONCERT: a cloud-based architecture for next-generation cellular systems[J]. Wireless Communications IEEE, 2014, 21(6):14-22.
- [7] GuoWei Zhai, Lin Tian, YiQing Zhou, JingLin Shi. Load diversity based optimal processing resource allocation for super base stations in centralized radio access networks. Science China Information Sciences April 2014, Volume 57, Issue 4, pp 1-12.
- [8] M. Qian, Y. Wang, Y. Zhou, L. Tian and J.L. Shi, “A Super Base Station based Centralized Network Architecture for 5G Mobile Communication Systems”, Digital Communications and Networks, Vol. 1, Issue 2, pp. 152–159, Apr. 2015.
- [9] H. Holma and A. Toskala, LTE for UMTS, Wiley, 2009.

Reference (2)

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- [10] Zhisheng Niu, Yiqun Wu, Jie Gong, Zexi Yang. Cell zooming for cost-efficient green cellular networks. IEEE Communications Magazine, Nov.2010, pp.74-79
- [11] G. Auer, V. Giannini, C. Desset, I. Godor, P. Skillermark, M. Olsson, M. A. Imran, D. Sabella, M. J. Gonzalez, O. Blume et al.. How much energy is needed to run a wireless network? IEEE Wireless Communications, vol. 18, no. 5, pp. 40- 49, Oct. 2011.
- [12] Deruyck M, Vereecken W, Tanghe E, et al. Power consumption in wireless access network[C]//Wireless Conference (EW), 2010 European. IEEE, 2010: 924-931.
- [13] Arnold O, Richter F, Fettweis G, et al. Power consumption modeling of different base station types in heterogeneous cellular networks[C]//Future Network and Mobile Summit, 2010. IEEE, 2010: 1-8.
- [14] S. E. Elayoubi, L. Saker, and T. Chahed. Optimal Control for Base Station Sleep Mode in Energy Efficient Radio Access Networks. In INFOCOM, 2011 Proceedings IEEE, 2011, pp. 106-110.
- [15] Weisi Guo, O'Farrell.T. Dynamic Cell Expansion with Self-Organizing Cooperation. Proc.of IEEE Selected Areas in Communications, volume:31, Issue:5, pp.851-860, Apr.2013.
- [16] S. E. Elayoubi, L. Saker, and T. Chahed. Optimal Control for Base Station Sleep Mode in Energy Efficient Radio Access Networks. In INFOCOM, 2011 Proceedings IEEE, 2011, pp. 106-110.
- [17] Zhu Y, Kang T, Zhang T, et al. QoS-aware user association based on cell zooming for energy efficiency in cellular networks. Personal, Indoor and Mobile Radio Communications (PIMRC Workshops), 2013 IEEE 24th International Symposium on. IEEE, 2013, pp. 6-10.

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Thank you!

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