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# Dynamic Cell Planning and Self-Organization for GREEN Cellular Networks

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2010/9/13

## Content

NiuLab

- ❖ **Why and What's GREEN?**
  - Globally Resource-optimized and Energy-Efficient Networks
- ❖ **Dynamic Cell Planning for GREEN**
  - Tradeoff between energy saving and coverage
- ❖ **Self-Organization for GREEN**
  - Cell Zooming and Dynamic BS Sleeping Control
- ❖ **Conclusion**

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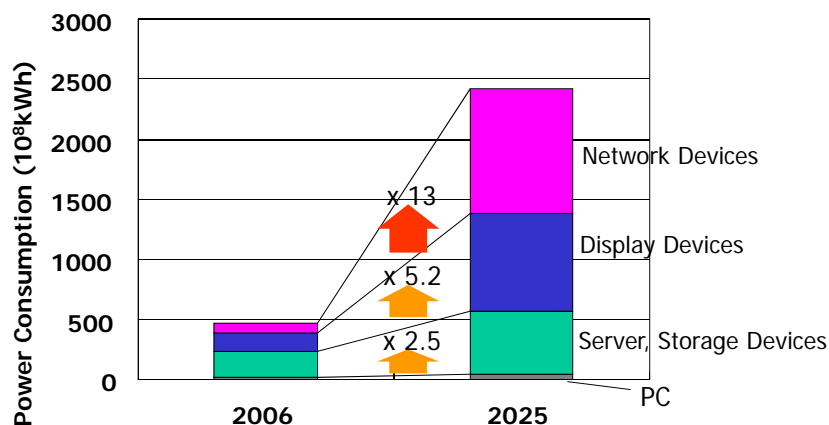
## Why Green, Why Now?



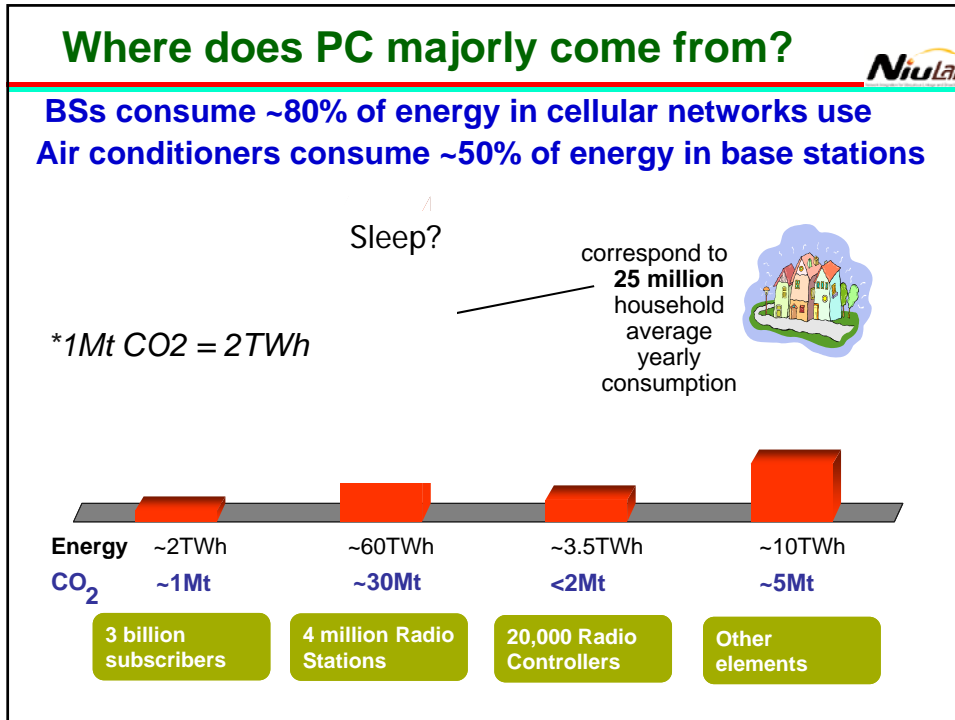
- ❖ **Energy consumption of cellular networks is growing rapidly with increasing data rates and No. of users/BSs**
  - China is the largest ICT market in the world and still in fast growing
  - PC of China Mobile: **6.4b'06** → **8.1b'07** → **9.4b'08** → **11.2b'09**
  - China Mobile has **460K+** BSs ('09) and will go to **600K** ('10)
- ❖ **There is a push for "green" from industry & government**
  - from *World-Wide-Web* to *World-Wide-Wireless*
  - for *World-Wide-Watch* & *World-Wide-Wisdom*
  - but definitely should not *World-Wide-Wait* and *World-Wide-Waste!*



## Where does PC majorly come from?



Source: Ministry of Economy, Technology and Industry "Promotion of Green IT", Feb. 2008



## Green as a fatal factor NiuLab

**Verizon's TEEER (Telecom Equipment Energy Efficiency Rating) since 2009**

Equipment Type	TEEER Formula	Min. TEEER Allowable
Transport	$-\log(P_{total} / \text{Throughput})$	7.54
optical and Video		7.54
P2P Microwave		5.75
Switch/Router	$-\log(P_{total} / \text{Forwarding Capacity})$	7.67
Media Gateway	$-\log(P_{total} / \text{Throughput})$	6.54
Access	$(\text{Access Lines} / P_{total}) + 1$	2.50
Power	$(P_{Out Total} / P_{In Total}) \times 10$	9.20
Power Amplifier (Wireless)	$(\text{Total RF Output Power} / \text{Total Input Power}) \times 10$	1.05
<b>BS?</b>		

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## What's Green, How to GREEN? NiuLab

- ❖ **Green**
  - Environmental friendly
  - Low power
- ❖ **GREEN**
  - **Globally Resource-optimized**
    - ✓ BS/AP cooperation in *homogeneous* networks
    - ✓ Network cooperation in *heterogeneous* networks
  - **Energy Efficient Networks**
    - ✓ from 3A to 3R: *Right time, Right place, and Right service*
    - ✓ dynamic adaptation to traffic variation and QoS requirement
    - ✓ sleep when traffic is low

**Green** : Globally Resource-optimized and Energy-Efficient Networks

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## Scarce resources are under-utilized NiuLab

- resources are distributed in heterogeneous overlaid NWs
  - WiFi, WiMAX, 2G, 3G, LTE, DTV, Operator A/B/C, ...
- And, they are quite under-utilized


Network	Example of Utilization
Carrier Network	33%
Internet Backbone	15%
LAN	1%

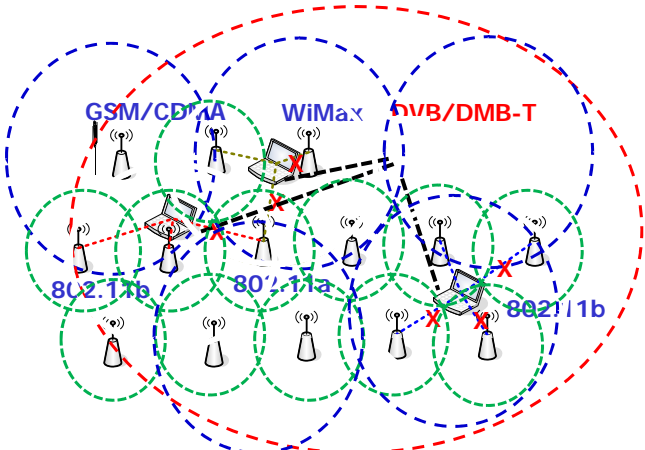
The figure is a spectrum plot with 'Amplitude (dBm)' on the vertical axis and 'Frequency (MHz)' on the horizontal axis. It shows several vertical spikes representing signal activity. The plot is divided into horizontal bands: 'Maximum Amplitudes' at the top, 'Heavy Use' in the upper-middle section, 'Less than 6% Occupancy' in the middle section, 'Sparse Use' in the lower-middle section, and 'Medium Use' in the lower section. The overall message is that resources are under-utilized.

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## CHORUS for GREEN







**Chorus** : Collaborative and Harmonized Open Radio Ubiquitous System

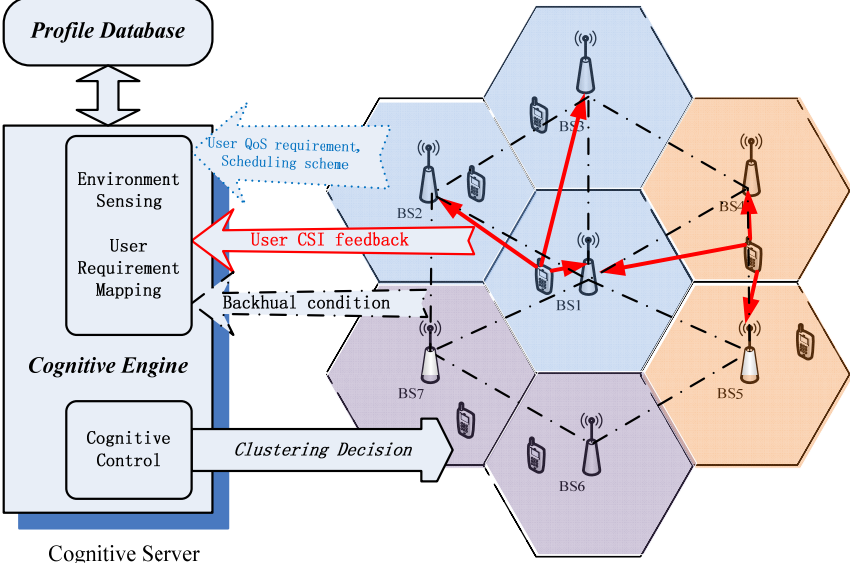
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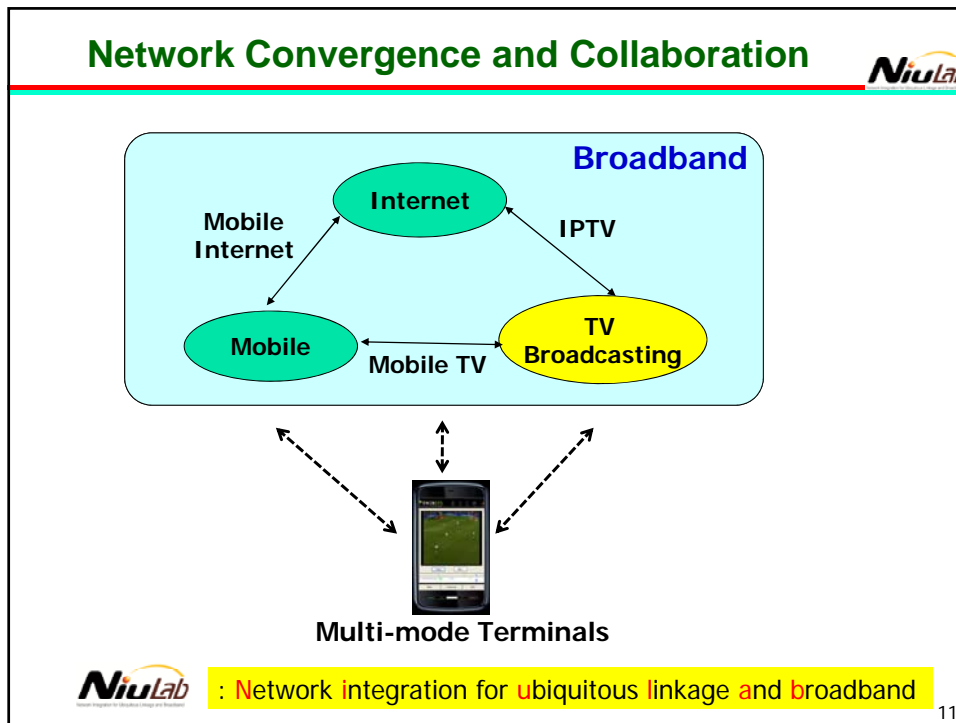
## Dynamic Base Station Cooperation



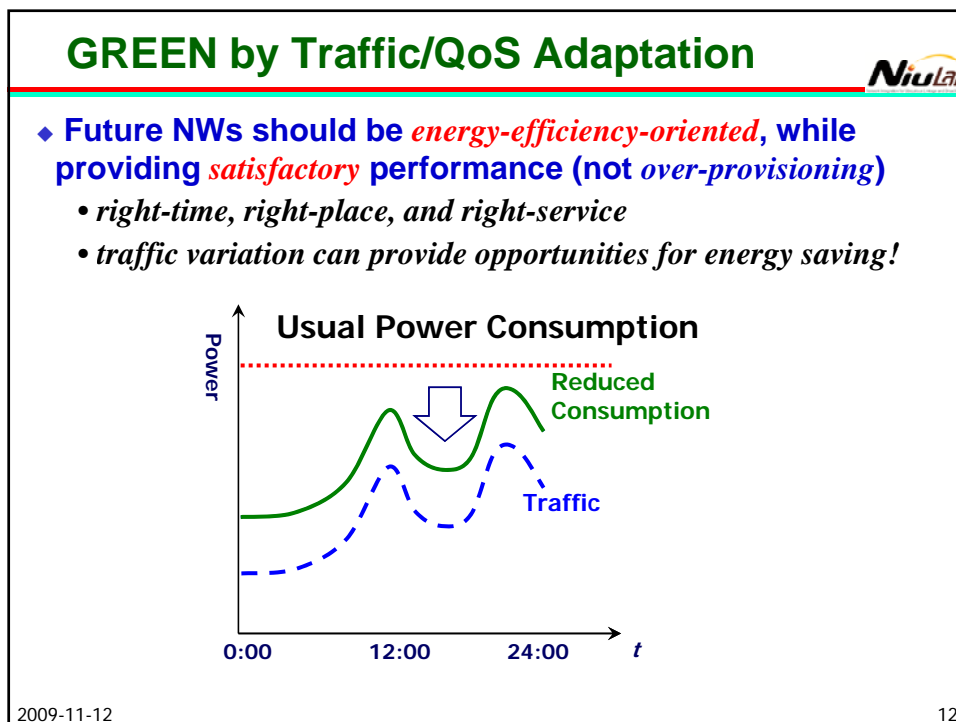


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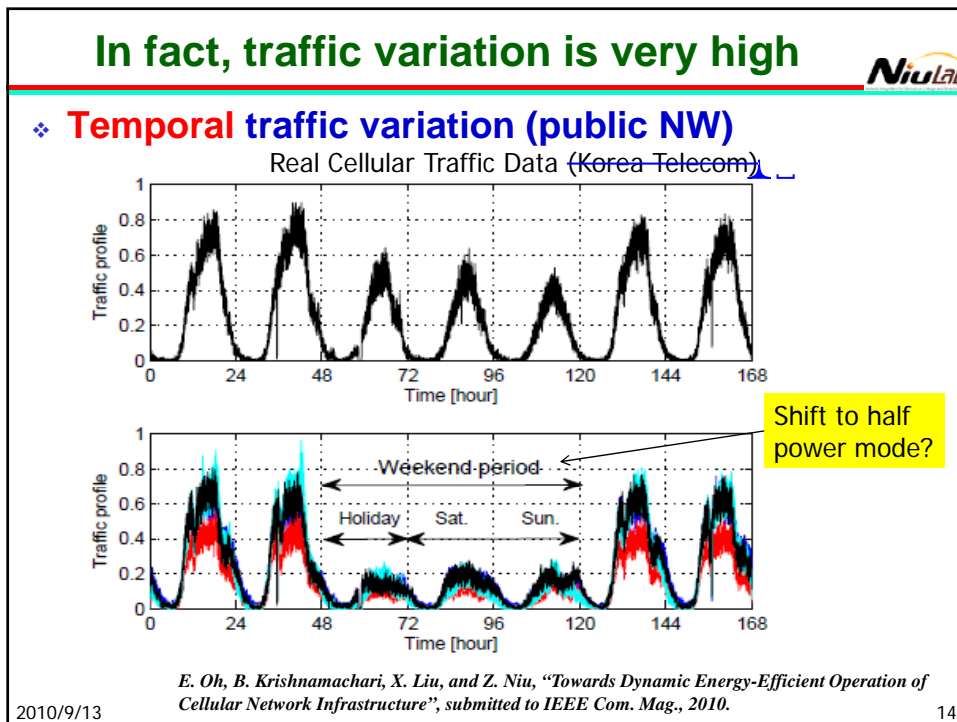
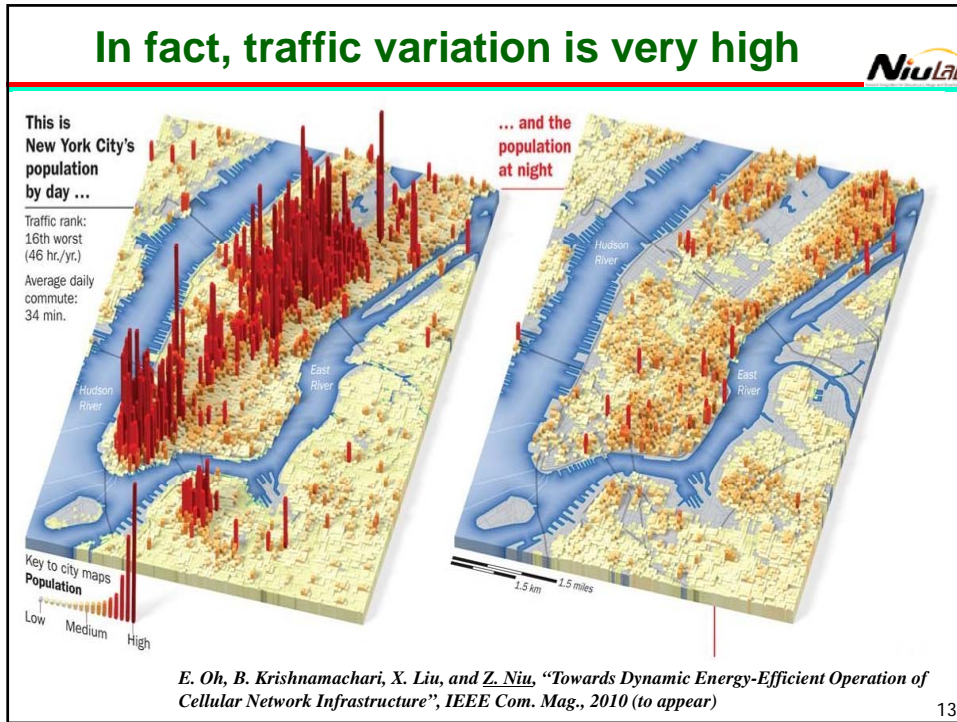
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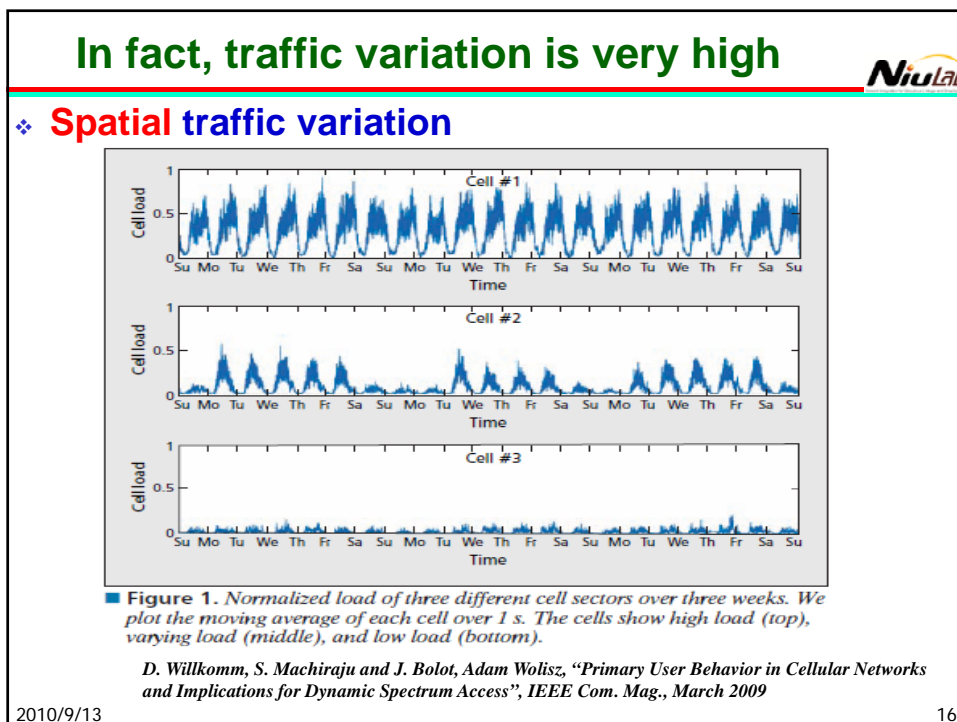
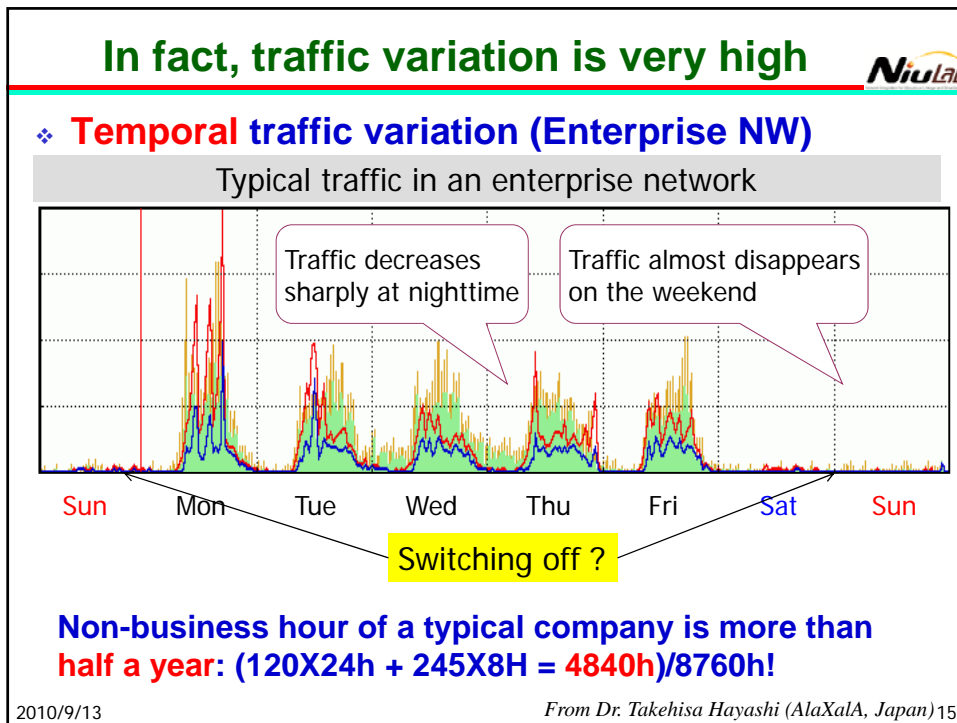


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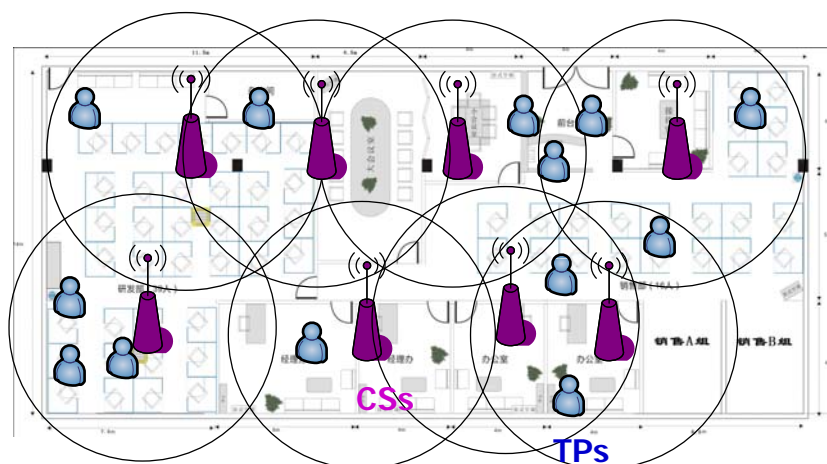
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- ❖ **Conclusion**

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## Concept of Cell Planning


- ❖ **Candidate sites: determined by buildings and geo info**
- ❖ **Test point: abstracted user distribution**



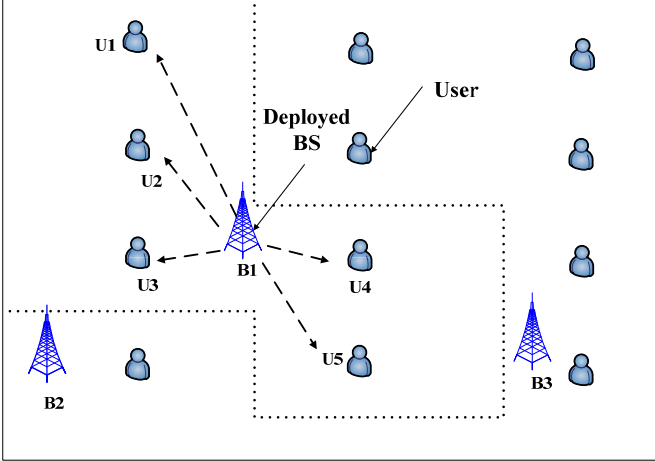
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### A Deployment example




- ✓ 3 candidate sites, 12 user
- ✓ Deployment result **without inter-cell Cooperation**

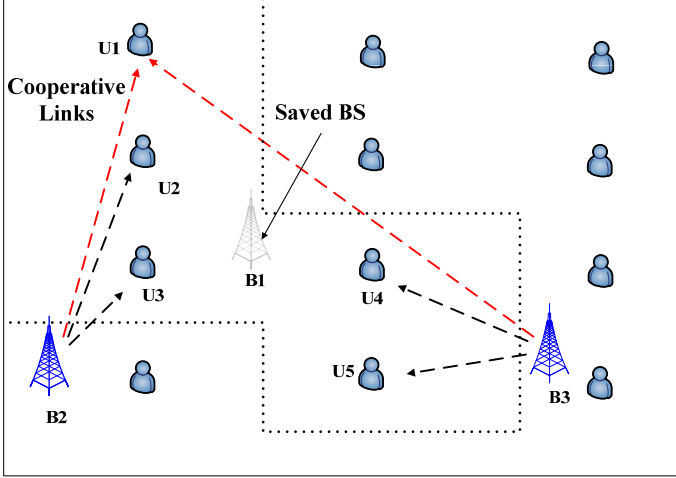


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### A Deployment example



- ✓ Deployment result with **inter-cell Cooperation**



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## Selected Published Papers



- [1] Zhisheng Niu, Sheng Zhou, Yao Hua, Qian Zhang, and Dongxu Cao, “**Energy-aware Network Planning for Wireless Cellular System with Inter-cell Cooperation**”, *Submitted to IEEE Trans. Wireless Commun., 2010*
- [2] S. Zhou, J. Gong, Z. Niu, Y. Jia, and P. Yang, "A decentralized framework for dynamic downlink base station cooperation," Proc. **IEEE Globecom'09**, Dec, 2009.
- [3] S. Zhou, J. Gong, Z. Yang, Z. Niu, P. Yang, “Green Mobile Access Network with Dynamic Base Station Energy Saving”, *ACM MobiCom2009 (Poster)*, Beijing, China, Sep. 2009
- [4] F. Zhu, Z. Niu, “Delay Analysis for Sleep-Based Power Saving Mechanisms with Downlink and Uplink Traffic“, *IEEE Commun. Letters*, 2009
- [10] E. Oh, B. Krishnamachari, X. Liu, and Z. Niu, "Towards Dynamic Energy-Efficient Operation of Cellular Network Infrastructure", *IEEE Commun. Mag.*, 2010 (accepted)

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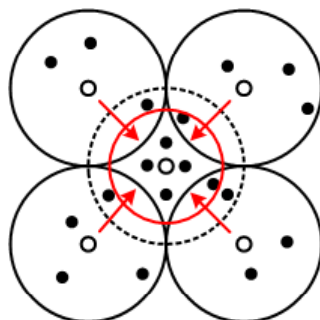
## Existing Cell Planning

- ❖ For given traffic (*mostly voice only*) demand and resources (*spectrum, power, etc*), plan the coverage and resource allocation
  - Coverage-oriented and performance optimized
- ❖ Issues
  - Traffic demand is getting highly uncertain due to smaller and smaller cells and higher mobility
  - Traffic category is getting more and more diverse (*Data and video traffic is going to dominate*)
  - New technologies (*MIMO, DAS, Relay, CoMP, etc*) are emerging
  - **Strong demand for energy consumption reduction (*energy-efficiency oriented cell planning*)**

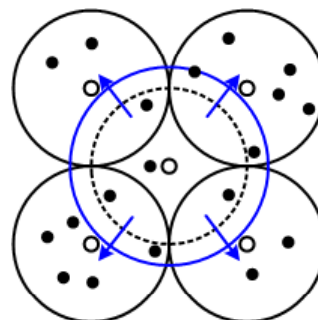
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## Cell Zooming by Dynamic Association Control

- ❖ Cell zooming for load balancing



Central cell zooms in as traffic load increases



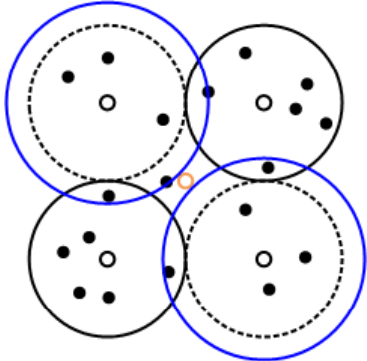
Central cell zooms out as traffic load decreases

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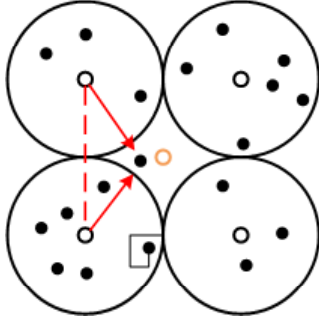
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## Cell Zooming by Dynamic Association Control NiuLab

❖ **Cell zooming for energy saving**



Central cell sleeps, and other cells zoom out

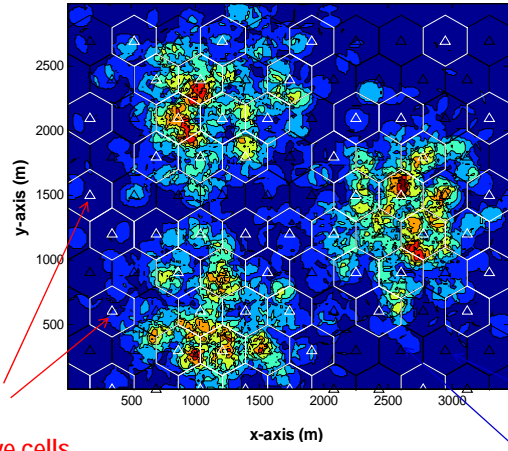


Central cell sleeps, and other cell cooperate to transmit

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## Cell Zooming for Energy Saving NiuLab

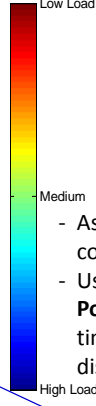
❖ **A snapshot of BS sleeping pattern**



Active cells

Sleeping cells

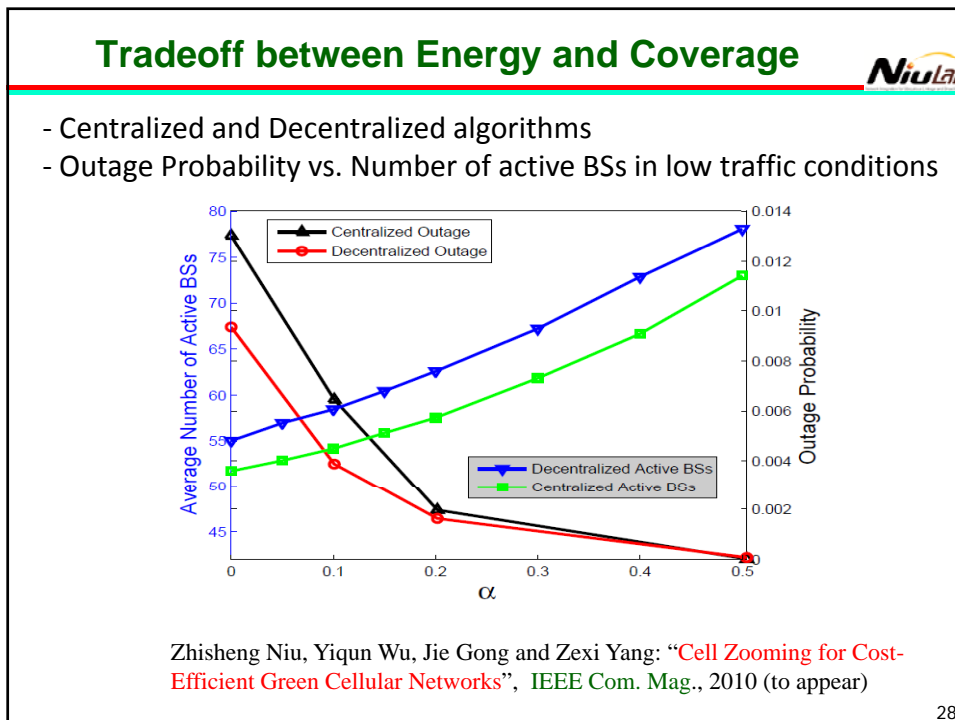
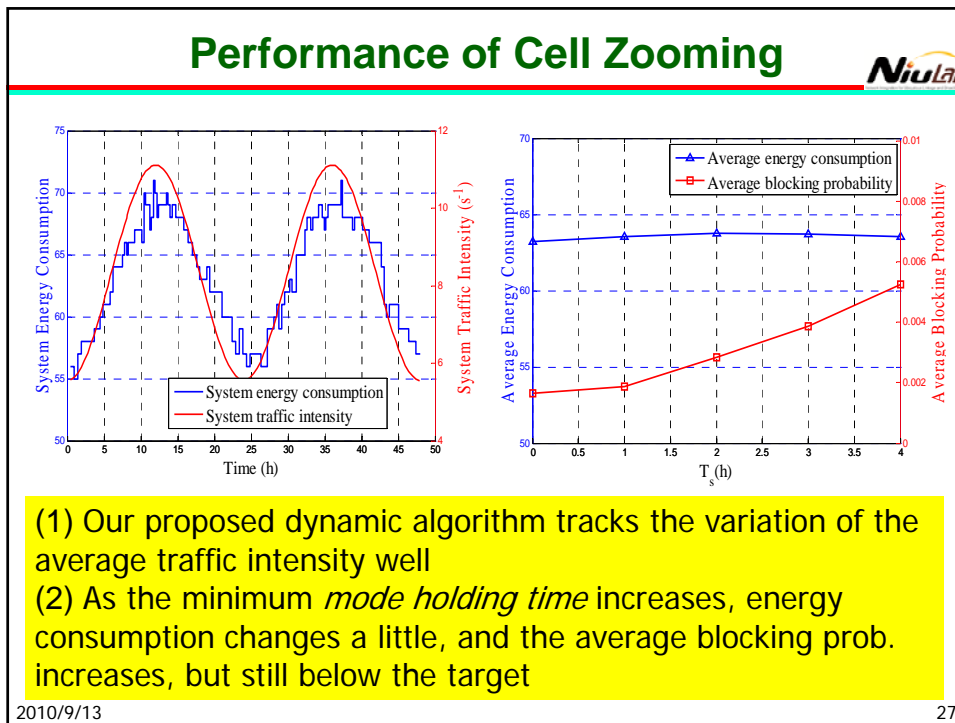
Low Load




High Load

- Assuming BSs can extend coverage from **200m** to **400m**
- Users arrive according to **Poisson** Process and service time is **exponentially** distributed

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## Selected Published Papers




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[1] J. Gong, S. Zhou, Z. Niu, and P. Yang, "Traffic-aware base station sleeping in dense cellular networks," **IEEE Int'l Workshop on Quality of Service (IWQoS'10)**, Poster, Jun. 2010.

[2] D. Cao, S. Zhou, C. Zhang, Z. Niu, "Energy Saving Performance Comparison of Coordinated Multi-Point Transmission and Wireless Relaying", **IEEE Globecom'10**, Miami, USA, Dec.2010

[3] Z. Niu, Y. Wu, J. Gong, and Z. Yang, "Cell zooming for Green cellular networks," **IEEE Communication Magazine**, 2010 (accepted).

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  - Globally Resource-optimized and Energy-Efficient Networks
- ❖ **Cell Zooming for GREEN**
  - Energy saving by dynamic association control
- ❖ **Self-Organized Networks for GREEN**
  - Energy saving by collaborative BS sleeping
- ❖ **Conclusion**

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## Summary: Existing Wireless Technologies



- ❖ **It's all about capacity!**
  - *but do we have enough traffic?*
- ❖ **It's all about voice!**
  - *but data & video will dominate*
- ❖ **It's all about single cell!**
  - *Micro cellular leads to high-density and overlapped cells*
  - *Multiple radio and multi-carriers coexist*
- ❖ **It's all about noise/interference**
  - *but power is also limited*

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## Summary: Green Wireless Technologies



- ❖ **It's all about traffic!**
  - Care more about carried traffic, not only channel capacity
  - Treat data/video differently (*from 3A to 3R*)
  - Adapt to traffic variation (*Cell Zooming*)
- ❖ **It's all about cooperation/collaboration!**
  - Cross-node design, not only cross-layer design (*CHORUS*)
  - Inter-network collaboration (*NiuLab*)
- ❖ **It's all about power/energy!**
  - Power/energy is limited and prohibited (*GREEN*)



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