NETWORK COOPERATION FOR ENERGY SAVING IN GREEN RADIO COMMUNICATIONS

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IEEE Wireless Communications – Oct. 2011

Outline

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Introduction

- <u>Green Communications Network Design Objectives:</u>

1. Reduce the amount of energy consumption by the networks' BSs
2. Maintain a satisfactory QoS for the users

Introduction Cont.

Motivations for Green Radio Communications

Service Provider's Financial Considerations

- Half of annual operating expenses are energy costs

Environmental Considerations

- Currently, 2% of CO_2 emissions from telecom.
- By 2020, 4% of CO_2 emissions

Outline

Energy Saving at Network Level

Solutions for Energy Aware Infrastructure

Renewable Energy Sources

- Reduce CO2 emissions by using renewable energy
- Reliability issues

Heterogeneous Cell Sizes

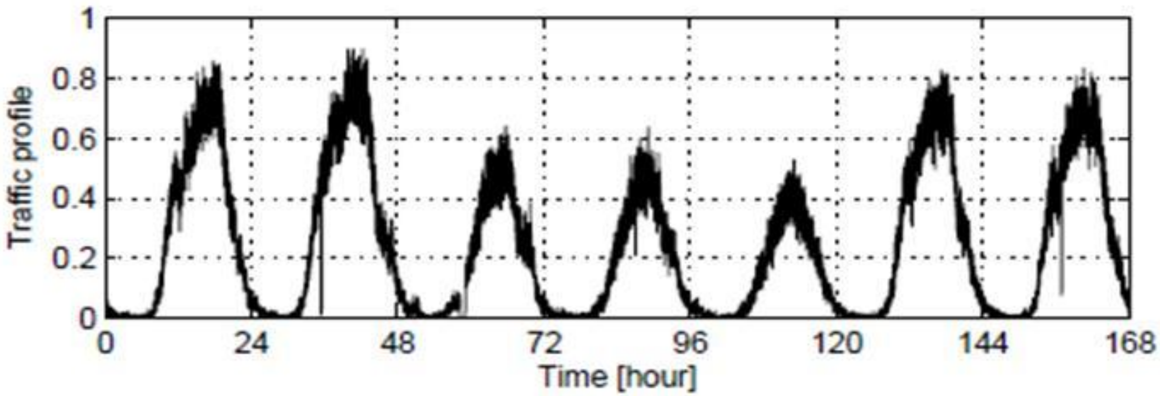
- Macro-cells ➔ Femto-cells
- Balance of different cell sizes is required

Dynamic Planning

- Exploit traffic load fluctuations
- Switch off available resources at light traffic load

Dynamic Planning

- Temporal fluctuations in traffic load



Resources on-off Switching

- Radio transceivers of active BSs
- Entire BS switch-off

Dynamic Planning Cont.

- Dynamic planning challenges

Service Provision Guarantee

- **Increase cell radii**
  - Increase transmission power
- **Relaying mechanism**
  - Unreliable for delay sensitive applications
- **Network cooperation**
  - Alternately switch on-off resources

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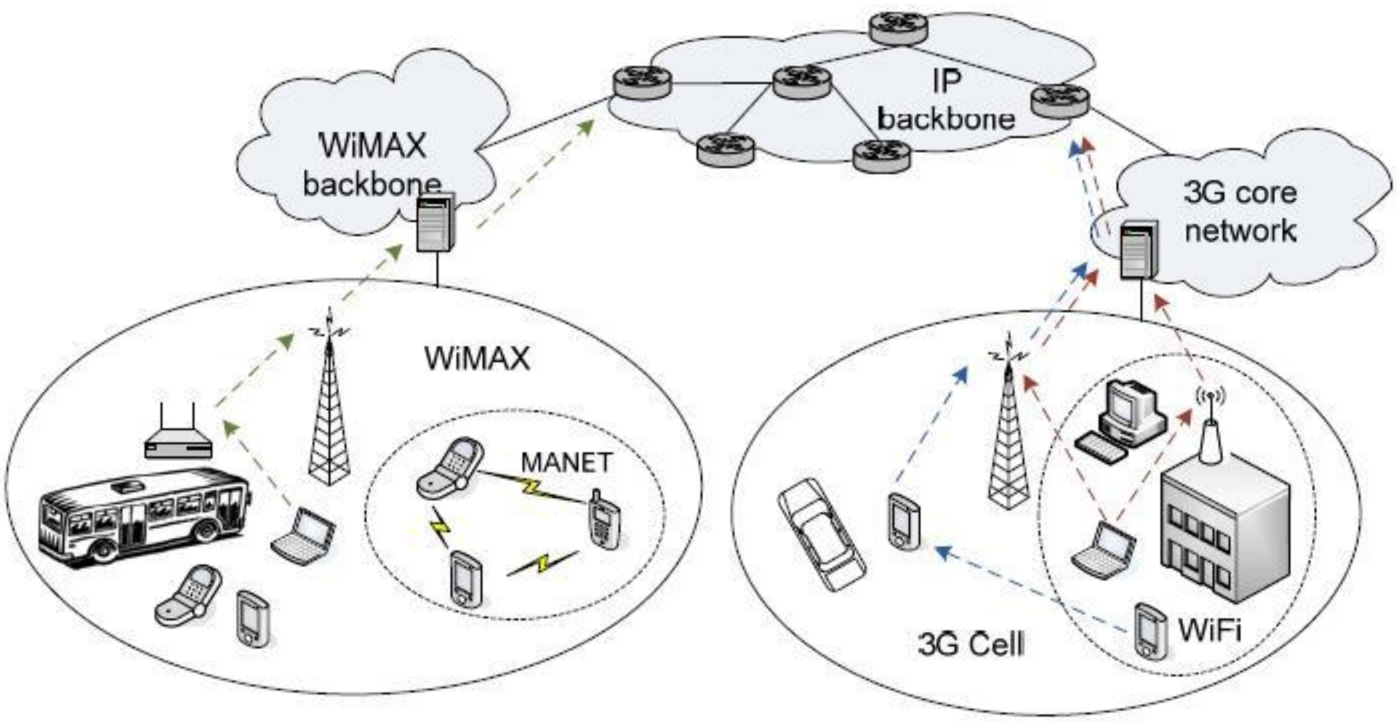
- Energy Saving at the Network Level
- The Potentials of Network Cooperation
- Network Cooperation for Energy Saving
  - System Model
  - The Proposed Strategy
  - Performance Evaluation
- Conclusion

Heterogeneous Medium

Heterogeneous wireless communication network



Heterogeneous Medium Cont.

Potential Benefits of Cooperative Networking

Mobile Users

- Always best connection
- Multi-homing

Networks

- Relaying
- Load balance
- Energy saving

Proposal

- In this article:

- Employ cooperative networking to achieve energy saving and avoid dynamic planning shortcomings

- Networks with overlapped coverage alternately switch on-off: 1. BSs, 2. radio transceivers of active BSs according to call traffic load conditions

Proposal Cont.

- Develop an optimal resource on-off switching framework:

1. Captures the stochastic nature of call traffic load
2. Adapts to temporal fluctuations in the call traffic load
3. Maximize the amount of energy saving under service quality constraints in a cooperative networking environment

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System Model

- Cellular/ WiMAX system

  - N cellular network cells covered by WiMAX BS

  - C channels available in cellular network BS ➔ k_{cn} active channels

  - M channels available in WiMAX network BS ➔ k_{wn} active channels

  - $X = [x_1, x_2, \ldots, x_N, x_{N+1}]$ Vector of BSs working modes in the overlapped coverage area

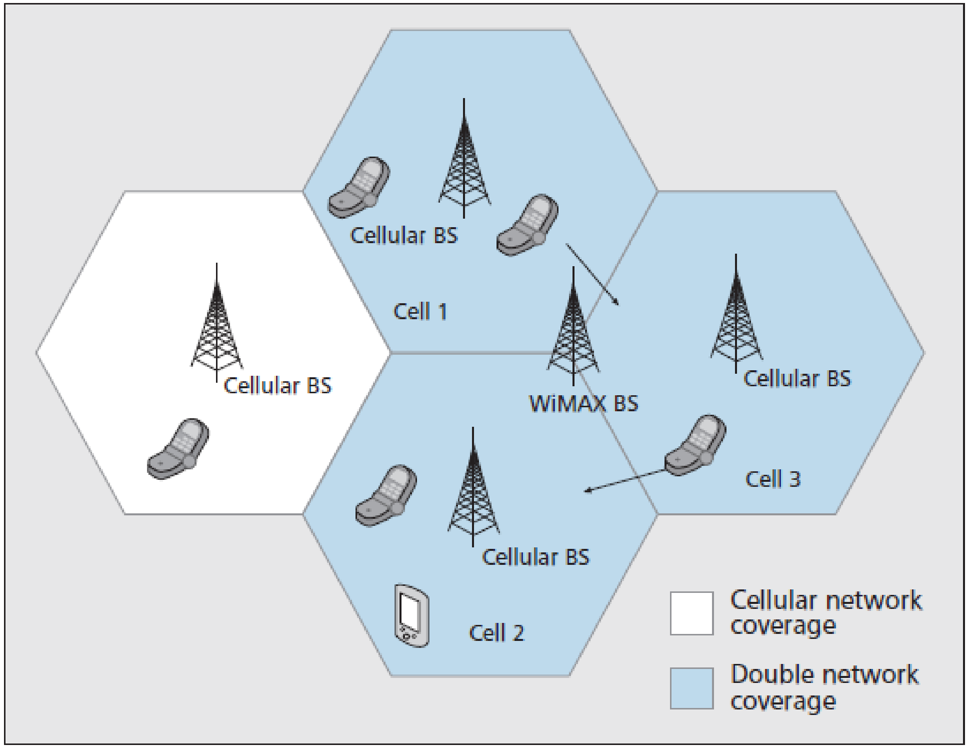


Figure 1. *The network coverage areas.*

System Model Cont.

- Power Consumption model

$P_w\ (P_c)$

Total power consumption of WiMAX(Cellular) BS

$P_{wo}\ (P_{co})$ Fixed component

$P_{wv}\ (P_{cv})$ Variable component

$P_{wf}\ (P_{cf})$ Power consumption of inactive BS

$\beta P_{wo}\ (\beta P_{co})$ Switching cost

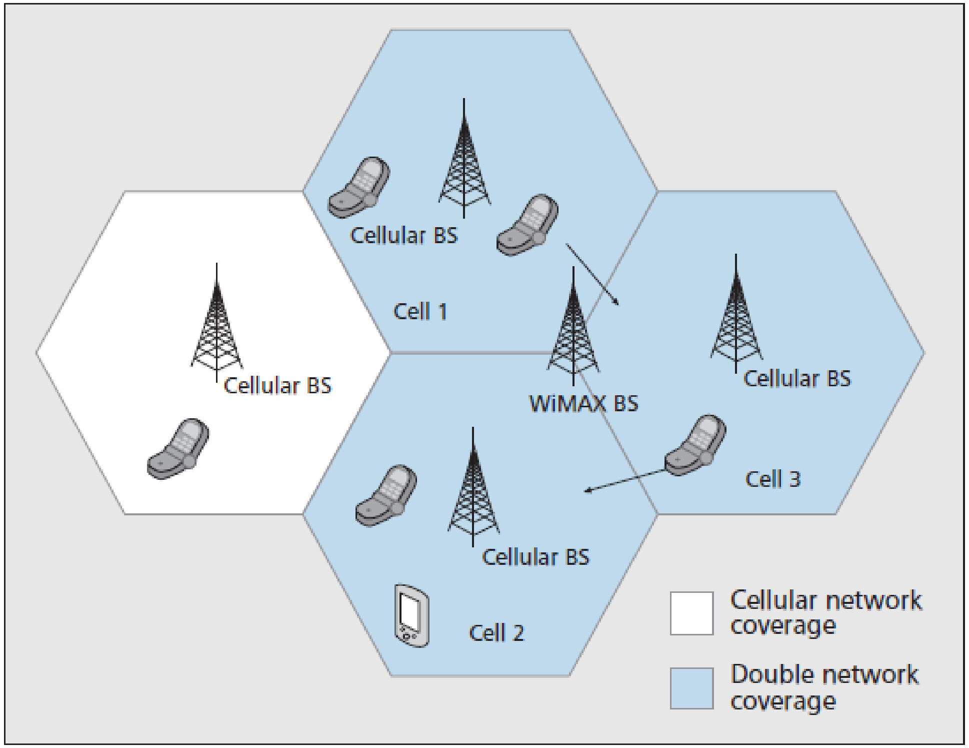


Figure 1. *The network coverage areas.*

System Model Cont.

- Call traffic and mobility

Assumptions:

A1. New call arrivals to cell n ➔ Poisson process with mean arrival rate ν_n

A2. Handoff call arrivals to cell n ➔ Poisson process with mean arrival rate υ_n

A3. MT dwell time ➔ exponential distribution with mean $1/\eta$

A4. Call duration ➔ exponential distribution with mean $1/\mu$

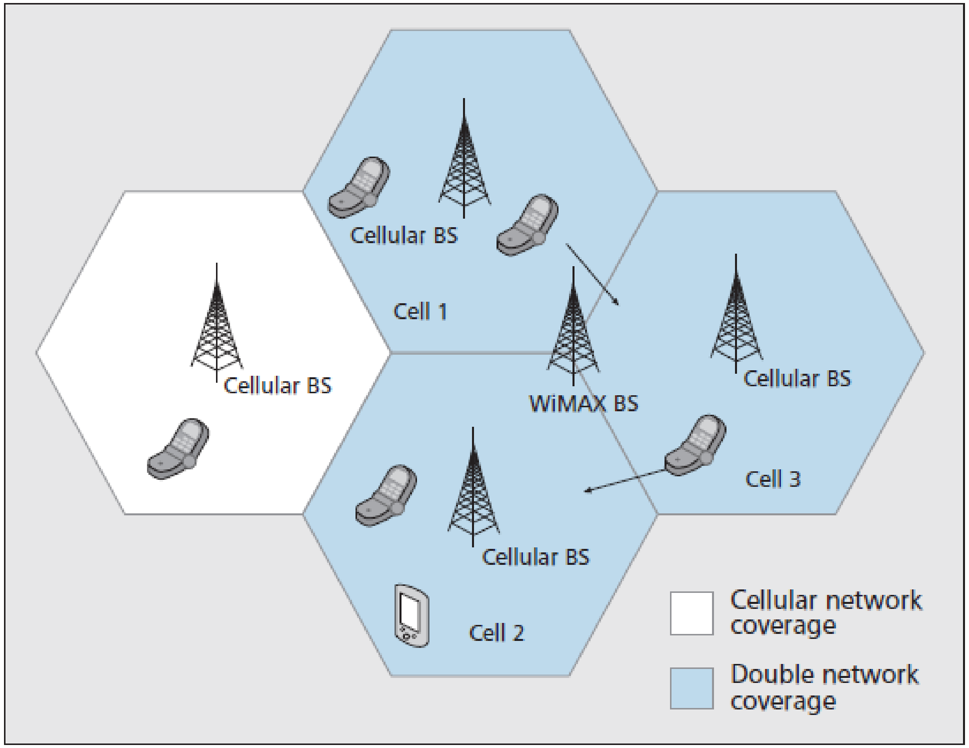
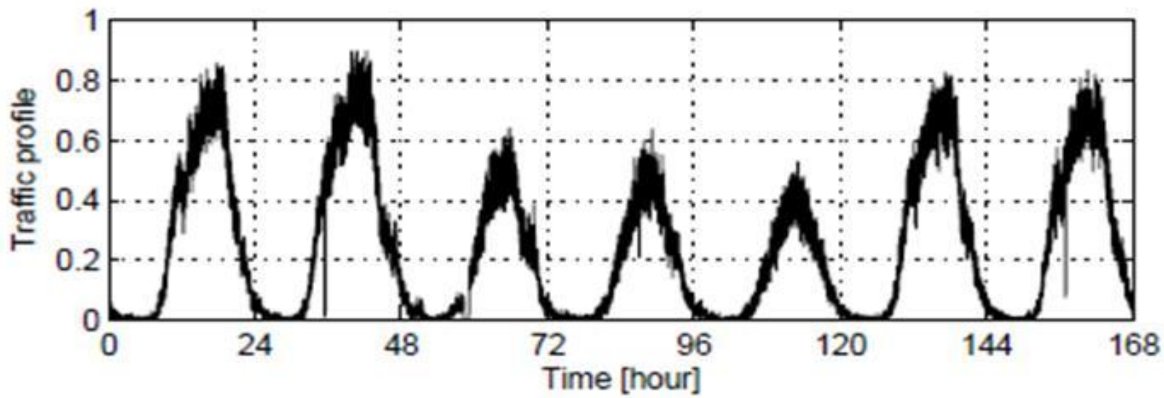


Figure 1. *The network coverage areas.*

The Proposed Energy Saving Strategy



Call Traffic Load Fluctuations

Large Scale Fluctuations

$$\mathrm{T} = \{1, 2, .., T\}$$

$$T = 24 / \tau$$

Small Scale Fluctuations

$$\mathrm{D} = \{1, 2, .., D\}$$

$$D = \tau / \Lambda$$

The Proposed Energy Saving Strategy

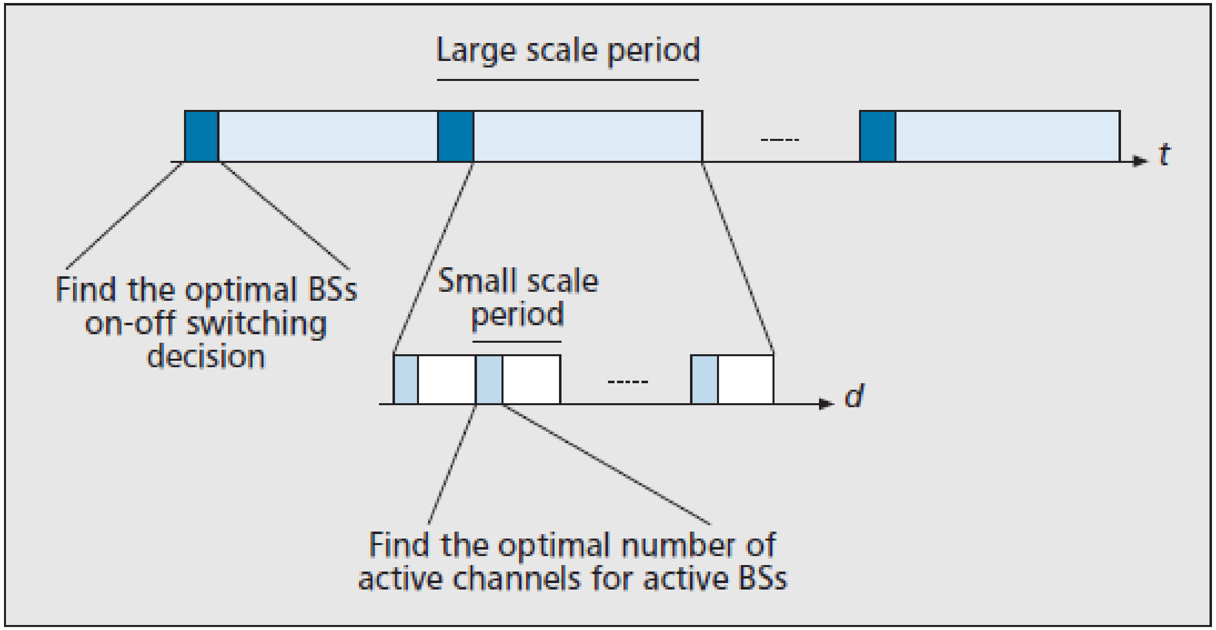


Figure 2. *Time sequence of optimization events for the network cooperation energy saving framework.*

The Proposed Energy Saving Strategy

- Decision on BS Working Mode:

- Maximize energy saving

- Minimize the frequency at which BS changes its working mode from inactive to active

- Achieve acceptable service quality (call blocking probability)

- Ensure radio coverage in the overlapped area

The Proposed Energy Saving Strategy

- **Large Scale Optimization Problem:**

$$\max_{S_n>0,J,X}\left\{\alpha\left[\sum_{n=1}^{N}(P_c-P_n)+(P_w-P_{N+1})\right]-(1-\alpha)\left[\sum_{n=1}^{N}\Delta P_n+\Delta P_{N+1}\right]\right\}$$

$$s.t.\quad \frac{(\lambda_n/\mu_u)^{S_n}/S_n!}{\sum_{s=1}^{S_n}((\lambda_n/\mu_u)^{S}/S!)}\le\varepsilon\qquad \forall n\in N$$

$$x_{N+1}=\begin{cases}1, & \exists S_n>C,n\in N\\ 0, & \text{otherwise}\end{cases}$$

$$\sum_{n=1}^{N}x_n=\begin{cases}N, & x_{N+1}=0\\ J, & x_{N+1}=1,\sum_{n=1}^{N}S_n\le M+JC\end{cases}$$

The Proposed Energy Saving Strategy

- <u>Small Scale Optimization Problem:</u>

$$\max_{S_n > 0} \left\{ x_n . \left[P_c - (P_{co} + k_{cn} P_{cv}) \right] + x_{N+1} . \left[P_w - (P_{wo} + k_{wn} P_{wv}) \right] \right\}$$

$$s.t. \qquad \frac{(\lambda_n / \mu_u)^{S_n} / S_n!}{\sum_{s=1}^{S_n} ((\lambda_n / \mu_u)^S / S!)} \leq \varepsilon \qquad \forall n \in N$$

Performance Evaluation

Parameter	Value	Parameter	Value	Parameter	Value
C	10	P_c	400 W	τ	1 hour
M	72	P_{co}	250 W	Λ	15 minutes
P_w	1500 W	P_{cf}	10 W	α	0.5
P_{wo}	400 W	$1/\eta$	4 min	β	0.1
P_{wf}	30 W	$1/\mu$	6 min	ε	0.01

Table 1. *System parameters.*

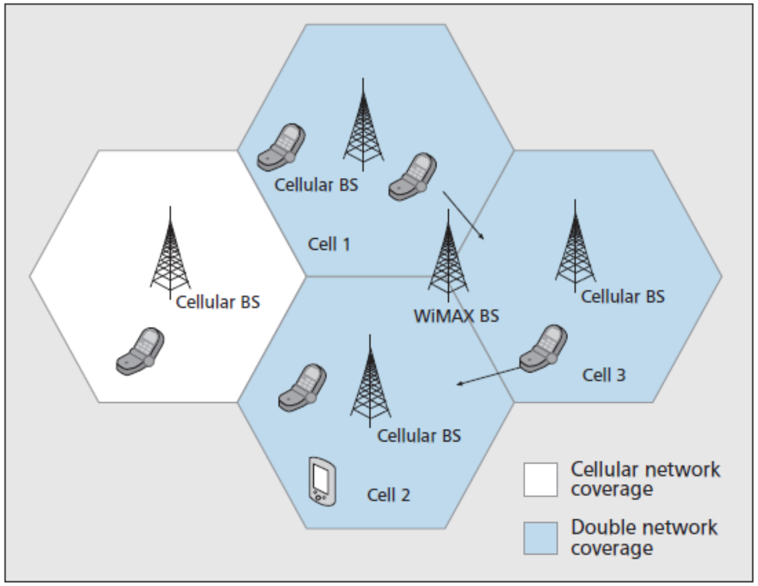


Figure 1. *The network coverage areas.*

Performance Evaluation Cont.

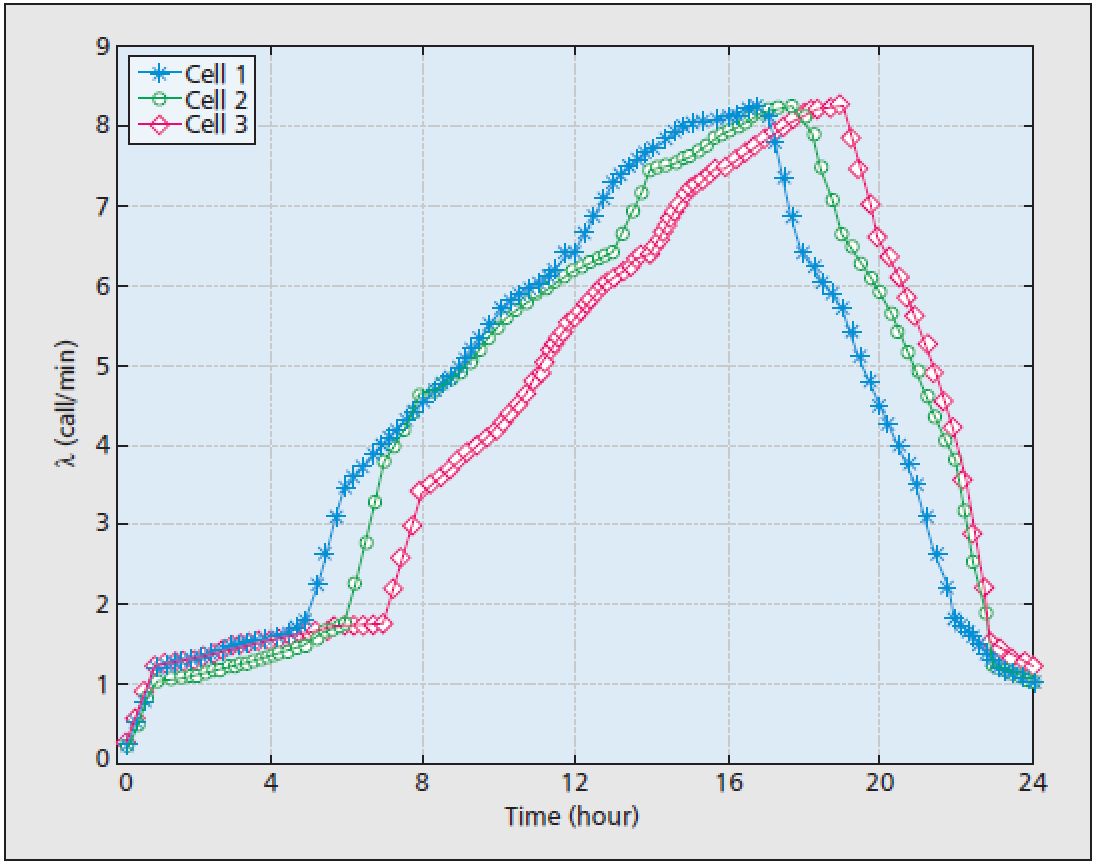


Figure 3. *The aggregate traffic mean arrival rate in each cell.*

Performance Evaluation Cont.

Period	1–5	6–12	13–14	15–19	20	21–23	24
X	1110	0001	1001	1101	0101	0001	1110

Table 2. *BS working mode.*

BS	Cellular 1	Cellular 2	Cellular 3	WiMAX
% Saving	44.68%	48.75%	73.13%	24.5%

Table 3. *Percentage energy saving without small scale optimization*

BS	Cellular 1	Cellular 2	Cellular 3	WiMAX
% Saving	46.33%	50.31%	74.06%	34.45%

Table 4. *Percentage energy saving with small scale optimization*

Performance Evaluation Cont.

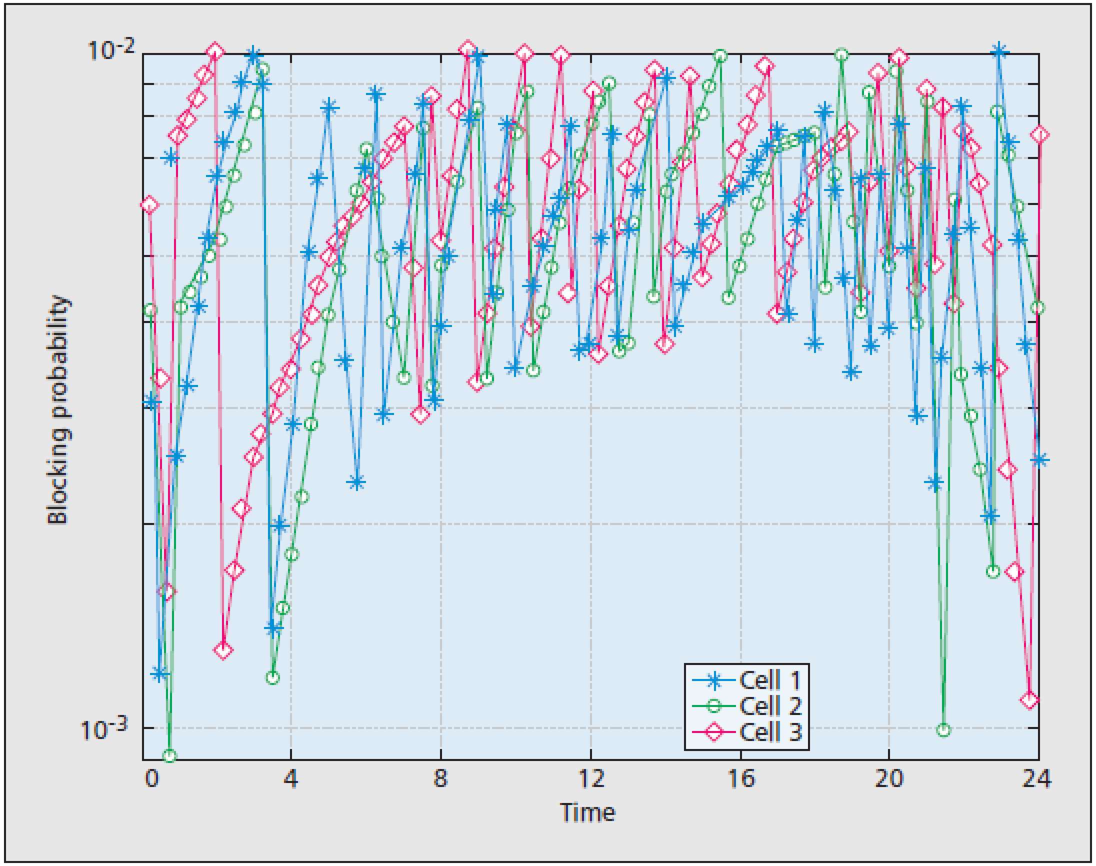


Figure 4. *Call blocking probability in each cell with the optimal number of active channels from the on BSs.*

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Conclusion

- Network cooperation for energy saving on two scales:

  - Large scale: networks with overlapped coverage alternately switch their BSs according to long-term traffic load fluctuations

  - Small scale: active BSs switches its channels according to short-term traffic load fluctuations

- Satisfactory service quality in terms of call blocking and large percentage of energy saving, ensure radio coverage
- Service quality constraints can be extended to: minimum achieved throughput for data applications and delay and delay-jitter for video streaming applications
- Incurred cost: synchronization overhead required

THANK YOU !

For more information please refer to: M.Ismail and W.Zhuang, "Network cooperation for energy saving in green radio communications," IEEE Wireless Communications, Vol. 18, No. 5, Oct. 2011.