

# ITU-T WORKSHOP "ICTs: Building the Green City of the Future"

(Shanghai, China, 14 May 2010)

## Cooperative Wireless Networks for Better Green Services

## 协作无线网络提供更佳绿色服务

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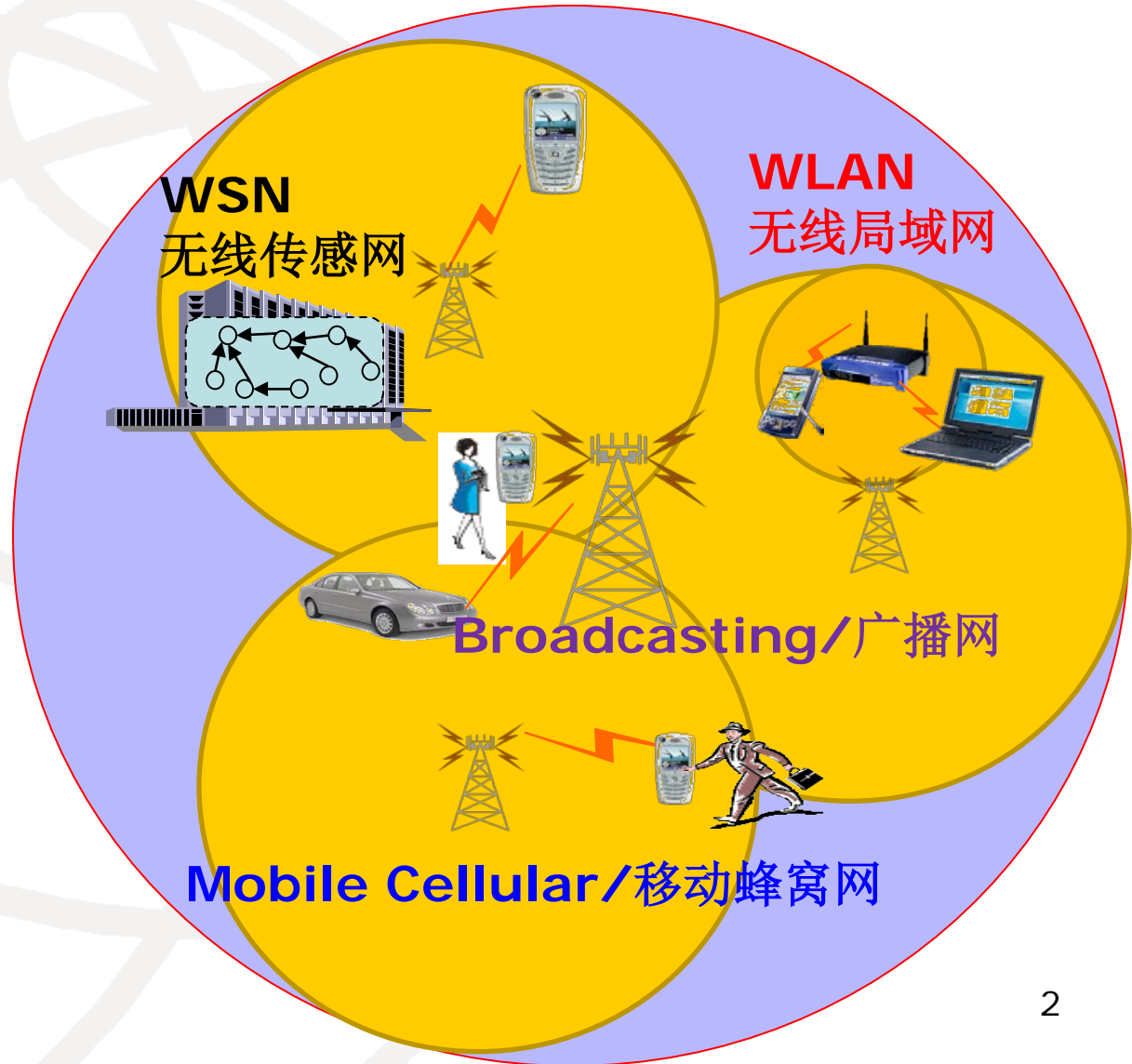
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Shanghai, China, 14 May 2010



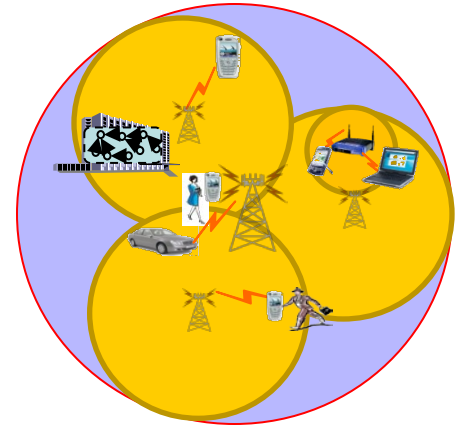
# Heterogeneous Wireless Networks

- Significant contributions to social progress and economic growth
- 无线通信产业发展迅速，有效推动社会进步和经济腾飞



# Heterogeneous Wireless Networks

- Overlapped network coverage
- Service convergence
- Strong competition
- Waste of resources
- More electromagnetic interference (EMI) and radiation pollution
- 重复覆盖，各自为战，相互竞争，浪费资源，电磁环境恶化。

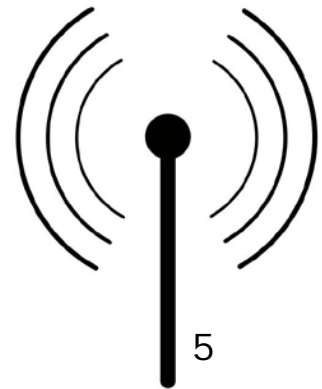
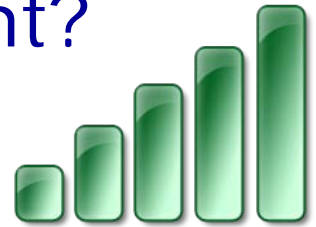


# Intelligent User Equipments

- Multi-mode and multi-interface
- Integration of new features and applications: camera, music, game ...
- User service requirements: diversity, personalized, interactive ...
  - ➔ No guarantee for cross-network services
- 多模智能终端日益普及，用户的服务需求（网络、业务、质量）更具自主性、多样性和互动性。
  - ➔ 但是，跨网服务质量和用户体验难以保障。

# Problem Definition

- We all have mobile devices
- We all want strong signals ... anywhere and anytime ... so are the operators
- But, Is this necessary? Is this efficient? Is this healthy? Is this sustainable?
- 我们都有各种各样的手机或移动终端
- 我们都希望无线信号强，服务覆盖广 — 在任何时间、在任何地点
- 但这是必须的吗？这样能量效率高吗？这样健康环保吗？这样可持续发展吗？



# Facts & Figures – Energy Consumption and Greenhouse Gas (GHG) Emission

- ICT is the 5<sup>th</sup> largest industry in energy consumption (2%-6%), and growing fast
- In 2009, the total energy consumption of China's mobile industry is about 20B KW·H, equivalent to 15.7M tons CO<sub>2</sub> emission.
- 信息和通信技术产业作为能源消耗的大户，占据了全球能源消耗的**2%-6%**，且增长迅速。
- 全国**2009**年移动通信耗电量大约是**200**亿度电，相当于**1570**万吨二氧化碳排放。

# Facts and Figures – Electromagnetic Interference and Radiation Pollution

- Numbers of base stations in China
  - ➔ GSM: 689K, TD-SCDMA: 180K, WCDMA: 110K, CDMA2000: 170K. ➔ Total: 1.1M and growing
- EMI and radiation pollution levels will exceed national standard, i.e.  $40\mu\text{W}/\text{cm}^2$ .
- 中国的**GSM**基站超过**68.9**万个，中国移动的**TD**基站将达到 **18**万个，电信已建成**CDMA2000**基站**17**万个，联通已建成**WCDMA**基站**11**万个。
- 电磁环境不断恶化，现有技术难以保证多网电磁辐射总强度低于 **$40\mu\text{W}/\text{cm}^2$** 的国家标准。

# Cooperative Wireless Networks

## ■ Key objectives

- ➔ Less energy consumption and GHG emission
- ➔ Less EMI and radiation pollution
- ➔ Better cross-network services and applications
- ➔ Sustainable business and economic growth

## ■ 关键目标

- 节能减排，减少电磁干扰和辐射污染
- 创造更多更好的跨网无线通信服务和应用
- 保障移动通信产业和国民经济的持续稳定发展



# Cooperative Wireless Networks

- **Approach:** Cross-network cooperation to match user distributions and requirements
  - ➔ Turn off the lights when you leave a room
  - ➔ Cross-network cooperation enables resource sharing, load balancing, interference avoidance
- **思路：多网能量和能力与用户的服务需求相匹配**
  - 比如：人少时少开灯，离开房间时要关灯。
  - 通过多网协作，实现资源共享、负载均衡、干扰抑制、性能共赢、业务创新、和谐共存和发展。



## Exercise



- Now, look at the lights on the roof ...
- Imagining different types of lights representing different wireless networks
- Yes, you are covered by overlapped networks
- If we can turn off some lights, how much energy can we save?
- 请看天花板上的灯
- 想象一下，不同的灯代表不同的无线网络 ...
- 是的，你被多个网络重复覆盖着 ...
- 在亮度足够的情况下，如果我们能关掉一部分灯，可以节省多少能量呢？

# Cooperative Wireless Networks

## ■ Key Research Challenges

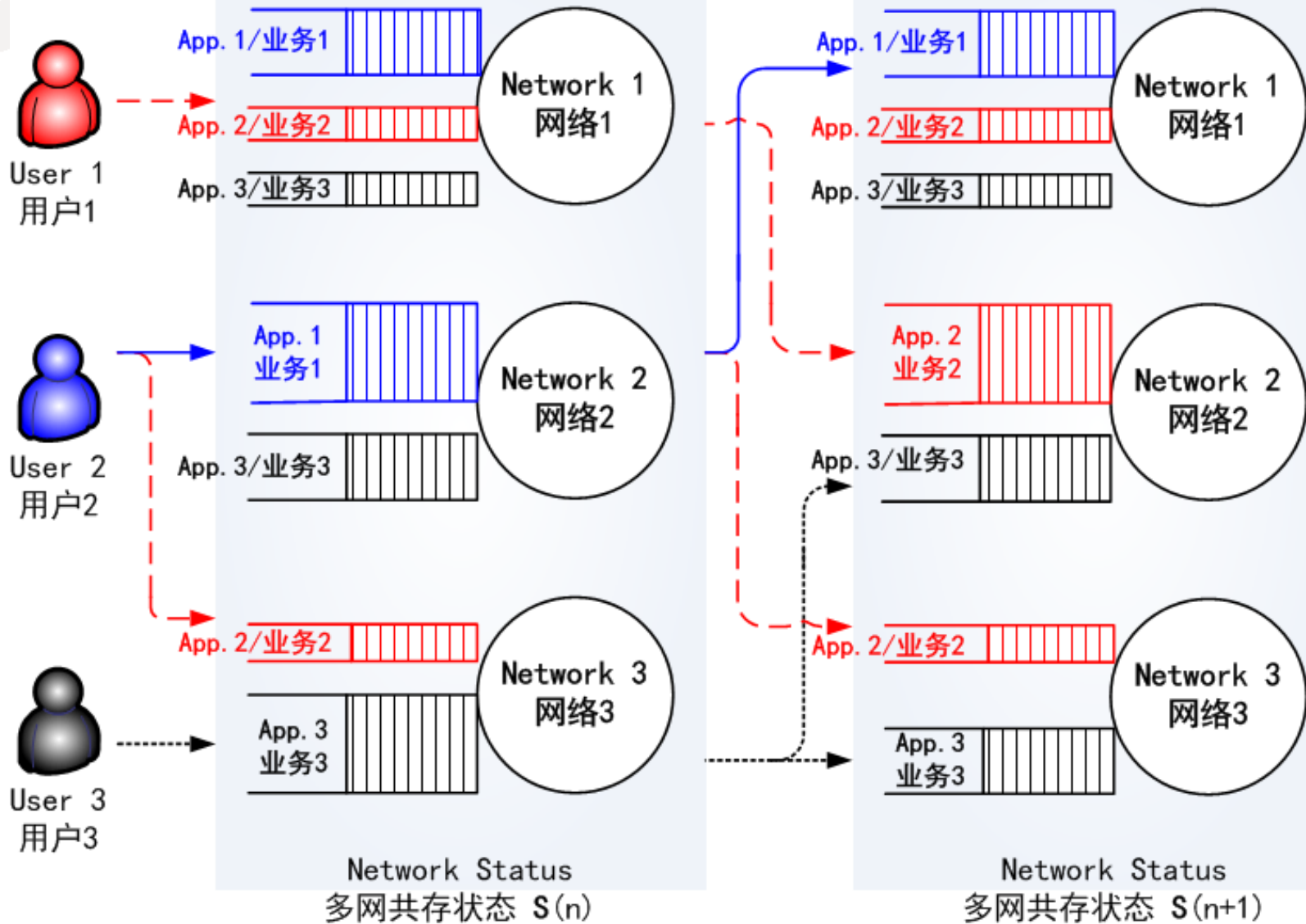
- ➔ To model the dynamics of user requirements, experience, behaviors, and traffic patterns
- ➔ To track and match the statistics of periodic and bursty user and traffic distributions

## ■ 关键研究问题和技术挑战

- ➔ 跨网络用户需求、用户体验、用户行为和业务分布的建模问题
- ➔ 基于用户和业务分布的统计特征，研究多网能量分布和用户需求匹配的匹配问题

# Cooperative Wireless Networks

Key research challenges  
关键研究问题和技术挑战



# Cooperative Wireless Networks

## ■ Key research Challenges/关键研究问题

Multi-network Capacity  
Distribution/共存网络容量分布

User Traffic  
Distributions

Probability Density  
Function/概率分布函数

用户业务需求的  
空间分布特性

$$\max_{\Omega_e} \int_{\Omega_s} \Pr \{ \mathbf{C}(\mathbf{e}) > \mathbf{R}(\mathbf{s}) \} \mathbf{d}\mathbf{s}$$

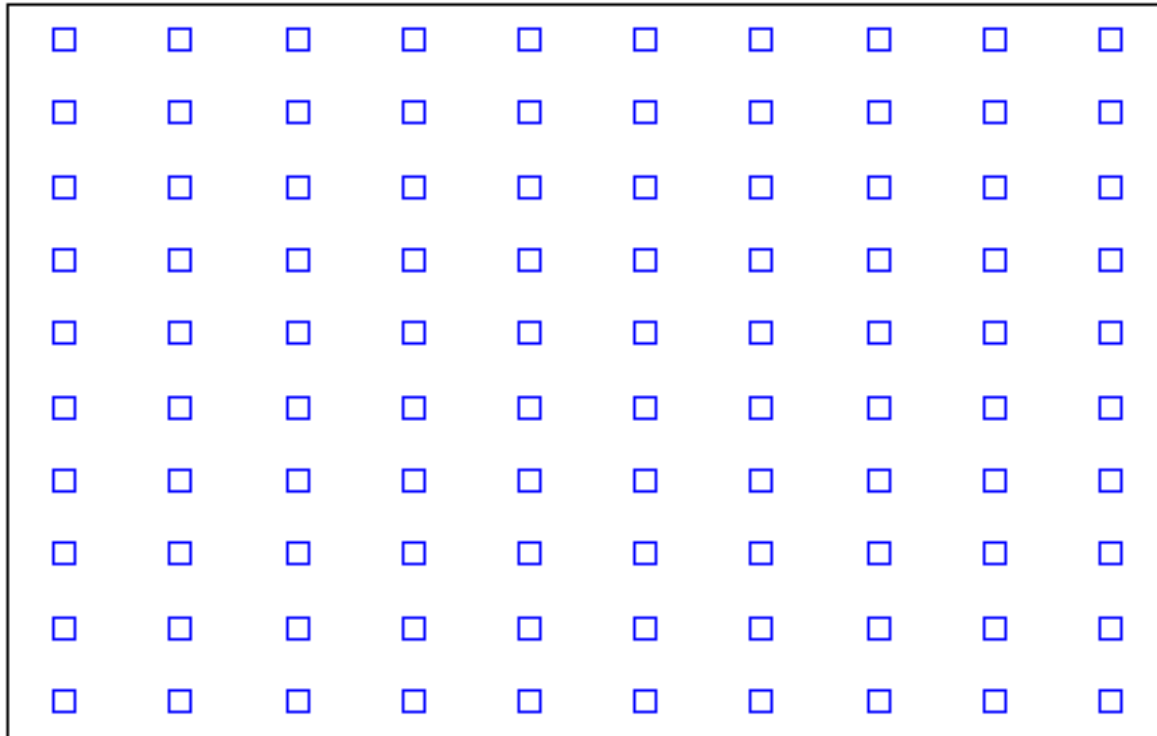
Space of Energy  
Distribution Function  
能量分布的函数空间

$$\Omega_e = \{ \mathbf{e}(t, f, \mathbf{s}) \}$$

Energy Distribution Function  
能量分布矢量，表征共存网络能  
量在时、频、空的分布特性

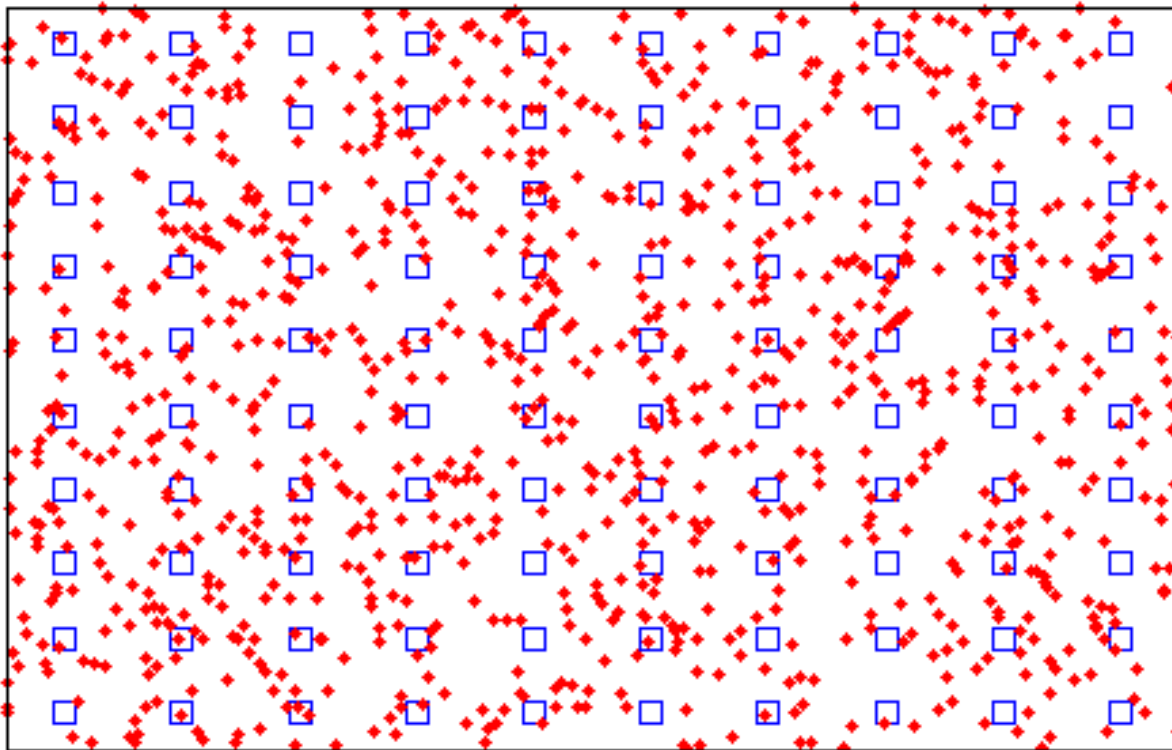
# Example

- Distribution of 100 base stations
- 100个基站的分布



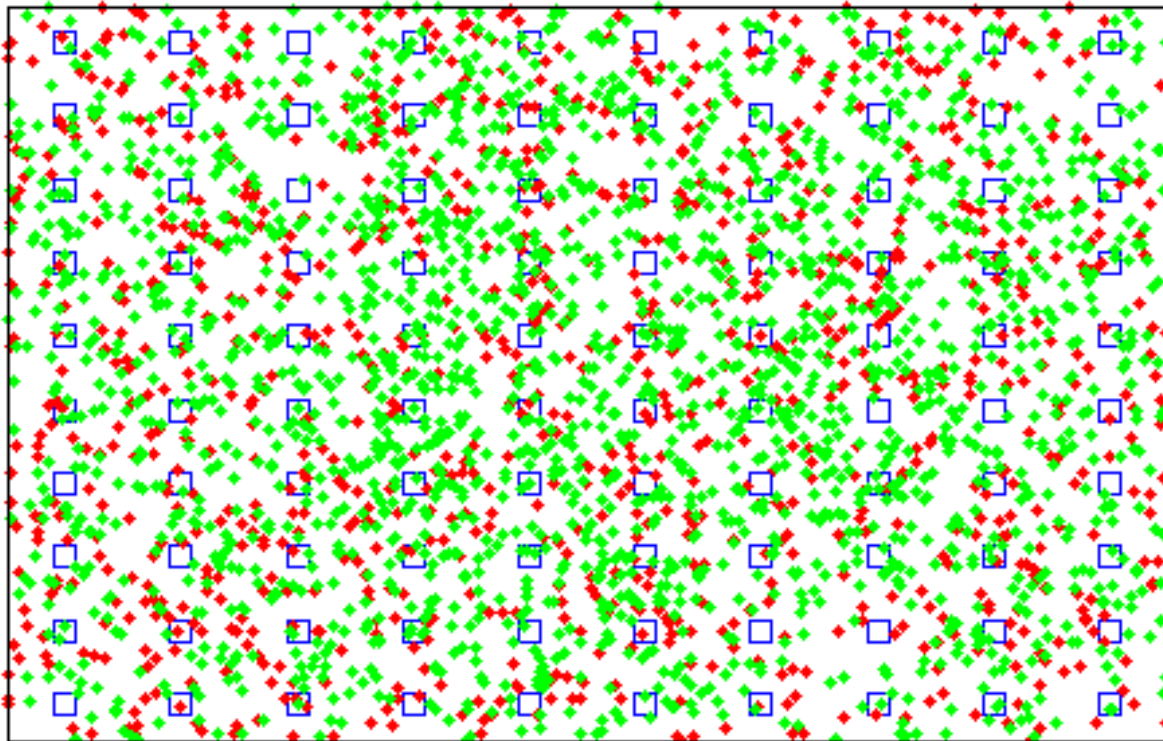
# Example

- Distribution of network-1 users (1K)
- 网络1的用户分布 (1千个)



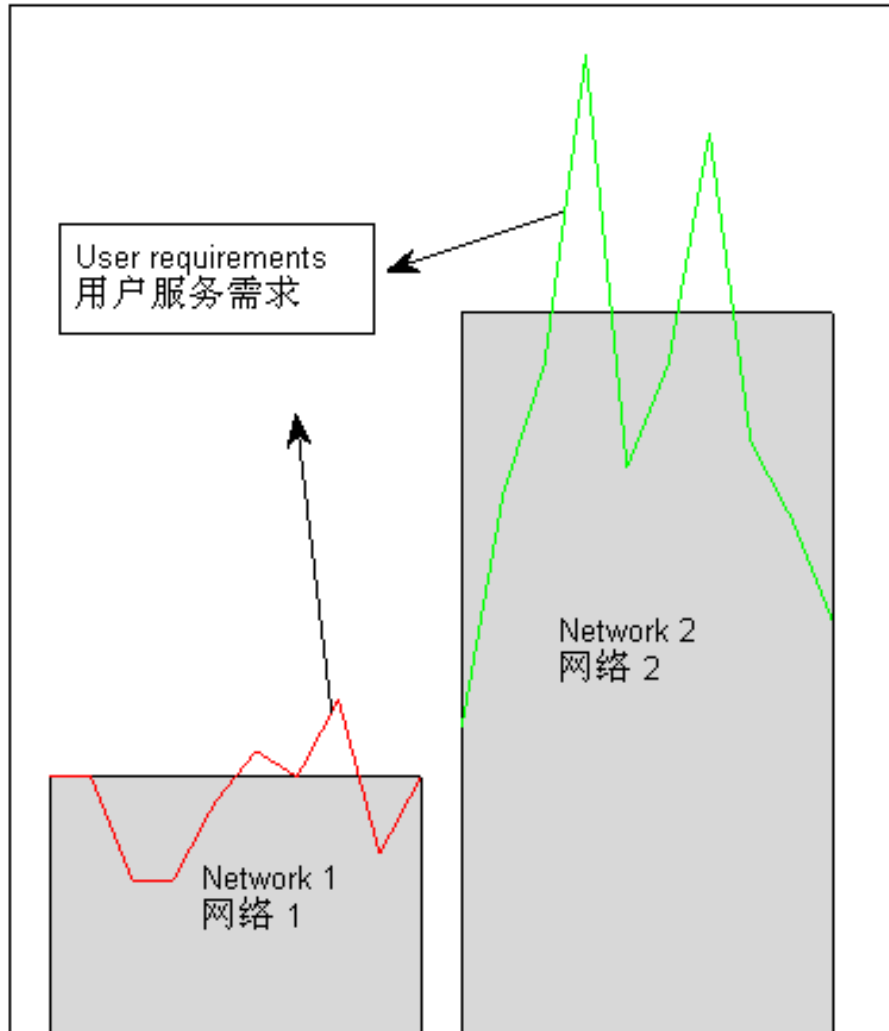
# Example

- Distribution of network-2 users (2K)
- 网络2的用户分布 (2千个)



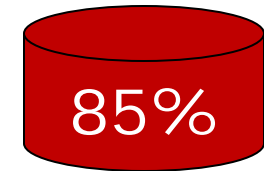
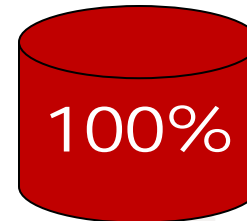


# Example



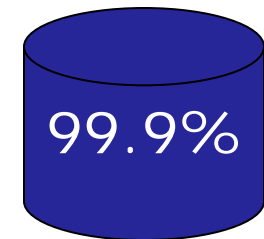
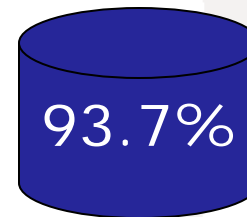
■ Energy Consumption

■ 能量消耗



■ Service Probability

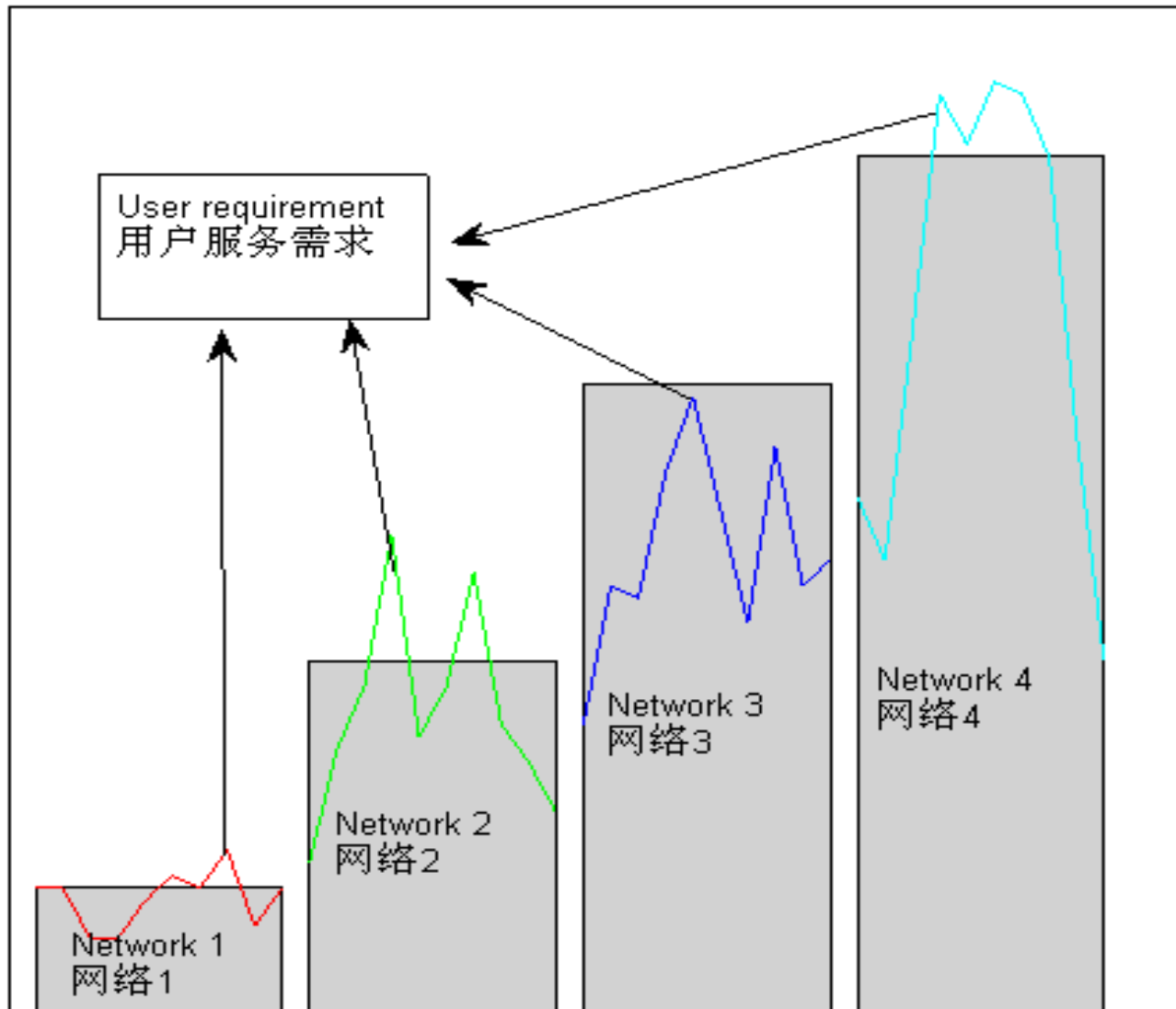
■ 服务概率



No Coop.  
不协作

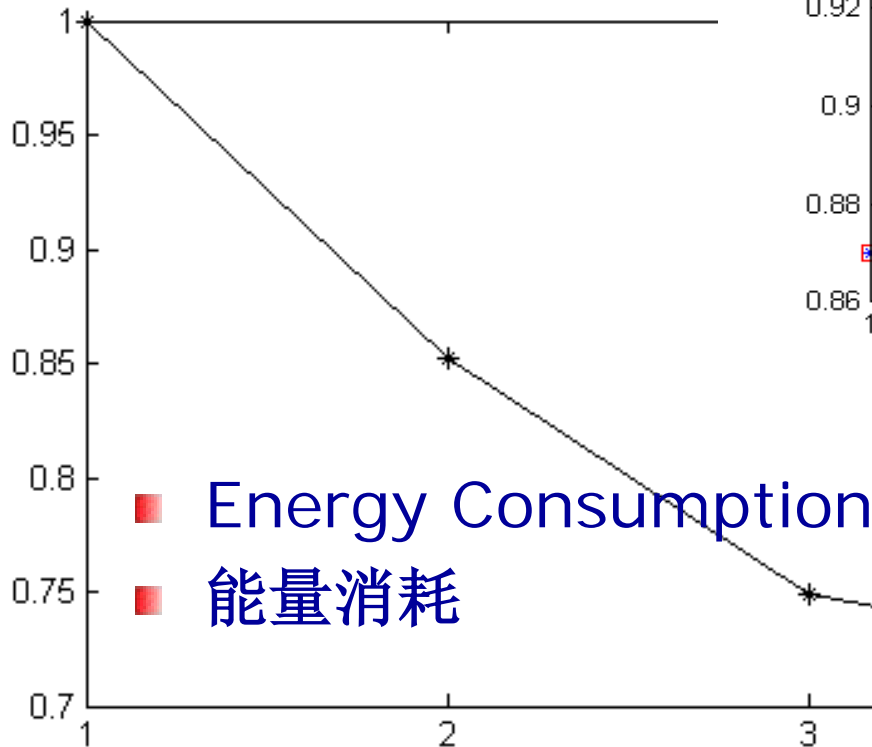
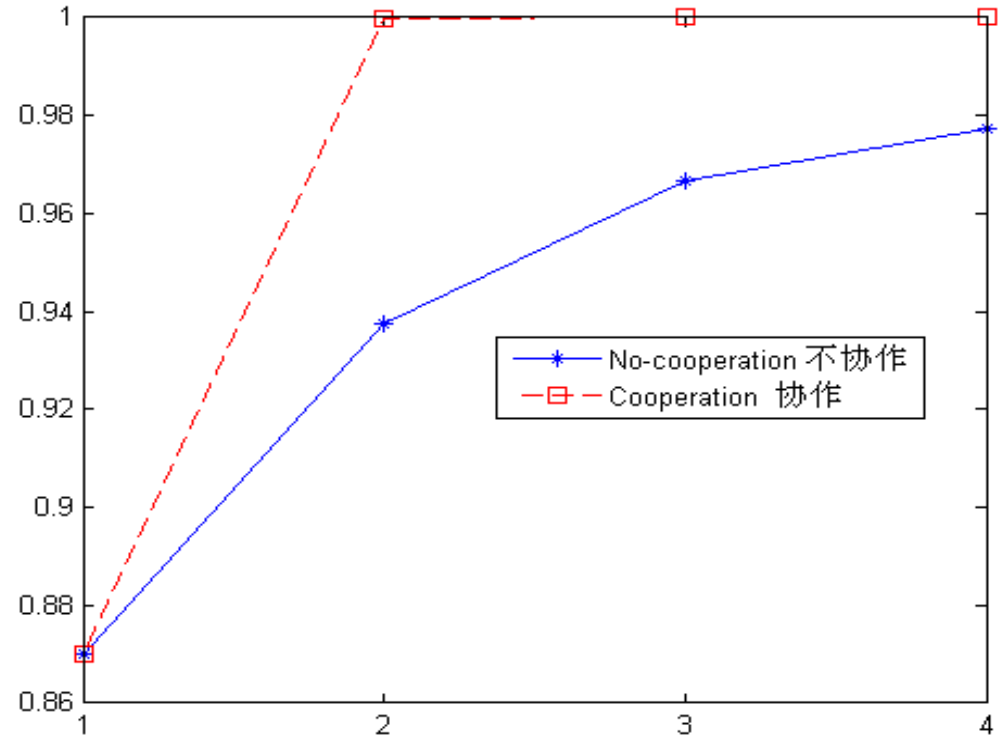
Coop.  
协作

# Example – 4 Networks

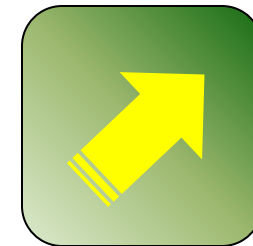


# Example – 4 Networks

■ Service Probability  
■ 服务概率 →



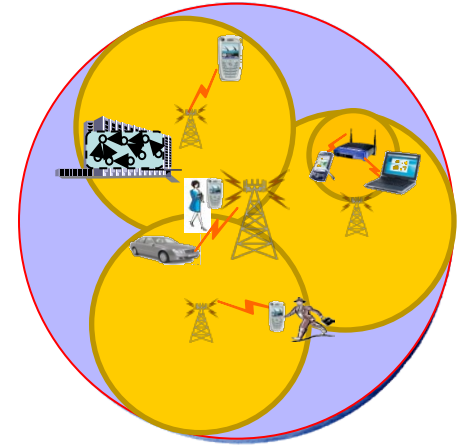
■ Energy Consumption  
■ 能量消耗



**Better  
Green  
Services**

# Conclusions

- Overlapped heterogeneous wireless networks are **not green**
- Cooperative wireless networks achieve
  - ➔ Less energy consumption (**cheap**)
  - ➔ Less greenhouse gas emission (**green**)
  - ➔ Less electromagnetic interference and radiation pollution (**healthy**)
  - ➔ and **better services (happy :)**



# It is time to make a change

- For you and me
- For our kids
- For **birds** and the Nature
- For **blue** sky
- For **green** cities
- For the Earth ...
  
- **Thank you ...**



**Green City, by Michael Pflöghaar**