Self-Energy Optimizations for Future Green Cellular Networks

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Outline

• Introduction (Background & Key enablers)
• Case study
  – Impacts for Homogeneous & Heterogeneous Deployments
• Cyclic activated based dynamic cell configuration for homogeneous deployments
• Cell sizing based energy optimization for joint macro-femto heterogeneous network (HetNet)
  – Utility based power control (UBPC)
  – Neuron control based power adjustment
• Future visions
• Conclusion
Increasing energy & resource crisis with exponential growth in data traffic

Fig. Data Traffic vs. Spectrum Deficit Forecast

[1] Source: Unstrung Pyramid Research 2010
Reduce the energy footprint
- “Green Radio” as an Enabler

e.g. 1. New protocol and infrastructure

e.g. 2. Self-healing Organization

e.g. 3. Sleep mode in Macrocells
Case Study:
- Homogeneous & Heterogeneous Deployments

Q. Critical interferences vs. Additional energy consumption

Q. Maintain QoS vs. Sudden traffic

Cross-tier interference cancellation

- Power adjustment of FAP
- Extend the coverage of FAP
- Exploit idle period of FAP with adaptive sleep patterns

More services by open access

Cross-tier interference (MBS to FUE)
Cross-tier interference (FAP to MUE)
Intra-tier interference (FAP to FUE)
Proposal 1:
Reduce the BS Power Consumption based upon Dynamic Cell Configuration

Fig. Active Cell Rotation Scheme with Cooperation
Traffic Variance Distributions

\( \lambda \): birth rate (times/hour)

TH\(_{\text{down}}\), TH\(_{\text{up}}\): Transition Thresholds

Q\(_{32}\), R\(_{33}\), P\(_{34}\): Transition Probability

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Probabilities of 7 States

7 States in different Traffic loads:
The number of active cells in a cell group
Summary 1

- Markov Modeling and Instantaneous Traffic Simulation

Active Cell Rotation Scheme

- 39% Power Savings of BS
- A little Power increase in MT
- Less Call Drop with Delay-tolerant

Cooperative Rotation Scheme

- 49% Power Savings of BS
- Acceptable Power Consumption of MT
- Balanced call drop and delay
Small-cell involved Heterogeneous Networks

In-building generated phone calls and data traffic are expected to account for 50 and 70% of the total volume in the near future.

Mobile networks are about to reach their capacity limits in terms of the number of supported end-users and the overall data rates.

Femto Access Point is as a cost-efficient way to improve both coverage and capacity while optimizing the energy consumption.

Fig. An example of typical heterogeneous networks
Proposal 2: Cell Sizing based Energy Optimization via Sleep Mode

- Utility based power control reduces the intra-interference while sleep activation reduces the cross-tier interference.
- Dynamic coverage extension with adaptive transmit power of FAP in variable traffic load.
- Variable sleep patterns for femto-cluster make the small cell deployment becomes energy-efficient.

Hybrid Access for Near-indoor FUEs
FAP Coverage Extension in Sleep Edge-MBS

Extension without power adjustment

Extension with power adjustment

(birth rate = 1 times/h, open access rate = 4, CBS is active)

Power Consumption of FAP Cluster

Energy Consumption Rating
Proposal 3:
Cell Sizing based Power allocation for Sleep Two-tier Networks

- Neuron control based power adjustment makes the transmit power of FAP become more accurate in a faster pace.
- The dynamic cell sizing can adapt to the variable traffic load in a self-optimized sense.
- Extended FAPs help the MBS sleep longer and make the two-tier system become energy-efficient.

Hybrid Access for Near-indoor MUEs
Neuron Control-Based Power Adjustment with Self-Optimizing

• Artificial Neuron Model
  – Multi-input indicator control with high speed and accuracy.
  – Changing transfer function during a learning phase.

\[ o_j = \varphi \sum_{i=0}^{n} (\omega_{ij} x_i + \theta_j) \]

\[ o_j = \varphi (\text{net}_j + \theta_j) \]

Fig. Basic neural control process
Simulation Results (2)

**Fig. Active Ratio of a Sleep MBS**

No Expansion

UBPC

Neuron Control

**Fig. Active Ratio vs. Power Consumption of two-tier system**

Balanced the system power consumption

$\lambda$: birth rate (times/h)

**Fig. Normalized Target Adjustment Ratio**
Conclusions

• Femtocell Extension in Sleep-Macrocell

Macro:
1. Sleep macro reduces the cross-tier interference
2. Extended FAPs help macro to sleep longer via hybrid access
3. Macro-cell group can be more energy-efficient

Femto Access Point:
1. Power control reduces the intra-interference
2. Dynamic extension with optimal power
3. Variable sleep patterns for femto-cluster
4. Femtocells can be more energy-efficient
Future Considerations & Trends

- A bright future for cellular is not assured.
- Rethinking “cells” in cellular is necessary.
- The sustainability and reliability should be given tradeoff.
- The “optimal” way to design cellular networks is wide open for innovation.
Thanks for your attention!

Q&A...