

Energy Efficiency of Cellular Networks-Femtocell

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Abstract— Vast advances in the field of Information Communication and Technologies (ICT) has significantly increased the energy requirement and CO₂ emissions which has adversely effected the atmosphere causing untimely and unanticipated changes. Nothing much is being done to address this major issue. We call it major as we have very limited energy resources and environmental degradation is unacceptable which can't be compromised for the facilities we are getting through the improvements in science and technology which are indirectly affecting the environment. In this paper, we survey and discuss various energy efficient technologies aka green technologies mainly targeting femtocell networks. Femtocell facilitates better in-door mobile call coverage .We discuss the technical and business arguments facing femtocell networks and how can possibly overcome them.

Key words— Energy Efficiency, Green Technology, Femtocell, Technical Challenges

I Introduction

Rapid Growth of energy consumption has made global environment issues more severe. As per a survey, 57% of energy consumption of ICT industry attributes to uses and network devices in mobile and wireless networks the scale of which is still growing exponentially. According to a survey, the global mobile traffic is expected to reach 6.3 exabytes per month by 2015 which is more than 26 times as much as traffic load per month in 2010. So, energy efficiency has become a critical issue for the government and industries. Current mobile network technologies didn't focus on these issues due to one or the other reason leading to following drawbacks:

1. Most of mobile communication technologies gave no attention to energy efficiency while focusing on achieving better performance metrics
2. Networking loads differ at different times on a day but the power consumption is same as there wasn't any technique discussed or thought of so as to dynamically adjust power consumption with respect to the current load (network) so as to consume power efficiently.

Recommendation-

The energy saving gain of the most green techniques is achieved out of a performance compare, hence a trade-off between the two must carefully be exploited.

II. Green Techniques-A new thing for mobile Networks

Green technology is a new technology which focuses on utilizing the available energy in any given form more efficiently. Nearly half of the operators' expenditure of a typical mobile system is for the consumed energy and hence effective green techniques are important to lessen the energy consumption of the mobile systems. Novel design of whole green cells is challenging and hence a lot of research is being carried out in the field. The Green Techniques can be sub-divided into three kinds :

- .Processing
- Communication
- System Techniques

The following are the major constituents of the mobile networks where the green techniques can be utilized for effective utilization of the available energy resources:

- A. Data Centers in Backhaul
- B. Macrocell
- C. Femtocell
- D. End-host
- E. Applications and Services

A. Data Centers in Backhaul

At present, the data centers used in mobile networks are increasing at a much faster speed due to the high demands of online storage and computation. Data centers are also consuming huge amount of energy for computing, storing, transmitting and computing. Green technologies are developed to reduce all these using ON/OFF research allocation and virtualization techniques.

General observation tells that data centers are always over provisioned for worst case handling. Therefore at most times the utilization of data centers is far below the

peak value. So, different approaches targeting effective scheduling or even turning off the software level function and hardware devices depending on the traffic load and user demands. All this is needed to be done optimally.

B. Macrocells

It is observed that nearly 60% energy consumption of a cellular networks is for operating the macrocell base station (BS). Hence, the research work related greenness of macrocell base station has recently gained momentums in these aspects :

- i. Dynamic scheduling of Base-Stations
- ii. Cells zooming and power saving of power amplifier (PA).

Again, it is practically observed that 50% of the energy consumption in BS is attributed to the PA. Therefore a method is needed that dynamically adjusts the supply voltage margin and the power losses in linear PA are reduced.

C. Femtocells

Femtocells is a recent research area. For the mobile operators, femtocell major features are to improve both coverage and capacity in the in-doors while optimizing the energy consumption and make BS deployment cost effective. Mobile users get better signal quality and longer battery life using femtocells. Green techniques for femtocell fall into two categories:

- a. Coverage Optimization
- b. Control & Interference Avoidance

The femtocell is discussed in detail in 3rd section.

D. End-Host

As mobile end-host devices have evolved very fast from simple phones to high-end computing and communication devices. This is driving researchers to consider power saving areas of the end-host devices as a new research direction.

Green techniques for end-users fall into 3 main categories

- i. Energy Profiling
- ii. Utilization of Multiple Radios and
- iii. Effective Transmission

These are summarized as under:

Energy profiling is needed to accurately know about the energy demands, local resources traffic patterns and user behaviours of mobile end-host systems.

Most of the current end-host devices utilize multiple radios e.g. bluetooth, WiFi and 3G with different magnitudes of energy consumption. Targeting multiple radios' energy consumption effectively may lead to effective utilization of the available energy sources.

Transmission is the most energy-consuming and hence the most important factor we need to focus while finding out ways to effectively utilize energy sources on demand.

Hence, we conclude that we need to focus not only on Quality of Service (QoS) but also the Quality of Experience (QoE) to get what is the need of the hour.

E. Applications and Services:

There are many trivial and advanced applications that have originated out of mobile smart phones. Hence the need of the hour is to use green techniques for mobile applications and services to introduce specific power-saving designs. The proposed methods may fail but they provide experience to move forward to better approaches later where the "Experience" leads to "Quality".

III. Femtocell

In the day-to-day life, the number of mobile users is significantly increasing and hence the bandwidth allocated to a particular operator can't effectively cover all parts due to the network range and other such issues related to spatial location of the Mobile subscriber. Femtocells are needed basically to provide better in-door coverage for the subscribers of a mobile operator and hence less energy of the operator is consumed for locating the subscriber when a call is made.

Concept of Femtocell:

A femtocell is a small base station. In fact, it is so small that it can be placed in a customer residence. It is like a wired antenna used in the villages to capture signal from prepaid or free television channel providers. The femtocell unit generates a personal mobile network using a standard broadband DSL on cable service and typically supports 2 to 5 mobile phones in a residency setting. This will provide improved coverage for each user to effectively utilize the available energy sources of mobile operators.

Need for Femtocells

As discussed earlier, third generation cellular technology suffers inadequate in-door coverage due to its additional services. Now, on an average a user spends 2/3rd of his time in-doors, there arises the need for a device which can provide better in-door signal quality and femtocell is the solution for this.

Technical Aspect

Shannon's law verifies the potential of femtocell. Shannon's law relates wireless link capacity (in bps) in a bandwidth of W Hz to the SINR. The SINR is a function of the transmission power of a desired and interfering transmitter, path losses and other unwanted (Noise) effects. Path losses cause the transmitted signal to decay as $A_d \alpha^{-d}$, where A is the fixed loss, d is the distance between the transmitter and receiver and α is the path loss exponent.

Femtocells enable a reduced transmit power maintaining good in-door coverage which implies that the penetration losses are overcome. Assuming a fixed receive power target with a path-loss propagation model (no fading) and denoting α (resp. β) as out-door (resp. In-door) path loss exponent, overlaying an area A_2 with N femtocells results in a transmit power reduction of the order of $[10(\alpha - \beta) \text{Log}_{10} A + 5\beta \text{Log}_{10} N]$ dB. To conclude, the capacity benefits of femtocells are achieved out of following features:

- i. Reduced distance between femtocell and user leading to better signal strength.
- ii. Penetration effects are overcome which leads to lower transmit power requirement.
- iii. One femtocell covers only 1-4 users, hence, they can devote larger portion of their resources to the subscribers. This provides better QoS in return.

Business Strategies for Femtocells

Business strategies are required to locate the physical locations where femtocells may be installed so that the budget requirement and the expected quality improvement can be achieved to compete with the ubiquitous WiFi and other upcoming technologies.

Standardization and Deployment

The current aggressive cost challenges identify a need to standardize the requirement across the different vendors and the heterogeneous mobile operators. So, a collaborative organization called the FemtoForum comprised of operators and femtocell vendors was formed in 2007 with an objective of developing open standards for product interoperability.

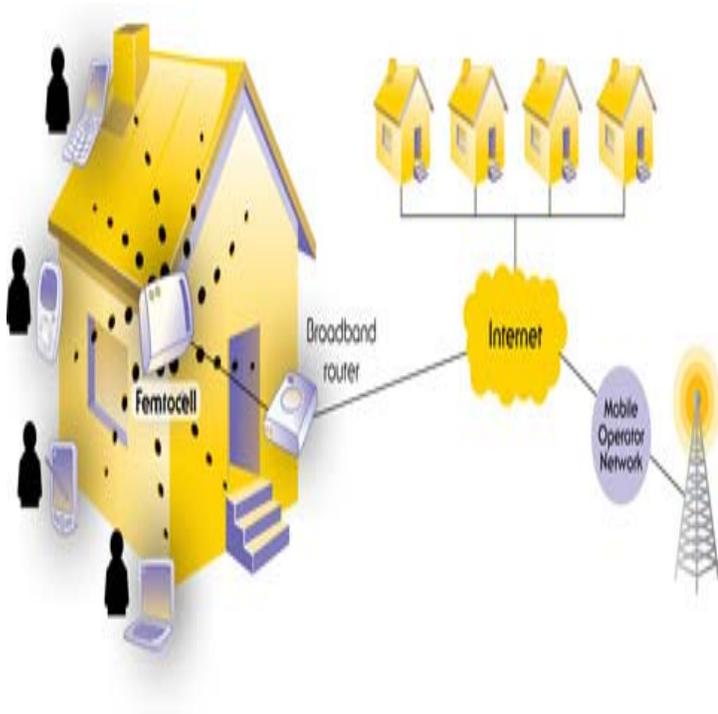


Fig 1. Femtocell Picture

Femtocells originated as an extension to distributed antenna and macrocells. Femtocells provide following key benefits:

1. **Better Efficiency:** As femtocells localize the mobile networks, it lowers the transmission power and prolongs the handset battery life to achieve a higher Signal Interference and Noise (SNIR) ratio. These translate into the so-called 5 bar coverage.
2. **Improved Reliability and Subscriber Turn-Over:** Femtocells provide a virtual way to make mobile phones available on the roof of a house where there is a better signal strength which improves reliability and increases customer satisfaction which in turn leads to decreased subscriber turn-over as customer satisfaction is increased and hence he doesn't think of changing over to another mobile network.
3. **Cost Benefits:** The femtocell provides cost benefits as the femtocell infrastructure is minimal as compared to installing a new tower which incurs additional costs such as site lease and additional back haul and electricity overheads.

IV. Technical Challenges

There are many challenges which are the current research topics. The key technical challenges facing the femtocell networks depend on their application domains such as:

- i. Broadband Femtocells: Resource Allocation Timing, Synchronization and backhaul.
- ii. Voice Femtocells: Interference Management
- iii. Network Infrastructure Femtocells: Security

The following are the key questions regarding the femtocell networks which need to be answered:

- a. How will a femtocell adapt to its surrounding environment and allocate spectrum in the presence of the intra and cross-tier interference owing to the absence of coordination between the macrocell and femtocell?
- b. How will a femtocell provide timing and synchronization?
- c. How will the backhaul provide acceptable quality of service?
- d. How will femtocell handle heterogeneous interferences in an open environment?
- e. Should femtocells provide an open or closed access?
- f. How can handshaking be perform in an open heterogeneous environment?
- g. Is it possible for the subscribers to carry their femtocells for use outside the home area?
- h. How will femtocells provide emergency services such as 911 and should they serve the users in vicinity having poor network coverage?

IV .Benefits of Femtocells

Femtocells have some unique and key benefits which have made them the buzzwords of the industry. These are listed as under:

- Better coverage and Capacity
 - Lower transmit power
 - Prolonged battery life
 - Higher SINR
 - Higher spectral efficiency

- Improved Macro Reliability
 - The traffic originating indoors can be absorbed into femtocell networks over IP backbone.
- Reduced Subscriber Turn-Over

V. Conclusion

Thus, in this paper, we have surveyed the various green techniques mainly focusing the mobile networks and specifically the femtocell networks. Femtocells utilize green techniques to efficiently utilize the energy resources in a mobile network. These are the most recent trend of the market causing “buzz” in the respective fields of applications. We have pin-pointed the issues that the femtocells face and which the researchers are trying to solve. Once these are solved, these can help mobile operators effectively utilize the network bandwidth and energy capabilities much more efficiently in the near future.

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