Energy Efficiency Techniques in Heterogeneous Networks

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Abstract: According to the present data 0.5% of global energy is consumed by wireless networks. Energy efficiency is required for the environment and to lower the network operational cost. In this paper, we are about to discuss various methods of energy conservation in the heterogeneous cellular network. Energy consumption is reduced by self-organization algorithm and message passing algorithm by switching off-peak Base station controllers (BSC). Along with the increasing demands for cellular networks, the various problems for energy conservation in cellular networking have also increased. There are various models present which help in increasing the energy efficiency of cellular networking such as the Novel power consumption model and refined power consumption model. Also, an increase in the higher performance of cellular networks leads to an increase in energy consumption. In this paper, we are about to discuss various challenges which are faces for increasing energy efficiency and their solution.

Keywords: Message passing algorithm, Self-organization algorithm, Green network, Novel power consumption model, Refined-power consumption model, Cellular data traffic, Wireless sensor network, Topology Control, Sensor coverages.

1. INTRODUCTION

A heterogeneous network is used for seamless connectivity. A heterogeneous network is a network which is used for connecting different heterogeneous nodes, Wireless heterogeneous network is a wireless network which is used for seamless connectivity while interchanging of cellular networks. Using heterogeneous networks can do a 30% improvement in increasing energy efficiency. It is considered that the nodes in the wireless sensor network are homogeneous but they rarely exist. In a heterogeneous sensor network, few nodes have more energy to perform the filtering of data fusion and transport [1]. For increasing the coverage area and to manage heavy traffic, these network uses high bandwidth connection. Power-efficient clustering protocol (PECP) is used to improve the nodes with higher energy. The energy efficiency of the cellular networks can be managed by the performance of the cellular networks. A decrease in the performance of the networks decreases energy consumption. Energy can also be conserved by switching off the base station controllers when not in use. Dynamic Base stations switching is also done for energy saving.

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For significant energy conservation, dynamic base station operation should be done more precisely and for that previous records of the daily data traffic profiles are uses. To increase the energy efficiency of the heterogeneous cellular network various methods can be used. Energy consumption can be decreased by doing appropriate changes in the Architecture of the base station controllers that can be either hardware or software. Changes in the channel which is used for the transmission of the signal also affects the energy efficiency of the network. When connected to the electrical supplies may result in more than $3000 per year for the operation.

The rest of this paper is represented as follows: Section 2 represents the literature review, Section 3 represents challenges for the energy conservation, Section 4 represents power consumption model, Section 5 represents the basis of green heterogeneous cellular networks, Section 6 represents energy efficiency in futuristic wireless systems, and Section 7 represents conclusion.

2. LITERATURE REVIEW

While focusing on Green cellular networks, E. Oh used real data traces to derive a first-order calculation of the percentage of power-saving one can assume by turning off the base stations during low traffic times and sustaining the coverage as well [2]. He also discussed several appropriate challenges and their solutions, such as maintaining coverage and enabling cooperation between operators. M. Ismail designed Network cooperation for energy saving on two scales:

- Large scale: networks with overlapped coverage consecutively switch their BSs according to long-term traffic load fluctuations.
- Small scale: active BSs switch their channels according to momentary traffic load variations. Acceptable service quality in terms of call blocking and large one-hundredth of energy-saving, confirm radio coverage.

Service quality constraints: minimum achieved quantity for data applications and delay and delay-jitter for video streaming applications.
Experienced cost: synchronization overhead require. The difficulties of BS switch for energy savings in wireless cellular networks.

K. Son proposed quite a lot of SWES algorithms, designed to be an online Message-Passing Algorithm that could be operated without any central control system. Finally, from the first-order analysis, he showed the total energy saving in need of upon the road traffic ratio of mean and modifications and the deployment of the base station. They empirically showed that the proposed algorithms can not only perform close to the optimum exhaustive algorithm but also they can attain significant energy savings of up to 80%. [2]

3. CHALLENGES FOR ENERGY CONSERVATION

3.1 Equipment level challenges

Radio base stations are optimized for the maximum load to handle. But the problem is that they lack scalability. This results in significant energy losses. To minimize Equipment Level Challenges Base station components should have the ability to adapt themselves according to the network traffic loads. Introduction to sleep modes plays a vital role in minimizing these challenges. In sleep modes, the radio base stations having zero transmission are shut down to minimize energy consumption.

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3.2 Node level challenges

This is similar to the Equipment level challenges. Radio Base Stations [3] are designed for providing a quality service at any instant. Thus this results in high energy consumption by the traffic. Energy efficiency is minimum in the case of lower load conditions. For minimization of Node level challenges, radio resources should be balanced according to the resource allocation and demands.

3.3 Network level challenges

This one is one of the major challenges which are faced because of the trade-off between energy efficiency and higher performance in the network. The higher performance of the network results in increased energy consumption thus decreases the energy efficiency of the network. This challenge should be minimized without affecting the quality of the service which creates a big hurdle [4]. This requires Base station cooperation and self-optimization for providing the energy-efficient network which is based on network capacity demands.

4. POWER CONSUMPTION MODEL

According to the present power consumption model, the total power consumption of the heterogeneous cellular network is divided into 2 different parts i.e.:

- Power is consumed by Base station controllers even when they are having no transmission.
- Power consumption depends upon the traffic load [5].

The power consumption of Base station controllers depends on various factors. The major part of the total power consumption is the power consumed by signal processing and functional side cooling. The power consumption also depends upon consumption due to the power amplifier. In a base station controller, energy efficiency is also decreased by the feeder losses i.e. energy losses due to the devices in between the path from antenna to the receiver.

Power input: Pin = NTRX (aPTX + bRADIO)
Power output: 0<POUT<PMAX

NTRX and PMAX is the maximum power transmission.
bRADIO is the power consumed by the active cooling side and signal processing.
a is the energy consumption due to feeder losses and power amplifiers.

The size of the base station controller also plays a vital role in the energy consumption of the base stations. The power consumption increases along with the size of the base station. Macro Base stations consume more power than the micro base stations. The order of the size of the Base station with decreasing energy consumption is:

Macro BS > Micro BS > Pico BS > Femto BS
(BS= Base stations)

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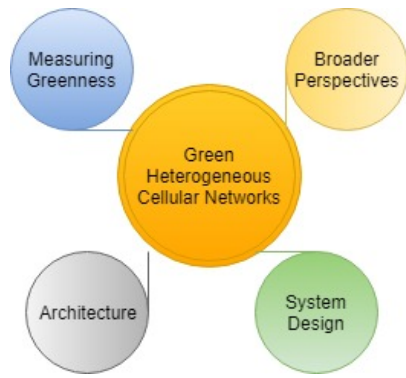

Figure1: Technical Roadmap for Green Heterogeneous Network

5. BASIS OF GREEN HETEROGENEOUS CELLULAR NETWORKS

5.1 Architecture

In the past couple of years, the demand for cellular networks has increased so much that the number of base station controllers has increased rapidly from a hundred thousand to millions. This has also increased the overall energy consumption by the Base station controllers [6]. A Basic cellular network is consisting of 3 elements:

1. Core network for switching
2. Base stations which provide an interface for radio frequency
3. Mobile terminals for data and voice connections

5.2 Energy consumption minimization

Energy efficiency can be increased by modifying the Base station's hardware design. Energy consumptions of a power amplifier depend on frequency band, modulation, and operating environment. The major parts of BSs are Radio, Feeder, and Baseband. The energy consumption of Radio is more than 80% of the energy required by the BS. From this 80 %, the power amplifier requires approximately 50% energy. In Power amplifiers, 90% of the energy consumed is wasted in the form of heat. Thus for the cooling of PAs, air conditioners are required which further increases the energy consumption of the BS. Thus modifying the power amplifier, increases energy efficiency to a larger extent. To conserve the energy of base stations during no transmissions, Sleeping modes are introduced, in which BSs to minimize the energy consumption. Cell zooming also plays a vital role in minimizing energy consumption [2]. Cell zooming is the technique that is used to automatically adjust the size of the cells according to the network and traffic loads. Energy consumption can also be increased by modifying software.

5.3 Base Station Power Management

During Day time, there is a huge traffic load in the office areas whereas during night time, the traffic load shifts to the residential areas. This results in low load conditions in residential areas during day time and office areas during the night time. Thus there are some cells under low load and some are in huge traffic at a particular time. Thus the optimization of staticity is not present in the cells which results in fluctuating traffic conditions. To overcome non-statical conditions, Cell breathing is used in CDMA networks. Cell breathing is the term which means that the coverage area of the Base Station in a CDMA system will be minimized if there are more subscribers.
When some cells are kept in sleep mode, they create gaps. These gaps are filled by the remaining active cells, this

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concept is known as Self-Organizing Networks (SON). The first technology to use the concept of SON was the 3rd Generation Partnership Project (3GPP) Long Term Evolution (LTE) 8th release. Mobile operators use the concept of SON to decrease their capital expenditures as well as operating expenditures.

5.4 System Design

According to recent researches on technologies, cognitive radio and cooperative relays have gained huge importance in Wireless Communication Systems. The Cognitive radio uses the radio waves spectrum in the more efficient ways and the Cooperative relays are based on the deployment of relay nodes between the terminals i.e. the source (BS) and the destination point (UE) and are used for the energy conservation by reducing the attenuation. Relay system has two types i.e. (i) Pure relay system (ii) Cooperative relay system. The major factor for the designing of relay networks is (i) the choice of the relay node (ii) The relay strategy and (iii) The allocation of power and bandwidth for each user.

5.5 Green Communication via Cooperative relays

Cooperative communication techniques are the basis of the virtual MIMO System. Due to MIMO systems, coverage can be enlarged and capacity enhancement can be achieved. Relay systems also increase the battery life which is a huge step in the development of energy-efficient networks. To transmit green communication by cooperative techniques, we have 2 methods: (i) installation of fixed relays in the network coverage areas for providing service using less power utilization. (ii) Utilization of users to act as relays.

5.6 Green communication via cognitive radio

To increase the bandwidth efficiency which plays a vital role in wireless communication, bandwidth-efficient systems were designed. But the allocated spectrum of bandwidth-efficient systems is highly under-utilized, thus cognitive radio was introduced. Cognitive radio works on a collection of information on spectrum usage and accesses the used frequency bands to reduce the under-utilization of the bandwidth [7].

6. ENERGY EFFICIENCY IN FUTURISTIC WIRELESS SYSTEMS

Low energy spectrum sensing

- Energy-aware MAC and green rooting
- Energy-efficient resource management
- Cross-layer design and optimization
- Uncertainty issues

6.1 Broader Perspectives

For the production of the network, the interface which should be considered should have the same energy consumption for data transmission and for receiving the data. According to the broader-perspective, there should be a database in base stations and mobile terminals that can save the traffic pattern throughout the day. Based on this database, the base stations should be switched to different power profiles according to the data traffic. According to the other perspective, the base stations are located in different areas are connected to a power grid. The power generators, transmission systems, and appliances utilizing 2-way communication lines are coordinated by the smart grid. These 2-way communication lines can either be terminals based on wireless channels or Internet protocol (IP) based connections. The power efficiency of the Base stations can be minimized by absorbing them in smart grids without affecting the quality of service [8].

The new Base stations are more sophisticated than the older ones and they consume more energy as

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compare to the older base stations. The energy which is responsible for the production of the equipment is called the Embodied energy. The embodied energy is a huge proportion of the total energy consumed by the base station.

6.2 Measuring Greenness

For the comparison of the cellular network components and the whole network based on energy consumption, Energy metrics are used. As the increasing demands and quality for the network, nowadays, the performance measurement of the network cannot rely on one metric. Energy efficiency metrics are classified in the following categories:
(i) Facility level metrics– It refers to high-level systems
(ii) Equipment level metrics– They are used for the evaluation of the performance of the individual equipment's.
(iii) Network-level metrics-It is the same as equipment level metrics but it also considers features and capacities of the network coverage.

The Facility-level efficiency metrics proposed by The Grid Green association is called Power Usage Efficiency. The reciprocal of Power usage efficiency is known as the Data Center Efficiency. The data center efficiency is used to evaluate the power performance. The power usage efficiency is a good metric for fast assessing the data center performance at a macro level. The disadvantage of Power usage efficiency is that it fails to evaluate the energy of individual equipment.

The performance of the communication systems is of different types such as several cells supported in each block of time, spectral efficiency, etc. and every performance has a different metric. It is more difficult to define the metrics at the network level than defining it at the equipment level. The deployment cost such as site construction and backhaul should also be considered by Green Metric in the future.

7. CONCLUSION

One of the major advancements of the 21st century is Information and Communication technology. These advancements play a very important role in everyday life and every field such as Business. Education, Research, etc. The demands for the cellular networks are increasing exponentially, thus for handling more traffic loads, more base stations are needed which will require more energy consumption. Thus the energy-efficient systems are required for minimization of the energy consumption to fulfill the dream of "The Green World". Not only minimizing the energy consumption but need for reducing the energy losses is also there. These energy losses are of different forms such as heat losses, feeder losses, attenuation, etc. Along with energy efficiency, the minimization of the operational and maintenance cost is also needed. In the manufacturing of the base station equipment, two major facts should be considered i.e. they should have cost friendly and they should support off-grid base stations. In the BS a huge power ratio is wasted in the power amplifiers, thus energy-efficient power amplifying systems are also required along with the power-saving protocols. There are several challenges in front of us for the development of the Green heterogeneous cellular network. A self-organizing algorithm is also equally important for minimization of energy consumption as it includes self-configuration, self-optimization, and self-healing. Since the resources available to are very limited and are getting exhausted at a fast rate, thus the use of renewable energy resources is equally important along with the energy efficiency of the network [9].
The major aspect of this paper is the minimization of the energy consumption without affecting the quality of service and the capacity of the heterogeneous cellular network. The power improvements will continue to challenge the design of next-gen energy-efficient data centers. For the achievements of power efficiency, such solutions are needed which are the result of a careful integration of hardware solutions such as efficient packaging techniques and energy proposal hardware designs that focus on memory subsystems that can reduce the power consumption of the central processing units. Standardization of the energy efficiency metrics is also required in the future for helping the network designers, researchers, etc. This talk briefly

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addresses many of the challenges and solutions for the improvement of the energy efficiency of the heterogeneous cellular networks along with the operational and maintenance cost.

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