REST Journal on Emerging trends in Modelling and Manufacturing
Vol:4(2),2018
REST Publisher
ISSN: 2455-4537

Website: www.restpublisher.com/journals/jemm

Techniques Driving Energy Efficiency Contributing to Environment Sustainability Goals

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Abstract
Wireless is the future. With the increase in handheld devices, the wired networks are becoming obsolete and are being replaced by wireless networks. A lot of research is put into increasing the energy efficiency of these networks. Both hardware and software play an important role in energy efficiency. MIMO [Multiple-Input and Multiple-Output] techniques and OFDM [Orthogonal Frequency Division Multiplexing], advanced MAC design techniques, dynamic power saving techniques, multiple access techniques are used to enhance the energy efficiency in the wireless networks. Increased energy consumption causes adverse effects to the environment and will act as a hurdle to the sustainability of a company. Energy efficiency is therefore very important in the field of Information and Communication Technology. In this paper, we talk about some of the techniques that strive to achieve energy efficiency.
Keywords: Energy Efficiency; Wireless Networks; Power Reduction; Sustainability; ICT.

I. Introduction

Many wireless networks are rapidly developing in our planet. The stakeholders' main concern is the energy efficiency of these networks. User satisfaction, green technology, design are the major driving forces for energy efficiency. Triple bottom line, the natural step framework requires a business to not cause an increase in the environmental degradation for a company to be sustainable. A major role is played by energy efficiency for the sustainability of a business and has to be taken seriously. The advancement in the fields like MAC design, MIMO, OFDM, Cross Layer Design have all contributed to the increase in energy efficiency. Eco-design tools have sky rocketed in the past few years which has resulted in many energy efficient techniques [1]. The telecommunication industry has set certain standards that will help in increasing Quality of Service and energy efficiency. Energy efficiency increasing techniques reduces power consumption and thereby increases the scope of the hardware. Hence, these techniques are beneficial for the sustainability of a business as well as the environment. The paper is organized as follows. Section II deals with wireless MAC design for energy efficiency. Section III presents energy efficiency in MIMO, OFDM and cross layer designs. Section IV deals with radio resource management for energy efficiency. The paper is concluded in section V.

II. Wireless MAC Design for Energy Efficiency

The goal of energy efficient Multiple Access Control design is to increase capability and decrease consumption of energy in a cell phone. It's not possible to achieve both since more performance would require more energy consumption or less energy consumption would reduce the performance. So the two things have to be optimized. Sources of unwanted energy consumption: A transceiver of a phone works in different modes. These are receive, transmit, idle, off and sleep mode. The mobile transmits data in transmit mode; in receive mode, mobile receives data in receive mode; the transceiver is active and ready to receive or send in idle mode; the transceiver shut down in sleep mode, except for a little part of circuit listening for incoming transmissions. There are certain events where it need not consume as much energy as they are consuming now [2]. Few of them include Applications like E-mail and browser require less energy than what is available in the idle mode; In the waiting time until which the transceiver will operate in full active mode before going to idle, energy is wasted; While switching between different modes, a lot of energy and time is used and the mobile will also incur overhead; If some data is not properly sent or received due to some error then the energy consumed for that process of sending or receiving data is wasted. So, more error rates will lead to higher energy consumption [3].

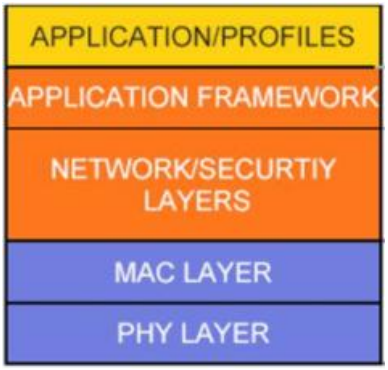

Figure 1: Position of the MAC layer in the OSI stack

Energy Efficient MAC design requires the following principles:

- The transceiver's unsuccessful actions must be avoided.

Collisions and errors are two main reasons for unsuccessful actions. In case a collision occurs between any two or more transmissions, then that data will have to be sent again after a certain delay. So, a protocol can be designed where traffic control to every mobile in its range can be broadcasted any particular base station with data containing information like a mobile when it is permitted to transmit or receive data. This decreases the event of collisions drastically. When new requests are made, collisions are more likely to occur. In a communication stream, new requests can be made per packet, per application of a mobile, or even per mobile. For fault tolerance in wireless networks, error control methods can be used to the currently present error condition in such a way that the energy consumed is very less. Since wireless networks are dynamic in nature, adaptive error control mechanisms are to be utilized to give elevated gains in bandwidth and energy efficiency.

- Minimize the number of transitions.

Data can be sent in bursts where a mobile continuously transmits or receives data, which would lead to reduction in number of transitions. QoS parameters like jitter and delay, are however affected. Suppose the traffic is continuous. Let's say that this traffic can be programmed for a lengthier period, then it is not required for the mobile to listen to the traffic control as it understands when it can anticipate data and when it may transmit. Another way of minimizing the number of transitions is to collect numerous requests of different applications on any mobile device and piggy-backing new requests on the present data streams.

- Synchronize the mobile and the base station.

By synchronizing mobile and base station, the mobile can be switched to standby or off mode and wake up only when it needs to communicate with base station. By reducing the time taken for receiver to check if there are any messages from the base station for the mobile, energy consumption can be minimized for downlink traffic.

- Migrate more work to the base-station.

Base stations, and the control unit it is connected to, have higher power and processing capabilities than a mobile. So few tasks of a mobile, whichever is possible can be migrated to the base station. This would result in lesser processing and energy consumption for a mobile. The energy consumed in practical wireless networks is very complex and contains many issues and hence, many tradeoffs have to be made.

III. Energy Efficiency In MIMO, OFDM And Cross-Layer Designs

Worldwide Interoperability for Microwave Access (WiMAX) and *the Third Generation Partnership Project* (3GPP) *Long Term Evolution* (LTE) form the future 4G wireless systems. MIMO and OFDM play a prominent role in 3G and 4G systems. The overall network carrying capacity of the spectrum values are increased by the OFDM. Various energy saving schemes have been developed with MIMO and OFDM techniques, In this section, we aim to provide a brief overview of MIMO, OFDM and Cross layer Optimization.

A. MIMO

MIMO is an advanced wireless technology. The basic wireless system consists of a transmitter and a receiver.

The transmitter has data that it wants to communicate to the receiver. The data could be the social media updates, news feed, webpages, and voice packets of the phone conversation. The TX and RX are separated by the dedicated wireless channel which consists of everything between the transmitter and receiver that is buildings cars, trains, planes, etc. The transmitter has limited amount of maximum power which is used to transmit the data. The data signal at the TX and RX may vary due to the superposition of the direct path and multipath signals. One possible solution to have more reliable communication with high data rate is through having many antennas at the reception site and transmission site and this framework is called MIMO

(Multiple input multiple output). MIMO system is able to deliver high data rate and increased reliability which is possible through the multipath which exists between the transmitter and the receivers. There are many techniques that facilitate MIMO, prominent among them are Beam forming and Multiplexing. In Multiplexing, the transmitter increases the overall data rate by sending parabolic beam of data streams on various antennas at similar times. In Beam forming, the transmitter basically focuses narrow signal beams in the direction of the receiver thereby improves the signal reliability factor. The transmitter must have the complete knowledge about the wireless channel for beam forming to be feasible. At present MIMO has been standardized and is used in IEEE 802.11n routers with 4X4 antennas and in 4G LTE mobiles with 4X4 and 8X8 antennas [4].

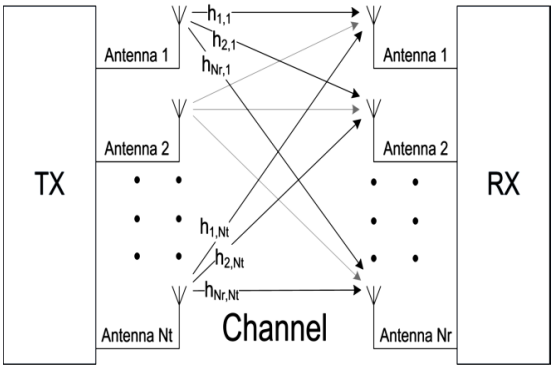

Figure 2: A basic MIMO system

B. OFDM

It is necessarily critical to have a basic comprehension of Orthogonal Frequency Division Multiplexing (OFDM) in light of the fact that this innovation is a fundamental building hinder for a significant number of the present adjustment plans including; 802.11 WLAN, 802.16 WiMAX, and 3GPP LTE. A single subcarrier is modulated using numerous other subcarriers confined in same single channel. This type of a digital modulation scheme is called OFDM. Instead of transmitting a stream of data with a high rate in a single subcarrier, OFDM utilizes a sizable quantity of subcarriers which are orthogonal to each other and closely spaced. Parallel transmission are used for these signals. A typical digital modulation scheme like QPSK, 16QAM is used to modulate each subcarrier having a symbol rate that is low. Nevertheless, the blend of various subcarriers permits data rates that are close to a typical single carrier modulation schemes confined in the particular bandwidths. Frequency Division Multiplexing (FDM) is the parent for the development of OFDM. The various streams of data are generalized against the frequency channels that are parallel but separate. A frequency guard band separates every FDM channel. The interference between the neighboring channels is thereby reduced to a minimum contributing to energy efficiency.

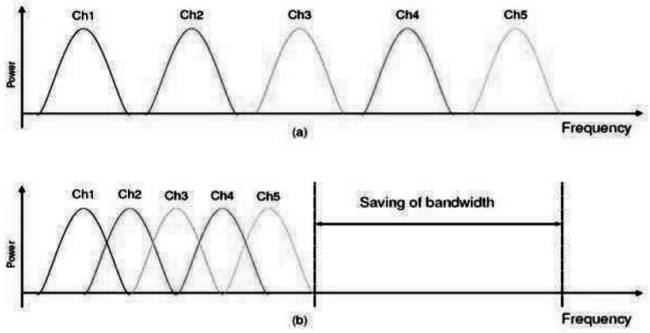

Figure 3: Illustration of bandwidth consumption between OFDM and Conventional FDM

The OFDM technique is distinguishable from the typical FDM technique as follows:

1. The data streams which contain the information are carried in many carriers called subcarriers.
2. Every subcarrier must be orthogonal to every other subcarrier.
3. In order to reduce Inter-symbol Interference and Delay-spread, a guard band is used between every symbol.

More subcarriers per bandwidth is allowed by the use of orthogonal sub carriers. A boost in spectral efficiency and energy efficiency can be seen as a consequence of this. Interference due to overlapping of symbols is inhibited in an ideal OFDM signal. However, adjacent signal overlapping in the spectrum causes interference for FDM schemes. In the case of OFDM systems, a depletion of orthogonality is the only way the subcarriers interfere with each other. For instance, subcarrier

frequencies shift such that the nulls in the spectrum would not be aligned and result in inter subcarrier interference when there in an error in the frequency.

Merits of OFDM:

- By incorporating overlapping techniques it allows an efficient use of spectrum.
- OFDM systems have more immunity to frequency selective fading than mono carrier systems.
- Uses cyclic prefix thereby completely eliminates ISI and IFI.
- Contributes to energy efficiency by controlling noises that are parasitic and impulsive and co-channel interference.

Demerits of OFDM:

- Immense peak to average power ratio amplifiers are required to eliminate noise like amplitudes.
- It is noticeably responsive to offsets in carrier frequency and drifts mainly because of the DFT leakage.

C. Design Optimization for the Cross Layer

Multiple layers optimization can be achieved by using cross layered optimization. This is a cumulative result of layered optimizations. A one-for-all centralized design for viable applications is provided by single layer optimization but it results in poor power efficiency. Reduction in energy consumption is the main specialty of cross layer design. In the main protocol stack, every part has an interrelation with every other layer. A significant enhancement of energy efficiency due to transmission which is adaptive can be observed in cross-layer strategies. In MIMO and OFDM transmission systems, it is noticeable to see that the cross-layered design strategies contribute to the energy consumption reduction.

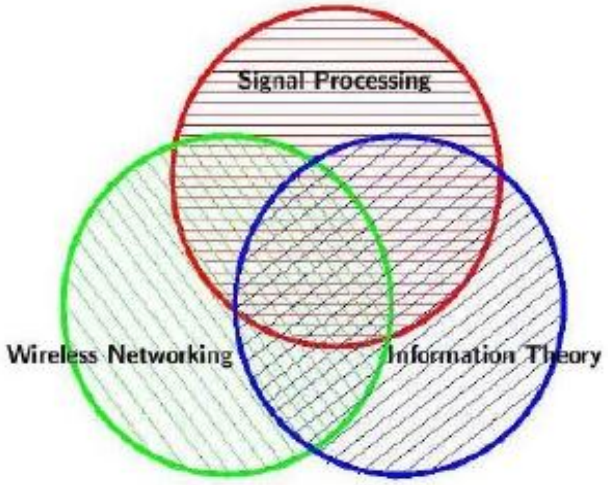

Figure 4: Cross Layer Design

Cross-layers have the following advantages:

- Highly efficient, low cost, large scale networks are possible.
- Life cycle of the system is lengthened.
- Power efficiency is drastically improved.
- System degradation and destruction can be prevented.
- Multiple functionality and applications, thereby supporting node versatility.

IV. Radio Resource Management for Energy Efficiency

Reduction in energy consumption can be achieved by using certain effective ways, one of them is the use of energy efficient radio resource management. Let us now discuss about energy reduction for low-traffic loads and by analyzing the Quality of Service (QoS) requirements and exploiting them.

A. Low Traffic Loads and Energy Reduction

Due to high expectation of the users' QoS requirements, most of the networks concentrate on high- peak load to meet those expectations. Studies have found out that traffic loads at base stations vary over time and space. When the traffic is low, a huge amount of energy is wasted. Operators and merchants have taken action about these problems. To minimize the repeated base station mode switching a minimum holding time over a defined range is preferred. Companies are coming up with new software features which can highly reduce the power consumed by base stations up to 27%. Projects have been proposed to provide solutions to save energy through cell-size breathing and sleep modes. Energy could be saved by turning off active cells when their traffic is low by saving 25-30% of the energy using ideal power-saving plans in a specific design. To minimize the transmit energy specifications scaling energy needs with traffic is considered to be one of the efficient way. Energy can also be saved by expanding the bandwidth at low traffic loads. Various radio resource management strategies including the power-aware link adaptation, exploitation of multi-user diversity and trading of bandwidth for energy efficiency are combined with the schemes of mimo techniques to reduce energy and also meet the needs of QOS target. Radio resource management scheme plays a very important role in saving energy at the base station [5].

B. Service Differentiation

The first problem to provide service differentiation is at the distributed wireless MAC layer. When providing this differentiation, a support from the MAC which differs the layers on their degree of separation is needed. Just by providing service differentiation at the radio interface is not enough to predict individual traffic types. The trade-off between consumption of energy and delay on the internet has been widely considered. Little has been done in the early systems for cellular networks because only a few service types were available. As the technology is growing, cellular networks is evolving and launching diverse applications for the people to learn and communicate. Applications like video conferencing, live seminars, live interviews and live games require a fast real time service; on the other hand, real time service may not be needed and can be delayed for applications, such as email, and downloading files for offline processing. So we need to differentiate the different types of traffic so that it will be useful in scaling the consumption of energy. To reduce the energy consumption in cellular networks, researches have exploited the service latency of applications.

V. Conclusion

Two primary points from the discussion are a significant amount of energy can be reduced by the traffic loads at the base stations that differ in time and space and adaptive load resources and a significant amount of energy can be reduced by exploiting the wide variety of QoS necessities. We have extensively examined certain energy-efficient wireless communications from the point of view of Information and Communication Technology. Research on increasing the energy efficiency is being done exhaustively even today. Circuit energy consumption can also be considered in practical scenarios which is of great importance for a wireless system design. This paper also gives information about the current energy efficient design techniques like OFDM, MIMO and also talks about energy efficient MAC Design and Radio Resource Management.

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