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THE REGULATORY FRAMEWORK FOR GREEN WI-FI: ANALYSIS AND DEVELOPMENT FOR ADAPTIVE NETWORKS

The article provides an analysis of standards which encourage the reduction of energy consumption within the Green Wireless concept. Basically, standards specification ignores the dynamic properties of the subscribers. However, the discussed standards offer the possibility to modify these parameters using the methods of adaptation as a natural reaction to the environment. Furthermore, static and dynamic scenarios as well as their limitations are briefly examined. In this paper, the methods of adaptation and control of the parameters of the access points that cover the principles of adaptation are discussed in order to highlight the advantages and disadvantages of each method and to better understand how the parameters affect the results.

Keywords: *Wireless Network Standards, Green Wi-Fi, Adaptive Wireless Network.*

Introduction

The climatic changes that have been occurring during the last decades and have led to irreversible changes in ecosystems gave impetus to the research for safer and more environmentally friendly, green energy resources as well as technologies designed to mitigate the effects of global warming. Given this information and the fact that technology is using more than 2% of the global energy consumption, there is a need to improve the efficiency of such technologies so as to increase their popularity and accessibility [1]. Wireless service providers have reported that up to 80% of their CO2 emissions result from network operation that emitted microwaves.

Furthermore, several studies in the field of health, published by the public organization «Health Protection Agency» [2], suggest that the extended exposure to microwave radiation may cause symptoms such as headaches, eyestrain, fatigue, depression or even sleep disorders. Despite the use of wireless networking technologies which are comparative to low-power electromagnetic signals, it is necessary to take into account the fact that, unlike television systems, microwave ovens, etc., wireless network in devices such as laptops, table computers, PDAs, etc. are in close proximity to humans for a long period of time. With regard to this, the Parliamentary Assembly of the Council of Europe (PACE) published a document [3] regarding WI-FI and mobile phones aiming to focus on «the risks of potentially harmful long-term biological effects on the environment and on human health, especially "targeting children, teenagers and young people of reproductive age». The document notes that the use of wireless networks can lead to serious economic losses due to their systemic effects on human health.

These factors are strongly motivating to reduce electromagnetic radiation from transmitters' wireless networks, as well as reduce the time of exposure. This is the basis for the development of green technologies or concepts of Green Computing in wireless network by adapting the parameters of accepted equipment, especially access points (APs), which would reduce the proportion of excess radiation and establish a well-distributed, but not concentrated radio signal.

Nowadays, there is one international green standard, ISO 14001:2004 which is required for prevention of pollution and for the reduction of emissions or discharge of any type of pollutant.

Some approaches to the development of adaptive wireless local area networks (WLAN) were studied in [4]. The analysis found that in a series of standards for WLAN - IEEE 802.11x a large number of parameters was identified [5] which can be dynamically modified under certain operating conditions, considering the concept of Green Computing, namely the power of transmission, the frequency range, the radius of coverage of wireless network station (STA), the number of active APs, the fragmentation threshold, etc.

1. The regulatory framework. WLAN Standards

The IEEE 802.11 standard defines that the organization of a wireless communication on a limited area within 100 m in the local network mode, provided for multiple users who have equal access to common data channel, may compare with the Ethernet network standards.

This standard specifies the order of organization WLAN on the media access control level (MAC-level) and physical layer. It defines one type of MAC and three types of physical channels.

Moreover, the IEEE 802.11 standard specifies authentication in order to verify the access right of a station (STA), and provide channel encryption to protect the channel and bring it closer to the Ethernet cable.

The physical layer has two types of wireless channels.

The basic idea of the 802.11 standard is cellular architecture. Wireless network may have one or several STA cells. Each STA is controlled by a basic station called access point (AP). The AP and STA situated within the effective zone, allowing users to have access to the network. At the multicellular WLAN, APs can cooperate with each other through a distributed system, which represents the idea of main segment of cable networks. Basic infrastructures that include the APs and distributed system form an extended service area. Simultaneously, the standard specifies a single cell WLAN, which can work in Ad-hock mode without the AP, meaning that the basic part of its functionality is performed by the STA.

There are several families of the IEEE 802.11 standards.

IEEE 802.11 – basic initial standard which specifies the main idea of WLAN.

IEEE 802.11a – specifies wireless data transmission with a throughput up to 54 Mbps in the frequencies of 5 GHz;

IEEE 802.11b – has additional specification for adding frequencies of 2,4 GHz wireless channels with a throughput up to 11 Mbps.

IEEE 802.11d – defines the requirements of physical channel i.e. requirements of transmitter power and frequency ranges, aligned to the requirements of different countries.

IEEE 802.11e – defines the Quality of Service (QoS). This standard organizes traffic prioritization which depends on the type of transmission data, such as web application, multimedia traffic (e.g. audio-, video-stream etc.) and so on.

IEEE 802.11F – Inter-Access Point Protocol defines interaction between APs. This standard determines the roaming mode and interaction between APs when the STAs are changing the location from one network segment to another. It specifies the interaction order between equal APs.

IEEE 802.11g – defines additional device-properties for modulation frequencies of 2.4 GHz. It is intended to provide throughput up to 54 Mbps.

IEEE 802.11h – specifies additions to meet the European Union requirements to wireless band. These additions may change the transceiver power.

IEEE 802.11i – (WPA2) defines the security for wireless networks. It implements a range of protective functions in exchange of information, through a wireless network - in particular, the technology of AES (Advanced Encryption Standard) for encryption algorithm supports key lengths of 128, 192 and 256 bits, under the provision that it is compatible with all applicable 802.11i-networks. It affects the protocol 802.1X, TKIP and AES;

IEEE 802.11j – designed specifically for Japan and expands 802.11a with additional channel 4.9 GHz.

IEEE 802.11n – high throughput, defines a throughput up to 300-600 Mbps by adding multiple-input multiple-output (MIMO). It increases a channel width from 20 up to 40 MHz to the physical layer, reduces the overhead of transferring large data (similar to Jumbo in Gigabit Ethernet) and adds the frame aggregation to the MAC layer.

IEEE 802.11p – defines access to wireless network from vehicles.

IEEE 802.11r – specifies universal interactions to accept a roaming STA from one network coverage in the coverage area of the other.

IEEE 802.11s – Mesh Wireless Network. It specifies the physical and MAC layers of simple mesh wireless network. APs are forming a resilient network. The cellular architecture network potentially provides high coverage, with the AP assumed to connect both vie cable and vie the wireless interface.

IEEE 802.11 u – identifies solutions for wireless interactions with external networks.

IEEE 802.11v – defines the functions of networks management for wireless network.

IEEE 802.11w – design for the protection of management frames.

2. Green part IEEE 802.11x

2.1. IEEE 802.11: Power Save Mode

When an STA is in power saving mode, it is required to wake up and contend for the channel when it receives traffic-indicator-map beacon frames. In this condition, its energy consumption involves all issues of an active-mode STA, plus two additional factors: the first refers to the time needed for an STA to successfully access the channel and retrieve all down-link packets and the second refers to the way in which the STA should determine the length of each listening interval.

Regarding the first parameter, when many down-link packets must be sent to more than one STA in power saving mode, the AP should make the packet service sequence to minimize the total energy consumed by all STAs by scheduling downlink packets at the AP to minimize the contentions and energy consumption of STAs.

In the second factor, an STA with a longer listening interval can stay in the doze state longer and conserve energy. However, a longer listening interval introduces packet delays, creating a trade-off between energy consumption and delays. Seeing as packet delays depend on packet arrivals, solutions usually have to consider cross-layer effects and the characteristics of packet arrivals, such as TCP and web accesses.

IEEE 802.11n suggests a power saving multi-poll scheme which avoids contentions in PS-Poll procedures and improves the energy efficiency of STAs. The scheme may also be extended to support the QoS of an STA and minimize its power consumption. The AP could consider different QoS requirements (delay constraints and bandwidth constraints) and schedule the packet transmission of STAs using this multi-polling mechanism, improving energy efficiency.

2.2. IEEE 802.11e: Quality of Service

IEEE 802.11e suggests two mechanisms for the automatic power-saving delivery it means, the scheduled automatic power-saving delivery and unscheduled automatic power-saving delivery. In the first case, the service period (SP) is used so that an STA exchanges data packets with the AP due to the periodic waking up of the STA, receives and sends packets with the minimal contentions. In the unscheduled automatic power-saving delivery, the STA sends an up-link frame which encourages an unscheduled SP to exchange the packets with the AP, meaning it saves more STA energy.

An AP sends a traffic-indicator-map frame allowing the STAs to receive queued packets, provided the traffic-indicator-map frame contends the channel. This makes WLAN contention very serious as many STAs send PS-Poll frames to the AP at the same time, meaning that the WLAN resources are wasted and the STAs consume extra energy. To avoid this, the IEEE 802.11n defines the power save multi-poll scheme, where the APs consider different QoS requirements (delay and bandwidth constraints) and schedule the packet transmission of STAs. Therefore, the STAs can wake up and receive packets based on the AP schedule, improving both energy efficiency of power saving mode STAs and WLAN utilization.

Wi-Fi peer-to-peer helps Wi-Fi devices to connect with each other without a WLAN infrastructure. Wi-Fi peer-to-peer leads to significant power save and notice of absence functions, through P2P Group Owner. For the power save, if all P2P Clients are in doze mode, the Group Owner can go to sleep. For the notice of absence, P2P Clients are informed that the P2P Group Owner is absent for a period. The P2P Clients could also perform the power saving mode and unscheduled automatic power-saving delivery procedures to conserve their energy.

3. Adaptation

3.1. Principles of adaptation in WLAN in the context of green computing

WLAN performance in changing conditions, such as the exact number of STA, their location and movements as well as the properties used by the STA equipment, is difficult to predict and can change dynamically. In this scenario, a static definition in the design of the WLAN parameters may not always be optimal, resulting in reduced capacity, inefficient use of power supplies and unreasonable "pollution" of the environment with ultrahigh and microwave electromagnetic radiation. Therefore, the current dynamic is changing the WLAN parameters in real time, which will adapt the work of wireless networks and network devices to the current operating conditions. The basic principle of adaptation in the WLAN is to consider the dynamically changing properties of the operating conditions (the current number of STA, their distance from the AP, the concentration of STA, the intensity of information exchange, the interference level, etc.) and to modify the parameters of wireless devices (power and direction of the radiation used, frequency range, the parameters of data link layer, etc.) in order to optimize the properties of functioning (performance, reliability, level of electromagnetic radiation).

3.2. Model adaptation and control of AP

Depending on the type of WLAN, a model of local adaptation can be used [4] considering the cooperation between the AP and the STA as well as the model of system adaptation, which, apart from local cooperation, includes a centralized cooperation between the APs in the WLAN. Under any circumstances, the adaptation will consist of a stage of WLAN appraisal parameters such as the analysis of the transmission media, the number of STA etc., the stage of analysis of results appraisals and the calculation of the optimal parameters for current state which, if necessary, will be modified these parameters. The modification of the adaptation parameters is possible either on the STA side or on the side of the AP. However, today there is a large number of diverse STAs network devices running on different operating systems, available from various manufacturers, making the WLAN development impractical. Therefore, attention should be focused on developing models of local and system adaptation for wireless APs.

3.3 System adaptation

System adaptations can be used in WLAN development, having a basis of mesh wireless network, WLAN topology with internal roaming or WLAN with extended coverage zone by APs which work as repeater. Otherwise stated, the original topology of these networks includes ensuring coverage by a certain number of active APs that cooperates either with the STA or with other APs. In this case, for each of the APs it is necessary to make a decision to change the parameters, not only on the basis of their own data cooperation with STA, but also based on the information of neighboring APs.

3.4 Hierarchy of scenarios for wireless adaptation

According to the location of the STAs and APs, the basic concept of WLAN can be formulated as STAs are seeking for an AP. In other words, WLAN availability, as well as the QoS, depends on the location of the STA. Research shows that this is not always the optimal concept, so another concept was found. An AP is seeking for STAs. According to these concepts, there are passive and active APs correspondingly. However, both concepts can be used in local and system adaptation which were described above. For the local concept of adaptation, the parameters that can be used are fragmentation threshold and frequency range. Apart from the above mentioned parameters, according to the system adaptation, it is also possible to change the maximal number of STAs, coverage radius of APs and other parameters.

Thus, based on the time factor, all scenarios are divided into static and dynamic scenarios. The static scenarios are originally based on the idea of a static location of STAs and APs static location; therefore it refers to local adaptation. On the other hand, the dynamic scenarios are taking into account the random traffic of STAs as well as mobile APs and focusing of beam antennas, according to the concept of APs seeking for STA. In order to better describe these scenarios, spotting problems such as optimal location of APs within both, passive and active APs has to be dealt with. Moreover, for active APs it is necessary to determine the shortest path for the optimal location of APs, optimal direction of beam antennas and location of STAs. As seen from fig. 1, the basic functional limitation for designing such an adaptive WLAN is that the modern AP is either completely unsupported by such functions or it is supported only by hardware.

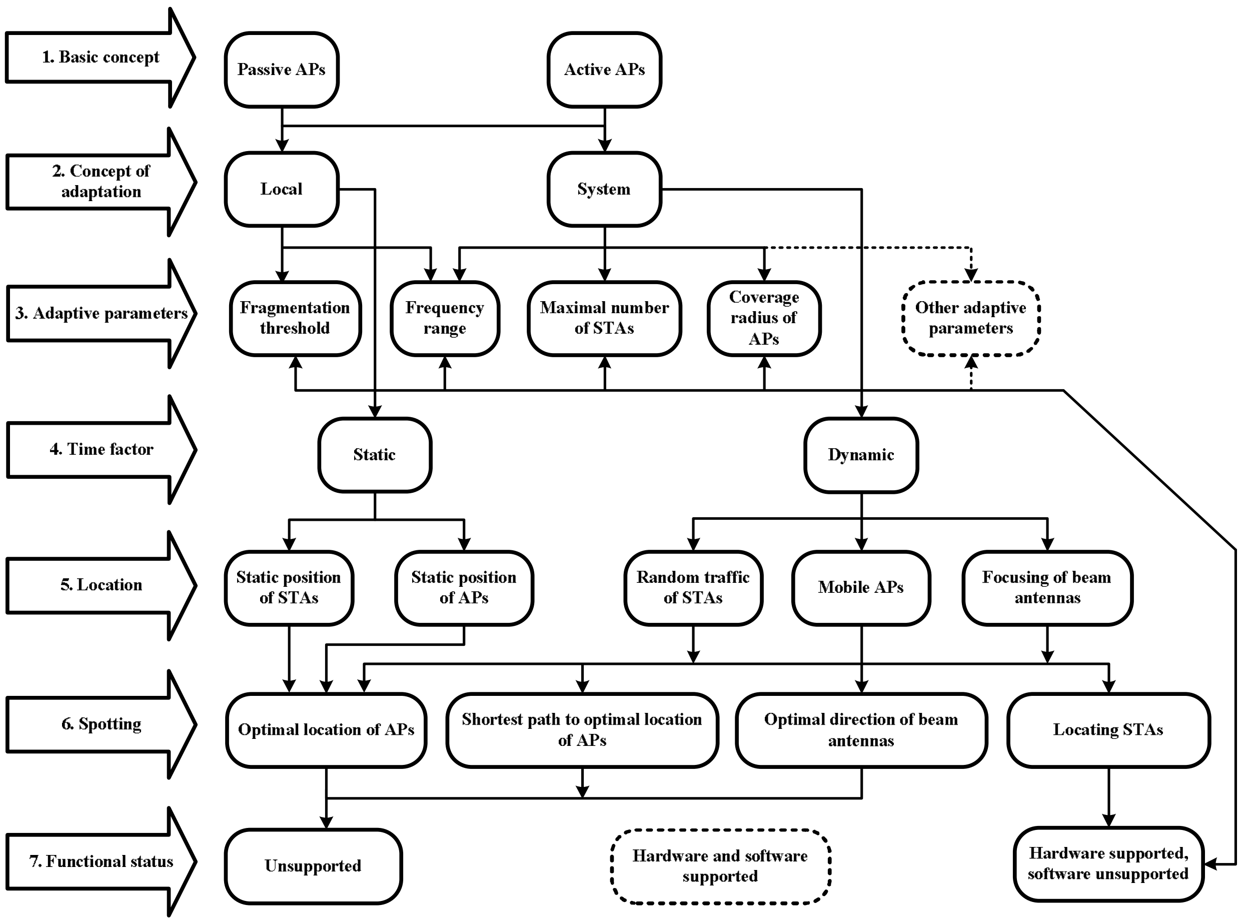

Fig. 1. Scenarios for Wireless Adaptation

Conclusion

There are a number of standards that defines of the Green Wireless concept, as well as some of the environmental requirements for wireless networks.

The dynamic adaptation of APs parameters allows the improvement of the performance and readiness of WLAN [4], the reduction of the power of the transceiver, and as a result, the reduction of energy consumption and electromagnetic pollution.

Further work is required to direct the development and the study of mathematical models and methods of centralized and decentralized management of APs of WLAN, including the aspect of reliability. Moreover, in the scope of improving the adaptive WLAN, the issues of providing the required level of security should certainly be included.

Therefore, it is essential to conduct research on the complex issues of creating adaptive and dependable wireless networks. On the basis of these issues, the information technology, the design and reengineering of WLAN can be developed, given the specific features of the concept of Green Computing. Such information technology can be of paramount importance due to the high-growth communications services and the increase in coverage zone of wireless networks in order to achieve the development of more environmentally friendly and energy-efficient WLANs.

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НОРМАТИВНА БАЗА ДЛЯ GREEN WI-FI: АНАЛІЗ ТА РОЗВИТОК ДЛЯ АДАПТИВНИХ МЕРЕЖ

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У статті наводиться аналіз стандартів, які регламентують зниження енергоспоживання в рамках концепції Green Wireless. Але, такі стандарти часто ігнорують динамічні властивості абонентів. Тим не менш, ці стандарти дають можливість змінювати параметри, використовуючи методи адаптації, як природну реакцію на навколишнє середовище. Розглянуті задачі статики та динаміки, а також обмеження пов'язані з ними. Так само в цій роботі визначаються методи адаптації та управління параметрами точок доступу, що підкреслює переваги та недоліки кожного методу, крім того дає можливість краще зрозуміти влив параметрів на результати.

Ключові слова: стандарти бездротових мереж, екологічні Wi-Fi, адаптивні бездротові мережі.

НОРМАТИВНАЯ БАЗА ДЛЯ GREEN WI-FI: АНАЛИЗ И РАЗВИТИЕ ДЛЯ АДАПТИВНЫХ СЕТЕЙ

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В статье приводится анализ стандартов, которые регламентируют снижение энергопотребления в рамках концепции Green Wireless. Однако, такие стандарты зачастую игнорируют динамические свойства абонентов. Тем не менее, эти стандарты дают возможность менять параметры, используя методы адаптации, как естественную реакцию на окружающую среду. Рассмотрены задачи статики и динамики, а так же ограничения связанные с ними. Так же в данной работе определяются методы адаптации и управления параметрами точек доступа, что подчеркивает преимущества и недостатки каждого метода, а также дает возможность лучше понять влияние параметров на результаты.

Ключевые слова: стандарты беспроводных сетей, экологические Wi-Fi, адаптивные беспроводные сети.

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