SON Mechanism for Green Heterogeneous Cellular Networks

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Abstract. Alternative energies are a good option to face the growing demand of energy consumption in the present and future telecommunications systems, particularly in the next generation cellular systems, where a significant increase in the number of nodes is expected. Although, there are still major challenges related to optimization of consumption in scenarios without grid connection, as well as the joint optimization of the radio resource and energy utilization.

A flexible architecture that allows to minimize the total energy consumption of the system is required, both for network design and power management, subject to variability of the alternative energy sources and operating restrictions of the cellular network, such as mobility parameters, coverage zone, load balancing and quality of service.

In this way, this project aims to propose a methodology for cellular phone network design in places without grid connection and a SON (Self Organized Networks) mechanism to dynamically control an energy-efficient system that includes renewable energy to power Heterogeneous Networks (HetNets), while optimizing the available radio resources.

Keywords: Energy efficiency · HetNets · SON · Green communications · Renewable energies · Optimal control

1 Introduction

The Green IT New Industry Shockwave published by Gartner [1] shows that the field of Information Technology and Communication (ICT) accounts for 2% of the CO_2 footprint. Similarly, within this field, mobile communications networks consume about 0.5% of global energy supply [2]. Therefore, the development of strategies to mitigate the environmental impact and improve energy consumption in future cellular networks is a field of research that is becoming paramount.

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Among several strategies studied by manufacturers and academia to improve the energy efficiency in cellular networks, there are some related to the optimization of the consumption in network components or techniques to switch on-off different nodes [3, 4, 5, 6], but is not common to find an approach from the viewpoint of the energetic processes, i.e. on-place energy availability is an issue, even more relevant for isolated nodes [7].

In this way, a recent research topic is the integration of renewable energy (RE), such as wind and solar in places without connection to power grid. This opens research issues providing an important opportunity for both green cellular networks and facilitates the integration of REs in the infrastructure of the country [8, 9].

Similarly, another important research field is Self-Organizing Networks (SON) technology [10], which is able to minimize human intervention in the design and management of networking processes, counting now with architectures proposed for implementation in future cellular systems.

Therefore, this paper presents an overview of the doctoral project in Energy Systems whose main research goal is to propose a dynamic control algorithm and a methodology for network layout that provides energy efficient management in HetNets through a power system based in alternative energies, supported in a SON layer that adapts itself to improve the consumption to the current RE availability and to optimize the power radiated in areas without grid connection.

This paper is structured as follows: Section 2 presents the research problem, Section 3 describes the methodology approach. In Section 4, the foreseen impacts are presented, and finally the expected contribution and some conclusions are presented in Section 5.

2 Research Problem

Heterogeneous Networks or HetNets, are composed by coexisting macrocells and low power nodes (LPNs) such as picocells, femtocells, and relay nodes with the target of establishing a flexible architecture and respond to the growing traffic demand [11].

The deployment of a large number of LPNs carries on the ever increasing energy consumption in wireless networks, consumption that is today almost exclusively provided by the fossil originated or grid electricity, hindering the service in places without connection to the grid. In this context, the concept of Green Power Technology appears in the mobile industry, traditionally referring to a renewable energy source used to generate and supply power to a mobile base station site [12].

The implementation of renewable energy sources in cellular networks has several challenges. Some of them come from the unavailability of grid connection in many places plus the variability of the sun and wind energy. To solve these problems, control strategies are needed to balance both, energy sources consumption and management of the service, that is: accepting or transferring user connections from node to node, or reducing coverage area by sector or by emitted power. The implementation of the above mentioned control management strategies could also cause reduction in electromagnetic emissions and at the same time energy saving. Besides the need to

modify dynamically the coverage area of the cell, structures a new and challenging research area.

In this sense, SON which is able to minimize human intervention in networking processes, combined with a dynamic optimization scheme to implement energy management control policies, offers a new perspective that has not been proposed yet in Green Cellular Networks research.

Thus, it is necessary to define a mechanism that combines the existing definition of SON with a dynamic optimization control system, such that it will be possible to perform an energy aware management of the network with a flexible and scalable scheme. To make this happen, the algorithms that optimize the operation of the alternative power supply and the communication protocols that coordinate the access to the network with the energy handling systems must be defined.

According to the above, we state that it is possible to generate a strategy that reduces the rate of global energy consumption in Heterogeneous Networks, by the implementation of an intelligent management system supported on alternative energy supply and by the implementation of a SON scheme that optimizes the use of radio resources that fulfills the requirements for quality of the service and properly manages the radiated power.

3 Research Objective and Methodology Approach

The objective of the project is to propose a dynamic control algorithm and a methodology for network layout that provides energy efficient management in HetNets through a power system based in alternative energies, supported in a SON layer that dynamically optimizes the radio resource utilization (coverages areas) and traffic management. In this sense, we propose an incremental methodology composed by the next steps:

1. Definition of an analytical model of alternative energy on-place availability and radio base consumption behavior: First step will be the Integration of the propagation model with the radio base consumption model [13] and the definition of the RE power availability based on geographical location of the base stations.
2. Static Optimization of the Network layout: Once the consumption model is defined, network layout could be defined by optimizing base stations location according to the availability of RE resource. This optimization is called “Static” in this work, because, quantity and location of base stations are defined prior to actual implementation of the cellular phone network.
3. Propose of a dynamic optimization mechanism: To optimize the utilization of green energy is necessary to formulate a model of the demand and consumption of energy by the different cells. This model should include the different parameters that affect the behavior of alternative energy sources, like traffic behavior, radio resources variation and weather forecasting to include them as constraints in the optimization process.

   The implementation of a SON based energy management system, will be used to optimize the consumption. This implementation will use renewable energy

sources according to its available power prediction through meteorological data and the power requested due to users of the area. This optimization is called "Dynamic" in this work, because a dynamic non-linear optimization will be performed by a controller each time step on each base station according to the technique described in [14].

4. Validation of the proposed architecture: Using weather forecast and traffic behavior data, simulation campaigns will be executed to test the proposed management optimization policies.

4 Foreseen Impact

The first impact of the project will be the formulation of an analytic model of energy consumption in heterogeneous networks including aspects related to quality of service and, from it, the implementation of a SON based energy management system to optimize the consumption using renewable energy sources.

In this way, the research project proposes to improve the energy efficiency and the reduction of CO_2 emissions with the design of a renewable energy system for cellular base stations. This will provide the opportunity to obtain greener communications and to integrate the renewable energy in the existing infrastructure at the same time.

Another important impact resulting of the Static optimization stage, will be a methodology for network design in places without grid connection.

According to the above, the main impact of this research will be to incorporate alternatives energies as a supplementary power source to traditional schemes and supporting the intelligence of the solution in an SON scheme, this way reducing the environmental impact of these technologies and guaranteeing the quality of service on isolated areas.

5 Conclusions

The use of alternative energy in telecommunication systems has been considered for decades, but there are still challenges to be overcome before its proper implementation in current systems. Within the fields of research that exist today, it is the development of control systems to establish load balancing between alternative energy sources and quality of service in places without grid connection.

One of the main current research topics is related to smart control systems, because the complexity of the new network architecture, the growing number of nodes and the presence of important variables as the traffic load, mobility and the radiated power, make optimization processes very complex, requiring therefore algorithms that are able to incorporate all these elements and generate feasible operation solutions.

For the proper application of renewable energy to HetNets, it is necessary to combine the strategy of supply with mechanisms to automatically organize the power levels that radiate each base station, to thereby minimize consumption fulfilling with the services requirements. Finally, is important say that one innovation factor of the doctoral proposal is the new approach to improve energy efficiency in HetNets.

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