The 7th International Conference on Sustainable Energy Information Technology (SEIT 2017)

Technical Economic Analysis of Photovoltaic Systems in Heterogeneous Mobile Networks

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Abstract

Mobile telecommunications operators are having to deal with an unprecedented increase in energy consumption due to the installation of heterogeneous mobile networks (HetNets), which are based on the deployment of macrocells and simultaneous use of large numbers of small cells. Although it has an efficient energy strategy, HetNets leads to a considerable increase in the consumption of energy, owing to its densification, because the importance of Backhaul is often overlooked. The use of renewable sources of energy is suggested as a means of overcoming this problem, since it entails diversifying the energy matrix and reducing the volume of CO₂ emissions in the environment, as well as being economically viable. Thus, the aim of this study is to make a techno-economic assessment of the acquisition and installation of photovoltaic systems within HetNets, while taking account of the combined energy consumption of radio networks, fronthaul and backhaul. On the basis of the results, there was clear evidence of its financial viability with regard to the adoption of the photovoltaic framework, as well as the environmental sustainability ensured by a considerable reduction in CO₂ emissions.

Keywords: Heterogeneous Mobile Networks, Grid-connected Photovoltaic System, CAPEX, Renewable Energy

1. Introduction

Currently, the ICT represents 0.5% of global energy consumption. Moreover, it is expected that this rate will increase as the result of the growing densification of heterogeneous mobile networks (HetNets). This context has caused a good deal of concern to the mobile network operators who foresee that improving energy efficiency not only requires environmental responsibility but will also involve financial factors since a significant proportion of the operating expenses can be attributed to the cost of electric power.

Several alternative means of overcoming this problem have been explored in the literature, such as a reduction of energy consumption in the front/backhaul links, the shutdown of redundant Base Stations (BSs) in periods of

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10.1016/j.procs.2017.05.346
low traffic, the allocation of resources for the optimization of energy efficiency and the design of architectures for HetNets. However, none of these alternatives focuses on the explicit reduction of CO₂ emissions by using renewable and clean sources.

Owing to constant concerns over the environment, a promising alternative has been to diversify the energy matrix by incorporating renewable types of energy sources, in particular photovoltaic systems. This is because it is economically viable to make substantial reductions in CO₂ emissions and depending on a number of variable factors, it is able to meet the energy needs of a particular geographical region and be adapted to different meteorological conditions.

Some countries like Germany, a world leader in terms of photovoltaic capacity, have invested heavily in sources of renewable energy as an alternative supply of energy. About 32% of this country’s energy is renewable and largely consists of photovoltaic systems even though its sunniest region has a rate of solar irradiance that is 40% below the least sunny region in Brazil.

A number of different research studies have investigated the question of energy efficiency within HetNets but despite this, as far as we are aware, none of them has analyzed the viability of investing in the photovoltaic equipment needed to generate energy for the mobile networks infrastructure and its transport layer. To this end, this work presents analytical models that cover the technical-economic planning, acquisition and implantation of photovoltaic systems in HetNets. Moreover, it is analyzed the feasibility of establishing renewable energy sources (photovoltaic systems within HetNets) as alternative infrastructure for huge mobile network systems.

The rest of this work is structured as follows. In Section 2, we discuss the questions of HetNets, photovoltaic energy systems and Capital Expenditure (CAPEX). The design of photovoltaic systems is investigated in Section 3, and the results are analyzed in Section 4. Finally, Section 5 summarizes the conclusions.

2. Heterogeneous mobile networks, the Photovoltaic system and CAPEX

2.1. Heterogeneous mobile network design

This work makes use of the heterogeneous mobile network designs set out by Fiorani et al., in which the authors examine several of the deployment alternatives for the radio sector and transport layer of the network, to estimate the costs incurred by the installation of photovoltaic systems in the scenario of heterogeneous mobile networks. In this work, two types of base stations (BS) are used: macro and small cells, where indoor users can be served by both macro and small internal BSs, whereas outdoor users are only served by macro BSs.

In this scenario, there are two strategies for the installation of small cells. The first is based on the concept of indoor Distributed Radio Architecture (DRA), which is a form of installation executed by network operators employing engineering techniques. The second uses Femto cells, that are characterized by the disordered use of small BS’s, which are generally installed at random by the end-users of the heterogeneous mobile networks.

Architectures based on DRA, can be distinguished both with regard to their framework and the technologies applied in the network transport layer. In the Macro+DRA-CF (DRA Curb Fronthaul Architecture), as shown in Fig. 1 (a), the Remote Radio Units (RRU) were installed in street booths that were able to communicate with more than one building. The RRUs are interconnected with a microdatacenter (Hotel DU) located in the central office, by means of fiber optics using the protocols of the radio-over-fiber (RoF) system. However, in the Macro+DRA-BF (DRA Building Fronthaul Architecture), as shown in Fig. 1 (b), the RRUs are hosted inside each building, and each RRU is directly linked to an Optical Network Unit (ONU). The ONUs interconnect the buildings to a central office through a Dense Wavelength Division Multiplexer (DWDM) – a Passive Optical Network (PON) infrastructure – and to the Optical Line Terminal (OLT), which in turn is connected to the DU Hotel.

In a similar way to the DRA-based projects, Fiorani et al. includes the use of two projects based on femto cells, one based on mature technologies, which employ Very-high speed Digital Subscriber Line (VDSL), Digital Subscriber Line Access Multiplexer (DSLAM) and Carrier Ethernet Switch transmission protocols, referenced as Macro+Femto-CB (Femto-Based Curb Backhaul), as shown in Fig. 1 (c). The other project is based on Next-Generation Passive Optical Network 2 (NG-PON2) technologies, consisting of ONUs and OLTs, referenced as Macro+Femto-BB (Femto-Based Building Backhaul), as shown in Fig. 1 (d).
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