Energy 115 (2016) 711–721

Contents lists available at ScienceDirect

Energy

journal homepage: www.elsevier.com/locate/energy

Energy savings through self-backhauling for future heterogeneous networks

Nasir Faruk [a, b, *], Kalle Ruttik [a], Edward Mutafungwa [a], Riku Jäntti [a]

[a] Department of Communications and Networking, Aalto University, Espoo 02150, Finland
[b] Department of Telecommunication Science, University of Ilorin, P.M.B 1515, Nigeria

ARTICLE INFO

Article history:
Received 4 March 2016
Received in revised form
21 August 2016
Accepted 7 September 2016

Keywords:
Base station powering
Self-backhauling
Small cells
Energy saving
Heterogeneous networks

ABSTRACT

Mobile operators face continuous challenge of enhancing network capacity and coverage so as to meet demand for ubiquitous high-speed mobile data connectivity. Unfortunately, these enhancements are typically accompanied by increased burden of network energy consumption. Heterogeneous network (HetNet) deployments of a large number of low power small base stations (SBS) to complement existing macro base stations is an approach that increases network capacity but potentially reduces overall network energy consumption. The SBS backhaul links in HetNets present a significant powering burden. In this paper, we show how self backhauling of SBS can reduce overall network power demand. A backhaul-energy consumption model is developed and used to investigate the energy efficiency of different backhauling options. We note that significant energy savings could be achieved through the use of self-backhauling when compared with the conventional microwave backhauling. The results presented would provide guidelines for energy- and cost-efficient backhaul implementation for future HetNets.

1. Introduction

The world's power consumption by Information Communication Technology (ICT) systems and devices grew from 2% in 2007 to about 10% in 2013 [1]. Large share of this growth is due to the power consumption of mobile networks. The networks demand for power is continuing its increase as the global mobile data traffic is expected to grow at a compound annual growth rate (CAGR) of 57% from 2014 to 2019 [2]. Mobile Network Operators (MNOs) worldwide have been facing vast increase of mobile data traffic volumes driven mostly by adoption of data-intensive devices, such as, smartphones and tablets. Moreover, the users have to come expect availability high quality mobile data connectivity regardless of their location. In an increasingly liberalized market, this has obliged the mobile operators to implement continuous network capacity and coverage enhancements, so as to, meet user expectations, sustain consumer loyalty and remain competitive. However, most approaches for increasing network capacity and filling coverage gaps are typically accompanied by increased energy consumption primarily due to increase in number of Base Station (BS) sites. Such growth renders traditional network energy provision solutions quickly unsustainable. Currently in industrialized countries the mobile network energy consumption accounts for about 15% of the total network operation expenses [3]. The situation is even more challenging in developing economies with limited or unreliable access to power from the grid. In these regions, there were 320,100 off grid and 701,000 unreliable (bad grid) BS sites in 2014 [4] and these are expected to reach 389,600 and 791,000 (i.e. about 1.2 million sites) in 2020 representing 22% and 13% increase (see Fig. 1). This obliges the MNO relying on diesel generators serving as both prime and standby power source to the cell towers, these large number of remote off grid base station sites means that the energy cost could exceed 50% of the total network operation expenses [3].

The aforementioned challenges have motivated plenty of research efforts towards characterizing and reducing power consumption of mobile networks [6–9]. Notably, most of the studies have focused on minimizing power consumption in the Radio Access Network (RAN) and specifically the base stations. Interestingly, the strategy of scaling network capacity by heterogeneous network (HetNet) deployment of a large number of low power small base stations (SBS) to complement existing macro base stations (MBS) umbrella coverage (see Fig. 2) is an approach that also has the potential to minimize overall network energy consumption [10]. In

* Corresponding author.
E-mail address: faruk.n@unilorin.edu.ng (N. Faruk).

http://dx.doi.org/10.1016/j.energy.2016.09.059
0360-5442/

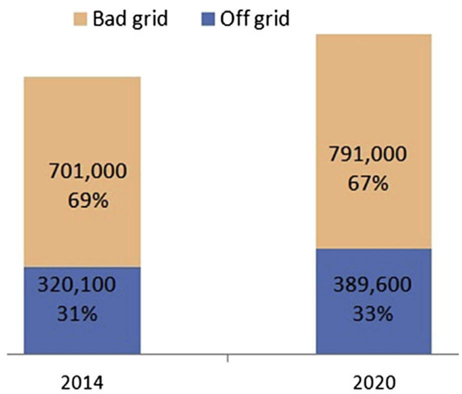

Fig. 1. Global off grid and bad grid BS sites: *data source GSMA*[5].

HetNets, the need for rolling out more high power MBS to meet capacity demands is replaced with deploying a larger number of low-power micro, femto and/or pico cells (collectively referred to as small cells or small base stations (SBS)). Such an approach is particularly attractive for remote sites or under-served areas where high power MBS are generally powered by diesel generators, whereas, low power SBS could potentially be operated sustainably off-grid with renewable energy sources [11]. The relatively low power needs of SBS are attributed to the fact that they have a smaller target coverage area (less radio transmit power) and can frequently be in powered-down (sleep mode) state. However, while energy-efficient operation is possible in the small cell radio access, there is always a need for powering in the high-capacity backhaul connection between SBS and the mobile core network. Currently, SBS backhauling is mostly implemented using point-to-point (PtP) or point-to-multipoint (PtMP) microwave radio links, due to unavailability of cabling and prohibitive cost of using a wired backhaul link towards each SBS [12]. For PtP backhauling, the total share of the power consumption is around 3% (see Fig. 4), this exceeds 13% of total share for the PtMP backhauling. The need for powering of the SBS backhaul links would in turn increase the energy consumption of the SBS sites beyond what could be supported with low-cost renewable energy solutions. It is worth noting the recent efforts of [13–16] that investigated the effect of backhaul power consumption and it was established that this cannot be neglected as it affects the total power of a HetNet. The upsurge in data traffic will require very large number of SBS deployments which would in turn require more backhauling. The increased SBS deployment density will almost certainly be accompanied by increased overall energy consumption mostly attributed to the SBS backhauling. Therefore, it is paramount to have a comprehensive and holistic approach towards achieving green backhauling for the deployment of HetNets in a way that is more energy-efficient and sustainable compared to traditional homogeneous macro network deployments.

This work proposes an energy-efficient backhaul solution for next generation wireless systems. The conventional microwave backhaul solution is compared in terms of energy efficiency to the proposed self-backhauling for typical dense HetNet environment. A heterogeneous network backhaul-energy model is proposed and used to investigate the energy efficiency of conventional microwave backhaul and self-backhaul systems. The comparison is presented with break-even point where one system is favorable to other. The analysis allows us to propose “safe operation regions” for optimum utilization of self-backhaul deployment. Furthermore, power system recommendations for mobile communication networks and power grid network benefits of the proposed approach are highlighted.

2. Heterogeneous network and base stations sites power consumption

The HetNet deployment environment is characterized by a mix of cellular base stations of different size (form factor) and coverage footprint as shown in Fig. 2. The diversity of technologies encompasses base stations that may be referred to as: macro, micro, pico or femto base stations. In this paper, we refer micro, pico or femto base stations as small base stations (SBS). In some literature, these small base stations are commonly referred to as small cells (SC). Therefore small cells (SC) may be used interchangeably where necessary.

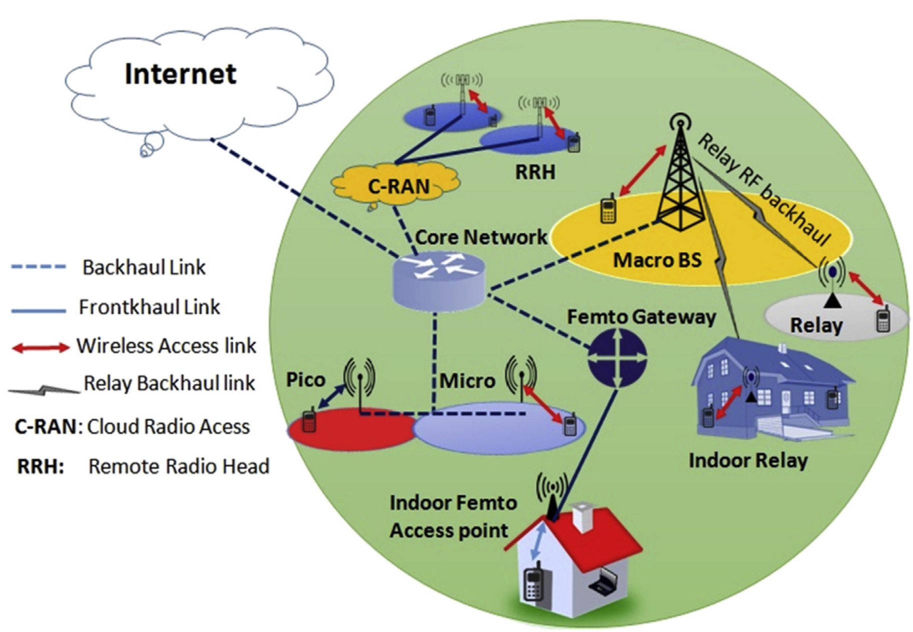

Fig. 2. Heterogeneous network.