

## A Review of Green Backhaul Solutions for 5G

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### ABSTRACT

*Energy efficiency and reduction of CO<sub>2</sub> emission (green) are one of the most promising but challenging features of the future Fifth Generation (5G) network is expected to exhibit. At the moment, the telecommunication networks are responsible for 2% (which has been forecasted to increase to 4% by 2020) of global CO<sub>2</sub> emission. Also, the energy consumption is expected to increase as there is expected to be more mobile users and traffic. This gave rise to Green research which is expected to deliver telecommunication network solutions with efficient energy consumption and low CO<sub>2</sub> emission. Recent researches reveal that green backhaul solution for 5G will significantly impact the overall energy consumption and CO<sub>2</sub> emission of 5G networks. Therefore, in this paper, we have discussed the evolution of mobile backhaul, existing green backhaul solutions and the future challenges of mobile backhaul.*

**Keywords:** Backhaul, CO<sub>2</sub> emission, Energy Efficiency, Green communication, 5G.

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### 1. INTRODUCTION

Climate change and energy crisis are undoubtedly two significant problems associated with the present age. Global warming as a result of Greenhouse emissions, such as CO<sub>2</sub> and methane has catastrophic effect on humans, other living entities and the planet. This if not addressed could be aggravated. The effort to reduce the effect has given birth to several research areas focusing on how each contributing factor (example Information Communication Technology, ICT) can be amended for better environment (Routray, 2016).

The development and integration of new technologies has been on drastic increase as ICT plays significant roles in human's life by allowing social and business interaction on a local and global scale. According to International Telecommunication Union (ITU) internet users have increased from 1.99 billion in 2010 to 3.39 billion in 2016 with the mobile broadband being the most dynamic market ("Green ICT Technologies: how they can help mitigate the effects of Climate Change," 2015). In addition, new architectures and technologies such as machine-to-machine communications, smart grid, automotive, smart cities, smart homes and devices contribute an extra degree of complexity and demand to the network design. The increment in ICT penetration rate is accompanied by massive growth of the number of user devices, wireless, indoor, transport, core and data centre networks and services, raising significant cost and sustainability concerns (Morgado, Huq, Mumtaz, & Rodriguez, 2017).

This menace resulted in both academia and industry attracted to work on efficient energy usage in wireless networks. Research efforts have led to various solutions that allow efficient use of energy in wireless networks. Such approaches are referred to as green wireless communication and networking (Gandotra, Jha, & Jain, 2017).

Green wireless communication has thus made green feature an important part of future fifth generation (5G) network (Gandotra et al., 2017). This requires 5G to be energy efficient compared to the previous generation networks. Heterogenous network concept has been tipped as promising solution to the expected drastic increase in energy consumption of 5G by 2020 as a result of exponential traffic growth. However, this in turn is likely to increase the backhaul energy consumption which is not desirable considering the environmental impact of the increment. Thus, it is important to have 5G backhaul solutions with low power consumption and high energy efficiency, green 5G backhaul (Tombaz et al., 2014). Therefore, this paper will focus on evolution of backhaul technologies, review existing backhaul solutions and give future research directions in green backhauling for 5G and beyond

## 2. BACKHAUL EVOLUTION

According to (Rony, Jain, Lopez-Aguilera, Garcia-Villegas, & Demirkol, 2017), backhaul (BH) was traditionally the link connecting Base Stations (BSs)/Evolved-NodeB (eNBs) (performing RAN processing) to the core network. Links connecting one BS/eNB to another BS/eNB are also considered as BH. Also, in the centralized approach, i.e. Centralized RAN (CRAN), BH is the link connecting Baseband Unit (BBU) and the core network. Additionally, in 5G networks, BH will carry large amount of traffic to/from the core network where both Distributed (RAN processing is distributed to BSs) RAN (DRAN), and CRAN co-exist. Backhaul in 5G is expected to have low latency and low power consumption. Different technologies have been considered for 5G backhaul to be able to meet the requirements. Each of these technologies have their advantages and disadvantages.

In terms of capacity, latency and QoS, optical fibre as wireline backhaul is the preferred technology. It however has shortcomings of less scalability and high deployment cost. Passive Optical Network (PON) technology for fibre has been evolving throughout the years, improving the performance of fibre-based solutions.

Besides, copper base wired backhaul with Asymmetric Digital Subscriber Line (ADSL), Very high-speed Digital Subscriber Line (VDSL) and G.Fast technologies also provide promising wireline backhaul solutions with high link capacity, yet again not suitable for many use cases of access points.

On the other hand, higher frequency wireless options provide larger link capacity, but they are very vulnerable to environmental effects. For instance, mmWave operating in three different bands, 60 GHz (V-band), 70/80 GHz and 90 GHz (E-band > 60 GHz) has recently begun to appear as attractive option for future wireless backhaul and access network technology, as it offers very large capacity (up to 10Gbps) compared to other wireless options. Moreover, advanced technologies, such as spatial multiplexing and beamforming can improve the overall performance of mmWave.

Besides mmWave, already popular wireless options, such as Free Space Optical (FSO), Sub-6GHz, traditional microwave (Point-to-Point (PtP), Point-to-multi-Point (PtMP)), can also be considered as wireless backhaul options for 5G according to their availability and particular requirements.

However, most of the wireless backhaul technologies require Line-of-Sight (LoS) propagation for reaching the expected performance. Figure 1 illustrates different backhaul solutions.

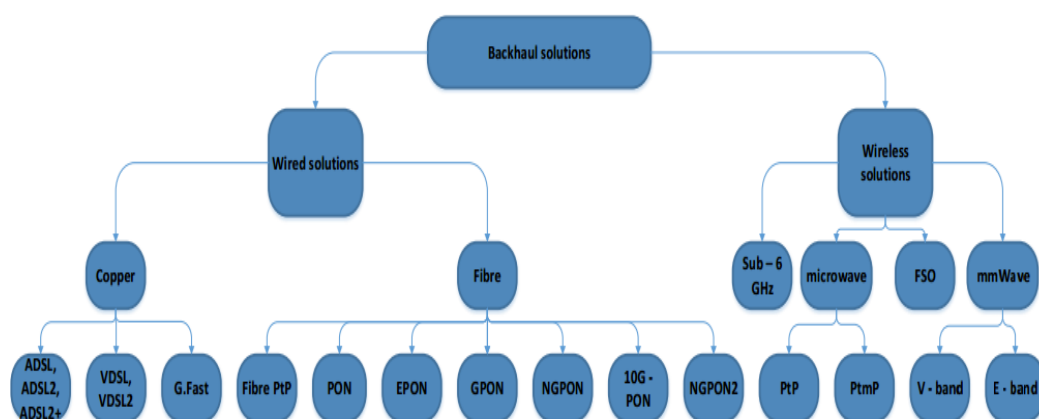


Fig 1: Distinct Backhaul solutions (Rony et al., 2017)

## 3. EXISTING GREEN BACKHAUL SOLUTIONS

(Lebedev et al., 2013) proposed and experimentally demonstrated a hybrid of fixed-wireless transmission system. This was a combination of fibre and 60 GHz wireless technology to provide Gigabit picocell wireless backhaul links fully integrated in a metro/access fibre network. They argued that the deployment of the 60 GHz links for fibre-supported picocell wireless backhaul is beneficial in terms of the link budget, the installation time and the capacity availability for the unlicensed use. Their set up is as shown in Figure 2.

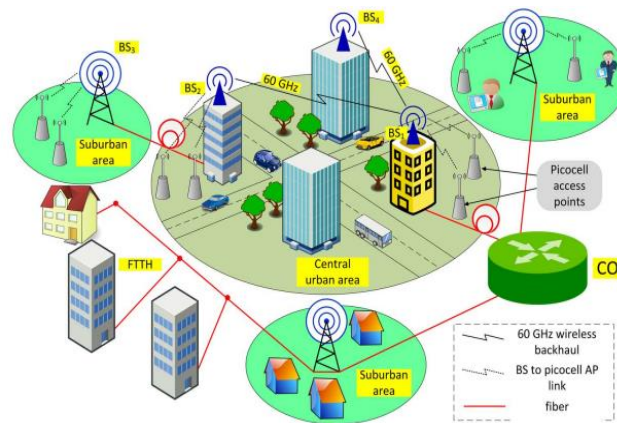


**Figure 2: Network scenario for the 60 GHz urban picocell mobile backhaul link fully supported with a diverse fiber infrastructure. (Lebedev et al., 2013)**

Key- CO: central office, BS: base station, FTTH: fiber to the home. BS1 and BS2 operate on the 60 GHz frequency, BS3 is suggested to operate in the lower frequency licensed bandwidth.

(Tombaz et al., 2014) assessed the impact of backhaul on the overall energy consumption of the cellular networks using different data traffic requirements from 2014 to 2020. They proposed three (3) backhaul architectures using three (3) different technologies (copper, fibre and microwave). Two (2) of the proposed architectures are hybrid thereby making use of two technologies simultaneously. Fibre-to-the-node (FTTN) using VDSL2, Microwave Only and Fibre-to-the-Building (FTTB) + Microwave are their three (3) architectural implementations. Their result showed that backhaul can be responsible for up to 50% of the power consumption on the network. The hybrid backhaul made up of Fibre-to-the-Building (FTTB) option and microwave links had better performance compared to the other architecture.

(Dehos, González, Domenico, Ktéas, & Dussopt, 2014) worked on green backhaul based on millimetre-wave, mmWave frequencies (57–66, 71–76, and 81–86 GHz) for 5G heterogeneous network. Their result made them conclude that mmWave is a strong candidate for 5G backhaul in terms of energy efficiency. The preferred backhaul configuration was a combination of low-latency high capacity connections based on fibre with non-line-of-sight (NLOS) microwave links and mmWave wireless links that operate in line-of-sight (LOS) conditions with peak capacity of 10–25 Gb/s.

(Suarez, Bouraoui, Mertah, Morvan, & Nuaymi, 2015) studied energy efficiency of backhaul in heterogeneous network. They proposed two (2) hybrid backhaul architectures: Fibre-To-The-Building (FTTB) + 10Gbps Passive Optical Network (10GPON) technologies and FTTB + microwave. Their analyses were based on Area Power Consumption [W/km<sup>2</sup>]. Their result showed that the two proposed architectures had better performance than the conventional backhaul in terms of Area Power Consumption [W/km<sup>2</sup>].

(Niu et al., 2017) formulated the problem of minimizing the energy consumption via concurrent transmission scheduling and power control into a mixed integer nonlinear program (MINLP) which produced an energy-efficient and practical mmWave backhauling scheme. They carried out simulation using different traffic patterns and system parameters. They demonstrated their scheme had better energy efficiency performance using the optimised mmWave backhaul. The performance metrics used were Energy consumption, Network Throughput, Energy Efficiency, Energy Ratio and Throughput Ratio.

(Mowla, Ahmad, Habibi, & Viet Phung, 2017) presented energy-efficient communication model for 5G heterogeneous networks (HetNets). They considered both access and backhaul. They investigated power consumption of various backhaul designs, then proposed two backhaul solutions. Wired passive optical network (PON) and wireless millimeter wave (mmWave). The performance evaluation was done through simulation using Network Simulator 2 (NS-2). They showed how to connect passive optical network units/terminals with 5G access units to reduce the overall power consumption in the first solution. The second solution integrated mmWave backhaul units with 5G SCN units to reduce power consumption. Backhaul power consumption in Watt and Backhaul Energy Efficiency Mbps/ Watt were the performance metrics used. The result revealed that their solution can save up to 48% power consumption.

In (Alsharif, Nordin, Abdullah, & Kelechi, 2018), among the key 5G technologies discussed are massive multiple-input multiple-output, green heterogeneous networks, green millimetre wave, green 5G device-to-device communication, green machine-to-machine communication, and energy-efficient 5G architecture.

#### 4. FUTURE DIRECTION FOR GREEN BACKHAUL SOLUTION

Green concept is an important concept in the 5G and future networks. Therefore, it is important to discuss achieving green backhaul in the future (Mowla et al., 2017).

mmWave and NG-PON2 has been identified to play major role in backhauling the emerging Ultra Dense Network. However, there are challenges identified with their implementation to achieve greater energy efficiency

#### 5. CONCLUSION

The concept of backhauling and how it has evolved over the mobile network generations has been discussed. Notable work in the field of green backhaul solutions were presented. Also, the future direction was highlighted for greener network in the future.

#### 6. ACKNOWLEDGMENTS

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Reference citation within the body of the paper is (Name, date) format, and should be listed in alphabetical order

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