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# Gigabit point to multipoint backhaul using Q-band

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**Abstract**—This paper defines a Q-band point to multipoint backhaul architecture including Q-band disruptive technology that provides multi-gigabit capacity in a cost-effective manner as proposed in the EU FP7 SARABAND project. The small-scale field-trial of the network platform providing Gigabit Ethernet communication is also described.

**Keywords**—*Millimetre-wave communication; wireless networks; backhaul; Q-band technology*

## I. INTRODUCTION

The availability of new services such as mobile video, OTT/multimedia messaging services, mobile cloud computing and the massive proliferation of mobile Apps is fundamentally changing the very fabric of mobile networks. This will lead to a massively dense and complex collection of radio access points in any given area, resulting in an exponential increase in capacity requirements. In such a scenario, the majority of operators have decided to deploy dense networks of low-power small cells located near to users, in order to supply sufficient capacity density and high-quality contiguous/ubiquitous coverage. Deploying large numbers of small cells helps solve the capacity problem for the radio access network, but adds novel challenges for small cell backhaul, of which the cost of backhaul is among the most important.

There are a number of backhaul solutions being proposed today for small cells. These range from low capacity solutions such as the sub-6 GHz non-line-of-sight (NLOS) technologies all the way up to the highly directional millimetre-wave (mm-wave) point to point (PTP) technologies in the 60 to 80 GHz bands. Such solutions have been used widely and successfully in macro cell backhaul. However, they present some limitations for the future small cell scenario in terms of capacity and/or cost requirements. Therefore, to achieve the low cost fundamental to small cell deployments, new technologies must be considered to enable a viable business case and here is where the EU FP7 SARABAND project can play a key role [1]. The SARABAND project proposes to join the advantages offered by millimeter wave technology in Q-band (40.5 – 43.5 GHz) with point to multipoint (PMP) architectures to provide the capacity, scalability and cost figures required for future small cell backhaul. On one hand, millimetre-wave (mm-wave) band, especially in the Q-band, is very promising for high data rate mobile applications because of its large amount of spectral bandwidth available suitable for wide channels. Actually, this band provides the bandwidth matching the current 100 Mbps per site and several Gbps/km<sup>2</sup> capacity demand and can be deployed in PMP architectures with the perfect range for small cell backhaul, i.e. up to 1-2.5 km from a base station. On the other hand, PMP architectures allow operators to keep the quantity of equipment low, reduce installation, alignment, rental, and maintenance costs as well as accelerating the time to market for the delivery of services and facilitating smooth network expansion. This results in a reduction of costs in terms of both CAPEX and OPEX (less equipment, reduction of site rental costs, inexpensive Q-band spectrum, etc.) and a “pay as you grow” business model. Actually, the analysis reported in [2] concluded that PMP provided the best return on investments (ROI) taking into account CAPEX and OPEX.

To supply the demanded requirements for the small cell backhaul, novel Q-band technology with better performances is required. To this end, SARABAND is focused on the development of new low-profile high-gain antennas, programmable multi-beam antennas and miniaturized radio front-end radios. These components will bring important benefits to end users (mobile network operators, service providers, etc) in terms of performance, cost reduction and compactness, what will directly have a positive effect on the total cost of ownership (TCO). Therefore, SARABAND, by producing solutions for better small cell developments, will have a strong impact on this market. Indeed, a recent report from ExelixisNet analyst confirms the potential of the Q-band as a solution for PMP backhaul, forecasting a dramatic 54% compounded annual growth rate (CAGR) revenues growth of the 42GHz band in the next 5-years [3].

This paper presents the network architecture as proposed in the SARABAND project and introduces the small-scale field-trial deployed inside the project to provide Gigabit Ethernet communications from a central site to several terminals, delivering a throughput of 120 Mbps to each terminal.

## II. SARABAND DEMONSTRATOR

### A. Network architecture

SARABAND architecture is a hierarchical, PMP Ethernet-based network composed of nodes linked by radio transmissions, and remotely managed by a backhaul network management system (NMS). The solution is architected as a distribution tree connecting a service provider's point of presence (PoP) to relay nodes and ultimately reaching: subscriber terminals, grouped terminals and mobile base stations. The main features of this solution are:

- It offers a highly flexible PMP network topology which can rapidly adapt to an operator's coverage and capacity requirements while simplifying radio deployment.
- The system uses a 1-GHz wide transmitter that can be loaded with 20 channels (nominally 40 MHz wide) in a manner that a base station can be configured to use as little as 40 MHz or all 3 GHz (by using 3 transmitters fully loaded) to deliver up to 2.5 Gbps half-duplex per 1-GHz radio transmission.
- Layer 1 and 2 of this network are based on the 802.11n and then 802.11ac standard and aggregation on 802.3ad.

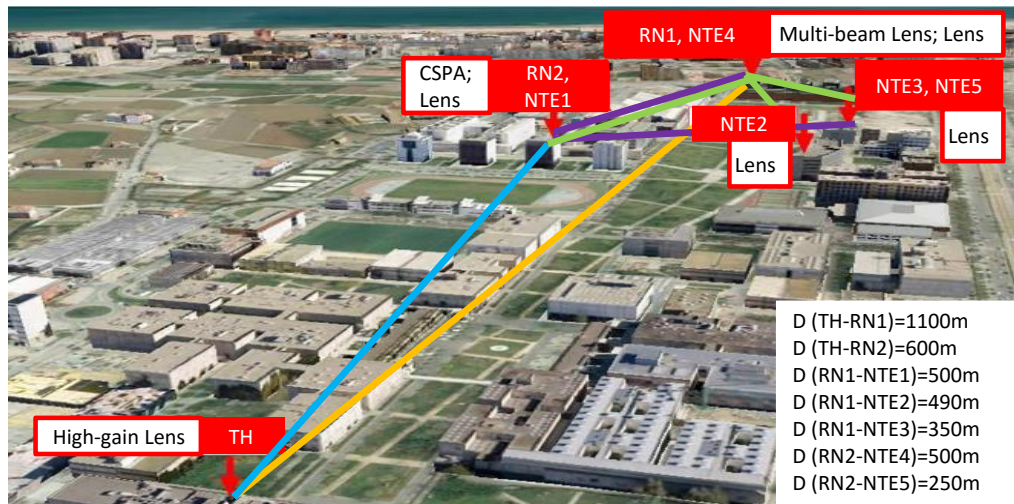
The traffic service is provided by VLAN connectivity (layer 2) between the backhaul interfaces to customers' PoP, i.e. traffic corresponding to each terminal is routed through a dedicated VLAN and another VLAN is dedicated to configuration and supervision of all the active network elements and transmitted over radio everywhere on the SARABAND network. The SARABAND architecture is composed of network nodes with high-gain and multi-beam antennas to enable any configuration of hierarchical PMP structure, and radios with high bandwidth and a high degree of integration to meet performance, cost-efficiency and acceptability. In particular, the SARABAND project has developed the following technology [4-5]:

- **Q-band low-profile high-gain antenna** based on an innovative lens design with a sub-wavelength (sub- $\lambda$ ) structure, which allows the lens efficiency to be improved, obtaining high gain (i.e.  $> 35\text{dBi}$ ) in a low-profile design. With this antenna, the system can reach distances over 2Km and can provide Gigabit capacity.
- **Low-cost electronic steerable antenna** based on the Circular Switched Parasitic Array (CSPA) principle to enhance coverage, reduce interference and save energy. Such an antenna gives moderate gain ( $< 16\text{dBi}$ ) and either large ( $270^\circ$ ) or limited field of view ( $180^\circ$ ) in the horizontal plane. Additionally, **multi-beam lens antenna** with a passive distributor component to form up to 5 beams with 20-dB gain to cover an angular coverage of  $\pm 30^\circ$  has been developed.
- One of the more challenging issue faced by SARABAND has been to successfully **miniaturize the front-end radio modules**. Thanks to the use of System in Package (SIP) integration and GaAs-based MMIC chip-sets developed by Bluwan compact and low-cost terminals have been obtained.

### B. Small-scale Field-trial

The antennas and radio frequency modules developed in SARABAND will be integrated in a wireless network platform deployed at the UPVLC campus, where specific smart-antenna and radio functionalities will be tested in the system platform and further evaluated in the small-scale field trial. This demonstrator, based on the backhaul architecture explained before, will provide Gigabit Ethernet communications from a central site to 5 terminals ( $T_i$ ) through a millimeter-wave network, as shown in Fig. 1.

The total capacity of the network will be of 600 Mbps, delivering a throughput of 120 Mbps to each terminal in an adaptive (upload/download) half-duplex mode. Ftp files will be loaded and the latency and throughputs in download and upload mode will be tested on the PC located at the terminals. This demonstrator will therefore prove relayed backhaul PMP performances of IP over Ethernet as well as the following capabilities: a) 120Mbps throughput to each terminal; b) the efficiency of the antennas, which provide high SNR for maximum capacity (64QAM); c) the multi-beam principle on one relay; the resiliency principle on the second relay, d) the frequency reuse on a dense deployment; and e) low latency on the modems and radio ( $\sim 2\text{ms}$ ).



**Fig. 1. SARABAND field trial architecture: Transmission Hub (TH); Relay Node (RN); Network Terminal Equipment (NTE)**

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