Vilar Mateo, R.; Martí Sendra, J.; Ramírez, A.; Bou, J.; Magne, F. (2015). Q-band Point to Multipoint Backhaul Deployment: the SARABAND Case Study. En 2015 European Conference on Networks and Communications (EuCNC). Institute of Electrical and Electronics Engineers (IEEE). 788-789.

Q-band Point to Multipoint Backhaul Deployment: the SARABAND Case Study

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***Abstract*—This paper describes the small scale field trial deployed within the SARABAND project to provide final network performances comparable to fibre optics in a cost-effective manner for the 4G small cell backhaul. The performances of the system have been measured, obtaining over 100 Mbps peak capacity and frame error rates compliant with operators' requirements.**

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

I. INTRODUCTION

The arrival of smart phones, mobile cloud computing, video streaming and other bandwidth-intensive multimedia services has triggered a huge demand for bandwidth in operators' networks. Mobile operators are responding to this demand with 4G Long Term Evolution (LTE) networks, enabling richer applications and faster connectivity, and the deployment of dense networks of low-power small cells located near to users, in order to supply sufficient capacity density and high-quality contiguous/ubiquitous coverage. In such a scenario, operators will be forced to increase backhaul capacity since most of these cells will require 100 Megabits per second or more to deliver the promised superfast mobile broadband. The biggest challenge will thus be to provide this capacity with scalable and cost-effective backhaul.

Millimetre wave technology fits nicely into these new backhaul scenarios as it provides extended bandwidth for high capacity links and adaptive throughput rate, which allows efficient and flexible deployment. In particular, the Q-band band (40.5 – 43.5 GHz) is very promising for high data rate backhaul applications because of its wide frequency spectrum (3 GHz), the compactness and lightness of the equipment and the ease of implementing interference-free system configurations. Actually, the SARABAND project proposes to joins together the millimeter wave technology in the Q-band and point to multipoint (PMP) architectures to provide the capacity, scalability and cost figures required for future small cell backhaul. [1].

However, the state-of-the-art Q-band technology on antennas and radios modules presents a series of technical challenges in terms of performances, cost efficiency and acceptability that needs to be resolved before its full deployment. For enabling efficient and high performance backhaul networks, the SARABAND project has developed disruptive millimetre wave technologies (high-gain antennas, multi-beam antennas and miniaturized radio front ends) to supply the demanded requirements for the small cell backhaul.

At the end of the project, all the technology developed in SARABAND has been integrated in a wireless network platform deployed at the campus of the *Universitat Politecnica de Valencia*, in Spain, where specific smart-antenna and radio functionalities have been tested in the system platform.

This paper presents the performances of the SARABAND system measured by using specific equipment designed to certify the stability of the links in a maximum capacity scenario, obtaining over 100 Mbps peak capacity in the higher modulations and dropped frame rate values below 10^{-6}.

II. SARABAND DEMONSTRATOR

A. Network architecture

The field trial is based on the backhaul architecture as proposed in the SARABAND project [2-3] and consists of the interconnection of 5 sites through millimeter-wave wireless links, in a point to multipoint architecture. As shown in Fig. 1, three types of nodes are employed in the SARABAND deployment: Transmission Hub (TH), Relay Nodes (RN) and Terminals (NTE).

The TH, in Site 1, is the central point of the deployment, where the capacity is distributed over the different sites covered by this PMP Sector. The Transmission Hub is composed of an Indoor Unit (IDU) dealing with the Baseband and Intermediate Frequency communications. The IDU accommodates up to 8 Intermediate Frequency modems, each of them capable of establishing a link of up to 125 Mbps over the millimeter-wave link. In the SARABAND field trial, the signal of 5 of those modems is transmitted through the coaxial cables towards the Outdoor Unit (ODU), responsible for the up and down-conversion of the Intermediate Frequency Channels to the 40 GHz band frequencies radiated by the antennas of this module. In this case, a high gain antenna fabricated in the project is employed to provide connectivity to two Relay Nodes (red links in Fig.1), which are used to extend the system range and to avoid the limitations of line of sight.

In Site 2, the millimeter-wave signal from Site 1 can be retrieved and retransmitted in Relay Node 1 (RN-1). For that, three of the radio channels emitted by the TH are down-converted, processed and again up-converted in an IDU to be transmitted to Terminals installed in Site 3, Site A and Site B through and innovative multi-beam lens antenna developed in SARABAND (blue links in Fig. 1). This antenna creates 3 narrow beams with high gain, each aiming at one terminal.

In Site 3 the Relay Node 2 is installed. In this case a full outdoor Network Terminal pointed towards the TH is employed to retrieve the millimeter-wave signal, downconvert it to intermediate frequency and demodulate it to provide the allocated capacity through a standard Gigabit Ethernet port. After that, a different Network Terminal is employed to provide coverage in the 40GHz band to terminal 4 and 5 (Site 2 and B), configured to share the capacity as if they were, for example, home subscribers of a Broadband Internet service.

In Site B, two of the 5 Terminals of the SARABAND deployment are installed. Terminal 3 is linked to Relay Node 1, while Terminal 5 is linked to Rely Node 2. Each of these terminals will receive a dedicated connection of up to 120 Mbps bandwidth.

Finally, in order to provide connectivity and monitor the deployed network, a dedicated optical fiber link, allowing Gigabit Ethernet, is employed between the SARABAND Network Operations Center in Site B and the TH in Site 1. At the Network Operations Center, real time and historical statistics can be obtained and the status of the different networks elements is monitored.

B. *Small scale Field trial Results*

As commented previously, a Network Operations Center has been prepared in order to be able to monitor the status of the network equipment in real time. In particular, a Network Monitoring System (NMS) software has been set up to obtain indicators of the performances of different network elements. In the event of a network failure or a degradation of the performances, the NMS generates alarms, allowing to make decisions based on that information. The NMS also keeps a database with the historical values of the key parameter indicators of the system. In SARABAND, the NMS continuously pulls information from the radio modems on which the wireless links rely. Bandwidth, dropped frame rate, received and transmitted signal strength are continuously monitored.

Additionally, the SARABAND system performances have been measured with specific equipment designed to certify the stability of the links in a maximum capacity scenario. After that certification, the system is continuously tested and monitored by using traffic generator software.

Table 1 summarizes the measured performance of the demonstrator. As shown, the system provides over 100 Mbps peak capacity in the higher modulations (64 QAM 2/3) and Frame Loss Rates compliant with tier 1 and tier 3 operators' requirements (i.e. value below 10^{-6}). Should be noted that we are currently optimizing the network to achieve 100 Mbps per terminal.

Moreover, it is worth mentioning that exploiting all the potential of the system (i.e. using 20 modems at the TH instead of utilizing only 5 as in the demonstrator) the system will provide the multi-gigabit capacity suitable for the small cell deployment. Additionally, we are also working to extend and enhance the performances of this system by using an additional frequency band at the millimeter wave spectrum over 90 GHz under the H2020 TWEETHER project.

ACKNOWLEDGMENT

The European Commission is gratefully acknowledged for funding the ICT-2011-288267 SARABAND project in the 7th Framework Programme and the H2020-644678 TWEETHER project.

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Table 1. SARABAND network performances

Link	Throughput	Frame Loss Rate
TH-RN1	120 Mbps	$1.1*10^{-6}$
TH-RN2	106 Mbps	$1.25*10^{-6}$
RN1-T1	72 Mbps	$<10^{-7}$
RN1-T2	72 Mbps	$<10^{-7}$
RN1-T3	72 Mbps	$<10^{-7}$
RN2-T4	54 Mbps	$<10^{-7}$
RN2-T5	52 Mbps	$<10^{-7}$

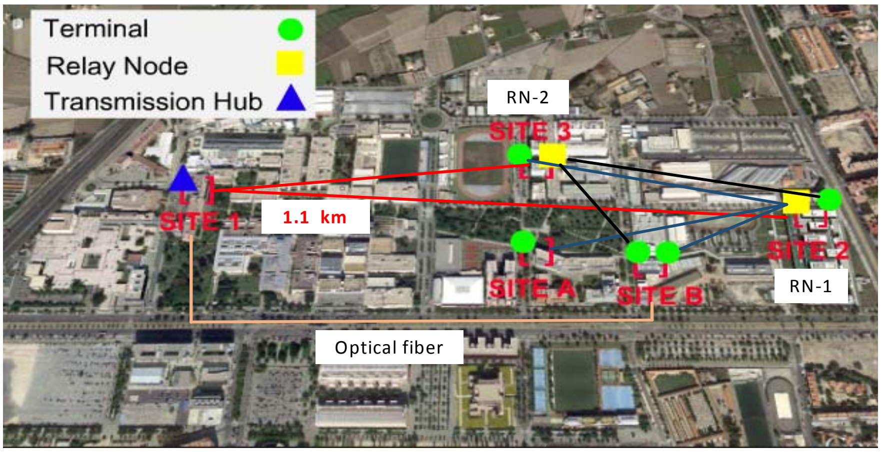

Fig. 1. SARABAND field trial architecture