Ultra Capacity Wireless Layer Beyond 100 GHz Based on Millimeter Wave Traveling Wave Tubes

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***Abstract*—The exploitation of the millimeter wave spectrum (100 – 300 GHz) for wireless communications needs a breakthrough in transmission power. Multigigabit per second data rate can be transported by the wide frequency bands available in the millimeter wave spectrum. The high atmosphere attenuation and the lack of solid state amplifiers with adequate power have so far prevented to achieve long transmission range. The new European Commission Horizon 2020 ULTRAWAVE, "Ultracapacity wireless layer beyond 100 GHz based on millimeter wave traveling wave tubes" is devoted to produce the millimeter wave technology for enabling a mesh of Point to multiPoint high capacity layers at D-band (141 – 148.5 GHz) connected by G-band Point to Point links (275 – 305 GHz) to the fiber access point.**

Keywords— wireless communications, backhaul, millimeter waves, traveling wave tube, point to multipoint

I. INTRODUCTION

The growth of the wireless traffic is impressive and unstoppable. Mobile traffic will reach the 20% of the total IP traffic and about 80% of the world traffic will be video by 2021 [1]. The new generation of smartphones and tablets needs high data rate networks to support the increasing use of real time high resolution videos. The actual networks are not able anymore to support this traffic demand. A great effort worldwide is devoted for defining new Internet distribution modality, with high capacity, energy and spectrum efficient. High density small cells architectures are the solutions to increase the throughput to user's terminal. However, the backhaul of dense networks is a challenge both for providing a suitable data rate to cells and for network layout. Data rate at level of tens of Gigabit per second per kilometer square (Gb/s/km^2) is needed in areas with high density of users, as high street, event venues, crowds. The fiber is available in many urban areas, but it has no flexibility and a new access point could need of permissions and expensive installation work. In a scenario where cells could have radius down to 50 m and be deployed with high density, the high number of base stations (BS) to backhaul would require a high number of fiber nodes, with very high cost. Wireless backhaul is, in principle, the most affordable and flexible solution, if multigigabit data rate at level of tens of Gb/s with architectures of easy deployment were available, as point to multipoint (PmP) distribution. Such a level of data rate can be supported only by multi-GHz wide frequency bands that are available above 100 GHz, excluding the E-band (71 – 86 GHz). In particular, three main bands, W-band (92 – 114.5 GHz), D-band (141 - 174.5 GHz) and the G-band (220 – 320 GHz) are investigated for enabling high capacity distribution. Transmitters and receivers with data rate at level of tens of Gb/s have been proved up to 400 GHz [2, 3]. The intrinsic high atmosphere attenuation at millimeter wave frequencies and the additional heavy losses due to rain have so far prevented the transmission over long links, especially in case of use of low gain antennas to cover wide areas. However, Point to Multipoint (PmP) distribution is demonstrated to be cost effective in comparison to Point to Point for backhaul, but the low gain antenna used to cover an area sector needs transmission power at Watt level presently not available at millimeter waves.

The European Commission Horizon 2020 ULTRAWAVE, "Ultracapacity wireless layer beyond 100 GHz based on millimeter wave traveling wave tubes" aims at a breakthrough in millimeter wave internet distribution by enabling a for the first time an ultracapacity layer with more than 100 Gb/s/km^2 area capacity [4].

The ULTRAWAVE Consortium includes eight partners in the field of millimeter wave technologies. Four universities, Lancaster University (UK), Goethe University of Frankfurt (Germany), University of Rome Tor Vergata (Italy), Universitat

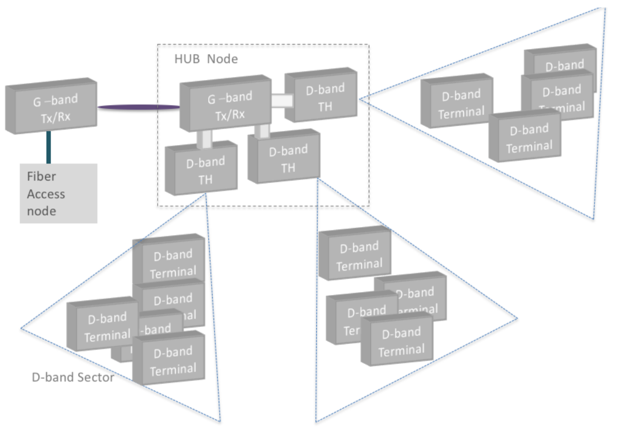

Fig. 1 Concept of Hub node with G-band Tranceiver and D-band transmission hubs. Terminals are arbitrarly distributed in the D-band area sectors.

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Politecnica de Valencia (Spain), one research institute, Ferdinand Braun Institute (Germany), three SMEs, OMMIC (France), HFSE (Germany) and Fibernova (Spain), with complementary expertise, will work for three years in the project.

The ultracapacity layer is conceived by deploying a number of sectors in Point to Multipoint (PmP) at D-band (7.5 GHz bandwidth) to distribute high capacity on areas of high demand. These sectors are connected by Point to Point G-band links (30 GHz bandwidth) in a mesh networks to a fiber access point. The challenges are to provide transmission power at D-band for PmP and to achieve G-band link length longer than 500 - 600 m to build a flexible network architecture. To note that advantage of the use high frequencies for the low foot print of equipment, beneficial for an easy deployment and low site renting [5]. The ULTRAWAVE high capacity layer will be the backbone for distributing Internet by intermediate layers, at lower frequency and data rate, to street level for backhaul of small cells base stations.

The bridge from the concept to the real high capacity layer is the availability of high transmission power. Both the D-band sectors generated by low gain antennas and the long links at G-band need transmission power at Watt level. The breakthrough of ULTRAWAVE is in the design and fabrication of novel high power traveling wave tubes to enabling long transmission distance for the ultracapacity layer.

II. ULTRAWAVE ULTRACAPACITY LAYER

The concept of the ULTRAWAVE architecture is shown in Fig. 1. Each Hub Node will consist of a G-band front end as fronthaul for a number of D-band transmission hubs in the same site. Each D-band transmission hub generates the coverage over an area sector. D-band terminals are arbitrarily distributed over the sector to feed intermediate layers, that in turn will backhaul small cells at street level.

To note that the G-band is more than 150 GHz higher than the D-band. This determines an increase of the total path loss of about 10 dB, even if the attenuation due to the rain is practically constant above 100 GHz. An important design parameter to consider is the decreasing of output power of amplifiers at the increase of the frequency.

The aim of ULTRAWAVE is to design, fabricate and test the full set of millimeter wave devices and system to enable the high capacity wireless architecture. The workflow of ULTRAWAVE is shown in Fig.2. Three main streams will produce the parts for the integration of the D-band and G-band front-ends to be deployed in the outdoor field test, at the end of the project.

The D-band (141 – 148.5 GHz) section consists of a transmission hub (TH) and a number of terminals. The radio is based on a D-band chipset in GaAs used in both the TH and terminals. The transmission hub is powered by a novel traveling wave tube, that will be described in the following section, to provide about 40 dBm output power.

The G-band (275 – 305 GHz) section includes a transmission hub based on a high data rate photonics transmitter powered by a traveling tube with more than 30 dBm output power over 30 GHz bandwidth.

III. MM-WAVE TRAVELING WAVE TUBES

The Traveling Wave Tube (TWT) is a device commonly used in telecommunications and satellites applications at microwave frequencies, to provide high power in the range of hundreds of Watt, not achievable by solid state devices. Recently, GaN amplifiers achieved up to 2 Watt at 100 GHz, but above this frequency the power drops substantially. The TWT working mechanism is based on the transfer of energy from an electron beam to a radiofrequency signal with phase velocity close to the velocity of the electrons. The high power is achieved because the electron beam travels in a high vacuum channel without collisions that limit the performance in solid state devices. TWTs up to 1 THz are reported in literature, based on lithography fabrication process [6]. TWTs at D-band and G-band will be designed and built by adopting slow wave structure of easy fabrication [7].

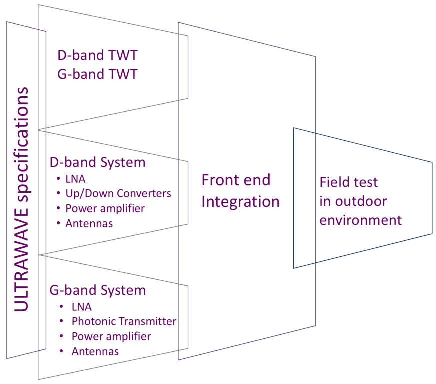

Fig. 2 ULTRAWAVE workflow

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