Scenarios and Use Cases in Tweether: W-band for Internet Everywhere

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Abstract—**Millimeter waves offer a promising solution to the data congestion that is fast overwhelming the actual network capacity. While the V- band (57-64GHz) and E-band (71-76GHz and 81-86 GHz) are widely targeted for Point to Point high data rate, the W-band (92-95GHz) is still unexploited and lightly regulated. In particular, Point to Multi-Point (PtMP) wireless backhaul architecture could benefit from 3 GHz frequency bandwidth at the W-band to achieve a capacity density up to 10 Gbps/km². The HORIZON 2020 TWEETHER project aims to solve the technological gap that presently prevents the use of W-band to distribute substantial capacity from a central point over a wide coverage surface. Moreover, each of the links of the PtMP TWEETHER system is conceived to provide a high level of flexibility in order to easily adapt to a large panel of deployment scenarios.**

Keywords—Millimetre-wave; Point to Multi-Point Wireless networks; 5G;small cells; Travelling Wave Tube (TWT), backhaul, capacity density.

I. Introduction

The future scenario of Internet distribution aims at high capacity everywhere. The new High Definition TV services, the huge demand for large image and video sharing by social networks, high definition video communications and many other data-hungry services will require a capacity so far not available. The microwave frequency range supports limited data rate. Therefore, the limitations of the actual mobile networks (using microwave spectrum) will become dramatic when those new services and applications will be widely available.

Moreover, in addition to the constraint of high capacity for each mobile access link, the peak of the user's density per square kilometer risks to increase due to the increase utilization of mobile terminals. By taking into consideration these factors, it becomes obvious that, in addition to a request for higher maximum capacity per mobile link, there will be a stringent demand for substantially higher capacity density (bits/km²) of the wireless mobile access networks.

Small cells are now considered to be essential to satisfy the constraint concerning high capacity density for the mobile access networks [1]. Moreover, 5G technology is seriously considering millimeter waves transmissions in order to achieve high peak capacity for each link of the mobile access network [2]. The spectrum taken into consideration for the 5G small cells access links are going as high as the Q band (39-43.5GHz).

If the small cells are vital for the 4G and 5G network deployment, the sensitive point of this technology is represented by the backhaul network of the small cells. There are two main constraints imposed to the small cells backhaul network: the capacity (up to 200 Mbps) that needs to be provided to each small cell and the Total Cost of Ownership (TCO) of each link of the backhaul network.

II. Small Cell Scenario

Given the constraint of the peak capacity per small cell, there are two candidate technologies for the small cells backhaul: optical fiber and millimeter wave wireless links.

The TCO of backhaul links using optical fiber technology excludes this candidate from the deployment scenarios where the optical fiber is not already deployed. This is due to the high level of OPEX (Operational Expenditures) that characterize the optical fiber deployment.

The wireless links are therefore considered the main candidates for small cell backhauling. Meanwhile, only by exploiting new portions of the spectrum with multi-GHz frequency coverage will enable the simultaneous provision of high capacity per backhaul link and multi-gigabit per square kilometer capacity density of the backhaul wireless network. The bands that allow multi-GHz frequency coverage for backhauling are the millimeter wave bands (V band, E band or W band).

Two radio network architectures have to be considered: Point to Point (PtP) and Point to Multi Point (PtMP). Wireless systems are already available, but limited to PtP links in the V band and E band (dedicated to PtP). This architecture is optimal to develop "pay as you grow" wireless networks.

Nevertheless, there are several drawbacks for this architecture to be chosen for small cells backhauling networks. The major one is the backhauling link TCO and more precisely the mast surface renting fee contribution to the backhauling link OPEX. If for the PtP architecture the OPEX is a major drawback, the PtMP architecture has the advantage of a significantly lower link OPEX. When comparing the TCO for the two types of link TCOs per link, the terminal TCO contribution to the link TCO can be considered identical while the hub TCO contribution is distributed between the different links that are using the same central hub [3].

Meanwhile, even though the PtMP architecture appears as being optimal for millimeter wave wireless networks, the availability of PtMP product segments is far from being achieved due to current technological limitations. The increasing attenuation at higher frequencies competes with the decrease of transmission power from the available solid-state devices. The 99.99% link availability constraint makes the technological requirements even more arduous under heavy rain condition. Even more serious is the lack of transmitted power for multi-point systems at the unexploited and lightly regulated W band.

III. TWEETHER PROJECT

The EU Horizon 2020 TWEETHER (Traveling wave tube based W-band wireless network with high data rate, distribution, spectrum and energy efficiency) project aims to set a milestone in the millimeter wave technology with the realization of the first W-band wireless system for distribution of high capacity everywhere [4].

In particular, the TWEETHER objective is to realize the millimeter wave PtMP segment to finally link fiber, and sub-6 GHz distribution for a full three segment hybrid network, that is the most cost-effective architecture to reach mobile or fixed final individual client.

A novel W-band technology with unique performances for boosting a wide adoption of W-band systems will be developed. A powerful and compact transmission hub will be based on a novel traveling wave tube power amplifier. This device, typically used at microwave frequency for wideband communications, will be designed and realized at W-band to provide performance precluded to any other technology.

In the following the three main aspects underpinning the TWEETHER project will be described, that is, the use of millimeter wave frequencies over 90 GHz, the proposed architecture based on a three segment hybrid network and the development of novel W-band technology.

A. *Millimetre wave frequencies*

The only region of the spectrum that can allocate frequency bands to complement and match the fibre capacity is at the millimetre wave domain. In particular, CEPT ECC in Europe and FCC in US have recently started investigations for potential applications such as point to multipoint communications and Internet broadband access between 92 and 95 GHz (and up to 96 GHz) since this frequency band offers some advantages such as the light licensing for PtMP, the atmospheric and rain attenuations comparable to the 35 GHz band (0.5 dB/km @ 94GHz vs. 0.3 dB/km @ 35GHz for relative humidity of 100% as shown in Fig. 1) and the compact equipment achievable at millimetre waves (a key point for easy and low cost installation and site leasing).

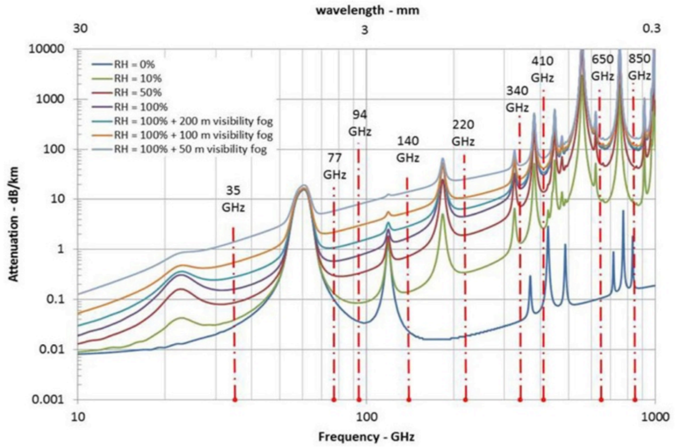

Fig. 1. Atmospheric attenuation curves under various levels of relative humidity (RH) and fog [5].

The TWEETHER project aims to exploit the W-band to provide a capacity up to 10 Gbps/km^2.

B. *Hybrid network architecture*

A strategy to develop a network architecture for mobile and fixed access based on three tiers has been conceived. The use of the best technology for each tiers permits to maximize the capacity for each tiers and minimize the deployment time.

The TWEETHER vision is that the most cost-effective hybrid network is constructed on three main segments: one based on fibre for large aggregated capacity (Terabits), the intermediate based on wireless millimeter wave "backhaul" for high capacity (10Gbps) and the final one will include important number of links, and sub-6GHz (few 100Mbps) technologies to serve mobile and residential with very large number of connections at low cost. This convergence in a 3-tier architecture common to backhaul and access, is indeed a source of synergies, cost saving, possibilities for operators to address both markets and thus to foster new competition for access which could be a vector for digital divide reduction.

TWEETHER project addresses the middle segment of this hybrid network concept, implementing a system that provides a huge aggregated capacity split to several terminals with massive savings in equipment, site rental and licensing costs due to the use of a PtMP architecture. The TWEETHER system will provide indeed economical broadband connectivity with a capacity up to 10 Gbps/km^2 and distribution of hundreds of Mbps to tens of terminals. Compact and low-cost terminals based on advanced chipsets will be developed.

C. *W-band technology*

The TWEETHER project aims to fill the technological gap to create an intermediate tier system to link the high capacity of the fiber tier with the granular distribution in the last tier.

Three different technological steps will be developed for the design and fabrication of the front end and the terminals at W-band.

The recent progress in millimeter wave vacuum electronics will be extended to realize a novel, compact, affordable power amplifier, a Travelling Wave Tube (TWT) with tens of Watt output power in a wide frequency band to enable the intermediate tier link (Fig. 2). The level of linear power that vacuum electron devices can provide is currently precluded from solid-state electronics.

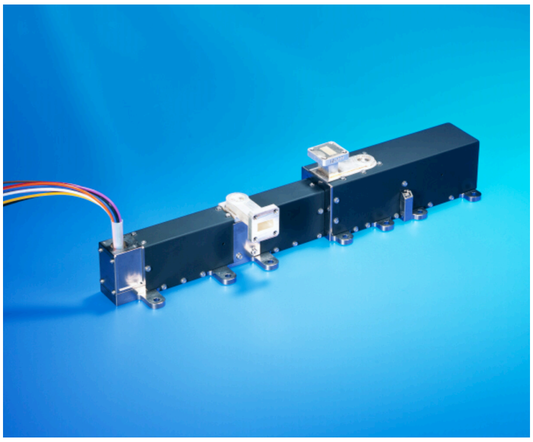

Fig. 2. Traveling wave tube

Advanced and high performance W-band transceiver chipset, enabling the low power high-speed operation of the system, will be developed and fabricated. This chipset includes a set of GaAs-based monolithic microwave integrated circuits (MMICs) such as power driver amplifiers, low-noise amplifiers down- and up-converters, multipliers, and Single Pole Double Throw (SPDT) switches.

Finally, these novel W-band components will be integrated by using advanced micro-electronics and micro-mechanics to achieve compact front end modules, which will be assembled and packaged with high-speed baseband interfaces and appropriate antennas for a field test to be deployed at the campus of the Universitat Politecnica de Valencia to prove the breakthrough of the TWEETHER system in millimeter wave wireless network field.

IV. Conclusion

The HORIZON 2020 TWEETHER project aims at a breakthrough to bridge the actual 4G to the 5G. The technological challenge to build the first front end at 94 GHz requires a joint effort of leading institutions and companies in the field of millimeter wave electronics, vacuum electron devices and high speed communications.

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