Is Fiber the Catalyst for Growth of the Mobile Wireless Network? (Invited)

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***Abstract*—:This paper will focus on how the growth of the mobile wireless technology can be supported by optical fiber, through wireless over fiber technologies. The paper will include recent advances in the field of fiber-wireless convergence such as cloud-based radio-over-fiber (RoF), point-to-point RoF system and millimeter wave network architectures. The advances in the mobile networks to meet the demand of mobile broadband, is driving the size of the cells to reduce. These small cells will be a prominent feature in the next generation 4G and 5G technologies and these cells must be connected with a high speed backbone. RoF offers a technology for seamless link between the small cells and macrocells. Therefore the convergence of mobile wireless and optical fiber will be essential to accommodate the growth of bandwidth requirements, thus enabling a high speed channel at the access network.**

***Index Terms*— Long Term Evolution (LTE), Optical Orthogonal Frequency Division Multiplexing (OOFDM), Radio-over-Fibre (RoF)**

I. Introduction

The growth in mobile broadband has been well documented and in the recent OECD (Organisation for Economic Co-operation and Development) 2013 report on Communications Outlook, the average subscription rate of mobile Internet access in OECD countries as a whole rose to 56.6% in June 2012, up from just 23.1% in 2009 [1]. In addition, the OECD report in measuring the digital economy noted that mobile broadband subscriptions represent 73% of all broadband access paths [2]. One of the emerging issues is the increase in demand for data with limited availability of spectrum. As a result the mobile networks will be offloading traffic to fixed/backhaul networks [3]. Since the mobile systems are moving to small cells architectures, the need for these fixed networks is more prominent where they can deliver higher bandwidth to the access networks. In order to provide seamless transitions from wireless to fixed networks, one of the promising technologies is radio-over-fiber (RoF), also known as wireless-over-fiber (WoF).

This paper will provide a brief overview of the current state of play in RoF/WoF. Firstly the paper will focus on Cloud-based radio access network and then point-to-point 4G long term evolution on RoF. Finally the paper will discuss the emerging WiGig standard which enables the use of unlicensed band at 60 GHz.

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II. Cloud-based Radio Access Network

As the mobile technologies are moving towards higher bandwidth, the distance between the user equipment (UE) and the base station will reduce, hence the introduction of small cells. These small cells will be the primary platform for 4G and 5G mobile systems. As the number of cells grows, the associated operating cost will also increase, namely due to increase in power consumption. One of the solution advocated by the operators and vendors is Cloud-based radio access network (Cloud-RAN) [4-6], where the backhaul is powered by fiber. The NSF Center for Optical Wireless Applications (COWA) at Georgia Institute of Technology, has demonstrated a novel multi-service small cell Cloud-RAN based on RoF technologies, which is capable of integrating legacy wireless services in a shared backhaul, as shown in Fig. 1 [7].

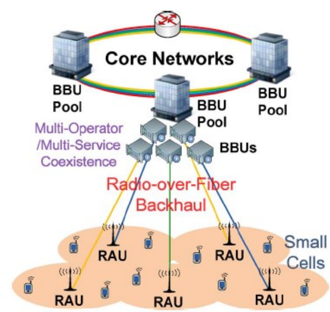

Fig. 1. Architecture of the proposed small-cell Cloud-RAN [7]

III. LTE on RoF

The base station of the 4G mobile networks, known as evolved node B (eNB), is highly complex and expensive, while its coverage radius is around 1km [8]. Therefore in order to extend the coverage of the eNB, the wireless signal can be seamlessly transported further over optical fiber. There are many architectures employing RoF that have been proposed and this paper will highlight a few of them. Kanesan *et al* has optimized the optical modulators and defined an optimum optical launch power for the RoF link that operates as the interface between an eNB and remote node (RN) for both 4G long term evolution (LTE) and LTE-Advanced, both theoretically [9] and experimentally [10, 11].

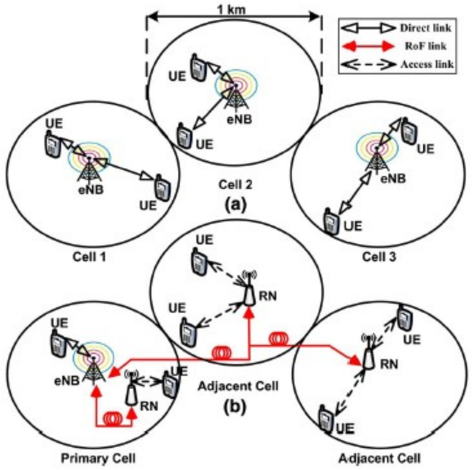

Fig. 2. Full Duplex LTE radio access network structure (a) without RNs and (b) with RNs in an urban environment [12]

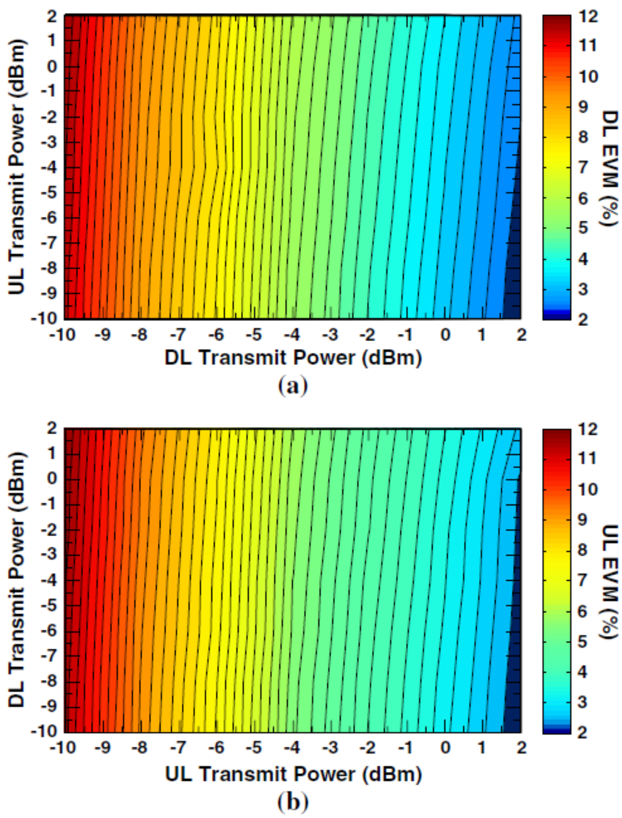

Fig. 3. Multiple EVM combinations of (a) downlink (DL) and (b) uplink (UL) radio frequency (RF) transmit power with respect to the interfering UL and DL RF transmit power, respectively. DL signal is transmitted at 2.62 GHz and UL at 2.57 GHz [12].

The Optical Communications Research Group (OCRG) at Northumbria University, UK, has successfully demonstrated a full duplex point-to-point RoF system for LTE uplink and downlink, which operates within the required error vector magnitude (EVM) specified by 3GPP specifications [12]. The full duplex scenario is depicted in Fig. 2, where one eNB can be used to support the adjacent cell using a simple RN. Fig. 3 shows the effect of the full duplex link with respect to the EVM performance.

The group also proposed using frequency dithering techniques in direct and external modulations to suppress the stimulated Brillouin scattering (SBS) in the LTE RoF system. By suppressing SBS, the overall signal to noise ratio of the optical signal improves dramatically [13, 14].

IV. Millimeter Wave on RoF

Recent technological advancement in unlicensed RF band at 60 GHz and the demand for higher speed have driven a new Wi-Fi standard known as WiGig [15]. An example of WiGig applications is depicted in Fig. 4. This emerging WiGig standard has given rise to research in millimeter wave (MMW) [16], however the transmission length of such system will be short due to high atmospheric attenuation. As a result, for in-building applications, optical fiber has the potential to provide a comprehensive distribution network for WiGig.

Research in MMW over fiber technologies is demonstrated by Chang and Liu [17], where multi access schemes are employed in an aircraft wireless sensor communications network, as shown in Fig. 5. The generation of optical MMW is a challenge and there are many researchers working on novel techniques and optimizing the overall performance of the optical MMW system [18, 19].

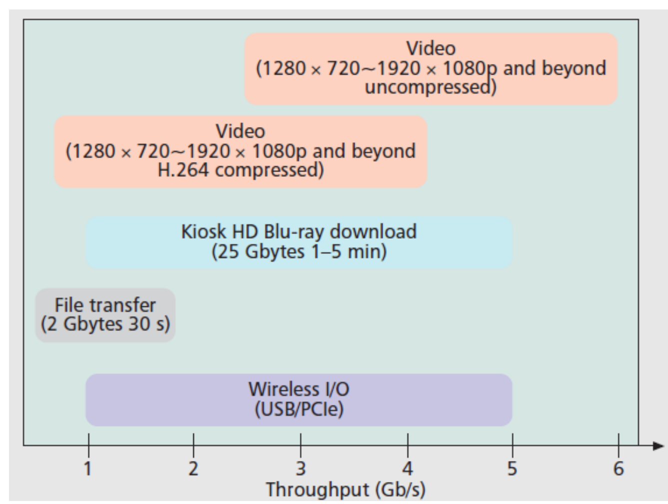

Fig. 4. Example of WiGig applications from Hansen [15]

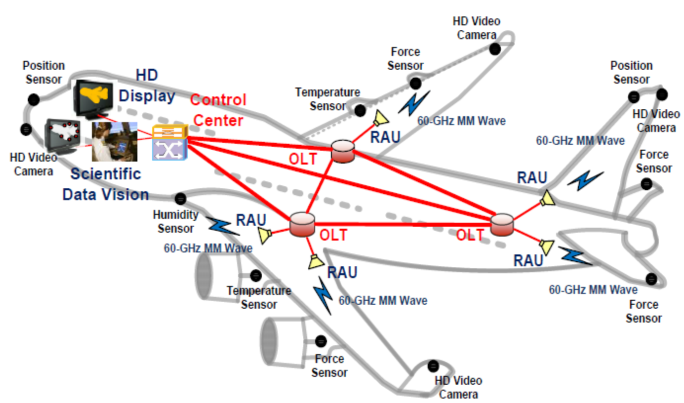

Fig. 5. MMW Wireless Sensor Communications Network [17]

V. Conclusion

This paper has provided an overview on the current emerging wireless technologies and as the need for higher speed grows, the cell size will reduce. The connectivity of these small cells are essential in delivering high quality mobile data services, hence the paper has reviewed some advanced technologies, where optical fiber can play a major role in such architecture. Therefore the answer to the title of the paper is a resounding "Yes!".

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