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Invited Papers

Options for future mobile backhaul and fronthaul

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ABSTRACT

This paper describes the options for constructing mobile backhaul (MBH) and mobile fronthaul (MFH) networks that can support mobile broadband services beyond LTE Advanced. It first reviews the current architecture of Radio Access Network (RAN) which comprises MBH and MFH as well as the wireless section to reach the user equipment (UE). Then, it describes technologies for future MBH/MFH networks that are capable to the drastic increase of wireless bandwidth as well as the massive deployment of small cells.

1. Introduction

In the last ten years, terminal equipment for the broadband communication has evolved from sophisticated computer machines to various smart devices. According to this evolution, the number of mobile broadband service users is increasing very rapidly: those now using Long Term Evolution (LTE), which provides bandwidths of up to 50 Mbit/s upstream and 150 Mbit/s downstream, exceeded 50 million in the middle of 2014 in Japan [1].

If we look at the trends in mobile communication standards, the 3rd Generation Partnership Project (3GPP) will release documents to complete LTE-Advanced (LTE-A), i.e. the fourth generation (4G) mobile, in early 2016 [2]: the key features include small-cell enhancement. LTE-A will provide upstream and downstream bandwidth of up to 1.5 Gbit/s and 3 Gbit/s, respectively.

It is anticipated that the 3GPP group will start working on the fifth generation (5G) mobile after completing LTE and LTE Advanced [3,4]. It is very likely that new radio access technologies (RAT) as well as the usage of higher frequency bands, including millimeter wave, will be explored. The target bandwidth is assumed to be 10 Gbit/s and over.

For supporting 4G and 5G mobile services, the roles of mobile backhaul (MBH) and mobile fronthaul (MFH) are becoming more important. This paper first describes the current architecture of Radio Access Network (RAN), comprising MBH and MFH, in addition to the radio section to reach the user equipment (UE). It next describes options for constructing future MBH and MFH considering the evolution of RAT towards 5G mobile.

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2. Radio Access Network (RAN) and future directions

2.1. RAN, MBH and MFH

2.1.1. RAN and MBH

Fig. 1 shows general architecture of RAN, which is defined as the network connecting a huge number of UEs to the core network: it is defined as evolved Universal Terrestrial RAN (E-UTRAN) in LTE/LTE-A [5]. RAN is a network to connect UEs to the Core Network (CN) via Base Stations (BSs). The network connecting BS to CN, which is a part of RAN, is called mobile backhaul (MBH).

In MBH, signals pass between CN and each BS (solid lines in Fig. 1) as well as between BSs (dotted lines in Fig. 1) in the logical layer. Various physical configurations can be used to support this depending on the requirement. A simple, thus cost-effective approach is just to connect each BS to CN, so that BSs are connected via CN, in the physical layer. It should be noted that this is realized not only with optical links but also with other options such as copper and wireless links, especially when optical links have not been deployed in the "last mile" to reach BSs from the CN side. Another approach is to use a ring-networking technology, e.g. Resilient Packet Ring (RPR) [6]. This realizes connection between neighboring BSs (and non-neighboring BSs if needed) with relatively low latency, so that inter-BS cooperation, e.g. for UE handover, can be smoother. A more sophisticated approach is to use the Optical Add Drop Multiplexing (OADM) ring technology [7], which connects neighboring BSs, as well as CN and BSs, by optical paths. This offers capacity assurance and minimal latency. Wavelength Division Multiplexing (WDM) is used to provide a large number of optical paths.

Synchronization of frequency as well as absolute time, so-called Time of Day (ToD), are important MBH requirements. Typical

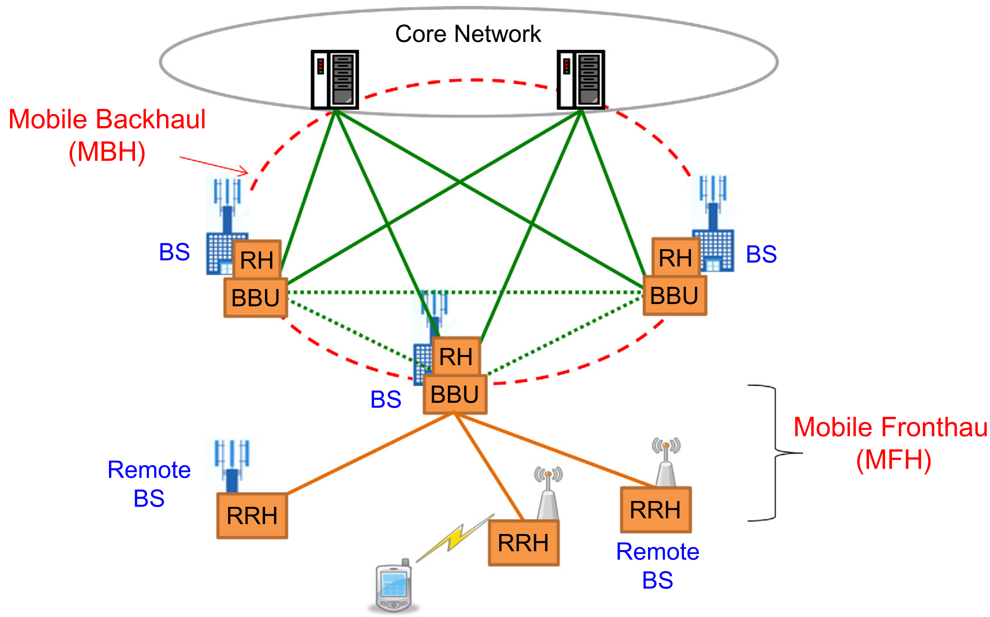

Fig. 1. RAN and MBH/MFH.

approaches to synchronize the frequency and ToD in all BSs is to use Synchronous Ethernet [8–10] and IEEE 1588v2 [11], respectively. Synchronization over the Optical Transport Network (OTN) is also under study in ITU-T.

2.1.2. MFH

While the basic BS consists of Base-Band Unit (BBU) and Radio Head (RH), some will offer only the RH function, the Remote RH (RRH) as illustrated in Fig. 1. This configuration offers small remote BSs as well as centralization of the BBU function. This configuration is called Centralized RAN (C-RAN), and the network between the centralized BBU and the RRHs is called mobile fronthaul (MFH). The C-RAN architecture makes it easy to realize high-speed inter-cell coordination, which improves mobile service performance. The popular BBU–RRH interfaces include Common Public Radio Interface (CPRI) [12], Open Base Station Architecture Initiative (OBSAI) [13], and Open Radio equipment Interface (ORI) [14–16]. All of these are based on the transmission of digitally-sampled radio signal(s). CPRI and OBSAI originated from the idea of radio signal transfer in some essential sections, e.g. from the BBU in a machine room in the operator's building to the antenna at the top of the building, but they are now being applied to also support relatively distant antennas far from BBU, e.g. up to 20 km. Due to their origin, requirements for the latency and the latency jitter are typically very tight in MFH.

It is sometimes effective to multiplex several CPRI/OBSAI/ORI signals, e.g. those for different sectors in a multi-sector antenna, those for different generations of mobile technologies, as well as components of multiple input multiple output (MIMO) signals, into a single fiber. Coarse Wavelength Division Multiplexing (CWDM) can be used for this while keeping the latency and the latency jitter low [17].

2.2. Future directions

Fig. 2 shows recent standardization trends for mobile communication technologies. 3GPP has been standardizing LTE-A as 3GPP releases 12 and 13, and completion by early 2016 is expected. Release 12 specifies dual connectivity as the key solution to realize the small-cell enhancement. This allows a UE to connect to the network via at least two paths, e.g. one is the primary path via the macro-cell antenna and the other is the secondary path via a small-cell antenna. The specification provides mobility robustness in terms that the connection is kept by the macro cell while high-capacity traffic can be offloaded to the small cell. By leveraging these features, we can expect wide deployment of small cells.

It is expected that the 3GPP group will start working on 5G mobile after completing LTE-A. The work has not been started, but it is very likely that new RATs will be explored in conjunction with the usage of higher frequency bands, including millimeter wave. The target bandwidth is taken to be 10 Gbit/s and over [3]. Although the standardization work has not started so technical solutions are not clear at this moment, a likely direction is discussed below.

Fig. 3 illustrates Future Radio Access and Mobile Optical Network (FRAMON) proposed as an implementation of the 5G network [18,19].

The network overlays densely-arranged small cells onto the macro cell. It applies the so-called C/U split, which is the decoupling of the control plane (C-plane) from the user data plane (U-plane). In this approach, the macro cell takes the roles of call control and mobility control (C-plane) as well as coverage support for data transmission while the small cells focus on the broadband data transmission (U-plane). The small cells are assumed to provide sub-10 Gbps capacity and use frequency slot(s) under 6 GHz.

The U-plane overlays spot cells for super broadband transmission, e.g. over 20 Gbps. The cell is selected according to the mobility situation and service type. Its frequency slot(s) can exceed 6 GHz: the use of millimeter waves, defined as those from 30 to 300 GHz, is also within the current scope.

These features, especially the anticipated small-cell deployment and the very high capacity, greatly impact the future evolution of MBH and MFH. The following sections review and discuss future MBH/MFH technologies to support mobile services in 4G, 5G and beyond.

3. Options for future MBH

3.1. Ring network

Given the assumptions as to future radio access capacity, bandwidth between the core network and each BS must be much more