**IEEE P802.15**

**Wireless Personal Area Networks**

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| Re: |  |
| Abstract | The aim of this contribution is to propose the modified texts in the Application Requirement Document (ARD). |
| Purpose | Proposing modified texts in section 6 of Application Requirement Document (ARD). |
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# Fronthaul

There are a lot of studies to transmit high-speed data signals around 10 Gbps to user terminals for future mobile services such as 5G which requires a huge number of base transceiver stations (BTSs) and small-cell networks[1]. The centralized radio access network (C-RAN) separates the function of the BTS to a modulation/demodulation unit (M/dMU) and a radio access unit (RAU), and will be configured with a centralized M/dMU and remotely located RAUs for last access to the user terminals. The connection between the M/dMU and RAU is called “fronthaul”, and currently, ITU-T SG15 defines mobile fronthaul including Radio over Fiber (RoF) [2]. Mobile fronthaul is defined as a connection between one and the other of separated radio transceiver functions within a base station.

## Description of the operational environment

Figure 6.1 indicates three fronthaul links. The first fronthaul link utilizes terahertz carrier frequencies to feed 5G signals to the user terminals in a small cell. The second utilizes RoF link to feed 5G signals to RAU, which cannot be electrically connected by terahertz carrier frequencies due to long distance and propagation high attenuation. Two links have the similar performance regarding waveform transmission which can be called radio over X where X is either terahertz or fiber [3]. The third link which is called RoRoF (Radio on Radio over Fiber) combines two above links to transmit/receive the radio signals from/to the user terminals. In Figure 6.1, RoF is defined as a fiber-optic transmission of waveform for radiocommunication services [2]. Although Radio on Teraherzt (RoT) is not defined by ITU-T, RoT can be defined as a terahertz transmission of waveform for radiocommunication services.



Figure 6.1 Mobile fronthaul using RoT, RoF and RoRoF.

Figure 6.2 explains the principle of encapsulation of microwave signals to terathertz. Microwave sugnals such as LTE and LTE-Advanced are upconverted to terahertz, and then transmitted to the air. The disadvantage of RoT is a short transmission distance because of high propagation attenuation, however the transmission distance can be extended by introducing RoF technologies in RoT, as shown in Figure 6.3. The RoT signals are converted to the optical signals, and transmitted to relay RAU. The terahertz which carriers microwave signals is detected and transmitted to RAU for a small cell. Due to the extremely low transmission loss, the distance between M/dMU and relay RAU can be extended on the condition that latency and availability are satisfied.



Figure 6.2 Encapsulation of microwave signals to terahertz



Figure 6.3 Blockdiagram of Radio on Terahertz over Fiber

Figure 6.4 shows the detailed blockdiagram of each fronthaul. In this figure, a modulation and demodulation unit represents one partial BTS located in the network side and a radio antenna unit represents the other partial BTS located in the antenna side (RAU). Taking the above situation into account, mobile fronthaul should be defined as the connection between one and the other of separated radio transceiver functions within the BTS. In addition, mobile fronthaul link should be also defined as a link to establish a mobile fronthaul. The Radio orver Terahertz (RoT) link corresponds to mobile fronthaul link whose carrier frequencies are terahertz waves and its transmission medium is air, while the RoF link whose carrier frequencies are light waves and its transmission medium is fiber cable.



Figure 6.4 Definition of mobile fronthaul [2].

Figure 6.5 shows the hybrid structure which utilized two fronthaul links to feed 5G signals to the user terminals in both the macro cell directly connected to M/dMU and the small cells via either RoT or RoF. The long distance RAUs from M/dMU are connected by the optical links because the propagation distance of terahertz waves is limited. The RoT link cannot be used to provide signals to long distance RAUs, but also short distance RAUs where M/dMU cannot see because of the obstacles such as high tall buildings, etc.



Figure 6.5 Hybrid structure using RoT and RoF.

## Definition of a typical transmission range

The typical transmissiondistance of radio over terahertz (RoT) mainly depends on propagation attenuation of carrier frequencies whose values have been already published by Recommendation ITU-R P.676, P.838, P.840, and the output power and antenna gain of M/dMU and the receiver noise figure of RAU, and vice versa. On the other hand, the transmission distance of RoF is determined by fiber insertion loss, fiber dispersion, non-linear characteristics of E/O and O/E devices, noise figure and latency of the fiber optic link. As shown in Figure 6.4, the shorter range between M/dMU and RAU is covered by RoT and the longer range by RoF.

Additional important parameters which define a typical transmission range are frequency interference and transmission latency. Frequency interferences cause the reduction of the capacity and connectivity between M/dMU and RAU. Terahertz-wave links can avoid the frequency interference between links due to high antenna directivities. RoF links, in principle, never cause frequency interferences because the radio signals are superimposed on the optical carrier in the fiber cable. The transmission latency of RoT and RoF is expected to be small due to digital signal processing (DSP) functions in the transceivers. Figure 6.6 shows one of examples of the transmission latency of RoF link which uses a MZM external modulator as an E/O device and UTCPD as an O/E device. The back to back delay time of the RoF link (fiber length is zero) is about 100 nsec. The additional delay time is proportional to the length of fiber cables. The transmission rage of the RoT and RoF links will be determined from the system technical requirement.



Figure 6.5 Example of ransmission latency of RoF link.

##  Description of the conditions to achive the Target data rate

Both RoT and RoF links transmit waveform from M/dMU to RAU, and vice versa. The modulated spectrum bandwidth of the waveform is determined by the modulation speed and the modulationscheme such as multi-level Quadrature Amplitude Modulation. The limiting factors of transmission bandwidth of the RoT and RoF links are up and down conversion frequency characteristics, and E/O and O/E frequency responses, respectively.

Figure 6.6 shows the experimental setup to evaluate EVM of 64-QAM modulation signal specified by LTE-Advanced standard. Although the carrier frequency of the RoT link is about 90-GHz band, the obtained EVM of 64-QAM signal is less than 5% which satisfies with LTE-Advance requirement.

*[Note: The EVM using 300-GHz link will be provided at the next meeting.]*



Figure 6.6 Experimental setup for transmission of LTE-Advanced signlas through RoRoF system.



Figure 6.7 EVM versus RF input power level.

## Specific issues with respect to regulation

ITU-T SG15 will publish Supplement on RoF technologies and their applications which incorporateRoF in the next generation of passive optical network (NG-PON2) [4]. Regarding terahertz waves, Radio Regulation does not have frequency allocation between 275 GHz and 3000 GHz, but identifies specific frequencies above 275 GHz for passive services only [5]. No frequencies have been identified for active services, specifically fixed services.

## Specific requirements with respect to the MAC

No additional MAC requirements are added to transmit waveform from M/dMU to RAU, and vice versa, because the link performance of RoT and RoF is based on relay transmission.

*[Note: The relay transmission only transports the analog RF signals from M/dMU to RAU, and vice versa. This does not impose the specific requirement to the MAC.]*

## Other issues

Optical Sub-Harmonic IQ Mixer (O-SHIQM) [6][7][8] techniques for mobile fronthaulwill be proposed to be included in the Technical Requirement Document as an optional requirement at the next meeting.

*[Note:The text will be submitted to the next meeting. ]*

##  References

[1] 5GPPP. <http://5g-ppp.eu/>

[2] Draft Supplement to ITU-T G-series Recommendations (G.Suppl.RoF), “Radio-over-fiber (RoF) technologies and their applications”.

[3] T. Kuri et al. “Proposal of “Radio over X” and “Modulation-Symbol-Format Maintaining Transmission” for the next generation mobile services ”, IEICE Technical Report, CS2014-17, July 2014.

[4] Recommendation ITU-T G.989.1, “40-Gigabit-capable passive optical networks(NG-PON2): General requirements”.

[5] Radio Regulation, Edition 2012.

[6] IEEE 802.15-14-0022-00-0thz, “Application of RoF-Based Terahertz Fronthauling using Optical Sub-Harmonic IQ”, January 2014.

[7] IEEE 802.15-0177-02-003d, “RoF-Based Terahertz Fronthaul for Mobile/Wireless Access Systems”, March 2014.

[8] IEEE 802.15-0177-0003d, “RoF-Based Terahertz Fronthaul for Mobile/Wireless Access Systems”, May 2014.

# Backhauling

## *[Note: Further information on section 7 will be provided at the next meeting.]*Description of the operational environment



Figure 7.1 Mobile backhaul using terahertz.



Figire 7.2 Definition of mobile backhaul.

## Definition of a typical transmission range

xxx

## Description of the conditions to achive the Target data rate

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## Specific issues with respect to regulation

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## Specific requirements with respect to the MAC

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## Other issues

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