**IEEE P802.15**

**Wireless Personal Area Networks**

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| Project | IEEE P802.15 Working Group for Wireless Personal Area Networks (WPANs) |
| Title | Proposal to TG3d Applications Requirements Document (ARD) |
| Date Submitted | 10 July 2014 |
| Source | Akifumi Kasamatsu, Norihiko Sekine, Iwao Hosako, Atsushi Kanno, Toshiaki Kuri, Tetsuya Kawanishi,and Hiroyo OgawaNICT4-2-1, Nukuikita, Koganei, 184-8795, Tokyo, Japan | Voice: +81 42 327 6824Fax: +81 42 327 6669E-mail: kasa@nict.go.jp |
| Re: |  |
| Abstract | The aim of this contribution is to propose new texts in the Application Requirement Document (ARD). |
| Purpose | Proposing new texts in section 6 of Application Requirement Document (ARD). |
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**6.　Fronthaul**

*[Note: This section focuses on RF transmission using optical fiber links. The original title of this section “Backhauling/Fronthauling” was amended.]*

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. RoF is defined as a fiber-optic transmission of waveform for radiocommunication services. Basic configuration and technical characteristics of mobile fronthaul using RoF are introduced for TG3d application requirements.

**6.1 Description of the operational environment**

Figure 6.1 indicates two 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. Tow links have the similar performance regarding waveform transmission which can be called radio over X where X is either terahertz or fiber [3].



Figure 6.1 Mobile fronthaul using RoF.

Figure 6.2 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 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 6.2 Definition of mobile fronthaul [2].

Figure 6.3 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 RoF 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 6.3 Hybrid structure using RoT and RoF.

**6.2 Definition of a typical transmission range**

The typical transmission distance 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 6.2, 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.

**6.3 Description of the conditions to archive 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 modulation scheme 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.

**6.4 Specific issues with respect to regulation**

ITU-T SG15 will publish Supplement on RoF technologies and their applications which incorporate RoF 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.

**6.5 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.

**6.6 Other issues**

Optical Sub-Harmonic IQ Mixer (O-SHIQM) [6][7][8] techniques for mobile fronthaul will be proposed to be included in the Technical Requirement Document at 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.