RoF Communication Technology and Its Application Prospect

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Abstract:
The Radio over Fiber (RoF) communication technology combines the technical advantages of both fiber communication and wireless mobile communication to solve the problems of bandwidth, flexibility and electromagnetic interference. Research of the technology is drawing wide concerns around the world. However, high cost becomes a drawback of this technology at present. In this article the RoF Multi-System Access (RoFMA) scheme is proposed. The scheme makes use of the Optical Time Division Multiplexing (OTDM) and multi-system multiplex/de-multiplex technologies to lower the access cost. The article also predicts good development and market prospect of the RoFMA technology.

The Radio over Fiber (RoF) technology has become a hot topic in recent years. Famous fiber communication magazines *IEEE/OSA Journal of Lightwave Technology* and *IEEE Journal. of Photonic Techniques*, telecom expositions the Optical Fiber Communication Conference and Exposition (OFC) and European Conference on Optical Communication (ECOC), as well as China's fiber communication conference, have been hosting frequent seminars and discussions on this technology. U.S. Department of Defense, the national natural science foundation and "863" program of China also provide funds for research of related topics. This article is covering future development and possible applications of the RoF technology, some possible implementation schemes of the RoF technology, and advantages and problems of the RoF technology.

1 Development Trend of RoF

The resource of radio frequency in the world is facing increasing pressure along with a growing demand of bandwidth and mobility. The communication networks of 2G, 3G and 4G systems are hence constantly turning to new frequencies. However, low frequency bands with good coverage performance are used up and the occupied frequencies cannot be freed up. The new generation mobile communication has to employ the new and wider frequency bands. The RoF technology has been born amidst this conflict of demand and supply. The problem of network integration has been in heated discussions in the OFC 2008 conference that also accepted many articles of RoF. What is new about the RoF papers accepted by the OFC 2008 is their focusing on research of applications with such typical schemes and research interests as: To adopt the Orthogonal Frequency Division Multiplex (OFDM) in the RoF system for higher spectrum use rate and less intersymbol interference; to adopt the technology of optical wavelength reuse during uplink transmission in order to get rid of the optical source of base stations; research on combination of the Worldwide Interoperability for Microwave Access (WiMAX) or Wireless Fidelity (Wi-Fi) technology and the RoF technology; research on the RoF system ring network based on Optical Add/Drop Multiplexer (OADM); and research on the RoF system based on multi-mode fiber and plastic fiber. A research group at Georgia Institute of Technology has done much research work on the RoF system at 40 G/60 G radio frequencies and has set up an optical radio transmission system, where the high-definition TV data source stored on DVD is modulated to the 40 G microwave and then modulated again to the optical carrier for transmission, next detected, received and transmitted through the antenna, finally sent from the receiving end to the high-definition TV set for playing. The lab result is good.

Meanwhile, the RoF communication technology is showing the industry one of its features, that is, the Remote Radio Unit (RRU) and BaseBand Unit (BBU) carry out, respectively, the RF processing part and baseband processing part of a base station. BBU and RRU are placed in separation but connected with each other through the electric or optical interface. For a TD-SCDMA system, such BBU + RRU scheme is realized with only three optical fibers instead of more than 20 feeder cables needed by a traditional base station, hence simplifying engineering construction of base stations greatly. The

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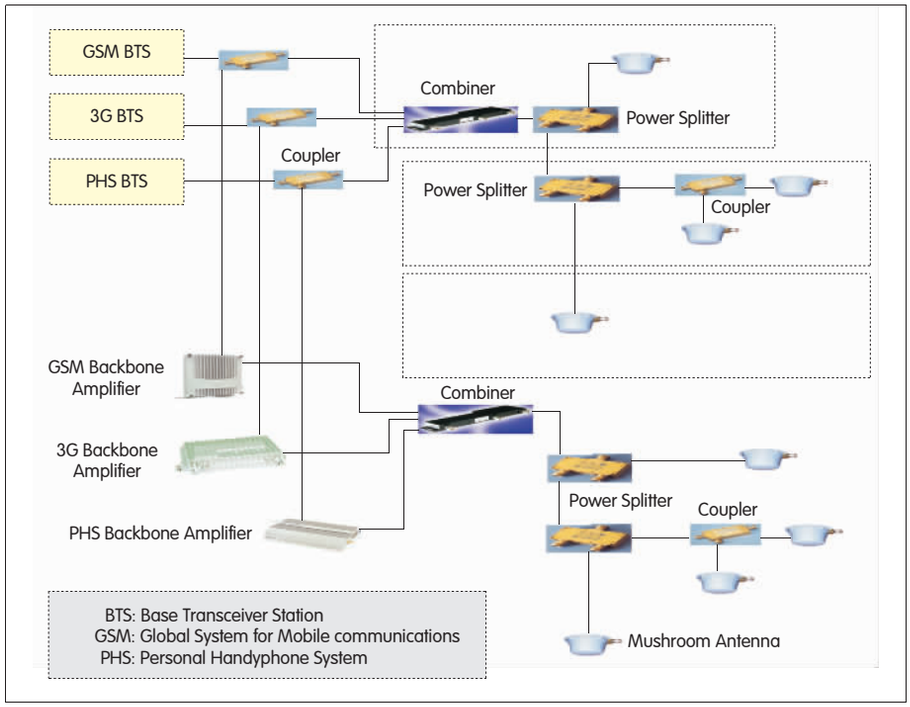
BBU unit can be expanded smoothly and configured flexibly. It also supports High Speed Downlink Packet Access (HSDPA), Multimedia Broadband Multicast Service (MBMS) and High Speed Uplink Packet Access (HSUPA). It adopts Asynchronous Transfer Mode (ATM) and Internet Protocol (IP) as the transmission protocol stack to guarantee smooth transition of the present network to the all–IP network. The network equipment supports smooth evolution from the present network to Long Term Evolution (LTE) network. The RRU unit is able to support the wireless access network solutions that are suitable for varying requirements from the network operator and different network environments, to meet the radio coverage needs of urban, suburban, rural, express way, railway and hot–spot areas. The RRU unit features compactness and light weight and can be mounted to the cement pole, anchor tower or wall of a building, obviating the need of a special telecom tower. The RRU supports dual carriers of discontinuous bands, namely, the span of uplink and downlink frequencies can be up to 100 MHz. In other words, for an operator who already owns the Frequency Division Duplex (FDD) band, its expenditures on construction and operation of a new network will be slashed because only half the RRUs, antennae, and towers will be needed as compared to those of a traditional network. Also the engineering part of the network will become much easier. The RRU supports the digital, free–of–fan, low–cost and high–power design of Power Amplifier (PA). The RoF technology supports transmit diversity, multi–level RRU concatenation, and only configuration data need be changed to expand one sector from one cell to two cells (no extra combiner or antenna feeder is needed for expansion to three or four cells)[1].

The research and development of RoF technology outside China is taking on these trends:

(1) The radio frequency of RoF is developing from low frequency to high frequency and millimeter wave. The carrier mode of the RoF communication is also developing from single system to multiple systems and multiple users.



▲Figure 1. Scheme of repeater–based multi–system sharing radio indoor coverage.

(2) The research level of RoF communication is changing from the network to the system and devices[2].

(3) The research range of RoF communication is changing from theoretical study to system development and service application.

(4) The product development of RoF communication is directing from remote baseband to remote mid–frequency and remote radio frequency.

(5) The interface standard of RoF communication is developing from CPRI to OBSAI and open applicable standard interface.

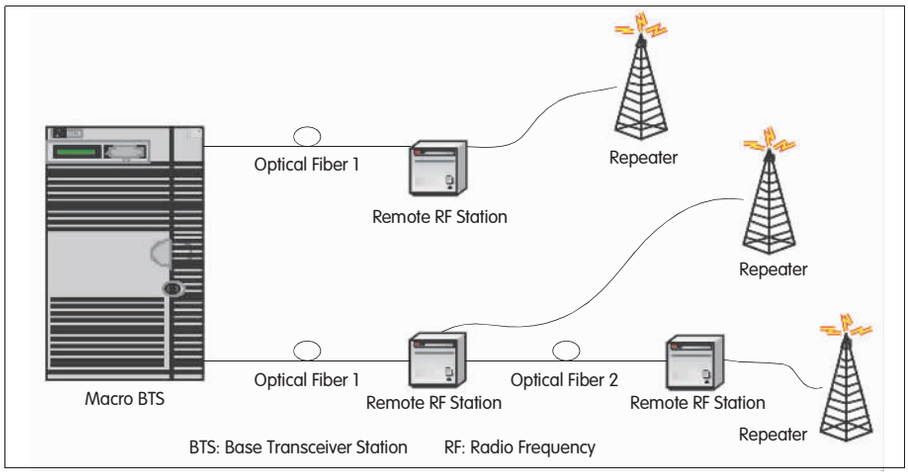
(6) Research of the theoretical model of RoF communication is developing from the outdoor information model to indoor coverage model.

2 Implementation Scheme of RoF Communication

The RoF communication technology is an interdisciplinary one that combines optical communication and wireless mobile communication. It reflects a new stage reached by the developing communication technology. The following application schemes are proposed to meet different application needs and technological levels:

- Repeater–based multi–system sharing radio indoor coverage system, shown in Figure 1;
- Remote base station + macro base station to cover the dead zone, shown in Figure 2;
- The RoFMA mode, shown in Figure 3.

As shown in Figure 1, the radio signals received by the antenna of the GSM, PHS and 3G base stations can be transmitted, through the optical fiber or directly the cable if the distance is short enough, to the multi–system combiner, and then transmitted by the indoor antenna after running through the power splitter. A power amplifier can be added before the combiner if there is a rather high loss of signal's transmission power. This radio coverage mode features simple structure and low cost. But as the antenna is used to receive the base station signals that are then amplified and allocated indoors, indoor and outdoor base station signals are prone to generate interferences. Especially in the era of 3G when signal bandwidth and carrier frequency increase all the time, the signal interference of repeaters is more serious in densely populated areas. Currently the mode of remote base station + macro base station is employed



▲Figure 2. Dead zone coverage with remote base station.

to cover dead zones, as shown in Figure 2.

For the BBU + RRU model of base station, the technically sophisticated Common Public Radio Interface (CPRI) and Open Base Station Standard Initiative (OBSAI) interfaces are used for the interconnectivity of the two units. This mode will produce no extra interference as RRU itself is a part of the macro base station. But it comes with rather complex structure and high cost. Figure 3 shows the proposed RoFMA mode on the BBU + RRU basis.

The RoFMA scheme brings together the advantages of the first two modes and has the multi-system multiplexer and demultiplexer, RoF Network Unit (RoFNU) and RoF Line Terminal (RoFLT) added between the BBU and RRU. Cost is expected to shrink with the multiplexing among several systems and multiple users, and interference becomes less due to the BBU + RRU mode. The fiber access network is used for connecting the RRU with BBU. This mode helps avoid interference and cut down unit cost, but its structure is rather complicated.

According to the abovementioned network structure and our research results, the possible applications of RoF wireless access are as follows:

(1) Military Application

For security reasons, the broadband microwave or RF signals received by the radar are transmitted through the optical fiber in the mode of RoF communication to the remote end. This will cause fewer casualties in the event of radar strikes.

(2) High-Speed Sensing

The RoF communication can be used for fast transfer of video monitoring signals on the high-speed trains and jumbo jets, as broadband transmission can be satisfied and also less electromagnetic pollution will be produced.

(3) 3G Mobile Communications

The third generation mobile communication relies on higher frequency than that of the second generation system, thus more repeaters and remote base stations are required to provide indoor coverage. The RoF mode will need much less cable in this case and thus less electromagnetic pollution.

(4) 4G Mobile Communications

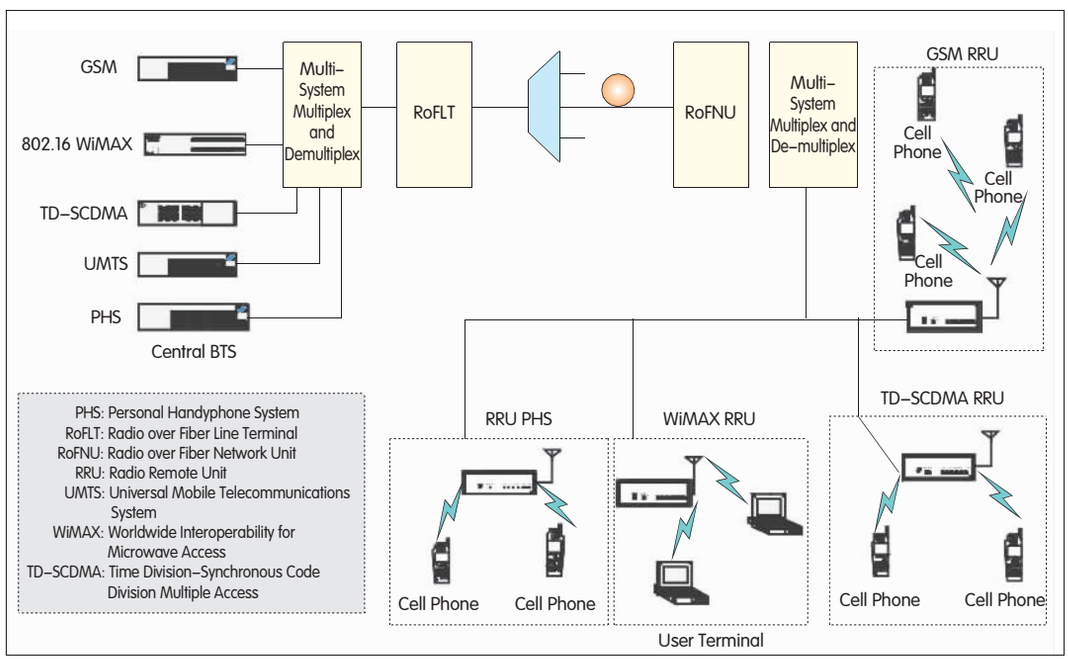
The fourth generation mobile communication employs even higher frequency than that of the third generation system and the bandwidth reaches up to 1 Gb/s. This requires the RoF mode to set up the networking with fiber-based distributed antennae and the mid-frequency remote unit to provide network coverage[3].

(5) Millimeter Fiber Transmission

The millimeter wave at 60 GHz and higher generates fast attenuation and less electromagnetic interference, thus is quite suitable for indoor coverage. Together with the RoF communication, the problems of electromagnetic interference and electromagnetic pollution will be addressed in a better way[4].

3 Pros and Cons of RoF Communications

At present, the interface standards adopted for the RoF wireless distributed



▲Figure 3. Radio coverage of RoF multi-system access.

base stations are not open enough. Devices concerning network management come with private interfaces that lead to the interconnectivity problem between products supplied by vendors supporting different systems and also hinder the development of RRU. However, this is more an issue of interests than technology. There are currently two major interface standards applied for the RoF wireless distributed base station. One is the CPRI standard for connecting RRU and BBU, the other is the OBSAI standard that has the baseband processing, RF, network transport and control layer all separated. The CPRI interface is simpler than the OBSAI interface as the latter comes with rather difficult standard. Anyway, both standards have to be more open to lower the cost of distributed base stations.

The RoF communication technology is one that integrates optical and wireless technologies and it has emerged to adapt to the developing communication technology. It has advantages and drawbacks at the same time.

Specifically, its promising aspects are as follows:

• Integration of optical and wireless communication brings more flexibility and bandwidth, and is more environmentally friendly;

• The RoFMA scheme is able to meet the needs of developing information technology for more environmentally friendly communication with more flexibility and bandwidth;

• Both wireless communication and fiber communication are mature on their own terms but their integration has just taken its first steps to reach the expectable rosy prospect.

On the other hand, the problems for the RoFMA to solve include:

• The System–On–Chip (SOC) for integration of optical and wireless technology;

• Shortage of high–speed microwave devices;

• Big size and high cost of horn antenna (good performance though) for the 60 GHz RoF system[5];

• Single application of RoF lacks of process basis for commercial scale development, and requires more work on integrated RRU[6];

• Interfaces for network integration, realization of Media Access Control (MAC) at the protocol layer, higher antenna gain, frequent handovers in pico cells during high–speed moving activity and Doppler effects.

4 Conclusion

The RoF communication technology is now developing toward a low–cost broadband multi–system wireless access solution without electromagnetic interference. Government agencies, academic bodies and the industry are all attaching great importance to its research and application. Problems in need of immediate solutions are the various high–frequency devices, SOC chip, interface standards and frequent handovers.

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Yu Jianguo, PhD, graduated from Beijing University of Posts and Telecommunications (BUPT). He is now a senior engineer at the Beijing Northern FiberHome Technologies Co. Ltd (branch of Wuhan Research Institute of Posts and Telecommunications). He is also a part–time professor and doctoral advisor of BUPT. Yu has undertaken more than ten research projects on fiber communications and wireless mobile communications supported by the National Natural Science Foundation and the "863" program of China, and has published more than 40 papers.

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