SPECIAL TOPIC

A Power Line-delivered and Lamp-based Broadband Mobile Communication System

Abstract:
A new mobile communications network architecture is proposed to solve four existing bottlenecks that restrict the rapid development of mobile communications, as well as to meet the development demands of future broadband mobile communications. The architecture introduces the Information Lamp (IL), a novel device carrying out transceiver function, as the access point, besides providing light. It fulfills information interaction between the access points and radio access network through the power line (or fiber). The new system, supported by core technologies such as multi-antenna based distributed space-time signal processing and distributed radio resource management, integrates the wired and wireless networks to provide high-speed and high-quality mobile communication services.

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The mobile communication technology develops fastest among communication technologies. Any breakthrough in concept or technology in the mobile communication field would lead to a leap in engineering and bring great economic benefits[1]. The introduction of the "cellular" concept initiated the first generation mobile communication system[2]; the maturity of digital signal processing technologies and devices promoted the flourishing of the second generation mobile communication system represented by Global System for Mobile Communication (GSM); the commercial application of Wideband Code Division Multiple Access (WCDMA) and the proposal of multimedia technologies satisfied the function requirements for the Third Generation (3G) mobile communication system[3].

To enable larger capacity in the future mobile communication system, the multi-antenna technologies, such as Multiple Input Multiple Output (MIMO), have become one of the hot research subjects in the wireless communication field[4-5].

Compared with 3G mobile communication systems, the next generation system is not only required to deliver faster transmission rates, bigger system capacity, higher spectrum efficiency and lower power consumption, but it also has to deal with a more complicated network environment where various communication networks co-exist. As a result, the following four bottlenecks in the development of mobile communication have to be thoroughly solved:

(1) Difficulty in Base Station (BS) address selection

The installation location of a BS has always been a problem for the telecom operator due to two reasons: one is that the land owners of some old BSs are reclaiming their usage of the lands, and the other is that a proper location for a new BS is difficult to find. Nowadays, the rooftops of the non-residential buildings in the urban areas have already been occupied with various kinds of BSs. However, the installation of a BS on the rooftop of a residential building is almost impossible for the sake of the residents' health.

(2) Large transmitting power of mobile phone

The average transmitting power of a GSM phone is 1 W[6-7] and that of a CDMA phone is 0.01 W-1 W[7-8]. In traditional cellular cells, mobile phones may be far away from BS, so they should have enough transmitting power to make sure communication reliability. However, the large transmitting power gives rise to strong radiation, and does harm to the user's health.

(3) Strong radiation around BS

A traditional BS often takes charge of the cellular cells within a radius of 100 m -1 000 m, so the transmitting power of its broadcast channel has to be large enough to meet the cell-wide coverage requirement. However, at a location near the BS, where only a small power is necessary, the strong radiation

This work was funded by the National Natural Science Foundation of China under Grants 60572090, 60472045 and 60496313, and by Ph.D Programs Foundation of Ministry of Education of China under Grant 20050614009.

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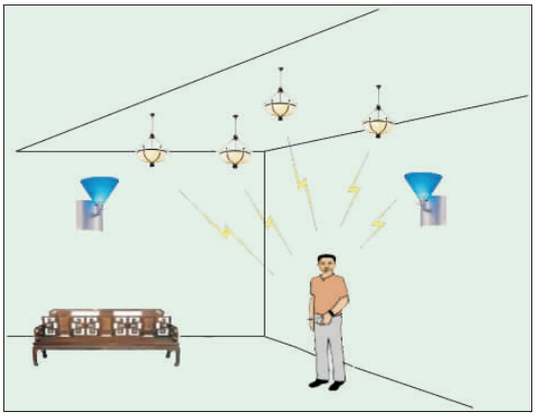
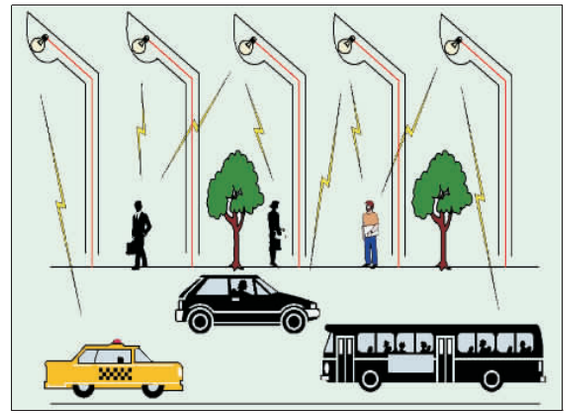


▲Figure 1. An indoor scenario of IL-based wireless access.



▲Figure 2. An outdoor scenario of IL-based wireless access.

arising from the large transmitting power is harmful to the user's health. It is for this reason that most residents object to installing a BS in their residential area.

(4) Expensive radio spectrum resources under 5 GHz

The available spectrums under 5 GHz are quite scarce and have become so expensive that the users can no longer bear. Meanwhile, the license-free spectrums (i.e., the Industrial, Scientific and Medical (ISM) bands), such as the 2.4 GHz, are now suffering crowdedness. (The Wireless Local Area Network (WLAN) and Bluetooth use ISM bands.)

To solve the above four bottlenecks, and to meet the requirements for the future mobile communication system concerning capacity and transmission rate, this paper proposes an Information Lamp (IL) based, new mobile communication system framework, which adopts the multi-antenna signal processing technology as its core technology. It also discusses the typical scenarios for indoor and outdoor access, as well as the technologies involved in the IL-based network.

1 Overall System Structure

As the indoor and outdoor lighting lamps spread over the urban areas, a user, at any location, can be very close to a lighting lamp. Therefore, an IL can be assembled, by integrating the wireless Access Point (AP) into the lighting lamp, to send and receive signals. In the uplink of an IL-based communication system, the signals received by the wireless APs will be sent to the central signal processor via the power line for necessary processing. While in the downlink, the processed signals will be transmitted from the central processor to the wireless receiving device (e.g., mobile station) via the power line and the wireless APs in the information lamps.

1.1 Typical Indoor/Outdoor Scenario

Figure 1 is an indoor scenario of an IL-based wireless access. With the APs integrated into the indoor lighting lamps, the wireless terminal (e.g., notebook PC, PDA and mobile phone) can set up connection(s) with one or more APs simultaneously. If the terminal has several antennas, a distributed MIMO system structure will be formed.

The AP in the information lamp performs some signal processing functions, and communicates with the central signal processor via the power line. After the radio signals are separated from, and uploaded onto the power line by the signal separator or coupler, they will be transmitted to the central signal processor via the power line (or via other media such as optical fiber after the signals are converted). At the central processor, the power line-delivered signals and some distributed space-time signals will be processed.

Figure 2 is an outdoor scenario of IL-based wireless access where the street lamps are used as wireless APs. The mobile terminal, or vehicle mounted station, accesses the communication network via the APs around it. These APs are connected to the central signal processor with the power lines, optical fiber cables or coaxial cables. In this way, the terminal communicates with the backbone network.

1.2 Network Hierarchy Model

Figure 3 gives a network hierarchy model for the IL-based mobile communication system. According to this model, there are three main layers from the user end to the core network: access layer, signal processing layer and management layer. The signal processing layer is further divided into three sublayers: wireless conversion, power line conversion, and processing. The functions of each layer are described as follows:

(1) Access Layer

The Access Layer mainly consists of user devices and information lamps. A user device can communicate with several information lamps at the same time to form a distributed MIMO structure. The interface between the user device and the information lamp is air interface (wired interface may be provided for special user device). The user devices here refer to all kinds of terminals supported by the network and have access demands like mobile phone, notebook PC, vehicle mounted station and GPS equipment, for instance.

(2) Signal Processing Layer

The Signal Processing Layer converts wireless signals into power line (or optical fiber) signals or vice versa, and processes some distributed space-time signals. It is further divided into three sublayers:

- Wireless conversion sublayer, which converts the physical format of air interface wireless signals into that of power line (or optical fiber) communication signals.
- Power line conversion sublayer, which connects the processing sublayer and the power line (or optical fiber) communication module, and converts the format from power line (or optical fiber) communication signals into wireless signals.

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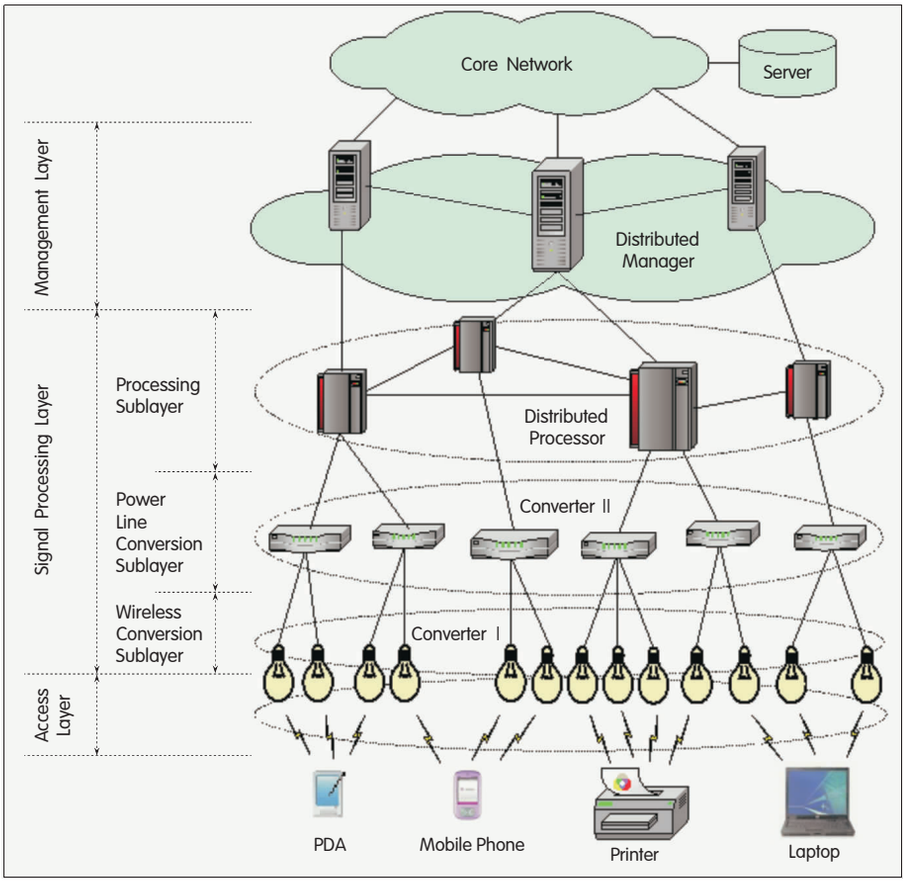

▲Figure 3. Network hierarchy model for the IL-based mobile communication system.

• Processing sublayer, which processes some distributed signals.

(3) Management Layer

The Management Layer manages the distributed signals, and directly interchanges its information with the core network.

2 Advantages and Challenges

Using the multi-antenna distributed signal processing technology as its core technology, and managing the distributed ILs with the distributed radio resource management technology, the IL-based communication system is advantageous in structure, and suggests a good solution for the four existing basic problems of mobile communications.

(1) The BS address selection problem is avoided.

With the AP installed in the lighting lamp, the BS address selection is no longer a problem. Besides, the AP is hidden in the lamp and is thus, good-looking.

(2) The low power mobile phone is possible.

As mentioned above, the average transmitting power of a GSM phone is 1 W, and that of a CDMA phone ranges from 0.01 W to 1 W. Suppose the average distance between the IL-based AP and mobile phone is 10 m, the average distance between the GSM or CDMA BS and mobile phone is 250 m (a conservative value), and the interference allowances of the distributed AP and the receiver of traditional GSM/CDMA BS are the same. Basing on the fading law of electromagnetic wave propagation in free space, the calculation indicates that the transmitting power of the mobile phone using IL-based access will be 28 dB less than that of the GSM/CDMA phone. Therefore, the short-distance, distributed IL-based access solution makes the extremely low power mobile phone possible.

(3) The transmitting power of BS is greatly lowered.

Generally, the average transmitting power of a CDMA base station with a coverage radius of 100 m – 500 m is 0.25 W. From the assumptions above, the distributed IL-based AP can lower the transmitting power of the broadcast channel by a maximum of 10 000 times.

(4) The use of higher band spectrum is possible.

In the IL-based wireless access, the Line-of-Sight (LOS) channel is likely to occur. As we know, the fading of short-distance LOS channel is insensitive to carrier frequency. So, it is possible for such a system to use a frequency band higher than 5 GHz.

(5) It is safe and good-looking.

The integration of the wireless AP into the lighting lamp can better protect the AP from fires or other damages and make it more beautiful in appearance.

(6) It enables easy, flexible and controllable access.

In an indoor environment, the APs can be installed or turned on/off by the user in the same way as the lighting lamp or in a way he likes. Therefore, the operation of the APs becomes quite simple and convenient. Besides, the users will not interfere with each other when using the APs respectively.

As a future-oriented, new wireless communication architecture, the IL-based distributed mobile communication system is still challenged in the core technologies, either for the distributed signal processing in the physical layer or for the distributed signal management in the protocol layer. Many initiative researches have to be done regarding the core technologies. Following are some critical problems that have to be solved:

(1) Integration of AP and lighting lamp

The integration of APs and lighting lamps, which should not be a simple put-together, but a perfect merging, is the primary problem for IL-based access.

(2) Conversion between wireless and wired communications

In indoor access environments like homes and offices for instance, the information lamp is connected with the power line and uses it to deliver information. As a result, the physical formats of the information have to be converted for wireless and wired communication respectively, and the

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high capability processing chip will be required.

(3) Information security

The power line is a typical information-sharing transmission media. Therefore, the information security on the power line is still an open issue. At present, standardization organizations for power line use the Data Encryption Standard (DES) as a temporary solution, which have been detailedly discussed in references [9] and [10].

(4) Resource management of distributed signals

Although the IL-based AP is similar to the traditional BS with regard to access function, its large number and irregular geographic distribution are difficult to be dealt with using traditional radio resource management methods. As a result, a distributed signal management method should be developed, including its concept, way of thinking and operation.

(5) Modeling based on short-distance channel characteristics

The application environment of information lamp determines that its access distance will decrease dramatically compared to the traditional mobile communication systems. Therefore, it is necessary to accurately measure the MIMO channel for short-distance access, and then set up a proper propagation model based on the channel's characteristics.

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Biographies

Tang Youxi received his B.E. degree in radar engineering from College of PLA Ordnance, Shijiazhuang, China, in 1985 and M.S. and Ph.D. degrees in communication and information system from University of Electronic Science and Technology of China (UESTC), Chengdu, in 1993 and 1997, respectively. He was a program manager in Huawei Technologies Co., Ltd., from 1998 to 2000, working in the area of IS-95 mobile communications and the third generation mobile communications. Since 2000, he has been with the National Key Lab of Communications (NCL) of UESTC, as a professor. His general research interests include spread spectrum systems and wireless mobile systems, with emphasis on signal processing in communications.

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Roundup

ZTE Corporation Selected for Telkom Indonesia's CDMA Network Expansion

August 30, 2007, Shenzhen, China – ZTE Corporation ("ZTE"), a leading global provider of telecommunications equipment and network solutions, announced that it has recently signed an agreement with Telkom Indonesia ("Telkom"), the largest InfoCom company and full-service network provider in Indonesia, to help expand the CDMA2000 network capacity for national coverage. Under the contract, the network expansion will cover the four main cities of the eastern part of Sulawesi, Indonesia.

"We endeavor to expand a high quality CDMA network in Indonesia and are delighted to have ZTE as our network provider and partner for the project. We have tested and evaluated multiple potential providers during the past two years, ZTE delivered good performance and cooperation, and also provided the solution that complies with all our network requirements," said Syarif S.A, executive general manager of Telkom Flexi. "We are confident that this collaboration will deliver an enhanced, robust and reliable CDMA network for the country."

Telkom is Indonesia's largest integrated infocom carrier with the largest CDMA network in the country. Its fixed wireless network brand, "TelkomFlexi", is currently being used by 5 million users representing 50 percent market share of Indonesia's CDMA total market size. As one of Telkom Indonesia's major providers, ZTE has almost 3.5 million lines of CDMA network capacity.

ZTE previously partnered with Telkom in August 2004, when ZTE supplied the optical network products for Telkom's national backbone network transmission project. ZTE was selected by Telkom among other bidders for the project due to its proven technical solution.

ZTE is currently the mainstream CDMA provider in the global market, with its CDMA users' capacity exceeding a hundred million. The company currently possesses the highest number of countries and operators using its CDMA network in the industry, with over 70 countries and more than 120 operators. To date, the total capacity of ZTE's CDMA network in Indonesia has reached 15 million lines, which makes the company as the key CDMA provider in the country.

(ZTE)

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