Human Area Networking Technology: *RedTacton*

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Abstract

Ubiquitous services that are genuinely user-friendly to everyone will require technologies that enable communication between people and objects in close proximity. Focusing on the naturalness, inevitability, and sense of security conveyed by touching in everyday life, this article describes human area networking technology that enables communication by touching, which we call *RedTacton*. Here, the human body acts as a transmission medium supporting IEEE 802.3 half-duplex communication at 10 Mbit/s. The key component of the transceiver is an electric-field sensor implemented with an electro-optic crystal and laser light.

1. Introduction

Today people can communicate anytime, anywhere, and with anyone over a cellular phone network. Moreover, the Internet lets people download immense quantities of data from remotely located servers to their home computers. Essentially, these two technologies enable communications between terminals located at a distance from each other. Meanwhile, all kinds of electronic devices including personal digital assistants (PDAs), pocket video games, and digital cameras are becoming smaller, so people can carry around or even wear various personal information and communication appliances during their everyday activities. However, user-friendly ubiquitous services involve more than just networking between remotely located terminals. Communication between electronic devices on the human body (wearable computers) and ones embedded in our everyday environments such as illustrated in **Fig. 1** is also critical, so this has driven extensive research and development on human area networks.

Wired connections between electronic devices in human area networks are cumbersome and can easily become entangled. Short-range wireless communication systems such as Bluetooth and wireless local area networks (IEEE 802.11b, etc.) have some problems. Throughput is reduced by packet collisions in crowded spaces such as meeting rooms and auditoriums filled with people and communication is not secure because signals can be intercepted. The principle drawback of infrared communications (IrDA) is the tight directionality of beams between terminals needed for the system to be effective.

The ultimate human area network solution to all these constraints of conventional technologies is "intrabody" communication, in which the human body serves as the transmission medium. In ubiquitous services (which imply communication between electronic devices embedded in the environment in close proximity to people), if we could use the human body itself as a transmission medium, then this would be an ideal way of implementing human area networks because it would solve at a stroke all the problems including throughput reduction, low security, and high network setup costs.

The concept of intrabody communication, which uses the minute electric field propagated by the human body to transmit information, was first proposed by IBM [1]. The communication mechanism has subsequently been evaluated and reported by several research groups around the world. However, all

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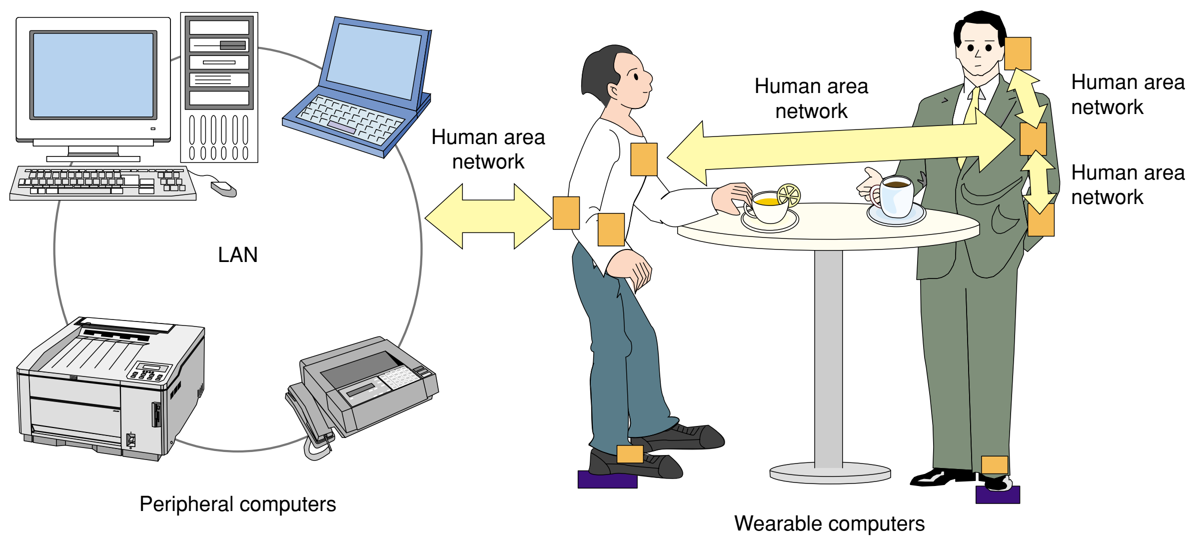

Fig. 1. Human area networking technology.

those reported technologies had two limitations: 1) the operating range through the body was limited to a few tens of centimeters and 2) the top communication speed was only 40 kbit/s. These limitations arise from the use of an electrical sensor for the receiver. An electrical sensor requires two lines (a signal line and a ground line), whereas in intrabody communication there is essentially only one signal line, i.e., the body itself, which leads to an unbalanced transmission line, so the signal is not transmitted correctly.

2. Human area networking

NTT has had excellent success with an electro-optic sensor combining an electro-optic crystal with laser light and recently reported an application of this sensor for measuring high-frequency electronic devices [2], [3]. The electro-optic sensor has three key features: (1) it can measure electric fields from a device under test (DUT) without contacting it, which minimizes measurement disturbance, (2) ultrawide-band measurement is possible, and (3) it supports one-point contact measurement that is independent of the ground, which is the most significant feature in the present context. NTT utilized this third feature to fabricate an intrabody communication receiver for its human area networking technology, which is called *RedTacton**.

The operating principle of *RedTacton* is illustrated in **Fig. 2**. The electric field induced toward the body by the transmitter's signal electrode is represented by E_a. The system requires a ground close to the transmitter signal electrode, so electric field E_b induced from the body can follow a return path to the transmitter ground. Moreover, since people are usually standing on a floor or the ground, electric field E_c escapes from the body to ground, mainly from the

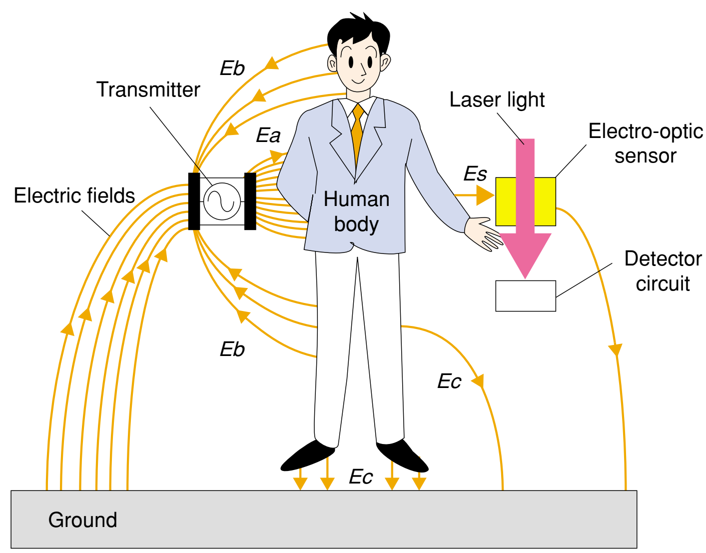

Fig. 2. Principle of *RedTacton*.

* *RedTacton*: The name we chose for this technology is derived from "touch-act-on" meaning "action triggered by touching" combined with red, which in Japanese culture is an auspicious color with connotations of warmth and love, to convey the cordiality and warmth of interpersonal communications [4].

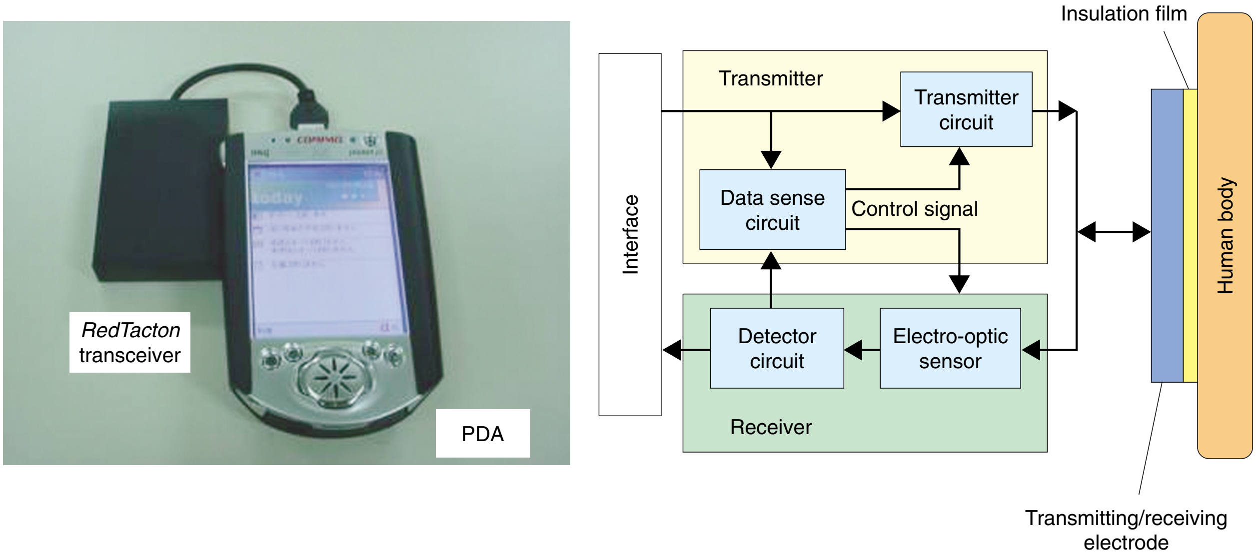

Fig. 3. *RedTacton* transceiver.

feet. The electric field *Es* that reaches the receiver is $Es = E_a - (E_b + E_c)$. It couples to the electro-optic crystal and changes the crystal's optical properties. This change is detected by laser light and transformed into digital data by a detector circuit.

3. *RedTacton* transceiver

Figure 3 shows a photograph of the *RedTacton* transceiver connected to a PDA and a block diagram of the *RedTacton* transceiver [5] developed by NTT. The transmitter consists of a transmitter circuit that induces electric fields toward the body and a data sense circuit, which distinguishes transmitting and receiving modes by detecting both transmission and reception data and outputs control signals corresponding to the two modes to enable two-way communication. We implemented a receive-first half-duplex communication scheme that sends only after checking to make sure that there is no data to receive in order to avoid packet collisions between terminals in compliance with the IEEE 802.3 protocol. The receiver consists of an electro-optic sensor and a detector circuit that amplifies the minute incoming signal from the electro-optic sensor and converts it to electrical signal.

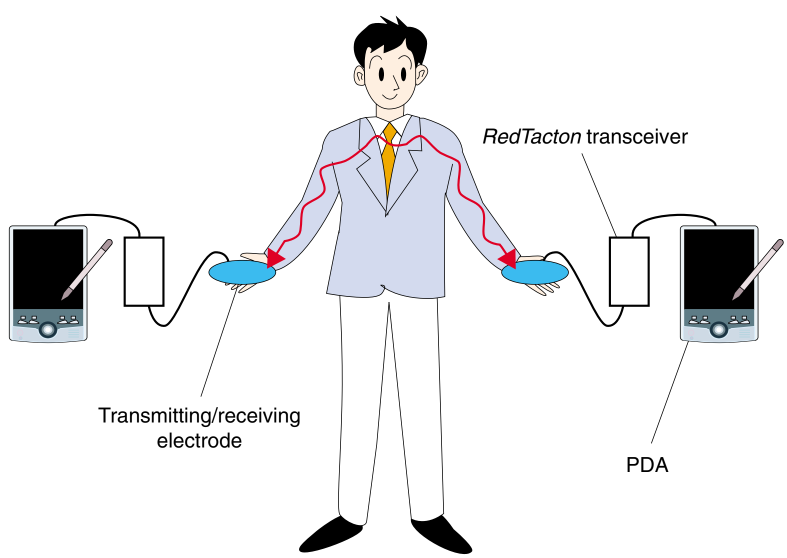

Fig. 4. Experimental setup for intrabody communication.

We conducted a series of trials in which data was sent through human bodies using *RedTacton* transceivers. The experimental setup for intrabody communication assuming communication between two electronic devices (PDAs) is shown in **Fig. 4**. We prepared two sets of *RedTacton* transceivers, each connected to a PDA. The subject held one transmitting/receiving electrode in each hand. We quantitatively measured the bit error rates of signals sent through the body. The results showed that the system had no significant practical problems at a transmission speed of 10 Mbit/s. Besides communication between two hands, we also demonstrated reliable communication between a foot and finger and between other locations on the person's body. We also verified that good communication was achieved not only when the electrodes were in direct contact with the person's skin, but also when the signals passed through clothing and shoes.

4. Human safety

We investigated the effects of *RedTacton* technology on human health, which is obviously an important issue. First, as shown in Fig. 3, the transmitting and receiving electrodes of the *RedTacton* transceiver are completely covered with insulating film, so the body of the person acting as the transmission medium is completely insulated. This makes it impossible for current to flow into a person's body from the transceiver.

When communication occurs, displacement current is generated by the electrons in the body because the body is subjected to minute electrical fields. However, such displacement currents are very common everyday occurrences to which we are all subjected. *RedTacton* conforms to the "Radio Frequency-Exposure Protection Standard (RCR STD-38)" [6] issued by the Association of Radio Industries and Businesses (ARIB). The levels produced by *RedTacton* are well below the safety limit specified by this standard.

5. Applications

In this section we highlight three distinctive features of *RedTacton*. First, a transmission path is formed automatically by body contact and this initiates communication between electronic devices. A device can be started, information can be obtained, or various services can be triggered by a wide range of natural human actions such as grasping, sitting down, walking, or standing in a particular place. Second, the communication is interactive and broadband. In contrast to RFID (radio frequency identification), which is only capable of one-way transmission of short ID messages, *RedTacton* supports two-way exchange of large amounts of data between portable electronic devices. In contrast to conventional wireless systems, *RedTacton* provides an independent transmission path for each individual person (that is, for each conductor) even in congested places, so it provides very secure, fast communication without any interference. Third, almost anything that acts as a conductor—a human or animal body, water, metal, etc.—can serve as a *RedTacton* transmission path. This means that there is no need for a dedicated cable or antenna.

Some representative applications of *RedTacton* are shown in **Fig. 5.** Figure 5(a) illustrates communication between mobile electronic devices on one person. In this case, the person is listening to music from a portable audio device through earphones. Instead of a physical cord tethering the two devices, the data is passed through the person's body. Similarly, one could envision a worker wearing a head-mounted display performing a complex task based on instructions delivered through his body from a pocket-sized computer. Figure 5(b) shows communication between devices on different people, enabling them to exchange electronic business cards by shaking hands. Figure 5(c) illustrates communication between an electronic device on a person and one embedded in the environment. One can easily think of a wide variety of applications of this type. For example, a person might carry a PDA that transmits an ID or a simple script (computer program) to a device embedded in the environment. Then, when the person briefly touches the system or simply walks through a gate, the transmission could trigger various kinds of action such as opening the gate or assessing the toll or charge. A natural gesture such as turning a knob to open a door could enable identification and authentication of the person seeking admission. Figure 5(d) shows a museum setting where a visitor can hear a detailed description of an object from an audio device embedded nearby by touching the object or simply by standing in front of the object. And finally, Fig. 5(e) illustrates a system where a metal surface acts as the conductor of electric fields instead of a human body. A conductive metal sheet is placed on top of a table, and a conferencing system is created simply by placing devices on it. Laptop computers could be connected to the Internet by simply placing them on such a table. Even different networks could be supported, such as an enterprise LAN (local area network) and Internet access, by providing separate metal sheets for each network.

6. Conclusion

RedTacton is an exciting new technology for human area networking. We have developed a transceiver that uses the human body as a data transmission medium based on an electric-field sensor that uses an electro-optic crystal and laser light. Using this transceiver, we succeeded in achieving 10BASE communication in accordance with IEEE 802.3 through a human body from one hand to the other hand.

While our immediate objective is to implement a

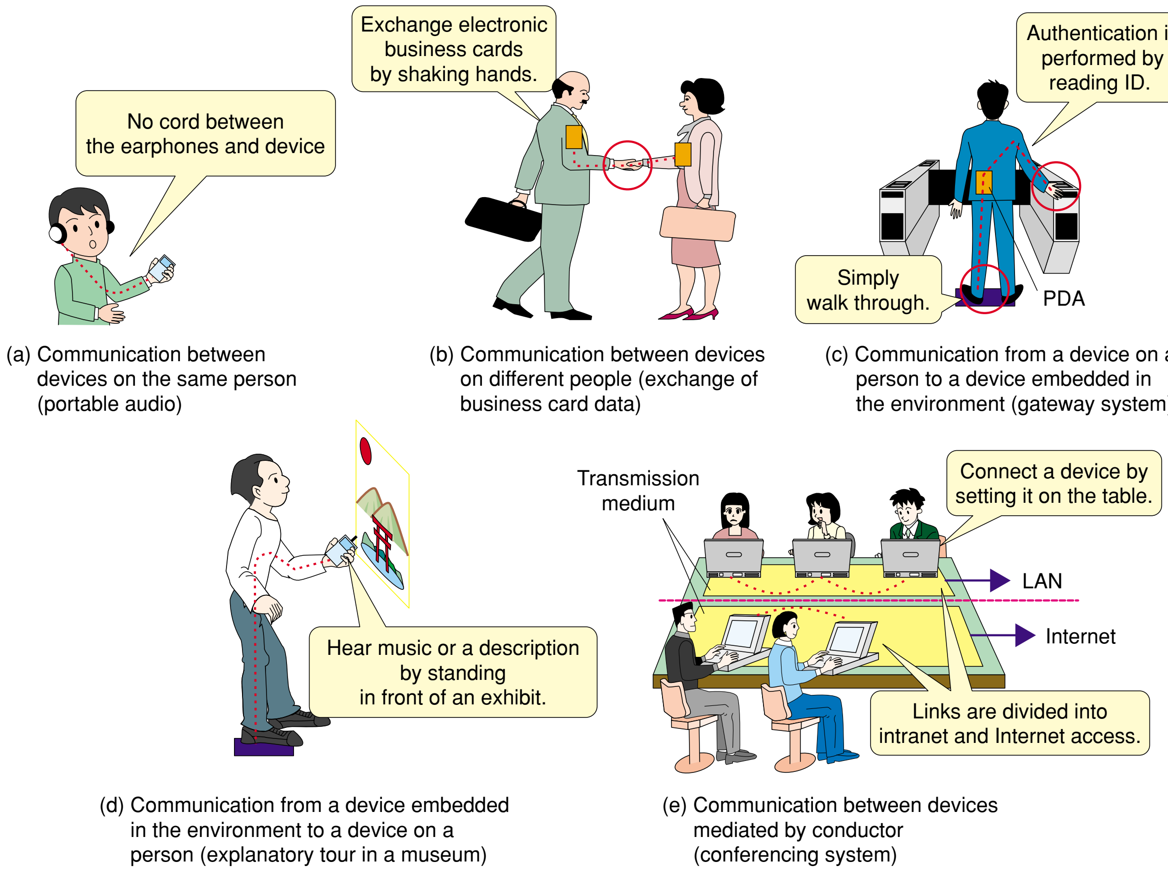

Fig. 5. Applications of *RedTacton*.

RedTacton system supporting two-way intrabody communication at a rate of 10 Mbit/s between any two points on the body, our longer-term plans include developing a mass-market transceiver interface supporting PDAs and notebook computers while continuing efforts to reduce the size and power consumption of the transceiver to enhance its portability. NTT is committed to using its comprehensive commercialization functions to push this research out to the marketplace as quickly as possible while moving ahead with tests and trials in collaboration with commercial partners as necessary [7].

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