Context Aware Service Using Intra-body Communication

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Abstract

An intuitive context aware service between two devices is possible using touch with the direct digital intra-body communication. Using this technology, users with multimedia devices may simply touch them to establish network connection, transfer data, and provide the required service; hence the name Touch-And-Play (TAP). Using TAP, users can disclose their context by touching the specific device. For instance, a user carrying a digital camera touches the TV to begin a slide show or a printer to print a photo. TAP is expected to enable the provision of intuitive, context-aware service. This paper discusses the communication protocol of TAP and its application.

1. Introduction

With mobile devices such as PDAs and digital cameras becoming necessities in our lives, consumers and corporate users need to connect their mobile devices with each other and with various peripherals. Several connectivity methods have been introduced by different mobile product manufacturers including proprietary docks, dongles, slots, connectors, and seven different memory card technologies. In particular, the recently adopted Universal Serial Bus On-The-Go (USB OTG) standard mirrors the growing requirements of exchanging data between two devices. Since these devices are mobile products, however, conventional wired methods such as USB OTG inconvenience the users since they must carry connection cables together with their devices. Furthermore, physically connecting and disconnecting two devices require user intervention, not to mention time and effort. This proves to be cumbersome if the task occurs frequently.

To overcome such disadvantages of wired methods, researchers have come up with wireless methods for device connection. Nonetheless, wireless technologies still need improvements in terms of power consumption and cost and frequency regulation issues. Alongside the increasing density of the device in the environment is the high probability of numerous devices occurring within a wireless network; thus causing network contention. Moreover, the network connection properties of mobile devices vary from those of the traditional network. Such network connections are frequently made and broken according to users actual activities, and their durations are generally short [8]. For example, in case of Bluetooth, a user who wants his/her picture on PDA to be printed has to scan the network, select a printer while navigating through the available devices in the network, connect to the device, select the picture to be printed, select the print menu, and disconnect the network. And the mobile device usually have less means for this kind of input compared to the conventional personal computer, which makes this task more difficult. Although performing these actions takes only a few clicks of the buttons in the device menu, and user preference settings can do away with some of them, learning the device manual still requires the users time and effort.

The user interventions required for these actions convey the information regarding what the user wants. In the previous example of printing a photo in PDA, the following context information can be observed:

- Identity of the user, i.e., authorization of the user to use the printer
- Selection of devices, e.g., printer and PDA
- Selection of the service, i.e., printing
- Data of interest, i.e., photo file to be printed

These kinds of information make up the *context*. Anind K. Dey defined *context* as any information that can be used to characterize the circumstances of an entity, which can be a person, a place, or an object that is considered relevant to the interaction between a user and an application including the user himself/herself and the applications themselves [1]. A context-aware system uses the context to provide the

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relevant information and/or services to the user, whereas relevance depends on the users task. One of the holy grails of context-aware computing is to have the applications do the right thing at the right time for users without their direct manipulation.

Realizing such autonomous, context-aware application requires a method of extracting the context without the manual input of the user. Previous works to extract more contexts from the touch action have been performed. What a person touches and when he or she does so can supply useful information for desktop environments [3]. The touch action can also be used to pick and drop data physically from one place to another [7]. Synchronous touch action between two devices has been used to connect two devices wirelessly [8]. These studies have used information on touch itself based on touch sensors.

These studies have used information on touch itself based on touch sensors. Still, Zimmerman proposed the use of the human body as a transmission medium [10]. Later, many studies have been conducted to enhance its features such as data rate; ditto for a study to understand its characteristics under various environments [2] [6] [5]. Using this communication method, a simple touch action can have more information. Rekimoto et al studied the use of a wearable key to personalize the environment object [4].

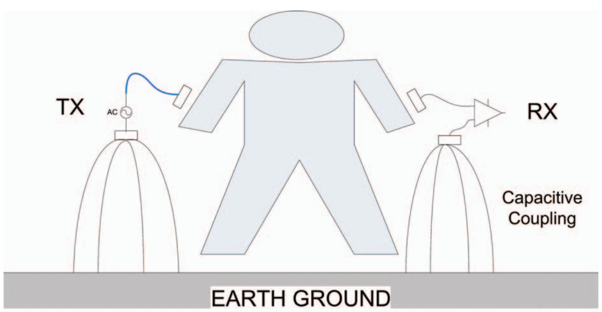

Figure 1. Near-field intra-body communication proposed by Zimmerman

However they usually have focus on the sending the data over the human body but they dont have focus on how the intra-body communication can be used and what will be the merit over the wireless network like bluetooth, Zigbee, UWB. As an application they usually showed the authentication and the sharing the business card. Recently M. Shinagawa et. al [9] succeeded sending 10 Mbps. But they showed sending multimedia data from the floor to the handheld device. Though it was novel, they couldnt provide the justification over the previous wireless network technology. Intra-body communication has a lot of potential and that its UI applications have not been explored deeply. In this paper we tried to explore the application of the intrabody communication. Intra-body communication has good points and bad points. One of the major bad points was it has to touch which require the physical movement of user while with the wireless technology, the user can do with a few button click. However our idea was that this disadvantage can be another advantage when the ubiquitous computing future has come. As there will be a lot of devices waiting to serve, the wireless technology cannot provide the specific context the user is, for it has wide coverage, while the touch action can provide the required context to offer services.

This paper presupposes that the touch, a simple and intuitive action, can be enough for a user to convey the necessary context between intelligent appliances. Using intra-body communication, network connection, data transfer, and selection of appropriate service can be realized. For example, a user reviewing pictures from his/her digital camera may simply touch a printer to establish network communication between the printer and his/her digital camera automatically upon seeing a picture that he/she liked. Likewise, based on the context that the user was looking at a particular picture when he/she touched the printer, the photo file in question is transferred to the printer using intra-body communication for printing. The same thing can happen when the user with a digital camera touches a high-definition television set to start a slide show. This technology was named Touch-And-Play or TAP for short. In this paper, the communication protocol to enable these kinds of service and the demo application are discussed.

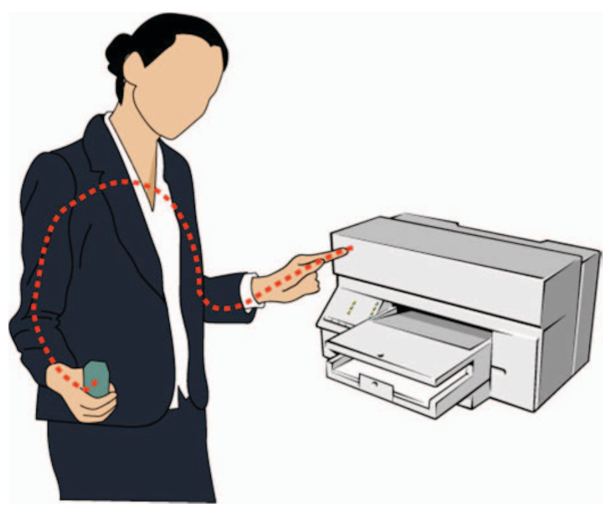

Figure 2. Using TAP, which enables the user to print the desired photo in the camera by touching the printer while holding the digital camera

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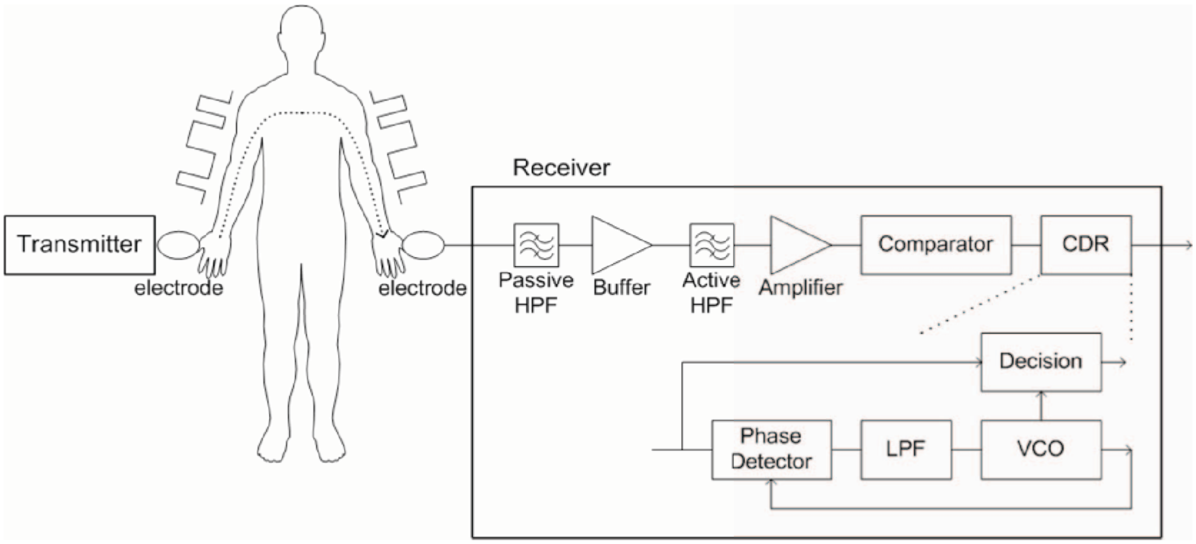

Figure 3. System block diagram of intra-body communication transceiver

2. Communication Protocol of Touch-And-Play (TAP)

2.1. Physical Signaling

The intra-body communication as originally proposed by Zimmerman used on-off keying (OOK), operating at 330 kHz with 2400 bps data rates [10]. Since then, various hardware devices have been developed using intra-body signaling. Kurt Partridge used frequency shift keying (FSK) operating at 180 kHz and 140 kHz carrier frequency with 38.4 kbps data rates [2]. On the other hand, ElectrauraNet from NTT Docomo achieved a remarkable 10 Mbps using electro-optic sensors and non-return to zero (NRZ) signaling without carrier frequency [9]. It used electro-optic sensor for the extremely high input impedance exceeding 100 M and ultra-wide bandwidth. Due to the electro-optic sensor, however, the system size was large (15 by 55 by 80 mm); ditto for power consumption (650 mW). In contrast, researchers in the authors laboratory have succeeded in transmitting and receiving 1 Mbps signal using NRZ signaling based on the electronic sensors. Figure 3 shows the system block diagram of the intra-body communication transceiver. The size of the transceiver was 22 by 22 mm, and power consumption, 30 mW. The output signal from the universal asynchronous receiver transceiver (UART) port of the microcontroller was used. Amplitude was 3 V, and data transmission speed, 1 Mbps with Manchester coding. The signal measured at the receiving site was about 100 mV peak to peak. Figure 4 shows the signal measured at various stages of the receiver. Figure 5 compares the size of the receiver.

2.2. Data Transfer

The broadband signaling of intra-body communication has one channel of communication. This means that transmission and reception cannot occur simultaneously, requiring communication protocol to avoid data collision. To achieve half duplex communication, various strategies can be used, including carrier sense multiple access (CSMA), Master/Slave structure, time division multiple access (TDMA), etc. Note, however, that CSMA requires

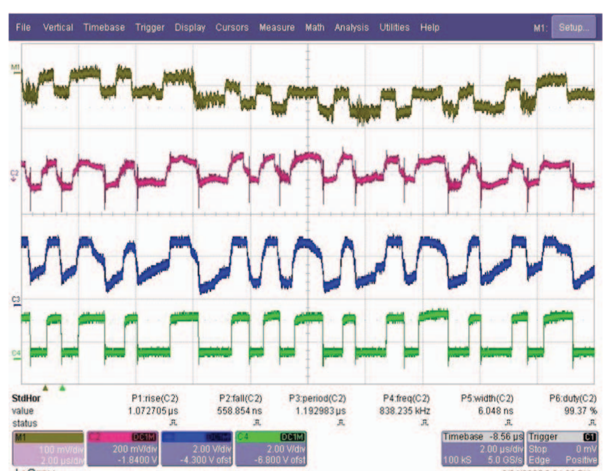

Figure 4. Signal pattern measured at the receiver; from top to bottom: receiver input, filter output, amplifier output, and CDR output as the waveforms

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Table 1. Context-aware matrix between two devices for TAP. The arrow shows which will be the master. F suggests that the first one who sends the packet will be the master. The interaction written in bold type font is group A. Others belong to group B.

	PC	TV	Printer	Camera	Mobile Phone	MP3 Audio
PC	(F)**Network connection**	(←)**Monitor connection**	(←)**Printer connection**	(←)**Camera connection**	(←)**Sync connection**	(←)**Network connection**
TV	(↑)**Monitor connection**		(←)Print TV schedule	(←)**Slide show**	(←)User identification	(←)**Play MP3 music**
Printer	(↑)**Printer connection**	(↑)Print TV schedule		(←)**Print photo**	(←)Print phonebook	(←)Print album title
Camera	(↑)**Camera connection**	(↑)**Slide show**	(↑) **Print photo**		(↑)Set as wallpaper	
Mobile Phone	(↑)**Sync connection**	(↑)User identification	(↑)Print phonebook	Set as wallpaper	(F)**Exchange name card**	(←)Set as ring tone
MP3	(↑)**Network connection**	(↑)**Play MP3 on TV**	(↑)Print album title		(↑)Set as ring tone	(F)**Playlist sync**

some physical means to sense the occurrence of data communication. This means additional hardware is required. Likewise, the TDMA scheme requires a synchronized, high-quality clock, which in turn needs additional hardware. Therefore, half duplex communication using the master/slave structure was used in TAP. Below is the basic flow of data communication:

- Communication is always started by the Master, with the reply given by the Slave.
- When the Master sends and the Slave receives, the Master informs the Slave that data transmission will occur and begins transmission.
- When the Slave sends and the Master receives, the Master queries the Slave at a predetermined frequency (twice every second) as to whether the Slave has something to send. Upon the Masters permission, the Slave begins the transmission.

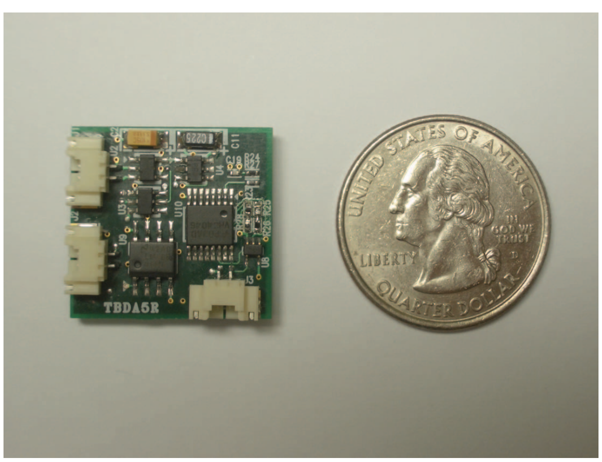

Figure 5. Size comparison of receiver board

The packet structure consists of the header and the data. The header includes information on the packet number, cyclic redundancy code to detect error, destination address, and control code indicating whether this packet is a data packet or a control packet including acknowledgment (ACK) or no acknowledgement (NACK).

2.3. Network Management

The network connection for TAP tends to be frequently made. The duration is also relatively short. Furthermore, the network member tends to change constantly. Thus, adhoc networking is required. The transceiver of the TAP that does not engage in network connection sends configuration packet twice every second. The configuration packet is sent randomly so that the possible collision should be avoided in successive trials. This packet includes the function ID of the device. Once the configuration packet is received, the receiver sends its own configuration packet and searches the context-aware matrix of the devices. The context-aware matrix determines which will be the Master. Table 1 shows the context-aware matrix. The next transmission is initiated by the master device. The context-aware matrix is based on the following properties:

- Computing resource, i.e., processing power of processor, size of RAM, etc.; the more powerful device becomes the Master

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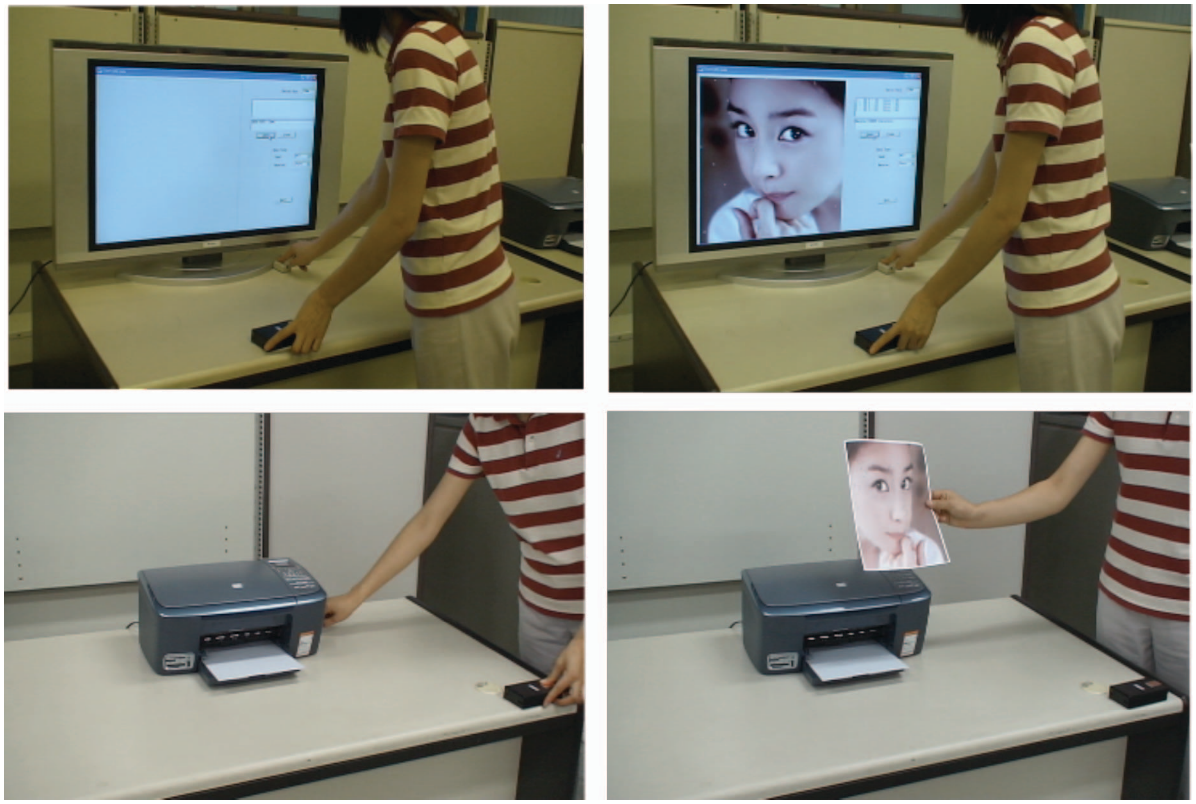

Figure 6. Picture of a demo application (the upper side shows the interaction between the camera and TV; the lower side shows the interaction between a camera and a printer)

- Source or Service, i.e., whether it is mainly a signal source or a service provider; the signal source becomes the Master
- Power resource, i.e., whether it is operated by battery or line power; the device operated by line power becomes the Master

2.4. Context-aware Service

Once the network connection is established, the Master requests for the function ID of the Slave. The function ID refers to the function of the intelligent device. Once it receives the function ID of the Slave, the master searches the context-aware matrix. If the Master is a digital camera, the context-aware matrix decides the required action, or printing in this case. Thus, the digital camera sends the data file to the printer. The user simply touches the printer to print, i.e., touch-and-play (TAP). The context-aware matrix is built such that the most intuitive interaction between two intelligent appliances can be realized. It can even be expanded when a new device is invented. For the most intuitive interaction set, the context action requires further research.

3. Demo Application of TAP

Based on this protocol scheme, the demo application was developed. The scenario of the demo application features the user who has a digital camera and touches the high-definition television (HDTV) to see the picture he/she was reviewing using the LCD display of the camera. Once the user touches the printer, the photo file is printed. A digital camera was replaced with the functional equivalent of the microcontroller (ATmega128L, Atmel, USA), with the picture file stored in flash memory. As a functional equivalent of HDTV, the LCD TV with a notebook computer was used. On the other hand, the printer with a notebook computer was used as a functional equivalent of the printer. The microcontroller was connected with the PC using the USB to the serial extension cable. The microcontroller with the picture file sends the picture data continuously. The program in the notebook computer then receives the picture data and provides the right service according to its functions. Figure 6 shows the action example of the demo application.

4. Discussion

4.1. Context Automation Level

Although there is obvious interaction between devices in case of the digital camera and printer, some interactions are not that intuitive in the case of the MP3 audio and digital camera; thus requiring some kind of interaction level that will prevent any unintended interaction. The context-aware matrix interaction was categorized into two groups: group A, which is intuitive enough for general use, and; group B, which is not intuitive enough but nonetheless helpful. In a context-aware matrix shown at Table 1, a group A interaction is written in bold font. The user can choose from the following context automation levels:

- High: Provide any possible service (group A and group B).
- Normal: Provide any good enough service (group A only).
- Low: Provide the service approved by the user.
- None: Do not provide any service.

4.2. Intuitiveness of Using TAP

Intuitiveness is an important requirement in future appliances. As more devices become complex, people have a hard time learning how to use them. TAP is very intuitive because the approach used in this study focuses more on the purpose of action than the process of action. In the example of camera and printer interaction, the previous approach of Bluetooth or USB requires the user to make a network connection before printing and break it after printing. These network management actions are not directly associated with the printing action that the user focuses on; they only form part of a required process to enable printing. Thus, they should consequently be learned. With TAP, the user simply touches the devices involved in the task. Although TAP is also characterized by network connection and disconnection, the main difference between the two approaches is that TAP does not require user intervention. All the context information required to make network connection and data transfer can be obtained even without user intervention through the simple touch action.

4.3. Security of Using TAP

The security of using TAP is needs to be evaluated for the privacy problem. This can easily be resolved since data communication is confined within the human body. Thus, the possibility of eavesdropping is low [5]. Figure 7 shows the experiment setting for the interference measurement. Figure 8 shows that the interference becomes weaker within 1 meter, with amplitude attenuation of 30 dBm. This means that the privacy of using TAP is secure.

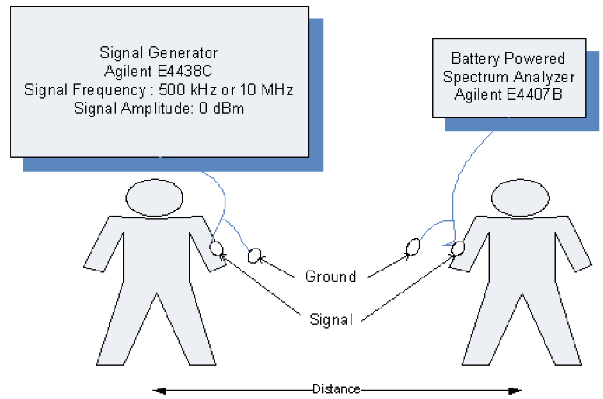

Figure 7. Experiment setting for the interference measurement

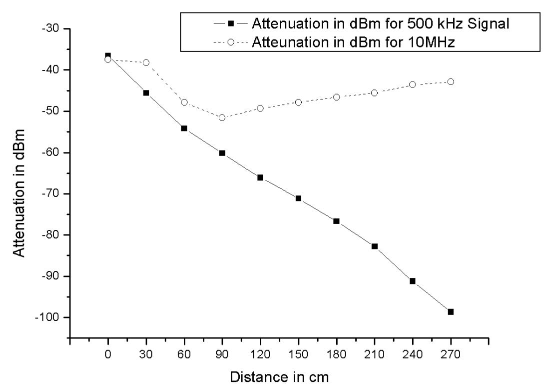

Figure 8. Measured result for the interference measurement

4.4. Intentional vs. Unintentional Touch

Since this service is done automatically, there is always the possibility that unwanted service will be provided. This problem is similar to how much responsibility can be given to servant devices. Although this problem can be minimized using the context automation level, so is the benefit of new technology. Thus, some kind of trade-off between automatic service and security is required. The specific trade-off point will require further research. However, there is some method to be used for differentiating unintentional touch

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and intentional touch.
First method is simple confirmation process required before execution of service. Todays mobile device has one or two mechanism for accepting and canceling maneuver. Using this simple mechanism the user can selectively execute the service. For example when the user viewing the picture touches the printer, after all process of establishing network and deciding context aware service and transferring the required data, the printer may ask the user if he/she wants to print the specific picture. At this stage the user can stop touching the printer and the camera. And the user push the button of printer to accept the printing or cancel it. Though this process is simple to build, it is most powerful to prevent unwanted service. However asking everytime unintentional touch has been established can make the user annoying. So it should be carefully chosen which service to adopt this scheme.
Second method is enabling the TAP service only when the device is activated and in use. For example when the user leaving the office to go home, grasp the PDA and the phone, nothing should happen, for usually these devices will be in sleep status to save battery. This scheme can prevent many cases for the many devices involved in the TAP service are battery sensitive portable devices.
Third method is using only small area of the surface of the device for TAP service. Preferably button type which require intentional pressure by user will make unintentional touching unlikely to happen. For example the user who does handshake are selective at giving his business card. In this case giving his business card only when the user is pushing TAP button of his mobile phone can be solution. This method is most effective but requires additional button hardware. Of course the additional button will cost small. But in the viewpoint of the mobile device design, which is very tight in space requirement, this can be problem.

4.5. Multi-function Convergence Device

It is difficult to define the default service in case of a multi-function device. For example, if the connection between the PC is made, one cannot identify the default service since there are many possible services that can be provided by the PC. Furthermore, the trend is toward convergence. The new printer has a scanner, a photocopier, and a fax. Thus, it is hard to make a decision as to which function ID it should have once it is registered for context-aware matrix.
One of the major application devices will be a smart phone. Nowadays, a smart phone usually has an MP3 player function, a digital camera function, and a PDA function with the basic mobile phone function. All of these functions are members of the function ID matrix. Thus, the static permanent function ID for smart phone is impossible.
One solution involves using a dynamic function ID allocation per communication session. Usually for human interface design, the system is designed to have only one focus of interaction at a time. For example the PC can have many windows for task. However usually only one window receives the input focus. Similarly the menu of the smart phone usually has one single focus. So the function ID of the smart phone can be determined with the function with the focus. For example of the smart phone, when the user is watching the pictures he taken, the configuration packet for TAP is the camera. When the user is listening to MP3, the configuration packet will be MP3. And when the user is reviewing his address book, the configuration packet will be mobile phone to enable exchanging the business card. So if the user was looking at the address book of the mobile phone when touching the printer, the address will be printed. Or if the user was looking at the photo when touching the printer, the photo will be printed.

4.6. Body Area Network

Although the body area network using intra-body communication is physically feasible, the touch-based, context-aware service with more than three devices is still not that intuitive from the viewpoint of user interface design. Likewise, the interaction between multiple devices is neither intuitive nor single; hence the insufficient context for the interaction.

4.7. Coexistence with other communication Method

Although intra-body communication has several advantages, it still have many disadvantages. To name a few, the user have to hold touching while communicating and the data rate is still low compared to the wireless LAN or ultra wide band (UWB) communication. However the TAP can be used with these technology to complement them. For example when the users with their laptop meet at the conference, they may establish the temporary network. This may require many contexts like MAC address, IP address, etc. These contexts can be transfered safely with TAP and once these information is shared, wireless LAN can be used to communicate. Similarly when the camcorder and TV is touched to enable TAP, the user can go to the sofa and watch the video while the movie data of camcorder is transfered to TV using wireless 1394 or wireless USB. In this way the complex network setting process can be simplified.

5. Conclusion

5.1. Novelty

What is novel about this approach is that all the context information for providing service to the user is combined in the simple touch action; thus enhancing user convenience through intuitive interaction.
Because our work deals with the higher layer in communication, it does not matter what physical layer is used to communicate. For example, previously developed electro-optic transceiver module [9] or FSK module by various group [6] [4] can be used to make TAP experience. This is like the upper layer of TCP/IP works regardless of the physical layer being 10base2, 10baseT, Wireless Lan or Optical fiber network.

5.2. Future Research Direction

The development of the fully functional protocol software stack working on the ARM7 microcontroller is ongoing. Likewise, the WinCE PDA with digital camera and MP3 functionality is under construction to demonstrate the real environment demo of TAP. Once the functional PDA is built, it will be possible to evaluate user experience. The context automation matrix should also be extended. Finally, a more standard way of imposing an automation interaction between two devices is required.

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