

Use Case and Service Framework for WPT (Wireless Power Transfer)

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Abstract — Wireless power transfer (WPT) is one of the promising technology of the near future with devices transferring electric energy from one device to another in wireless manner. Currently, many researchers and organizations focus on the wireless power transfer technologies itself concentrating on device to device(s) interaction. However, a standardized infrastructure with interaction of various applications and services is needed to deploy the wireless power transfer technology. Therefore, it is necessary to develop a WPT based service framework in order realize various types of commercial services such as electric car charging system on public highway and outdoor charging system for wearable/mobile devices. This paper describes some of the use cases that should be considered and define a service framework consisting of various players in providing service control and charging policy for WPT based application and services.

Keywords—Wireless Power Transfer, Use case, Service Framework

I. INTRODUCTION

Wireless power transfer (WPT) is a technology that can transfer electric energy from a power source to other units in wireless manner. This research was started from the 19th century [1]. WPT technologies have many potential benefits that can be adopted in various parts of today's society. WPT technologies are applied to mobile phones, smart pads, electric cars, moving robots, healthcare equipment, and also various wearable devices. WPT is defined as a method of getting useful electricity from one place to another without the need for electrical conducting media. Usually, this process involves a phenomenon known as electromagnetic induction. WPT is realized by two core technologies, i.e., inductive coupling and resonant coupling. Inductive coupling can transfer electrical wireless energy in very short range, approximately a few centimetres. On the other hand, resonant coupling technology can transmit energy up to 2 meters.

Currently, many researchers and organizations focus on the wireless power transfer technologies itself concentrating on device to device(s) interaction. However, a standardized infrastructure with interaction of various applications and services is needed to deploy the wireless power transfer technology. Therefore, it is necessary to develop a WPT based service framework in order realize wireless electric charging of various types of commercial services as electric car charging system on public high-way and outdoor charging service of wearable/mobile things at public areas. Those

services need to provide standardized service control and management, reliable authentication/authorization, fare-charging policy, etc. Figure 1 shows an example of wireless power transfer services that can be applied to various parts of our lives. The object of this paper is to define a service framework that needs to be considered in order to deploy the WPT based services and applications.



Figure 1. Examples of wireless power transfer service

This paper is organized as follows. The following chapter describes some related standardization activities with the description on the standard documents for WPT. Chapter 3 describes some of the service use cases for WPT in various areas such as home/office appliances, public space and roadway vehicle. Chapter 4 defines a service framework for WPT-based services. This paper ends in chapter 5 with the concluding remarks.

II. RELATED STANDARDIZATION ACTIVITIES

WPT has been recognized to be one of the key technologies in the future with many standard organizations working on various aspects of WPT technologies. Although there are several small and large standardization groups that is working on the WPT, this chapter looks at four major standardization organizations for WPT and observes some of the issues that are being considered.

A. ISO/IEC JTC 1/SC 6

ISO/IEC JTC 1/SC 6 entitled as “Telecommunications and Information Exchange Between Systems” standardizes various communication technologies regarding physical and data link layers, network and transport layers, directory, ASN.1 and registration [2]. The ISO/IEC JTC 1/SC 6/WG 1 has been standardizing technologies regarding physical and data link layers including Magnetic Field Area Network (MFAN). The MFAN is an in-band wireless network system that enables wireless communication and wireless power transfer within a single frequency band [3]. The standardization on MFAN has

started in 2009. The MFAN consists of 4 parts, which are Part 1: Air Interface, Part 2: In-band Control Protocol for Wireless Power Transfer, Part 3: Relay Protocol for Extended Range, and Part 4: Security Protocol for Authorization. The Part 2, In-band Control Protocol for Wireless Power Transfer, defines basic protocol between coordinator (power source) and node (powered device) for wireless power transfer. The coordinator and node exchange information regarding charging control.

B. IEC TC 100 TA 15

IEC TC100 develops International Standards in the areas of audio, video and multimedia systems and equipment. Recently, TC 100 focuses on emerging technologies – such as the smart home and smart phone – and their systems aspect [4]. The TC100/TA 15 was initiated in 2011 and standardizes technologies related to WPT for multimedia systems and equipment, and interoperability between the WPT transmitting and the WPT receiving functions. TC100/TA 15 has finished a technical report document which surveys current development and standards activities on wireless power transmission and provides a view for possible new work item proposals. It is working on two draft standards which are PT 62827 “Management Protocol of Wireless Power Transfer for Multi-devices” and PT 62857 “Wireless Power Transfer - multiple sources control management”. PT 62827 defines protocol between a single WPT transmitting function and multiple WPT receiving functions. PT 62857 defines standards for wireless transfer from multiple WPT transmitting functions.

C. WPC (Wireless Power Consortium)

Wireless Power Consortium (WPC) is an industry standard group that develops Qi global standards for wirelessly charging electronic products [5]. The Qi standard guarantees that any device carrying the Qi logo will work with any charging surface that carries the Qi logo, regardless of manufacturer or brand. WPC focus on tightly-coupled inductive coupling solutions across a range of power levels [6]. WPC has developed “low power” Qi specification in which the Qi transmitter delivers up to 5 Watt power to Qi devices. This is adequate for small devices such as smart phone, mobile phone, remote control, headset, digital camera, camcorder, etc. The communication in the Qi devices is unidirectional from power receiver to power transmitter to exchange information for the two devices to work together. WPC is working to extend the Qi specification to support medium power which will be able to deliver up to 120 watts.

D. A4WP 9 Alliance for Wireless Power)

The Alliance for Wireless Power (A4WP) is also an international industry standard group that focus on non-radiative, near-field range magnetic resonant wireless power transfer [7]. It provides spatial freedom for charging of electrical devices in cars, on table tops and for multiple devices simultaneously. A4WP mission includes development of industry specifications, management of an A4WP Certification program, including consumer-recognizable certification logo and the coordination with national and international Regulatory agencies regarding WPT policy and

compliance [8]. A4WP have developed V1.1 standard to transfer power between power receiving unit and power transmitting unit through non-radiating magnetic resonance at 6.78MHz. A4WP use Bluetooth Low Energy (BLE) at 2.4GHz for exchanging control message between the two modules. A single power transmitting unit can server multiple independent power receiving unit.

III. SERVICE USE CASES OF WPT

A. WPT Service @ Home/Office

WPT can be used effectively in home or office. There are many appliances and devices in almost every room in the house such as living room, bedroom, kitchen, bathroom, etc. Figure 1 only shows some of the small and midsize appliances that can benefit from wireless electric cord. Although not illustrated in figure 2, large-size appliances can also benefit from WPT, if the WPT can support control and management of WPT devices.



Figure 2. WPT use case for devices at home

There are many benefits from the cordless devices at home. WPC has listed some of the cordless kitchen appliances, although the benefit also pertains to other different appliances and devices at home or office. The listed benefits are as follows.

- Convenient & Clean: appliances can be completely sealed and waterproof; this enables the appliances to be safe from water.
- Easily move appliances: it enables flexibility in placing the appliances. It is possible to enjoy warm and cold food in the balcony or front porch without any long electric extension cords extended from the electric outlet.
- Space efficient: It is possible to store away non-frequently unused appliances.
- Safe and robust: no more electric shock hazard, even if the work surface is wet and full of water.
- Smart: it is possible to control the power source for automated cooking.

The WPT devices at home or office may not have critical authentication and accounting issues compared to devices in public space. However, in order to provide smart WPT service, there is an issue of management and control of WPT devices. It is possible to define a unified method of managing and controlling WPT devices.

Although it is not an issue for current stage of WPT technical development, the use of wireless electricity by unauthorized devices should also be considered in the future. Many homes in the metropolitan area tend to be close together, which can be face with issue of wireless electricity leakage.

B. WPT Service @ Public Space

There are many types of electric devices people carry when leaving home to go out to the public spaces. Such devices include smart phone, radio, camera, notebook, etc. Some people need to carry various medical or healthcare devices wherever they go. People tend to rely on the battery of the electronic devices and try to make sure that the batteries are fully charged before leaving home or office. It is possible to recharge the battery in the public space, but, there are many inconveniences to endure. Some of the problems include finding an adequate place for recharge, waiting for the devices to be recharged, need of carrying charging adaptor, etc.



Figure 3. WPT use case for devices at public space

If the public can provide WPT-based charging service, many of these problems would be solved. People would not have to worry about having dead batteries. Figure 3 shows some of the example of installing WPT power source. It can be installed in the bus stop where people would have to wait for some time for the bus to arrive. For large parks or in open space, it is possible to provide WPT service directly from the electric pole. It is possible to provide various types of services in the public space. Some examples are as follows.

- User can pay certain amount of fee to be provided with the WPT-based charging service from the WPT service provider in the public space. The WPT service provider will need to authenticate the user when using WPT service.
- WPT charging service can be used as part of an advertisement reward, where a company can provide a charging coupon to increase charging effect. A user can use the charging coupon to get free charging service from WPT.
- People with health problem may need to carry various health devices with battery. It is possible for the health device to send the measured figure to the hospital during charging. In this case the transmitted information needs to have integrity and protection from disclosure.

It is possible to associate various types of services with WPT in the public space.

C. WPT Service @ Road

The greatest potential is the use of WPT service in electric vehicles [9]. The conventional electric vehicles would need to go to an EV charging station and plug-in to the charger which can supply high current to the electric vehicles. A normal charging time is 20 minutes to 8 hours depending on the type of power supply is used. Thus, this is a long time for a car to wait in order to start moving. With WPT, electric vehicles would not need an electric cable and avoid the electric discharge from the lack of the electric station. A public road such as crossroad and uphill slope can have a wireless

inductive charging service as shown in figure 4. Any place in the road in which the car would need to stop or move in low speed can be a candidate for electric charging. Since the car is charged frequently, visiting time to the EV charging station would reduce.

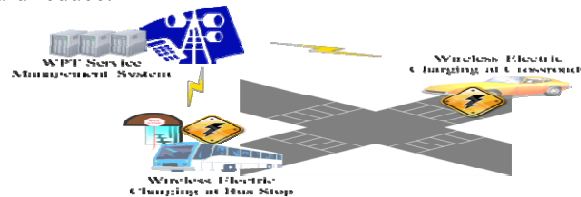


Figure 4. WPT use case for electric vehicles at crossroads

When an electric vehicle comes to WPT-based charging areas, it requests the electric charging for electric transmitter. The electric transmitter responds with the request and starts to charge the car with WPT. Electric vehicles use high power energy during charge, and a service provider for WPT can request the fare for charging service at the roads. In order to provide this service, WPT needs to consider the following capabilities:

- Authentication & authorization for mobile things and users
- Security imposed on the exchanged data
- Proper metering and accounting information
- Interoperability between WPT devices & services

IV. SERVICE FRAMEWORK FOR WPT

The following figure 5 shows the proposed WPT service framework in which several domains are involved: Customer domain, Reseller/Distributor domain, WPT service domain, Power supplier domain, communication service provider domain, ICT service provider domain and conference testing domain.

Customer with multiple devices needs WPT charging service. Devices may include mobile phone, radio, sensors, etc. WPT service provider offers WPT charging service to customers with help of location management, AAA, OAM. Reseller/distributor relays WPT service provider's charging service to customers. To relay charging service, it meters, charges, and controls WPT charging service.



Figure 5. Reference model for WPT service

Communication service provider enables customer's communication during the charging service. ICT service

provider enables 3rd party application services. Power supplier provides electricity to reseller/distributor. All the domains are interconnected via wireless/wired network.

The following figure 6 shows how WPT application service can be provided by electric provider and electric charging service provider.

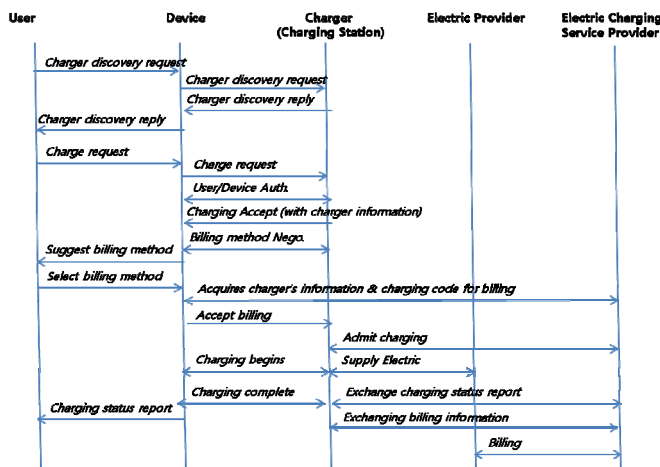


Figure 6. WPT charging service flow diagram

Phase I is to discover nearby charging station (aka, charger). A user who has a mobile device with a lack of electric power starts wireless power charging by activating its mobile device to discover nearby WPT charger. User's device finds nearby charger (WPT charging station) through a periodic discovery request messages. Once the device finds an available charger, it reports the information of the charger to the user.

Phase II is to initiate WPT charging service. To start WPT charging service, the user request its mobile device to start charging then the device relays user's request to charger. After the request of charging, authentication for user and device follows. After successful authentication, charger answers with charging acceptance as well as charger's information. Example of charger's information includes MAC address and service code of charger.

Phase III is to negotiate how to pay for the charging service. A user can pay for its power charging with various methods such as coupon, pre-paid card, or any credit number. A procedure to negotiate how to pay the bill between the user and charging service provider is necessary. Assume that the charging service provider has already set the guidance of payment method. A user selects one of billing methods provided by the charger. After selecting billing method, the charger relays billing method to charging service provider.

Phase IV is charging electricity. After the billing agreement has been reached, electric charging starts. During electric charging, charging status is monitored by the charger, after the charge is completed the charger reports the charging status to charging service provider and the device notifies the charging status to the user.

Phase V is to billing between WPT service provider and electricity provider. Exchanging billing information between the charging service provider and electric provider is followed.

V. CONCLUSION

This paper has proposed a service framework that that needs to be considered in order to deploy the WPT based services and applications. In order to define a service framework, this paper has looked at various works of standard organization and level of technical development that should be considered in defining service framework. This paper has also looked at the various use case in areas of home, public, and transportation to find various factors that should be considered in the service framework. The service framework is involves many players, such as service provider, ISP, WPT service provider, power suppliers. This paper has proposed a relationship of the listed players and their roles in providing WPT-based service.

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