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SERIES Y: GLOBAL INFORMATION INFRASTRUCTURE, INTERNET PROTOCOL ASPECTS, NEXT-GENERATION NETWORKS, INTERNET OF THINGS AND SMART CITIES

Internet of things and smart cities and communities – Requirements and use cases

Framework of wireless power transmission application service

Recommendation ITU-T Y.4202

International Telecommunication Union

ITU-T Y-SERIES RECOMMENDATIONS

GLOBAL INFORMATION INFRASTRUCTURE, INTERNET PROTOCOL ASPECTS, NEXT-GENERATION NETWORKS, INTERNET OF THINGS AND SMART CITIES

GLOBAL INFORMATION INFRASTRUCTURE	
General	Y.100–Y.199
Services, applications and middleware	Y.200–Y.299
Network aspects	Y.300–Y.399
Interfaces and protocols	Y.400–Y.499
Numbering, addressing and naming	Y.500–Y.599
Operation, administration and maintenance	Y.600–Y.699
Security	Y.700–Y.799
Performances	Y.800–Y.899
INTERNET PROTOCOL ASPECTS	
General	Y.1000–Y.1099
Services and applications	Y.1100–Y.1199
Architecture, access, network capabilities and resource management	Y.1200–Y.1299
Transport	Y.1300–Y.1399
Interworking	Y.1400–Y.1499
Quality of service and network performance	Y.1500–Y.1599
Signalling	Y.1600–Y.1699
Operation, administration and maintenance	Y.1700–Y.1799
Charging	Y.1800–Y.1899
IPTV over NGN	Y.1900–Y.1999
NEXT GENERATION NETWORKS	
Frameworks and functional architecture models	Y.2000–Y.2099
Quality of Service and performance	Y.2100–Y.2199
Service aspects: Service capabilities and service architecture	Y.2200–Y.2249
Service aspects: Interoperability of services and networks in NGN	Y.2250–Y.2299
Enhancements to NGN	Y.2300–Y.2399
Network management	Y.2400–Y.2499
Network control architectures and protocols	Y.2500–Y.2599
Packet-based Networks	Y.2600–Y.2699
Security	Y.2700–Y.2799
Generalized mobility	Y.2800–Y.2899
Carrier grade open environment	Y.2900–Y.2999
FUTURE NETWORKS	Y.3000–Y.3499
CLOUD COMPUTING	Y.3500–Y.3999
INTERNET OF THINGS AND SMART CITIES AND COMMUNITIES	
General	Y.4000–Y.4049
Definitions and terminologies	Y.4050–Y.4099
Requirements and use cases	**Y.4100–Y.4249**
Infrastructure, connectivity and networks	Y.4250–Y.4399
Frameworks, architectures and protocols	Y.4400–Y.4549
Services, applications, computation and data processing	Y.4550–Y.4699
Management, control and performance	Y.4700–Y.4799
Identification and security	Y.4800–Y.4899
Evaluation and assessment	Y.4900–Y.4999

For further details, please refer to the list of ITU-T Recommendations.

Recommendation ITU-T Y.4202

Framework of wireless power transmission application service

Summary

Recommendation ITU-T Y.4202 defines a framework for wireless power transmission (WPT) application service by describing concept, functional model, requirements, basic service flows and use cases. Wireless power transmission is a technology to transmit electric power wirelessly.

Applications using WPT technology are expanding to mobile and portable devices, home appliances and office equipment, and electric vehicles. In particular, WPT technology is useful in providing electric power to the Internet of things (IoT) devices in constrained environments. The WPT application service is an application service to realize various types of WPT charging for devices capable of receiving electric power wirelessly.

History

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The approval of ITU-T Recommendations is covered by the procedure laid down in WTSA Resolution 1.

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Table of Contents

Recommendation ITU-T Y.4202

Framework of wireless power transmission application service

1 Scope

This Recommendation defines a framework for wireless power transmission (WPT) application service.

WPT is a technology to transmit electric power wirelessly. WPT can be realized in various ways, and applications using WPT technology are expanding to mobile and portable devices, home appliances and office equipment, and electric vehicles. In particular, WPT technology is useful in providing electric power to the Internet of things (IoT) devices in constrained environments.

The WPT application service is an application service to realize various types of WPT charging for devices (IoT devices in the context of this Recommendation) capable of receiving electric power wirelessly.

The scope of this Recommendation includes the following:

– concept of WPT application service;

– functional model of WPT application service;

– requirements of the WPT application service;

– basic service flows for WPT application service.

Use cases of WPT application service are also provided in Appendix I.

NOTE – Electric hazard related issues are out of scope of this Recommendation.

2 References

The following ITU-T Recommendations and other references contain provisions which, through reference in this text, constitute provisions of this Recommendation. At the time of publication, the editions indicated were valid. All Recommendations and other references are subject to revision; users of this Recommendation are therefore encouraged to investigate the possibility of applying the most recent edition of the Recommendations and other references listed below. A list of the currently valid ITU-T Recommendations is regularly published. The reference to a document within this Recommendation does not give it, as a stand-alone document, the status of a Recommendation.

[ITU-T Q.1742] Recommendation ITU-T Q.1742 (2014), *IMT-2000 references to ANSI-41 evolved core network with cdma2000 access network.*

[ITU-T Y.1271] Recommendation ITU-T Y.1271 (2014), *Framework(s) on network requirements and capabilities to support emergency telecommunications over evolving circuit-switched and packet-switched networks*.

[ITU-T Y.2233] Recommendation ITU-T Y.2233 (2010), *Requirements and framework allowing accounting and charging capabilities in NGN*.

[ITU-T Y.4000] Recommendation ITU-T Y.4000/Y.2060 (2012), *Overview of the Internet of things*.

3 Definitions

3.1 Terms defined elsewhere

This Recommendation uses the following terms defined elsewhere:

3.1.1 authentication [ITU-T Q.1742]: The act of verifying the identity of an entity (e.g., a user, device).

3.1.2 authorization [ITU-T Y.1271]: The act of determining if a particular privilege, such as access to telecommunications resource, can be granted to the presenter of a particular credential.

3.1.3 charging [b-ITU-T Q.1741.1]: A function whereby information related to a chargeable event is formatted and transferred in order to make it possible to determine usage for which the charged party may be billed.

3.1.4 wireless power transmission [b-ITU-R SM.2110-0]: The transmission of power from a power source to an electrical load using the electromagnetic field.

3.2 Terms defined in this Recommendation

This Recommendation defines the following terms:

3.2.1 accounting: The process of collecting and analysing service and resource usage metrics for the purposes of capacity and trend analysis, cost allocation, auditing, billing, etc. Accounting management requires that resource consumption be measured, rated, assigned, and communicated between appropriate business entities.

NOTE – This definition is based on the definition of 'accounting' found in [ITU-T Y.2233].

3.2.2 electric charging: The act of providing electric power to devices.

3.2.3 WPT application service: An application service provided in the wireless power transmission (WPT) charging infrastructure for support of WPT devices and WPT base stations.

3.2.4 WPT base station: A module transmitting electric power to the WPT device in a wireless manner.

3.2.5 WPT charging: The act of providing electric power to devices using WPT technology.

3.2.6 WPT device: An IoT device capable of receiving electric power from a WPT base station in a wireless manner.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

AA Authentication and Authorization

IoT Internet of things

RLC Resistor (R), Inductor (L) and Capacitor (C)

WPT Wireless Power Transmission

5 Conventions

In this Recommendation:

The keywords **"is required to"** indicate a requirement which must be strictly followed and from which no deviation is permitted, if conformance to this Recommendation is to be claimed.

The keywords **"is recommended"** indicate a requirement which is recommended but which is not absolutely required. Thus, this requirement need not be present to claim conformance.

The keywords **"can optionally"** indicate an optional requirement which is permissible, without implying any sense of being recommended. This term is not intended to imply that the vendor's implementation must provide the option and the feature can be optionally enabled by the network

operator/service provider. Rather, it means the vendor may optionally provide the feature and still claim conformance with the specification.

6 Overview

6.1 Concept of wireless power transmission

As described in [b-ITU-R SM.2303-2], "Technologies to transmit electric power wirelessly have been developed since the 19th century, beginning from induction technology. Since the Massachusetts Institute of Technology innovation on Non-Beam wireless power technology in 2006, technologies of wireless power transmission (WPT) under development vary widely; e.g. transmission via radio-frequency beam, magnetic field induction, resonant transmission, etc. WPT applications are expanding to mobile and portable devices, home appliances and office equipment, and electric vehicles. New features such as freedom of charging device placement are added. Some technology claims simultaneous multiple device charging. Inductive WPT technologies are widely commercially available today. Nowadays, resonant WPT technologies are coming out to consumer market. Automotive industry looks at WPT for electric vehicle (EV) applications in the upcoming future."

Inductive WPT technology can transmit electrical energy by magnetic field. It can transmit energy to devices in very short range, approximately a few centimetres. Examples include electronic toothbrush chargers, radio frequency identification (RFID) tags and smart cards.

Resonant WPT technology can also transmit energy by magnetic field to devices, and it can cover an area up to several meters. As shown in Figure 1, WPT technology can be used in various areas such as homes, vehicles, offices and public areas.

WPT technology can be applied to any electrical devices such as mobile phone, smart pads, electric cars, moving robots, wearable devices, healthcare equipment, etc. WPT enables placing electric devices anywhere within the range of the WPT base station. The WPT base station is a device that supplies wireless electrical energy to a receiver within a certain coverage range.

With outdoor WPT, people do not need to carry a large capacity battery or an adaptor to recharge portable devices when leaving their home or office. With WPT at home, it is possible to eliminate complex wire cables and plugs for many electronic devices.

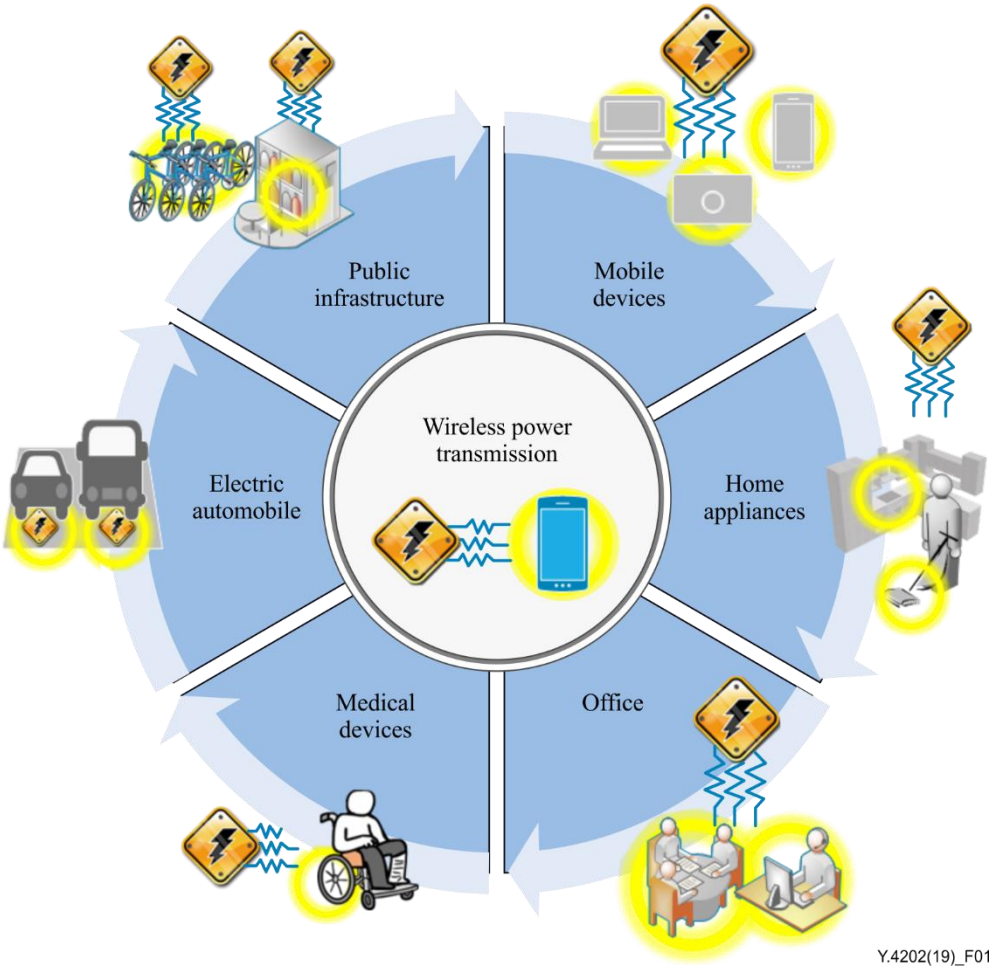

Figure 1 – Examples of application areas of WPT technology

Because of the great potential of WPT in various application areas, a standardized infrastructure for WPT application service is needed to achieve the possibilities of high service effectiveness. The standardized infrastructure for WPT application service can provide various types of commercial or non-commercial WPT charging; examples of WPT application service concern WPT charging for electric cars at public parking lots and WPT charging for wearable or mobile devices at public areas.

6.2 WPT application service

To realize various types of WPT charging, a standardized infrastructure for WPT application service is needed. Figure 2 shows, in the perspective of the IoT reference model [ITU-T Y.4000], this standardized infrastructure in terms of a functional model of WPT application service.

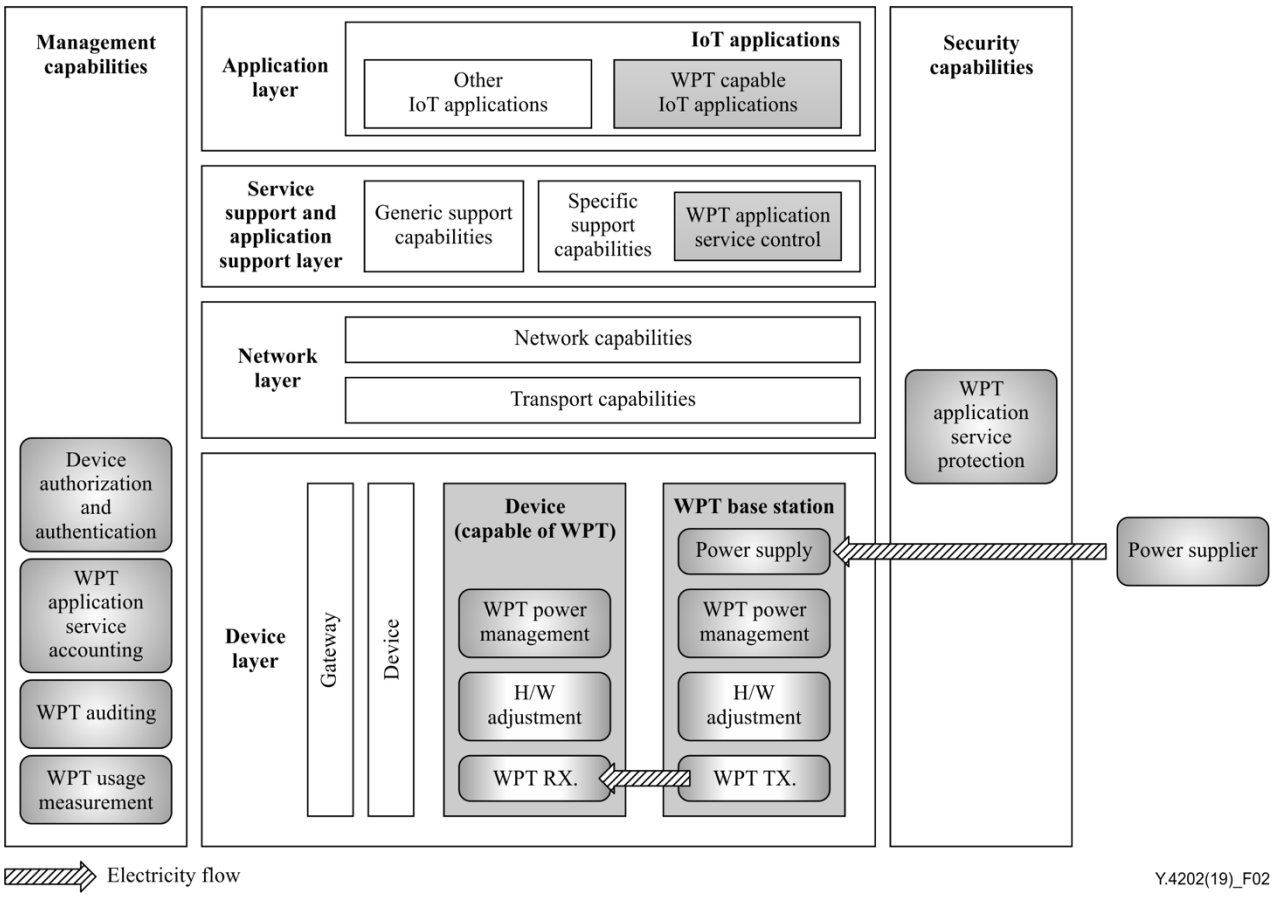

Figure 2 – Functional model of WPT application service

The following provides a description of the functional model shown in Figure 2.

A WPT base station transmits electric power wirelessly to WPT devices; these devices, as defined in clause 3, are IoT devices capable of WPT. The wireless power transmission, i.e., WPT charging, is performed from the WPT transmitter component of the WPT base station to the WPT receiver component of the devices.

The hardware (H/W) adjustment components of WPT devices and WPT base station perform impedance matching of resistor (R), inductor (L) and capacitor (C) (RLC) circuit to maximize the efficiency of wireless power transmission.

WPT application service functionalities associated with WPT devices are WPT power management, WPT usage measurement, WPT auditing, WPT application service accounting, device authorization and authentication, and WPT application service protection. WPT application service functionalities associated with the WPT base station are identical to that of the WPT devices with additional functionalities such as WPT power supply and WPT accounting.

The power supplier, which is beyond the scope of this Recommendation, provides electricity to the WPT base station.

The WPT power management function associated with the WPT base station and the WPT device negotiate with each other to provide electric power as requested by the WPT device.

NOTE 1 – In terms of power transfer efficiency from a user's preference point of view, two components, H/W adjustment and WPT power management, interact in order to adjust RLC coupling.

The WPT usage measurement function measures the usage of WPT power used by the WPT device; The WPT application service accounting component records measured WPT power usage.

The WPT auditing function continuously examines electricity flow to prevent overcurrent or power leakage.

The device authorization and authentication function authorizes both WPT devices and WPT base station involved in the WPT application service.

NOTE 2 – Before providing electric power, WPT application service needs to check if a WPT device is authorized to get electric power. This prevents unauthorized WPT devices from accessing electric power.

The WPT application service control function is used by both WPT devices and WPT base station to exchange control information for discovery and negotiation.

The WPT application service protection function should provide appropriate levels of confidentiality, integrity, availability and authenticity of information and communications.

Finally, WPT-capable IoT applications utilize the WPT application service.

7 Requirements

This clause defines requirements for the WPT application service.

7.1 WPT application service

The followings are general requirements for the WPT application service:

– WPT application service is required to provide a method of a user's registering WPT application service in public areas;

– WPT application service is required to provide appropriate levels of confidentiality, integrity, availability and authenticity of information and communications;

– WPT application service is required to provide a method of hiding the existence of private WPT base station and user's services;

– WPT application service is recommended to have the ability to be offered temporarily;

– WPT application service is recommended to have the ability to be offered according to the given basic conditions for WPT charging;

– WPT application service can optionally collect data from WPT devices during WPT charging;

– WPT application service can optionally provide price information for the WPT charging;

– WPT application service can optionally provide a method of sharing private WPT base station with the public;

– WPT application service can optionally set basic conditions to meet a given level of service;

– WPT application service can optionally provide incentives to the owner of the WPT base station who shares electricity;

– WPT application service can optionally provide accounting capabilities.

7.2 WPT device

The followings are requirements for a WPT device:

– WPT device is required to have a unique identification;

– WPT device is required to locate the WPT base station;

– WPT device is required to be configured to interact with the WPT base station. The use of adequate device authorization mechanism can be considered;

– WPT device is recommended to provide to the WPT base station its temporary authorization information received from the WPT application service provider;

– WPT device is required to monitor electricity flow to control and manage its WPT usage;
– WPT device is required to measure the usage of WPT application service (e.g., for accounting purposes);
– WPT device is required to inform its charging status to the WPT application service provider and the concerned WPT base station;
– WPT device is recommended to have an auditing function to prevent overcurrent or power leakage.

7.3 WPT base station

The followings are requirements for WPT base station:
– WPT base station is required to retrieve electricity from the power supplier;
– WPT base station is required to provide electricity to one or more WPT devices;
– WPT base station is required to be uniquely identified in a WPT charging area;
– WPT base station can optionally store device-related information of WPT devices (e.g., to support device authentication);
– WPT base station is recommended to charge multiple devices simultaneously;
– WPT base station is recommended to adjust its impedance dynamically to enhance WPT charging efficiency;
– WPT base station is recommended to serve the authorized WPT device only for a temporary period as assigned by the WPT application service provider;
– WPT base station is recommended to collect accounting information related to billing (e.g., duration, amount);
– WPT base station is required to have user authentication functions;
– WPT base station is required to monitor electricity flow;
– WPT base station is required to measure, control and manage WPT devices' usage of electric power and WPT application service;
– WPT base station is required to inform that the service is correctly configured to the WPT application service provider;
– WPT base station is recommended to inform its WPT charging status to WPT devices;
– WPT base station is recommended to have an auditing function to prevent overcurrent or leakage.

8 WPT application service flows

8.1 Basic service flows

The basic service flows for the WPT application service are shown in Figure 3. The WPT application service provider controls one or more WPT base stations. The electricity is generated by the electric power supplier and is then sent to WPT devices through the WPT base station with the consent of the WPT application service provider.

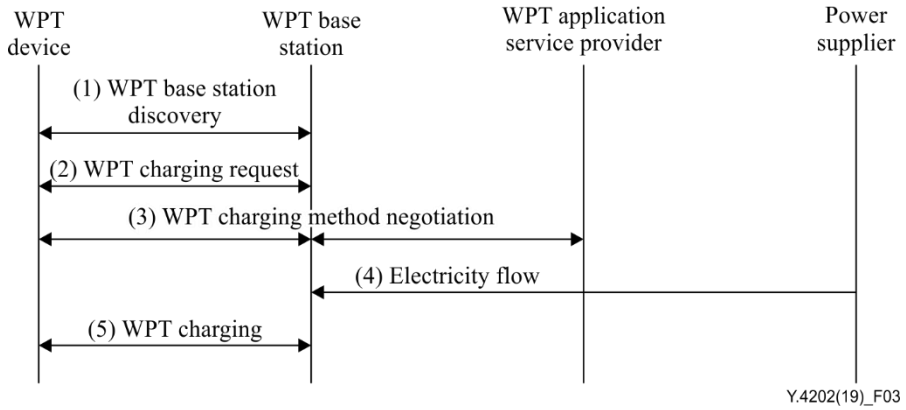

Figure 3 – Basic service flows for WPT application service

(1) WPT base station discovery: WPT base stations are discovered through this step. As an example of this discovery method, a WPT base station periodically sends WPT charging related information to its surroundings; any WPT devices in that area can receive the periodic information and can start sending WPT charging requests.

(2) WPT charging request: A WPT device can send a WPT charging request to the WPT base station with information such as the WPT device's identification associated with the WPT application service, the amount of electricity required by the WPT device, etc.

(3) WPT charging method negotiation: A WPT device and WPT base station exchange information in order to set the WPT charging policy between the two pieces of equipment.

NOTE 1 – During this procedure, RLC parameters for the WPT device and WPT base station can be negotiated.

NOTE 2 – This procedure can be also used to negotiate billing aspects, which are out of scope of this Recommendation. For small devices (consuming limited amounts of electricity), the WPT application service may be provided free of charge (a limit to the amount of electricity free of charge can be imposed).

(4) and (5) Electricity flow and WPT charging: A WPT device is electrically charged in this phase. During WPT charging, the WPT device periodically reports its WPT charging status to the WPT base station to notify it of how much it has charged. WPT usage measurement and electric power management functions are involved in this process. When a user notices that the device is sufficiently or fully charged, the user may terminate WPT charging. WPT auditing is involved in making sure that the WPT application service is provided safely.

8.2 Authentication and authorization flows

This clause describes the service flows for authentication [ITU-T Q.1742] and authorization [ITU-T Y.1271] process of the WPT application service. The purpose of this clause is to provide a fundamental understanding of how requirements needing authentication and authorization capabilities are applied in providing the WPT application service.

The service flows for authentication and authorization of the WPT application service are shown in Figure 4. Although every use case would need to go through some sort of authentication and authorization processes to be provided for the WPT application service, the use cases that certainly need authentication and authorization would be WPT charging of WPT devices in public areas, such as electric vehicles, drones, etc. Figure 4 shows the WPT application service provider for the WPT base station and WPT device's authentication.

NOTE 1 – From a deployment point of view, the required authentication and authorization (AA) function can be provided by the WPT application service provider or a third party.

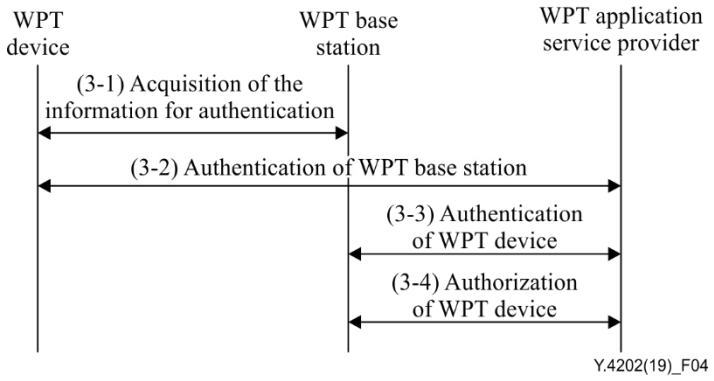

Figure 4 – Service flows for authentication and authorization

The following, as shown in Figure 4, are the detailed steps necessary for authentication and authorization in relation to procedure (3) of the basic service flows identified in Figure 3.

(3-1) Acquisition of the information for authentication: This step is to acquire related authentication information from WPT devices and the WPT base station. A WPT device provides information to identify itself, such as: authentication key, serial number, type, model. The WPT base station provides information to identify itself such as: WPT base station service provider, authentication key, serial number, type, mode.

NOTE 2 – A user of the WPT device can also provide information, such as authentication key, username, identification number, password, etc., which is associated with the WPT device.

(3-2) Authentication of WPT base station: This step is to authenticate the WPT base station. An improper or defective WPT base station can impair WPT devices because the WPT base station provides electricity to the devices. Also, an abnormal WPT base station can impersonate normal a WPT base station to collect private information acquired from the step (3-1). In order to protect a WPT device from these threats, a WPT device is needed to authenticate the tentative WPT base station with the help of the AA function.

(3-3) Authentication of WPT device: The WPT base station can authenticate a WPT device through the AA function in case it is needed to hide private information associated with the WPT device. This procedure enables the WPT base station to use other information, such as authentication key, that is allocated from the AA function, in case a user does not want to provide personal information, such as user ID and user password associated with the WPT device.

(3-4) Authorization of WPT device: This step is for the WPT base station to request authorization of WPT charging from the AA function. The WPT base station checks if a WPT device has permission to get the requested WPT charging amount.

NOTE 3 – As an example, A user can pre-set the WPT charging amount per month in public areas.

8.3 Usage measurement flows

This clause describes the service flows for measuring WPT application service usage. The usage measurement is one of the basic features that need to be considered when deploying WPT application service in public areas. The purpose of this clause is to provide a fundamental understanding of how the usage measurement of the WPT application service can be applied.

The service flows for usage measurement of the WPT application service are shown in Figure 5. Example use cases that need usage measurement are WPT charging of WPT devices in public areas such as electric vehicles, drones, etc. Figure 5 shows the use of WPT accounting function for usage measurement.

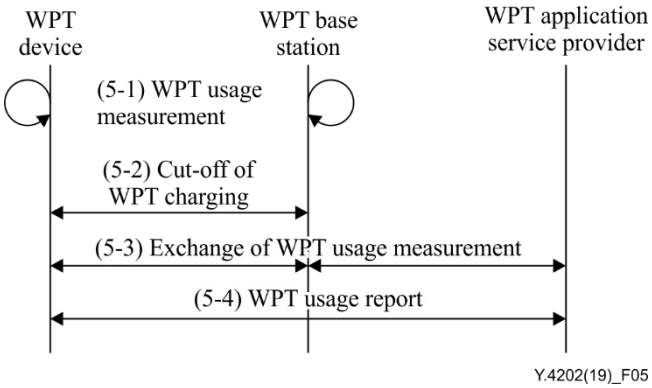

Figure 5 – Service flows for usage measurement

The following, as shown in Figure 5, are the detailed steps necessary for usage measurement of WPT application service in relation with procedure (5) of the basic service flows identified in Figure 3.

(5-1) WPT usage measurement: this step is for both of a WPT device and WPT base station to perform usage measurement by themselves. A WPT device checks if it has received the electric power according to the negotiated electric consumption power amount (e.g., 2 Wh, 100 Wh). Meanwhile, the WPT base station checks whether it has sent the negotiated amount of electricity to the WPT device.

NOTE – Because the charging efficiencies of the WPT base station and device are not equivalent, both the base station and device need to exchange charging status during WPT charging. WPT charging is completed when the delivered electricity has reached the negotiated amount.

(5-2) Cut-off of WPT charging: this step is responsible for stopping WPT charging. At the same time, the WPT usage measurement is ended.

(5-3) Exchange of WPT usage measurement: this step is to exchange measured WPT usage information between the WPT base station and the WPT device, as well as to transmit their usage information to the WPT application service provider.

(5-4) Report of WPT usage measurement: this step is to report the WPT usage measurement status (e.g., WPT charging amount, WPT charging statistics) to the accounting function of the WPT application service provider.

8.4 Auditing flows

This clause describes the service flows for auditing the WPT application service. The WPT application service needs to monitor the WPT base station and WPT devices continuously for any problems that can occur during WPT charging; if a problem is found, an appropriate adjustment procedure is performed.

The service flows for auditing of the WPT application service are shown in Figure 6. The auditing enables safe WPT application service.

The following are the detailed steps necessary for auditing the WPT application service in relation with procedure (5) of the basic service flows identified in Figure 3.

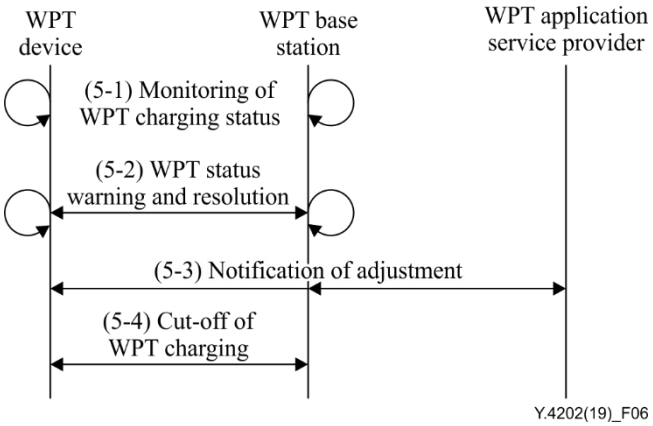

Figure 6 – Service flows for auditing

(5-1) Monitoring of WPT charging status: This step is for both the WPT device and the WPT base station to monitor WPT charging status by themselves. This process is needed to check for any ongoing problems, such as overhead, overcurrent, short circuit, and fault defection in the WPT device or WPT base station.

(5-2) WPT status warning and resolution: This step is to provide resolution to a problem discovered by WPT charging status monitoring. A typical resolution is to perform RLC adjustments between the WPT device and WPT base station, including change of WPT charging speed, change of electric consumption power amount, and change of electric emission power amount. If the problem cannot be resolved by any adjustment, WPT charging must be stopped. In this case, information about adjustment failure is reported to the WPT application service provider (similarly to step (5-3)) and then WPT charging is stopped (similarly to step (5-4)).

(5-3) Notification of the adjustment: This step is to inform the WPT application service provider of the adjustment (if the adjustment cannot solve the problem, WPT charging is cut-off).

(5-4) Cut off of WPT charging: This step is responsible for stopping the WPT charging.

Appendix I

Use cases of WPT application service

(This appendix does not form an integral part of this Recommendation.)

For a better understanding of the WPT application service, this appendix provides a number of use cases.

I.1 Fixed WPT devices

The WPT base station can perform WPT charging only for identified WPT devices. It will not perform WPT charging for unidentified WPT devices. This environment can be an office or home in which devices are registered beforehand as shown in Figure I.1.

If a user wants to install new WPT devices in their home or office, the new devices are required to be registered to the WPT base station. The WPT base station will keep information related to the new devices, such as device identification and type of WPT charging.

Figure I.1 – WPT devices at home

Usually there are many devices which need electric power at home. As shown in Figure I.1, there are many appliances and devices in almost every room in a home such as living room, bedroom, kitchen, bathroom, etc. Some benefits of WPT at home include: devices can be completely sealed and waterproofed, and can be easily moved; there is no need to worry about electric shot hazards in kitchen and bathrooms; it is easy to control power usage.

I.2 Simultaneous charging of multiple WPT devices

A WPT base station can electrically charge multiple devices in form of time sharing, i.e., sharing of electricity by taking turns of WPT charging of devices for a certain period of time. It will be needed to adjust WPT charging related parameters for each device to achieve the most effective charging rate. Figure I.2 shows an example of charging multiple devices. A WPT base station provides WPT charging for each device one-by-one with a fixed amount of time, so that every device in the area requesting WPT charging can be charged simultaneously.

Figure I.2 – Multiple WPT devices on conference table

I.3 WPT devices with data acquisition

There are many possible uses of wireless sensors. They can be installed in farms to diagnose status of various farm products. They can be installed in underground facilities such as sewage, electric wires, gas line, etc., to be used to detect operational status and problems in the facilities. Sensors can be used in humans as in portable medical devices to trace and diagnose one's health.

However, the greatest problem of sensors is lack of battery power. For sensors installed underground, it is almost impossible to recharge the battery. These sensors can bring the highest potential with wireless power. Combining sensors with WPT can enable data acquisition during WPT charging.

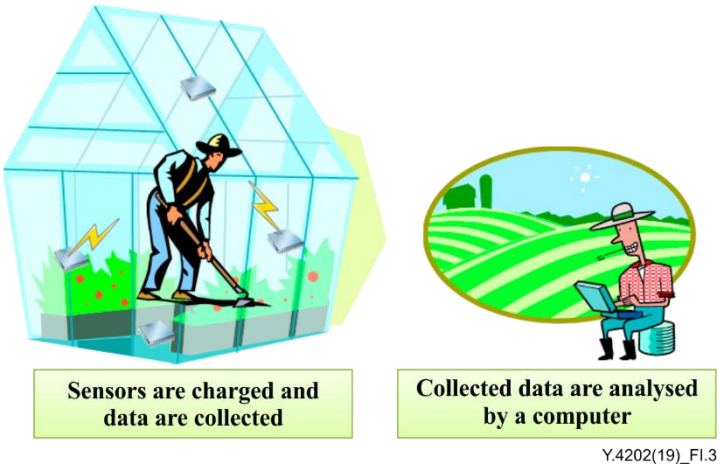

Figure I.3 – WPT devices at greenhouse with data acquisition

For instance, as shown in Figure I.3, a greenhouse can have many sensors that collect information on environmental status of the greenhouse and growth status of the agricultural products. Sensors are placed in the area that is appropriate to take measurements. Wireless sensors use batteries for power. Since sensors have a limited amount of power, they tend to conserve energy when in operation. They may have two operating modes: eco mode and communication mode. In eco mode, they detect and measure events or changes from the environment using minimum electricity. In communication mode, they provide measured data to the receiving device such as the farmer's computer. Without WPT, the farmer would need to physically move the sensors, change or charge the battery, collect measured data, and replace the collected sensors to their original location. However, this process is very inconvenient. Also, some measured data from sensors can be incorrect or missed because of the replacement of sensors in slightly different positions.

With WPT, this process can be automated, and accurate measured data can be collected from sensors. A farmer can bring the WPT base station to the green house to charge the sensors and collect the data

from the sensors at the same time. The collected data are later analysed using a computer by the farmer as shown in Figure I.3.

I.4 WPT devices in public areas

People carry various electric devices when leaving home to go to public areas. Such devices include: smart phones, radios, cameras, notebooks, and healthcare devices. People rely on battery power and try to make sure that these batteries are fully charged before leaving their home or office. It is possible to recharge a battery in public areas, but there are many inconveniences such as finding an adequate place for recharge, waiting for devices to be recharged, the need of carrying a battery charging adaptor, etc. If public areas can provide the WPT application service, some of these inconveniences can be solved.

Figure I.4 – WPT devices in public transportation area

There are many public areas in which people can wait during battery charging of their WPT devices.

A handheld WPT device can be carried in a public transportation area such as a bus area or a train area. Although idle time can be short (e.g., 10 minutes or less), it is possible to perform battery charging to some extent. Figure I.4 shows an example of WPT charging in a public transportation area. The power source can be installed at a bus stop or inside the bus. There are many places in the outdoors in which power sources can be installed. Some of such places can be bus stops, rail stations, street lights, traffic lights, electric poles, etc.

User management for authentication of service users needs to be performed. Although WPT charging for small device does not cost much, as people start to use this service the costs will add up. With authentication of service users, the service users can pay for the use of public electricity and use it as needed.

Another example is WPT application service for electric vehicles. Electric vehicles are mostly used in public areas as shown in Figure I.5. Since these vehicles consume much energy, they need to be charged often. People park cars in public parking lots when shopping, dining, going for coffee, business, sightseeing, etc. Public parking lots can provide wireless WPT charging to users. It is possible to perform WPT charging in public parking lots during the time the vehicle is parked. Using a wireless method of electric charging can be efficient for users and the (WPT-enabled) car, so the user can control the electric charging time and electric charging amount.

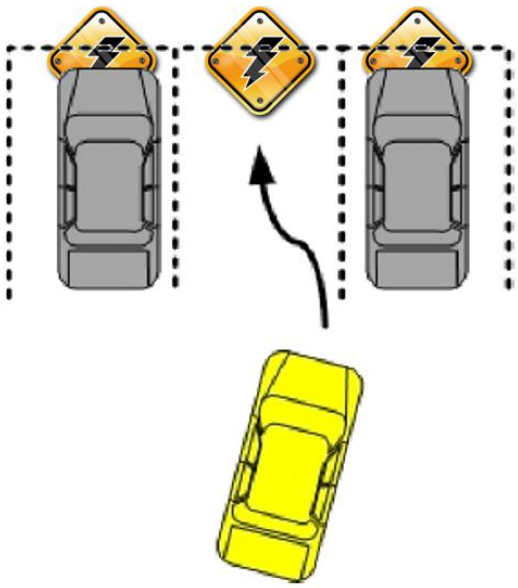

Figure I.5 – WPT-enabled electric vehicles in parking lots

However, if a number of cars are charging simultaneously, an electricity blackout can occur. It is very important to control the WPT charging of electric vehicles.

As the cost of electricity may change very often (e.g., based on the time, location), it would be efficient to charge electric vehicles when the cost of the electricity drops (electricity price information can be accessible by the user). If a user thinks it is appropriate to buy electricity, they can start the WPT charging of their car.

I.5 WPT devices for assigned temporary period

Commercial areas such as restaurants and cafes can provide WPT charging for customers as part of a service as, shown in Figure I.6. A business owner can provide an access code for a customer to get free WPT charging while the customer enjoys the service that is provided, e.g., enjoying ordered food and drinks. An access code is a temporary code that is valid for a certain period of time. The owner will need a database that carries and manages these access codes. WPT charging should be provided for a predetermined length of time that is preassigned by the owner. If the same customer returns to the business the next day, they can be provided with a different access code.

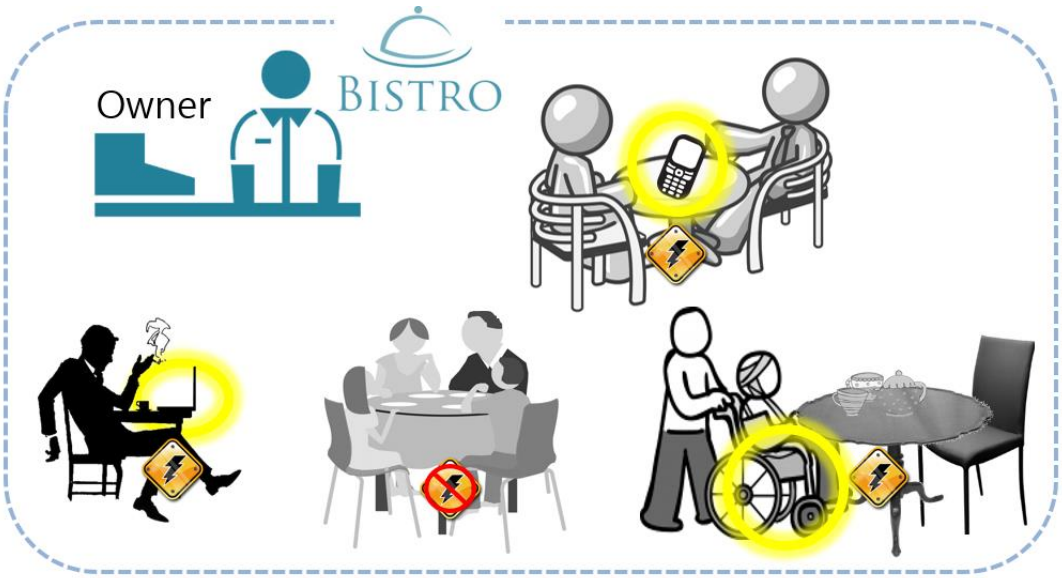

Figure I.6 – WPT devices at cafe

A similar use case can be applied to hotels, where hotel guests can get the WPT application service throughout the entire hotel including the hotel's diner room, fitness room, lobby, etc. Guests can use the WPT application service for the length of their stay. The hotel owner can set the range of the WPT charging area and different operation times of the WPT application service according to the length of hotel guests' stay.

Bibliography

[b-ITU-T Q.1741.1] Recommendation ITU-T Q.1741.1 (2002), *IMT-2000 references to release 1999 of GSM evolved UMTS core network with UTRAN access network*.

[b-ITU-R SM.2110-0] Recommendation ITU-R SM.2110-0 (2017), *Frequency ranges for operation of non-beam wireless power transmission systems*.

[b-ITU-R SM.2303-2] Report ITU-R SM.2303-2 (2017), *Wireless power transmission using technologies other than radio frequency beam*.

[b-ITU-R SM.2392-0] Report ITU-R SM.2392-0 (2016), *Applications of wireless power transmission via radio frequency beam*.

[b-IEC 62827-1] IEC 62827-1:2016, *Wireless power transfer – Management – Part 1: Common components*.

[b-IEC 62827-2] IEC 62827-2:2017, *Wireless power transfer – Management – Part 2: Multiple devices control management*.

[b-IEC 62827-3] IEC 62827-3:2016, *Wireless power transfer – Management – Part 3: Multiple source control management*.

[b-ISO/IEC 15149-2] ISO/IEC 15149-2:2015, *Information technology – Telecommunications and information exchange between systems – Magnetic field area network (MFAN) – Part 2: In-band Control Protocol for Wireless Power Transfer*.

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