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

Accessibility requirements for the Internet of things applications and services

Recommendation ITU-T Y.4204

International Telecommunication Union

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Recommendation ITU-T Y.4204

Accessibility requirements for the Internet of things applications and services

Summary

Recommendation ITU-T Y.4204 provides accessibility requirements specific to Internet of things (IoT) applications and services.

Benefits of accessible IoT applications and services are addressed, and accessibility requirements for IoT applications and services for persons with disabilities, persons with age-related disabilities and those with specific needs to utilize IoT applications and services, are specified. Some use cases are also provided in Appendix I to illustrate the need for IoT accessibility.

This Recommendation complements existing Recommendations specifically defined for certain platforms in case such platforms are applied in the IoT context.

History

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FOREWORD

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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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Introduction

Internet of things (IoT) applications and services may increase the quality of peoples' lives, especially those with disabilities or age-related disabilities and those with specific needs; lack of accessibility is a main barrier to realize these potential IoT benefits.

An accessible IoT application or service can be achieved by understanding the requirements of those who may not be able to easily access the applications or services. Many standardization activities have been successful to secure information and communication technology (ICT) accessibility, but they need implementation.

Many accessibility features have been introduced to resolve accessibility issues in many mainstream standards. However, accessibility standards were mostly developed through specific technology or specific service platforms. In IoT environments, the interoperability and heterogeneous characteristics of IoT may create conflicting accessibility requirements when only the technology or platform-specific accessibility features are considered. Therefore, accessibility requirements specific to IoT applications and services still exist even when all the technology or platform accessibility features are met.

By inheriting general ICT accessibility requirements and user needs defined elsewhere, this Recommendation aims to fill the gap between the general ICT accessibility user needs and the technology or platform accessibility features in the context of IoT.

Recommendation ITU-T Y.4204

Accessibility requirements for the Internet of things applications and services

1 Scope

This Recommendation specifies accessibility requirements for Internet of things (IoT) applications and services.

The scope of this Recommendation includes:

– possible use cases to identify the need for IoT accessibility for persons with disabilities, persons with age-related disabilities, and those with specific needs;

– accessibility requirements for IoT applications and services for persons with disabilities, persons with age-related disabilities, and those with specific needs to utilize IoT applications and services.

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 F.790] Recommendation ITU-F.790 (2007), *Telecommunications accessibility guidelines for older persons and persons with disabilities.*

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

3 Definitions

3.1 Terms defined elsewhere

This Recommendation uses the following terms defined elsewhere:

3.1.1 accessibility [b-ITU-T F.791]: The degree to which a product, device, service, or environment (virtual or real) is available to as many people as possible.

3.1.2 accessibility feature [b-ITU-T F.791]: An additional content component that is intended to assist people hindered in their ability to perceive an aspect of the main content.

3.1.3 assistive technology (AT) [b-ITU-T F.791]: Is an umbrella term that includes assistive, adaptive, and rehabilitative devices used by a person with disabilities to prevent, compensate, relieve, or neutralize any resulting impairment.

3.1.4 Internet of things (IoT) [ITU-T Y.4000]: A global infrastructure for the information society, enabling advanced services by interconnecting (physical and virtual) things based on, existing and evolving, interoperable information and communication technologies.

NOTE 1 – Through the exploitation of identification, data capture, processing and communication capabilities, the IoT makes full use of things to offer services to all kinds of applications, whilst ensuring that security and privacy requirements are fulfilled.

NOTE 2 – In a broader perspective, the IoT can be perceived as a vision with technological and societal implications.

3.1.5 persons with age related disabilities [b-ITU-T F.791]: Persons when they age, often develop cognitive and physical disabilities that are caused by the aging process itself. Examples are diminished eyesight, deafness in varying degrees, reduced mobility, or cognitive abilities.

3.1.6 persons with specific needs [b-ITU-T F.791]: Includes persons with disabilities (PWD), persons who are not literate, those with learning disabilities, children, indigenous people, older persons with age related disabilities, and anyone who has a temporary disability.

3.1.7 platform accessibility features [b-ITU-T F.791]: Accessibility functionality provided as standard on a particular hardware/software platform.

3.1.8 specific needs [b-ITU-T F.791]: This replaces the use of the term 'special needs'. This term refers to a wide range of categories including women, children, youth, indigenous people, older persons with age related disabilities, persons with illiteracy, as well as persons with disabilities (PWD), see [b-ITU PP Res.175], [b-WTDC Res.58], and [b-WTDC AP] and clause 6.39 of [b-ITU-T F.791].

3.1.9 thing [ITU-T Y.4000]: With regard to the Internet of things, this is an object of the physical world (physical things) or of the information world (virtual things), which is capable of being identified and integrated into communication networks.

3.1.10 universal design [b-UNCRPD]: The design of products, environments, programmes and services to be usable by all people, to the greatest extent possible, without the need for adaptation or specialized design. "Universal design" shall not exclude assistive devices for particular groups of persons with disabilities where this is needed.

3.2 Terms defined in this Recommendation

This Recommendation defines the following term:

3.2.1 smart speaker: A speaker that is capable of anything beyond just emitting sound.

NOTE – Typically, smart speaker refers to an artificial intelligence speaker that utilizes voice recognition technology and is equipped with Internet connectivity.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

ICT	Information and Communication Technology
IoT	Internet of things
IPTV	Internet Protocol Television
UI	User Interface
UNCRPD	UN Convention on the Rights of Persons with Disabilities
WWW	World Wide Web

5 Conventions

In this Recommendation:

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

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

6 ICT accessibility in IoT

The UN Convention on the Rights of Persons with Disabilities (UNCRPD), an international human rights treaty of the United Nations, refers the term accessibility as "to ensure to persons with disabilities access, on an equal basis with others, to the physical environment, to transportation, to information and communications, including information and communications technologies and systems, and to other facilities and services" [b-UNCRPD]. The Convention, and more specifically its Article 9, creates the first universal framework addressing the accessibility of information and communication technologies (ICTs) and assistive technologies.

ICT accessibility has been focusing on retrofitting to rectify the lack of access to ICTs for persons with disabilities and persons with age-related disabilities including those with specific needs. Many standardization activities have been successful to secure ICT accessibility, but they need implementation. The most important concept of the UNCRPD is that of universal design from the beginning to include accessible features into standards. Many accessibility features have been introduced to resolve accessibility issues in many mainstream standards.

One approach to providing ICT accessibility involves the use of a specific technology or service platform. Examples include Internet protocol television (IPTV), e.g. [b-ITU-T Y.1901], and the world wide web (WWW), e.g. [b-W3C WCAG 2.0], which incorporate accessibility features.

However, IoT is not a specific service platform or a specific technology according to the definition of IoT [ITU-T Y.4000]. Rather, it is a much broader concept that is loosely defined as a global infrastructure. Specific accessibility issues related to IoT applications and services arise from two key aspects of IoT, namely, interoperability and the 'thing' on how persons with disabilities may use these applications and services.

Figure 1 shows the relationship among IoT accessibility requirements, the general ICT accessibility requirements and accessibility requirements specific to user interface (UI). IoT accessibility requirements fill the gap between the general ICT accessibility requirements, e.g., [ITU-T F.790], [b-ITU-T H-Sup.17], [b-ISO/IEC TR 29138-1], [b-ISO TR 22411] and the IoT accessibility requirements specific to UI, e.g. [b-ITU-T Y.1901], [b-W3C WCAG 2.0] in IoT environments.

One of the distinct characteristics of IoT is interoperability; 'things' connect and interchange data through this IoT infrastructure. They create value through processing of data acquired from other 'things'.

Because accessibility standards were mostly developed through specific technology or specific service platforms, one of the potential difficulties could be that the interconnection of heterogeneous technology or service platforms may create conflicting accessibility requirements.

Moreover, IoT utilizes 'things', which are any objects that are capable of being identified and integrated into communication networks [ITU-T Y.4000]. For example, in home automation services, many conventional home appliances, such as refrigerators, microwave ovens, televisions and laundry machines, supply and interchange data through IoT and present processed information to users. Each 'thing', however, has its own accessibility requirements as a home appliance. At the same time, there could be a need to fulfil IoT accessibility requirements as well.

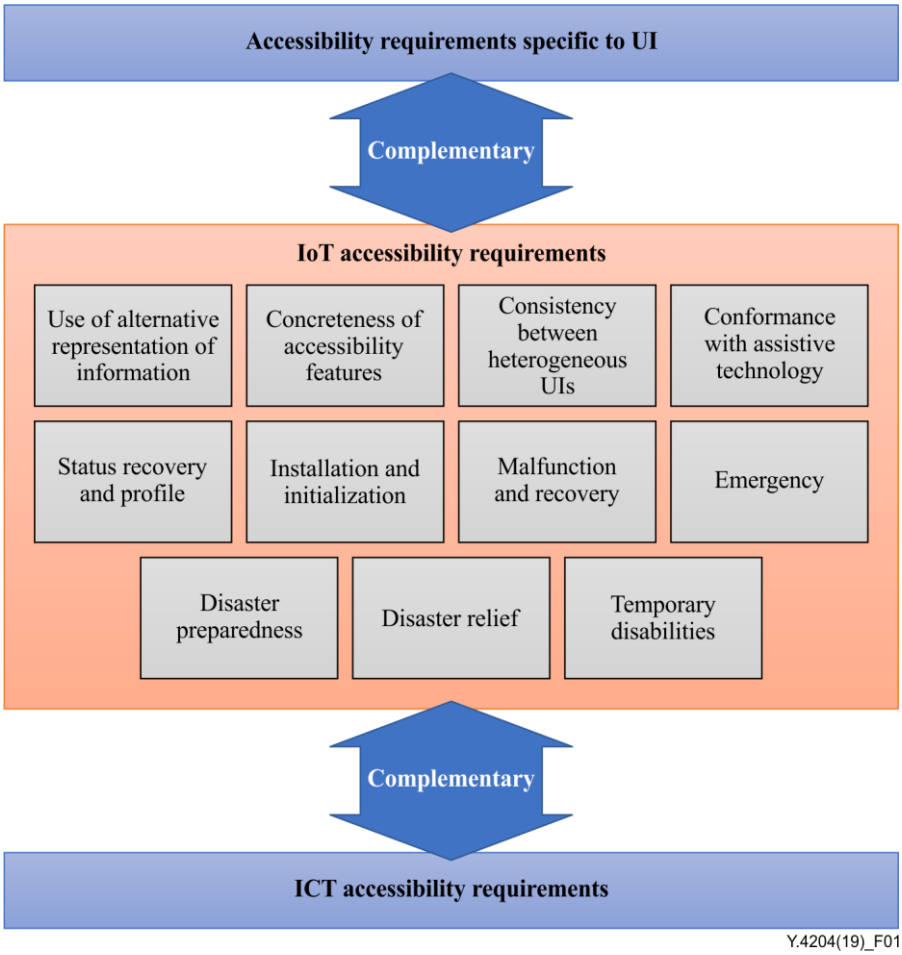

Figure 1 – Relationship among IoT accessibility requirements and other accessibility requirements

Therefore, the intention of including accessibility in IoT is that it will be based on using principals of universal design. All IoT applications and services designed for users should include, from the beginning, persons with disabilities, persons with age-related disabilities and those with specific needs.

7 The benefits of accessible IoT applications and services for persons with disabilities

There are many possible IoT applications and services in various environments that provide accessibility services such as home automation services, IoT for work environments, transportation services, etc. For example, home automation services can increase the capacity for independent living for persons with disabilities, persons with age-related disabilities and those with specific needs.

Home automation services can utilize an IoT platform to control the environment inside a house and many devices within it. This service can provide the status of home appliances and provide services that can control these home appliances remotely using a UI attached to the IoT platform. Moreover, sensory environmental data and parameters of home environments such as room and outside temperature and air pollution conditions of the city retrieved from outside sources can also be monitored.

With such interfaces and IoT platforms, windows, room lights, electricity plugs and air conditioners can be controlled remotely by persons with disabilities. It could be even possible to answer a phone remotely and transfer a call to wide screen television to better view sign language from a relay service call.

A user can turn on or turn off any home appliance using the UI attached to the IoT environment. Users with disabilities may utilize available UIs of their choice because various UIs can be attached to the IoT application or service. Each different UI can be customized to accommodate its owner's accessibility requirements. Persons with physical disabilities can use an interface as in a smartphone with built-in assistive technology or a console like the one Stephen Hawking used for speech. These could be adapted to remotely control home appliances in IoT environments.

Although a home automation service is illustrated here as an example of accessibility applications and services, the benefits of IoT applications and services for many other application areas are also feasible. Such application areas include home automation services, smart cities, smart manufacturing, smart car applications, etc.

Possible accessibility needs that must be supported to enable persons with disabilities to utilize the benefits of IoT include, but are not limited to:

– signalling for persons with hearing disabilities;
– signalling for persons with visual disabilities;
– tools for access for persons with physical disabilities;
– tools to access household appliances;
– direct tools for long-distance access to healthcare professionals;
– tools to access to emergency services.

Some example use cases that illustrate the benefits that IoT applications and services can provide persons with disabilities are described in Appendix I.

8 Accessibility requirements for IoT applications and services

This clause categorizes IoT accessibility requirements and identifies common accessibility requirements for IoT applications and services for persons with disabilities to utilize the benefits of IoT applications and services.

NOTE – Accessibility requirements relevant only to IoT environments are addressed in this Recommendation. For a summary of general and platform specific ICT accessibility requirements, see [ITU-T F.790] and [b-ISO/IEC TR 29138-1].

8.1 Categories of IoT accessibility requirements

Although IoT applications and services may increase the quality of peoples' lives, especially persons with disabilities, persons with age-related disabilities and those with specific needs, lack of accessibility is a main barrier to realize such potential benefit of IoT. An accessible IoT application or service can be achieved by understanding the accessibility requirements of those who may not be able to easily access such applications or services. It is recommended that universal design (see [b-UNCRPD]) be used in designing, developing and maintaining IoT applications and services.

In this Recommendation, the accessibility requirements for IoT applications and services are classified into five different categories.

An IoT application or service is accessible when it provides:

1) Category I: Ability to perceive all information and capabilities of an IoT application or service. See clause 8.2;
2) Category II: Ability to understand the information presented by an IoT application or service. See clause 8.3;
3) Category III: Ability to perform the required operations of an IoT application or service. See clause 8.4;

4) Category IV: Ability to use suitable assistive technology with an IoT application or service. See clause 8.5; and

5) Category V: Ability to satisfy a user's specific needs. See clause 8.6.

Figure 2 summarizes the categorization of IoT application and service requirements including the requirements identified in clauses 8.2 to 8.6.

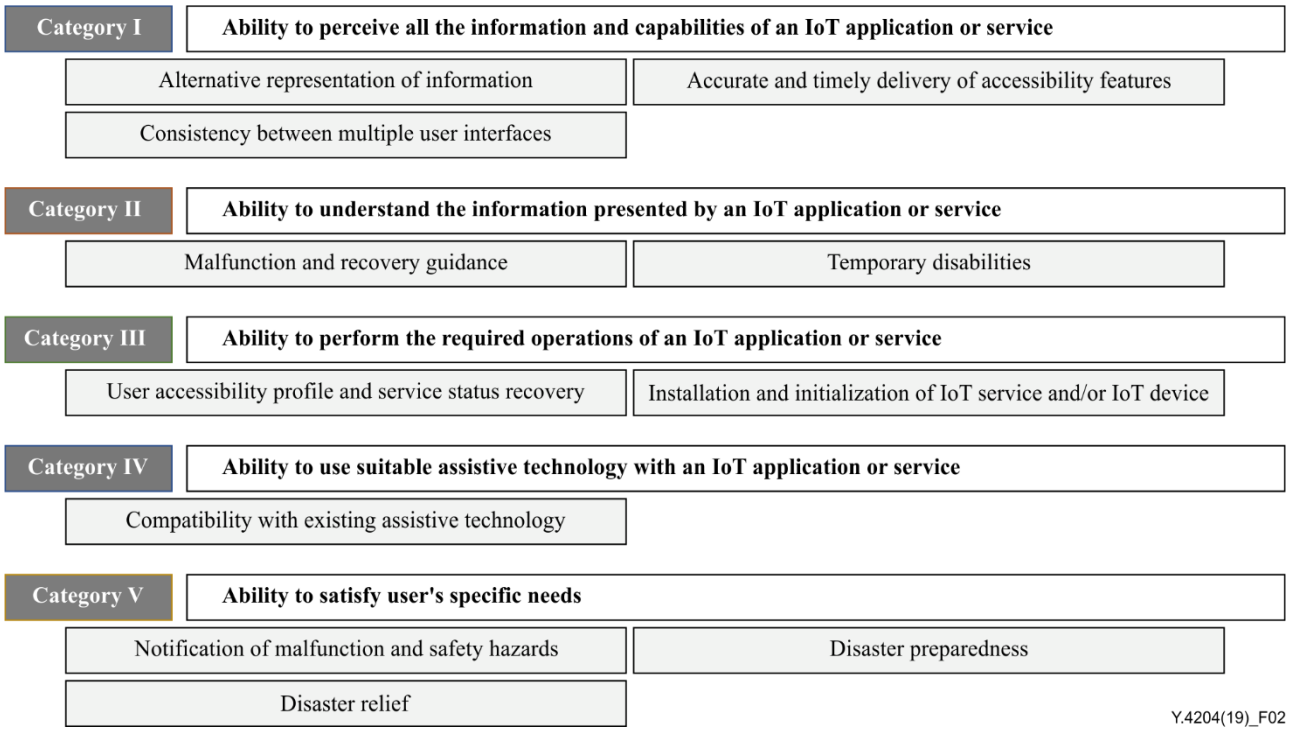

Figure 2 – Categories of IoT application and service requirements

8.1.1 IoT specific accessibility considerations for Category I

The following characteristics of IoT must be considered for Category I:

– user interfaces of an IoT application or service can be of any form (e.g., visual, audio, haptic);

– user's interactions with IoT devices can be done through various methods including: computer software, WWW, remote control, physical buttons, etc.;

– an IoT application or service may have multiple UIs at the same time that operates the same function.

8.1.2 IoT specific accessibility considerations for Category II

The following characteristics of IoT must be considered for Category II:

– an IoT device can be controlled by a different IoT device in an IoT application or service;

– two different IoT applications or services can communicate with each other.

8.1.3 IoT specific accessibility considerations for Category III

The following characteristics of IoT must be considered for Category III:

– physical locations of IoT devices attached to an IoT application or service may be scattered;

– IoT devices can be added to or removed from the IoT application or service at any time.

8.1.4 IoT specific accessibility considerations for Category IV

The following characteristics of IoT must be considered for Category IV:

– an IoT device that is attached to an IoT application or service may not be compatible with known assistive technologies;
– some IoT devices that are attached to an IoT application or service may interfere with operations of assistive technologies.

8.1.5 IoT specific accessibility considerations for Category V

The following characteristics of IoT must be considered for Category V:

– some IoT applications and services can be used as tools for signalling safety hazards;
– some IoT applications and services can be used to assist disaster management systems.

8.2 Category I: Ability to perceive all information and capabilities of an IoT application or service

8.2.1 Alternative representation of information

IoT applications and services utilize various types of creative UIs. Examples of such creative interfaces may include: touchscreen, motion sensors, voice recognition technology, wearable devices that incorporate vibration, haptic, light and sound signals, smart speakers, etc. Although introduction of such novel creative interfaces may increase usefulness of IoT applications and services, such interfaces sometimes overlook the fact that not everyone may be able to use them. For example, a 'smart speaker' is useless for people with hearing disabilities. However, due to its design concept, it may be difficult to provide alternative representations of information through the smart speaker itself. Even in such cases, the IoT application or service must provide alternative interfaces, e.g., through a mobile application, a WWW interface, which can be applicable to users with different types of disabilities.

Having multiple UIs is one advantage of using IoT. In an IoT application or service, different UIs may be available to fulfil different needs. For example, a touchscreen interface may prohibit persons with visual or physical disabilities from accessing information. However, providing a remote-control interface may be a feasible alternative for those who cannot utilize a touchscreen interface. Likewise, when designing the UI for an IoT application or service, providing alternative representations of information must be considered, and this could be done through utilizing different types of IoT devices (hence, different UIs) in an application or service.

1) An IoT application or service is required to provide at least two different types of alternative representations of information.

For persons with hearing disabilities, vibration, haptic, visual, caption, sign language and light symbols can be used as an alternative representation of auditory information. For persons with visual disabilities, audio, braille and enlarged characters can be used as an alternative representation of visual information.

2) Non-text information (e.g., video, image, audio signal, voice output) is required to provide text description of the information.

Text information can be easily converted into other representation types such as audio, caption, braille output, etc., without human intervention. However, non-text information such as a video, image, audio signal and voice output, etc., may need human intervention or special treatments such as voice recognition. Thus, converting such non-text information into an alternative representation may not always be feasible. IoT applications and services utilize data acquired from sensors (e.g., surveillance camera, temperature sensor, motion sensor) as well. In the design phase of IoT applications and services, how such non-text information should be described, must be considered to provide proper alternative representation of information.

8.2.2 Accurate and timely delivery of accessibility features

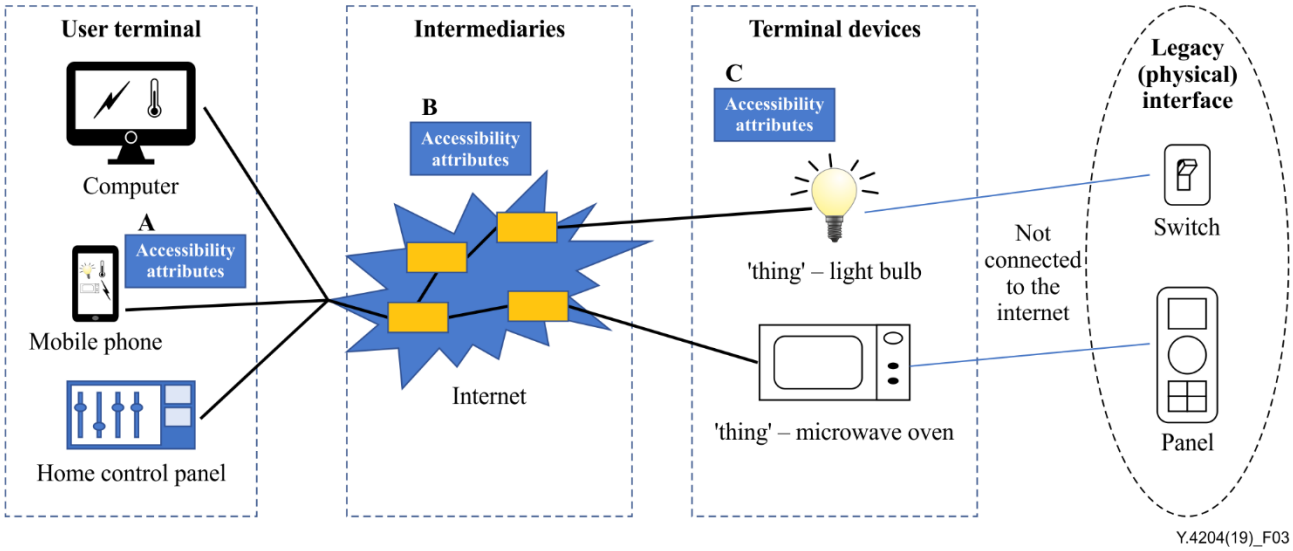

Figure 3 – Example on flow of the accessibility features

In an IoT environment, many 'things' that are participating in the IoT application or service may contribute creating accessibility features such as video description along with text (i.e., captioning), audio text description (i.e., audio captioning), etc. As an example, Figure 3 illustrates a home automation system with two devices – a light bulb and a microwave oven, several intermediaries, and three user terminals – a computer, a mobile phone and a home control panel. In this scenario, the user terminals that are connected to the IoT applications and services may create such accessibility features (case 'A'). Or, alternatively, the intermediaries may be responsible to create such accessibility features according to the data from the terminal devices (case 'B'). One other possibility is that terminal devices may be responsible for creating accessibility features and passing the information to the user terminals through some intermediaries (case 'C').

The flexibility of the IoT environment may allow all three cases. In any case, however, accessibility features must be maintained and should not be altered throughout the network from the point of creation to the destined user terminal. A device that is designed to perform a specific function may also be used as an interface to an IoT application or service; for example, an IPTV system can be used as an interface to a home automation IoT application. As captured in [b-ITU-T H.702], IPTV itself may provide accessibility features. However, if contents created by an IoT device do not provide accessibility features to an IPTV application, the content would not be accessible to persons with disabilities even though the IPTV application has the capability to support accessibility features as described in [b-ITU-T H.702]. Many existing platforms, such as IPTV, WWW, smart phones, smart speakers, etc., can be used as an interface to IoT services. However, they could, under the same circumstances, face the same issues if the IoT device was not configured to provide accessibility features.

Contents can be created anywhere and at any time in the IoT network. The contents and the accessibility features associated with the content must be provided at the same time.

1) Accessibility features associated with a given content created by a 'thing' are required to be provided at the time of creation of that content.

In an IoT environment, content created by one source may be modified to a different format or combined with other content during the delivery process. However, accessibility features associated with the content must be retained along the delivery process.

2) Accessibility features associated with content are required to be delivered to a user without being omitted or changing the meaning of the content, regardless of the changes made to the content.

8.2.3 Consistency between multiple user interfaces

In IoT environments, multiple UIs may exist as shown in Figure 3, which includes physical devices such as a light lamp and a microwave oven. In such cases, physical interfaces may coexist with IoT applications or services' UIs. Many instances of UIs in different media may be possible. For example, an IoT service may have multiple UIs (e.g., a home control panel, a mobile application, and a personal computer) at the same time. Such supposition may provide opportunity for persons with disabilities as they can choose a UI that provides most accessibility features.

But, at the same time, it may create unnecessary accessibility barriers as well. For example, persons with physical disabilities may benefit from an IoT service that remotely controls the light lamps in a house. However, if each different UI of an IoT service provides its own features that are different from one another, accessibility issues may arise from non-conformity. For example, if a smart speaker provides only a limited functionality, and a mobile application is required to perform a more sophisticated operation, users with disabilities may not be able to fully utilize the IoT services if any of the UIs are not accessible. This lack of accessibility functionality should be avoided in line with the [b-UNCRPD] whenever technically possible.

1) When a 'thing' has its own UI that is independent from the IoT network (e.g., built-in touchscreen interface on a refrigerator), the UI associated with the IoT network is recommended to provide the same functionality as its non-IoT UI counterpart.

2) When an IoT application or service provides multiple UIs (e.g., a mobile application and an IoT remote control), all UIs are recommended to provide the same functionality.

8.3 Category II: Ability to understand the information presented by an IoT application or service

8.3.1 Malfunction and recovery guidance

Malfunctions may be caused by hardware or software that is attached to the IoT application or service, or may be due to user errors. Users including persons with disabilities or those with age-related disabilities may not realize that an IoT system is malfunctioning. Even if they realize the malfunction of the IoT application or service, they might not understand what is causing the issues. In an IoT application or service, this situation may be much complicated with support for multiple UIs.

Notification of malfunctions and errors must be provided unambiguously, meaning that the statement must clearly indicate that the malfunction or error has occurred, provide information as to the cause of the malfunction, and, preferably, supply guidance to recover from the malfunction or error. In an IoT environment, many devices are involved to perform an application or service and they are connected through the network. When a malfunction occurs, it may be very difficult for a user to locate the cause of the malfunction due to the complexity of the environment. Moreover, such notification must be provided in multiple representations (see clause 8.2.1).

1) It is required to notify a user unambiguously when the IoT system detects errors or malfunctions.

2) It is recommended to provide resolution guidance in the event of a reported malfunction.

8.3.2 Temporary disabilities

When a person faces disabilities from injury or lack of foreign language skills, they face lack of accessibility. Types of the temporary disabilities may vary depending on the cause of the disability. These may include, but not limited to, hearing, visual, physical, cognitive, learning and lack of language ability. Thus, general accessibility considerations for persons with disabilities can be

applied to persons with temporary disabilities. The main issue with persons with temporary disabilities is that they are not familiar with their specific needs due to their environments. They also may not be aware of accessibility features including assistive technology.

1) An IoT application or service is required to provide clear instructions and intuitive activation functions for any accessibility features.

2) Accessibility features that are provided by an IoT application or service are recommended to be as easy to use as possible.

3) An IoT application or service is recommended to use culturally independent wording and symbols that could be recognized internationally.

Recently, the automated language translation application utilized by mobile devices may act as an assistive technology for persons with a temporary language disability, i.e., foreigners. Culturally independent words and symbols used in an IoT application or service that are recognized in multiple cultures would enhance the use of such automated language translation applications and would increase accessibility using existing technology.

8.4 Category III: Ability to perform the required operations of an IoT application or service

8.4.1 User accessibility profile and service status recovery

Persons with disabilities, persons with age-related disabilities and those with specific needs may find difficulty and spend more time figuring out the current status of IoT services and setting up user accessibility profiles such as captioning settings, screen reader settings, etc. Such increased complexity may be discouraging when utilizing IoT applications and services.

1) Accessible information on the current status of 'things' is required to be provided at any time.

At times, the current status of an IoT application or service, and the status of all attached devices, may seem obvious; however, this may not always be true. For example, a loud sound from an audio system obviously indicates that the system is on. Similarly, a light bulb is surely on when the bulb illuminates. However, for some people, these may not be obvious indications. Persons with hearing disabilities may find it difficult to adjust the audio volume of a system based on the sound of the speaker. Likewise, persons with visual disabilities cannot tell whether the bulb is on or off by looking at the bulb. Proper feedback of information on the status of the 'thing' (e.g., light bulb, stereo) is important for persons with disabilities, persons with age-related disabilities and those with specific needs to operate an IoT application or service properly.

2) An IoT application and service is required to provide the means to reset the status of all attached 'things' to a certain predefined status.

When there are too many options that need to be set up, users can easily get lost. A simple resetting option that resets to a certain status may provide a simple method to go back to a known status. The user may start over from this status. The user may set up the predefined status in advance, or a simple factory reset may be sufficient. An IoT environment may involve changing status of multiple devices. In some cases, the sequence of operation may matter. The reset operation must be made as easy as possible to operate and should not assume user expertise in device operations.

3) It is recommended to enable the capability to retrieve user accessibility profiles (such as captioning settings) that are stored in an IoT environment by another thing.

In many cases, a user is required to set up accessibility profiles to accommodate their needs. To avoid confusion and difficulty with repeating the setup process each time, it is recommended to store and retrieve such profile information throughout the IoT application or service as well as to attached devices.

8.4.2 Installation and initialization of an IoT application or service, and/or an IoT device

For many users, installing and initializing an IoT application or service for the first time is not an easy task. Whether the user installs the application or service by themselves or relies on professional installation services, they must initialize the system including setting up the initial preferences and profiles, to learn how to use the system. For persons with cognitive, language and learning disabilities, and persons with age-related disabilities, it is not easy to understand the mechanisms of new applications or services. It may take time to learn to use newer applications or services.

1) It is required to provide information on how to use a new IoT application or service comprehensively and unambiguously when installing a new IoT application or service.

When installing a new IoT device to an existing IoT application or service, a user must be able to understand the installation and initialization process of the device itself, as well as the process of connecting and registering the device to the IoT application or service. For example, when a user wants to add an IoT-enabled smart plug to their home automation service, they must be able to understand the usage of the smart plug itself (e.g., how to turn it on or off using the physical switch) and, also, must be able to understand how to properly add it to their home automation service so that they can remotely control and monitor the smart plug through the mobile application.

In order to utilize accessible features of newly installed IoT devices for persons with disabilities, the IoT devices must be installed and initialized properly. Obviously, the accessibility features must be properly set up to facilitate a user's specific needs. Accessibility features may or may not be immediately available or may be limited during this initial process of installing and initializing. Thus, the installation manual should be in accessible format to support persons with disabilities to be able to install and set up accessibility features properly and to add new IoT devices. Moreover, the installation manual must contain the methods explaining how to enable available accessibility features or provide feasible means to install and initialize new devices.

2) It is required to provide information on how to use a new IoT device comprehensively and unambiguously when installing a new IoT device to an existing IoT application or service.

3) It is recommended to provide a manual in various formats including a text format such as printed materials, books, and electronic publishing, and a visual format with interactive technology using the virtual reality or augmented reality technology.

Often, an IoT application or service may be a very complex system. Therefore, developers often try to provide a manual that depicts the conceptual layout of the application or service in a visual presentation, which indeed helps some persons with cognitive or language disabilities. On the other hand, such visual presentation or a conceptual sketch of a system, including diagrams, icons, pictures and graphics, may not help persons with visual disabilities as they cannot see it. Providing multiple formats according to users' specific needs may help better understanding of a new IoT environment and enrich the user experience.

4) The predefined users' accessibility profiles are required to be maintained and transferred into the newly added IoT device.

5) The accessibility features are required to be provided according to predefined users' accessibility profiles during the entire installation process.

Another issue related to the installation and initialization is that often a new IoT device may be added to an existing IoT application or service and needs to be connected and recognized. In such cases, installing and initializing a new IoT device is not an easy task especially for persons with cognitive difficulties including persons with age-related disabilities even when plug-and-play features are supported. Moreover, persons with disabilities may also require additional installation processes to set up accessibility profiles prior to use (e.g., screen resolution adjustments, personalizing settings of captioning, screen reader and other assistive technologies).

8.5 Category IV: Ability to use suitable assistive technology with an IoT application or service

8.5.1 Compatibility with existing assistive technology

IoT applications and services may utilize diverse UI technologies. For example, an IoT application or service may use a dedicated kiosk for its UI. Some such UIs may have assistive technology built-in. However, greater accessibility may be retained when proper information is provided about the compatibility of the external assistive technology that users may choose depending on their types of disabilities.

1) An IoT application or service is recommended to provide information about its compatibility to known assistive technologies.

2) An IoT application or service is recommended to provide information about its possibility of interference with existing assistive technologies provided for persons with disabilities including assistive listening devices and medical devices (e.g., IoT devices must not interfere with hearing aids).

8.6 Category V: Ability to satisfy user's specific needs

8.6.1 Notification of malfunction and safety hazards

When an IoT application or service causes a safety hazard due to user malfunction, or it detects a safety hazard through its sensory technology, the usual reaction to this hazard should be to notify the user and stop the operation. However, persons with cognitive and physical disabilities and those with age-related disabilities may not be able to fully deal with the safety hazard with only one type of notification. For example, if the notification of the safety hazard is provided only visually, persons with visual disabilities may not be able to understand the system was in an emergency mode. The persons described above may not also be able to respond in time.

1) An IoT application or service is required to notify a user immediately if a malfunction of operation is detected that has a risk of a safety accident. Then, the IoT application or service must immediately cease to operate if there is no feedback from the user.

2) When safety hazard warnings occur and there is no user response, the IoT application or service is recommended to automatically notify emergency services (e.g., fire, ambulance, police) using the previously entered user's accessibility profile (e.g., type of disabilities, age, specific needs, the type of sign language interpreter if needed).

8.6.2 Disaster preparedness

There are many types of disasters, both man-made and natural. Each disaster will not affect people equally. Persons with disabilities are more prone to be negatively impacted by all disasters. Other vulnerable people to disasters are, but not limited to, children, especially those 15-years-old and under, older persons, especially those 65-years-old and over, and pregnant women. Other persons negatively affected are foreigners who do not speak the local language, persons who are not literate, persons who live in rural areas and those with low incomes.

The use of an IoT in a disaster management system is advantageous as many ICT features can be integrated into an IoT application or service. There are also a number of IoT applications available that are beneficial in disaster relief. The possibility of using IoT applications and services as an aid to disaster management systems and their general requirements are identified in [b-ITU-T Y.4102].

However, if disaster preparedness does not contain considerations for persons with disabilities and those specific needs including the other vulnerable persons listed above, disaster relief will not be useful as many will have been severely injured or will have perished. IoT applications and services could greatly contribute to early warning systems thus preventing the loss of life and minimizing injury to all persons especially those with disabilities. Use of IoT may diversify delivery channels of

disaster preparedness contents through their multi-user interface ability, and is essentially helpful reducing the gap between persons with and without disabilities.

1) It is recommended to provide comprehensive contents and functions of disaster preparedness for all people, including persons with specific needs.

Although the developments of content and functions of disaster preparedness are important, it is also important to continuously maintain existing content and functions and update and refine them to be even more effective. There should be one IoT system for disaster preparedness that takes in the needs of all persons including persons with disabilities and those with specific needs. This is in accordance with the concept of universal design (see Article 2 of [b-UNCRPD]).

8.6.3 Disaster relief

In case of disaster, persons with disabilities may require a much longer time to evacuate and more resources according to the category of the disaster. The main issues for vulnerable people to any disaster include:

– difficulties in understanding;

– difficulties in communicating information;

– lack of ability to avoid risk;

– difficulties in maintaining daily routines; and

– difficulties in psychological and mental faculties.

Thus, at the time of disaster, the needs that should be supplied include medical needs, communication needs, transportation needs, etc. At the state of disaster relief, it is important to devote all resources and efforts towards response activities designed to provide emergency assistance for those who are affected. This involves proper dispatch of emergency services and first responders, situation assessment and requirements assessment, and execution and monitoring of emergency evacuation procedures.

1) It is recommended that the IoT application or service include guidelines for disaster relief to fulfil specific requirements for all people, including those of persons with disabilities and with specific needs. Whether it be verbal, in sign language, or in pictographs, these communication tools should be incorporated into the IoT application or service.

IoT can assist disaster relief procedures by supplying proper updates and guidelines on assessment, monitoring, and execution of emergency evacuation procedures. The goal must be to consider an actionable plan for persons with disabilities at the time of disaster. Accessibility features that are incorporated in IoT that are essential for normal operation of IoT applications and services can be used to identify, support and supply needs of those who are vulnerable during a disaster.

Appendix I

Use cases illustrating the need for IoT accessibility

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

In this Appendix, IoT applications and services use cases that benefit persons with disabilities are presented. They concern eleven areas of accessibility requirements that are specific to IoT applications and services, and are described in clause 8.

I.1 Use case 1: Use of alternative representation of information

Mr. A is deaf. He is home alone. A visitor comes to his home and presses an IoT-enabled doorbell. The doorbell signals Mr. A's smartwatch and the smartwatch vibrates to notify Mr. A that there's a visitor at the door. Mr. A calls the relay service and the relay service representative answers the doorbell through the kiosk at the door. Mr. A and the visitor communicate through the relay service. The visitor was a mail man and Mr. A successfully received mail from his beloved son.

I.2 Use case 2: Concreteness of accessibility features

Ms. B is blind. She is waiting for a subway train. The incoming subway train sends its information including its destination to the smart city service. Ms. B's smartphone is notified. Information about the destination of the incoming subway train is spoken to Ms. B through her smartphone's screen reader. Ms. B realizes that the incoming train is the one she is waiting for. She successfully gets on the train.

I.3 Use case 3. Consistency between multiple user interfaces

Mr. C has a physical disability. Mr. C cannot move from his bed, by himself, due to his disability. When he is home alone, he grabs and IoT-enabled remote controller and turns the lights on. He also opens windows using the remote controller.

I.4 Use case 4: Compatibility with existing assistive technology

Ms. D is blind. She lives in an apartment that has built-in IoT smart home technology. However, she cannot use the IoT-enabled home control kiosk as it does not support accessibility input features for persons with visual disabilities, but it has built-in screen-reading capability. However, the kiosk has an option to connect a braille keyboard that she owns. She connects the braille keyboard to the kiosk. She can now control many of her home appliances that are connected to the IoT smart home service.

I.5 Use case 5: User accessibility profiles and service status recovery

Mr. E is 90 years old. His son bought him a smart phone and a IoT smart home service. Mr. E often forgets to turn off the lights and close the windows when he goes to bed. He very often forgets to turn off the TV. Mr. E's son usually sets Mr. E's home status to predefined 'sleep mode' through the IoT smart home service. The IoT service shuts the windows and all the lights as well as the TV at once.

I.6 Use case 6: Installation and initialization

Mr. F is blind. He owns and operates an IoT smart home system. Mr. F has a newly purchased microwave oven that is connected to his existing IoT smart home system. He unboxed the microwave oven and turned it on. His smart home system recognized the new microwave oven device and transferred Mr. F's accessibility profiles including the screen reading settings. Mr. F now can use his new microwave oven that is connected to his IoT smart home system in the same way the other devices that are already attached to it with his preferred accessibility features turned on.

I.7 Use case 7: Malfunction and recovery

Ms. G is deaf and works for a manufacturing company. Her company adopted a smart factory system using IoT. One day, one of the machines stopped due to a malfunction. The smart factory system notified Ms. G of the issue through her smartwatch by vibrating it as well as activating conventional audio alarm sound. The smart factory system automatically rerouted the production process and halted the malfunctioning devices. Ms. G went to the floor to find the cause of the malfunction and reset the device according to guidance from the smart factory system.

I.8 Use case 8: Safety hazard

Mr. H has a physical disability and does not have the ability to sense temperature. On a very warm summer when he was alone at home, Mr. H suddenly collapsed due to a sudden increase in blood pressure. Mr. H's wearable device, which is connected to his smart home IoT service system, detected the sudden change in Mr. H's blood pressure. The IoT system generated an alarm signal. The unconscious Mr. H did not respond to the alarm signal for a specific period of time. The smart home service recognized this and notified emergency service of Mr. H's difficulty. Mr. H's IoT emergency service called the ambulance with Mr. H's location. Mr. H was safely rescued.

I.9 Use case 9: Disaster preparedness

Ms. I has low vision. She lives in a town that has recently experienced many earthquakes. She is very concerned about possible disaster in the future due to an earthquake. Her home town adopted a smart city system and provides information on earthquake forecasts, emergency escape plans and other useful information related to disaster preparedness. This is done through printed materials as well as mobile applications. Due to her disability, she cannot read the printed materials, but she can utilize mobile applications on a smart phone with the aid of screen magnifying tools and a screen reader.

I.10 Use case 10: Disaster relief

Mr. J is deafblind. He was riding on a bus on his way home from work when a big tsunami smashed into the bus. When he awoke a few minutes later after the incidence, he had no idea what had happened to him. He was unable to move. The city-wide disaster management system, which incorporated IoT technology, detected Mr. J's smart watch, and his watch sent his vital condition and physical status as well as his personal health information. This included his GPS location to the disaster management system. The operator of the disaster management system identified Mr. J as endangered person. Rescuers found him in two hours. They already identified his personal information along with his specific needs associated with his disability. He was transferred to a hospital with the full care and services that he needed.

I.11 Use case 11: Temporary disabilities

Ms. K is Korean. She cannot speak French. She was asked to take a business trip to France for three months. She was staying at a residence hotel which is equipped with IoT services. The room at the residence hotel provided IoT services through a kiosk in the room. It can control the room temperature, room lights and phone services. She could not use the service through the kiosk directly as it only supported the French language. However, she was able to use the IoT services through her smart phone application which also supports language translation of French into Korean.

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