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TECHNICAL REPORT

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Internet of things (IoT) – Socialized IoT system resembling human social interaction dynamics

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INTERNET OF THINGS (IoT) – SOCIALIZED IoT SYSTEM RESEMBLING HUMAN SOCIAL INTERACTION DYNAMICS

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The text of this Technical Report is based on the following documents:

Draft	Report on voting
JTC1-SC41/227/DTR	JTC1-SC41/240A/RVDTR

Full information on the voting for its approval can be found in the report on voting indicated in the above table.

The language used for the development of this Technical Report is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs and www.iso.org/directives.

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INTRODUCTION

The Internet of Things (IoT) technology is the third wave of information industry, following the computer, communications network and the Internet. It provides the technology tools to build an effective interactive IoT system connecting human users and the physical world, which causes the changes in individual's daily life and also in the operations of human society. The innovative ideas can be implemented in IoT systems creating new markets for technology-based but user-friendly services. The technologies in the IoT systems will keep evolving with improving the existing technology and also the insertion of new technologies.

The communications network focuses on connection and transmission, and it realizes transmission service. The Internet focuses on information sharing, and provides services related to information sharing. The IoT systems focus on the objective physical world, realizing the basic sensing service and other services for the objects of interest (i.e. targets), events, etc., in the physical world.

In order to realize the sensing of the complex physical world, an IoT system needs to have an organized and coordinated sensing capability. For a specific target, this capability activates relevant sensor nodes, and division of labour and cooperation strategies are applied, which is similar to an enterprise that organizes people with required capabilities to form a project team and completes the project with proper division of labour and cooperation. In this perspective, therefore, it can be stated that the IoT system has socialized attributes as IoT nodes and terminals establish an orderly socialized system.

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This document comprises five main clauses. Clause 5 introduces the background and motivations for the study of the socialized IoT system. Clause 6 discusses the essential differences of the IoT systems compared to the communications network and the Internet. This comparison is summarized with the key features of the socialized IoT system. Clause 7 further analyses the socialized network, socialized collaboration and socialized service, which are designated as the three pillars of the IoT socialized attributes. Clause 8 addresses the sensing security issue for IoT systems. Clause 9 discusses the application methods of the socialized IoT attributes using a use case analysis, such as the intrusion prevention system or infrastructure protection. This document provides readers with the knowledge of the socialized characteristics and features of the IoT system, and inspires readers to adopt them in the design of IoT systems and provision of IoT services.

INTERNET OF THINGS (IoT) – SOCIALIZED IoT SYSTEM RESEMBLING HUMAN SOCIAL INTERACTION DYNAMICS

1 Scope

This document describes:

- key features of the socialized IoT systems, e.g. sensing the external physical world, resolving the uncertainties of targets, satisfying users' demand and providing quality service, etc.;
- socialized attributes, i.e. socialized network, socialized collaboration, and socialized services, which are derived from the key features; and
- guidelines on how to use or apply the socialized attributes in the design and development of IoT systems.

2 Normative references

There are no normative references in this document.

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3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

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- IEC Electropedia: available at http://www.electropedia.org/
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3.1
event
something that happens in the physical world and is observable or detectable by sensors

[SOURCE: IEC 60050-113:2011, 113-01-04, modified – In the definition, "subspace time of space-time" is replaced with "the physical world and is observable or detectable by sensors.]

3.2
object
person or thing that is observable or detectable by sensors

Note 1 to entry: Thing can be any living one (animals, plants, etc.) or any material one (table, car, etc.).

3.3
target
object or event about which information is searched by interest to IoT system

[SOURCE: IEC 60050-713:1998, 713-04-14, modified – In the definition, "or event" is added and "radar" is replaced with "interest to IoT system."]

3.4
socialized
having organized and constructive behaviour of functions in a system or among systems built with the attributes of the division of labour and the collaboration of tasks

3.5
socialized IoT system
system providing functionalities of IoT built on *socialized* (3.4) capability

Note 1 to entry: A socialized IoT system can include, but not be limited to, IoT devices, IoT gateways, sensors and actuators.

[SOURCE: ISO/IEC 20924:2021, 3.2.9, modified – In the term, "socialized" is added. In the definition, "built on *socialized* (3.4) capability" is added.]

4 Symbols and abbreviated terms

ICT information and communication technologies

IoT Internet of Things

D/I data/information

SNR signal-to-noise ratio

5 Introduction to the socialized IoT systems

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5.1 Three technological waves in ICT

Information acquisition, information transmission and information processing constitute the three pillars of information technology. The impact of IoT technology on information technology has caused significantly positive ripples on these pillars, which are denoted as "three waves" as described below and also shown in Figure 1.

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1) The first wave: The rise of the computer brings us to the digital world, which has changed the way of processing data/information (D/I). The first wave is labelled as "digitalization".
2) The second wave: The rapid development of communications technology and the Internet has created a world of inter-networking, which changes the way of transmitting D/I. The second wave is marked as "networking".
3) The third wave: IoT technology is the third revolution in information technology, which has changed the way of acquiring D/I. The third wave is designated as "socialization".

IoT technology has been moving forward to realize comprehensive information systems by sensing the physical world and providing sensing services, which requires the IoT physical and virtual entities to form an organized infrastructure in order to cooperate and collaborate with each other to accomplish given purposes or tasks similar to the teamwork by organized human teams. Therefore, an information system with such abilities can be characterized as a "socialized" system resembling human social dynamics.

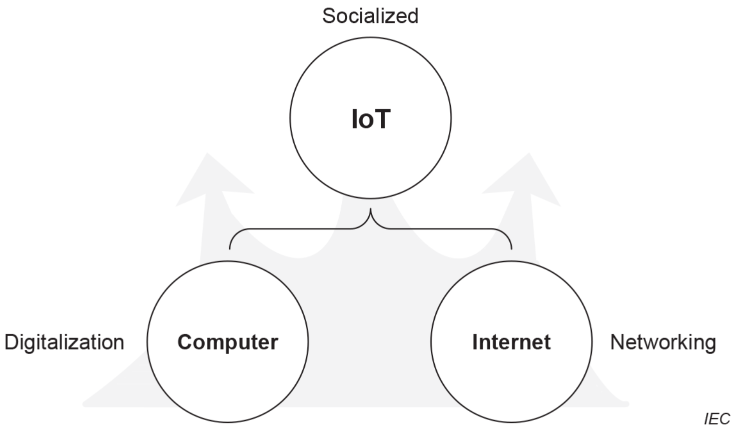

Figure 1 – IoT promotes the third wave in information technology

5.2 Resemblances between comprehensive IoT systems and human social dynamics

There exist many similarities between the comprehensive IoT system and human social dynamics, which can be illustrated by the three hierarchical levels described below.

1) Various types of sensors – bio-mimetic sensors, electronic sensors, chemical sensors, etc. – act as an extension of our sensory organs such as eyes, nose, ears, etc., to enable us to explore the physical world.
2) After the D/I are received from sensors, they are transmitted via sensor networks and/or data communication networks to D/I processing unit(s) for extracting and generating hidden information, situational information, predictive information, decision-aiding information, etc., by D/I aggregation, integration, fusion, mining, analytics, etc. This is analogous to the D/I collected by the human sensor organs which are transmitted to the brain through the human neural system for further processing.
3) In order to realize a comprehensive sensing and understanding of the physical world, the cooperation and collaboration of the D/I processing units from various types of sensor networks is required, which takes after human individuals in teams collaborating with each other and sharing their information and knowledge to make better decisions with available D/I.

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From the observations made in the three hierarchical levels, resemblances, i.e. social characteristics, between comprehensive IoT systems and human social dynamics do exist; thus, comprehensive IoT systems built on socialized capability are called "socialized IoT systems".

6 Key features of socialized IoT systems

The emergence and advancement of communications network and the Internet have greatly transformed how human society operates. An IoT system is inextricably linked with the communications network and Internet, and plays an irreplaceable role in realizing the integration of "Operational Technology (OT)" and "Information Technology (IT)". In essence, the key features of IoT are illustrated by comparing IoT with communications network and Internet in terms of purpose, provided services and the connecting ways.

1) The communications network is a network which focuses on data transmission. It focuses on the transmission of data itself and provides data delivery services.

   The Internet focuses on the information sharing and provides the services related to information sharing. The Internet takes information sharing as the core and promotes big data services. The big data services involve analytics and data mining of a large number of historical data and estimate or predict future trends.

An IoT system is a comprehensive information system with the purpose of sensing the external physical world, and one of its major services is the sensing service. An IoT system focuses on events occurring in the physical world that are both predictable and unpredictable. It encapsulates data related to events (such as target, task, environment, etc.), and it triggers decision-making process to manage the events. Thus, the IoT system transforms "big data service" to "big event service".

2) The communications network connects people. For example, people make phone calls and send messages through the mobile networks. As long as the network transmits voice or text messages from one mobile phone to another, the communication between people is completed. Communications network is concerned with the transmission of information and network coverage. Therefore, the communications network is an information transmission network connecting people.

   The Internet connects computers. The Internet provides people with rich and constantly updated information. People can get a plenty of electronic information by browsing news, downloading materials and using various online multimedia services.

   An IoT system connects things that exist in the complex and changing physical world. It aims at sensing the external physical world and provides sensing services. Therefore, an IoT system is a system providing a platform for interactions between human beings and the objects in the physical world.

From the comparisons between the communications network and the Internet, the IoT systems exhibit the following key features.

a) The IoT system focuses on the external physical world.

   The application scenarios concerned by the IoT system come from the external physical world. Massive sensor nodes acquire data from the physical world, and sensing nodes form a network for the needs of information transmission and processing. In order to achieve an effective management of the massive sensing nodes, an efficient network organizational structure is necessary.

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b) There are uncertainties for sensing targets in the IoT systems.

   For the IoT system, there are many uncertainties in the temporal and spatial distributions in target sensing. Because it is difficult for a single sensing node to achieve the all-around coverage and continuous sensing in all-weather conditions, it is necessary to place sensing nodes in different spatial locations, and carry out continuous real-time sensing. Thus, the division of labour and coordination between different sensing nodes in time and space is necessary.

   Different targets have different external shapes and characteristics, and the environment around the targets in different locations is also significantly different. A single sensing node has limitations in functional capability and sensing ability. It is necessary to utilize a variety of sensing nodes to realize a comprehensive sensing of the targets in order to eliminate the negative impact of the uncertainties so that an accurate sensing of the targets can be achieved. It facilitates the division of labour and collaboration in function types and processing capabilities between multiple sensing nodes.

   Further, changes brought by the updated information about targets, events and environments need to be fully explored based on historical information. The prediction or estimation of the target's future states (e.g. position, location, status, trajectory, and/or behaviour) can be learned based on the historical trends. Therefore, a single sensing node needs to have self-learning ability and the organized learning mechanism needs to be established among different sensing nodes.

c) IoT system is both demand- and service-driven.

   The IoT system is not driven by data, but driven by external demands. The emergence of external targets or tasks, or changes in the environment will trigger the IoT system to respond. The sensing approach and network topology need to be adjusted based on the targets' current and future predicted states.

7 Socialized attributes of IoT system

7.1 General

From the above analysis on the key features of IoT systems, the challenges faced by the IoT systems are clearly shown, and effort is being made to find reasonable and effective solutions. The solutions for the key points of the requirements can be summarized as follows.

1) For sensing of the real physical world better, a large number of sensing nodes are needed and IoT system needs to be built with an effective and efficient organizational structure.
2) To minimize or remove the uncertainties associated with the target being sensed by the IoT systems, the sensing nodes in the IoT system are facilitated to form the effective division of labour and cooperation among them. In order to improve the capability of sensing, the IoT system should have the ability to learn and establish a learning mechanism.
3) Driven by the goals and tasks, the sensing mode and networking topology of the IoT systems need to be adjusted and updated in order to provide better IoT services.

Through comparative analysis, it is not difficult to find the characteristics of the system's reasonable organizational structure, division of labour and cooperation, and service orientation are unique to social groups. These three characteristics, i.e. socialized network, socialized collaboration and socialized service, reflect the sensing behaviour of the IoT system and are the bases of the socialized attributes; therefore, these are designated as the three pillars of IoT system socialized attributes.

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7.2 Socialized network

7.2.1 General

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The network is not only the basic organizational structure of the IoT systems, but also the important foundation to support the applications and services of the IoT system. Socialized network refers to the internal mechanism of the establishment and operation of the IoT systems, which embodies the characteristics and attributes of socialization, including four types of network, i.e. topology-driven network, target-driven network, task-driven network and environment-driven network.

7.2.2 Topology-driven network

In order to effectively handle the management of massive heterogeneous sensor nodes, the IoT system needs to establish a well-designed organization structure. The well-designed organization structure with an effective networking and collaboration as well as efficient services helps the IoT system be more responsive when it is driven by external targets and tasks.

The network supporting this organizational structure constitutes the basic network of the IoT system, which is named "topology-driven network". The characteristics of topology-driven network are described as follows.