INTERNATIONAL STANDARD

ISO/IEC 30145-3

First edition
2020-08

Information technology — Smart City ICT reference framework —

Part 3: Smart city engineering framework

Reference number
ISO/IEC 30145-3:2020(E)

ISO copyright office
CP 401 • Ch. de Blandonnet 8
CH-1214 Vernier, Geneva
Phone: +41 22 749 01 11
Email: copyright@iso.org
Website: www.iso.org

Published in Switzerland

Contents

Page

Foreword

ISO (the International Organization for Standardization) and IEC (the International Electrotechnical Commission) form the specialized system for worldwide standardization. National bodies that are members of ISO or IEC participate in the development of International Standards through technical committees established by the respective organization to deal with particular fields of technical activity. ISO and IEC technical committees collaborate in fields of mutual interest. Other international organizations, governmental and non-governmental, in liaison with ISO and IEC, also take part in the work.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of document should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO and IEC shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents) or the IEC list of patent declarations received (see http://patents.iec.ch).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

This document was prepared by Joint Technical Committee ISO/IEC JTC 1, *Information technology*.

A list of all parts in the ISO/IEC 30145 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

0.1 General

The purpose of this document is to assist city chief information officers (CIO) and other stakeholders in planning and implementing a smart city. It comprises the following three parts:

— Part 1: Smart city business process framework

— Part 2: Smart city knowledge management framework

— Part 3 (this document): Smart city engineering framework

Each of the three parts is aimed at a different role or viewpoint within the city and thus separate focus needs to be maintained. The "separation of concerns" is a principle for the development of a city as it uses ICT to deliver the vision and objectives for the city. The value of using the separation of concerns is to simplify development and maintenance of the architecture as the city both develops and delivers improved outcomes for the city stakeholders.

Figure 1 shows the components of the smart city ICT reference framework, which consist of 5 components: stakeholders, vision and outcomes, the business process framework, the knowledge management framework, and the engineering framework. While stakeholders, vision and outcomes, and the engineering framework are described in this document, the business process framework and knowledge management framework are described in ISO/IEC 30145-1:—[1)] and ISO/IEC 30145-2:—[2)], respectively.

1) Under preparation. Stage at the time of publication: ISO/IEC DIS 30145-1:2020.

2) Under preparation. Stage at the time of publication: ISO/IEC DIS 30145-2:2020.

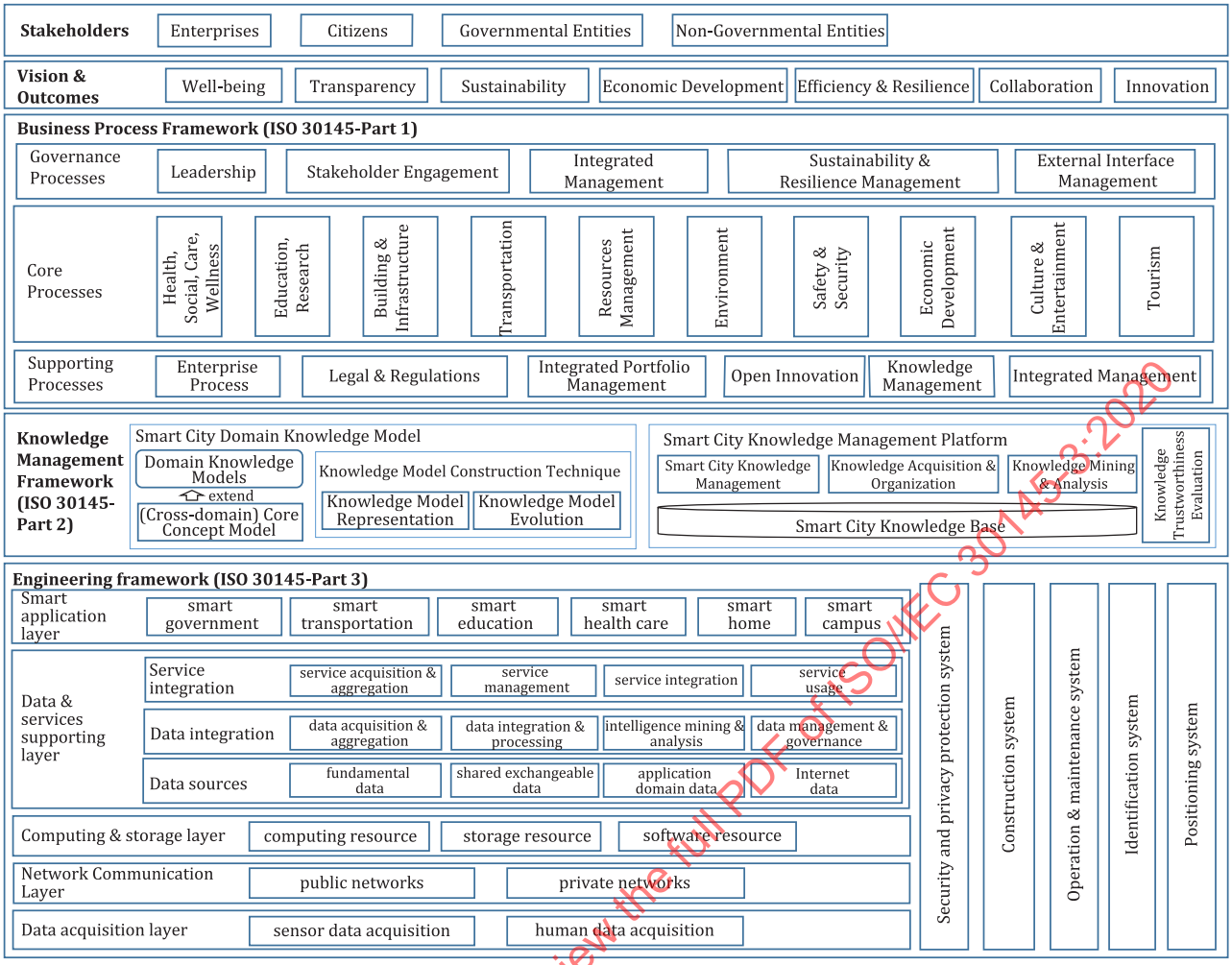

Figure 1 — Smart city ICT reference framework

0.2 Stakeholders

The stakeholders served by the smart city ICT reference framework are businesses, citizens, government organizations and non-government organizations. This stakeholder list is not exhaustive but defines the key stakeholders in a smart city and the user for the smart city ICT reference framework.

0.3 Vision and outcomes

The motivation of making a city smart is a result of a shared vision and a set of agreed outcomes from all of the city stakeholders. The vision and outcomes of the smart city ICT reference framework are well-being, transparency, sustainability, economic development, efficiency and resilience, collaboration and innovation. This vision and outcomes list is not exhaustive but defines the key vision and outcomes of a smart city. The smart city ICT reference framework articulates a vision that the smart city will be transparent in the delivery of city services which meet city sustainability ambitions. This vision uses collaboration and innovation approaches to deliver desired city outcomes. City outcomes are expected to improve efficiency and resilience of city services and promote economic development activities which enhance the well-being of citizens.

Information technology — Smart City ICT reference framework —

Part 3:
Smart city engineering framework

1 Scope

This document describes a framework, structured in layers of ICT technologies, essential for smart cities' operation. This framework also provides the mapping of the ICT techniques to various system entities in order to support the smart city's business, knowledge management, and operational systems from the engineering perspective.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

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

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

3.1 General terms

3.1.1
data
symbols and signals that represent properties of objects, persons, events and their environment

Note 1 to entry: In the English language the term "data" is generally used as a plural noun. For use in the singular, the term "data item" is sometimes used.

3.1.2
information
structured *data* (3.1.1) that are endowed with meaning and purpose

Note 1 to entry: Information is data that have been shaped into a form that is meaningful and useful to human beings.

3.1.3
positioning system
system of instrumental and computational components for determining position

EXAMPLE Inertial, integrated, linear, optical and satellite positioning systems.

[SOURCE: ISO 19116:2019, 3.24]

3.1.4
positional accuracy
closeness of coordinate value to the true or accepted value in a specified reference system

Note 1 to entry: The phrase "absolute accuracy" is sometimes used for this concept to distinguish it from relative positional accuracy. Where the true coordinate value may not be perfectly known, accuracy is normally tested by comparison to available values that can best be accepted as true.

[SOURCE: ISO 19116:2019, 3.22]

3.1.5
heterogeneous computing
system that uses more than one kind of processor or cores

3.1.6
heterogeneous computing resources
combination of hardware and software that can support *heterogeneous computing* (3.1.5)

3.1.7
data integration
process of combining *data* (3.1.1) residing in different sources and providing users with a unified view of them

3.2 Abbreviated terms

WGS84	world geodetic system
GPS	global positioning system
GLONASS	global navigation satellite system
PZ-90	parametry zemli 1990 goda

4 Smart city engineering framework

4.1 Introduction

This document gives descriptions of a Smart city from an engineering perspective. It consists of two parts, the horizontal engineering layers and the vertical systems. For each of the business processes defined and categorized in ISO/IEC 30145-1, a city uses the knowledge defined by the knowledge management framework in ISO/IEC 30145-2. Additionally, the knowledge defined by the knowledge management framework in ISO/IEC 30145-2 is used to understand how the engineering framework is implemented. The function of the horizontal layers is to provide a clear mapping of different techniques and components needed for smart city business processes. The function of the vertical systems is to guarantee the consistency of the technical implementation of a smart city.

4.2 Overview of the smart city engineering framework

Figure 2 shows the smart city engineering framework from the ICT perspective. The framework consists of 5 horizontal layers and 5 vertical cross layer systems with 4 types of smart city stake holders. The five layers are data acquisition layer, network communication layer, computing and storage layer, data and services supporting layer and smart application layer; whereas the five systems are security and privacy protection system, construction system, operation and maintenance system, identification system and positioning system. In addition, the four types of city users are citizens, enterprises, governmental entities and non-governmental entities. The five layers and five systems are introduced in detail in 4.3 to 4.12 respectively.

The data acquisition layer provides the capability to sense the world and take actions. The network communication layer consists of Internet, the telephone network, the cable television network and their convergence. The computing and storage layer includes resources for computing, data storage and foundation software. The data and services supporting layer fuses the data capture capability, communication capability, data storage capability and computing capability into data management and service management capability. The smart application layer offers smart applications and their integrations across industries and domains with support from the layers underneath. The security and privacy protection system addresses the security requirements of a smart city. The operation and maintenance system addresses the ability of a smart city to operate and maintain its IT services. The construction system addresses the ability of a smart city to transit its IT services into sustainable operations for design, planning, construction, maintenance and other aspects of smart city needs. The identification system provides all layers of the engineering framework with identification services. The positioning system is one of the basic systems in a smart city providing inertial, integrated, linear, optical and satellite positioning services.

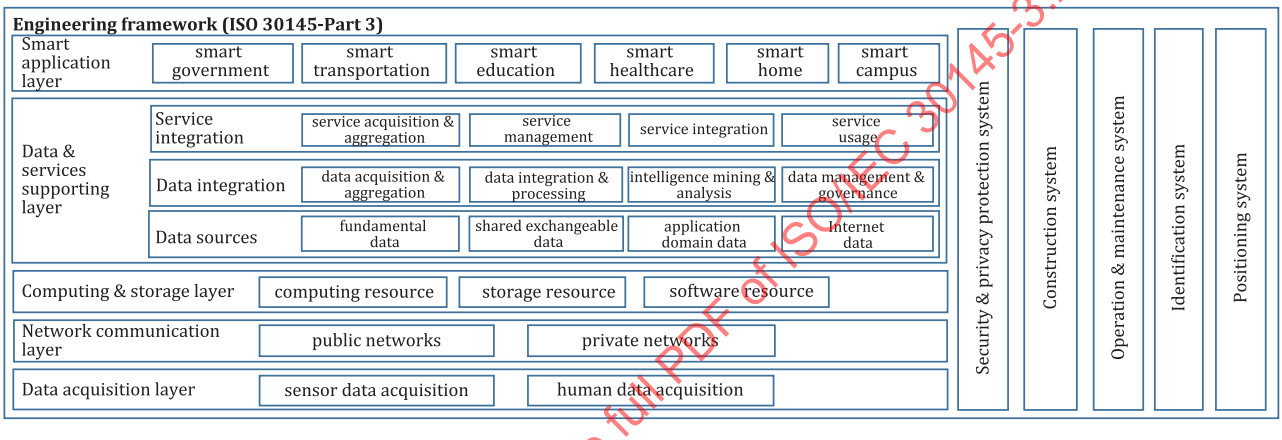

Figure 2 — Smart city engineering framework

From the six-domain IoT Reference Model (RM) and Reference Architecture (RA) in ISO/IEC 30141, the entities in the smart city engineering framework, which is a layer-based framework, shown in Figure 2, can be mapped as shown in Table 1.

Table 1 — Mapping of the layers and entities in the smart city engineering framework to the six domains of ISO/IEC 30141 IoT RA

ISO/IEC 30141 IoT RA	Smart City Engineering Framework		
Domain	**Layer**	**Sub-layer**	**Entities**
User Domain (UD)	stakeholders (not identified within the Engineering Framework)	NA	— Not specified in the Engineering Framework; but in takeholders. They are: — business entities; — citizens; — government organizations; and — non-government organizations

Table 1 *(continued)*

ISO/IEC 30141 IoT RA	Smart City Engineering Framework		
Domain	**Layer**	**Sub-layer**	**Entities**
Operation & Management Domain (OMD)	data & services supporting layer	service integration	— service management — service integration — service usage
		data integration	— data management & governance
Application & Service Domain (ASD)	smart application layer	N/A	— smart government — smart transportation — smart education — smart healthcare — smart home — smart campus
	data & services supporting layer	service integration	— service acquisition & aggregation
		data integration	— data integration & processing — intelligent mining & analysis
	computing & storage layer	N/A	— computing resource — storage resource — software resource
Resource Access & Interchange Domain (RAID)	data & services supporting layer	data resources	— fundamental data — shared exchangeable data — application domain data — Internet data
	computing & storage layer	N/A	— computing resource — storage resource — software resource
Sensing & Controlling Domain (SCD)	data & services supporting layer	data integration	— data acquisition & integration
Physical Entity Domain (PED)	smart application layer		— physical entities in each application domain, e.g., transportation, healthcare, etc.
	data & services supporting layer	data acquisition & aggregation	— physical entities being monitored for data acquisition

4.3 Security and privacy protection system

The security and privacy protection system addresses security requirements such as confidentiality, integrity and availability. It provides authentication, authorization, non-repudiation, user and role identity management, integrity, audit, security monitoring, incident response and security policy

management. This system is applicable to the design, planning, construction, maintenance and other aspects of the ICT systems of a smart city. This includes protecting the confidentiality and rights of individual citizens[9].

4.4 Construction system

The construction system provides the capabilities of design, planning, construction maintenance and other aspects of a smart city.

4.5 Operation and maintenance system

4.5.1 General

The operation and maintenance system provides an overall plan for the operation and maintenance services capabilities; provides necessary resources to implement operation and maintenance service capabilities, management and services content; ensures the quality of delivery to meet service level agreement requirements; carries out supervision, measurement, analysis, evaluation and improvement of operation and maintenance service results and service delivery processes. Existing standards for ICT service operation and maintenance, such as the ISO/IEC 20000 series, can be used by a smart city. Subclauses 4.5.2 to 4.5.5 summarize that approach to service operation and maintenance[3].

4.5.2 Planning

Planning includes the following aspects:

1. planning operation and maintenance service objects and requirements according to the business location and capacity, and forming a service catalogue;
2. establishing the appropriate organizational structure and management system following the service catalogue;
3. implementing operation and maintenance team, processes, and goals, carry out personnel, resources, technology and process planning, and establishing adapted assessment methods and a service support system;
4. planning to manage, review and improve the quality of service, and establish internal review and evaluation mechanisms.

4.5.3 Implementation

Implementation includes the following aspects:

1. developing an overall implementation plan, and performing according to the overall implementation plan;
2. establishing a communication and coordination mechanism with demand-side;
3. creating appropriate documentation to ensure the traceability of implementation; ensuring documentation results can be evaluated and measured;
4. constructing an operation and maintenance centre responsible for implementing system monitoring, operation command, maintenance, equipment management, service response and other functions;
5. creating the ability to monitor the operational state of hardware, control systems, applications from the data acquisition layer, the network communication layer, the computing and storage layer, the data and services supporting layer, the smart application layer, and responding in a timely manner.

4.5.4 Check

Check includes the following aspects:

1. periodic reviewing of Planning and Implementation to ensure their suitability and effectiveness;
2. investigating customer satisfaction, and statistically analysing the results of Planning and Implementation;
3. carrying out assessments based on the indicators illustrated in ISO/IEC 30146.

4.5.5 Improvement

Improvement is the ability to continuously improve operation and maintenance services. Improvement includes the following aspects:

1. establishing an improvement mechanism;
2. analysing planning, implementation and checking triggers the loop of planning- implementation-check-improvement.

4.6 Identification system

The identification system provides all layers of the engineering framework with identification services. The identification services provide unique identifiers for people, places, events, etc. as required by each layer of the framework. At the lowest level of the engineering framework, identification is facilitated by positioning systems that are based on a common i.e. "shared" reference framework, e.g., World Geodetic System (WGS84)[16]. Identification of people can be as simple as country or city specific unique identifiers (e.g., citizen ID), or as complicated as using biometric recognition technology to identify a person with some degree of accuracy, or even more complex where fragmentary information from multiple sources is combined/fused to hypothesize identify with perhaps an even lower degree of accuracy. The assignment of unique identifiers by identification system applies also to events, places, and documents.

4.7 Positioning system

The positioning system ensures that all other systems have a common idea of the spatial position of things. Many of these positioning services will be operated outside the city architecture and will provide a positioning service into various components of the city - sensors, applications, autonomous vehicles, etc. For consistency across the city, it is important that all the positioning uses a common spatial reference system, as described in ISO 19111. Often, this is a national or international (geodetic) reference framework. Examples include WGS84 (used by GPS) and PZ-90[17] (used by GLONASS), both of which are realizations of the International Terrestrial Reference Framework[14]. In many cases, a city can simply select a single international or national reference system and ensure that all other systems use it. The level of positional accuracy required depends on the use to which the positional information will be put. The level of accuracy achievable depends both on the equipment (system) used and the spatial reference system and supporting technology.

4.8 Data acquisition layer

4.8.1 General

The data acquisition layer provides the capability to sense the world and take actions. The core of the data acquisition layer is IoT technique. This layer provides several basic capabilities of a smart city such as sensor data acquisition and human data acquisition.

4.8.2 Sensor data acquisition

4.8.2.1 General

The capability leverages electronic devices such as sensor, RFID and camera, etc. to identify and collect information from the infrastructures, environment, buildings, etc., then to perform situation monitoring and controlling.

Sensor data acquisition includes two categories of equipment, sensing equipment and actuating equipment.

4.8.2.2 Sensing equipment

4.8.2.2.1 General

Sensing equipment is classified by capabilities and functions. Categories of sensing equipment are listed in Table 2.

Table 2 — Categories of sensing equipment

No.	Category of sensing equipment
1	Identification recognition equipment
2	Geolocation sensing equipment
3	Image sensing equipment
4	Environment sensing equipment
6	Security sensing equipment
7	Facility sensing equipment

4.8.2.2.2 General function

The general functions of sensing equipment are as follow:

1. Sensing equipment is the equipment through which a smart city can acquire different types of information about a city, based on which overall sensing and identification information acquisition and collection can be performed.

2. Sensing equipment of a smart city performs identification recognition, information collection and monitoring. It includes but is not limited to the following: identification recognition equipment, geolocation sensing equipment, image sensing equipment, environment sensing equipment, security sensing equipment, facility sensing equipment and other sensing equipment. Smart city sensing equipment has internet access functions by which it can transmit data to upper level layers.

4.8.2.2.3 Identification recognition equipment

Identification recognition equipment includes identification recognition tags, sensors, read and write equipment, etc. The identification recognition equipment includes but is not limited to the following capabilities:

1. Capable of unified identification encoding of infrastructure, equipment and people within a city.

2. Capable of unified recognition and management of above identification encoding.

3. The identification recognition tag and sensor support wireless network transmission protocols.

4.8.2.2.4 Geolocation sensing equipment

Geolocation sensing equipment meets at least the following two requirements:

1. Capable of supporting satellite network, mobile communication network, wireless network technologies, ability to locate the equipment or people's geolocation.
2. Capable of real time or non-real time tracking of above sensed geolocation.

4.8.2.2.5 Image sensing equipment

Image sensing equipment meets at least the following two requirements:

1. Capable of sensing appearance and motion factors of objects,
2. Capable of capturing video image and digital encoding.

4.8.2.2.6 Environment sensing equipment

Environment sensing equipment meets at least the following two requirements:

1. Capable of sensing and collecting environmental information such as temperature, humidity, pressure, wind force, wind direction, precipitation, etc.
2. Capable of sensing and collecting environmental pollution information such as PM2.5, noise, pollution emissions, etc.

4.8.2.2.7 Security sensing equipment

The security sensing equipment has the ability to sense and collect information relevant to city safety and security. Relevant fields include but are not limited to the following aspects: density of population, building safety, stream discharge, rainwater depth, density of poisonous gas, gas leakage, fire alarm, etc.

4.8.2.2.8 Facility sensing equipment

The facility sensing equipment meets at least the following requirement:

1. Capable of sensing and collecting infrastructure operation information such as water pipes, gas pipe lines, power supply lines, elevators, machines, etc.

4.8.2.3 Actuating equipment

The actuating equipment is equipment fulfilling the function of management and control of a smart city infrastructure, environment, equipment and people. It is used by various smart city applications and users for which the smart city has the capability of automatic or manual control function based on application requests. The abilities of smart city actuating equipment include but are not limited to the following:

1. the environment actuating equipment is capable of unified or partial environment control through manual or automatic environment control methods.
2. the warning equipment has the ability to send announcement and warning to people managing or using smart city services through sound or light signals.
3. Some examples of actuating equipment are: air filter, air temperature regulator, humidifier, dehumidifier, window opener, window shutter, and light switch.
4. Other actuating equipment is capable of controlling and managing functions over different smart city elements through different types of operation.

4.8.3 Human data acquisition

4.8.3.1 General

Human data acquisition leverages social sensing techniques to identify and collect information from the citizens to share their location, sentiments, demographics, and health data, then provide personalized services to them.

When human data is collected from social media, smart city engineering managers take into consideration the copyright and privacy laws or policies in each country to protect location privacy, anonymity and pseudonyms. Private information retrieval and privacy-preserved data mining technologies are also valuable for addressing issues.

4.8.3.2 Human location data acquisition

Human location data acquisition is capable of collecting human location data through smartphones or geo-tagged (check-in) services to detect citizen request locations and citizen real-time population density per area relevant to traffic congestion, full/vacancy status of parking lots, public transportation scheduling and disaster evacuation.

4.8.3.3 Human health data acquisition

Human health data acquisition is capable of collecting human health information such as heartbeat, blood sugar, blood pressure, sleep/wakefulness time, etc. using wearable sensors including smart watches and smartphones to advance human health and wellness, especially for addressing healthcare demands for aged people.

4.9 Network communication layer

4.9.1 General

The network communication layer consists of Internet, telephone network, cable television network and their convergence (ex. Mobile Internet). The layer provides communication infrastructure to smart cities with a high-capacity, high-bandwidth and high reliable optical networks and metropolitan wireless broadband network.

The network communication layer connects sensing equipment and the computing and storage layer. The network communication layer can be divided into public networks and private networks. Public networks can provide services to public users, including internet, telecommunication networks, broadcast networks, etc. IoT and sensing equipment can communicate with smart applications through public networks. Public networks include wired networks, wireless networks and backhauls. Private networks are wired networks or wireless networks organized and deployed according to the special purpose of a certain field. The private networks are used to connect distributed computing or virtual computing networks, or virtual private networks established based on public network infrastructures.

4.9.2 General functions

The network communication layer meets at least the following five capabilities:

1. It deploys and supports automatic connection and configuration, real time management and maintenance.
2. It is reliable and robust. Technologies such as backup, load balancing and redundant design should be considered to enhance reliability and robustness of the system.
3. It supports remote management of the equipment to simplify the operation and management,
4. It supports the visualization of QoS to realize quick fault location.

5. It constructs green communication networks from the viewpoints of temperature control and renewable energy.

4.10 Computing and storage layer

4.10.1 General

The computing and storage layer includes resources for computing, data storage and foundation software. It equips the smart city with a hardware and software platform for building and hosting upper layer services and applications. The platform leverages resources to address application requirements, for example, data management on storage, and data processing through computing capability.

The computing and storage layer consists of software resource, computing resource and storage resource. These three parts can provide storage, computing and other relevant software resources to guarantee the data demand from the data and services supporting layer and the smart application layer.

4.10.2 Computing resource

4.10.2.1 Centralized computing resource

Centralized computing is computing performed at a central location, using terminals that are attached to a central computer. The Centralized computing resource is the combination of hardware and software that can support centralized computing. Centralized computing resource supports:

1. high performance computing;
2. customized server design;
3. on demand, virtual computing resource allocation;
4. administration of computing resources by different categories of users;
5. dynamic storage and disc expanding to the operating virtual machines.

4.10.2.2 Distributed computing resource

Distributed computing is a model in which components located on networked computers communicate and coordinate their actions by passing messages. The distributed computing resource is the combination of hardware and software that can support distribution computing. A distributed computing resource has the following capabilities:

1. Capable of supporting distributed storage;
2. Capable of supporting interoperability of heterogeneous computing resources;
3. Capable of supporting data sharing and exchange protocols;
4. Capable of supporting connection and management of heterogeneous computing resources.

4.10.3 Storage resource

4.10.3.1 Centralized storage resource

The centralized storage resource meets at least the following seven capabilities:

1. Supports common storage methods;
2. Supports storage and application of structural data, semi-structured data and unstructured data;

3. Supports the operation of command line and graphic interface management. Storage equipment supports monitor functions;
4. Supports storage resources management, such as resource creation, expansion, allocation, scheduling, allocation, etc.;
5. Supports automatic deployment of storage system, including software installation and configuration, plug and play, hot plug, etc.;
6. Supports self-detection and fault isolation without stopping the system;
7. Supports the access control rules set up based on IP address, user or user group, by which a safe and isolated storage pool can be created.

4.10.3.2 Distributed storage resource

The distributed storage resource meets at least the following seven capabilities:

1. Supports various types of ports and their protocols;
2. Supports automatic deployment and configuration by software;
3. Supports simplified resource configurations according to different categories of user or user groups;
4. Supports symmetry structure;
5. Supports concurrent access in distributed storage resourced environment and supports various load balancing policies based on node polling policy, node connections, node capacity or node processing capabilities (processor, memory or bandwidth), etc.;
6. Supports dynamic classified storage, hot data migration, and system performance enhancement;
7. Supports smart load balancing, cross node terminal load balancing, automatic capacity and performance balancing, and enhance cluster resource; supports global buffer to accuracy of data access.

4.10.3.3 Data integrity and availability

Data integrity and availability meets at least the following six capabilities:

1. Supports mainstream operating systems and backup softwares;
2. Supports redundancy of the system to avoid the data loss caused by single node fault;
3. Supports deployment data redundancy protection policies; supports centralized data backup and multisite data backup and cloud backup;
4. Supports unified data protection and recovery management;
5. Supports data encryption functions to avoid unauthorized access;
6. Supports automatic operation of data protection policies, guarantees the data recovery of data under the condition of system fault.

4.10.4 Software resource

The smart city software resource includes all the basic software that can support the operation of normal functions of a smart city. The basic software includes but is not limited to operating systems,

database, middleware, and resource management software. The software resource has the following capabilities:

1. Software installed on the servers should be able to support the physical computing resource or virtual machines and support distributed deployment, cluster and load balancing.
2. It provides modules, tools and environments to support the application research and development, testing, deployment, operation and monitoring.
3. It supports the unified operation and monitoring of smart city supporting equipment such as servers, storage, network and security.
4. It supports data backup.

4.11 Data and services supporting layer

4.11.1 General

The data and services supporting layer is the layer between the smart application layer and the computing and storage layer. It takes critical responsibility. The layer fuses the data capture capability, communication capability, data storage capability, and computing capability into data management and service management capability which could be consumed by the smart application layer directly.

The data and services supporting layer consists of three parts: data sources, data integration and service integration. On the base of stressing the data sources for smart city, the data and services supporting layer provides a variety of data and services for the applications to serve the construction of all kinds of applications.

The data sources include a variety of information resources in different sectors or fields, such as fundamental data, shared exchangeable data, application domain data and Internet data. Information resource refers to the information itself or information content, i.e., the processed and supportive data for decision making.

Data integration is the capability of integrating and analyzing the data, data acquisition layer and smart application layer of different sectors or fields. It includes four capabilities: data acquisition and aggregation, data integration and processing, data mining and analysis and data management and governance.

Service integration contains the basic technical service requirements that support smart city applications, and its typical composition includes at least service aggregation, service management, service convergence, and service use.

Data sources meet at minimum the following three capabilities:

1. Includes demographic, legal, geo-spatial, macroeconomic and other basic information resources;
2. Includes the data from application information systems of industry sectors, enterprises, organizations and other fields;
3. Includes other information sources in cyberspace.

4.11.2 Data integration

4.11.2.1 Data acquisition and aggregation

Data acquisition and aggregation capability includes the following aspects:

1. Provides the capability to discovery, access, transmit, receive, recognize and store different types of data from sensors, industrial applications and the internet, and so on;
2. Supports structured data, semi-structured data, unstructured data, and other different types of data;

3. Provides the capability of real-time data transmission and processing;

4. Provides monitoring and management capabilities for the data acquisition layer.

4.11.2.2 Data integration and processing

Data integration and processing capability includes the following aspects:

1. Provides extract, transform and load functions for structured data and semi-structured data;

2. Provides automatic or semi-automatic identification, extraction, tagging and other digital means for unstructured data;

3. Provides integration and processing tools or components with the capabilities of monitoring and management capabilities and support of local language interface operation.

4. It provides semantic harmonization of acquired data into a common language for the city.

4.11.2.3 Intelligent mining and analysis

Intelligent mining and analysis capability includes the following aspects:

1. Diagnostic analysis, predictive analysis, causality analysis, sentiment analysis, etc.

2. Provides a variety of analytical methods and models based on statistical analysis and machine learning technologies which have advanced in 2010's, such as deep learning and reinforcement learning using neural networks, probabilistic graphical models, and so on. The target materials for analytics include not only sensory data but also multimedia and social data such as texts, images, videos, sounds, tweets, and so on.

3. Provides graphical and geographical visualization tools to clarify the chronological and special relationships, characteristics, or trends in the data. Visualization tools present animation function to replicate the chronological transition vividly and also provide graphics and images on the area map to evoke the association between the data and the physical entities or citizens' concern in the real world.

4.11.2.4 Data management and governance

Data management and governance capability includes the following aspects:

1. Provides metadata management capabilities, supports persistent storage of metadata, supports the creation and maintenance of metadata organization model, and provides update, search query, version control and other functions for metadata;

2. Provides data quality management capabilities, supports the definition of data quality rules, and supports data content inspection, cleaning and calibration activities based on data quality rules;

3. Provides life-cycle management of data and supports the clear development by users for data management policies, procedures and activities; manages and controls data creation, receiving, distribution, use and destruction;

4. Provides master data management, that is, the management of internal and external codes and controlled lists.

4.11.3 Service integration

4.11.3.1 Service acquisition and aggregation

Service acquisition and aggregation capability includes the following aspects:

1. Provides adaptation and conversion functions for common communication protocol;