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Recommendation

ITU-T Y.4485 (03/2023)

SERIES Y: Global information infrastructure, Internet protocol aspects, next-generation networks, Internet of Things and smart cities

Internet of things and smart cities and communities – Frameworks, architectures and protocols

Requirements and reference architecture of smart education

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Recommendation ITU-T Y.4485

Requirements and reference architecture of smart education

Summary

Recommendation ITU-T Y.4485 specifies requirements and reference architecture of smart education to support IoT-based education services, devices and management.

This Recommendation provides concepts, features and technical challenges of smart education requirements, reference architecture and common capabilities of the smart education different layers.

History

Edition	Recommendation	Approval	Study Group	Unique ID*
1.0	ITU-T Y.4485	2023-03-28	20	11.1002/1000/15484

Keywords

Internet of things (IoT), reference architecture, requirements, smart education, smart education cloud platform (SECP).

* To access the Recommendation, type the URL http://handle.itu.int/ in the address field of your web browser, followed by the Recommendation's unique ID. For example, http://handle.itu.int/11.1002/1000/11830-en.

FOREWORD

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

In some areas of information technology which fall within ITU-T's purview, the necessary standards are prepared on a collaborative basis with ISO and IEC.

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1 Scope

This Recommendation specifies requirements and reference architecture of smart education to support IoT-based education services, devices and management.

The scope of this Recommendation includes:

– Concept, features and technical challenges of smart education;

– Requirements of smart education;

– Reference architecture of smart education;

– Common capabilities of smart education.

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

[ITU-T Y.4101] Recommendation ITU-T Y.4101/Y.2067 (2017), *Common requirements and capabilities of a gateway for Internet of things applications*.

3 Definitions

3.1 Terms defined elsewhere

This Recommendation uses the following terms defined elsewhere:

3.1.1 application [b-ITU-T Y.2091]: A structured set of capabilities, which provide value-added functionality supported by one or more services, which may be supported by an API interface.

3.1.2 device [ITU-T Y.4000]: With regard to the Internet of things, this is a piece of equipment with the mandatory capabilities of communication and the optional capabilities of sensing, actuation, data capture, data storage and data processing.

3.1.3 gateway [ITU-T Y.4101]: A unit in the Internet of things which interconnects the devices with the communication networks. It performs the necessary translation between the protocols used in the communication networks and those used by devices.

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.

3.2 Terms defined in this Recommendation

This Recommendation defines the following term:

3.2.1 smart education: An Internet of things (IoT)-based educational framework for an enhanced learning experience, improved teaching efficiency, and high content adaptability to provide digitalized, interactive and intelligent services with ubiquitous connectivity.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

3G	Third Generation
4G	Fourth Generation
5G	Fifth Generation
API	Application Programming Interface
AR	Augmented Reality
BFB	Biological Feedback
CO_2	Carbon Dioxide
DDM	Digital Dynamic Modulation
DRM	Digital Rights Management
GNSS	Global Navigation Satellite System
IaaS	Infrastructure-as-a-Service
ICm	Interactive Classroom
ICT	Information Communication Technology
IoT	Internet of Things
MIS	Management Information System
OnL	Online Learning
PM	Particulate Matter
PaaS	Platform-as-a-Service
SaaS	Software-as-a-Service
SECP	Smart Education Cloud Platform
TaL	Teaching and Learning
VR	Virtual Reality
WIFI	Wireless Fidelity

5 Conventions

The following conventions are used in this Recommendation:

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

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

6 Introduction to smart education

Traditional education system with teacher-centred, book-centred, and classroom-centred teaching mode often leads to a situation where students engage only in one-way interaction and passively receive one-size-fits-all teaching with little or no feedback.

Along with information communication technology (ICT) development and its usage, more and more digitalized facilities are used in classrooms for teaching and learning purposes. Many educational institutions build high-speed and broadband campus networks to support school management and services. Digitalized teaching resources and online educational resources also emerge rapidly.

Most of these applications realize the digitalization of learning materials and networking of specific teaching and learning (TaL) environments, which has improved teaching and learning efficiency to a certain extent.

However, there are still many technical problems to be solved. Students are not able to study anytime and anywhere. Students learning experience in classrooms might be poor because of the lack of real-time interaction. Additionally, educational resources and data are distributed in isolation and cannot be shared. It is difficult for students to get personalized resources based on their individual needs and learning preferences, and for teachers to collaboratively conduct teaching research and improve teaching efficiency, as well as for school administrators to make data-driven evaluations of teaching quality and data-informed decisions on school management.

With the development and usage of the Internet of things (IoT) and other ICTs in the process of educating, IoT-based learning environment improves the perception and experiences of students, as well as the interaction between teachers and students. Students benefit from highly individualized learning experiences since education-related information can be integrated into the database on the cloud and shared with users at anytime and anywhere.

Smart education is an innovative educational framework based on digital solutions such as IoT, big data and cloud technologies for an enhanced learning experience, improved teaching efficiency, and high content adaptability.

Smart education aims at eliminating the pitfalls in the traditional education system and improving the perception and learning experiences of students as well as in the meaningful interaction between students and teachers.

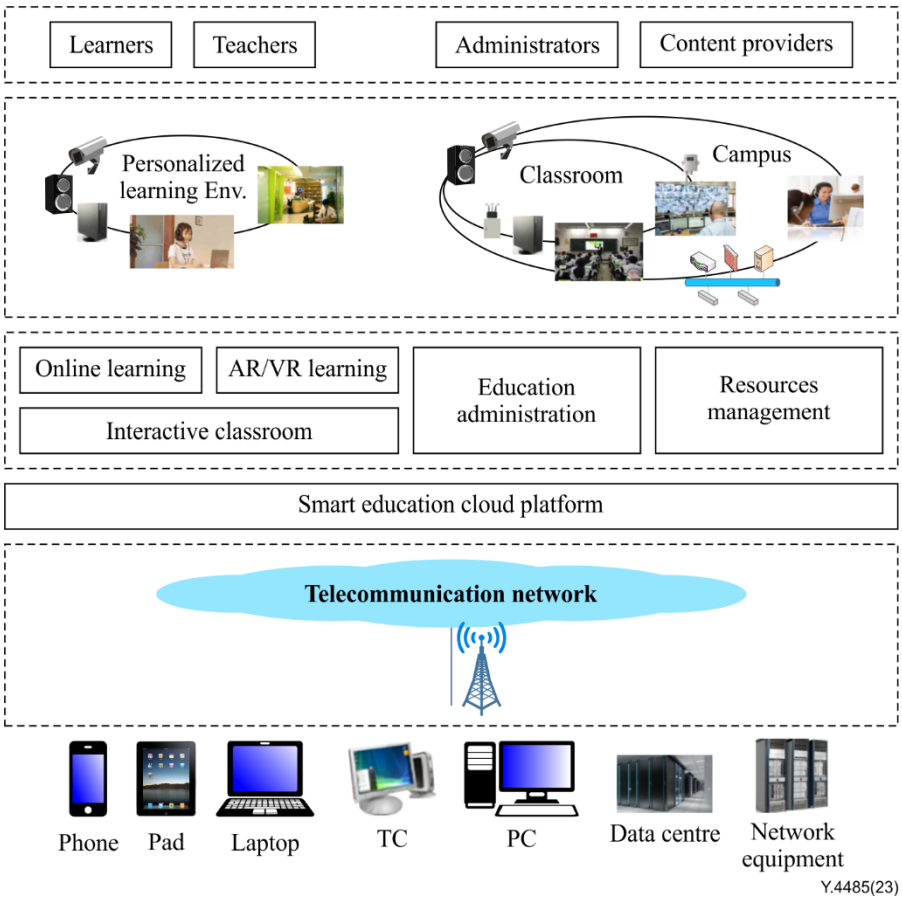

Figure 6-1 – Overview of smart education

The overview of smart education is shown in Figure 6-1. Smart education provides:

1) various smart education applications for different users. Student-centered teaching applications include interactive classrooms (ICm), online learning (OnL) and augmented reality (AR)/virtual reality (VR) learning based on the analysis of students' learning needs and habits. Education administration includes basic education information management, educational research, teaching quality evaluation, etc., through the integration of external systems. Resource management includes education resources management, teaching and learning (TaL) devices management, etc.;

2) learning behaviour data and education resources information integrated through a telecommunication network into a smart education cloud platform (SECP) which provides capabilities of data storage, integration analysis and computation for personalized services;

3) wired or wireless telecommunication network for comprehensive interconnection of users, machines and things, in order to transport data among them, which is a basic function to fulfil the requirements of smart education;

4) different kinds of teaching and learning environments with connective, perceptive, interactive TaL equipment, where TaL equipment (e.g., electronic whiteboard, multimedia booth, recording and broadcasting system), IoT devices related to the environment (e.g., hygrometer, curtain and lighting system), and edge computing facilities (e.g., computer responsible for processing data on-site) are deployed on-site on-demand.

7 Requirements of smart education

7.1 TaL devices

TaL terminals/devices are required to:

– apply smart education services in the interactive classroom, online learning and AR/VR learning environment;

– support uploading and receiving information from the IoT area network.

NOTE 1 – TaL terminals may include various digital computing devices (such as smartphones, tablet computers, and multimedia equipment) connecting to wired or wireless networks.

Multimedia equipment is recommended to support text communication, interactive demonstration, audio-video dialogue, and synchronous or asynchronous display of multiple screens, which enable learning for persons with disabilities.

NOTE 2 – Multimedia equipment may include an interactive intelligent panel, electronic whiteboard, multimedia booth, electronic class board, recording and broadcasting system, and other digital electronic display equipment and related control equipment.

Recording and broadcasting equipment are recommended to support video/audio recording and broadcasting in an interactive classroom or on an online learning site.

Environment-specific IoT devices are recommended to support automatically sensing, acquiring and transmitting environment parameters in the classroom.

NOTE 3 – Environment parameters may include light intensity, carbon dioxide (CO2), particulate matter (PM)2.5, noise, temperature, humidity, etc.

Auto control functions are recommended to be supported for power switch and linkage control of electronic devices, such as air conditioners, curtains and lighting systems, according to environmental parameters.

7.2 Communication networks

A safe and stable network is required to be provided to support access to data and services from IoT devices.

A wireless communication network such as wireless fidelity (Wi-Fi), third generation (3G)/fourth generation (4G)/fifth generation (5G) is required to be provided to transfer data between TaL terminals and SECP, as well as to transfer data inside an interactive classroom (ICm), online learning sites or AR/VR sites.

It is required for telecommunication networks including wired communication networks (e.g., copper network and optical network) to transfer data between ICm and SECP, as well as transfer data inside the school campus.

Cost-effective network access service with low bandwidth-intensive requirements in terms of usage and affordability is recommended to be provided to support the deployment of smart education systems in rural and semi-urban areas.

The network transport capability is required to meet the service requirements such as bandwidth, latency and packet loss rate, etc.

Network control and management functions such as traffic and congestion control, fault and performance management, and authorization are required to support the data and services transmission in the network.

7.3 Requirements of smart education applications

7.3.1 TaL applications

7.3.1.1 Interactive classroom (ICm)

ICm is required to:

– provide real-time information interaction and feedback in various media forms (e.g., text, audio, video, or a combination of them) between teachers and students to meet their personalized teaching and learning needs and other management businesses;

– enable learning for persons with disabilities via sound, light, image and other means using adequate multimedia equipment;

– provide access service for teachers and students to meet their TaL needs especially in the peak period.

ICm is recommended to:

– support text communication, interactive electronic-whiteboard-data demonstration, audio-video dialogue, and synchronous or asynchronous display of multiple screens in the classroom;

– collect, and integrate information on the teaching process in various media forms;

– provide classroom-teaching recordings, group-teaching recordings, large-scale live broadcasts, on-demand broadcasts, remote interactive activities, and teachers interactive teaching activities;

– automatically sense, acquire, store and process environmental parameters in the classroom;

– auto control power switch and linkage control of electronic devices in the classroom, particularly according to the change of environmental parameters.

7.3.1.2 Online learning (OnL)

OnL is required to:

– provide screen sharing, courseware sharing, the interaction of multimedia equipment, as well as various teaching terminals switching;

– support encryption of live broadcasting and on-demand broadcasting courses, prevention of video/audio recording, and protection of data copyright.

OnL is recommended to:

– provide online video communication training and coaching for educators;

– provide multiple network teaching modes, such as on-demand broadcast and live broadcast;

– provide a searching tool for online content like learning toolkits, aggregated resources, etc.;

– provide classroom management functions, including classroom roll call, desktop monitoring, class statistics, screen lock, etc.

7.3.1.3 AR/VR learning

AR/VR learning is required to:

– provide a virtual learning environment for teachers and learners;

– provide a learning mode where teachers, learners, learning objects and the environment can interact with each other.

AR/VR learning is recommended to:

– collect and integrate information of the learning process in various AR/VR devices;

– automatically sense, acquire, store and process learning objects and environmental parameters in the learning environment.

7.3.2 Education administration

Education administration is required to:

– integrate internal and external systems associated with TaL applications;

– support applications such as basic TaL information management, quality evaluation and analysis, resources allocation and other functions;

– provide a service portal for authorized users to access various management information systems (MIS) according to access privilege/authority;

– provide collection, aggregation, storage and retrieval of educational information.

Education administration is recommended to provide real-name online space which integrates personalized services and data for students, teachers and other users.

NOTE – Real-name online space, which can support resource sharing, teaching interaction and learning innovation, may include students' personal space, teachers' personal space, administrators' personal space, and institutional space.

Basic TaL information management includes user information management, exam and score management, library information management, school asset management, etc.

7.3.3 Resource management

Resource management is required to provide:

– remote operation and manage the information resources and devices;

– a service portal for authorized users to access various management information systems according to access privilege/authority;

– collection, storage, retrieval and monitoring of resources.

Resource management is recommended to support education resources and TaL devices management for authorized users to manage the status.

7.4 Smart education cloud platform (SECP)

SECP is required to provide:

– flexible deployment of virtualized resources on infrastructure-as-a-service (IaaS), software-as-a-service (SaaS) and other service modes;

– remote status perception and control management of the equipment in the classroom, and automatic switching of the teaching environment, in order to form a physical and intelligent equipment management environment;

– integration, processing and analysis of data from environmental sensing devices, teaching devices and other devices in the classroom;

– cloud storage, synchronization and backup of teaching resources, upload and download of teaching resources, quick retrieval and other functions, as well as statistical analysis of resources;

– resource development tools for content providers to make courseware and other multimedia resources;

– a unified portal to support user access.

SECP is recommended to provide:

– decentralized cloud computing resources deployment, where edge computing facilities responsible for on-site data processing and storage can be deployed on-demand in the classroom, campus, or on an online learning site;

– the corresponding "cloud service" mode of application covering teaching, learning, management, evaluation, research and other school core business;

– teaching data collection and analysis, which include real-time statistics, tracking of TaL and operation data, as well as intelligent and personalized applications using artificial intelligence, big data analysis and other technologies.

NOTE – Based on the data integration, big data analysis and evaluation index system, the analysis of students learning behaviour and teachers teaching behaviour is carried out to provide a scientific evaluation on the improvement of the educational environment and teaching methods.

8 Common capabilities of smart education

8.1 Reference architectural model for smart education

Figure 8-1 shows a reference architectural model for smart education based on the IoT reference model in [ITU-T Y.4000].

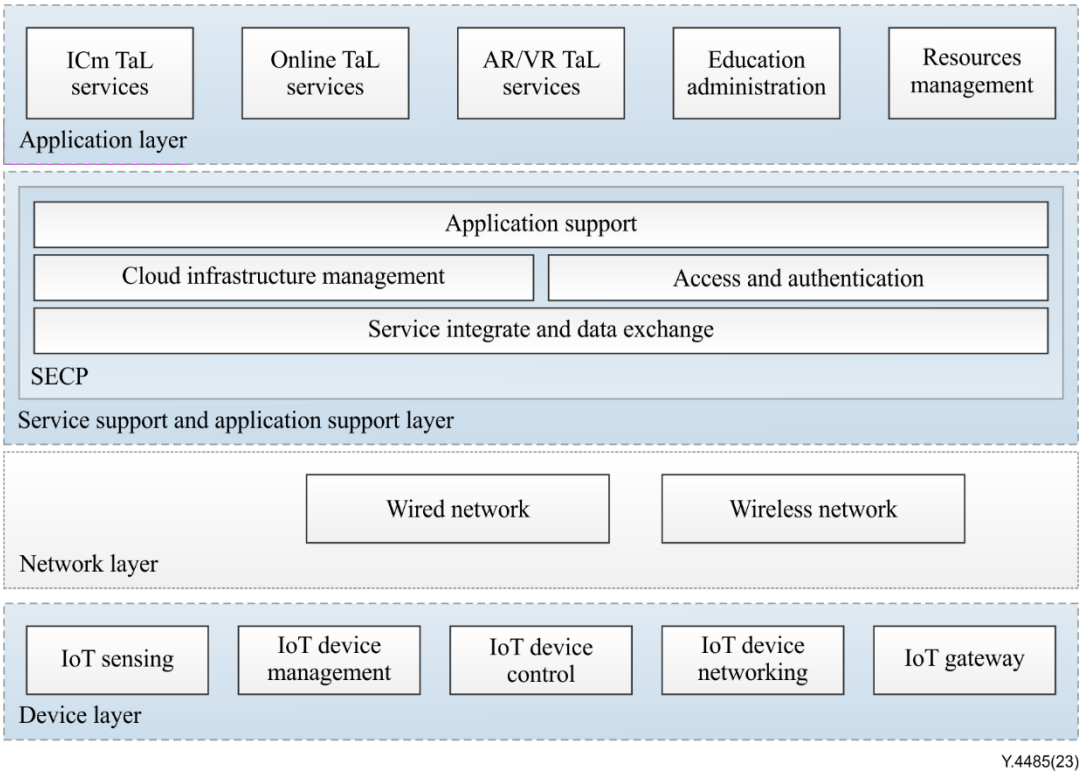

Figure 8-1 – Reference architectural model for smart education

8.2 Device layer

The device layer supports various capabilities to acquire sensing data, field control, transfer data and deliver data to the network layer.

8.2.1 IoT sensing capabilities

Through a variety of information acquisition equipment, sensors, surveillance cameras, and the global navigation satellite system (GNSS) terminals, it provides the ability of intelligent perception of an educational environment, and other aspects of educational infrastructure, and the atmospheric

environment. It subsequently implements information collection, identification and detection. It uses perceptual technology to timely perceive all kinds of resources and static/dynamic attribute information.

8.2.1.1 Environment sensing

This capability supports the sensing of the surrounding environment. Sensors installed in a classroom, a TaL terminal device or an AR/VR site measure environmental parameters in real time. The various parameters (e.g., light intensity, CO_2, PM2.5, noise, temperature, humidity, location, etc.) are measured to evaluate whether the indoor environmental quality standard is met. The sensed data is transferred to the environment control function periodically or on request.

8.2.1.2 TaL behaviour sensing

This capability supports collecting the behaviour data of teachers and students in a classroom. A recording system, camera or AR/VR device installed in a classroom, a TaL terminal device or a learning site records the audio/video and other information in real-time. The information data are transferred to the SECP through a communication network and processed to make learning behaviour analysis.

8.2.1.3 TaL information interaction

This capability supports information communication and interaction between teachers, students, learning objects and the environment on TaL sites. Multimedia equipment can send, receive and display text, image, voice, video and other media information in real-time. It can have video recording, high-definition photo shooting, wireless sound amplification, screen sharing and other functions.

The AR/VR devices build a virtual learning environment based on the sensing data. The user's behaviours can be mapped into the virtual environment and interact with the virtual objects. The AR/VR devices also provide users with auditory, visual and tactile feedback functions in a virtual educational environment after data processing and simulation.

8.2.2 IoT device control capabilities

8.2.2.1 Environment control

This capability supports the adjusting parameters of the surrounding environment integrated with actuators such as conditioners, fresh air systems, and lighting systems in a classroom. Environment control receives environmental parameters from environment sensing, measures the status of environmental quality, and sends an open/close/adjust action control command to the relevant actuators. It monitors the status of the environment sensors and actuators. It gathers and reports the controlling information to the SECP through a communication network, and also receives configuration commands from SECP at the same time.

8.2.2.2 TaL terminal control

This capability supports the control of multimedia equipment in a TaL environment. TaL terminal control receives the request from users or SECP and sends a start/stop/lock action command to the relevant actuators periodically or on request. It supports text, photo, audio, and video communication in a synchronous or asynchronous mode which enables learning for persons with disabilities. It gathers and reports controlling information to the SECP through a communication network, and also receives configuration commands from SECP at the same time.

8.2.3 IoT device management capability

This capability supports to retrieve status, detect exceptions, and manage the sensor and controller. It can retrieve device status and sensing data of a sensor or controller periodically or on request. When any IoT sensor or controller has an abnormal status, IoT device management generates exception

information or alarms, and correspondingly start/stop/lock/calibrate/recover the sensor or controller. The management data and operate log is collected and transferred to the smart education cloud platform (SECP).

8.2.4 IoT device networking capability

This capability supports the configuration of a wired/wireless integrated IoT network in smart education sites. Adequate access technology should be selected in terms of usage, affordability and cost-effectiveness. A wireless network, which supports real-time multimedia information transmission, can be mainly configured and connected to the access points of the wired network on a campus. A wired network, which support stable and safe data transmission and service access, can be mainly configured and connected to the access points to the communication network.

8.2.5 IoT gateway capability

This capability supports the interconnection between an IoT network and a wideband communication network (e.g., backbone network or mobile communication network) for IoT operation [ITU-T Y.4101]. All of the sensing, controlling, and business data are delivered to a network layer via an IoT gateway. IoT gateway can provide firewall, intrusion detection, antivirus, and harmful information filtering function to protect network data safety. IoT gateway can control and manage the use of the Internet.

8.3 Network layer

8.3.1 Wired network capabilities

This capability supports the interconnection for delivering sensing, management, and multimedia data to an SECP using a wired network (e.g., optical or Ethernet network). An optical network is useful for the massive real-time sensing data and wideband multimedia data long-distance transmission.

8.3.2 Wireless network capabilities

This capability supports the interconnection for delivering sensing, and management data to an SECP using a wireless network (e.g., Wi-Fi or mobile network). Adequate access technology should be selected in terms of usage, affordability and cost-effectiveness. A Wi-Fi network is useful for sensing data and multimedia data transmission, whereas a mobile network is useful for management data and other business data transmission.

8.4 Service support and application support layer

8.4.1 Application support

8.4.1.1 ICm TaL support

This capability supports interactive teaching and learning management for teachers and students.

Teachers can analyse students learning behaviour, then prepare lessons by refining the courseware, explanation content, and practice using lesson prepare function.

Teachers can demonstrate teaching resources and provide remote-control guidance by multimedia equipment, which supports the synchronous or asynchronous display of multiple screens through the mode of text communication, electronic whiteboard data interactive demonstration and audio/video dialogue. Teachers can use teaching terminals for normal teaching and office work, and students can use learning terminals to learn and complete homework independently before, during and after class. The teaching/learning terminals realize real-time interaction and feedback between teachers and students. The teaching/learning terminals support various media forms to enable learning for persons with disabilities.

Real-time feedback and interactive function, including test, inspection, vote, questionnaire survey, and roll call in class, realizes timely feedback from students and significantly raises the efficiency of the teaching process.

8.4.1.2 Online TaL support

8.4.1.2.1 Lesson producing

This capability supports the production of teaching resources for teachers or other content providers.

It can provide convenient resource development tools for teachers to make courseware and other multimedia resources. Resource development tools can support the batch import and export of resources, the production of various format resources, and the format conversion of resources.

It can provide recording and broadcasting devices to collect, integrate and analyse the behaviour information of the teaching process. Classroom teaching recording can simultaneously record and broadcast the video signals, audio signals, blackboard writing, and computer dynamic screens under the mode of full-automatic/semi-automatic/manual. Group teaching recordings can support group discussions and group experiment scenarios, with a hybrid automatic tracking strategy that can be set to completely record the teaching process.

8.4.1.2.2 Teaching and learning management

This capability provides the management of teaching and learning, which supports students to watch the live broadcast in real time or on-demand broadcast after class anywhere or anytime.

It can provide large-scale live broadcasts for different terminals to concurrently display audio or video live broadcasts online, as well as provide broadcast recorded video resources on demand with high-quality video resources and an on-demand viewing function. It can provide remote audio-video interaction in order to realize classroom interactive teaching across classrooms, campuses, regions and other teaching places. The TaL terminals for online learning support various media displays and interactive forms to enable learning for persons with disabilities.

It can encrypt live and on-demand courses based on the digital rights management (DRM) encryption technology, to prevent recording the course, and comprehensively escort the copyright of the content.

8.4.1.3 AR/VR learning support

8.4.1.3.1 Lesson producing

This capability supports the production of teaching resources for teachers or other content providers.

It can provide teaching resource development tools for teachers or content providers conveniently to make courseware and other multimedia resources. Resource development tools can support batch import and export of resources, the production of various format resources, and the format conversion of resources.

It can provide a recording and a broadcasting system to collect, integrate and analyse the behaviour information of the teaching process. Recording devices can simultaneously record and broadcast video signals, audio signals, and other virtual operations. It also provides data processing and simulation functions, and the results will be fed back to the virtual learning environment in real-time.

8.4.1.3.2 Teaching and learning management

This capability provides the management of teaching and learning, which supports students to watch and operate in the virtual environment in real time or on an on-demand pause and repeat the lesson anywhere or anytime.

It can provide remote interaction in order to realize interactive teaching and operations. The AR/VR terminals for virtual learning support various media displays and interactive forms.

8.4.1.4 Education administration support

8.4.1.4.1 Education information management

This capability provides basic educational information management, educational administration management information system (MIS), asset management, daily service, and other management and services by integrating external systems or services deployed inside the campus based on the interface specification. It should control access to various management and services for teachers, students, researchers, administrators and other users according to authority.

8.4.1.4.2 Education quality management

This capability supports the comprehensive evaluation of teaching quality and decision-making of management by aggregating teaching and learning (TaL) behaviour data and quantitative teaching objectives based on big data, artificial intelligence algorithms, and other information technologies. Based on data integration, big data analysis and the evaluation index system, the analysis of students' learning behaviour and teachers' teaching behaviour is carried out to provide a scientific evaluation on the improvement of the educational environment and its teaching methods.

8.4.1.5 Resources management support

8.4.1.5.1 Teaching resources management

This capability supports the management of resources. It can provide various types and formats of data storage, synchronization and backup, batch import and export of teaching and learning resources in the data cloud. It can provide resource upload and download services supporting the use of different terminals, multiple types of file transmission and sharing, as well as resource permission settings and management. It can also support the pushing of different types of resources according to different dimensions, as well as intelligent pushing and adaptive presenting of resources based on students' requirements and their learning habits.

8.4.1.5.2 Personal online space management

This capability provides a personalized online space which integrates resources, services and business data for a student, a teacher or any other user to support resource sharing, teaching interaction and learning innovation.

8.4.1.5.3 Device configuration and management

This capability supports the configuration and management of IoT sensors, controllers, multimedia equipment, teaching/learning terminals, and IoT gateway.

It can create, modify and delete configuration policies of environmental sensors based on data collecting frequency and period. It can create, modify and delete configuration policies of multimedia equipment based on objects and the area monitored or the accuracy requirements. It can create, modify and delete configuration policies of electronic equipment controllers based on environmental quality, energy-saving, and business requirements. It can create, modify and delete configuration policies of teaching/learning terminals based on the device's operating system version and status, application (apps) availability and access permissions, user's authentication and authorization, and all relevant consent requirements for collecting user data.

It can start/stop/lock/calibrate/recover the sensors or controllers themselves or the applications on them remotely. It can mask/open, encrypt/decrypt, delete/restore specific data stored in the sensors or controllers remotely.

It can receive data about the operating status, performance, and fault report of the sensors or controllers.

8.4.2 Cloud infrastructure management

This capability provides the management of cloud infrastructure, which can be deployed in a public cloud, private cloud or hybrid cloud, with centralized or decentralized deployment, supporting multi-tenant mode. In the decentralized deployment, edge computing facilities in an interactive classroom (ICm) or in its school premise are responsible for on-site data processing, storage, and services on-demand. Cloud infrastructure management includes software and hardware resources information management. The software resources information management includes virtualized computing resources, unified file storage and database, cloud services (such as IaaS, platform-as-a-service (PaaS), and SaaS) management, along with the operation and maintenance support functions which realize the scheduling, monitoring and management of software resources.

The hardware resources information management is required to collect, analyse hardware devices information and store the association relation between them. The management function provides interfaces for managing the hardware devices information and querying virtual resources related to hardware devices. The cloud platform is recommended to manage the hardware devices information by providing application programming interface (API), authority management, information collection, feature and association information analysis through the hardware resources information management. The API provides an external interface for adding, deleting, modifying, and checking the hardware device information. The interface also provides querying virtual resources related to the hardware devices. The authority management provides identity authentication and other authentication functions. The information collection can collect and maintain the hardware device information based on the registered hardware device list. The feature analysis can find out the relevant hardware device from the cloud resource address based on the feature analysis algorithm and return it to the user. The collected hardware device-associated information can be analysed and saved. When the cloud platform displays the cloud resources, it queries and displays the associated hardware device information by the information management interfaces.

8.4.3 Access and authentication

This capability supports unified user authentication and authorization, unified account login and authority management functions.

8.4.4 Service integrate and data exchange

This capability supports data exchanges with synchronous data updating and asynchronous data switching of external systems, as well as the services to develop, register, integrate, manage and access data of the internal systems. It limits data exchanges to ensure that only data that is consented to be shared with specific external systems is exchanged and provide data exchange services based on the interface specification.

Appendix I

Use cases of smart education

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

I.1 A use case of e-backpack supported smart education

I.1.1 Background

There are several problems regarding the traditional TaL. First, traditional classroom learning tends to be unidirectional where teachers mainly focus on instructing words and articles. There are very few cognitive interactions between teachers and students. Second, there is a lack of formative assessment in traditional classroom learning, which leads to poor judgement of learning performance. Third, traditional classroom learning fails to satisfy learners' need for personalized support.

This use case introduces an example of how to use e-backpacks to enhance cognitive interactions in smart education platforms in some TaL scenarios.

I.1.2 E-backpack

In order to address those problems, an e-backpack which is an electronic terminal usually in the form of a tablet is employed. Based on the hardware and network environment, the smart education environment forms an e-backpack platform that integrates teaching and learning tools, digitalized materials, and a management information system (MIS) as shown in Figure I.1.

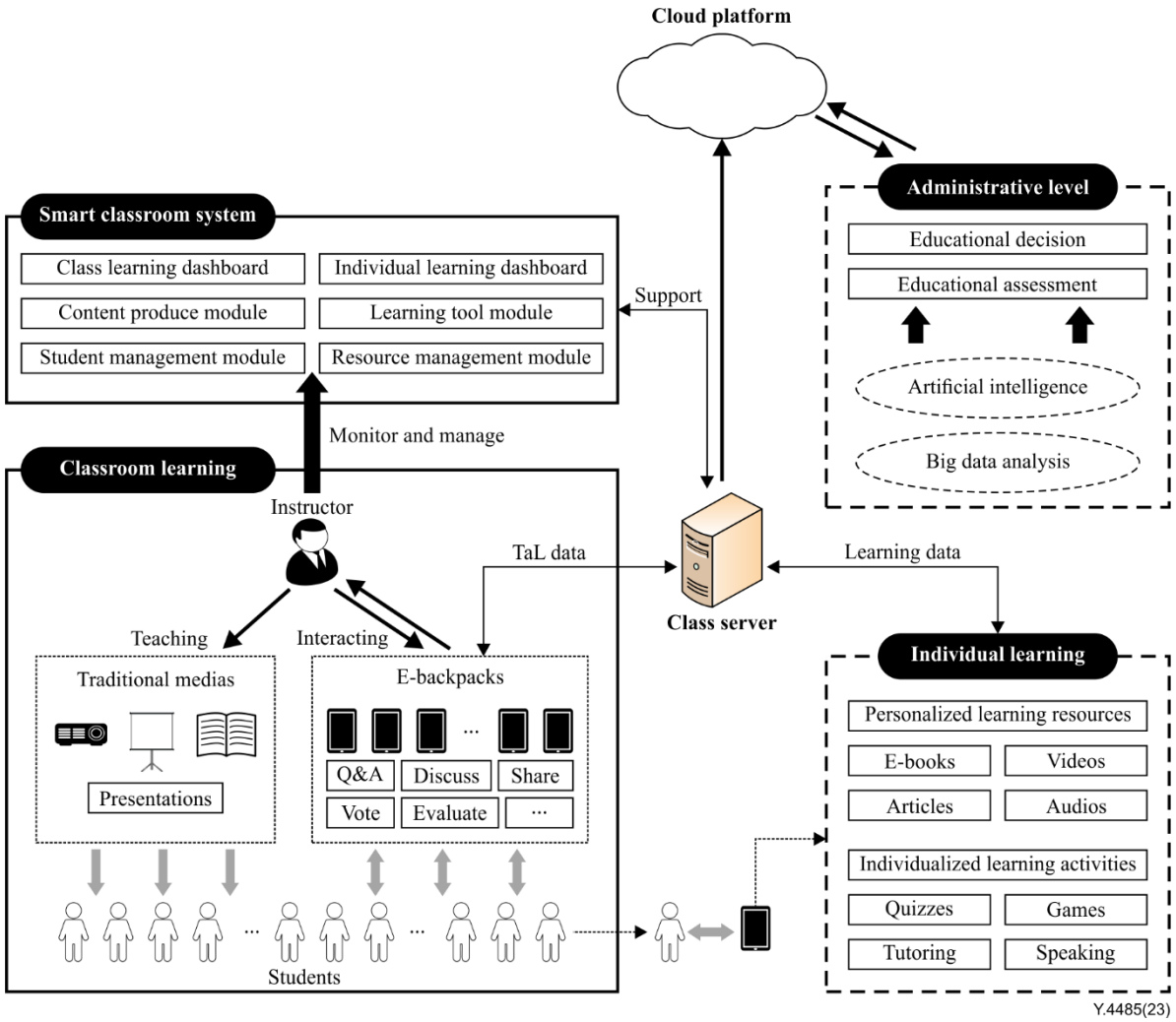

Figure I.1 – Overview of an e-backpack supported smart education architecture

I.1.3 Key features

This use case possesses several key features and functions that can be addressed to solve the problems in traditional classroom learning.

I.1.3.1 Interactive classroom learning

Traditional classes are usually equipped with medias such as a projector, TV, or blackboard, which mainly support one-way teaching. Students seldom have a chance to lead their own learning or express themselves. This situation changes with the implementation of e-backpacks. Through these personal tablets, teachers are able to design and carry out interactive activities such as Q&As and surveys. Answers and opinions from all students can be aggregated and presented. In the meantime, students can use e-backpacks to produce and share their work with both the teacher and their peers. This will effectively give students a sense of involvement. On the other hand, e-backpacks can record various behaviour data that may be a source of formative assessment and help teachers better understand the dynamics in their classes.

I.1.3.2 Personalized individual learning

Besides using e-backpacks in class, students may also study independently. What highlights the personalized learning function is that e-backpacks can access the previous learning data of any specific student. It will then analyse a student's learning profile, evaluate their current level, and recommend them with the most appropriate learning resources. Also, e-backpacks can provide these resources in multiple formats like text, audio, or video based on a student's preferences. Furthermore, a student's personal learning experience may also be logged to enable further teaching assistance.

I.1.3.3 Multi-level multi-modal learning assessment

The structure of this smart education architecture enables learning assessment on the individual level, class level, school level, and even higher levels. On the individual level, the e-backpack can automatically check students' responses to quizzes and tests. Then, students can immediately know their performance and where they might need to improve. This may help promote students to be aware of their own learning. The e-backpack can also collect data such as response time, clicking behaviours, and learning sequences. All of these data can supplement test performances to build a more complete learning profile for a single student. For classroom learning, e-backpacks provide teachers with a means to capture the formative and fine-grained learning performance of students. For example, in collaborative learning, e-backpacks can record the process of collaboration. Thus, teachers can access these data and analyse students cognitive interactions during their collaboration and understand how their collaboration leads to the final resolution. On the school and administrative level, the educational data can be analysed with data mining technology to generate meaningful outcomes. These outcomes present administrators with clear and immediate feedbacks in terms of the status of the education in the school. This helps decision making on the efficient management of educational resources in the school.

I.2 A use case of effective e-learning with IoT biological feedback

I.2.1 Background

IoT technologies used in individual learning and self-education allow increasing the efficiency of study. During the video lesson, the IoT devices are monitoring the level of concentration by biological feedback.

I.2.2 IoT in the individual learning process

Distance learning and self-education are becoming more and more popular in our days. The main problem is that it is impossible to have instant feedback between the teacher and the student. During classroom learning, it is useful for the teachers to get the attention level of the students and adopt the teaching process accordingly. During distance learning this control is difficult to achieve. Moreover, the levels of attention are quite personalized and depend on many factors and vary over time. IoT devices together with modern digital technologies can make this process more efficient and provide attention control to create the best learning pattern for each person. Figure I.2 is the overview of individual smart education with biological feedback (BFB) and digital dynamic modulation (DDM) technology.

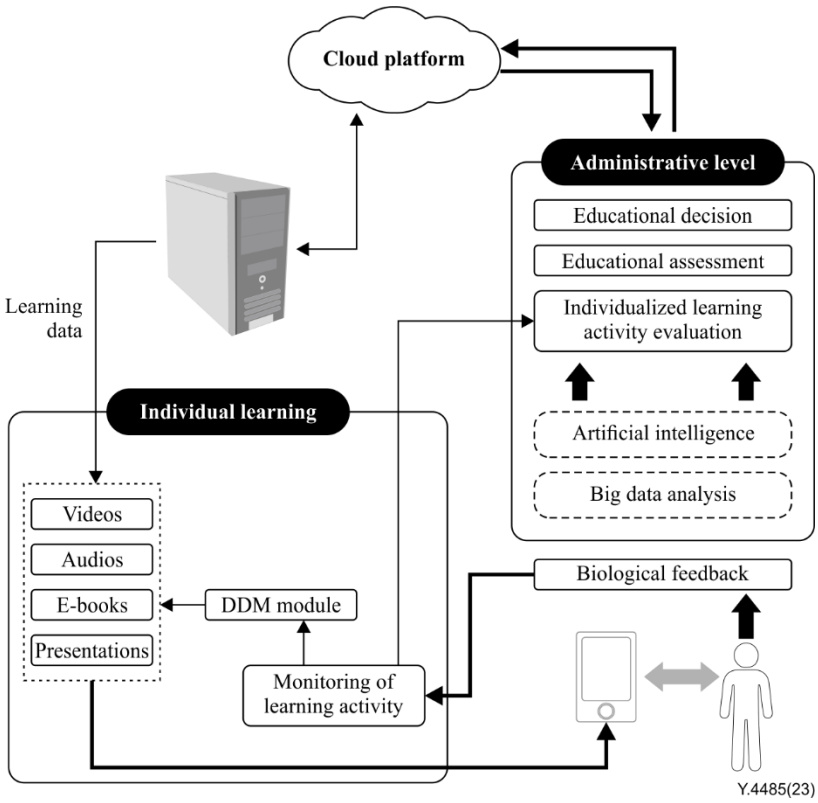

Figure I.2 – Overview of individual smart learning education with BFB and DDM technologies

Learning data including video lessons, audio lessons, e-books, and presentations are presented on the personal computer of the student. At the same time, the BFB IoT device monitors the concentration level during the lesson.

I.3 Air quality management for smart education

I.3.1 Background

Smart education involves not only providing high quality education related facilities but also ensuring safety and health for both students and staff in school. Nowadays, air pollution has raised big concerns throughout the world, and efforts are being made to improve the situation in almost every industry. Besides, factors of air quality such as indoor oxygen content also affect students' study efficiency. With the technologies of IoT, air quality management can be provided to support smart education both inside and outside classrooms.

I.3.2 Air quality management for smart education

In this use case, the air quality management solution includes sensors collecting air data, a fresh air system, a communication network, an air quality management cloud platform, and clients with different forms as shown in Figure I.3.

The sensors collect air quality parameters such as SO_2, NO_2, CO, CO_2, PM2.5, and uploads the data to the platform. The air quality management cloud platform is responsible for aggregating and analysing the data and providing related guidance according to the preconfigured air quality management policies. The fresh air system introduces the filtered fresh air from outside into the classroom according to the instruction from the platform. The clients show a whole picture of the real-time situation of air quality in the school.

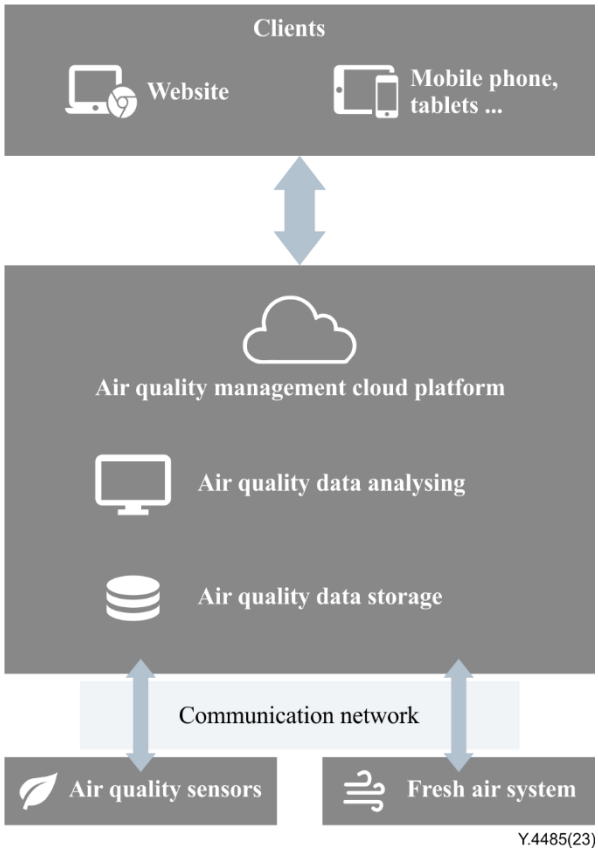

Figure I.3 – Overview of air quality management for smart education

I.3.3 Key features

I.3.3.1 Outdoor air quality management

This feature offers an air quality monitoring function for the outdoor environment of a school such as a playground. The main purpose is to monitor outdoor air quality in real time and arrange outdoor events properly according to the analysis results. For example, if air pollution is too severe, the relevant events such as physical education (PE) lessons and sports meetings are suggested to be cancelled.

I.3.3.2 Indoor air quality management

This feature focuses on monitoring indoor air quality data such as the density of carbon dioxide in the classroom. If the density is above the threshold, the platform will inform the fresh air system to exhaust the indoor oxygen-deficient polluted air to the outdoors and pump the filtered fresh air into the classroom, which can enhance the concentration of students and thus improve their studying efficiency.

I.3.3.3 Air quality management visualization

This feature visualizes the data of air quality in schools so that it can provide a whole picture of the air quality management. With the help of this function, the related staff in the school can percept the air quality situation directly which helps them to make easier and quicker decisions. It is supported to show the visualized information through different ways such as websites, mobile phones, etc.

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[b-ITU-T Y.2091] Recommendation ITU-T Y.2091 (2011), *Terms and definitions for Next Generation Networks.*

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