Chapter 2
WaaS—Wisdom as a Service

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Abstract An emerging hyper-world encompasses all human activities in a social-cyber-physical space. Its power derives from the Wisdom Web of Things (W2T) cycle, namely, "from things to data, information, knowledge, wisdom, services, humans, and then back to things." The W2T cycle leads to a harmonious symbiosis among humans, computers and things, which can be constructed by large-scale converging of intelligent information technology applications with an open and interoperable architecture. The recent advances in cloud computing, the Internet/Web of Things, big data and other research fields have provided just such an open system architecture with resource sharing/services. The next step is therefore to develop an open and interoperable content architecture with intelligence sharing/services for the

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organization and transformation in the "data, information, knowledge and wisdom (DIKW)" hierarchy. This chapter introduces Wisdom as a Service (WaaS) as a content architecture based on the "paying only for what you use" IT business trend. The WaaS infrastructure, WaaS economics, and the main challenges in WaaS research and applications are discussed. A case study is described to demonstrate the usefulness and significance of WaaS. Relying on the clouds (cloud computing), things (Internet of Things) and big data, WaaS provides a practical approach to realize the W2T cycle in the hyper-world for the coming age of ubiquitous intelligent IT applications.

2.1 An Emerging Hyper-World

According to estimates by the International Telecommunication Union (ITU) (February 2013) [1], global Internet users and mobile Internet (MI) users will reach 2.7 billion and 2.1 billion, respectively, in 2013. A huge number of sensors, embedded appliances, and actuators have been deployed in almost every part of cities. The Internet, MI, Internet of Things (IoT) and Web of Things (WoT) [2] connect humans, computers and things to form an immense network, by which various information technologies (IT) and their applications are permeating into every aspect of our daily lives. The continuously extending IT applications have resulted in a *hyper-world*, consisting of the social, cyber, and physical worlds, and using data as a bridge to connect humans, computers, and things [3, 4].

In the hyper-world, the most important changes and characteristics include the following two aspects:

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- The first is the change of the human-computer relationship. In the past, we lived separately from the cyber world and accessed computers and networks only when we needed IT services. There was a loose coupling between humans and computers. The appearance of the hyper-world changes this kind of loose coupling. Owing to the fusion of the social, cyber, and physical worlds, today we live within a huge network of numerous computing devices, storage devices, and u-Things, where the real physical things are attached, embedded, or blended with computers, networks, and/or some other devices such as sensors, actors, e-tags and so on [5]. Adapting and utilizing this kind of new human-computer relationship is an urgent task for the development of IT applications.
- The second is the emerging big data. The extension of the Internet, IoT and MI greatly accelerates the production of data. IDC (a technology research firm) estimates that data has been constantly growing at a 50 % increase each year, or more than doubling every 2 years. Big data [6] becomes an important characteristic of the hyper-world in terms of four measures: volume, variety, velocity, and value. How to effectively manage, mine and utilize big data to improve the ability and quality of IT applications also becomes an urgent task and is attracting more and more attention [7, 8].

These changes have led to the appearance of many new phenomena and research issues. For example, in China, there is a phenomenon called Human Flesh Search Engine (HFSE), in which a large number of Web users voluntarily gathered together to collaborate and conduct truth-finding tasks, mostly without money reward. The organizational structure of people collaboration and the incentives that motivate people to contribute shed light on the intrinsic understanding the voluntary large-scale crowdsourcing and how the collective intelligence is fulfilled with the help of the Internet [9, 10]. The hyper world is bringing profound influences in both work and life to the whole human society. How to realize the organic amalgamation and harmonious symbiosis among humans, computers, and things in the hyper-world by using the network (consisting of numerous computing devices, storage devices and u-Things) and big data becomes a significant scientific and social issue.

2.2 From Wisdom Web to Wisdom Web of Things

Web Intelligence (WI) [11–15] may be viewed as an enhancement or an extension of Artificial Intelligence (AI) and Information Technology (IT) on the Web. One of its goals can be defined as the development of the Wisdom Web with top 10 problems [16, 17].

In the hyper-world age, this goal is extended to the development of Wisdom Web of Things (W2T) [4], where the "Wisdom" means that each of things in IoT/WoT is aware of both itself and others to provide the *right service* for the *right object* at a *right time* and *context*. W2T is a WI solution to the harmonious symbiosis of humans, computers, and things in the hyper-world. Its core concept is a processing cycle,

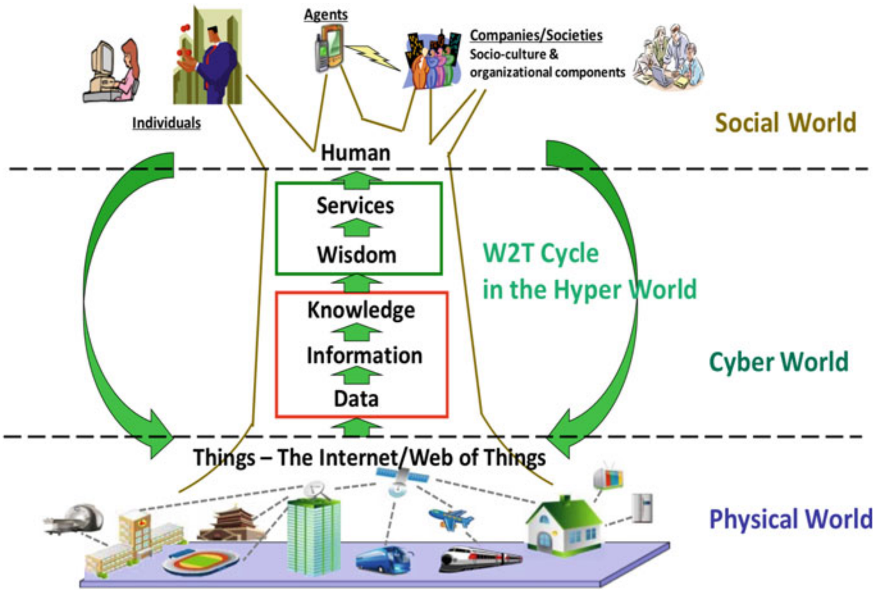

Fig. 2.1 A W2T cycle in the hyper-world

namely "from things to data, information, knowledge, wisdom, services, humans, and then back to things" (the W2T cycle, for short), as shown in Fig. 2.1. Similar to the real world material cycle that ensures the harmonious symbiosis of animal, plant, and microbe, the W2T cycle realizes the harmonious symbiosis of humans, computers and things in the hyper-world.

Constructing the W2T cycle relies on the large-scale converging of intelligent IT applications with an open and interoperable architecture. In recent years, two significant innovations have appeared in the IT field for meeting such a challenge:

- **Web of Things (WoT)** [18] focuses on the application layer and is to build an open and interoperable architecture on IoT by adapting technologies and patterns commonly used for traditional Web contents. By such an architecture, the Web is extended from the cyber world into the physical world. Various u-Things can be integrated into a common platform with traditional software for different applications in the hyper-world.
- **Cloud computing** [19] is a new trend in IT industry with the potential to realize a pay-as-you-go manner. From the viewpoint of IT technology, it also provides an open and service-oriented architecture for the converging of IT applications. On the one hand, by such an architecture, all IT applications can be deployed on a uniform platform and organized flexibly for varied applications. On the other hand, the enormous storage and computing resources needed by big data can be obtained by each IT application for improving its ability and quality.

However, both WoT and cloud computing mainly focus on the system resource service architecture of IT applications, i.e., infrastructures, platforms and software (developing and scheduling abilities). For the large-scale converging of intelligent IT applications, it is necessary to develop an open and interoperable intelligence service architecture for the contents of IT applications, i.e., data, information, knowledge, and wisdom (DIKW). The hyper-world with its W2T cycle will serve this purpose.

2.3 From Data to Wisdom

"Where is the life we have lost in living?"
"Where is the wisdom we have lost in knowledge?"
"Where is the knowledge we have lost in information?"
– T.S. Eliot, "The Rock", Faber and Faber 1934.

For developing a content architecture of IT applications, the first step is to investigate the relationships among the DIKW hierarchy. As suggested by T.S. Eliots poetic lines, a common understanding is the DIKW hierarchy [20] with the following four levels:

- Data are the un-interpreted, raw quantities, characters, or symbols collected, stored and transmitted.
- Information is a collection of interpreted, structured or organized data that is meaningful and useful for certain applications.
- Knowledge is acquaintance or familiarity about facts, truths, or principles, gained through study or investigation.
- Wisdom is sagacity, discernment, or insight to know what is true or right for making correct judgments, decisions and actions.

Each level in this hierarchy can affect the other and be changed into another: Data comes from the study or investigation about fact and truth; information can be obtained from data by data structuring, relational connection, distillation or pattern recognition; knowledge can be refined by collecting and understanding the information; and wisdom can be realized by transforming outside knowledge to the inner and judicious application of knowledge. Such creation, organization and transformation are the essence of the DIKW hierarchy and a core research issue of intelligent IT technologies. Because of the fusion of humans, computers, and things in the hyper-world, developing human-level intelligence becomes a tangible goal of the DIKW related research. Realizing it will depend on a holistic intelligence research [4], a joint effort of researchers and practitioners from diverse fields in exploring the key research problems of the interplay between the studies of human brain and informatics [21].

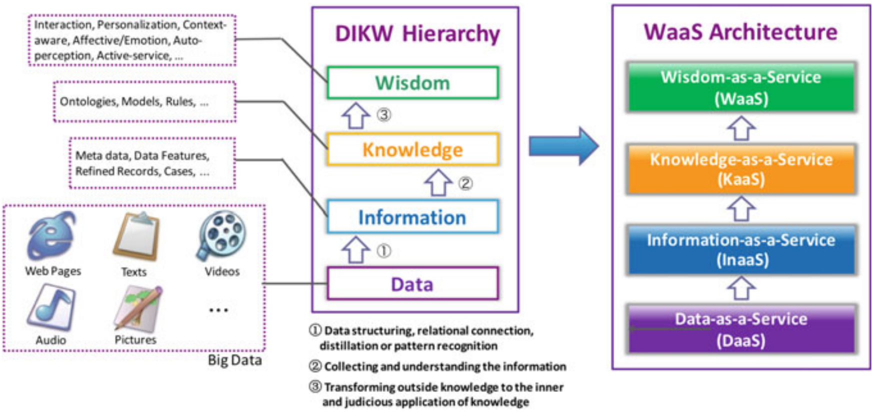

Fig. 2.2 From the DIKW hierarchy to WaaS

2.4 WaaS: Wisdom as a Service

2.4.1 What Is WaaS?

Based on the DIKW hierarchy, we propose "Wisdom as a Service" (WaaS) as a content architecture for intelligence services to IT applications shown in Fig. 2.2. WaaS is open and interoperable and constructed from a service-oriented viewpoint. It integrates many fields of research related to the DIKW-like service hierarchy, including the following four service categories:

- **Data as a Service (DaaS)** is to provide services based on both already-created and will-created raw data. Providing already-created data is just the data sharing service which is realized by all scientific databases, such as fMRIDC [22]. In order to realize data sharing, the data collection service is also necessary for finding and integrating dispersive data into a unified database. Providing will-created data is the data production service which obtains data according to users demands. For example, various experimental studies of Brain Informatics [21] can become a kind of data production service which designs and performs experiments to product brain data for the intelligence study and industry.
- **Information as a Service (InaaS)** is to provide services by using both already-created and will-created information. Providing already-created information is the activity of obtaining needed information from diversified information resources. Information retrieval is typical one. Providing will-created information is to extract information from data for users demands. Related services include data mining services and data curation services [7].
- **Knowledge as a Service (KaaS)** is to provide services with respect to existing and will-refined knowledge. The knowledge includes implicit knowledge and explicit knowledge. Knowledge stated in KaaS contains only explicit knowledge,

such as formal ontologies, user models, etc. Providing existing knowledge is just knowledge query services. Providing will-refined knowledge is to refine knowledge according tousers demands. Related work is concerned with knowledge retrieval [23], the development and management of knowledge base, etc. The model is a core issue in the W2T research. From this viewpoint, the KaaS can be specialized as the Model as a Service (MaaS) [24] which involves many interesting and important research issues and challenges.

- **Wisdom as a Service (WaaS)** is to provide various intelligent IT applications, including software and u-Things, as "Wisdom" services. Intelligent technologies are core of WaaS and involved with personalization, context-aware, affective/emotion, interaction, auto-perception, active services, and so on. By using these intelligent technologies on data, information and knowledge, those software and u-Things can make correct judgments, decisions and actions to provide the *right service* for the *right object* at a *right time* and *context*.

In the Internet protocol model, TCP/IP denotes both the whole protocol stack and two important protocols in this stack. Similarly, WaaS also includes two levels of meanings. Strictly speaking, WaaS is an intelligent service layer which includes various intelligent IT applications. Broadly speaking, WaaS is a service hierarchy, including the DaaS, InaaS, KaaS and WaaS, just like a Web hierarchy model [25].

2.4.2 WaaS Standard and Service Platform

A WaaS standard and service platform should be constructed as the infrastructure of WaaS. It integrates W2T-cycle-related theories and technologies. Figure 2.3 gives its architecture, with four components according to the four service categories. Each component includes a software platform and a standard system, which provide a practical and propagable approach for realizing all services in the corresponding service category. The software platform is an open portal on which different service modules can be deployed to provide various services of the corresponding service category. The standard system is a group of standards and specifications which describe the requirements and methods for developing and using service modules on the software platform. All of software platforms and standard systems can be described as follows:

- **The DaaS platform** includes the data collection module, data cleaning module, data management module, and data query module to support the three types of DaaS services. The core is the data collection module consisting of many data collection interfaces for "reading" data from the Web, information systems, deploying sensors, embedded chips, experimental devices, etc.
- **The DaaS standard system** consists of four types of standards, i.e., data collection interface standards, data transmission protocols, data content and format standards, and data accessing standards. These standards or protocols are based

on applications and can be classified into different types according to different data sources, application environments and application purposes. For example, different data transmission protocols should be designed and used in the Internet and MI.

- **The InaaS platform** includes the information retrieval module, data mining module, information management module and data curation module to support the three types of InaaS services. The data curation focuses on information organization, including metadata construction and case creation. Because the hyper-world includes mutable data, computing, and network environments, it is necessary to perform the off-line information extraction and organization before services are requested.
- **The InaaS standard system** consists of four types of standards, i.e., information-retrieval-related standards, data-mining-related standards, metadata standards, and information accessing standards. Information-retrieval-related standards mainly focus on application service definition and protocol specification. Data-mining-related standards are involved with mining languages, result representation languages, mining system architectures, etc. Metadata standards are classified and defined according to application domains. Information accessing standards are

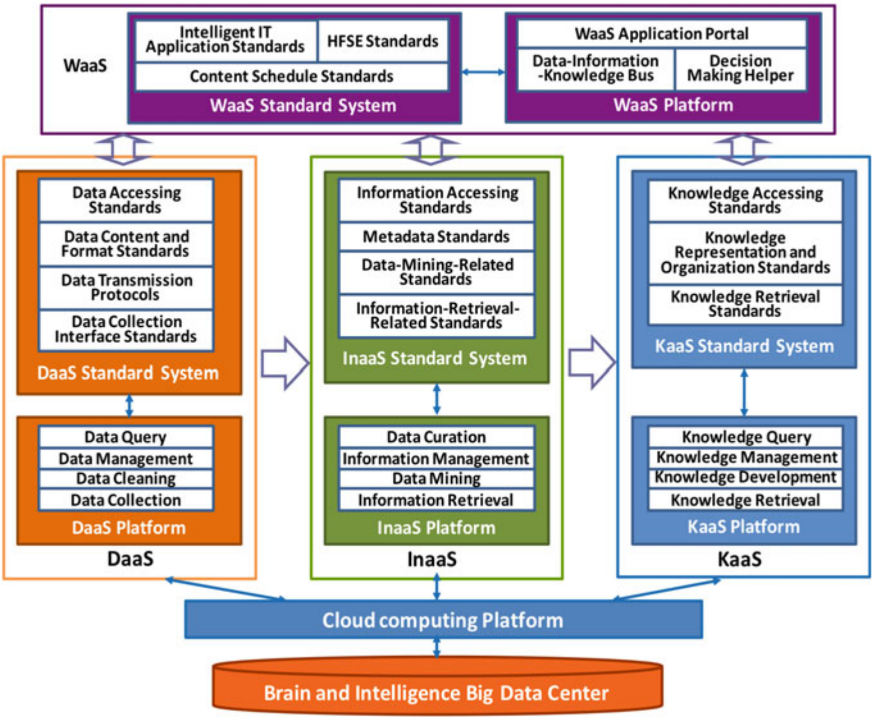

Fig. 2.3 The architecture of WaaS standard and service platform

used to define accessing interfaces and transmission protocols of InaaS service modules on the InaaS platform.

- **The KaaS platform** includes the knowledge retrieval module, knowledge development module, knowledge management module and knowledge query component for various KaaS services. The knowledge retrieval module is developed based on the WI-specific technology that extracts knowledge from enormous information sources. The knowledge development module provides various tools for the development of ontologies, models, as well as other types of formal knowledge. The knowledge management module and knowledge query module are used to manage formal knowledge and provide knowledge sharing services, respectively.
- **The KaaS standard system** consists of knowledge-retrieval-related standards, knowledge representation and organization standards, and knowledge accessing standards. The knowledge-retrieval-related standards are mainly used to define application services and protocols. The knowledge representation and organization standards focus on knowledge representation languages, for example, the cyber-individual (Cyber-I) representation language [26]. Knowledge accessing standards mainly involve knowledge query languages, knowledge accessing interfaces, knowledge system architectures, knowledge transmission protocols, and so on.
- **The WaaS platform** includes the data-information-knowledge bus, decision making helper and WaaS application portal. The data-information-knowledge bus is a special Enterprise Service Bus (ESB) for discovery and integration of DaaS services, InaaS services and KaaS services. The decision making helper is used to assist judgments and decisions. Based on them, various intelligent IT applications can be deployed on the WaaS application portal to make correct actions, namely, provide intelligent services. Furthermore, HFSE can also be regarded as a kind of special intelligent applications.
- **The WaaS standard system** consists of content (data, information and knowledge) schedule standards, intelligent IT application standards and HFSE standards. They concern content schedule languages, application interfaces, application wrappings, application communications, as well as HFSE related technical standards and laws.

As shown in Fig. 2.3, all platforms are constructed on a cloud computing platform and a brain and intelligence big data center. These platforms are open. Based on the standards and protocols in the four standard systems, any third party can develop and plug in their service modules on platforms. These platforms are also interoperable. Because of adopting the same standards and protocols, different service modules on platforms can effectively communicate and cooperate with each other for providing various services in the DIKW hierarchy. Furthermore, other systems and platforms can also access service modules on platforms by using those public standards and protocols in the standard systems, for realizing complex intelligent IT applications. Such open and interoperable platforms make it possible to converge all technologies and resources in the intelligence study and industry into a unifying framework for realizing a W2T cycle.

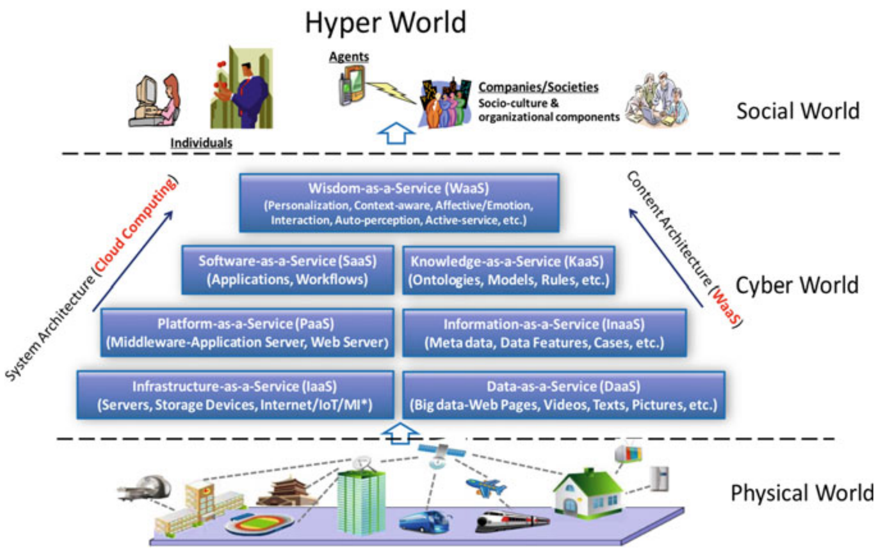

Fig. 2.4 An open and interoperable architecture of IT applications for W2T

2.4.3 An Open and Interoperable Architecture of IT Applications: Binding WaaS with Cloud Computing

The development of intelligent IT applications needs to meet various demands, not only system-level demands but also content-level demands. The system-level demands are related to infrastructures (network, storage and computing resources), running platforms and software (developing and scheduling abilities). The content-level demands are related to big data and their processing.

Figure 2.4 shows an open and interoperable architecture of IT applications by binding WaaS and cloud computing. It meets two types of demands in a unified and pay-as-you-go manner. As shown in Fig. 2.4, cloud computing provides an open IT architecture for sharing system resources, including infrastructures, platform and software, by means of IaaS, PaaS and SaaS. Paralleling to the cloud model, WaaS is for sharing content resources and processing utilities and closely related to big data and their processing through DaaS, InaaS and KaaS. By these layers of "as a service", six factors, i.e., infrastructures, platforms, software (developing and scheduling abilities), data, information, and knowledge, will converge into an open and interoperable uniform platform, on which all factors can be effectively utilized by various intelligent technologies to form an intelligent service layer, i.e., the WaaS layer. A large number of intelligent IT applications will converge into the WaaS layer towards a W2T cycle.

Based on the successful practices on existing cloud computing platforms, it would be reasonable to expect that the large-scale converge of intelligent IT applications can be realized by such IT architecture, towards a W2T cycle for realizing the harmonious symbiosis of humans, computers, and things in the hyper-world.

2.5 A Case Study: The Portable Brain and Mental Health Monitoring System Based on Peculiarity-Oriented Mining of EEG Data

With the accelerating process of urbanization, brain and mental health has become a huge public-health problem. According to a survey in 2011 [27], mental disorders affect more than 160 million Europeans—38 % of the population. Mental disorders also make up China's largest disease burden—20 % of total burden of disease—in 2011. It is necessary to strengthen the monitoring of brain and mental disorders for diagnosing and treatment as soon as possible. However, only depending on doctors and nurses to complete the monitoring is unpractical because of the giant susceptible population. Using information technologies to support the monitoring of brain and mental disorders becomes a promising approach.

We have developed a prototype of the portable brain and mental health monitoring system (brain monitoring system, for short) whose technological framework is shown in Fig. 2.5. It adopts the architecture integrating cloud computing and WaaS to meet system-level and content-level demands in developing IT applications:

- **Cloud computing** (including IaaS, PaaS, SaaS) is adopted to meet system-level demands of the brain monitoring system based on the "anything as a service" paradigm. As a cross-platform and data-intensive intelligent system, the brain

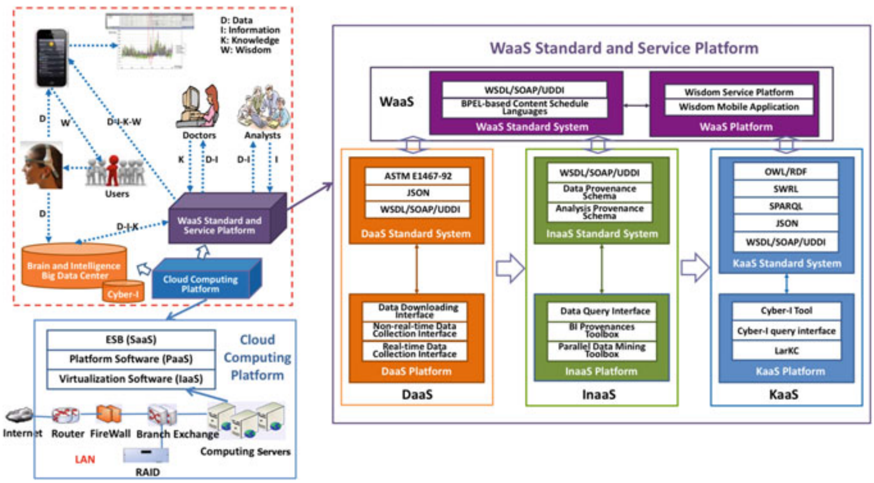

Fig. 2.5 The technological framework of the portable brain and mental health monitoring system

monitoring system needs credible infrastructures (network, storage and computing resources), an open running platform and an extensible developing and scheduling mode. We construct a private cloud having a group of servers and a redundant array of independent disk (RAID) for meeting these demands. As shown in Fig. 2.5, servers, RAID, mobile phones, the local area network, the Internet and MI form a powerful infrastructure, on which virtualization software is stepped up to dynamically provide needed infrastructure resources as services for the brain monitoring system based on the IaaS mode. Furthermore, open platform software, e.g., Web application server software, is used to provide the needed running platform as a service based on the PaaS mode, and Web service technologies are adopted to develop all functional components and software systems as services on the ESB based on the SaaS mode.

- **DaaS** is adopted to meet the data demands of the brain monitoring system. As shown in Fig. 2.5, it is realized by the DaaS platform. Data collection interfaces and a data downloading interface are developed as Web services and deployed on the DaaS platform for the data production service. They collect users' EEG (Electroencephalogram) data for data analysts. Data collection interfaces include a real-time interface and a non-real-time interface. The real-time interface is deployed on mobile phones, which is regarded as an extending part of DaaS platform, to collect patients EEG data continuously. The non-real-time interface is deployed on the server part of DaaS platform to collect EEG data stored in mobile phones periodically and sent them to the brain and health big data center. In addition to the collection of EEG data, other non-real-time data, such as users information, are collected. If the data come from other information systems, the corresponding data collection interfaces are developed and deployed on the DaaS platform. Such a DaaS platform is based on the data collection and accessing interface standards WSDL (Web Services Description Language)/SOAP (Simple Object Access Protocol)/UDDI (Universal Description, Discovery, and Integration), the data transmission protocol JSON (JavaScript Object Notation), and the data content and format standard ASTM E1467-92, etc.; they form the DaaS standard system of this case study.
- **InaaS** is adopted to meet the data mining and data curation demands of the brain monitoring system. As shown in Fig. 2.5, a core component of the InaaS platform is the parallel data mining toolbox, which includes many distributed mining tools. These mining tools are developed as Web services and can perform distributed data processing and mining on the cloud computing platform. By using the mining toolbox, data analysts can perform peculiarity-oriented mining (POM) [28] to extract useful peculiar indexes. Another core component is a BI provenances toolbox which is used to support the construction of BI provenances. BI provenances, including data provenances and analysis provenances, are the metadata of describing the origin and subsequent processing of various human brain data [29]. In this use case, data provenances mainly include users information and analysis provenances focus on describing processes and results of data mining. The data query interface based on BI provenances is also an important component of the InaaS platform. All modules are developed as Web services. As metadata stan-

dards, mining language and result representation language, the schemata of data and analysis provenances are major contents of the InaaS standard system.

- **KaaS** is adopted to meet the knowledge extraction, management and query demands of the brain monitoring system. As shown in Fig. 2.5, its realization depends on the KaaS platform developed on the LarKC (Large Knowledge Collider, a cloud platform for massive distributed incomplete reasoning) [30]. Because the management and query services of knowledge can be realized by the LarKC, the core of the KaaS platform is the Cyber-I tool, which provides Web services of knowledge extraction and the construction of diagnosis models. The knowledge extraction service can extract individualized rules from domain ontologies and BI provenances through reasoning and mining on the LarKC. The rules can be used to identify users brain risk states. Integrating them and POM-centric arithmetic modules, individualized diagnosis models can be constructed as a kind of special Cyber-I. Furthermore, in order to effectively utilize these models, a Cyber-I query interface was also constructed on the KaaS platform. The KaaS standard system includes the ontological language OWL (Web Ontology Language) and RDF (Resource Description Framework), rule language SWRL (Semantic Web Rule Language), knowledge query language SPARQL (Simple Protocol and RDF Query Language), model transmission language JSON and knowledge accessing interface standards WSDL/SOAP/UDDI. The KaaS platform is developed based on these standards.
- **WaaS** is adopted to organize and deploy the brain monitoring system as a kind of wisdom service for the monitoring of brain and mental health. It is realized by a wisdom service platform and a wisdom mobile application. The wisdom service platform is a Web service deployed on the WaaS application portal, providing various remote monitoring functions, such as data collection, data mining, model publishing, domain knowledge publishing, risk state discovery, message sending to the third parties, etc. All these functions are realized by using the data, information and knowledge buses to call the corresponding DaaS, InaaS and KaaS. The wisdom mobile application provides various local monitoring functions, including data collection, data mining and result display, risk state discovery and reminding. Various intelligent technologies, including personalization, context-aware, auto-perception and active services, need to be applied on the service platform and the mobile application to provide right service for the right object at a right time and context. Related standards include intelligent IT application standards WSDL/SOAP/UDDI and BPEL (Business Process Execution Language) based content schedule languages.

The brain monitoring system can provide a smart monitoring service for suspected/mildbrain and mental patients. For example, Bob is a suspected epilepsy patient and needs some reliable evidences to persuade himself to receive a comprehensive physical examination. This can be realized by using the brain monitoring system. The whole process integrates services in the DIKW hierarchy and is involved with users, analysts and doctors as explained in the following:

- The DaaS services: before Bob gets the system, a large number of EEG data have to been collected from mild epilepsy patients and normal subjects, and provided to analysts. This DaaS service is realized by the above DaaS platform. All of EEG data are collected into the brain and intelligence big data center by the real-time and non-real-time data collection interfaces, and analysts obtain fit EEG data by the data downloading interface.
- The InaaS services: Dr. Motomura is a senior analyst of EEG data. He is both user and provider of InaaS services. On the one hand, he uses the data-related information retrieval service provided by the data query interface to find fit EEG data. On the other hand, he provides a data mining service to extract peculiar indexes of patients EEG databy using the mining toolbox. Finally, obtained indexes and other related information are integrated into BI provenances and provided to doctors by the data query interface.
- The KaaS services: Dr. Wang is a doctor which has rich experiences on the diagnosis and treatment of epilepsy disorder. He provides a knowledge service to construct individualized epilepsy diagnosis models based on domain knowledge, obtained peculiar indexes, patients information and other related information. Such a KaaS service is realized by using the Cyber-I tool.
- The WaaS services: Bob can get needed diagnosis evidences by the WaaS service provided by the brain monitoring system. He only needs to download the wisdom mobile application from the WaaS platform. When he wears the custom portal EEG device, the mobile application will collect his EEG data continuously and identify epilepsy-like peculiar indexes based on his individual diagnosis model. These indexes are just the needed evidences and will be provided to Bob by an easy-to-understand mode.

Generally speaking, an open and interoperable platform can be built by adopting the architecture with binding WaaS and cloud computing. It can meet all system-level and content-level demands of the brain monitoring system. Furthermore, other intelligent IT applications can also be realized on this platform. Such a uniform platform will effectively support the large-scale convergence of intelligent IT applications to realize the W2T cycle for the harmonious symbiosis of humans, computers, and things in the hyper-world.

2.6 WaaS Economics

WaaS will bring the "paying only for what you use" mode for intelligence IT industry, one of the most important IT business trends with a huge economic value. This section discusses WaaS economics from three different aspects.

2.6.1 Reducing the Risk

Although the economic appeal of cloud computing is often described as "converting capital expenses to operating expenses" (CapEx to OpEx) for reducing the cost, the purchase mode "paying only for what you use" does not mean an absolutely low price. Hence, it may not be able to ensure that WaaS can reduce users cost by providing cheap DIKW services.

WaaS is an effective approach to reduce the risk for each member of the intelligence industry, including research institutions and manufacturers. From data to wisdom, the development of smart software and u-Things needs large numbers of input. Each member in the intelligence industry has to face high capital, time and human resource risk. By realizing WaaS on cloud computing, IoT/WoT and big data, the achievements in each stage of the development of intelligent IT applications can be shared quickly and multi-level global cooperation will be possible. Various risks will be balanced in the whole intelligence industry and ensure that both large-sized and medium/small-sized research institutions/manufacturers are able to participate in the research and development of intelligent IT applications.

2.6.2 Enlarging the Value

From data to wisdom, the development of each intelligent IT application needs a large number of efforts and produces a lot of intermediate achievements, such as experimental data, analytical methods/experiences, domain ontologies, and so on. These intermediate achievements are often important for other similar research and development. At present, the sharing of these achievements is limited within a research group or small-scale cooperative members.

The hyper-world requires human-levels intelligent IT applications, which are based on an understanding of not only IT technologies but also mechanisms of human intelligence. For developing an intelligent IT application, its direct research and commercial value may be lower than the input. The existing small-scale sharing of achievements cannot effectively solve this problem. Large-scale sharing is necessary for intelligence IT industry in the age of the hyper-world.

WaaS provides an open mode to share at each stage of achievements in the research and development. The value can be enlarged to ensure a reasonable input-output ratio. It is very important for realizing W2T, which needs not only small-scale research but also the large-scale development and converging of intelligent IT applications.

2.6.3 Building the Intelligence Industry Chain

The large-scale development of intelligent IT applications needs a complete intelligence industry chain to integrate various abilities and resources. The core issue is to develop an effective distribution mode for transferring industrial value among all the chain nodes. Furthermore, the W2T cycle shows that the intelligence industry has a long industry chain. An effective value distribution mode is especially important, because it is difficult to complete all steps on such a long chain based only on individual enterprises or institutions.

WaaS is an open and interoperable content architecture of IT applications for the hyper-world. By WaaS, large-scale sharing and cooperation can be realized on a uniform platform during the DIKW organization and transformation. An effective distribution will be created to transmit industrial value from the sell node, namely "Service to Human", to other industrial nodes, namely "Data to Information, Knowledge, Wisdom, and Services", towards a complete W2T cycle.

2.7 Perspectives of Challenges and Issues on WaaS

WaaS is a multidisciplinary and interdisciplinary research field for the open intelligence service architecture, and also a business mode for the intelligence service industry in the era of IoT and big data. It requires cooperative efforts from science, technology and industry, and presents new challenges and issues from the scientific, technological, social and business perspectives.

2.7.1 Scientific Perspective

WaaS focuses on the DIKW organization and transformation, whose core is human brain intelligence. As one of the most important scientific issues in the 21st century, the study of human brain intelligence involves many challenges, such as:

- How to investigate human brain intelligence, including individual human differences and similarities, by means of the research on holistic intelligence?
- How to obtain sufficient brain intelligence big data through powerful equipments?
- How to manage and mining the huge volume of brain intelligence big data to gain a systematic investigation and understanding of human intelligence?

Brain Informatics (BI) [21, 31, 32] provides a systematic methodology for dealing with these challenges and many problems must be addressed.

How to develop brain intelligence inspired information technologies for realizing the DIKW organization and transformation is another core scientific issue in the WaaS research and industry. An important aspect is the cyber-individual (Cyber-I) which is a comprehensive digital description of individual humans as a counterpart in the cyber world [26]. In order to develop a "telepathic partner" for the real-individual at all times and contexts, the creation of Cyber-I brings many scientific challenges and issues, including the study of individual human differences, individual human modeling, and CI-Mind [26].

2.7.2 Technological Perspective

WaaS is an open and interoperable content architecture of IT applications for supporting large-scale sharing and cooperation on the DIKW hierarchy. It is important to have an open, flexible and friendly platform, for example, the web-scale knowledge integration and reasoning platforms (e.g., the LarKC), for any third party to develop and plug in its WaaS applications.

The WaaS applications include various kinds of software and u-Things and will be involved in a sustainable development process. Hence, another basic technological challenge is how to design a scalable and sharable system architecture based on cloud computing platforms, allowing the maximum utilization of limited resources.

A conflict often exists between a systems openness and security. The security and privacy protection is an important challenge for the open WaaS. The technological architecture of security and privacy protection should be fit for different application environments, including not only the Internet but also IoT and MI.

2.7.3 Social Perspective

WaaS will impel a global cooperation in research and in industry and might cause potential socio-economical issues, such as:

- How to create an effective incentive mechanism to accelerate the concentration of DIKW resources from different government departments, research/social institutions and enterprises? It could involve such problems as related to DIKW right, protection, management, evaluation, value distribution, and so on.
- How to build a high-efficiency identification and arbitration mechanism to quickly identify responsibilities and solve dissensions? Are the existing laws and regulations perfect enough for supporting such a mechanism?

2.7.4 Business Perspective

At present, cloud computing has great effects on intelligence industry and causes a platform-leading value distribution mode. The providers of software or hardware platforms, such as Internet service providers and manufacturers of operating systems, play a leading role in the value distribution. The DIKW hierarchy and the W2T cycle have revealed that the content of IT applications is another core issue for the development of intelligent IT applications in the hyper-world age. A huge business challenge brought by WaaS is to transform the value distribution from the existing platform-leading one to the platform-and-content-leading one. It is necessary to let the market and capital know the importance of resources and technologies with respect to the DIKW hierarchy. It is also necessary to develop an effective business model for these resources and technologies, including evaluation mechanism, transaction mode, pricing/payment methods, and so on.

2.8 Conclusion

Recent advances in cloud computing, IoT, WoT, big data, W2T and other research fields have created a great opportunity to study and realize WaaS based on achievements and accumulations of intelligence science, BI and other intelligent computing technologies. We have presented the basic concepts, infrastructure and applications of WaaS, as well as the first step toward the final goal of constructing the W2T cycle to realize the harmonious symbiosis of humans, computers and things in the hyper-world. As a demonstration, we discussed the development of portable brain and mental health monitoring system. The WaaS standard and service platform will be fine-tuned continuously as a core infrastructure for intelligence industry and smart city to support the development of various intelligent IT applications. WaaS will be the core architecture of IT applications in the coming age of the hyper-world. It will bring a huge economic value for intelligence IT industry by realizing the pay-as-you-go manner.

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