Design and Research of Healthy Ecology System Framework Based on IPV9

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***Abstract*—With the improvement of living standard and the change of life, people’s health awareness has been enhanced as a whole, and the health demand has changed from single medical service to multiple services such as disease prevention, health promotion, healthcare and rehabilitation. The wisdom medical system, Internet + medical service mode and digital hospital have become the direction of medical development. In order to build Tai'an healthy big data ecological domain, accelerate the traditional medical process informatization reform, and improve the application level of information service, we build a medical system with the support of new generation network IPV9 technology. The system is based on the medical institutions in Tai’an city, Shandong province, and has researched and implementation of the health ecosystem business structure, core technology, network architecture, system software and hardware, and system security. The system was put into trial operation in the medical institutions of the whole city and has achieved perfect results.**

Keywords-IPV9; Internet +; Healthy Ecology; Health Platform

I. THE CURRENT STATUS OF HEALTH CARE

A. Medical health background

A new round of scientific and technological revolution and industrial changes are accelerating. Life science technologies continuously made new breakthroughs, and major technologies such as genetic engineering, molecular diagnostics, stem cell therapy, and 3D printing are accelerating applications. The new generation information biology and engineering technologies such as big data, cloud computing, Internet, artificial and intelligence are increasingly integrated into the medical and health fields. The rapid

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development of telemedicine, mobile medical care, precision medical care, smart medical care and other technologies have promoted the vigorous development of new formats and models of health industry, such as health management, health care, health tourism, leisure and health care, and “Internet + health”.

“13th Five-Year Plan for National Population Health Informatization Development” pointed out: We should strengthen population health informatization and health care big data service system construction, promote integration of government health care information system and public health medical data fusion, and eliminate information barriers, focus on improving the ability and level of population health information governance, vigorously promote the development of health care big data applications, and explore new models and new formats of innovative "Internet + health" services. We will build a unified, authoritative and interconnected platform for population health information, standardize and promote "Internet+ health care" services, and create new models of Internet health care services. Data collection, integration and sharing and business coordination of applied information systems such as public health, family planning, medical services, medical security, drug supply and comprehensive management are realized.

In recent years, the aging population in Shandong province is characterized by large base, rapid growth and empty nest. On the one hand, the needs of elder's life care and medical health care are superimposed, and the consumption demand in the field of medical care, health care are strong, with huge space for the development of related industries. On the other hand, the health care industry in Shandong province is still in its infancy, with relatively insufficient supply-side capacity, structural contradictions and policy barriers, lack of high-quality resources, narrow coverage of medical care, and insufficient professional personnel, making it difficult to meet the needs of the elderly for different levels of health care services.

B. Tai'an health care platform

In 2016, Tai'an City proposed in the of “Tai'an City transformation and upgrading of medical and health service industry implementation plan” to accelerate the construction of "smart medical" system, explore the "Internet + medical" service mode, and build a digital hospital. We will build a sound healthy Tai'an big data ecological domain, accelerate the informatization reform of traditional medical treatment process, and improve the application level of informatization services. The government encourages medical and health institutions to make full use of the advantages of Internet development.

The design and research of this system is based on the medical informatization of Tai'an City, Shandong Province, which is led by Tai’an Central Hospital of Tai'an City, Tai'an Central Hospital and Tai'an City Hospital of Traditional Chinese Medicine. The district and county people's hospitals are the main force, and the informatization development of the hospital is relatively perfect. However, some secondary hospitals, primary health care institutions, medical associations, medical communities, Internet hospitals, regional medical and health platforms and other information systems are not perfect, and they are unable to meet the growing needs of medical information development. Take the construction of medical and health information in Feicheng City as an example.

With the rapid development of IT technology, SOA technology, SaaS application, wireless network and other new technologies, the price of IT equipment is getting lower and lower, which makes the construction of smart city feasible technically and economically. Meanwhile, with the continuous application of cloud computing technology in the practice of medical informatization, the construction of regional medical informatization can achieve better results on this basis.

In August 2007, the Ministry of Information Industry Officially defined IPv9 as a new generation Internet to distinguish IPv6 next-generation Internet. The Internet based on TCP/IP protocol has been unable to meet the needs of future development by increasing bandwidth and gradual improvement. In order to break through the future network basic theory and support a new generation of Internet experiment. It is necessary to build test facilities include: original network equipment system, resource monitoring management system, covering cloud computing services, Internet of Things applications, spatial information network simulation, network information security.

On November 20, 2018, the General Staff Department of the People's Liberation Army organized the IPv9 Technology Project Application Seminar at the No. 9 Dacheng Road in Beijing. They discussed and demonstrated the application of the healthy Tai’an Big Data Ecological Domain as an IPv9 technology application. It is required to speed up construction of the Tai’an big data ecological domain and rapidly increase the scale of the IPv9 network, and strive to build an IPv9 network technology demonstration zone through healthy Tai’an big data ecological domain.

Tai’an City "smart medicine" was achieved through the establishment of a unified data standard for health information in Tai'an City, public health information resources sharing, and electronic two-way referral and inspection results in the city mutual recognition and health card application in the city. With the healthy Tai’an big data ecological domain as the core, it realizes information interconnection and sharing, as well as comprehensive business collaboration. It promotes the development of a large health industry, achieves a more scientific management, smarter business, and benefits more residents, and promotes the openness of the health and family planning business in Tai'an City. Through the construction of this platform, the informatization construction of health and family planning in Tai'an City has reached the national first-class level.

II. ECOLOGICAL DOMAIN SYSTEM

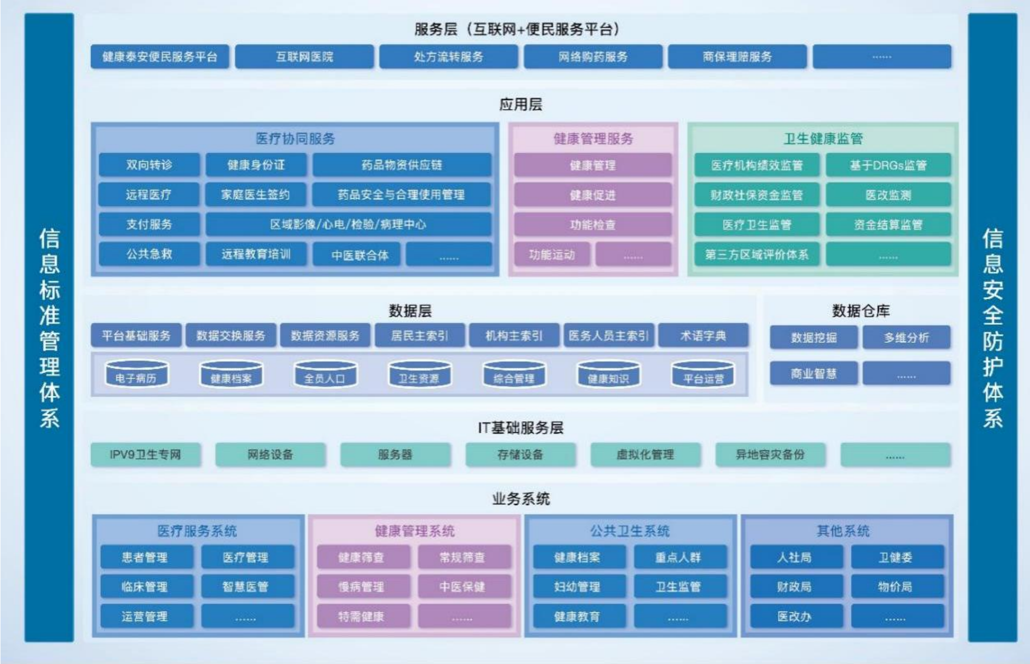
Tai’an big data ecological domain can provide personalized health management and health care for residents, improve residents' satisfaction. It can provide life-cycle health information for residents, and provide residents with network and information health services and health management. It enables residents to obtain continuous, comprehensive and high-quality health care services. It improves the efficiency of health services and reduces the waiting time of residents. We will support the rational use of high-quality regional health resources; effectively resolve the rational division of labor and allocation between primary and secondary large hospitals.

A. System business architecture

The health Tai’an big data ecosystem consists of five parts: business system layer, IT basic service layer, data layer (data warehouse), application layer and service layer (Internet + convenient service platform).

The business systems layer includes the business systems of medical institutions, health management centers, public health institutions, and other administrative agencies. Through the IPv9 service private network, network equipment, servers and storage equipment in the IT basic service layer, data such as electronic medical records, health files, population, and health resources are stored in the data layer. We divide the platform business system into three categories according to the different roles of data usage. The first category is the Internet + service platform for residents (including health Tai’an website, health Tai’an APP, Internet hospital, etc.). The second category is the medical collaborative service system for medical and health personnel (including hierarchical diagnosis and treatment platform, health identity card management system, telemedicine, health Tai’an imaging/ECG/inspection/pathology, etc.). The third category is the medical and health supervision system which serving the medical and health administrative institutions (including the medical and health supervision platform, medical reform monitoring system, third-party regional evaluation system, etc.). Meanwhile, business intelligence in data warehouse can be used to support the development of big data analysis and artificial intelligence.

The entire platform architecture conforms to the international and national information standard management system and information security protection framework to ensure the consistency and security of the exchange of data. Meanwhile, the remote disaster recovery and backup mode in line with international requirements is specially used to ensure the safe storage of data from natural or man-made disasters.


信息标准管理体系
服务层（互联网+便民服务平台）
健康泰安便民服务平台
互联网医院
处方流转服务
网络购药服务
商保理赔服务
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应用层
医疗协同服务
双向转诊
健康身份证
药品物资供应链
远程医疗
家庭医生签约
药品安全与合理使用管理
支付服务
区域影像/心电/检验/病理中心
公共急救
远程教育培训
中医联合体
......
健康管理服务
健康管理
健康促进
功能检查
功能运动
......
卫生健康监管
医疗机构绩效监管
基于DRGs监管
财政社保资金监管
医改监测
医疗卫生监管
资金结算监管
第三方区域评价体系
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数据层
平台基础服务
数据交换服务
数据资源服务
居民主索引
机构主索引
医务人员主索引
术语字典
电子病历
健康档案
全员人口
卫生资源
综合管理
健康知识
平台运营
数据仓库
数据挖掘
多维分析
商业智慧
......
IT基础服务层
IPV9卫生专网
网络设备
服务器
存储设备
虚拟化管理
异地容灾备份
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业务系统
医疗服务系统
患者管理
医疗管理
临床管理
智慧医管
运营管理
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健康管理系统
健康筛查
常规筛查
慢病管理
中医保健
特需健康
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公共卫生系统
健康档案
重点人群
妇幼管理
卫生监管
健康教育
......
其他系统
人社局
卫健委
财政局
物价局
医改办
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信息安全防护体系

Figure 1. Business architecture of health Tai’an big data ecological domain

B. *Overall technical architecture*

The health Tai’an big data ecological domain database uses relational databases such as MySQL, Oracle, SQL Server, and the development language uses JAVA and .net.

The platform service is built with ESB bus and SOA architecture, which provides perfect technical support for big data, and realizes rapid access to massive data. The flat platform provides complete functions such as collaborative support services and configuration management, and provides a comprehensive monitoring mechanism for the operating environment, which facilitates the rapid positioning and troubleshooting of problems. The overall technical framework of the platform conforms to the national standard and standard system, and adopts the data exchange standard of the industry standard, and adopts a variety of security mechanisms and security technologies to ensure the stable operation of the platform.

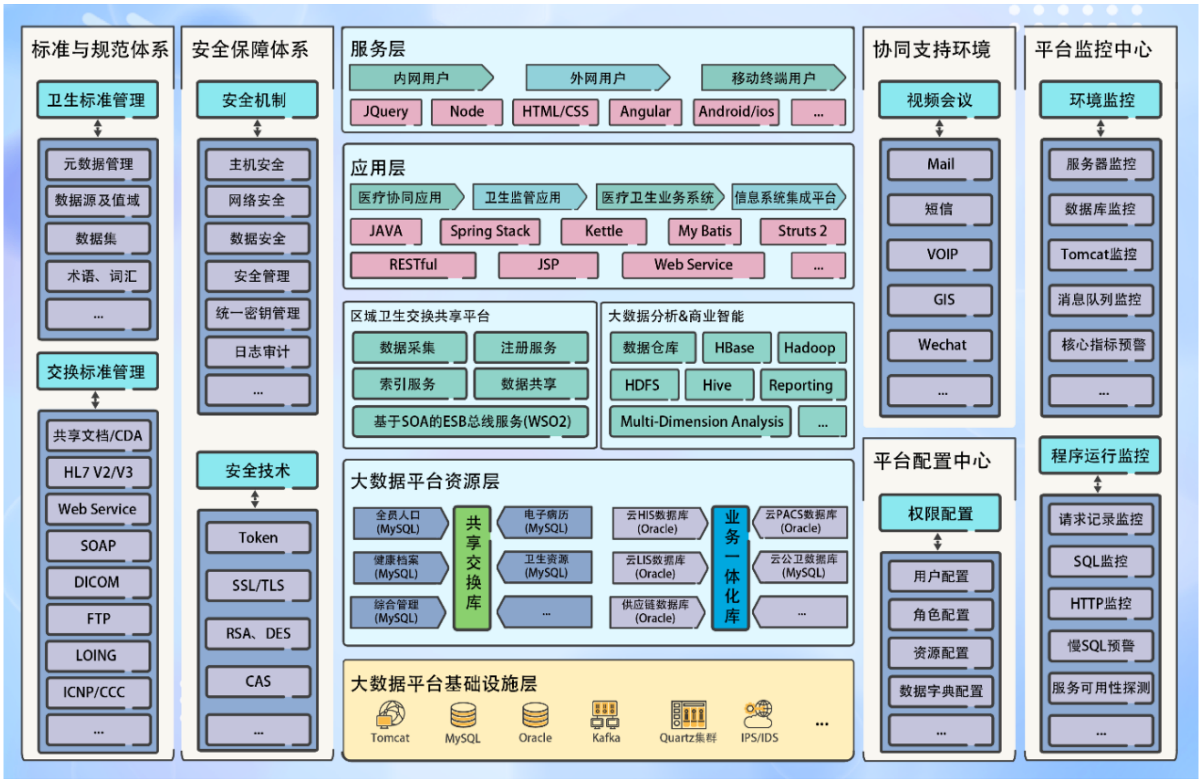

标准与规范体系
卫生标准管理
元数据管理
数据源及值域
数据集
术语、词汇
...
交换标准管理
共享文档/CDA
HL7 V2/V3
Web Service
SOAP
DICOM
FTP
LOING
ICNP/CCC
...
安全保障体系
安全机制
主机安全
网络安全
数据安全
安全管理
统一密钥管理
日志审计
...
安全技术
Token
SSL/TLS
RSA、DES
CAS
...
服务层
内网用户
外网用户
移动终端用户
JQuery
Node
HTML/CSS
Angular
Android/ios
...
应用层
医疗协同应用
卫生监管应用
医疗卫生业务系统
信息系统集成平台
JAVA
Spring Stack
Kettle
My Batis
Struts 2
RESTful
JSP
Web Service
...
区域卫生交换共享平台
数据采集
注册服务
索引服务
数据共享
基于SOA的ESB总线服务(WSO2)
大数据分析&商业智能
数据仓库
HBase
Hadoop
HDFS
Hive
Reporting
Multi-Dimension Analysis
...
大数据平台资源层
全员人口 (MySQL)
健康档案 (MySQL)
综合管理 (MySQL)
共享交换库
电子病历 (MySQL)
卫生资源 (MySQL)
...
云HIS数据库 (Oracle)
云LIS数据库 (Oracle)
供应链数据库 (Oracle)
业务一体化库
云PACS数据库 (Oracle)
云公卫数据库 (MySQL)
...
大数据平台基础设施层
Tomcat
MySQL
Oracle
Kafka
Quartz集群
IPS/IDS
...
协同支持环境
视频会议
Mail
短信
VOIP
GIS
Wechat
...
平台配置中心
权限配置
用户配置
角色配置
资源配置
数据字典配置
...
平台监控中心
环境监控
服务器监控
数据库监控
Tomcat监控
消息队列监控
核心指标预警
...
程序运行监控
请求记录监控
SQL监控
HTTP监控
慢SQL预警
服务可用性探测
...

Figure 2. Technical architecture of health Tai'an big data ecological domain

1) *SOA architecture support*

The platform adopts the Micro services architectural mode. Micro services are an updated version of the traditional SOA architectural pattern that supports for fine-grained control. Each system accessed in healthy Tai'an big data ecological domain is equivalent to micro services component, which dynamically realizes service scheduling and balance through registration and discovery mechanism. In addition, each service component can deploy multiple instances, effectively improving the overall stability of the platform.

A service component is a mineralized project with distributed deployment and invocation that provides a type of interface services. In terms of interface granularity division of service components, appropriate granularity should be adopted to split the interfaces to ensure the flexibility of top-level application calls and reduce the number of calls between different components to avoid complex business logic dependencies between components.

2) *ESB bus technology*

ESB (Enterprise Service Bus) is the combination of traditional middleware technology and XML, Web Service technology. The ESB provides the most basic connectivity hub in a network and is an essential element in building an enterprise nervous system. The enterprise service bus is the latest way to provide reliable, guaranteed messaging technology.ESB middleware products leverage Web services standards and interfaces with recognized reliable messaging protocols. Common features of ESB products include: connecting heterogeneous MOM, encapsulating the MOM protocol using the Web services description language interface, and the ability to transport Simple Object Application Protocol (SOAP) transport streams on the MOM transport layer.

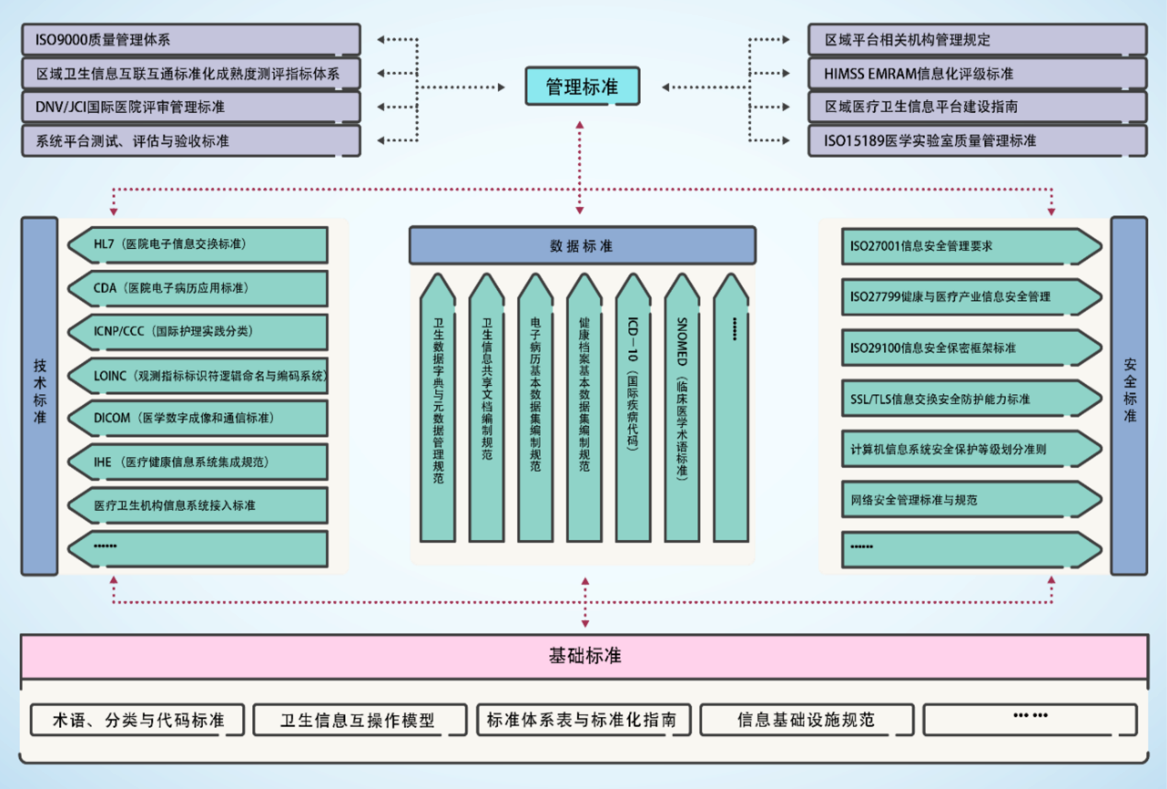
The ESB uses the "bus" model to manage and simplify the integration topology between applications, based on open standards to support dynamic interconnectivity between applications at the level of messages, events, and services.

The platform adopts B/S architecture and SaaS deployment mode, which is different from traditional medical information platform manufacturers and the overall architecture design, is more advanced and efficient.

C. Overall standard architecture of the platform

Following the unified standard, unified code, unified interface, under the principle of combing and standardized data through canonical business definition, strictly in accordance with established standards and technical route, so as to realize multiple departments, multiple system, information technology, as well as heterogeneous platform environment, interconnection, make sure that the maturity of the whole system, expansibility and adaptability, to evade the risk of system construction.

Under the principle of “unified specification, unified code, and unified interface”, the system strictly abides by established standards and technical routes, thereby achieving information interconnection in multi-sector, multi-system, multi-technology, and heterogeneous platform environments.


ISO9000质量管理体系
区域卫生信息互联互通标准化成熟度测评指标体系
DNV/JCI国际医院评审管理标准
系统平台测试、评估与验收标准
管理标准
区域平台相关机构管理规定
HIMSS EMRAM信息化评级标准
区域医疗卫生信息平台建设指南
ISO15189医学实验室质量管理标准
技术标准
HL7（医院电子信息交换标准）
CDA（医院电子病历应用标准）
ICNP/CCC（国际护理实践分类）
LOINC（观测指标标识符逻辑命名与编码系统）
DICOM（医学数字成像和通信标准）
IHE（医疗健康信息系统集成规范）
医疗卫生机构信息系统接入标准
……
数据标准
卫生数据字典与元数据管理规范
卫生信息共享文档编制规范
电子病历基本数据集编制规范
健康档案基本数据集编制规范
ICD－10（国际疾病代码）
SNOMED（临床医学术语标准）
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ISO27001信息安全管理要求
ISO27799健康与医疗产业信息安全管理
ISO29100信息安全保密框架标准
SSL/TLS信息交换安全防护能力标准
计算机信息系统安全保护等级划分准则
网络安全管理标准与规范
……
安全标准
基础标准
术语、分类与代码标准
卫生信息互操作模型
标准体系表与标准化指南
信息基础设施规范
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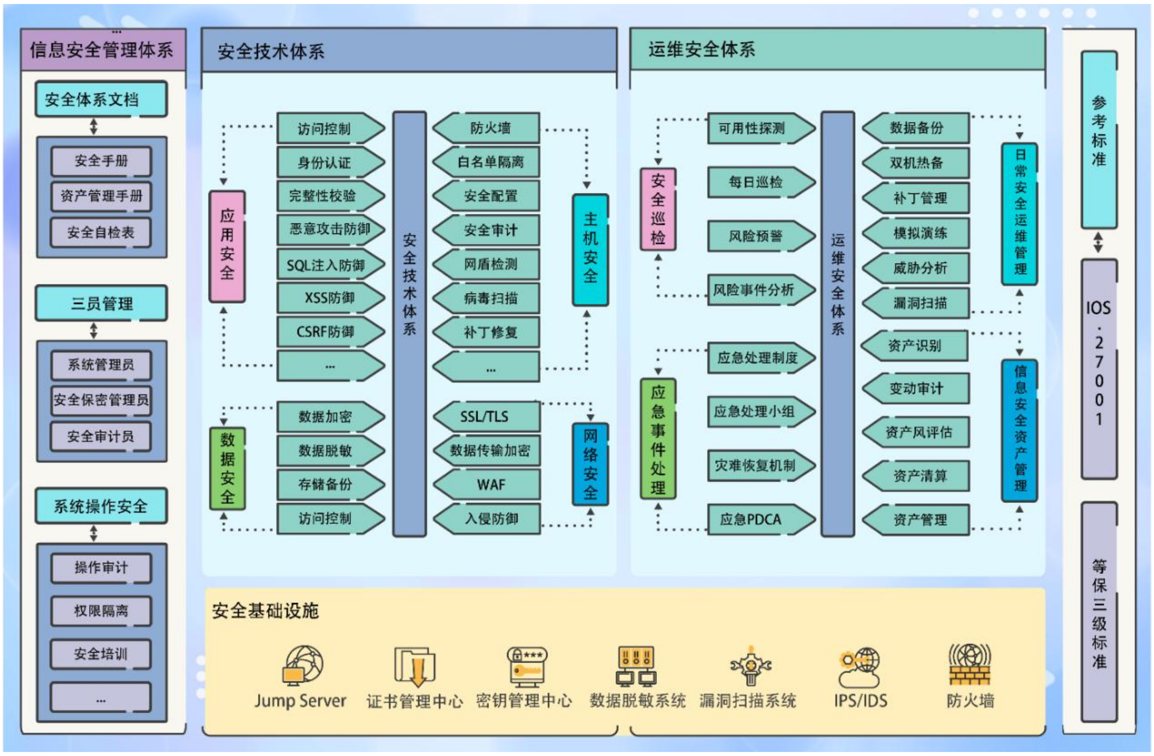
Figure 3. The standard architecture health Tai’an big data ecological domain

D. Platform security architecture

The platform security architecture refers to ISO-27001 and the third level of the national information security level protection system requirements. From the aspects of technology, operation and maintenance, management system and infrastructure, it is divided into security technology system, operation and maintenance security system, information security management system, security infrastructure and other parts.


信息安全管理体系
安全体系文档
安全手册
资产管理手册
安全自检表
三员管理
系统管理员
安全保密管理员
安全审计员
系统操作安全
操作审计
权限隔离
安全培训
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安全技术体系
应用安全
访问控制
身份认证
完整性校验
恶意攻击防御
SQL注入防御
XSS防御
CSRF防御
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安全技术体系
防火墙
白名单隔离
安全配置
安全审计
网盾检测
病毒扫描
补丁修复
...
主机安全
数据安全
数据加密
数据脱敏
存储备份
访问控制
SSL/TLS
数据传输加密
WAF
入侵防御
网络安全
运维安全体系
安全巡检
可用性探测
每日巡检
风险预警
风险事件分析
应急事件处理
应急处理制度
应急处理小组
灾难恢复机制
应急PDCA
运维安全体系
数据备份
双机热备
补丁管理
模拟演练
威胁分析
漏洞扫描
日常安全运维管理
资产识别
变动审计
资产风评估
资产清算
资产管理
信息安全资产管理
参考标准
IOS.27001
等保三级标准
安全基础设施
Jump Server
证书管理中心
密钥管理中心
数据脱敏系统
漏洞扫描系统
IPS/IDS
防火墙

Figure 4. The security architecture health Tai'an big data ecological domain

The security technology system is mainly divided into application security, data security, network security and host security.

1) *Application security. Application security mainly against common WEB security vulnerabilities published by OWASP.* It mainly includes SQL injection, invalid authentication and authentication management, XSS attacks, invalid access control, sensitive information disclosure, CSRF, use of known vulnerability components, unprotected API, insufficient logging and monitoring and other WEB vulnerabilities.

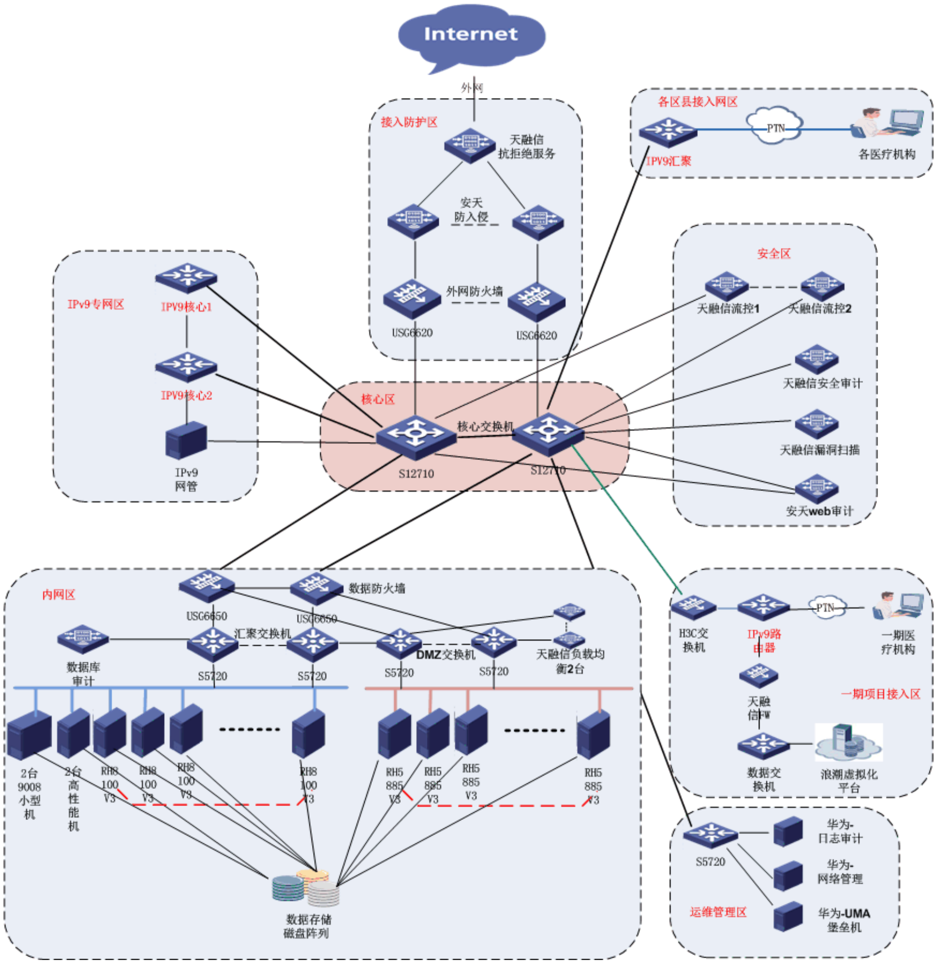
2) *Data security. Database security relies on various technologies and management measures to ensure data security, availability, integrity and confidentiality through data encryption, data desensitization, data storage backup, and access control.*

3) *Network security. Network security is mainly to ensure the integrity, confidentiality and non-repudiation of data in the process of network transmission.* Through data transmission process encryption, intrusion prevention guarantees network security.

4) *Host security. Host security solves the main security risks faced by the server, builds a server security protection system to prevent information leakage and risk by firewalls, white list isolation, security configuration, etc.*

III. SYSTEM NETWORK ARCHITECTURE

The system is divided into six areas, and the core area is two Huawei S2710 data center level switch clusters. The core area is connected to all other areas using dual gigabit connections. The network topology is shown in figure 5.


Internet
外网
接入防护区
天融信
抗拒绝服务
安天
防入侵
外网防火墙
USG6620
USG6620
各区县接入网区
IPV9汇聚
PTN
各医疗机构
IPv9专网区
IPV9核心1
IPV9核心2
IPv9
网管
核心区
核心交换机
S12710
S12710
安全区
天融信流控1
天融信流控2
天融信安全审计
天融信漏洞扫描
安天web审计
内网区
USG6650
USG6650
数据防火墙
汇聚交换机
数据库
审计
S5720
S5720
DMZ交换机
S5720
S5720
天融信负载均
衡2台
2台
9008
小型
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2台
高
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V3
数据存储
磁盘阵列
H3C交
换机
IPv9路
由器
PTN
一期医
疗机构
一期项目接入区
天融
信FW
数据交
换机
浪潮虚拟化
平台
S5720
华为-
日志审计
华为-
网络管理
华为-UMA
堡垒机
运维管理区

Figure 5. Topology architecture of healthy Tai’an big data ecological domain network

The access area is the area where all health cares institutions access. Two Huawei 10 Gigabit firewalls are used for isolation and aggregation. The business volume in the early stage is limited, and each of the two firewalls uses a 10 Gigabit connection, which can be expanded at any time with the business development in the future.

The internal network area is centered on two IPv9 backbone routers and Huawei 6650 data firewall. The data firewall isolates the internal network from the core switch 12710 to protect it. The establishment of virtual servers and storage devices in the internal network area is completed through optical fiber switches. The IPv9 router backbone router encrypts the address of the core data area of the internal network for higher security.

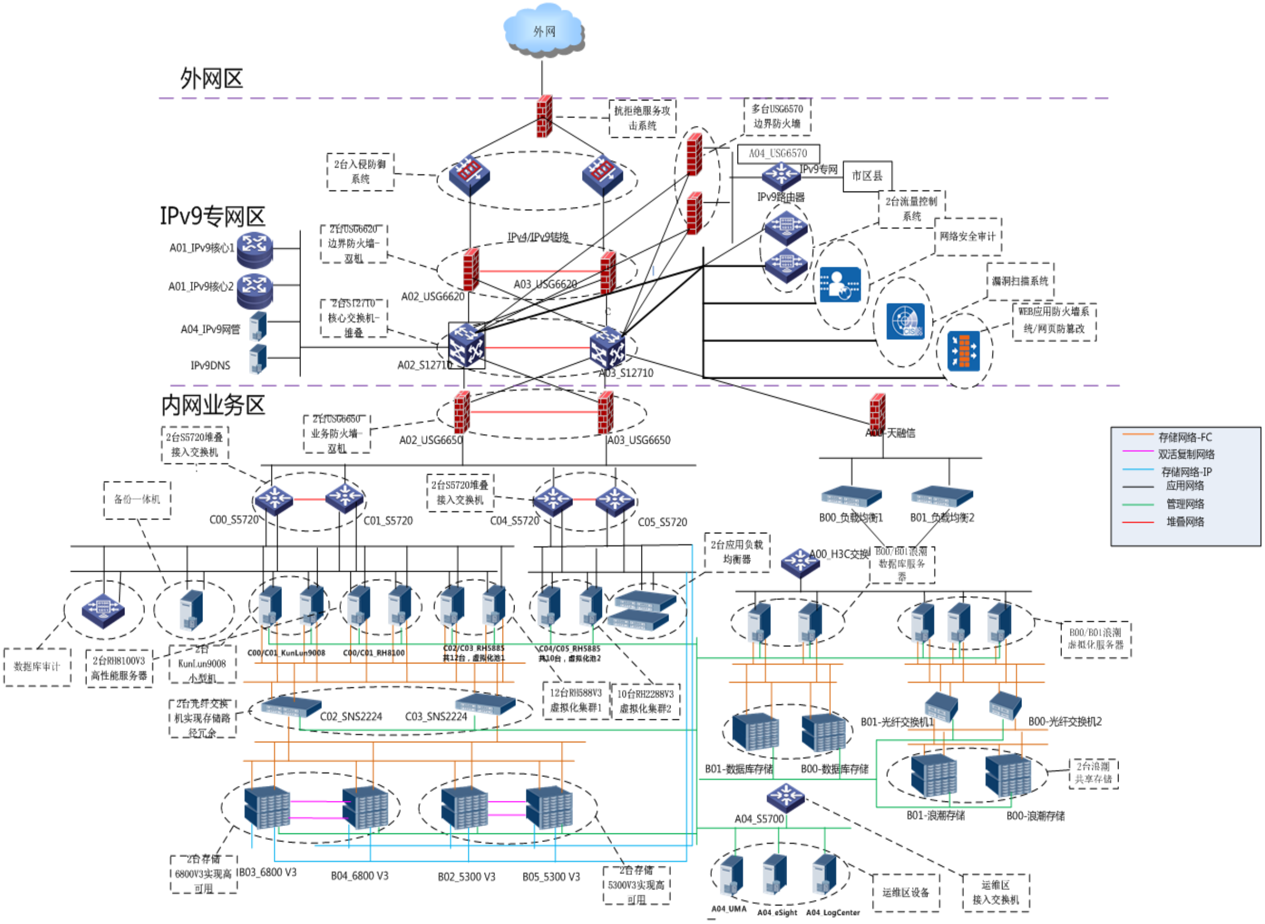
The external network deployment has the external network firewall. The anti-attack device is deployed to further increase the security protection of the external network. Platform logging, auditing, monitoring and IPv9 management are deployed in the management area. The security zone is used to deploy TOPSEC vulnerability scanning, network auditing, and flow control devices, which mainly provide security auditing and vulnerability scanning andother protection functions for the network.

IV. DESIGN OF SYSTEM HARDWARE ARCHITECTURE

The system is equipped with Huawei key business server minicomputer, which is mainly used in HIS system. It gives full play to the characteristics of strong processing capacity and high reliability of the minicomputer to ensure the normal operation of the hospital's daily business for 24 hours. The system is equipped with Huawei high-performance data server, which serves as the city's population health records database to ensure the security of these important data.

The high-performance generic server runs the LIS system, supply chain system, PACS system, medical business collaboration, Internet applications, and other applications. The cloud mode dynamically adjusts the computing resources of the server according to the running status of the service. Each virtual machine can be used as a backup. If a hardware server fails, the service will not be affected.

The hardware architecture of the system is shown in figure 6.



外网
外网区
抗拒绝服务攻击系统
多台USG6570边界防火墙
A04_USG6570
IPv9专网
市区县
IPv9路由器
2台入侵防御系统
IPv9专网区
A01_IPv9核心1
A01_IPv9核心2
A04_IPv9网管
IPv9DNS
2台USG6620边界防火墙-双机
IPv4/IPv9转换
A02_USG6620
A03_USG6620
2台S12710核心交换机-堆叠
A02_S12710
A03_S12710
2台流量控制系统
网络安全审计
漏洞扫描系统
WEB应用防火墙系统/网页防篡改
内网业务区
2台USG6650业务防火墙-双机
A02_USG6650
A03_USG6650
A00-天融信
2台S5720堆叠接入交换机
备份一体机
C00_S5720
C01_S5720
2台S5720堆叠接入交换机
C04_S5720
C05_S5720
数据库审计
2台RH8100V3高性能服务器
2台KunLun9008小型机
C00/C01_KunLun9008
C00/C01_RH8100
C02/C03_RH5885 共12台，虚拟化池1
C04/C05_RH5885 共10台，虚拟化池2
12台RH588V3虚拟化集群1
10台RH2288V3虚拟化集群2
2台光纤交换机实现存储路径冗余
C02_SNS2224
C03_SNS2224
2台存储6800V3实现高可用
B03_6800 V3
B04_6800 V3
B02_5300 V3
B05_5300 V3
2台存储5300V3实现高可用
B00_负载均衡1
B01_负载均衡2
2台应用负载均衡器
A00_H3C交换
B00/B01浪潮数据库服务器
B00/B01浪潮虚拟化服务器
B01-光纤交换机1
B00-光纤交换机2
B01-数据库存储
B00-数据库存储
2台浪潮共享存储
B01-浪潮存储
B00-浪潮存储
A04_S5700
A04_UMA
A04_eSight
A04_LogCenter
运维区设备
运维区接入交换机
存储网络-FC
双活复制网络
存储网络-IP
应用网络
管理网络
堆叠网络

Figure 6. Topology diagram of health Tai’an big data ecological domain equipment.

According to the outpatient volume of all levels of hospitals within Tai’an region, the available storage capacity of healthy Tai’an big data ecological domain is 202.5T, which can meet the business needs in the next 3 to 5 years. The storage portion consists of Huawei OceanStor6800 V3 and Huawei

OceanStor5300 V3 virtualized Shared storage disk array.

The system plans HUAWEIRH2288HV3, (CPU E5-2620V4, 16G memory 600G hard disk) server, as a silver enterprise server, deploys two independent physical machine servers. System antivirus virus database upgrade server, and system antivirus virus database requires independent physical server.

V. SYSTEM IMPLEMENTATION

Tai'an City health big data ecological domain designed in accordance with the above framework system, it has completed the overall planning of nearly 300 platforms and products in 8 categories, including basic platform, medical service, health service, healthy family, business system, benefit people service, business supervision, emerging technology since its construction in 2017. The system has completed the construction of all basic platforms, including platform standard management system, platform basic service, data exchange service, data resource service, information system integration platform, platform operation and maintenance system, platform security system. It has completed the construction of the information system of all primary medical institutions, including cloud HIS, cloud LIS, cloud PACS, cloud EMR and so on. Some health services have been completed, including basic public health services and family doctor services. It has completed the construction of some business collaboration systems, including medical group/medical association/medical community/specialist alliance system, health ID card management system, health record access system, two-way referral system, remote consultation system, imaging center system. It has completed the construction of some beneficial services, including health Tai'an website/app, Internet hospital, prescription sharing platform, pharmacy purchasing, sales and storage management system, online drug purchase management system, etc. It has completed the construction of some business supervision system, including medical and health supervision system, financial fund supervision system, medical insurance control system, etc. The detail is as follows:

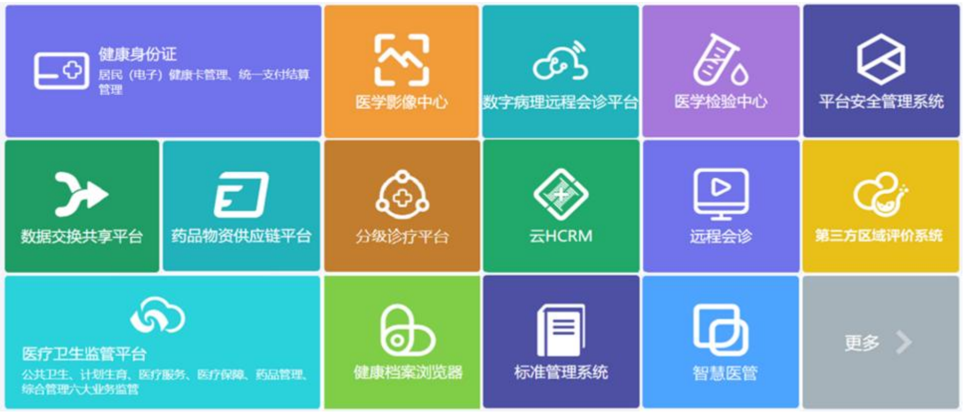


Figure 7. Application system module map

In the above system, the financial capital clearing platform has been used in various medical and health unit in the whole city. The Fourth People's Hospital of Tai'an City, Tai'an Traditional Chinese Medicine Hospital, and Wangzhuang Town Health Center of Feicheng City of medical informatization and Internet + application have been comprehensively. It has been fully launched and stable, and has been highly praised by visiting experts. The Fourth People's Hospital of Tai'an City, the Wangzhuang Town Health Center of Feicheng City is applying for a typical case of the national universal medical health information platform.

The overall platform has achieved good application results, and the operation based on IPV9 network platform is stable and reliable.

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