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Smart Health Service System Based on Service-oriented Architecture

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Abstract. Smart health service means utilizing the integration and collaboration of Internet of Things technology and modern health service technology to realize intelligent health service featuring ubiquity and personification. In consideration of the requirement and objective of health service and based on the Smart Service System of Internet of Things, this paper attempts to study and establish a user-centered, service-oriented and software defined smart health service system (SHSS), which consists of heterogeneous terminal control system, ubiquitous network control system, integrated information control system and health service control system, providing solutions for smart health service. The proposed system has the following advantages: (i) The devices contained in this system cover multiple types of traditional physical examination terminals. (ii) The communications network in this system is a converged network, which coordinates all kinds of existing networks. (iii) The services and applications in this system cover all health service areas, also it presents adaptability to new health services.

Keywords: Internet of Things, multi-network cooperation, service-oriented, smart health service, smart service system

1 Introduction

Internet of Things (IoT) is featured by the high integration and comprehensive utilization of new-generation information technologies. The original objective of IoT lies in connecting various physical and virtual things in the world via information network, including Internet, to create an IoT environment where real-time and dynamic interaction of information between human, machines and things can be realized, and to make things in the world "actively connected" so as to provide service through the way of personification, and ultimately realize smart service [1]. Smart health service means integrating IoT technology with traditional health services like health monitoring, health checkup, health management, etc, taking advantage of the integration and collaboration of information network technology and modern health technology, and making all health service terminals into network information service terminal through the connection of various networks targeting at people, so as to realize the smart health service featuring "ubiquity and personification". Therefore, it become an important industrial development trend and an urgent social demand to provide human-centered and health management-featured health service for society. This paper attempts to study and establish a user-centered, health service-driven and software defined multi-terminal and multi-network smart health service system, to provide solutions for smart health service.

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This paper proposes a novel smart health service system based on Service-oriented architecture which supports heterogeneity, reconfiguration, and scalability of networks, devices, and services. The remainder of this paper is organized as follows. Related work of intelligent health service system is given in Section II. In Section III, we present a high-level description of the smart health service problem and objectives. Section IV describes the system architecture, and section V presents the smart health service system. In addition, a household health service system demonstration developed on the proposed in section VI, which demonstrates the capabilities of the proposed system. Finally, we draw the conclusion in Section VII.

2 Related Work

With the rapid development of information society, the demands for uplifting traditional health service through utilizing the integration between information network technology and modern health technology have bacome more and more urgent. The global health service market has shifted from traditional health service to information network based smart health service, hence easing the pressure on current health service resources and improving the efficiency and coverage of health service. At present, smart health service across the globe mainly focuses on health management informationization, health monitoring, electronic medical record and remote medical treatment, etc.

Currently, the United States and Europe are at the advanced level of the world in terms of smart health service industry. Five EU member states (Britain, Germany, Netherlands, Sweden and Spain) have jointly made the Attendance and Health Plan, i.e., using wireless communication technology and body area network (BAN) to connect the sensors on patients to automatically transmit physiological signals, which has been widely adopted in disease prevention and control, disease diagnosis, remote assistance and clinical research [2]. The Sukoyaka Family 21 Plan in Japan focus on the remote physiological check and emergency rescue of the aged, which can use Internet to send physiological check data to storage center at medical institutions for convenience of grasping the health condition of users. The American military has developed a personal physiological status monitor used at wartime, This satellite instrument is worn by soldiers to monitor over their breath, temperature, heartbeat and other physiological parameters. The IDEATEL Plan of the United States uses remote detection equipment to send glucose data to rear-end medical units supporting Yahoo website, which will further provide individual glucose health information. The United States has also established a countryside remote medical national lab to improve medical quality and reduce medical fees. Europe has promoted the remote medical service of “e-doctor” in a grand scale, which expands the coverage of medical system. Japan has developed a remote medical service to ease pressure in countryside, while India has launch a remote medical service satellite to help patients in remote rural areas [3-6].

Since 2013, smart health service market has gradually become the mainstream with an increasing preference for individual consumers. Companies like Apple and Google have actively put investment in smart health area, with an attempt to grasp the opportunity brought by ongoing digital health revolution and promote digital health product and service to each and every household through necessary talents, experience and intellectual property.

In China, the government is attaching great importance to accelerating the development of smart health industry. Authorities like National Population and Family Planning Commission demand health departments at all levels to fully recognize the importance and urgency of population health informationization, with a view to enabling the whole population information, medical health file and electronic medical record database to basically cover the national population and fully putting in place interconnected health information platform through information integration and sharing.

3 Problem Description and Objectives

Smart health service system is expected to take full advantage of the technologies, such as intelligent processing of big data, data integration and information resources service, integrate the existing information system, expand regional information platform coverage, and uplift networking level, thus realizing system interconnection, information sharing and business collaboration, improving health

service capacity and level, uplifting scientific decision-making supporting ability and improving health service experience for people [7-9].

3.1 Problem Description

To meet the demands for human body health service, with the help of mobile internet connection including various health service terminals like smart wristband, turgoscope, falling monitor and fat tester, typical multi-terminal and multi-network smart health service environment can be constituted using the heterogeneous networks like cellular network, WiFi, bluetooth and Zigbee, with a view to realizing the real-time and accurate obtainment of various human body health parameters, transmitting physiological data to health information platform, information platform and hospital, community service center and gym quickly, safely and wirelessly, and ultimately conducting various interactive health services at any time and place [10].

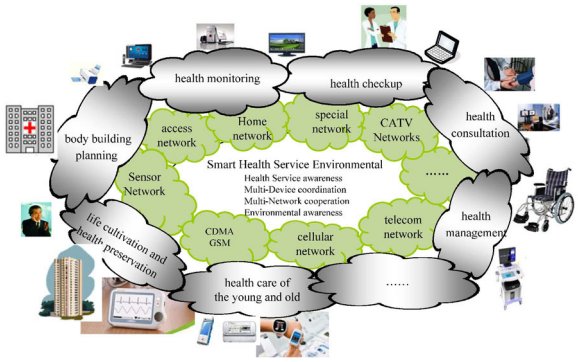

Fig. 1. Smart health service environment

3.2 Objectives

Smart health service system needs to provide enough extensible health service and content as well as the mechanism of mutual understanding and collaboration between service and service, service and content. The system has to solve the problems of the combination of enormous and differentiated health services, the synergy of various services, and the mutual perception and collaboration between health service and network, so as to ensure unified identification and understanding of resources by health service and network [11].

Health Service awareness. The essence of health service orientation lies in taking health service as center [12], i.e., sealing and aggregating the health service modules with certain feature, synergizing and combining these service modules according to certain logic, so as to optimize service effect. Health service-oriented system divides service process into health service portfolio, resources negotiation and network selection, and the system will automatically conduct search and combination for health services according to the health service needs of users.

Multi-device coordination. The heterogeneity of health service terminal supports various access technologies and networking modes [13]. Through aggregating multiple existing health service terminals, an enhanced virtual terminal can be created. Smart health service system can automatically select certain suitable health terminal devices and connect them with certain wireless network based on the environment where users are in. Therefore, the user-centered and health service-orientated virtual terminal formed by multiple terminals constitutes a multi-terminal and collaborative health service terminal system.

Multi-Network cooperation. Multi-network collaboration refers to the collaboration of various functions, including heterogeneous network resources' access, connection, transmission and management. Given that multi-terminal collaborative health service system adopts different heterogeneous networks for transmission and various wireless access technologies, the existing various health service terminals are required to break through the limitation of certain single network, so as to realize more efficient health service. In this way, suitable network should be selected according to the environment where users are in to provide service [14].

Environmental awareness. In an environment where various health service terminals and the network work together for transmission, due to the network's heterogeneity and user features, the network is required to recognize users and surrounding environment information and automatically select suitable services. Mutual understanding and negotiation can be realized for service demand, network resources and external environment, so as to uplift health service efficiency [15].

4 System Architecture

Smart service system framework of Internet of Things is proposed by Nanjing University of Posts and Telecommunications, the core of which lies in creating a sharing and integrated platform named Smart Service System (3S) to manage various businesses of users and provide smart services.

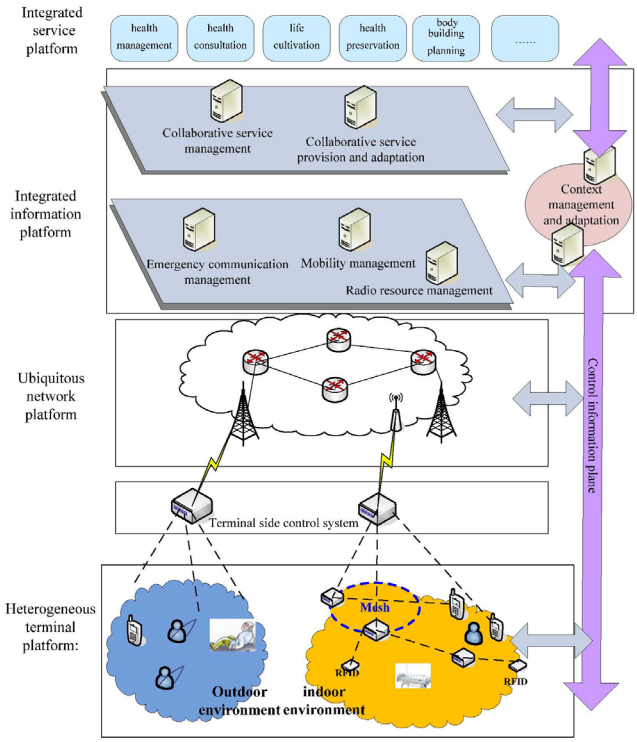

Fig. 2. Smart service system framework of Internet of Things

The system structure of 3S model mainly includes four virtual integration platforms.

4.1 Heterogeneous terminal platform

It interacts directly with man and things, and utilizes information input or output device to collect information of Internet of Things or realize smart service.

4.2 Ubiquitous network platform

It integrates various heterogeneous networks to realize enormous information transmission between heterogeneous terminal virtual platform and comprehensive service virtual platform.

4.3 Integrated information platform

It obtains and organizes various open information, adopts measures like classification, adaptation and intermediation to conduct information integration, so as to provide wide information basis for various application services.

4.4 Integrated service platform

It utilizes information integrated by integrated information virtual platform to provide various information and service to users. This platform includes management supporting system and safety guarantee system, etc.

These four platforms establish an integrated and open service environment that will provide safe, convenient and ubiquitous smart service for users and satisfy personalized and differentiated demands of different customers. Any terminal user in the 3S system can access the system through unified portal with unified identification, so as to use all the resources and enjoy all the services, hence realizing resources integration and services sharing.

5 Smart Health Service System

Smart health service system means utilizing the 3S smart service system of Internet of Things in Part IV to provide solutions for health service. Against human health status and service demand and based on 3S smart service system, wearable health sensing terminal is utilized for collecting health information, so as to realize real-time obtainment of human multi-dimensional health parameters; heterogeneous network technology is used to transmit health data to health information platform, so as to realize interactive health services oriented at home care for the aged, urban community and mobile site as well as all-time life monitoring and health management.

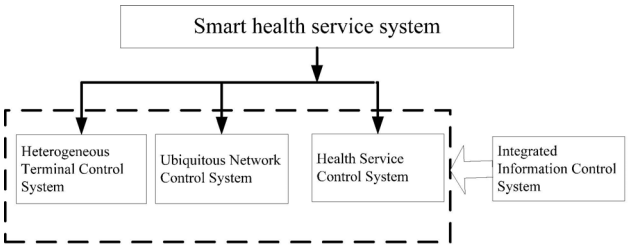

Fig. 3. Logical relationship of main parts of smart health system

5.1 Heterogeneous Terminal Control System

Heterogeneous terminal control system can discover, register and identify various heterogeneous health terminals, including the perception of multiple physics, bioelectricity and biochemical parameters, and the integration and application of new-type sensors like integrated sensor, portable chemical sensor, low-power sensor as well as the smart modification of common medical equipment. Meanwhile, short distance networking technology is used to dynamically aggregate devices with the same or different functions into one virtual health terminal with enhanced ability, more interfaces and externally displayed collaboration. Heterogeneous terminal includes the virtual terminals that transcends physical device.

Under multiple health service environments like medical institutions, community, health and fitness, traveling, automobiles and boats, outdoors, and disaster relief, these terminal devices are under the control and management of heterogeneous terminal control system, and aggregate to form unified virtual health terminals according to business requirements that have rich interfaces at the upper part, thus providing diverse health services for users. Heterogeneous terminal control system can discover usable collaborative terminal in the surrounding, sends registered information to network control system for authentication, and completes authorization to receive network status information detected at the terminal and send them to network control system so as to collaborate with mobile terminal for business realization.

The development of current portable medical health devices is still in its initial stage, mainly including electronic manometer, oximeter, glucometer and fat teller. These terminals are connected to terminal control system through various wireless access methods, so as to realize sharing and integration of terminal data of different brands. Heterogeneous terminal control system can break through previous terminal manufacturer closed-up mode through service standardization, so as to seek a service mode benefiting more parties, promote cooperation among enterprises in different field within the industrial chain of smart health, thus realizing resources optimization and efficiency improvement [16].

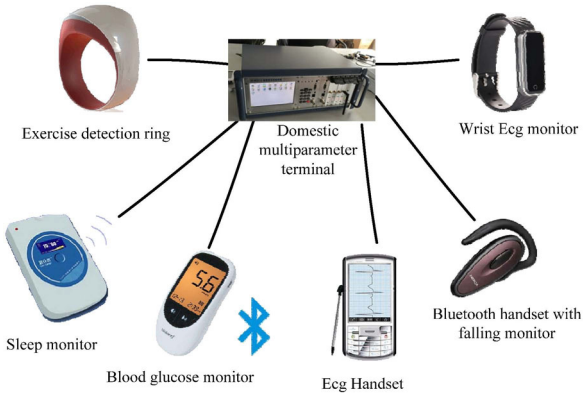

Fig. 4. Heterogeneous terminal control system

Under a ubiquitous network environment, for health service demand, it is necessary to combine various health terminal devices with different communication mechanisms and functions into an organic whole with enhanced capacity, increased ports and collaboration, so as to form a user-centered virtual health terminal and realize health service diversification and enhancement of user experience. The so-called virtual health service terminal is a distributed system that can conduct capacity synthesis in a self-adaptive way through integrating surrounding health service devices and according to dynamic changes of environment, thus offering users rich health service experience. To obtain more bandwidth and stability, the connection to different networks might be needed, but terminal devices are highly heterogeneous. To offer users richer health service experience, context information is to be utilized for decision making. Given the wide application of P2P technology in peer computing, collaboration work, search engine and file exchange, it can be introduced into virtual terminal system environment to solve the above issues, so as to realize more effective collaboration of devices.

Fig. 5 is the extensible virtual health terminal system framework adopted in this paper. Therein, capacity of devices is abstracted into Capability Server(CS) based on environment context information, and health service will reasonably call CS of each health device according to certain algorithm. Layered design is adopted, where several devices in virtual terminal system jointly provide control function and extract basic service from collaboration management function to make aggregation function module independent from collaboration management function. According to whether devices can provide collaboration management function or not, they are divided into main control device and member device. Several main control devices with collaboration management function collaboratively provide collaboration management function based on distributed mechanism. Meanwhile, applications running on distributed system can perceive service capacity information at terminal and interact with collaboration management to process service capacity information.

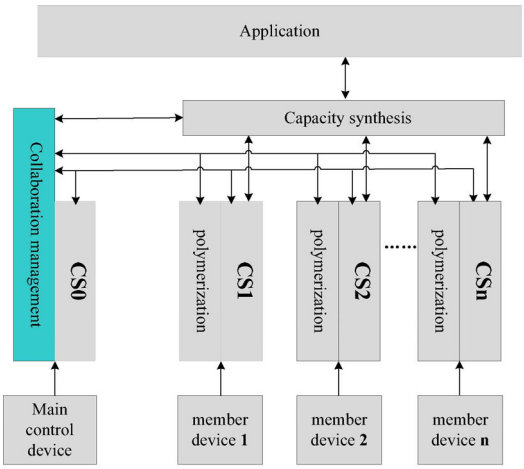

Fig. 5. Framework of virtual terminal system

In the distributed system of virtual terminal, these devices form one Ad hoc network, whose main control devices are interconnected forming a peer-to-peer network; and member device joins the network by attaching to one main control device as shown in Fig.6. Multi-terminal collaboration must be user-centered, and collaborative multiple terminals can aggregate into one virtual terminal with dynamic restructuring. Collaborative multiple terminals can distribute in Personal Area Network (PAN) or Wide Area Network (WAN).

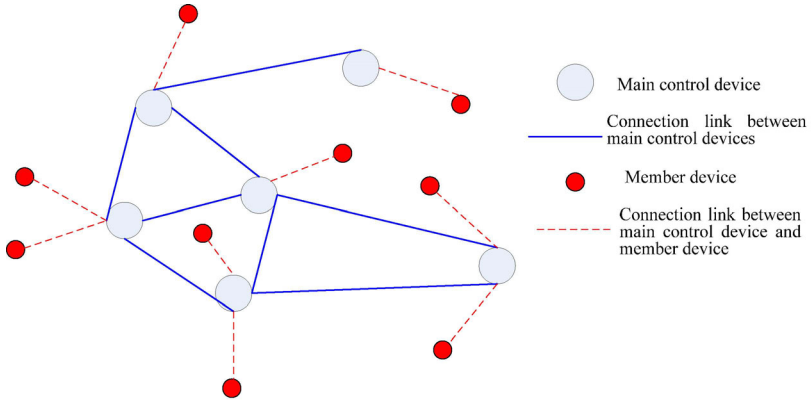

Fig. 6. Network topology of virtual terminal system

5.2 Ubiquitous Network Control System

Ubiquitous network includes various extensible heterogeneous networks, which can be extended to personal activities, family activities and special activities of some users and provide different access technologies [17-18]. Future health service oriented network has to realize communication between man and man, man and things, things and things, solve the problem of connection between different communication subjects in ubiquitous network, support the diversification of network and devices and the application of wireless communication means, hence boasting rich heterogeneity.

Ubiquitous network control system organizes the health information resources collected by heterogeneous terminals to provide comprehensive, virtual and well organized health information basic structure for upper structure. Its information basic structure includes network ability provided by network operators, and computation and storage ability provided by basic structure service providers as well as open terminal and sensing ability of open application agents.

Ubiquitous network control system needs to complete the connection to heterogeneous terminal, and protocol conversion and control, and realize the extension of traditional network from information transmit and exchange to information processing. And its final goal is that anyone can access the network to enjoy health service at any time and place.

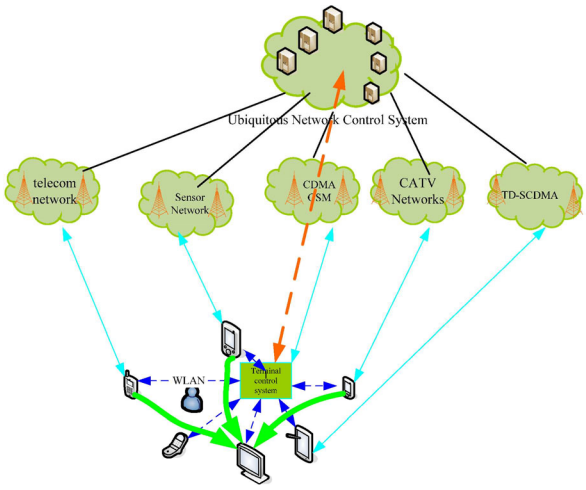

Fig. 7. Ubiquitous network control system

Heterogeneous convergence network includes not only the convergence of difference access networks (such as UMTS, WLAN, LTE) but also the convergence of communication network, computer network as well as radio and TV network, so as to enable heterogeneous network environment to provide connection channels with safety and QoS guarantee for multiple health terminal collaboration services effectively, and adjust in a self-adaptive manner according to the movement of users and terminals as well as the change of network resources.

The collection, processing/reasoning and provision of information with multi-dimensional features are treated as network control (such as access network selection, heterogeneous convergence network load balancing) input. Environment information includes user environment information, network (especially access network) environment information and business information. User environment information includes user preference and strategy, terminal type and capacity, terminal movement speed, terminal holder information, quality of wireless channel quality used by terminal, terminal status (such as remaining power of battery, access business and network), etc. Network environment information includes the type and name of network/access point, access point position and coverage, base station transmitting power and use frequency band, network capacity, and resources status, etc. Business environment includes business demand, business subscription and conversation status, etc. The environment information has different dimensional features and distributional features, so distributed multi-dimensional environment perception and decision-making model must be established. In this model, the dimensional features of environment information like precision/vagueness, fast variable/slow variable, time/space, reality/expectation, etc. are given special consideration.

According to multi-dimensional processing model of environment information, through drawing upon environment information representing and modeling technology and starting from the demand of environment information users, necessary environment information description must be extracted, storage and updating mechanism for these environment information descriptions must be determined, and the needed environment information and its pre-processing model must be deduced from them so as to ultimately nail down the collection means and frequency of environment information.

Load balancing refers to the matching between load type/load as well as network property/capacity, so as to uplift resources utilization rate and satisfy QoS requirement of users. It includes two aspects, namely load balance of wireless heterogeneous access network and business flow property based heterogeneous network flow engineering. For wireless heterogeneous access network, the goal of load balancing lies in automatically, timely and accurately detecting the unbalancing degree of access network load, and reaching load balance through load transfer. Environment information base provides access network environment information like uplink and downlink load, resources utilization rate and QoS to load balancing evaluation and triggering module, and load balancing optimization module can optimize access network load through handover, QoS adjustment, network selection incentive, and access network parameters optimization, etc.

5.3 Integrated Information Control System

Integrated information control system needs to aggregate, integrate, classify and exchange information and data collected by terminals to obtain and organize various open information, and adopt measures of classification, adaptation and intermediation to integrate information according to actual demand, thus providing information basis for various application services. The data and information in integrated information control system are based on shared and open data widely distributed in the open environment, and each service needs to quickly and conveniently obtain needed data information item to form a multi-source information sharing system.

Integrated information control system serves as the data basis for realizing smart health service, which can provide technical support for health monitoring, health management, health warning and decision making, hence offering comprehensive and convenient health services for users [19]. Various advanced data processing technologies, including data integration technology, data digging, artificial intelligence, expert system and decision-making support, are adopted. According to the internal relation between health service requirement and services, comprehensive health information from different monitoring terminals and with inconsistent format is extracted, integrated, analyzed and processed, to obtain decision-making model, mode and repository.

At the same time, centering on the core technological thought of "integrating sharing and smart service", the information and data from different health service departments, health service systems and health perception terminals are aggregated, integrated, classified and exchanged, so as to form a multi-source health information sharing system featured by trans-department, trans-service and trans-system, and enable each health service to obtain the needed data information item quickly and conveniently [20].

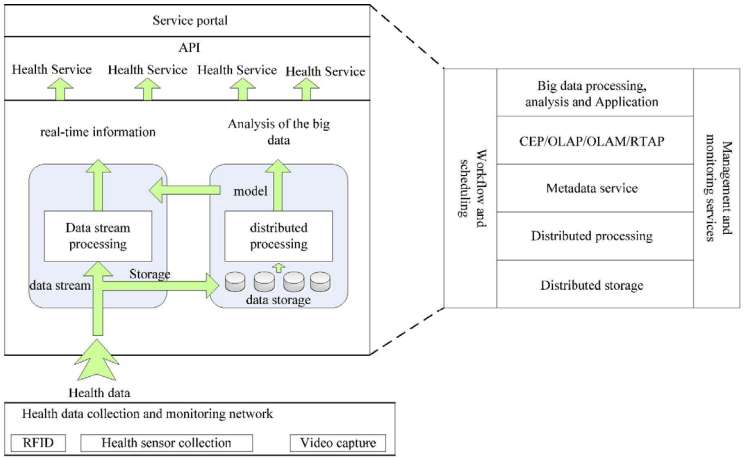

Fig. 8. Integrated information control system

5.4 Health Service Control System

Health service control system faces users directly, involving the adaptation of health service, the shunted transmission of service, mobility management, and the extension of terminal management. Health information integrated via integrated information control system is used to provide various health information and services for users. This system can construct health repository and health service decision making supporting system according to users' demand, so as to realize smart services like health monitoring, warning and decision making.

Health service control system provides health service information for the outside. Various health services are connected through one unified service interface, which can provide consistent calling interfaces for the upper-layer application and block lower-layer details. It is an interface specification, used for separating services to achieve independence. Smart health service system is featured by expansibility, real-time, support for heterogeneous environment, openness and usability.

How to provide smart health service and effectively search for and match health service serves is the key content for smart health service system. Considering the unicity of health service identifier, smart health service system needs to process a lot of health service identifier. To realize pervasive and smart health service, service identifier is adopted to conduct unified naming of services. The definition of health service identifier SID is as follows:

$$\mathrm{H}SID \triangleq \Phi(\mathrm{H}S_{type}, \mathrm{H}S_{data}). \tag{1}$$

Where, HS_{tpye} and HS_{data} refer to health service type and health service itself, $\Phi(\ )$ refers to service identifier generation function.

To represent health service behaviors, health service behavior is introduced to describe $HSBD$. Health service behavior description is to further describe health service on the basis of health service naming, including topological description, performance description and function description, etc. Network entity service behavior description $HSBD$ can be defined as below:

$$HSBD \triangleq \begin{bmatrix} \{b_L^{ST}, b_C^{ST}, \cdots\}_T \\ \{b_Q^{SP}, b_B^{SP}, b_D^{SP}, b_L^{SP}, b_M^{SP}, \cdots\}_P \\ \{b_T^{SF}, b_N^{SF}, b_S^{SF}, b_P^{SF}, \cdots\}_F \end{bmatrix}. \tag{2}$$

Where, T , P , F refer to topological behavior, performance behavior and function behavior, respectively. For $HSBD$, topological information includes service position b_L^{ST} and service cache position b_C^{ST} , etc. Performance information includes quality requirement b_Q^{SP} , bandwidth requirement b_B^{SP} , delay requirement b_D^{SP} , packet loss requirement b_L^{SP} and optimal communication means b_M^{SP} , etc. Function information includes health service type b_T^{SF} , version number b_N^{SF} , credit nature b_S^{SF} and provider signature b_P^{SF} , etc. Among them, service position and service cache position represent NID information of network modules where the health service takes place, used for identifying network position information where service is obtainable. Health service type refers to business types, including blood pressure, state, picture and movement, etc. Service credit nature includes user perceived evaluation of the service as well as other service feedback information. Version information is used for updating its version number without changing its service identifier when service provider is issuing new version. Provider signature is used for ensuring information authenticity and reliability for the sake of safety.

6 Protype Implementation

Household health service system is designed according to the design of smart health service system. In houses, various health terminals, including falling monitor, fat tester, electronic sphygmomanometer, can be deployed, and patients can carry terminals like pedometer and handsets on them. All these terminals can upload the collected data to network control platform through heterogeneous networks like 2G/3G network or WiFi. All these terminals and networks constitute a typical multi-terminal and multi-network health service environment. Smart health service system is consisted of network control platform, ubiquitous network environment (WLAN, WCDMA, CDMA 2000), camera, smart medical test terminals (sphygmomanometer, body composition tester, pedometer, life detector on cushion, carpet falling monitor) and testing handset, as shown below.

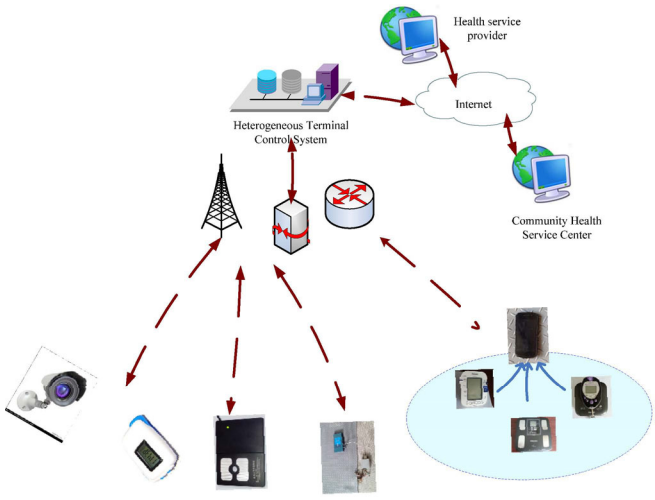

Fig. 9. Household health service system

Network control platform can analyze and process the data collected by these terminals, and provide corresponding health service to patients. Sphygmomanometer can be used to test blood pressure, body tester can be used to measure fat data, and meanwhile patients can carry pedometer to record the exercise state. The data can be uploaded to network control platform real time through network, while the platform will record and store them. When patient falls down, the network control platform will send a warning and message to doctors. In the meanwhile, network control platform will initiate camera close to the patient, which will transmit the video information to server through multi-flow concurrence transfer control system formed by multiple heterogeneous terminals. When doctors receive warning information, they can see real-time high-resolution video of the patient and various health data as well, so as to support following diagnosis.

Specific realization steps are as follows:

(1) Smart medical system connects the electronic sphygmomanometer, pedometer and falling monitor system through WiFi and bluetooth, and accesses network control platform through Internet. Network control platform supports 3G network and WiFi network access, data processing, analysis and decision-making. Real-time collected data at multiple terminals can be watched through the platform. Sphygmomanometer tests and gets blood pressure data, and uploads them through bluetooth.

(2) Body measurement tester tests fat data and uploads them through bluetooth.

(3) Pedometer tests movement and uploads relevant data through bluetooth.

(4) Cushion-style life detector monitors the heart rate on bed and uploads relevant data through WiFi.

(5) Network control platform conducts statistical analysis and processing of original data and stores the processed results in server.

(6) Users can observe real-time data collection and analytic results through Web with terminal.

(7) When abnormality arises, short-message warning will be sent.

(8) When warning information is received and after system detects abnormal information, the camera will be opened to transfer video information to other terminals to obtain site information.

(9) Network control platform conducts statistical analysis and processing of received original data and stores processing results in server. When abnormality arises, network control platform will send warning through message.

Real-time collected data at multiple terminals can be checked through network control platform. When abnormality arises, network control platform will send warning through GSM network in the form of message, and meanwhile open site camera to upload site video to multi-flow concurrence transmission control system formed through several heterogeneous terminals like CDMA2000 and WCDMA, etc.

7 Conclusion

This paper establishes a user-centered, health service-driven and software defined multi-terminal and multi-network smart health service system, which aims to provide solutions for smart health service. In fact, smart health service platform needs to be established urgently, so as to improve big data's intelligent processing, data integration and overall information resources utilization. Besides, it also expands regional information platform coverage and networking level to realize system interconnection, information sharing and business collaboration, so as to increase the service ability and level in terms of health care and family planning. In the future, the wireless virtualization will be integrated into the wireless access part and the corresponding mapping algorithm will be studied, so as to improve the utility of the wireless network resources.

Acknowledgements

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