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A Design Characteristics of Smart Healthcare System as the IoT Application

Joon-Soo Jeong[1], Oakyoung Han[2] and Yen -You You[1*]

[1]Department of Knowledge Service and Consulting, Hansung University, Seoul, 02876, Korea; heinem@naver.com, threey0818@hansung.ac.kr
[2]Department of Computer Education, Sungkyunkwan University, Seoul, 03063, Korea; oakyoung@skku.edu

Abstract

Objectives: The big-data analysis with IoT is decisively helpful to provide diagnosis and treatment for patients and it becomes useful in healthcare industry. **Methods/Statistical Analysis:** Implementation of IoT healthcare is divided into five key characteristics: Stability, continuity, confidentiality, reliability and efficiency must be applied to the smart healthcare system to reliable the features of the IoT. **Findings:** Within this concept, we introduce iotHEALTHCARE to provide improved patients monitoring and diagnosis for shifting toward prevention and early detection of disease and those who want intensive monitoring for health conditions. **Improvements/Applications:** In this paper, we present the design features of iotHEALTHCARE and its logical architecture along with methodology of implementation.

Keywords: Big-Data, Cloud Computing, Healthcare, IoT, Sensor Technology

1. Introduction

The Internet of Things (IoT) is a system of inter-operating computing devices, mechanical and digital machines, livestock or people that are classified with unique identifiers, connects any object with the Internet, performs on the exchange of information and the correspondence, realizes the object intellectualized recognition, the localization, the tracking, the monitoring and the management[1]. It offers solutions based on the integration of Information Technology (IT), which is the application of computers to store, retrieve, transmit and manipulate data without requiring human-to-human or human-to-computer interoperation. In this respect, IoT can be defined as "a dynamic global network infrastructure with self-configuring capabilities based on standard and interoperable communication protocols where physical and virtual things have identities, physical attributes and virtual personalities"[2]. Realization of the IoT concept into the real world is possible through the integration of several promising technologies [3]. Identification, sensing and communication technologies can be integrated with IoT. For identification technology, RFID tags that interact with IoT can be characterized by a unique identifier and be applied to objects. RFID systems can be used to monitor objects in real-time, hence, RFID can be used in an advanced healthcare system. For sensing and communication technologies, wireless sensor networks that integrated with IoT can make communication be peer-to-peer whereas, it is asymmetric for the other computing and communication possibilities in a passive system. It is clear that IoT can be applied to identify sense and communicate for a better healthcare system. Therefore, our research adopts IoT to collect data with sensing technology and to communicate for a smart healthcare system. Instead of applying IoT to a certain task as a narrow scope, IoT can be dealt as a wide scope. The Service Oriented Architecture (SOA) often requires the middleware which interposed between the technological and the application levels. In middleware architecture, IoT can be associated to develop a specific application. Even though many researchers develop a middleware in the domain of IoT, there exists no generic middleware which can be applicable across all possible smart devices -

** Author for correspondence*

like smart home, smart vehicle, smart hospital, smart city and so on[4]. Nonetheless, in this study, we try to provide a concept of a smart hospital by extending the scope of IoT. The strength of types of systems. Consequently, RFID sensor network are the capability of supporting sensing, this research is appearance of machine learning to analyze big-data stored in cloud computing which is a model for allowing convenient, ubiquitous, on-demand network approach to a shared pool of configurable computing environments with minimal management effort. To service a true smart healthcare system, ubiquitous sensing devices of IoT must collect data, join networks to save data and analyze data as experts[5]. Machine learning is essential to convert information to knowledge. The application of machine learning models in the field of healthcare for human disease diagnosis helps medical staffs in the identification of diseases based on the feature that is apparent to the patient[6]. Machine learning in medical field can process to transform human expertise knowledge and skills gathered through clinical practice to application software. By engaging machine learning, software can make accurate decisions for diagnosis and treatment, so unnecessary jobs can be reduced for medical staffs. In Section 2, we review our previous research in healthcare systems as a background. Section 3 addresses the current technologies those can be applied for a better healthcare system in two different approaches: Research and industry. In Section 4, we present blueprints of our proposal to a smart healthcare system IoT healthcare and its logical architecture. Section 5 explains the methodology for implementation of IoT healthcare. Conclusion and future study are discussed in Section 6.

2. Background

2.1 Expansion of the Healthcare System

The preliminary study was focused on proposing an ideal healthcare system by converging technologies. Figure 1 shows the expansions of time, space, beneficiaries and services for the ideal healthcare system in the preliminary study[7]. The study suggested that a health management organization should provide a healthcare system to serve anybody at anytime and anywhere using personalized health management system to create an ideal healthcare system. To accomplish this service, it is necessary to figure out which high technologies have been developed for healthcare systems. Sensor technology, network technology and data processing technology can be primary high technologies for better healthcare systems[8]. The purpose of the IoT is to perform a variety of functions and objects present in the environment to be linked to interact and conduct "anytime, anyplace, with anything and anyone, ideally using any path or network and any service"[9]. The expansion of healthcare systems can be achieved by applying IoT into a healthcare system.

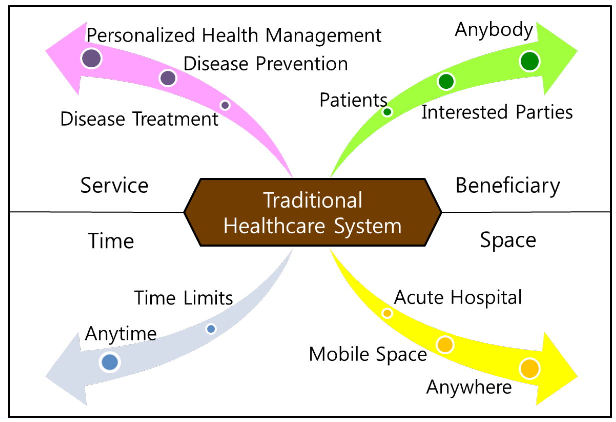

Figure 1. The expansion of healthcare systems.

2.2 IT Convergence on the Healthcare System

Figure 2 shows a paradigm of an ideal healthcare system. The major high technologies for the ideal healthcare system are sensor technology, network technology and data processing technology. Data processing includes digital imaging processing, diagnostic software and electronic health record systems. Recent researches in the IoT have offered more possibilities than in the field of medicine, where its principles are already being applied to improve the quality of care, the accessibility of care and most importantly save the cost of care. A few recent researches are concentrated on IoT sensor devices to propose a healthcare system[10–12] while some researchers try to expand the concept of IoT to several possible components in a healthcare system[13–15]. The IoT provides care to patients in remote locations and monitoring systems that deliver a continuous meaningful data stream for better decisions in accepted micro wireless physiological sensors to establish mobile healthcare system in their research. In their research, using micro wireless physiological sensors combined with smart mobile devices, that is able to implement patients intensive monitoring, emergency care, tracking, analysis, diagnosis, alarm-triggering, locating and collaboration with medical staffs[16]. This is the case that IoT sensor technique is applied to gather patient's data to establish a mobile healthcare system. In expanded the concept of IoT to several components in a healthcare system, he proposed the IoT platform for healthcare as an appropriate self-management model for chronic disease such as obesity, hypertension and diabetes. The proposed platform includes 4 elements. The first element is a medical sensor device to acquire and transfer the medical data. The second element is a virtual medical sensor which is a software sensor having an intelligent diagnosis algorithm and big-data analysis from various physical medical sensor networks. The third element is a mobile application that is browsing medical data about patient or user from medical IoT device as well as using for self-operation. The fourth element is a platform and its manager that enables all components to communicate with each other by using interoperable software. This research showed that user can manage their own disease by oneself as access to healthcare services in the platform for healthcare by using medical IoT devices. Even though this research requires further study on providing a method to develop an extension of the platform to access to other platform for interoperability, this research proved that adopting IoT concepts into an overall healthcare system can improve a medical system.

An integration of devices has been developed to improve healthcare system and a number of agencies are working on developing further interoperability to improve not only communications between healthcare providers and patients, but Point-of-Care diagnostics as well[17]. The healthcare industry is actively improving IoT initiatives to help evolve stand alone systems to distributed systems, connect devices to pursue patient cares and replace dedicated wiring with networks. Healthcare systems in IoT can be categorized into three groups: Devices for medical and health services, hospital systems and open healthcare platform for consumers.

Some products of devices for medical and health services are as seen in Table 1. Scope of medical and health services are defined in five subjects: Treatment, prevention, management, safety and welfare. Several IoT-based hospital systems are as seen in Table 2. The IoT-based hospital systems provide not only RFID technologies, but also information management systems. The listed hospitals include solutions such as convergent network, cloud-based hospital data center, telemedicine, wireless hospital and so on; these solutions cover hospital management, ICT-based clinical services and ICT infrastructure[18]. Open healthcare platform for consumers challenges to collect the prime challenges for personal health informatics to find and present health data to

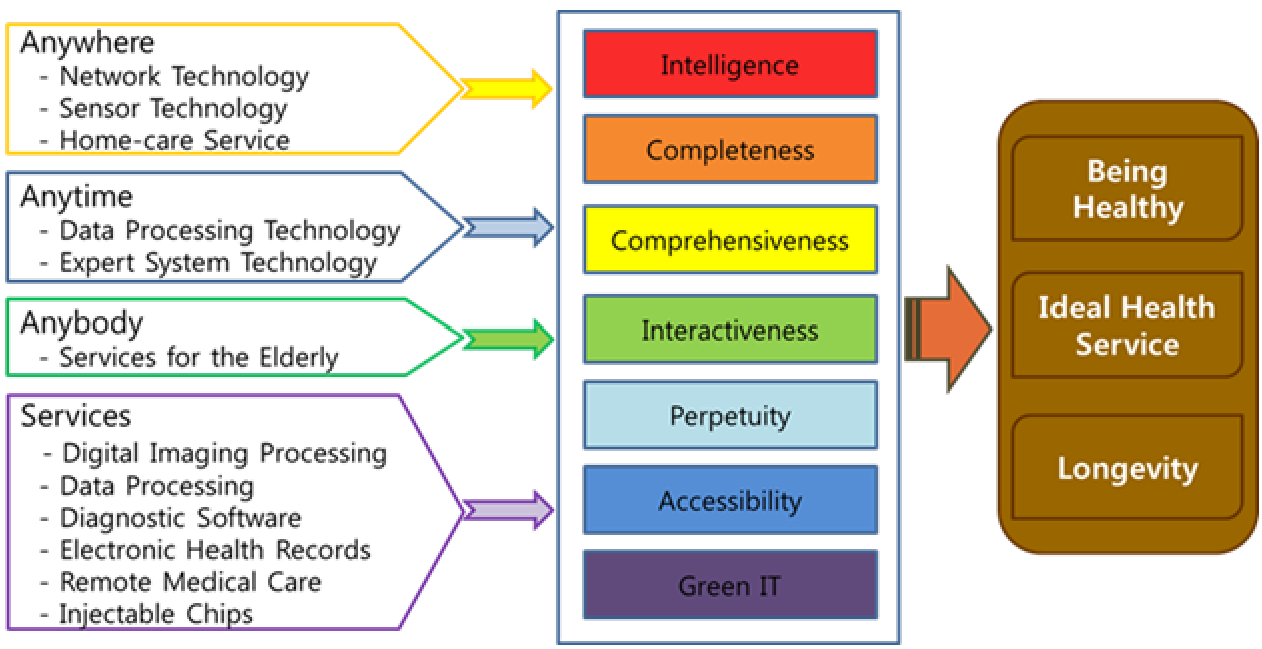

Figure 2. Paradigm of an ideal healthcare system.

Table 1. Devices for medical and health services

Product Name	Manufacturer	Objective	Services				
			Treatment	Prevention	Management	Safety	Welfare
Helius	Proteus	Ingestible Pill Sensor	√	√	√	√	√
Bee+	VIGILANT	Insulin Injection	√	√	√	√	
iBGStar	Sanofi Diabetes	Blood Glucose Meter		√	√	√	
CGM	Dexcom	Continuous Glucose Monitoring		√	√	√	
NUVANT	Corventis	Cardiac Monitoring		√	√	√	
Smart Watch	Apple	Health and Fitness Tracker		√	√	√	
FRAM RFID	Fujitsu	Tracking Vital Products		√	√	√	
PA700MCA	Unitech	RFID Reader		√	√	√	
Remote-i	CSIRO	Remote Eye Screening		√	√	√	
BodyGuardian	Preventice	Wearable Sensor System		√	√	√	
Mimo Kimono	Mimo	Smart Nursery		√		√	
Lullaby	Philip AVENT	Sensor for Sleep Environment		√		√	
Glow Caps	Vitality	Medication Taking			√	√	√
BP7	iHealth	Blood Pressure Monitor		√	√	√	√
Be Close System	Be Close	Monitor an Elderly People		√	√	√	√

people in meaningful and significant ways[24]. Google Fit, Apple Healthkit and Samsung SAMI are healthcare systems that developed IoT platforms for healthcare as a appropriate self-management model for chronic diseases. Google Fit is a health-monitoring system implemented by Google for the Android platform. It is a single set of APIs that combines data from multiple applications and devices. Google Fit uses sensors in a user's smart device or activity tracer to monitor physical fitness activities, which are measured against the user's fitness goals to perform a comprehensive view of their activities[25]. Apple Health Kit performs applications that provide health and fitness services to share their data with the new Health application software and with each other. A user's vital signs are stored in a cloud computing storage and safe location and the user decides which data should be shared with the user's application software[26]. Samsung SAMI stands for Samsung Architecture for Multimodal Interactions. It allows devices and sensors to bring data to the cloud regardless of the source. The open nature of SAMI and its APIs allow for easy aggregation of the data from a variety of devices. SAMI is a platform designed to analysis between devices that collect data and algorithms in the cloud computing storage that analyze that data; hence, SAMI can make more information available, break open information silos and give algorithms access to data. SAMI is a multimodal platform that will integrate an infinite number of data streams and devices to deliver breakthrough intelligence[27].

Table 2. IoT-based hospital systems

Medical Institution	Country	Major Function
Colchester General Hospital[19]	The United Kingdom	Real-time Patient Tracking
Aventura Hospital[20]	The USA	Medication Administration Record
North Shore University Hospital[21]	The USA	Remote Video Auditing
Chennai-based Apollo Hospitals[22]	India	Robotics Surgery
First Affiliated Hospital of AHMU[23]	China	Smart Hospital Clinic

2.3 A Smart Healthcare System

A smart healthcare system must provide a care to people in remote locations and monitoring systems that deliver a continuous data stream for better decisions. IoT revolutionizes a healthcare system by dramatically improving quality and IoT will accomplish a smart healthcare system to people. In this section, we describe blueprints of our proposal to a smart healthcare system iotHEALTHCARE and the logical architecture of IoT healthcare.

3. Components of a Smart Healthcare System

Five components compose iotHEALTHCARE to serve a smart healthcare system. Figure 3 shows the components of a smart healthcare system iotHEALTHCARE. Five components of iotHEALTHCARE form a circular system. The system starts with the sensor technology to collect data. The collected data goes to the next step which is an intelligent network to communicate with the system. Sending data through the intelligent network is stored at cloud computing which is the third component of the system. Once the data is stored in the cloud computing, the data has to be analyzed for proper decision in the fourth component big-data analysis. After deciding proper result of data, refined data are sent to a smart hospital to inform the result to healthcare professionals. The smart hospital takes actions for appropriate diagnosis and treatment. Even though the smart hospital is the last component of iotHEALTHCARE the system keeps continuing to collect data to confirm that the system has set right diagnosis and treatment. Hence, the system goes to the first component again to hold the circular system.

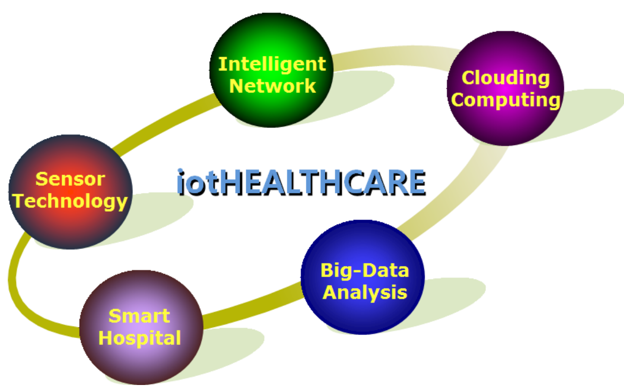

Figure 3. Components of iotHEALTHCARE.

3.1 Logical Architecture of iotHEALTHCARE

In order to achieve the smart healthcare system with the previously mentioned five components, iotHEALTHCARE is suggested to compose its logical architecture as illustrated in Figure 4. In this section, each component of iotHEALTHCARE is discussed as a feature. Key characteristics of each feature must be retained to perform its task. These are the characteristics of five features:

- Stability: Continuous real-time monitoring of sensor technology requests stability for trustworthy data collection.
- Continuity: Interoperability support for intelligent network requests continuity to communicate with users, internet, and among each other.
- Confidentiality: A powerful storage for computing resource in cloud computing requests confidentiality to save dynamic data.
- Reliability: Big-data analysis requests reliability to transform dynamic data into valuable information.
- Efficiency: Smart hospital requests efficiency for proper diagnosis and treatment.

Building IoT applications for iotHEALTHCARE requires integration of five different features. If one of the mentioned characteristics is missing, it breaks perfection of features and it turns into a valueless system.

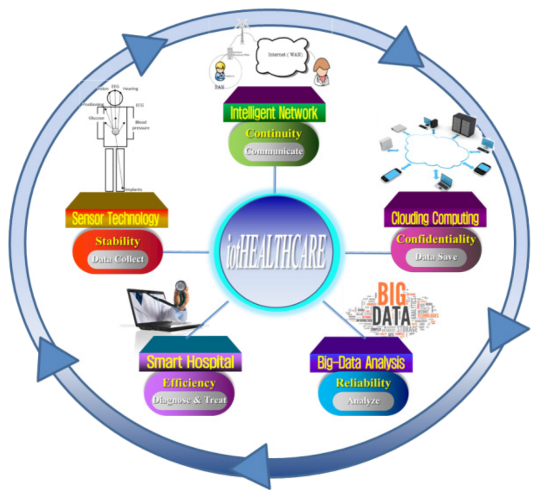

Figure 4. Logical architecture of iotHEALTHCARE.

3.2 Implementation

iotHEALTHCARE is implemented into the five main features as discussed in the previous section. The methodology of implementation is described as the following sections.

4. Data Collection

The data collection feature consists of IoT-driven sensors to collect real-time monitoring data from smart sensors. Sensor technology achieves progress to handle data in bio optic sensor. EEG biotelemetry, ECG sensor, heart bit rate sensor, blood pressure monitoring, glucose monitoring, virus monitoring and healthcare watch. It is an example for implementing ubiquitous, on-demand access to a shared pool of configurable computing environments. Fundamental functions to collect data from smart sensors are listed in Table 3.

Table 3. Fundamental functions of data collection

Function	Description
Accept Sensor Device (device)	Accept a new sensor device into iotHEALTHCARE
Drop Sensor Device (device)	Cancel the usage of the device from iotHEALTHCARE
Reset Device (device)	Reset the device to erase buffered data
Enable Device (device)	Enable a device after accepting the device
Disable Device (device)	Disable the device to quit a usage
Get Data (device)	Get signals from the device
Put Data (device, NetID)	Send signal data from the device for network ID
Check Signal (device, NetID)	Check the signal from the device going on network ID
Skip Signal (device, NetID)	Skip/Ignore the signal from the device going on network ID

4.1 Intelligent Network

The data collection feature consists of IoT-driven sensors to collect real-time monitoring data from smart sensors. Sensor technology achieves progress to handle data in bio optic sensor. EEG biotelemetry, ECG sensor, heart bit rate sensor, blood pressure monitoring, glucose monitoring, virus monitoring and healthcare watch. Wireless Sensor Network (WSN) is an essential integral part for the intelligent network for iotHEALTHCARE. IP-based WSN technologies can be a promising solution for the everyday objects. Identified by a unique address, any object including sensors, computers, RFID tags or smart phones will be able to dynamically connect the network, collaborate and cooperate efficiently to achieve different tasks. The information collected from the sensors should be available in the cloud computing environments to be managed and operated properly. Therefore, a central point of software manipulates the information from the sensors remotely distributed data. Furthermore, the industrial processes make necessary to implement wireless communication systems (due to the hostile environment and the difficult access to the places) to transmit the signals received by the remote sensors tracking the control loop. This is the reason why the requirement analysis, design and development of a remote wireless system applied to an industrial process are already done[28]. Personal Area Network (PAN) is the communication of information technology devices within the range of a personal space, typically within a range of around 10 meters. PAN is useful for an application to monitoring movement of elderly people. WSN, PAN and general network are enough to establish an intelligent network for iotHEALTHCARE.

4.2 Cloud Computing

Cloud computing, also on-demand computing is a kind of Internet-based computing environments that provides shared processing devices and data to computers and other computing resources on-demand remotely. The cloud computing paradigm provides flexible, reliable and powerful storage and computing resources, which supports extreme scale computation through virtualization, dynamic data integration and combining from multiple data sources[29]. The major goal of cloud computing is to implement scalable and easy-to-access computing resources and IT services. In a particular hospital, it is difficult to share patient's data since the data format is not compatible to others. If a patient needs to transfer to another hospital, examinations have to be done again. It is waste of time and resource. Therefore, it is necessary that hospitals share patient's data confidentially. Furthermore, each hospital doesn't need to keep every raw data that is collected to analyze patient's symptom. That is why the cloud computing is the answer for a storage system in iotHEALTHCARE.

4.3 Data Analysis

The data analysis module performs by machine learning. Machine learning is the science of developing computers to act without being explicitly programmed. Machine learning has given us intelligent car, practical voice recognition, effective web search and a vastly improved understanding to optimize a performance criterion using example data or past experience[30]. To summarize meaningful result from stored data machine learning needs to be adopted; otherwise, computers waste processing effort to handle meaningless data. Improved data collection, networking and faster processors accelerate machine learning while human experts are having difficulties to extract knowledge from overflowing data. Algorithm strategy improves the level of reliability in the result of the analysis. The algorithm strategy is as seen in Figure 5. Define the meaning of 'enough data' is ambiguous, so it is regarded as a condition of enough data if it is marked as a successful practice for more than three times. The result of analysis assists the system advices and warnings in real time the medical staffs and assistants about the changing of vital signs or the transition of the patients and also about major variations in environmental parameters, in order to provide the precautionary cares.

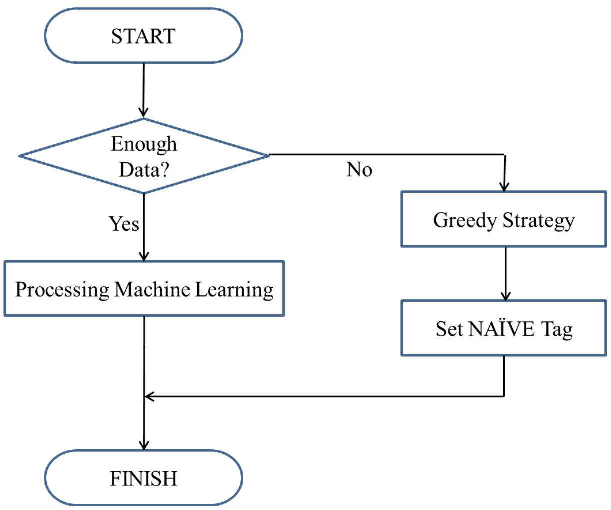

Figure 5. Flowchart of algorithm strategy for data analysis in iotHEALTHCARE.

4.4 Data Practice as Diagnosis and Treatment

The interface and management module provides an interface for the authorized personnel including doctors, insurance companies and manages medical records such as the every analyzed data of patients and the previous medical history. Visualization of data for patient's information is an important concept of data practice to diagnose and treat. No matter how accurate the analysis, data practice perform poorly if the visualization is not fulfilled certain standard. The data practice module for diagnosis and treatment is a core result of iotHEALTHCARE while other modules are embedded process.

5. Conclusions

This paper proposed blueprints of a smart healthcare system iotHEALTHCARE and its logical architecture. Medical data is collected by sensors, the gathered data processes via mobile and intelligent network, the data goes to cloud computing for analyze the data with complex algorithms and medical professionals can make diagnoses and treatment recommendations in a smart healthcare system such as iotHEALTHCARE. Implementation of iotHEALTHCARE is divided into five features and the details of the implementation are presented in Section 5. This study needs to integrate the five components to build an IoT-based smart hospital. It can improve a healthcare service if the final product of iotHEALTHCARE is in hand. As the technology for analyzing, collecting and exchanging data in IoT continues to smart, the systems will change more and more exciting new IoT-driven healthcare applications.

6. Acknowledgement

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