Fog Computing for Personal Health Principles

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Fog Computing for Personal Health Principles

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Abstract: Ambient Assisted Living (AAL) environments rely on ambient sensing and environment control to enable elderly people to continue to live in their preferred environments. Unlike smart homes where the target audience is usually a family unit, AAL goal is to be able to interact with care receivers and care providers. This provides possibility in case of home based AAL, the care recipient not to be under constant monitoring by the care providers which reduces care costs and increases care efficiency. Cloud paradigm and fog computing fits well for this scenario as data from homes can be aggregated and analyzed in a centralized location. An interface for the care providers can be provided from the cloud using web and mobile devices.

In this article, we describe principles for AAL based on fog computing. The edge nodes process and detect local activities of daily living (ADL) events, and have direct control of the local environment. The fog nodes further process and transmit data. The cloud is used for data computation that requires greater resources.

1. Introduction

Technology for monitoring, assisting and improving personal health has improved considerably with the advancements in affordable wearable and environmental sensors, improved Internet connectivity and the advances in the field of cloud computing. The presence and rapid growth of Internet of Things (IoT) has also impacted how people monitor their health [1]. Wearable devices monitor heart rate and physical activity [2]. More appliances come with internet connection capability and smart sensors are becoming common. The sensor and usage data can paint a more detailed picture about health and personal habits [3].

For elderly and disabled people technology has direct impact on their ability to remain at home and live more independent lives [4]. A rich research filed of Ambient Assisted Living (AAL) is improving the means and methods for improving the health of the elderly and disabled. AAL is also facing different challenges [5]. Enhanced Living Environment (ELE) is field that provides resources for personal health for the general population [6]. AAL and ELE address different target audience but both fields benefit from similar technology [7].

A single device, individual or group of sensors, both wearable or environmental, present in the ELE can provide input on limited set of health aspects. Smart watches and health trackers can track body temperature, hearth rate, walking, or running, environmental sensors can detect temperature, humidity, can perform fall detection and movement within the home. To get even more out of these devices and sensors we connect them to the cloud where all the data is analyzed for a more holistic picture. Having data from many users, machine learning (ML) algorithms can learn and predict health hazards and find correlations between the environment and human health [8].

While the benefits of IoT cloud computing are visible both in research and daily use, when it comes to personal health there are many drawbacks. News about lack of security of IoT devices and bad practices of certain corporations that gather and abuse personal data from owners of connected devices have made consumers wary of the technology and more proactive in protecting their personal data [9,10]. There is a potential of targeted advertisement to identify personal health details, future employers might refuse potential employees because of their health risks or personal habits, and insurance companies can purchase personal data and use it to deny coverage or increase premiums. Protections against these practices vary and can be loose in some jurisdictions. Even when such protections exist the legal expenses can be high and the case can be difficult to prove. Fog computing can have a role in data protection by moving some data analysis to the edge nodes and anonymizing the data that is sent to the cloud [11].

Personal healthcare and AAL can generate a significant quantity of data and for some scenarios, such as fall detection, the requirement is to have immediate reaction of the system by triggering alarm to the care provider. Data pre-processing on edge nodes can significantly reduce the bandwidth requirement and the need for real time cloud communication [12].

Cloud downtime or connectivity issues can be a problem in the case of AAL. While many of the large cloud providers have multiple availability zones, the cost of having high availability of the cloud is higher. Edge nodes can more easily be clustered allowing for high availability of the fog computing.

2. FOG BASED ARCHITECTURE

Fog computing adds an extra layer to the cloud computing architecture but it is not merely an extension of the cloud. Fog computing has the following characteristics: it spans to adjacent physical locations; has support of on-line analytics; the service is provided by smart but not powerful devices; supports various communications networks; and is distribute computing [13]. There are four logical layers as shown in figure 1.

On the first layer the data is generated by sensors that can be wearable or body sensors, and peripheral or environmental sensors. Data can also be generated from external sources such are: social networks, clinical center information systems or medical databases. Data collected by the sensors can include: vital signs, personal habits, or environmental factors. External data sources can provide different information including: medical check results, medical databases for diagnostics.

The fog layer gathers the sensor data and process them and passes either processed or some raw data to the cloud. The devices directly connected to the sensors are called edge nodes and aside from collecting data they can take actions with the user. Each LAN environment can have one or more edge nodes, depending on the application requirements and scale. In cases of elderly care facilities data for multiple tenants could be processes on the same edge nodes. These actions can include providing feedback to the person to take their medicine or to start exercise, and can provide direct interaction with the environment such as activating the humidifier or

regulating the room temperature, control electrical appliances and emergency cut-off for water, gas and electricity. The fog network usually has more limited capacity than the cloud for data computation and is not able to do complex machine learning and feature extraction. However, for nodes could be able to run algorithms developed by machine learning. As the machine learning system improved and evolves regular updated could be pushed down to the fog network to improve detecting patterns in the sensor data. Using this methodology ADL detecting ML could receive continuous data and improve the detection rate. Events that take brief time, such as when person falls, can be detected by the nodes in the fog using the latest ML model improved in the cloud.

The cloud layer collects data from multiple sources and process the data. Machine learning and feature extraction is done at this layer. Data from the fog and from external sources is collected by the global data fusion component, this data is processed. The could can process data from multiple locations and create a machine learning models. The output is continuously improved knowledge base. This knowledge base in turn is used by the service layer.

The service layer is the product of the system. Knowledge obtained by analyzing the data is used for services including creating customized recommendations for diet and exercise, improve diagnostics systems, provide updates to the health providers, and add additional information in medical databases.

A. Smart e-health gateway

In fog computing the nodes closest to the devices or things are called edge nodes. In healthcare systems, these nodes can be smart e-health gateways. The gateway serves as a bridge for medical sensors and home/hospital building automation appliances to IP based networks and cloud computing platforms. The main requirement of a gateway is to support various wireless protocols and inter-device communication. Its role can be extended to support several features such as acting as repository to temporarily store sensors' and users' information, and bringing intelligence by enhancing with data fusion, aggregation, and interpretation techniques, essential to provide preliminary local processing of sensors' data, becoming thus a Smart e-health gateway. Smart e-health gateway can tackle many challenges in ubiquitous healthcare systems such as energy efficiency, scalability, interoperability, and reliability issues [14].

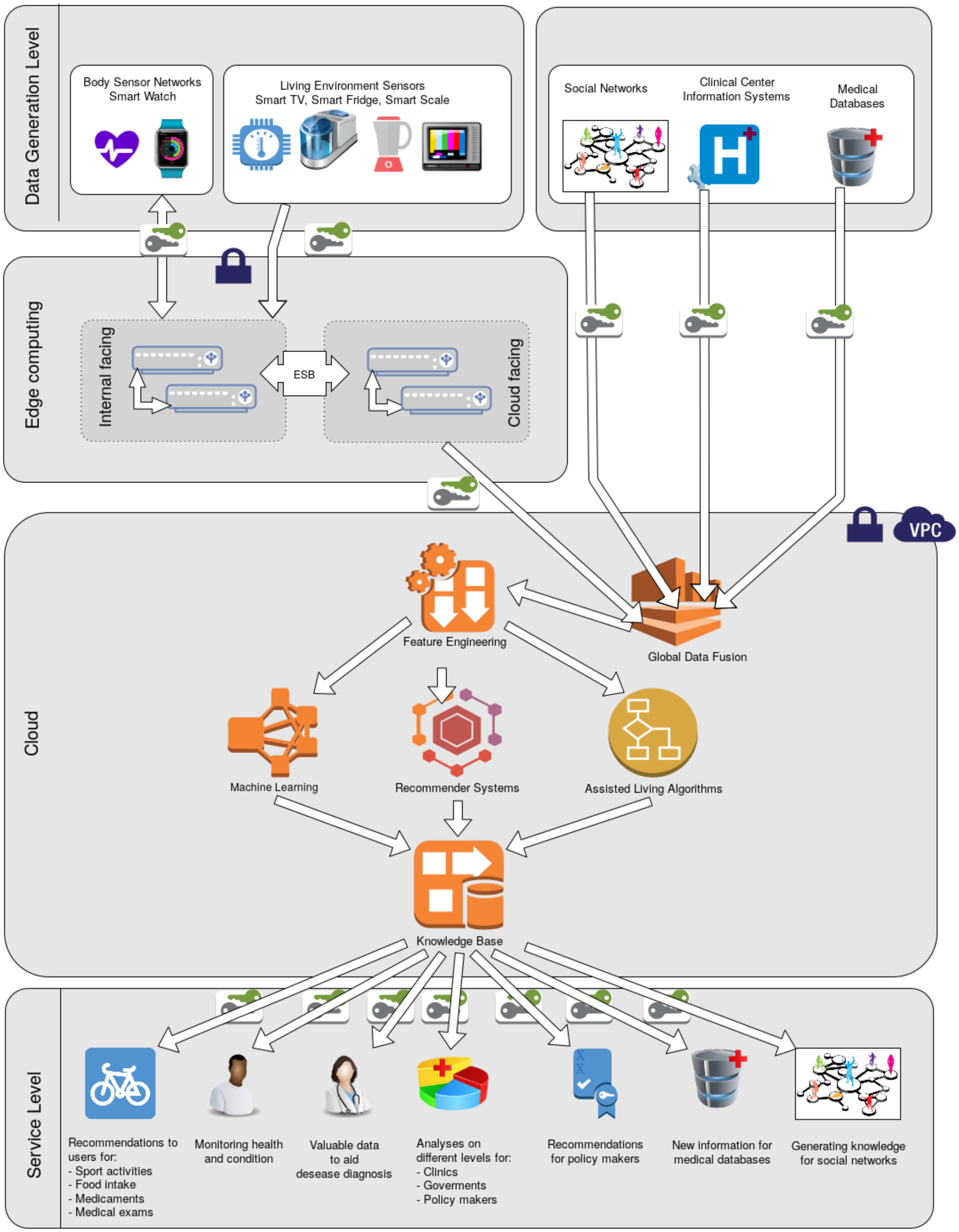

Figure 1: Architecture for fog computing for personal health

3. INTEROPERABILITY

There are many frameworks proposed in the literature and numerous studies have explained the importance and proposed solutions to achieve connected interoperable systems [15]. However, interoperability is only accomplished within individual frameworks and only for subset of considered devices, sensors or modules. A major obstacle of system integration with the cloud is to make all things connected and operating in a way that data can be collected and used in consistent manner across all devices. For example, a kitchen appliance may send its usage data to the cloud on events it is being used, body sensor might be sampled at high rate while environmental sensor at a much slower rate, and yet another device might have an API but would require external script to pull the data. Collecting metrics in a flexible way that would allow even more devices with different properties to be added at any point in the system can become hard to implement in a typical cloud scenario.

An AAL solution is an integrated system-of-systems composed of systems, subsystems and components, providing a part of the overall AAL system and its services [7]. In a fog computing scenario integration can be cascade in nature, some processing nodes will deal with components based on one framework while other nodes will provide multi-framework integration. The fog nodes interfacing with the cloud would have unified presentation for the data they transport. Application-level interoperability benefits from Web technologies, such as the RESTful architecture, that provide an elevated level of interoperability. Using these technologies, an abundance of programming APIs can be distributed across entire fog domains and utilized to increase the flexibility of loosely coupled management. [16]

Interoperability for personal health devices has many aspects. One aspect is the physical layer. Various sensors can generate different signal. In the case of video or Laser Radar (LADAR) or other sensors that generate massive data sets they might be above the bandwidth limits to be uploaded to the cloud. Other devices such as temperature sensors are periodically sampled and generate only few bytes. Sensors can also generate analog and digital signals. Analog signals must be converted to digital to be processed. Some analog devices might have different working voltage and the readings would have to be scaled properly. In the proposed fog computing AAL architecture this will be handled transiently so all data is preprocessed by the time it reaches the cloud.

At the edge node or the smart gateway node interoperability requires that the gateway supports most of the common communication standards, both wired and wireless. A gateway with good connectivity allows the sensor network to be easily expanded and upgraded.

4. DATA FLOW

Having in mind the privacy concerns as well as the technical aspects for scalability and interoperability, it is important to identify and trace the data flow in the system. Sensor data originates when sensors acquire measurement from the physical world. This measurement is represented by electrical signal that is transferred to a controller that would interpret the signal. Some sensors are manufactured to include the electronic circuits to digitalize the reading and some are even Internet connected enabling them to directly upload the data to a remote system. The sensor data is then passed to the local processing nodes. These nodes are part of the fog and can communicate to other layers of the fog. The data on these edge nodes is processed for local events detection.

Only the edge nodes or smart e-health gateways should be able to get unfiltered raw sensor data. The data that is passed on to other layers of the fog is pre-processed. From this point, the data can be split to multiple paths depending on the desired function as shown on figure 2. Data that has personal identifiable data can only be passed to the areas of the fog used for healthcare provider retrieval that is certified to be compliant with local regulations for handling medical data. Data used for science research can also contain medical data but personal identifiers should be stripped or hashed. Other service types might require aggregated data that doesn't expose user medical conditions. This, for example, can include the average time spent outdoor. Such data can be correlated with local weather to determine the best time to organize group activities for the senior members of the community. Some data might be of the type that the person would like to share on social media or other platforms. This might include exercise data such as walking, hiking or riding a bike.

Each of the services dealing with user data are logically independent and can be hosted on separate cloud platforms. The health provider service is independent from the social media or from research medical databases. The separation of the cloud can be implemented by separation on any level in the fog network.

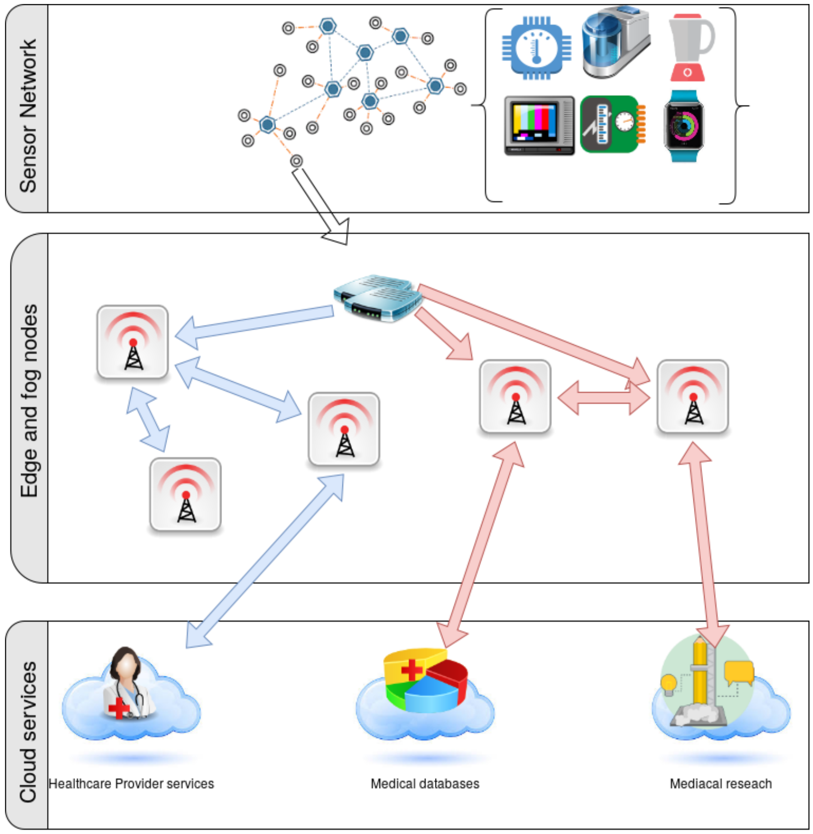

Figure 2. Data flow in Fog architecture for personal health

5. Conclusion

As personal health become more pervasive and part of daily live, and as the data generated by it increases in volume, a fog computing offers solution for many issues that would arise. The added flexibility of the fog architecture enables better placement of computing and network resources. Smarter data flow could protect personal data, bandwidth cost could be reduced and more scalable, secure and interoperable systems can be designed.

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