Modularized Service Provisioning at Fog Networks

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***Abstract*—Wearable devices have become ubiquitous and can provide various convenient features to users. By default, the wearable devices will always send service requests to the local-hub and wait for the results. Communication via Bluetooth, however, is only functional within a narrow connection range, whereas communication via Wi-Fi interface suffers from the long response time since existing solutions require data traveling via the Internet to the remote cloud server before reaching the local-hub. Thus, motivated by fog computing, we propose a system design of Virtual Local-Hub (VLH) to address these shortcomings. The proposed system deploys wearable services at edge devices and modifies the system behavior of wearable devices. Consequently, wearable devices can be served at the edge of the network to significantly reduce the service response time. We build a testbed using off-shelf hardware and conduct a practical experiment. The results show that the execution time of wearable services can be reduced by up to 60%.**

I. Introduction

Wearable devices grow explosively recently, bringing a more intuitive way of using technology to ordinary people. Those wear devices, including watches, wristbands, and eyewear, are designed to be lightweight and power-saving; thus, their computing capability is limited. To eliminate the limitation on computing, it relies on a local-hub to do computing tasks for wearable devices via Bluetooth Low Energy (BLE) or Wi-Fi interface, depends on the different situations. When they are connected via BLE, two devices must be near to each other. Once they are not within the BLE networking coverage, wearable devices can only connect to the local-hub via Wi-Fi interface. However, the user of the wearable device will suffer a long response time since existing solutions require data traveling via the Internet to the remote cloud server before reaching the local-hub. Hence, the user experience might be severely affected due to the long response time.

Recently, a new computing paradigm and network architecture, fog computing arises. The main idea of fog computing is to provide computing, storage, and networking services on the edge of network [1]. Under the co-working between edge network and cloud server, it can provide latency-sensitive services for users [2]. Inspired by fog computing, we proposed a concept, named Virtual Local-Hub (VLH), to eliminate the restrictions of using wearable devices [3]. The main idea of VLH is to utilize edge devices to serve wearable devices; hence, edge devices can be treated as a virtual local-hub. VLH can be set up on edge devices, such as Wi-Fi AP, such

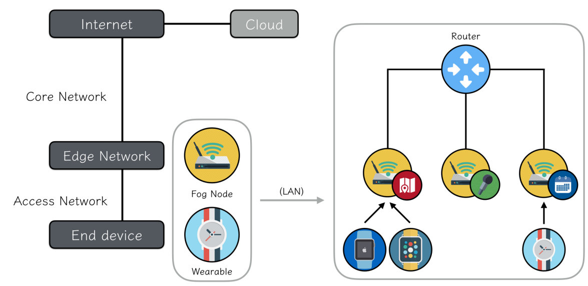

Fig. 1. The prototype implementation of VLH

that wearable devices can connect to it directly via Wi-Fi interface. As shown in Fig. 1, the VLH provides wearable services on the edge devices, which can serve the wearable devices without data traveling via the Internet, significantly reducing the response time. In this paper, we focus on the implementation of the VLH on off-the-shelf devices.

II. Proposed Method

To ensure that all the components cooperate with each other correctly, we modify the operating system of end devices and set up corresponding wearable services on fog nodes. Moreover, the controller manages fog nodes to balance the workloads among them. The core of the design is around the end device since we need to provide precious information with correct data format at the same time to prevent our modifications crushing the system. Thus, the implementation of fog nodes and the controller need to accommodate the system behavior of end devices. We present how we implement all the design on every component as follows.

- End device: The service request sent from wearable devices will be caught and completed by edge devices. To have this feature, we decide to intercept method calls of the system and modify its operation in advance via Cydia [4] and Xposed [5].
- Fog node: To provide the speech recognition service, we use an open source project of CMU, CMUSphinx [6], to build the service on fog nodes. Also, fog nodes are managed by the controller; they always listen to the command sent from the controller to turn on/off the service.

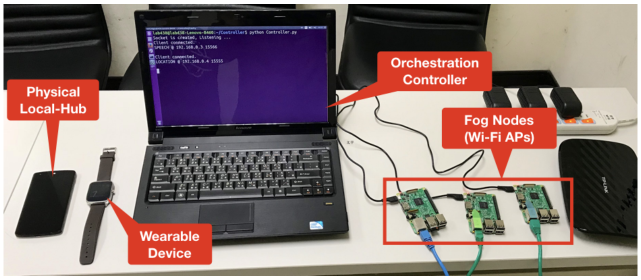

Fig. 2. The prototype implementation of VLH

- Controller: It runs a socket client which receives the requests sent from wearable devices and redirects the requests to fog nodes according to the computing capacity of fog nodes.

III. Performance Evaluation

A. Experiment Setup

As shown in Fig. 2, we build a local area network (LAN) using TP-Link AC750 router. The wired interface of the router is connected by three fog nodes and one controller. Fog nodes are set up as AP and end devices connect to it via Wi-Fi interface, and the wireless speed is around 20-30Mbps. The wearable device is a ASUS smartwatch, Zenwatch 2, installed with Android Wear 1.5. By default, Android smartwatch needs a physical local-hub to help them process service requests and reply results. The physical local-hub is a mobile device, Nexus 5, installed with Android 6.0. The fog node is a development board, Raspberry Pi 3, installed with Ubuntu Mate. The fog node equips wireless LAN interface, so it can be set up as an access point (AP). The controller is a laptop, Lenovo B460, which is installed with Ubuntu 16.04.

The comparison methodologies are Physical Local-Hub (PLH), Remote Physical Local-Hub (RPLH) and Virtual Local-Hub (VLH). In PLH, because the smartwatch is close to the local-hub, they communicate to each other via Bluetooth Low Energy (BLE). But in RPLH, the smartwatch and the local-hub are not within the same BLE coverage, so the smartwatch only can build connection via Wi-Fi interface. The service requests and the data will travel through the Internet and reach to the local-hub via Google server. After local-hub completes services, results are replied to the smartwatch through the same path. In our solution, VLH, wearable devices are served by fog nodes instead of the local-hub. Thus, service requests and the data do not need to enter into the Internet because fog nodes are on the edge of network. The performance metric is the execution time of the selected application, speech recognition.

B. Experiment Result

In Fig. 3, we compare the execution time of different schemes under different length of sentences for speech recognition. We can see that longer the sentence, longer the execution time. This is because longer sentence means more complex speech recognition. Also, regardless of the sentence

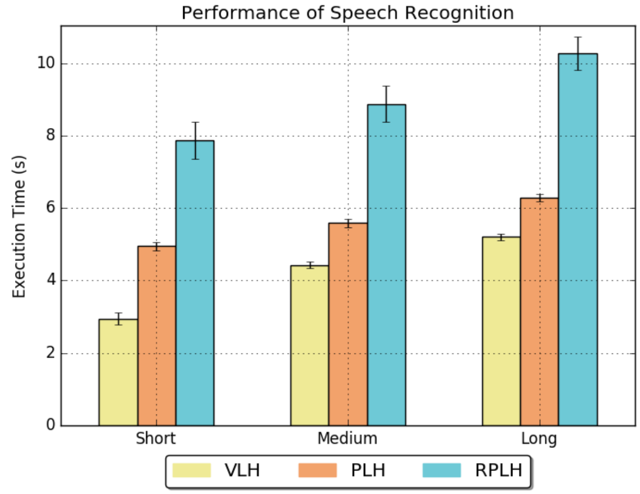

Fig. 3. The performance of speech recognition.

length, RPLH performs worse than both PLH and VLH since RPLH requires the data to travel through the Internet while both PLH and VLH requires only one-hop data transmission. In addition, VLH performs better than PLH. This is because the end-device connects to the Fog node via Wi-Fi for VLH while for PLH, the end-device connects to the phone via Bluetooth, and the bandwidth of Wi-Fi is larger than that of Bluetooth. This result shows that we reduce the execution time of wearable services by up to 60%.

Acknowledgement

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