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WaterLady: A Case Study for Connecting Physical Devices into Social Networks

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***Abstract*—An increasing number of connectable devices have been used in our everyday living environments. However, their working status usually cannot be remotely monitored in a ubiquitous way, leading to potential inefficiency in energy consumption. In this paper, we conducted a case study to investigate the effectiveness of connecting devices into social networks for status monitoring. In our study, we developed WaterLady, a water dispenser that posts its working status automatically to one of the biggest social networks in China, and interacts with human beings in this social network. Our evaluation revealed that this approach is convenient, efficient and reliable. Moreover, users' acceptance is much higher than expected. Finally, the personification of physical device is well received by social network users.**

***Keywords*-social network; cyber-physical systems; smart environment**

I. INTRODUCTION

Modern living environment is equipped with various kinds of devices, such as laundry machines, microwave ovens, water dispensers, air conditioners, and etc. These devices utilize simple indicators, such as LED lights, to present their working status. However, the status of these devices can only be observed in a relatively short distance, due to the lack of a ubiquitous way for status monitoring. Such limitations make it difficult for users or applications to respond promptly to device status changes, leading to potential inefficiency in energy consumption.

Therefore, several status monitoring systems have been developed to address this problem [1–6]. These systems acquire device status via heterogeneous sensors, and deliver these message to users and applications via various publish/subscribe paradigms, such as SMS and email [1], [2]. However, the development, deployment, and maintenance of these systems require extra efforts. Moreover, due to various socio-technical factors, such as privacy, effectiveness, and convenience, these systems are not well adopted by users [3].

Considering these issues, we conducted a case study to investigate the effectiveness of connecting physical devices into existing social networks to provide a ubiquitous platform for monitoring devices status. By definition, social networks allow their users to construct a profile, articulate a list of connected users, and share messages between them [18]. Connecting physical devices into social networks leverages the existing functionalities of these networks in a natural way: devices are regarded as users, and thus can be found easily via profile search; device status can be published as messages and subscribed by other users (i.e. followers). Moreover, since social networks have been widely used by the general population [18], this social network based approach not only reduces the cost of development and deployment, but also benefits from existing interfaces and user behaviors in social networks.

In our case study, we develop WaterLady, a water dispenser that can post its status automatically to a social network. We then investigate the effectiveness of the system. Our experiment result confirms that this approach is convenient, efficient and reliable in device status monitoring. Moreover, the WaterLady have dramatically gained about 45,000 followers in five days since it launched, receiving broad coverage by Chinese media [19], [20]. We analyze the reason for the extraordinary popularity among Chinese netizens [19], and explore further study on the fusion of physical devices and social networks.

II. WATERLADY: A CASE STUDY

A. Motivation

Our application case study utilizes a water dispenser in our lab. In China, most homes and offices are equipped with water dispensers to provide boiled drinking water. Instead of making coffee with coffee machines, Chinese people use boiled water to make tea, cereal, soymilk, and so on. In our lab, the water dispenser boils drinking water and keeps it warm until water is consumed. A dispenser usually has three LED lights, power, boil and warm, to indicate its working status (Fig. 1).

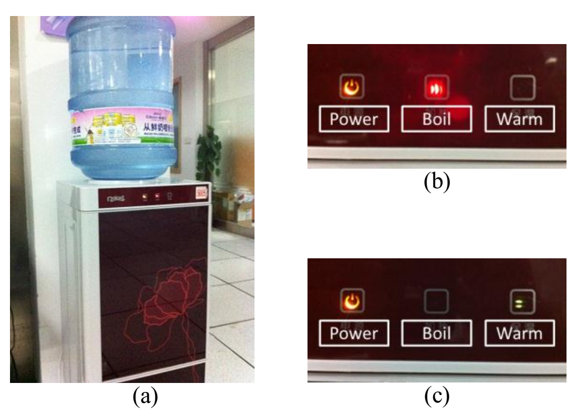

Figure 1. (a). The water dispenser in our lab. (b). The dispenser is boiling water. (c). The dispenser is keeping water warm.

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Usually, if no one fetches water after it's boiled, the water dispenser keeps it warm at 75-85 degrees Celsius by heating the water repeatedly. Such repeating procedures not only waste electricity, but also affect the quality of drinking water. On the other hand, people have to come over to the water dispenser to check whether there is boiled water. Since boiled water is best suitable for making tea or coffee, many people tend to wait at the dispenser until the water is boiled again.

Therefore, we developed WaterLady, a system that connects the water dispenser into a Chinese social network named Sina Weibo, to enable remote and ubiquitous monitoring of boiled water status. Sina Weibo[1] is a Chinese microblogging website launched by Sina Corporation on August 14th, 2009, and has more than 300 million registered users as of February 2012 [8]. Akin to a hybrid of Twitter and Facebook, it enables users to post messages of up to 140 characters, as well as media links formatted by Sina's URL shortening service [9]. Sina Weibo features a variety of mobile and desktop clients on different platforms, most of which support push notifications of message updates [8].

B. *System Overview*

Fig. 2 presents the overview of the WaterLady system. First, a camera mounted in front of the LED lights monitors the working status of the machine. Second, a color sensing procedure is employed to detect the status changes and post it to Weibo. Finally, a status update message is delivered to users via different Weibo clients (web, desktop, mobile, etc.).

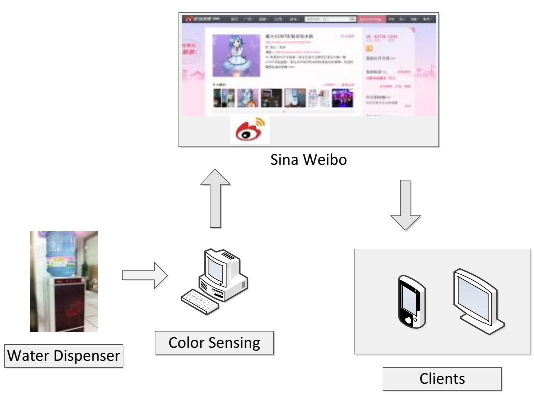

Figure 2. Flowchart of the status recognition procedure.

In the system design and implementation, we follow three design principles to guarantee the system usability:

- **Principle A: Less modification.** Modifying device structure not only reduces system reliability, but also introduces complexity in system maintenance. Therefore, we add external tools instead of modifying internal components.
- **Principle B: Personification.** Since social network entities are human beings, a personified character of device will be easily understood and accepted.
- **Principle C: Unified image design.** In order to create a unified identity of the personified device, its name, avatar, status contents, and voice should be carefully designed.

C. *Implementation*

1) Vision-based Status Sensing: In order to sense the working status of the drinking fountain, we mount a camera in front of the LED lights, and connect it to a PC near the drinking fountain via a USB cable (Fig. 3).

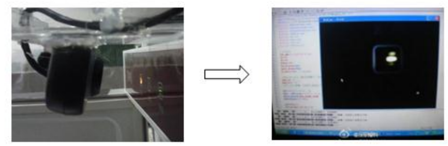

Figure 3. A camera is mounted in front of the LED lights to sense the working status, and grab picture frames to the color sensing procedure.

We design a simple color sensing algorithm to detect the lighting area in every frame returned by the camera, as described in Algorithm 1. The lighting area is predefined as the place of the LED light indicating the "warm" status. The algorithm detects the LED light status by calculating the average RGB value of the lighting area, and returns the corresponding working status of the machine.

Algorithm 1 *Color sensing algorithm*

Input: camera frame: f
Output: status: s
globals lighting area: A
globals threshold: T $(0 \leq T \leq 255)$
globals sum: S
$S \Leftarrow 0$
for each pixel p in A **do**
    $v \Leftarrow$ RGB value of p
    $S \Leftarrow S + v$
end for
if Ave(S) > T **then**
    $s \Leftarrow$ **WARM**
else
    $s \Leftarrow$ **BOIL**
return s

2) Status Publication and Notification: Sina Weibo provides an open platform for third-party developers to publish messages to a connected account. Like Twitter, the platform utilizes OAuth standard [10] to perform application authorization. The Sina Weibo SDK and documents we used can be found in [11]. Besides text status, audio clips and geo location can be attached when publishing (Fig. 4). Most Weibo clients have built-in support for message notification. The web client uses a pop-up window on the top-right

[1] Sina Weibo: http://www.weibo.com.

corner to notify users, while the mobile clients utilize the push notification mechanism to deliver status updates to users.

Figure 4. Tsundere status messages with real voice contributed by Sina Weibo users.

3) Visual Identity Design: The visual identity of the water dispenser is designed as a young lady who serves hot water to people conscientiously, and knows a lot about the pop culture of Chinese netizens. Specifically, we focus on the design of the following aspects:

- **Charming nickname:** We named the account as *WaterLady* (*yǐn shuǐ jī niáng* in Chinese Pinyin), which recalls people to the image of a cute girl[2]. This nickname turned out to be well accepted by Chinese netizens and media [19].
- **Comic-style portrait.** The design of WaterLady portrait is much in line with the comic concept of cuteness (Fig. 5). It's depicted with blue hair to resemble pure water, big eyes and cute skirt, and a hair clip with the logo of Zhejiang University.
- **Tsundere language.** Tsundere is a Japanese anime term which refers to the characteristic of *"cold outside but warm inside"*, especially for girls. We designed several tsundere messages to indicate water status, as shown in Fig. 4. Such tsundere messages, along with corresponding audio clips (Fig. 4), turned out to be well received by Chinese netizens (Fig. 8).
- **Real human voice.** We asked Sina Weibo users to record voice clips for the status messages, and selected some of them to post along with status messages. This approach greatly enhanced the personification effect of the WaterLady.

[2] WaterLady Sina Weibo account: http://weibo.com/waterlady1.

Figure 5. Comic-style portrait of the WaterLady. Image contributed by @Bison_ (http://weibo.com/bisonbison).

III. Evaluation

We deployed the system on December 23th, 2011. Since then, we've been analyzing the performance of the system, and investigating the interest and reaction of Sina Weibo users. This section covers our experiment results and observations. We also investigate how these observations may impact on our future work.

A. System Performance

We conducted an experiment to evaluate the efficiency of the system. The experiment includes 40 independent sets. In each set, we record the time taken for a status message to be delivered to two different Weibo clients, a web client running on Google Chrome, and a mobile client running on iPhone over China Mobile GPRS network. The results are shown in Fig. 4.

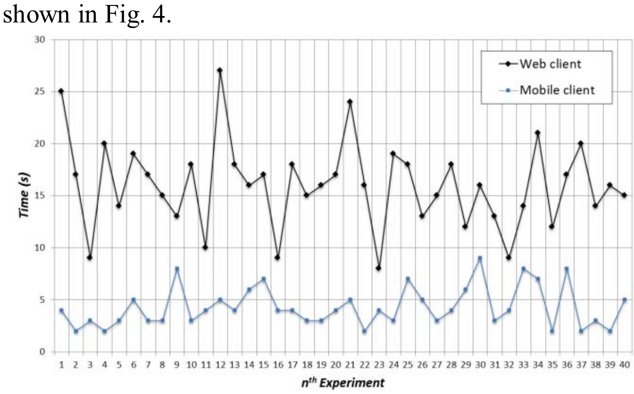

Figure 6. Experiment results of system performance. In each experiment, the time taken for a message to be delivered to both clients is recorded.

The results show that for the web client, the average delivery time is 16 seconds with a standard deviation of 4.2 seconds; for the mobile client, the average delivery time is 4 seconds with a standard deviation of 1.9 seconds. Meanwhile, no message is missed by either client during the experiment. Therefore, we conclude that social network platforms are efficient enough to provide message delivery service in our scenario.

B. Growth of Followers

The WaterLady had attracted more than 30,000 followers within 48 hours of its launch on Weibo, becoming the cyber buzz among Chinese netizens. Fig. 5 shows the growth of followers in 7 days.

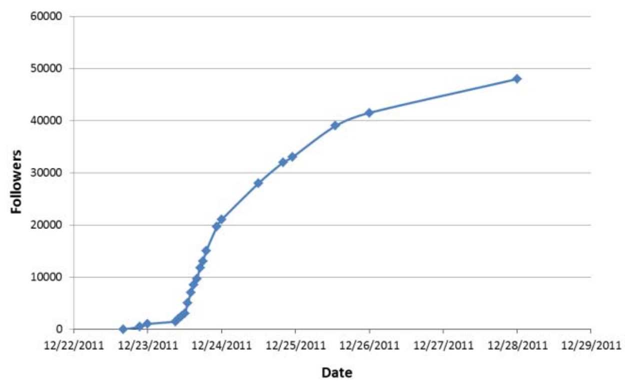

Figure 7. The growth of followers in 7 days since the system is online.

This extraordinary phenomenon can be analyzed from the following aspects. First, followers are curious to know how a machine can post status updates automatically, forming a curious crowd on the Sina Weibo community. Moreover, social network celebrities play an important role in attracting followers. For instance, the number of followers increased rapidly after WaterLady is mentioned by a national news agency account on December 24th, 2011.

Second, since the system utilizes Sina Weibo interfaces and operations, finding and following the WaterLady account is intuitive and convenient for social network users. The *Forward* and *Comment* operations of Sina Weibo also help spread the messages to more users.

Last but not least, the messages we posted to Sina Weibo include interesting slangs and endearing voices, which instantly became popular among users (Fig. 6). People forwarded these messages to their followers, drawing more attention to this interesting account.

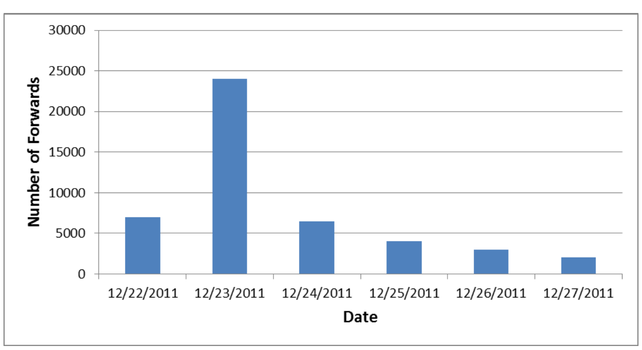

Figure 8. Number of forwards of the drinking fountain's message on Weibo in the first 6 days.

C. Lessons Learned

Social networks can be regarded as specialized publish/subscribe systems for human beings. Therefore, these platforms can be utilized for remote status monitoring of physical devices. Our case study not only confirmed the effectiveness of the idea, but also revealed its potential benefits.

However, connecting physical devices to social networks may bring privacy issues. In our study, some followers of WaterLady estimated the number of staffs in our lab by the consumption of water per day. In general, home appliances status can be used to reveal rich user context information, which should be well protected in social networks. Fortunately, many social networks provide access restrictions to messages and users [13]. Our further research will involve study of these privacy mechanisms.

In addition to status monitoring, social networks can provide a ubiquitous platform for more human device interaction. For instance, remote status query and device control can be accomplished by sending messages to devices on social networks. Furthermore, hybrid workflow combining human and device services can be achieved on social networks involving devices.

IV. Related Work

Prior to WaterLady, several social network bots have been developed. Big Ben has an unofficial Twitter account (@big_ben_clock) that tweets a number of "BONG"s every hour to tell the time [14]. Earthquake Bots are a series of Twitter accounts that automatically tweet earthquakes in areas such as San Francisco and Los Angeles [15]. Unfortunately, these bots lack a sensing layer to gather physical status directly. In contrast, our approach utilizes sensors to detect device status automatically.

On the other hand, a lot of systems have been proposed to provide users and applications with device status and physical information [16], [17]. The Context Toolkit [4] proposed by Salber et al. enables sending context messages to pagers, mail lists, and phones, via a set of toolkits and widgets. The remote monitoring system developed by I. Aziz et al. [1] utilizes wireless sensor and Short Message Service (SMS) to monitor and predict temperature changes in agricultural greenhouses. *AlertMe*, a semantics-based context-aware notification system developed by Leonidis et al., provides both SMS and Web interface to deliver notifications to users [2]. Logan et al. also propose a mobile phone based remote patient monitoring system, which utilizes web servers and mobile phones to notify care providers [7]. These systems, however, require extra effort for development and deployment. In contrast, our approach leverages existing social networks as a simple context framework, and benefits from the existing functionalities and resources in the network. Moreover, according to [2], the perceived ease of use [12] greatly affects user acceptance of information technology systems. Previous mentioned systems lack intuitive and convenient message delivery mechanisms, while our approach utilizes commonly used social networks to reduce the learning curve.

V. Conclusions

In this paper, we investigated the possibility of connecting physical devices into social networks to provide remote monitoring of device status. We conducted a case study in a Chinese social network to evaluate the effectiveness of this approach. Our experiment results confirmed the reliability and efficiency of the system. Moreover, the WaterLady account received great attention among users, making it the most popular social network bot among Chinese netizens. We analyzed the reason for this phenomenon, and compared our system with several existing work. Our future work will focus on leveraging the usage of existing social networks in the physical world.

Acknowledgments

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