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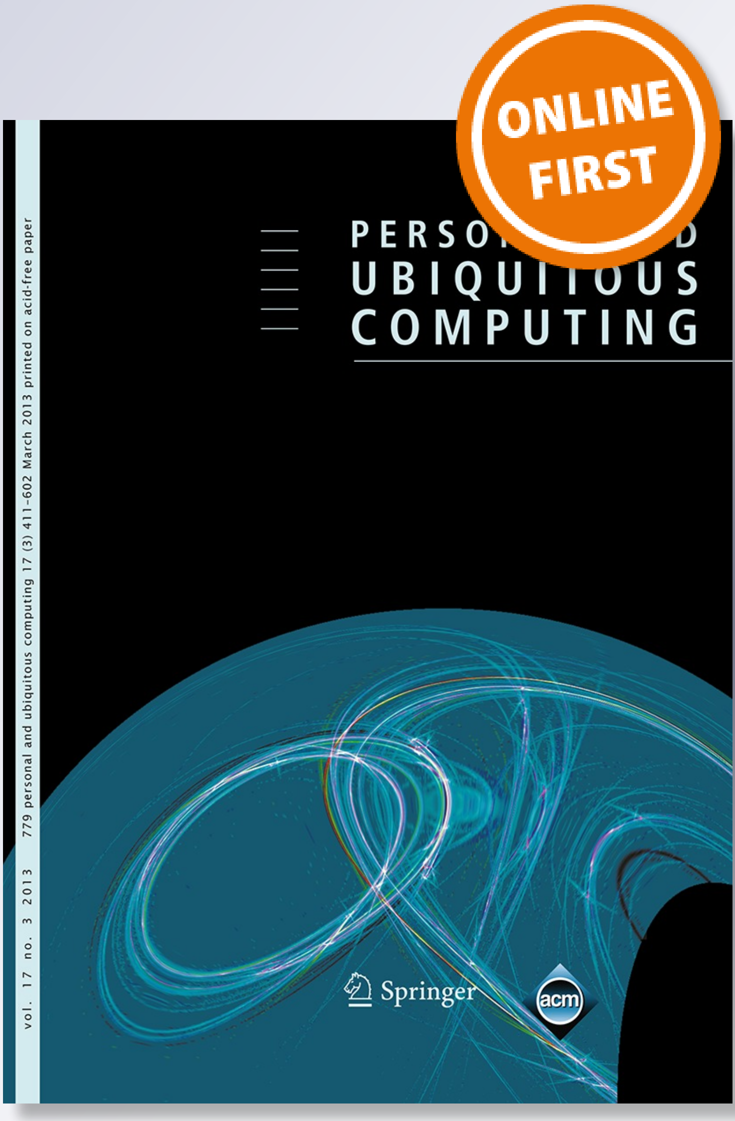

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ORIGINAL ARTICLE

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Abstract Personal task reminders have been indispensable for modern people, in order to remind them of their tasks at specific circumstances. Traditional paper-based reminders are still useful, but they cannot be organized efficiently. Electronic reminders based on the calendar in cell phones are more efficient and gaining popularity, but such reminders are mostly triggered by time. In many situations, tasks are only meaningful to be performed at a specific location, so it would be useful if reminders for those tasks can be triggered only when the person to be reminded is physically near or located at that location. Therefore, in this research, we develop a location-based personal task reminder for Android-based smartphones and tablets. To distinguish our work from existing ones that rely solely on the GPS technology, we take advantage of the ubiquity of IEEE 802.11 WLAN infrastructure to compliment the "blind spots" of GPS location sensing. Combining the two technologies makes it possible for the personal task reminder to be effective in both indoor and outdoor environments. We also propose two operating models for the personal task reminder to boost the usability of the application. Furthermore, as long as the WLAN infrastructure is available, our work as a foundation of location-based services can easily be extended to be used in many other scenarios, such as guiding in public transportation systems or tourist attractions, location-based learning, and even caring of the Dementia residents.

Keywords Location-based services · GPS · Wi-Fi · Locationing

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1 Introduction

In contemporary society, many people are overwhelmed by numerous tasks waiting to be done. Tasks are of a wide variety, ranging from daily tasks such as meetings at work to non-daily tasks such as buying groceries after work. To help remind ourselves of these tasks, common practices are to take notes on the paper-based day planners or Post-it and to use personal task manager software on computers and/or cell phones so as to take notes electronically. The latter, which is getting more and more popular in recent years, benefits by the trend of increasing penetration of smartphones. According to [1], in 2013, smartphone shipments will rise to account for more than half of all cell phones for the first time. Tablet PCs such as Apple iPad and Google Android-based tablets also boost the use of personal task management applications in our daily life.

In general, tasks can be broadly classified into two categories: (1) *time-based* tasks, (2) *location-based* tasks. If a task is time-based, we mean that the task should be carried out at a specific time. For example, taking medicine at 9 p.m. every day is a time-based task. To remind ourselves of this kind of tasks, we can set an alarm in the personal task manager to make a "just-in-time" prompt. On the other hand, if a task is location-based, we mean that the task should be performed at a specific location, such as to buy a bottle of milk at the convenient store nearest to your home. In this case, setting an alarm triggered by time may not be appropriate if you are not sure when you will be passing by the convenient store. This motivates us to design a *location-based personal task reminder*, which can provide a "just-in-place" prompt to users. That is, in the above scenario, we would like the alarm to beep and show a reminder when you are getting close to the convenient store. It is noteworthy that a task can be both time-based

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and location-based; however, in this research, we emphasize on designing a reminder application for the location-based tasks. With the capability of locationing sensing, the reminder application can be extended to support both conditions easily.

It is for sure that the concept of a location-based reminder is not brand new, which is merely one of the examples of the *location-based services* [2]. Nevertheless, we found that most existing location-based reminders rely solely on the Global Positioning System (GPS) technology to do location sensing, which limits the effectiveness of such applications. Specifically, GPS technology uses line of sight to satellites, so it does not work when a user is indoors or in other circumstances when the line of sight is obscured. Although Assisted GPS (A-GPS) can help to some extent, it requires the support from the infrastructure of cellular operators. Therefore, we choose another technology, IEEE 802.11 WLAN, to complement the "blind spots" of GPS location sensing.

The IEEE 802.11 WLAN technology, also known as "Wi-Fi," has been massively deployed around the globe. Take the municipal wireless networks (also called municipal Wi-Fi) as an example, more than 100 cities own such networks operated by the city governments or ISPs. Take Taiwan as another example, airports, MRT/train stations, museums, homes, hotels, campuses, restaurants, convenient stores, offices, and shopping areas are mostly deployed with Wi-Fi hotspots. The ubiquity of Wi-Fi infrastructure is therefore without a doubt. Moreover, on the Wi-Fi client side, the hardware specification of built-in WLAN interface and GPS receiver becomes the de facto standard on the latest smartphones and tablets. Based on these observations, we find it feasible to implement a location-based task reminder in smartphones and tablets, which combines the GPS and the WLAN technologies for location sensing.

The main features of our location-based reminder are as follows. First, it can be used to remind the users of the tasks in both indoor and outdoor environments, with the aid of the built-in GPS receiver and WLAN interface in smartphones/tablets. Second, it gives users a unified user experience because all the established personal-meaningful locations can be displayed and managed on the Google Maps UI [3], regardless of the location types. Last but not least, it can become a value-added service for telecom operators with WLAN infrastructure. We believe that the reminder application we developed can contribute to the promotion of individual well-being.

The rest of this paper is organized as follows. In Sect. 2, we will describe the related works. The design of our location-based personal task reminder is shown in Sect. 3. The implementation and experimental study of this application are then shown in Sect. 4. In Sect. 5, we propose two operating models of the location-based reminder to increase the usability of this application. The conclusions and future work are presented in Sect. 6.

2 Related works

In this section, we review some related technologies and previous works on the topic of location-based reminders.

Geolocationing is the first step to providing location-based services. Common locationing technologies include GPS, Wi-Fi, Cellular, Bluetooth, Infrared, and Radio Frequency Identification (RFID), to name a few. The applicable environment for these technologies varies, and their locationing accuracy also varies, so there has been a great deal of researches aiming at improving the two factors. Using a single locationing technology, Ni et al. [4] improved the locationing accuracy of RFID by deploying reference tags in the field. Locationing accuracy can also be improved by combining two or more locationing technologies. For instance, [5] and [6] use both GPS and Wi-Fi, and [7] uses RFID, GPS, and Cell-ID. However, Bhasker et al. [8] took a different approach by employing user feedback to correct system geolocations with low computation overhead, and their experimental results show very good accuracy in indoor environments. In terms of the applicability of locationing technologies, our previous work [9] combines GPS and RFID to make a logistics management application applicable for an entire itinerary consisting of both outdoor and indoor environments.

Sohn et al. [10] designed a location-based reminder application named "Place-Its," running on the Symbian S60 mobile phones. They emphasized that compared with Post-it notes or PDAs, mobile phones are a convenient and truly ubiquitous platform to deliver reminders. Through their experiments, they found that using one's location to trigger reminders is a valuable piece of context to improve the way people use reminders, regardless of the fact that the locationing accuracy of mobile phones is relatively low. They also observed that location was widely used as a cue for other contextual information which is difficult to be detected by any system, inferring the merit of location-based reminders. A similar work can be found in [11], where Ludford et al. developed a location-based reminder system named "PlaceMail." Their field study shows the usefulness of such a system and also discovers that effective delivery of reminders depends on people's moving patterns and the geographic layout of the space. Location-based reminders can also be used for advertisements. Instead of pushing the advertisements unsolicitedly to mobile phone users, the work proposed by Li et al. [12] triggers reminders based on previous settings (interested products) by the user oneself.

Based on the findings of [10], we are motivated to improve the location sensing capabilities of mobile devices, so as to make location-based personal task reminder more viable in our daily life. It is apparent that the daily schedule for most people includes both indoor and outdoor environments. Therefore, a practical location-based reminder should support location sensing in both environments. Moreover, the user study in [10] pointed out that the "Place-Its" reminders triggered on departure were not satisfactory; the reminders came to users' attention several kilometers away from where the reminders were needed. Furthermore, a number of location-based reminder applications available at the Google Play [14] such as "Location Alert" [15] and "Location Based Task Reminder" [16] also suffer from the same problem, because they are unable to sense the location information in the indoor environment. If we can make the location sensing more accurate, this kind of reminders can become more useful.

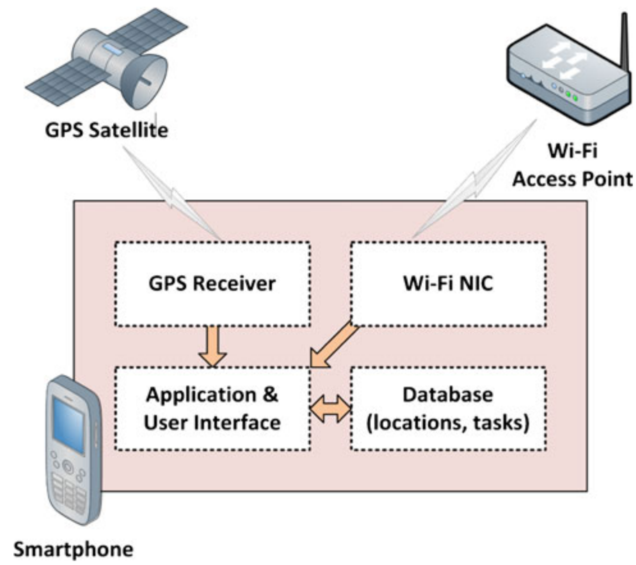

Fig. 1 Schematic diagram of the proposed location-based personal task reminder application

3 The proposed location-based personal task reminder application

3.1 System architecture

The schematic diagram of our location-based personal task reminder application is shown in Fig. 1. This application employs four hardware/software components in the smartphone, described as follows. The smartphone is built-in with both a GPS receiver and a Wi-Fi network interface card, which can receive radio signals from GPS satellites and Wi-Fi APs, respectively. Based on the GPS readings and the information from the Wi-Fi APs, the application can perform geolocationing to estimate the current location of the user. The database is designed to store personal-meaningful locations and location-based tasks, which are stored in separate tables. If a location-based task exists in the database, then the application will compare the currently sensed location with the location associated with the task. When the user is physically close to the predefined location, the reminder then will be triggered to remind the user of his/her task.

3.2 Indoor locationing

As described in Sect. 1, the deployment of Wi-Fi infrastructure is essentially ubiquitous nowadays. By taking advantage of the Wi-Fi infrastructure, indoor locationing is handily achievable by sensing the existence of some specific Wi-Fi APs' wireless signals. That is, sensing a specific Wi-Fi AP's wireless signal conceptually means that the user is in vicinity of the location at which the Wi-Fi AP is deployed. Specifically, every AP will broadcast *beacon frames* periodically, which contain the *MAC address* of its Wi-Fi interface and its *service set identification*. Accordingly, a Wi-Fi client device can scan for the beacon frames to acquire the MAC address of the AP in vicinity and then associate the discovered MAC address with a *personal-meaningful location*. By personal-meaningful locations, we mean that the locations to be saved in the location database can be named according to users' own will. For example, one can name a location "My Office", which needs not be meaningful to other people. Also, we would like emphasize that a Wi-Fi client device can do Wi-Fi scanning even when APs are running the Wi-Fi Protected Access (WPA) security protocols, because we only need to receive the beacon frames rather than establish a Wi-Fi connection with the WPA-enabled AP.

It is possible that a Wi-Fi client device can discover a number of APs simultaneously when scanning for Wi-Fi connections. This is very common especially in urban areas. Therefore, in our implementation, we allow multiple APs to be associated with one location, to increase the success rate of indoor locationing. In addition, in our application, the indoor personal-meaningful locations should be pre-visited by the user before they are used in the reminders. More precisely, the user should be physically located at the location, scan the Wi-Fi APs, and then save the location into the application database. With this pre-requisite setting, the users may create reminders and then associate them with the pre-established locations.

3.3 Outdoor locationing

For outdoor locationing, we also utilize the most popular locationing technology—GPS. To ease adding a personal-meaningful location into the database, we use Google Maps as the user interface in our application. That is, by clicking at a specific location on the Google Maps, users can add that location into the database and then use it in location-based reminders. As noted in Sect. 3.2, in the location database, indoor locations are associated with the discovered MAC addresses of the Wi-Fi APs, so the indoor locations should be pre-visited by the users. However, outdoor locations are treated differently—we associate outdoor locations with their GPS coordinates. Most importantly, since the GPS coordinates of the outdoor personal-meaningful locations can be obtained from the Google Maps API, the users are not required to be physically located at those locations before using them in the reminders.

3.4 Flow of operation

Using the location-based reminder application is straightforward. Basically, the flow of operation follows three steps:

1. Users establish personal-meaningful locations
2. Users create location-based reminders
3. The application triggers the reminder when user is at the predefined location

The detailed flows of the three steps are shown in Figs. 2, 3, and 4, respectively. Figure 2 depicts the flow of establishing personal-meaningful locations. First, the user manually selects to establish an indoor or outdoor location. We can see that establishing indoor and outdoor locations follows different procedures. As described in Sect. 3.2, indoor locations can be associated with the discovered Wi-Fi APs. However, in our implementation, we chose to associate each indoor location not only with the Wi-Fi AP (MAC address), but also with the GPS coordinates of the indoor location. We can see from Fig. 2 that once the user decides to establish an indoor location, our application will first get the current GPS coordinates and then scan for Wi-Fi APs. We will explain why this is needed later in this section. After the Wi-Fi APs scanning is completed, we may select some of the discovered Wi-Fi AP(s) to be associated with the indoor location and then input the location name for this indoor location. The mechanism of selecting appropriate Wi-Fi APs to be associated with an indoor location will be discussed in Sect. 4.1. Each saved Wi-Fi AP in the **AP** table will be assigned a unique *AP Identifier* (**AP_ID**), and each pair of the saved GPS coordinates in the **OUTDOOR** table will also be assigned a unique *Outdoor Identifier* (**OUTDOOR_ID**). The location name along with **AP_ID** and **OUTDOOR_ID** is then saved in the **INDOOR** table of the location database, which ends the process of establishing an indoor location. It is simpler to establish an outdoor location—as long as the user manually pinpoints a location on the Google Maps UI, the GPS coordinates of this location along with the user-supplied location name can be saved in the **OUTDOOR** table in the location database. After a location is established, it can be used in setting up a location-based reminder.

As shown in Fig. 3, creating a location-based reminder is fairly straightforward: choose a location, edit the event name and details, done. During the process, the *Location Identifier* (**LOC_ID**) of the location along with the event name and details, and the *Location Type* (**LOC_Type**, i.e., *Indoor* or *Outdoor*) are saved in the **EVENT** table. After reminders are created, the application follows the process shown in Fig. 4 to trigger the reminders. First of all, the application keeps reading the GPS signal and comparing the current GPS coordinates with those in the **OUTDOOR** table. Once a match is found and the **LOC_Type** of the matched record is "Indoor", then the application scans for Wi-Fi APs and tries to find a match in the **INDOOR** table. If a match is found and there is at least one event (i.e., reminder) associated with the matched indoor location, then the application triggers the reminder immediately. If the above-mentioned **LOC_Type** of the matched record is "Outdoor", then the application checks the **EVENT** table directly to determine whether to trigger a reminder. The design of **OUTDOOR** table, **INDOOR** table, **AP** table, and **EVENT** table is shown in Fig. 5.

Now we would like to elaborate on our design of associating indoor locations with both the Wi-Fi APs and the corresponding GPS coordinates. From the **INDOOR** table, we can see that there is an "**Outdoor**" field, which corresponds to one of the entries in the **OUTDOOR** table, where the **LOC_Type** is *Indoor*. That is, if an entry in the **OUTDOOR** table has the **LOC_Type** of *Indoor*, this entry keeps the record of the GPS coordinates of an indoor location. This kind of entries will be established automatically at the end of establishing an indoor location. Specifically, when establishing an indoor location, the latest obtained GPS coordinates serve as the outdoor location for this indoor location. Although the GPS coordinates may not reflect the accurate indoor location, it normally will be around the indoor location, such as the entrance to a building.

Therefore, associating an indoor location to both the Wi-Fi APs and the corresponding GPS coordinates brings a twofold benefit. First, indoor locations with the GPS coordinates can be pinpointed on the Google Maps UI, from which users can visualize the locations and events they have already created. It also gives users a unified user experience, no matter the event is associated with an indoor or an outdoor location. Second, if an indoor location is only associated with the Wi-Fi AP information, the application needs to scan the APs all the time for indoor location

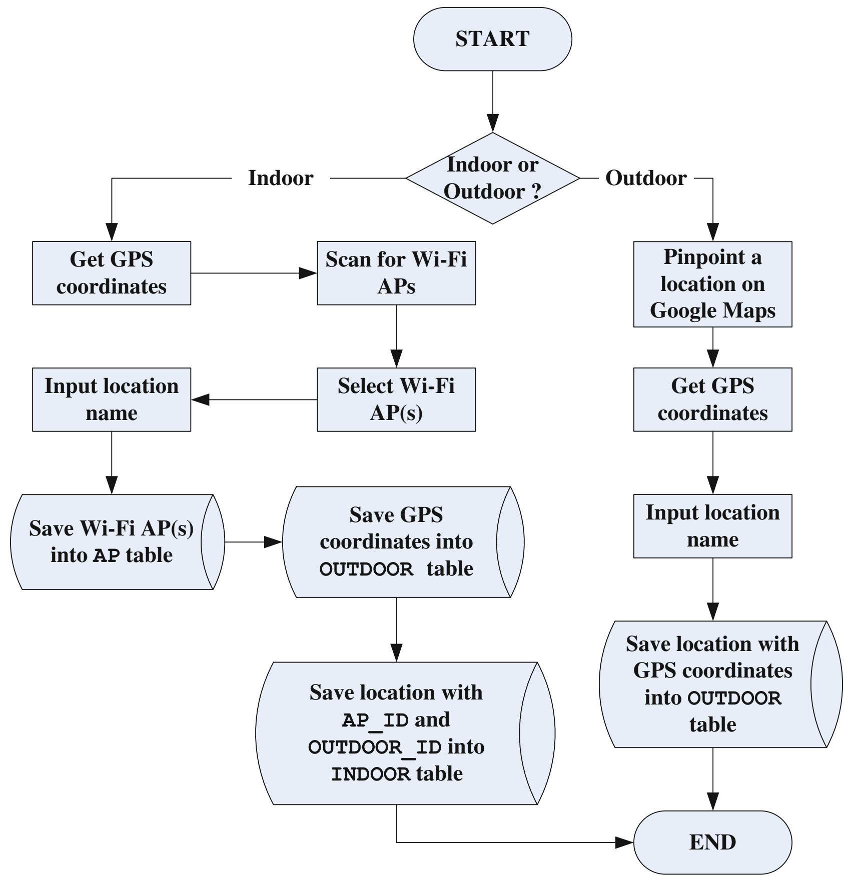

Fig. 2 Flow chart for establishing personal-meaningful locations

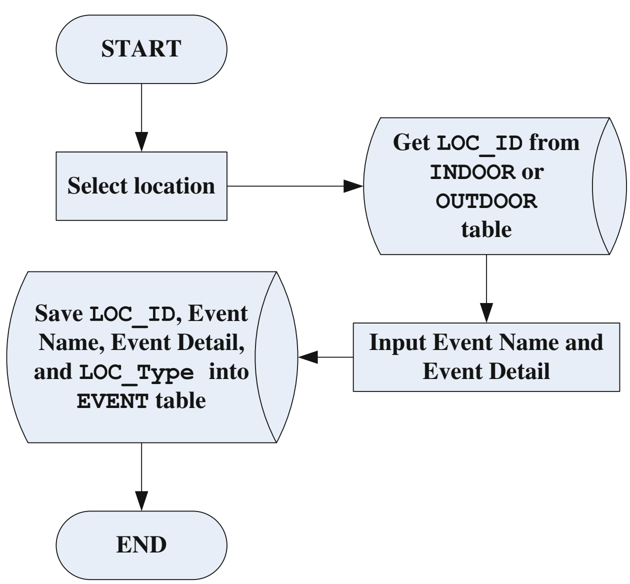

Fig. 3 Flow chart for creating location-based reminders

sensing, which may incur considerable power consumption to smartphones and tablets. With the GPS coordinates of the indoor locations, only the GPS receiver needs to be always on, because the function of Wi-Fi scanning will not be enabled until a location match in the **OUTDOOR** table is found.

4 Implementation and experimental study

In this section, we describe the implementation and experimental study of the proposed location-based task reminder application and then discuss the implementation issues we have encountered. Finally, we compare our work with the existing location-based reminders on the locationing technologies.

4.1 Implementation

We developed the location-based task reminder application using the Eclipse IDE with Android Development Tools plugin and tested it on an ASUS Eee Pad Transformer TF101 with Android version 4.0.3. In the following, we briefly introduce some important features of our implementation.

Figure 6 shows a snapshot of the Google Maps-based user interface, in which we can see three pin icons. Red and purple pin icons indicate the established outdoor and indoor locations, respectively, and the digit labeled inside the pin icons indicates the number of events associated with that specific location. Beside the purple pin icon labeled 2, there is a light blue circle, which indicates the current location of the user. As we pointed out in Sect. 3.4, since indoor locations are also associated with their GPS

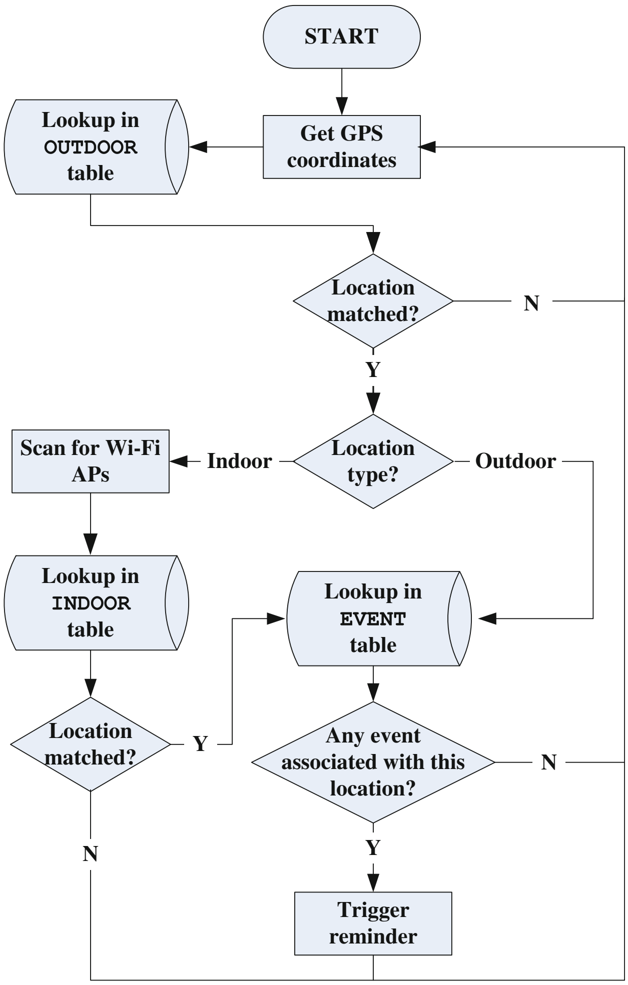

Fig. 4 Flow chart for triggering location-based reminders

coordinates, they can be pinpointed on the map. Therefore, regardless of the location types, users are able to see the established locations through the map UI.

By pressing the "ADD LOCATION" button in Fig. 6, we can establish an indoor or outdoor location (manually selected by the user). Figure 7 shows a snapshot of adding an indoor location. The message box over the up-right corner displays the number of detected Wi-Fi APs at the location. After the user enters the name of the indoor location and presses the "Save" button, this location is then established in the **INDOOR** table. Note that during this process, users are not hassled by the problem of selecting appropriate Wi-Fi APs to be associated with the current location—the application will do it automatically. When doing Wi-Fi AP scanning, we will measure the *received signal strength indicator* (RSSI) of each Wi-Fi AP, which is a measurement of the power present in the received radio signal. In our current implementation, the measured RSSI of the Wi-Fi AP must be over -70 dBm to be eligible for being associated with an indoor location. The reason is that if the measured RSSI of a Wi-Fi AP is lower than -70 dBm, it normally means that the AP is far away from the Wi-Fi client (i.e., the user), and in this case, the measured RSSI can fluctuate severely. For this reason, we only associate those APs that are closer to the user, so the measured RSSI will typically be more stable. We have also measured the behavior of RSSI versus distance, which will be shown later in Sect. 4.2.

Furthermore, in order to make indoor locationing more accurate, the measured RSSI values of the selected Wi-Fi APs during the location establishment procedure are saved in the **AP** table of the database (shown in Fig. 5c). When performing location sensing, a specific Wi-Fi AP is declared to be matched only when the measured RSSI value of this AP falls into the zone of "saved RSSI $\pm\ \delta$". For simplicity, currently we use a fixed δ value of 5 dBm. The concept of this methodology resembles that of the location fingerprinting approach [13], which utilizes a radio map built in the offline phase to assist locationing. That is,

Fig. 5 The design of tables in the location database: **a OUTDOOR** table, **b INDOOR** table, **c AP** table, **d EVENT** table

OUTDOOR				
_ID	LOC_Type	LOC_Name	Latitude	Longitude

(a)

INDOOR							
_ID	LOC_Name	Outdoor	AP1	AP2	AP3	AP4	AP5

(b)

AP			
_ID	SSID	BSSID	RSSI

(c)

EVENT					
_ID	LOC_Type	LOC_ID	Event_Name	Detail	isDone

(d)

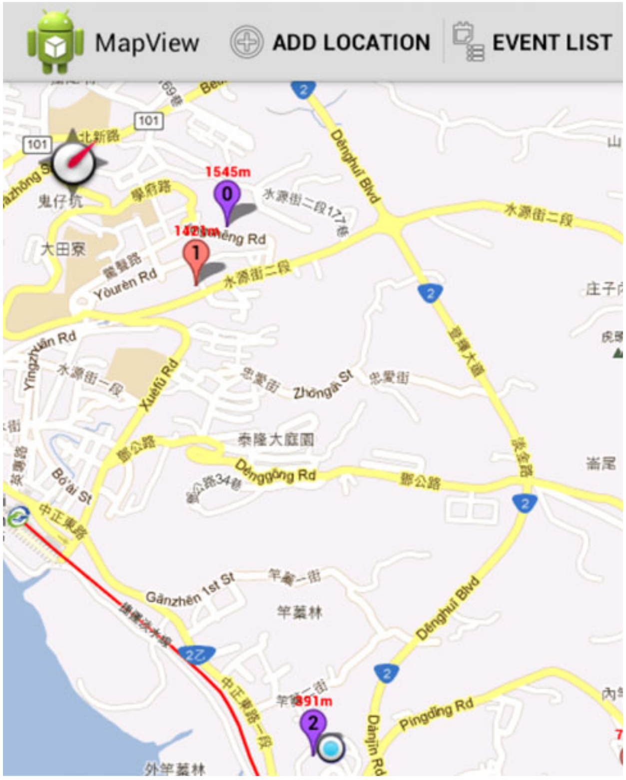

Fig. 6 The map UI of the location-based reminder application

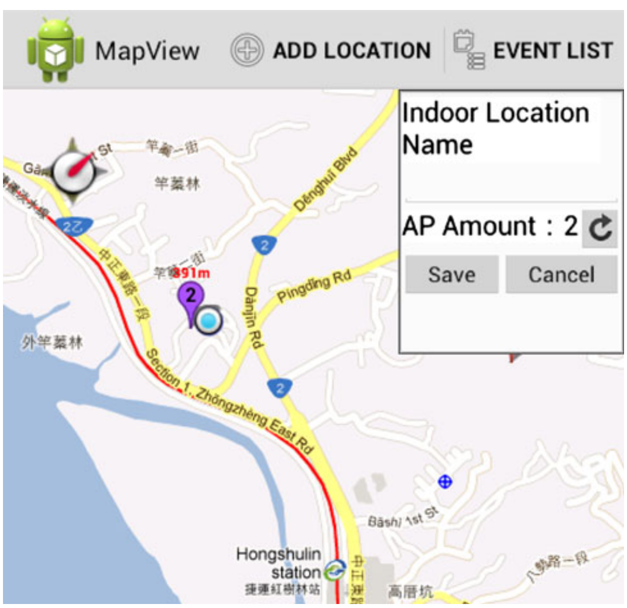

Fig. 7 A snapshot of adding an indoor location

if the measured RSSI is within the region, it means that the user is very likely to be physically close to the same spot where the user established the indoor location previously.

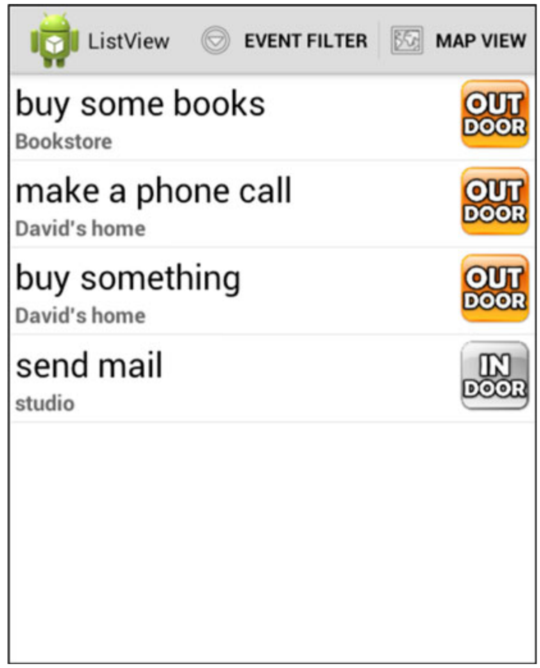

Fig. 8 A snapshot of the event list

On the up-right corner of Figs. 6 and 7, there is an "EVENT LIST" button. By pressing the button, we can view the list of events (i.e., location-based reminders), as shown in Fig. 8. In the list of events, each entry is with the event name, location name, and also the location type associated with the reminder. We can also use the "EVENT FILTER" function to set the filter options (e.g., location name, reminded or not), so as to show the events in specific categories.

4.2 Experimental study

Since the process of indoor locationing depends on comparing the RSSI values of the Wi-Fi radio signal, we performed an experiment to measure the RSSI values at various distances from the Wi-Fi AP. At each distance, we measured the RSSI values for 1,000 times at the sampling rate of one RSSI value every three seconds. The result is plotted in Fig. 9, where at each distance the average value is labeled using the green diamond icon, and the blue and the red bars centered at the average value show the range of the standard deviation (σ) and 2σ, respectively. The regression line (orange curve) clearly shows the declining tendency of the RSSI values with respect to the distance from the Wi-Fi AP. We can also observe that the standard deviation of the RSSI value grows larger with the distance. That is, the measured RSSI value becomes more and more unstable as the distance gets larger. For simplicity, if we

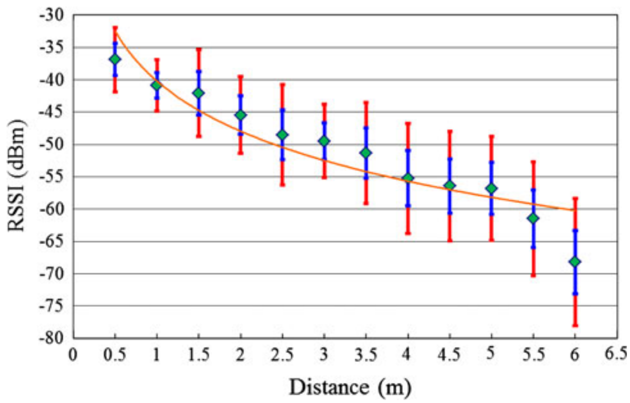

Fig. 9 Measured RSSI versus distance from the Wi-Fi AP

only need to tell whether the user is in the proximity of the Wi-Fi AP, it suffices to use the measured RSSI value as a clue, just as we did in our application.

4.3 Implementation issues

In this section, we discuss some requirements and implementation issues of our reminder application.

4.3.1 *Indoor locations should be pre-visited before being used in reminders*

As described in Sect. 3.2, our application requires that the indoor personal-meaningful locations should be pre-visited by the users prior to using these locations in the reminders. Otherwise, our application has no way of knowing the Wi-Fi AP information at those locations. Although this requirement seems to be a weakness in usability, it may not be an issue if the indoor locations are those visited by the users on a daily or frequent basis, such as users' homes, offices, and the nearby convenient stores. In Sect. 5, we will propose two operating models to cope with this usability problem.

4.3.2 *RSSI as a measure of distance is disputable*

It is noteworthy that use of RSSI as a measure of distance has been disputable in the research community. For example, the evaluation results of [17] show that the RSSI for a given link has very small variation over time, and the packet reception rate is at least 85 % when the RSSI is above the sensitivity threshold (about −87 dBm). The work in [18] gives the conclusion that indoor locationing based on signal strength should be feasible if we can construct a sound method for signal propagation in the indoor environment. However, in [19], the experimental results show that even under ideal conditions, the RSSI cannot be used to determine inter-nodal distances in wireless sensor networks. Nevertheless, in our location-based reminder application, we do not have to determine the exact distance; knowing that the user is in the proximity of the Wi-Fi AP suffices our application.

4.3.3 *Dynamic RSSI range for more flexible locationing*

Regarding the δ value used in Wi-Fi AP matching, we mentioned in Sect. 4.1 that it is currently a fixed value. From the experimental result shown in Fig. 9, we find it a viable solution to make the δ value equal to 2σ, given that the measured RSSI values follow the normal distribution [20, 21]. Doing so, we can make the indoor location sensing more flexible. That is, the δ value can change with the distance, which will be useful especially for locations that are slightly far from the Wi-Fi AP, with the measured RSSI values fluctuate severely. However, this requires extra work to be done during the establishment of an indoor location—monitoring the RSSI for a longer period of time in order to compute the σ value.

4.3.4 *Associating multiple Wi-Fi APs for more accurate locationing*

As we pointed out in Sect. 3.2, a location can be associated with multiple Wi-Fi APs to increase the accuracy of indoor locationing. Specifically, an implementation issue arises in this circumstance. If a location is associated with multiple Wi-Fi APs, in location matching, we can set the criterion to be either "match *any* of these APs" or "match *all* of these APs". Using the former criterion can make location matching easier and quicker because a location match can be declared as soon as any of the APs associated with the location is sensed. In contrast to this, using the latter criterion can make location matching more accurate, because intuitively it will require the user to be physically close to the spot where he/she established this location previously in the reminder application. However, doing so can sometimes make location matching difficult if one of the APs is removed from the location.

4.3.5 *Issues regarding power consumption in smartphones/tablets*

A location-based reminder application is useful only if it can sense the current location information within a reasonable delay time, which inevitably will lead to substantial power consumption in the smartphones/tablets. For example, with the average walking speed of 4.85 ft/s (1.478 m/s) for younger pedestrians [22], it takes about 7 s for a young person to walk 10 m. It means that choosing a strategy such as doing location sensing once 10 s to save energy is unrealistic. In our implementation, we set the period of location sensing to 3 s to achieve the balance of power consumption and response time. Another solution to saving the energy can be doing location sensing only when the user is moving. This can be accomplished by using the built-in accelerometer of the mobile device to detect the movement of users.

4.4 Comparison

Table 1 compares the locationing technologies used in our application and the related works described in Sect. 2. "Place-Its" [10] and "PlaceMail" [11] use Bluetooth and AGPS for indoor locationing, respectively. The main problems of using Bluetooth for location sensing are its limited communication range and the limited ubiquity of stationary Bluetooth devices. Wi-Fi APs, however, are ubiquitous and stationary, which are more handily available for location sensing than using Bluetooth. AGPS can achieve acceptable locationing accuracy in indoor environments, but it requires the support from both the infrastructure of cellular operators and the cell phones. Deploying Wi-Fi APs is easier since anyone can set up an AP to be used in their premises, including in the basement of a building which is not covered by the cellular network.

Both "Location Alert" [15] and "Location Based Task Reminder" [16] use the LocationProvider Android API [23] to support outdoor locationing and indoor locationing. The accuracy of indoor locationing using the LocationProvider API depends on the density of Wi-Fi AP information collected by Google. In our work, the users can scan the Wi-Fi AP information at the desired indoor locations, which can be either a public location or a private location. In the case of a private indoor location such as a user's office or bedroom, Google may not have the Wi-Fi AP information at that location. Therefore, using our approach can certainly be more accurate in indoor locationing, which leads to better user satisfaction.

Table 1 Locationing technologies used in various location-based reminders

Location-based reminders	Outdoor locationing	Indoor locationing
Place-its [10]	GSM cell tower	Bluetooth
PlaceMail [11]	GPS	AGPS
Location alert [15]	LocationProvider API in Android SDK	LocationProvider API in Android SDK
Location based task reminder [16]	LocationProvider API in Android SDK	LocationProvider API in Android SDK
The proposed location-based reminder	GPS	Wi-Fi

Fig. 10 A snapshot of the "CHT Wi-Fi" Android application

5 Operating models

As mentioned previously, the current version of our location-based reminder requires that the personal-meaningful locations should be pre-visited by the users. However, this restriction can be lifted in some ways. In this section, we propose two operating models to solve this problem: *telecom-assisted locationing* and *social-assisted locationing*. Both models can largely boost the usability of the location-based reminder application.

5.1 Telecom-assisted locationing

As described in Sect. 1, many telecom and/or broadband operators have deployed Wi-Fi APs extensively in urban areas. This effort not only facilities Internet access of their subscribers, but also alleviates the burden of the increasing data traffic over 3G cellular networks. Take Taiwan's largest telecom operator—Chunghwa Telecom (CHT) as an example, it has deployed more than 36 thousands Wi-Fi hotspots around the island [24]. Subscribers of CHT can use the "CHT Wi-Fi" Android application [25] (snapshot shown in Fig. 10) to search the CHT-operated Wi-Fi hotspots (the red pins) around them (the blue pin).

In this operating model, these telecom-operated APs play a crucial role for indoor locationing. Specifically, telecom operators not only own these Wi-Fi APs, but also

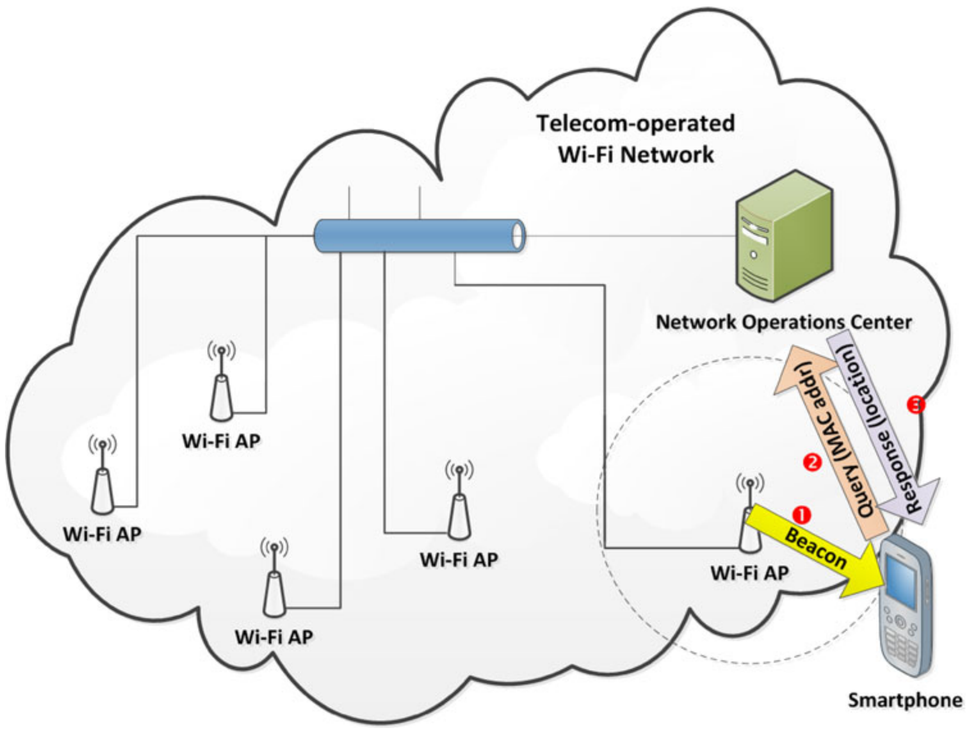

Fig. 11 Flow of operation in the telecom-assisted operating model

have the knowledge of the MAC address associated with each Wi-Fi interface and the *location* information at which every AP is deployed. That is, this database with all the Wi-Fi MAC addresses and the associated location information is exactly the asset that telecom operators can take full advantage of. In other words, various location-based services can be supported by the telecom-assisted locationing service.

Therefore, as long as telecom operators establish the Wi-Fi AP database, within which each entry is a pair of a MAC address and a location, smartphones can follow the flow of operations to do locationing (shown in Fig. 11):

1. User's smartphone receives the beacon frames of a specific Wi-Fi AP
2. The smartphone queries the database with the sensed MAC address
3. The database returns the location information associated with the Wi-Fi AP

5.2 Social-assisted locationing

With the emergence and popularity of social networking, people are able to share all sorts of information such as photos and videos with others in various social groups. In this operating model, location information is made shareable among the social groups. The idea is similar to the *check-in* functionality of Facebook [26], by which Facebook users are able to share his/her current location. When a Facebook user presses the check-in button, the nearby landmarks will show up in a list to be selected by the user. If the user's current location is not included in the list, he/she can create a new one by himself/herself. This newly created location information will be saved in the location database of Facebook, which then can be used for other Facebook users.

In our proposed social-assisted operating model, indoor locations established (visited and then AP-scanned) by a user can be uploaded to a location database server if the user decided that the location information is safe to be shared with his/her social group. As a consequence, users of the same social group can download the shared location information to their smartphones and use them for future locationing. It should be noted that in this operating model, those locations to be shared require a unified naming scheme. Otherwise, a location name such as "My office" is meaningless for other social members. For simplicity and ease of management, it is feasible to design the user interface that forces the creator of a location to pin-point the location on the Google Maps. Therefore, the GPS coordinates of the location can be saved in the location database, just like the way we handle indoor locations as described in Sect. 3.4. The flow of operation of this operating model is shown in Fig. 12. Assume that User *A* and User *B* are of the same social group. User *A* acquires the Wi-Fi AP information by sensing the beacon frame and then saves this indoor location into the local **INDOOR** table. When establishing this indoor location, User

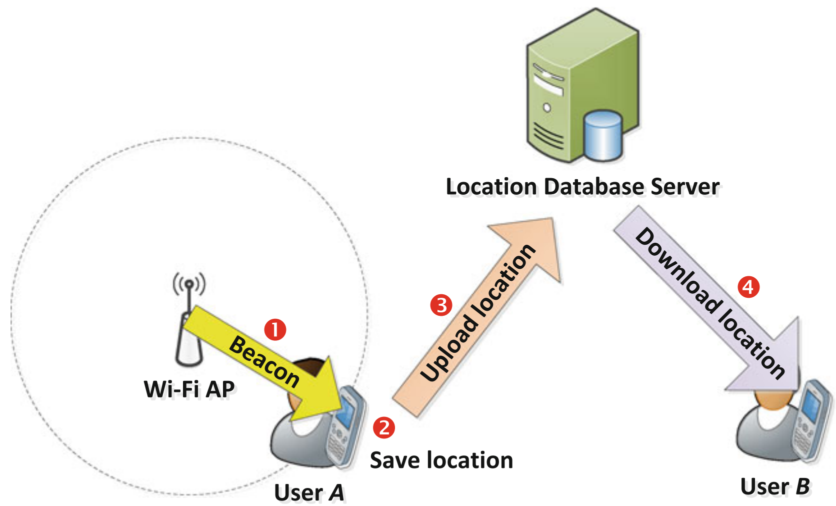

Fig. 12 Flow of operation in the social-assisted operating model

A decides to make this location shareable, so this indoor location information is uploaded to the remote location database server automatically. User *B*, as User *A*'s friend, may check the location database server and find that his/her friend *A* has established an indoor location. If *B* is interested in this location information, he/she then can download the indoor location information to be used in his/her location-based reminders.

6 Conclusions and future work

In this research, we implemented a location-based task reminder application for Android-based smartphones and tablets. Compared with the existing works, our application takes full advantage of the ubiquitous WLAN infrastructure to achieve better accuracy in indoor locationing. Furthermore, our application gives users a unified user experience because all the established personal-meaningful locations can be displayed on the Google Maps UI, regardless of the location types. Although the current version requires that indoor locations should be pre-visited by the users, this restriction can be easily lifted by incorporating the proposed operating models—telecom-assisted locationing and social-assisted locationing. With the telecom-assisted locationing operating model, the locationing service can become a value-added service for telecom operators with WLAN infrastructure. Furthermore, our work as a foundation of location-based services can be further extended to be used in many other scenarios which comprise both indoor and outdoor environments. We believe that the reminder application we developed can contribute to the promotion of individual well-being.

Currently, we are developing a new software version by incorporating the social-assisted operating model to boost the usability of our reminder application. At the same time, we will try to lower the power consumption of executing the reminder application. As described in Sect. 4.3, it is a viable solution to use the built-in accelerometer of the mobile device to detect the movement of users, so the application will do location sensing only when the user is moving. Finally, after the new version is completed, we will evaluate the usability of our system through the questionnaire on the users.

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