PhoneLets: offloading the phone off your phone for energy, cost and network load optimization

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ABSTRACT

This demo presents *PhoneLets*, a system to provide offloading of phone functionality of mobile cellular devices to a neighboring, potentially powered one. Phone offloading happens through providing access to cellular network subscriber credentials over a short-range wireless link and selecting the device that uses them to register to a particular network. As a result, we can use a single identity (SIM card) across multiple clients without increasing their connectivity costs, the load for the network handling large numbers of other subscribers and we are able to optimize mobile clients' energy consumption by leveraging powered *PhoneLets* or using them to share the energy consumption load across distributed nodes.

1. WHAT PHONELETS ARE

Not only the modern smartphone has more in common with a computer than a phone, but connectivity to the Internet as well as the increasing number of surrounding devices (the *Internet of Things*) is tipping the balance even further. Cellular networks, however, are just as important as they provide almost ubiquitous Internet connectivity around the world. There are multiple problems with cellular connectivity.

Firstly, it is relatively expensive for the users [4] and typically the end user needs to obtain a separate subscription for each of his devices connected to the cellular network, e.g. smartphone and tabled as well as broadband connectivity at home and at work, each with its underutilized caps and subscription fees.

Secondly, the price is largely driven by the high infrastructure costs which increase with the growing number of network users - the increasing number of connected, periodically communicating clients also increases cellular network load, in the extreme cases causing *signaling storms* [6] that can bring down an entire network.

Finally, energy consumption of always connected clients is high compared to short-range radio technologies. We have analyzed in the past power consumption of cellular communication [1] and careful communication optimization is necessary for battery-powered devices.

These factors all motivate the need for *PhoneLets*, a wireless system that enables offloading of cellular connectivity off a device to share subscriber identity between multiple devices, balance energy consumption of a group of devices or replace the cellular link with a short-range link to a powered device.

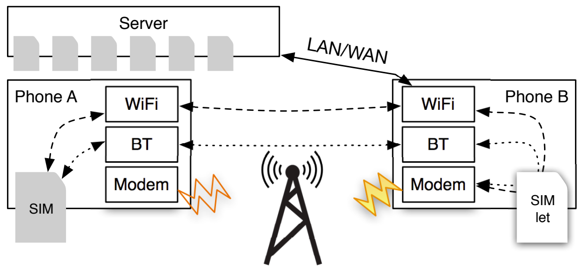

Figure 1: Architecture

PhoneLets enable the functionality by exploiting remote SIM functionality of existing hardware, whereby a cellular module accepts to exchange commands with a SIM/UICC module over a separate communication link rather than direct, physical connection. Some uses of such technology in the past have included automotive as well as electronic currency [5]. *PhoneLets* infrastructure establishes and manages secure communication channels between participating entities and allows a device to connect to a cellular network without a physical SIM module being present.

2. STRAWMAN DESIGN

The overall concept and system architecture is shown in Fig. 1. There are three types of entities: 1) mobile server, a mobile device which can share its SIM with other clients, 2) SIM server which may host and provide more sets of credentials over local or wide-area networks and 3) a mobile client which can use either of the methods.

Some of the components are only loosely coupled as our selected module supports the standardized remote SIM protocol version. The SIM on the other hand is a smartcard which can be interfaced with a standard smartcard reader, allowing for a relatively simple server design. Our work for this demo focused primarily on the client and SIM server design, and we are using off-the-

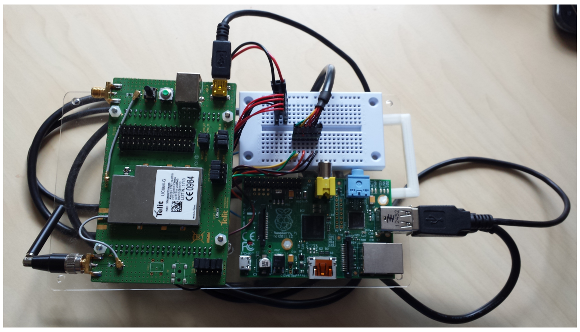

Figure 2: Client prototype

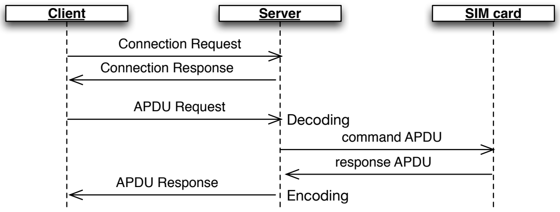

Figure 3: Communication sequence between client, server and remote SIM card

shelf hardware as the mobile server to show compatibility with the specification.

Our demo mobile client (Fig. 2) consists of a Telit UC864 cellular module connected to a raspberryPI as a controller, which also uses WiFi and BlueTooth dongles for local wireless connectivity. The controller runs a modified version of the Ofono open telephony stack and manages communication between the cellular module and multiple backends.

In addition to an unmodified Galaxy S4 running as the mobile server, we have also implemented a server that only interfaces with SIM cards through a smartcard reader. Once a connection is established to either backend (over BlueTooth to the mobile server or an encrypted network connection to the SIM server), the cellular module communicates with the remote card using standard Application Protocol Data Unit (APDU) messages (Fig. 3) and registers with the network. In our design we replace the BlueTooth communication channel with an arguably more secure option in that we use certificate-based authentication of both client and server, and strong encryption for all data exchange.

An important point is that we do not clone the SIM card and by design the system disables connectivity for one device before enabling it for another one to prevent multiple devices sharing the same credentials simultaneously. Therefore, only one device is connected to the cellular network and may share (*tether*) the connectivity to other devices over another channel. One cellular module is also only capable of being registered with one network, enforcing a strict one-to-one mapping.

One part of the network's security is that the network authenticates the subscriber for any major operation (e.g. placing or receiving phonecalls, establishing PDP context), therefore the link between the client and the corresponding server must be always maintained, simplifying security requirements.

Use case	Energy consumption (mA)
Idle - airplane mode	5
Ifle - BlueTooth	6
Idle - WiFi	8
Idle - 3G	10
Apps background - WiFi	27
BlueTooth SIM access	28
Apps background - 3G	40
WiFi tethering (idle)	80

Table 1: Energy consumption of the different usage scenarios of a mobile device.

3. ENERGY SAVING OPPORTUNITIES

A major motivation for using *PhoneLets* is reduced mobile client energy consumption. In this section we provide energy consumption of a few example scenarios using our early prototype. Since the client itself is not yet energy-optimized, i.e. does not use the full energy saving capabilities of the radio module and the controlling RaspberryPI is not meant for mobile uses, we focused on energy comparison of the mobile SIM server.

Energy consumption of a Samsung Galaxy S4 was measured[1] in a number of scenarios. The different values are presented in Table. 1[2]. Energy consumption of an idle device with applications in background (*Apps background*) considers a device with Google Apps, and Facebook installed and running in background and is consistent with our earlier observations [1]. We have only run the test on a single WiFi network, therefore we expect the figure to vary, especially because our used network is a public one with some background traffic affecting energy consumption of the device.

With the default implementation of Remote SIM Access over BlueTooth, the device consumes three times the amount of energy of an idle device connected to a 3G network, which is a high energy cost to pay, however the amount is comparable to that of an idle device with multiple applications running in background.

Since we have implemented SIM sharing over WiFi using our custom client, we verified that the BlueTooth version is unnecessarily wasteful - once the PhoneLet has registered to the network all communication with the SIM server (for authentication) happens on demand, *e.g.,* when a new phonecall is received after 30 minutes of no activity. We therefore expect energy consumption of an optimized implementation over WiFi to be very close to that of an idle WiFi channel. For comparison, energy consumption of WiFi tethering even with a single idle client is significantly higher than that of sharing

[1]Using Monsoon Power Monitor `http://www.msoon.com/LabEquipment/PowerMonitor/`

[2]Energy consumption provided as average current drawn because it is independent of current battery voltage

connectivity by offloading the phone functionality.

These are early results, and we have not yet been able to replace the BlueTooth channel for an Android device. Nevertheless, the results point to a potential use-case where a powered *PhoneLet* would be registered to the network on behalf of a WiFi-connected client with a considerable energy benefit. The benefit is further improved when network access is shared across multiple such devices and SIM access load is balanced across them. The approach is highly suitable for providing wide-area network connectivity for a larger number of devices where other options are not available.f

4. DEMO: WIRELESS SIM SHARING

To demonstrate the working prototype of the system, we show our client *PhoneLet* (Fig. 2), communicating with an off-the shelf mobile device or our SIM server to share their credentials for network registration in the following steps:

1. Make a phone call to the mobile server (phone) and show that it is ringing
2. Start sharing its SIM card with the client and show that the client is registered to the network with the same ID by making a phone call to it
3. Start using SIM card in the SIM server over WiFi and show that the client is registered to the network with a different ID by making a call to the other number.

In the three steps we show our prototype's ability to offload phone functionality off a phone - share subscriber credentials between multiple clients and select which one will be connected to the network.

5. DISCUSSION

If we only consider Internet connectivity, one could claim that *PhoneLets* can be replaced by simple tethering as supported by all modern smartphones, however it would not take into account battery consumption, resource savings from sharing a single connection or even the lower energy consumption of sharing the SIM card than sharing Internet connectivity as discussed above.

PhoneLets also offers management of part of an individual's ID - the phone number. In the past, multiple providers have offered a service in the past whereby multiple SIM cards would be associated with the number and multiple handsets would ring on an incoming call, *e.g.,* Google Voice, however it does not solve the problem of an increasing number of cellular clients and billing depends on the exact agreement with the service provider. One cellular network in UK has even offered a service to make phonecalls from tablets and laptops over WiFi to its users using a special app[3].

Reprogrammable SIM cards [3] and more recently embedded SIM [2] have been proposed as a solution to the provisioning problem for M2M communication. Essentially, it still uses physical secure element to store credentials, but provides mechanisms to manage them over the air, primarily for long lifetime applications where replacing SIM cards is difficult. The architecture, unsurprisingly, allows operators to retain full control over the credentials, including when new ones can be installed or old ones removed, necessitating centralized management and reducing flexibility on the client side.

Finally, questions that remain to be answered in future work include not only optimizations of the management and control protocols, but also the development of usage policies in multi-user environments and guaranteed isolation properties as well as adaptation of energy-aware routing protocols for distributed nodes.

6. SUMMARY

A peculiar feature of the smartphone has been the decreasing importance of it as a phone, instead becoming an Internet device. Subscription to cellular networks, however, becomes expensive and energy-consuming for multiple devices. *PhoneLets* is a system that allows for offloading of phone functionality of a cellular device, instead sharing a single subscription and therefore a single link amongst multiple devices in order to save costs and energy, decreasing cellular network infrastructure load at the same time.

More information and demonstration video is available via `phonelets.smart-e.org`.

Resource Requirements

(1) *Desk/table of approximately 2m, standard-width* to accommodate the demo. (2) *Two standard UK power sockets.* (3) *Two cellular network subscriptions (SIM cards)*, but are to be sources by the presenters, (4) WiFi AP for local communication. Setup time - up to an hour for connecting the demo up and verifying operation. Other equipment includes a laptop, two smartphones and the custom-build hardware described above.

7. REFERENCES

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