WiZi-Cloud: Integrating ZigBee into Mobile Phones for Energy Efficient Internet Access in WLANs

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1. INTRODUCTION

In this demo, we present WiZi-Cloud, a system that utilizes a dual WiFi-ZigBee radio on mobile phones and Access Points, supported by WiZi-Cloud protocols, to achieve ubiquitous connectivity, high energy efficiency, and real time intra-device/inter-AP handover. WiZi-Cloud system is completely transparent to user applications and needs no modification or configurations on the existing application settings. WiZi-Cloud runs on commodity hardware such as Android phones and OpenWrt capable access points. Our prototyped system provides reliable and extremely efficient Internet access across the WLAN with seamless handover among APs. We have successfully tested various applications over the ZigBee link, such as web browsing, VoIP, and streaming radio/video.
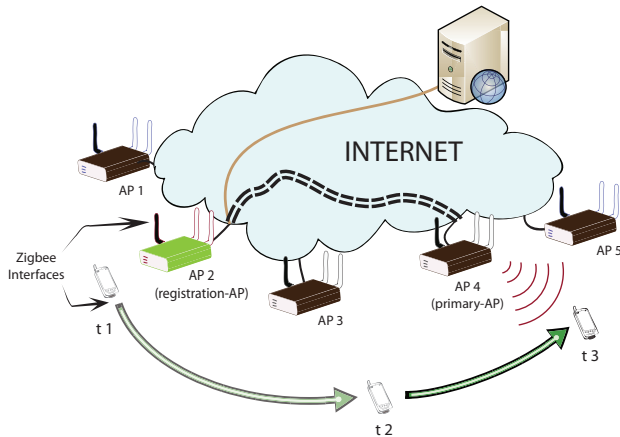

Figure 1: Dual radio mobile device moving across the WiZi-Cloud system

This project was motivated by the recent advance of smart phones. As hardware evolves, the ability of smart phones has gone far beyond the traditional telephony devices. Nowadays, smart phones are able to run a huge set of interesting applications and more importantly a lot of Internet based applications have become more and more popular for daily use. Increasing number of smart phone clients and applications demand reliable and ubiquitous Internet access.

Cellular network, by itself, has issues when serving a large volume of clients. In some urban areas, dropped calls can reach 30% [1–5]. The service quality and scalability of cellular systems is limited by fundamental constraints that the channel bandwidth is *shared* by all the clients of a base station. Therefore, scaling cellular networks requires a high density of base stations [9] which incurs a substantial cost in terms of sites construction and maintenance.

WiFi networks can significantly help scale wireless access, in cooperation with cellular technologies, especially within urban areas. WiFi networks have the advantage of operating over large licensing free bands and they have been very densely deployed in urban areas [7]. In addition, WiFi hardware and communication standards have been well developed for years. Therefore, WiFi networks are good candidates to alleviate cellular networks limitations.

However, today's integration of WiFi interface on mobile devices suffers from high energy consumption even in Power Save mode [6]. Particularly, our experiments show that WiFi is very inefficient when *no communication* is occurring or when the *traffic load is low*. This is especially limiting for applications that require continuous reachability such as VoIP but cannot afford the energy cost of periodic wakeups of WiFi.

Therefore, we propose WiZi-Cloud to solve the dilemma. We envision that future mobile phones will equip with multiple radios that can connect to the Internet, e.g., the current commercial mobile phones already have WiFi, Bluetooth [8], and GSM. The ZigBee link we propose will co-exist with other available network interfaces on the phone. Each of these network interfaces has different characteristics in terms of energy consumption, capacity, and coverage. The mobile phone should be able to determine which network interface to carry the packets according to its traffic demands and other system conditions. The ZigBee link we prototyped in WiZi-Cloud is an ultra low power link, but has a limited bandwidth compared to WiFi interface. It is particularly designed for mobile phone applications with low demand

traffic. Our extensive set of experiments demonstrate that for maintaining connectivity, WiZi-Cloud achieves more than a factor of 8 improvement in energy consumption in comparison with energy-optimized WiFi, and a factor of 5 in comparison with GSM. WiZi-Cloud has a better coverage than WiFi, and a low delay resulting in a good Mean Opinion Score (MOS) between 3.87 and 3.97 for a VoIP US cross-country communication.

2. SYSTEM DESIGN AND PROTOTYPE
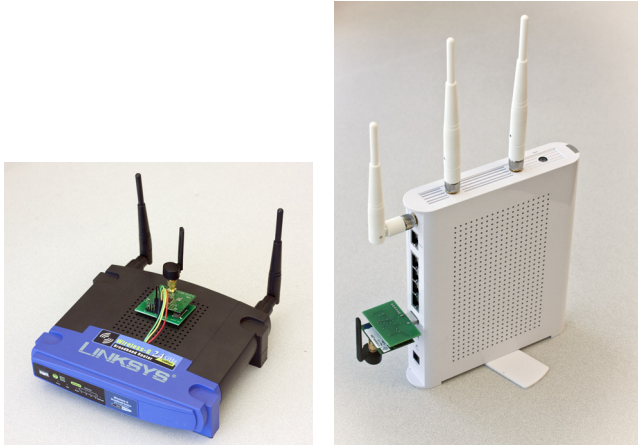
(a) With UART connection   (b) With USB connection

Figure 2: Router Setup in WiZi-Cloud

In WiZi-Cloud system, ZigBee devices are integrated into mobile phones and wireless routers to establish a new link for accessing the Internet. In such a network, each mobile phone can communicate with the AP via either WiFi or ZigBee interface. The power consuming Wi-Fi interface is kept off as much time as possible. When there is light traffic or no traffic between the client and AP, only the ultra low power ZigBee interface keeps active and delivers data packets. Even the ZigBee interface can be periodically turned off to further conserve energy if the traffic demand is allow. The Wi-Fi interface is turned on when the traffic load between the client and AP exceeds the capacity of the ZigBee link, or when multiple clients co-exist and link quality degrades due to increasing contention.

For hardware support, we have designed our boards to connect a ZigBee device to the Android phone and wireless routers through serial links. We have prototyped a hardware module, *WiZi-kit*, which integrates the ZigBee system-on-chip solution TI CC2530, on-board PCB antenna, and connectivity interfaces including UART and FTDI-USB. WiZi-kit can be attached to mobile devices and laptops as a small dongle. In addition, we have modified Android kernel to support establishing and utilizing the new ZigBee interface. Furthermore, we have designed a complete MAC layer protocol, called
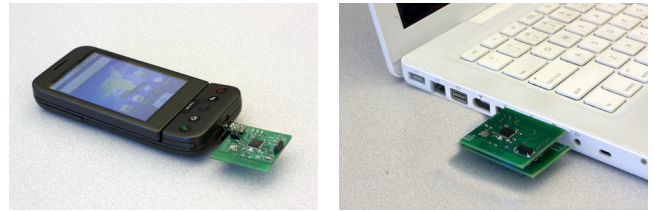
(a) Phone Dongle   (b) Laptop Dongle

Figure 3: WiZi-kit

WiZi software stack (Figure 4), to deliver IP packets between mobile phones and routers via ZigBee links, as well as to coordinate mobile phone and router to achieve intra-device ZigBe WiFi interface switching and inter-AP handover.
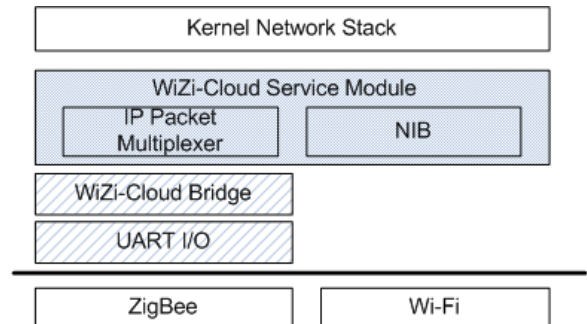

Figure 4: WiZi Software Stack

3. EVALUATION

Here we present some preliminary results of evaluation. In Table 1 we measure and compare the power consumptions of the WiFi interface and ZigBee interface in different transmission modes. As we can see,

WiFi			ZigBee		
PSM	TX	RX	Sleep	TX	RX
8.3	333.21	213.82	0.045	29.59	24.07

Table 1: WiFi and ZigBee Energy Consumption in Different Modes Measured on Android G1 (mA)

the ZigBee interface consumes much less energy during the transmission as well as the idle time.

Additionally, we have evaluated the network performance of WiZi-Cloud. The results are listed in Table 2. The system throughput is around 60∼70Kbps[1] which is sufficient for a lot of low-demand applications. We have further tested SIP traffic and observed very small de-

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[1]The TCP and UDP throughput value is the net throughput excluding headers overhead.

lay and jitter which results in good voice quality in the experiments.

TCP Throughput [1]Kbps)	60.2
UDP Throughput [1]Kbps)	70.4
Client-AP Ping RTT (ms)	61.2
SIP Traffic (GSM 8K Codec)	
Total bandwidth / Jitter	40 Kbps / 2.95 ms

Table 2: Preliminary Network Performance Measurement on Android G1

4. DEMONSTRATION

We will demonstrate the following features of WiZi-Cloud system to depict the typical user scenarios:

- **Client-AP Association:** The mobile phone enabled with WiZi-kit periodically scans the proximate WiZi-AP's. The user may choose to associate with certain WiZi-AP, and mobile phone switches from WiFi mode to energy efficient WiZi mode.

- **Popular Internet applications running on WiZi:** In WiZi mode, user may access the Internet through WiZi interface. We will demonstrate some popular mobile applications that do not require large bandwidth. The demo applications include: Instant Messenger, Email, Google Map, etc.

- **VoIP and Video call on WiZi:** We will demonstrate making VoIP call and Video call in WiZi mode with Skype and one of the most popular SIP clients on android, called Sipdroid.

- **WiZi client roaming:** As user is moving away from currently associated WiZi-AP, the WiZi client can seamlessly roam to another WiZi-AP without dropping the call.

The following equipments will be used in the demo

- T-Mobile G1 cell phone running Android 1.6;

- TI CC2530 ZigBee extension modules for G1 & USB dongle designed and prototyped in our lab;

- Linksys wireless routers running OpenWrt;

- Laptops.

We need a desk to place the equipments and around 15 minutes for setup and test. In addition, we need a power supply and the Internet access for this demo. This demo is eligible for the student demo competition and the lead student is Tao Jin from Northeastern University.

5. REFERENCES

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