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CERTIFICATE

This is to certify that the seminar II entitled *Ambient Backscatter*, submitted by

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in partial fulfillment of the degree of *Bachelor of Engineering* in *Computer Engineering* has been satisfactorily carried out under my guidance as per the requirement of North Maharashtra University, Jalgaon.

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Abbreviations

API	Application Programming Interface
CSS	Cascading Style Sheets
EFL	Enlightenment Foundation Libraries
EULA	End User Licence Agreement
GPS	Global Positioning System
HTML	Hyper Text Markup Language
IDE	Integrated Development Environment
LiMo	Linux Based Mobile Platform
LSM	Linux Security Module
NFC	Near Field Communication
OBS	Open Build Services
OSP	Open Service Platform
SDK	Software Development Kit
SLP	Samsung Linux Platform
SMACK	Simple Mandatory Access Control Kernel
TSG	Technical Steering Group

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Abstract

We present the design of a communication system that enables two devices to communicate using ambient RF as the only source of power. Our approach leverages existing TV and cellular transmissions to eliminate the need for wires and batteries, thus enabling ubiquitous communication where devices can communicate among themselves at unprecedented scales and in locations that were previously inaccessible. To achieve this, we introduce ambient backscatter, a new communication primitive where devices communicate by backscattering ambient RF signals. Our design avoids the expensive process of generating radio waves; backscatter communication is orders of magnitude more power-efficient than traditional radio communication. Further, since it leverages the ambient RF signals that are already around us, it does not require a dedicated power infrastructure as in traditional backscatter communication. To show the feasibility of our design, we prototype ambient backscatter devices in hardware and achieve information rates of 1 kbps over distances of 2.5 feet and 1.5 feet, while operating outdoors and indoors respectively. We use our hardware prototype to implement proof-of concepts for two previously infeasible ubiquitous communication applications.

Chapter 1

Introduction

1.1 Introduction

Small computing devices are increasingly embedded in objects and environments such as thermostats, books, furniture, and even implantable medical devices . A key issue is how to power these devices as they become smaller and numerous; wires are often not feasible, and batteries add weight, bulk, cost, and require recharging or replacement that adds maintenance cost and is difficult at large scales . In Ambient Backscatter, we ask the following question: can we enable devices to communicate using ambient RF signals as the only source of power? Ambient RF from TV and cellular communications is Communication between two battery-free devices. One such device, Alice, can backscatter ambient signals that can be decoded by other ambient backscatter devices. To legacy receivers, this signal is simply an additional source of multi-path, and they can still decode the original transmission. widely available in urban areas (day and night, indoors and outdoors). Further, recent work has shown that one can harvest tens to hundreds of microwatts from these signals . Thus, a positive answer would enable ubiquitous communication at unprecedented scales and in locations that were previously inaccessible. Designing such systems, however, is challenging as the simple act of generating a conventional radio wave typically requires much more power than can be harvested from ambient RF signals . In this paper, we introduce ambient backscatter, a novel communication mechanism that enables devices to communicate by backscat- tering ambient RF. In traditional backscatter communication (e.g., RFID), a device communicates by modulating its reflections of an incident RF signal (and not by generating radio waves). Hence, it is orders of magnitude more energy-efficient than conventional radio communication. Ambient backscatter differs from RFID-style backscatter in three key respects. Firstly, it takes advantage of existing RF signals so it does not require the deployment of a special-purpose power infrastructurelike an RFID readerto transmit a high-power (1W) signal to nearby devices. This avoids installation and maintenance costs that may make such a system impractical, especially if the environment is outdoors or spans a large area. Second, and related, it has a very small environmental footprint because no additional energy is consumed beyond that which is already in the air. Finally, ambient backscatter provides device-to-device communication. This is unlike traditional RFID systems in which tags must talk exclusively to an RFID reader and are unable to even sense the transmissions of other nearby tags. To understand ambient backscatter in more detail, consider two nearby battery-free devices, Alice and Bob, and a TV tower in a metropolitan area as the ambient source, as shown in Fig. 1. Suppose Alice wants to send a packet to Bob.

1.2 Summary

In this chapter,whole introduction of Ambient Backscatter is given. To achieve this, we introduce ambient backscatter, a new communication primitive where devices communicate by backscattering ambient RF signals.

Chapter 2

Literature Survey

Ambient backscatter differs from RFID-style backscatter in three key respects. Firstly, it takes advantage of existing RF signals so it does not require the deployment of a special-purpose power infrastructurelike an RFID readerto transmit a high-power (1W) signal to nearby devices. This avoids installation and maintenance costs that may make such a system impractical, especially if the environment is outdoors or spans a large area. Second, and related, it has a very small environmental footprint because no additional energy is consumed beyond that which is already in the air. Finally, ambient backscatter provides device-to-device communication. This is unlike traditional RFID systems in which tags must talk exclusively to an RFID reader and are unable to even sense the transmissions of other nearby tags.

Section 2.1 describes Background and History.Tizen various versions is describe in section 2.2.Relate work of Tizen Operating System is described in section 2.3.Finally last section is summary.

2.1 Background

Ambient backscatter is a new form of communication in which devices can communicate without any additional power infrastructure (e.g., a nearby dedicated reader). An ambient backscattering device reflects existing RF signals such as broadcast TV or cellular transmissions to communicate. Since the ambient signals are preexisting, the added cost of such communication is negligible. Designing such devices, however, is challenging for three main reasons: First, the ambient signals are random and uncontrollable. Thus, we need a mechanism to extract the backscattered information from these random ambient signals. Second, the receiver has to decode these signals on a battery-free device which significantly limits the design space by placing a severe constraint on the power requirements of the device. Third, since there is no centralized controller to coordinate communications, these devices need to operate a distributed multiple access protocol and develop functionalities like carrier sense.

In the rest of this section, we describe how our design addresses the above challenges.

This section describes the background of Ambient Backscaterr.To achieve this, we introduce ambient backscatter, a new communication primitive where devices communicate by backscattering ambient RF signals.

2.2 History

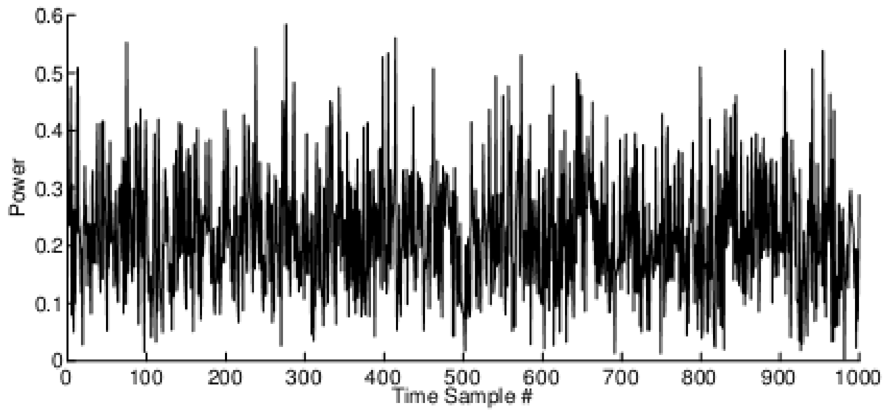
Ambient backscatter uses existing radio frequency signals, such as radio, television and digital telephony, to transmit data without a battery or power grid connection. Each such device uses an antenna to pick up an existing signal and convert it into tens to hundreds of microwatts of electricity.

This section describe the history of Ambient Backscatter. In the next section we describe the related working of AmBackscatter.

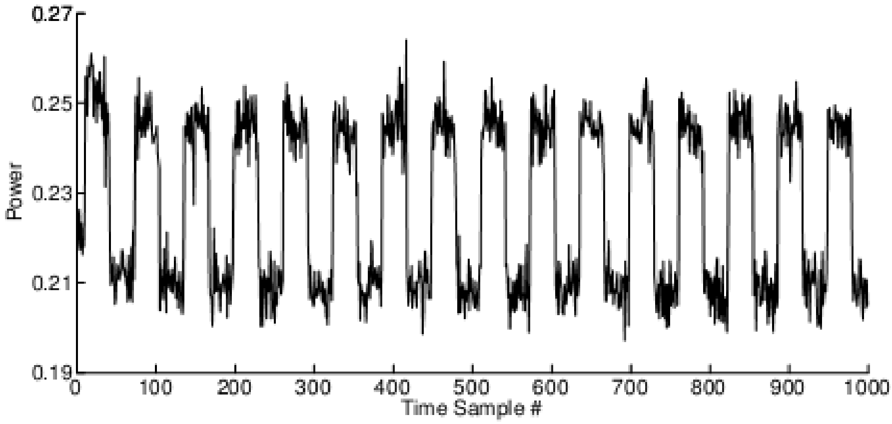
2.3 Related Work

The design of our ambient backscattering transmitter builds on conventional backscatter communication techniques. At a high level, backscattering is achieved by changing the impedance of an antenna in the presence of an incident signal. Intuitively, when a wave encounters a boundary between two media that have different impedances/densities, the wave is reflected back . The amount of reflection is typically determined by the difference in the impedance/density values. This holds whether the wave is a mechanical wave that travels through a rope fixed to a point on a wall or an electromagnetic wave encountering an antenna. By modulating the electrical impedance at the port of the antenna one can modulate the amount of incident RF energy that is scattered, hence enabling information to be transmitted. To achieve this, the backscatter transmitter includes a switch that modulates the impedance of the antenna and causes a change in the amount of energy reflected by the antenna. The switch consists of a transistor connected across the two branches of the dipole antenna. The input signal of the switch is a sequence of one and zero bits. When the input is zero, the transistor is off and the impedences are matched, with very little of the signal reflected.When the switch input signal is one, the transistor is in a conducting stage which shorts the two branches of the antenna and results in a larger scattered signal amplitude. Thus, the switch toggles between the backscatter (reflective) and non-backscatter (absorptive) states to convey bits to the receiver. We note the following about our design: Firstly, the communication efficiency is high when the antenna topology is optimized for the frequency of the ambient signals. Our implementation uses a 258 millimeter dipole antenna, optimized for a 50 MHz subset (in this case, from 515-565 MHz) of the UHF TV band. Other antenna topologies such as meandered antennas and folded dipoles can result in smaller dimensions, and further design choices can be made to increase the bandwidth of the antenna in order to make it capable of utilizing a larger frequency band. However, exploring this design space is not within the scope of this paper. Secondly, RF switches can have a large difference between their conducting and non-conducting impedance values, but only in the specific frequency range that they are designed for. For example, using a switch that is optimized for use in RFID tags that operate in 915 MHz would not be optimal for ambient backscatter of lowerfrequency TV signals. Thus, the ambient backscattering transmitter should select a switch that is optimal for the operational frequencies of the ambient signals. Finally, the switches and antennas are not designed to specifically backscatter and receive on a particular TV channel. For example, in ATSC, each TV channel has a 6 MHz bandwidth and different TV channels are typically allocated to adjacent non-overlapping frequencies. Since ambient backscattering devices backscatter all these signals, they do not require fine tuning for each frequency and can work as long as there are TV transmissions on at least one of the frequinces.

Designing an ambient backscatter receiver is challenging for two main reasons: First, ambient signals already encode information and hence backscattering additional information over these signals can be difficult. Second, the backscattered information should be decodable on an ultra-low-power device without using powerhungry hardware components such as ADCs and oscillators. To address these challenges, we first show how one can extract the backscattered information from the ambient signals using a conventional digital receiver.We then describe an ultra-low-power receiver design that uses only analog components. Ambient signals like TV and cellular transmissions encode information and hence are not controllable. To illustrate this, shows an example of the time-domain ambient TV signal captured on a USRP operating at 539 MHz. For comparison, plots the typical time domain signal received on a USRP from an RFID reader transmitting at 915 MHz. While the traditional RFID transmission is a constant amplitude signal, the ambient TV signal varies significantly in its instantaneous power. This is expected because the captured ATSC TV signals encode information using 8VSB modulation, which changes the instantaneous power of the transmitted signal. Thus, the receiver should be capable of decoding the backscattered signals in the presence of these fast changing signals. In this section, we describe our mechanism assuming a powerful digital receiver that samples the analog signal and performs demodulation and decoding in the digital domain. In the next section, we extend it to work using only analog components. Our key insight is that if the transmitter backscatters information at a lower rate than the ambient signals, then one can design a receiver that can separate the two signals by leveraging the difference in communication rates. Specifically, ambient TV signals encode information at a bandwidth of 6MHz, so if we ensure that the transmitter backscatters information at a larger time-scale than 6 MHz, then the receiver can extract the backscattered information using averaging mechanisms. Intuitively, this works because the wideband ambient TV signals change at a fast rate and hence adjacent samples in TV signals tend to be more uncorrelated than the adjacent samples in the backscattered signals.



(a) Original TV plus Backscatter signal



(b) Signal After Averaging

Figure 2.1: Comparison of the incident signal on a backscattering transmitters antenna in both (a), ambient backscatter, and (b), conventional RFID.

We apply the above mechanism to the ambient ATSC TV signals. Specifically, we set our ambient backscattering transmitter to transmit an alternating sequence of ones and zeros at a rate of 1kbps. Fig. 5(a) plots the received signal on an USRP that is placed one foot from the transmitter. Fig. 5(b) plots the effect of averaging every 100 received samples. As the figure shows, averaging reduces the effect of the fast-varying ambient TV signals. Further, the receiver can now see two average power levels which it can use to decode the backscattered information. We note that ambient backscatter can either increase or decrease the average power of the received signal. Specifically, the channel, is a complex number and hence —1 + — can be either less than or greater than one. This means that a zero bit can be either a lower power than the average power, P, in the TV signal, or can have a higher power than the average. Intuitively, this is because the additional multi-path created by the backscattering transmitter can either constructively or destructively interfere up with the existing signal.We use differential coding to eliminate the need to know the extra mapping between the power levels and the bits.

2.4 Summary

In this chapter,background and history of Ambient Backscatter and describe the related working of Ambient Backscatter. Related working of Ambient Backscatter with its Transmitter and Receiver.

Chapter 3

Methodology

We implement our prototype on a 4-layer printed circuit board (PCB) using off-the-shelf circuit components. The PCB was designed using Altiumdesign software and wasmanufactured by Sunstone Circuits. A total of 20 boards were ordered at a cost of 900. The circuit components were hand-soldered on the PCBs and individually tested which required a total of 50 man-hours. As shown , the prototype uses a dipole antenna that consists of two 2 sections of 5.08 in long 16 AWG magnetic copper wire. The prototypes harvesting and communication components are tuned to use UHF TV signals in the 50 MHz band centered at 539 MHz4.

Section 3.1 theoretically describes Prototype Implementation of Ambient Backscatter.Finally last section is Summary.

3.1 Prototype Implementation

We implement our prototype on a 4-layer printed circuit board (PCB) using off-the-shelf circuit components. The PCB was designed using Altiumdesign software and wasmanufactured by Sunstone Circuits. A total of 20 boards were ordered at a cost of 900. The circuit components were hand-soldered on the PCBs and individually tested which required a total of 50 man-hours. As shown , the prototype uses a dipole antenna that consists of two 2 of 5.08 in long 16 AWG magnetic copper wire. The prototypes harvesting and communication components are tuned to use UHF TV signals in the 50 MHz band centered at 539 MHz4. The transmitter is implemented using the ADG902 RF switch connected directly to the antenna. The packets sent by the transmitter follow the format shown in Fig. 7. Further, it is capable of transmitting packets at three different rates: 100 bps, 1 kbps, and 10 kbps. We also implement both preamble correlation and energy detection in digital logic to perform carrier sense at the transmitter. Our implementation currently does not use error correction codes and has a fixed 96-bit data payload with a 64-bit preamble. Our implementation of the receiver circuit, described in 3.3, uses TS881 [8], which is an ultra-low-power comparator. The output of the comparator is fed to the MSP430 microcontroller which performs preamble correlation, decodes the header/data and verifies the validity of the packet using CRC. We implement different bit rates by setting the capacitor and resistor values, R1, R2, C1, and C2 in Fig. 6, to (150 k , 10 M , 27 nF, 200 nF) for 100 bps, (150 k , 10 M , 4.7 nF, 10 nF) for 1 kbps, and (150 k , 10 M , 680 pF, 1 F) for 10 kbps. Table 1 compares the power consumption of the analog portion of our transmitter/receiver with that of the WISP, an RFID-based platform[33]. The table shows that the power consumption numbers for ambient backscatter are better than theWISP platform, and almost negligible given the power budget of our device. This is because ambient backscatter operates at lower rates (10 kbps) when compared to existing backscatter systems like the WISP, which operates at 256 kbps. So, we were able to optimize the power consumption of our prototype and achieve lower power consumption values. Our prototype also includes two sensing and I/O capabilities for our proof-of-concept applications that are controlled by the microcontroller: low-power flashing LEDs and capacitive touch buttons implemented on the PCB using a copper layer. However, these sensors as well as the microcontroller that drives them can significantly add to the power drain. In fact, in the smart card application (see 7.1), the transmit modulator consumed less than 1total system power, while the demodulator required another; demonstrating that ambient backscatter significantly reduces the communication power consumption. The power management circuitry required an additional 8 of the total power. Flashing the LEDs and polling the touch sensors at the intervals used in 7.1 consumed 26 of the total power. The remaining 64 was consumed by the microcontroller.5 We note that in scenarios where the TV signal strength is weak, our prototype uses duty cycling to power the sensors and the microcontroller. Specifically, when the prototype is in the sleep mode, it only harvests RF signals and stores it on a storage capacitor. Once enough energy has been accumulated on the capacitor, it goes into active mode and performs the required operations. In hardware, the duty cycle is implemented by a voltage supervisor that outputs a high digital value (indicating active mode) when the voltage on the storage capacitor is greater than 1.8 V. 5We note that the high power consumption for the digital circuit (i.e., microcontroller) is an artifact of our prototype implementation. Specifically, the microcontroller is a general-purpose device that is not typically used in commercial ultra-low-power devices. Instead, commercial systems use Application-Specific Integrated Circuits (ASICs) that can consume orders of magnitude less power than general-purpose solutions [25, 33]. In ASIC-based low-power devices, the power consumption of the analog components often dominates that of the digital circuit [10].

3.2 Summary

In this chapter,theoretically describe the prototype of implementation of Ambient Backscatter.The transmitter is implemented using the ADG902 RF switch connected directly to the antenna.

In the next chapter Discussion of Application's, Future scope and future Applications of Ambient Backscatter .

Chapter 4

Discussion

Ambient backscatter enables devices to communicate using only ambient RF as the source of power. We believe that this opens up a new form of ubiquitous communication where devices can communicate by backscattering ambient RF signals without any additional power infrastructure. In this section, we demonstrate proof-of-concepts for two applications that are enabled by ambient backscatter: a bus card that can transfer money to other cards anywhere and a grocery store application where item tags can tell when an item is placed in a wrong shelf. These proof-of-concepts are similar to existing RFID applications, but differ in ways that were previously impossiblethey are able to function anywhere and with no maintenance.

4.1 Observation of Ambient Backscatter

We evaluate our prototype design in the Seattle metropolitan area in the presence of a TV tower broadcasting in the 536-542 MHz range. We ran experiments at six total locations to account for attenuation of the TV signal and multipath effects in different environments. The TV signal power in the 6MHz target band for the given locations ranged:

- Location 1 (Indoor and near): Inside an apartment 0.31 mi away from the TV tower. The apartment is on the seventh floor of a large complex with 140 units and is located in a busy neighborhood of a metropolitan area.
- Location 2 (Indoor and far): Inside an office building 2.57 mi away from the TV tower. The office tested is on the sixth floor of the building.
- Location 3 (Outdoor and near): On the rooftop of the above apartment.
- Location 4 (Outdoor and far): On the rooftop of the above office building.
- Location 5 (Outdoor and farther): On a street corner 5.16 mi away from the TV tower.

- Location 6 (Outdoor and farthest): On the top level of a parking structure 6.50 mi away from the TV tower.

4.2 Applications of Ambient Backscatter

- Embed into building, bridges, infrastructure to alert Engineers about potential weaknesses
- Because they are require no batteries, can be imbedded into materials like concrete
- Example from video: Devices built into couches and can send an alert to the users phone that they left their keys on the couch or table.
- Example from Grocery store:Ambient Backscatter devices can be used for inventory systems. To alert when stock needs refilled.Can also help customers locate items by transmitting the location to a users phone
- Transfers are currently slow More research needed to speed up transmission Can be possible to improve this using different signal strengths

Chapter 5

Conclusion

As devices get smaller, providing room for wires and batteries becomes more expensive Came up with a novel concept that requires no batteries or wires . Backscatter: A reflection of waves, or signals back to direction from which they came A new communication primitive where devices communicate by backscattering ambient RF signals No batteries. Computers were tethered by their power cords and were rendered useless without a nearby power outlet. Wireless communication combined with battery packs liberated these devices for short periods of time so that they could compute and communicate, untethered, as long as their batteries were occasionally recharged or replaced.

Bibliography

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