ALMOND

Acoustic Localization for Mobile Open-Source Network Deployment

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Outline

- Acoustic Localization
- Motivation
- Setup and Processing
- Signal Detection
- Time Synchronization
- Results
- Conclusions and Future Work

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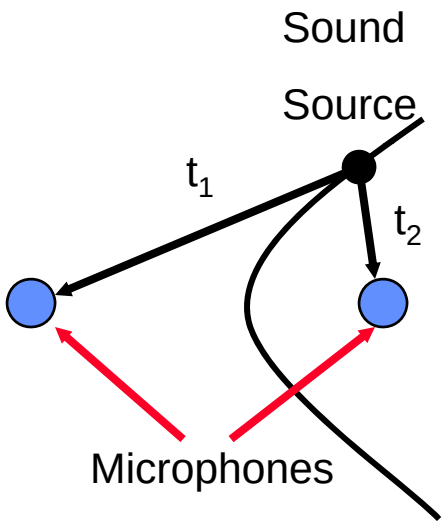
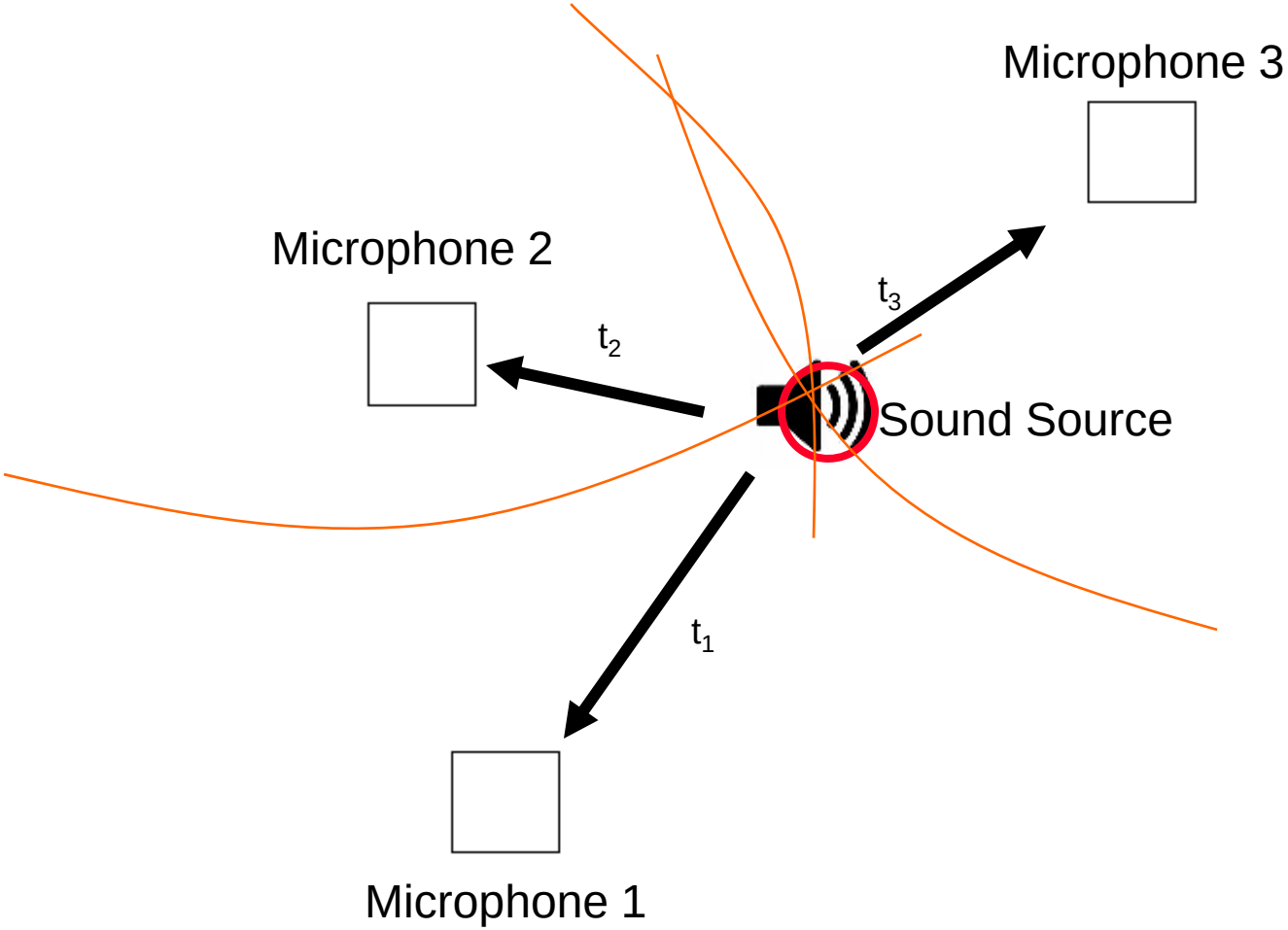
Acoustic Localization

- **Determining the location of a sound source by using an array of sensors**
- **The difference in arrival times is used to calculate an approximate position of the sound source**



Time Differences of Two Microphones Result in a Hyperbola

Acoustic Localization



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Motivation

Mobile phones are readily available and have lots of functionality

- **GPS**
- **Camera**
- **Wireless Communication**
- **Microphone**
- **Operating System**

Phone architecture suitable for many applications

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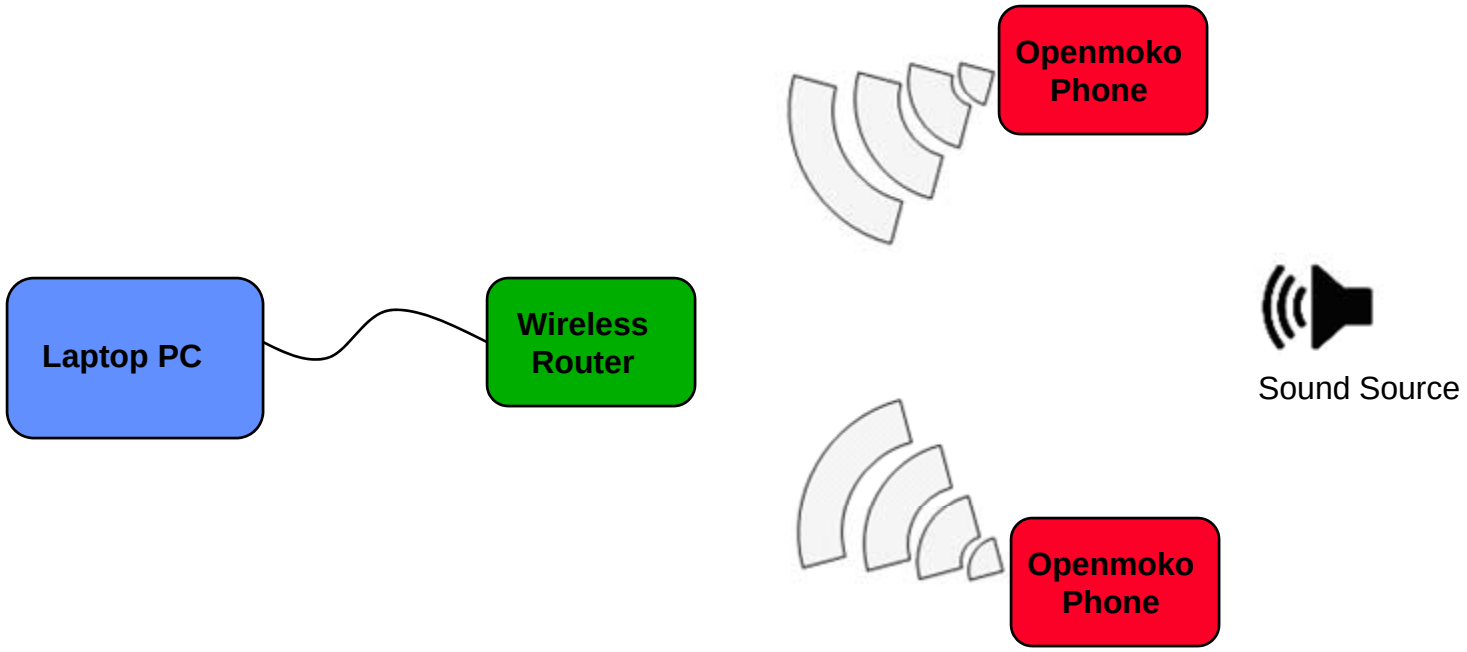
Setup and Challenges

Computation

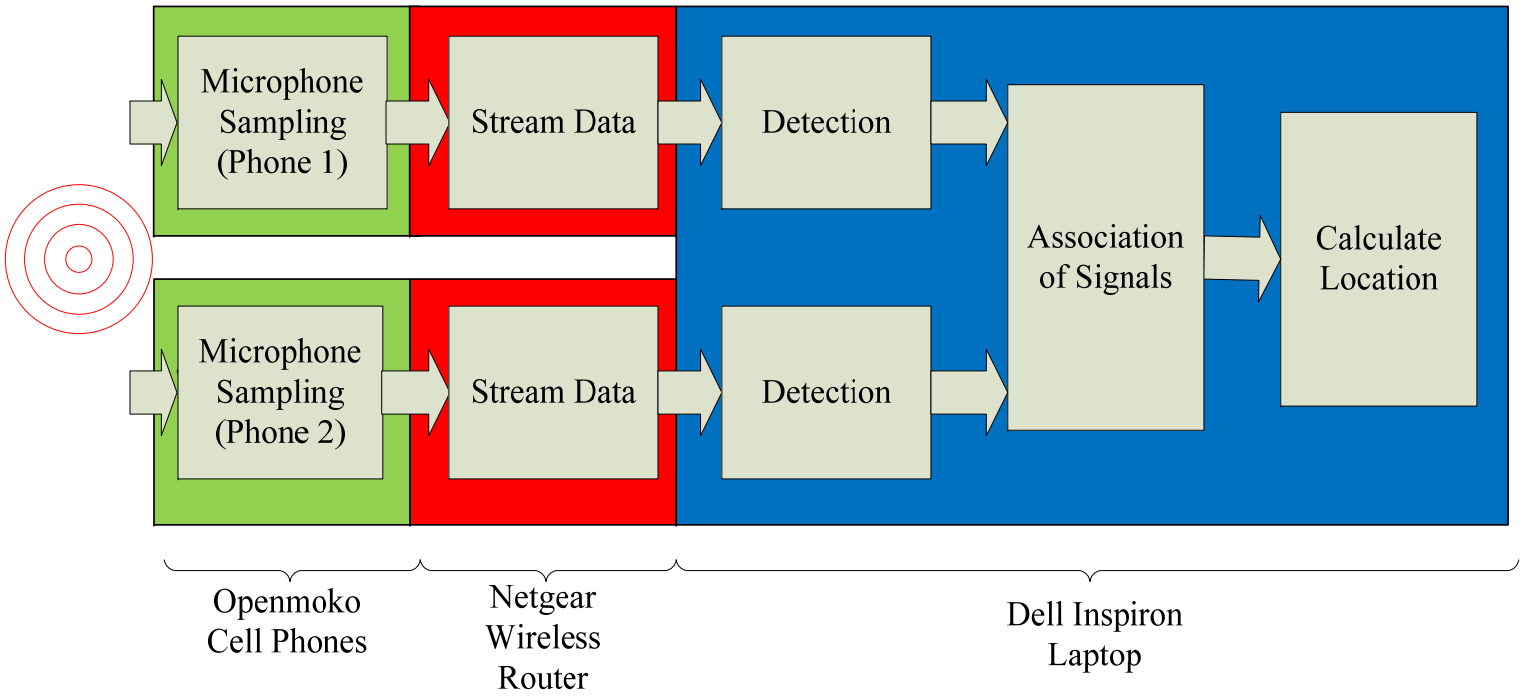
Signal Detection

Time Synchronization



Processing Overview

Phones are Unable to Perform Necessary Processing



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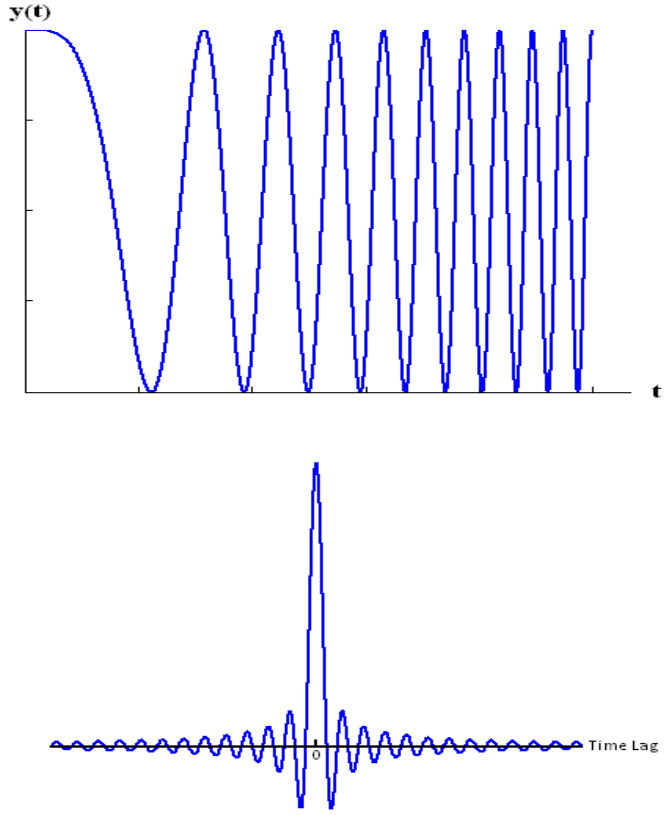
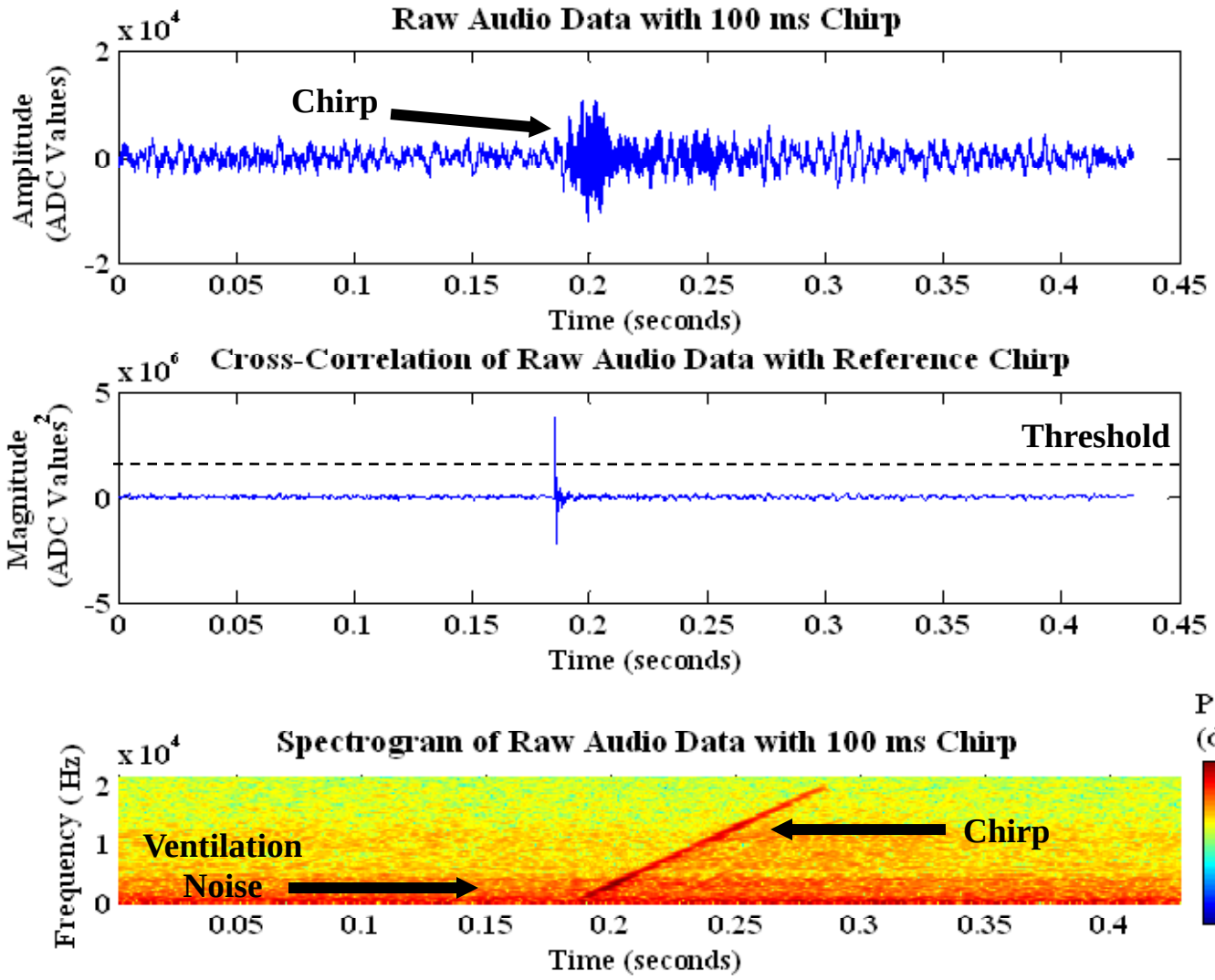
Signal Detection

- **Chirps are signals that can be easily detected because of their unique characteristics**
- **They can be detected using a cross correlation**
- **Cross correlation of two similar chirps will create a peak**



Detection of Chirps is Simple

Signal Detection



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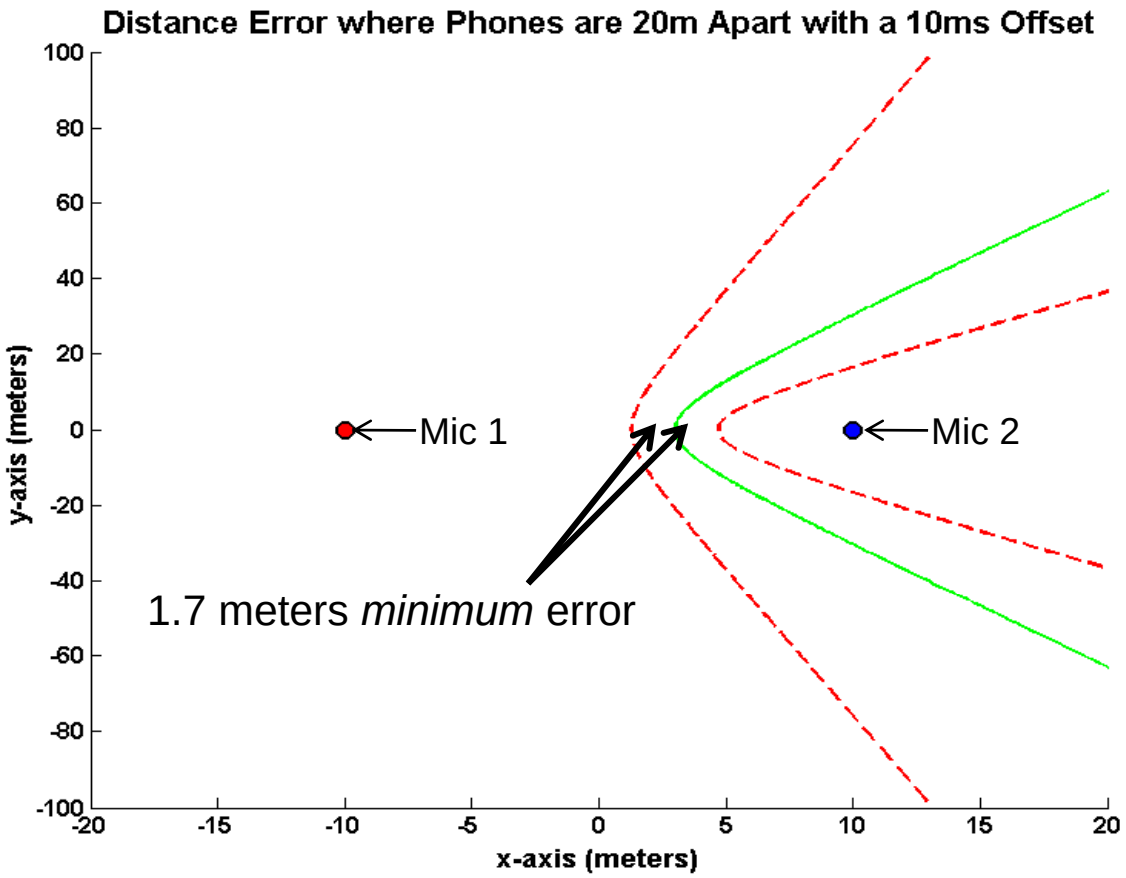
Time Synchronization

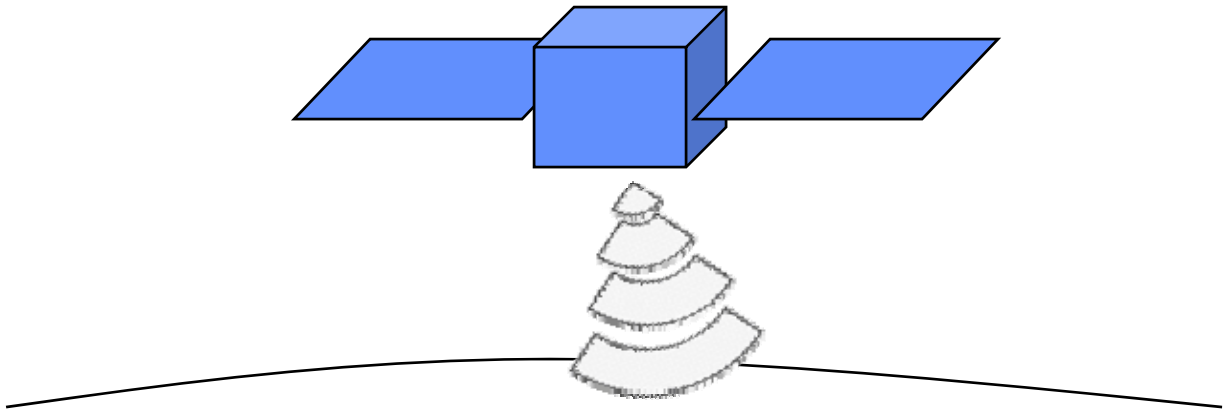
Time synchronization errors are the greatest source of positional error



GPS Time Synchronization

Global Positioning System (GPS)

- Precision of 100 nanoseconds 99% of the time
- Can be used with Network Time Protocol (NTP) to discipline the phones' clocks



Openmoko hardware is not built to take advantage of precise GPS timing

Time Synchronization Methods

Network Broadcast Signal

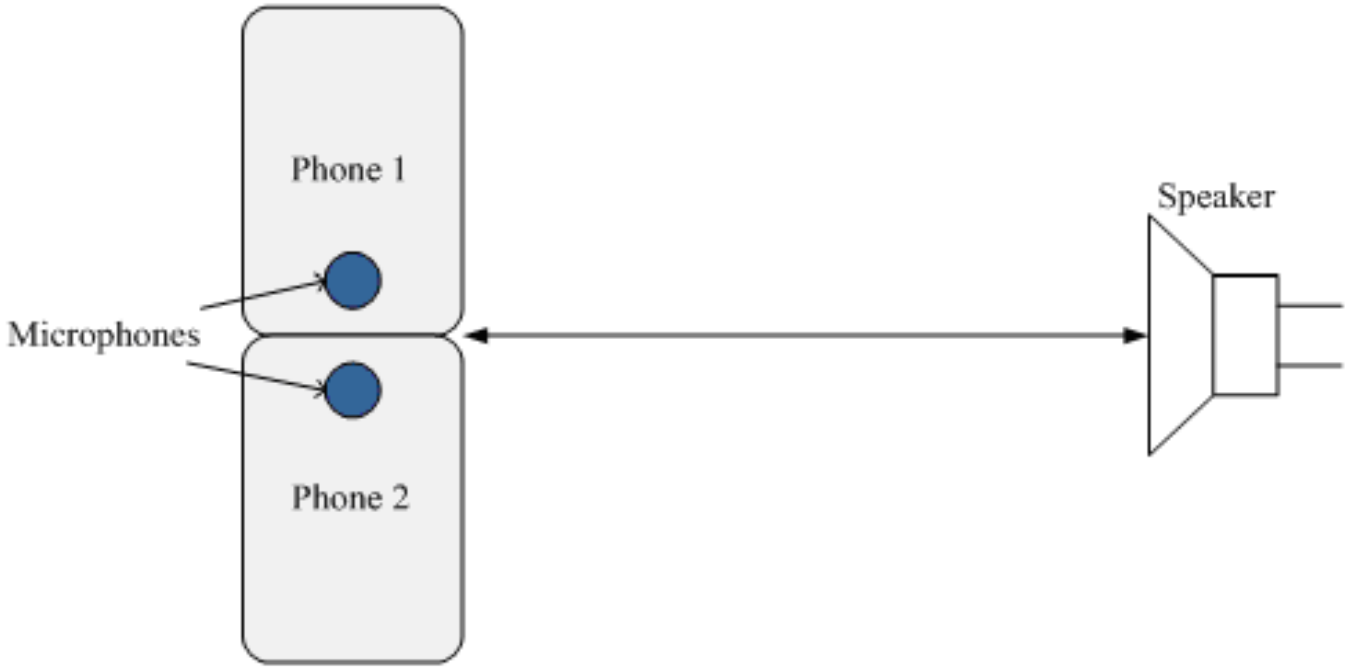
- A message is broadcasted across the network
- When the phones receive the message time is reset
- Both phones receive the signal at the same time resulting in synchronization

Calibration Chirp

- An initial chirp is produced for calibration
- The time offset from the two phones is calculated based on known positions
- Future detection calculations adjust time based on the offset

Time Synchronization Test Setup

If the phones are equidistant from the sound source, the time difference of arrival should be zero



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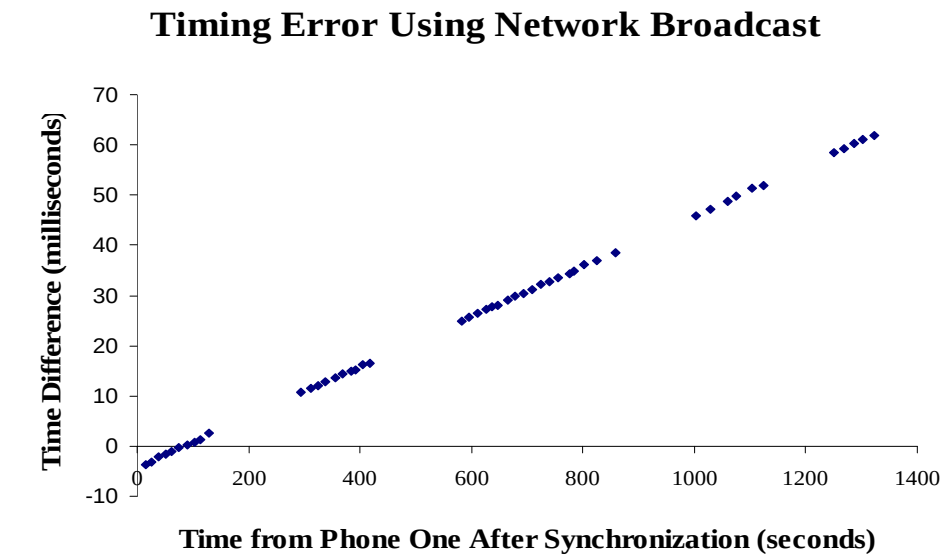
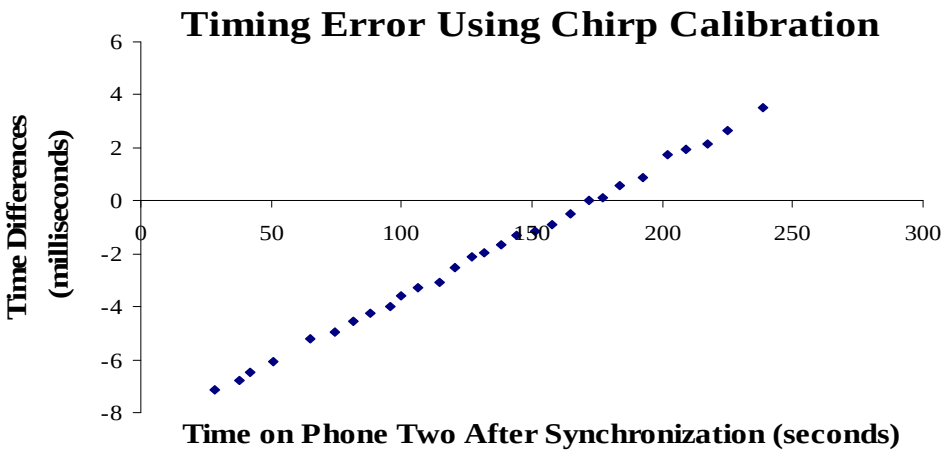
Results


Timing Error Using Network Broadcast
Time Difference (milliseconds)
70
60
50
40
30
20
10
0
-10
0
200
400
600
800
1000
1200
1400
Time from Phone One After Synchronization (seconds)


Timing Error Using Chirp Calibration
Time Differences (milliseconds)
6
4
2
0
-2
-4
-6
-8
0
50
100
150
200
250
300
Time on Phone Two After Synchronization (seconds)

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Conclusions and Future Work

- Sound detection is possible with cell phones
- With the current setup, time can be synchronized to within 10 milliseconds for several minutes
- A more refined method of time synchronization would probably be required for future applications
  - Correction for drift rate
  - More precise calibrations
  - Periodic synchronizations
- Bandwidth can be saved by performing processing on more capable phones