CountMe! - Low Cost Crowd Counting using Audio Tones

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1. INTRODUCTION

With mobile devices becoming ubiquitous, collaborative applications have become increasingly pervasive. In these applications, there is a strong need to obtain a count of the number of mobile devices present in an area, as it closely approximates the size of the crowd. Ideally, a crowd counting solution should be easy to deploy, scalable, energy efficient, be minimally intrusive to the user and reasonably accurate. Existing solutions using data communication or RFID do not meet these criteria. We propose a crowd counting solution based on audio tones, using the microphones and speaker phones that are commonly available on most phones, addressing the above criteria.

2. SYSTEM DESIGN

We propose a simple algorithm called **Unique Frequency** approach and more advanced duplicate in-sensitive, **probabilistic counting** algorithm which is similar to those used in RFID counting. The unique frequency approach associates a single unique frequency as id for each mobile device. Mobile devices also listen to frequency tones emitted by other devices, stores and plays the tones simultaneously and periodically. The count is the number of unique frequencies in the emitter list. Probabilistic Counting (PC) algorithm is similar to the unique frequency approach, except that, each mobile has an id (geometric distributed ids). R is the bit position of the rightmost zero in the id(bit-pattern). Each frequency tone represents a bit in the bit-pattern. For PC algorithm, counting is performed multiple times and average value E(R) obtained. The final count N is calculated as $N = 1.2897 * 2^{E(R)}$ (see [1]).

3. IMPLEMENTATION

CountMe (deployed on Android 2.2 and above) has four components as shown in Figure 1: **FFT Analyzer** obtains the frequency spectrum of the audio sample, **Peak Finder** identifies the peaks in high Frequency spectrum (15KHz - 22KHz), **Counter** aggregates the count (using above mentioned algorithms), and, **Tone Generator** simultaneously transmits multiple high frequency tones.

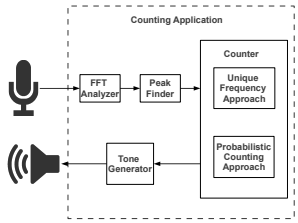
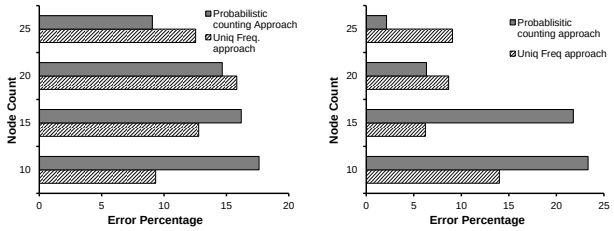
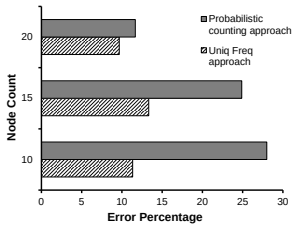


Figure 1: CountMe: implementation architecture



(a) Indoor(Quiet) (b) Outdoor(Bus stop)



(c) Outdoor(Bus)

Figure 2: Error percentage results for three representative environments

4. RESULTS

Figures 2(a),2(b),2(c) show the accuracy results for 25 smart phones. The results indicate up to 90% accuracy and 61%-82% reduction in power consumption compared to WiFi or 3G technology. Simulation results show that PC approach scales up to 2000 nodes. Also, the use of high frequency tones is minimally intrusive.

5. DEMONSTRATION REQUIREMENTS

Space & Power for 1 laptop and 1 WiFi AP, no network access & board for our poster.

6. REFERENCES

[1] Qian, C., Ngan, H., and Liu, Y. Cardinality estimation for large-scale rfid systems. *PerCom'08*, 2008.