Ears on the Ground: An Acoustic Streaming Service in Wireless Sensor Networks

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The emergence of wireless sensor networks provides a great opportunity for fine grained sensing and tracking, which means we have knowledge about what happens and where the event is. Moreover, with acoustic sensors we have the possibility of picking up sound anywhere in the network in real-time. When an interesting event happens, we may want to listen to the sound related to the event. This is a valuable property especially in military surveillance applications [2], because we can obtain extra information about the enemy by monitoring their conversations in real-time.

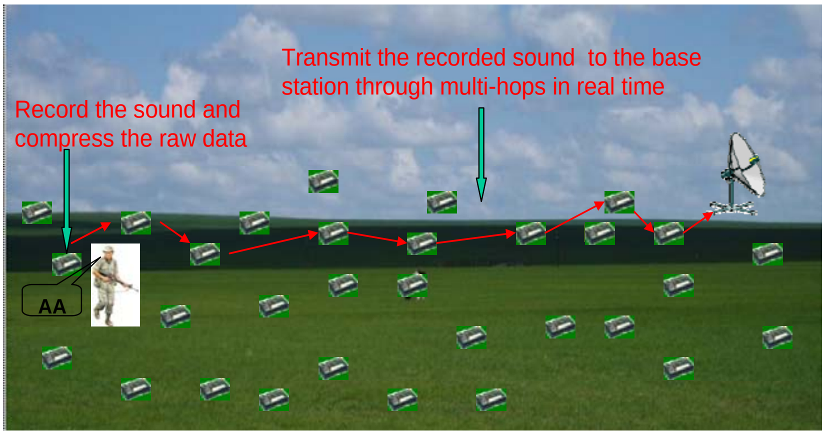

Figure 1: An application scenario for an acoustic streaming service

Figure 1 shows an application scenario where an acoustic streaming service can be applied. When an interesting conversation appears in the network, the node nearest to it is initiated to record the sound and compress the raw data. The compressed data is sent back to the base station through multiple hops in real-time. In this way, the people in the back end can monitor and analyze the enemy's conversation in real-time.

However, the limitations of current sensor motes make the problem challenging. For example, Micaz motes are equipped with a 7.37MHz CPU, 4KB memory and 250Kbps radio. The limited computation abilities prevent the motes from using complex compression schemes, such as Mixed-Excitation Linear Predictive (MELP) and Linear Predictive Coding (LPC), if no extra Digital Signal Processing (DSP) chips are used [3]. The limited bandwidth makes it difficult to schedule large volume traffic.

In our demo, we use Micaz motes which have a bandwidth of 250Kbps. We use a sampling rate of 4KHz for the microphone, and use the 4-bit Dialogic Adaptive Differential Pulse Code Modulation (Dialogic ADPCM) [1] for data compression, which results in a total of 16Kbps data. By sticking to the convention of TinyOS, in which the payload of each packet is 29 bytes, a node generates 26Kbps of data, including the packet header and bookkeeping information. With this large volume of data, a contention based MAC, such as B-MAC, works poorly in a multi-hop sensor network, and TDMA becomes a better choice. However, TDMA incurs extra overhead. First, it requires precise time synchronization, which is costly. Plus, if the time synchronization is not accurate, the bandwidth wasted by using a larger time slot can be significant. For example, if the accuracy of the time synchronization is 1 *ms*, we need to prolong each time slot by 2 *ms* to compensate for the possible time drift. For the Micaz, sending 1 packet takes 2.47 *ms*. In this case, 45% of the bandwidth is wasted. Moreover, it requires a traffic adaptive TDMA design, which incurs more overhead.

Our solution to this problem is to use a hybrid MAC protocol for Periodic Streams (PS-MAC). PS-MAC is specifically designed for high volume real-time periodic streams. PS-MAC does not require time synchronization. We envision that a sensor network handles some sporadic low volume traffic, such as commands and tracking reports, and some high volume periodic streams, such as acoustic streams and image streams. In PS-MAC, we assume that a spanning tree is adopted for routing and the periodic streams go from or to the root of the tree. The periodic streams use implicit TDMA for packet forwarding, in which the nodes on the route use the arrival of the periodic packets, rather than the global time, as the time information for packet forwarding. If a node on the route is scheduled to forward a packet after it receives a periodic packet, the node sends out the packet immediately after it receives it. The sporadic traffic uses CSMA for transmission. However, it is not always enabled. When a node is close to a stream, CSMA is enabled for transmission only after the traffic has passed it, which can be detected by overhearing the periodic packets passing through. Before the arrival of the next traffic, CSMA for transmission is disabled by setting a timer. PS-MAC schedules periodic streams efficiently without blocking the sporadic traffic. It even supports two way acoustic streams in a single route, which functions as a walkie-talkie.

In our demo, we first show a one way real-time acoustic stream being transmitted across multiple resource limited Micaz motes. We also demonstrate that a telephony service can be built upon Micaz motes, in which two people can talk to each other in real-time through multiple hops.

REFERENCE:

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