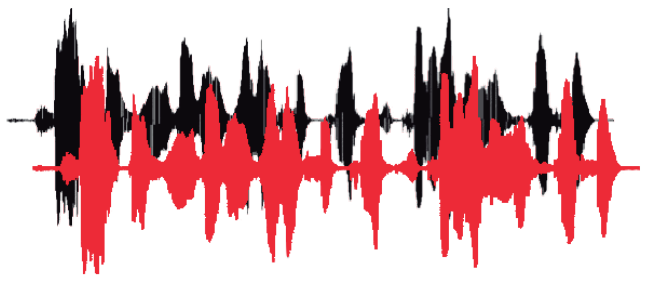
Fully Functional prototype for the monitoring of use of explosive weapons with real time display capabilities

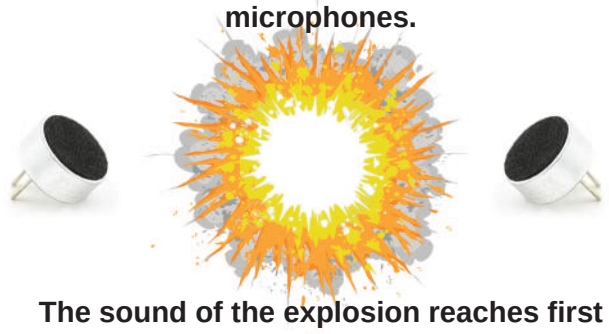
The Time Difference of Arrival on the microphones allows to compute the Angle of Arrival (AoA) that determines the direction of propagation of the incident sound wave. If a wave is incident upon the microphone at broadside, then a 180° phase difference will be measured between the elements, corresponding to a 90° AoA.

With a distance of only 20 cm between the microphones and 4 times interpolation at 44.1 kHz, the numbers give < 1 degree resolution

Sound phase-difference is measured between the two microphones



The sensing node has several embeded microphones.

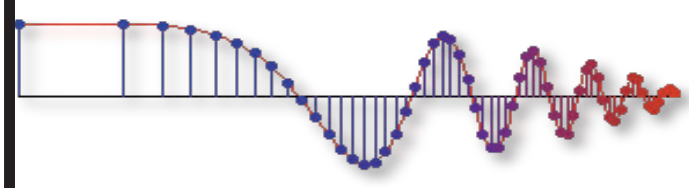


The sound of the explosion reaches first the closest microphone.

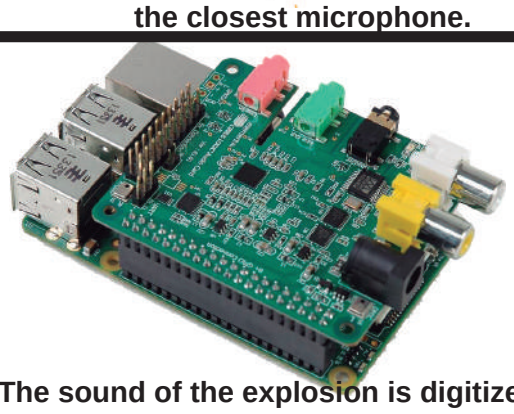
When it is necessary to capture audio covering the entire 20–20,000 Hz range of human hearing, such as when recording acoustic events, audio waveforms are typically sampled at 44.1 kHz (CD).

The embedded Cirrus Logic Audio Card supports sampling up to 176.4 Khz. The sampled data are “time-stamped” using the Real Time Clock of the GPS and a Network Time Protocol (NTP) server installed on each node.

In signal processing, sampling is the reduction of a continuous signal to a discrete signal.



The explosion sound wave in transformed into a sequence of samples.

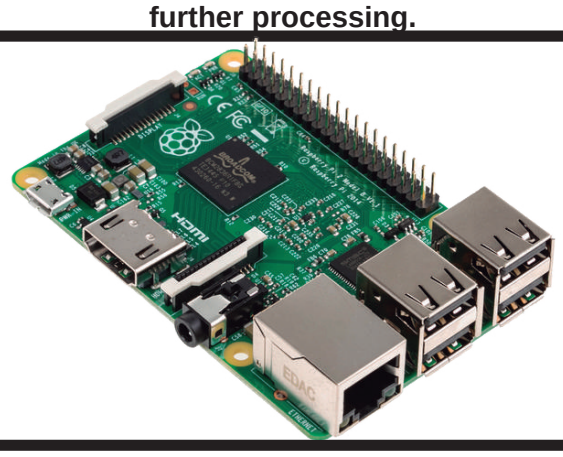


The sound of the explosion is digitized for further processing.

Raspberry Pi 2, is a reduced size computer featuring a quad-core ARM Cortex-A7 CPU, a VideoCore IV dual-core GPU and 1 GB of RAM. For a price of 35$.

Actual analysis involves more than 200 hundreds FFTs per seconds. The graphics processing unit (GPU), which typically handles computation only for computer graphics, can be used to help the CPU.

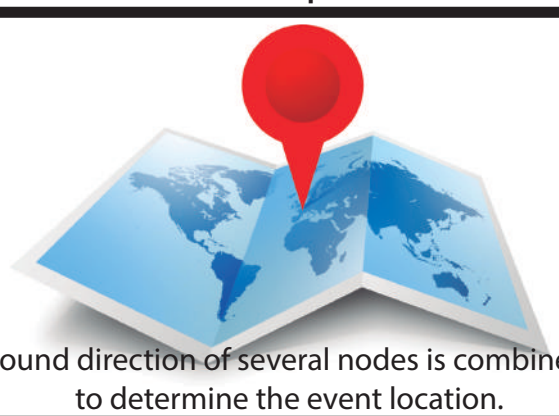
The sound stream is analysed in real time to detect explosions.



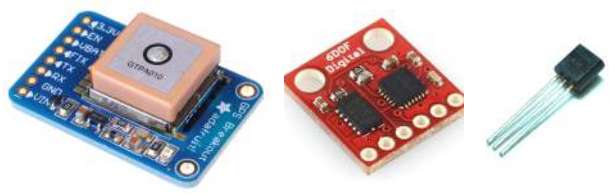
A GPS receiver provides absolute position and velocity measurements in Earth co-ordinates but can’t determine the node microphone orientation.

To overcome this problem, a magnetometer is used. The speed of sound is accuratly computed using the ambient temperature sensor probe.

Using all this data, the sound incidence can be accuratly measured.



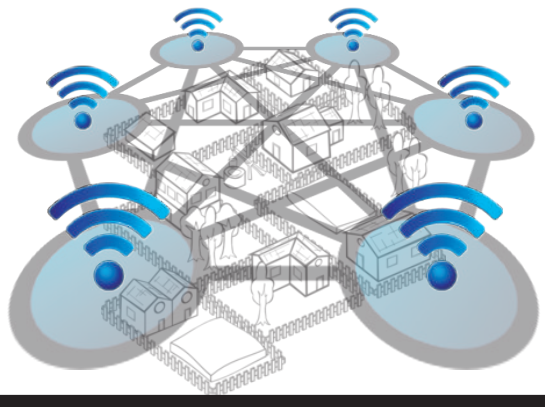
Sound direction of several nodes is combined to determine the event location.



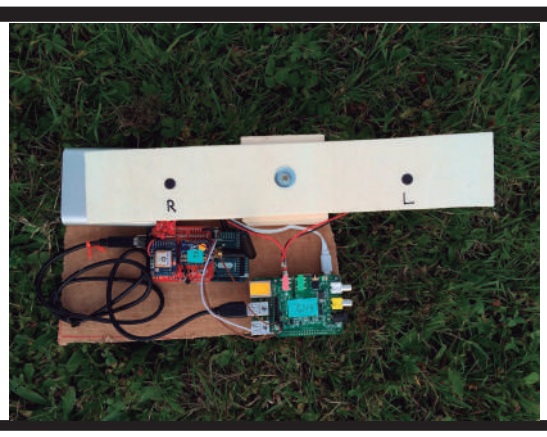
Location, orientation and air temperature data are recorded.

The node has an embedded radio modules allowing over-the-air baud rates of 250 kbit/s. A mesh network is a network topology in which each node relays data for the network. To ensure all its paths' availability, the network allows continuous connections and reconfigure itself around broken paths, using self-healing algorithms.

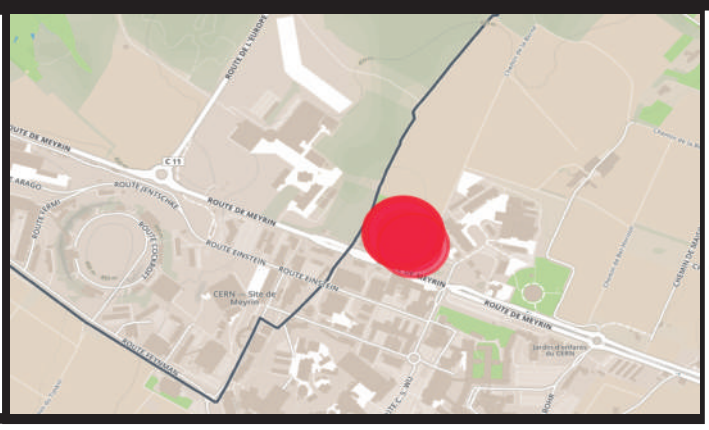
When data reach a node connected to Internet the data are uploaded to the E3E Server.



Data are Transmited through the nodes toward gateway.



First Sensing Node prototype during outdoor field test campaign



First results collected in real-time at http://blastbusters.org

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