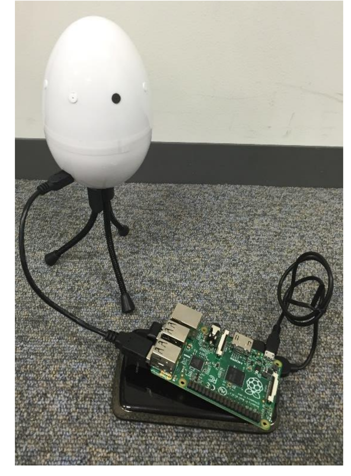
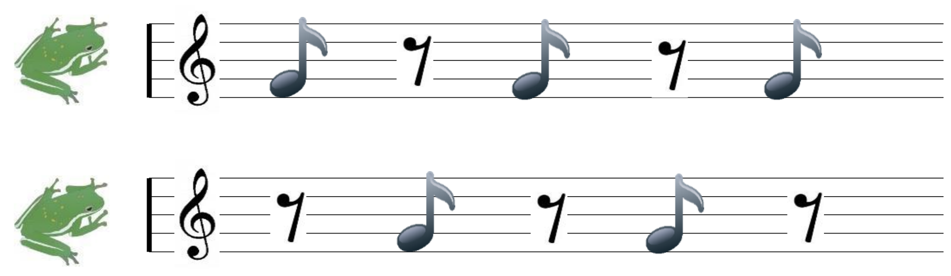
Real Time Localization Method for Calling Frogs using a Wireless Sensor Network

Yasuharu Hirano, Daichi Kominami, and Masayuki Murata (Osaka University)
Ikkyu Aihara (University of Tsukuba)

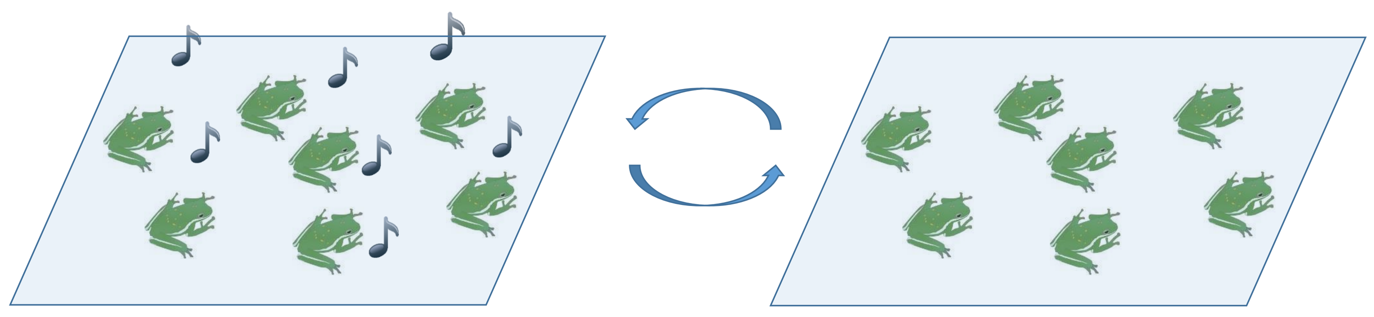


Introduction

- *Background:* Observing and modelling the chorus of Japanese tree frogs that have amusing characteristics
  - Anti-phase synchronization in local communication



  - Synchronization in global communication

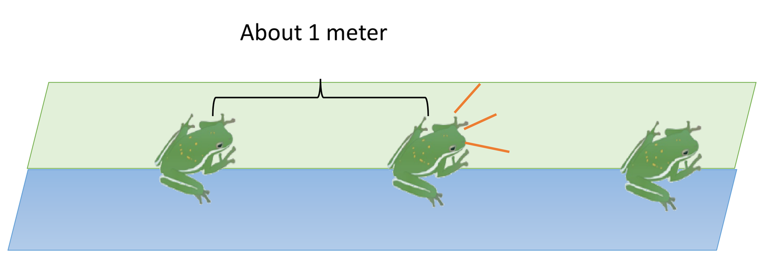


- *Goal:* Localizing frogs' position using their advertisement calls
  - with a high precision
  - in real time
  - with facility to deploy the localization system

Japanese tree frogs

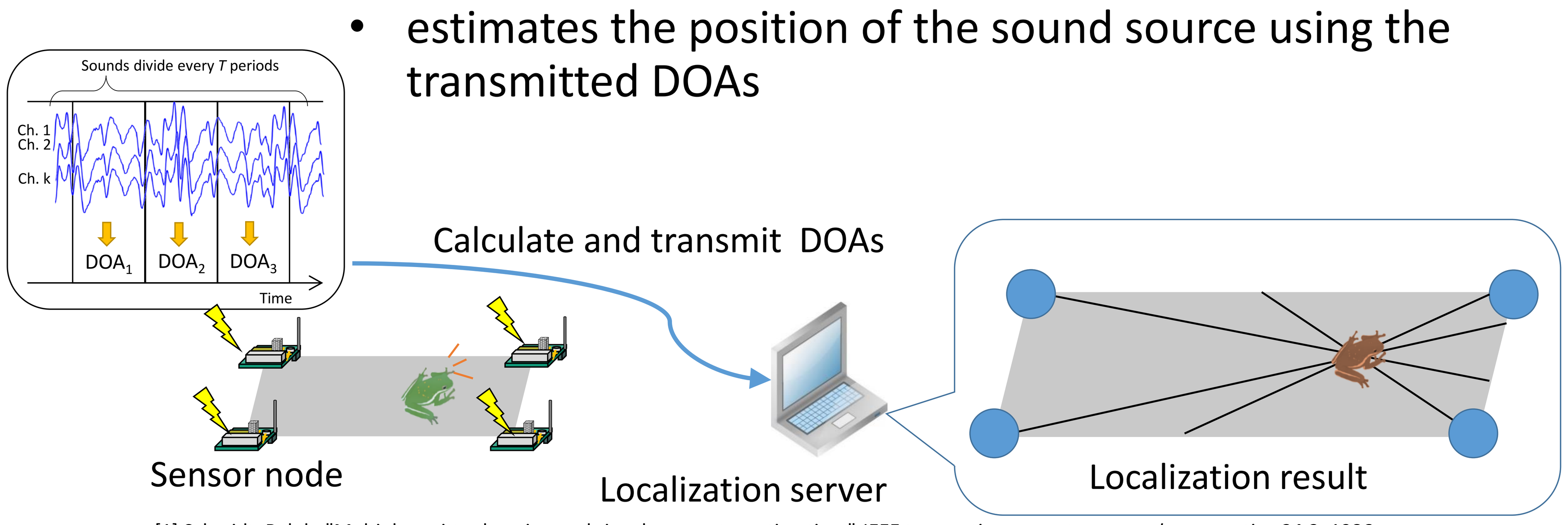
- Features
  - Length: 20 mm – 45 mm
  - Nocturnal
  - Frequency of their calls: about 2 – 4 kHz
  - Chorus duration: about 5minutes
  - Not move while their calling
  - They inhabit and call on ridges between rice paddies at approximately 1 m interval

Rice paddy: this photo is taken in our field work



Localization system design

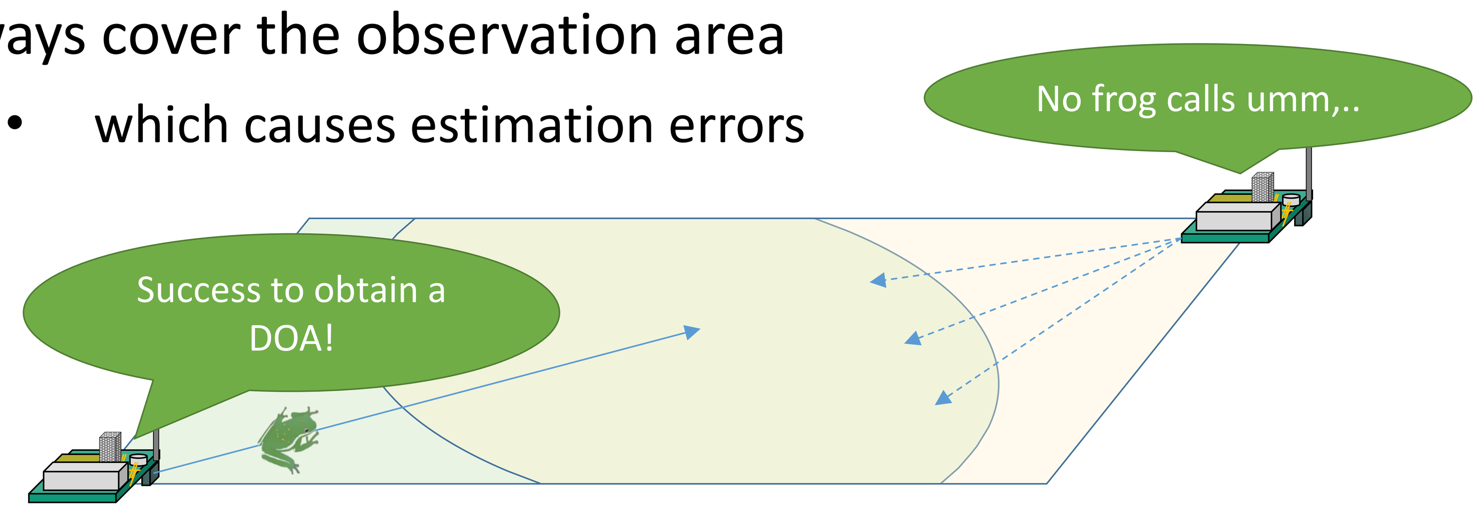
- How to achieve (1) feasible deployment, (2) high accuracy, and (3) real-time property?
  1. *Using wireless communication devices*
  2. *Using a microphone array and the MUSIC[1] method to calculate the direction of sound arrival (DOA) for localizing frogs' position*
  3. *Using a localization method in a distributed manner*
- Devices
  - Sensor nodes with a microphone array
    1. record sounds and divide them into small parts
    2. calculate the direction of the sound arrival (DOA) for each part
    3. transmit the "direction" to a localization server
  - Localization server
    - estimates the position of the sound source using the transmitted DOAs



[1] Schmidt, Ralph. "Multiple emitter location and signal parameter estimation." *IEEE transactions on antennas and propagation* 34.3, 1986.

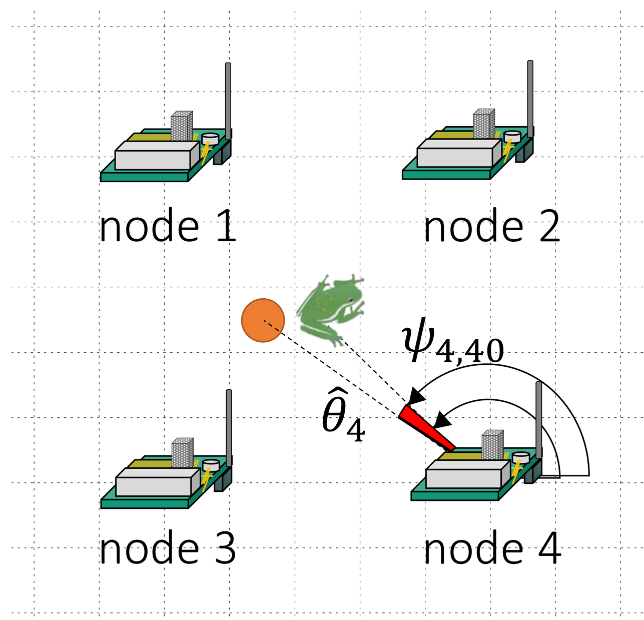
A Problem in an outdoor environment

- Constraint on deployment: sound collection range does not always cover the observation area
  - which causes estimation errors



Localization method

- Grid-based localization[2]
  1. Split the observation area into a grid that has N cells. Each cell is represented by its coordinates of center
  2. Obtain every angle of a vector from each sensor node to each cell (denoted by $\mathbf{\Psi}$)
  3. Find the cell n ($\in N$) that minimizes the cost function: $\sum_{m=1}^{M}[A(\hat{\theta}_m, \psi_{m,n})]$

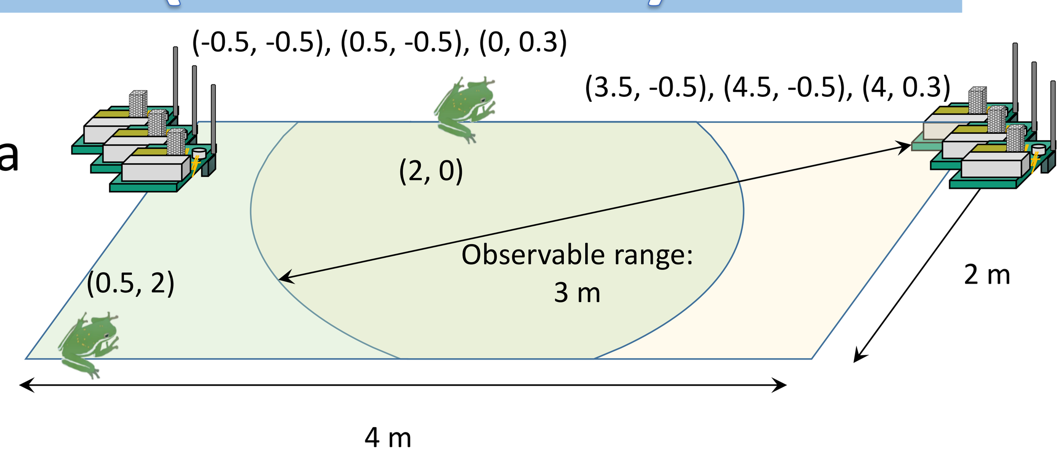


M	Number of sensor nodes
$\psi_{m,n}$	Angle of a vector from sensor node m to cell n
$\hat{\theta}_m$	A DOA received from sensor node m
$A(X,Y)$	Angular distance defined by: $A(X,Y) = 2\sin^{-1}(\frac{e^{jX}-e^{jY}}{2})$

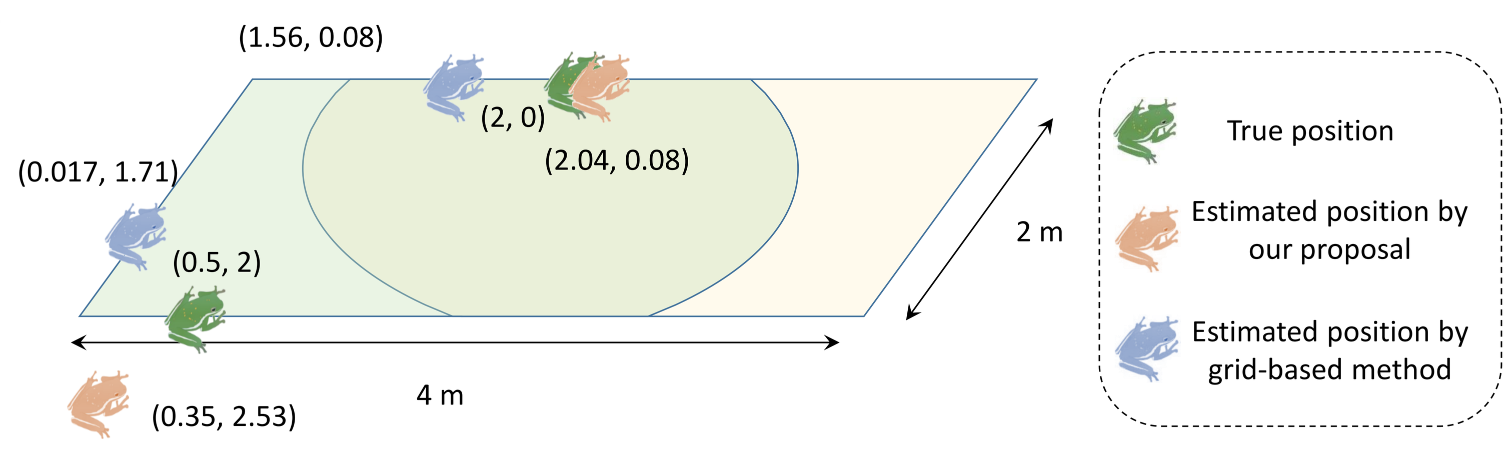
- Our approach for the above problem
  1. Put 3 sensor nodes at a short distance (called *node set*)
  2. Deploy node sets over the observation area
  3. Each node set makes localization for their observable area using the above grid-based method and transmits the estimated positions to the localization server
  4. The localization server merges the estimated positions

Localization results (simulation)

- Simulation settings
  - 4x2 m² rectangle area
  - 2 node sets
  - 2 sound sources



- DOA model
  - We implement the MUSIC method into a Raspberry PI 2, widely known wireless device, that connects with a TAMAGO-03, 8ch-microphone array developed by System in Frontier Inc.
  - In our implementation, the resolution of an obtained angle is 5° considering computation cost and accuracy
  - $DOA = true\ DOA + \varepsilon$, ($\varepsilon = 5° * \lfloor r + 0.5 \rfloor$, $r \sim N(0,1)$)
- Results



  - Computational time of our method
    - MUSIC method by a Raspberry PI-2: 27 s
    - Localization by a laptop (Core i7 5600U, DDR3-8G): 10 s

[2] Griffin, Anthony, et al. "Real-time localization of multiple audio sources in a WSN," in Proc. *22nd European Signal Processing Conference*, 2014.