Adaptive Synchronization of Robotic Sensor Networks

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What time is it?

- Low-cost built-in clocks - **local time notion**
  - A read-only counter register
  - A low-cost crystal oscillator
    - temperature, voltage level and aging of the crystal
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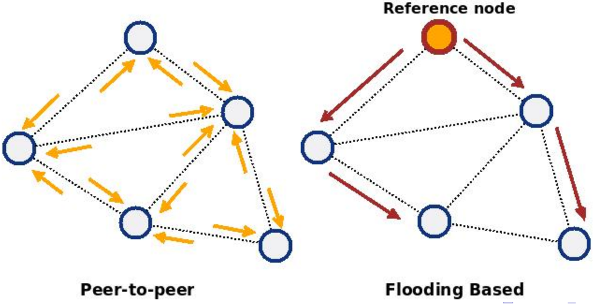
- Sources of errors
  - *transmission delay*
    - composed of deterministic and non-deterministic components
    - reception of outdated time information due to delays
  - *frequency* of the built-in clock
    - *quantization errors* - low-frequency built-in clocks

Exchange of Time Information

- **Flooding Time Information**
  - A **reference** node **floods** its current time - **periodically**
    - ★ built-in clock $\overset{\textit{relationship}}{\Longleftrightarrow}$ reference time
    - ★ broadcast predicted time - **network-wide synchronization**
- **Peer-to-Peer Communication**
  - No special **reference** node
    - ★ Communicate with and synchronize to direct neighbors.



Calculation of the Logical Clock

Least-Squares Regression - PulseSync [Lenzen et al., 2009]
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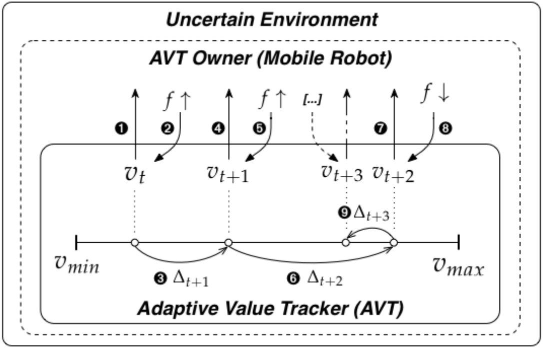

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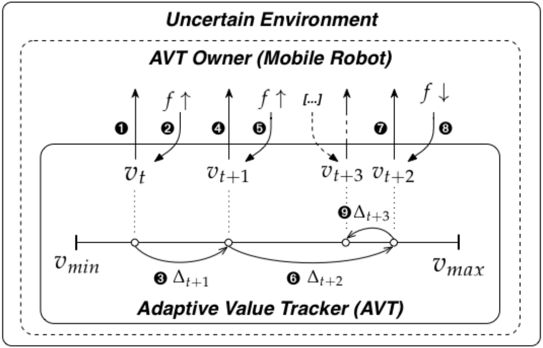

AVTS - **STSP** [Gürcan and Yildirim, 2013, Yildirim and Gürcan, pear]

ALGORITHM 1. *Speed tracking code for robot u*
1: *if error>0 then* $avt_u.adjust(f\uparrow)$
2: *else if error* < 0 *then* $avt_u.adjust(f\downarrow)$
3: *else* $avt_u.adjust(f\approx)$

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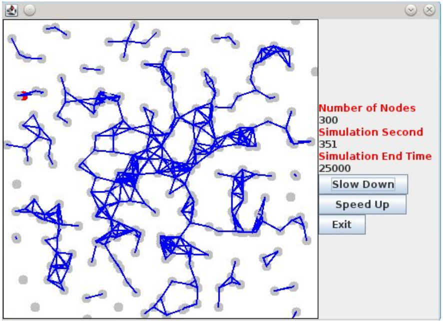
Our Question

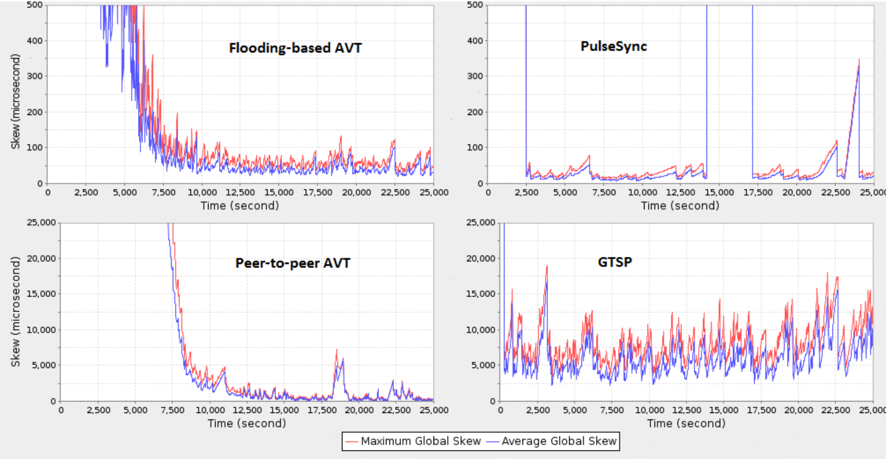
Are networked robots still be able to adapt themselves and self-adjust their logical clocks while meeting the pre-defined synchronization performance?

Simulations



- Implemented PulseSync, GTSP, AVTS and STSP in our simulator.
- 300x300 meter square area, Transmission range - 25 meters.
- Probabilistic radio model (Gaussian wireless channel) with CSMA based MAC layer.
- Beacon period of 30 seconds.
- **Random Waypoint Mobility Model**
- 1 MHz built-in clocks with **constant drift clock model** (drift is uniformly distributed within the interval of $\pm$ 100 ppm.
- The least-squares regression tables are **composed** of 8 entries and each node tracks at most 10 neighbors

Results



Flooding-based AVT
PulseSync
Peer-to-peer AVT
GTSP
Skew (microsecond)
Time (second)
Maximum Global Skew
Average Global Skew

Lessons Learned

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  - detection of the **neighborhood change** is another crucial problem
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- **Peer-to-peer** approaches are expected to have a better performance in mobile networks.
- However, **flooding-based options perform better** and **establishes** network-wide synchronization **faster**!

Future Questions

- What happens if the reference node dies?
  - Reference node election?
- How to achieve gradient time synchronization faster and better?
- How to seperate stable and unstable nodes ?
  - Synchronize to well-synchronized nodes?

THANK YOU!

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