Collaborative tracking of devices in historical architecture
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• Motivation:
  o Localization of hundreds of devices in unstructured environments
  o 48 rooms => Expensive fixed infrastructure
  o Requires access and can damage historical buildings

• Goal:
  o localization with minimal setup

• Proposal:
  o use Ultra-wideband (UWB) receivers and Collaborative Localization

• Challenges:
  o Network sharing
    • UWB sensor limitation (delay, collision)
    • Large number of devices
    • Changing topology of network
  o Collaborative localization
  o Dynamic nature of devices

How we solve these challenges?

• Synchronization:
  o A Gradient clock synchronization
    Hardware clock $H_i(t) = \int_{t_0}^{t} h_i(t)dt + \phi_i(t_0)$
    Logical clock $L_i(t) = \int_{t_0}^{t} h_i(t)dt + \theta_i(t_0)$
    Average offset $\theta_i(t_{k+1}) = \frac{\sum_{j \in N_i} (L_j(t_k) - L_i(t_k))}{|N_i| + 1}$

• Time-Division Multiple Access
  An adapted Unifying Dynamic Distributed Slot Assignment Protocol (USAP) to schedule slots in distributed manner.
  o Simplified packet format: SlotID+ActionCode
  o Two lists are maintained: SendList and ReceiveList
  o Three Actions included Proposal, Refuse, Regret

Example of solving conflict
Situation:
E has slot i to broadcast, C is to listen E at slot i, A/B/D’s slot i are free.
1. B \rightarrow A/C/D (Proposal)
2. C \rightarrow B/D (Refuse)
3. B \rightarrow A/C/D (Regret)

• Usage of UWB network:

Results:
Experiments with 15 devices in Chambord Castle, France.
Tags topology splits into 3 groups.
Time slot usage adapts to dynamic network topology.
Tag located with decimeter accuracy.

• Collaborative Localization

Collaborative EKF
  o Sensor fusion of UWB and IMU
  o Collaborative localization with neighbors

State Definition: $[x, y, \dot{x}, \dot{y}, z, \dot{z}]$
State transition matrix:
$F = \begin{bmatrix} D_F & 0 & 0 \\ 0 & D_F & 0 \\ 0 & 0 & D_F \end{bmatrix} \text{ with } D_F = \begin{bmatrix} 1 & \delta t \\ 0 & 1 \end{bmatrix}$

Measurement:
doPositioning (trilateration with 3 anchors)
doRanging (with neighbors broadcasting)
IMU measurement

Decision flow for each device

- At least 3 anchors?
  - Yes
  - No

- Select anchor or neighbor
  - doPositioning
  - Fuse measurements (EKF)

- Broadcast position and wait
  - doRanging