FONDAZIONE BRUNO KESSLER

E3DA
ENERGY EFFICIENT EMBEDDED DIGITAL ARCHITECTURES

Dynamic group management with wearable WSN

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Scenario

- IoT, smart cities, pedestrian mobility
- **Moving group** of people where one chief legal can be elected (supervised groups)
- Walking buses, school trips, guided tours…

CLIMB project aim:

- Promoting the **independent mobility** of children with the help of technological tools

Related work

M. Cattani, Ş Gună and G. P. Picco, "**Group monitoring in mobile wireless sensor networks**," *DCOSS*, Barcelona, 2011

- focus on decentralized group management
- propose some protocols and compare them in a simulated environment
- **No implementation is given**

Lineable - http://www.lineable.net/

- Low cost, long battery life beacon for kids monitoring
- Uses crowdsourcing GPS from other app user's smartphone
- **Not scalable** (not adapt for more than 7 nodes)

Requirements and features

- Based on wireless nodes
- **Discover** new members in the neighborhood
- **Track** their **presence** within the group during a period of time
- Rise an **alert** if any group component goes too far
- **Bi-directional** and multi-hop communication
- Raw spatial localization
- Latency (5s discovery latency)
- Scalability (**up to 150 nodes**)
- Low power (battery life in the order of one month)
- Compatibility with established technologies (smartphones)

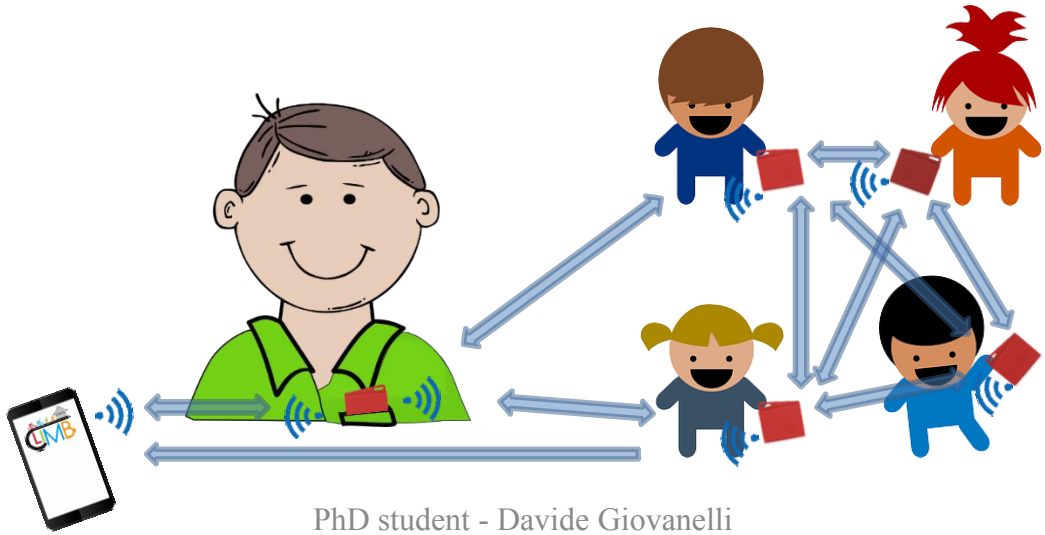
The nodes

LEADER node*:*

- is owned by the group manager
- has a direct connection with a smartphone
- can communicate with **member** nodes
- acts as a **bridge** between **member** nodes and the smartphone.

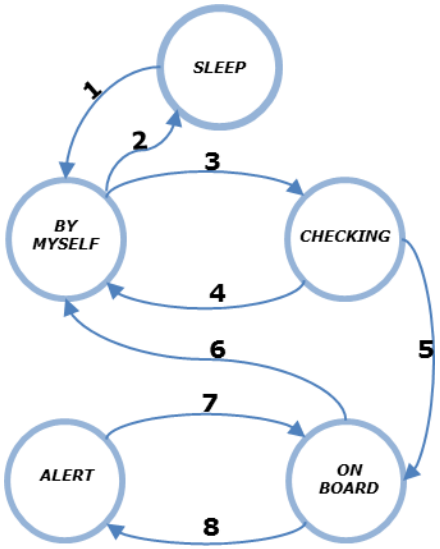
MEMBER nodes:

- each group member has one
- can communicate with the **leader** and others **members**
- they can receive commands only from the **leader**



Group management service

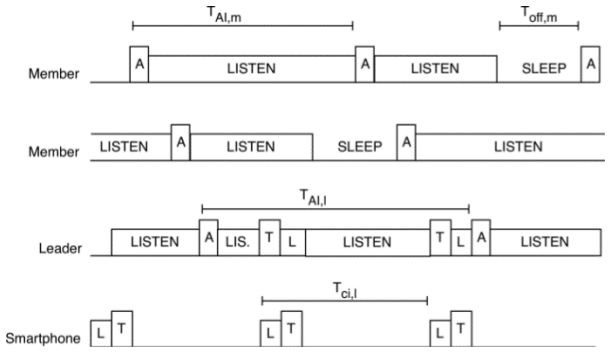
- Each **member** node has an internal state machine
- **Members**' valid states are: **BY_MYSELF**, **CHECKING**, **ON_BOARD**, **ALERT**.
- When the **member** is ON_BOARD its presence is monitored.
- If a **member** is ON_BOARD, but its packets are no more received by the leader, an alert is triggered.
- When a node is not used it can be set to SLEEP.

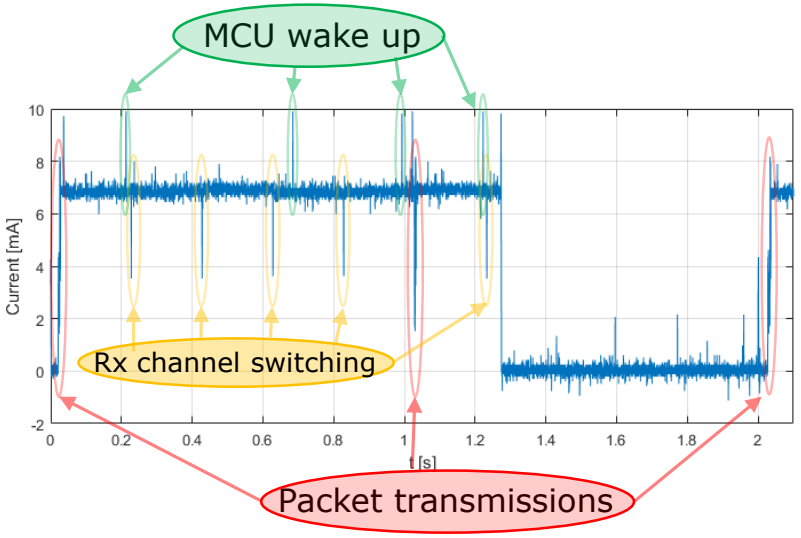


	Event
1	Timer or button event
2	Timer or button event
3	The Member node enters in the Leader communication range
4	The Member goes out of Leader range or the Leader reject to monitor the Member
5	The Leader adds the Member to its friend list
6	The Leader stops monitoring the Member
7	The Member returns in Leader communication range
8	The Member no longer hears the Leader

The network

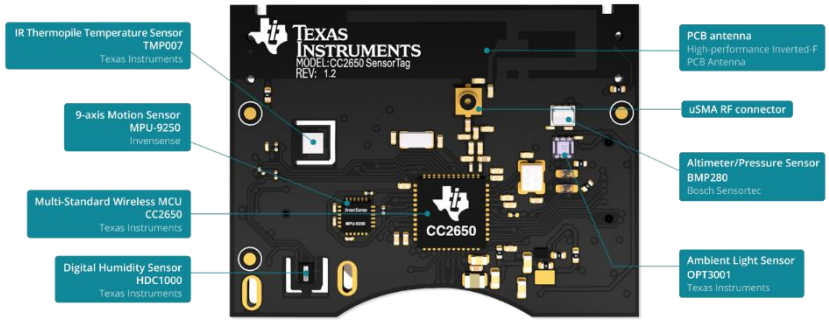
- Data transmission is done using **small packets** that are broadcasted **periodically** by members' and leader's node.
- Between two packets the radio peripheral can be switched to receiver or switched off to save energy.
- **Full-mesh** network topology
- Only **leader** node exchange bidirectional packets with the smartphone.





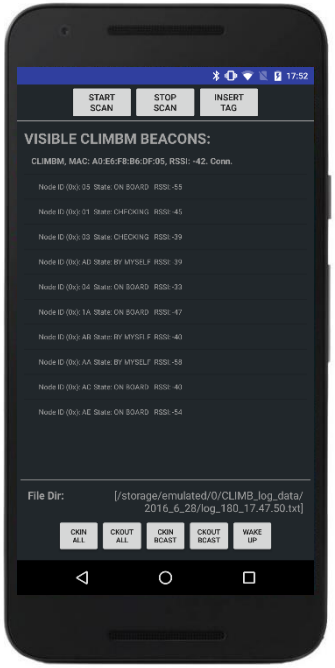
Methods/Tools

- **Bluetooth Low Energy beacons** with a custom firmware
- Implementation based on a ready to use development board (Texas Instruments SensorTag)
- An Android smartphone/tablet with a custom app



The smartphone

- Almost everybody has one.
- A **graphical interface** ease the interaction with the network.
- It can provide an **internet connection** to download/upload information.
- It can run **complex algorithms** (i.e. localization) with nodes data providing a simple and readable feedback on the screen in real time.
- It can **vibrate** or **ring** to signal an alert



Challenge 1: BLE limits

Two main limits:

- *the broadcast **packets length** (no more than 31 bytes)*
- *the **absence** of **synchronization** between nodes.*

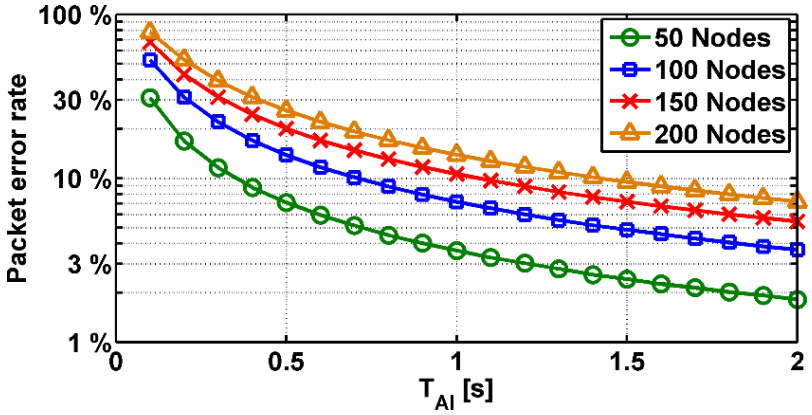
- The first is approached with a proper and effective packet formatting.
- The second must be accepted to comply BLE protocol specifications.

Challenge 2: Beacon interval trade-off

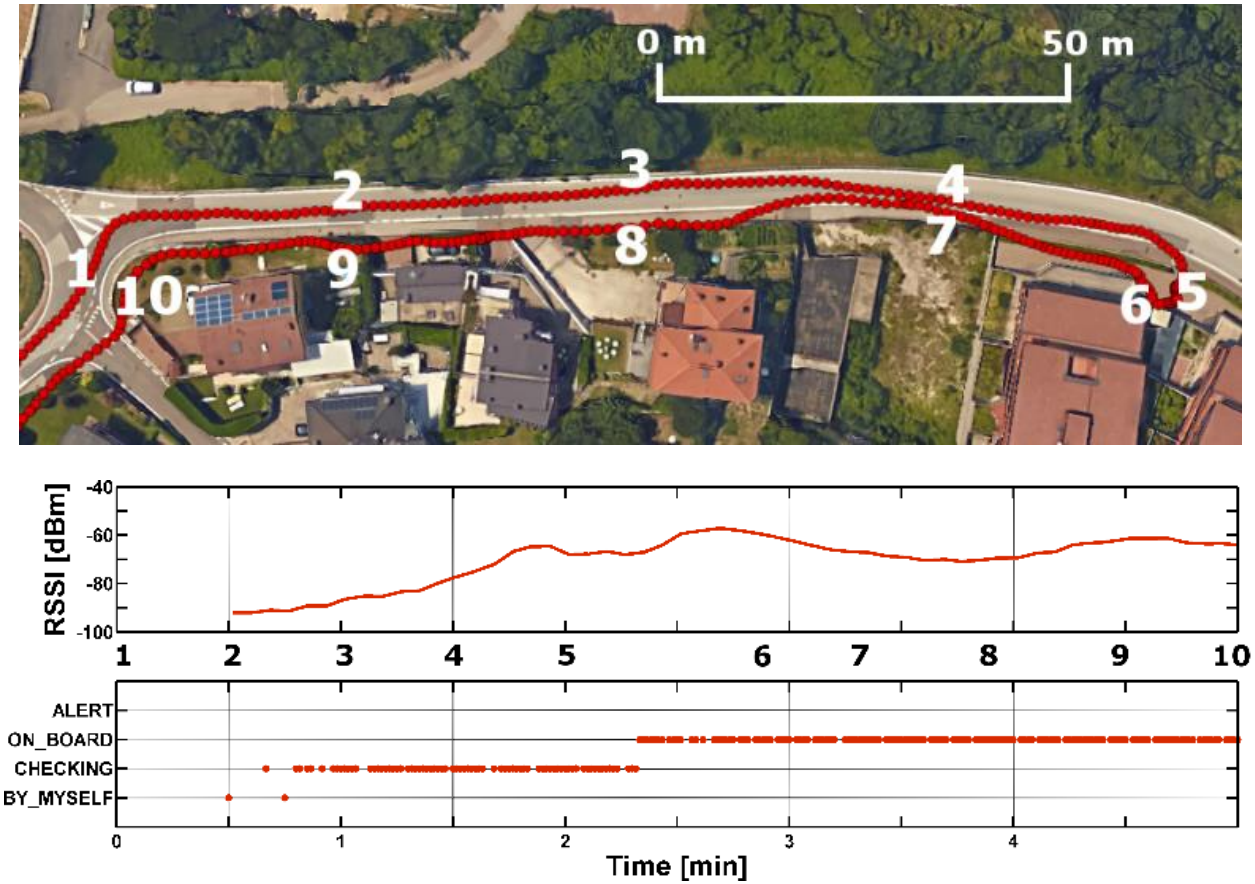
*Packet **collision** vs node **density** vs network **latency***

- *A packet collision will **corrupt** received data. The packet collision probability can be adjusted by tuning the **beacon interval**.*
- *If the number of nodes grows the number of collision also grows.*
- *If the beacon interval is too long the introduced latency made the network **unusable/instable***

This is solved by choosing the correct beacon interval with the help of network simulation.



Results



- The first version of the is **under test** in Meano (north of Trento) on a **pedibus** service- only the group management service is implemented for now.

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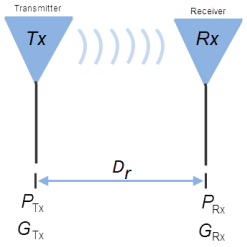
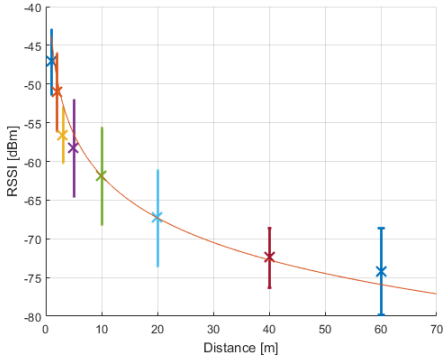
Future developments

- Node **localization** (group behavior) is under active development
- Intelligent node **wake up**
- **Adaptive** advertising and listening **intervals**

Localization algorithm

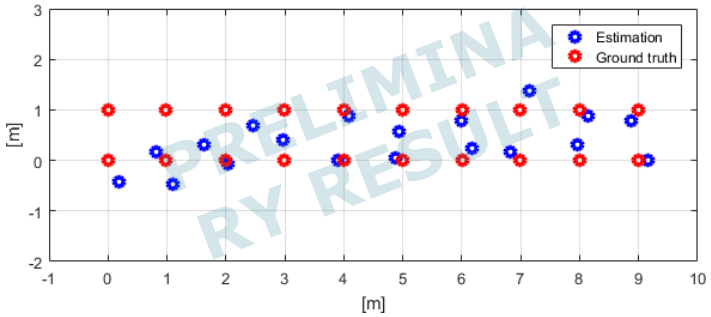


$$\frac{P_{RX}}{P_{TX}} = G_{TX} G_{RX} \left(\frac{\lambda}{4\pi D_r} \right)^2$$



The localization algorithm is under development/optimization.

- The first step converts **RSSI** [dBm] link data to **distance** [m]
- To locate nodes it will use masses-springs **physical simulation**
- The **equilibrium** position is taken as nodes **locations**



Simulation conditions:

- Noise amplitude 16dBm (total range ~75dBm)

Result:

- Mean localization error = 43cm.

FINE

Thanks for the attention