# Low power wireless sensor network protocols for real-time applications in Industry 4.0


Student: Marco Reno
Tutor: Prof. Lucia Lo Bello
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Dottorato di Ricerca in
Ingegneria dei Sistemi, Energetica, Informatica e delle Telecomunicazioni
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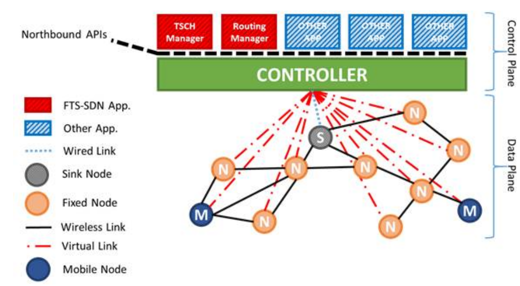
### Research Topic

The application of the IoT paradigm to the manufacturing industry is called IIoT. The IIoT will revolutionize manufacturing by enabling the acquisition and accessibility of far greater amounts of data, at far greater speeds, and far more efficiently than before. A number of innovative companies have started to implement the IIoT by leveraging intelligent, connected devices in their factories. The IIoT can greatly improve connectivity, efficiency, scalability, time savings, and cost savings for industrial organizations. Companies are already benefitting from the IIoT thanks to predictive maintenance, improved safety, and other operational efficiencies.
The main goal of this research is to develop a new solution for low power wireless sensor networks for real-time applications in Industry 4.0. Industrial Wireless Sensor Networks (IWSNs) are found in many application domains that require low latency, robustness, and determinism.

## FTS-SDN Architecture




The architecture of FTS-SDN consists of two main parts:

- **Data plane**, i.e., the software running inside the IWSN nodes, and the
- **Control plane**, running on one or more devices placed outside the IWSN.

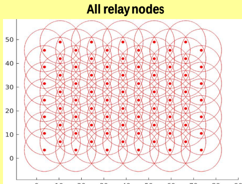
Inside the Control plane, there are two layers, i.e., the Application layer and the Controller.
In the Application layer, different applications use the information provided by the Controller to manage the network, while the Controller collects information about the IWSN state. We added to TSCH the support for mobility and for the correct scheduling of all the transmissions between the nodes. In particular, the proposed architecture adds two applications inside the Application layer:

- The TSCH Manager, a module that decides the channels and time-slots in which nodes have to communicate
- The Routing Manager, that builds and sends to all the nodes the flow rules containing the forwarding decisions.

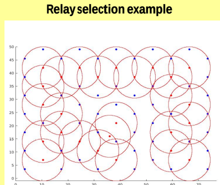
## Relay Selection in Bluetooth MESH Network

Assigning the relay role only to a subset of the devices is an efficient way of reducing the amount of traffic due to duplicated packets.

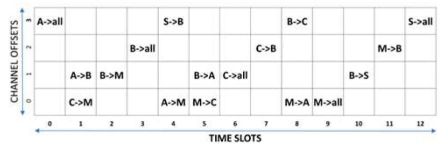

All relay nodes

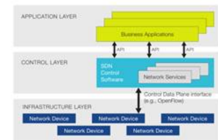


Relay selection example



## FTS-SDN (Forwarding and TSCH Scheduling Over SDN )

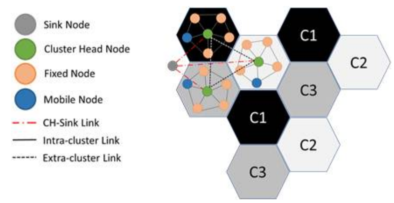


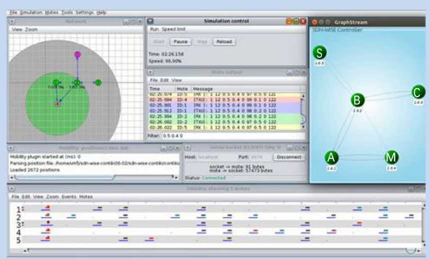

The proposed solution presents a new SDN approach to handle node mobility and scheduling in IWSN based on the Time Slotted Channel Hopping (TSCH) protocol of the IEEE 802.15.4 standard. We called our solution FTS-SDN, i.e., Forwarding and TSCH Scheduling over SDN.
FTS-SDN combines the real-time support and reliability of TSCH with the SDN ability to promptly react to topology changes, thus supporting mobility.

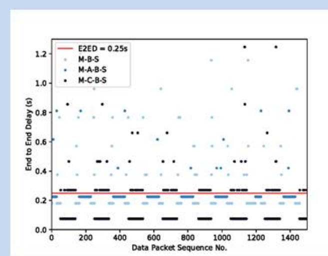
## FTS-SDN Clustering

An application inside the Application layer, called the "**TSCH Clustering Manager**", decides the channels and time-slots in which nodes are scheduled to communicate. Furthermore, the Manager is able to create clusters based on the data received from each node.




## FTS-SDN Simulation

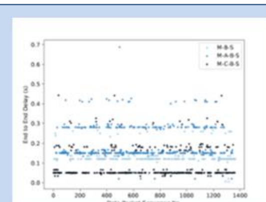





To test the feasibility and the performance of the FTS-SDN, we run an extensive simulation campaign in a virtual IWSN scenario involving both fixed and mobile nodes using Cooja and Contiki. Contiki is an operating system for networked, memory-constrained nodes, tailored for low-power wireless Internet of Things devices.
The Contiki operating system includes Cooja, an extensible Java-based network simulator capable of emulating Tmote Sky (and other) nodes.
One of the main features of Cooja is that the code to be executed by the node is exactly the same firmware that can be uploaded to physical nodes, thus making Cooja more similar to an emulator than a simulator.
Furthermore, Contiki contains an implementation of TSCH, whose APIs were used here to perform the simulations.

## FTS-SDN Test-Bed

Porting and testing of the FTS-SDN to the OpenMote Platform (Open-Source Prototyping Platform for the Industrial IoT).



## FTS-SDN Conclusions

Simulation and testbed results showed that the proposed solution is able to handle a mobile node during multiple handoffs without losing any packet at the application layer.
In the addressed case study most of the data packets sent are received within .3s and the maximum end-to-end delay is below 1.2s. These delays mainly depend on both the schedule and the number of enqueued packets to be sent.
When the report-period is faster than the topology change frequency, our approach provides good performance, as the Controller always has an up-to-date view of the network and therefore it can send the correct rules to the nodes.