UNIVERSITÀ
degli STUDI
di CATANIA

LoRa for Internet of Things applications: LoRaWAN and LoRa-based protocols to support real-time communications

Luca Leonardi, Lucia Lo Bello, Gaetano Patti
Department of Electrical, Electronics and Computer Engineering
University of Catania, Catania, Italy

luca.leonardi@unict.it, lobello@unict.it, gaetano.patti@unict.it

IWES 2020

Research group:
Real-time systems and networks

Lucia Lo Bello
Gaetano Patti
Luca Leonardi

Department of Electrical, Electronics and Computer Engineering

University of Catania

Outline

- Overview of LoRa/LoRaWAN
- LoRaWAN Medium Access Control protocols
  - Listen before Talk vs ALOHA
- Real-time communications over LoRa
  - RT-LoRa and Industrial LoRa
- Our research topics

IWES 2020

Research group:
Real-time systems and networks

Lucia Lo Bello
Gaetano Patti
Luca Leonardi

Department of Electrical, Electronics and Computer Engineering

University of Catania

Where do LPWANs fit?

Low Power Wide Area Networks (LPWANs) offer multi-year battery lifetime and are designed for sensors and applications that need to send small amounts of data over long distances.

Long Range

Low Power

Low Data Rate

LoRaWAN is one of the most popular LPWANs

IWES 2020

Research group:
Real-time systems and networks

Lucia Lo Bello
Gaetano Patti
Luca Leonardi

Department of Electrical, Electronics and Computer Engineering

University of Catania

LoRaWAN™ applications

LoRaWAN for Smart …

IWES 2020

Research group:
Real-time systems and Networks

Lucia Lo Bello
Gaetano Patti
Luca Leonardi

Department of Electrical, Electronics and Computer Engineering

University of Catania

Differences between LoRa and LoRaWAN™

LoRa is a spread spectrum modulation technique, patented by Semtech, that exploits the Chirp Spread Spectrum (CSS) technology. LoRa supports robust long-range transmissions and operates in the unlicensed sub-GHz ISM band.

LoRaWAN™ defines the communication protocol and system architecture for LPWANs that use LoRa modulation scheme. It is designed to wirelessly connect battery operated nodes, and targets key Internet of Things (IoT) requirements, such as bi-directional communication, end-to-end security, mobility and localization services.

IWES 2020

Research group:
Real-time systems and networks

Lucia Lo Bello
Gaetano Patti
Luca Leonardi

Department of Electrical, Electronics and Computer Engineering

University of Catania

LoRa physical layer

- Several customizable parameters
  - Spreading Factor (SF)
  - Code Rate (CR)
  - Bandwidth (BW)

- Tuning these parameters has an impact on:
  - Communication range
  - Bit rate
  - Time on Air (ToA)
  - Robustness to interference or noise
  - Error-correction capability
  - Ease of decoding

IWES 2020

Research group:
Real-time systems and networks

Lucia Lo Bello
Gaetano Patti
Luca Leonardi

Department of Electrical, Electronics and Computer Engineering

University of Catania

LoRaWAN Medium Access Control Protocols
Listen before Talk vs ALOHA

The LoRa behavior is mainly limited by the ETSI regulations.

To comply with the ETSI regulations, LoRaWAN can adopt as medium access control (MAC) layer

- a pure ALOHA approach with duty-cycle limitations
    - Duty cycle: maximum time the transmitter can be on or the maximum time a transmitter can transmit per hour
- a polite spectrum access technique, such as Listen Before Talk (LBT)

IWES 2020

Research group:
Real-time systems and networks

Lucia Lo Bello
Gaetano Patti
Luca Leonardi

Department of Electrical, Electronics and Computer Engineering

University of Catania

Listen before Talk vs ALOHA
Packet Loss Ratio (PLR)

- LBT performs better than ALOHA under high traffic load
  - Whenever the channel is found busy
    - LBT: each node reacts waiting for a backoff delay or running an Adaptive Frequency Agility (AFA) mechanism before retrying transmission. As a result, LBT avoids losing several messages.
    - ALOHA: each node transmits without sensing the channel through a CCA mechanism.
- Under low traffic conditions the PLR results of LBT and ALOHA MAC protocols are similar.

IWES 2020

Research group:
Real-time systems and networks

Lucia Lo Bello
Gaetano Patti
Luca Leonardi

Department of Electrical, Electronics and Computer Engineering

University of Catania

Real-time communications over LoRa: Challenges

LoRa

- Duty-cycle limitations

LoRaWAN

- Designed for sporadic nontime-constrained communications among a relatively large number of nodes
- No support for real-time industrial applications

IWES 2020

Research group:
Real-time systems and networks

Lucia Lo Bello
Gaetano Patti
Luca Leonardi

Department of Electrical, Electronics and Computer Engineering

University of Catania

RT-LoRa and Industrial LoRa

Two novel medium access strategy for LoRa networks.

- Beacon
- Contention Access Period (CAP)
- Contention-Free Period (CFP)
- Downlink Period
- CFP Ack

IWES 2020

Research group:
Real-time systems and networks

Lucia Lo Bello
Gaetano Patti
Luca Leonardi

Department of Electrical, Electronics and Computer Engineering

University of Catania

LoRaWAN, Industrial LoRa and RT-LoRa

	LoRaWAN	Industrial LoRa	RT-LoRa
Topology	Star (*)	Star	Star
Synchronization	Not supported	Beacon-based	Multiple beacons based
Transmission of real-time periodic flows	Not supported	Supported	Supported
Smart selection of Spreading Factors	Supported through ADR	Not supported	Supported through multiple beacons
MAC strategy for aperiodic transmission	Pure ALOHA	Pure ALOHA	Slotted ALOHA
MAC strategy for periodic transmission	Pure ALOHA	Multi-CH and Multi-SF TDMA	Multi-CH and Multi-SF TDMA
QoS classes	Downlink only (3 device classes provided)	Not supported	Uplink only (3 QoS classes provided)
Support for retransmission	Uplink only	Not supported	Not supported
Frequency rotation	Pseudo-random channel hopping	Not supported	Supported

(*) star-of-stars when multiple gateways are used

IWES 2020

Research group:
Real-time systems and networks

Lucia Lo Bello
Gaetano Patti
Luca Leonardi

Department of Electrical, Electronics and Computer Engineering

University of Catania

RT-LoRa – Simulation results

The simulated scenario includes both stationary and mobile nodes.

Real-time flows

- e2e delay
  - always lower than the deadline (i.e., 30s)
- Packet Loss Ratio (PLR)
  - No messages are lost for the flows with R (Reliable) and R+ (Most Reliable) QoS classes
  - PLR lower than 2.5% for the flows with N (Normal) QoS class

Aperiodic flows

- The Slotted ALOHA-based MAC layer used for transmissions in the CAP of RT-LoRa outperforms (lower PLR) the Pure ALOHA-based MAC layer used by both Industrial LoRa and LoRaWAN.

IWES 2020

Research group:
Real-time systems and networks

Lucia Lo Bello
Gaetano Patti
Luca Leonardi

Department of Electrical, Electronics and Computer Engineering

University of Catania

Our research topics

- Medium Access Control (MAC) protocols over LoRa
- Novel approaches to support LoRa-based real-time communications
- Design of enhanced version of some LoRaWAN mechanisms (e.g., Adaptive Data Rate)
- Design of novel approach to support LoRa/LoRaWAN dynamic networks
- Evaluation of the impact of the LoRa customizable parameters on network performance
- Evaluation of simultaneous transmissions on a specific channel using different Spreading Factor values in realistic scenarios

IWES 2020

Research group:
Real-time systems and networks

Lucia Lo Bello
Gaetano Patti
Luca Leonardi

Department of Electrical, Electronics and Computer Engineering

University of Catania

References

- L. Leonardi, L. Lo Bello, F. Battaglia, G. Patti, “Comparative Assessment of the LoRaWAN Medium Access Control Protocols for IoT: Does Listen before Talk Perform Better than ALOHA?”, in Electronics, vol. 9, no. 4, 2020.
- L. Leonardi, F. Battaglia, L. Lo Bello, “RT-LoRa: A Medium Access Strategy to support Real-time flows over LoRa-based networks for Industrial IoT applications”, in IEEE Internet of Things Journal, vol. 6, no. 6, pp. 10812-10823, Dec. 2019.
- L. Leonardi, F. Battaglia, G. Patti, L. Lo Bello, "Industrial LoRa: a Novel Medium Access Strategy for LoRa in Industry 4.0 Applications", 44th Annual Conference of the IEEE Industrial Electronics Society (IECON 2018), Washington D.C., USA, 10/2018.

IWES 2020

Research group:
Real-time systems and networks

Lucia Lo Bello
Gaetano Patti
Luca Leonardi

Department of Electrical, Electronics and Computer Engineering

University of Catania

Thank you for listening!

luca.leonardi@unict.it, lobello@unict.it, gaetano.patti@unict.it

IWES 2020

Research group:
Real-time systems and networks

Lucia Lo Bello
Gaetano Patti
Luca Leonardi

Department of Electrical, Electronics and Computer Engineering

University of Catania