Duty-Cycle-Aware Real-Time Scheduling of Wireless Links in Low Power WANs

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Popularity of **L**ow **P**ower **W**ide **A**rea **N**etwork

- Long Range
- Low Power
- Low Data Rate

LPWAN is becoming popular day-by-day

Different LPWANs

SIGFOX
One network A billion dreams

LoRa™

LoRa is one of the most popular LPWANs

Features of LoRa

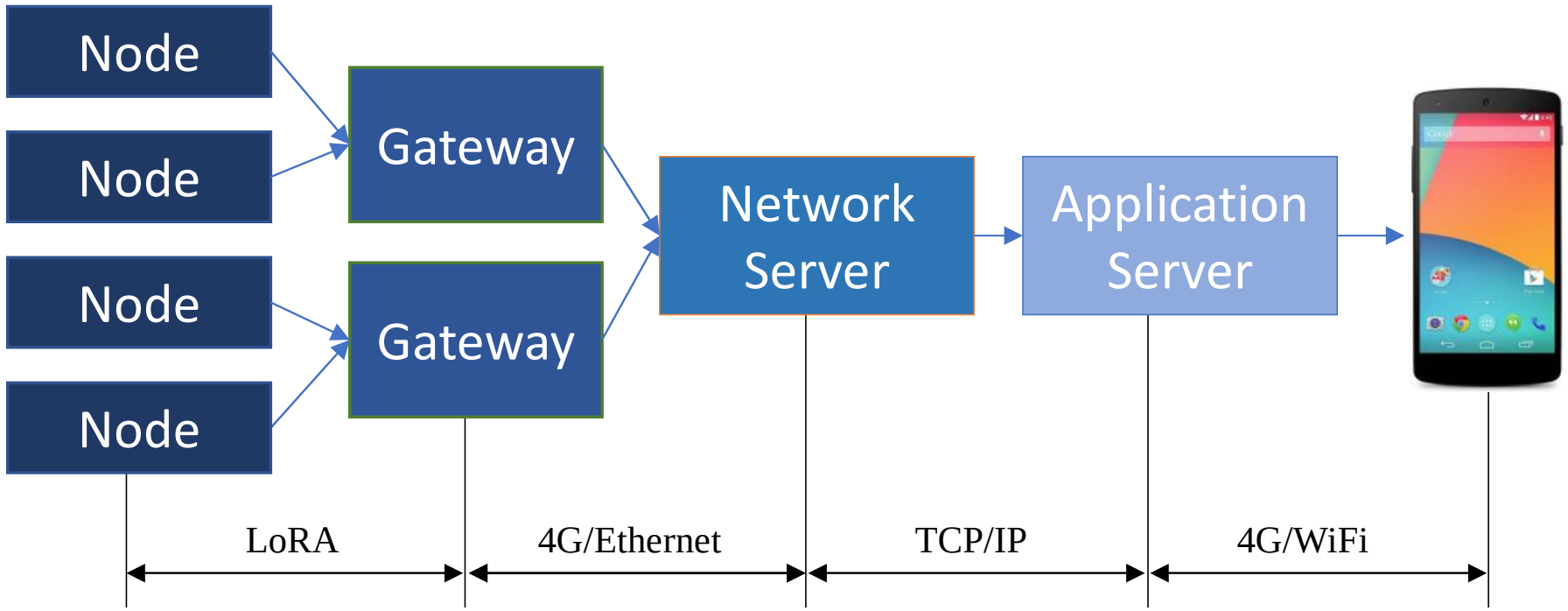
9 miles

50 kbps

10 years

Overview of LoRa

Overview of LoRa



LoRa Properties

- Chirp Spread Spectrum (CSS) Modulation

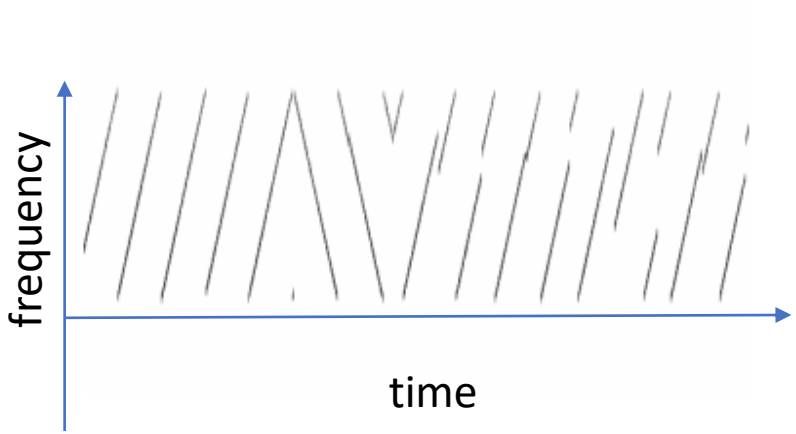
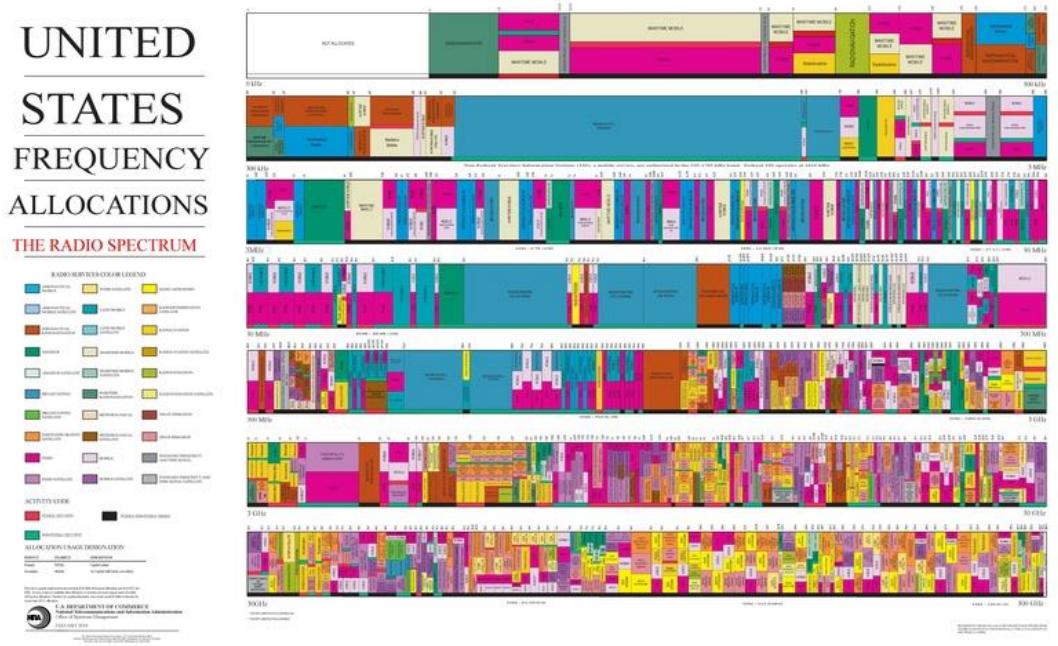


Figure: CSS



Operates on ISM band

Issues

Uses ALOHA for MAC Layer protocol.

Duty-Cycle Limit

- L_1: Node
- τ_{11}: 1st transmission
- C_1 :Channel 1
- Duty Cycle: 50%

Duty Cycle Limit, δ =50%

$$T_{off} = T_a \times (\frac{1}{\delta} - 1) = 1 \times \left(\frac{1}{0.5} - 1\right) = 1$$

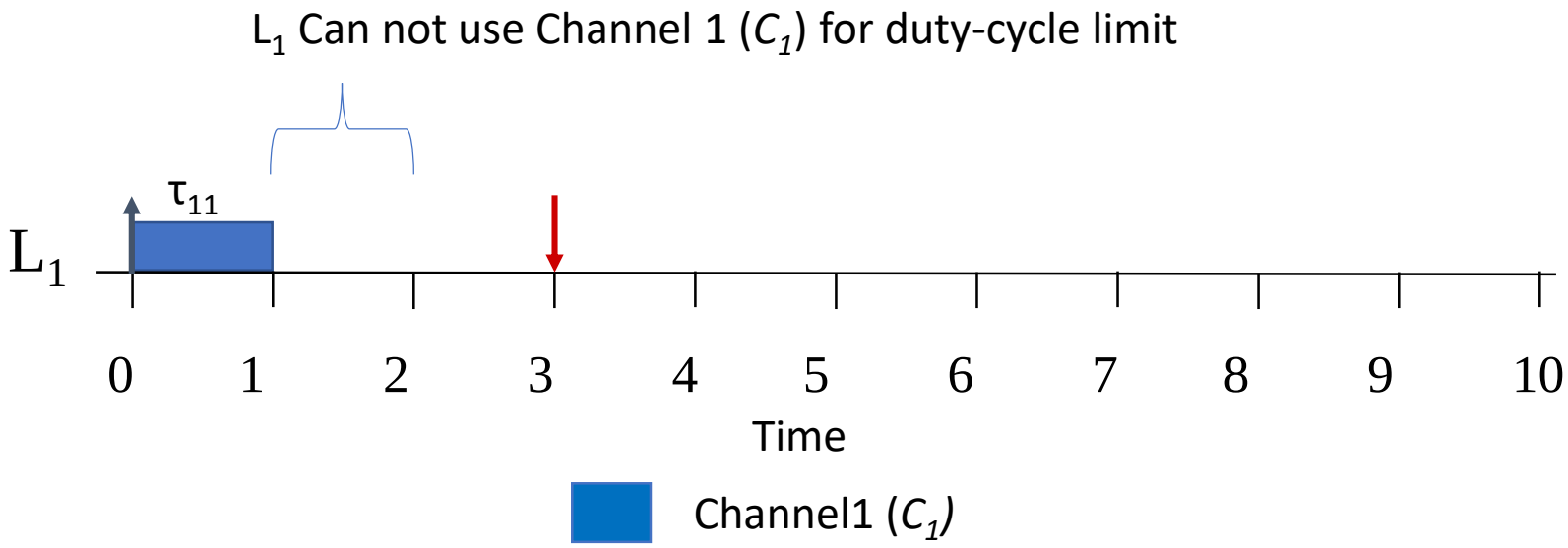


Figure: Duty Cycle Limit

Duty-Cycle Limit

- L_1: Node
- τ_{11}: 1st transmission
- C_1 :Channel 1
- Duty Cycle: 10%

Duty Cycle Limit, δ =10%

$$T_{off} = T_a \times (\frac{1}{\delta} - 1) = 1 \times \left(\frac{1}{0.1} - 1\right) = 9$$

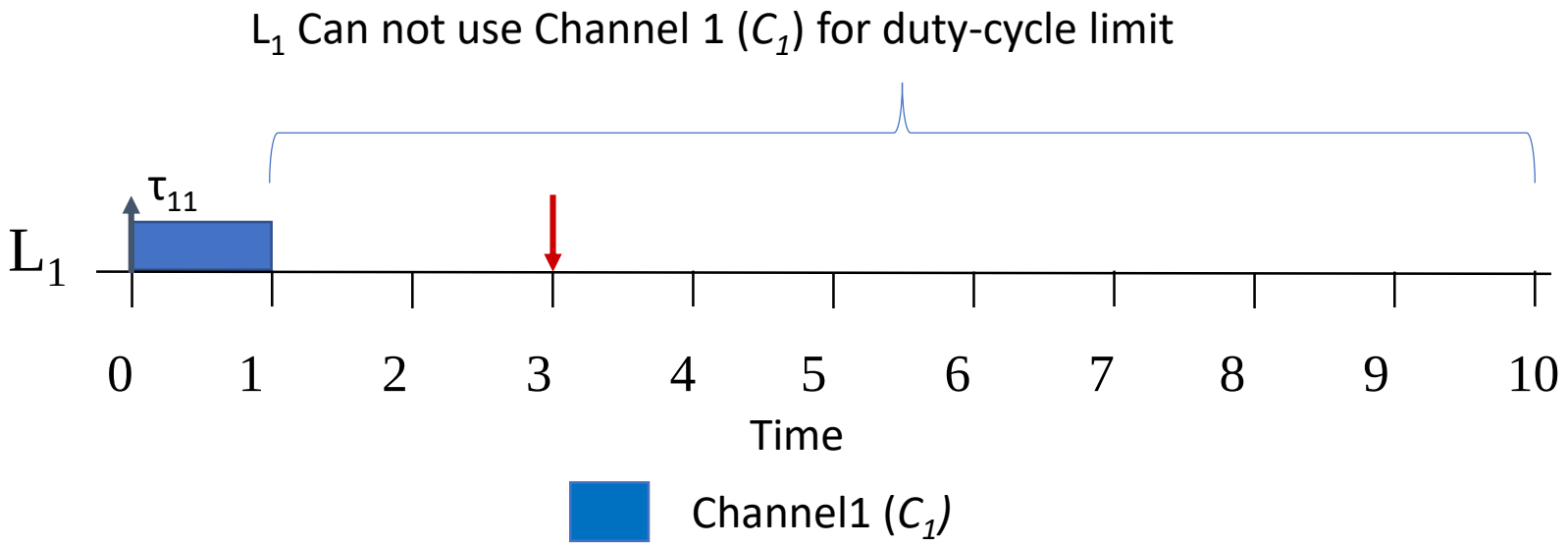


Figure: Duty Cycle Limit

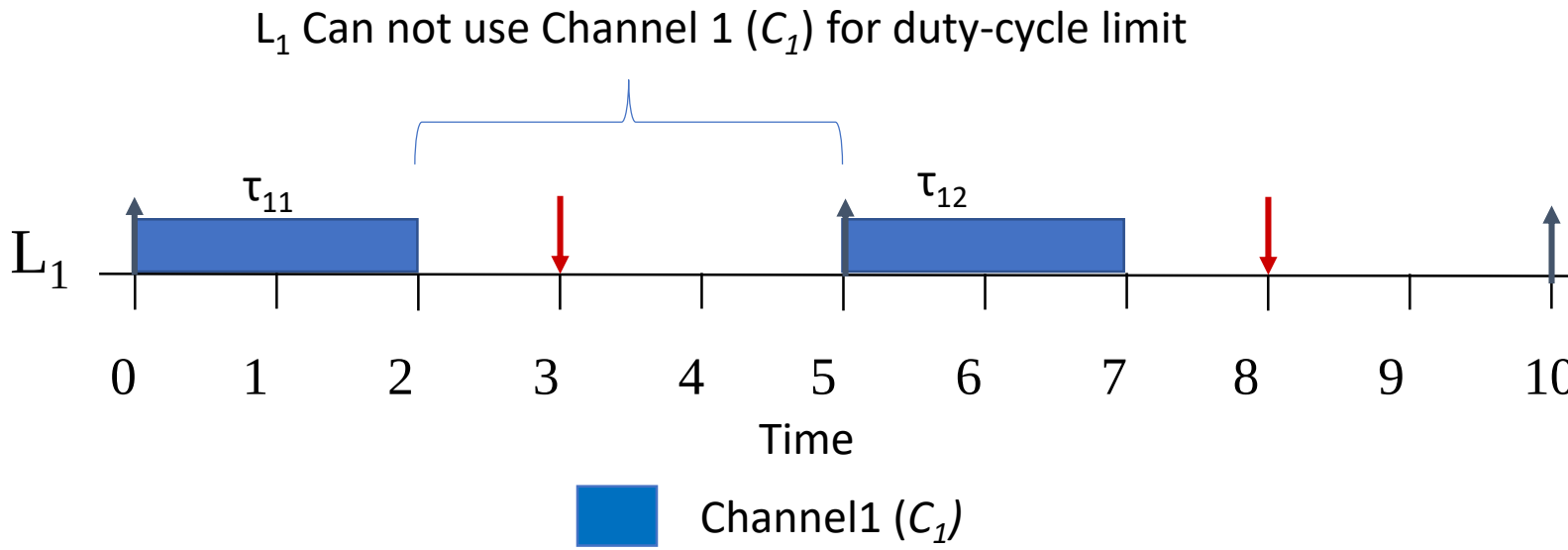
Real Time Scheduling for LoRa

Motivation

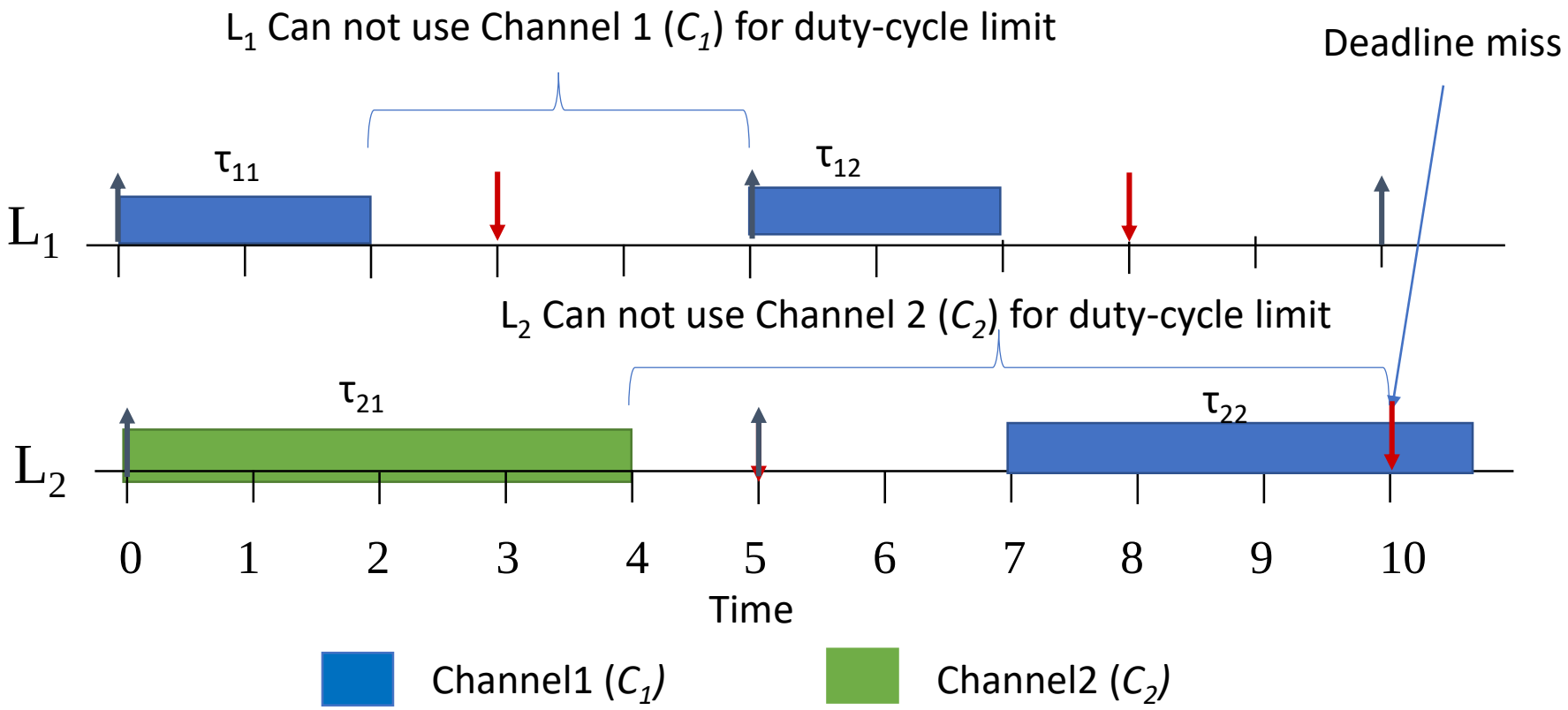
Link	Release Time	Time on Air	Deadline	Period
L1	0	2	3	5
L2	0	4	5	5

Duty Cycle Limit, δ =40%

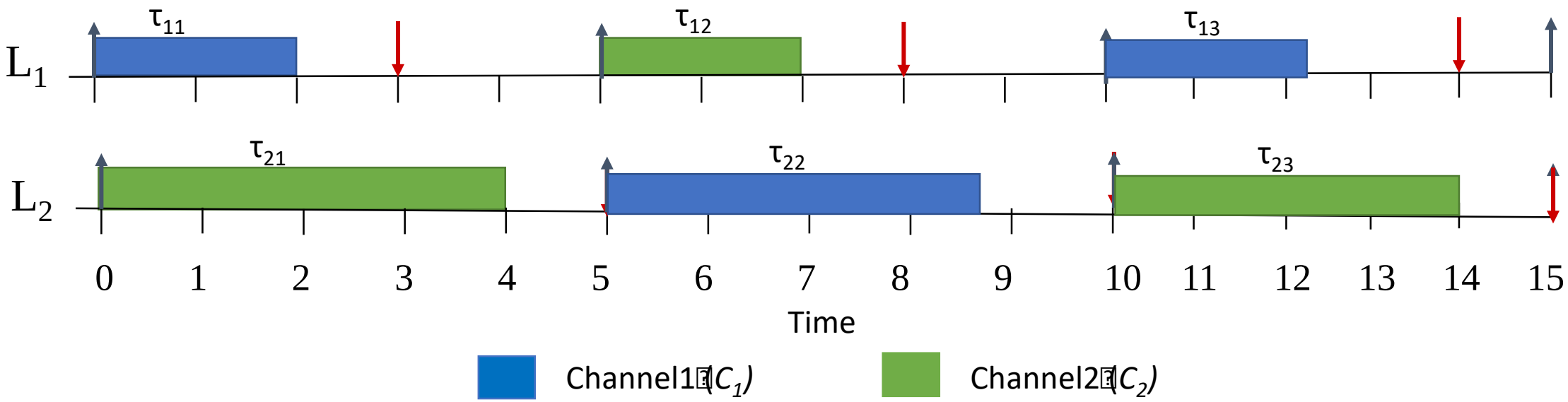
$$T_{off} = T_a \times (\frac{1}{\delta} - 1) = 2 \times \left(\frac{1}{0.4} - 1\right) = 3$$



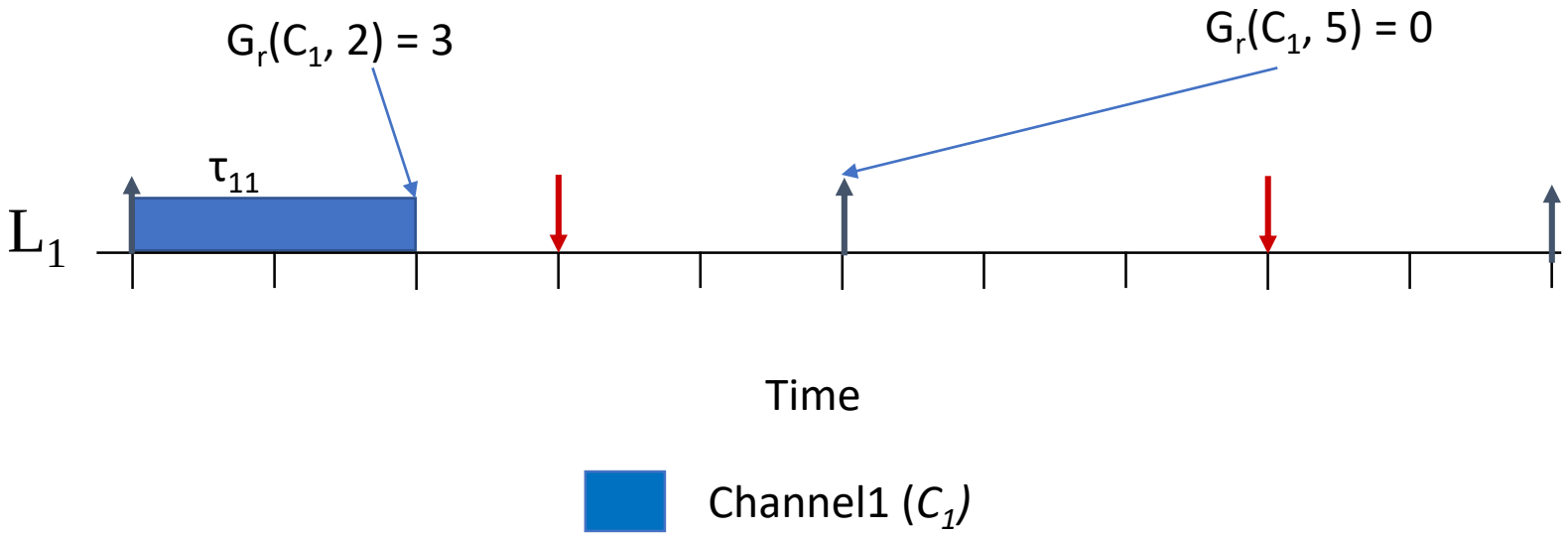
Traditional Scheduling Algorithm



Desired Scenario



Proposed Solution



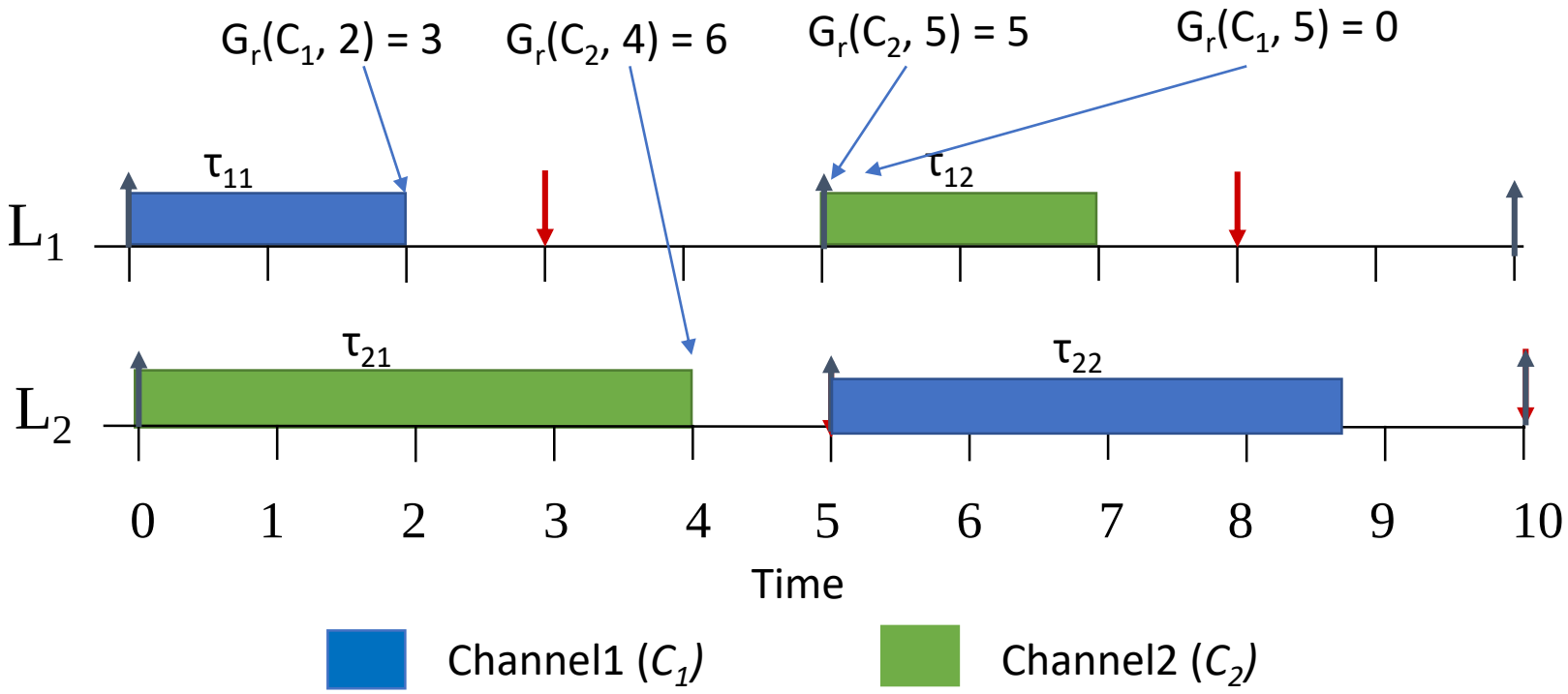
$$T_{off} = T_a \times (\frac{1}{\delta} - 1) = 2 \times \left(\frac{1}{0.4} - 1\right) = 3$$

$$G_r(C_1) = \max(G_r(C_1), T_{off}) = \max(0,3) = 3$$

Proposed Solution

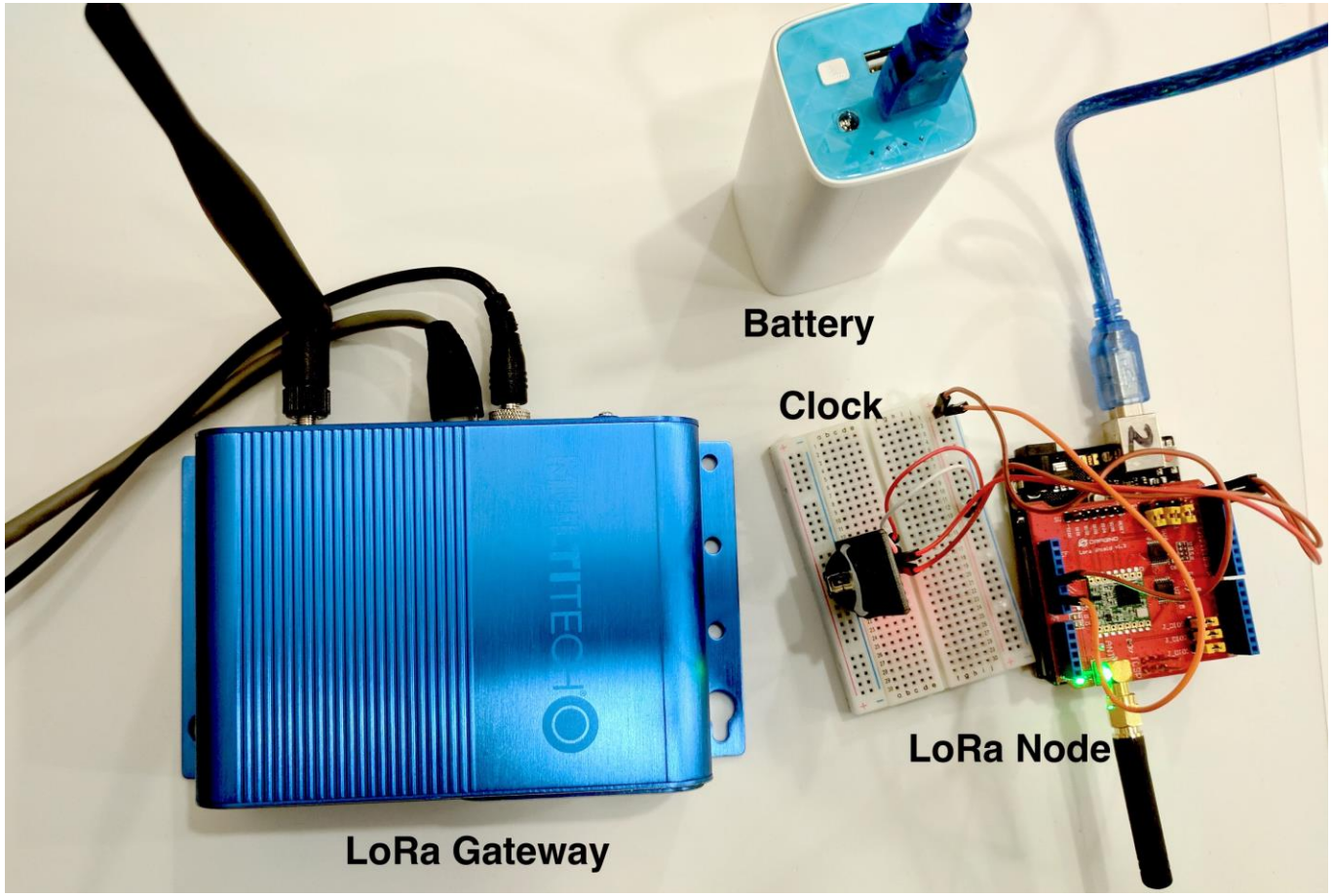
- Packet Selection: Least Laxity First
- Channel Selection: Available channel with the maximum gravity.

Proposed Solution



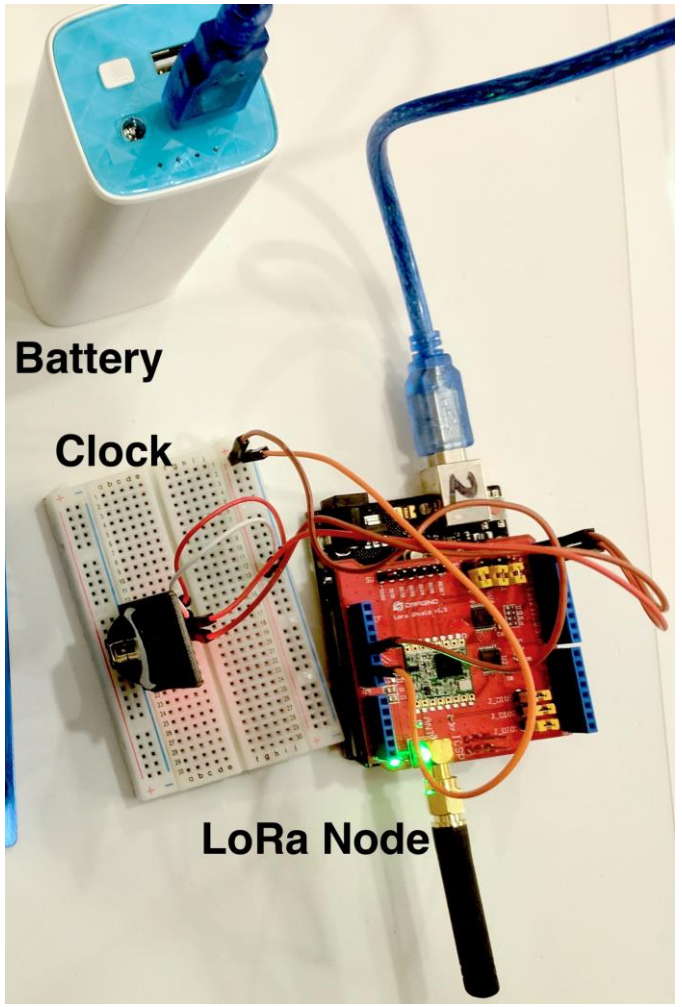
Implementation & Setup

Implementation



Implementation (LoRa Node)

- Components: A LoRa radio shield with an Arduino Uno.
- LoRa radio shield: transceiver SX1272/73.
- Software: IBM lmic Library.
- Power: 10,000mAh USB power bank.
- Clock: an external real-time clock.

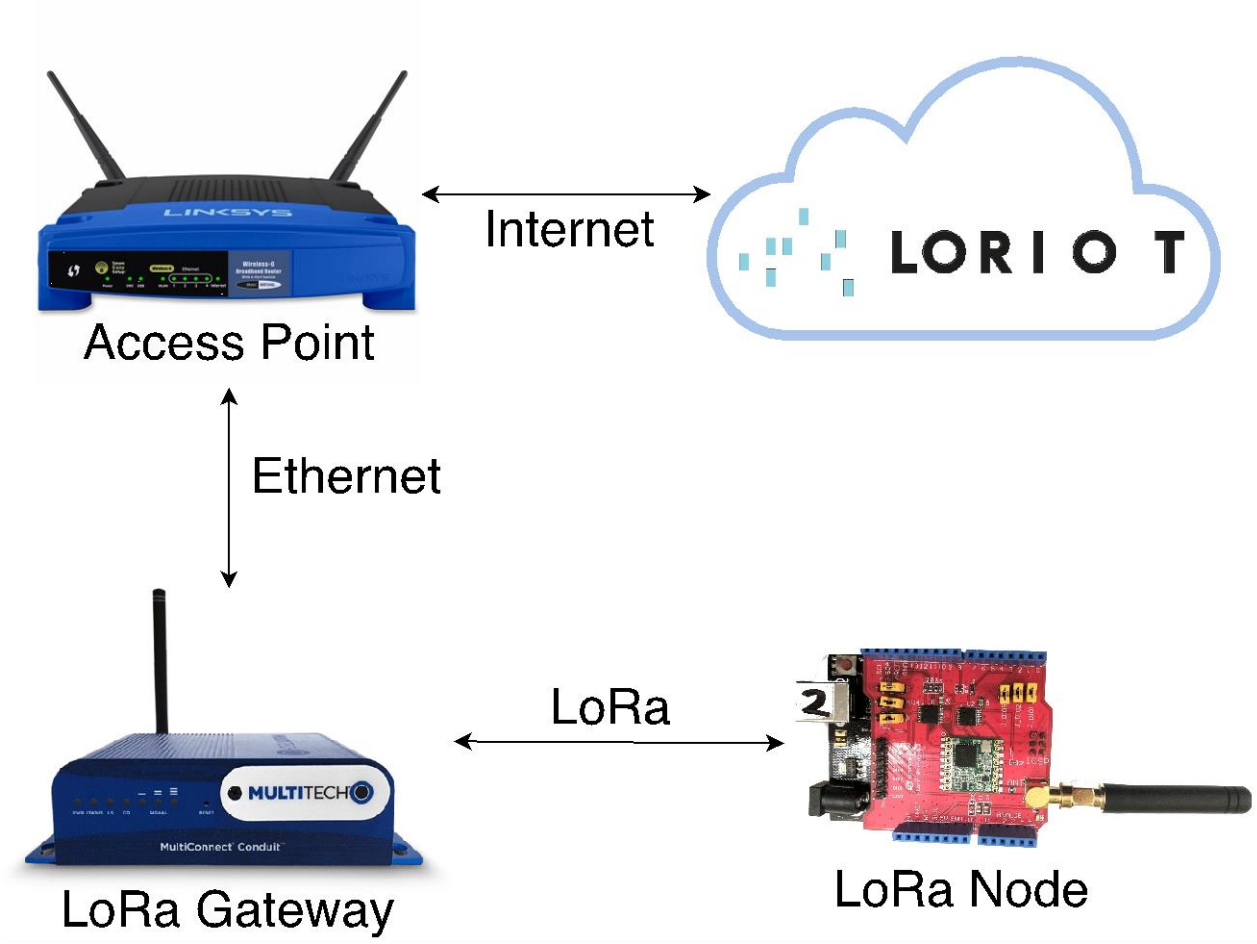


Implementation(Gateway)

- Multitech Conduit device.
  - Runs on an enhanced closed source embedded Linux platform.
  - a configurable and scalable Internet gateway for industrial IoT.
- listens to one sub-band at a time.
  - a gateway can listen to eight channels simultaneously.

Implementation (Application Server)

Setup


Internet
LORIOT
Access Point
Ethernet
LoRa
MULTITECH
MultiConnect Conduit
LoRa Gateway
LoRa Node

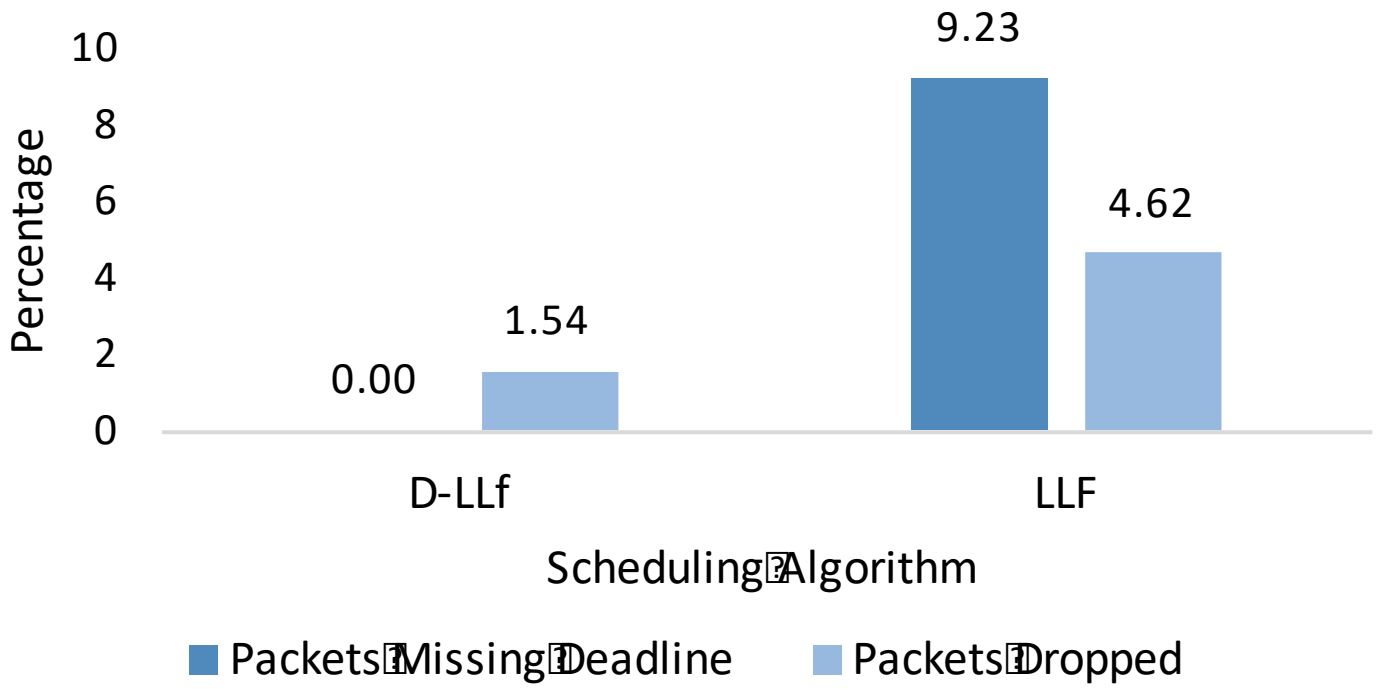
Setup


MULTITECH
PWR STATUS LS CD SIGNAL RESET
MultiConnect® Conduit™

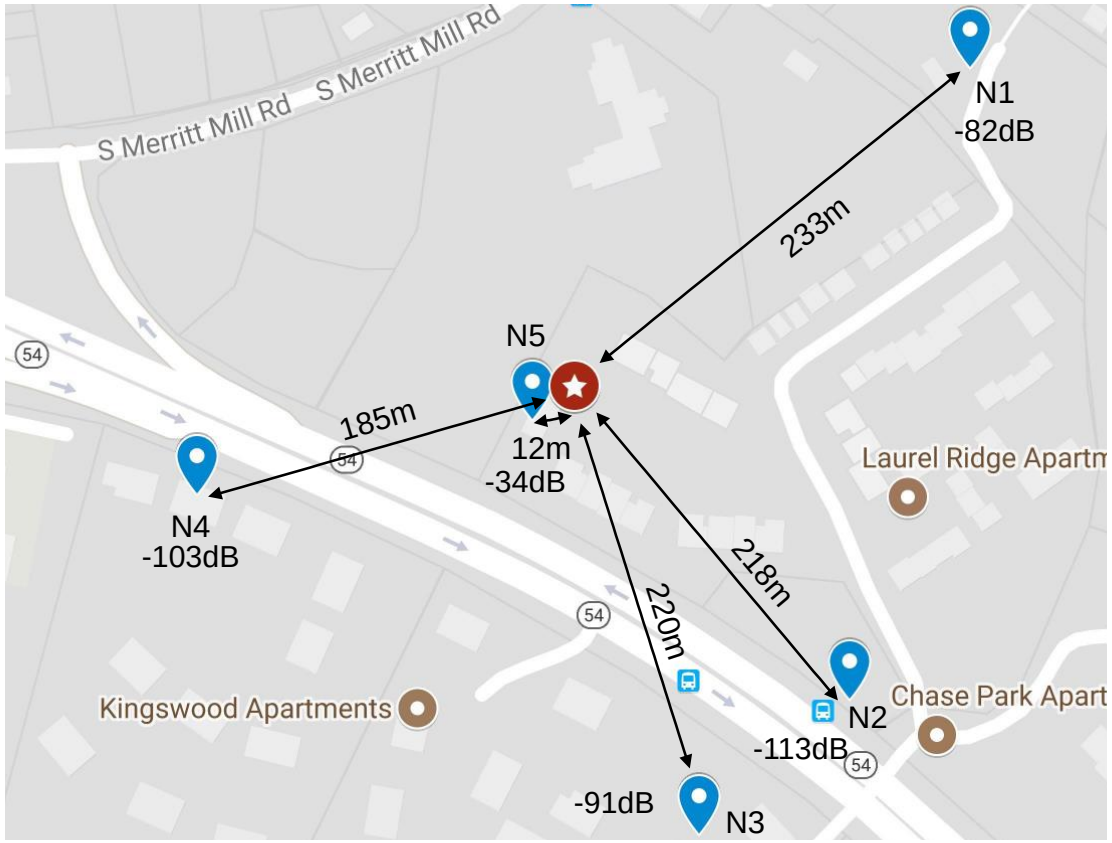
Indoor Setup

5 transmitters
1 receiver

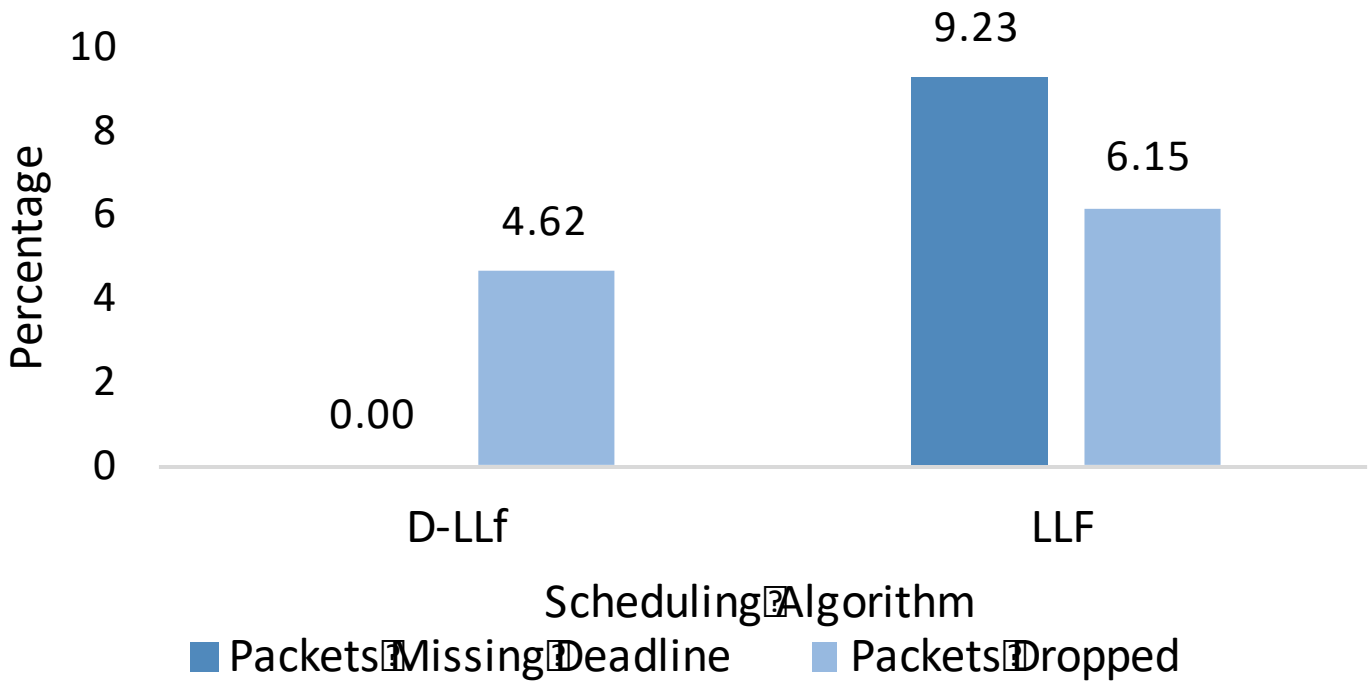
Result Indoor



Outdoor Setup



Result Outdoor



Future Work

- Fixing issues in simulation.
- Necessary/sufficient condition for schedulibility.
- Distributed version of scheduling algorithm.

Thank You