SATELLITE LORAWAN NETWORKS

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Date: 06 July 2023

LORSAT
https://www.lorsat.lu/

CORE MULTI-ANNUAL THEMATIC RESEARCH PROGRAMME

Fonds National de la Recherche Luxembourg

LUXEMBOURG INSTITUTE OF SCIENCE AND TECHNOLOGY LIST

LORSAT PROJECT

LORSAT (Design of LoRaWAN protocol Optimisation over SATellite Connection for precision agriculture applications) is a national research project funded by the Luxembourg National Research Fund under the FNR CORE 2019 framework. LORSAT was kicked-off in September 2020 to develop technical solutions that allow the smooth integration and interoperability of satellite and LoRaWAN networks, while ensuring the target Quality of Service (QoS), over the entire end-to-end (e2e) system.

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Unifying LPWA Networks
Frontier Connect
GOMSPACE
IETF
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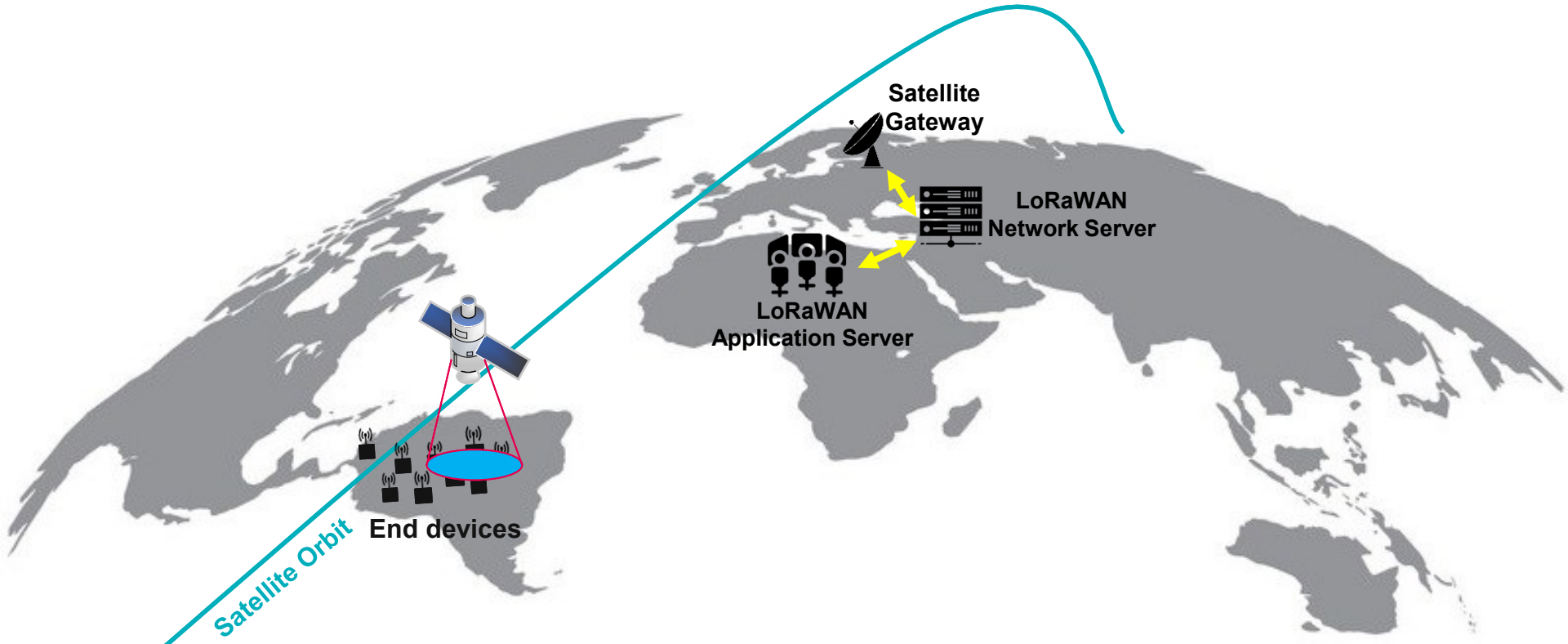
DUNAV NET

Funded by:

Fonds National de la Recherche Luxembourg
CORE MULTI-ANNUAL THEMATIC RESEARCH PROGRAMME

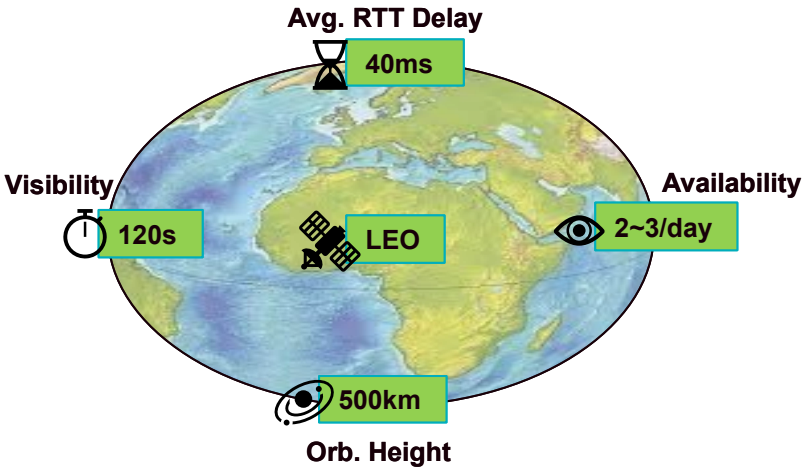
LIST

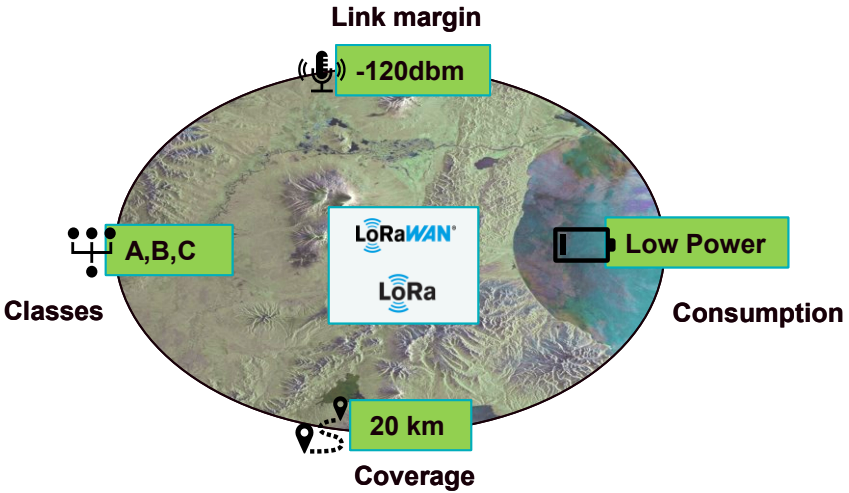
LORAWAN WITH LEO SATELLITE



LORAWAN WITH LEO SATELLITE

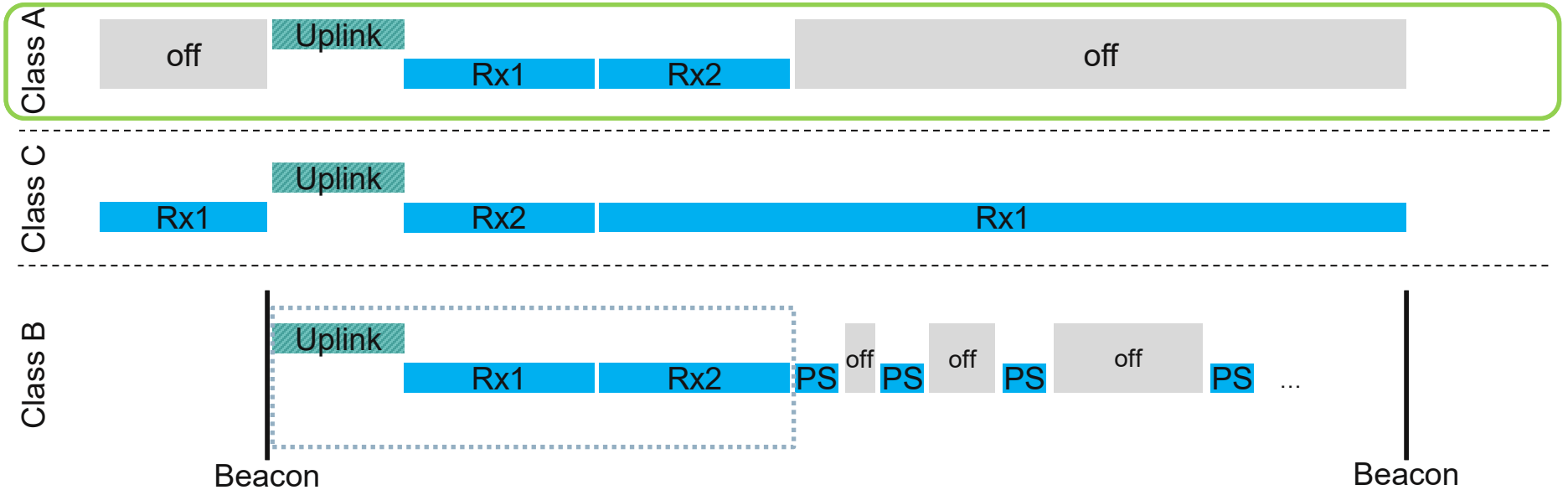
HYPOTHESIS: LORAWAN AND LEO SATELLITE SPECIFICATIONS





LORAWAN

LORA COMMUNICATION MODES



Uplink (TX) End Device → Server

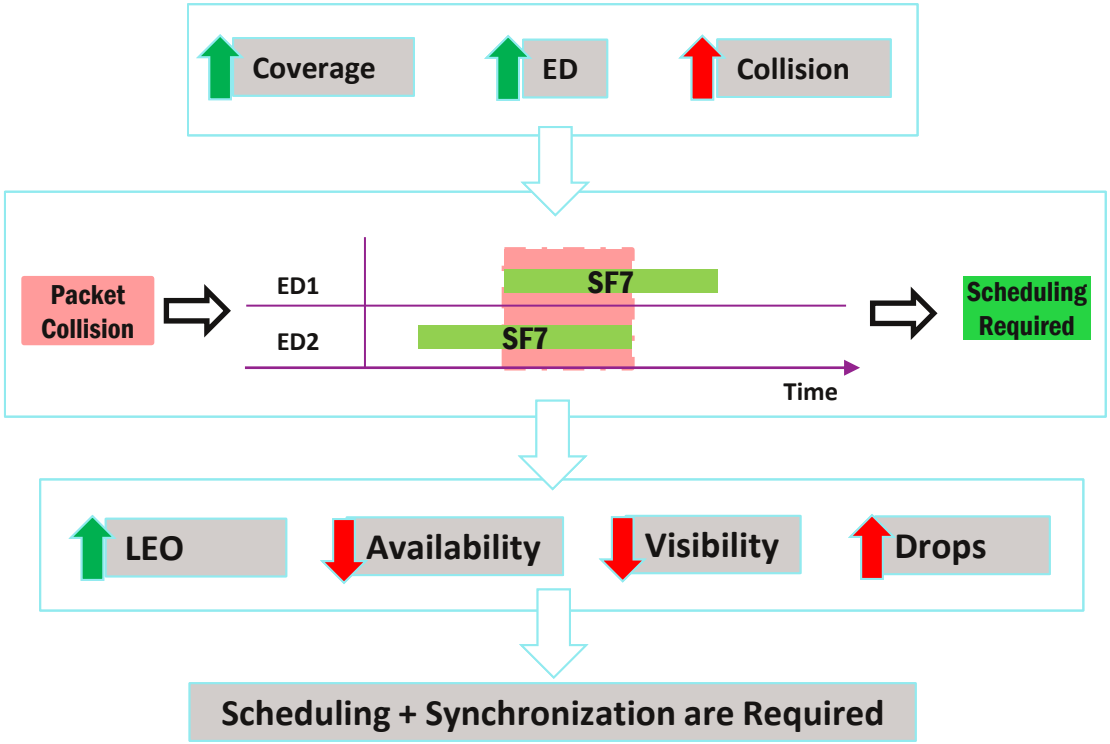
Downlink(Rx) End Device ← Server

PS Ping Slot

Rx Receive Window

PROBLEM STATEMENT

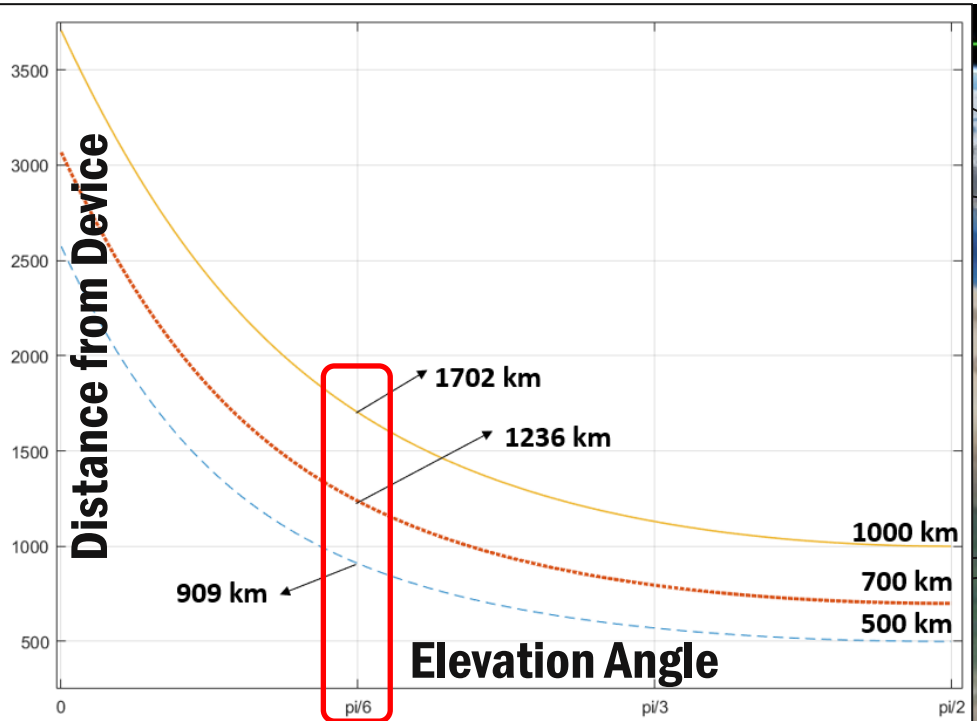
REQUIREMENTS: SCHEDULING AND SYNCHRONIZATION

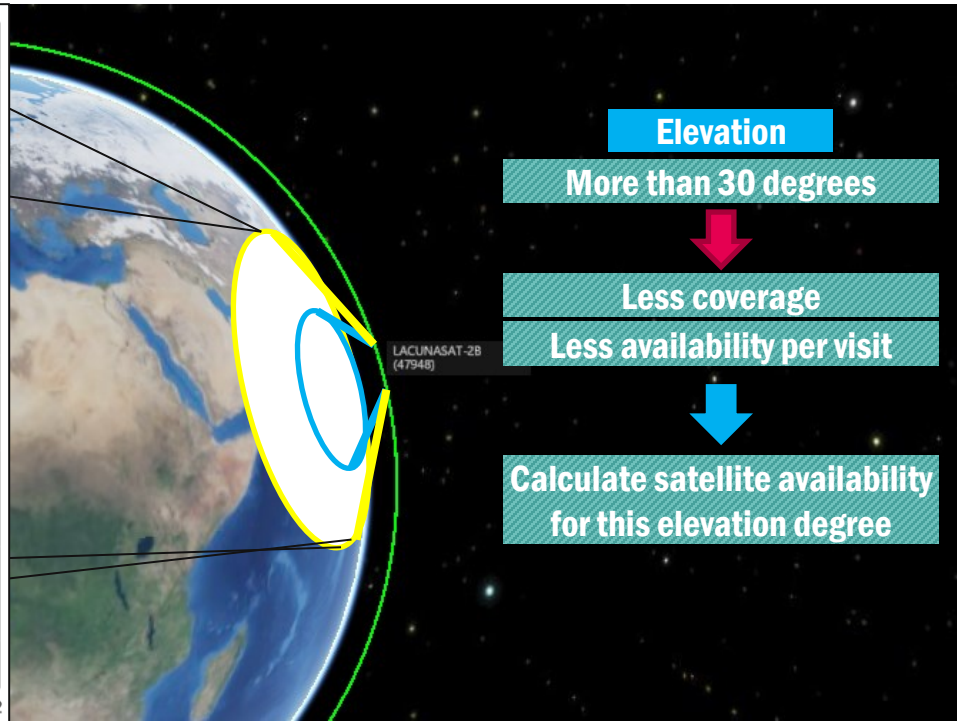


SCHEDULING

PROBLEM STATEMENT

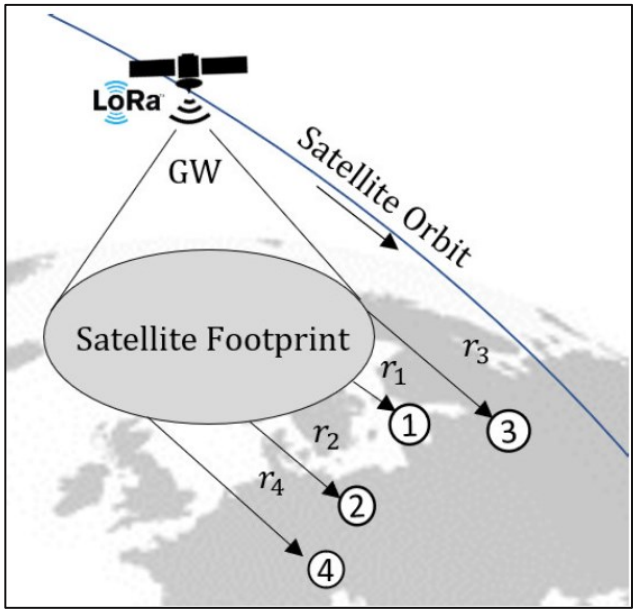
SATELLITE FOOTPRINT





SCHEDULING ALGORITHM

SALSA : SCHEDULING ALGORITHM FOR LORA TO LEO SATELLITES

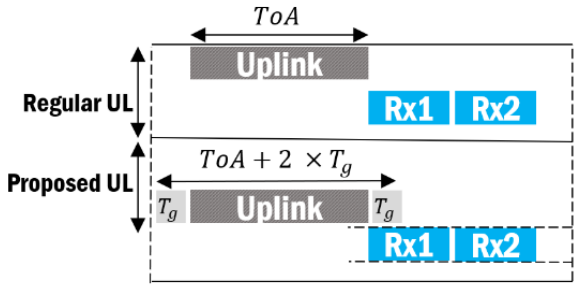


Considerations

- Having mobility in the footprint
- Collisions in the dense areas
- Uncertainty in design

↓

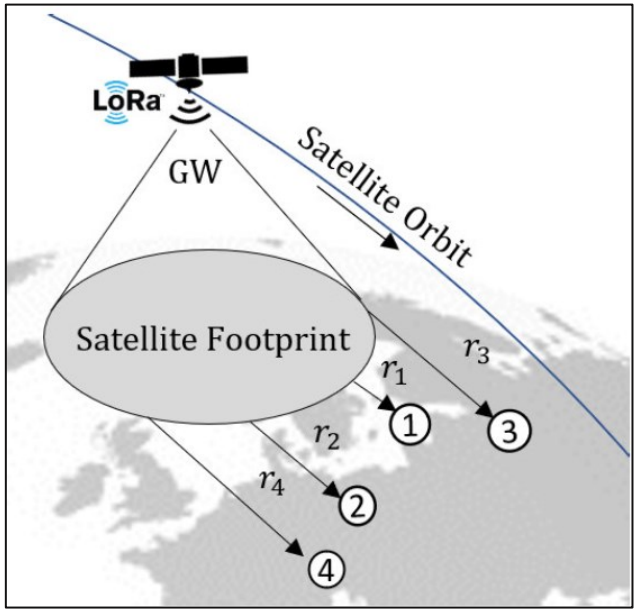
- Update the available slot for Uplink



M. Afhamisis and M. R. Palattella, "SALSA: A Scheduling Algorithm for LoRa to LEO Satellites," in IEEE Access, vol. 10, pp. 11608-11615, 2022, doi: 10.1109/ACCESS.2022.3146021.

SCHEDULING POLICY

SALSA - FIRST COME FIRST SERVE POLICY



Algorithm 1 SALSA With FCFS Policy

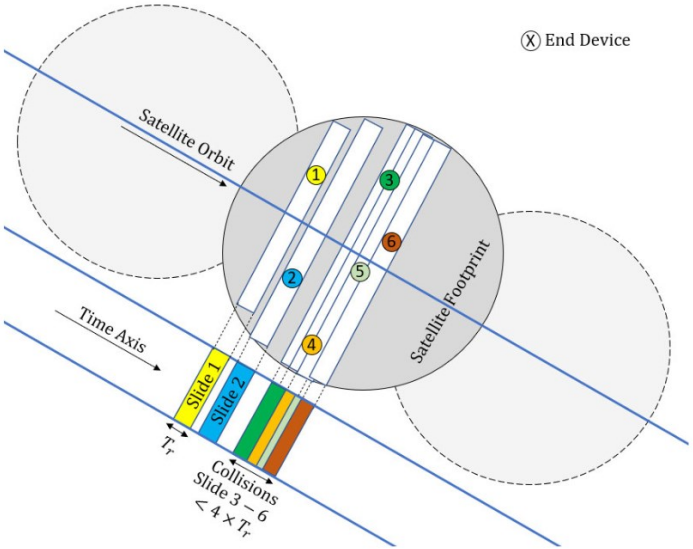
```
for slide_k do
  for ED_i do
    if T_SSV_i < T_E_j then
      T_S_i ← T_E_j                    ▷ TX after last ED
    else
      T_S_i ← T_SSV_i                  ▷ TX when satellite is available
    end if
  end for
end for
```

Closer ED to Satellite footprint → **More Priority**

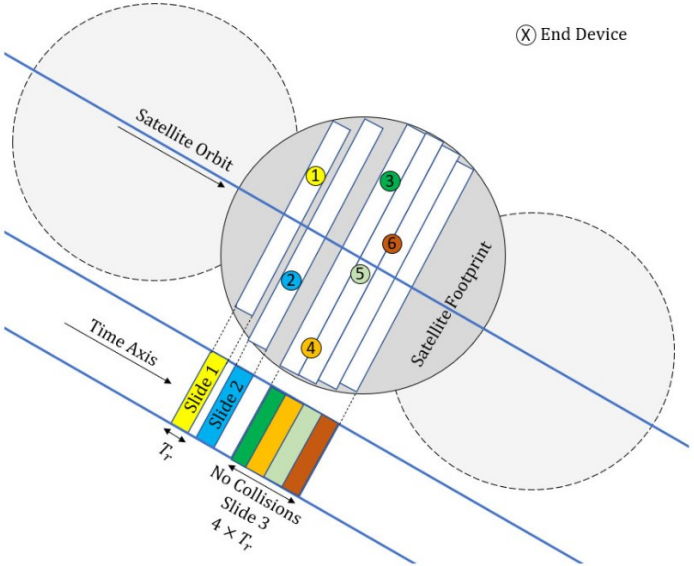
LIST

SCHEDULING POLICY

SALSA - SLIDE CONCEPT- CANCELLING THE COLLISIONS



(a) Overlapping transmissions.



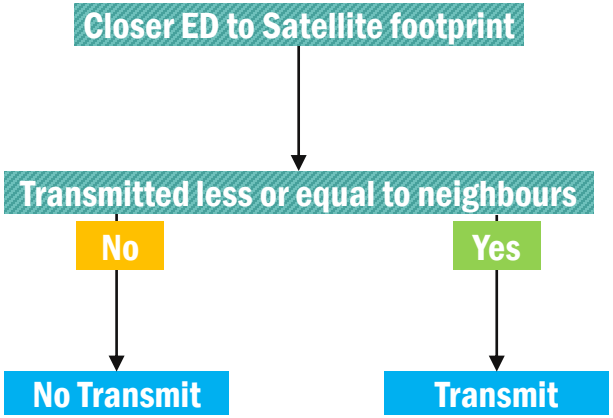
(b) Collision Cancellation.

SCHEDULING POLICY

SALSA -FAIR POLICY

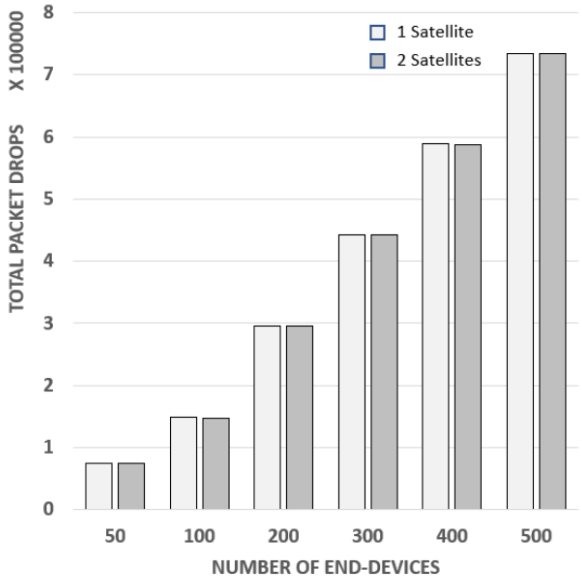
Algorithm 2 SALSA With Fair Policy

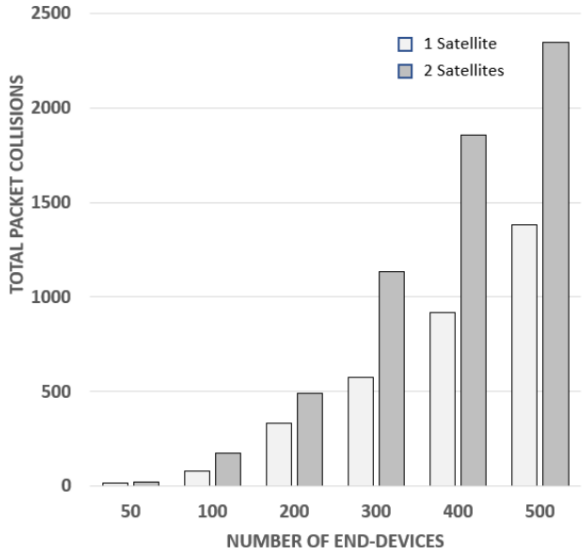
```
for slide_k do
  for ED_i do
    if n_txi ≤ n_txj then                          ▷ Fairness check
      if T_SSVi < T_Ej then
        T_Si ← T_Ej                                ▷ TX after last ED
      else
        T_Si ← T_SSVi                              ▷ TX when satellite is available
      end if
    else
        Do not TX                                  ▷ Give the chance to the next ED
    end if
  end for
end for
```



PERFORMANCE EVALUATION

WITHOUT SCHEDULING – EVERY 30 MINS





PERFORMANCE EVALUATION

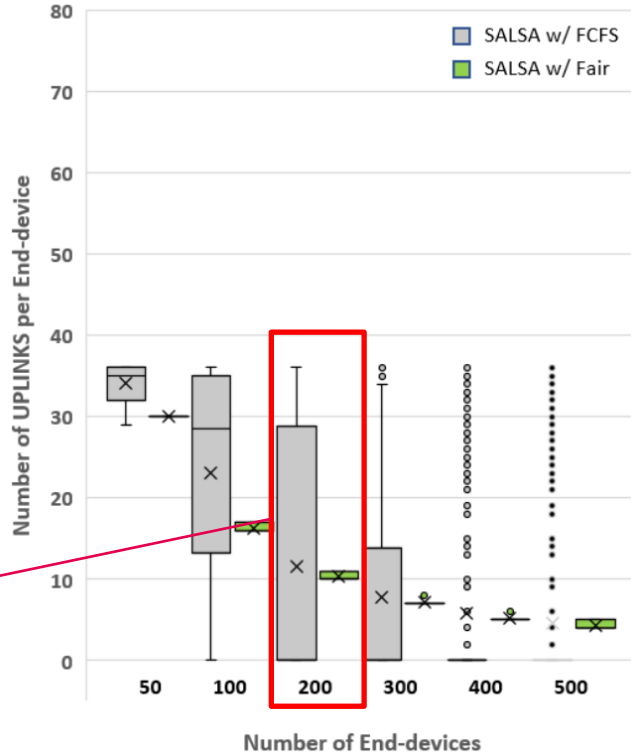
WITH SCHEDULING

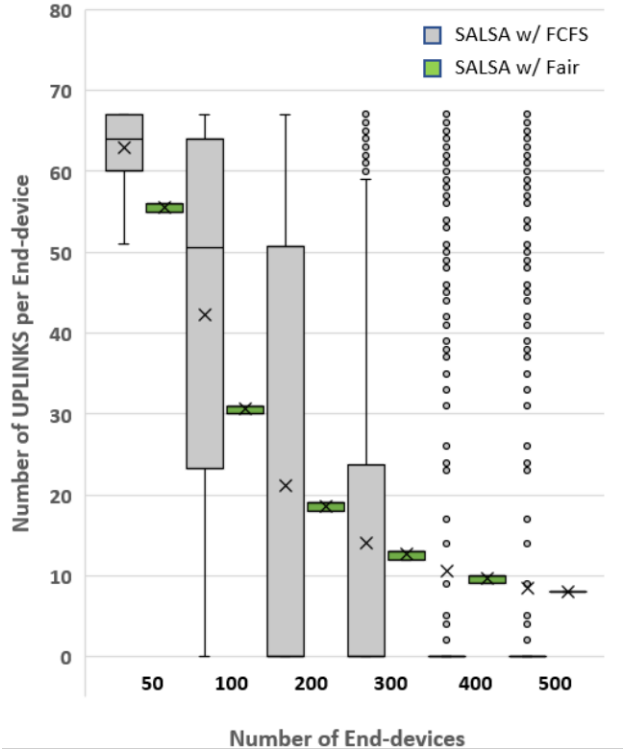
Fair Policy

Efficient resource sharing

Same chance for all EDs

Policy	FCFS	FAIR
No. TX	0-36	10-11

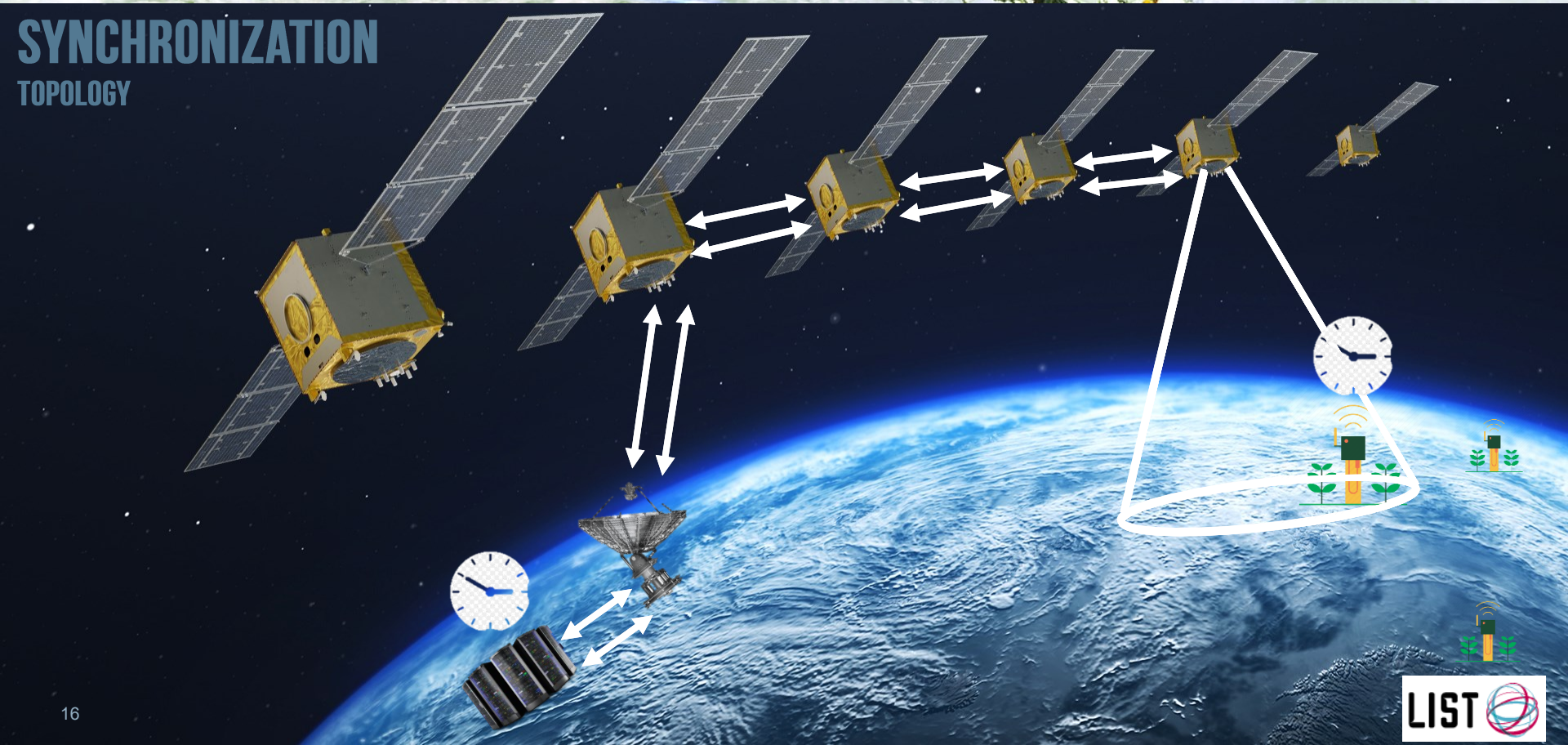




SYNCHRONIZATION

SYNCHRONIZATION

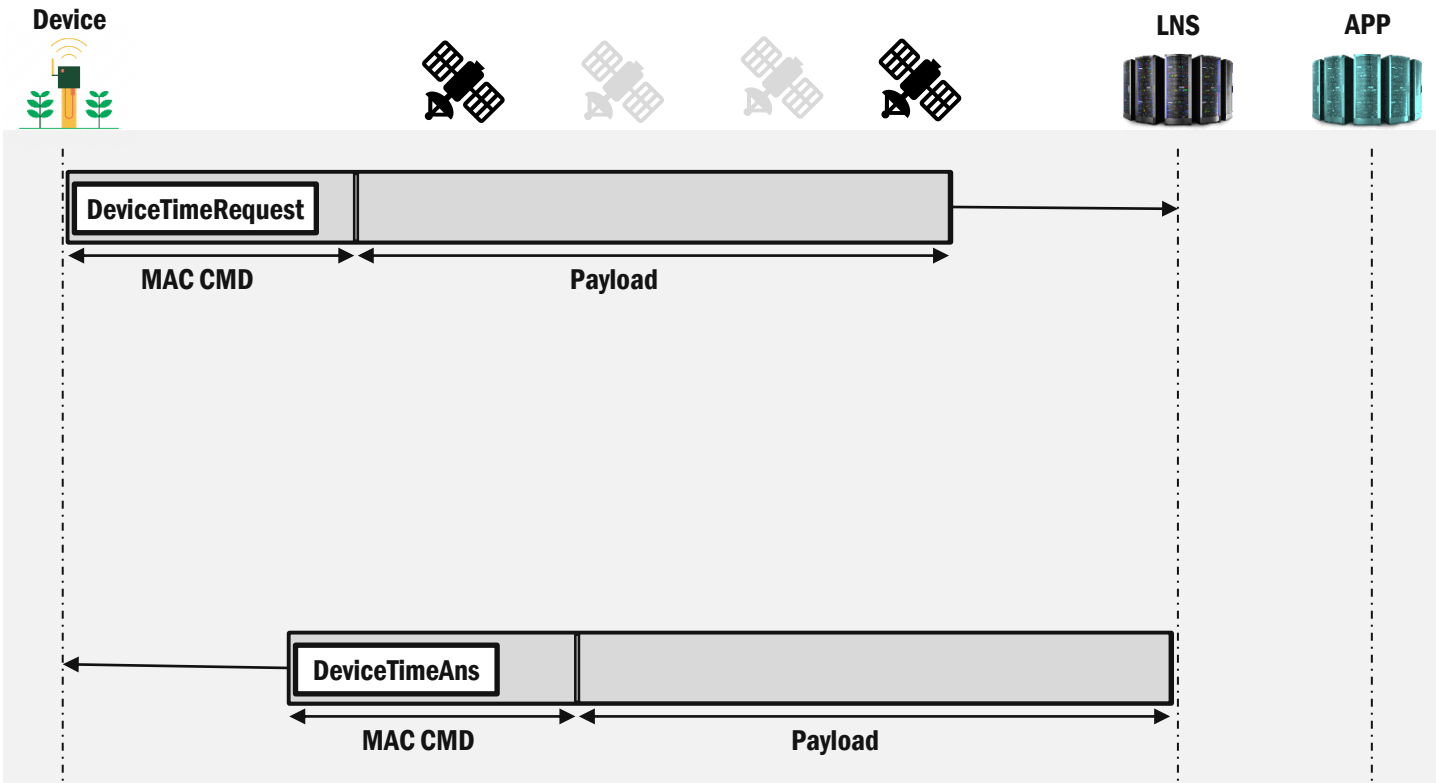
TOPOLOGY



LIST

SYNCHRONIZATION

STANDARD MAC METHOD



VALIDATION WITH PROOF OF CONCEPT

TESTBED

ARCHITECTURE

GPS
(Time Reference)

python

Application Layer

LoRaWAN MAC

LoRa PHY

Stratum 0

ED

GW

ChirpStack

Stratum 1

Backhauling

OpenSAND

ChirpStack

ChirpStack
Server

Client

LNS

APP

APP

gRPC

gRPC

MQTT

NTP
Server

MQTT

Stratum 3

Stratum 3

Packet
Forwarder

MQTT

MQTT
Broker

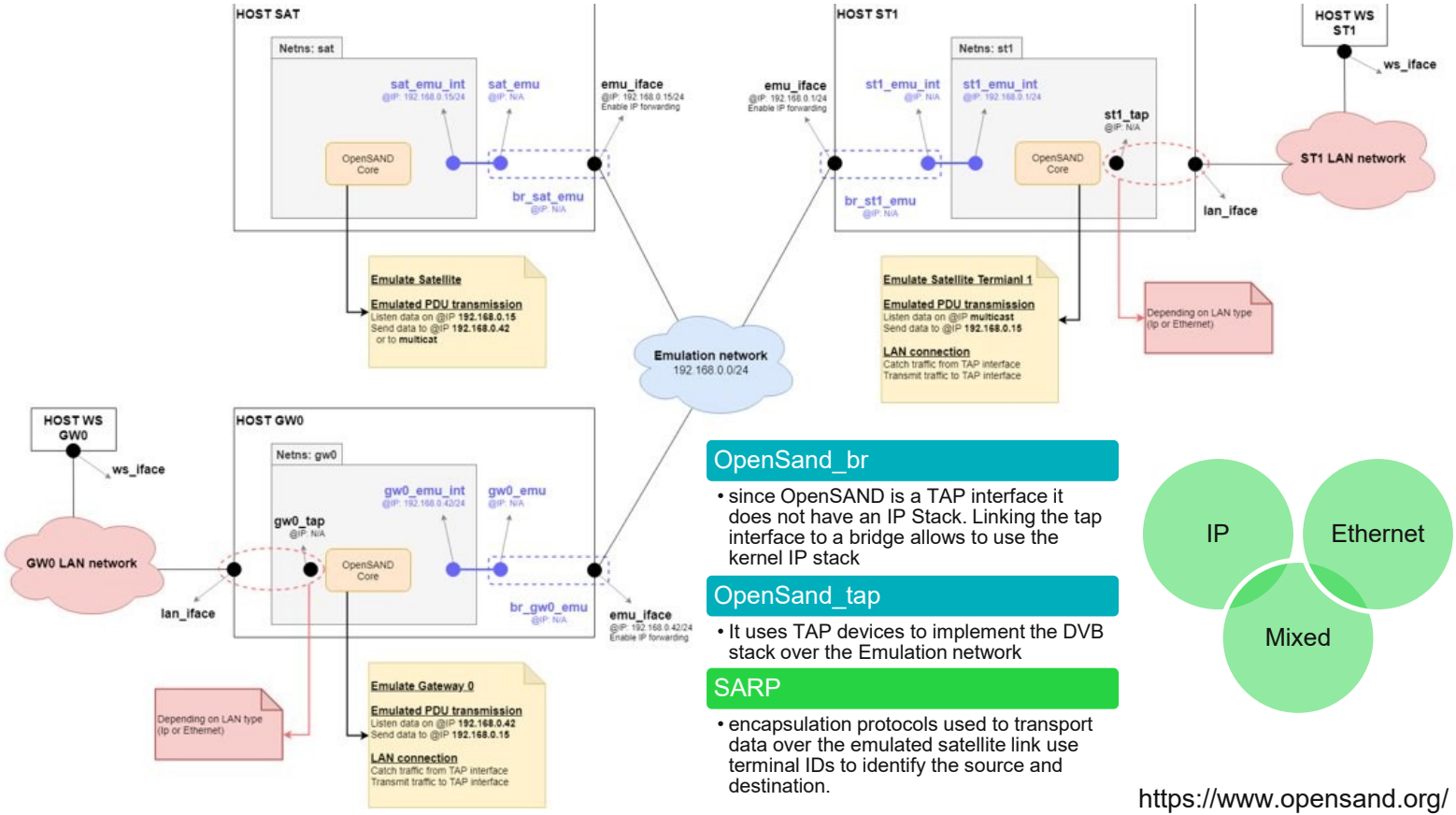
NUCLEO WL55JC1

RAK WIRELESS 7244C

LIST

TESTBED

SATELLITE EMULATOR



OpenSand_br

- since OpenSAND is a TAP interface it does not have an IP Stack. Linking the tap interface to a bridge allows to use the kernel IP stack

OpenSand_tap

- It uses TAP devices to implement the DVB stack over the Emulation network

SARP

- encapsulation protocols used to transport data over the emulated satellite link use terminal IDs to identify the source and destination.

https://www.opensand.org/

TESTBED

APPLICATION SERVER

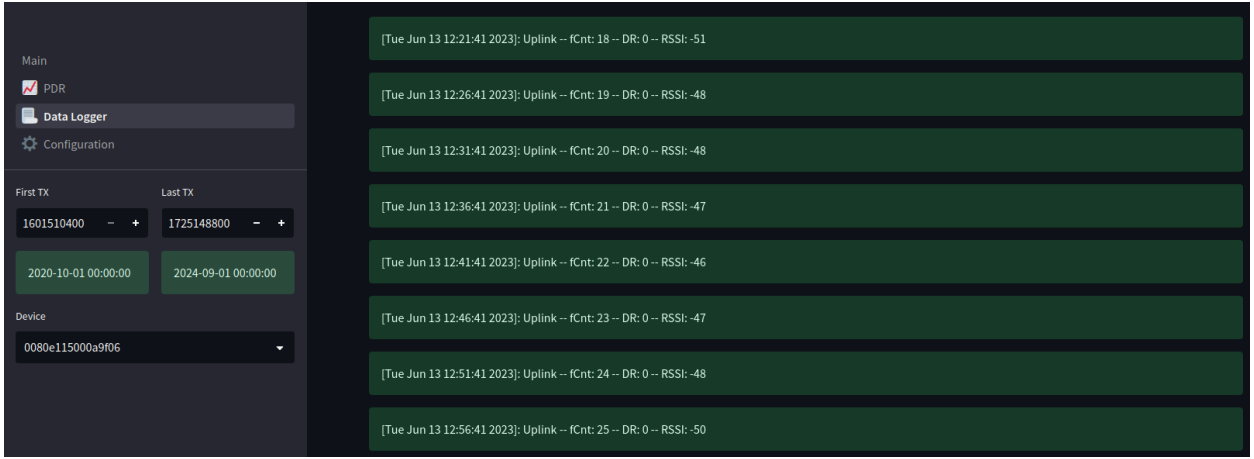
- Verify Satellite Availability
- Manage the network
- Manage the scheduling
- Store Data

```
[2023-06-29 13:57:41.592907] LACUNASAT-2B Visibility file generated in the data/VisData/8.txt for 0080e1150530ffbd
[2023-06-29 13:57:57.212594] LACUNASAT-3 Visibility file generated in the data/VisData/8.txt for 0080e1150530ffbd
[2023-06-29 13:58:11.366453] LACUNASAT-2B Visibility file generated in the data/VisData/9.txt for 0080e11505310699
[2023-06-29 13:58:26.768295] LACUNASAT-3 Visibility file generated in the data/VisData/9.txt for 0080e11505310699
[2023-06-29 13:58:40.794607] LACUNASAT-2B Visibility file generated in the data/VisData/10.txt for 0080e11505310704
[2023-06-29 13:58:56.397620] LACUNASAT-3 Visibility file generated in the data/VisData/10.txt for 0080e11505310704
[2023-06-29 13:58:56.405802] Visibility service done
[2023-06-29 13:58:56.424197] Starting SALSA-FAIR Scheduling service
[2023-06-29 13:58:56.435283] 10 EDs selected for scheduling
[2023-06-29 13:58:56.446869] The existing schedule data/schedule/0080e115000a9f06.csv deleted.
[2023-06-29 13:58:56.458234] The existing schedule data/schedule/0080e115000ad747.csv deleted.
[2023-06-29 13:58:56.468271] The existing schedule data/schedule/0080e115000adb3e.csv deleted.
[2023-06-29 13:58:56.476069] The existing schedule data/schedule/0080e1150500dafd.csv deleted.
[2023-06-29 13:58:56.484121] The existing schedule data/schedule/0080e1150530f82d.csv deleted.
[2023-06-29 13:58:56.491678] The existing schedule data/schedule/0080e1150530fe43.csv deleted.
[2023-06-29 13:58:56.500071] The existing schedule data/schedule/0080e1150530feba.csv deleted.
[2023-06-29 13:58:56.507176] The existing schedule data/schedule/0080e1150530ffbd.csv deleted.
[2023-06-29 13:58:56.521377] The existing schedule data/schedule/0080e11505310699.csv deleted.
[2023-06-29 13:58:56.531072] The existing schedule data/schedule/0080e11505310704.csv deleted.
[2023-06-29 13:58:56.538360] Reading the files, converting to array and creating visibility time tables ...
[2023-06-29 13:59:33.578784] Scheduling service done
[2023-06-29 13:59:33.592523] GW Availability service started
[2023-06-29 13:59:47.467867] GW Availability service done
[2023-06-29 14:00:03.150922] GW Availability service done
[2023-06-29 14:00:03.176771] MQTT connected successfully
[2023-06-29 14:00:03.183728] Subscribed to all MQTT events
```

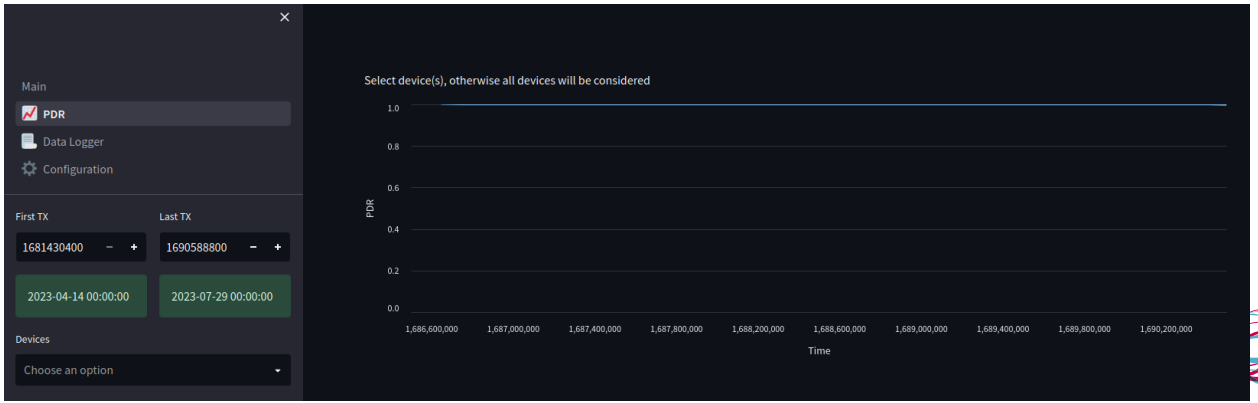
TESTBED

APPLICATION SERVER

Process the data

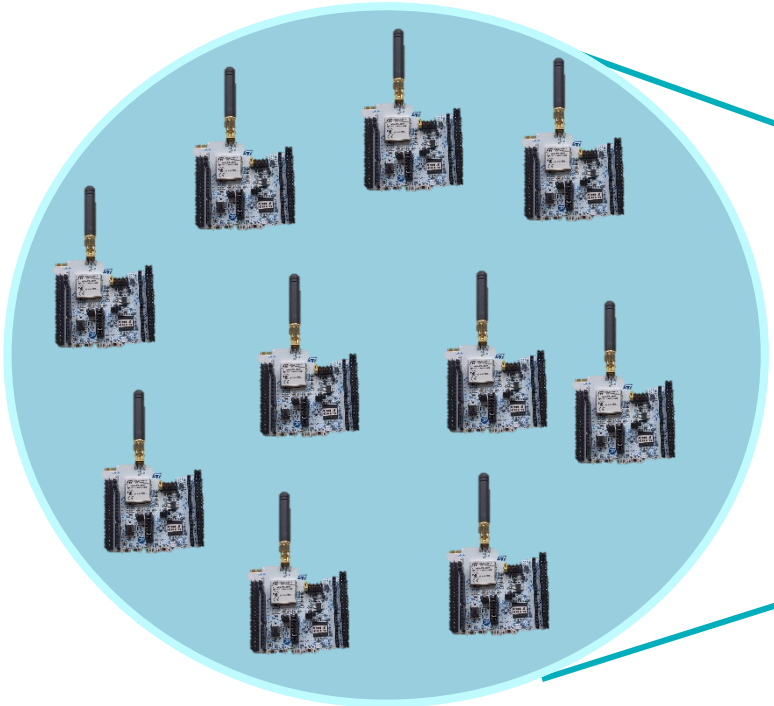


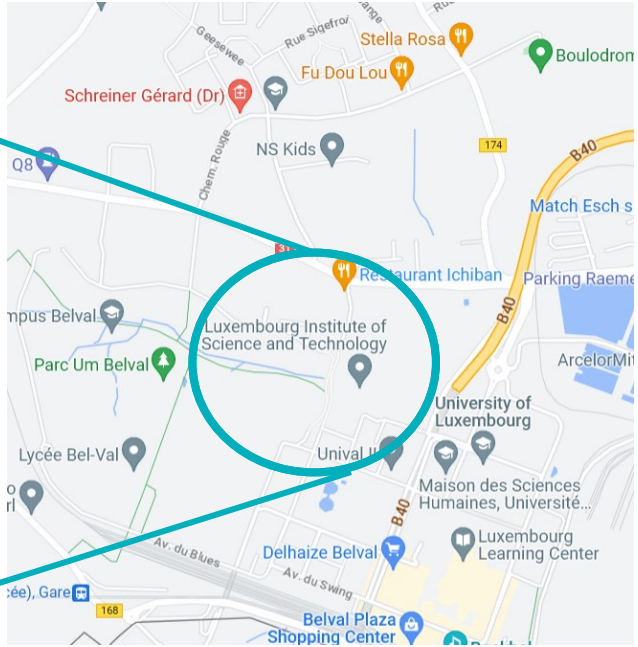
Measure the KPI



TESTBED

DEVICES



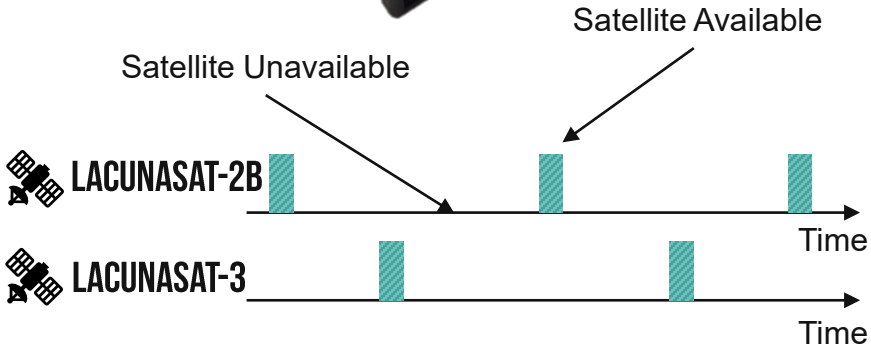


Same Location

LIST

TESTBED

LORAWAN GATEWAY



Satellite Availability = Gateway Availability

ELECTRO HAUSER
www.hauser.lu
LGW

```
pi@rak-gateway:~ $ ping 192.168.4.20
PING 192.168.4.20 (192.168.4.20) 56(84) bytes of data.
64 bytes from 192.168.4.20: icmp_seq=1 ttl=64 time=516 ms
64 bytes from 192.168.4.20: icmp_seq=2 ttl=64 time=533 ms
64 bytes from 192.168.4.20: icmp_seq=3 ttl=64 time=532 ms
64 bytes from 192.168.4.20: icmp_seq=4 ttl=64 time=529 ms
64 bytes from 192.168.4.20: icmp_seq=5 ttl=64 time=513 ms
64 bytes from 192.168.4.20: icmp_seq=6 ttl=64 time=540 ms
64 bytes from 192.168.4.20: icmp_seq=7 ttl=64 time=527 ms
64 bytes from 192.168.4.20: icmp_seq=8 ttl=64 time=524 ms
```

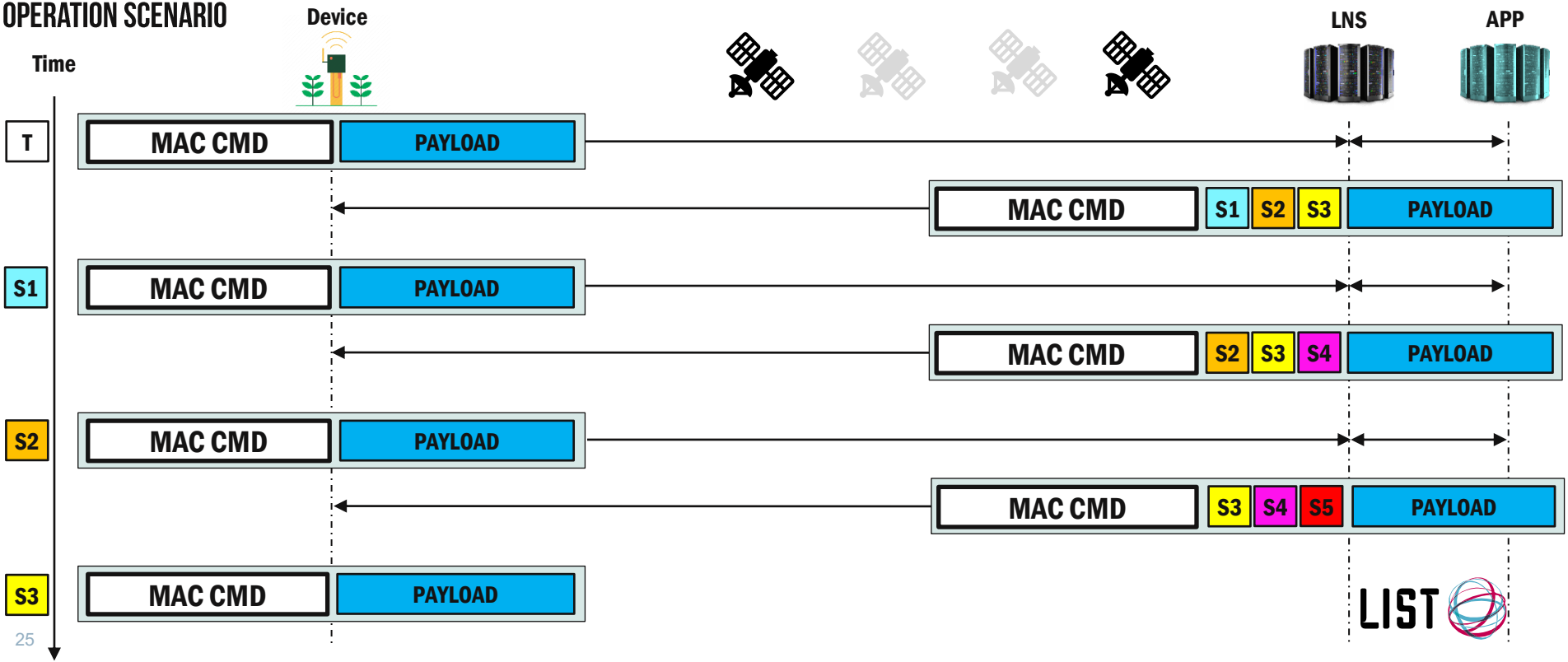
ELECTRO HAUSER
www.hauser.lu
LGW

```
pi@rak-gateway:~/vis $ sudo ./GatewayService
LORSAT Project -- Luxembourg Institute of Science and Technology (LIST)
Satellite LoRaWAN Gateway Emulator -- Written by Mohammad Afhamisis
Emulating LEO satellite availability
Program started ..............

>>>>>> Satellite is Available -- 1688390490
<<<<<< Satellite is Unavailable -- 1688390621
```

E2E SYSTEM

OPERATION SCENARIO



LIST

CONCLUSION

- Integrated smoothly LoRaWAN with Satellite network
- Implemented the Scheduling technique on the real network
- E2E network operated efficiently (Uplink/Downlink)
- Network is reliable and scalable
- The network can answer the requirements of the agricultural applications

LIST

Thanks
Merci

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