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QUALITY OF INFORMATION AWARE LORAWAN FOR MOBILE NODES

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WHAT IS LORAWAN?

Long Range Wide Area Network or in short LoRaWAN is a type of Low Power Wide Area Network (LPWAN) which uses unlicensed frequency band and LoRa protocol at physical layer for data transmission.

- LPWA networking protocol designed to wirelessly connect battery operated devices.
- uses sub-GHz frequency (unlicensed frequency band)
  - EU 433,05 – 434,79 (433 MHz), 863 - 870 MHz (868 MHz).
  - US 902 – 928 MHz (915 MHz).
  - Very good penetrating ability for indoor uses
  - Wide coverage area (up to 40 km rural areas)

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WHAT IS LORAWAN?

LoRaWAN ®Network Architecture

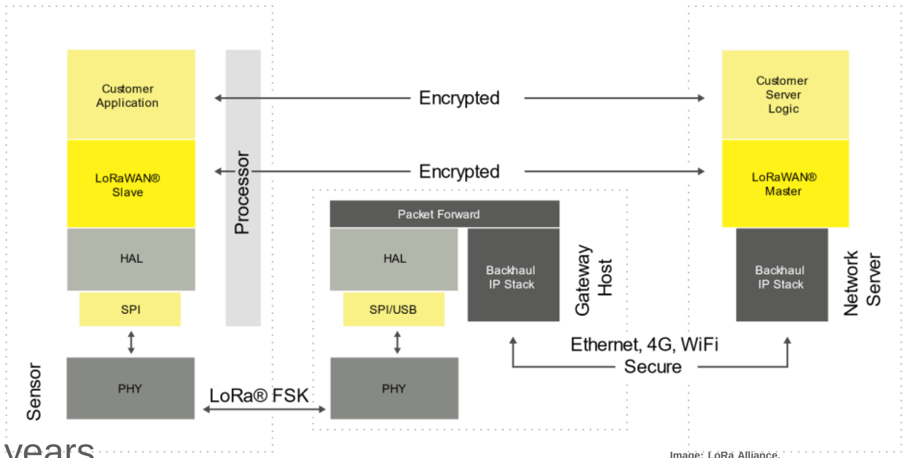

Image: LoRa Alliance.

- Open-source to develop solutions
  - Can use existing infrastructure if available OR
  - Can be built by user when required.
- Low power consumption
  - LoRaWAN nodes battery life expected to be 5+ years.
  - Sleep mode – device sleeps when not transmitting or receiving.
- Very high Packet Error Rate (PER) – up to 50%
- Variable but low data rates and low Time on Air
  - In EU Time on Air (ToA) is regulated to 1%
  - Data rates regulated by Adaptive Data Rate algorithm (ADR) (0.3-50 Kbps).

ADAPTIVE DATA RATE ALGORITHM (ADR)

- Algorithm to modify data rate dynamically
  - depending on the environment.
  - LoRaWAN devices closer to Gateway can get higher data rate than devices farther away.
  - dynamic trade-off between communication range and message duration.
- Each LoRaWAN device gets Data Rate (DR) and Transmission Power (TP) setting assigned by Gateway.
- ADR algorithm makes use of
  - Spreading Factor (SF).
  - Transmission Power (TP).

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SPREADING FACTOR & TRANSMISSION POWER

- Spreading Factor (SF) – Defines the number of bits used to encode a symbol.
  - LoRaWAN supports 6 SF.
  - SF are orthogonal to each other.
    - Parallel use of different SF by different devices is possible at the same time.
  - The higher the SF the higher the signal to noise ratio (SNR).
    - More immunity to interference.
  - Increasing SF also increases range but decreases DR.
- ADR selects optimal SF to max. coverage, DR and minimizes ToA, for a LoRaWAN device.
- Transmission Power (TP) – The output power of antenna of a LoRaWAN device (-4 to 20 dBm).
  - Directly affects the communication range of device.
  - Affects the power usage of device (battery life).

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LIMITATIONS OF ADR ALGORITHM

- ADR performs well for stationary LoRaWAN nodes.
- With mobile nodes, ADR becomes severely handicapped [2].
- Continuously changing environment results in slow convergence rates for LoRaWAN devices.
    - Each **device must request Gateway to change SF and TP –** several messages until new values in place.
    - With mobility, low ToA and delay between requesting new SF, TP, convergence times increase.
- **Gateway on receiving new ADR request computes new SF, TP values.**
    - Updated SF, TP are for network conditions at time of receiving ADR request.
- Due to mobility & network conditions variation, device must request new SF, TP again after **short time** period.
    - Updated values are again valid for very short time.
- Improve by use of higher-level information while computing SF, TP values via ADR algorithm → **Q-ADR.**

QUALITY OF INFORMATION AWARE ADR (Q-ADR)

- Q-ADR makes use of higher layer application data to update SF, TP values.
- Application data in LoRaWAN is usually frequently send sensor data.
- Q-ADR do not evaluate the sensor data itself but makes note of the update interval (***ui***) and packet sizes (***p***).
- Q-ADR algorithms performs two steps:
  - Update QoI metrics (***ui, p***) at every sensor message reception.
  - Execute Q-ADR if LoRaWAN device has sent the ADR update request.
- Q-ADR compatible with standard LoRaWAN clients.
  - No update is need at end devices.
  - Q-ADR modification affects only Gateway.

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QOI METRICS

- What is QoI metric Update interval ***ui*** ? [1].
  - ***ui*** is a metric derived from the usual update frequency of the sensor data.
  - Describes maximum time between two consecutive sensor packets received at Gateway.
  - Reward and punishment algorithm is used to compute normalize rating → ***ui*** metric.
- What is QoI metric Packet size ***p***? [8].
  - Size of the data set sent by sensor.
  - It is used where sensor can increase of decrease the dataset depending on the network capacity.
- Q-ADR uses ***ui*** and ***p*** to computer QoI state ***s*** of the device sending the sensor data.
- QoI state ***s*** is then used to determine new SF, TP values.

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Q-ADR ALGORITHM

```
For every incoming message m do
    Unpack sensor data and compute ui and p
    if m contains SF, TP update request from LoRaWAN device n then
        Get QoI state s for device n
        if s is high then
            Use default LoRaWAN ADR
        else if s is low then
            if TP >= 14 then          (value of TP, starts from 2, incremented with 3dBm each step [9])
                if SF < 12 then       (6 SF values used in ADR are 7-12 [9])
                    increase SF
                end if
            else
                Increase TP
            end if
        else
            Keep SF, TP same          (indicates that QoI state s is stable)
        end if
        Send SF, TP to device n
    end if
end for
```

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SIMULATIONS SCENARIO

- Defined scenario – a bus within a city.
- City of Aarhus, Denmark is modeled in simulator.
  - Aarhus is part of Open Data Denmark platform.
  - It offers a set of data sources publicly available.
- A dataset is taken from these sources:
  - Provides location of multiple LoRaWAN sensors present in the city.
  - Three LoRa gateways are also shown.
- Empty area between these nodes is filled with randomly placed 250 LoRaWAN nodes.
- Each sensor provide 24 bytes of data every 5 minutes.

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SIMULATIONS SCENARIO

- A bus route is defined on the map shown as red line:
  - A mobile node moves on the bus route.
  - 11 bus stops with waiting times between 10-30 sec.
  - Speed of bus (mobile node) varies between 10-30 Km/h.
- Mobile node sends 24 bytes every 1 min instead of 5 mins.
- Antenna height of every node is 1m and every Gateway is 5m.
- Okumura Hata model [12] is used for Free Space Path loss (FSPL).
  - Allows to model radio propagation in (sub-)urban and rural areas using correction factors.
  - Capable of modeling path loss between 150MHz – 1500MHz.
- Simulation with FLoRa framework in OMNeT++ simulator.

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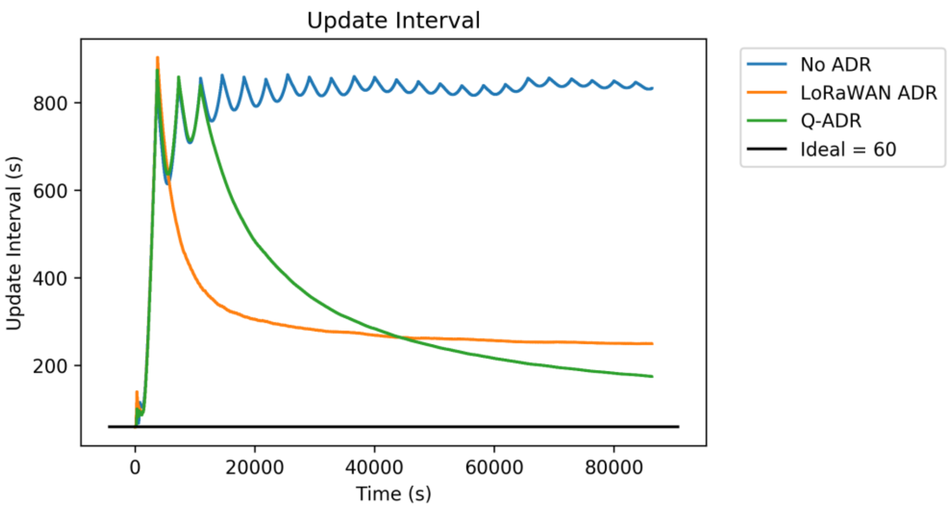
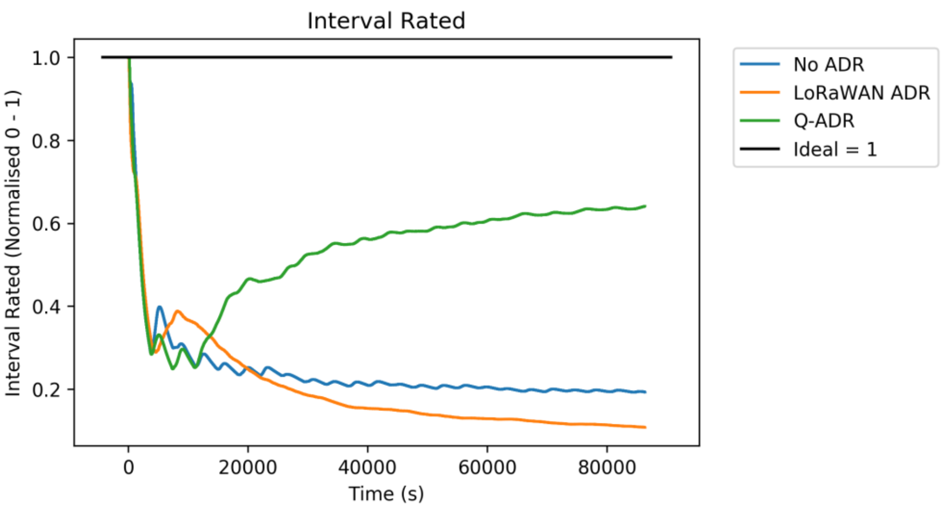
SIMULATION FINDINGS





- Fig shows after how much time is the data received by Gateway.
- Goal 60 seconds as defined in the scenario.
- Without ADR it is around 800 sec.
- With ADR, it decreases down to 300 sec.
- With Q-ADR, it is higher at start but after some adaptation time, it drops to 200 secs.

- Fig shows how much data is received within its specified time limit.
- Time limits: stationary nodes to 5min & mobile nodes 1min.
- ADR performs worse than no ADR.
- With Q-ADR 60% of the data is received within time limit.

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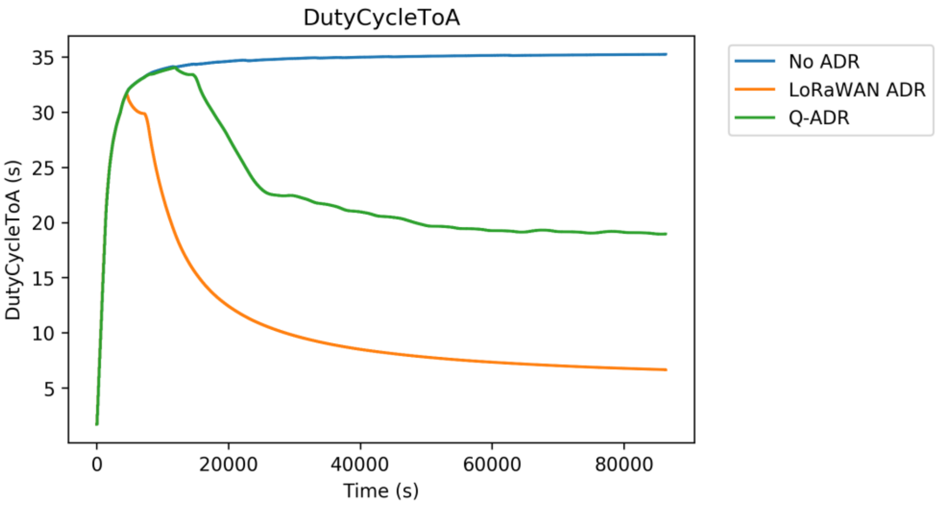
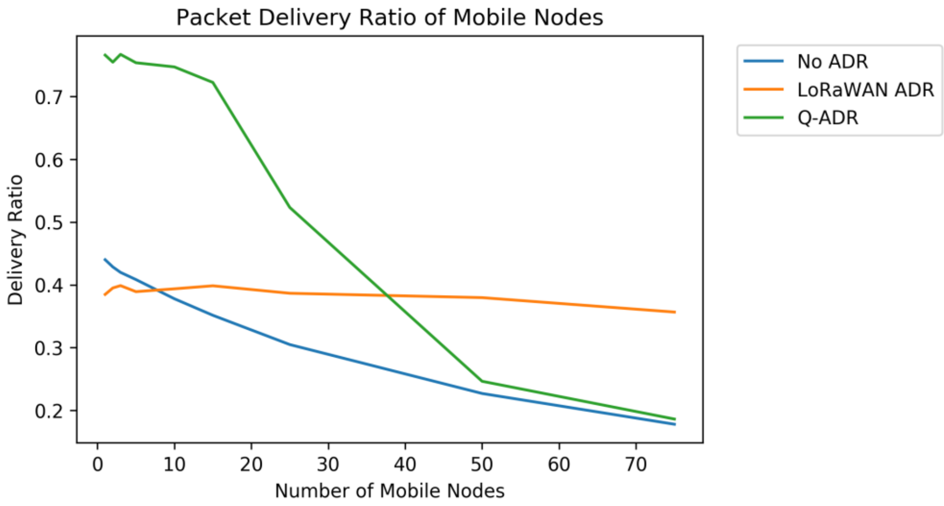
SIMULATION FINDINGS II



- Fig shows ToA used by each configuration.
- Duty cycle of 1% in EU results in 36sec/hour ToA.
- Without ADR, ToA is right on edge ~ 36 secs thus dropping messages.
- With ADR and Q-ADR, ToA is withing acceptable limits.
- Less ToA per device means more devices can be part of the network.



- Fig shows PDR for ADR, Q-ADR and no ADR with increasing number of mobile nodes (random mobility pattern).
- More nodes means less ToA for each node thus resulting in lower PDR.
- Side effect of faster adaptation of SF in Q-ADR.

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CONCLUSION

- Q-ADR can improve data transmission results for mobile nodes.
- Using higher-level Quality of Information with ADR can help optimize low level parameters according to higher level information.
  - Instead of slow adaptation with default ADR algorithm.
- No need for modification at client side of LoRaWAN network.
- Q-ADR needs to be implemented only on Gateways.
- Spreading factor and transmission power can be adjusted more quickly for nodes with high mobility.

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THANK YOU FOR YOUR ATTENTION!

REFERENCES

[1] D. Kuemper et.al., “Valid.IoT: a framework for sensor data quality analysis and interpolation,” in Proceedings of the 9th ACM Multimedia Systems Conference. ACM, 2018, pp. 294–303.

[2] S. Li et.al., “How agile is the adaptive data rate mechanism of LoRaWAN?” in 2018 IEEE Global Communications Conference (GLOBECOM). IEEE, 2018, pp. 206–212.