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Dynamic Spreading Factor and Power Allocation of LoRa Networks for Dense IoT Deployments

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Agenda

- Background: LoRa and LoRaWAN
- Evaluation of ADR
- literature review
- Proposed ADR algorithm
- Simulation Results

Background: LoRa and LoRaWAN

- The LoRaWAN belongs to the category of non-cellular low power wide area network wireless communication protocols and operating in the license-free spectrum

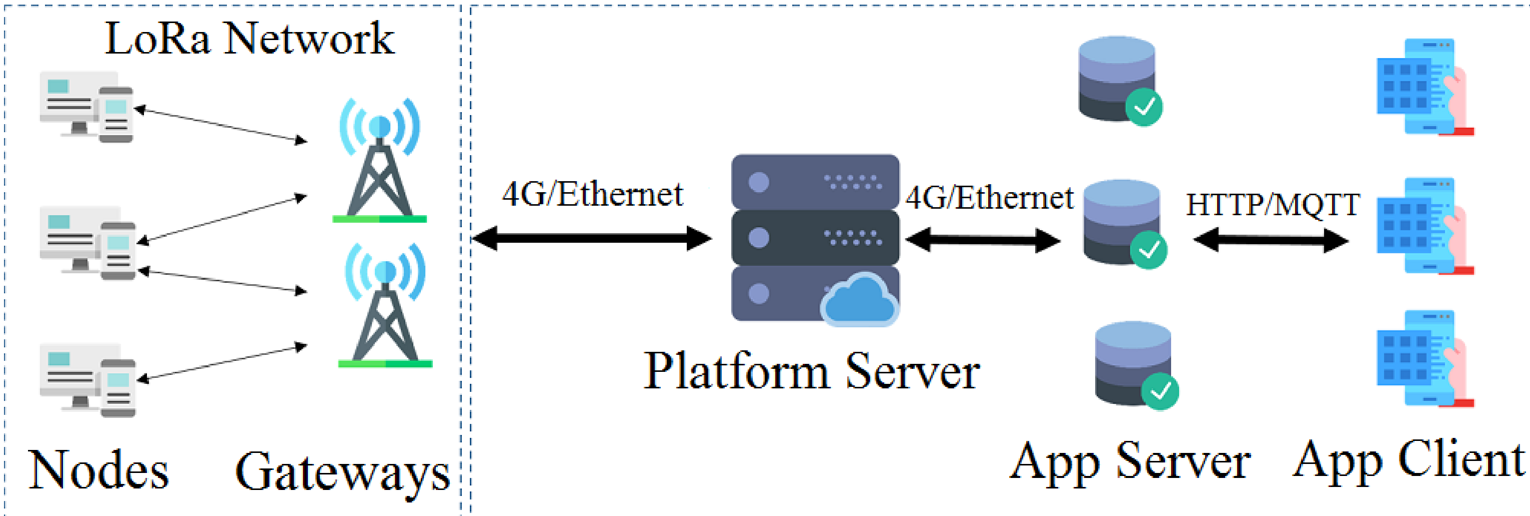
- A LoRa network relies on two components, LoRa and LoRaWAN

- LoRa is a physical layer modulation developed by Semtech

- LoRaWAN is implemented on top of the LoRa and includes data link and network layers

- BandWidth(BW) $BW = \{125,250,500\}$
- Spreading Factor(SF) $SF = \{7,8,9,10,11,12\}$
- Transmit Power (TP) $TP = \{2,5,8,11,14\}$
- Code Rate(CR) $CR = \{\frac{4}{5},\frac{4}{6},\frac{4}{7},\frac{4}{8}\}$

Background: LoRa and LoRaWAN



Evaluation of ADR

- Depending on the channel conditions between the nodes and gateways, the spreading factor and the transmit power are determined. This determination is made by the ADR algorithm.

- The ADR algorithm allows the platform to change the TP and the SF for the uplink data transmissions of nodes.

- To this end, the network server estimates the link budget of each node by using the SNR of received frames

- The platform considers the maximum SINR of the last 20 packets received from the node as an estimated of packets' SINR, and accordingly determines the spreading factor and the transmit power of the node.

- The newly calculated parameters are communicated to the LoRa node through a downlink frame.

- The details of the Orginal ADR algorithm are presented in LoRaWAN Specification (v1.1) [9].

Related work

- It is shown in [13] that selecting a function for combining the data related to the last the ADR algorithm allows the platform to change the TP and the SF for the uplink data transmissions of nodes.

- it is shown in [13] that the maximum SINR of the last 20 packets (as used in [9]) is an optimistic approximation of the area's noise condition and is not efficient if there is shadowing noise in the network.

- Thus, the average SINR of the last 20 packets is used in [13] instead of maximum SINR which enhances the packet delivery ratio by 20%.

Proposed ADR algorithm

- We propose a dynamic ADR algorithm that uses the OWA operator to dynamically configure the spreading factor and transmit power of nodes based on the channel condition which is implicitly represented by SINR of the last 20 packets.

Proposed ADR algorithm

A mapping function $F: R^n \rightarrow R$

$$F_w(a_1, a_2, \dots, a_n) = \sum_{i=1}^{n} w_i a_i$$

F_w is the fusion function, n is the number of samples obtained from data aggregated with F_w

$(a_1, a_2, \dots, a_n)$ is the descending sorted set of samples

w_i is the weight of the ith sample. The vector of weights is denoted by W

$$W = (w_1, w_2, \dots, w_n)^T \quad w_i \in [0,1], 1 \leq i \leq n \quad \sum_{i=1}^{n} w_i = 1$$

Proposed ADR algorithm

Optimistic:

$$w_1 = \alpha;\ \ w_2 = \alpha(1-\alpha);\ \ w_3 = \alpha(1-\alpha)^{\,2}; \ldots; w_{n-1} = \alpha(1-\alpha)^{\,n-2}; w_n = (1-\alpha)^{\,n-1}$$

Pessimistic:

$$w_1 = a^{n-1};\ \ w_2 = (1-\alpha)a^{n-2};\ \ w_3 = (1-\alpha)a^{n-3}; \ldots; w_{n-1} = \alpha(1-\alpha)\ ; w_n = (1-\alpha)$$

$$where\ 0 \leq \alpha \leq 1$$

Proposed ADR algorithm

Pessimistic:

$$w_1 = a^{n-1};\ \ w_2 = (1-\alpha)a^{n-2};\ \ w_3 = (1-\alpha)a^{n-3}; \dots ; w_{n-1} = \alpha(1-\alpha)\ ; w_n = (1-\alpha)$$

$\alpha = 0 :\ W[0,0, \dots, 1]$ $\quad MIN$

$\alpha = 1 :\ W[1,0, \dots, 0]$ $\quad MAX$

Proposed improvements to ADR

- In our proposed dynamic ADR algorithm, we configure α dynamically based on the network condition.

- To do this, we use the packet loss ratio as an indicator of the channel condition.

- More specifically, the higher value of the packet loss ratio indicates higher channel noise and its lower value represents the channel with lower noise.

Proposed improvements to ADR

- Let denote the packet loss ratio as PLR.

$$PLR = \frac{(LastCounter - FirstCounter - 20)}{LastCounter - FirstCounter} * 100$$

$$PLR = \frac{(50 - 10 - 20)}{50 - 10} * 100 = 50\%$$

$$\alpha = 1 - PLR$$

Frame counter	SNRmax (dB)	GtWDiversity
10	-6	2
11	-7	2
12	-25	1
Etc…		
50	-10	3

Proposed improvements to ADR

- Specifically, if PLR is high, the value of would be low, and thus the OWA operator would be closer to the minimum function of the SINR of the last 20 packets. On the other hand, the low value of PLR results in a higher value of leading to the OWA operator would approximate to the maximum function of the SINR of the last 20 packets.

Simulation Results

$$PL(d) = \overline{PL}(d_0) + 10n\log\left(\frac{d}{d_0}\right) + X_\sigma$$

Scenario	d0[m]	PL(d0)dB	n	σ[dB]		
				Ideal	Moderate	Typical
Urban	40	127.41	2.08	0	1.785	3.57
Sub-Urban	1000	128.95	2.32	0	3.54	7.08

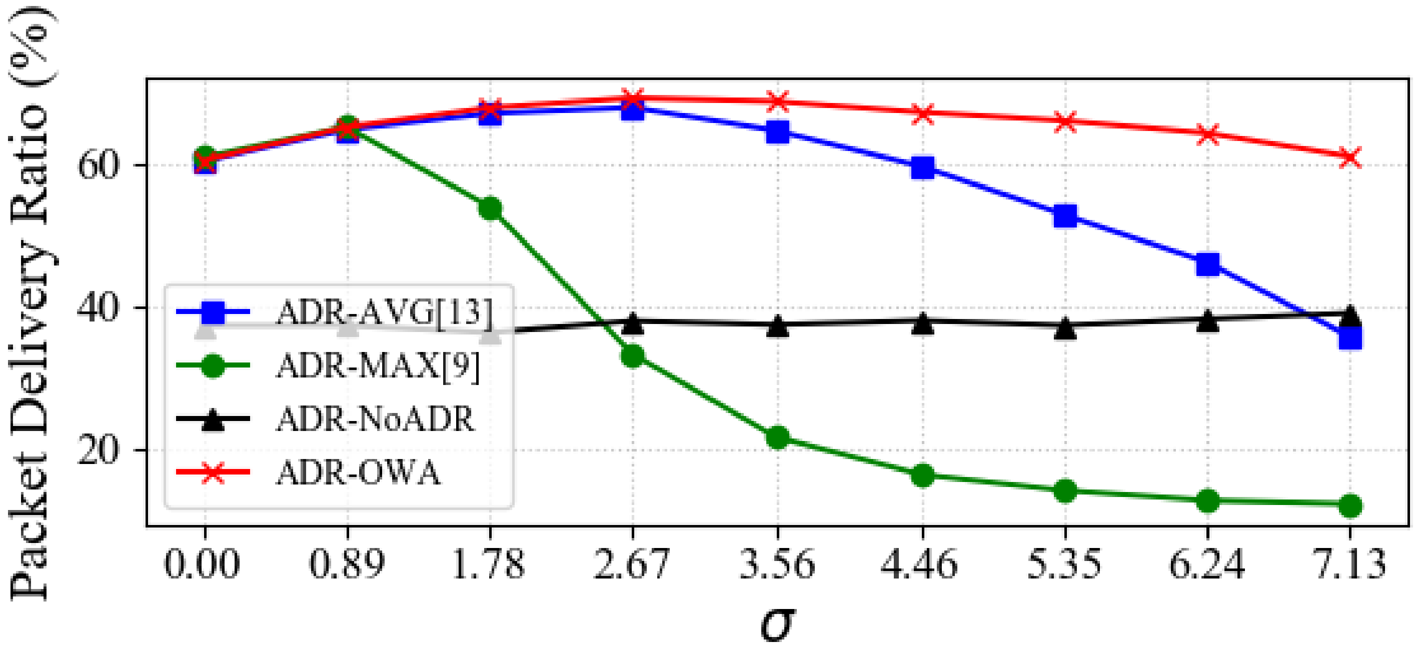
- Omnet++

Proposed improvements to ADR

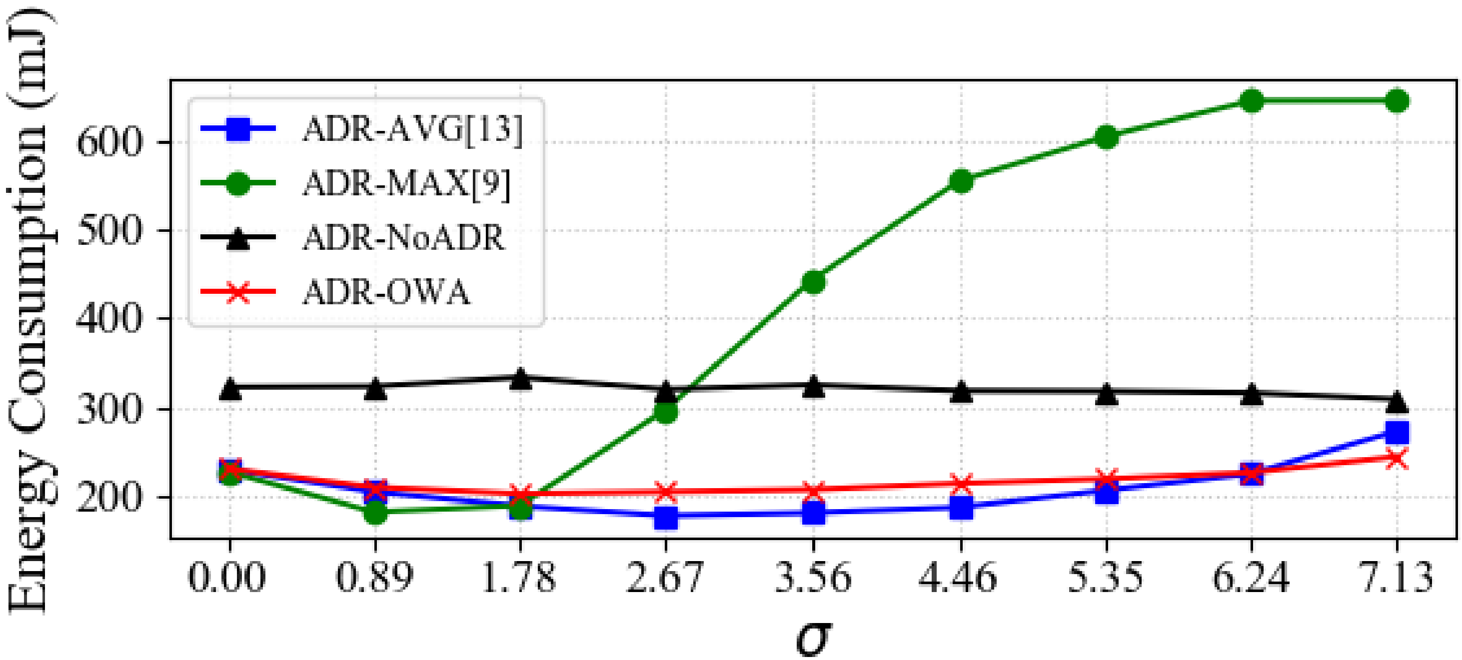
- We evaluate the performance of our proposed algorithm and compare it with other existing algorithms based on two criteria The packet delivery ratio (%) and The energy consumption (mJ)

- To compare the performance of our ADR algorithm called as ADR-OWA, we consider two schemes presented in [9] and [13] called as ADR-MAX and ADR-AVG, respectively, as well as the scheme with no ADR algorithm called NoADR.

Simulation Results



Simulation Results



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Thanks for
your attention.