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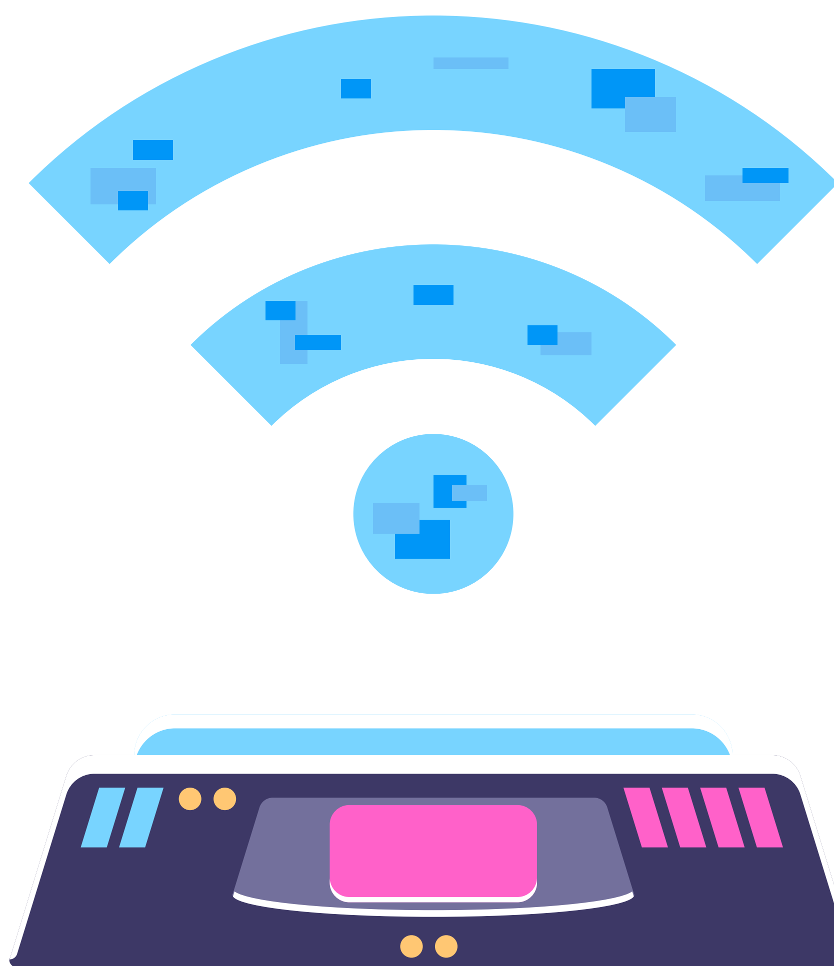
WHITEPAPER

Optimizing LoRaWAN Network Capacity:

key influencing factors, calculation methods, and enhancement strategies



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A LoRaWAN network capacity refers to the maximum number of devices a LoRaWAN network can handle simultaneously, essentially its ability to efficiently transmit data from a large number of low-power IoT devices within a specific geographical area.

This paper explores the key factors influencing LoRaWAN network capacity, providing insights into how these elements interact and impact overall performance. Furthermore, it offers a step-by-step guide to estimating this capacity, outlining the necessary calculations and considerations for real-world deployments. Finally, the paper discusses various strategies and techniques for increasing LoRaWAN network capacity to accommodate growing IoT deployments and maximize network efficiency.

What Factors Influence LoRaWAN Network Capacity?

1) Frequency band and bandwidth

The frequency band and bandwidth used by LoRaWAN directly affect data transmission speed and capacity. A wider bandwidth allows for more data transmission but consumes more spectrum resources. This is fixed data in LoRaWAN, which is 125KHz, and 500KHz (in some cases in US915 and AU915; refer to the LoRaWAN protocol for details). Also, please refer to the link below on "LoRaWAN Frequency Plan by Country or Region".
https://www.lansitec.com/blogs/lorawan-frequency-plan-by-country-or-region/

2) Data Rate

LoRaWAN uses an Adaptive Data Rate (ADR) mechanism.

Higher data rate
- Less transmission time
- Less time each node occupies the network
- More overall network capacity
- Lower the communication distance

Lower data rates
- More transmission time
- More time each node occupies the network
- More overall network capacity
- Lower the communication distance

3) Number of Nodes

The more devices connected to the network, the more competition there is between nodes, especially when they share the same frequency.

4) Duty Cycle Limitations

LoRaWAN transmissions are constrained by duty cycle limits, meaning each node can only send data for a small portion of time. This restricts the frequency of transmissions from each node and impacts the overall network capacity. For details, refer to LoRaWAN Regional Parameters.

5) Channel Utilization

LoRaWAN typically uses multiple channels for data transmission. Load balancing across different channels can increase overall network capacity. If some channels are overutilized, it can lead to network congestion.

6) Propagation Conditions

Signal propagation conditions (such as geography, obstacles, and electromagnetic interference) affect signal coverage and quality, which in turn impacts network capacity.

7) Number and Distribution of Gateways

The number and location of gateways affect the network's coverage and capacity. More gateways can reduce the load on individual gateways and increase the overall network capacity.

8) Ratio of Uplink to Downlink Communication

A typical LoRaWAN gateway has 8 uplink channels and 1 downlink. LoRaWAN is primarily designed for uplink communication (from devices to the network), but downlink communication also uses channel resources. If downlink demand is high, it can reduce the overall network capacity.

How to calculate the network capacity of LoRaWAN?

To calculate the network capacity of LoRaWAN, several technical factors must be considered, including channel bandwidth, spreading factor (SF), data rate, message size, duty cycle limitations, number of gateways, and the message transmission frequency of devices. Below is a detailed step-by-step guide to help estimate LoRaWAN network capacity:

1) Identify Key Parameters

- **Bandwidth (BW):** Typically 125 kHz.
- **Spreading Factor (SF):** LoRaWAN supports SF7 to SF12, where higher SF values mean lower data rates and longer transmission times.
- **Data Rate (DR):** Determined by the bandwidth and SF; different DR values result in different transmission times.
- **Payload Size:** Usually measured in bytes, assuming 12 bytes here.
- **Message Transmission Frequency:** Assume each device sends 10 messages per day.
- **Duty Cycle Limitation:** Assume 1% (a typical restriction in Europe).
- **Number of Channels:** Assume 8 channels.
- **Number of Devices:** This is the parameter we need to estimate.

2) Calculate the Transmission Time for a Single Message

Use the following formula to calculate the airtime of a single LoRa message:

[T_{msg} = Symbol Time × (Payload Symbols +Preamble Length)]

Where Symbol Time depends on SF and BW, and Payload Symbols are related to the payload size and coding rate (CR).

- **Symbol Time** = (2^{SF}/BW)
- **Payload Symbols** depend on CR and the payload size.

For example, with a 125 kHz bandwidth and SF12, sending a 12-byte message may take about 1.5 seconds (this is an approximation, and specific values can be calculated using specialized tools).

A simple way to calculate this number is to use the tool below.
https://www.semtech.com/design-support/lora-calculator

3) Calculate the Maximum Number of Messages Per Channel

Assuming the channel is working at the maximum duty cycle:

[$N_{max\ per\ channel}$ =$T_{available}$/T_{msg}]

Where is the total available time in a day (typically 24 hours multiplied by 3600 seconds) and the duty cycle limit (e.g., 1%).

4) Calculate the Maximum Number of Messages Per Gateway

If there are 8 channels:

[$N_{\text{max per gateway}} = N_{\text{max per channel}} \times 8$]

5) Estimate the Maximum Number of Devices

Assuming each device sends 10 messages per day:

[$N_{\text{devices}} = N_{\text{max per gateway}}$/Daily Messages per Device]

6) Final Network Capacity Estimation

By following the steps above, you can estimate the theoretical maximum capacity of a LoRaWAN network. However, the actual capacity is typically lower due to real-world factors such as device distribution, signal interference, package confliction and transmission failure rates. In practice, the actual capacity of an 8-channel gateway might range from several thousand to tens of thousands of devices.

Example:

- If the transmission time (T_"msg") for a single message is 1.5 seconds and the duty cycle is 1%, then one channel can handle approximately 576 messages per day.
- Across 8 channels, this totals around 4608 messages per day.
- If each device sends 10 messages per day, the gateway can support approximately 460 devices. We recommend to use ~15% of the total capacity of a gateway to avoid repeatedly package conflicts and lost.

This calculation method can be applied to various LoRaWAN deployment scenarios, with specific values varying based on network configuration and environmental conditions. Please contact us to get the “8 Channel LoRaWAN Network Capacity Evaluation Tool”

How to increase the capacity of a LoRaWAN network?

To increase the capacity of a LoRaWAN network, several strategies can be employed:

1) Optimize Data Rates and Spreading Factors (SF)
LoraWAN uses different spreading factors (SF7 to SF12), with higher SF values increasing transmission range but lowering data rates. By optimizing the adaptive data rate (ADR), the network can assign lower SF values to devices closer to gateways, reducing transmission time and increasing overall network capacity. Devices further away can use higher SF values, benefiting from the longer range.

2) Increase Gateway Density
Deploying more gateways in strategic locations can significantly increase the network capacity. More gateways mean more frequency channels and higher chances of devices communicating without collisions. This is especially important in areas with a high density of devices. The addition of gateways improves the geographic coverage and helps balance traffic loads.

3) Use Frequency Planning
Efficient allocation of frequency channels is essential to avoid interference and maximize the use of available bandwidth. By implementing a robust frequency management strategy, you can reduce collisions and improve data throughput. Using multiple frequencies and balancing the network load across different channels improves performance.

A typical LoRaWAN gateway has 8 uplink channels and 1 downlink. One 16-channel gateway or two 8-channel gateways can double the capacity by distributing nodes or LoRaWAN trackers into different sub-bands. US915 supports 8 sub-bands, so technically, a user can deploy 8 LoRaWAN gateways in the same location to increase the network capacity to 8 times.

4) Implement Network Segmentation
You can split large LoRaWAN networks into smaller, more manageable segments by using lower TX power on both end nodes and LoRaWAN gateways so that they can only communicate with the nearest one. This method reduces congestion within each segment, ensuring smoother communication for all devices.

5) Utilize Duty Cycle Management
The duty cycle, which restricts how frequently devices can transmit, impacts network capacity. By optimizing the duty cycle and reducing the number of transmissions from each device, you can free up airtime for more devices to communicate. For example, devices can send less frequent status updates or transmit only when certain thresholds are reached.

6) Efficient Device Scheduling
LoRaWAN networks can benefit from time-synchronized device transmissions, where devices are scheduled to transmit at specific intervals. This reduces collision risk and ensures more efficient use of available channels.
Lansitec LoRaWAN Bluetooth gateways support this feature to maximize network capacity usage and report as many beacons as possible.

These techniques, when applied together, can effectively increase the overall network capacity of a LoRaWAN deployment.