Smart Spreading Factor Assignment for LoRaWANs

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Outline

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Introduction: LPWAN Overview

- Number of Internet of Things applications increased exponentially in last few years [1]
- How to provide connectivity for <u>low power</u> devices distributed over large geographical areas?
- Example LPWA application areas;
  - Smart city
  - Industrial assets monitoring
  - Smart grid metering
  - Agriculture
  - Logistic
- LPWAN fills the technology gap between:
  - Short range wireless technologies (ZigBee, Bluetooth, WiFi)
    - Range is limited to a few hundred meters at best
    - Very costly to deploy dense network
  - Cellular (2G, 3G, LTE)
    - Optimized for voice and data
    - Complex and expensive
    - High power consumption

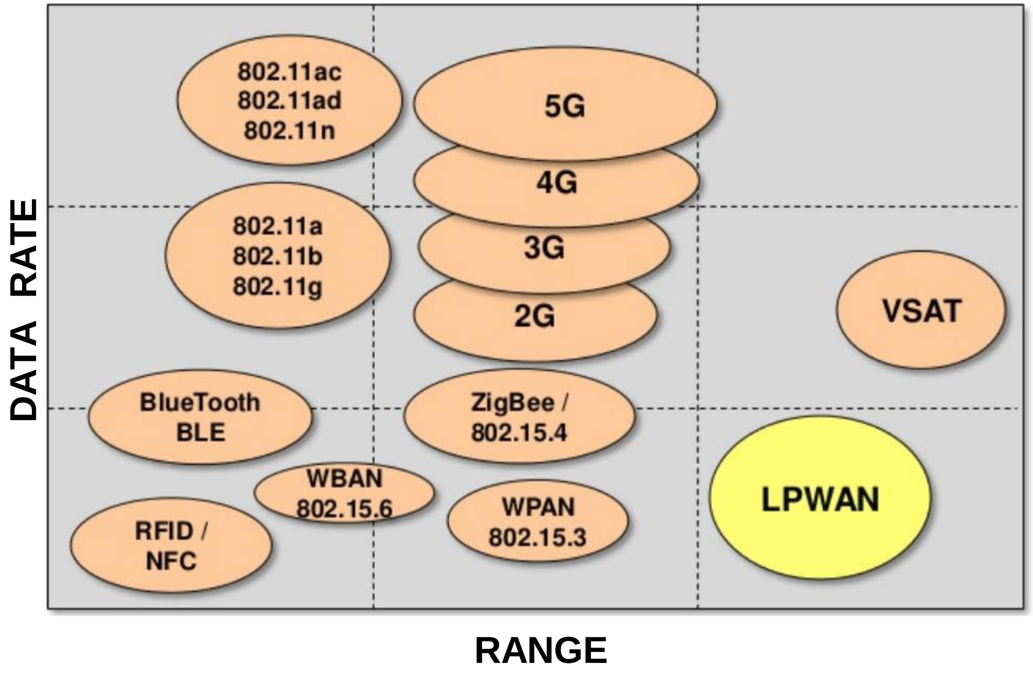

Figure 1: Wireless technologies with respect to range and data rate[1]

1. Image Source: https://www.slideshare.net/PeterREgli/lpwan

Introduction: LPWAN Key Features

- Low Power Wide Area networks:
  - \+ Low power (ten years and beyond)
  - \+ Long range (a few to tens of kilometers)
  - \+ Low cost
  - \- Low data rate (in orders of tens of kilobits per second)
  - \- High latency (in orders of seconds or minutes)
- LPWAN applicable applications:
  - Delay tolerant
  - Low data rates
  - Low power consumption
  - Low cost
- Several competing LPWAN technologies and alliances:
  - LoRa
  - Sigfox
  - NB-IoT
  - LTE-M

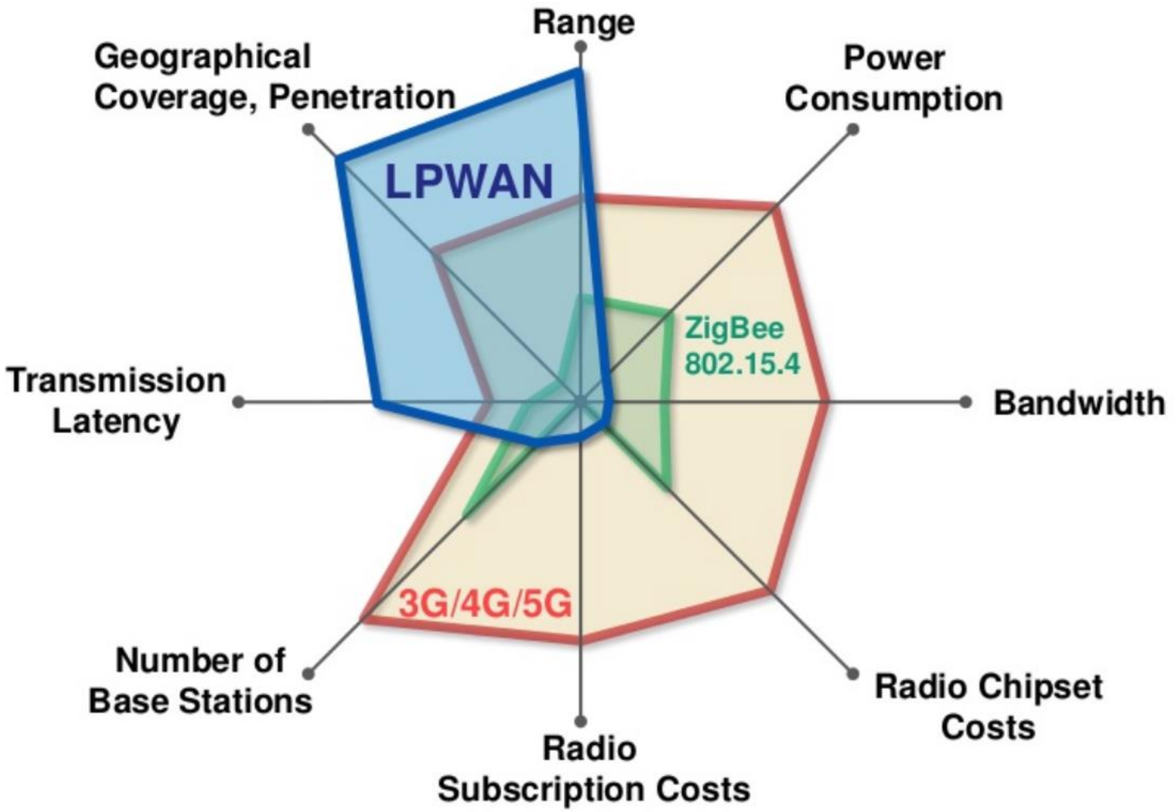

Figure 2: Wireless technologies with respect to various properties[1]

1. Image Source: https://www.slideshare.net/PeterREgli/lpwan

LoRaWAN

- LoRaWAN is open standard MAC layer protocol for LoRa physical layer, developed by LoRa Alliance
  - End Node (EN): Low power embedded device that only communicates to gateways
    - Battery Powered: Class A
    - Low Latency: Class B
    - No Latency: Class C
  - Gateway (GW): Receive/transmit packets coming from/to end nodes
  - Network Server (NS): Routes messages from application to end nodes
- The messages transmitted by the end devices are received by all the base stations in the range
  - Star of stars
- Pure ALOHA
  - No CSMA/CA
  - No forwarding, no waiting for others’ messages to arrive
- NS can request to change communication parameters of nodes
  - Spreading factor, transmit power
- Move complexity to backend system

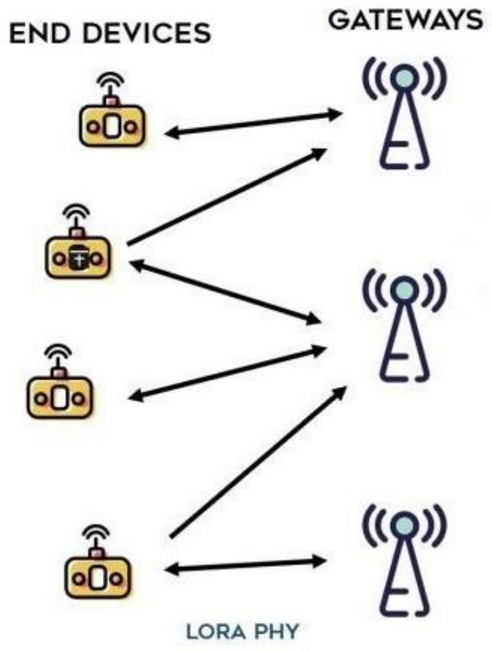

Figure 3: LoRaWAN Topology[1]

1. Image Source: https://i1.wp.com/www.zerynth.com/wp-content/uploads/2017/05/lorawan-architecture.jpg

LoRa: Modulation

- LoRa modulates the signals in Sub-GHz ISM band using a proprietary modulation technique based on Chirp Spread Spectrum (CSS)
- Chirp is a sinusoidal signal of frequency increase or decrease over time
- Resilient to interference and noise

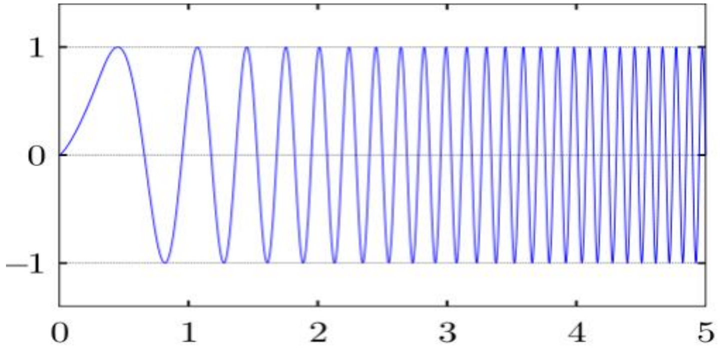

Figure 4: Chirp[1]

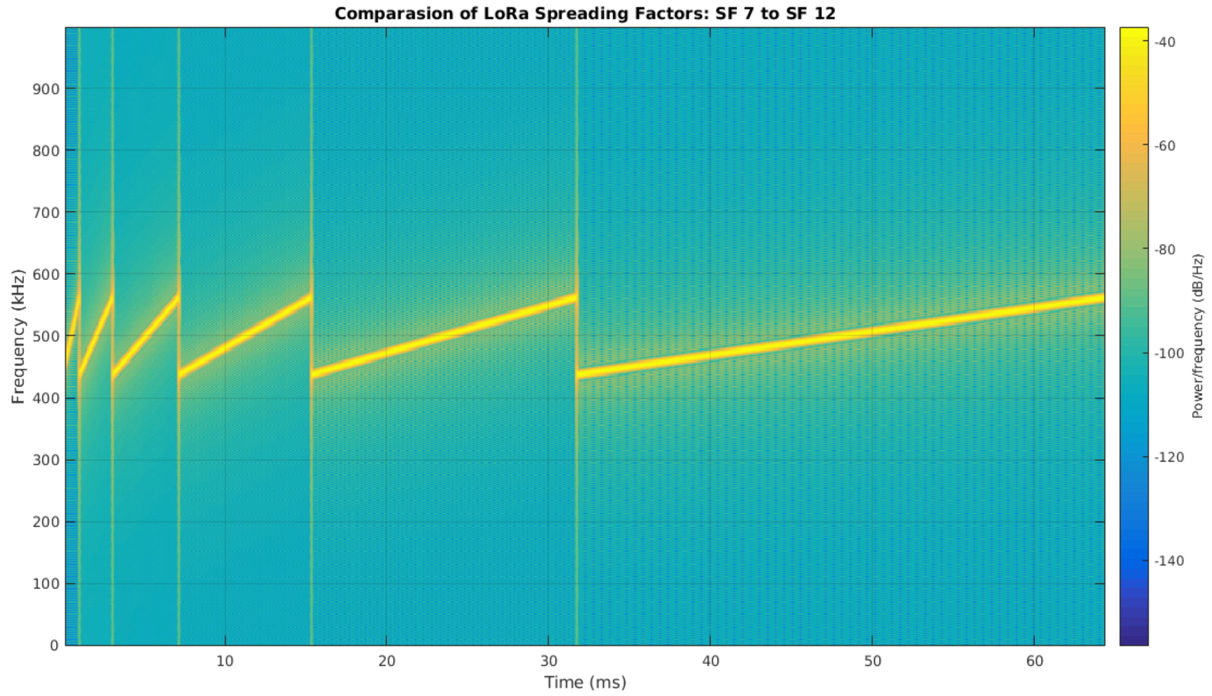

Figure 5: LoRa modulation SF 7 to 12[1]

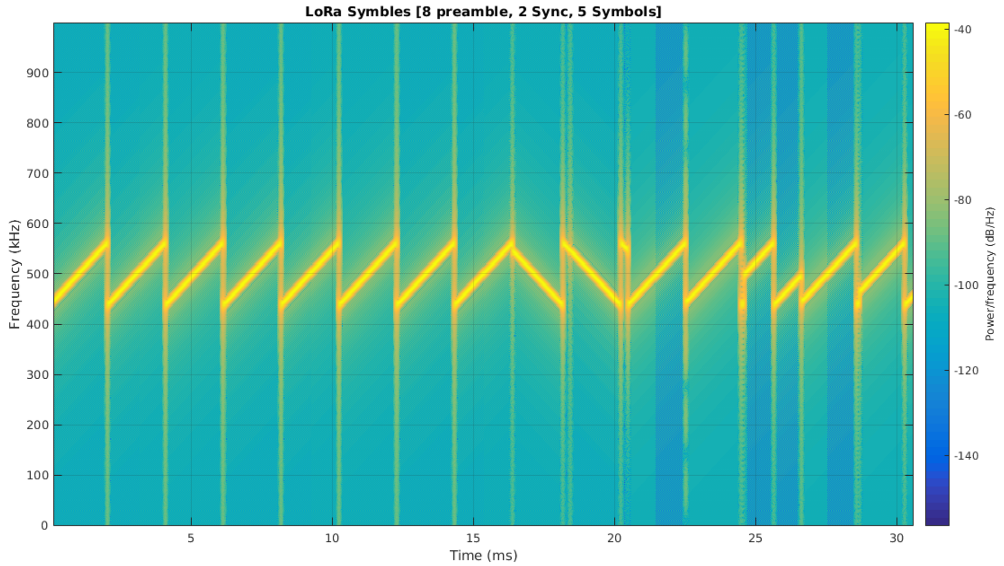

Figure 6: LoRa modulation example[1]

1. Image Source: http://www.sghoslya.com/p/lora-is-chirp-spread-spectrum.html

LoRa: Spreading Factor

- LoRa uses spreading factor for rate adaptation
- Ratio between symbol rate and chirp rate
  - Can be 7 to 12
- Provides tradeoff between data rate, range and power consumption
- Lower SF:
  - Higher transmission rate
  - Shorter transmission time
  - But requires a higher SNR
  - Shorter range
- SFs are orthogonal up to some extent:
  - Packets with different SFs in same channel can be received simultaneously

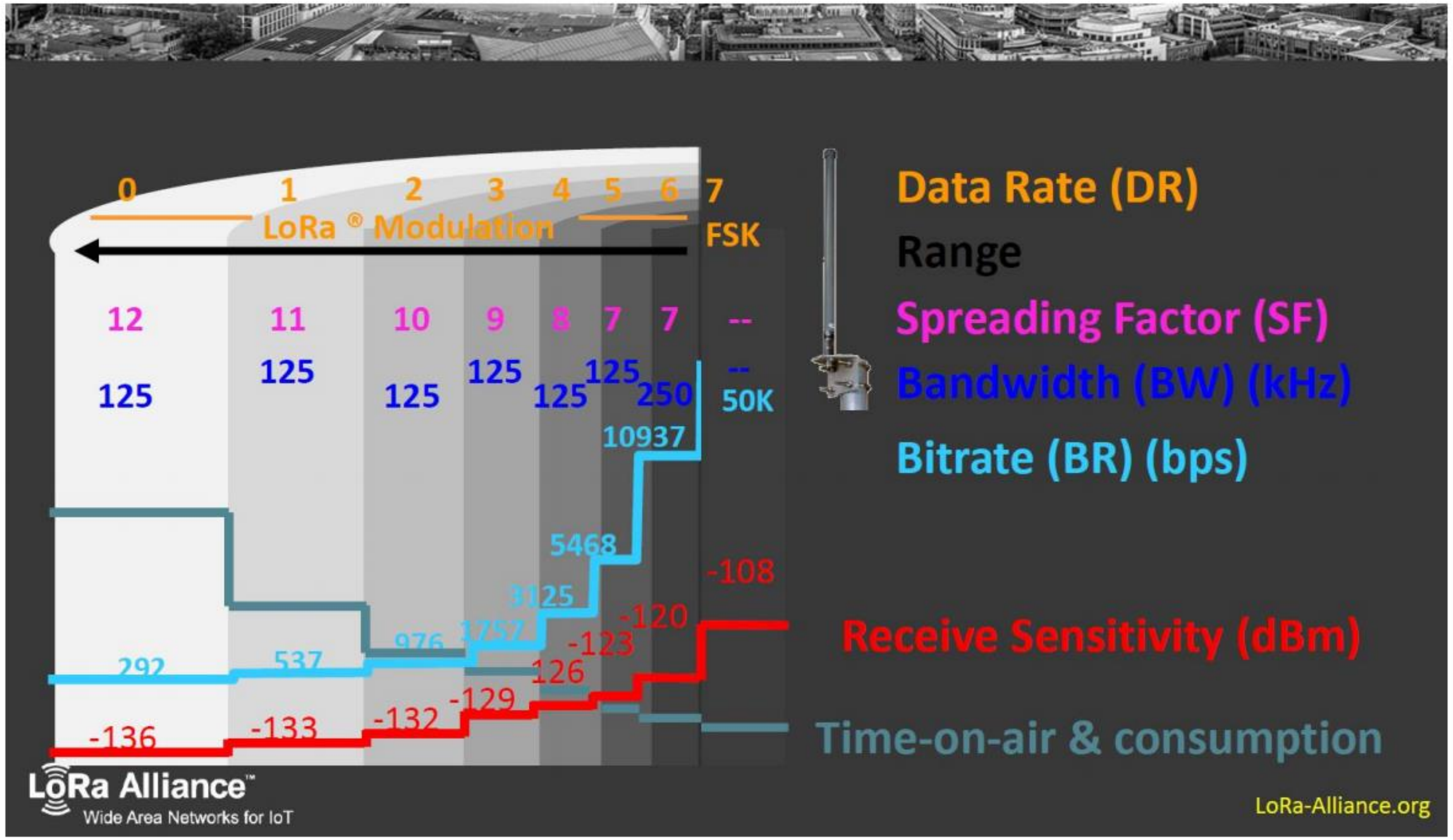

Figure 7: LoRa CSS modulation SF, data rate, time-on-air comparision[1]

1. Image Source: https://home.zhaw.ch/~rumc/wcom2/unterlagen/wcom2chap3CSS.pdf

Proposed Technique: Issue

- End nodes select SF according to signal strength of the downlink transmission from GW
- End nodes which close to the GW will probably select lowest SF all the time
    - Same SF transmission collision
    - Number of collisions increases while number of end devices close to the GW increases

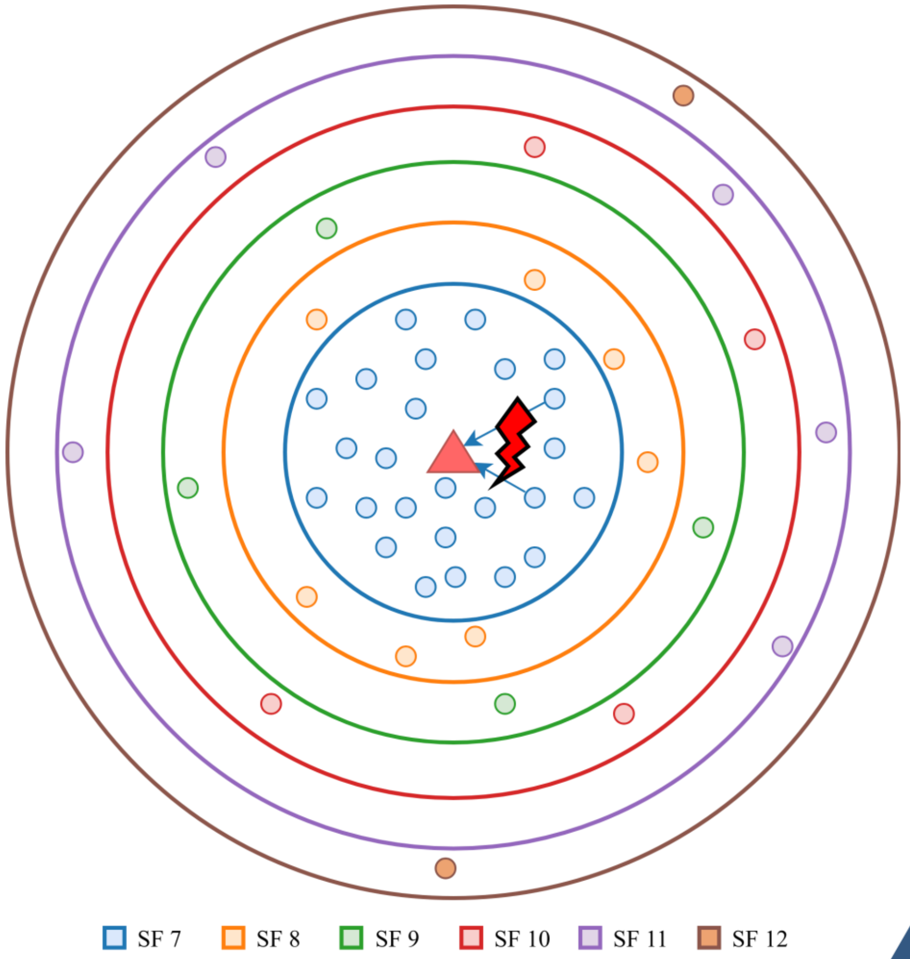

Figure 8: SF assignment issue on single gateway

Proposed Technique: Solution

- Network server can force some of the close end nodes to select higher SF
- Number of collision may decrease due to the orthogonality of different SF
- However, higher SF:
    - Higher time on air
    - Prone to collision with other higher SF transmissions
- How network server should assign which SF to which node?

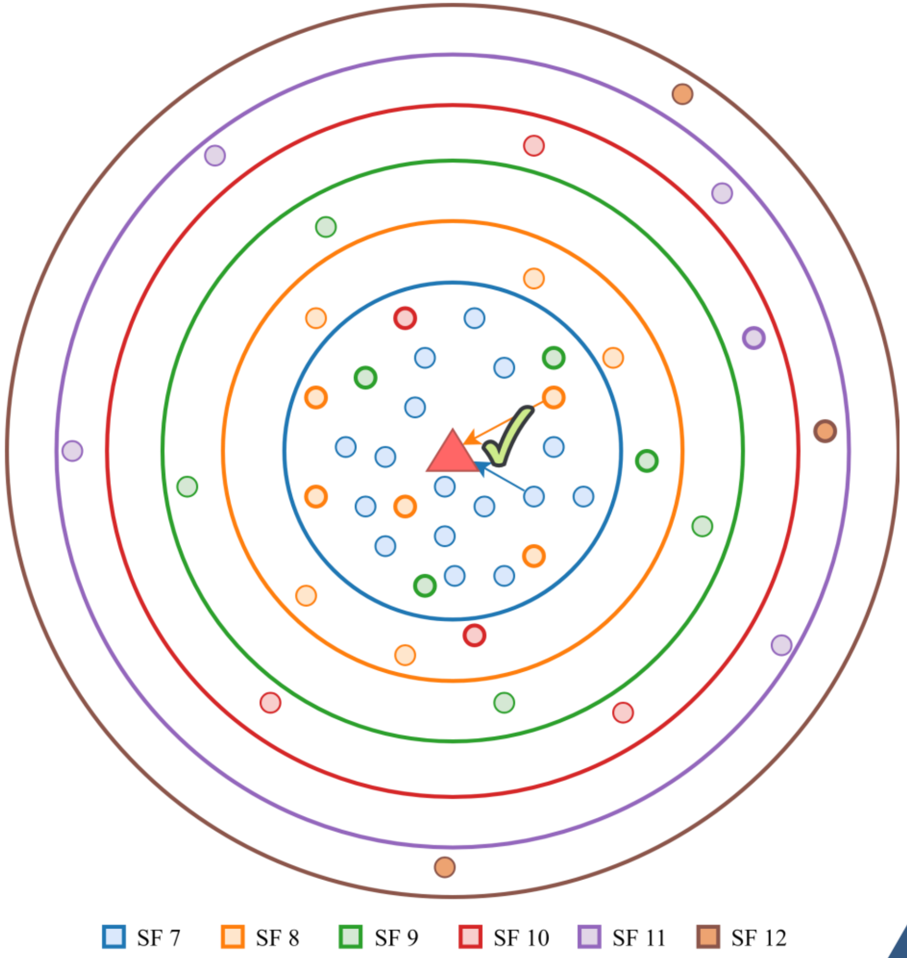

Figure 9: SF assignment issue proposal

Proposed Technique: Solution

- This approach may increase the collisions with nodes in other GW's range
- Extra care must be taken for nodes in intersection area

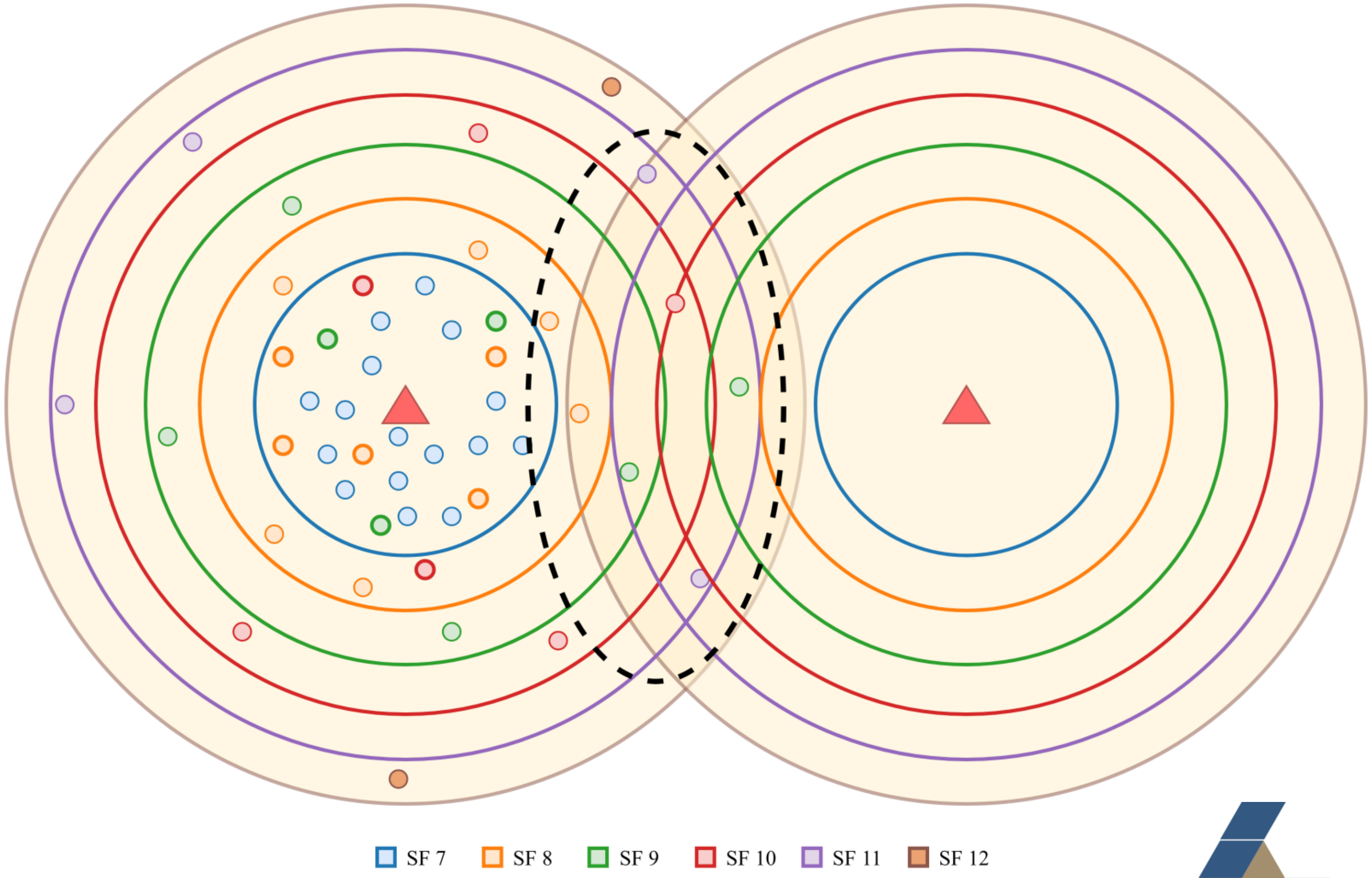

Figure 10: SF assignment issue on multiple gateway

Proposed Technique

- NS can keep track of transmission logs:
  - Location
    - Latitude and longitude
  - Spreading factor
  - Transmission result
    - Successful
    - Interfered
    - Under sensitivity
- NS can train a model for predicting transmission result for a specific location and specific spreading factor
- NS can assign the lowest possible SF to nodes considering prediction of transmission

Simulation Environment

- A discrete event simulator is implemented to study effects of different SF strategies in LoRaWANs
  - Open space propogation loss model
  - Co-technology interference model
- Network topology input parameters:
  - Radius (m)
  - Number of nodes
  - Number of gateways
- Simulation input parameters:
  - Duration (s)
  - Packet size (B)
  - Packet generation rate (p/s)
  - Spreading factor assignment method
- Simulation outputs:
  - Number of generated packets, successfully received packets, interfered packets, under sensitivity packets
  - Network packet delivery ratio percentage (PDR)
  - Network throughput (bps)
  - Total transmit energy consumption

Simulation Results

- Topology radius is 3000 meters, packet generation rate is 0.01 packet per second

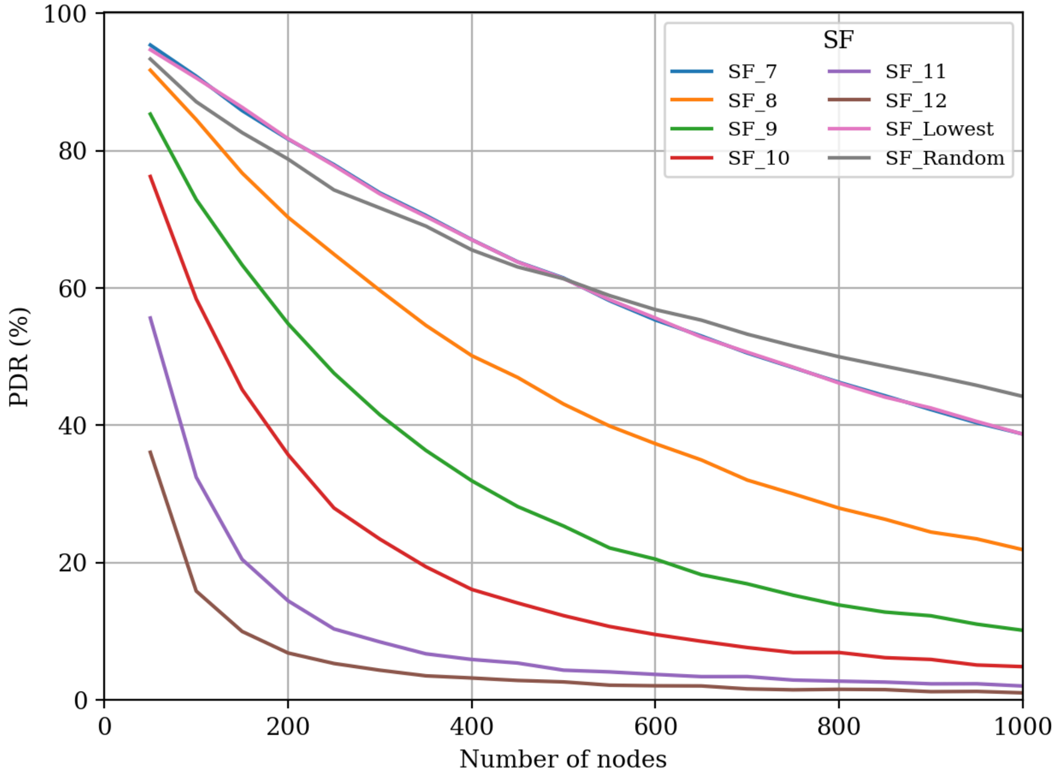

Figure 11: PDR of different SFs

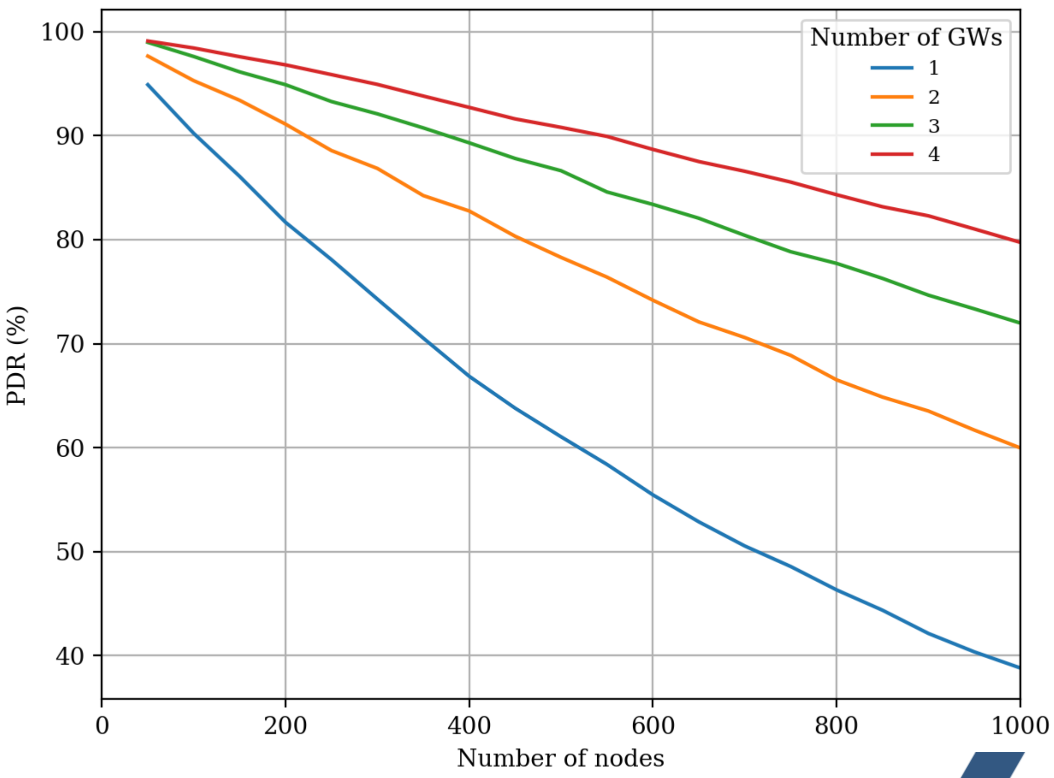

Figure 12: PDR of different number of gateways

Simulation Results

- Number of GW is 1, packet generation rate is 0.01 packet per second, lowest possible SF assignment scheme

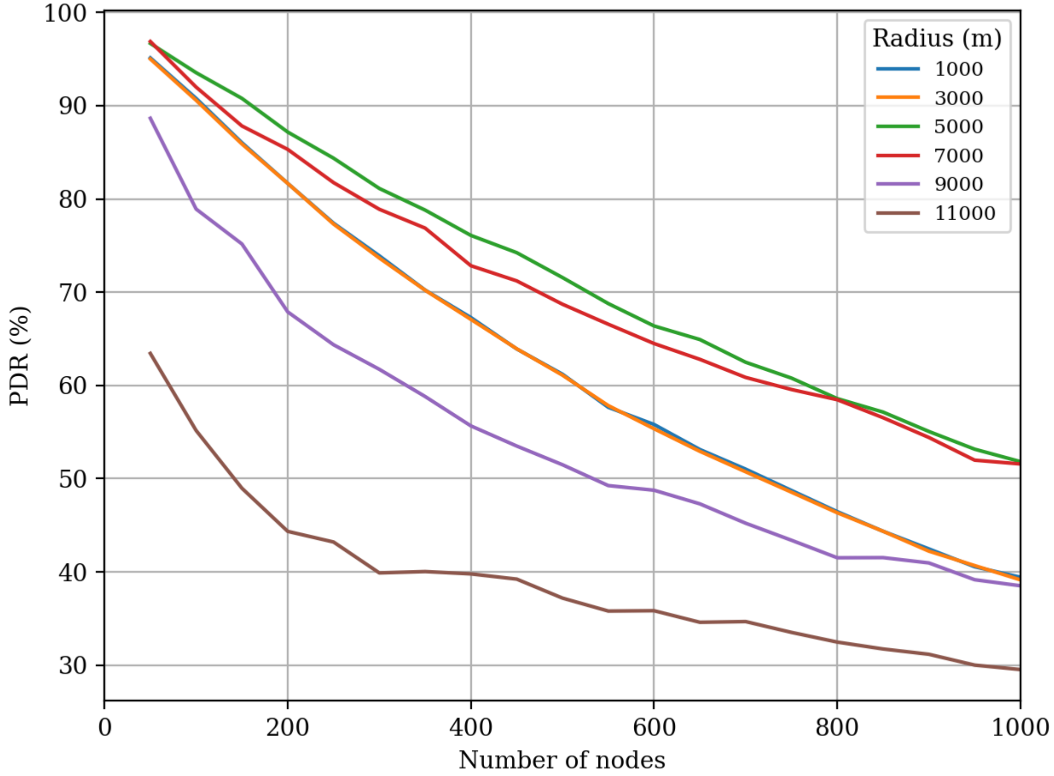

Figure 13: PDR of different topology radius

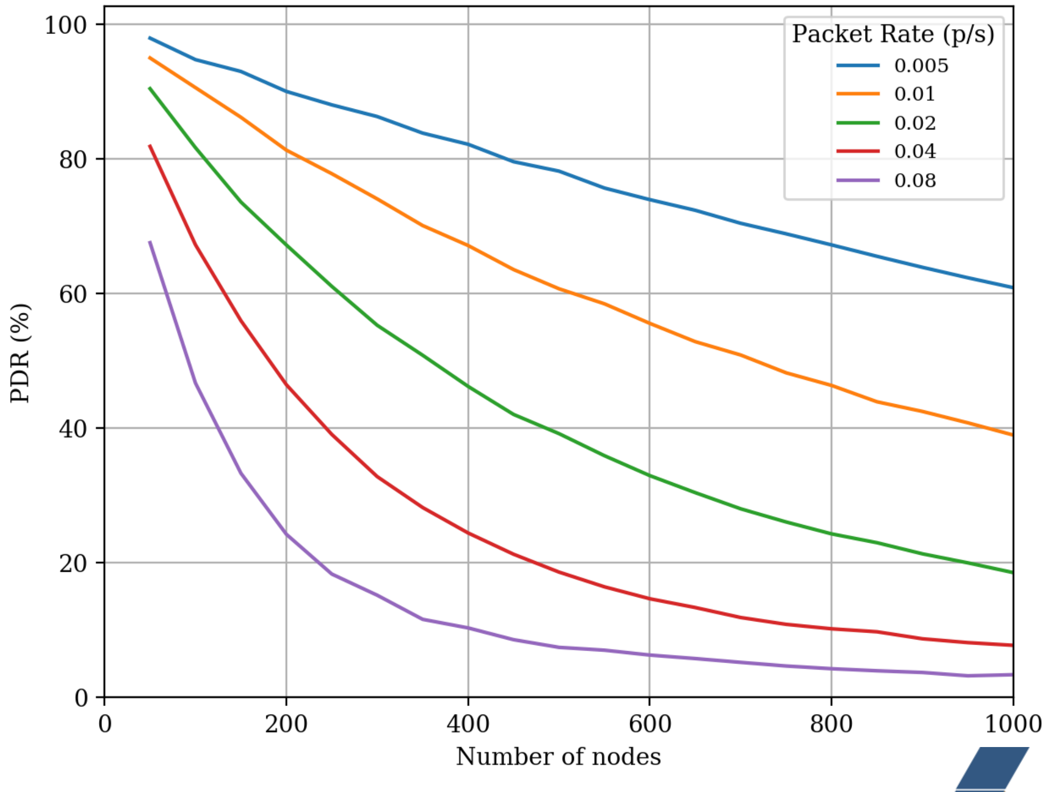

Figure 14: PDR of different packet rates

Simulation Results

- Topology radius is 5000 meters, number of GW is 3, packet generation rate is set to 0.01 packet per second
    - At least 3 GW is required to locate nodes positions by triangulation
- Python scikit-learn decision tree classifier is used
- Prediction scheme gives better PDR when:
    - Number of nodes increases
        - Interference increases
    - Nodes are deployed close to the gateway
        - Nodes have margin to increase SF

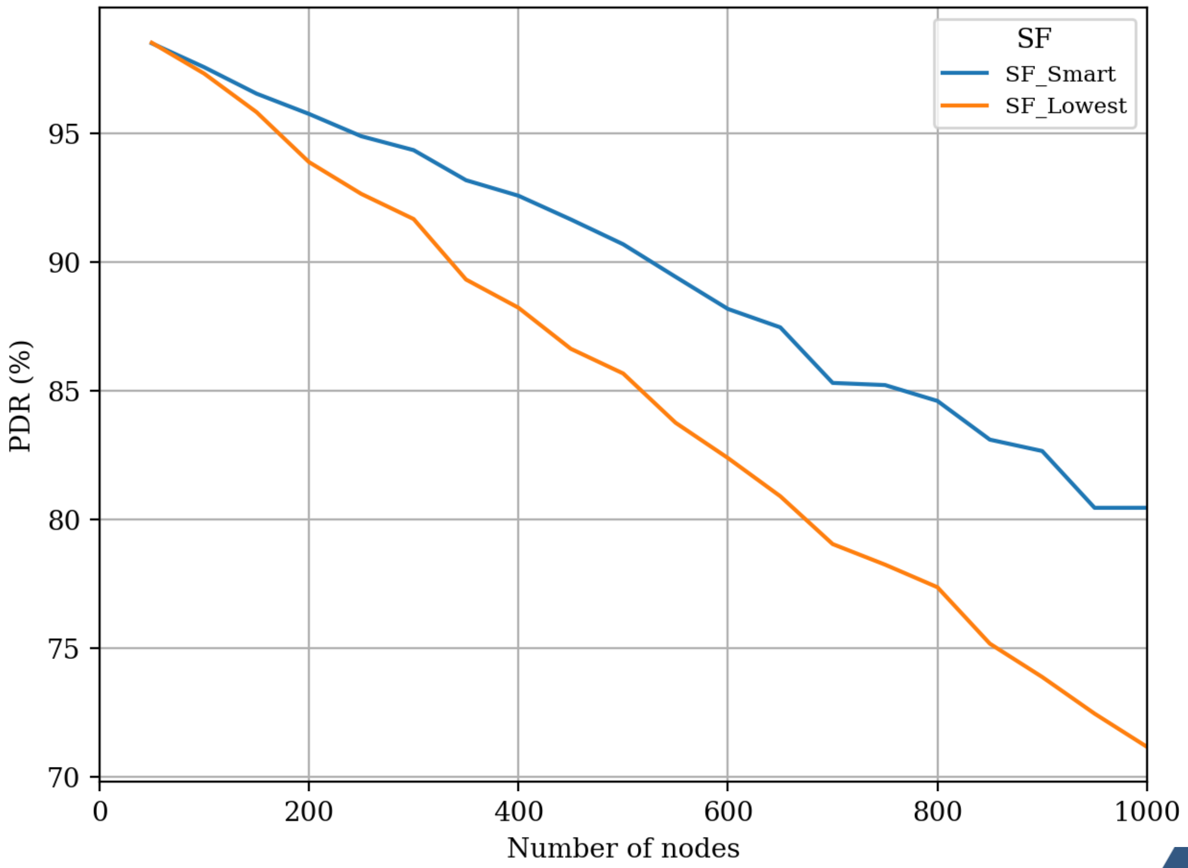

Figure 15: PDR of SF prediction scheme

Thanks for your attention…

Questions, Comments ???

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