



Smart Spreading Factor Assignment for LoRaWANs

Tugrul Yatagan

yatagan@itu.edu.tr

Advisor: Prof. Dr. Sema F. Oktug

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Outline

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3. LoRa
4. Proposed Technique
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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 low power 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

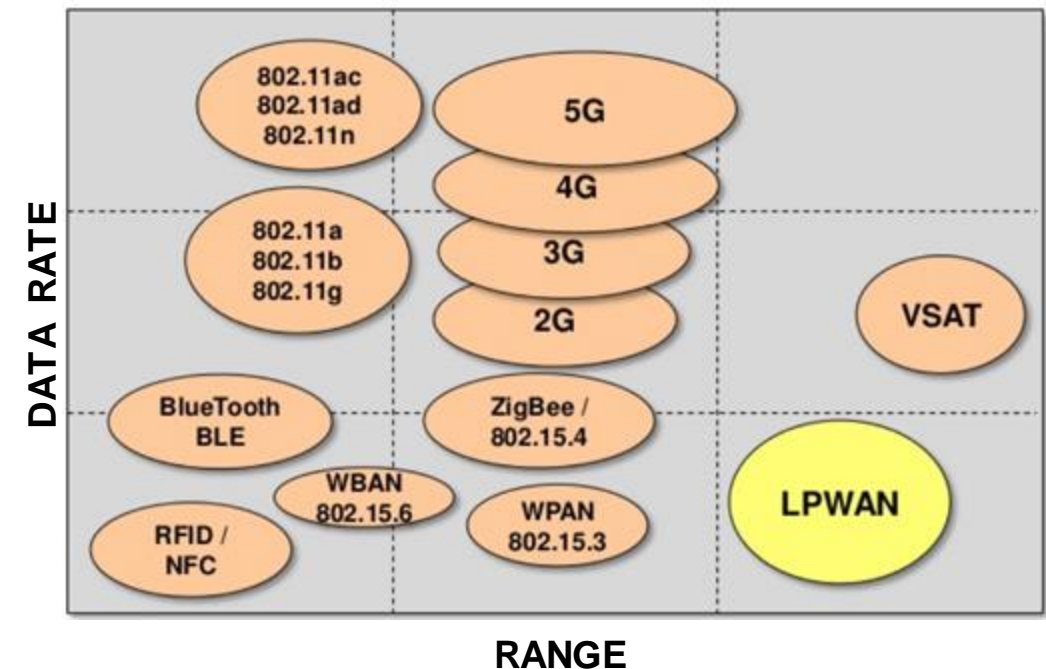


Figure 1: Wireless technologies with respect to range and data rate¹



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 seconds)
 - 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

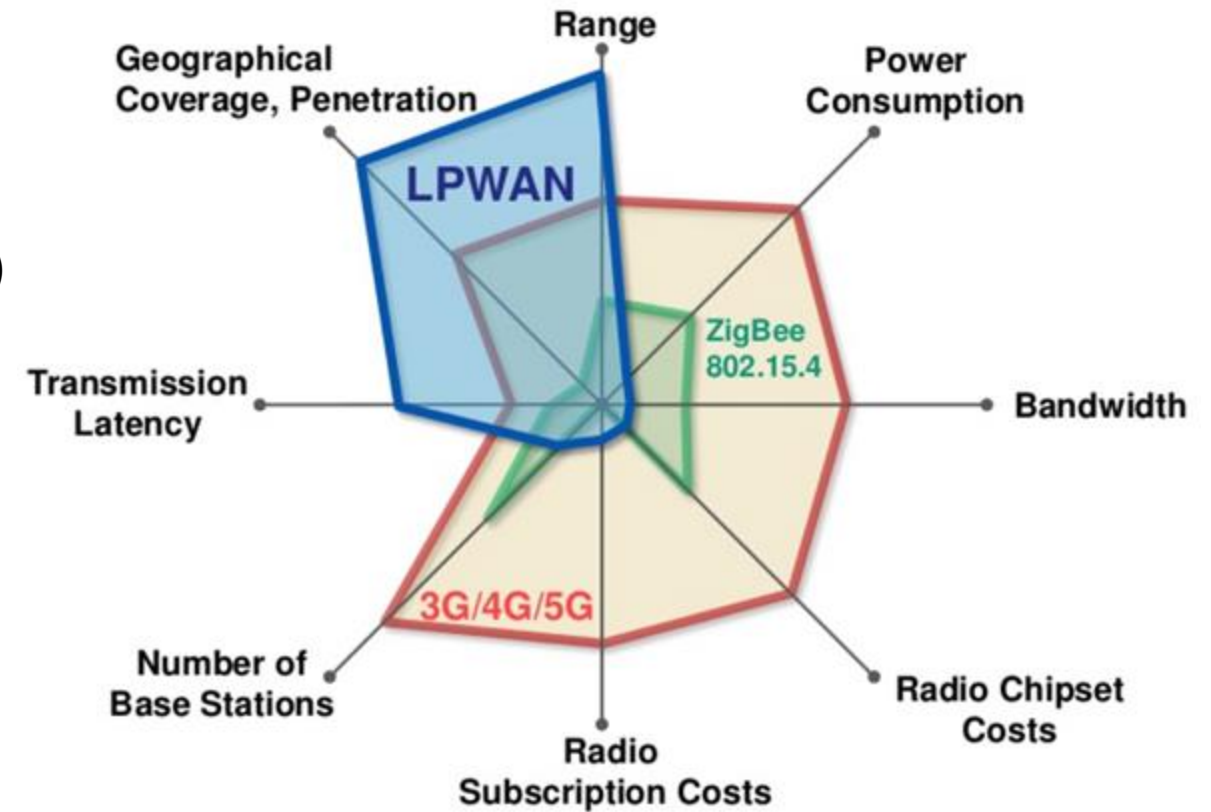


Figure 2: Wireless technologies with respect to various properties¹



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

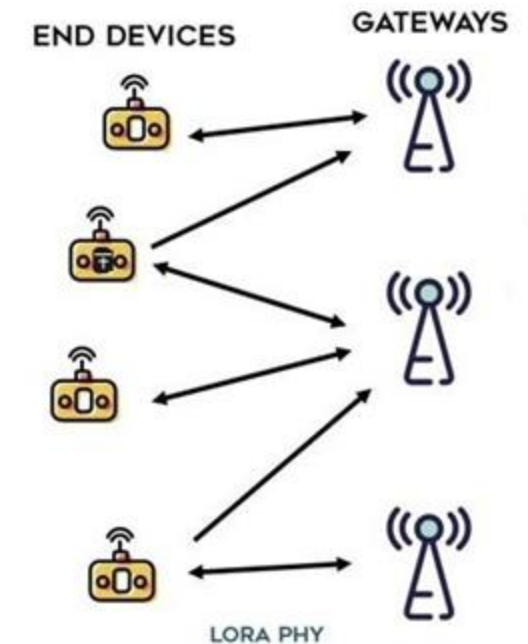


Figure 3: LoRaWAN Topology¹



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

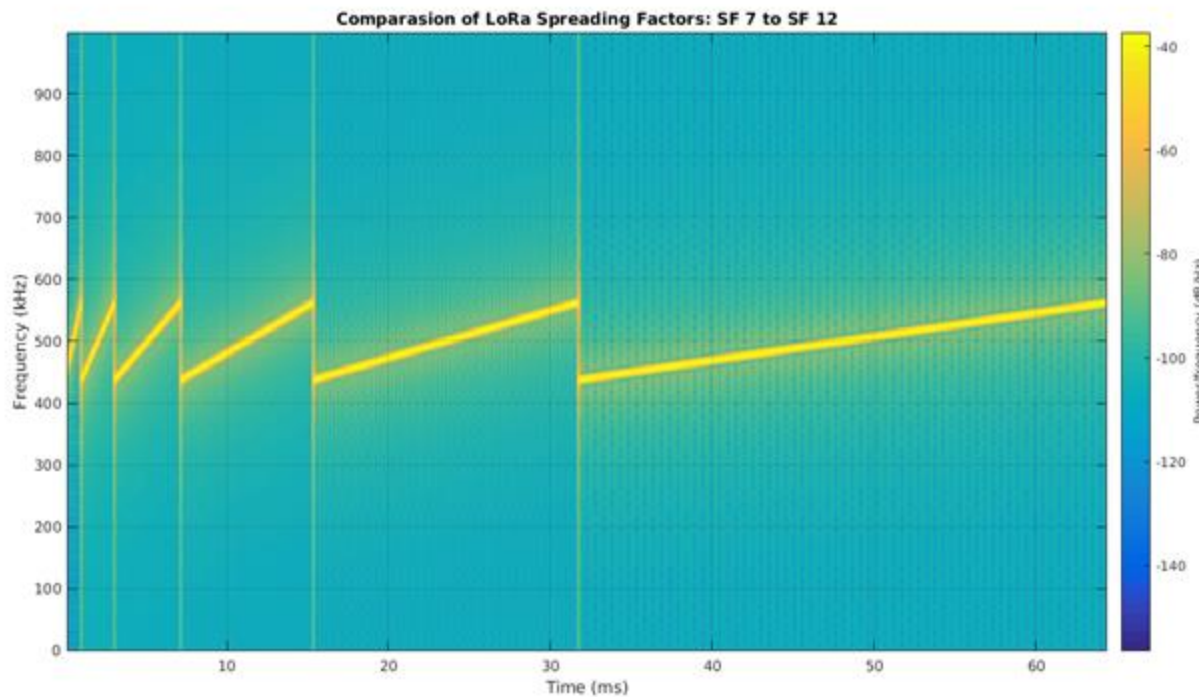


Figure 5: LoRa modulation SF 7 to 12¹

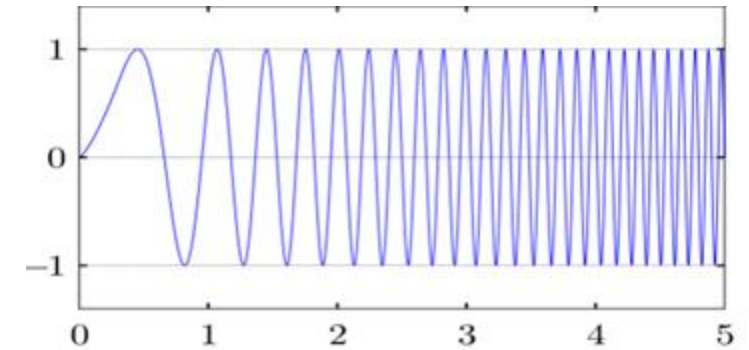


Figure 4: Chirp¹

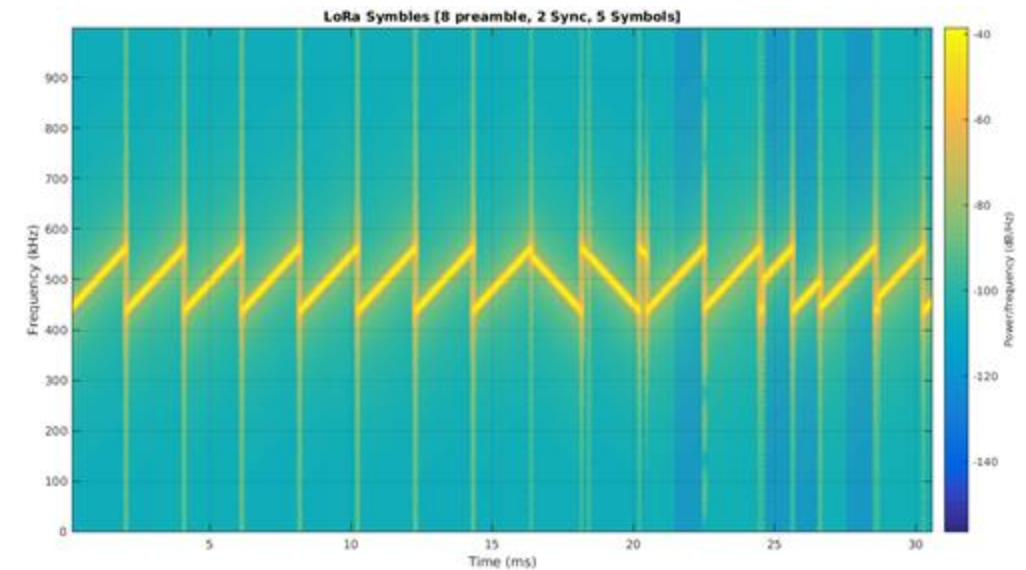


Figure 6: LoRa modulation example¹



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

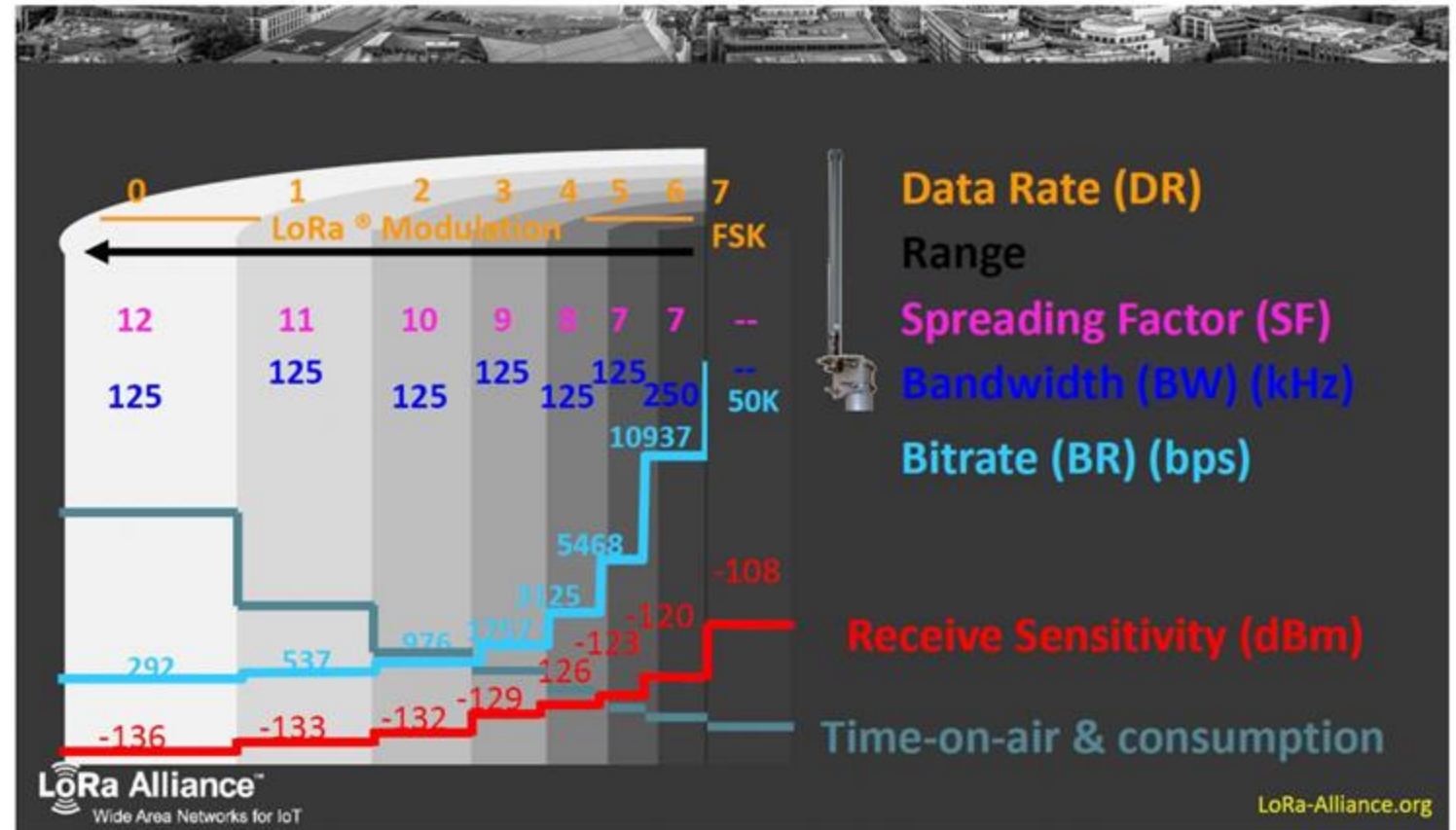
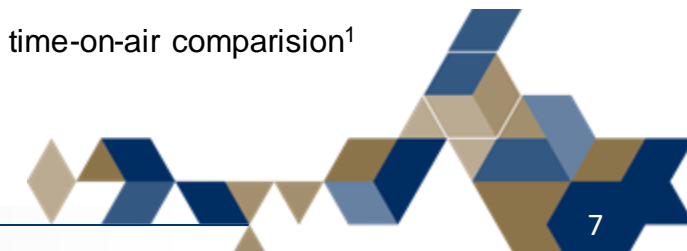


Figure 7: LoRa CSS modulation SF, data rate, time-on-air comparison¹



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

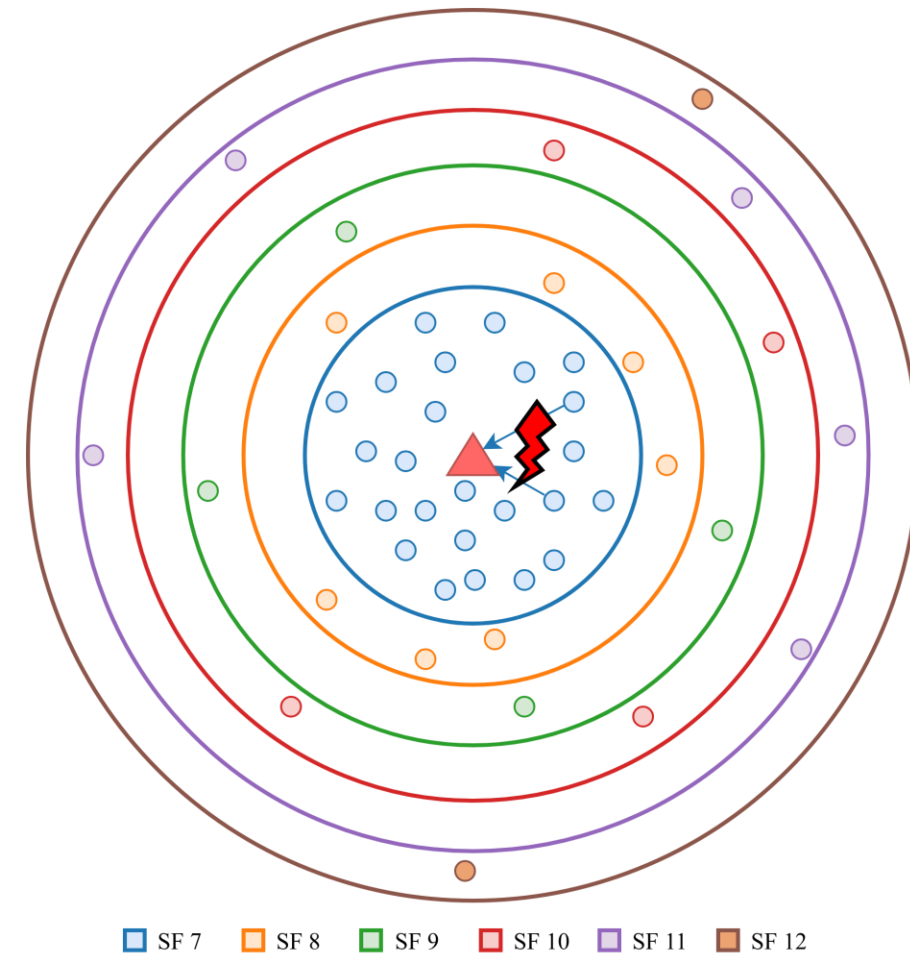


Figure 8: SF assignment issue on single gateway

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?

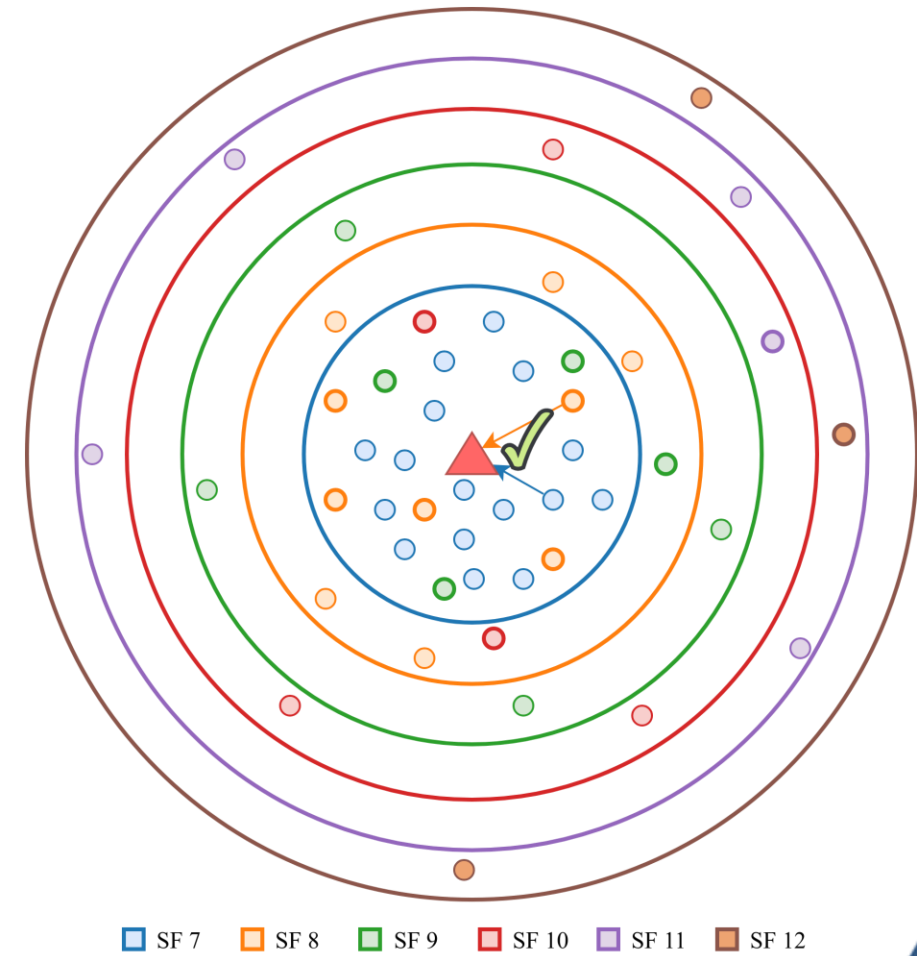


Figure 9: SF assignment issue proposal

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

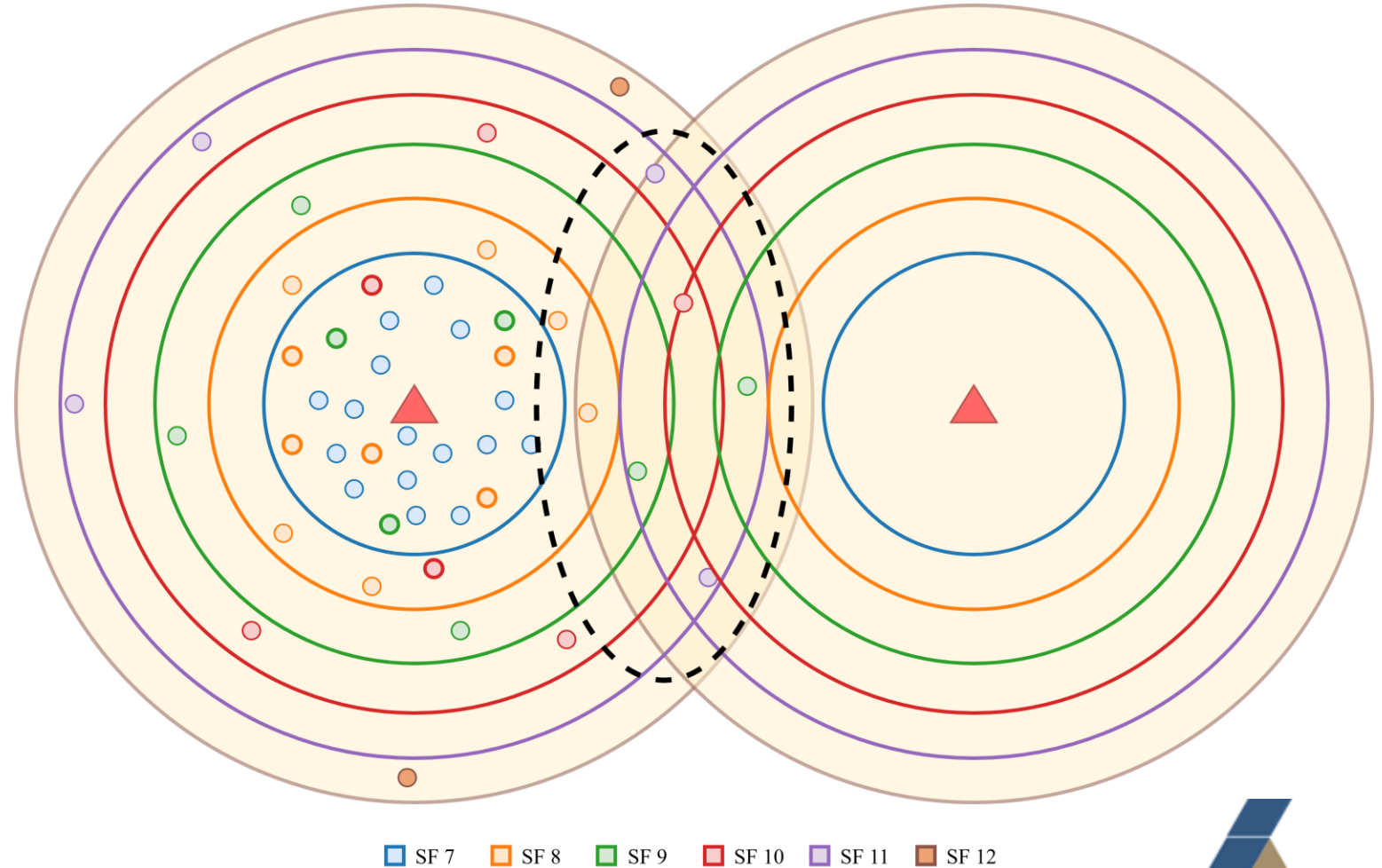


Figure 10: SF assignment issue on multiple gateway

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 propagation 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

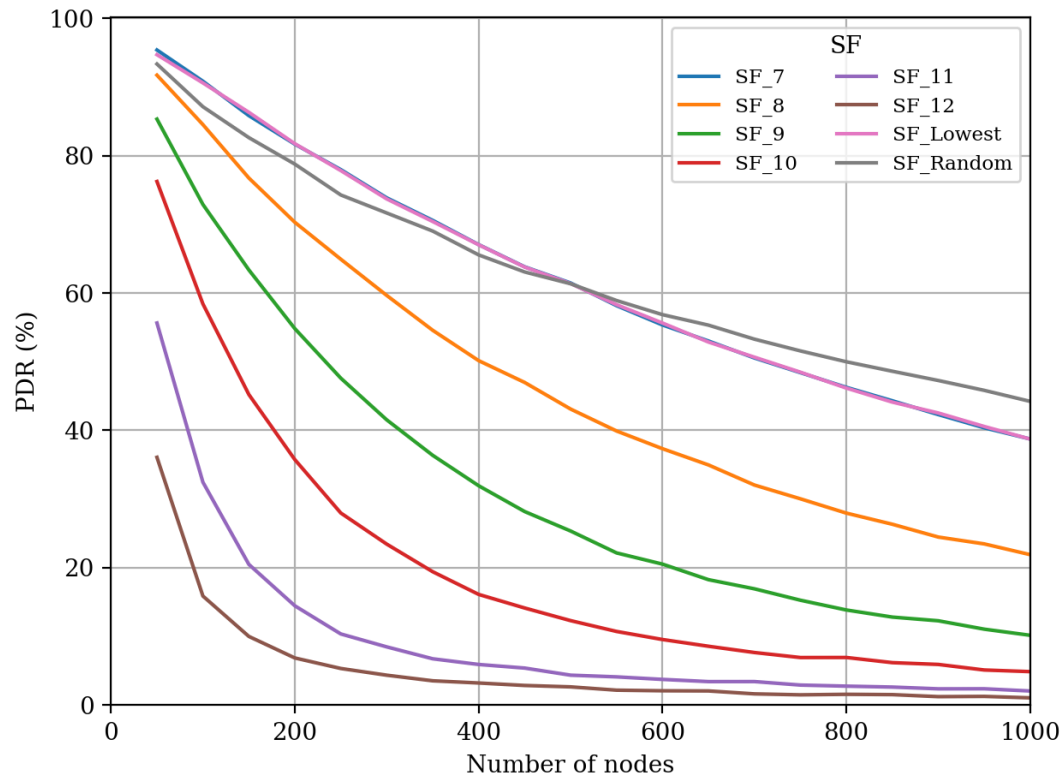


Figure 11: PDR of different SFs

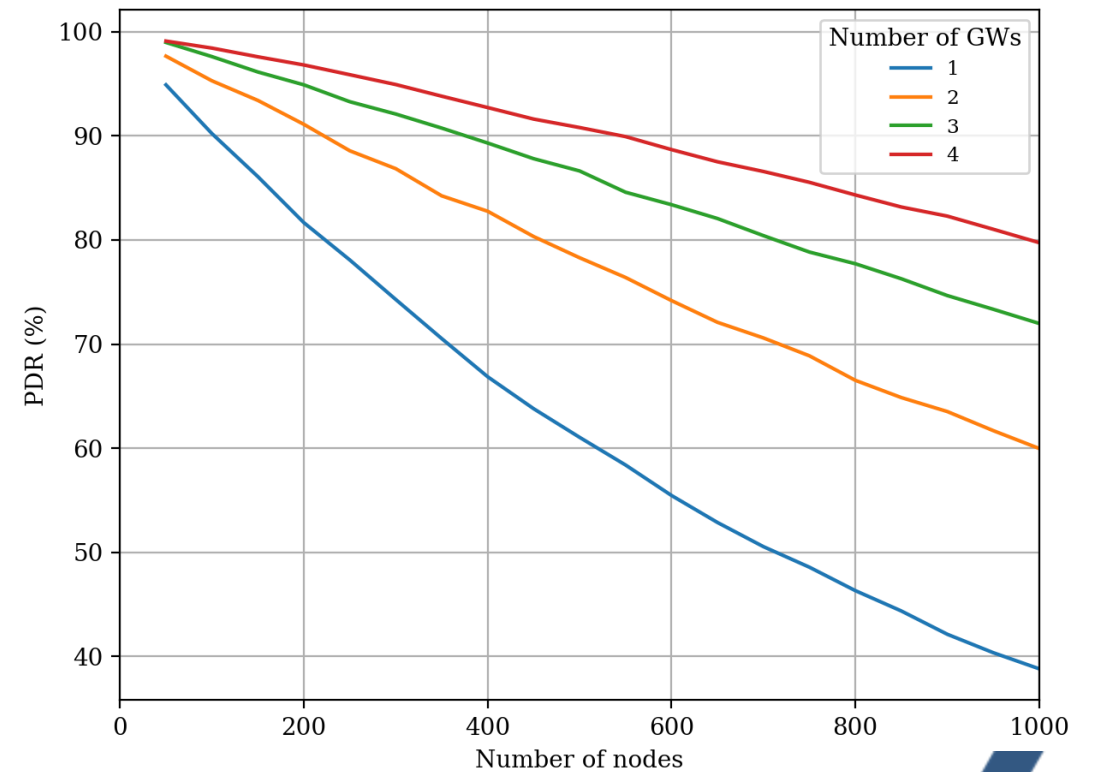


Figure 12: PDR of different number of gateways

Simulation Results

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

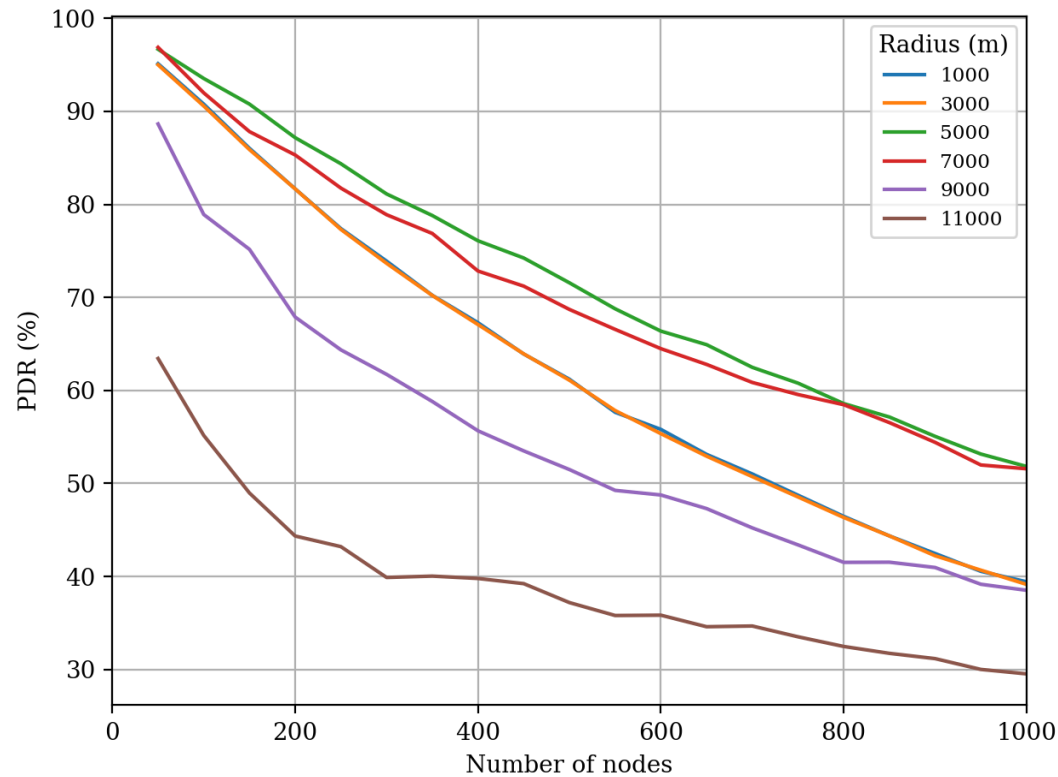


Figure 13: PDR of different topology radius

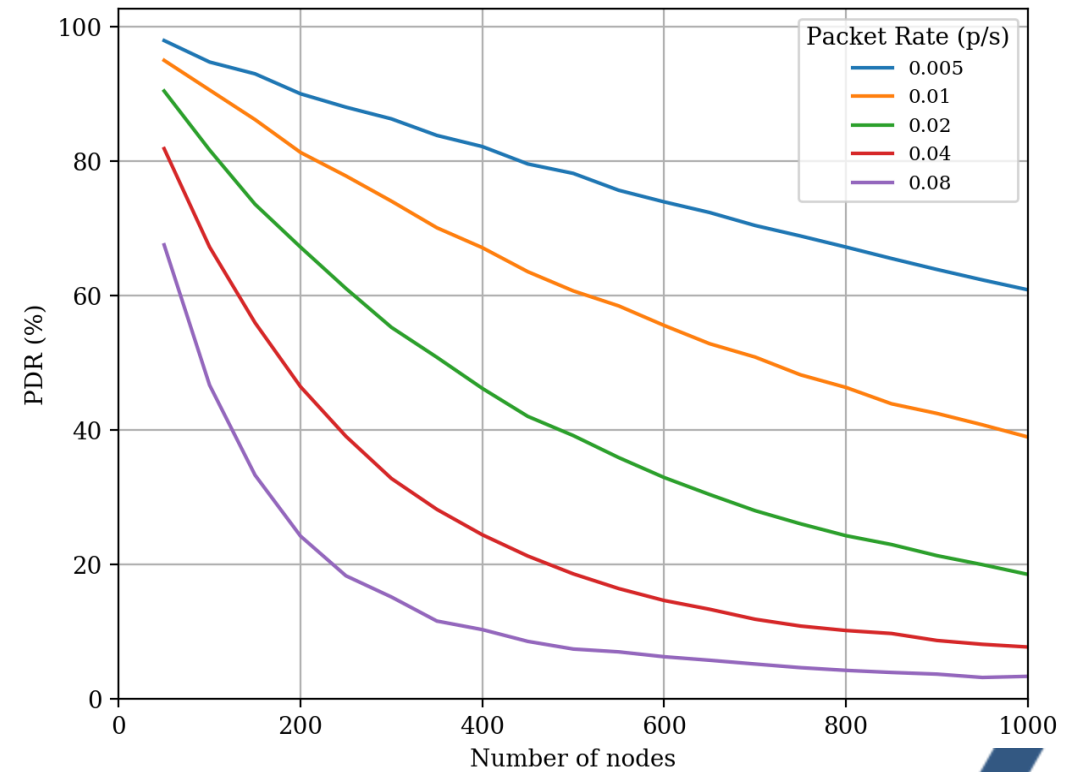


Figure 14: PDR of different packet rates

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

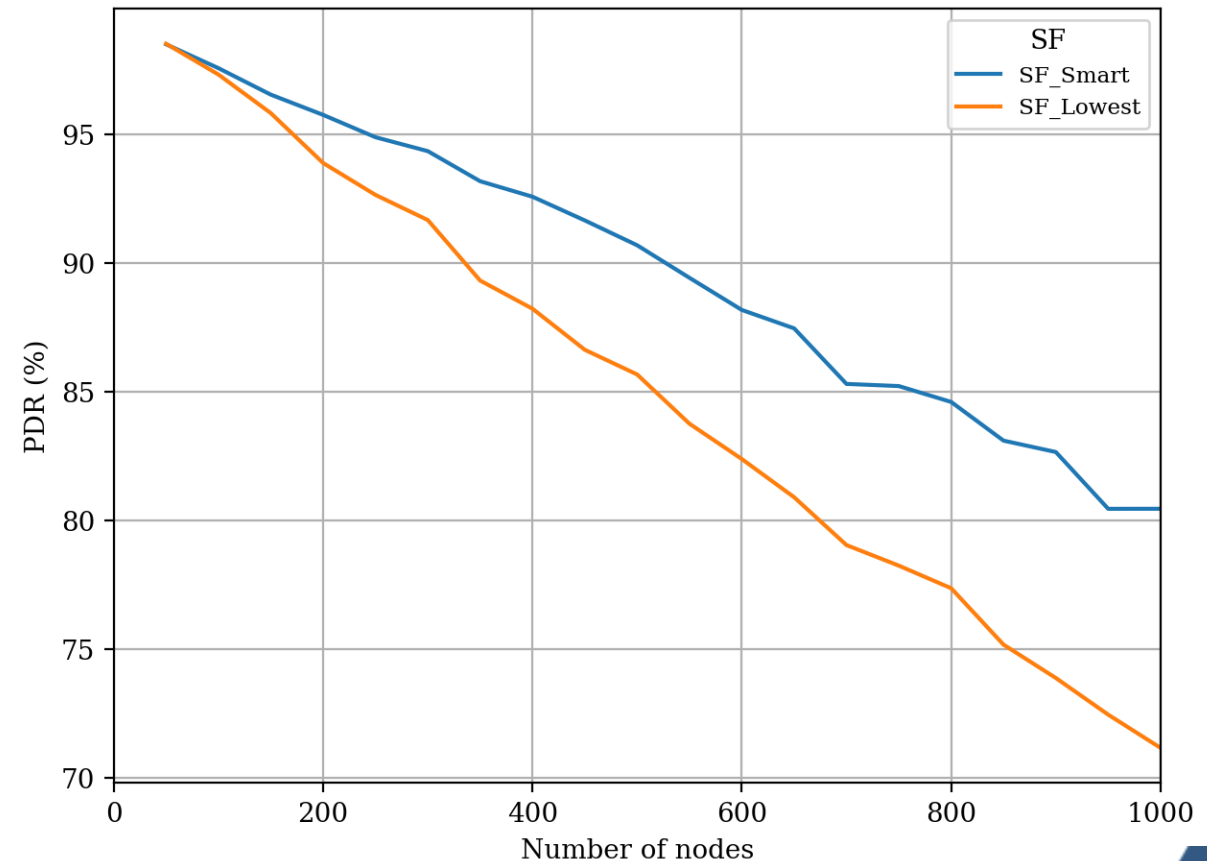


Figure 15: PDR of SF prediction scheme

Thanks for your attention...

Questions, Comments ???

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