Low Power Wide Area Networks: LoRa

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Outline

1. LPWAN Overview
2. LPWAN Design Goals and Techniques
3. LoRa
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LPWAN Overview: Introduction

- Number of connected M2M devices and consumer electronics will surpass the number of human subscribers by 2020 [2]
- IoT industry is expected to generate a revenue of 4.3 trillion dollars by 2024 [3]
- How to provide connectivity for <u>low power</u> devices distributed over large geographical areas?
- LPWA application areas;
  - Smart city
  - Personal IoT
  - Smart grid metering
  - Agriculture
  - Industrial assets monitoring
  - Home automation
  - Logistics
  - Wildfire monitoring

- LPWAN fills the technology gap between;
  - Short range wireless technologies (ZigBee, Bluetooth, Wi-Fi)
    - Very costly to deploy massive/dense # of devices
  - Cellular (2G, 3G, 4G)
    - Optimized for voice and data
    - Complex and expensive
    - High power consumption

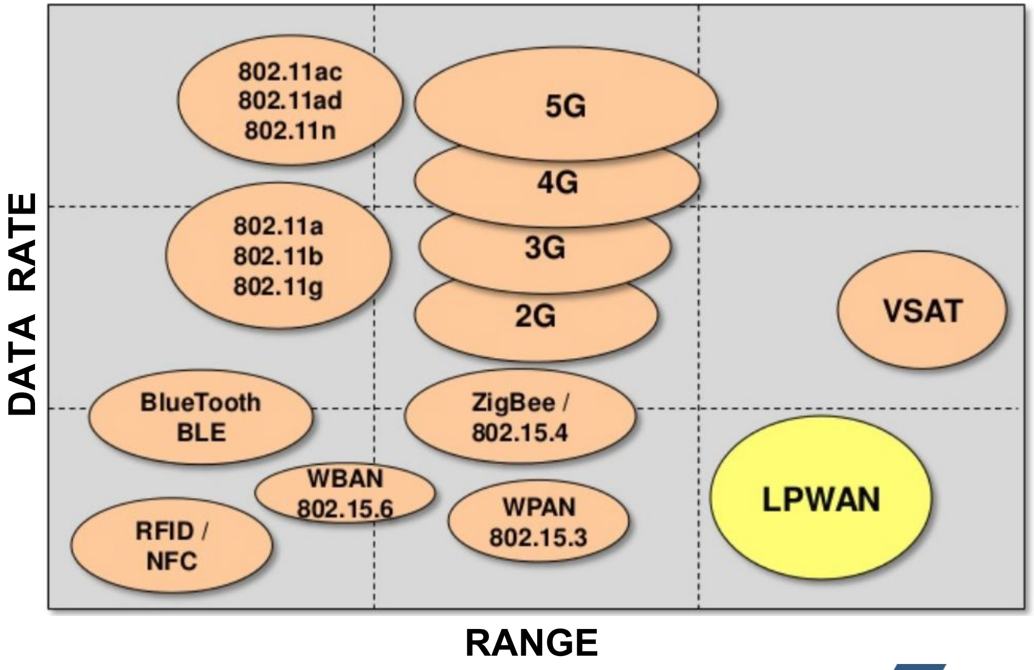

Figure 1: Wireless technologies with respect to range and data rate[1]

LPWAN Overview: Key Features

- Low Power Wide Area (LPWA) networks;
  - \+ Low power (ten years and beyond)
  - \+ Long range (a few to tens of kilometers)
  - \+ Low cost
  - \+ High scalability
  - \- 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 technologies and alliances;
  - LoRa
  - Sigfox
  - NB-IoT
  - Weightless SIG

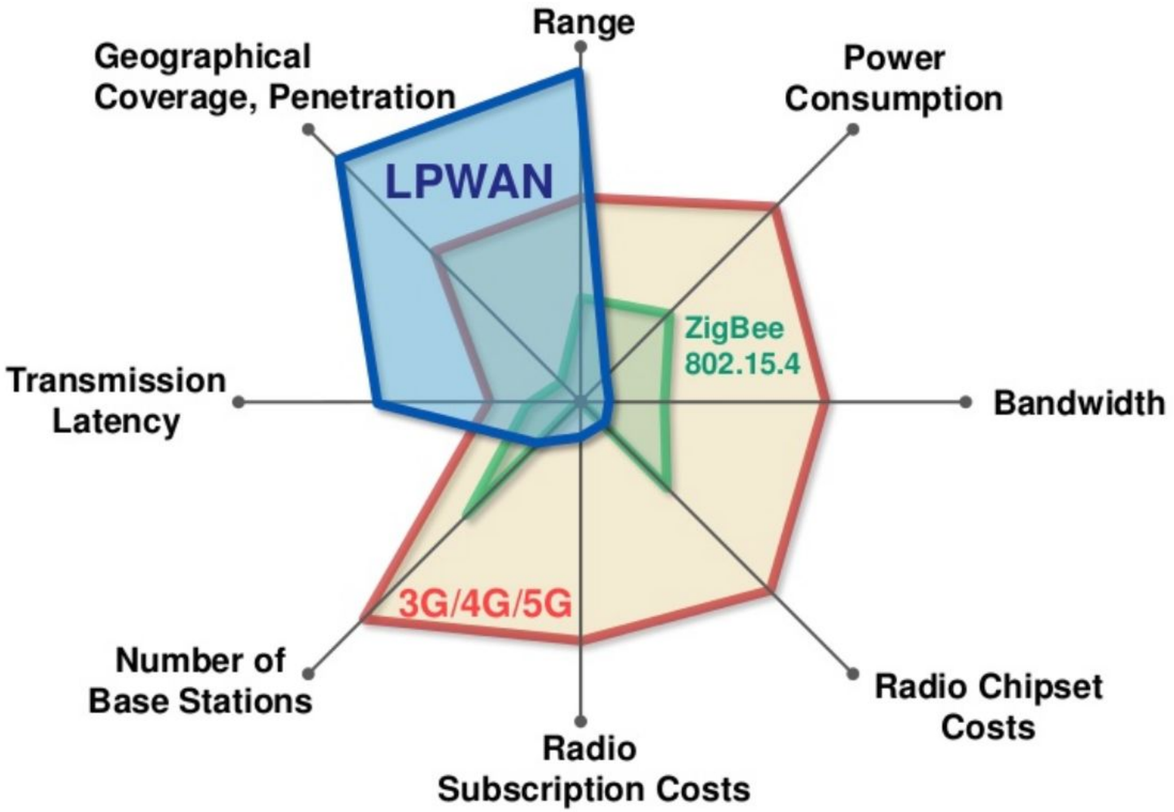

Figure 2: Wireless technologies with respect to various properties[1]

LPWAN Design Goals and Techniques

- Key objectives of LPWAN technologies; long range + low power + low cost
- Long range
  - Sub-GHz band
    - Lower frequency signals experience less attenuation and multipath fading
  - Special modulation techniques
    - Designed to achieve range of a few km and tens of km
    - Two classes of main modulation techniques;
      - Narrowband; encoding the signal in low bandwidth (usually less than 25kHz)
        - Reduce noise, decrease data rate
      - Spread spectrum; spread signal over a wider frequency band but with the same power density
        - Resilient to interference, harder to decode
- Low cost
  - Cost of hardware should below $10 and connectivity subscription per unit should low as $1
  - Reduction in hardware complexity
  - Minimum infrastructure
  - Using license-free or already owned licensed bands

LPWAN Design Goals and Techniques

- Ultra low power operation
  - Simple topology
    - No mesh, direct connection from end devices to base stations
  - Duty cycling
    - End devices to turn off their transceivers when not required
  - Lightweight medium access control
    - Widely used MAC protocols (cellular, WLAN) are too complex. Mostly ALOHA is used
  - Offloading complexity from end devices
    - Simplify the design of end devices, move complexity to base stations and backend system
- Scalability
  - Diversity; channel, time, space, and hardware
  - Densification
  - Adaptive channel selection and data rate
- Quality of service
  - Limited or no QoS

LoRa: Medium Access Control

- Multiple spreading factors (between 7-12) to decide the tradeoff between range and data rate
- Data rate ranges from 300 bps to 37.5 kbps depending on spreading factor
- 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
- LoRaWAN is open standard MAC layer protocol for LoRa physical layer
  - Battery Powered – Class A
  - Low Latency – Class B
  - No Latency – Class C
- Base stations can adapt communication parameters
  - Data rate
  - Modulation parameters
- Base stations support mobility of devices and handover mechanisms
- Base stations are stateless

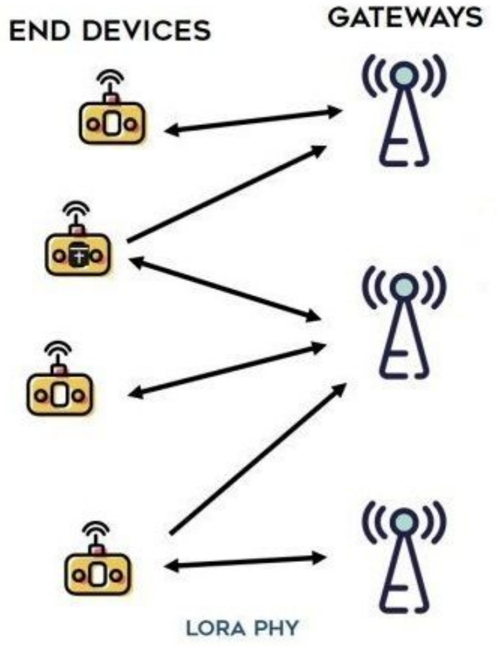

Figure 3: LoRa Topology[1]

1. Image Source: https://i1.wp.com/www.zerynth.com/wp-content/uploads/2017/05/lorawan-architecture.jpg?resize=1024%2C561&ssl=1

LoRa: Modulation

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

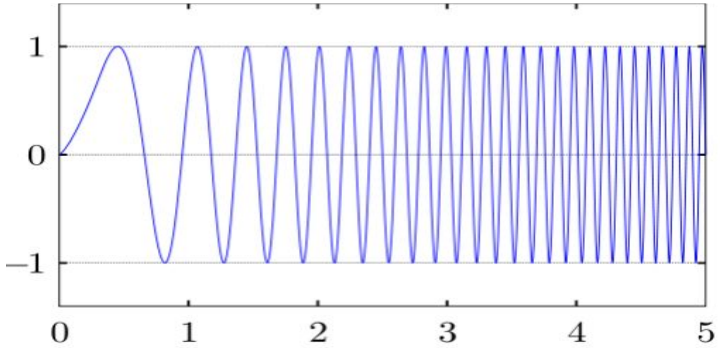

Figure 4: Chirp[1]

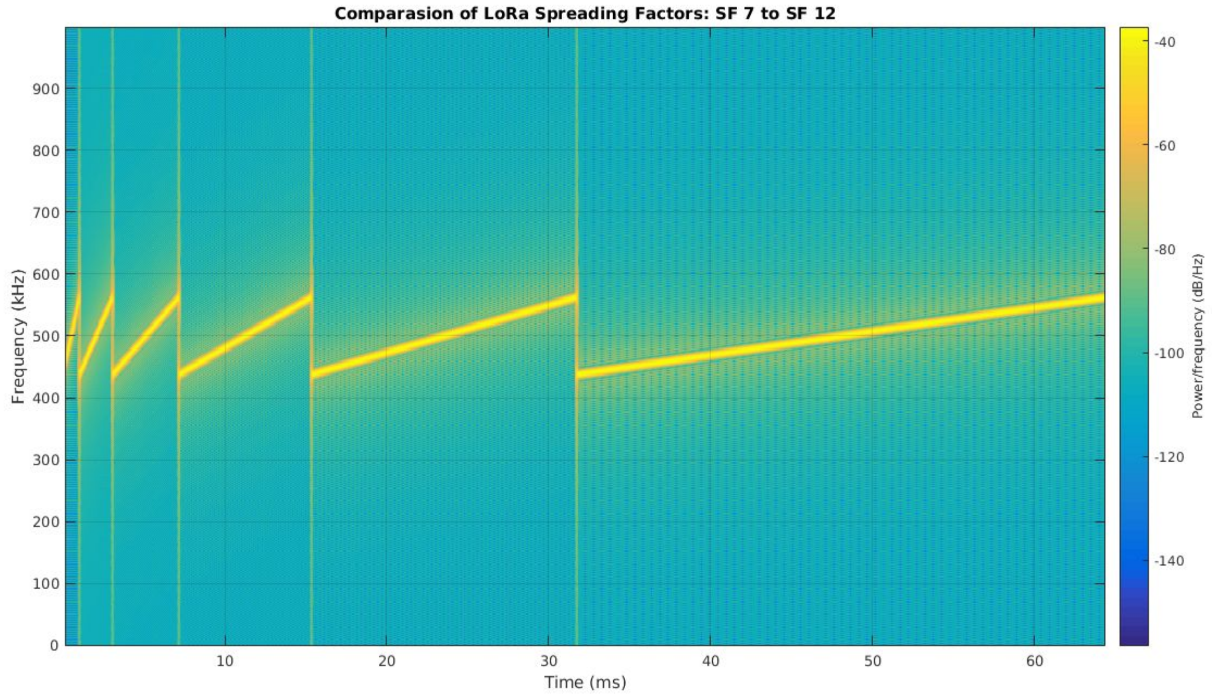

Figure 5: LoRa CSS modulation SF 7 to 12[1]

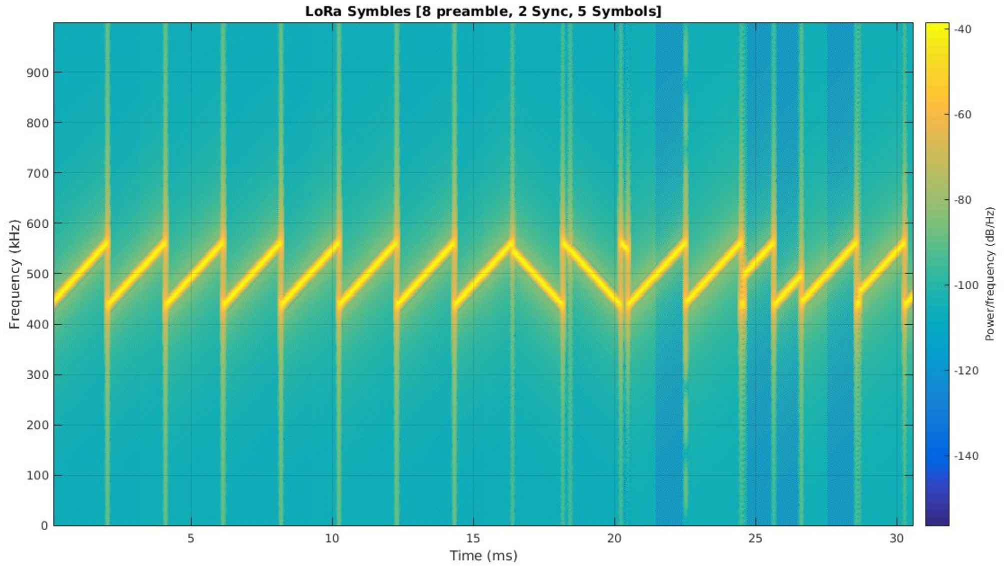

Figure 6: LoRa CSS modulation[1]

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

LoRa: Spreading Factor

- LoRa uses Spreading Factors for rate adaptation
  - SF can be SF7 to SF12
- Lower SF leads to:
  - Higher transmission rate
  - Shorter transmission time
  - But requires a higher SNR
  - Lower sensitivity
- SFs are orthogonal (not 100%):
  - Packets with different SFs in same channel can be received simultaneously

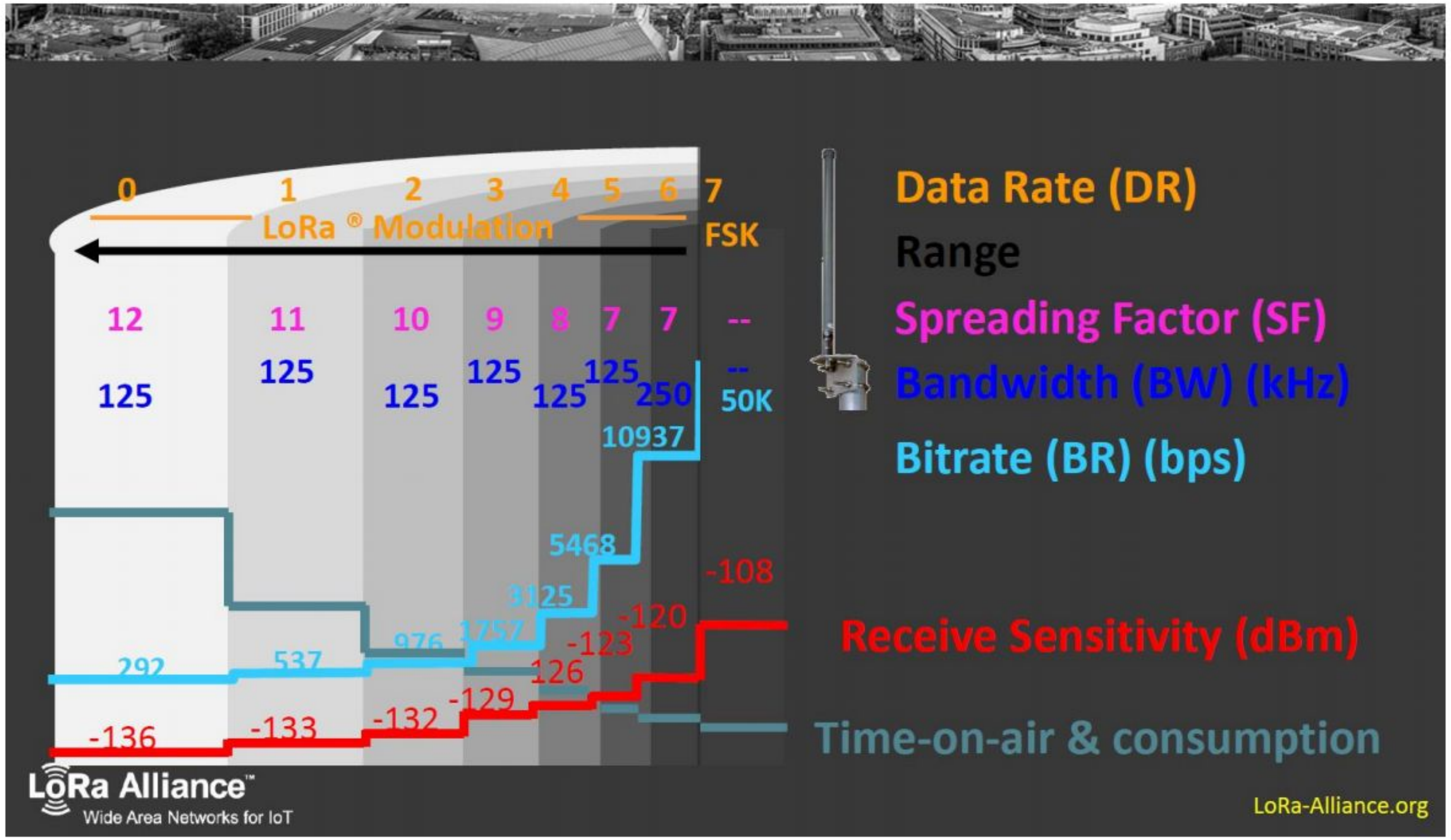

Figure 7: LoRa CSS modulation SF, data rate, time-on-air comparision[1]

Research: Problem

- Less collisions occur if more SFs used:
  - More SFs could result in longer messages and more energy consumption
- End nodes choose SF according to their GW transmission signal strength
- Most of the end devices which close to GW will choose lowest SF which increases collisions

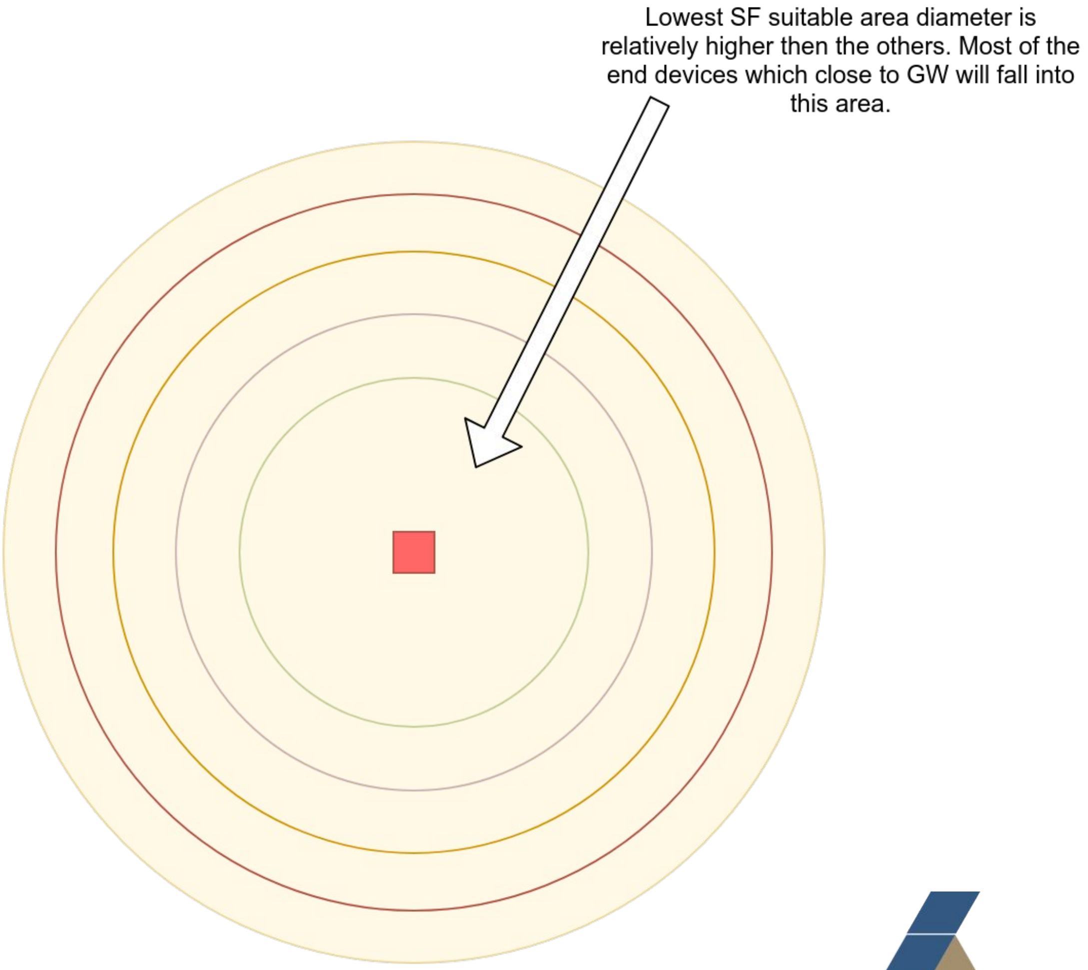

Figure 8: SF assignment issue on single gateway

Research: Problem & Proposal

End devices which close to GW will probably select lowest SF all the time. Which results a lot of collisions between lowest SF transmissions while close end device number increases..

If GW force some of the close end nodes to select higher SF even if they can able to communicate with lower SF, this will result lower collisions due to the orthogonality of different SF.

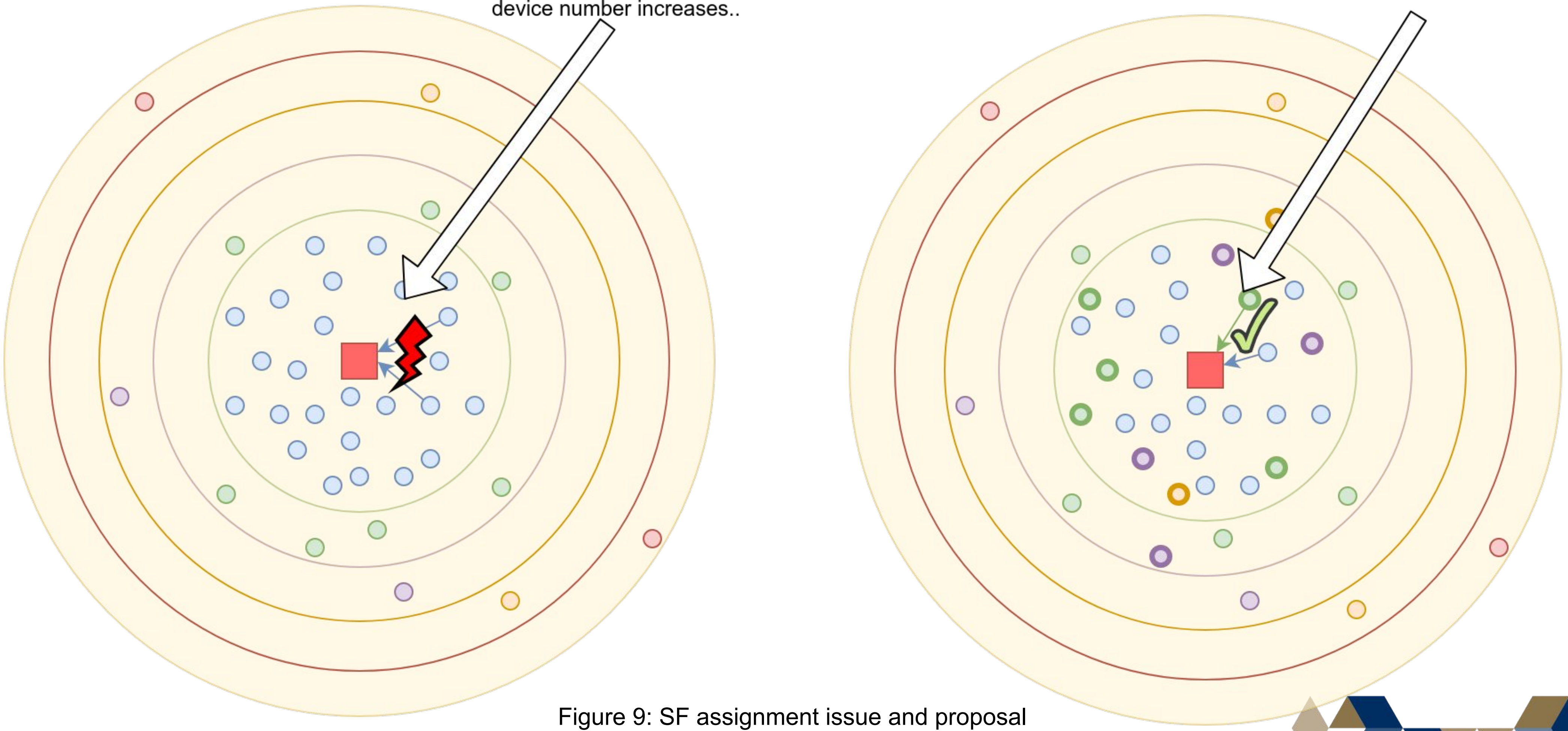

Figure 9: SF assignment issue and proposal

Research: Problem & Proposal

GW can avoid increasing SF of end nodes which is close to other GWs using location information obtained by triangulating the signal strength of end nodes.

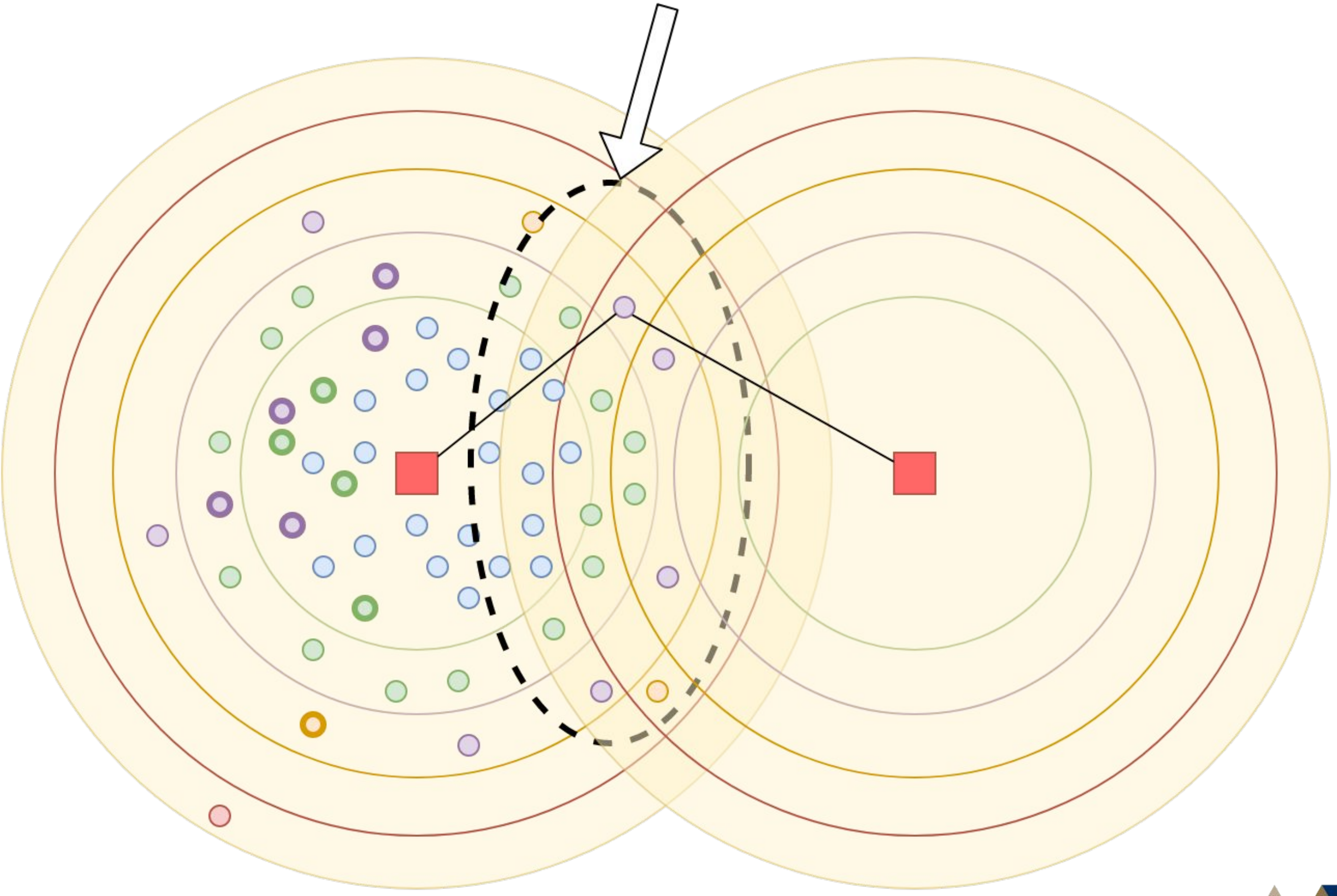

Figure 10: SF assignment issue on multiple gateway

Research: Proposal

- Gateway can keep track of transmissions
  - Spreading factor
  - Transmission result
- Gateway can train a model for predicting transmission result for a specific location and specific spreading factor
- Trained model can be loaded into end nodes as a function
- End nodes can use utilize this function to select spreading factor to decrease the probability of collisions

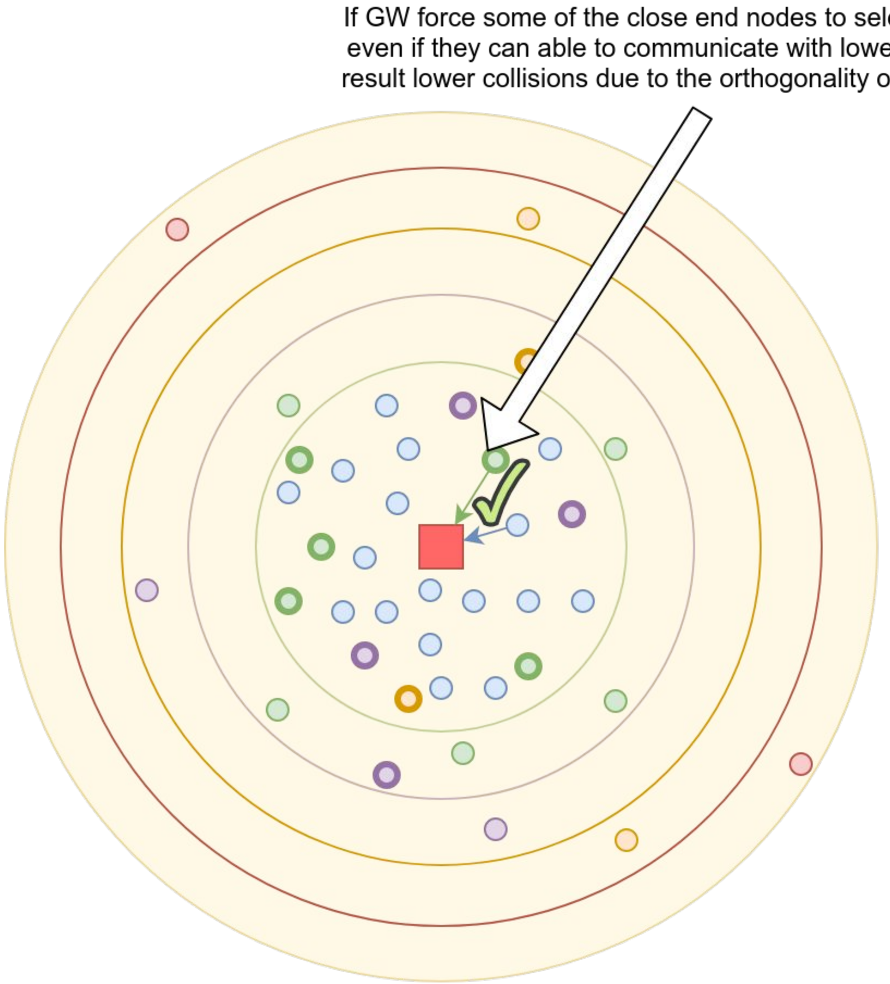

Figure 11: SF assignment issue solution proposal

Thank you for your time.

Any questions?

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