QMesh: A long-range, low-cost wireless mesh network for digital voice communications

Dan Fay, KG5VBY

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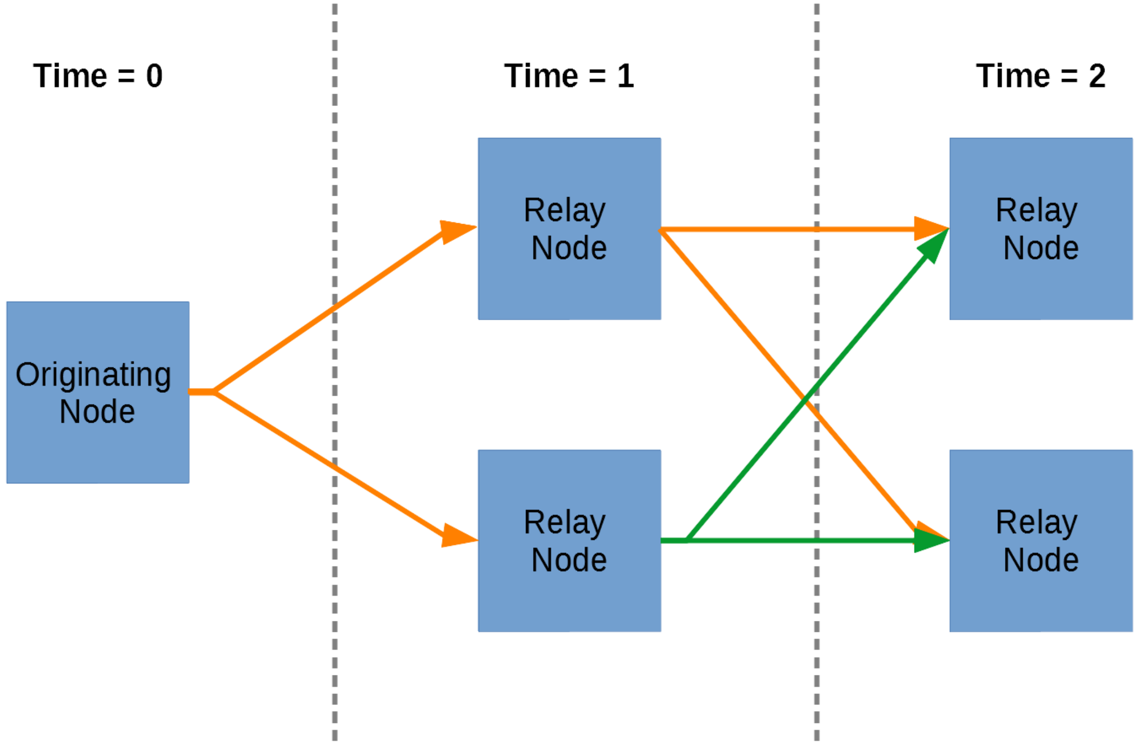
What is QMesh?

- It’s another MANET/wireless mesh network protocol
- What makes it unique
  - Isochronous -- can handle streaming data like voice
  - Self-healing/self organizing
- Relatively low datarate (at most 10’s of Kb/s)
  - Enough to support vocoded voice (700bps-1600bps)
  - Can also carry small amounts of data (location, telemetry, etc.)
- Uses the LoRa Chirp Spread Spectrum (CSS) waveform
  - Provides better Eb/N0 than “standard” modulations (FSK, PSK, etc.)
  - Unique properties of the LoRa waveform (spread spectrum, low symbol rate) enable QMesh to work

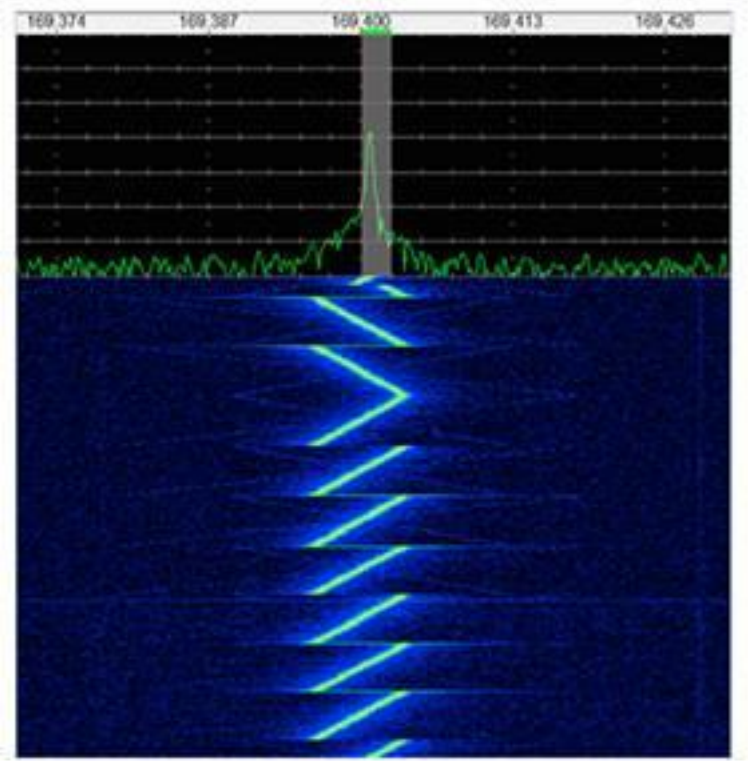
MANETS/Wireless Mesh Networking

- MANET = Mobile Ad-Hoc NETwork
  - Self-assembling
  - Self-healing
- Mesh networking
  - Nodes relay packets until they reach their destination
  - Two major types: routed and flooded
- QMesh uses a synchronized flooding network
  - Retransmit at the same time
  - Good for streaming voice



LoRa

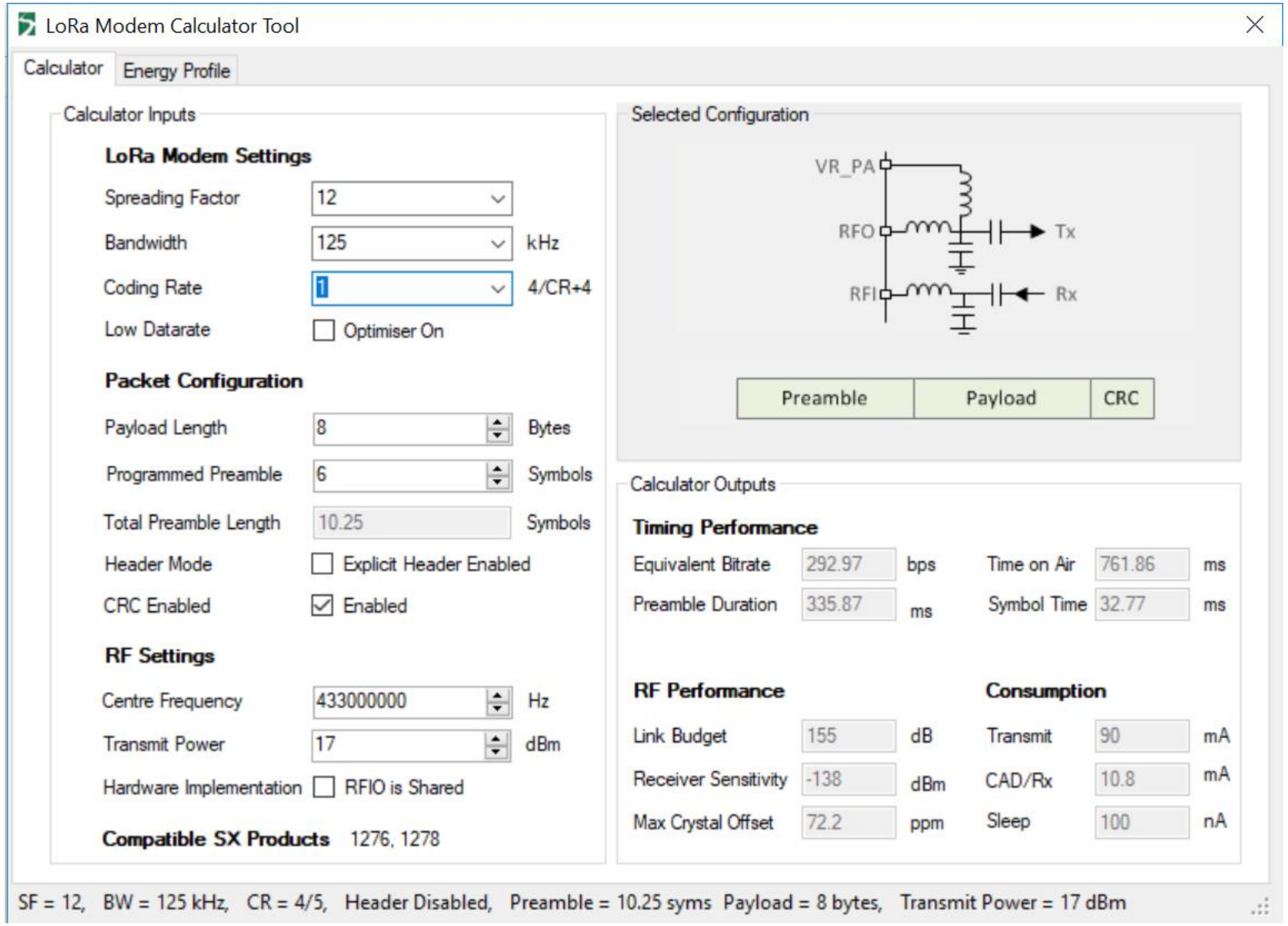
- LoRa is Semtech's proprietary implementation of Chirp Spread Spectrum (CSS)
  - Targets battery-powered, Internet-of-Things (IoT) devices
  - Used to implement LPWAN protocol LoRaWAN
- Benefit: CSS gives large processing gain vs. FSK/OOK
  - LoRa@1172bps: -132dBm Rx sensitivity on 70cm
  - FSK@1200bps: -123dBm Rx sensitivity on 70cm
  - LoRa supports bitrates up to 37500bps (62500bps on newer chipsets)
- LoRa is becoming increasingly popular, so products are easy to find
  - HopeRF is a popular module maker; some integrated w/MCU emerging
  - 33cm and 70cm modules easy to find
  - LoRa chipsets support 137MHz through 1GHz, as well as the 2.4GHz band
- **LoRa provides large sensitivity improvement (9dB or more) vs. FSK**



Source: [*https://www.digikey.com/en/articles/techzone/2016/nov/lorawan-part-1-15-km-wireless-10-year-battery-life-iot*](https://www.digikey.com/en/articles/techzone/2016/nov/lorawan-part-1-15-km-wireless-10-year-battery-life-iot)

LoRa Parameters

- **Spreading Factor (SF)**
  - 2^{SF} = number of chips/symbol
  - Higher SF gives higher Rx sensitivity in exchange for lower data rates
  - Different SF's are somewhat orthogonal, as well as different IQ polarities
- **Bandwidth** – how "wide" the chirp is
  - Wider bandwidth gives higher data rates at expense of Rx sensitivity
  - 500KHz, 250KHz, and 125KHz are typically used
- **Coding Rate** specifies the FEC (Hamming code)



Using the Capture Effect

- Capture effect means that we can successfully receive collisions if the colliding packets are far enough apart in received power
- Can leverage capture effect to make synchronized flooded protocols work without everyone interfering with each other
- LoRa has some features we can use to increase the likelihood of successful capture
  - Frequency separation between chips
  - Low chirp (symbol) rate
  - Tolerance of frequency error (up to +/- 25% of the LoRa bandwidth)
- Randomly “wobble” the frequency
- Can also shift things around by adding a timing offset

Increasing Capture Success with LoRa

- Basically, “spread out” the overlapping LoRa signals so they interfere less with each other
- LoRa has some features we can use to increase the likelihood of successful capture
  - Frequency separation between chips
  - Low chirp (symbol) rate
  - Tolerance of frequency error (up to +/- 25% of the LoRa bandwidth)
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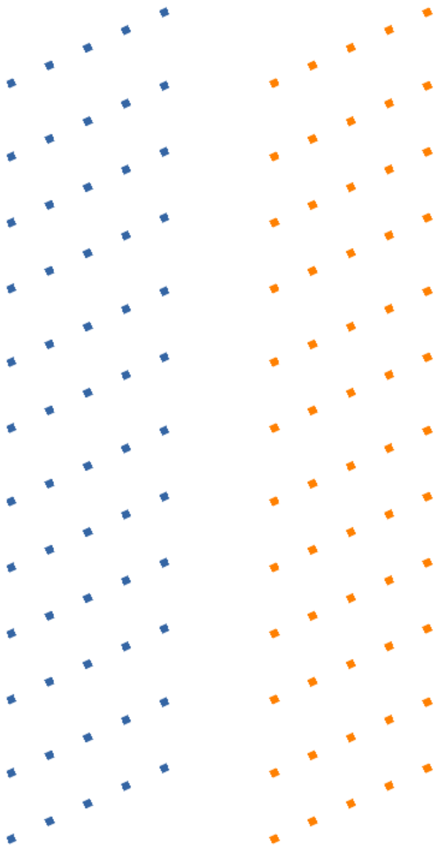
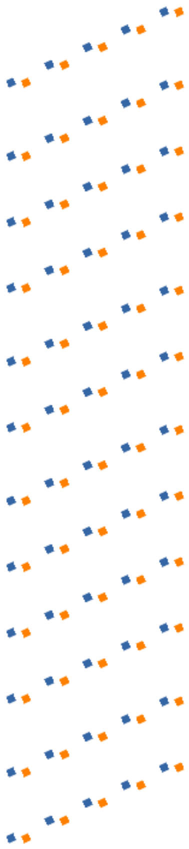
Chip-Level LoRa Overlap Reduction



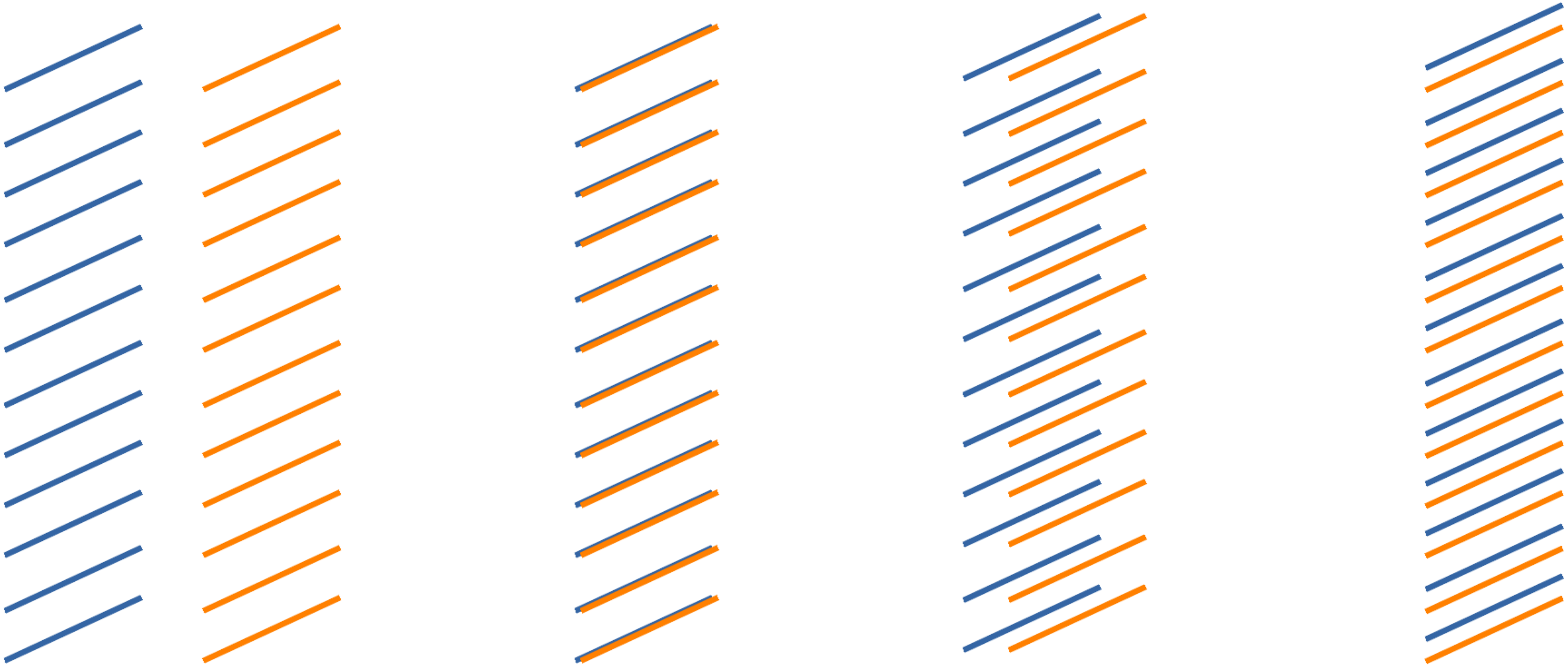
Two LoRa signals on completely Different channels

Two LoRa signals on the same frequency



Two LoRa signals with a very small frequency offset

Symbol-Level LoRa Overlap Reduction



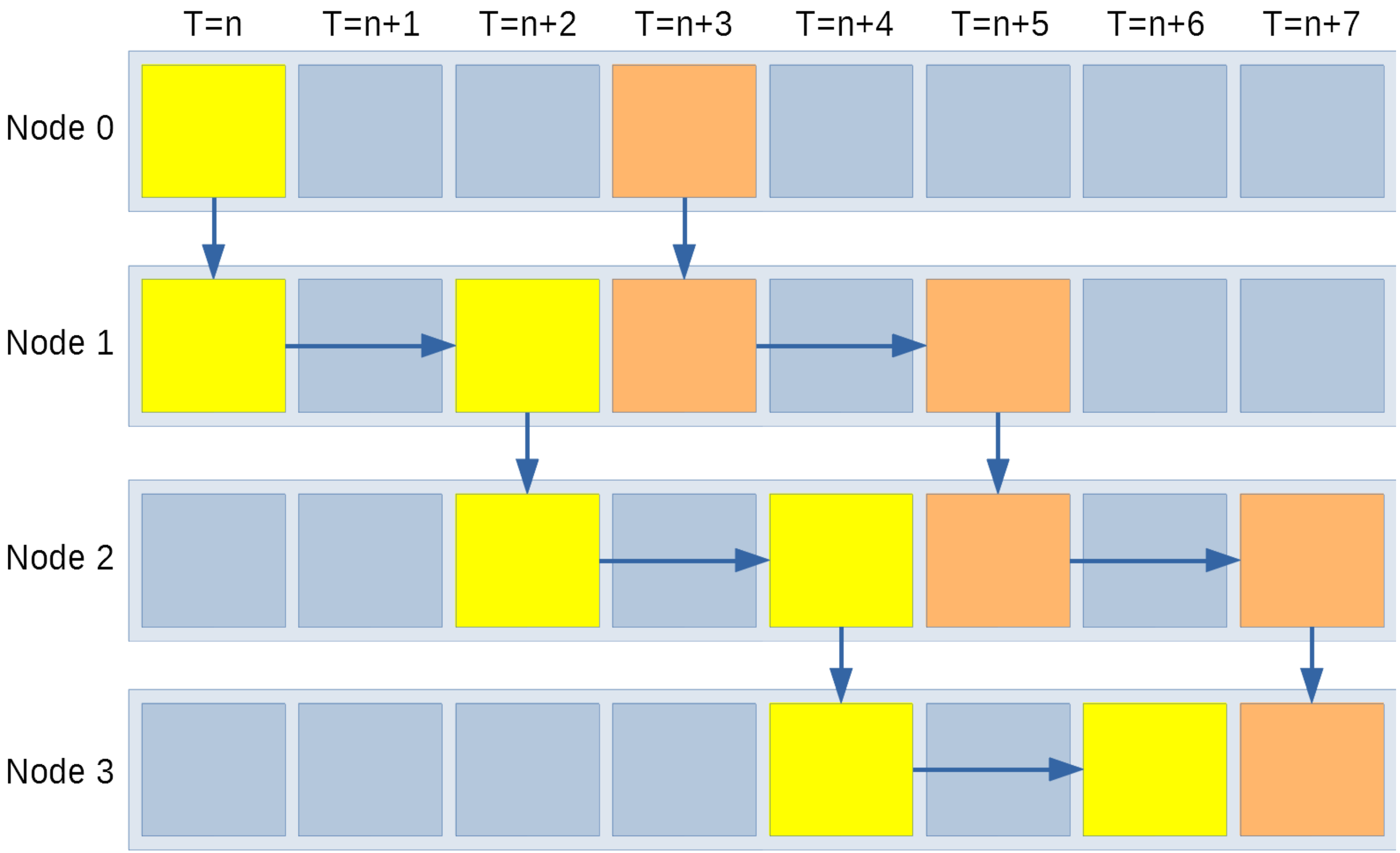
Two LoRa signals on completely Different channels

Two LoRa signals on the same frequency

Two LoRa signals with a small frequency offset

Two LoRa signals with a timing offset

QMesh Protocol In Action

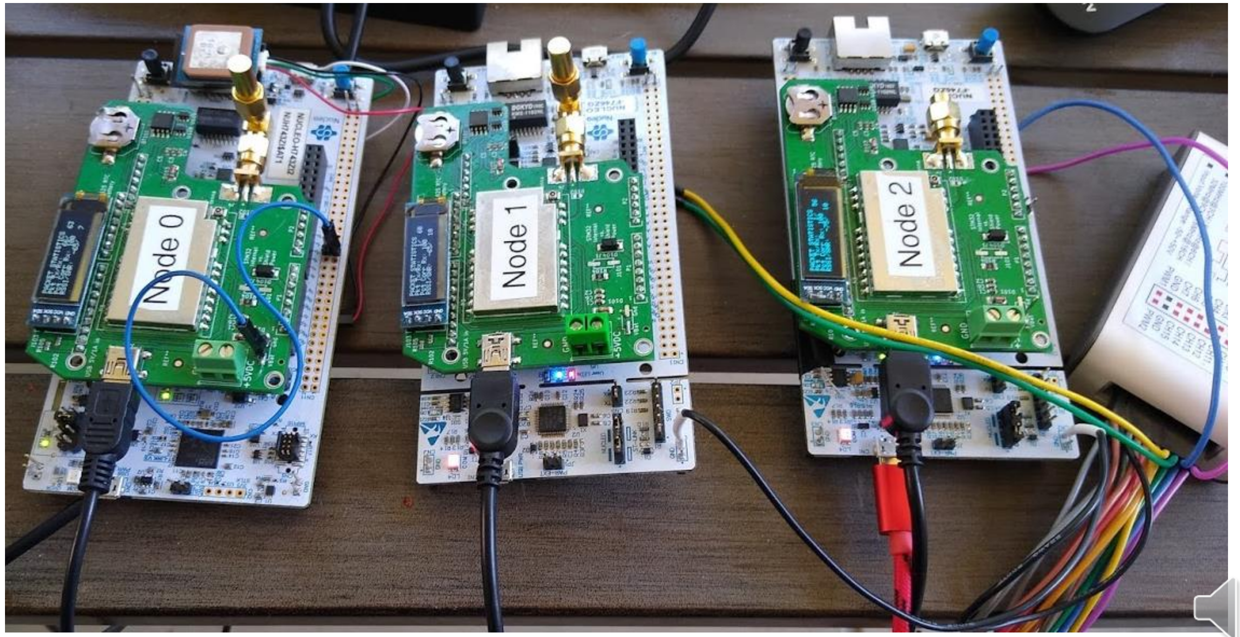


Forward Error Correction (FEC)

- LoRa has a very simple, Hamming Code-based FEC built into it
- Can likely gain at least a few dB of performance with a decent FEC
  - Theoretical gain may be 2-10dB of coding gain in an AWGN channel (Additive White Gaussian Noise – free space line-of-sight)
  - Possibly even better in multipath-heavy situations
  - **Substantial benefits in a collision-heavy environment**
- Currently using Reed-Solomon-Viterbi (RSV) coding

QMesh Test Node

- Custom LoRa Shield + STM32 NUCLEO-144 Board
- USB on the shield (black cable) supplies power to both boards
- Red USB cable connects to computer, provides debug and serial port
- OLED display provides live information without needing a connected PC



Results

- Testing collisions
  - Worst case scenario for interference
  - Antennas are ¼ wavelength apart
- When FEC is used, PRR is 99%+ for one, two and three node setups
- FEC seems to make a big difference here
  - One node has 99%+ PRR w/o FEC
  - Two nodes has ~93% PRR w/o FEC
  - Three nodes has ~90% PRR w/o FEC
- Appears the raise the noise floor
  - Weak signals do not get received

CR=0 is an undocumented feature in the SX126X that completely disables the built-in error correction

Next Steps

- Short term goals
  - Replace JSON-based interface with a protobuf-based interface
  - Make the serial interface KISS-compatible for use with APRS apps
- Longer term: Develop small FM repeaters that encode/decode voice as `codec2` and use QMesh as a backhaul
  - Compact, can run off solar power
  - Easy to stand up a series of linked repeaters
  - Can also be used to extend coverage of existing repeaters
- Big benefit is accessibility
  - People can use their existing radios, so can benefit from QMesh without having to design special radios
  - Less hardware needed by users to benefit from QMesh


DX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miady
LIFEPO4 RECHARGEABLE BATTERY
12.8V | 8Ah | 102.4Wh
• Advanced Cell Design
• Long Life Cycle and Environmentally Friendly
• Lightweight and Lower Self-Discharge
Caution
Made in China

Contact Info

- **QMesh project**
  - **Github:** https://github.com/faydr/QMesh -- source code
  - **Hackaday.io:** https://hackaday.io/project/161491-lora-based-voice-mesh-network – project overview
- **Blog:** https://faydrus.wordpress.com (describes a lot of my radio/maker experiments)
- **E-mail:** Daniel.fay@gmail.com (kg5vby@arrl.net should also work)
- **Twitter:** @faydrus