LoRa Parameter Choice for Minimal Energy Usage

Ben Dix-Matthews
Rachel Cardell-Oliver
Christof Huebner

University of Western Australia
University of Applied Sciences Mannheim

RealWSN, Shenzhen, China

November 2018
Motivating Applications

Long range, wide area

Very low energy use

Unknown and changeable environment

Low data rates
Goal: identify optimal LoRa parameter selection given

- LoRa physical layer
- Lowest energy
- Data recovery strategies
- Test Sites: suburb, campus, farms
PARAMETER CHOICES

Multi-objectives of low energy and high reliability
LoRa
Physical Layer

- Transmission power $P_{TX}$
  - Settable from -2 dBm to 20 dBm
  - $\downarrow P_{TX}$ gives $\downarrow$ Energy

- Bandwidth BW
  - Frequency range for chirp sweeping: 125, 250 or 500 kHz
  - $\uparrow$ BW gives $\downarrow$ Energy but Less Rx sensitivity

- Coding Rate CR
  - LoRa built in forward error correction (always 4/5 here)
  - $\downarrow$ CR gives $\downarrow$ Energy but Less Rx sensitivity

- Spreading Factor SF
  - $2^{SF}$ chirps in a symbol
  - $\uparrow$ SF gives More Rx sensitivity but $\uparrow\uparrow$ energy
LoRa energy model

- Bit rate \( BR = \frac{SF \times CR \times BW}{2^{SF}} \)

- Total Energy

\[
\begin{align*}
\text{Total Energy} &= \text{Power} \times \text{Time on Air} \\
&= V_{\text{supply}} \times I_{tx} \times BR \times \text{Len}_{\text{pkt}}
\end{align*}
\]
LoRa channel and receiver sensitivity model

- Channel RSSI = $P_{TX} + \text{Gains} - \text{PathLoss}$

- Receiver sensitivity = tolerable path loss = data sheet values given BW and SF
Tolerated path loss vs per-packet energy for all LoRa parameter combinations.
Per-parameter Contributions to Tolerated Path loss
LoRa PARAMETERS FOR REAL WSNs

Which LoRa settings are best in real-world channels?
Data Sets
Mobile Nodes

Spatial Variability of Channels

Path Loss in Residential Area

- **Experimental Data**
- **L-PE (n=5.46)**
- **L-PE (n=4)**
- **LSR (n=1.98, B=75.61)**

Distance from Transmitter (metres) vs. Path Loss (dB)
Static Nodes

Temporal Variability of Channels
Estimating Packet Reception Rates

Strawberry Packet Fates

Path Loss (dB)

Date

Sat 13:00 Sat 18:00 Sat 23:00 Sun 04:00 Sun 09:00 Sun 14:00

Received
Lost
Energy vs Packet Reception Rate Trade-offs
DATA DELIVERY RATE

How much can we improve the raw PRR for a given setting? At what energy cost?
Some Data Recovery Strategies

- **ARQ**: acknowledge received packets and re-transmit any lost ones
  [Cattani 2017 effective bit rate]

- Naïve repetition coding: transmit multiple copies, or include copies of past messages in one packet

- **DARA**: Replication with data aware compression
  [Cardell-Oliver 2013]

- Fountain codes and Convolutional Coding
  [Marcelis 2017]
Comparison of Data Recovery Strategies
Conclusions

Goal: experiment-based study of optimal parameter selection given
- LoRa physical layer
- Lowest energy
- Data recovery strategies
- Test Sites: suburb, campus, farm

- Findings:
  - A pareto-front of minimal energy settings was derived
  - Nodes can self-configure depending on current channel conditions
  - Data replication with compression gives the best energy-data delivery trade-off
Future Work
Adaptive Protocols

• Implement an adaptive protocol and test data replication strategies and parameter choices in a real setting

• UWA Farm underground sensors
Future Work

LQI

- Investigate other parameters that affect path loss
- Develop a Link Quality Indicator for very low power LoRa applications
Thank You

Water Corporation of Western Australia CEED scholarship

Australia-Germany Joint Research Cooperation Scheme