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Adaptive Data Rate Techniques for Energy Constrained Ad Hoc LoRa Networks

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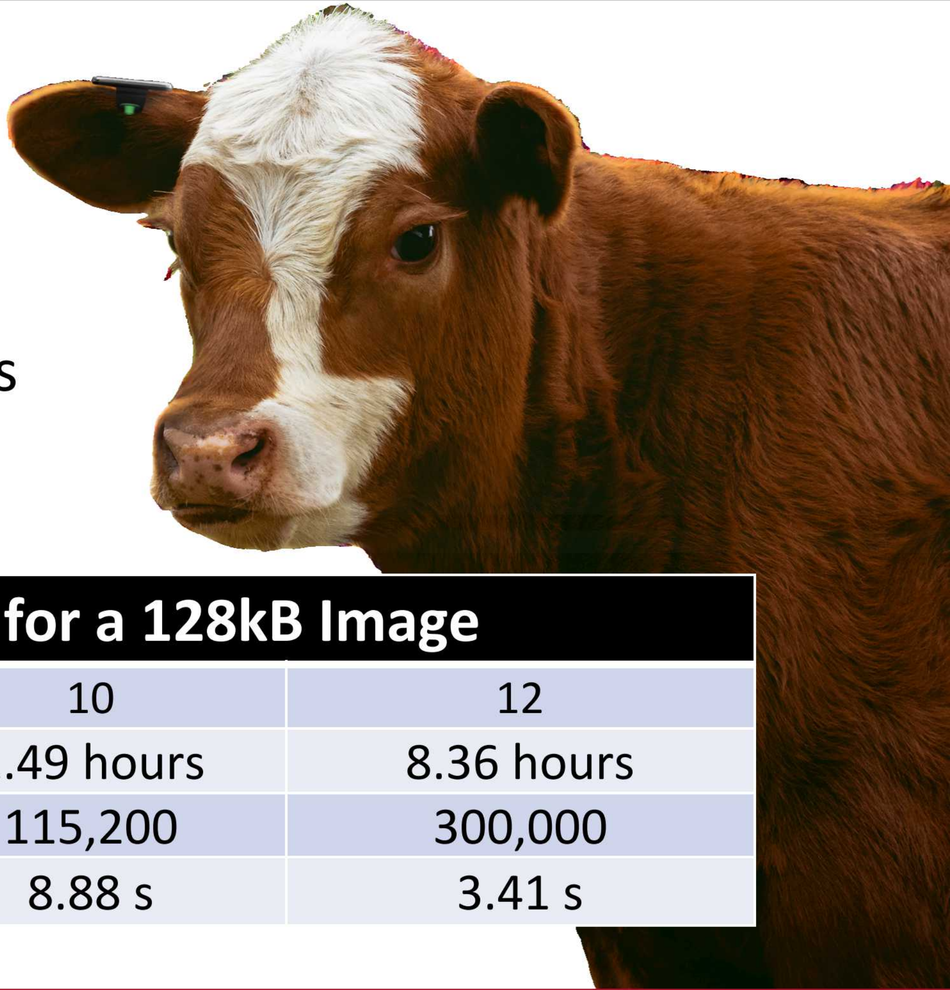
Outline

- Motivation
- LoRa Transmit Time Model Validation
- Communication Infrastructure
  - Packets
  - Settings
- Adaptive Data Rate (ADR)
  - Linear
  - Binary
  - RSSI/Greedy
- Implementation Results
- Conclusion and Future Work

Motivation

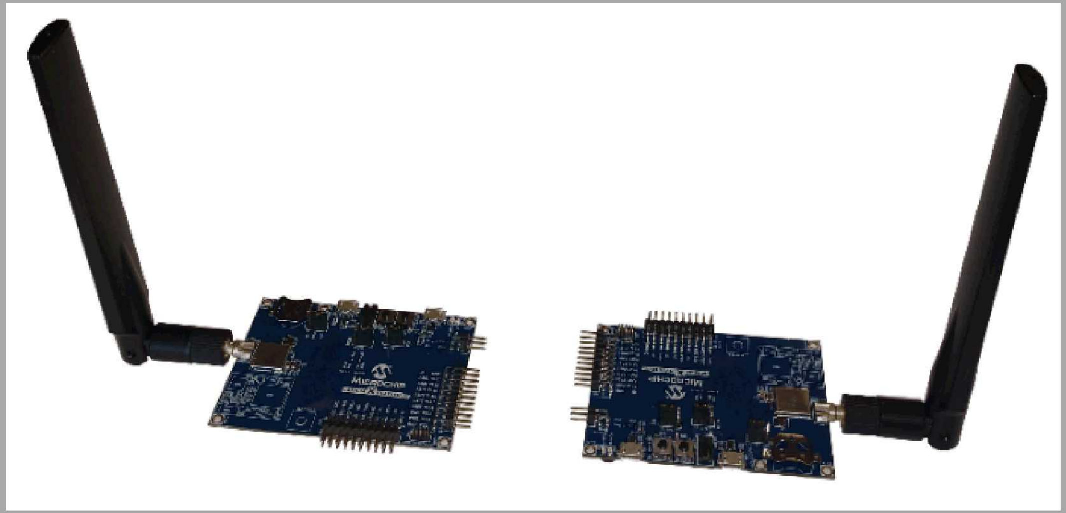
- Cattle Monitoring Application
- Firmware Updates
  - Valid for any large data exchange
- LoRa Ad Hoc Networks
  - LoRaWAN insufficient to meet performance specs



	Time to Update Firmware for a 128kB Image			
LORA SF	6	8	10	12
Time	16 minutes	46 minutes	2.49 hours	8.36 hours
FSK (bps)	19,200	57,600	115,200	300,000
Time	53.3 s	17.7 s	8.88 s	3.41 s

LoRa Background

- Chirped spread spectrum technology to increase noise immunity
- Closed source protocol developed by the LoRa Alliance
- Typically used with LoRaWAN
- Configurable to increase range at the expense of data rates
- Parameters
  - Spreading Factor
  - Bandwidth
  - Transmission Header
  - Error Coding Rates
  - CRC
- LoRa and FSK

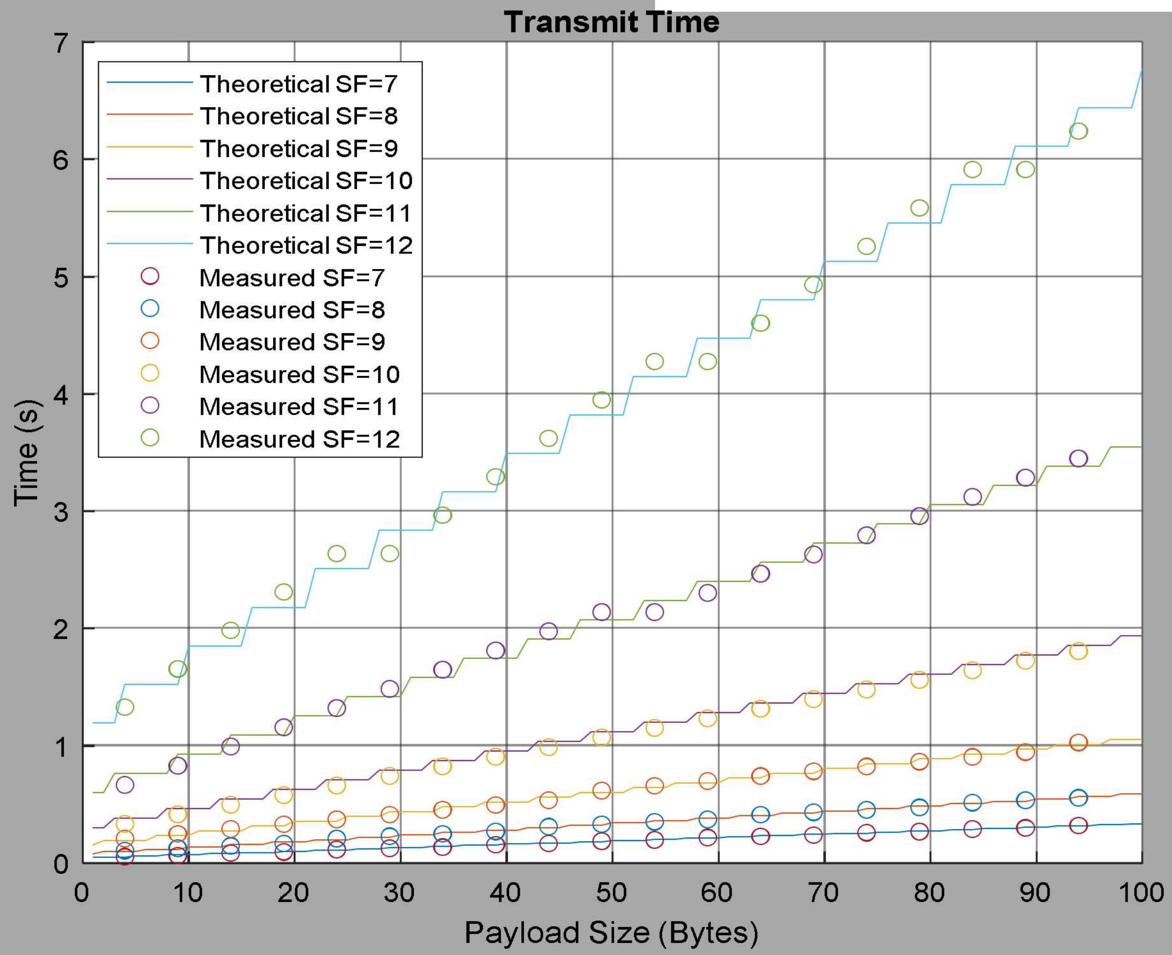


LoRa Transmit Time Model Validation

- Model based on:

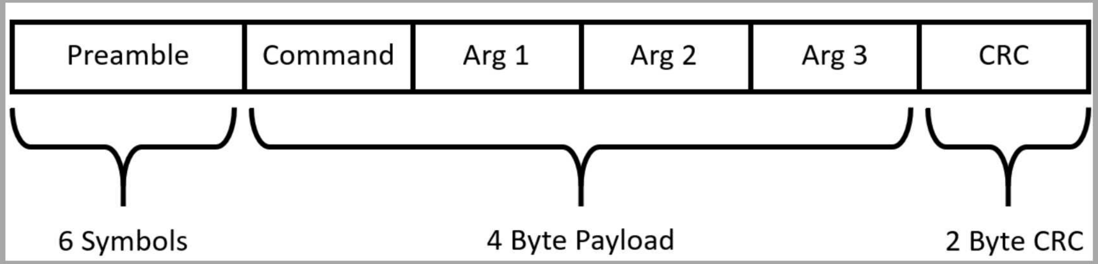
$$n_{payload} = 8 + \text{ceil}\left[\frac{8PL-4SF+28+16CRC-20IH}{4(SF-2DE)}\right](CR+4)$$

- Experimentally Validated
  - Loading Tx data into a buffer
  - Starting timer on a microcontroller
  - Transmitting data
  - Stopping timer when Tx terminates
  - Looping through all settings
- Error sources
  - ~3% in oscillator tolerance
  - Clock cycles to start and stop timer



Communication Infrastructure

- 12 Possible Settings
- 5 commands
  - Go to ADR mode
  - Go to a specific settings
  - Exit ADR
  - Ping
  - Acknowledge Receipt



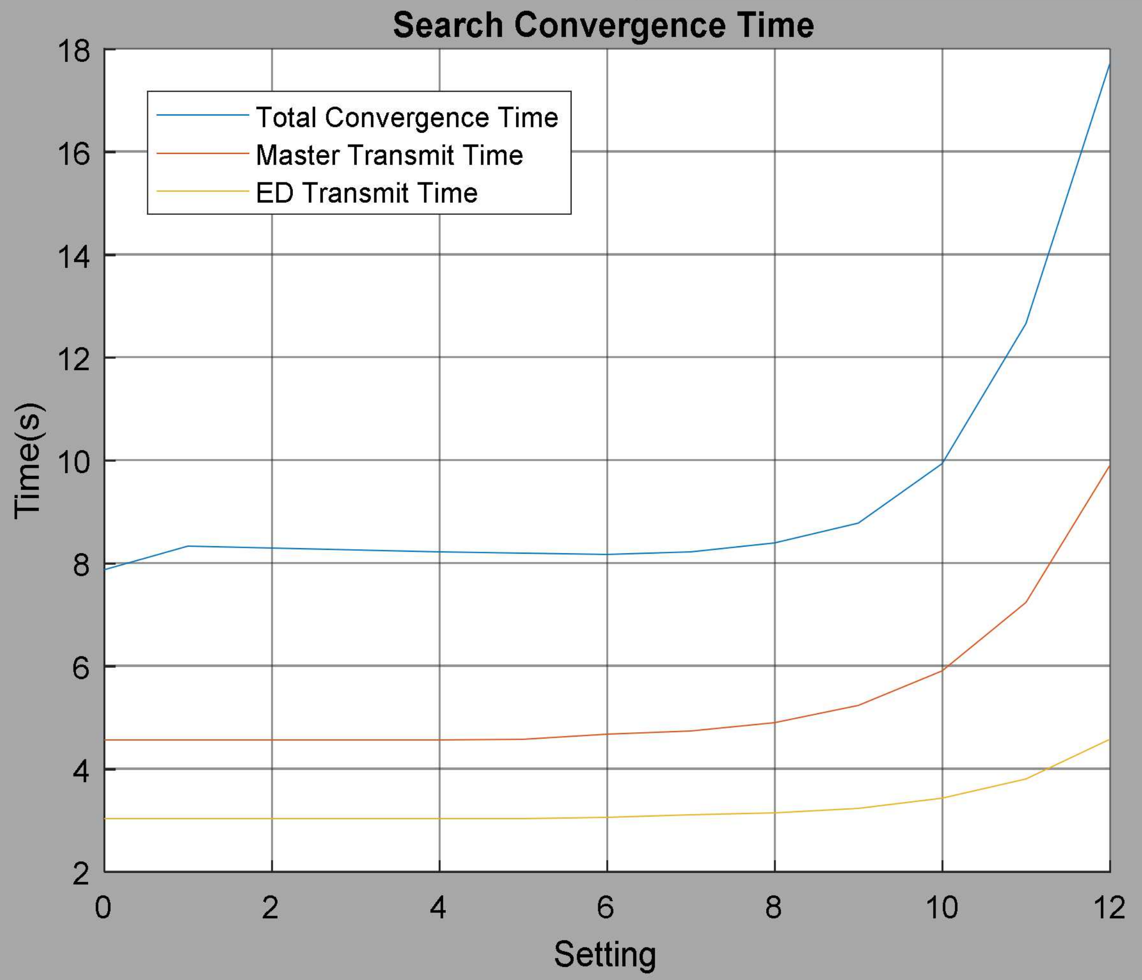
ADR Settings and Timeouts				
Setting Number	**Modulation Type**	**Setting Config**	**Master Timeout**	**ED Timeout**
0	FSK	300 kbps	0.1 s	0.4 s
1	FSK	200 kbps	0.1 s	0.4 s
2	FSK	115.2 kbps	0.1 s	0.4 s
3	FSK	57.6 kbps	0.1 s	0.4 s
4	FSK	19.2 kbps	0.1 s	0.4 s
5	FSK	9.6 kbps	0.1 s	0.4 s
6	LoRa	SF=6	0.1 s	0.4 s
7	LoRa	SF=7	0.2 s	0.8 s
8	LoRa	SF=8	0.25 s	1 s
9	LoRa	SF=9	0.4 s	1.6 s
10	LoRa	SF=10	0.7 s	2.8 s
11	LoRa	SF=11	1 s	4 s
12	LoRa	SF=12	3 s	12 s

ADR Sequence

1. Initiate an exchange on the lowest data rate setting to establish communication.
2. The master sends the command to the end device to go to an improved data rate setting. The value of this setting depends on the algorithm being used.
3. Upon receiving the command, the end device will automatically reconfigure itself to that setting and acknowledge at the higher data rate.
4. If the devices are unable to communicate at a lower setting, the master will initiate the error recover process.
5. If both devices time out, they return to the setting they last successfully communicated on.

Incremental Search

- Easiest to implement but can cause lengthy convergence times
- Walk down the settings - 12 to 0
- Better performance for higher settings as compared to other methods
- Poor performance for low settings as compared to other methods

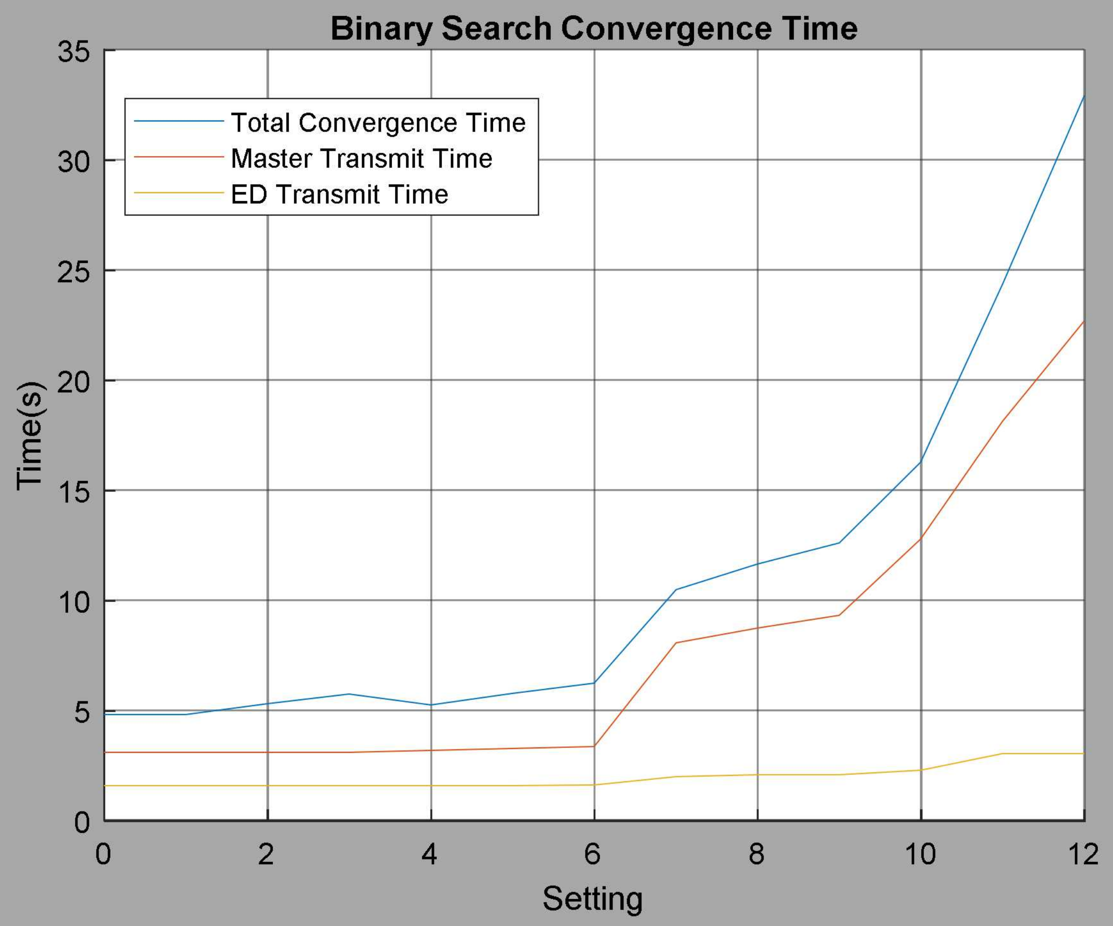


Binary Search

- Alternative strategy to reduce convergence time for lower settings
- Search according to

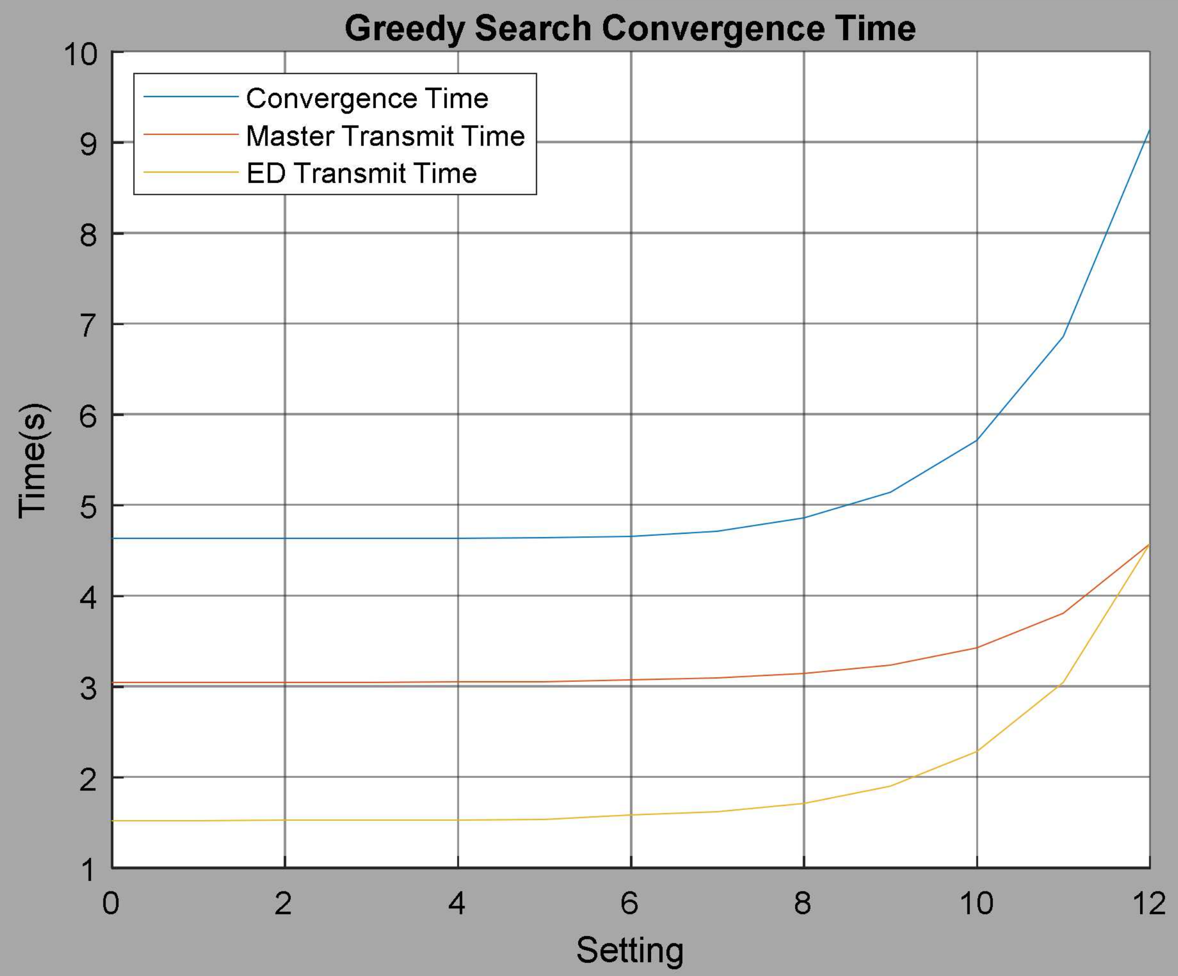
$$S_{next} = S_{current} - ceil(\frac{S_{current} - S_{highest,failed}}{2})$$

- Optimal performance for low settings
- Poor performance for high settings

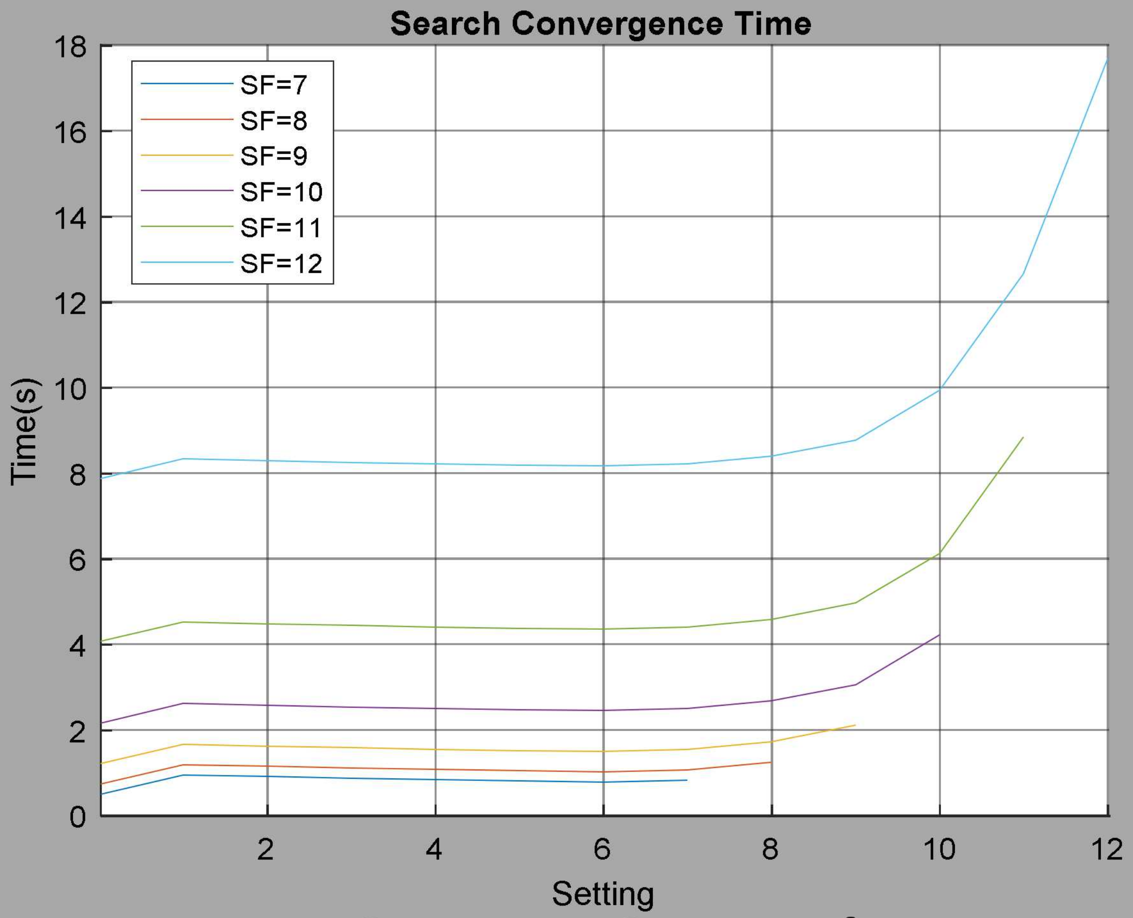


Greedy Search

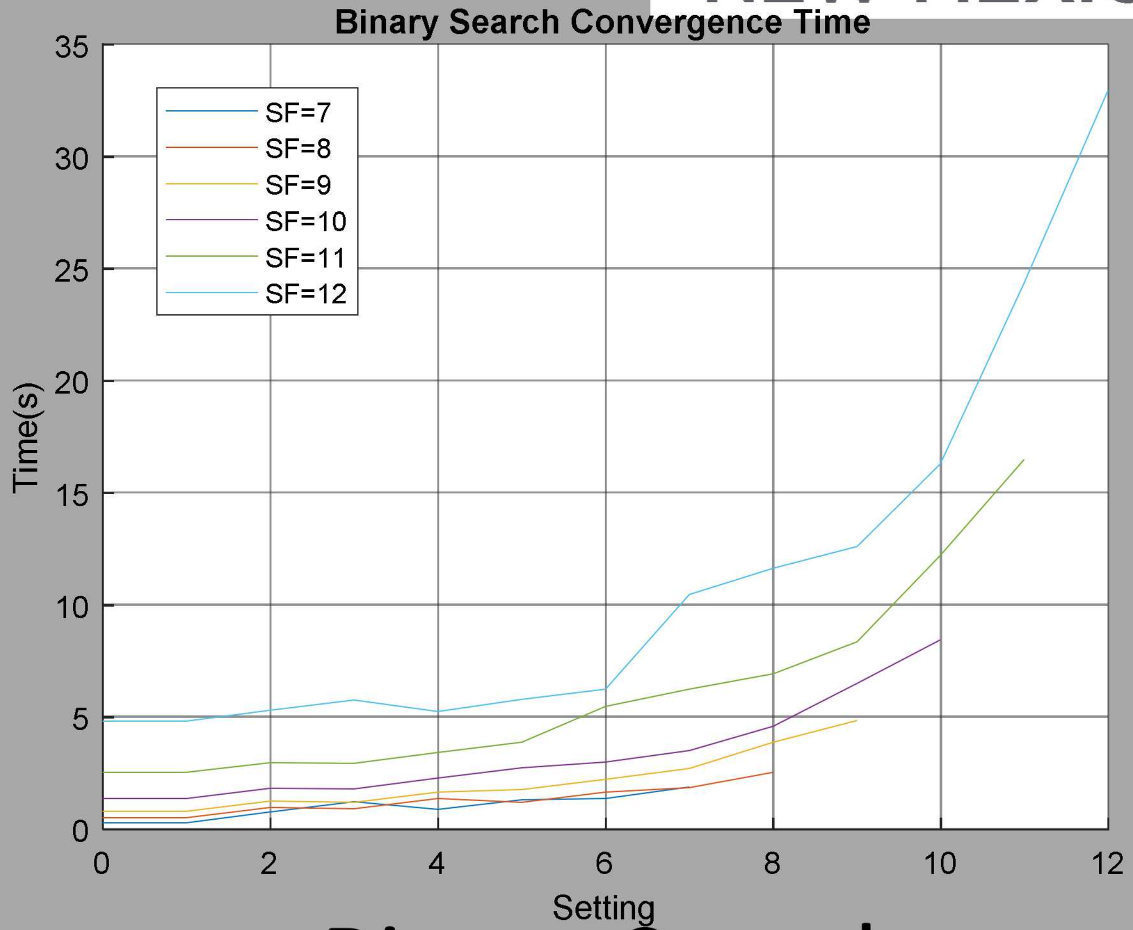
- Improves search performance by defining next setting based on RSSI/SNR
- Does not require a communication failure to stop
- Slightly better than binary search for low settings
- Outperforms incremental search in the high settings
- Harder to implement due to measurement noise



Effect on Starting Search Setting



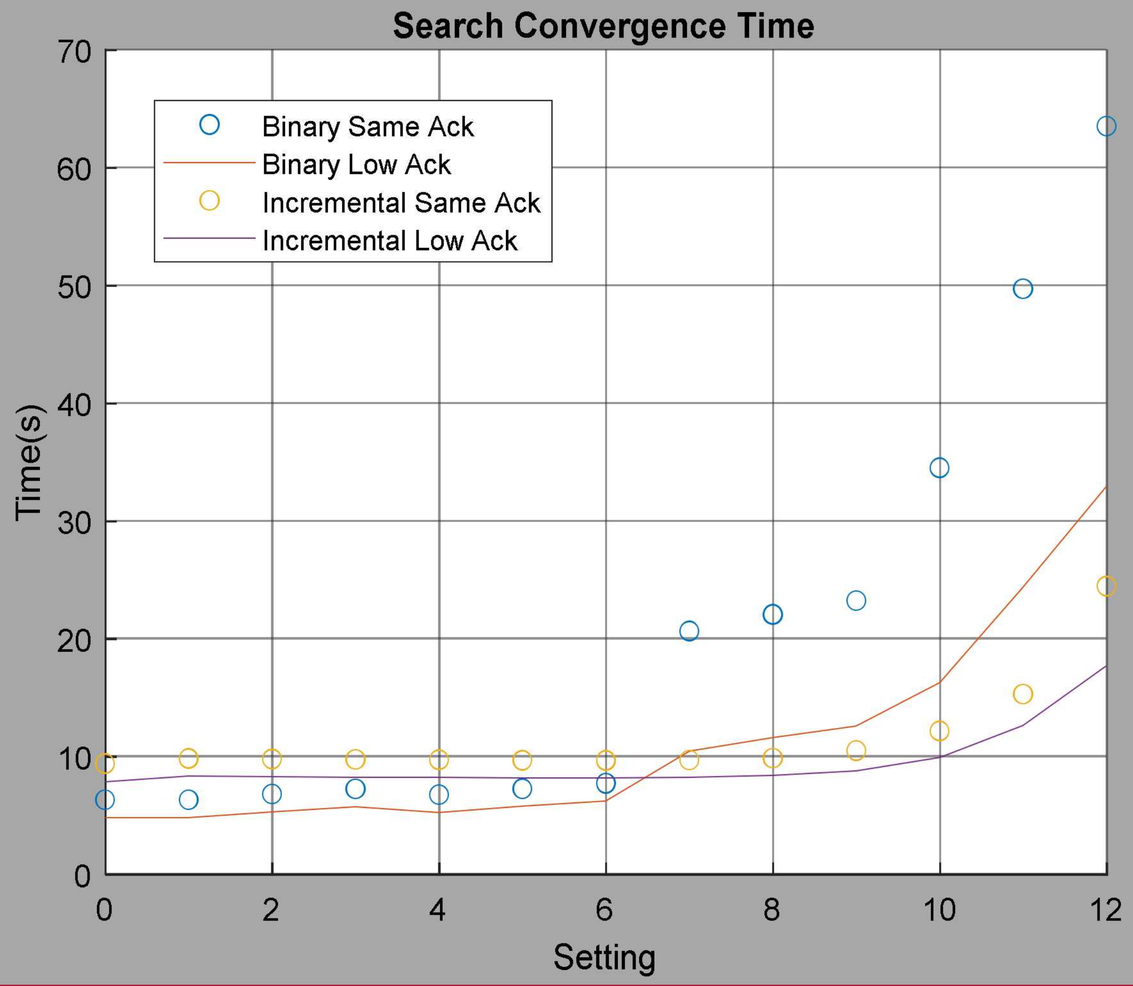
Linear Search



Binary Search

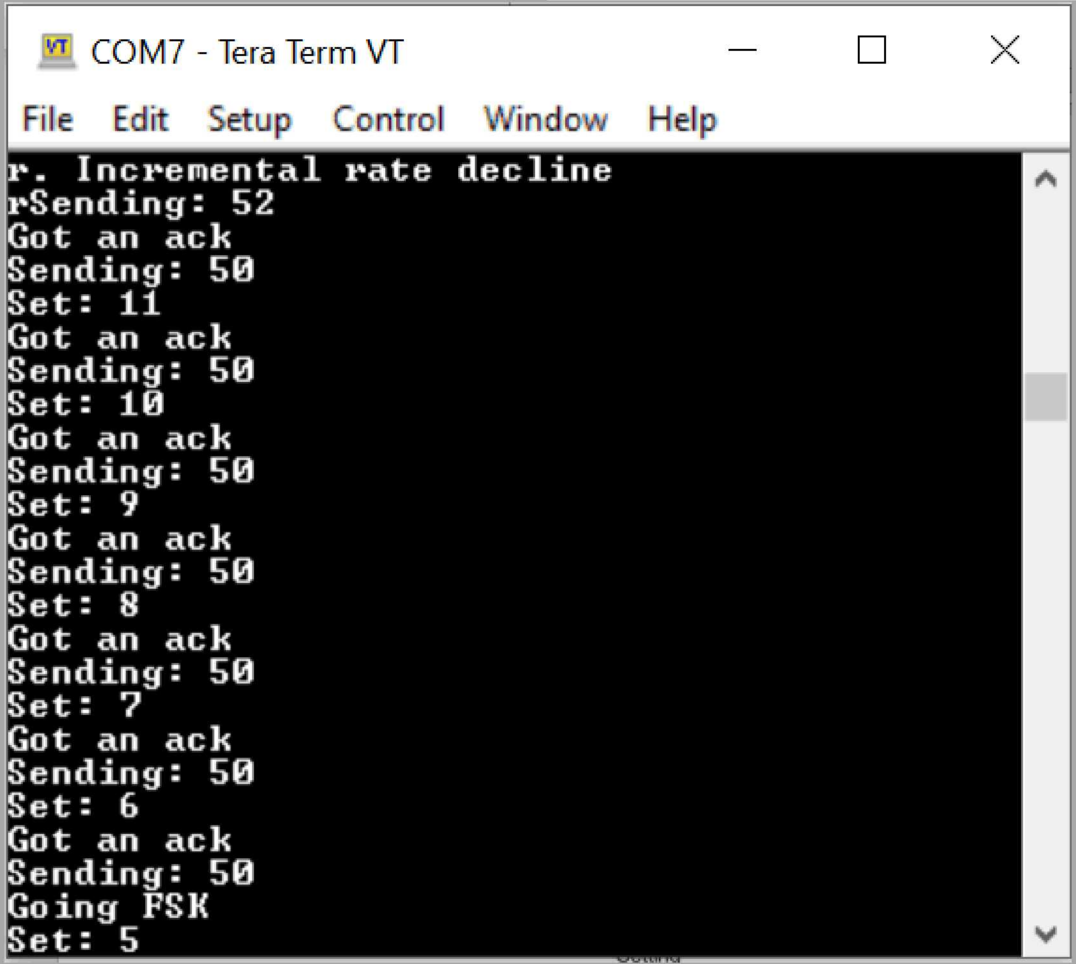
Acknowledgement Setting

- Master sends command to go to lower setting
- Where does the end device ack?
  - Same setting
  - Lower setting
- We assumed the lower setting for modeling
  - Lower convergence time due to master spending significantly less time receiving the ack



Experimental Setup & Results

- Atmel SAMR34 Boards with code developed in C using Atmel Studio
- Data recorded and debugged using Tera Term
- Implemented linear and binary search
- Unable to implement greedy search due to noise in RSSI and SNR measurements
- Master timed the exchange
- Most communication errors due to the master missing the ack
- Matched modeling or was worse



Conclusion

- Investigated performance between a linear, binary, greedy search
- Expanded adaptive data rate to include FSK when possible
- The greedy RSSI/SNR optimal search theoretically outperforms everywhere but is challenging to implement
- Binary search outperforms linear search when the devices are expected to be close
- Linear search outperforms binary search when the devices are far apart
- Future work
  - Implement the greedy search
  - Implement the firmware update and apply ADR to make the system resilient to mobile devices
- Questions to heegerds@unm.edu

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