Improving LR-FHSS Goodput by Optimizing Header Redundancy

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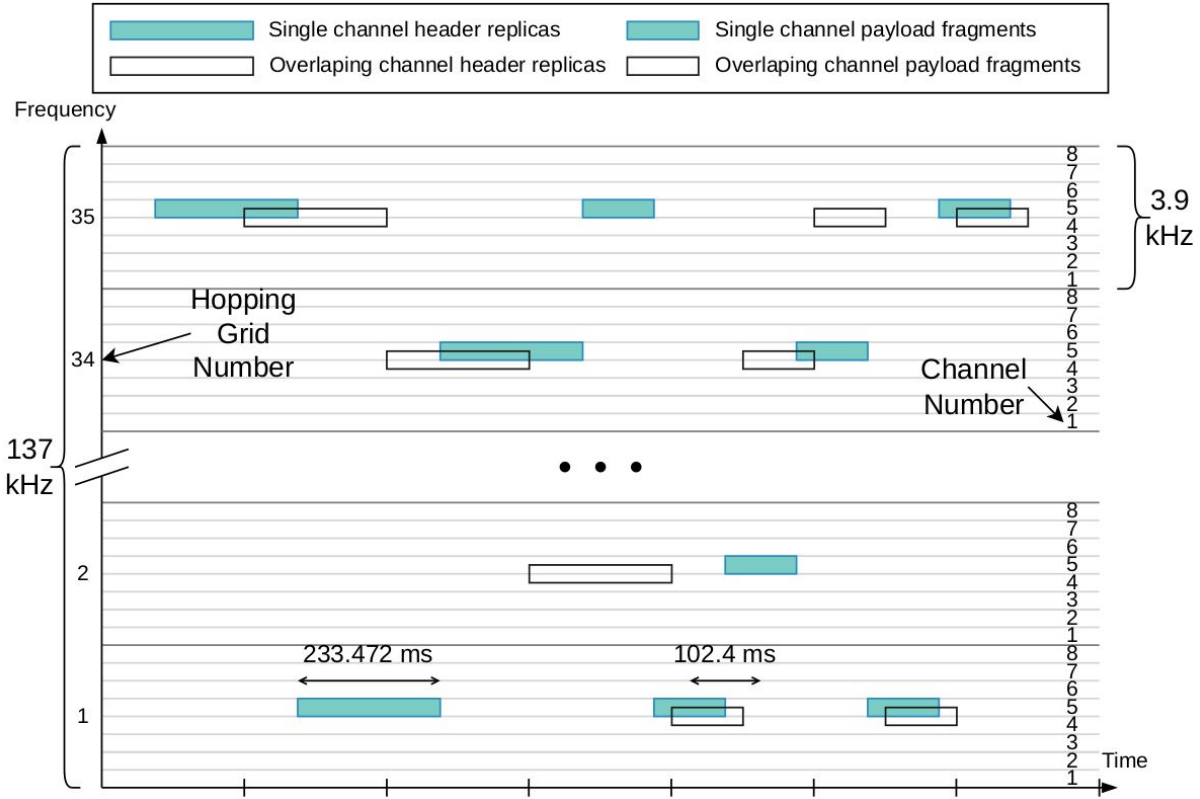
Summary

- Introducing LR-FHSS
- Developing an analytical model for LR-FHSS
- Comparing the analytical model with simulations
- Optimizing header redundancy
- Conclusion

Introducing LR-FHSS

Key points on LR-FHSS

- Packets are split into header replicas and data fragments
- The band is split into 8 channels, witch are combs of 35 or 86 subchannels, depending on the data Rate



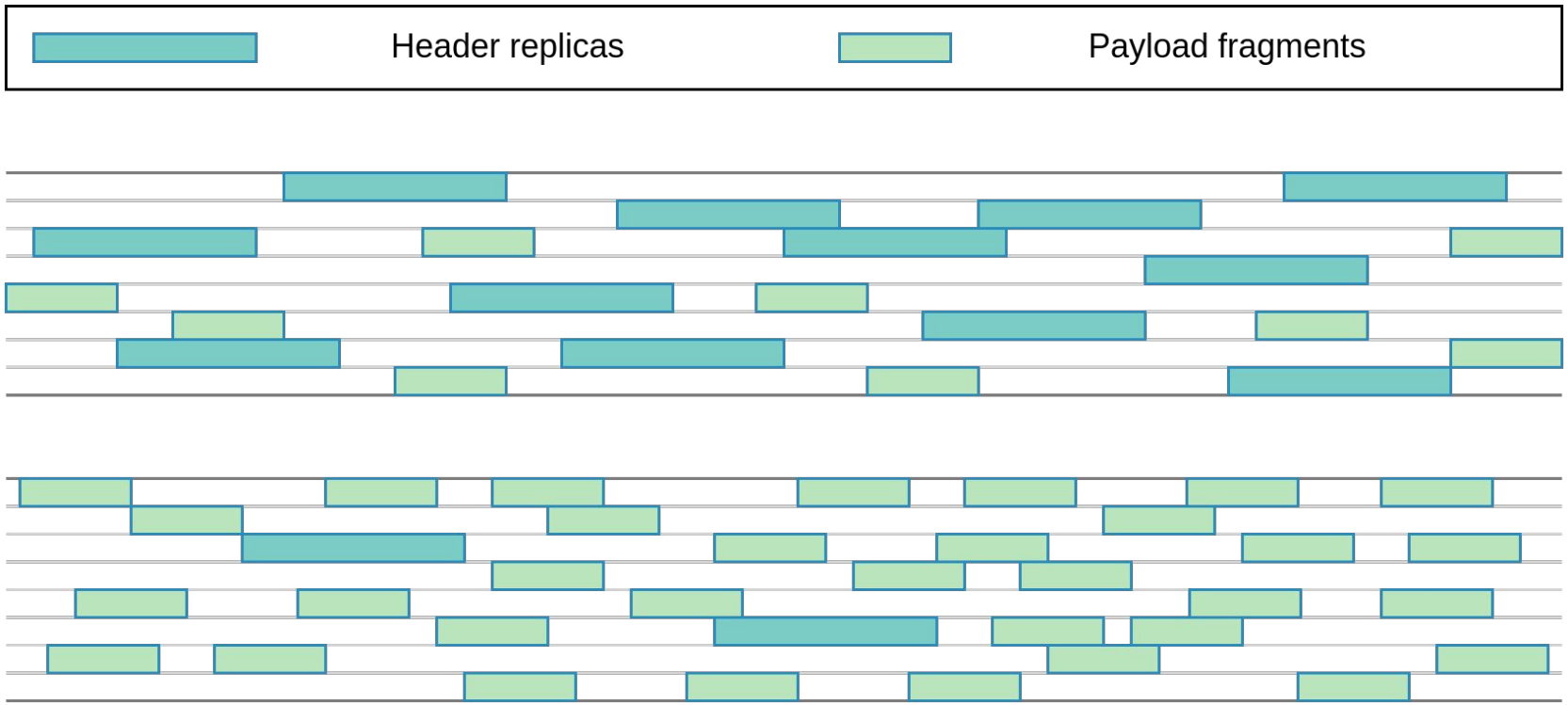
Key points on LR-FHSS

- Uses Gaussian Minimum-Shift Keying (GMSK)
- Splits packets on different channels
- Uses error correcting codes
- Only used in uplink. (End device to gateway)

Data Rate	Payload Coding Rate	Bandwidth	# header replica
DR8	1/3	137 kHz	3
DR9	2/3	137 kHz	2
DR10	1/3	336 kHz	3
DR11	2/3	336 kHz	2

Default LF-FHSS configuration in ETSI regions

How many headers should be used?



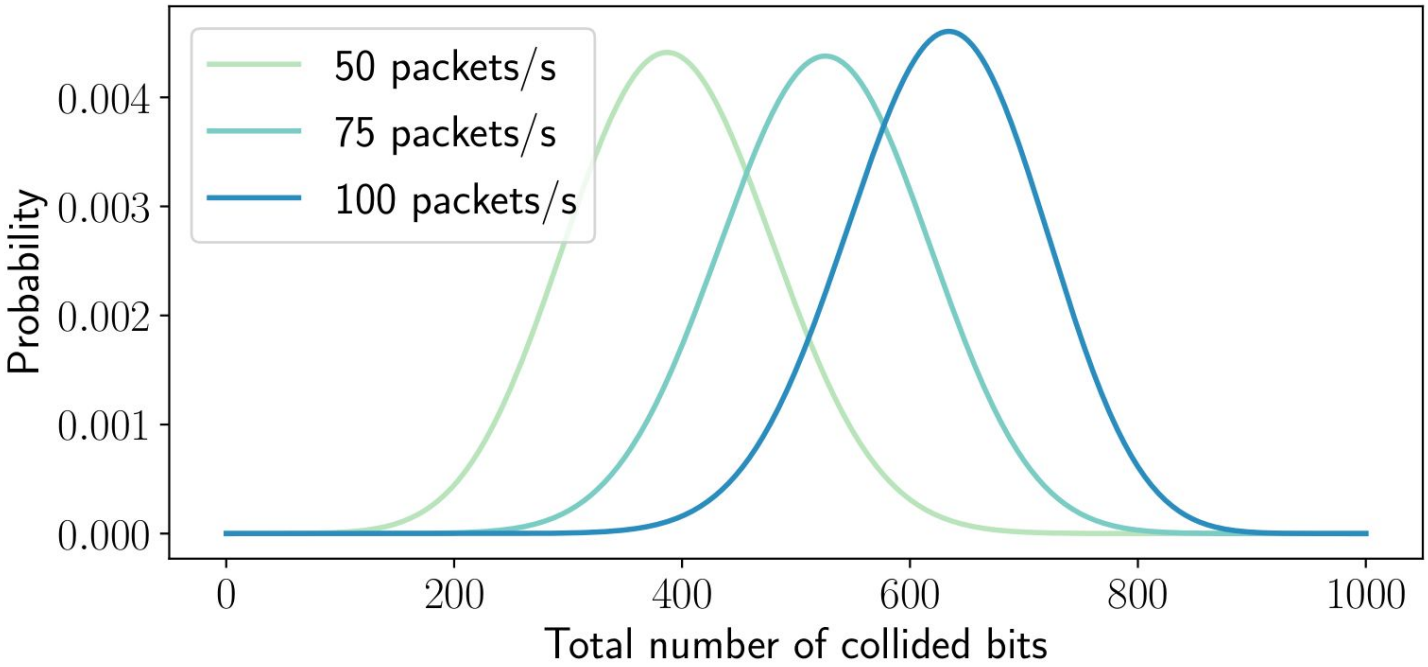
Developing an analytical model for LR-FHSS

Assumptions

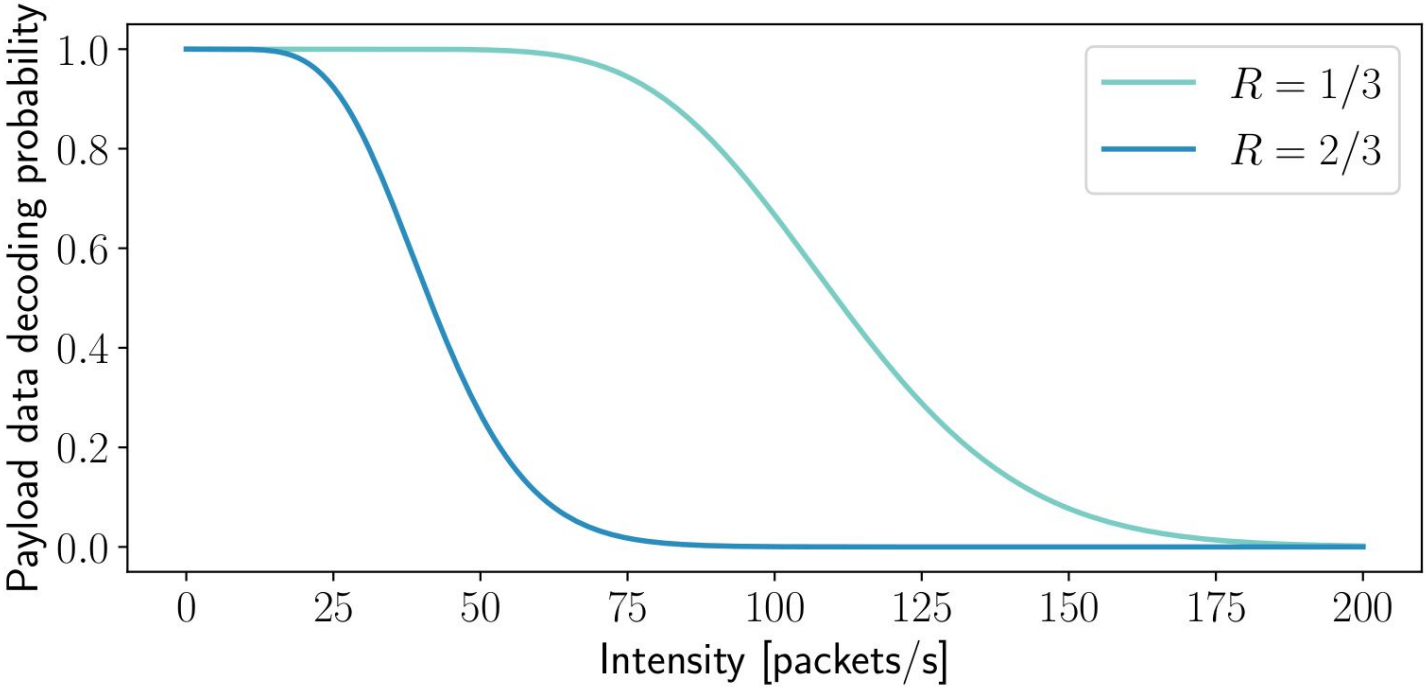
Here are our strong assumptions:

- LR-FHSS headers and payload fragments are sent following a poisson process
- Collisions are the only source of packet loss
- All packets are identical
- For now, o frequency overlap
- Collided bits are randomized independently from their original value

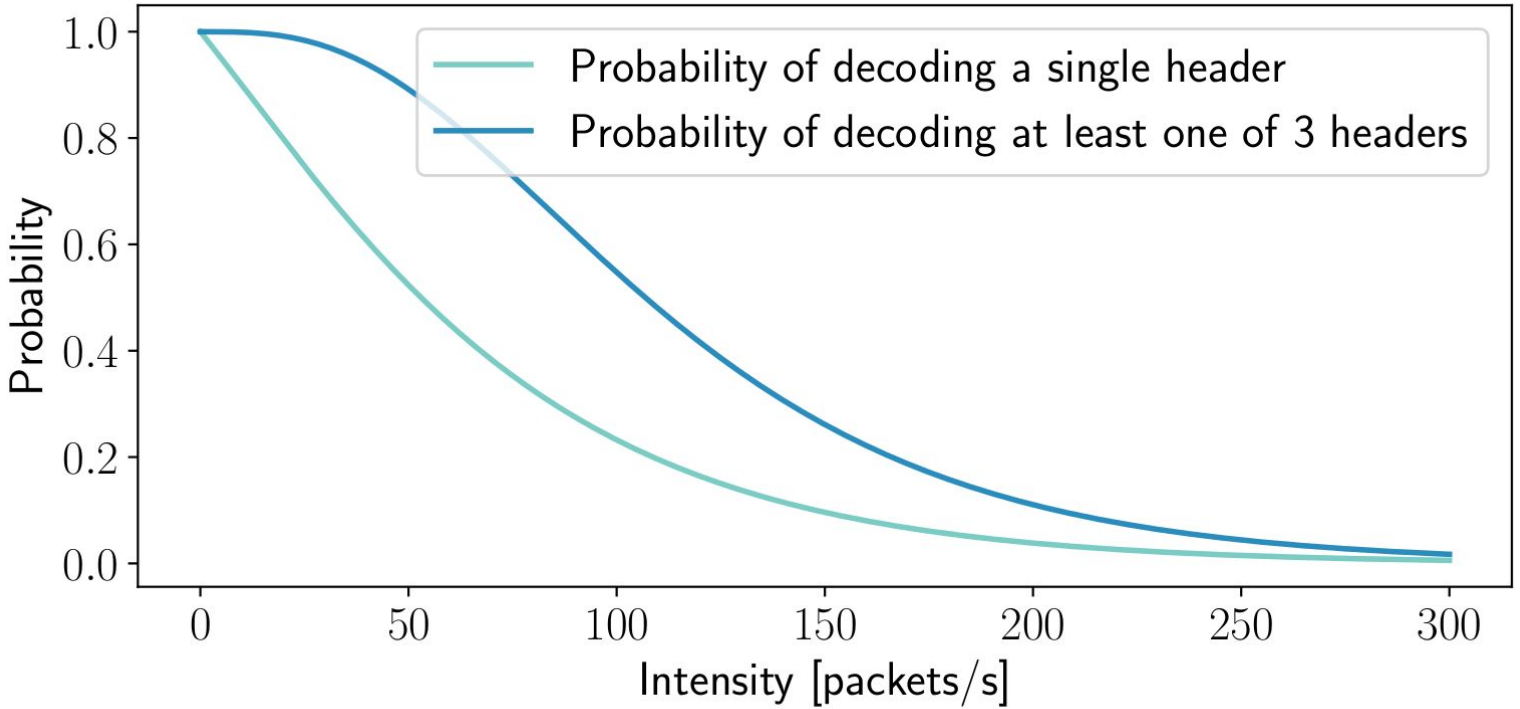
Number of collided bits on 20 payload fragments



Payload data decoding probability

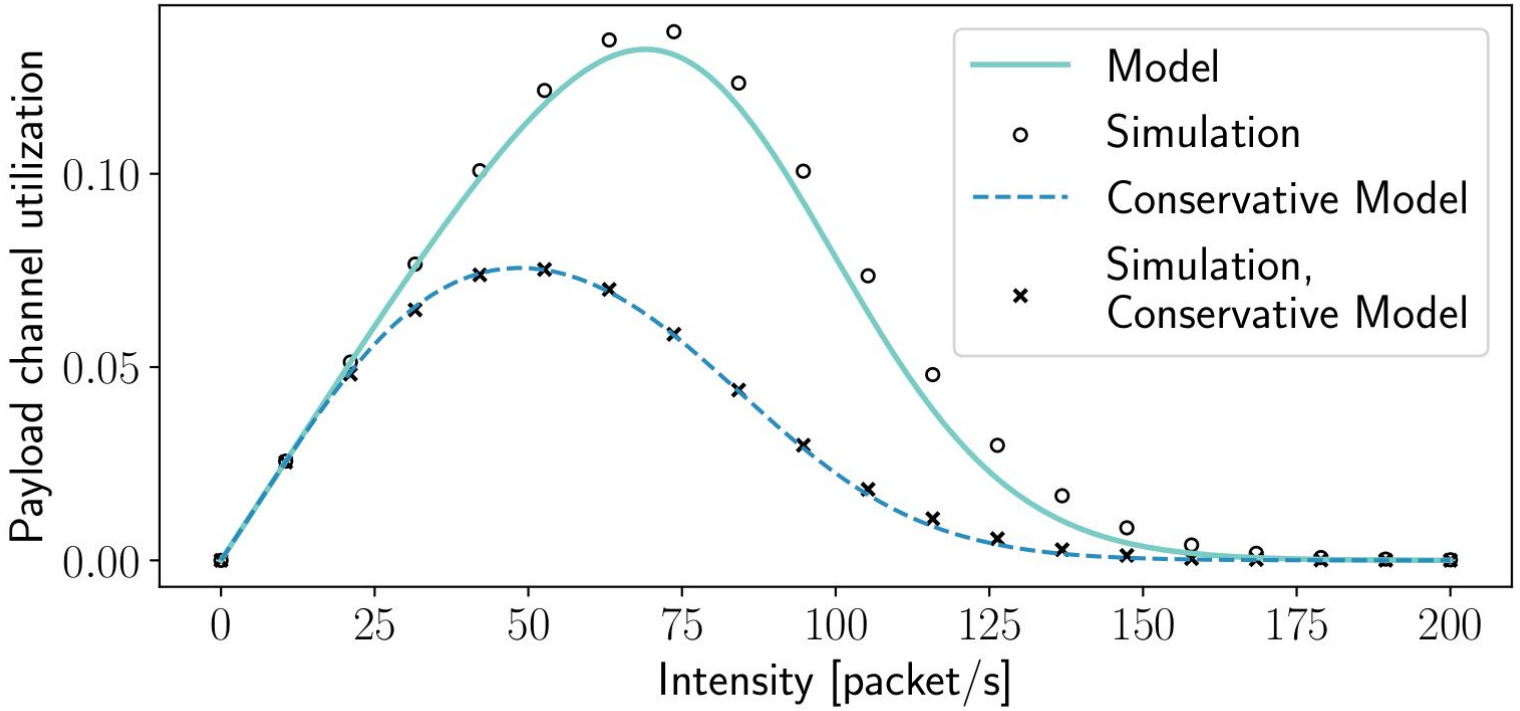


Header decoding probability



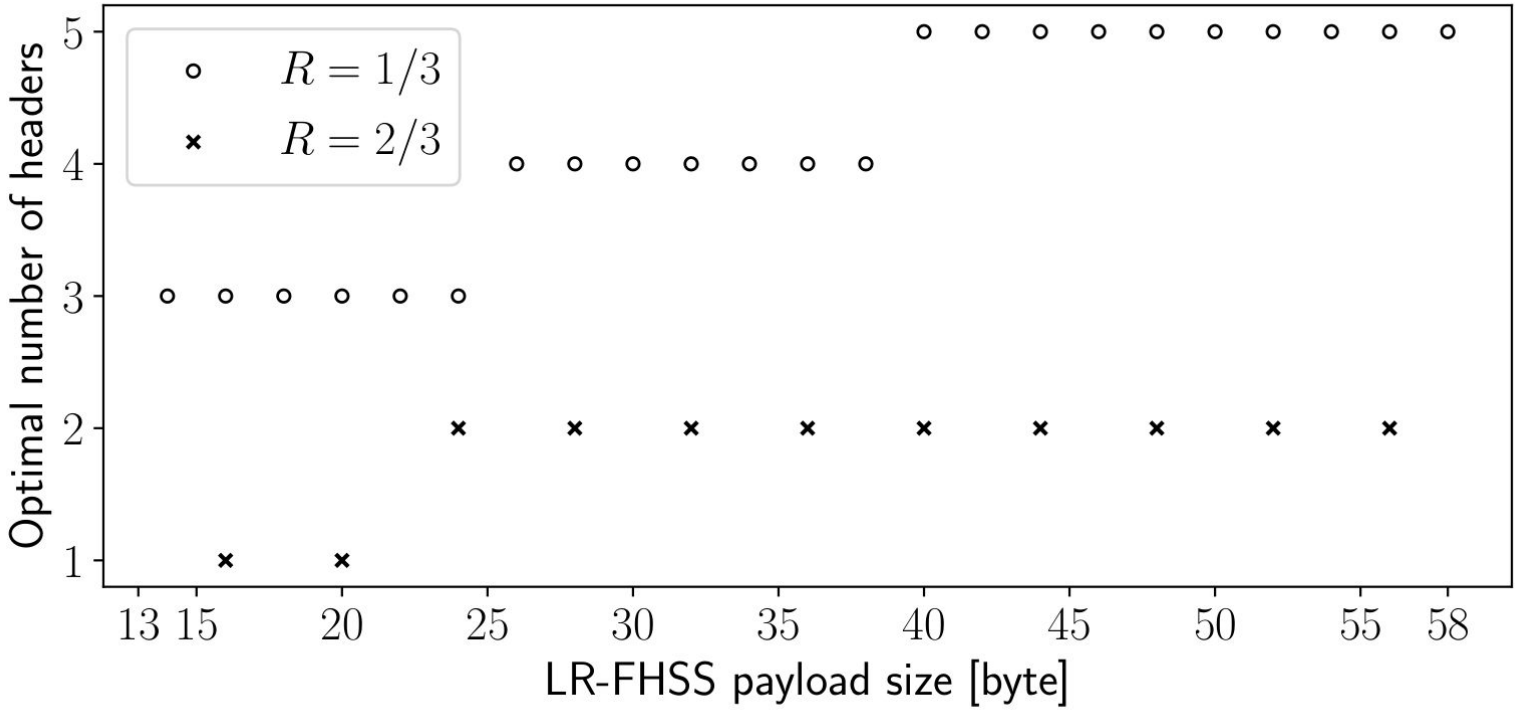
Comparisons with simulations

Channel utilisation

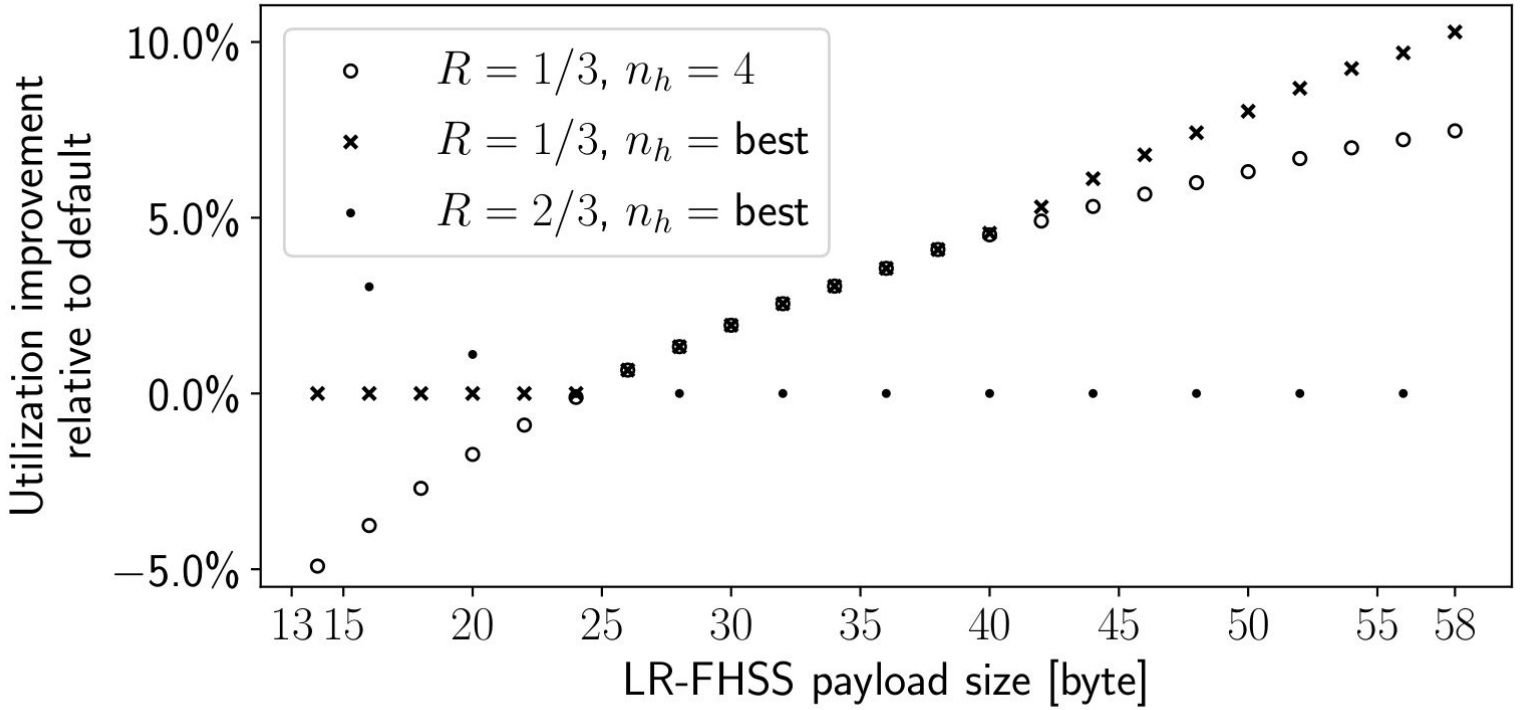


Optimizing header redundancy

Optimal number of headers



Utilization improvement compared to default



Comparison with real world data

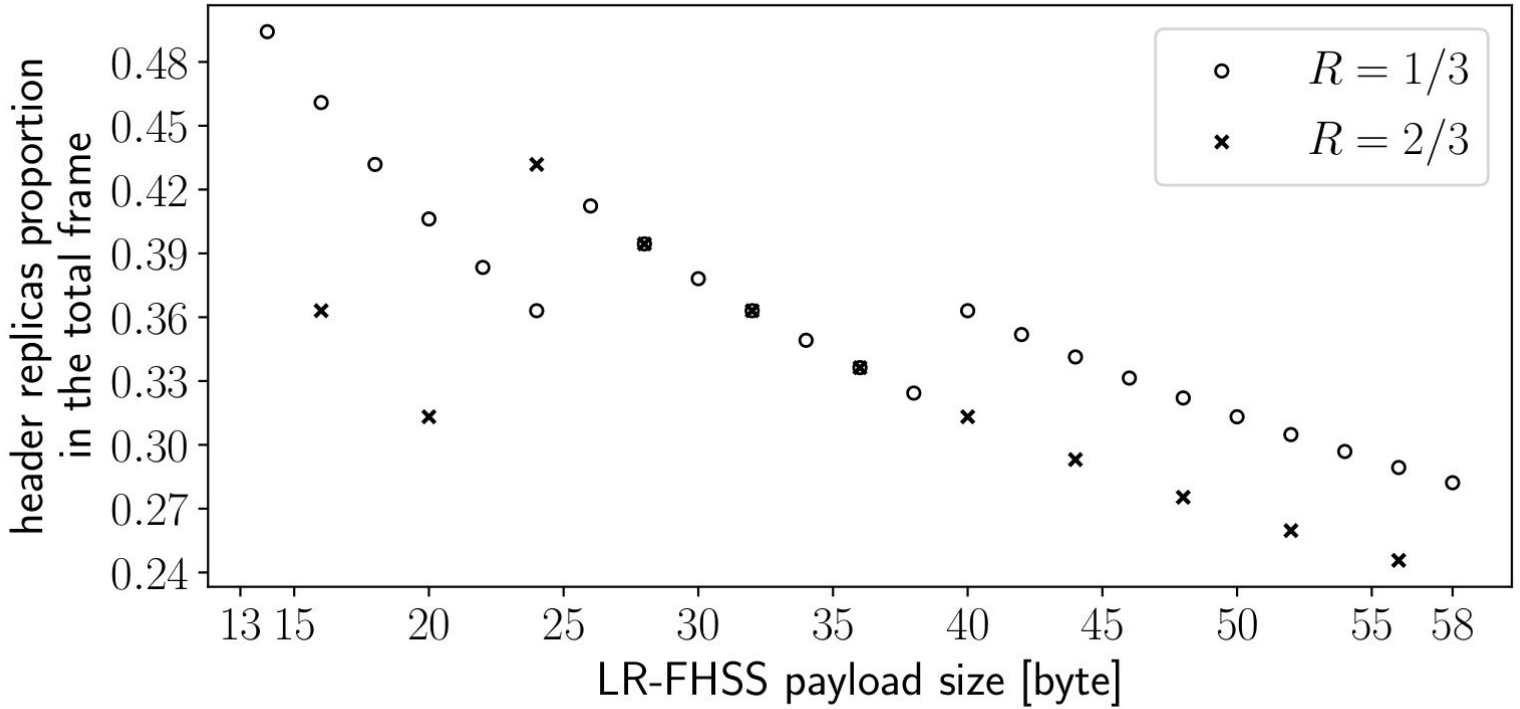
Using an updated version of the CampusIOT dataset we observed:

- 41% of the packets are under 24 bytes,
- 26% of the packets are over 40 bytes.

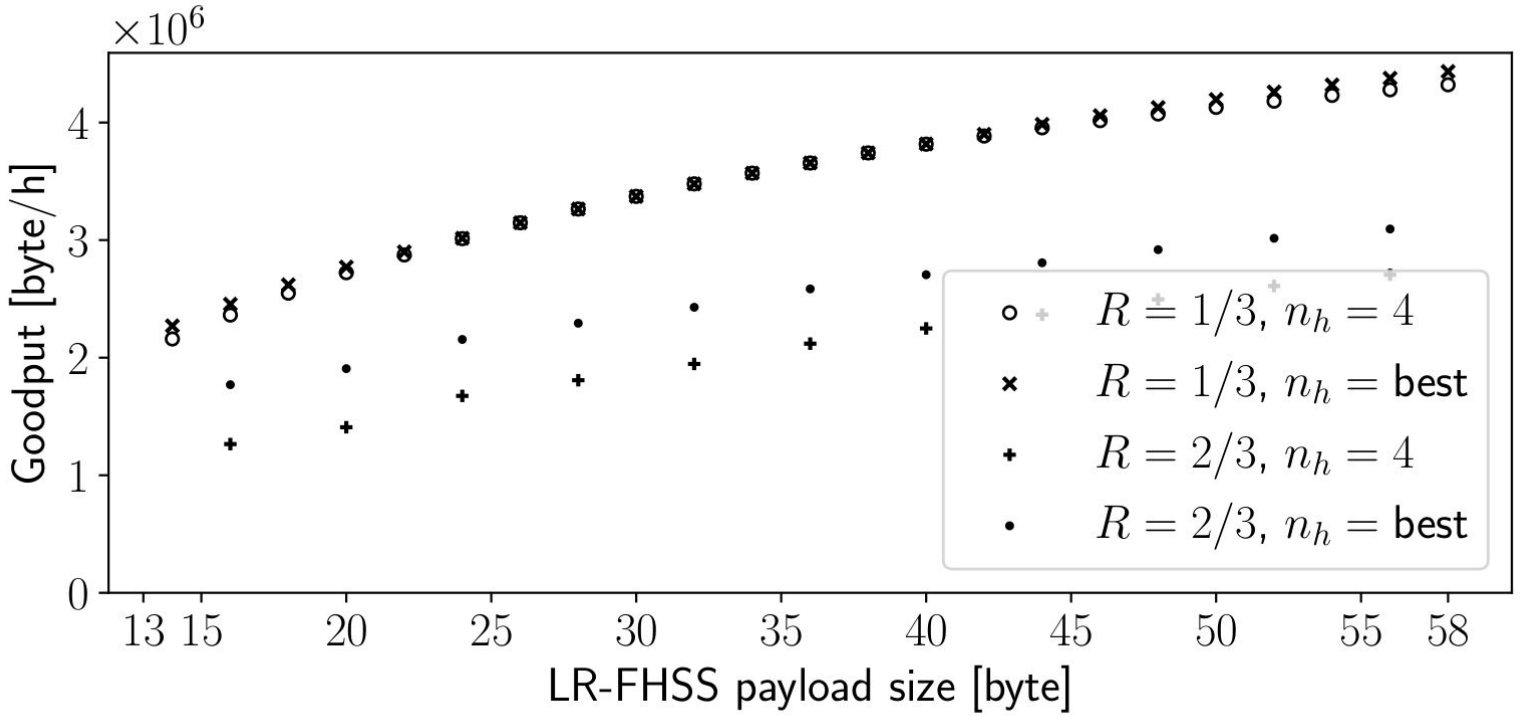
Therefore, if all this traffic was using LR-FHSS with a payload coding rate of 1/3:

- using 4 headers would be optimal in 15% of the packets,
- using 4 headers would be better than the default values in 59% of the packets

Proportion of headers in packet when optimal.



Goodput at maximum utilisation



Conclusion

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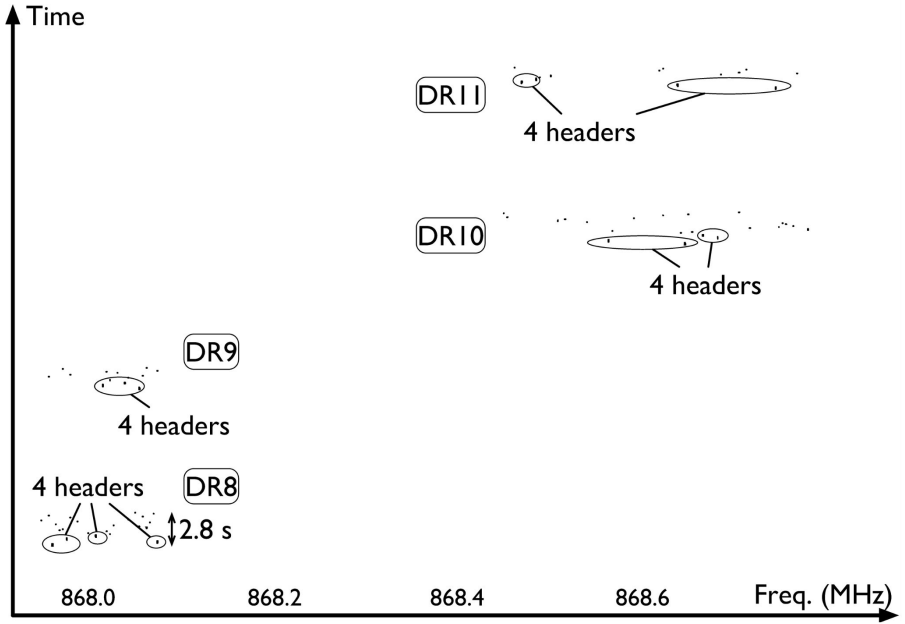
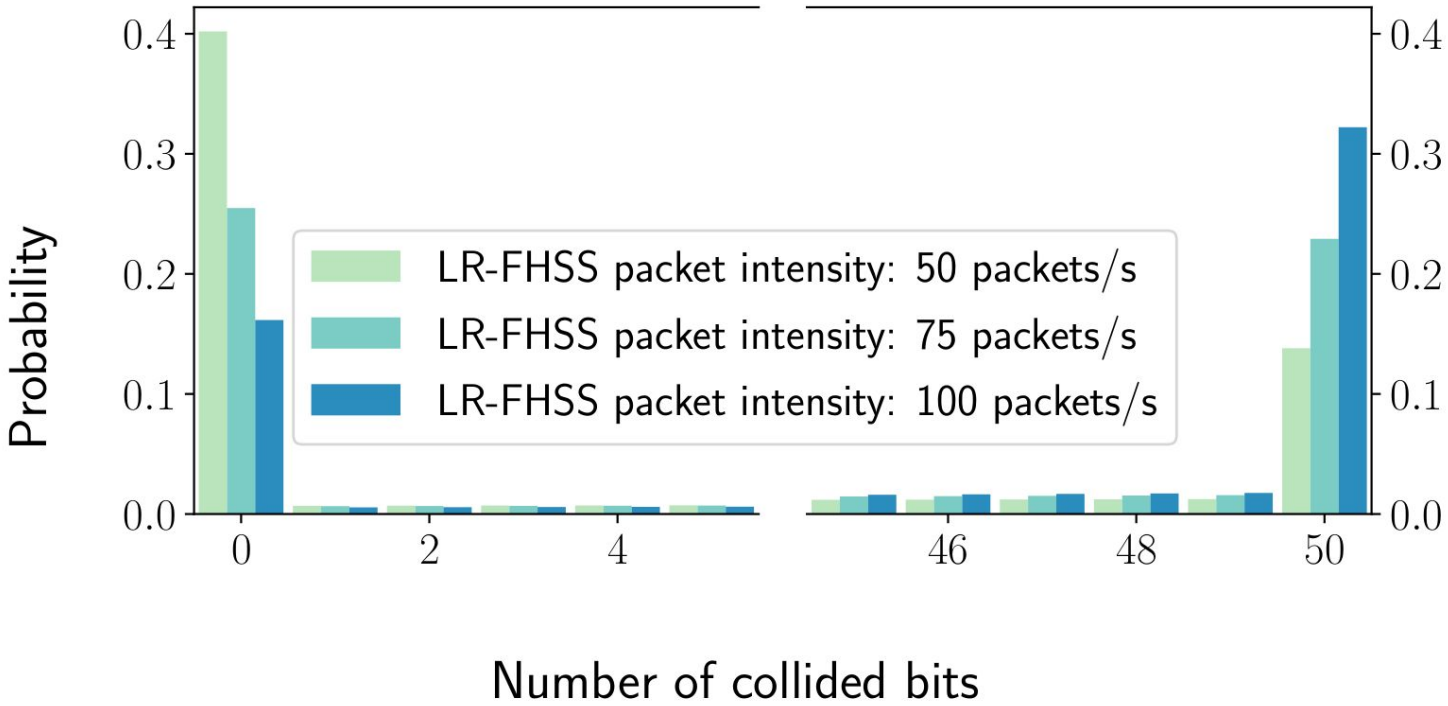
- Performance analysis of LR-FHSS using an analytical model
- Optimization of the number of header replicas
- Sanity check of the model with simulation

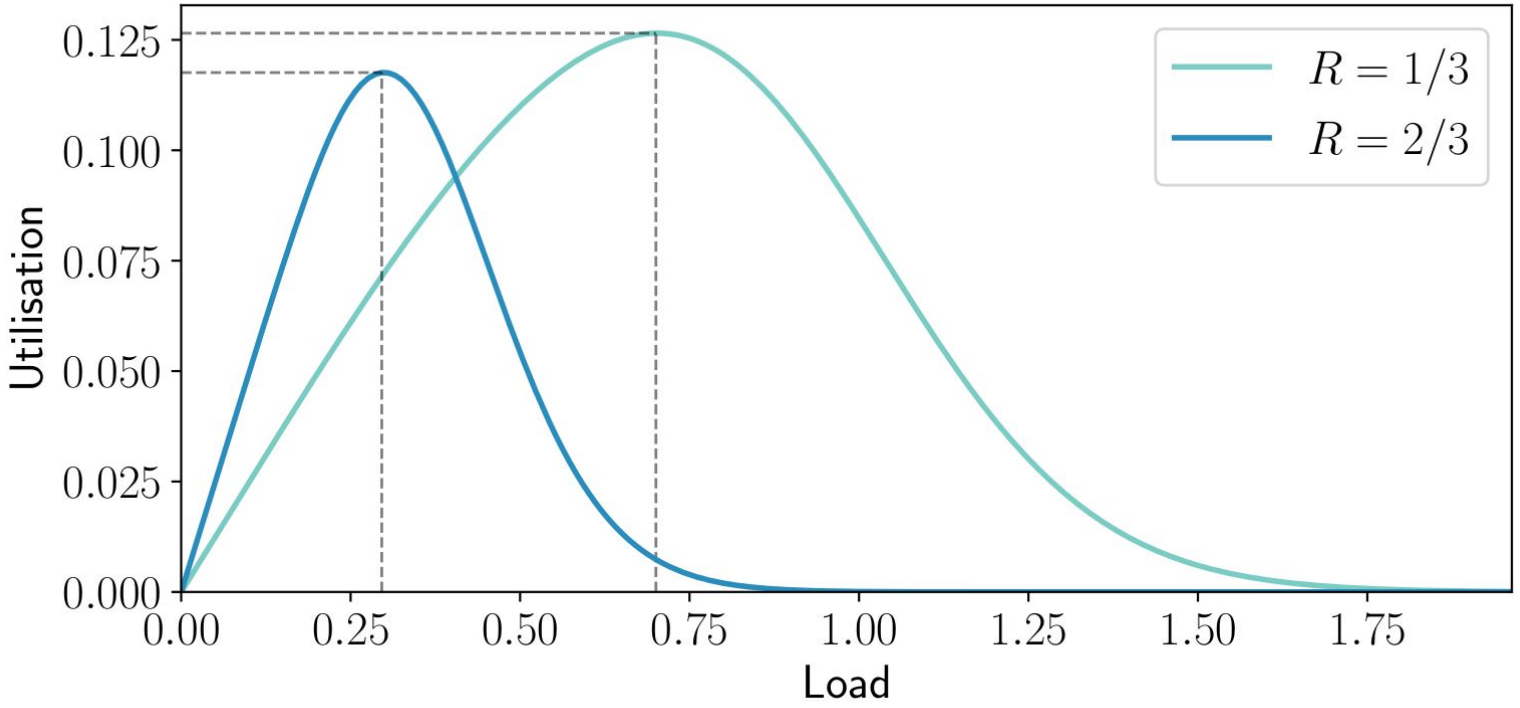


Thank you for your attention!

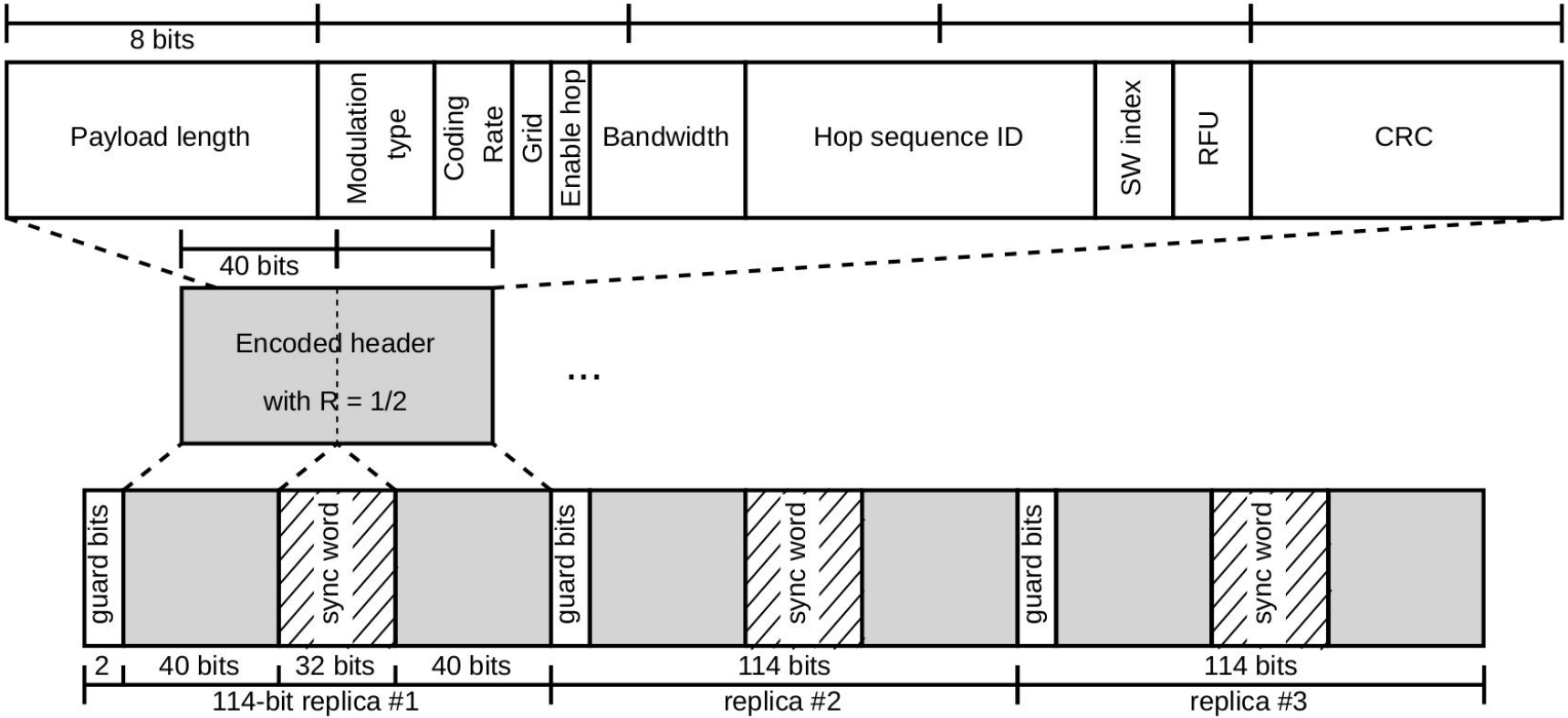
Number of collided bits on a single payload fragment



Channel utilisation



LR-FHSS Header encoding



LR-FHSS Payload fragment encoding