DPP HGHE Packet Collision Analysis

March 7, 2025

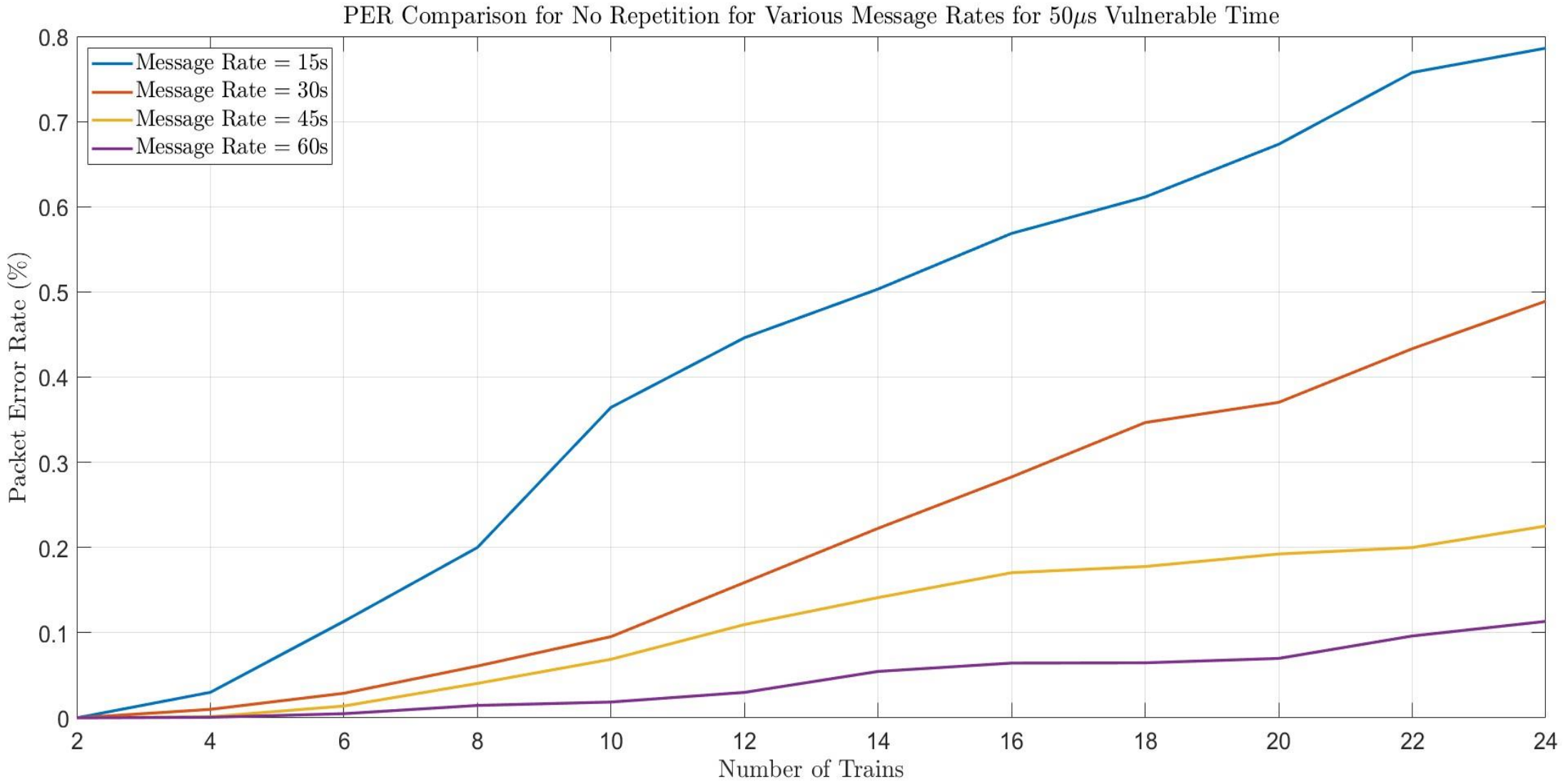
Objective

- The white paper “Repetition combining vs simple repetitions” explains why employing repetition combining is essential to secure reliable EOT to HOT communication.
- The use of repetition/combining however increases the over the air duty cycle relative to no repetitions. This presentation shows the probability of packet collisions for the worst-case scenario (12/24 trains in range when a single/two 12.5 kHz channels are used) with repetition factor = 8, for various message intervals between 15 seconds to 60 seconds.
- The analysis shows that the probability of collisions with 8 repetitions is small even under the worst-case scenario. Note that the probability of packet collision can further be improved by adapting the message interval according to the speed of the train, the lower the speed the higher the interval.

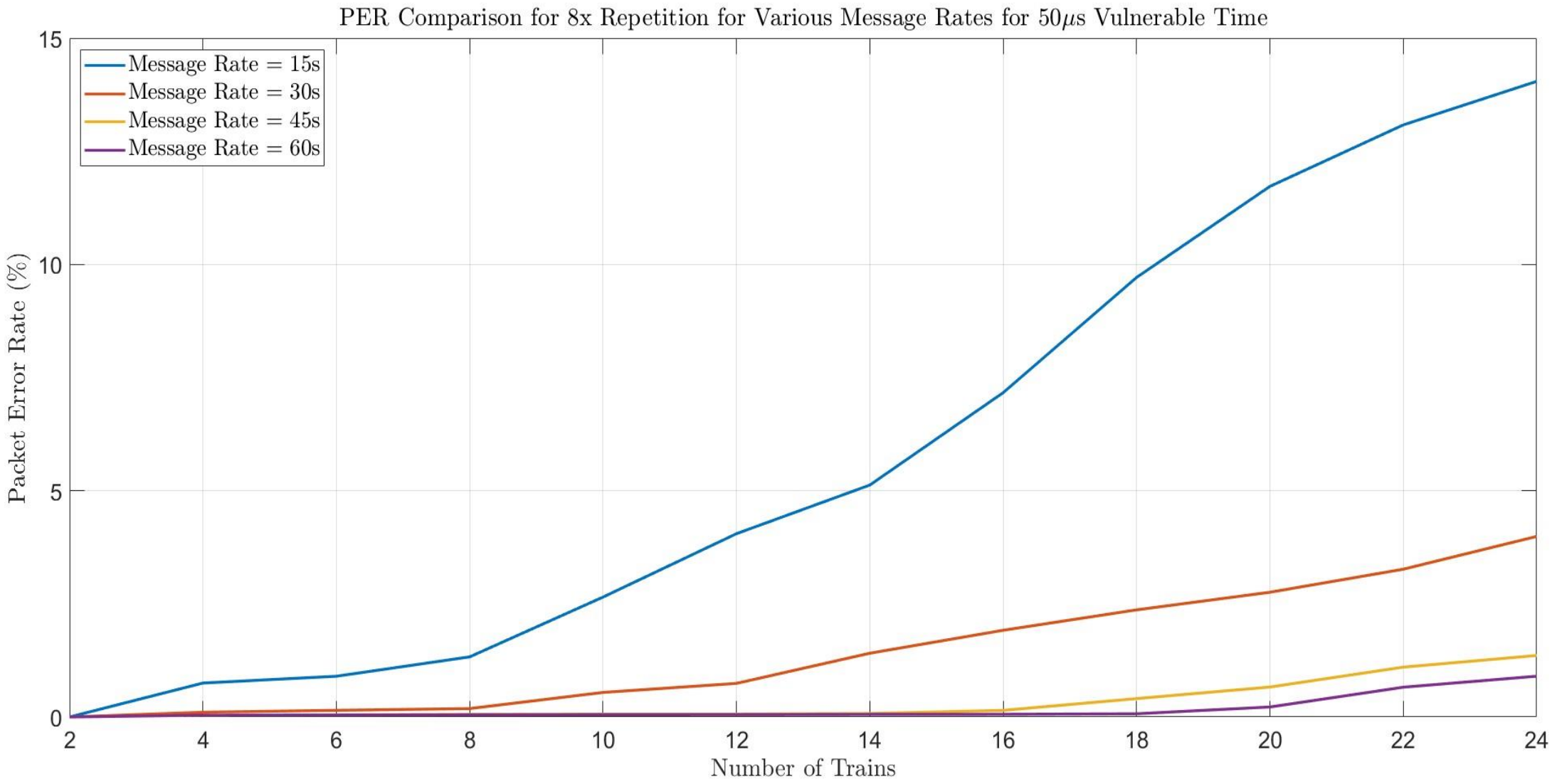
Simulation Framework

- Mode: Simplex
- Type of message transaction: with positioning
- Modulation & Coding Scheme: QPSK with CTC rate ½
- Messages duration for no repetitions:
  - Command – 30.87 ms
  - Response (with position) – 64.89 ms
  - Response (without position) – 35.73 ms
  - Acknowledgement – 26.01 ms
- Messages duration for 8 repetitions:
  - Command – 132.93 ms
  - Response (with position) – 405.09 ms
  - Response (without position) – 171.81 ms
  - Acknowledgement – 94.05 ms
- Message Intervals – 15, 20, 30, 45 & 60 secs (with randomness added by a window of 1 sec with resolution 1 ms)
- Random Backoff Window – 500 ms with resolution 1 ms
- Deferral Scheme followed: Once command transmission is successful, the channel will remain busy for the entire message transaction (Command, Status with positioning, Ack). If the HOT senses the channel is busy before transmitting the Command message, the HOT defers transmission for 500 ms. If the channel is sensed to be busy before a Status or Ack message is transmitted, the sensing station (HOT or EOT) performs random backoff by a window of 500 ms with a resolution 1 ms.

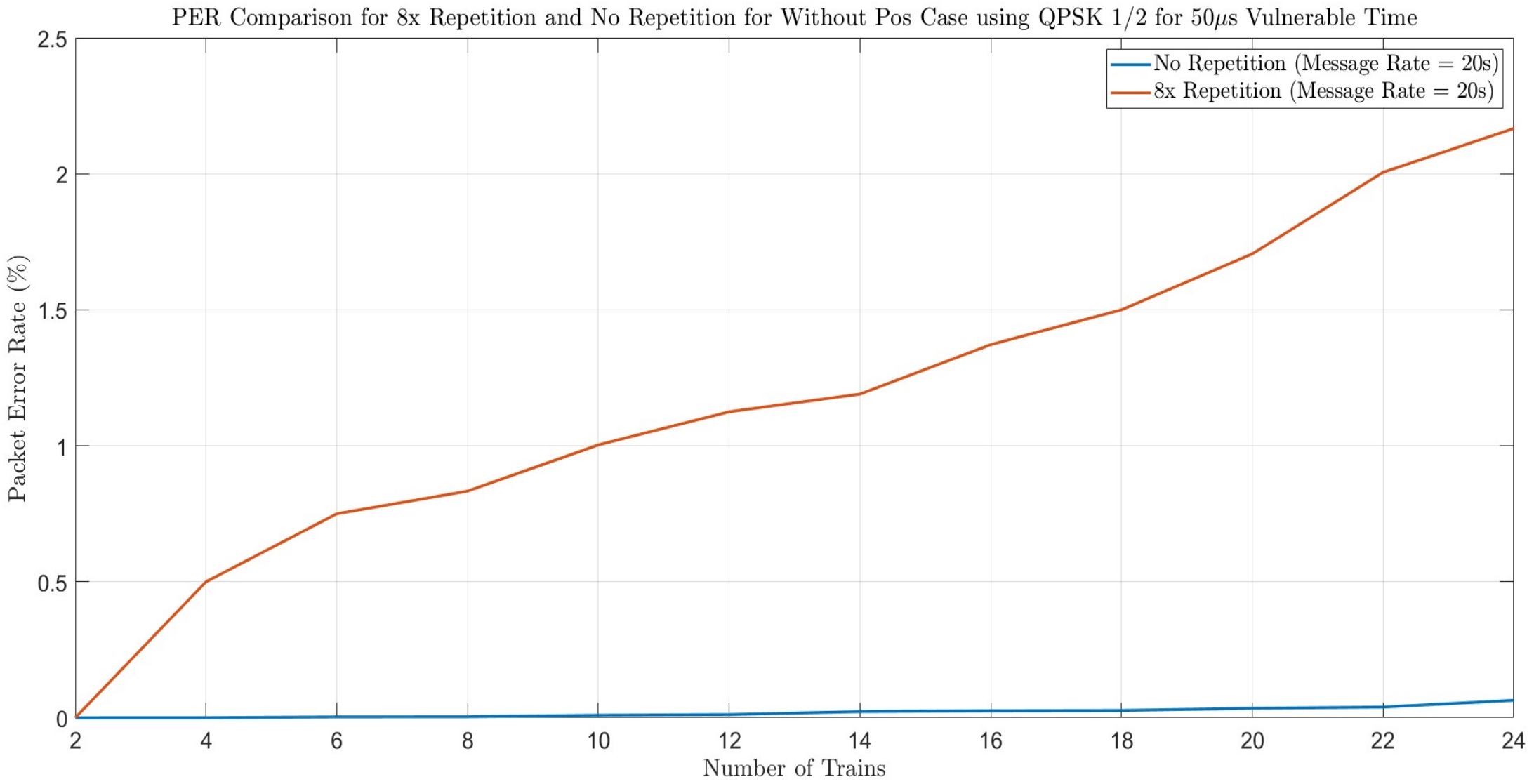
Simulation Output for No Repetitions (50us Vulnerable Time)



Simulation Output for 8 Repetitions (50us Vulnerable Time)



Simulation Output Without Positioning (50us Vulnerable Time, 20s message interval)



Summary and Conclusions

- The probability of packet collision with 8 repetitions/combing with 12 trains in range (this was defined the worst-case scenario for Simplex in the HSL test), is about 4% when the message transaction rate is every 15 seconds. The probability of packet collision drops to 1% when the message transaction rate is once very 30 seconds.
- The probability of packet collision with 8 repetitions/combing with 24 trains in range (this is double the worst-case scenario for Simplex in the HSL test), is about 14% when the message transaction rate is every 15 seconds. The probability of packet collision drops to 4% when the message transaction rate is once very 30 seconds.
- The probability of packet collision can be reduced by:
  - Change in message transaction rate depending on speed
  - Dynamic selection of the repetition factor in F to R and in R to F direction, independent of each other.