Uncoordinated Multiple Access for Vehicular Networks

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Motivation

V2X communications

- Numerous applications, e.g., cooperative intelligent transportation systems, automated driving, traffic safety, traffic efficiency, etc.

State-of-the-art ad hoc V2X communications

- 802.11p (slightly modified Wi-Fi) using carrier sense medium access (CSMA)

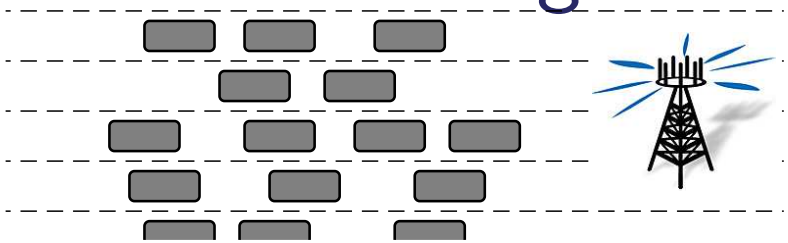
Main challenges

- difficult propagation channels
- potentially fast changing network topologies
- very strict delay requirements
- very strict reliability requirements
- all-to-all broadcast

Outline

1. Coded Slotted ALOHA: Unicast
2. Error Floor Analysis for Finite Frame Lengths
3. Coded Slotted ALOHA: Broadcast
4. Coded Slotted ALOHA vs Carrier Sense Multiple Access
5. Conclusions and Future Work

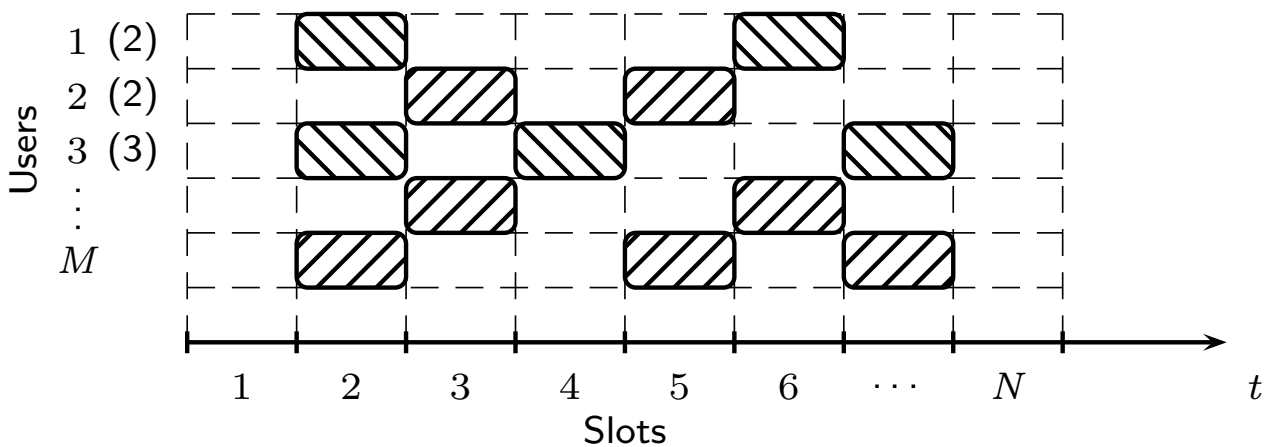
Encoding



Assumptions

- Time is divided into frames each of N slots of equal duration.
- At the beginning of each frame every user has a message to transmit.
- The message size matches the slot duration.

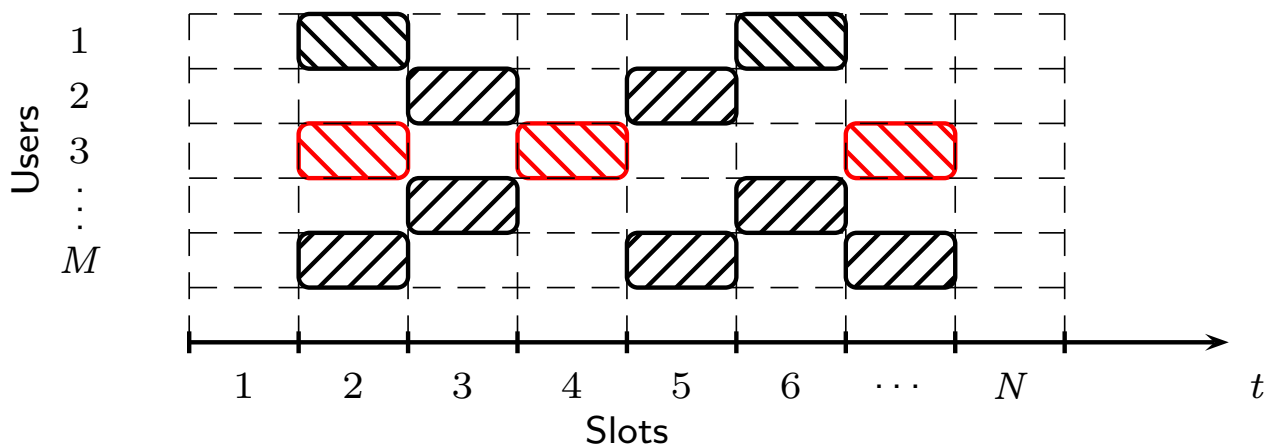
Distribution: $\Lambda(x) = 0.75x^2 + 0.25x^3$



Decoding

Assumptions

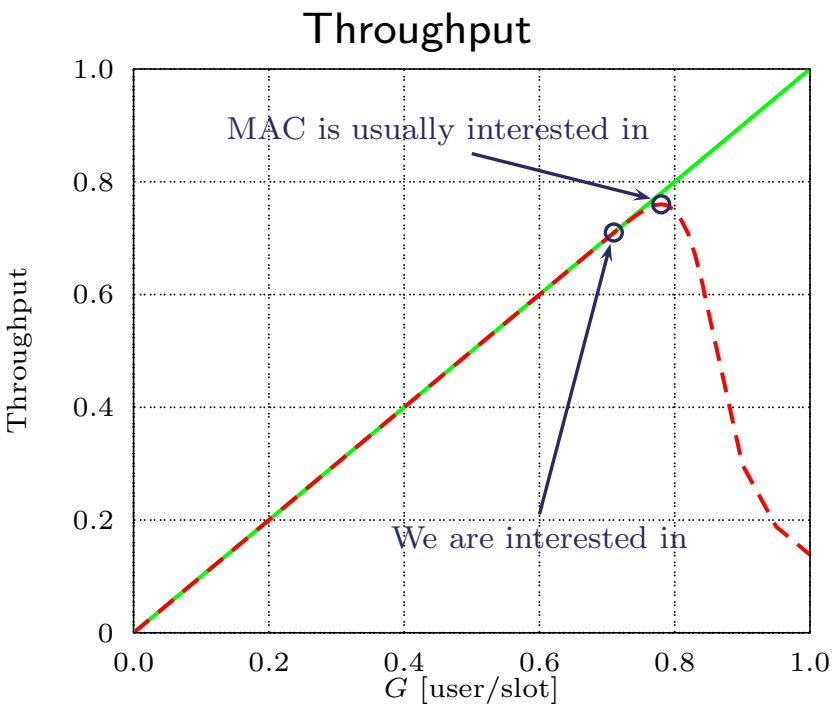
- The base station records the entire frame.
- A packet can be reliably decoded if no collision occurs.
- Each packet contains pointers to its replicas.
- The replicas of a received packet can be perfectly removed from the signal.

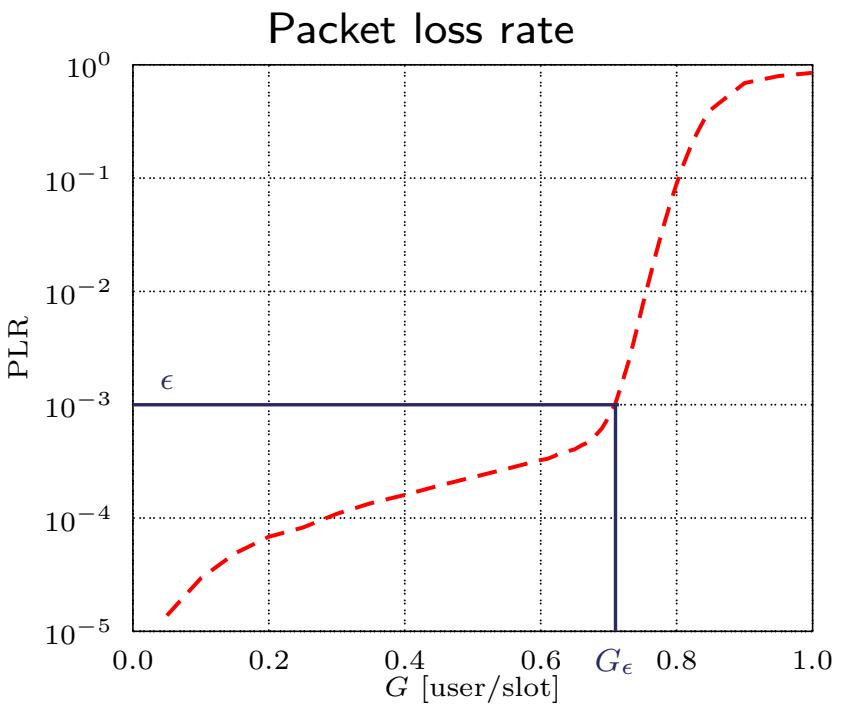


Performance Measure

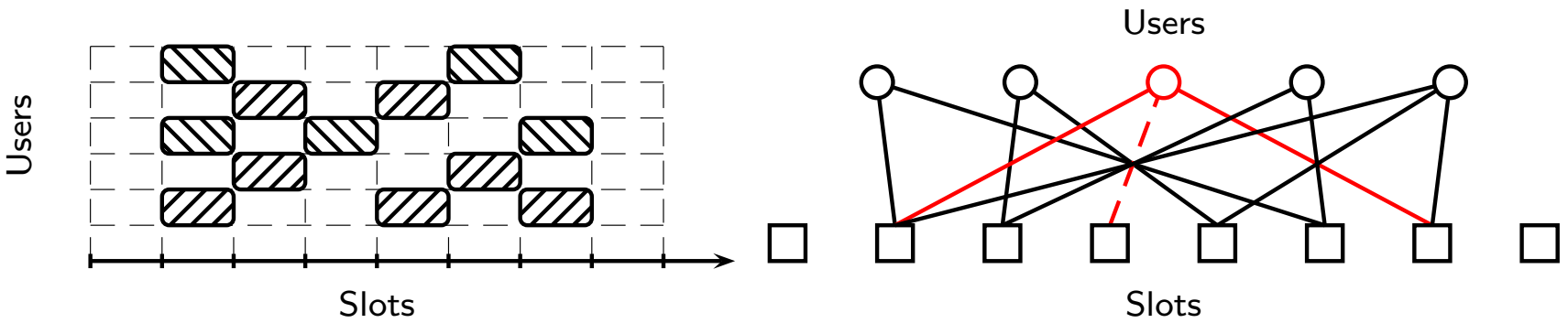
Parameters

- number of slots N
- number of users M
- channel load $G = \frac{M}{N}$
- throughput $\mathrm{Th} = \frac{\#\text{ resolved users}}{N}$
- packet loss rate $\mathrm{PLR} = \frac{M - \#\text{ resolved users}}{M} = 1 - \frac{\mathrm{Th}}{G}$





CSA and Codes on Graphs



Identical to LDPC decoder on binary erasure channel!

Similarities

- believe propagation on erasure channel
- density evolution (EXIT chart)
- threshold phenomenon

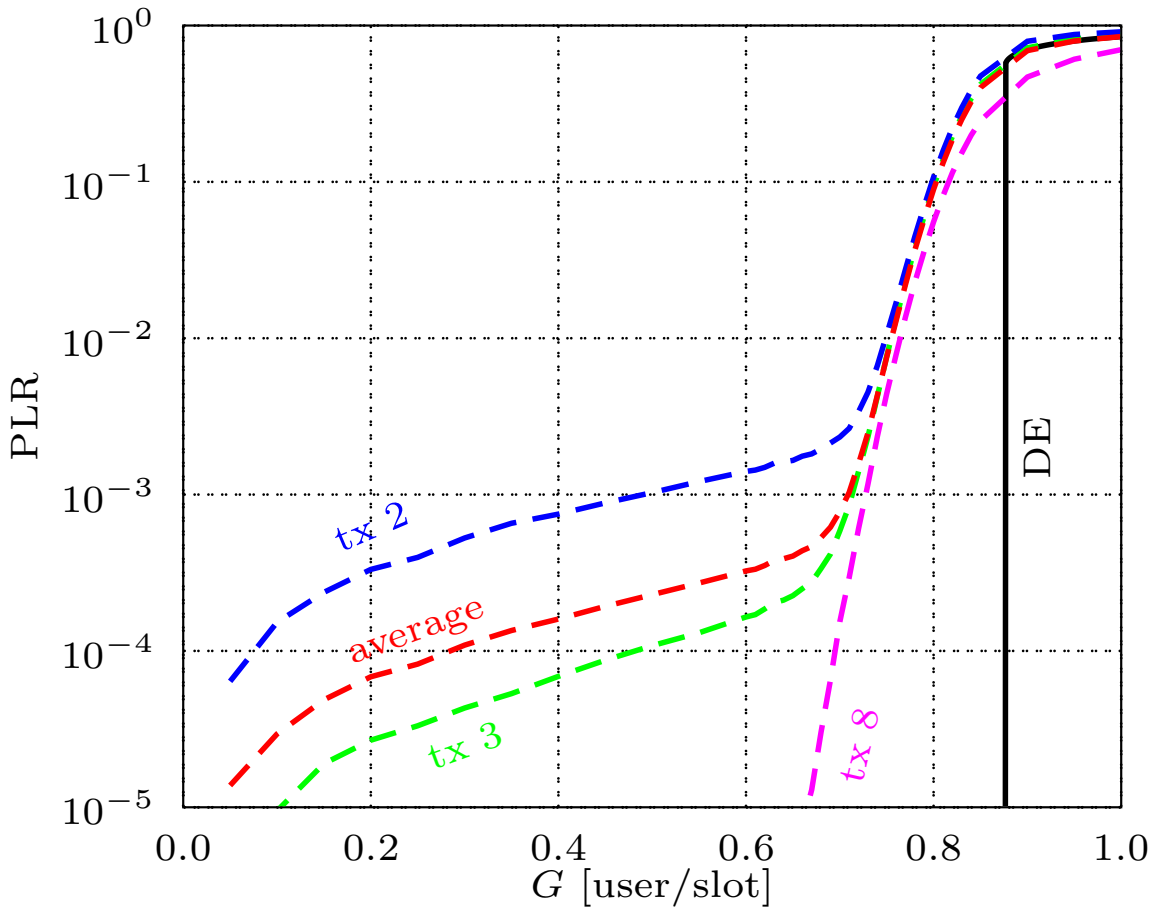
Differences

- no channel
- graph is not known a priori
- negative code rate

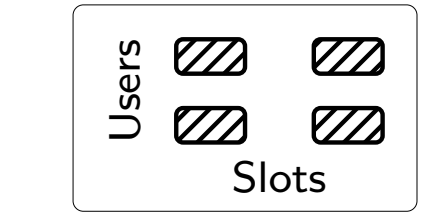
Finite Frame Length

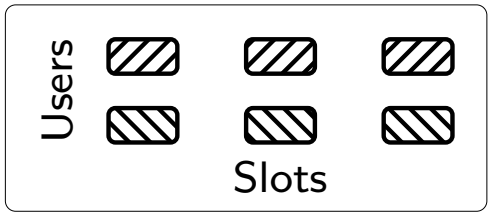
Distribution $\Lambda(x) = 0.15x^2 + 0.69x^3 + 0.16x^8$

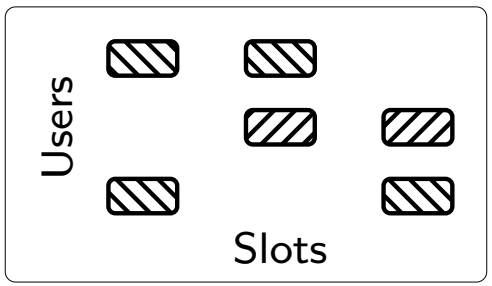
Frame length $N = 200$

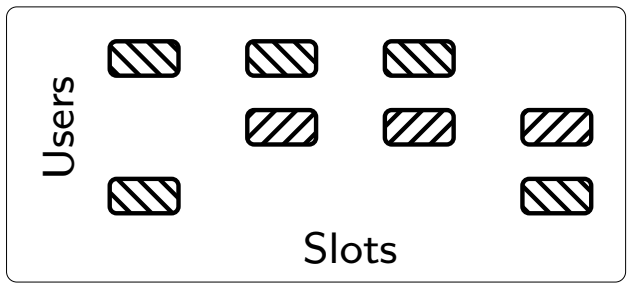


Stopping Sets





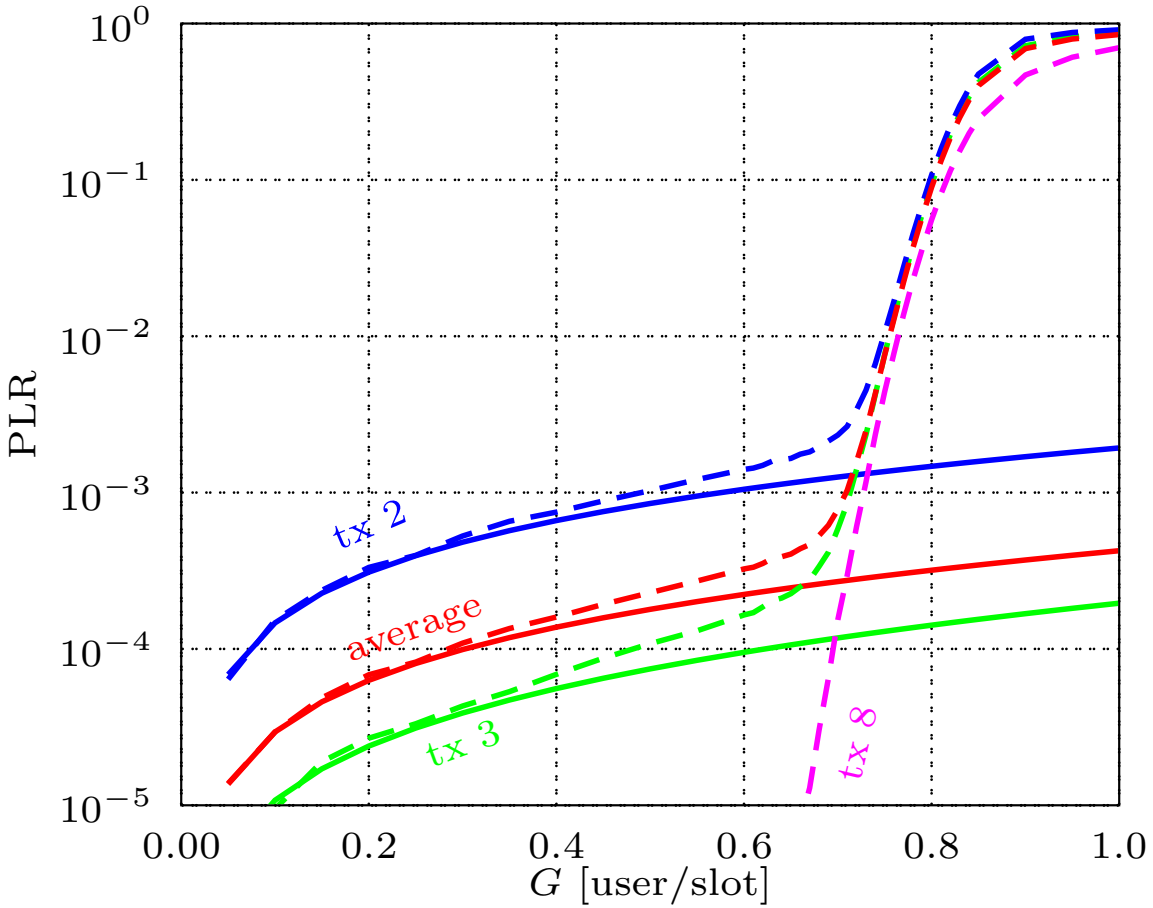




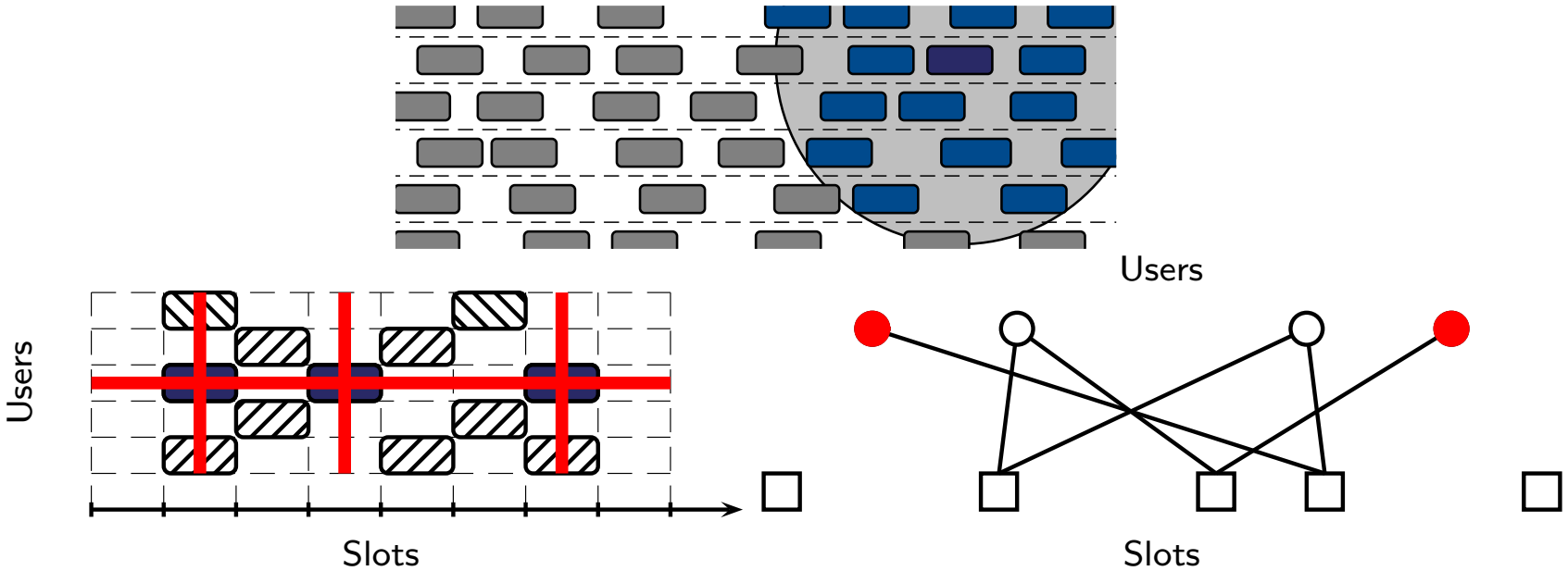
Error Floor

Distribution $\Lambda(x) = 0.15x^2 + 0.69x^3 + 0.16x^8$

Frame length $N = 200$



All-to-All Broadcast

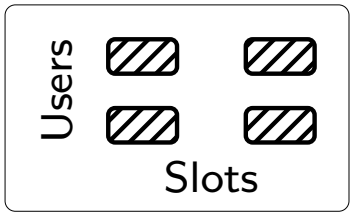


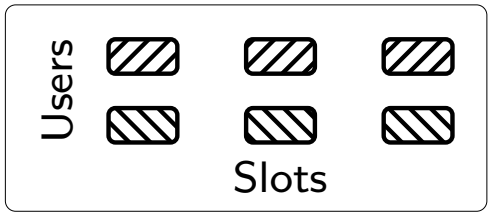
Nothing is decodable!

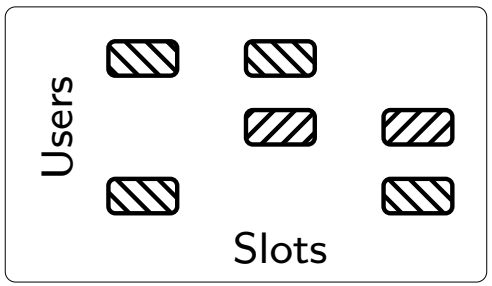
Notes

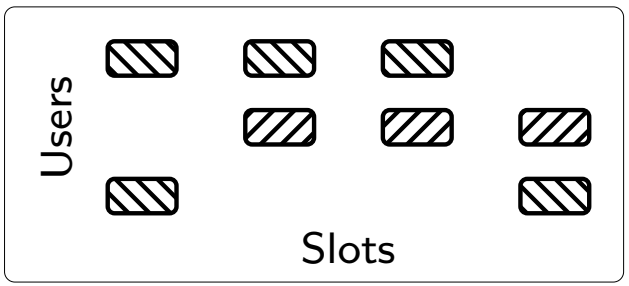
- Users with different degrees have different decoding capabilities.
- Removing a finite number of the columns does not affect the asymptotic analysis.
- Removing slots can be seen as changing the distribution.
- Degree-1 users are present in the new distribution.

Stopping Sets

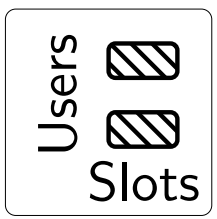


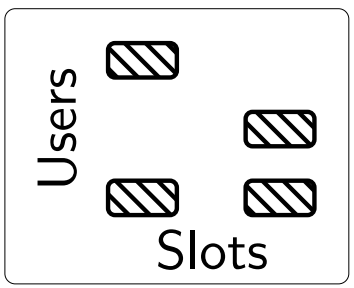


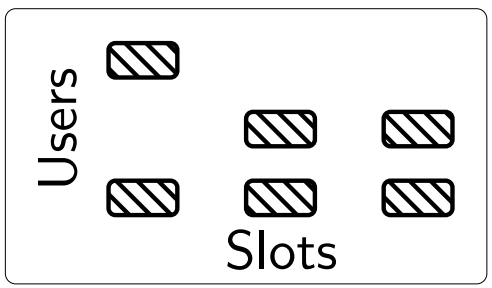


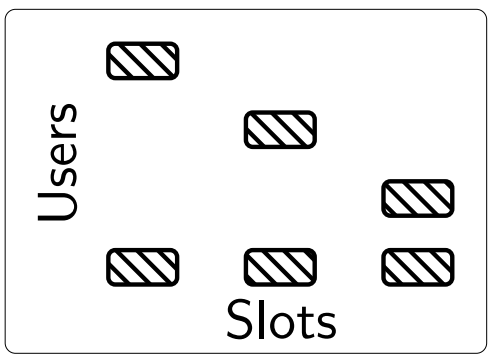


Additional Stopping Sets





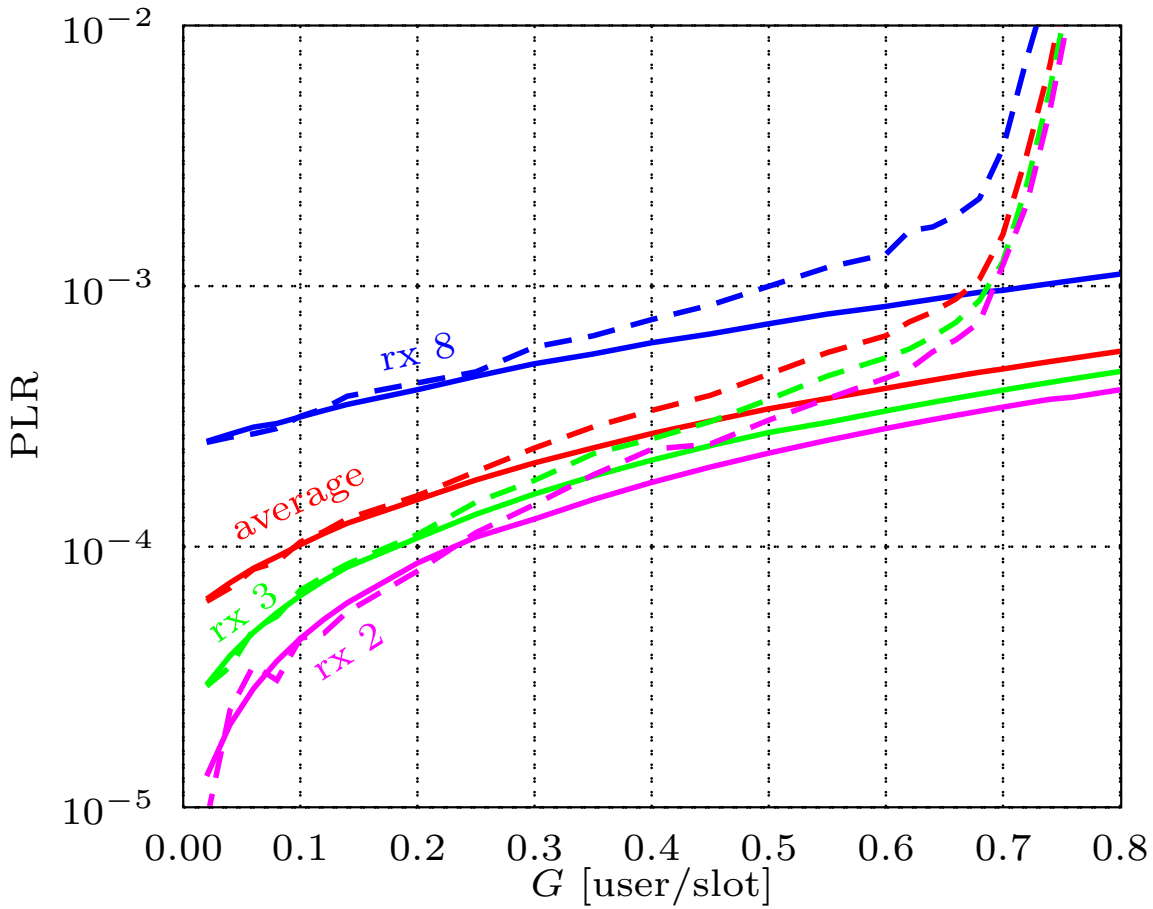




Simulation Results

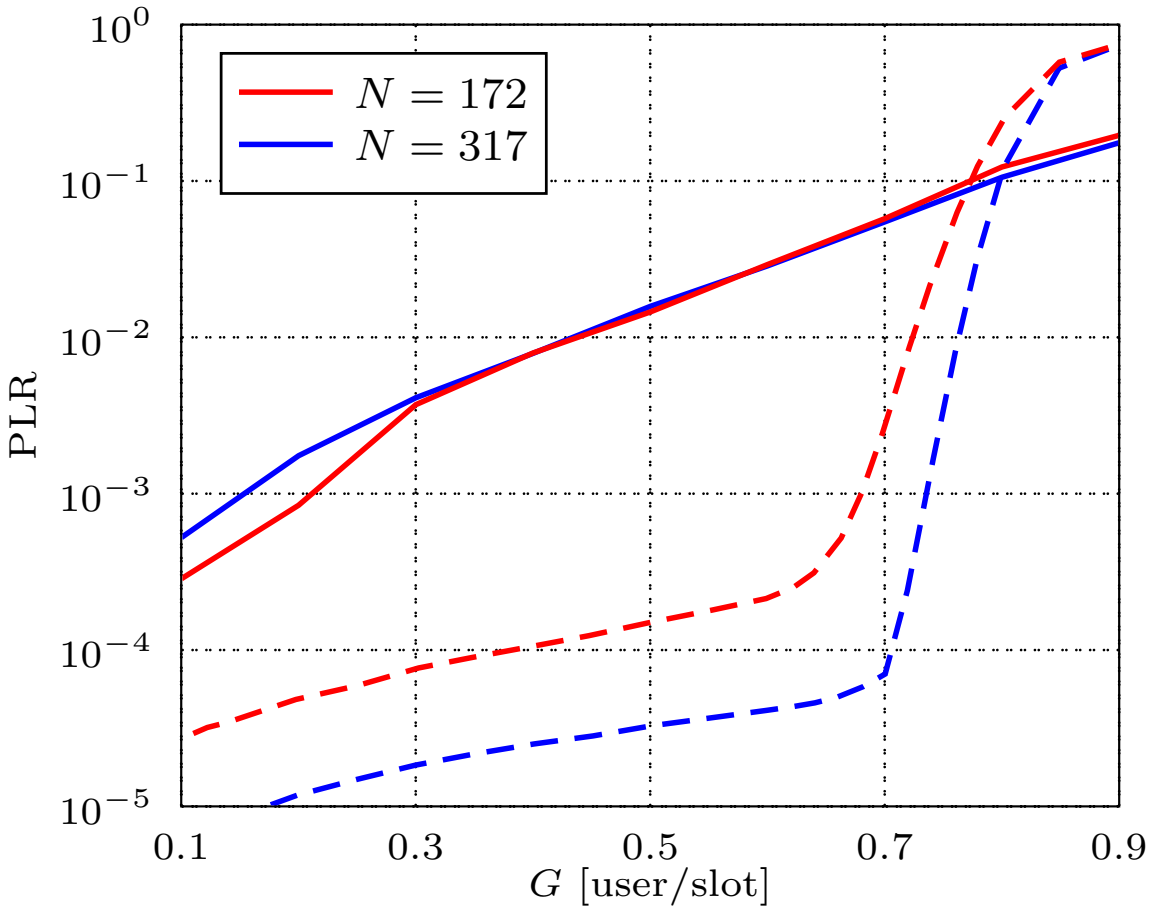
Distribution $\Lambda(x) = 0.15x^2 + 0.69x^3 + 0.16x^8$

Frame length $N = 200$



CSA vs CSMA

Distribution $\Lambda(x) = 0.86x^3 + 0.14x^8$



Conclusions and Future Work

Conclusions

- Finite frame length analysis is reasonably accurate
- Finite frame length is needed for controlling latency
- All-to-all broadcast is different from traditional MAC both in terms of performance metrics and analysis
- CSA seems to significantly outperform CSMA

Future work

- Design of good distributions for all-to-all broadcast
- Error floor reduction
- How to utilize (priorities?) or remove unequal error protection
- SINR model for interference cancellation
- Introduce frameless structure

Thank you!