Experimental Evaluation of MAC Protocols for Fairness and QoS Support in Wireless Networks

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Introduction

- Many wireless MACs suffer from severe unfairness, priority inversion, lack of quality of service, starvation.
- Applications come with diverse fairness policies and requirements.
- System design principles: Decouple mechanisms from policies.
  - MACs implement these mechanisms, and provide controlling knobs to these mechanisms to applications so that they can implement their own fairness policies.

Goals of this Paper

- Evaluate MAC mechanisms under various Fairness "Policies".
- MAC Priority Resolution Categories
  - Differentiated Backoff based schemes (802.11E)
  - Beacon based schemes (EY-NPMA, SIREN)
  - Scheduling based solution (DWOP)

Comparison of MAC PR schemes under different Fairness "Policies"

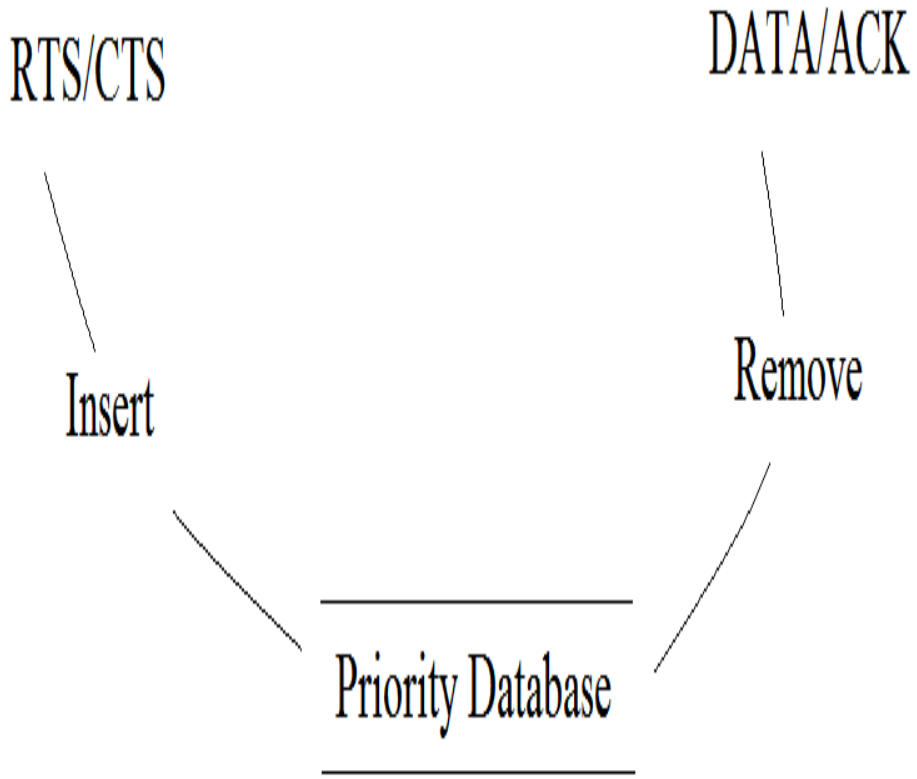
- Fairness & QoS Policies
  - Static Priority
  - Earliest Deadline First Scheduling
  - Proportional Fairness
  - Proportional Rate Allocation

MAC Mechanisms

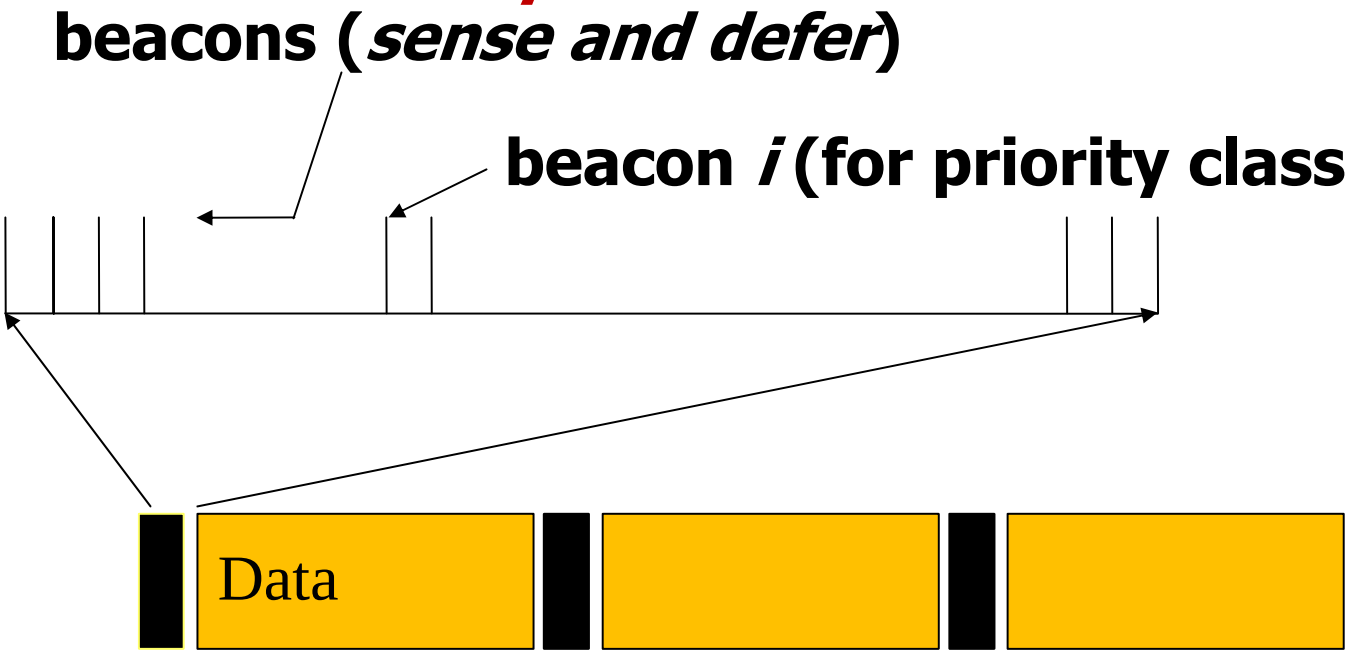
- Differentiated Backoff based PR (802.11E)
  - Backoff period inversely proportional to priority
  - Backoff periods assigned for *absolute prioritization* based on a variant of 802.11E
  - Mixing contention resolution with priority resolutions.

Scheduling based Mechanisms

- Scheduling Based (DWOP)
  - Exchange priority information before packet transmission
  - Piggyback priority information in RTS/CTS
  - Nodes coordinate using overhearing and scheduling
  - Mixing PR with CR.

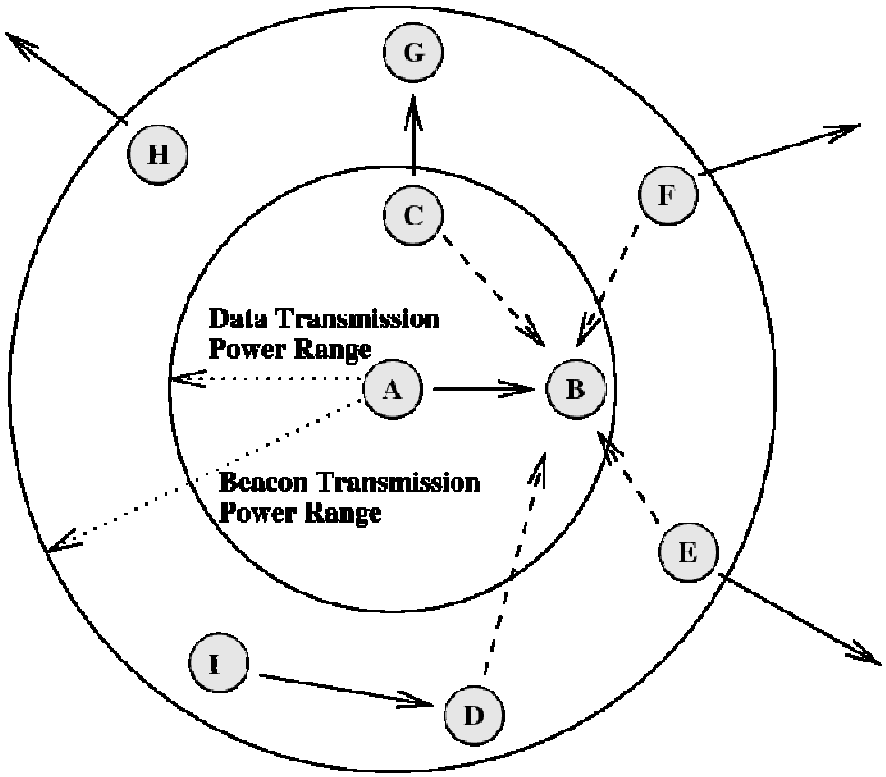


Beacon-based Approach MAC Priority Resolution in SIREN



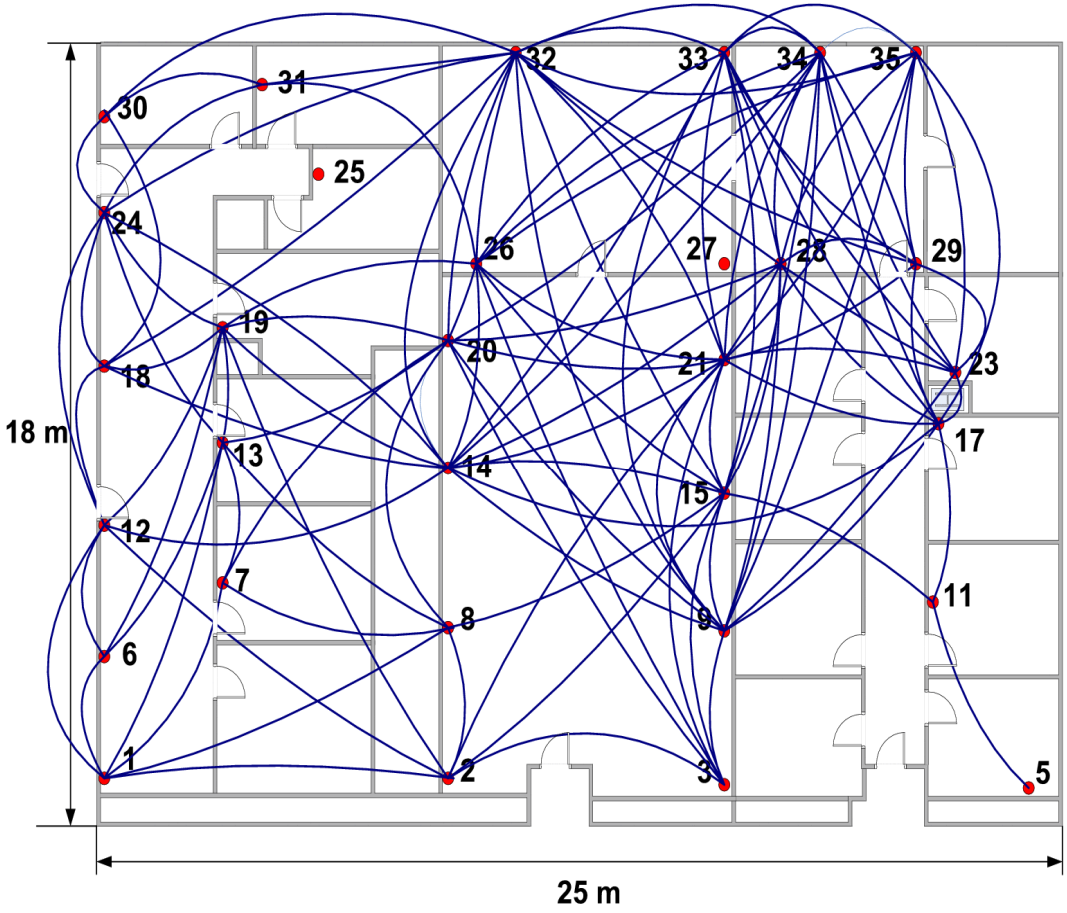
- A node with priority I will send a beacon at i-th beacon slot.
- Beacon may collide, but only those nodes with the highest priority can compete in the data transmission.

Adaptation to Multihop Environment



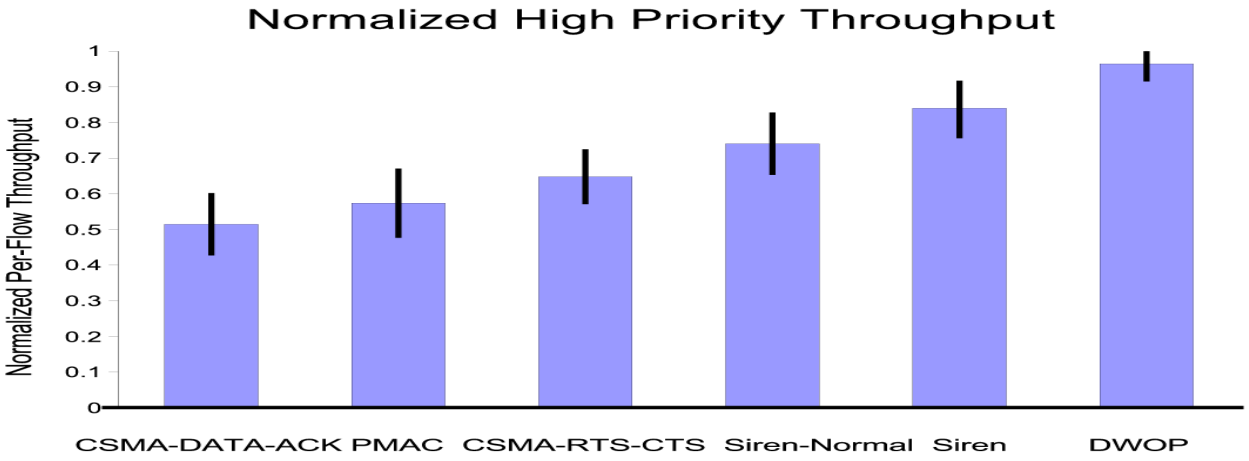
- Beacon Packets Transmitted with High Power
  - Alleviate hidden terminals
- Time Synchronization
  - Aligns beacons for priority resolution across multiple hops in interference range.

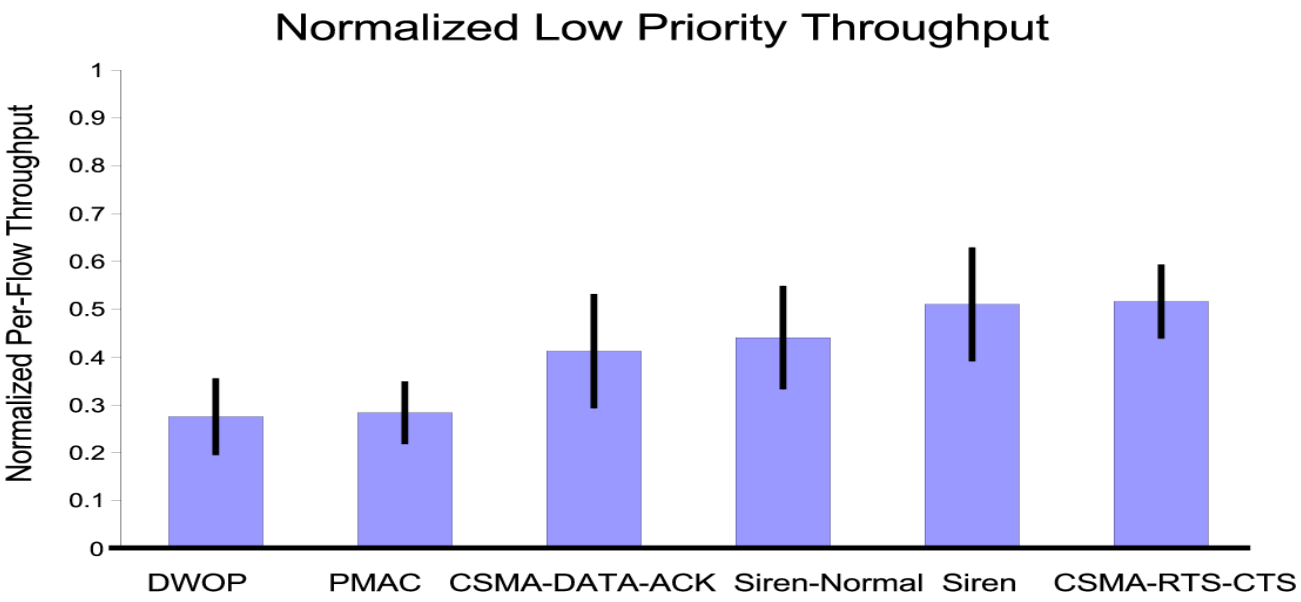
Environment for Evaluation



- MicaZ testbed with 30 nodes
- ZigBee based CC2420 radios
- 250 Kbps link speed
- Clear Channel Assessment
- Provide the common platform for evaluation of different MAC schems.

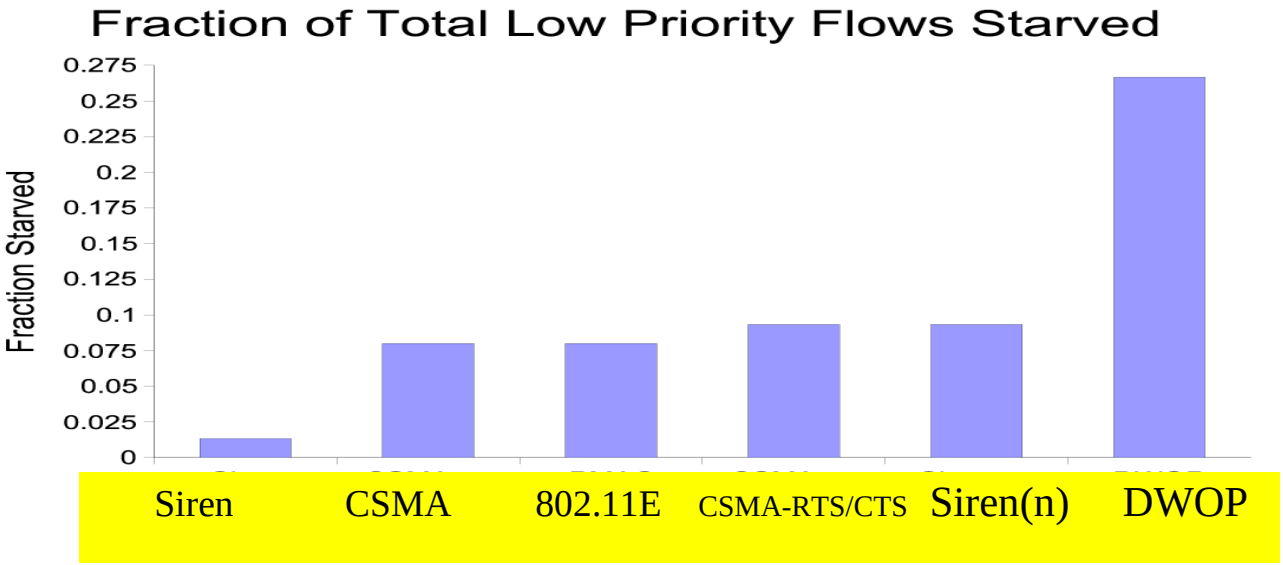
Static Priority

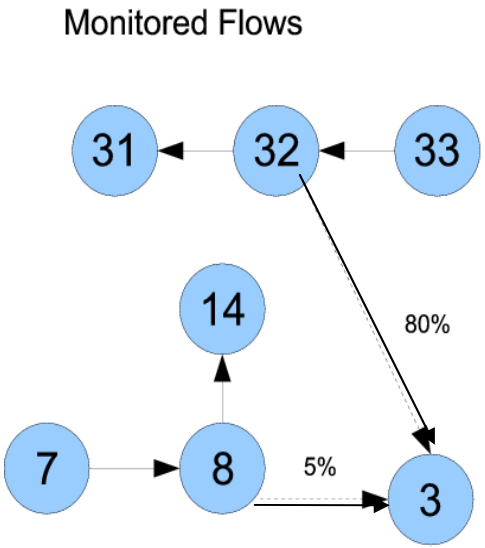


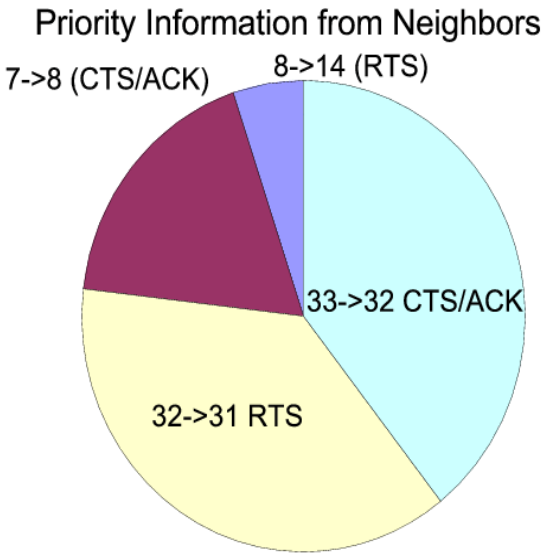


- 5 HP flows and 5 LP flows
- DWOP has highest throughput for HP and lowest throughput for LP due to deadlocks

Deadlock in DWOP

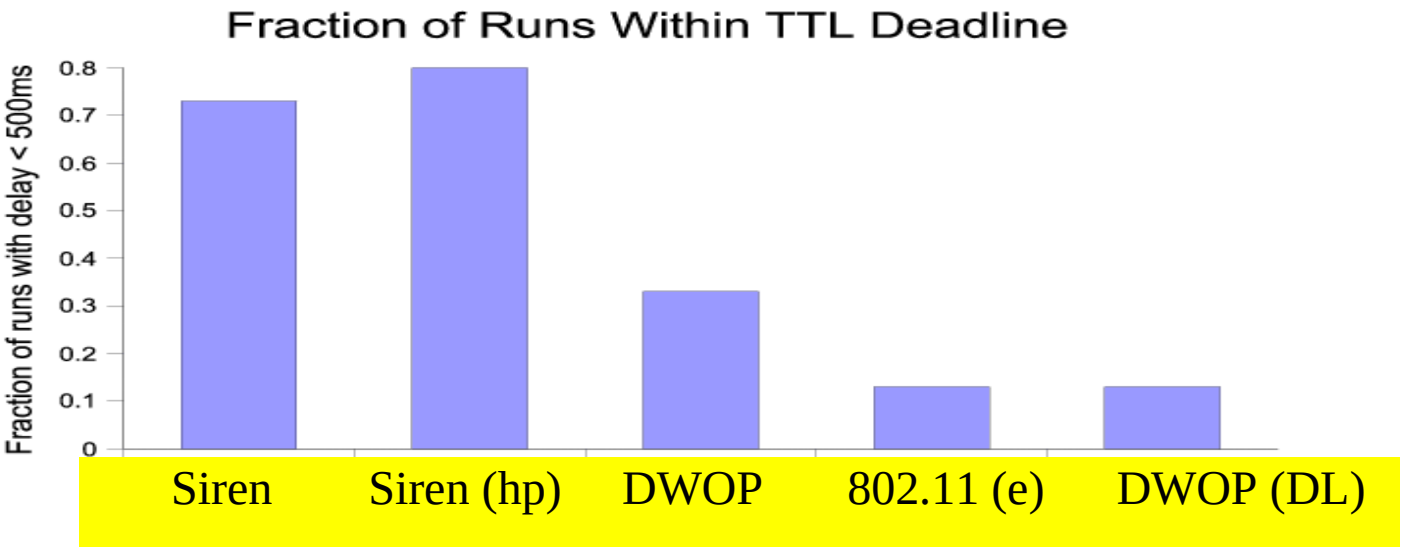


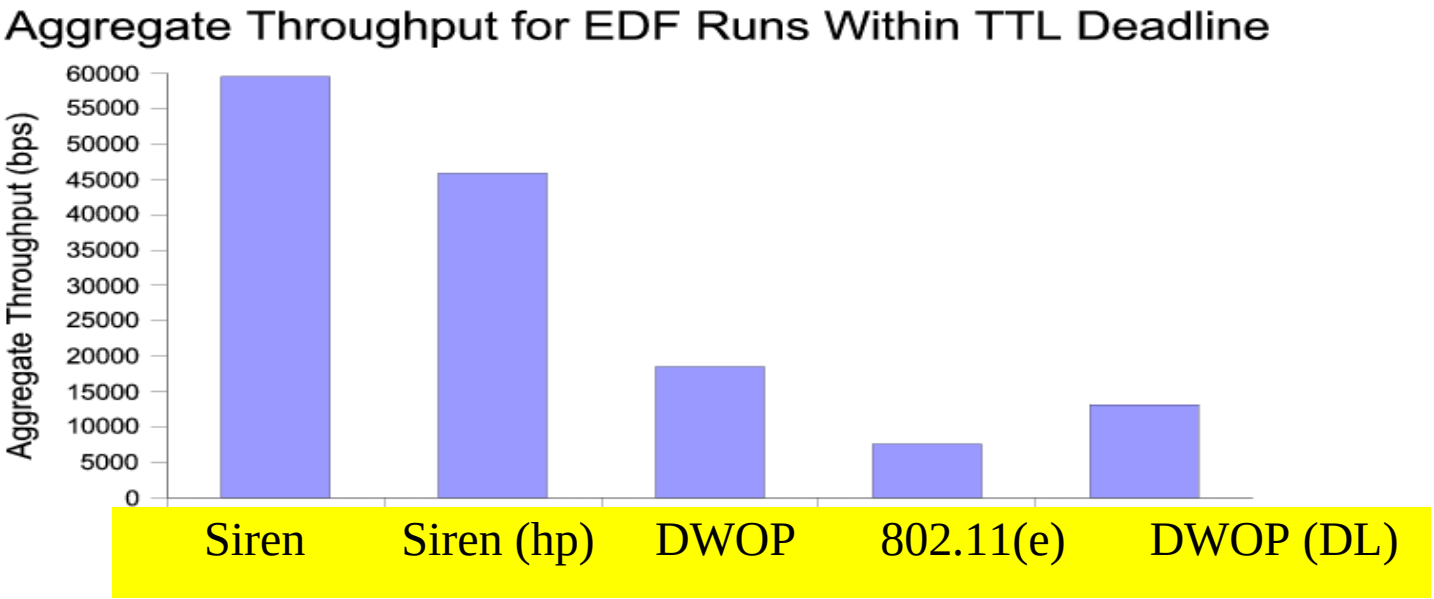




- High amount of starvation of LP flows
- Loss of Data Packets leaves stale entries in Priority Database
- Results in deadlock
- Timeout based Heuristic for reducing deadlock

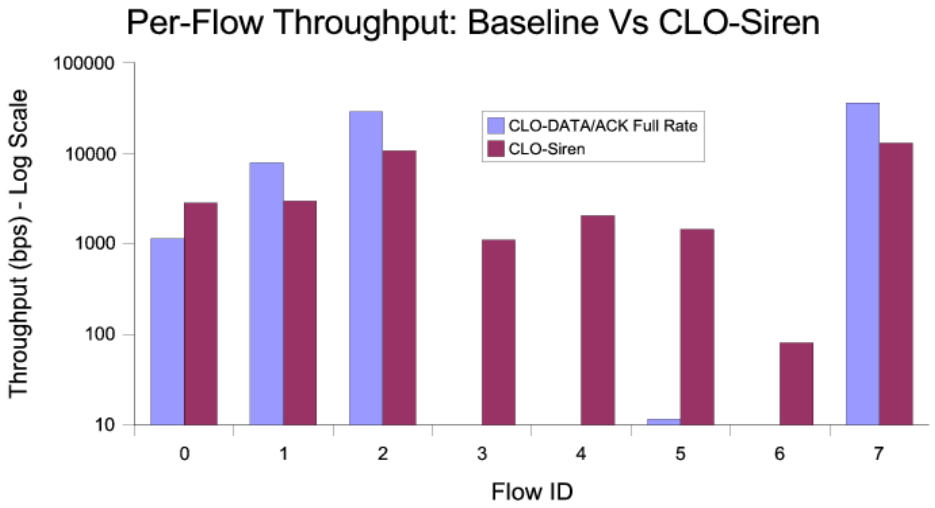
Earliest Deadline First

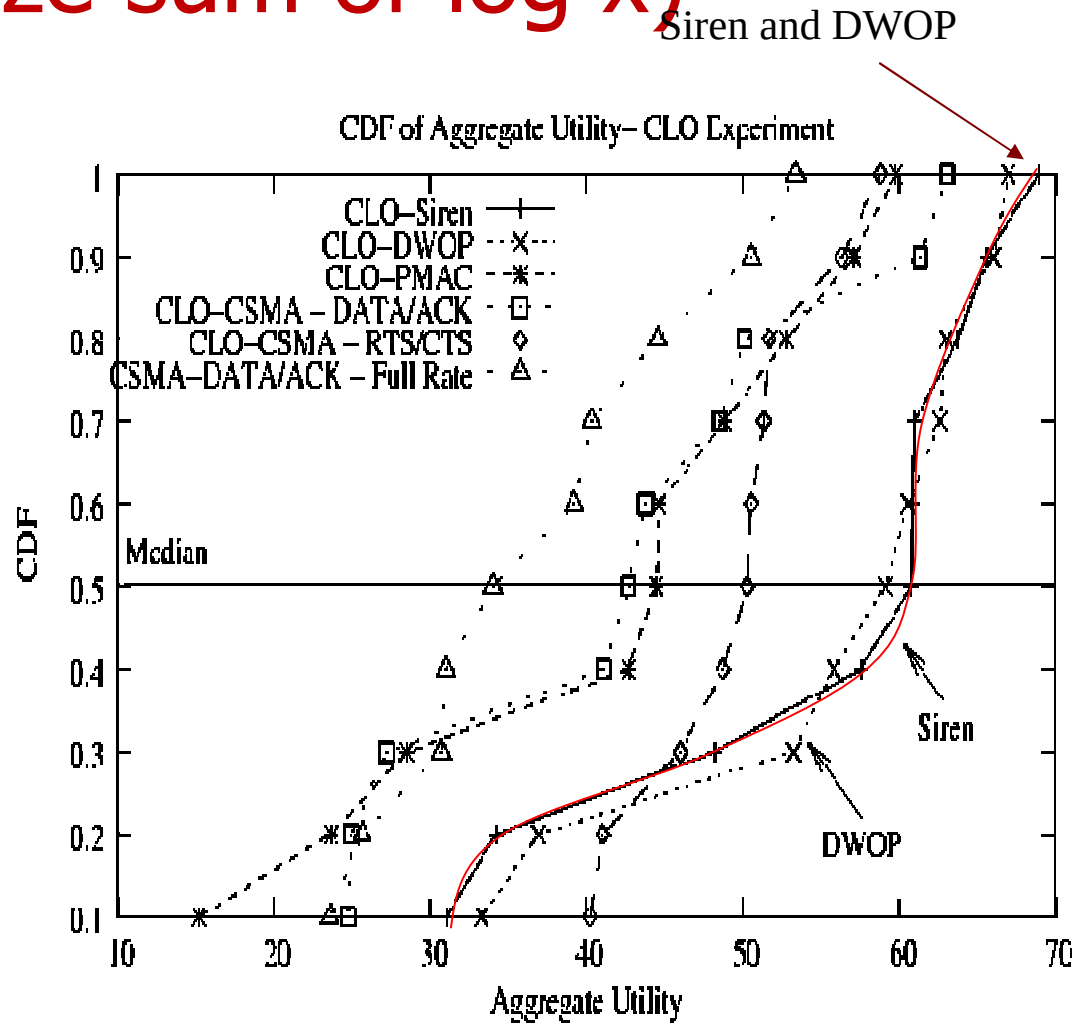




- Prioritize based on deadline.
- Siren Normal uses normal power.
- Siren Normal shows higher number of flows satisfying deadline though at the expense of throughput

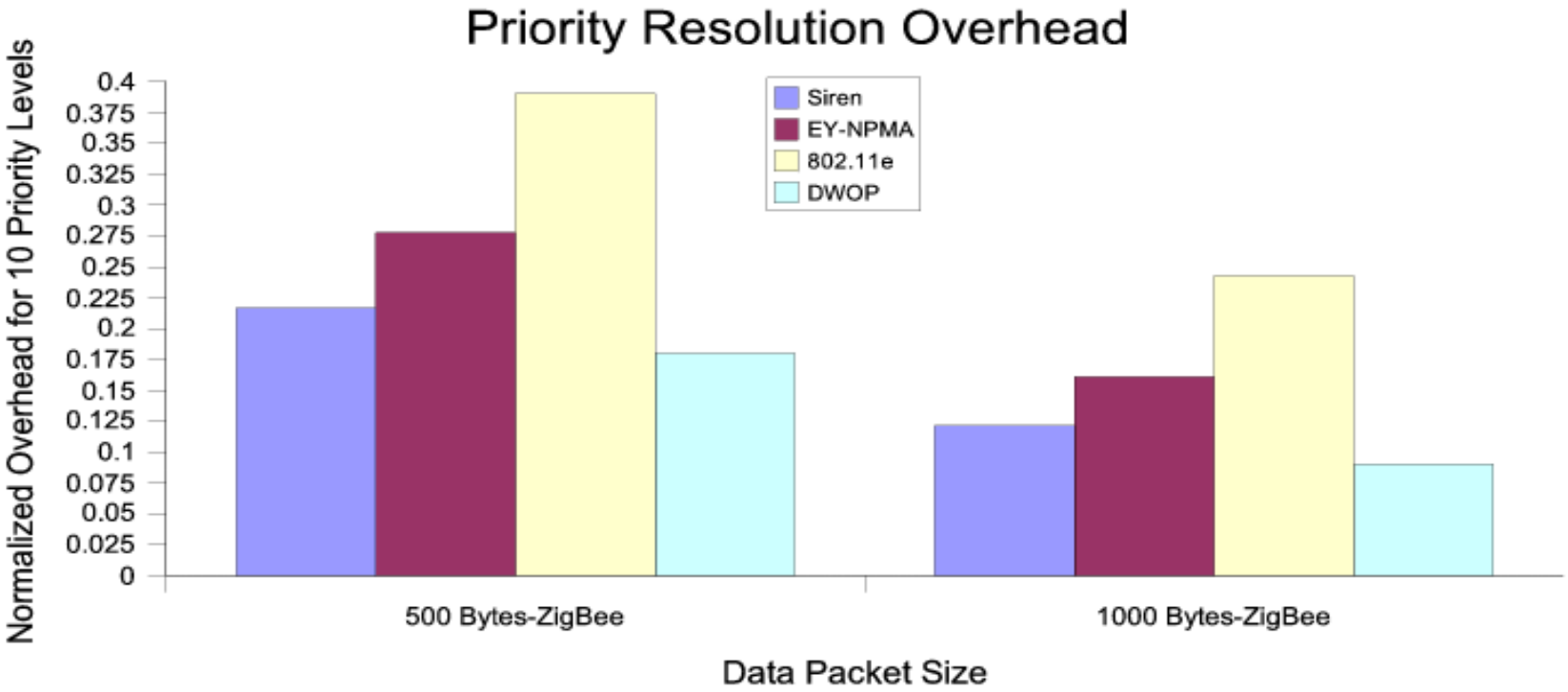
Proportional Fairness (utility: maximize sum of log x)





- 8 flows run with source rate control, flow scheduling and MAC PR.
- SIREN and DWOP obtain high utility

Overhead of MAC PR Mechanisms



- SIREN has relatively high overhead due to implementation of beacons on CC2420. Despite this overhead, it gives better performance.

Summary and Conclusion

- Decoupling priority resolution (PR) from contention resolution (CR) enables more faithful implementation of fairness policies.
  - IEEE802.11 and DWOP combine CR with PR, making it difficult to implement fairness policies and also has side-effect of deadlock (DWOP).
  - Siren completely decouples them, thus good for individual evolutions.

Thanks !