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Understanding Spatio-Temporal Uncertainty in Medium Access with ALOHA Protocols

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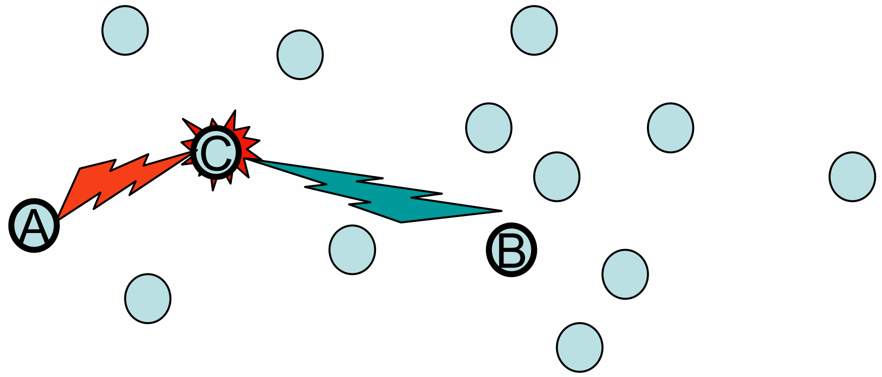
Goals and Contributions

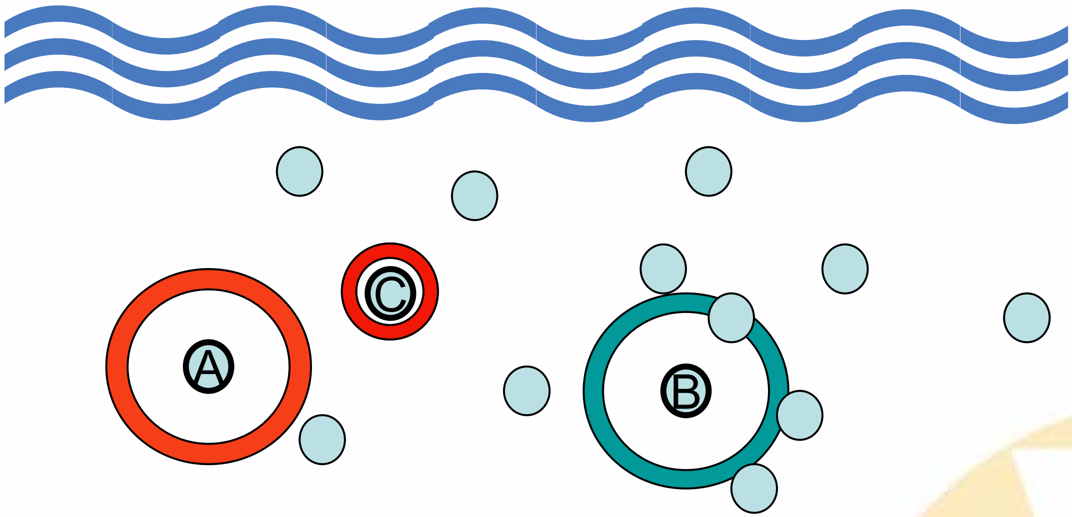
- Propose framework to understand high latency's impact on MAC in UWSN
  - Assumed in prior research; not formalized
- Why ALOHA?
  - Simple
  - Predicts trend in complex protocols
- Propose solution to minimize impact
  - Not a new MAC design!
- Show short hops can be throughput efficient

Conventional View - RF



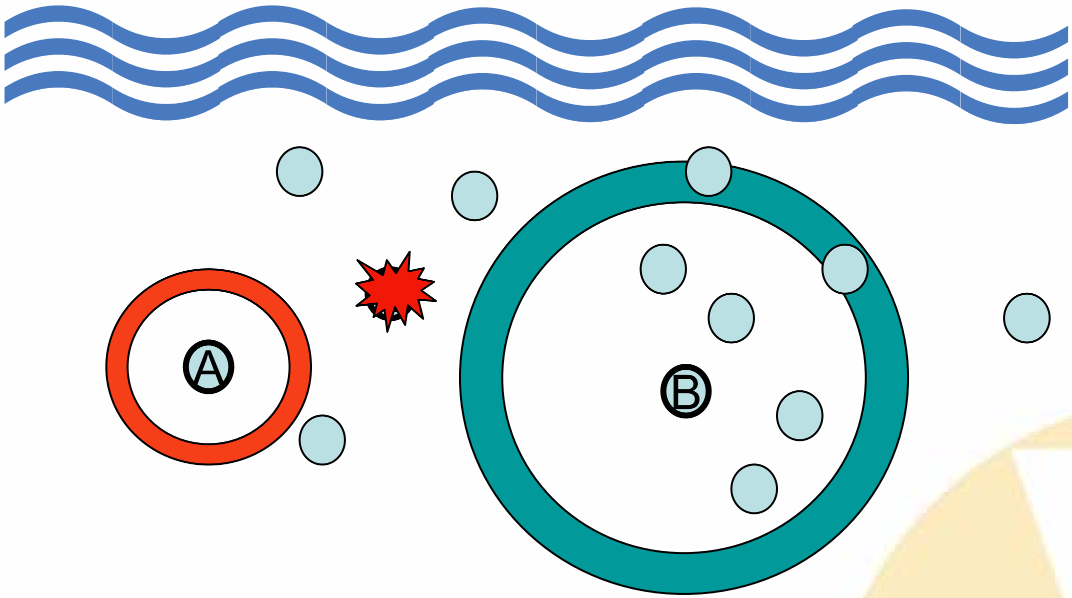
- Transmission at same time - collision at C
  - Essentially true for RF as *reception* is almost instantaneous
  - *Only* ***uncertainty*** in transmit ***time*** needs to be removed

Concurrent Acoustic Transmission



- Transmit at same time; **no** collision at C

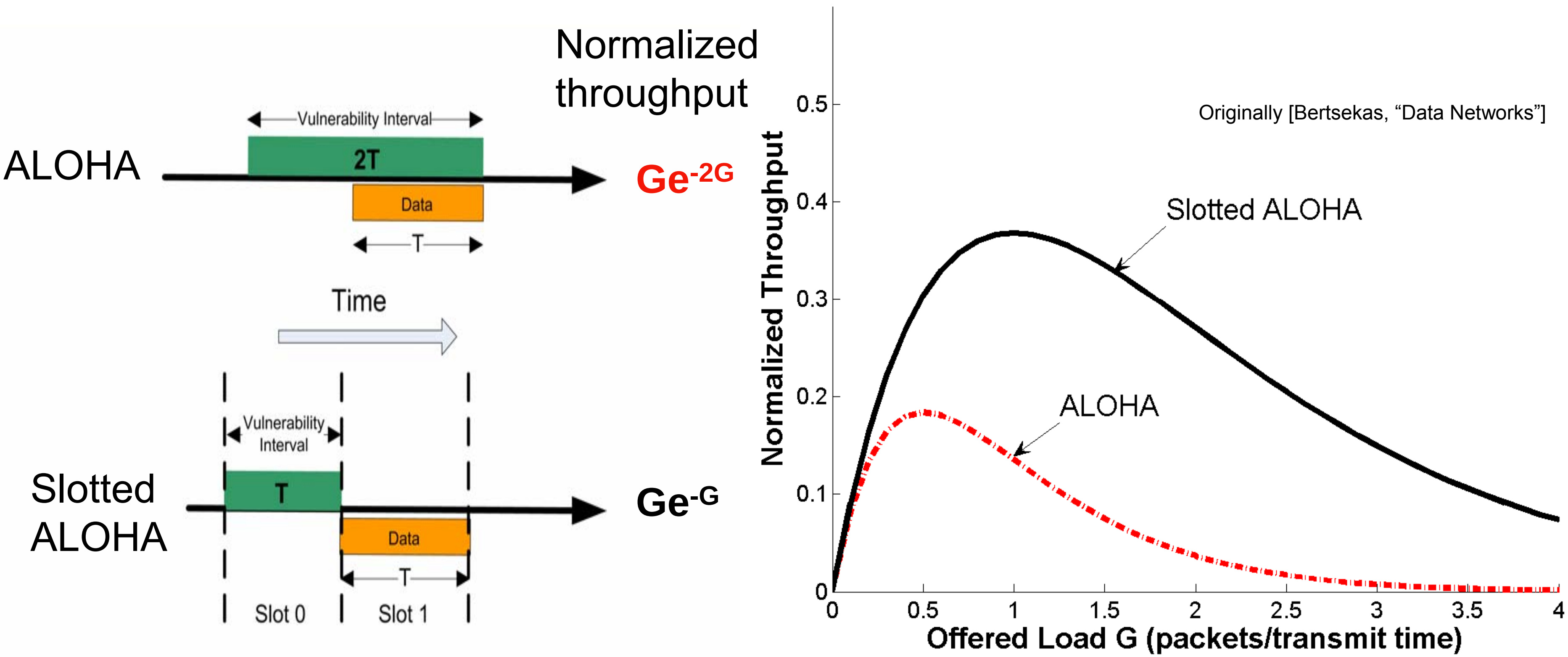
Disjoint Acoustic Transmission



- Transmit at different time, *collision* at C
  - Remove ***spatial*** *uncertainty* (location dependant) at receiver

Space **Time** Uncertainty (STU) =
location based variable delay to receiver
+ **uncoordinated transmission time**

Wireless MAC 101- ALOHA

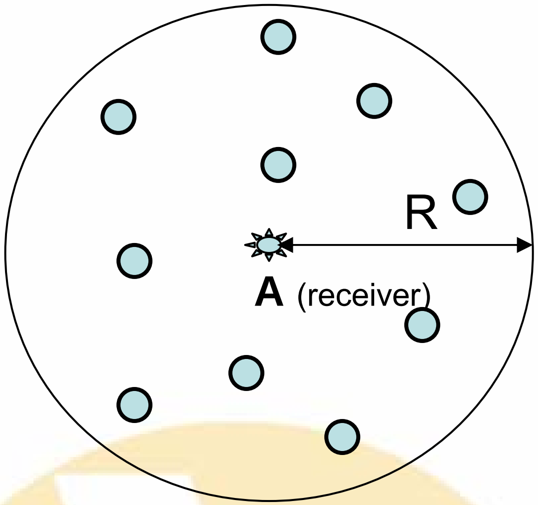


- ALOHA analysis considers time at transmitter
  - Only *transmit time uncertainty* results in collisions
- Slotted transmission reduces the impact of this uncertainty

Evaluation Methodology

- Packet level simulator
  - Custom and variable delay aware
- Single receiver
  - Random deployment of 32 nodes in circular region
  - Equivalent to multihop uniform distribution around **A**
- Poisson offered load (G) to *network* in packets/**T**
- Average with 95% confidence intervals

Random deployment



Normalized Delay Analysis

- Delay variable $a = \tau_{max}/T$
  - τ_{max} = maximum propagation delay
  - **T**= packet transmit time
- Why normalize to packet size?
  - Generic analysis; independent of specific network parameters
  - R=500m @ 8Kbps and 600byte pkt; **a =0.55**
  - R=500m @ 1Kbps and 75 byte pkt; **a =0.55**
  - R=100m @ 8Kbps and 120byte pkt; **a =0.55**

Pure ALOHA in UWA

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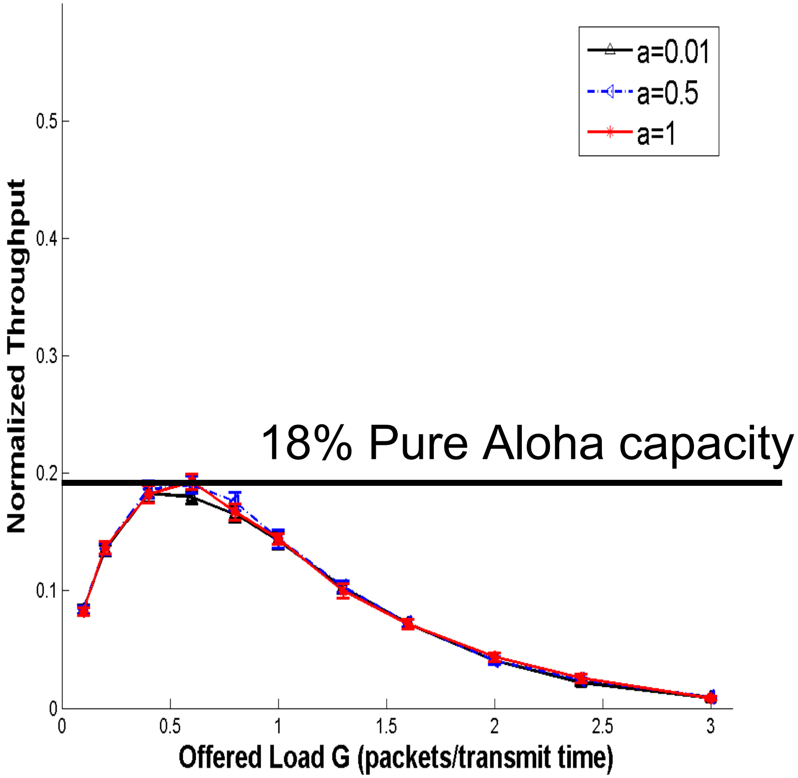
- How does delay affect ALOHA?
  - No impact on capacity!
- Reason:
  - Mechanistic: arrival at receiver Poisson
  - From principle: Pure ALOHA doesn't consider time uncertainty either!



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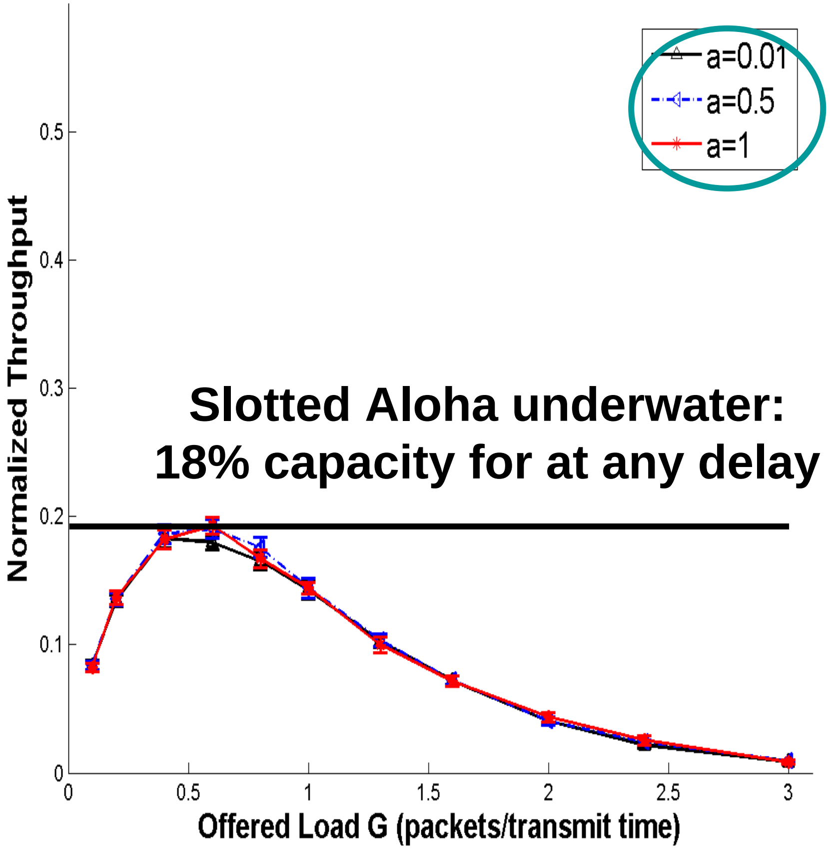
Slotted ALOHA in UWA

- Intuition; since propagation delay not considered
  - *Throughput curve degrades for larger delays*
- Reality: slotting doesn't help throughput!
  - Performs like Pure ALOHA with ***any*** delay!
  - Spatial uncertainty ignored
- Result in poster WUWNET06 [Viera, 2006]
  - We put in perspective of space uncertainty
  - Propose a solution and analyze it



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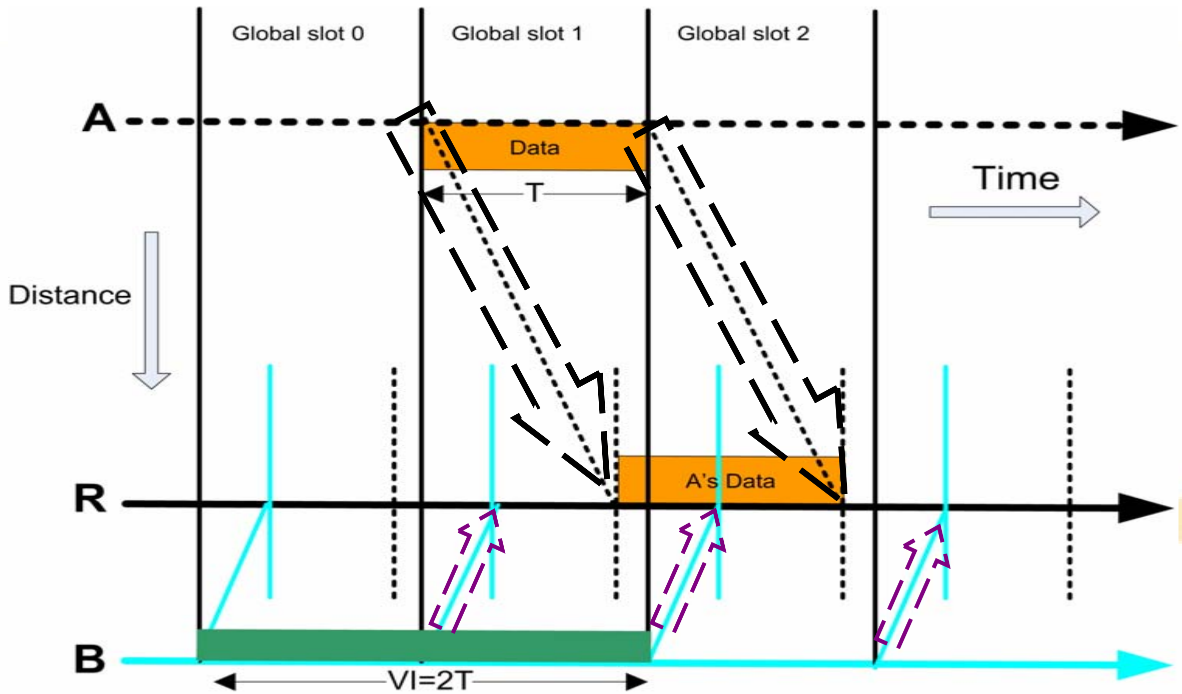
Why no benefit of slotting?



- Unequal delay *looses synchronization* at receiver
  - Pure ALOHA from receivers perspective
- Why don't we see for a real RF network?
  - Few symbol overlap handled by encoding (30m@10Mb/s)
  - For UWA channel the data rate and speed are slow (~1m@1kb/s)

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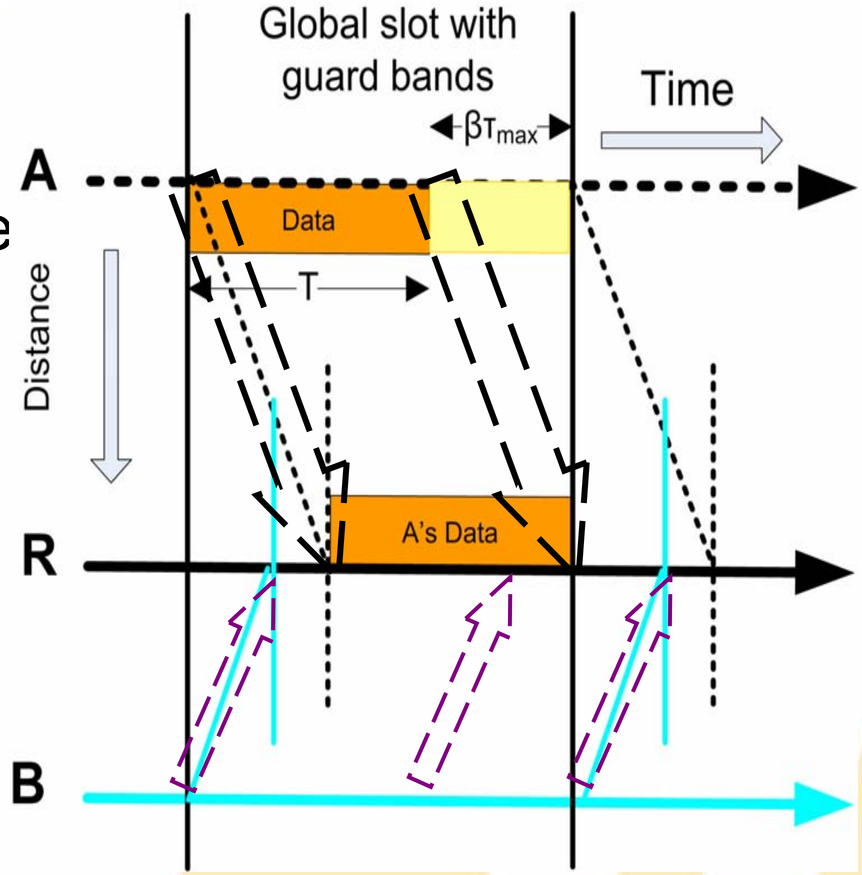
Can we Regain Capacity?

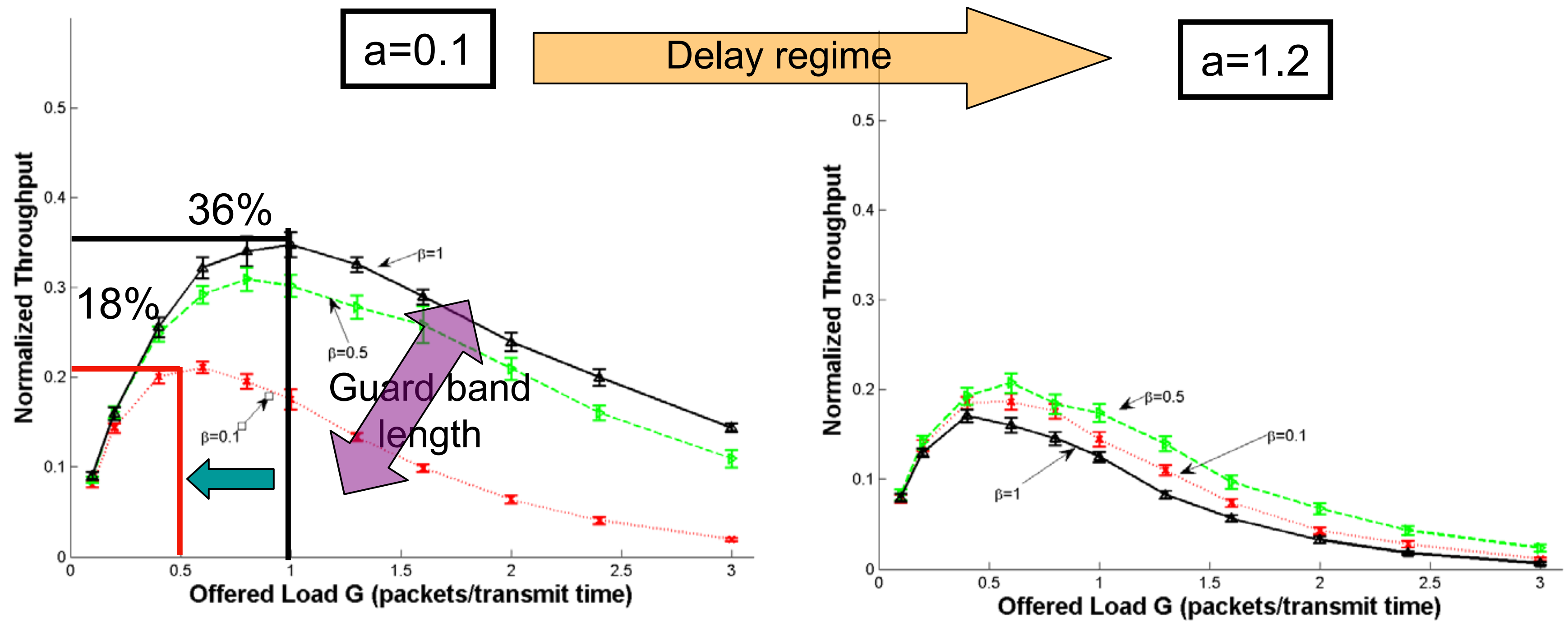
- Yes… almost!
- How?
  - Enforce arrival at receiver in same slots
  - For adhoc networks
    - Add guard bands to slots
    - Similar to sloppy slotted Aloha for satellite networks

Length of guard bands

- Define guard band length as $\beta \tau_{max}$
  - For collision guarantee same as S-ALOHA, $\beta=1$
    - Increased latency and bandwidth overhead
- Observation:
  - Delay to R for node pair often < τ_{max}
  - Varying β
    - Tradeoff between collision probability and overhead



S-ALOHA with Guard Bands



- Guard bands regain throughput!
  - Curves shift between Pure Aloha (G_{max}=0.5) to S-Aloha (G_{max}=1)
- Improvement depends upon
  - Guard band fraction - β
  - Delay regime – *a*

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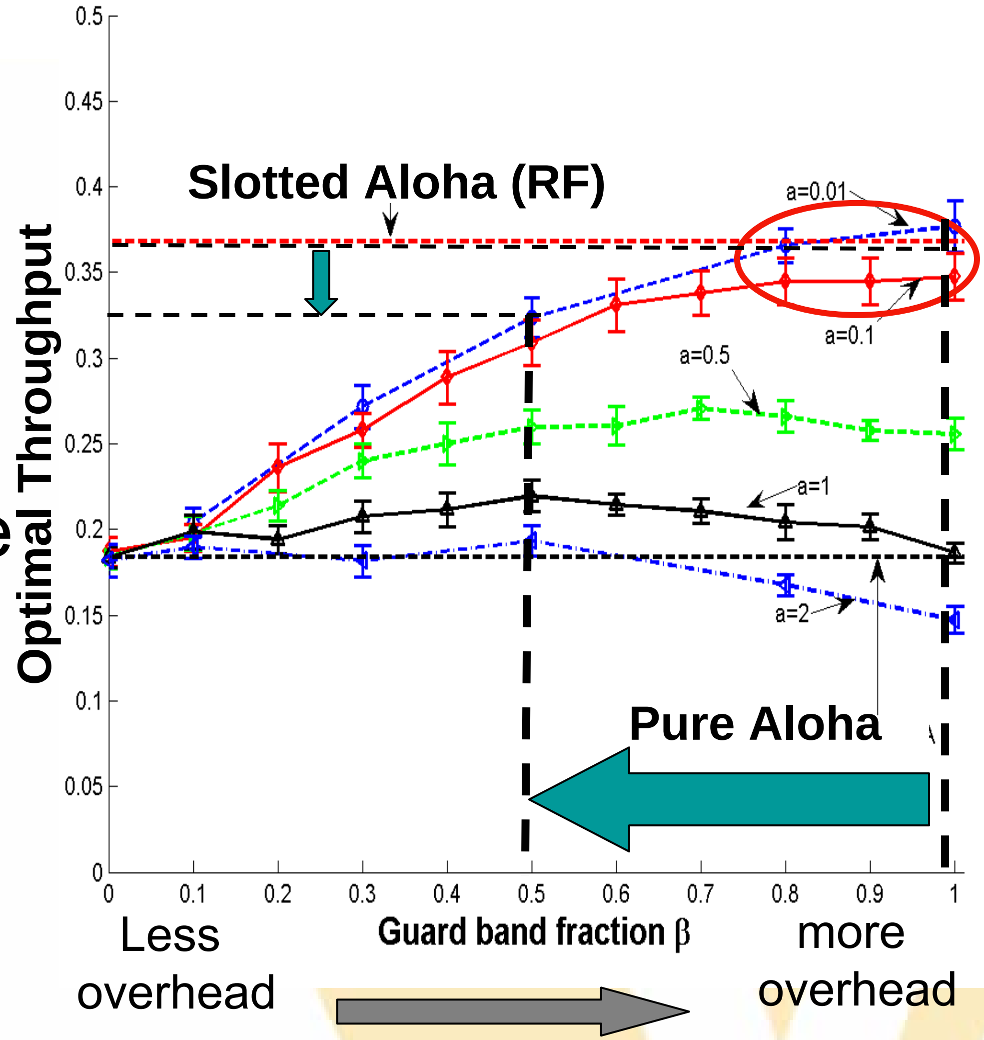
Varying Guard Band (β)

- Tradeoff throughput and overhead
- Short hops = throughput efficient
  - Small *a* can achieve high throughput
- Guard bands can be less than τ_{max}
  - Save on latency



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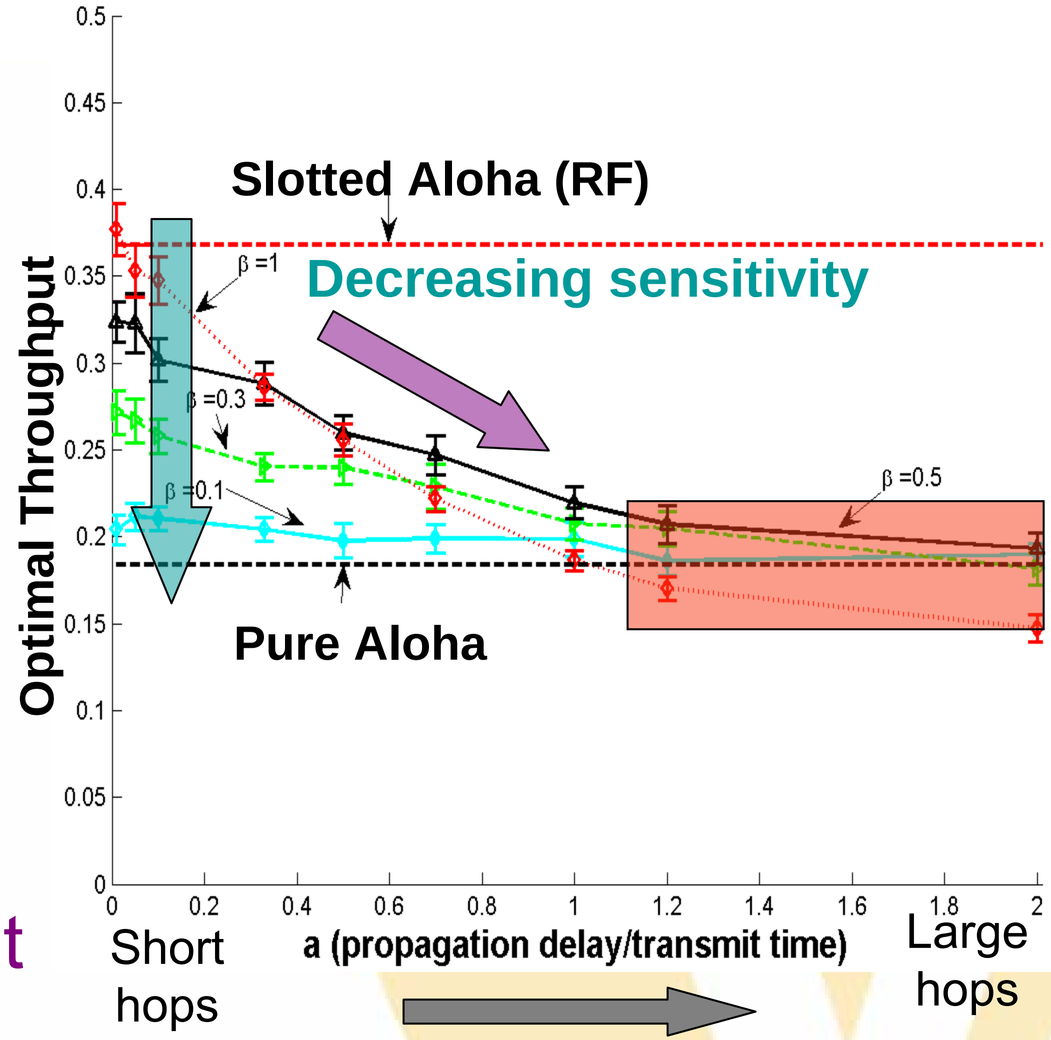
Varying the Delay Regime (*a*)

- Study impact of large latencies
- Guard bands don't help for large delays
  - For delay regime a > 1
- Sensitivity to *delay regime* increases with large guard bands
  - β =0.5 effective over *a* [0,1]
- Monotonically decreasing throughput capacity



First order analysis

- Single receiver, *n* nodes deployed randomly in circular region around it
- Bernoulli arrival process with parameter *p*
- For a>0 and βa ≤ ; optimal throughput is:

$$S^*(\beta, a) = \frac{f(\beta)}{1+\beta a}$$

- The analysis backs our experimental results

Future Work

- Impact of guard bands on latency
- More rigorous analysis

Conclusion

- Space time uncertainty framework:
  - Identify a problem in MAC
  - Propose and analyze solution
- Short hops throughput efficient for ALOHA

Thank you

http://www.isi.edu/ilense/snuse/