An Adaptive Tree Algorithm to Approach Collision-Free Transmission in Slotted ALOHA

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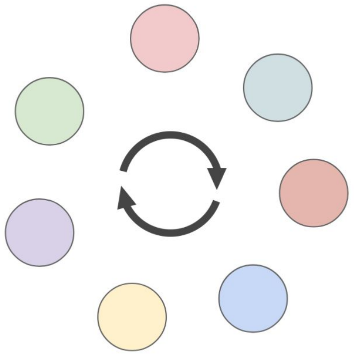
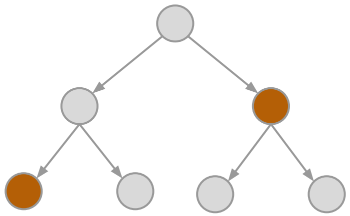
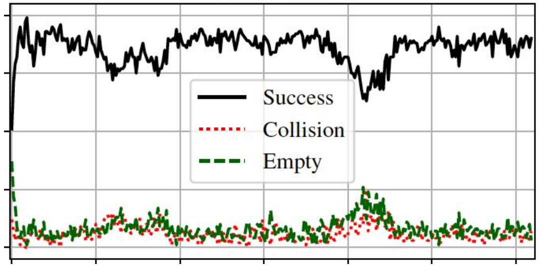
Outline



Problem Statement

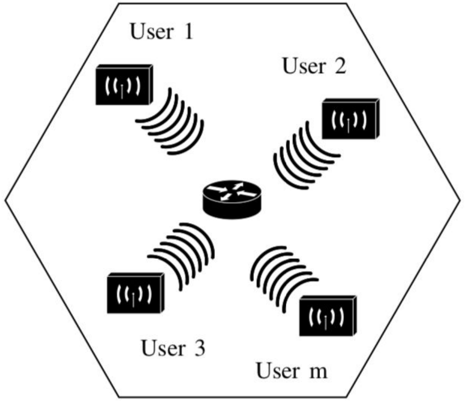


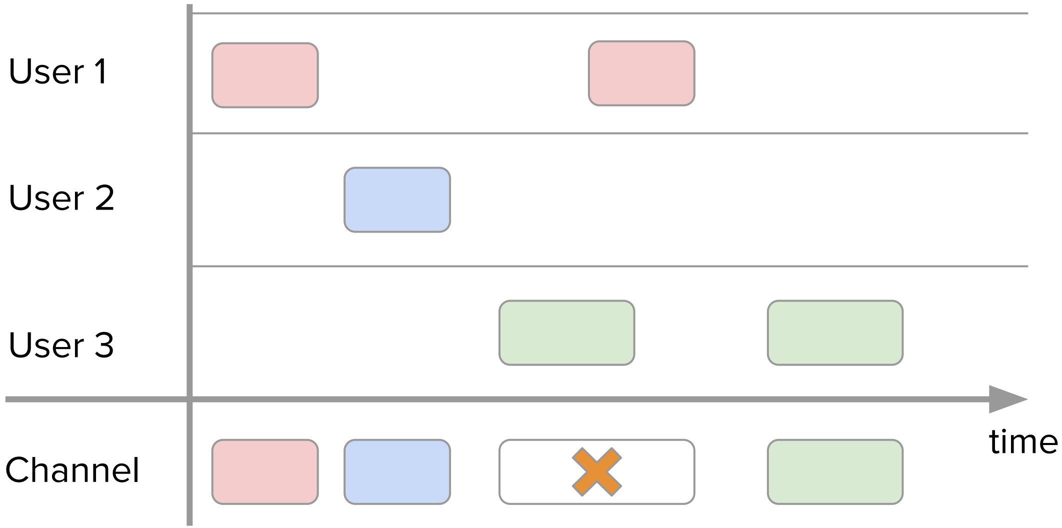
Adaptive Tree ALOHA



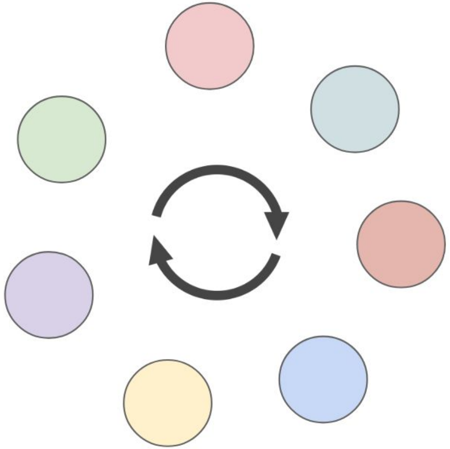
Performance

Setting: Time-Slotted Channel Access



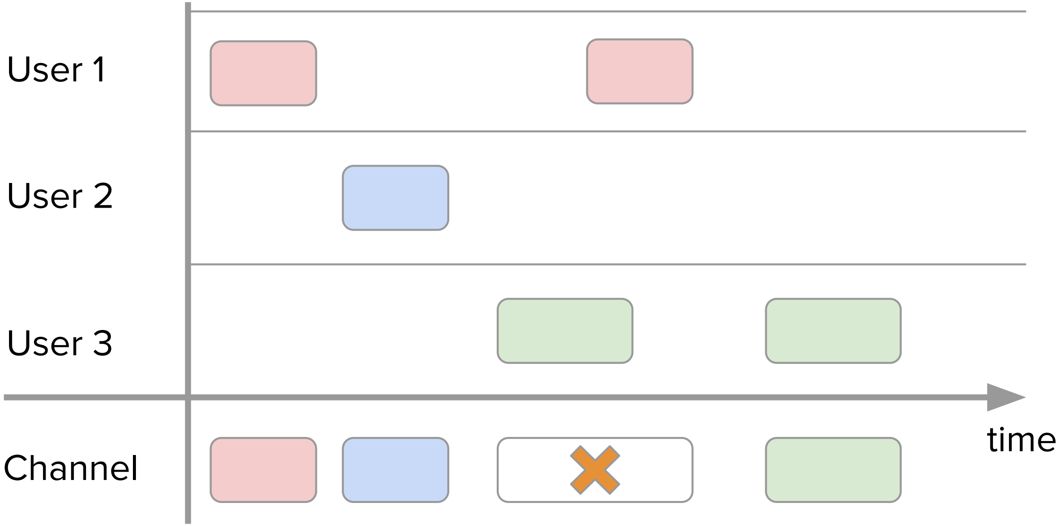


Goal: Learning Coordination in Channel Access



- Turn Taking
- High Network Utilization
- Avoid collisions
- Avoid empty time slots

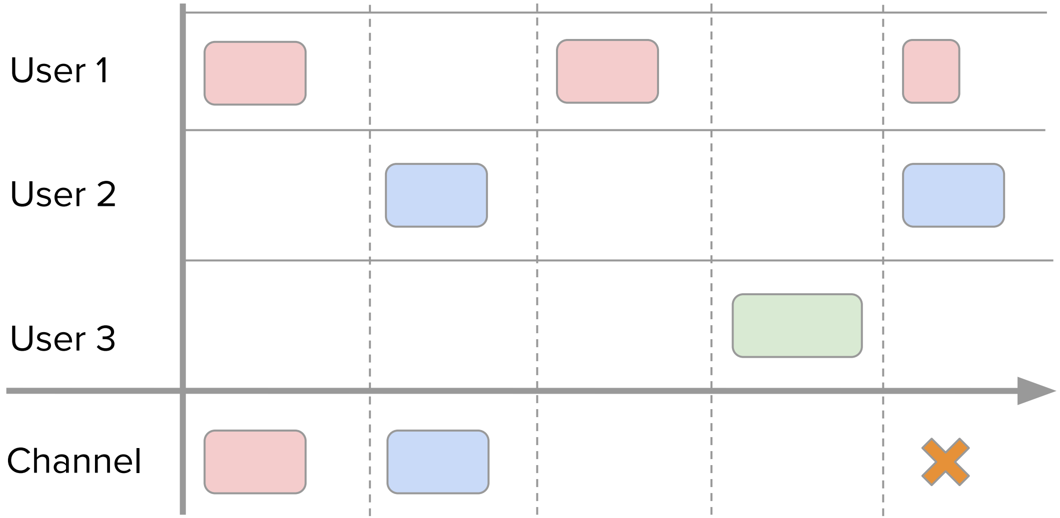
History: ALOHA



ALOHA protocol:
Transmit when you like, and if there are collisions, retry.

Max utilization ≈ 18%

History: Slotted ALOHA



Slotted ALOHA protocol: Time divided to time slots. Transmit at the beginning of time slots.

Max utilization ≈ 37%

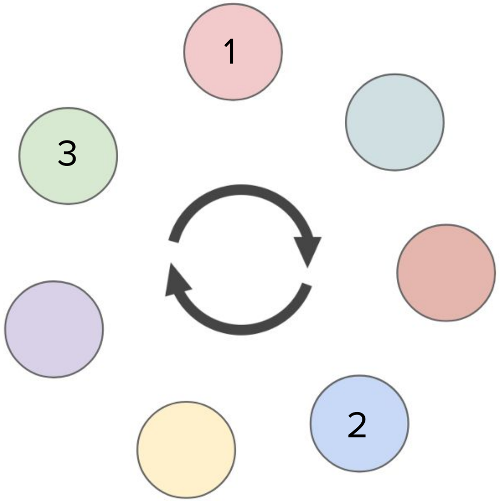
History: Slotted ALOHA with Exponential Backoff

Exponential Backoff

- Transmit with probability p
- Collision: halves p
- Success: doubles p

Max utilization ≈ 100% (very unfair condition)

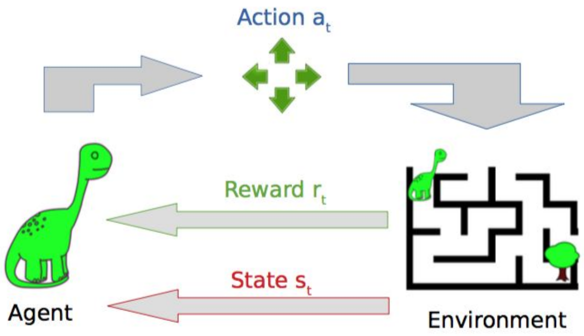
Goal: Learning Coordination in Channel Access



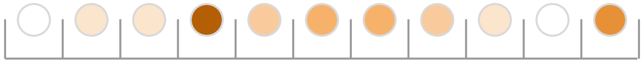
Can we do better?

Can nodes learn to coordinate with Reinforcement Learning or Machine Learning?

Reinforcement Learning and Expert-based Learning

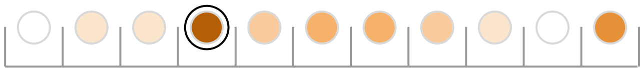


ALOHA-Q: Choosing transmission slot [Chu et al, 2012]



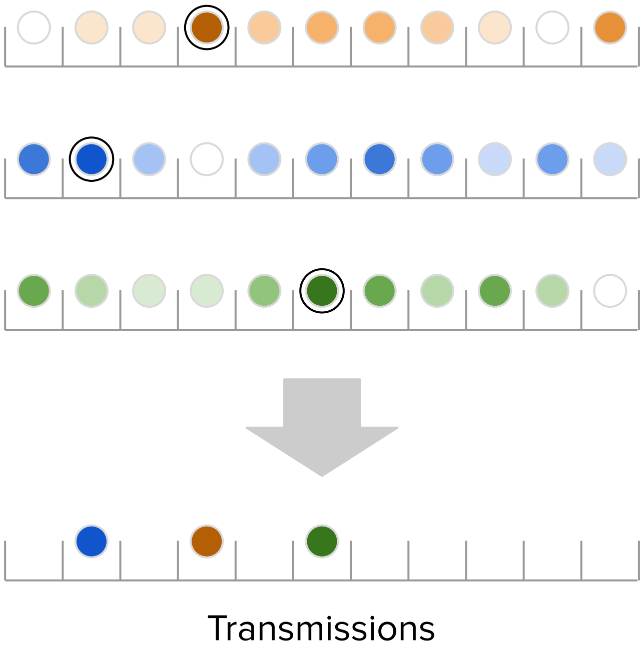
- Learn the weight of slots in a frame.

ALOHA-Q: Choosing transmission slot [Chu et al, 2012]



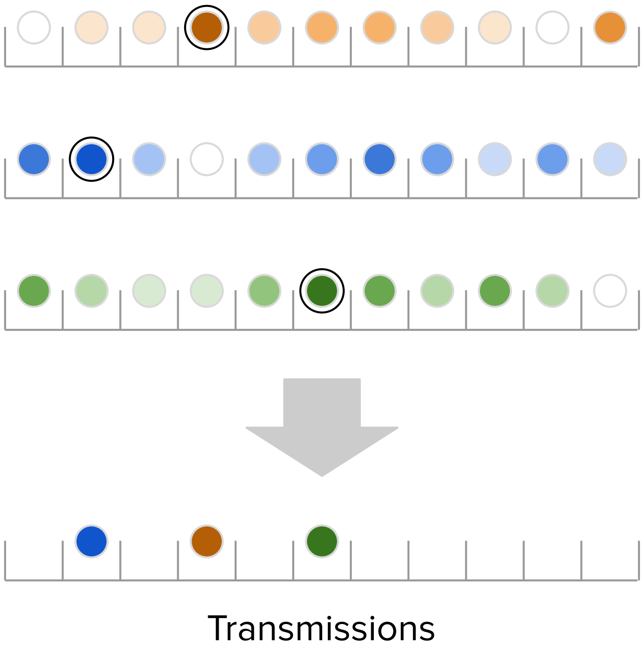
- Learn the weight of slots in a frame.
- Transmit in the highest-weight slot

ALOHA-Q: Choosing transmission slot [Chu et al, 2012]



- Learn the weight of slots in a frame.
- Transmit in the highest-weight slot
- Different nodes learns different slot

ALOHA-Q: Choosing transmission slot [Chu et al, 2012]

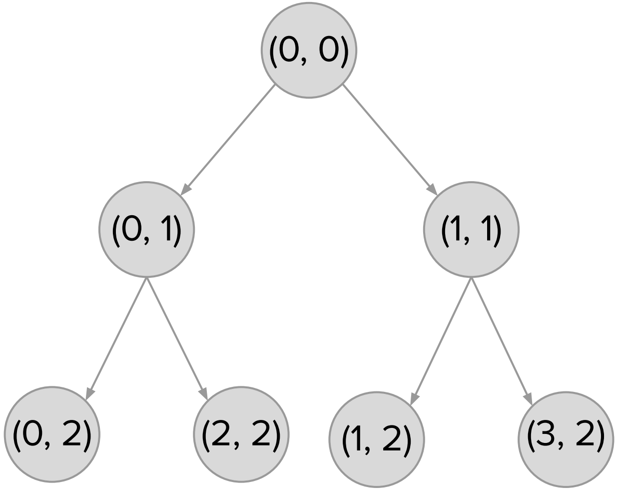


Problems:

- Frame length N selection
- Slow learning

AT-ALOHA

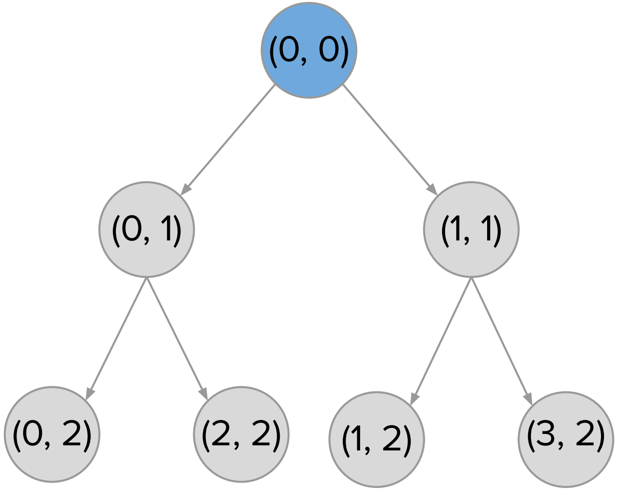
Guide learning and conflict resolution via a policy tree.



(i, m) : transmit at time **i** every $\mathbf{2^m}$ slots

AT-ALOHA

Guide learning and conflict resolution via a policy tree.



AT-ALOHA

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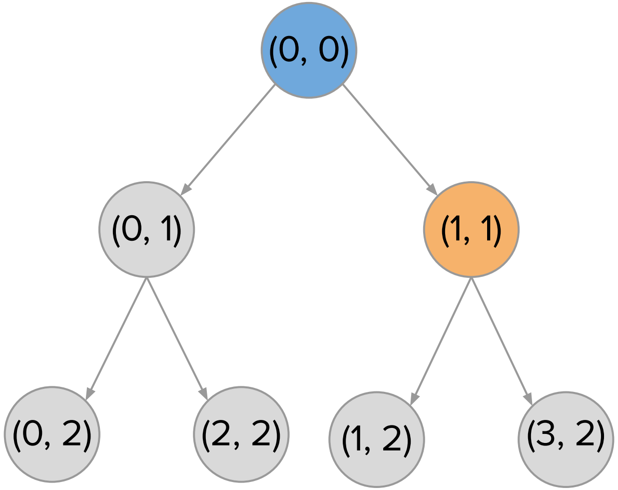

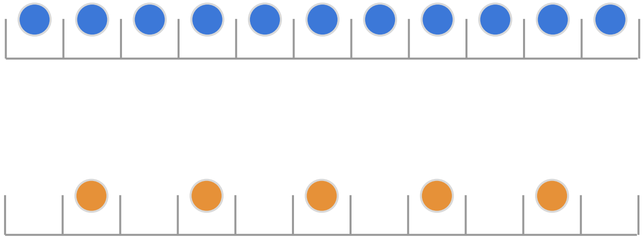

AT-ALOHA

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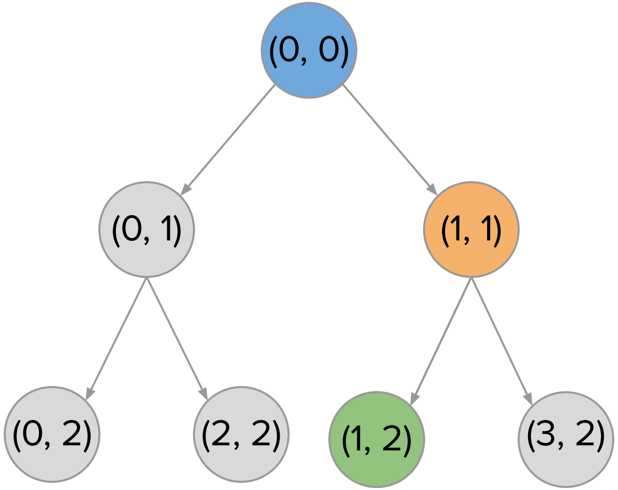
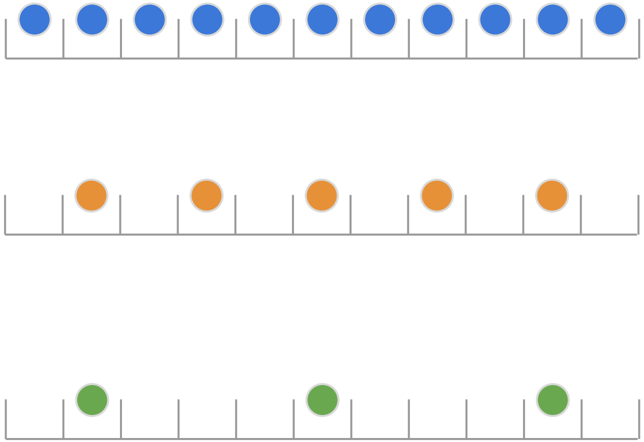
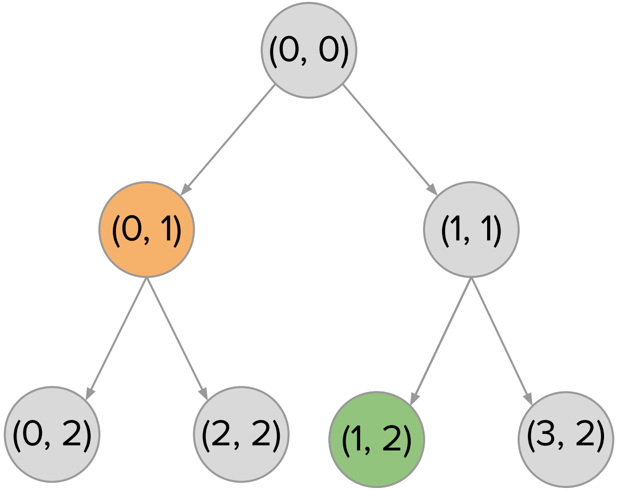




Every child transmits half the times of the parent.

AT-ALOHA

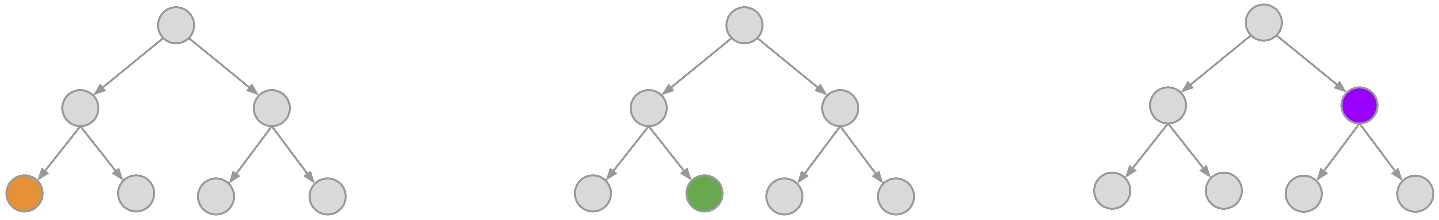
Guide learning and conflict resolution via a policy tree.



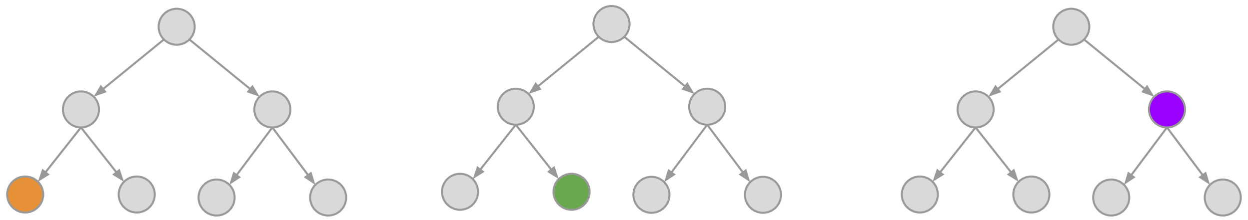
- Nodes that are not one the descendant of the other do not conflict.
- Conflicts are rare. Coordination is facilitated.

AT-ALOHA

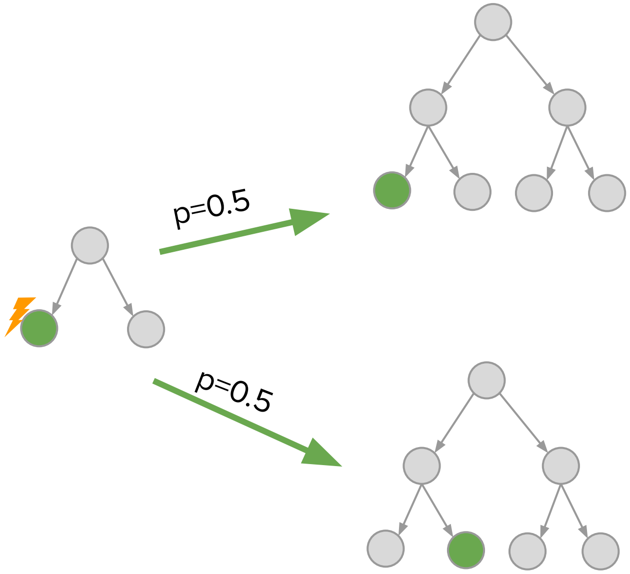
Different nodes learn a different tree to co-exist conflict-free



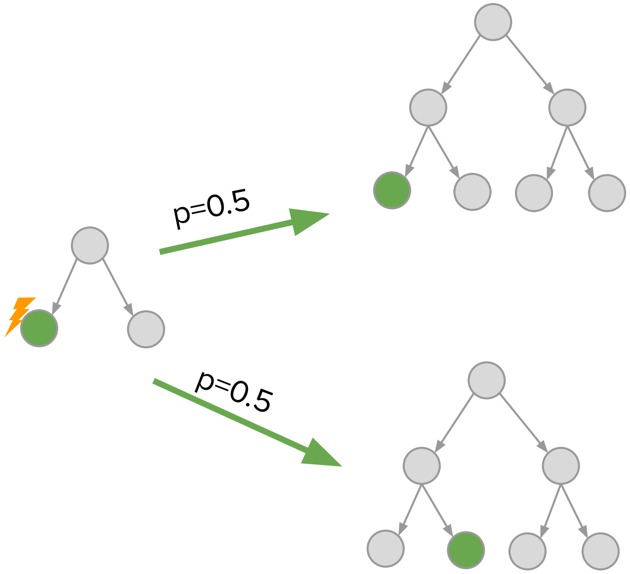
Next: How do the AT-ALOHA nodes learn different trees ?

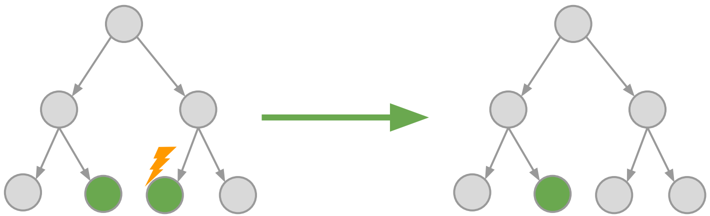


AT-ALOHA Update: Demotion After Collision

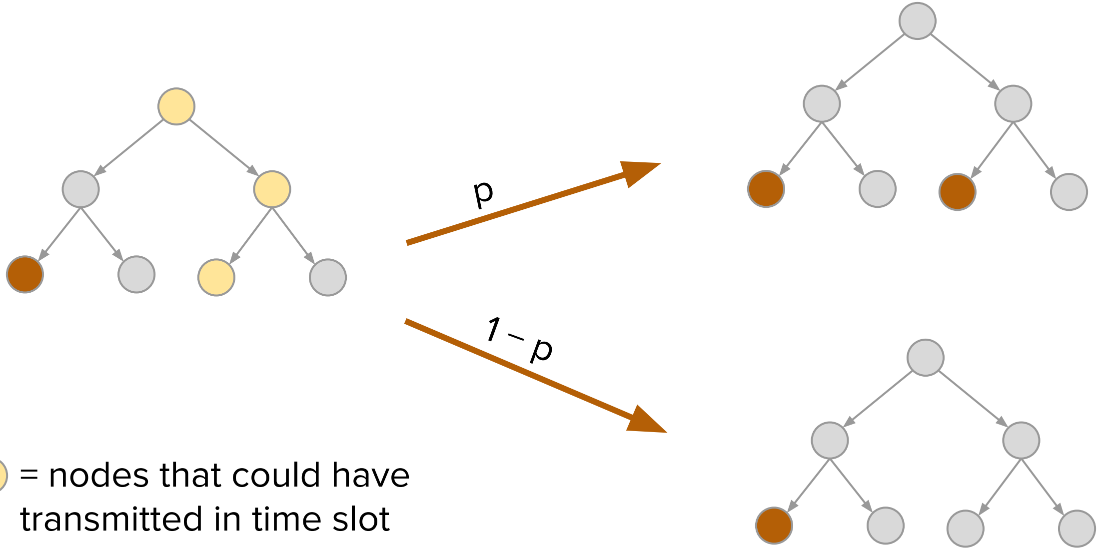


AT-ALOHA Update: Demotion After Collision





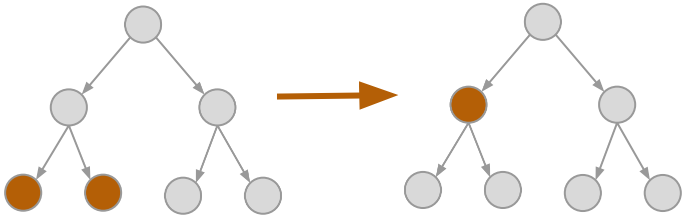
AT-ALOHA Update: barge into empty slots



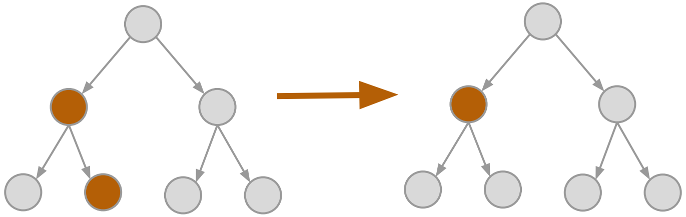
The *barge-in* probability p is tuned based on the number of active nodes in a network.

= nodes that could have transmitted in time slot

AT-ALOHA Update: Normalization



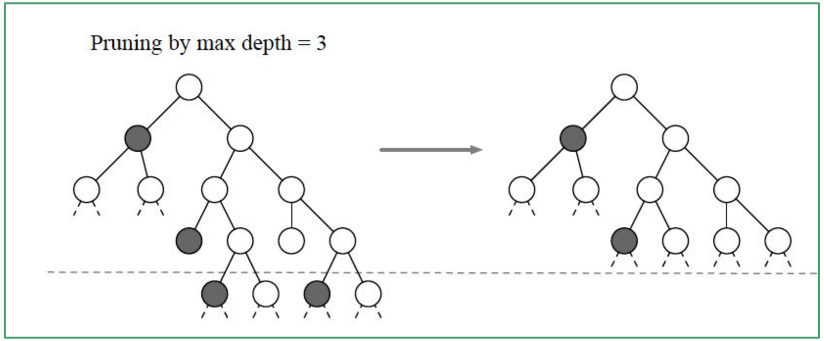
merge sibling nodes

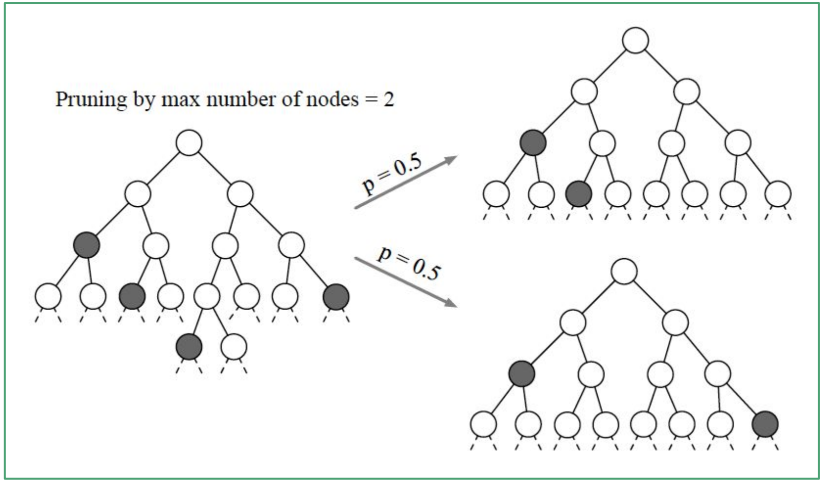


remove redundant descendants

AT-ALOHA Update

Pruning to max depth and max number of nodes





AT-ALOHA: additional tuned parameters

- Maintaining 5% empty slots
  - “Transmission Tax”: a node has to give up its transmission policy at a small probability

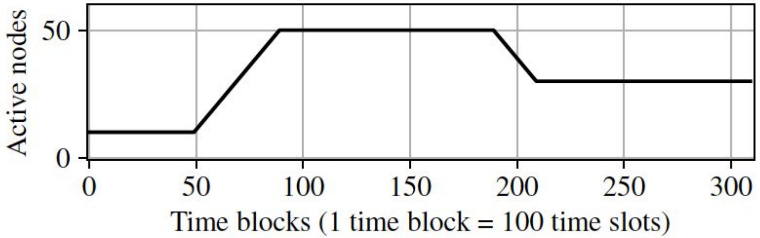
- Maintaining a constant (1.4) empty-to-collision ratio
  - By tuning barge-in probability
  - Maximize likelihood of only one transmitting into empty slot

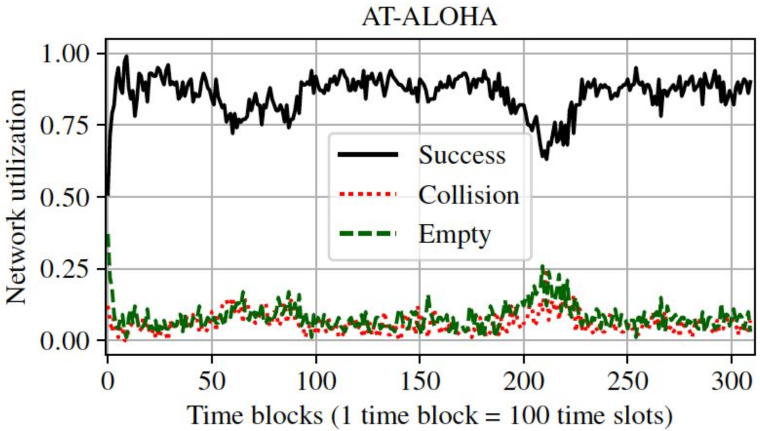
AT-ALOHA Performance Metric

- Network Utilization: Ratio of successful transmission
- Fairness Metric: Jain index

$$J = \frac{B^2}{n \sum_{i=1}^{n} b_i^2}$$

AT-ALOHA Performance

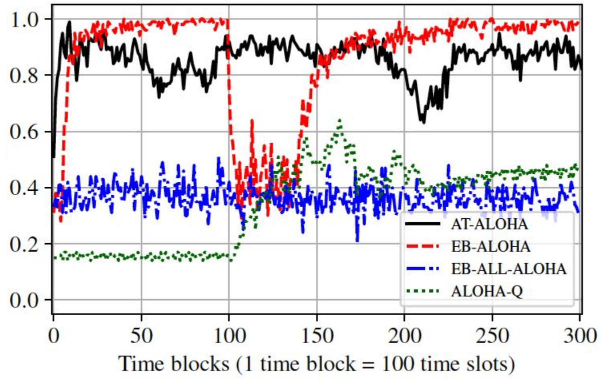




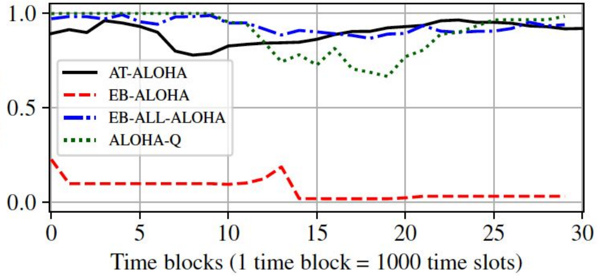
- 10 nodes -> 50 nodes -> 30 nodes
- High Utilization and Low Empty slots or Collisions throughout

AT-ALOHA Performance comparison

Network Utilization



Fairness

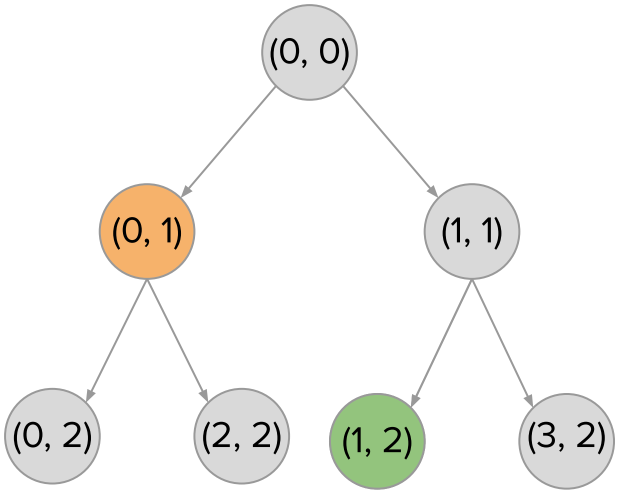


- AT-ALOHA
- EB-ALOHA: ALOHA with exponential backoff
- EB-ALL-ALOHA: ALOHA with exponential backoff applied to all nodes
- ALOHA-Q: Chu et al.

AT-ALOHA has both high network utilization and high fairness under varying network conditions

Conclusions

- We introduced a “Adaptive Tree” ALOHA protocol.
- Learns to maintain high utilization and fairness under varying network condition



Thank you!