Tight Trade-off in Contention Resolution without Collision Detection

Yonggang Jiang

Nanjing University

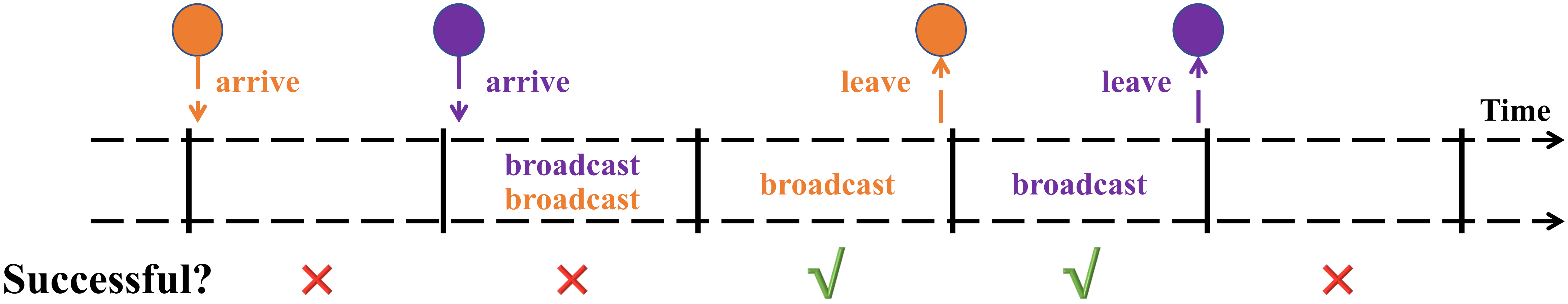
Joint work with: Haimin Chen (Nanjing University)

Chaodong Zheng (Nanjing University)

PODC 2021

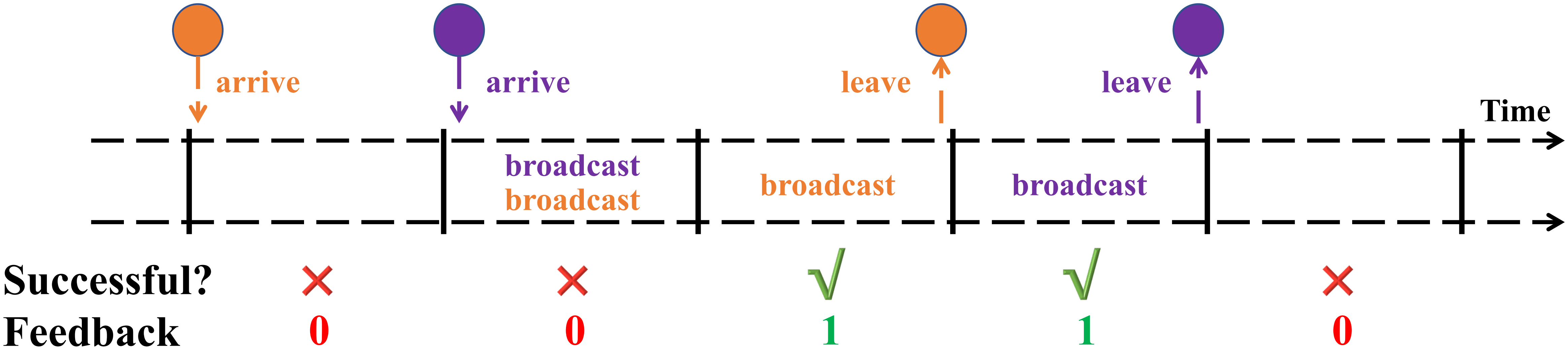
Shared channel

- Time is divided into synchronized slots.
- Nodes arrive over time.
- Each slot, each node either broadcast or idle.
- Successful broadcast happens if **exactly one** node broadcasts in a slot.



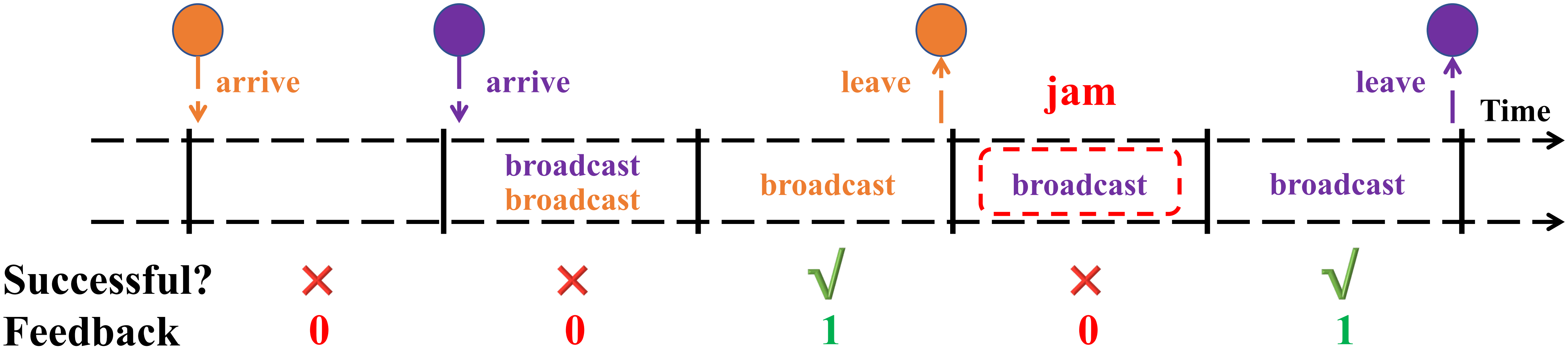
Feedback

- The feedback is $\begin{cases} 0 \text{ (not success)} \\ 1 \text{ (success)} \end{cases}$



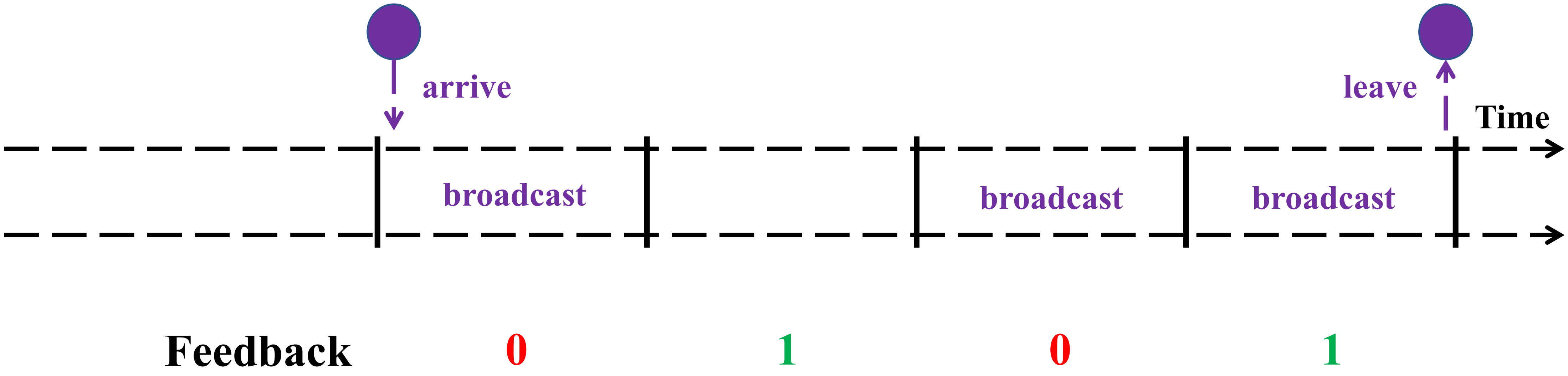
Jamming

- A slot can be jammed, in which case the slot is always unsuccessful.



The view of one node

- No global clock.
- Behavior of each node: based on feedback.



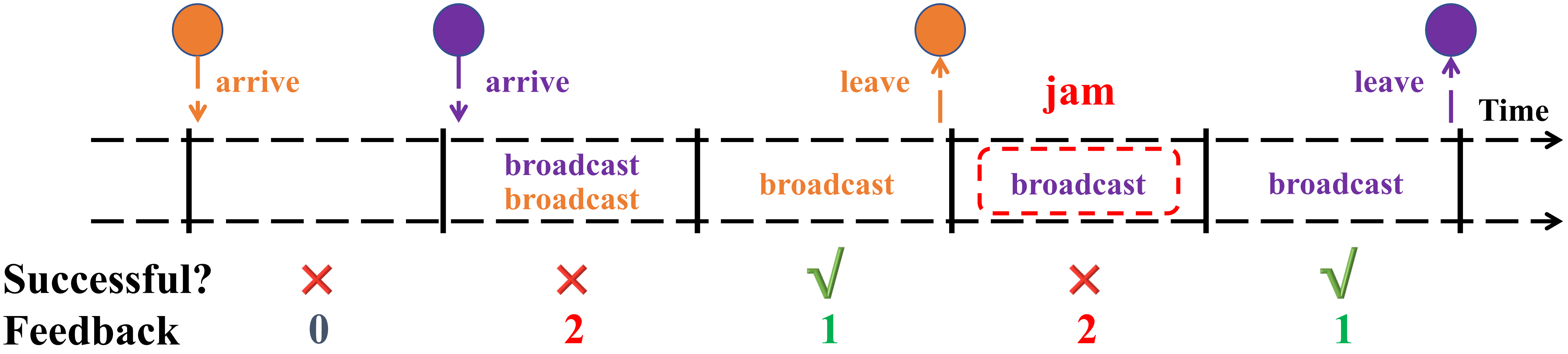
Goal: achieving high throughput

- Throughput: the fraction of successful slots.
- Question: What is the optimal throughput one can achieve, given different fraction of jammed slots?

- **This paper:** Answer this question by proving tight upper bound and lower bound.
- What if the adversary is guaranteed to jam
  - Constant fraction slots? Answer: The best algorithm achieve $\Theta(\log n)$ throughput.
  - $\frac{1}{2^{\sqrt{\log n}}}$ fraction? Answer: The best algorithm achieve $\Theta(\log n)$ throughput.
  - $\ldots$
  - $\frac{1}{g}$ fraction? Answer: The best algorithm achieve $\Theta(\log n \,/\, \log^2 g)$ throughput.

Collision Detection

- Suppose n nodes broadcast in a slot. The feedback is $\begin{cases} 0\ (n = 0, \text{empty}) \\ 1\ (n = 1, \text{success}) \\ 2\ (n \geq 2, \text{noise}) \end{cases}$



Previous results

	With Collision Detection	**Without Collision Detection**
Without jamming	-	Constant throughput [Bender, Kopelowitz, Kuszmaul, Pettie 20]
With jamming (constant fraction)	Constant throughput [Bender, Fineman, Gilbert, Young. 18]	$\Theta(\log n)$ throughput Our result

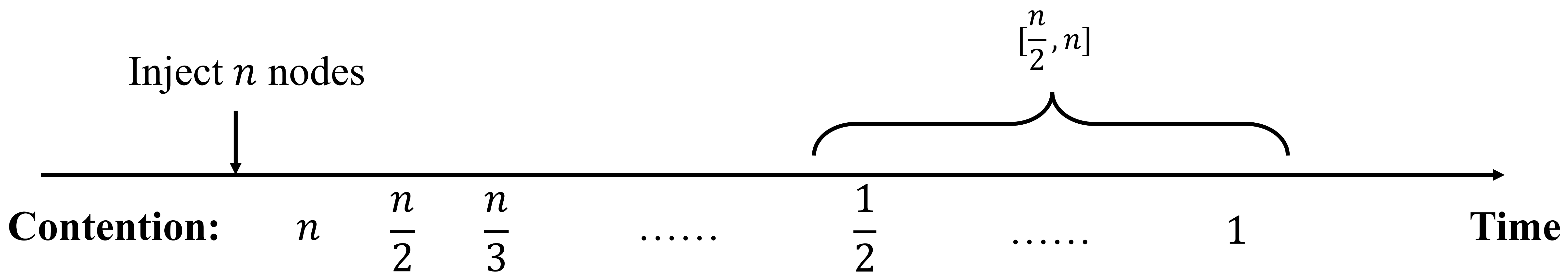
- Our work close the gap of the contention resolution problem with jamming, and without collision detection.

Outline

- [Bender, Kopelowitz, Kuszmaul, Pettie 20] The contention resolution problem can be reduced to two facts (not correct when there are jamming).
- Proposed new changed algorithm and facts that fit the situation with jamming.
- Prove lower bounds.

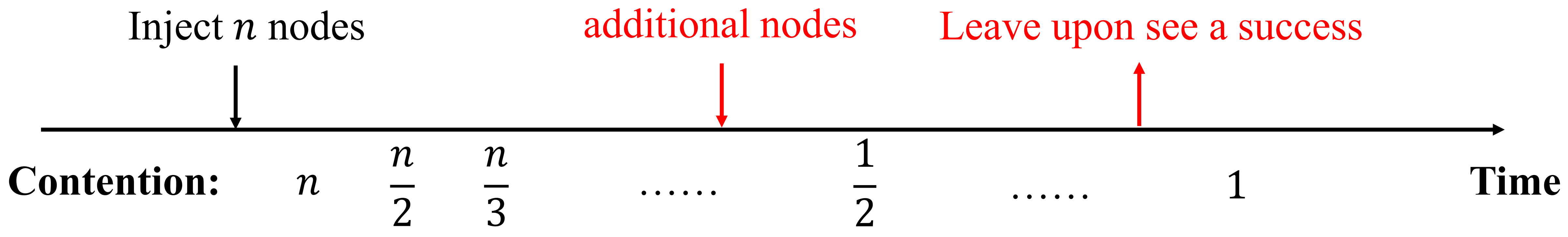
Exponential backoff

- Each node broadcasts with probability $1/i$ in the i-th slot, after arriving the system.
- If n nodes arrive in the first slot (with no additional nodes), $\Theta(n)$ successes happens in slots $[\frac{n}{2}, n]$.



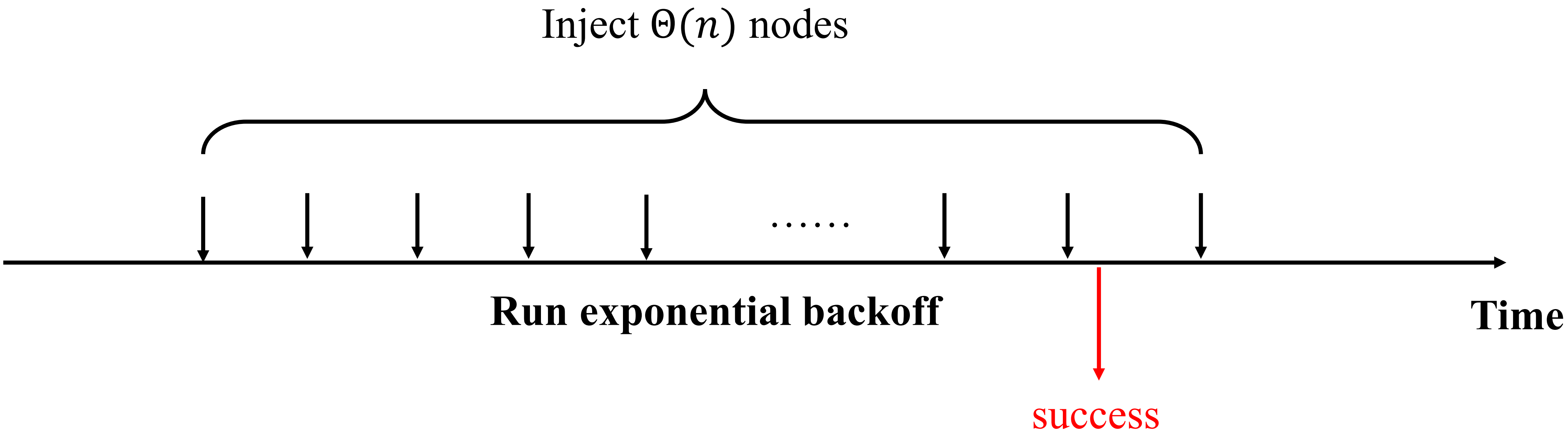
Exponential backoff

- **Fact 1:** Even with $\Theta(n)$ additional nodes that will leave the system upon seen any success slot, $\Theta(n)$ successes happens in slots $[\frac{n}{2}, n]$.
- ***Fact 1** is still correct even with constant jamming.



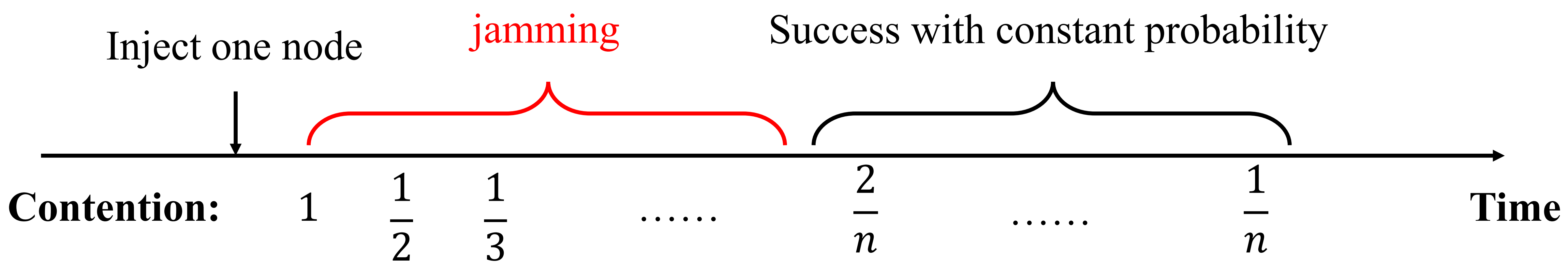
Exponential backoff

- **Fact 2:** $O(n)$ nodes arrive arbitrarily, at least one success will happen.



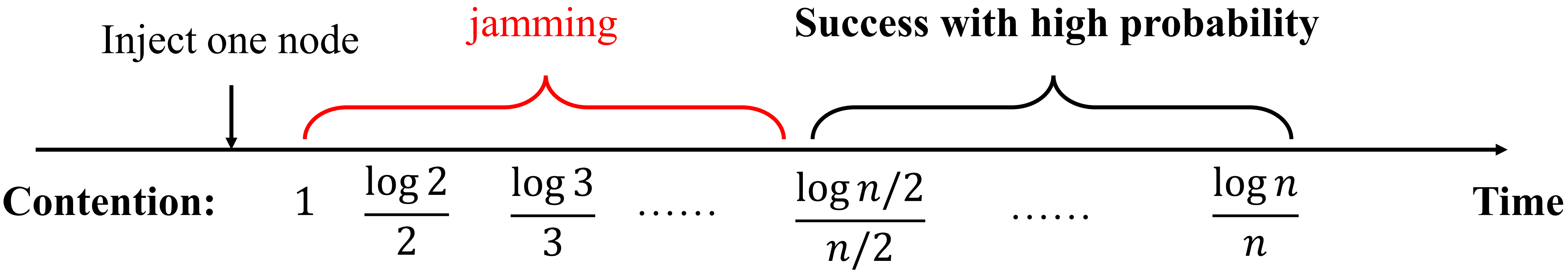
Exponential backoff

- **Fact 2** is not correct with constant fraction of jamming!



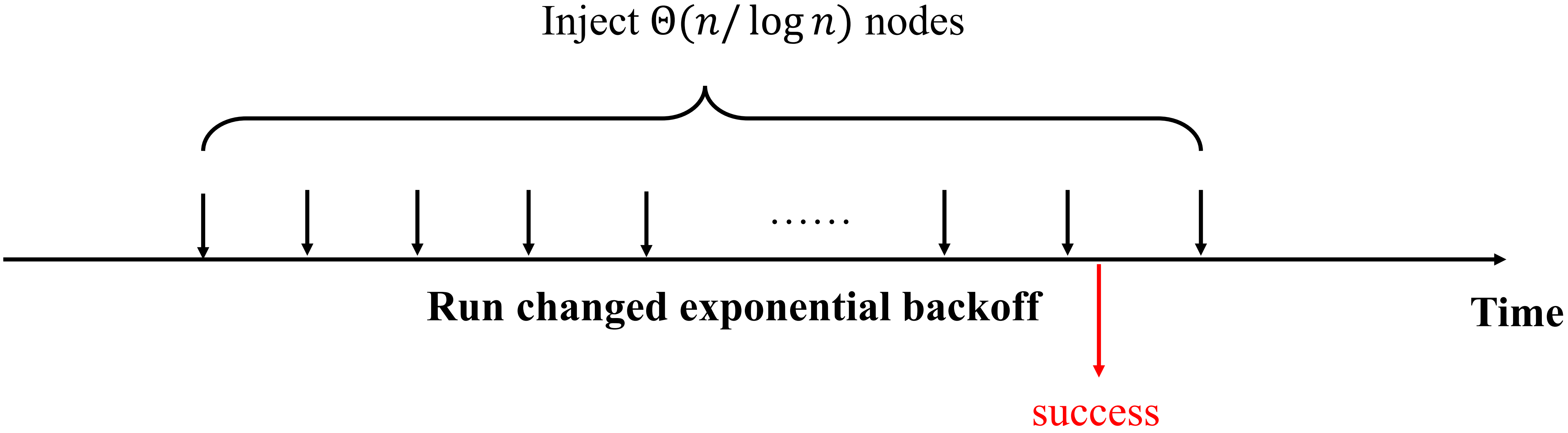
Changed Exponential backoff

- Our change: send with probability $\frac{\log i}{i}$.
- More general: send with probability $\frac{f(i)}{i}$, where $f(i)$ depends on the guaranteed fraction of jamming.



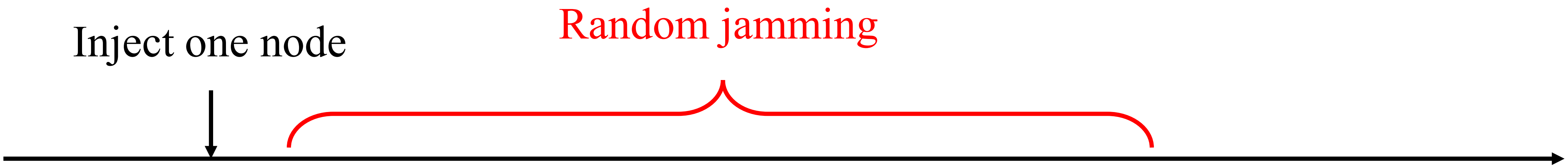
Changed Exponential backoff

- **Fact 2 (new):** $O(n/\log n)$ nodes arrive arbitrarily, at least one success will happen.



Lower bound

- Stronger results: no success in the first t slots, with $O(t/\log t)$ arriving and constant jamming.
- Consider the expected broadcast time of one node in the first t slots, **before seeing the first success**.
  - If it is too small: Broadcast with low probability.



Lower bound

- Consider the expected broadcast time of one node in the first t slots, **before seeing the first success**.
  - If it is too large: Collision happens with high probability.