

# Mysticeti

The new core of the Sui blockchain

Alberto Sonnino

# Tailoring the Talk

## Do you know:

1. How blockchains work (roughly)?
2. What Byzantine Fault Tolerance (BFT) means?
3. What DAG-based consensus are?
4. How Narwhal / Bullshark work (roughly)?

# Byzantine Fault Tolerance



$> 2/3$



# Byzantine Fault Tolerance



$\geq 2f+1$



$3f+1$

# Partial Synchrony



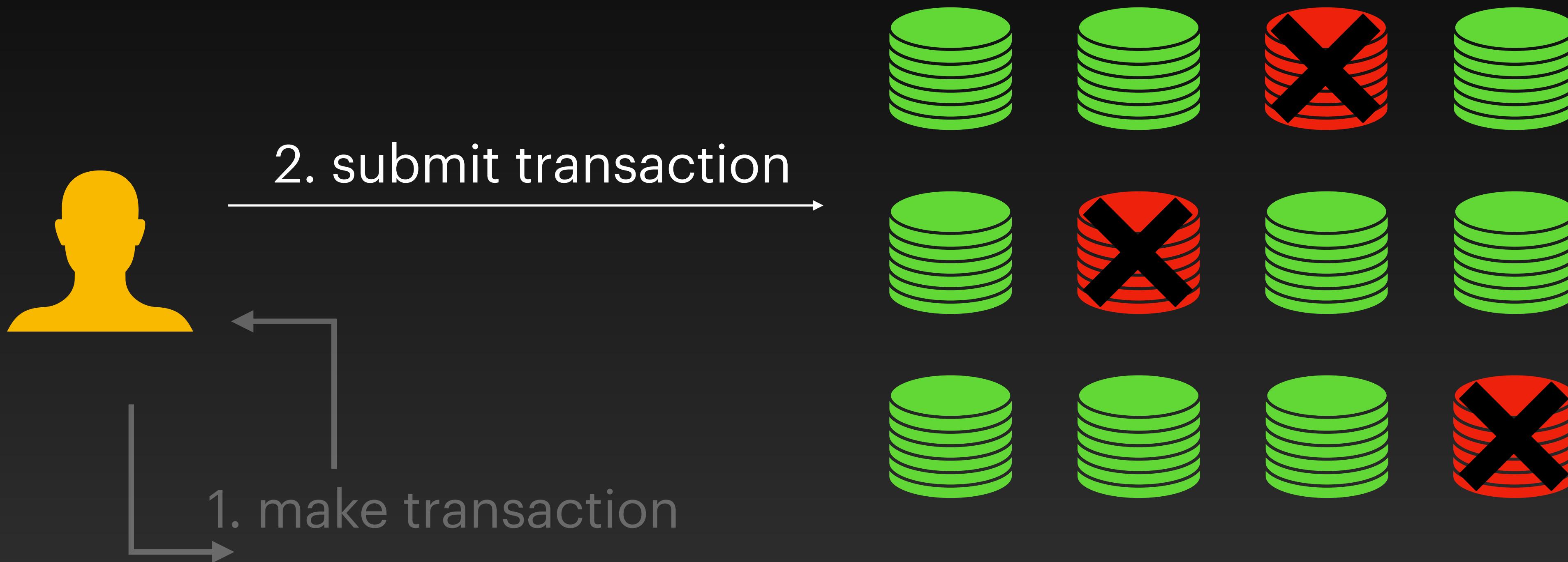
# Blockchains



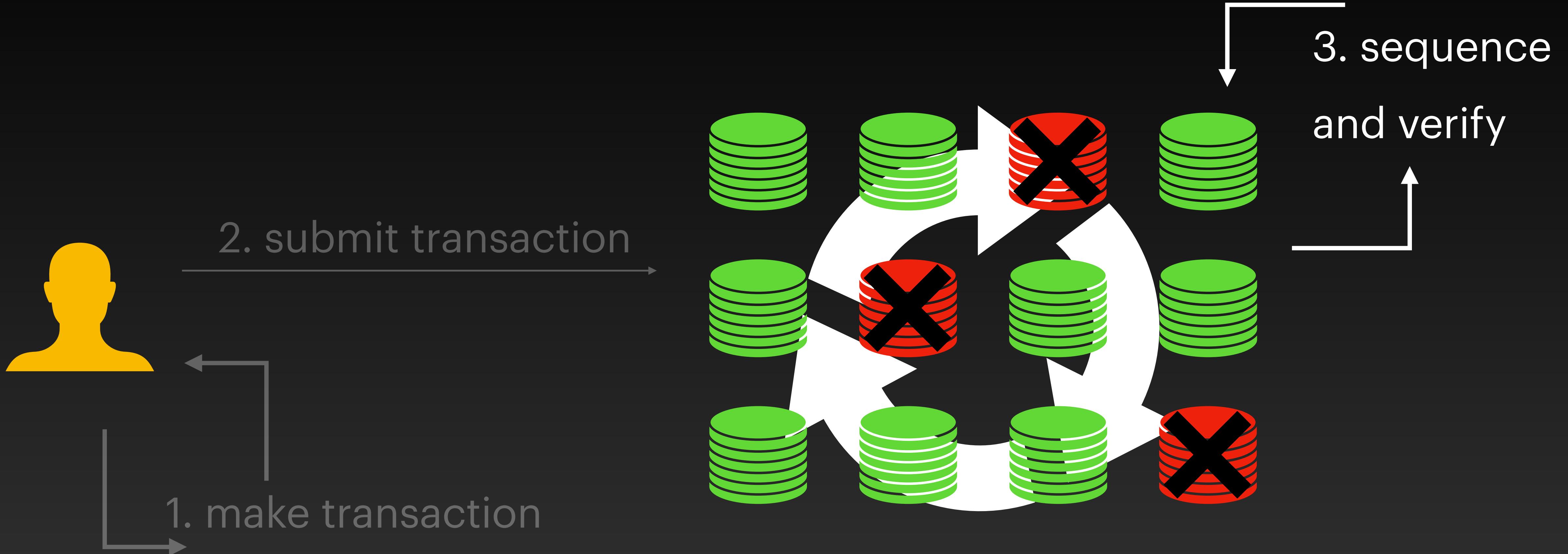
1. make transaction



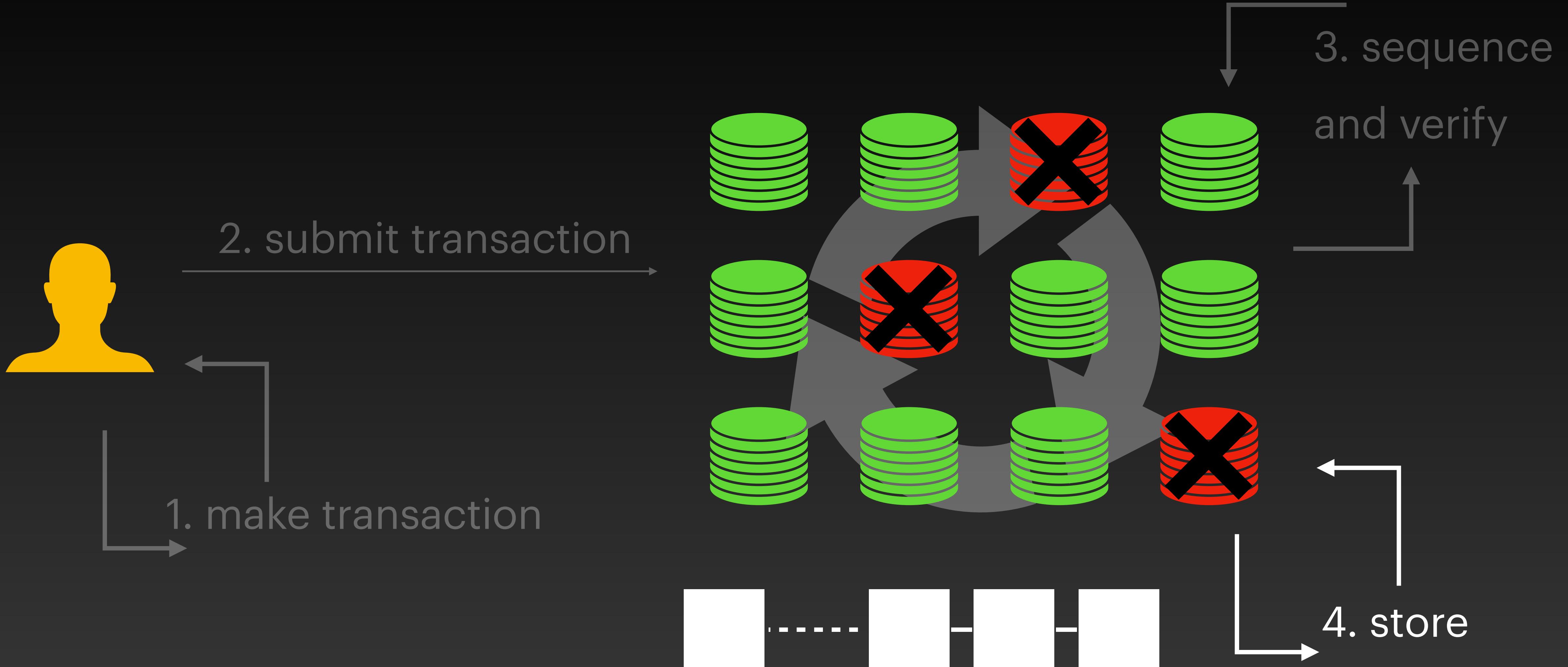
# Blockchains



# Blockchains



# Blockchains



# Keeping the Talk Short

## In scope

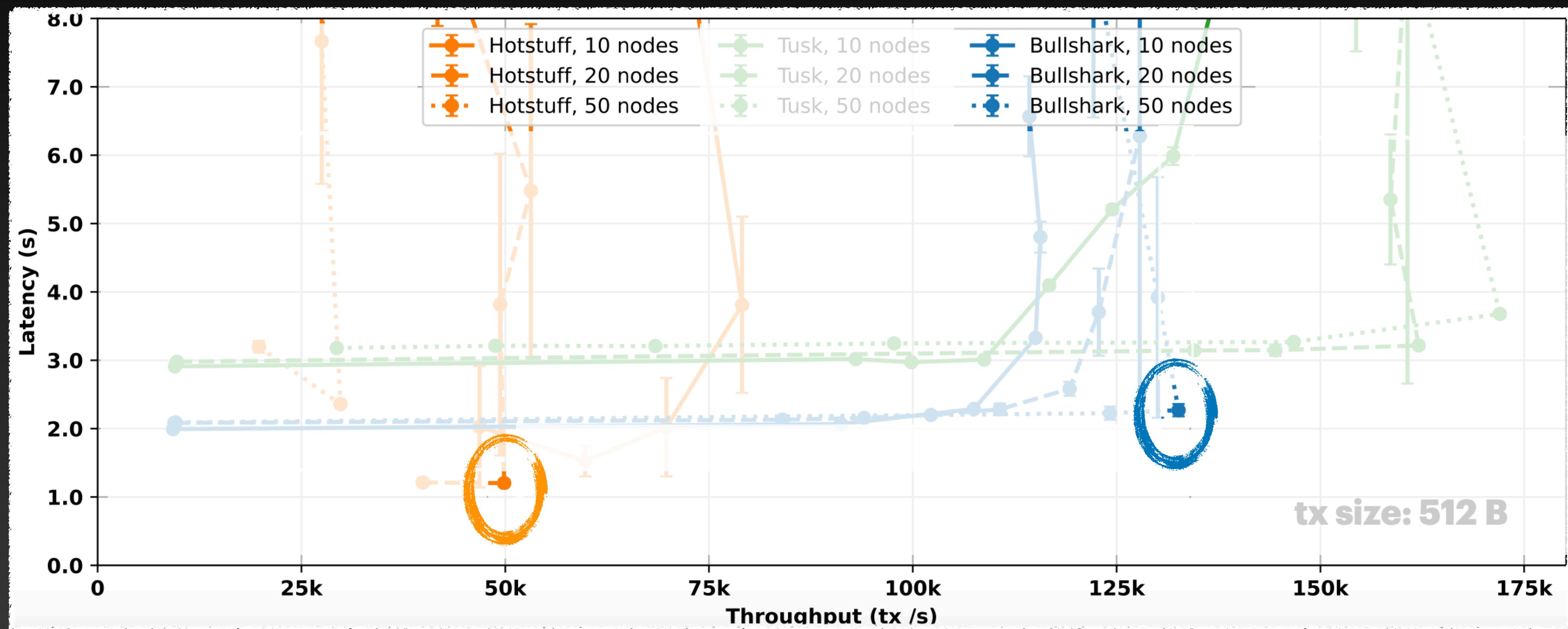
- Ordering (quorum-based)



## Not in scope

- Nodes selection?
- Committee reconfiguration?
- Transactions execution?
- Transactions language?
- Financial incentives?
- etc

# Why? Latency



# Why? Crash Faults

In a year of running Sui:

# Why? Crash Faults

In a year of running Sui:

- How many Byzantine faults?

# Why? Crash Faults

In a year of running Sui:

- How many Byzantine faults? 0

# Why? Crash Faults

In a year of running Sui:

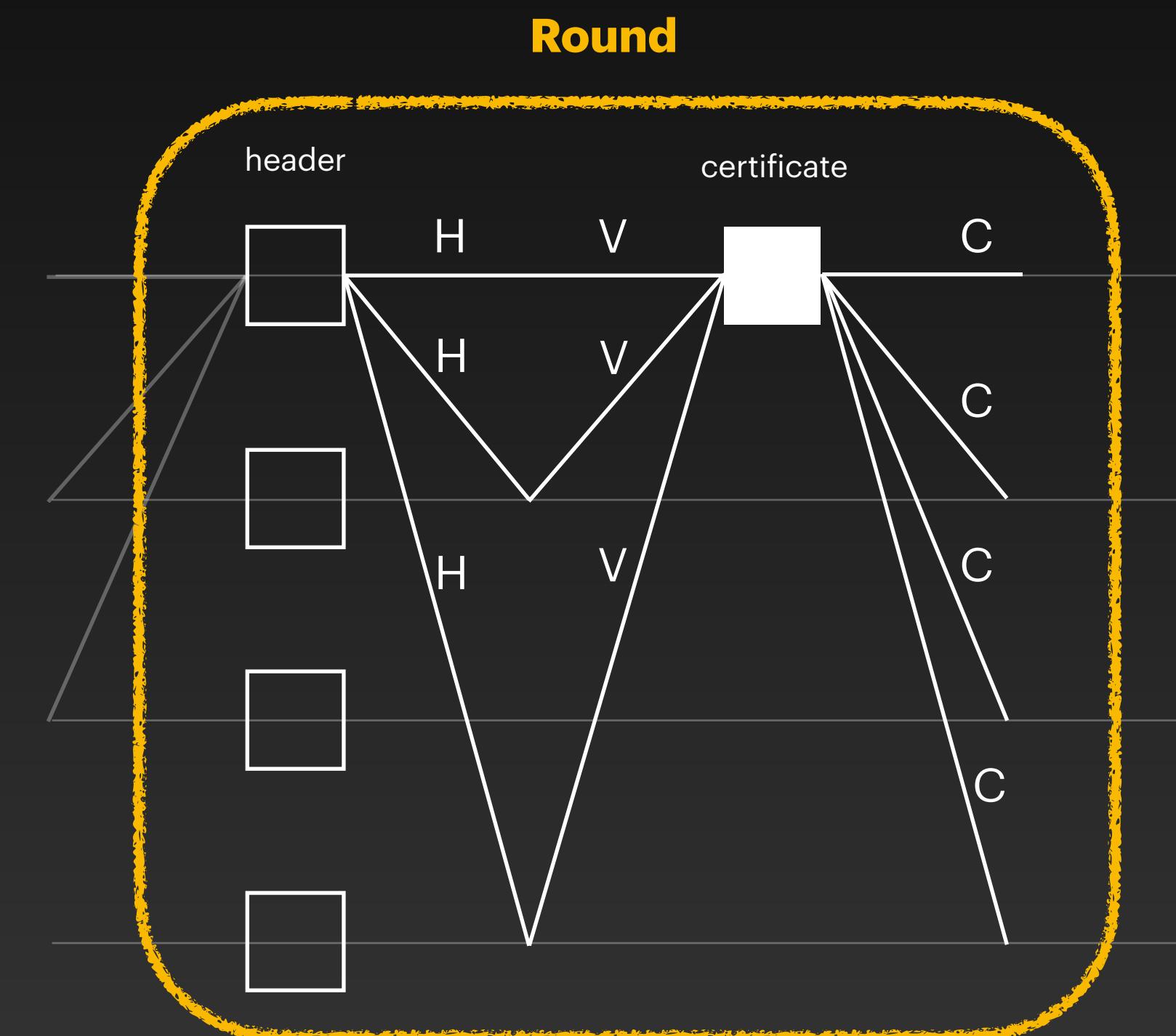
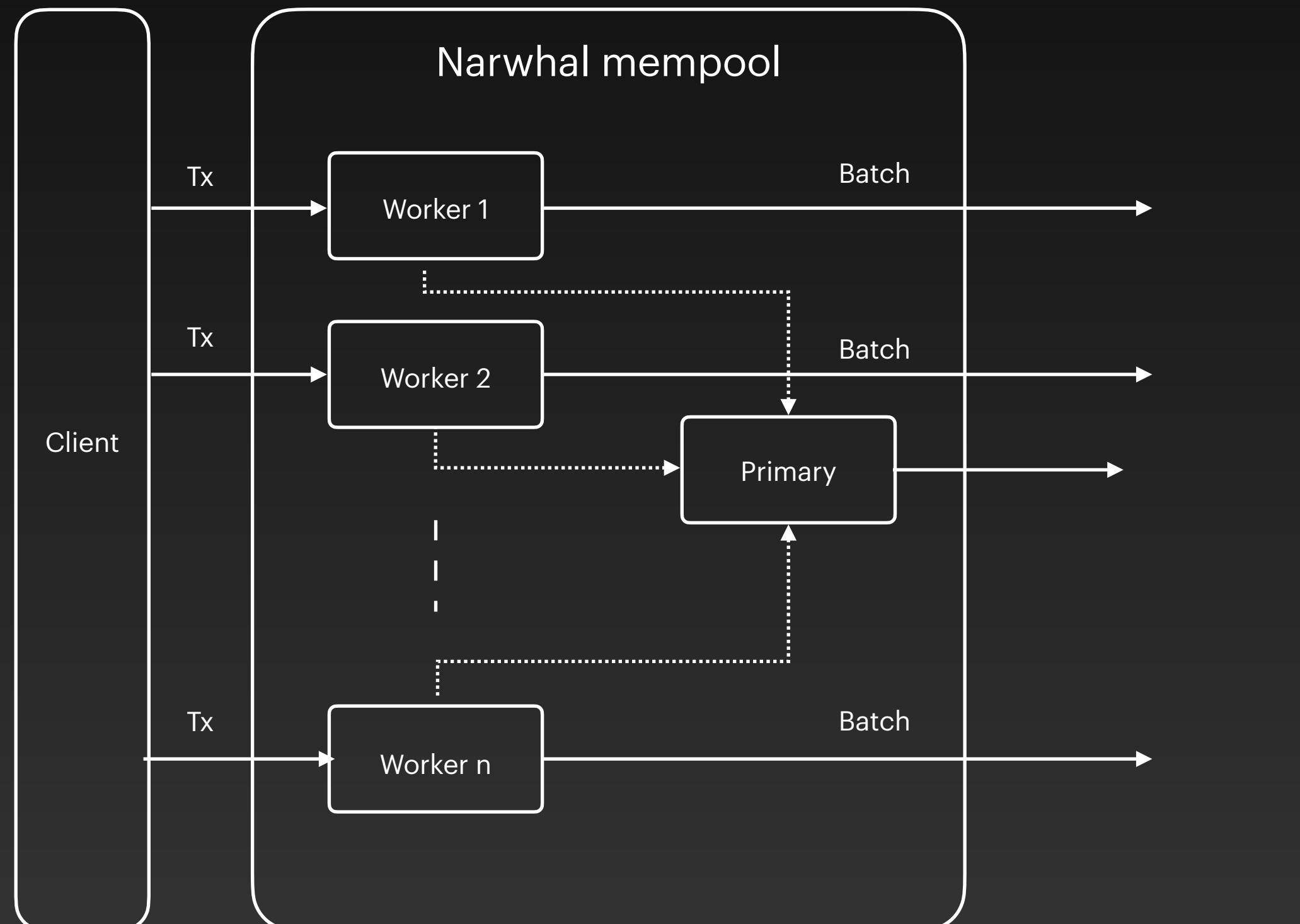
- How many Byzantine faults? 0
- How many Crash faults?

# Why? Crash Faults

In a year of running Sui:

- How many Byzantine faults? 0
- How many Crash faults? 😭

# Why? Engineering Complexity



# Lamport Diagram

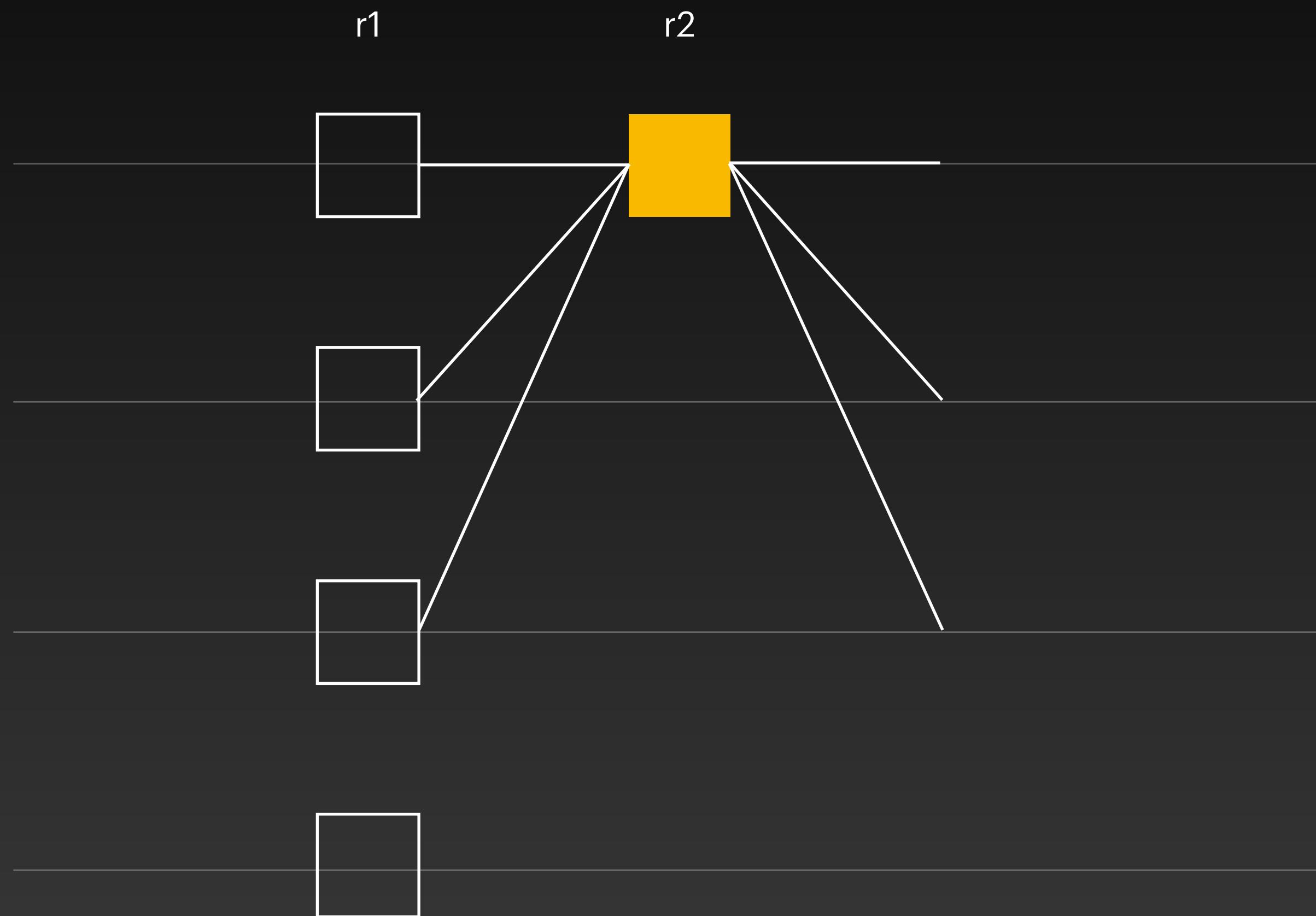


# The Mysticeti DAG

Uncertified DAG

# The Mysticeti DAG

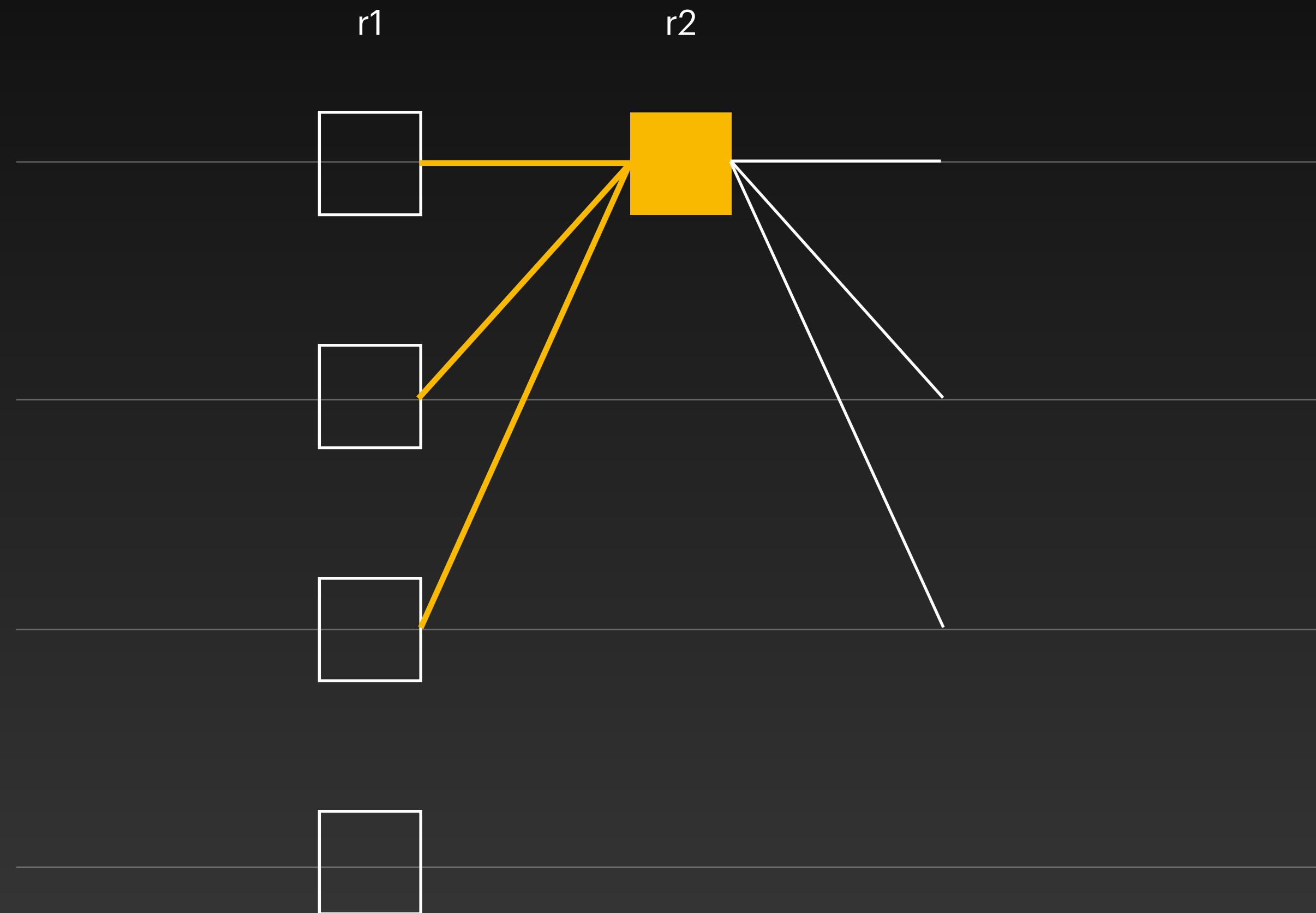
## Block Creation



- Round number
- Author
- Payload (transactions)
- Signature

# The Mysticeti DAG

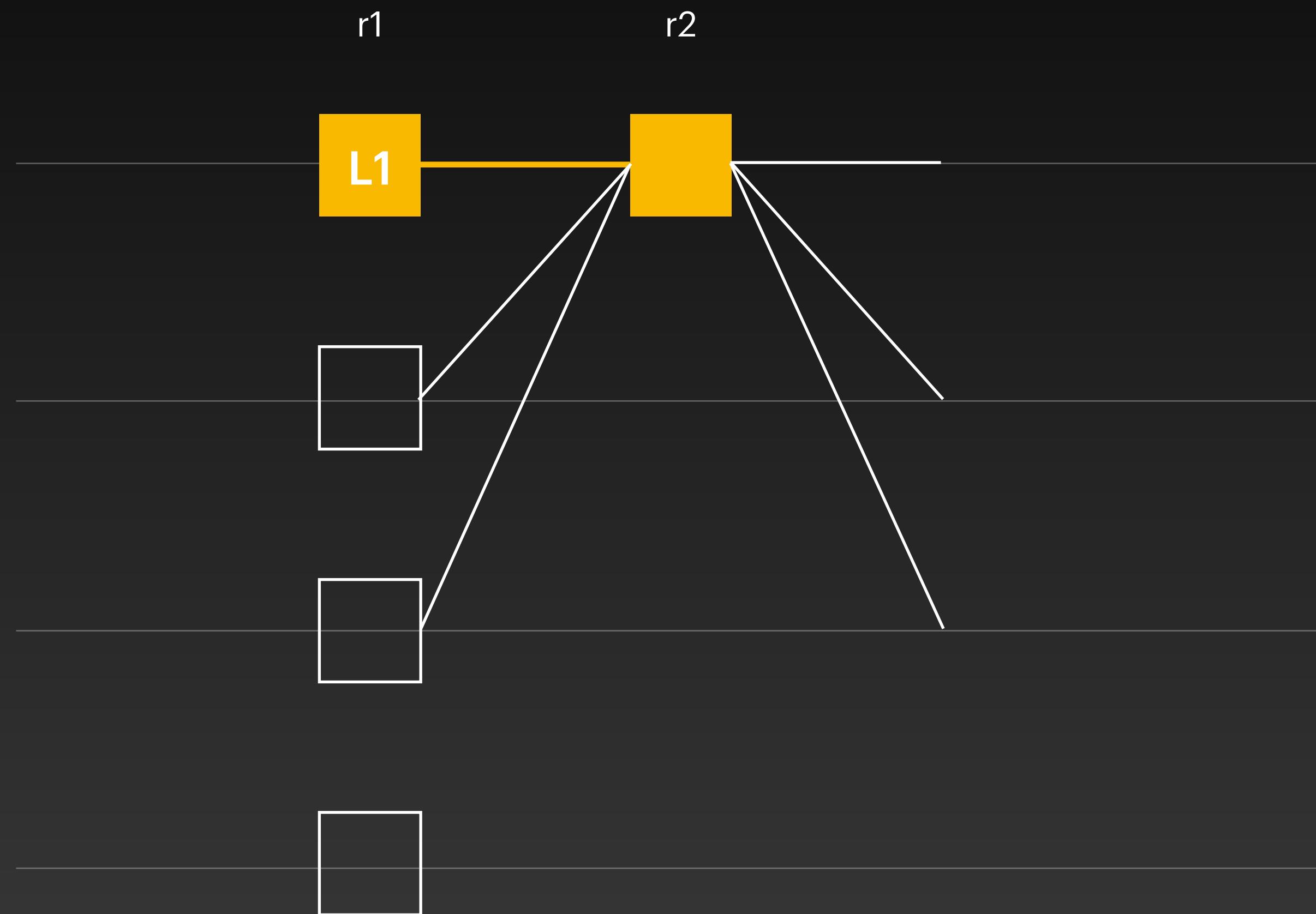
## Rule 1: Link to $2f+1$ parents



- Total nodes:  **$3f+1 = 4$**
- Quorum:  **$2f+1 = 3$**

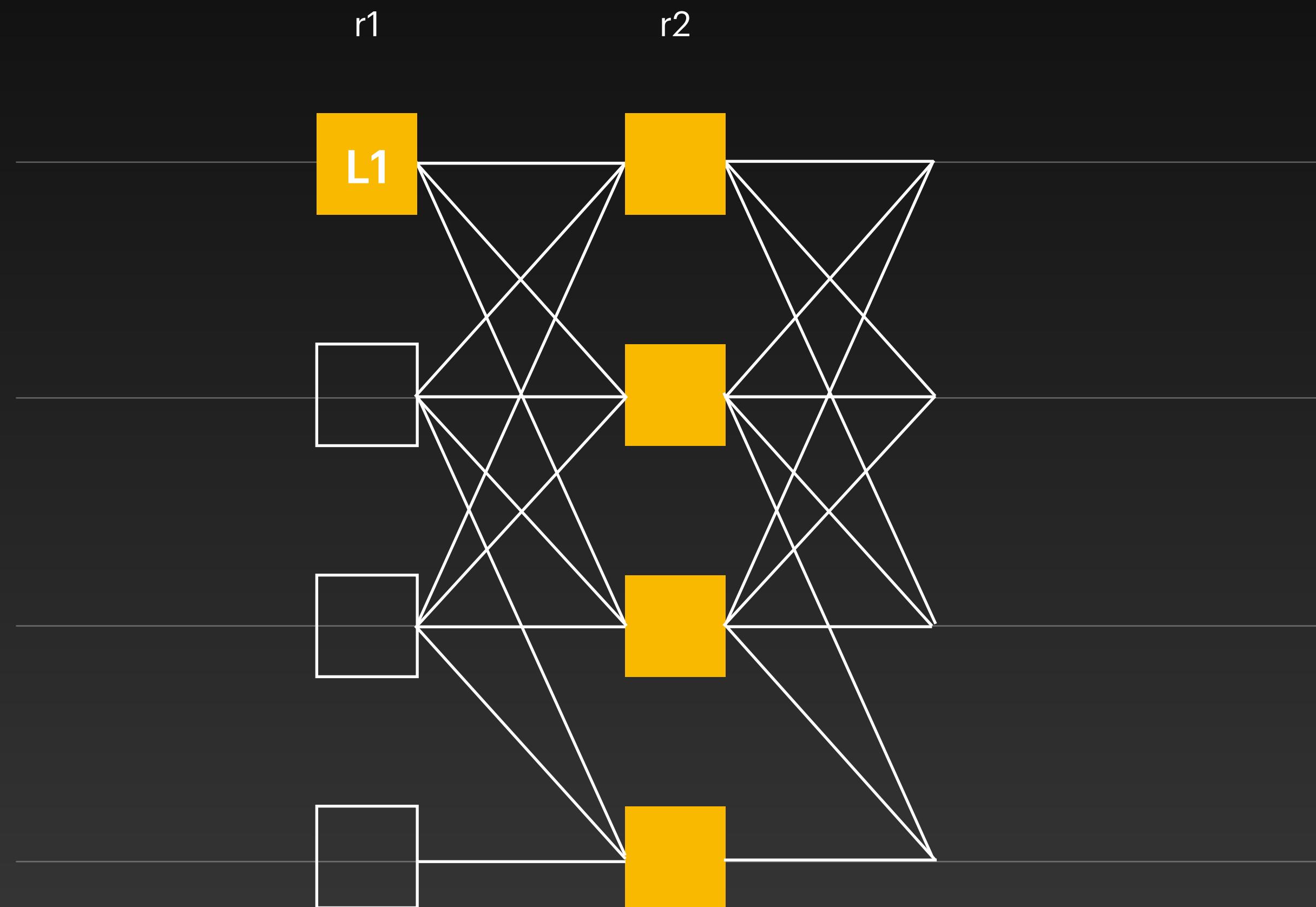
# The Mysticeti DAG

## Rule 2: Every node waits and links to leaders

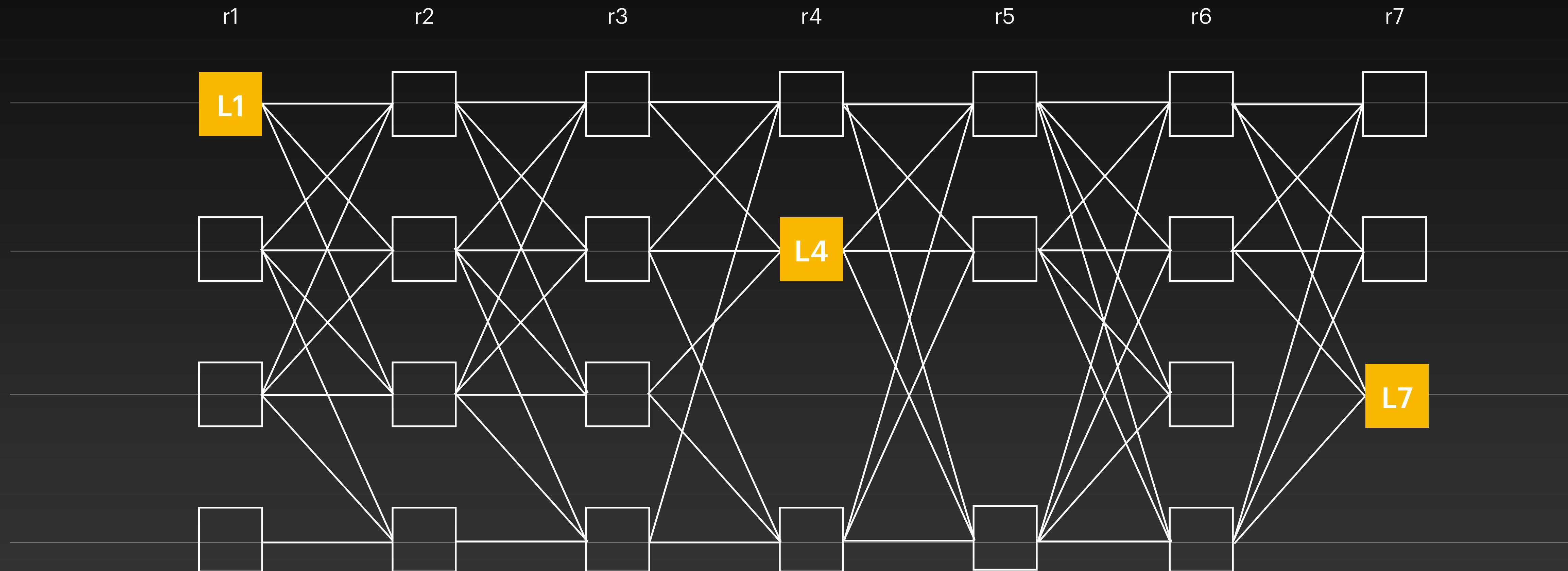


# The Mysticeti DAG

## Rule 3: All node run in parallel



# The Mysticeti DAG

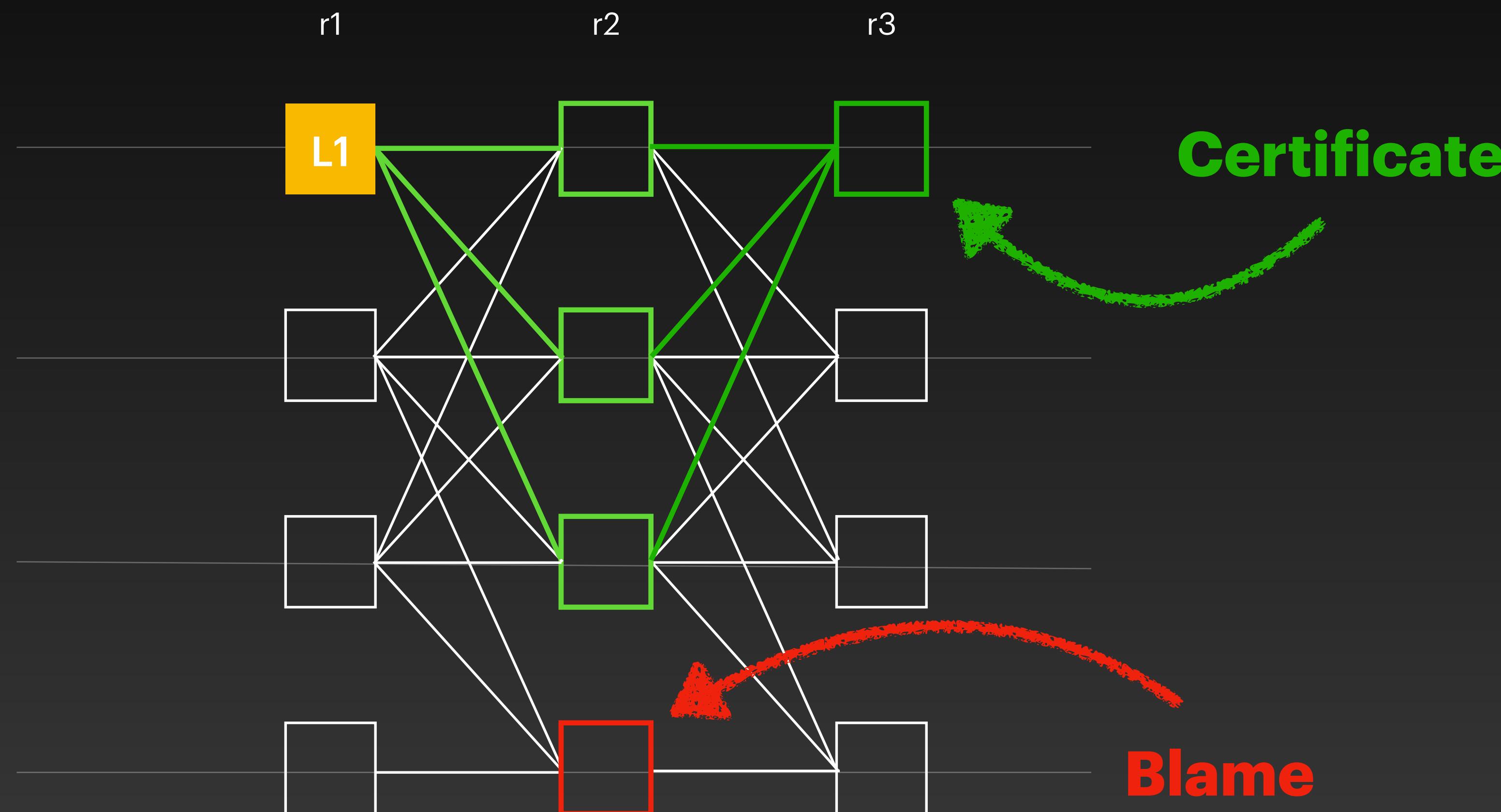


# Main Ingredient:

All messages embedded in the DAG

- Fewer signatures
- Isolated engineering component
- Define interpretable patterns on the DAG
- Run multiple protocols on the same DAG

# Interpreting DAG Patterns



# Two Protocols, One DAG

## Mysticeti-C Consensus

- No rounds without leader
- Multiple leaders per round

## Mysticeti-FPC Adding Fast Finality

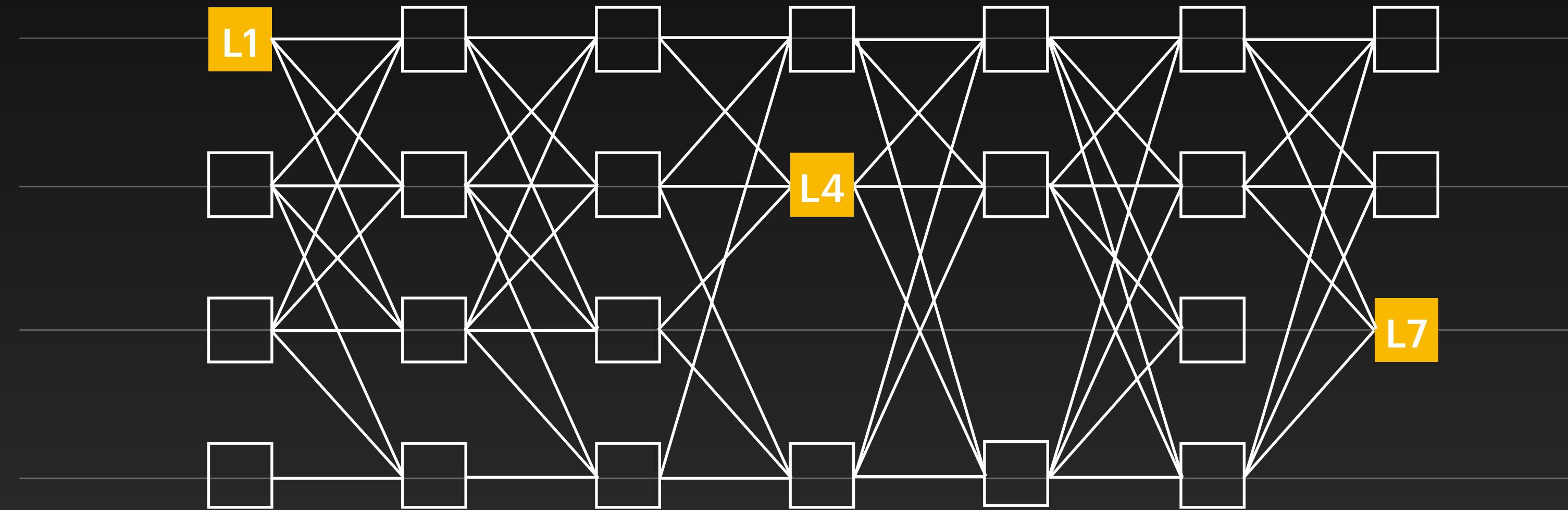
- Interpret BCB on DAG

# Mysticeti-C

The consensus protocol

# End Goal

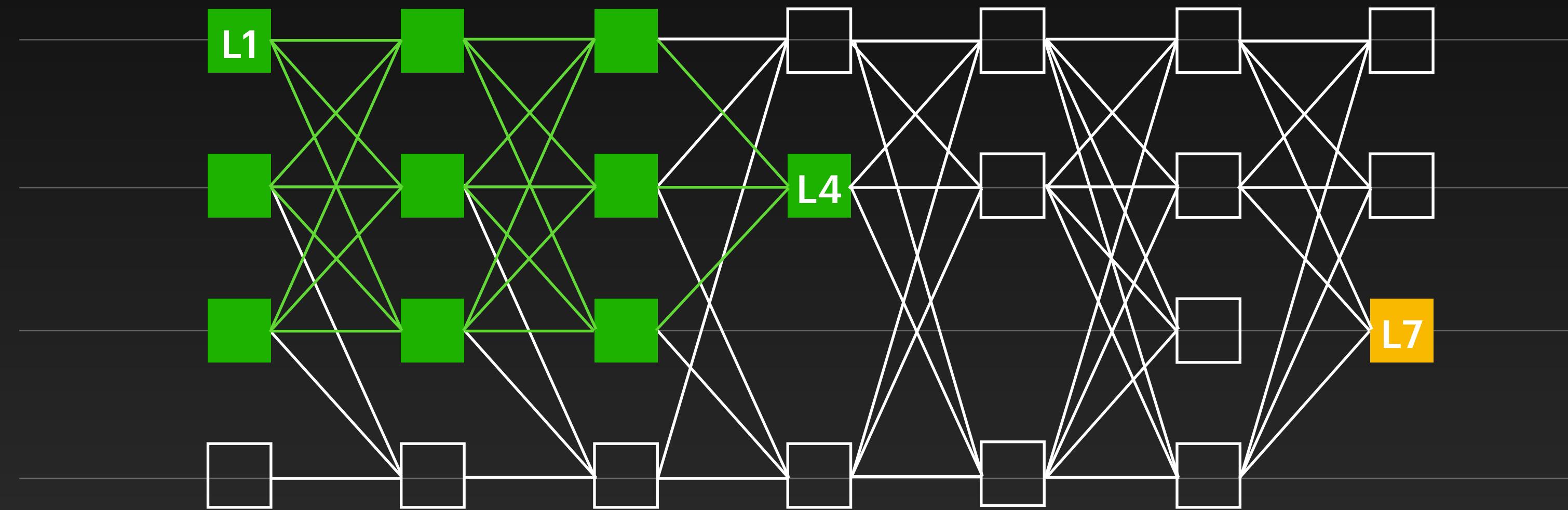
## Ordering leaders



- We focus on ordering leaders: L1 L4 L7

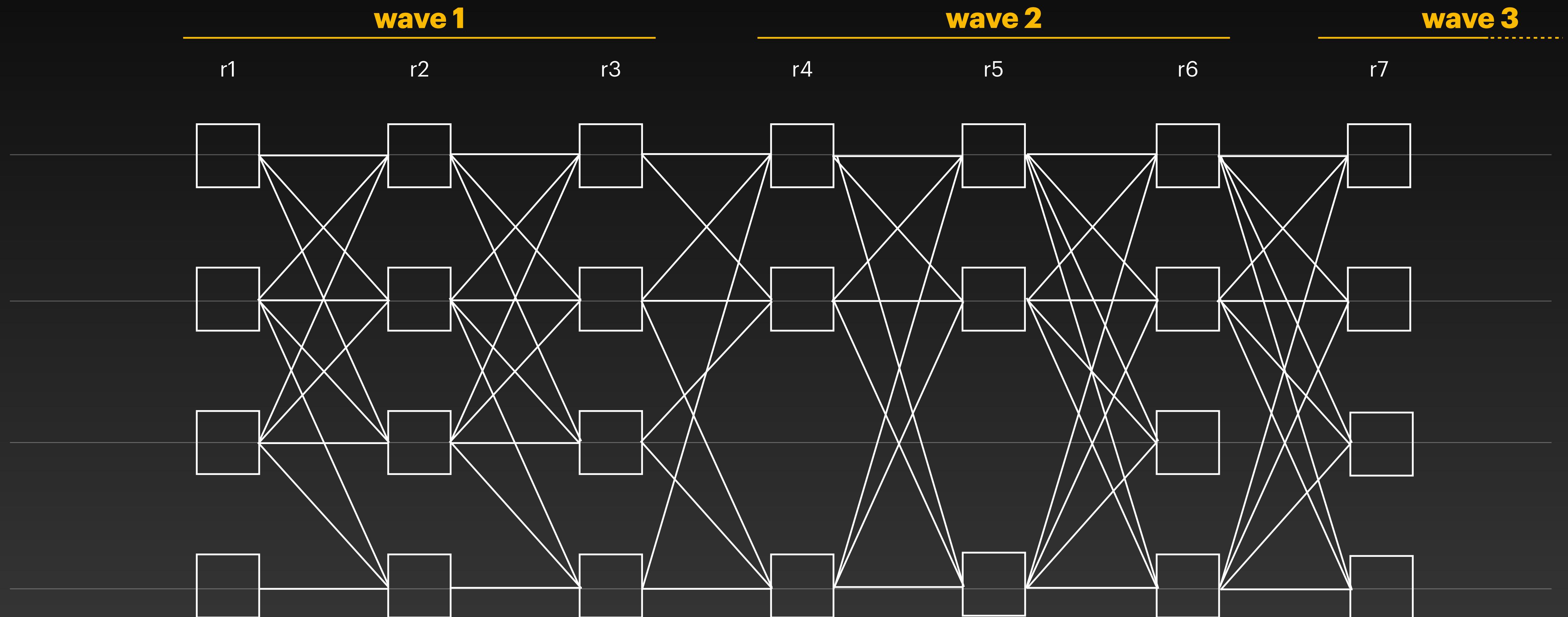
# End Goal

## Ordering leaders

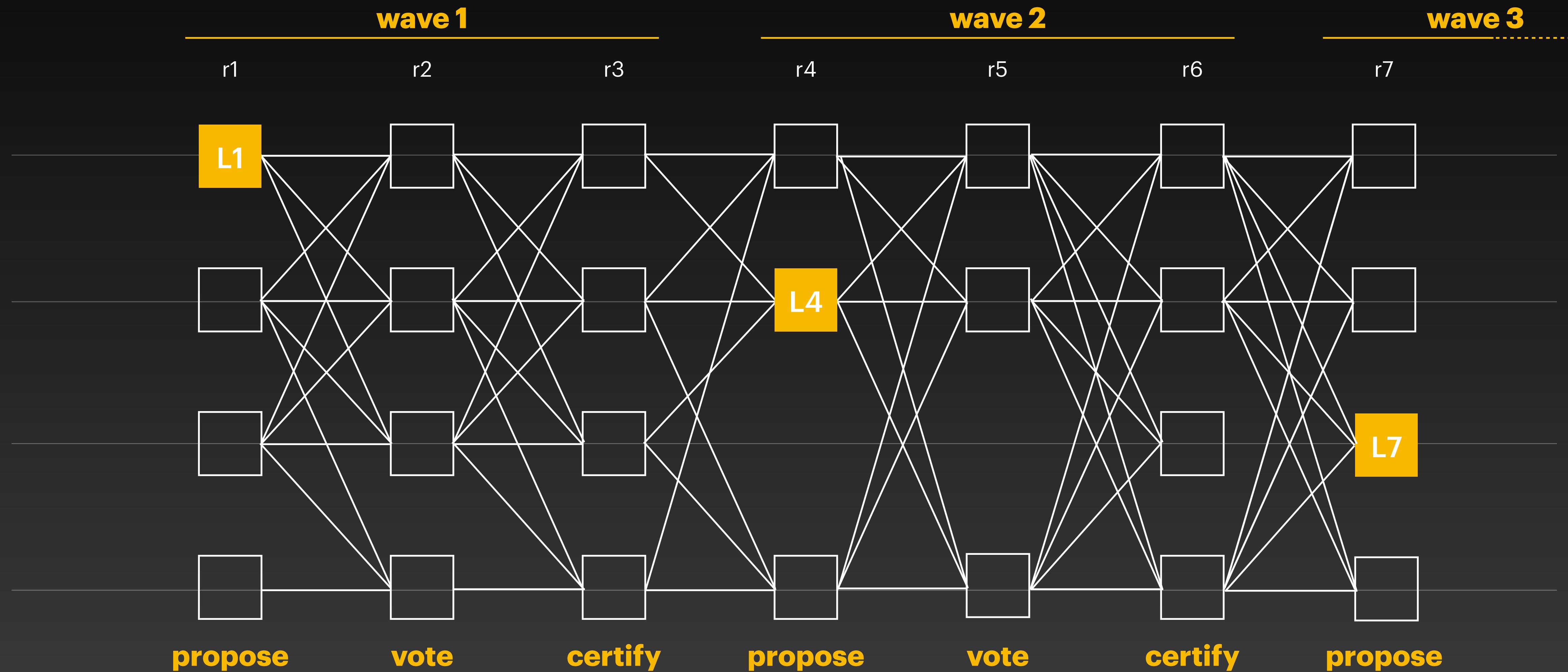


- We focus on ordering leaders: **L1** **L4** **L7**
- Linearising the sub-DAG is simple

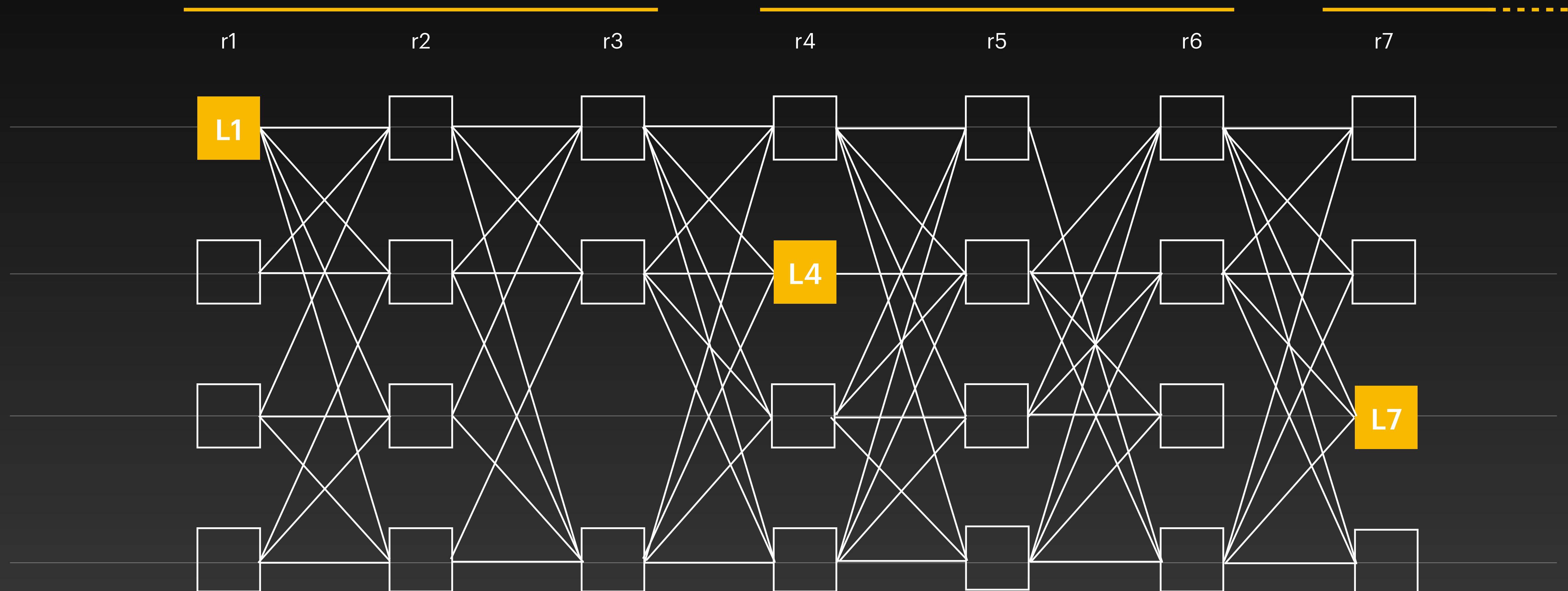
# DAG Structure



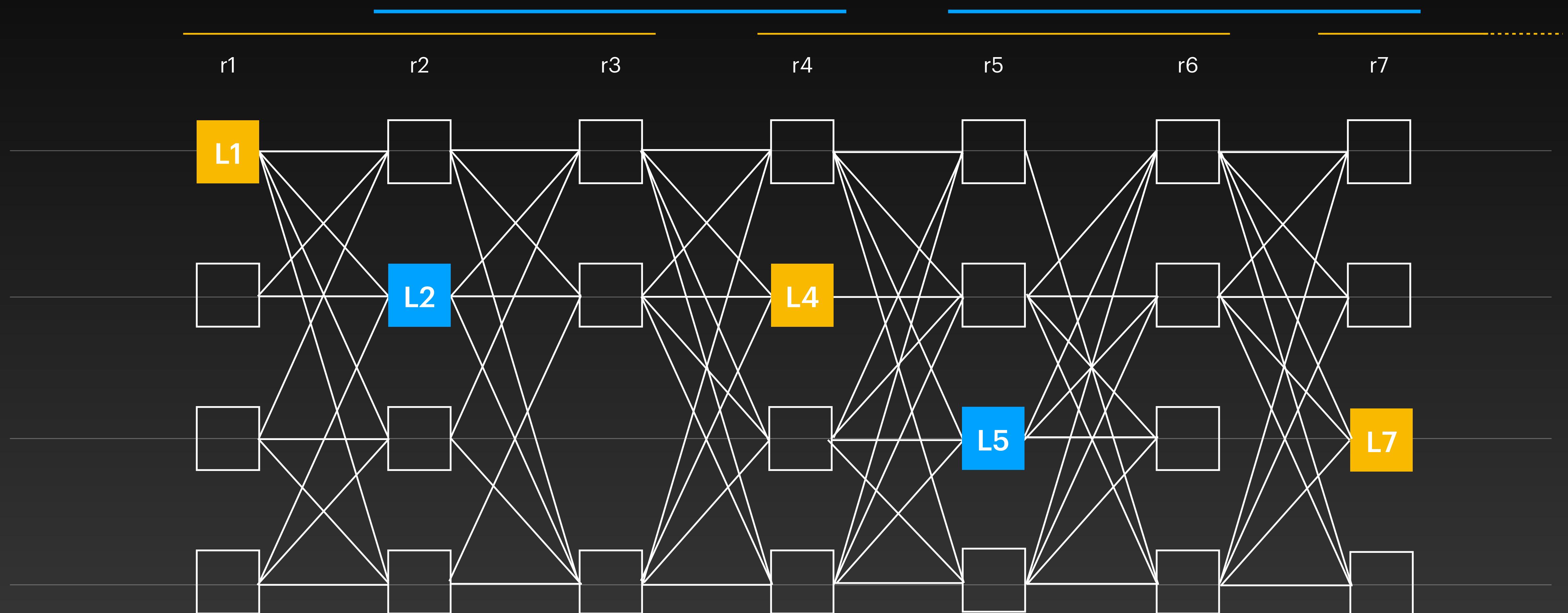
# DAG Structure



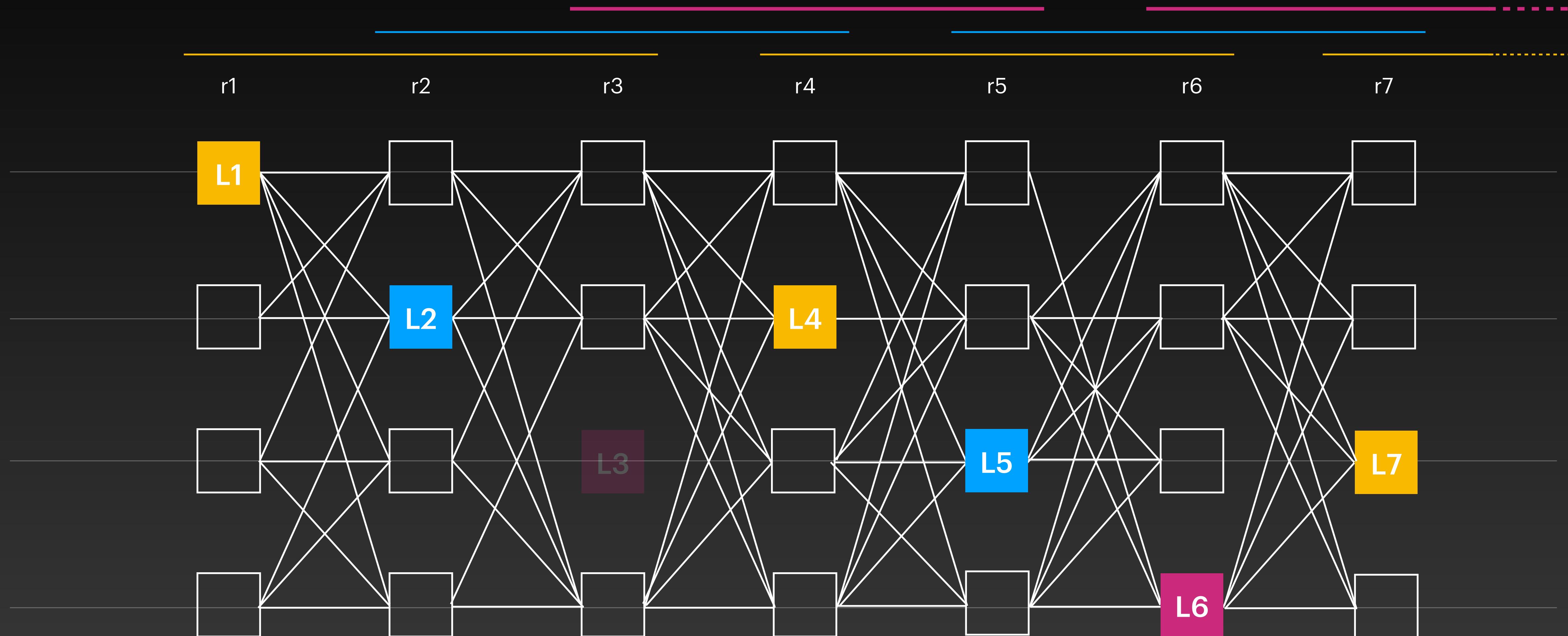
# DAG Structure



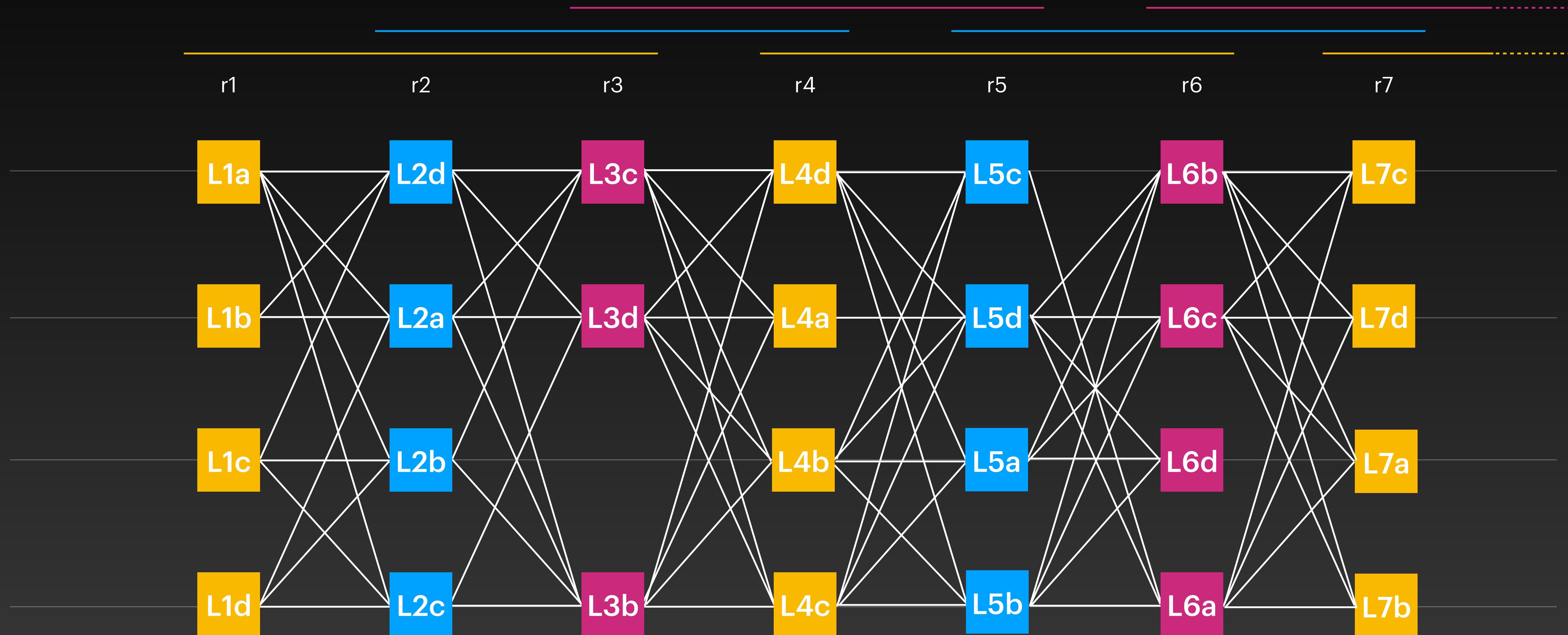
# DAG Structure



# DAG Structure

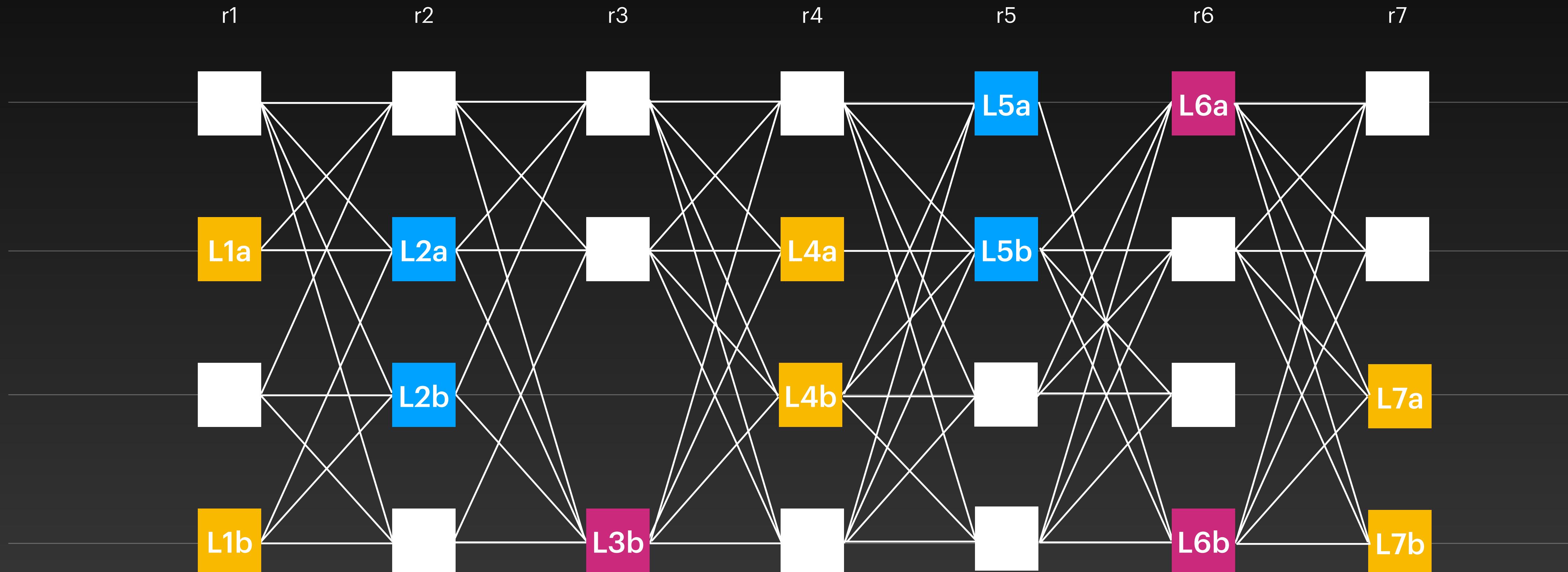


# DAG Structure



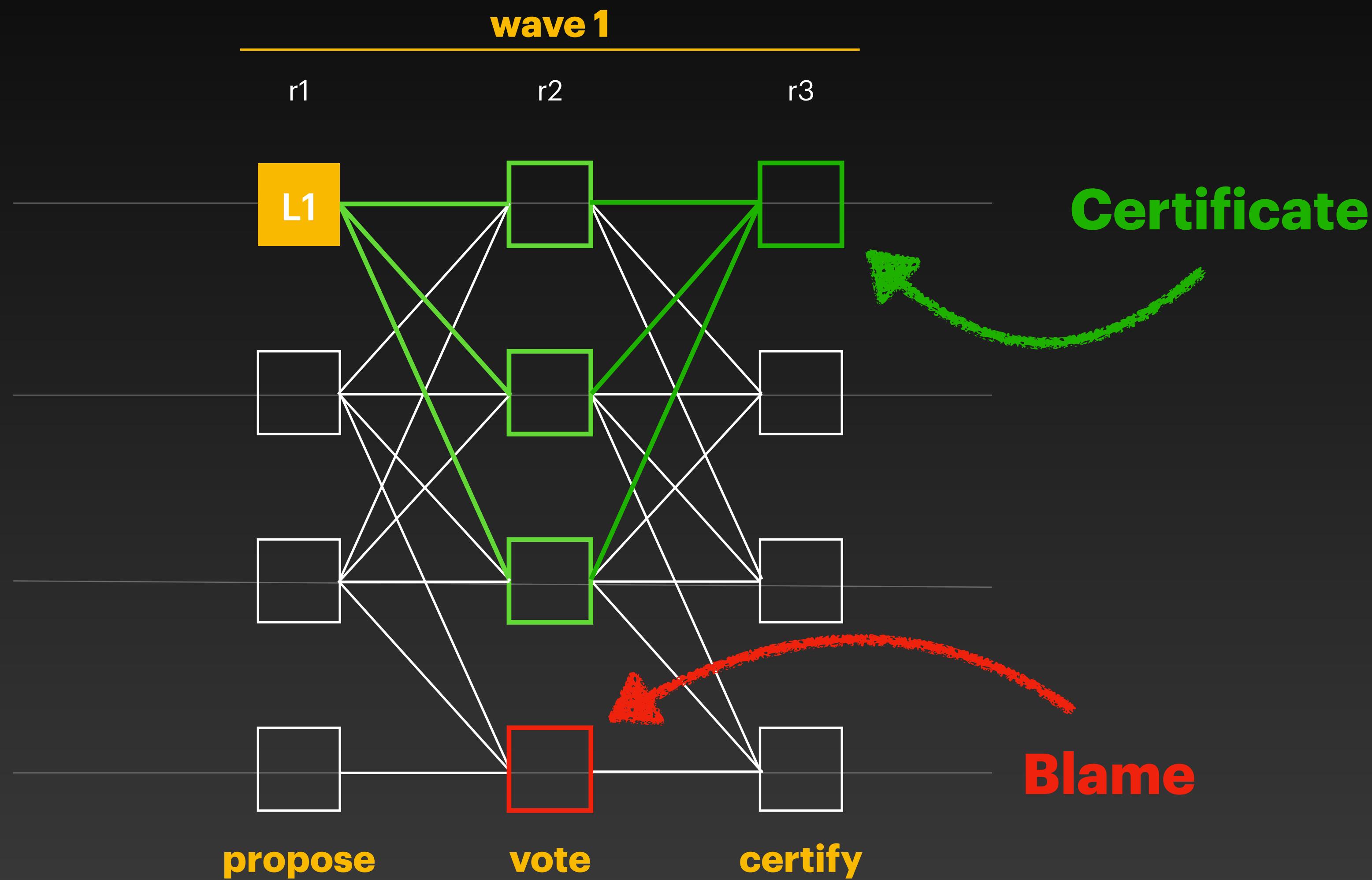
# Practical Implementation

Select only 2 leaders per round



# Interpreting DAG Patterns

Reminder



# Direct Decision Rule

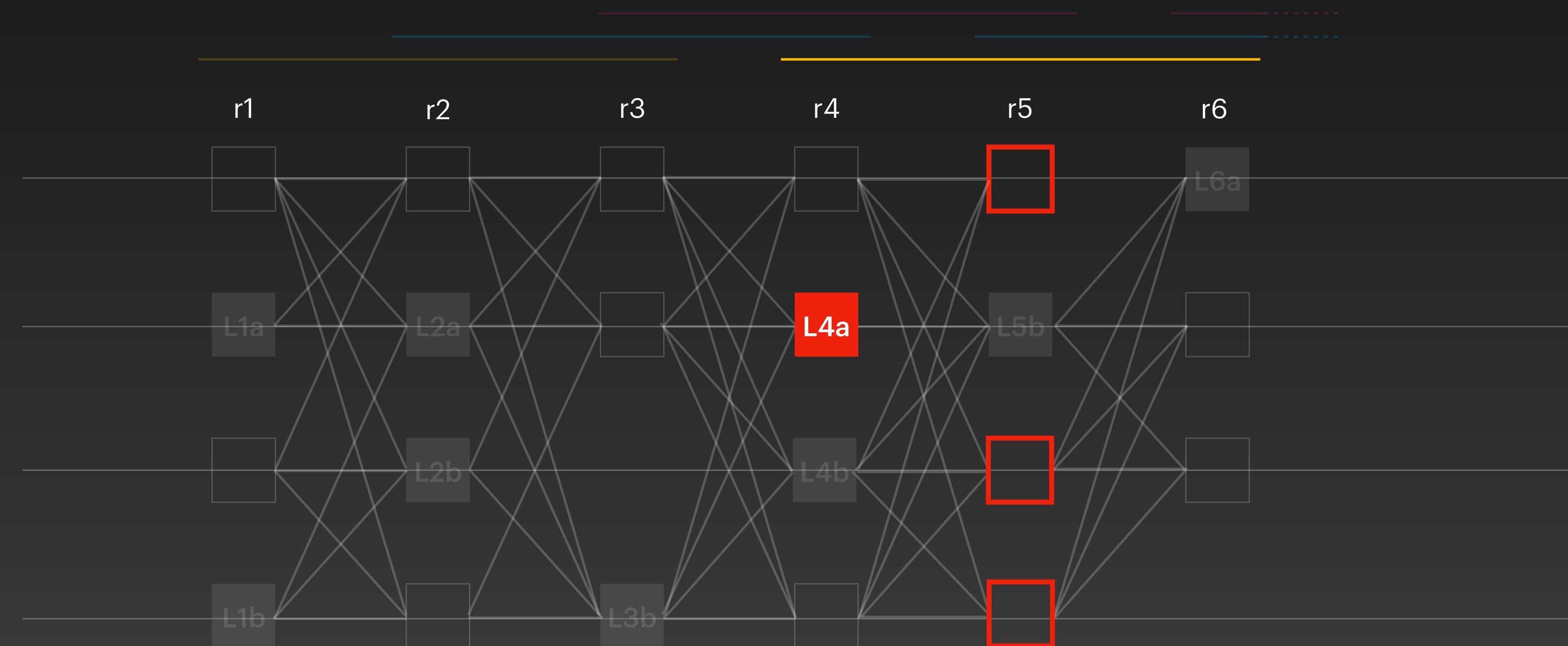
On each leader starting from highest round:

- **Skip** if  $2f+1$  blames
- **Commit** if  $2f+1$  certificates
- **Undecided** otherwise

# Direct Decision Rule

On each leader starting from highest round:

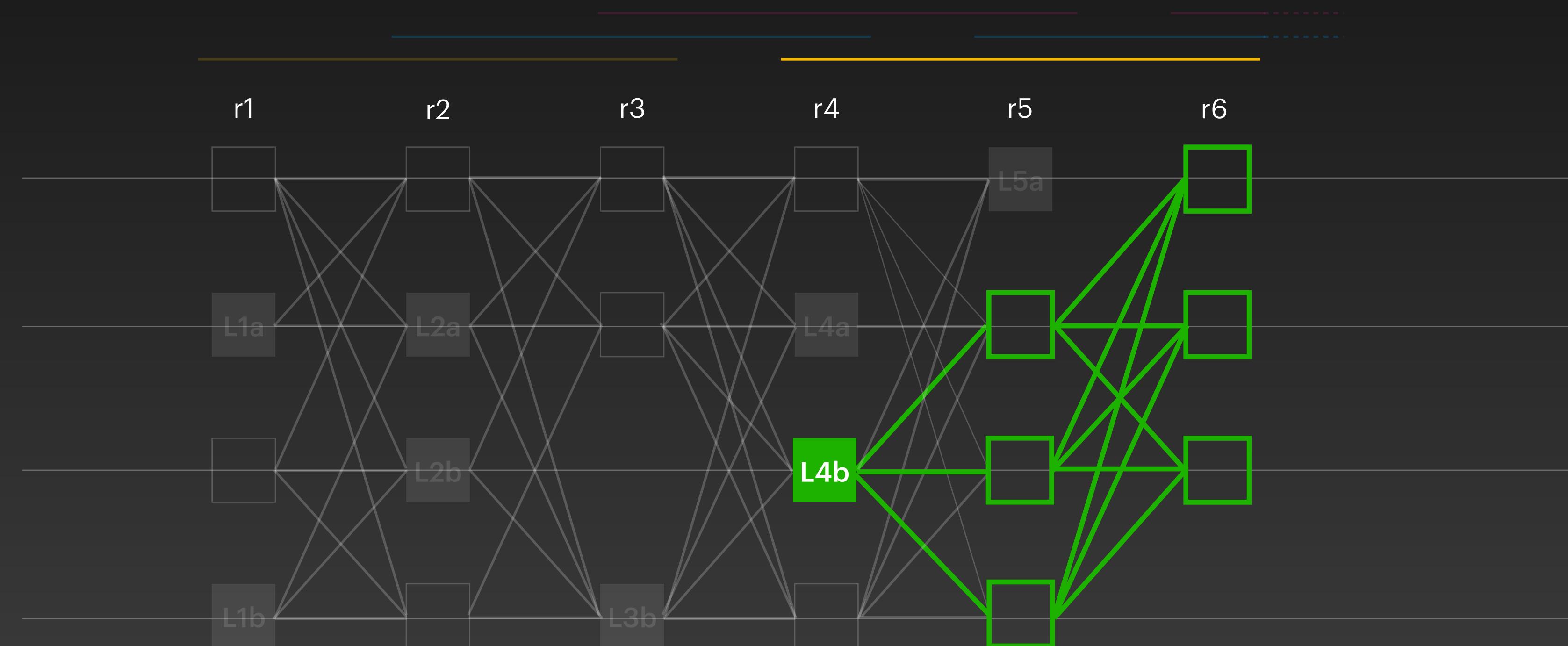
- **Skip** if  $2f+1$  blames
- **Commit** if  $2f+1$  certificates
- **Undecided** otherwise



# Direct Decision Rule

On each leader starting from highest round:

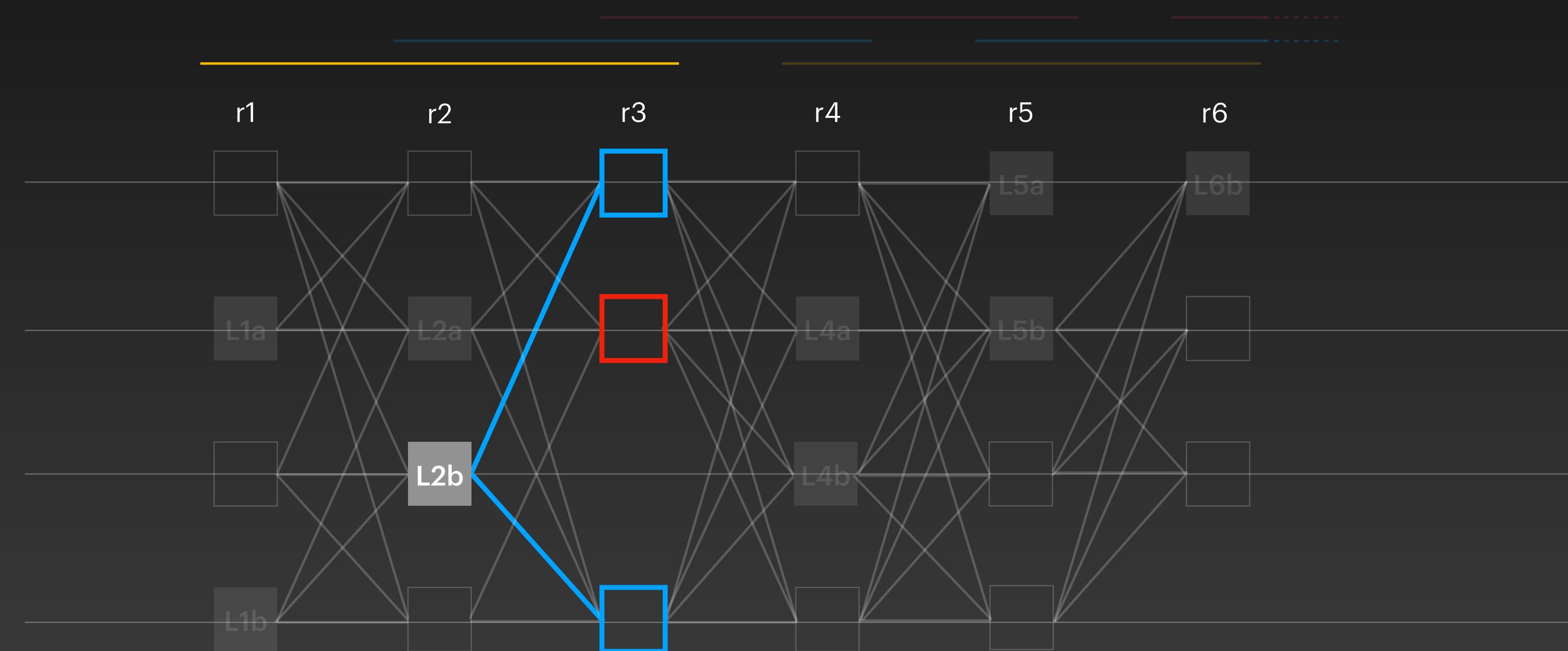
- **Skip** if  $2f+1$  blames
- **Commit** if  $2f+1$  certificates
- **Undecided** otherwise



# Direct Decision Rule

On each leader starting from highest round:

- **Skip** if  $2f+1$  blames
- **Commit** if  $2f+1$  certificates
- **Undecided** otherwise

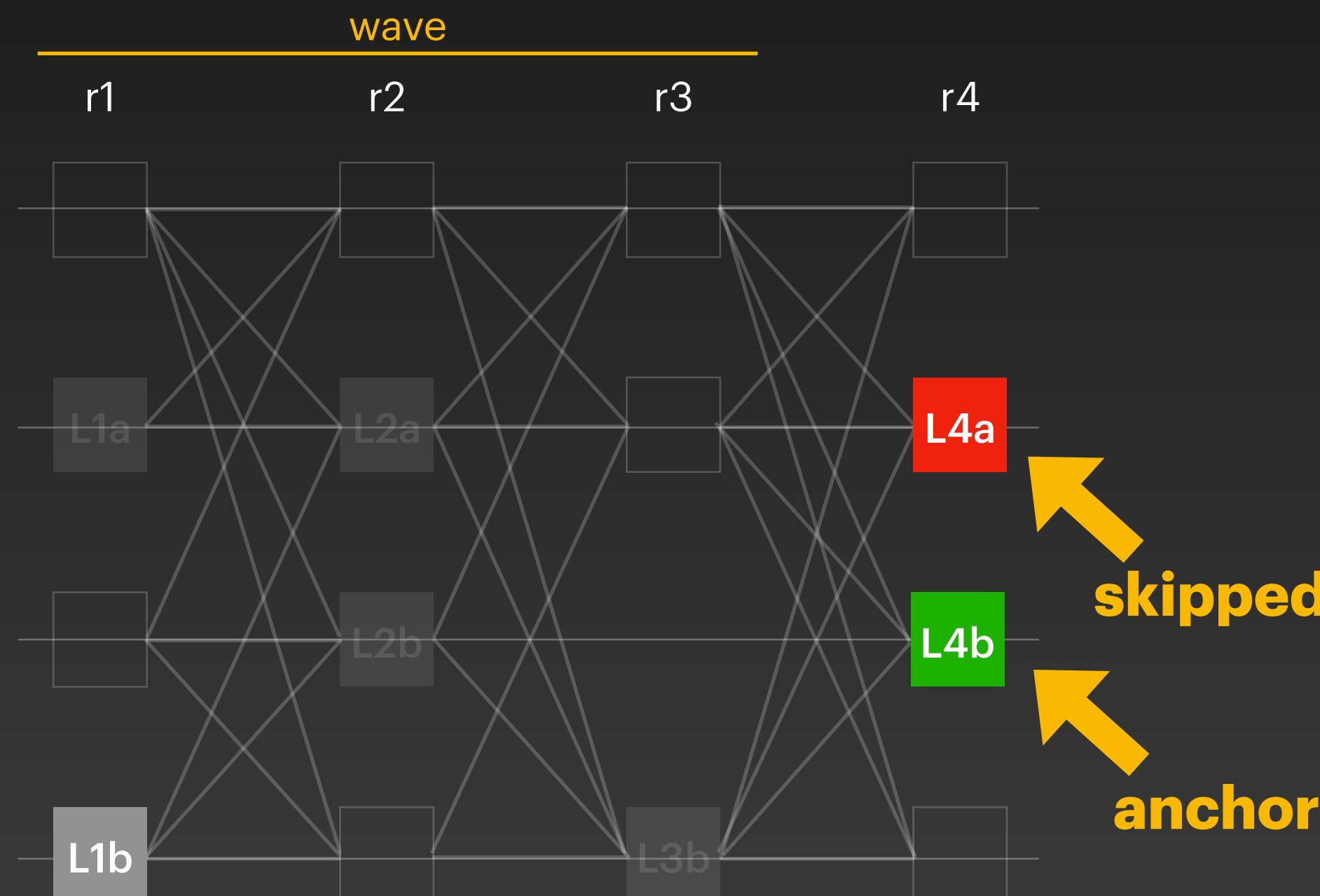


# Indirect Decision Rule

# Indirect Decision Rule

## 1. Find Anchor

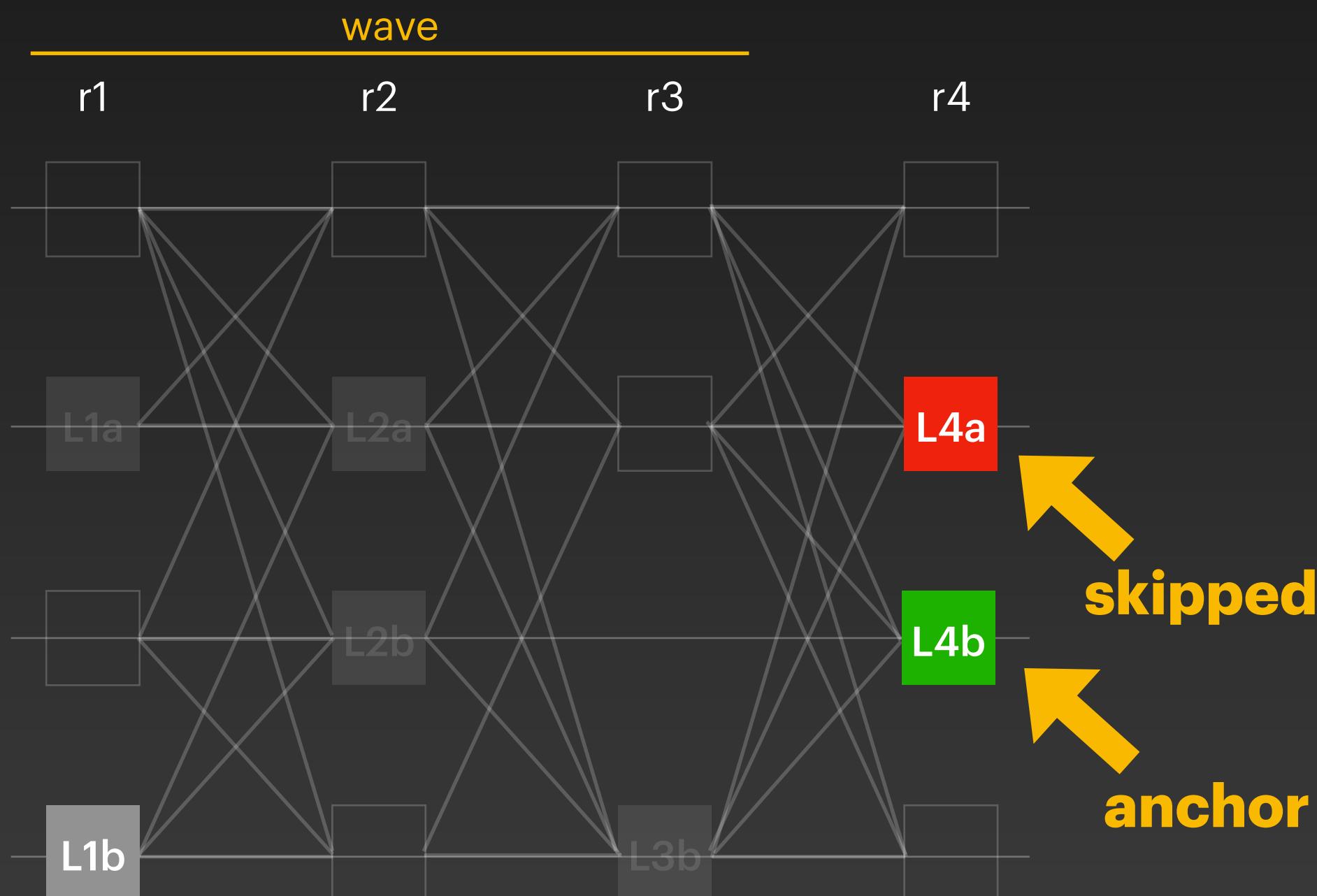
- First block with round  $> r+2$  that is **Commit** or **Undecided**



# Indirect Decision Rule

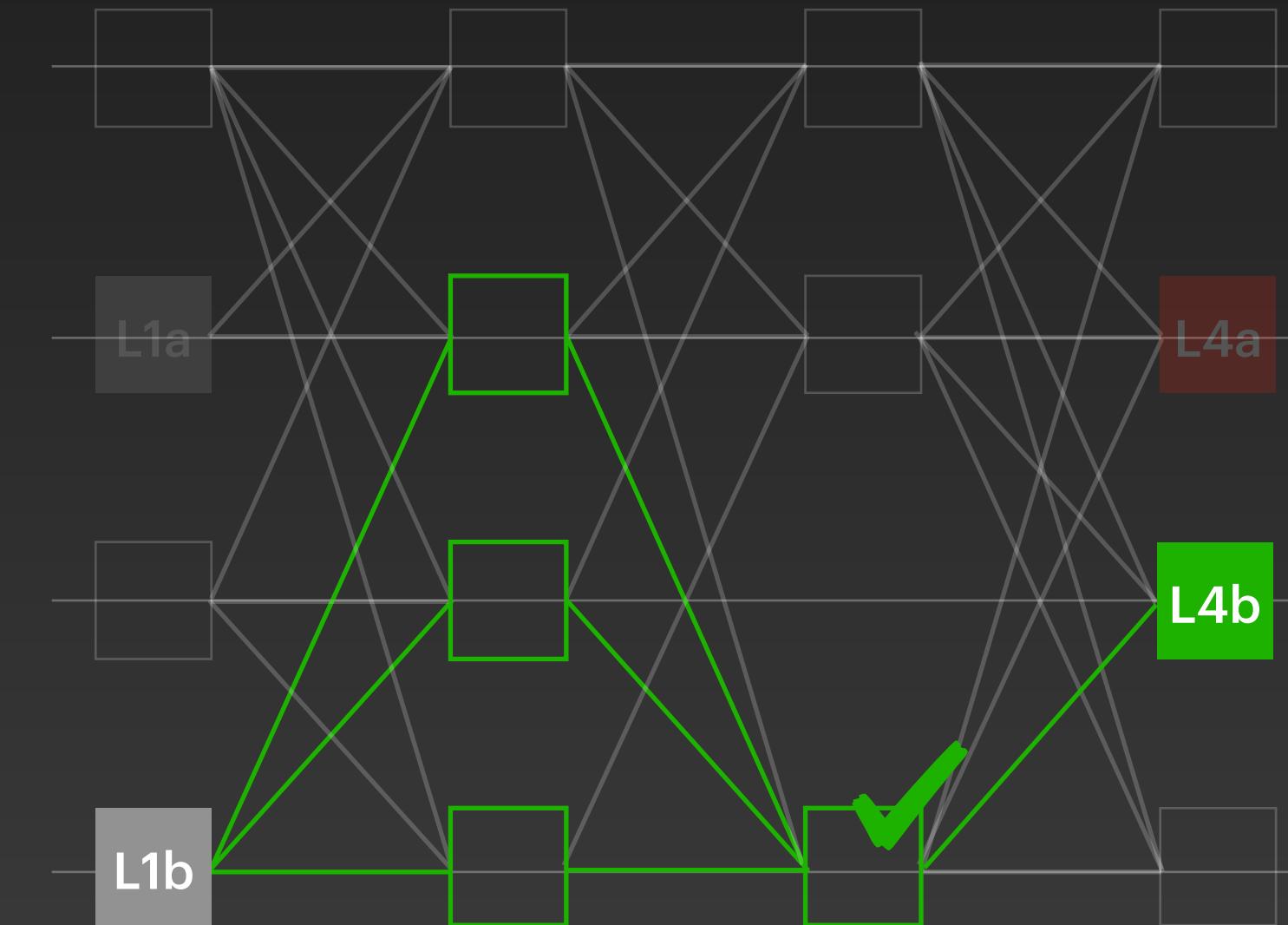
## 1. Find Anchor

- First block with round  $> r+2$  that is **Commit** or **Undecided**

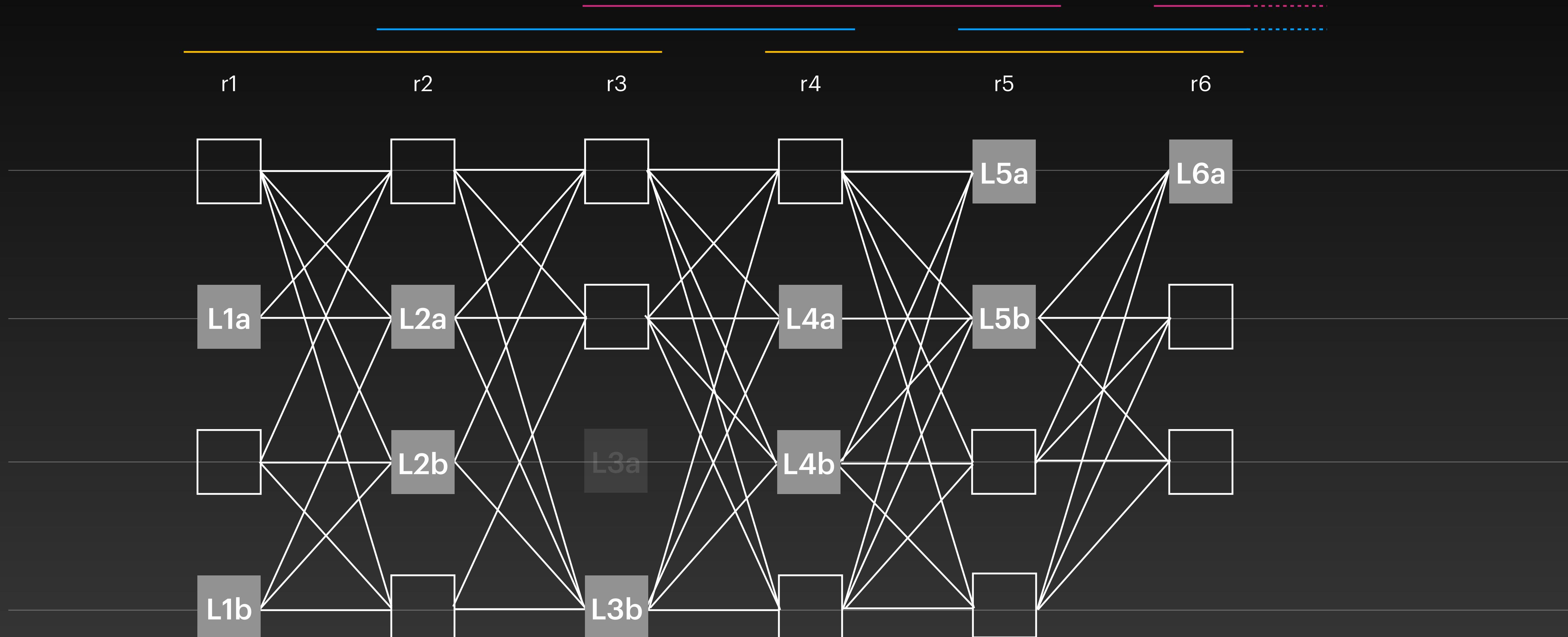


## 2. Certified link

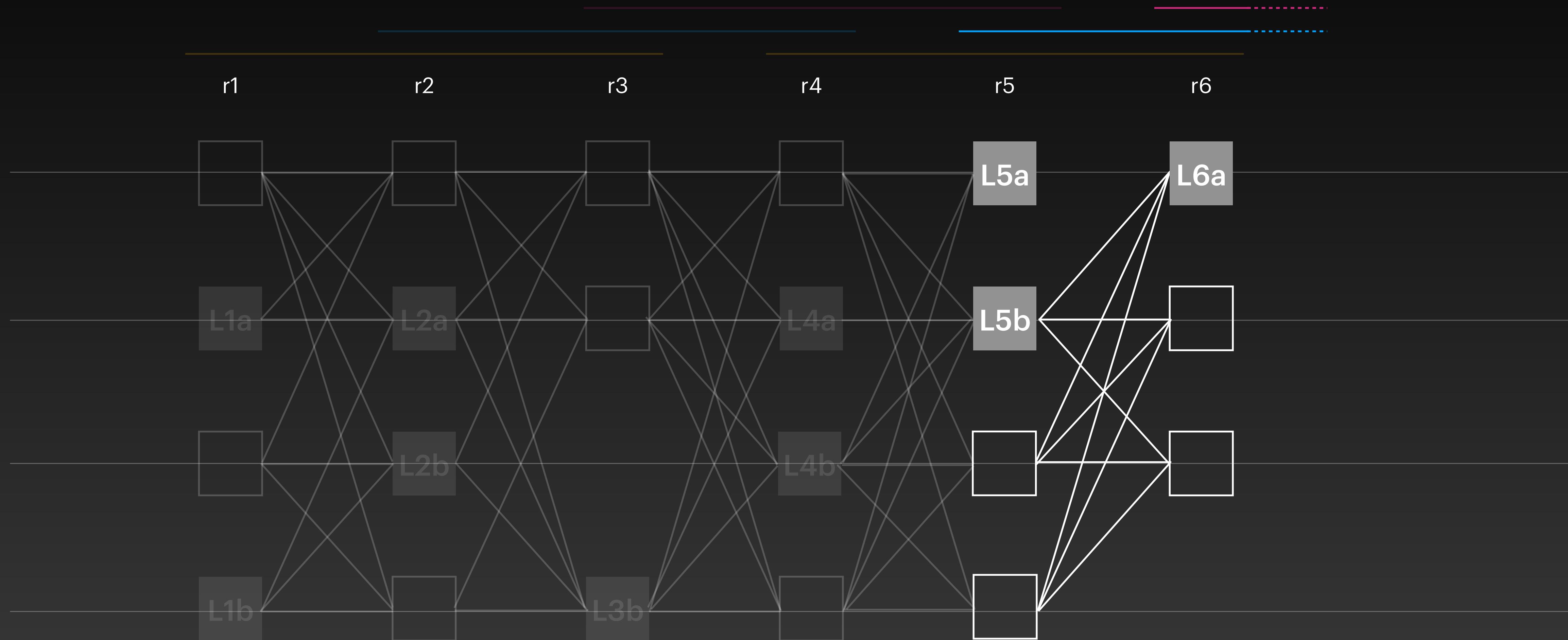
- Commit** if  $B <->$  certified link  $<->$  A  
otherwise **Skip**



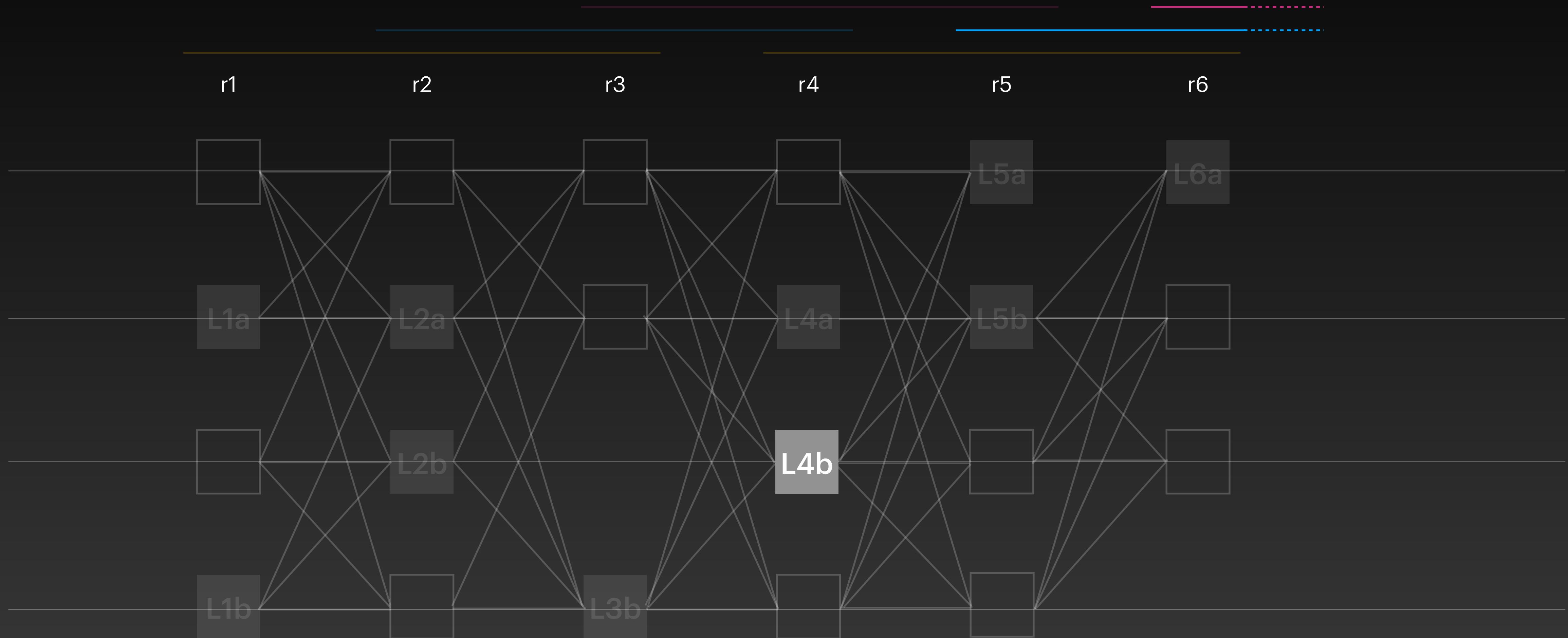
# All Start at Undecided



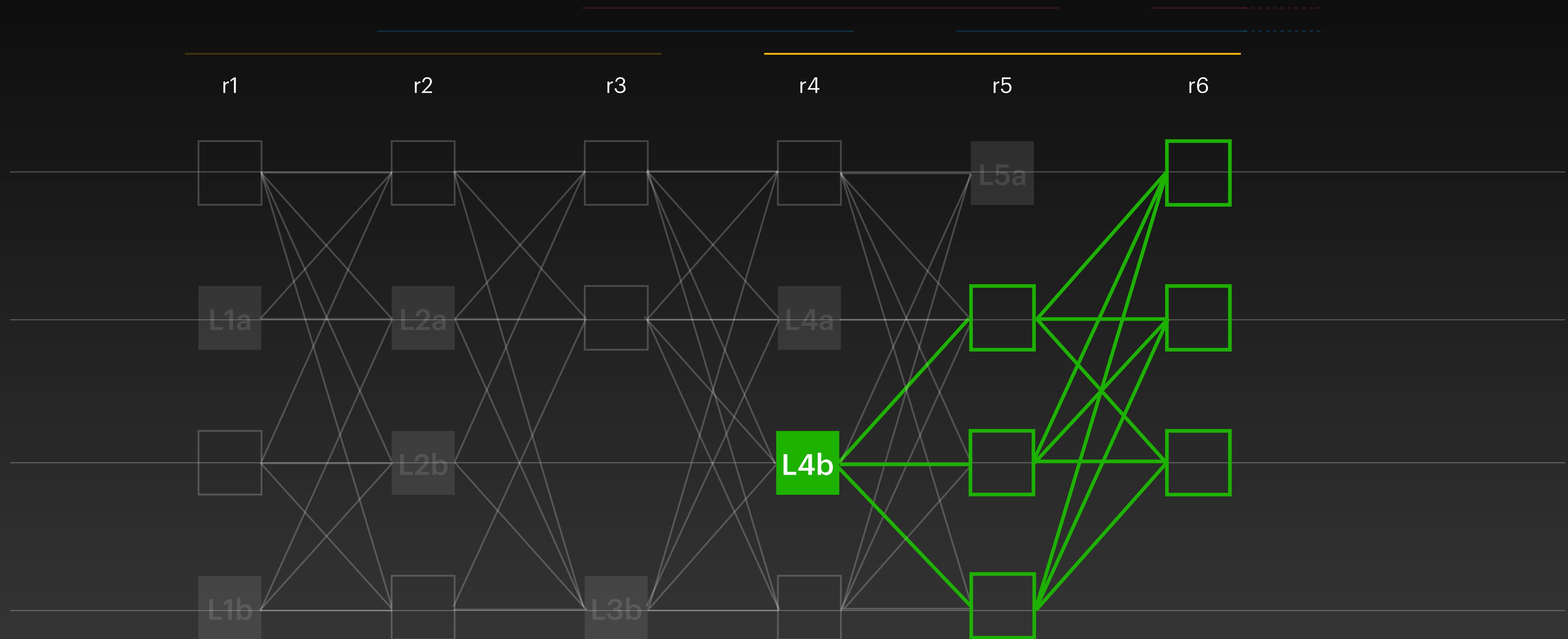
# Ignore Incomplete Waves



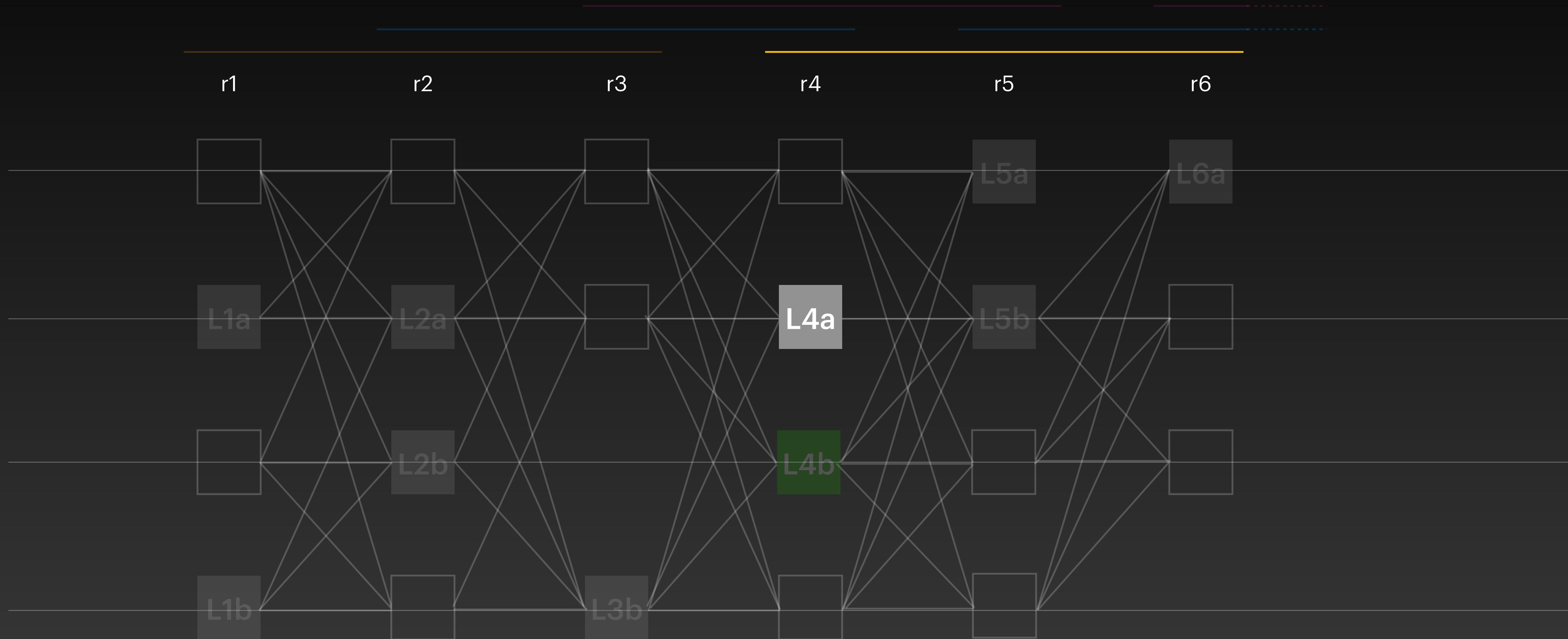
# Apply Direct Rule



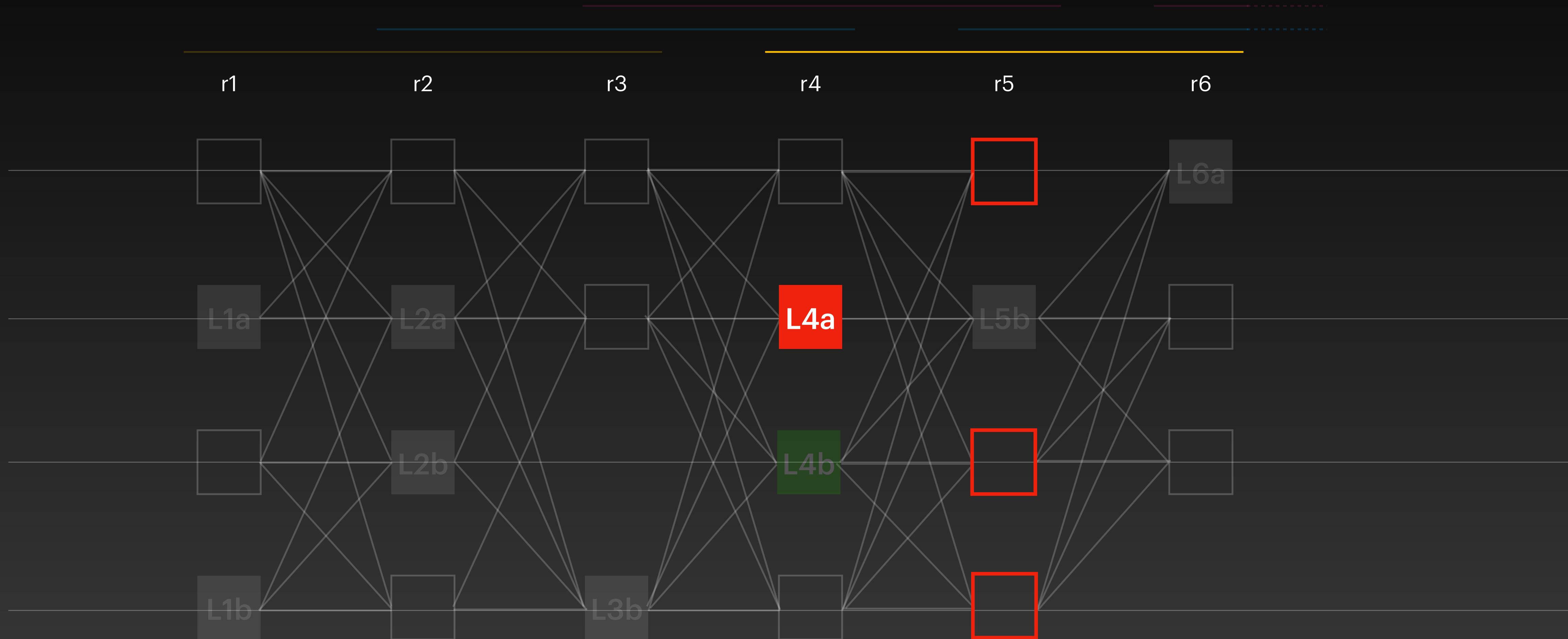
# Apply Direct Rule



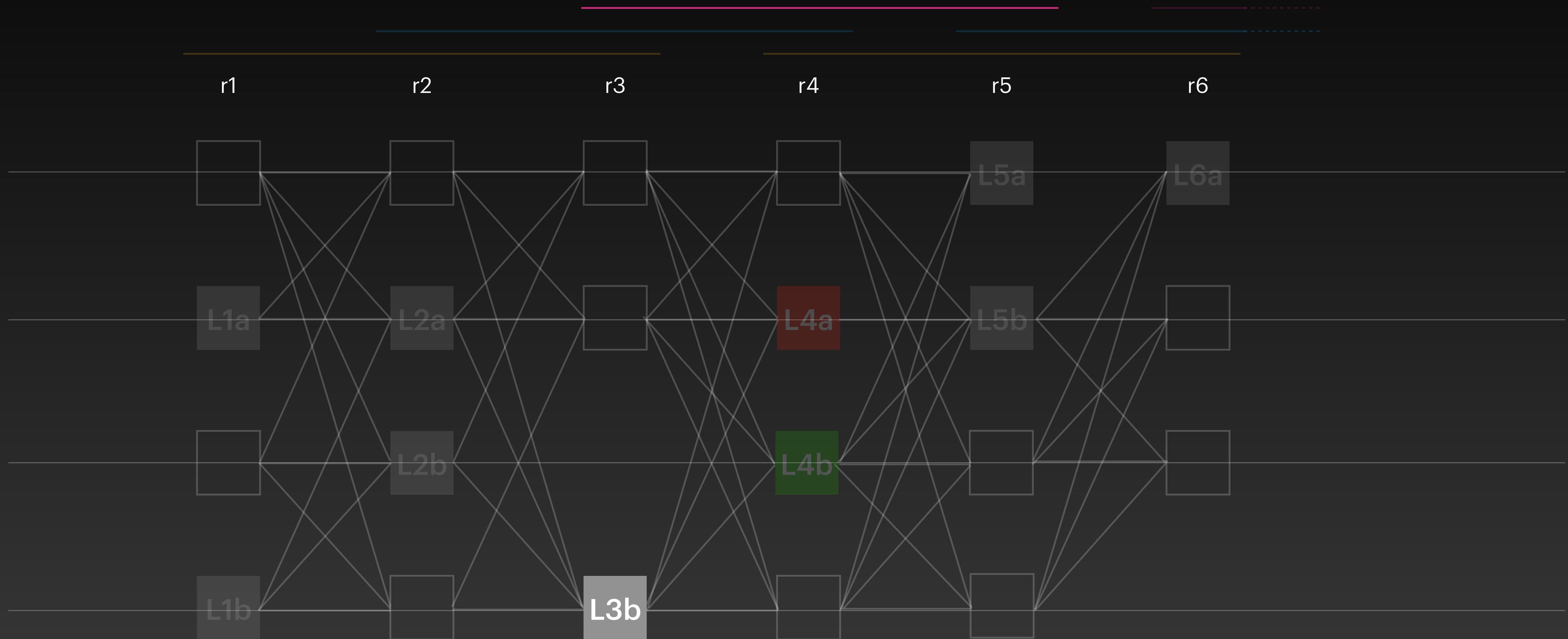
# Apply Direct Rule



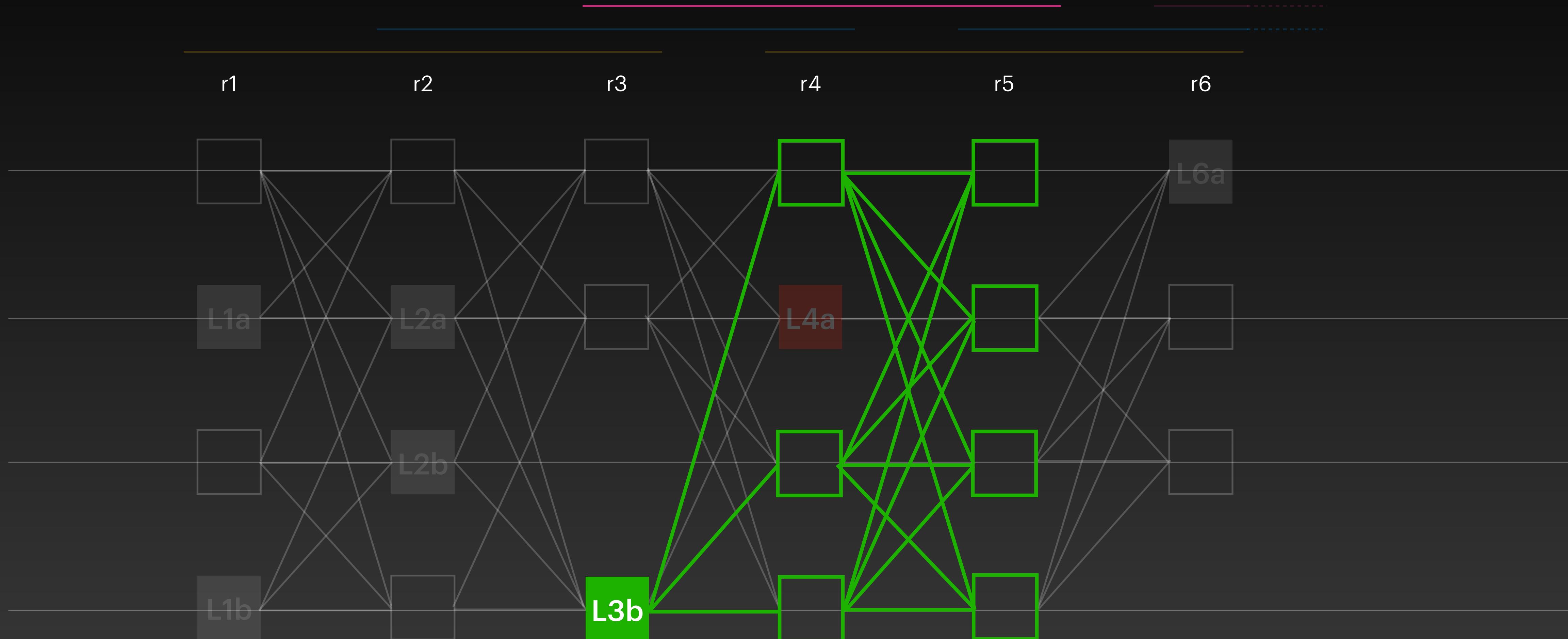
# Apply Direct Rule



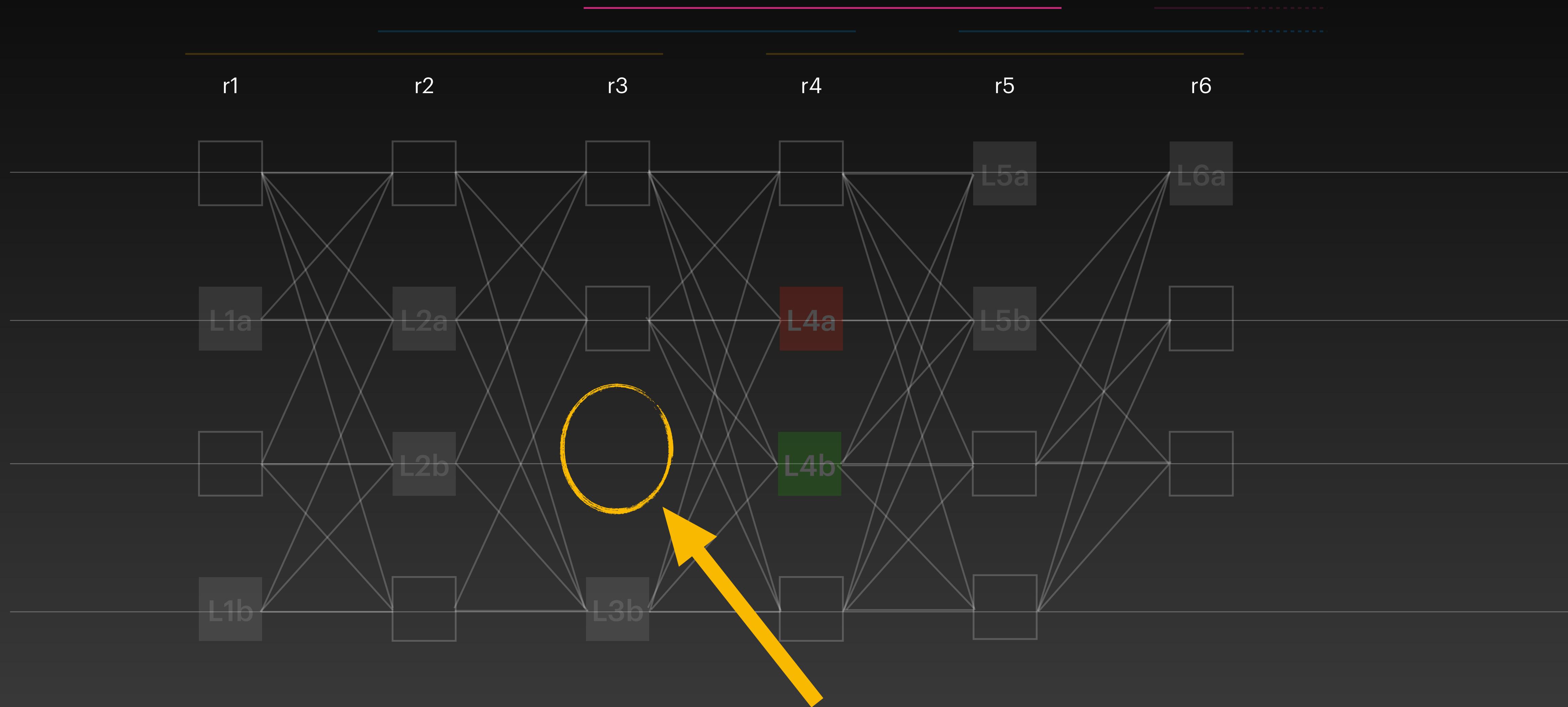
# Apply Direct Rule



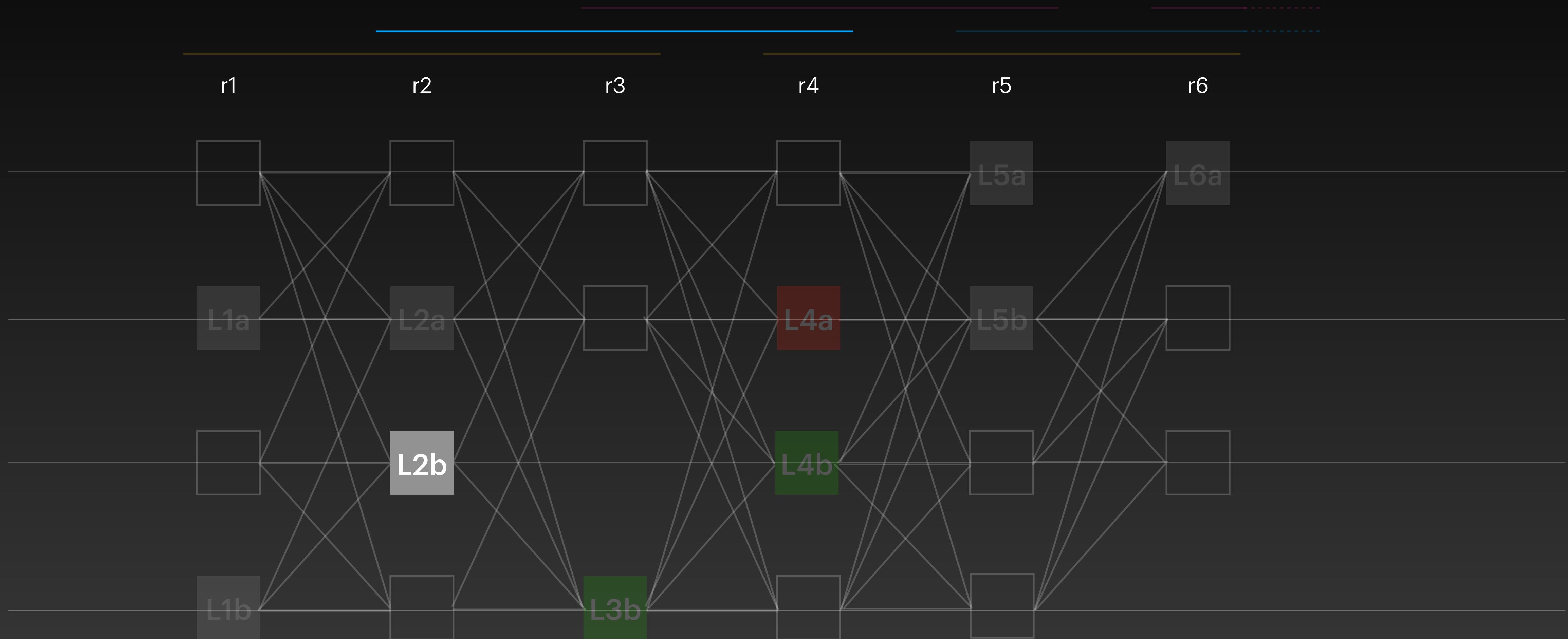
# Apply Direct Rule



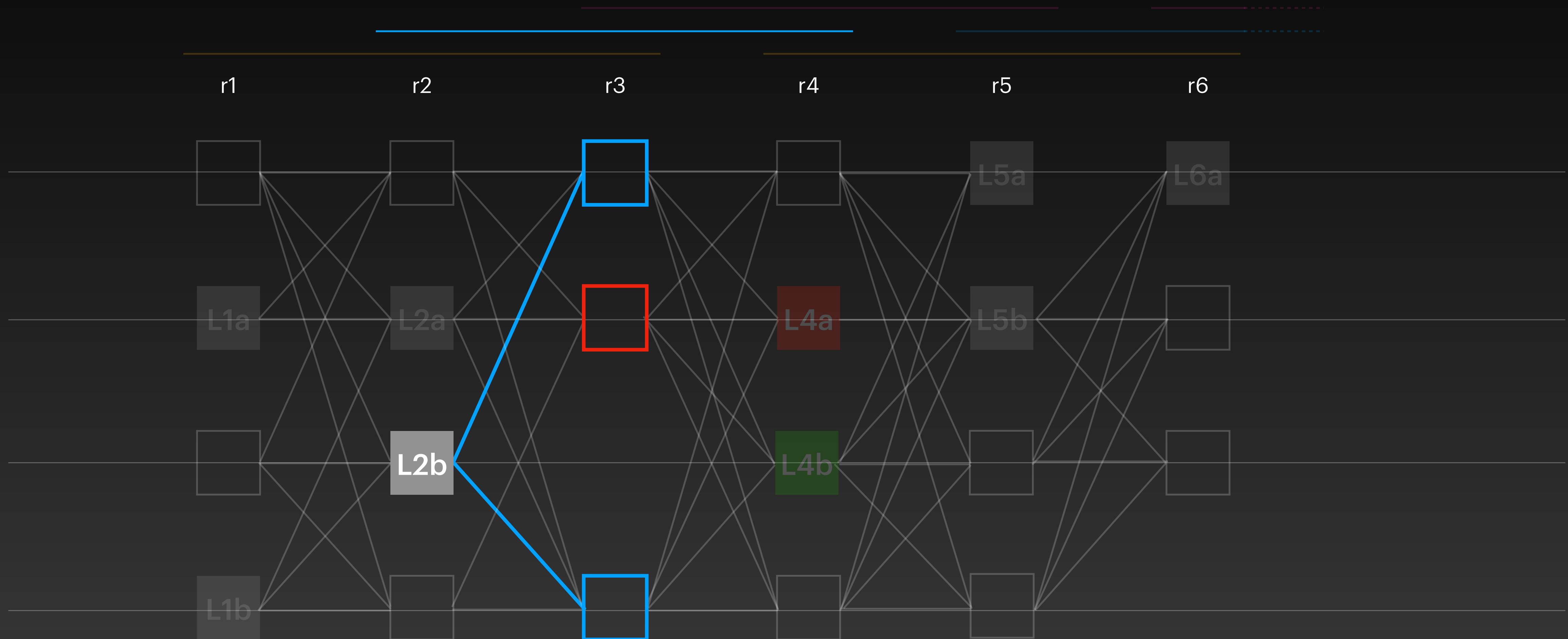
# Ignore Missing Leader



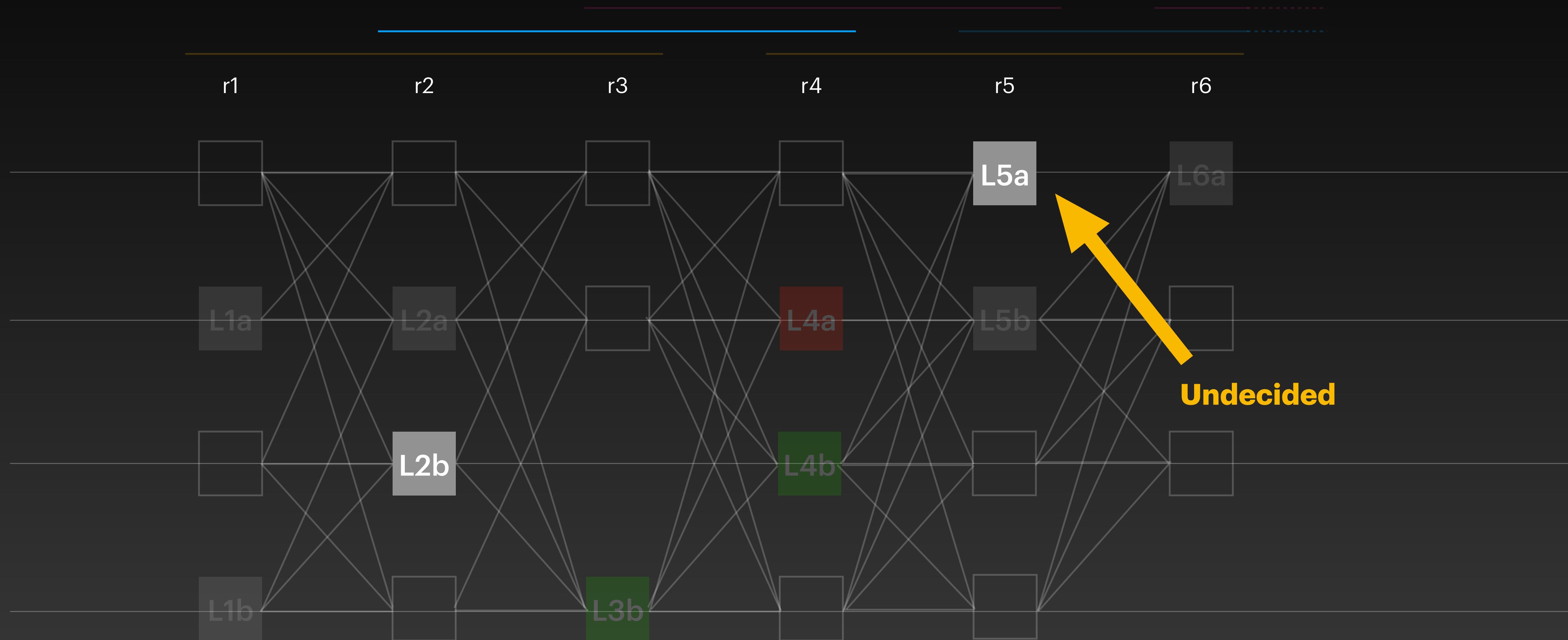
# Apply Direct Rule



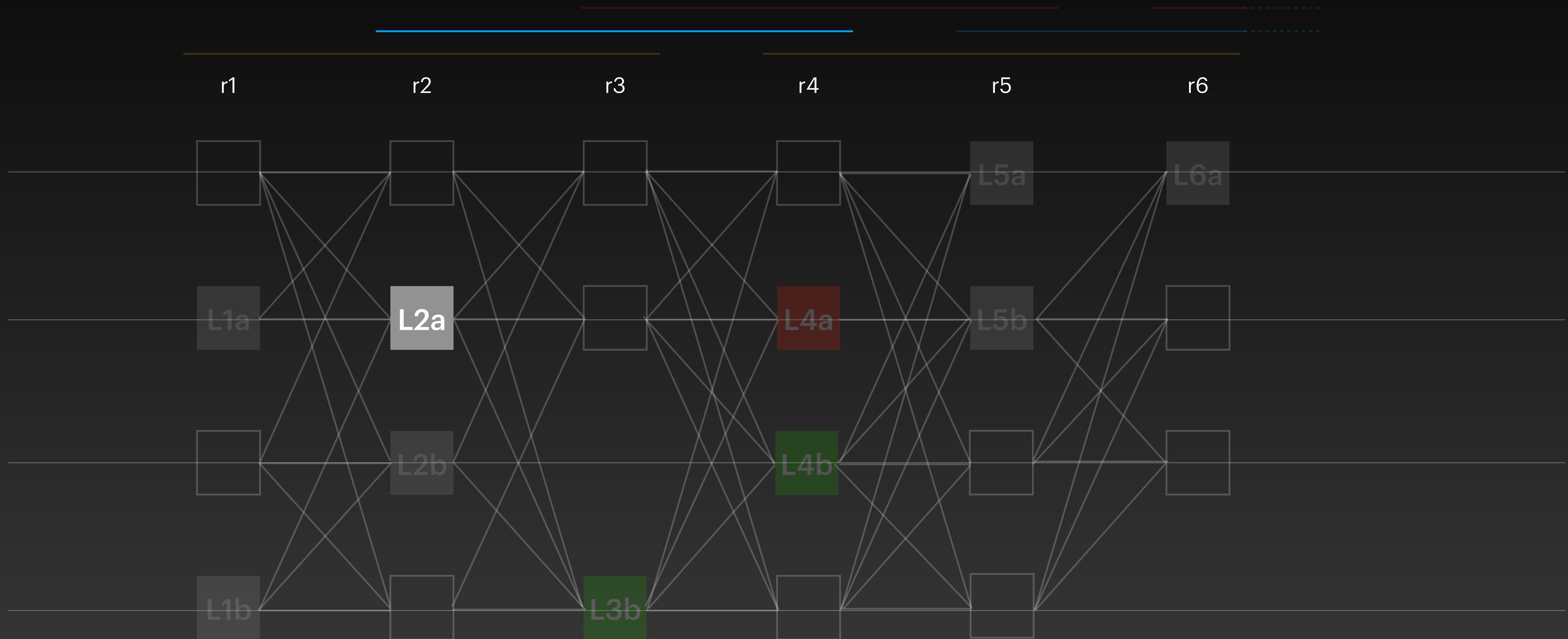
# Apply Direct Rule



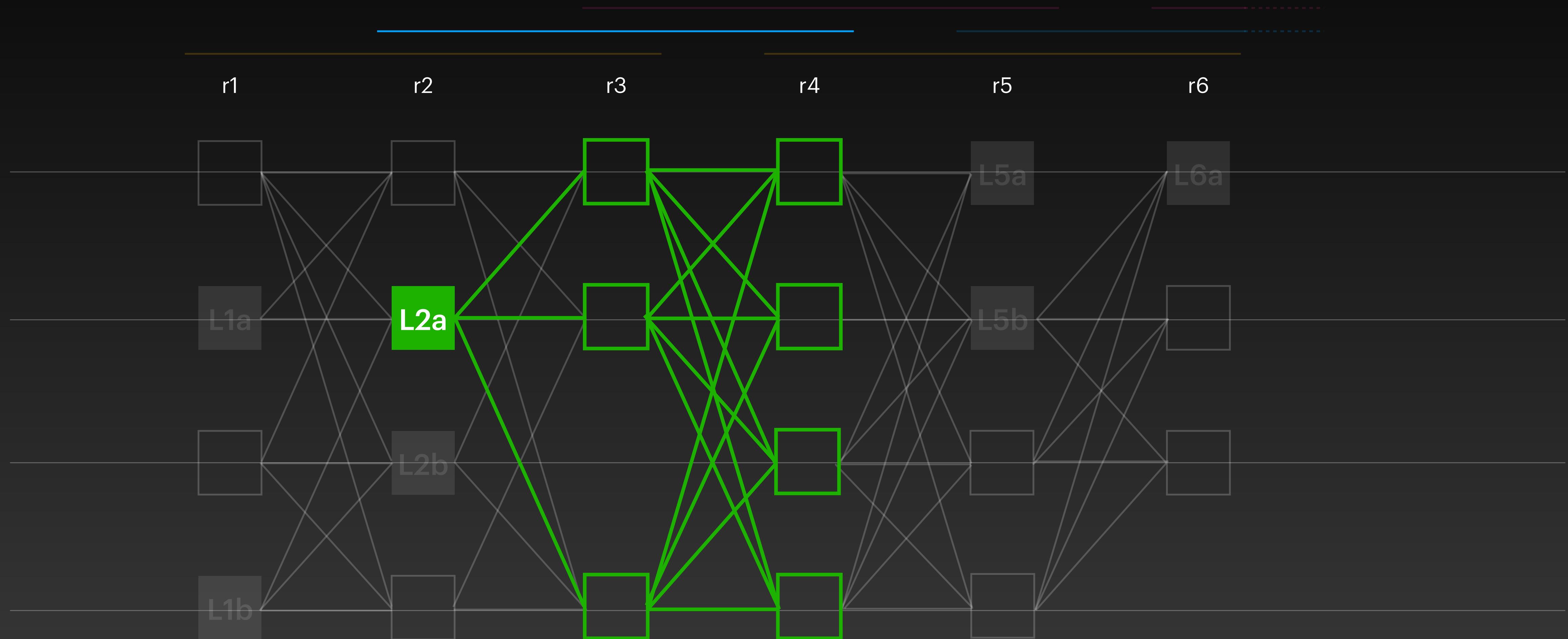
# Apply Indirect Rule



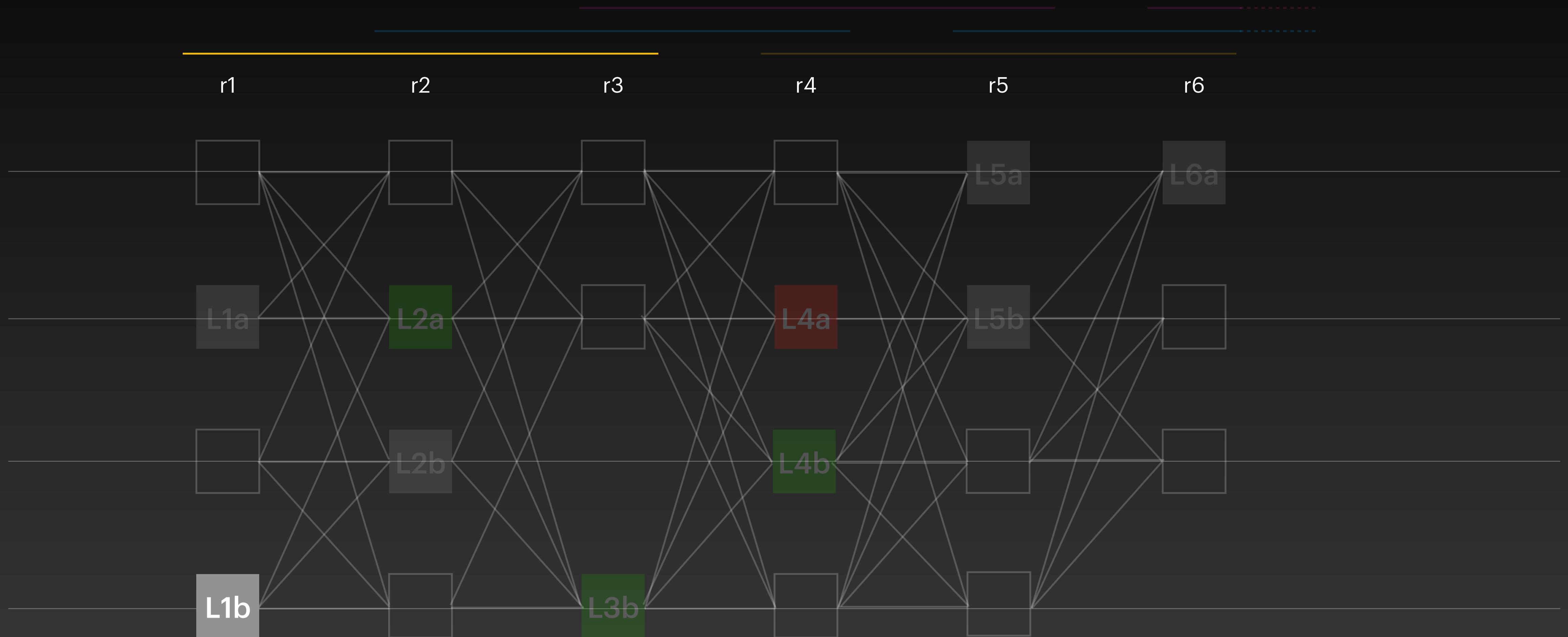
# Apply Direct Rule



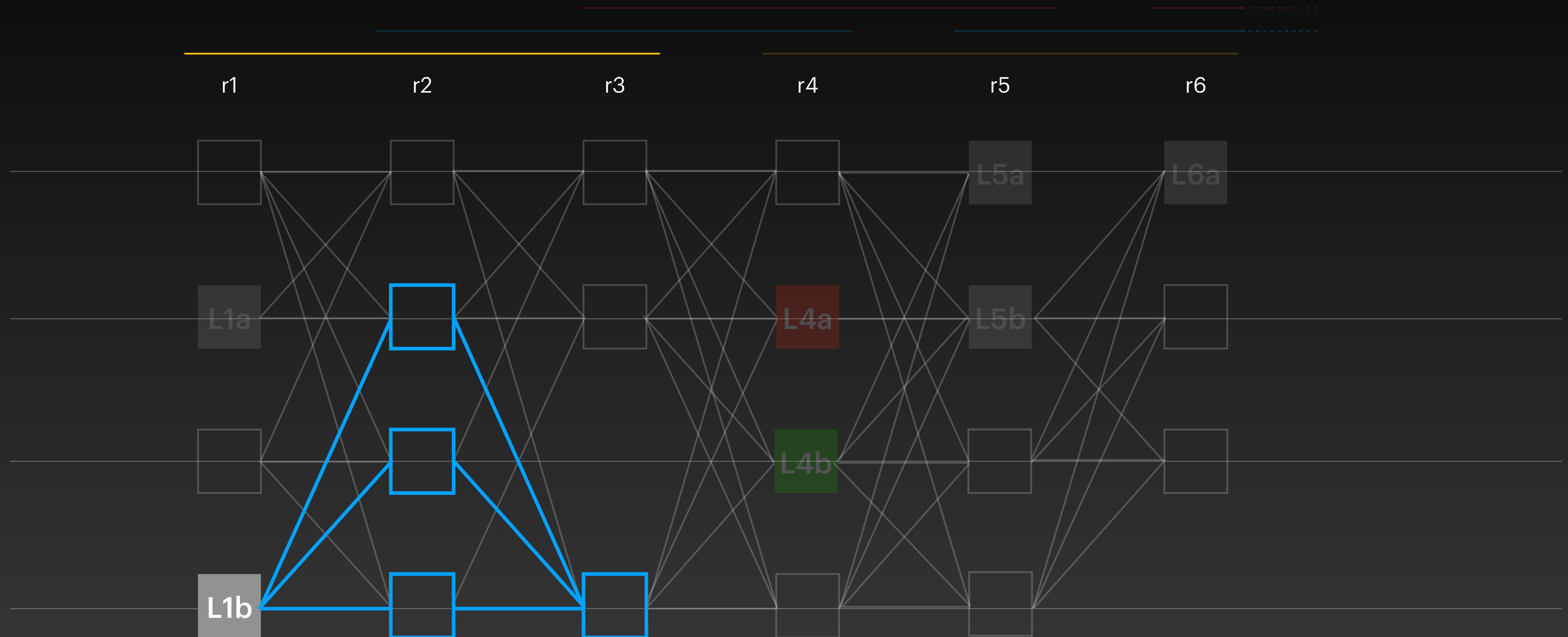
# Apply Direct Rule



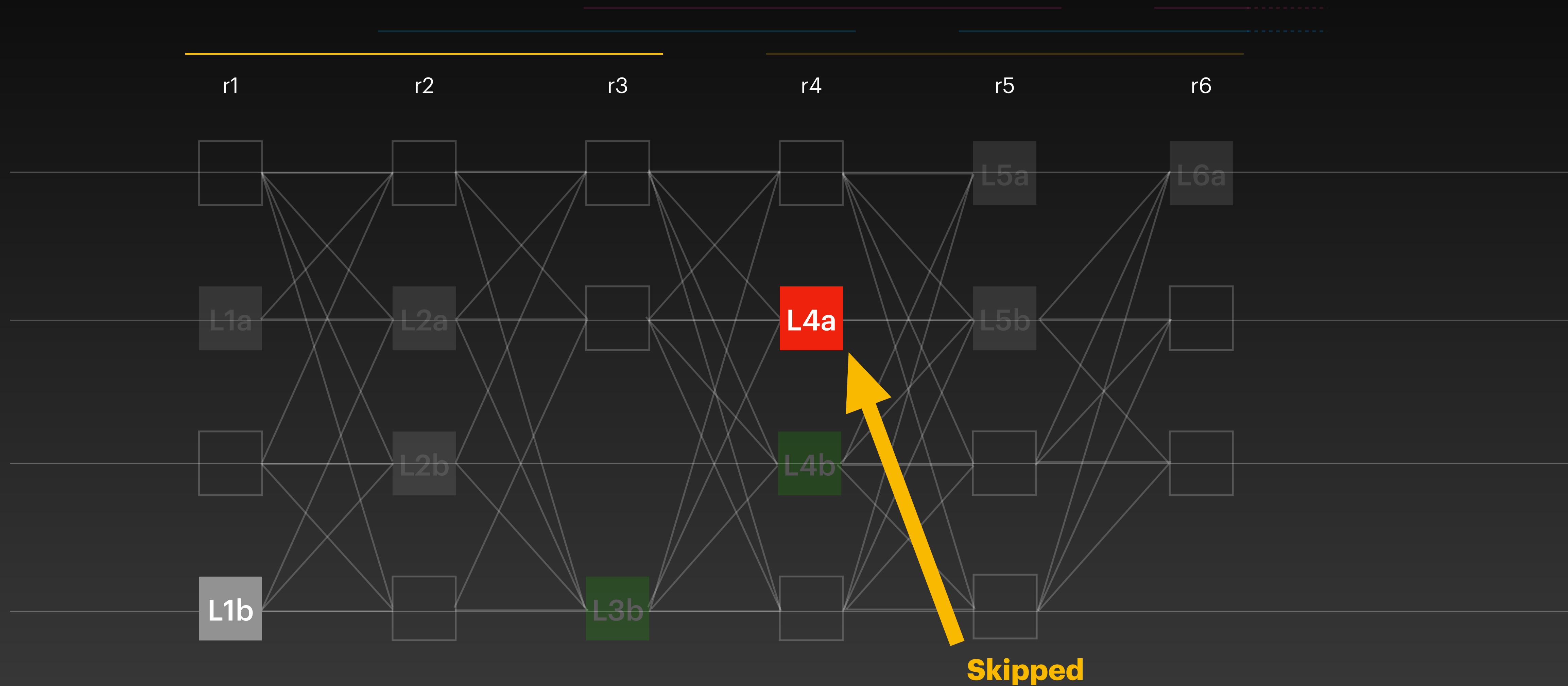
# Apply Direct Rule



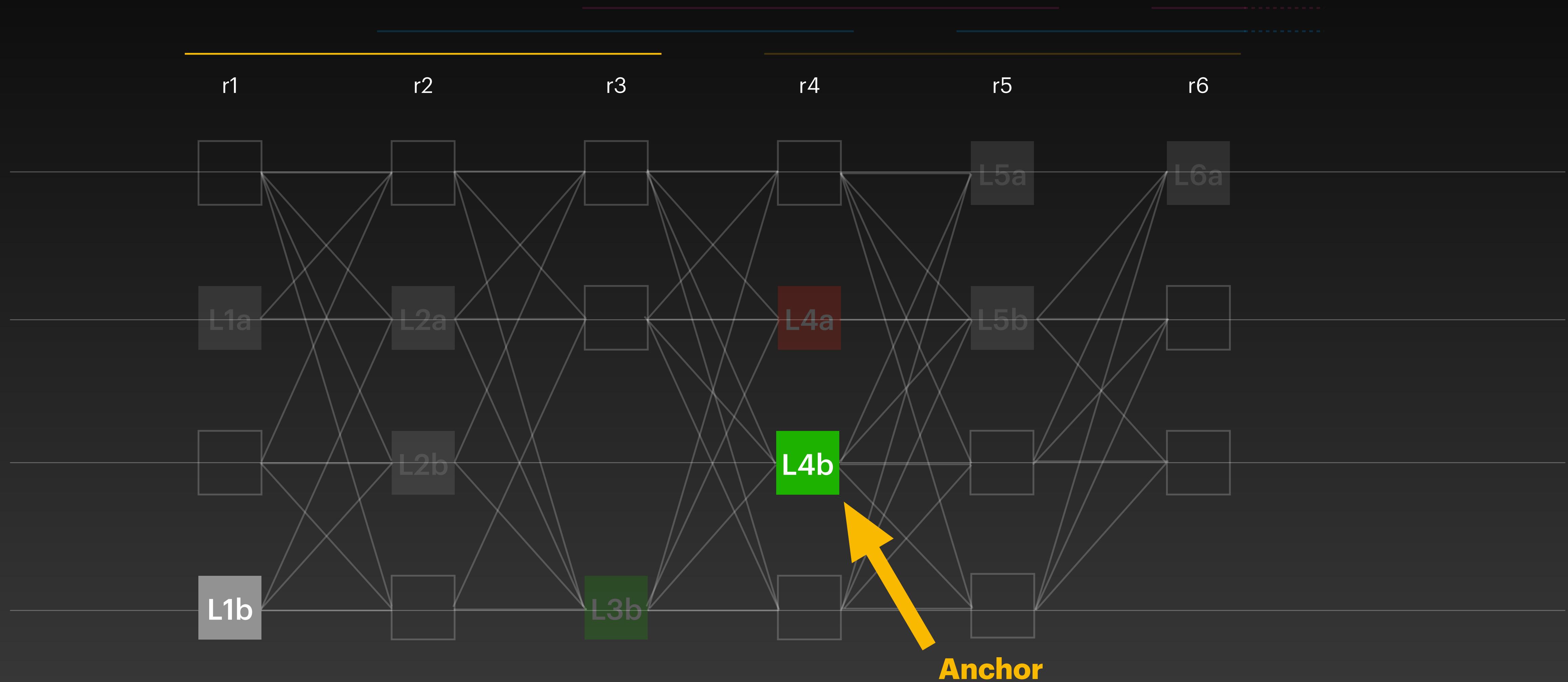
# Apply Direct Rule



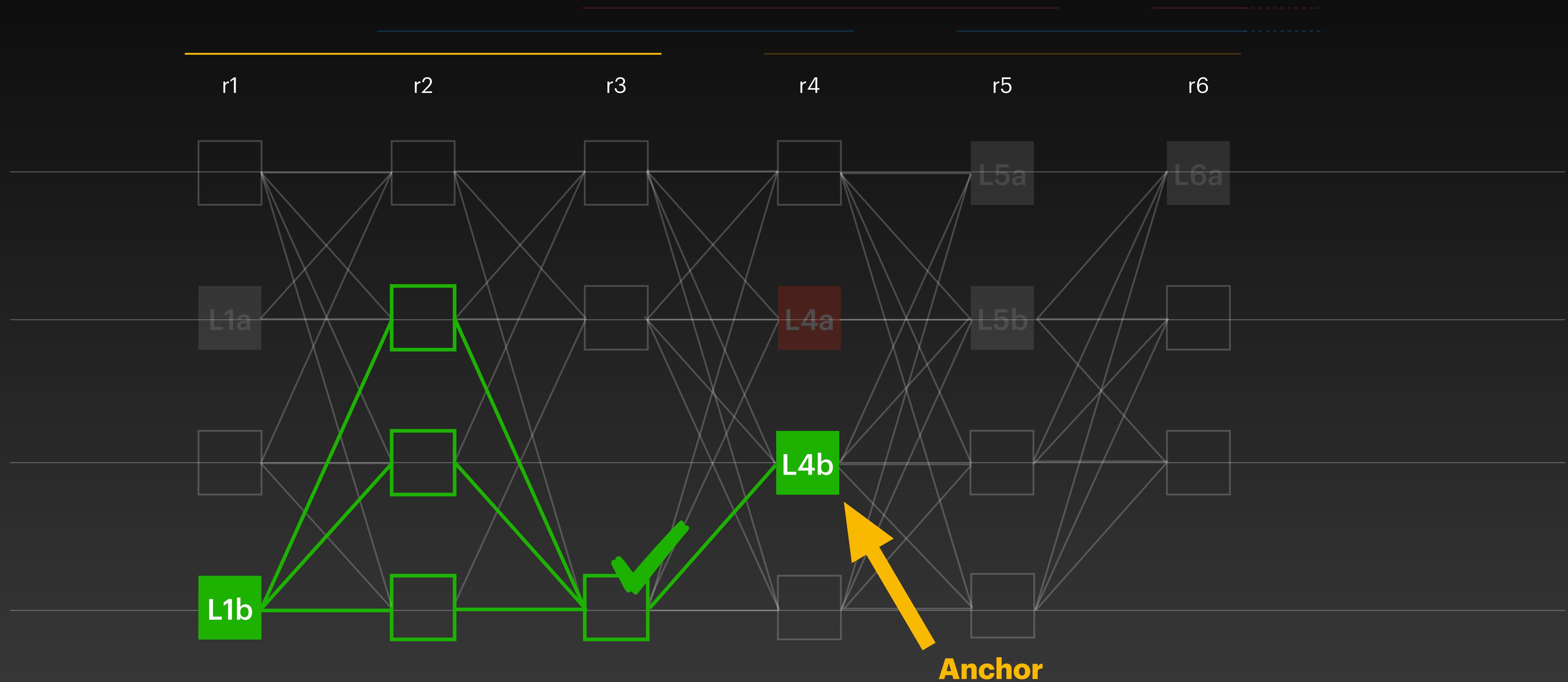
# Apply Indirect Rule



# Apply Indirect Rule

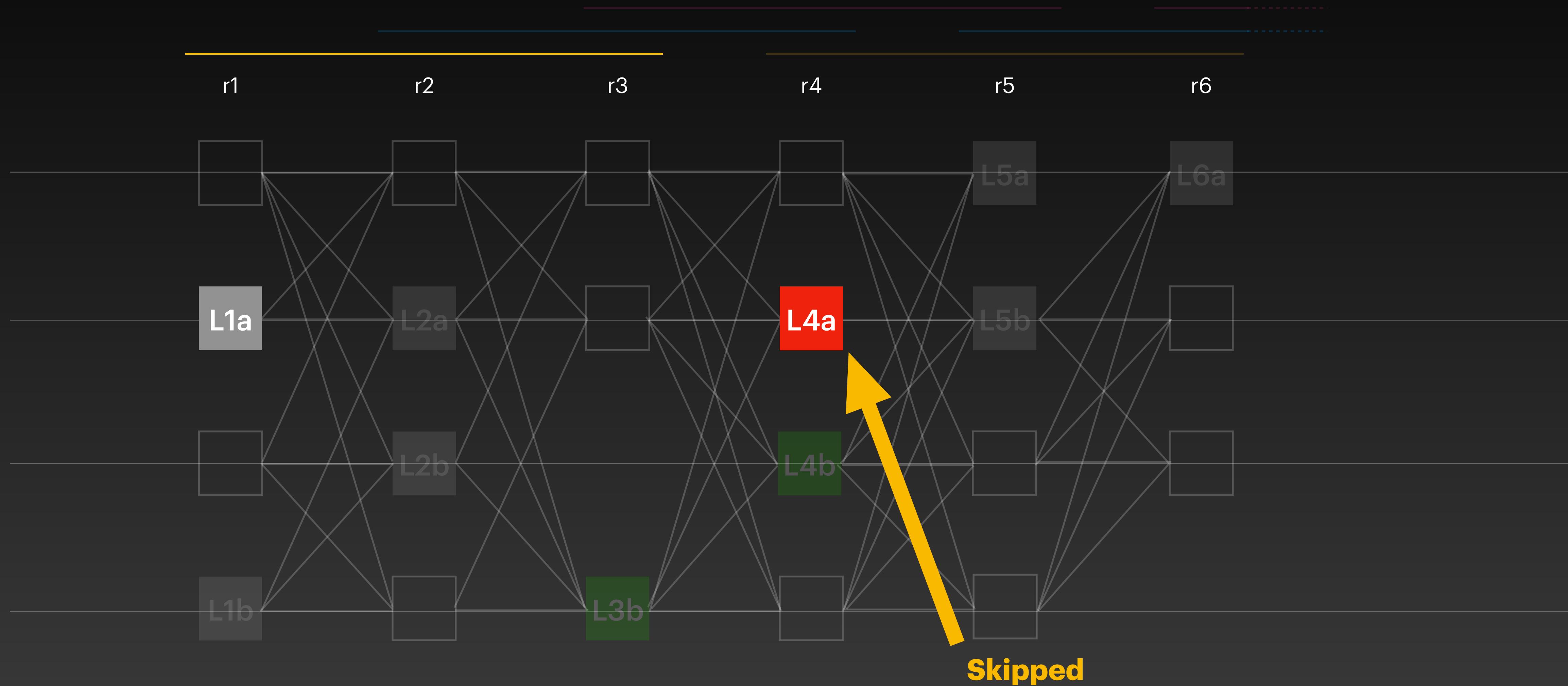


# Apply Indirect Rule

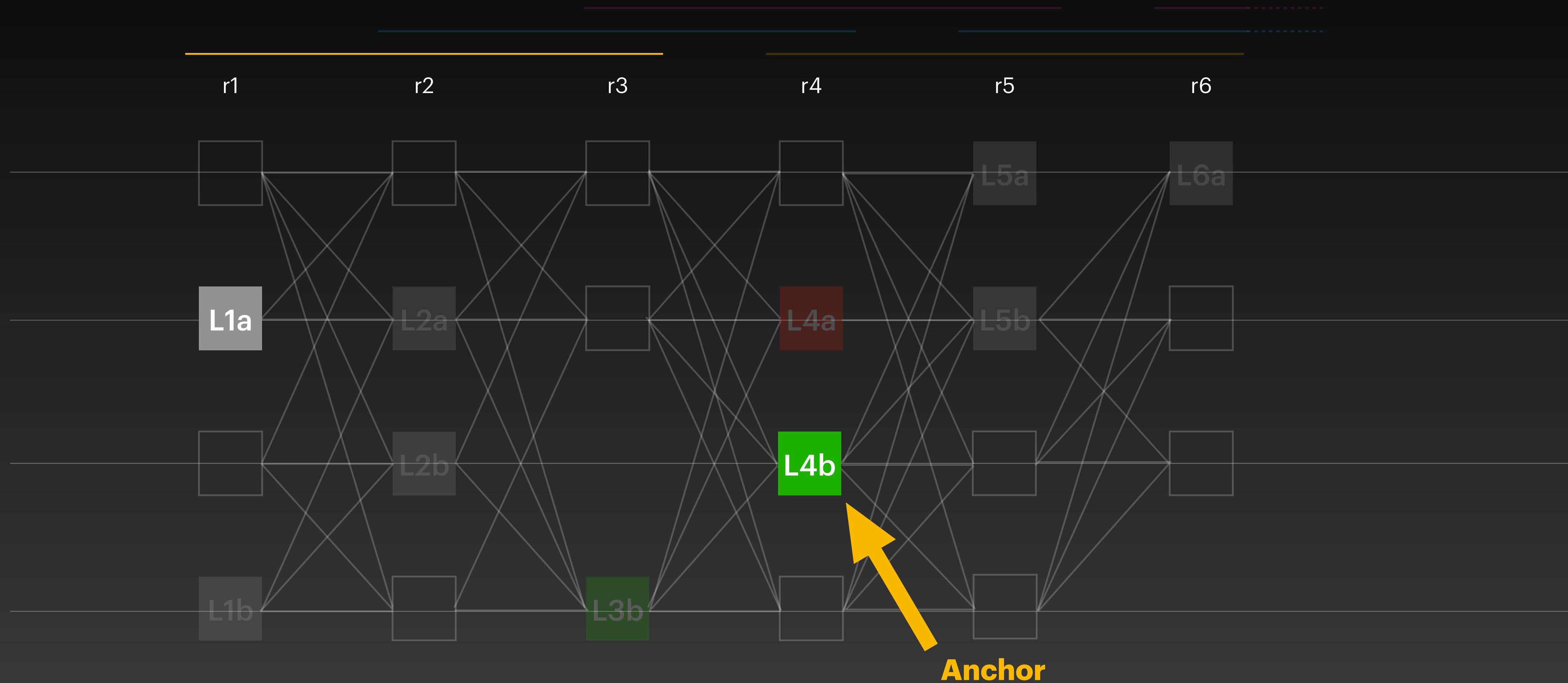


# Apply Direct Rule

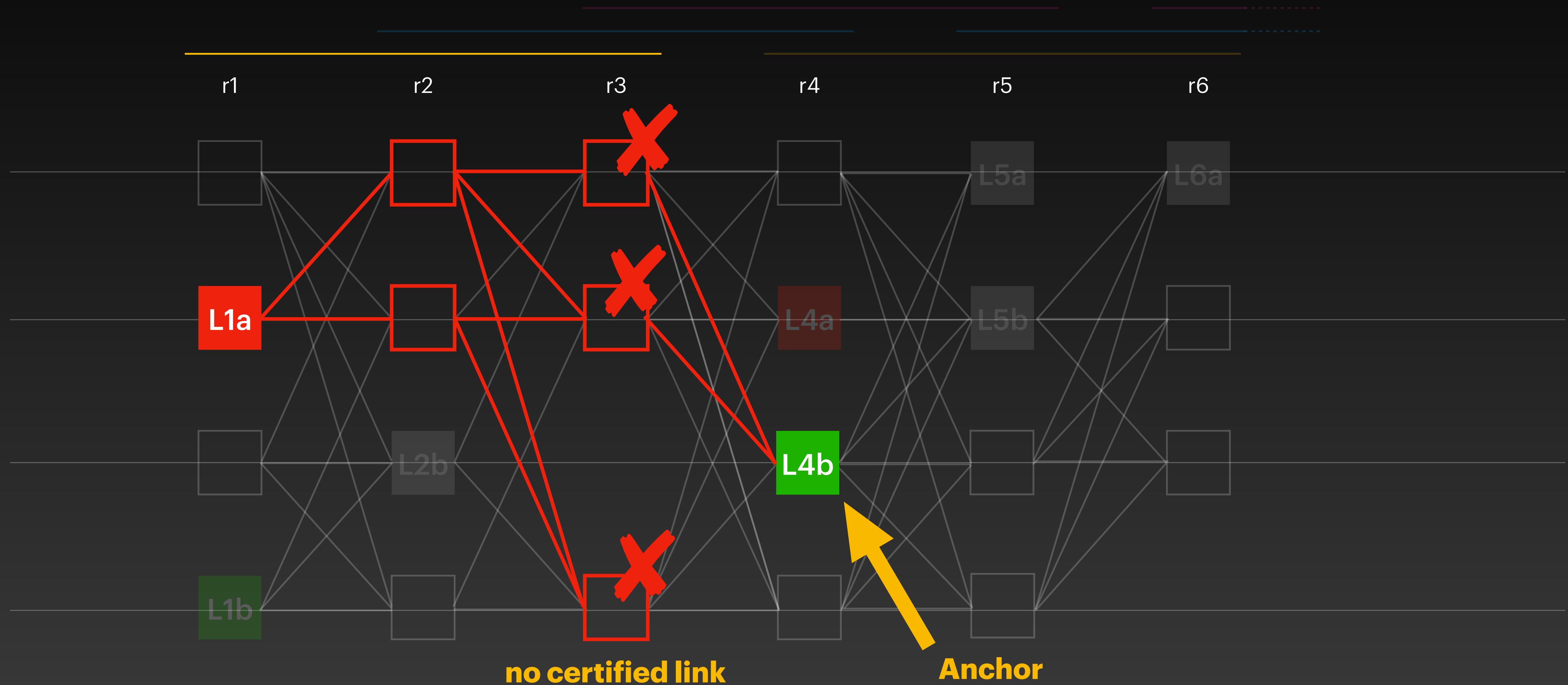
# Apply Indirect Rule



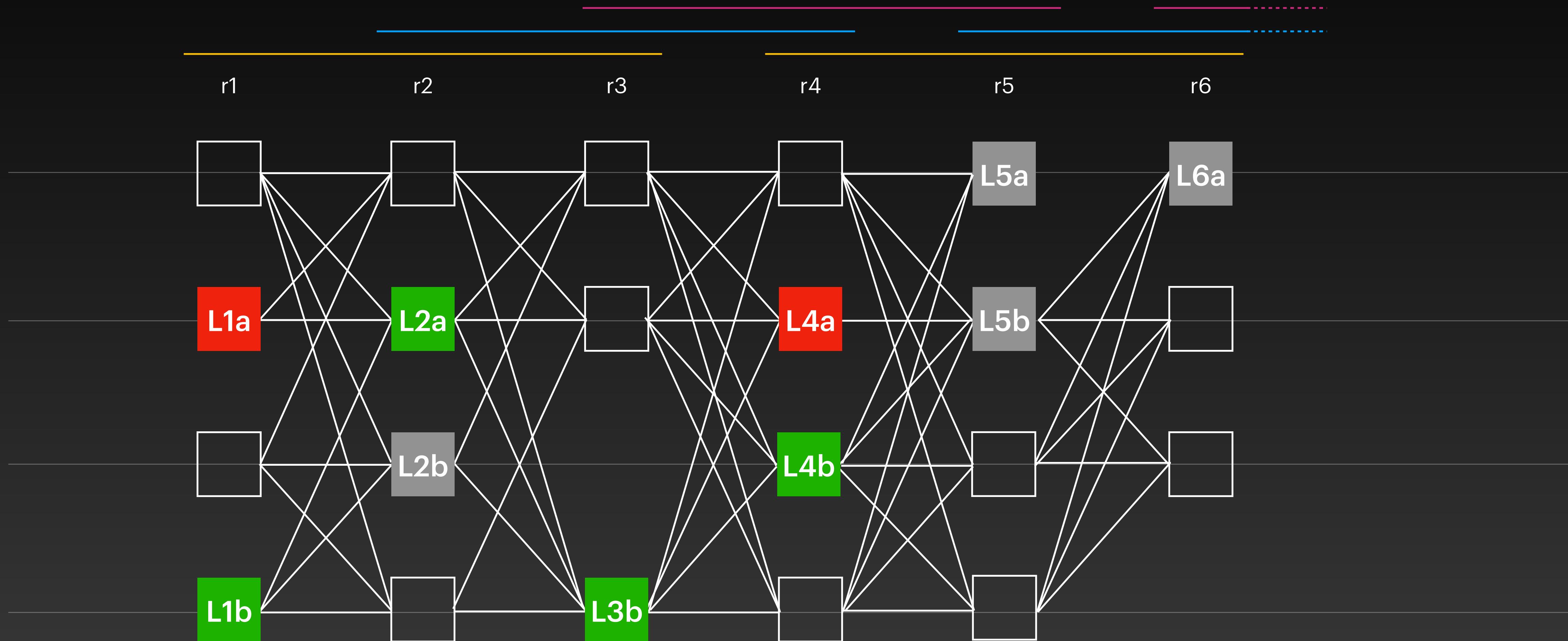
# Apply Indirect Rule



# Apply Indirect Rule

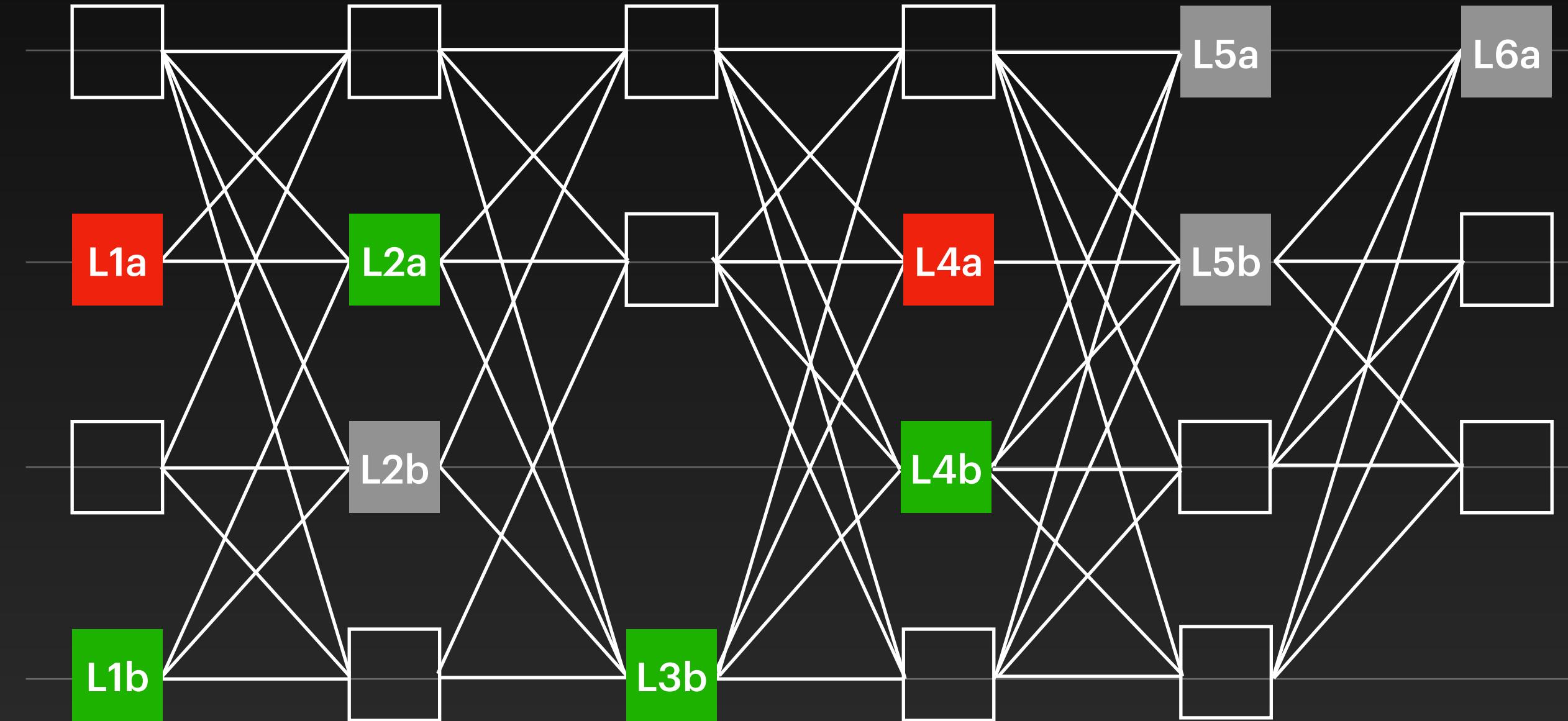


# Current Status



# Commit Sequence

## Take all leaders in order

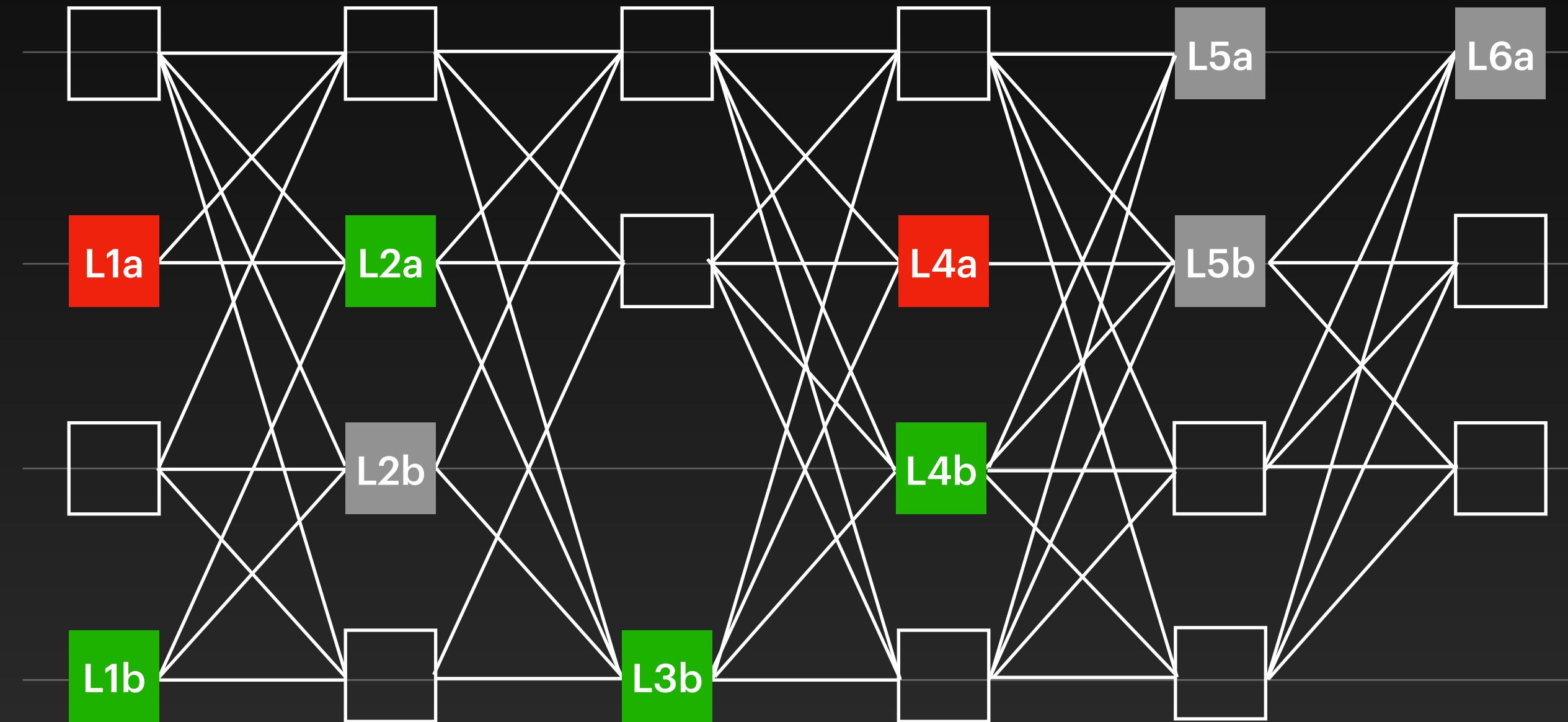


**leaders sequence:**

L1a L1b L2a L2b L3a L3b L4a L4b

# Commit Sequence

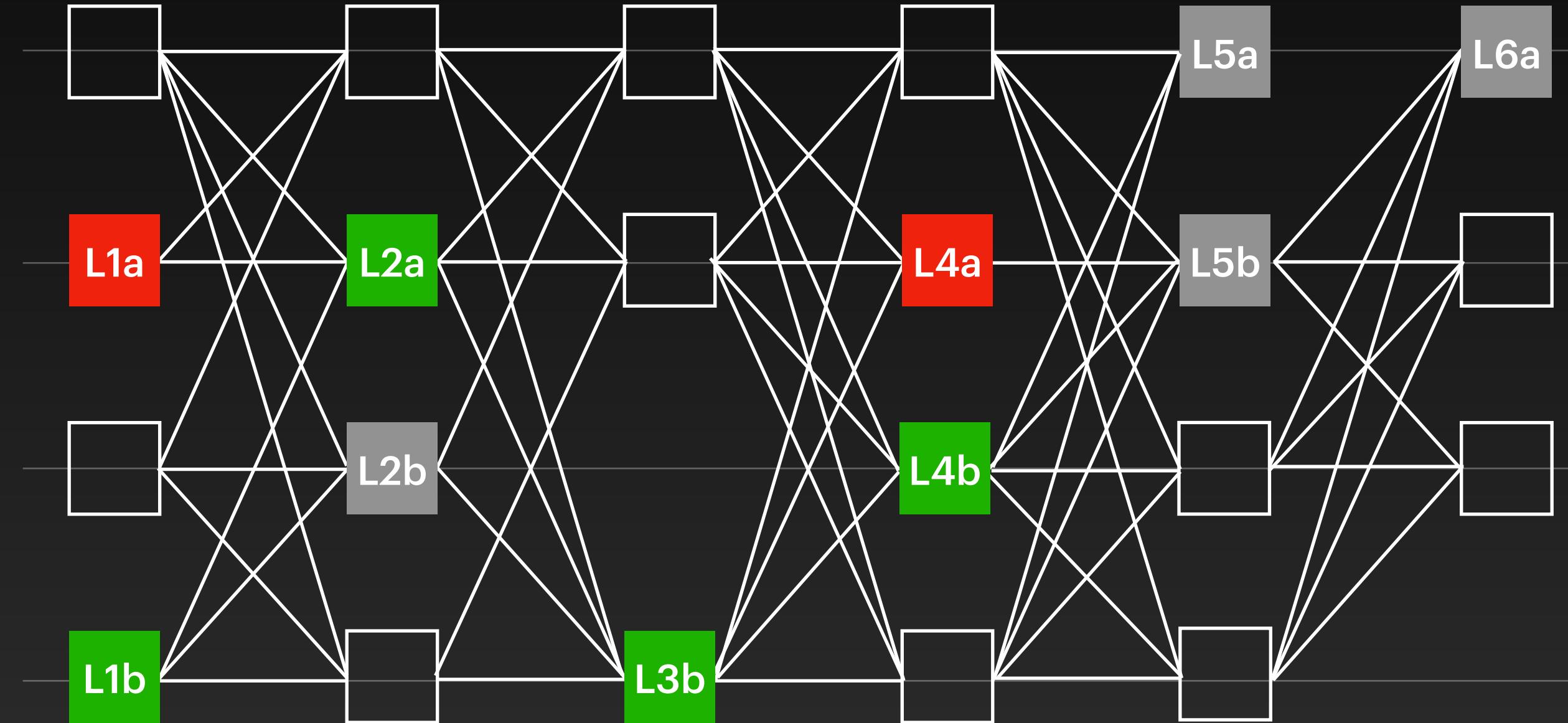
Stop at the first Undecided leader



**leaders sequence:** L1a L1b L2a | L2b L3a L3b L4a L4b

# Commit Sequence

## Remove skipped leaders

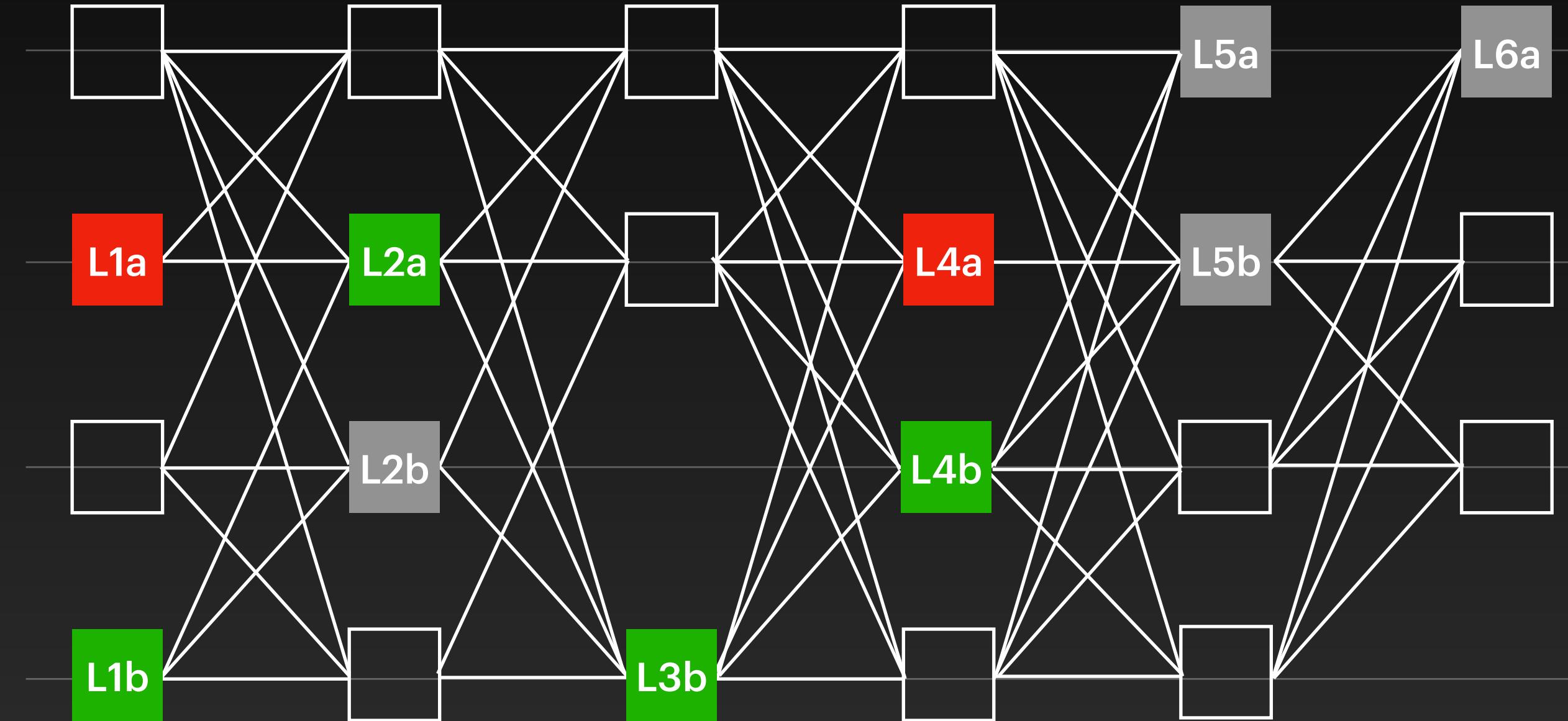


**leaders sequence:**

L1a    L1b    L2a    L2b    L3a    L3b    L4a    L4b

# Commit Sequence

## Final leader sequence

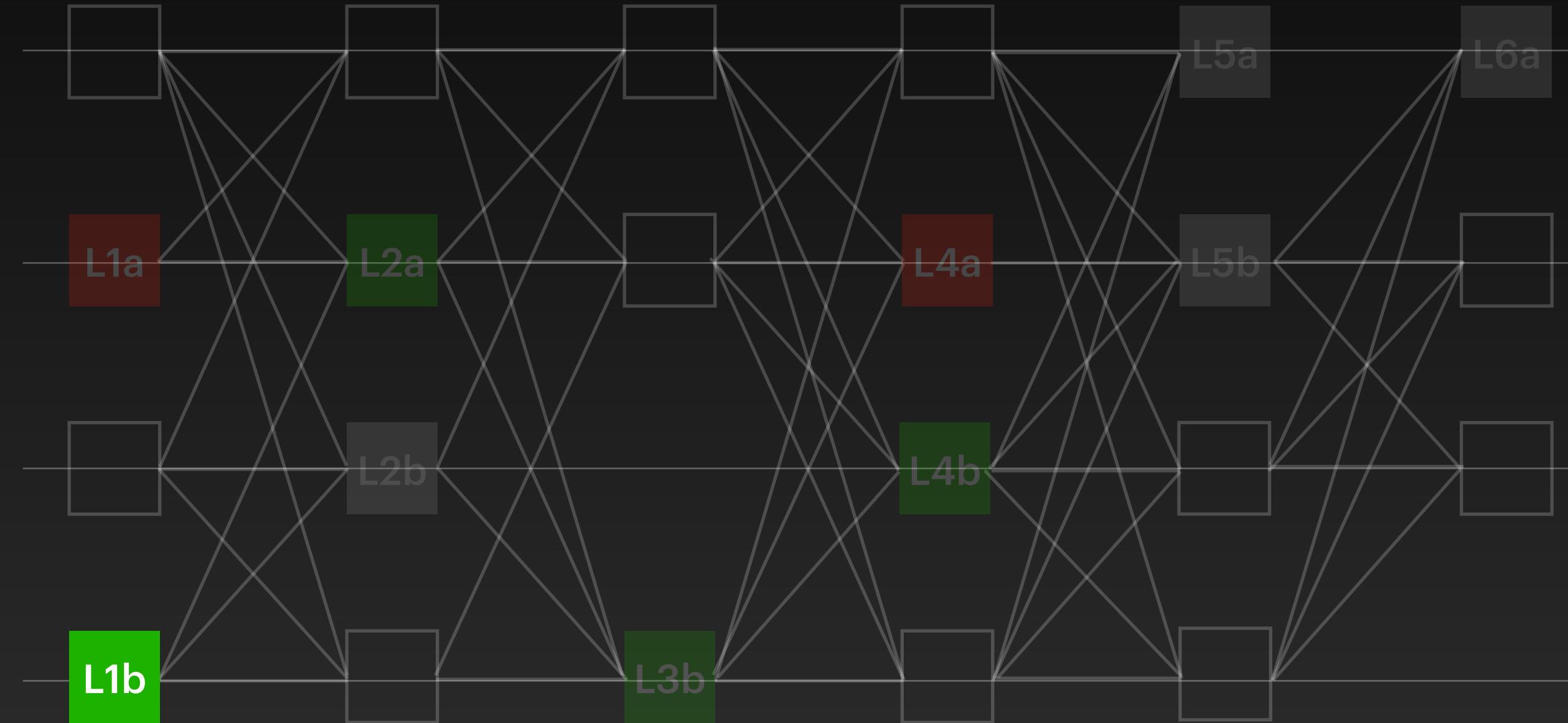


**leaders sequence:**

L1b L2a

# Commit Sequence

## Commit sub-dag



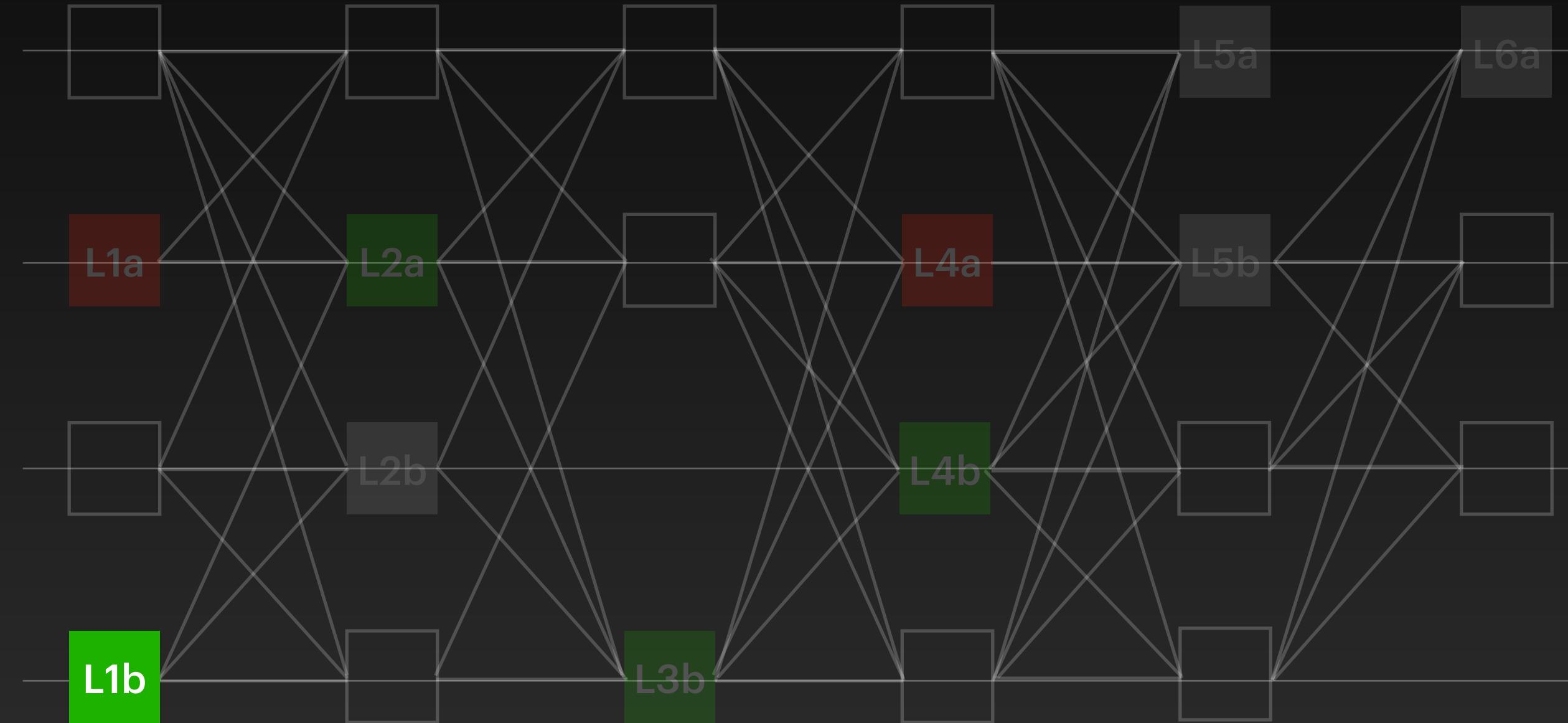
**leaders sequence:**



**output sequence:**

# Commit Sequence

## Commit sub-dag



**leaders sequence:**

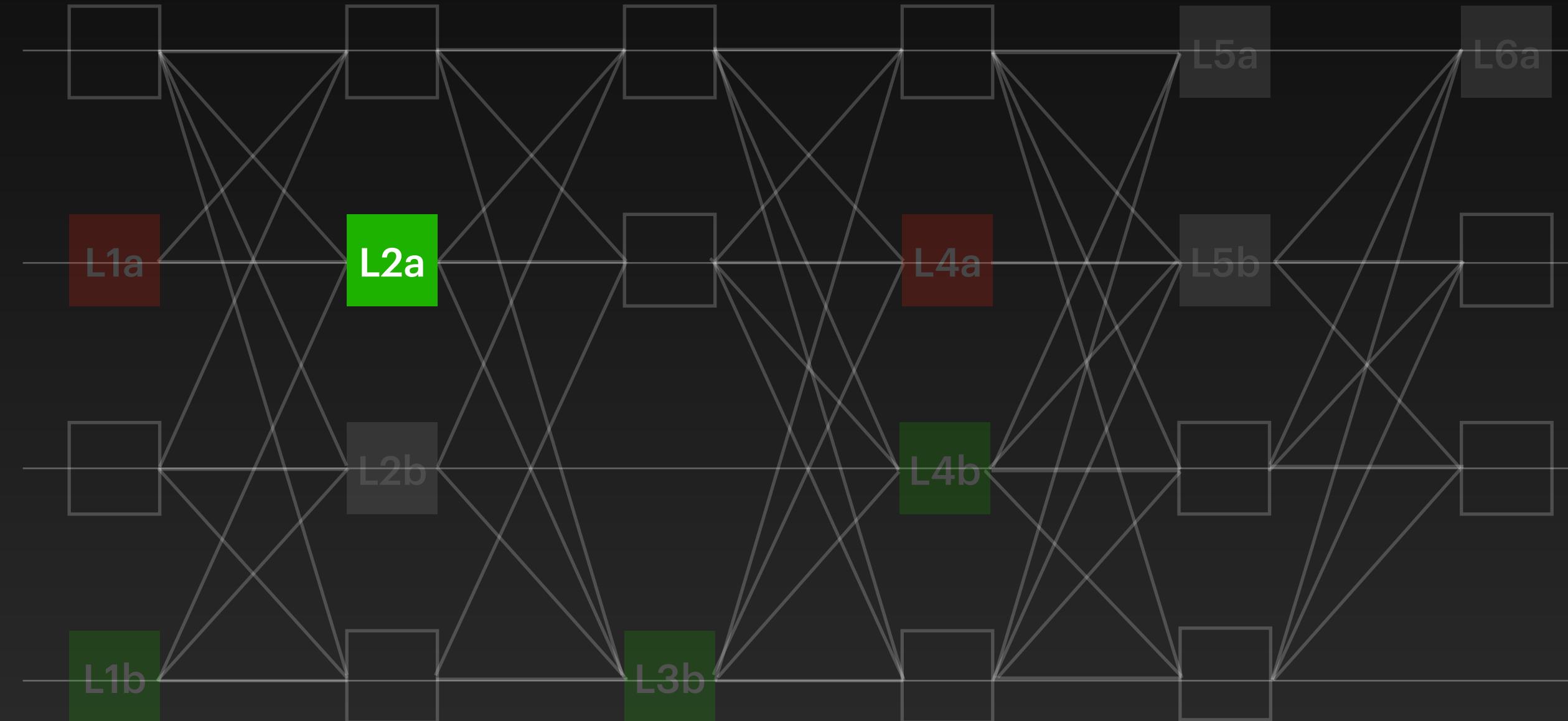
L2a

**output sequence:**

L1b

# Commit Sequence

## Commit sub-dag



**leaders sequence:**

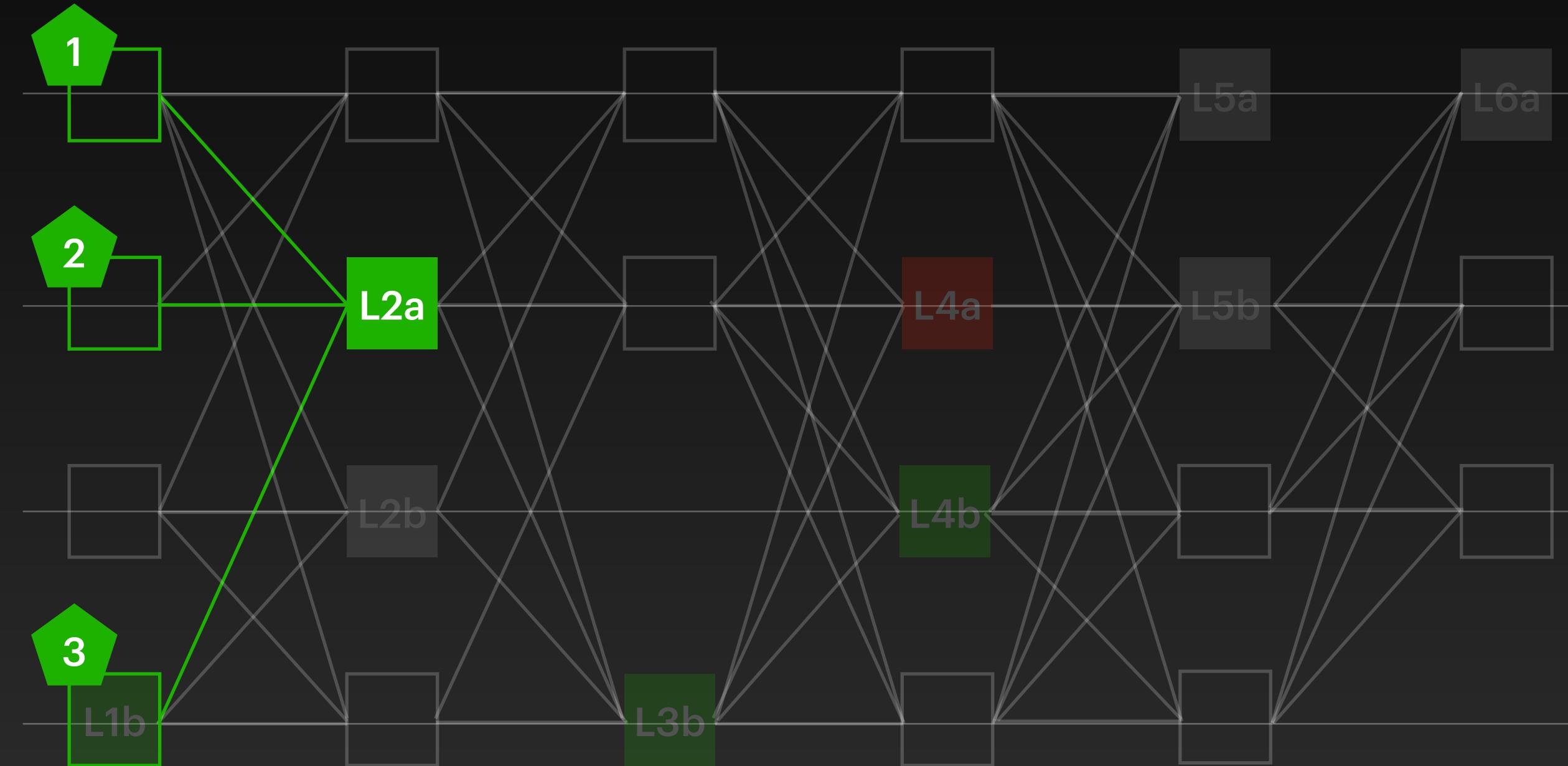
L2a

**output sequence:**

L1b

# Commit Sequence

## Commit sub-dag



**leaders sequence:**

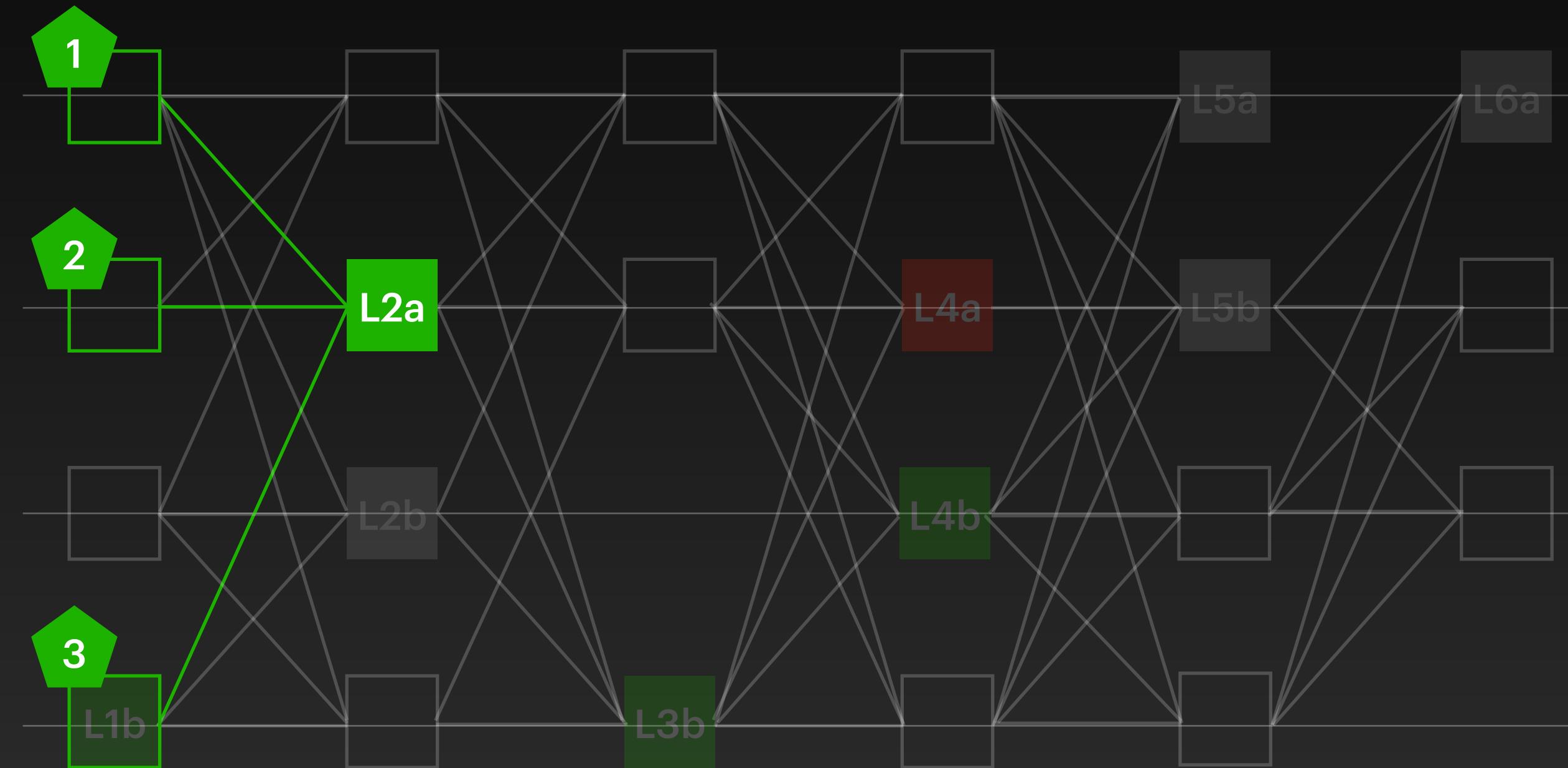
L2a

**output sequence:**

L1b

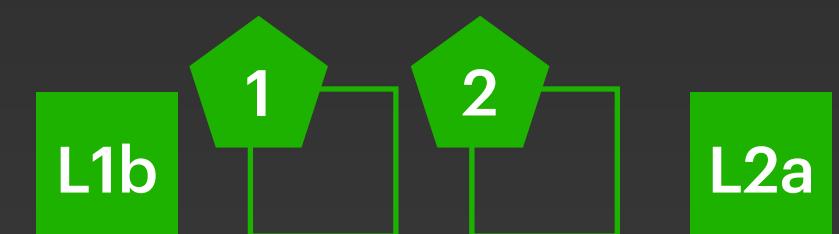
# Commit Sequence

## Commit sub-dag



**leaders sequence:**

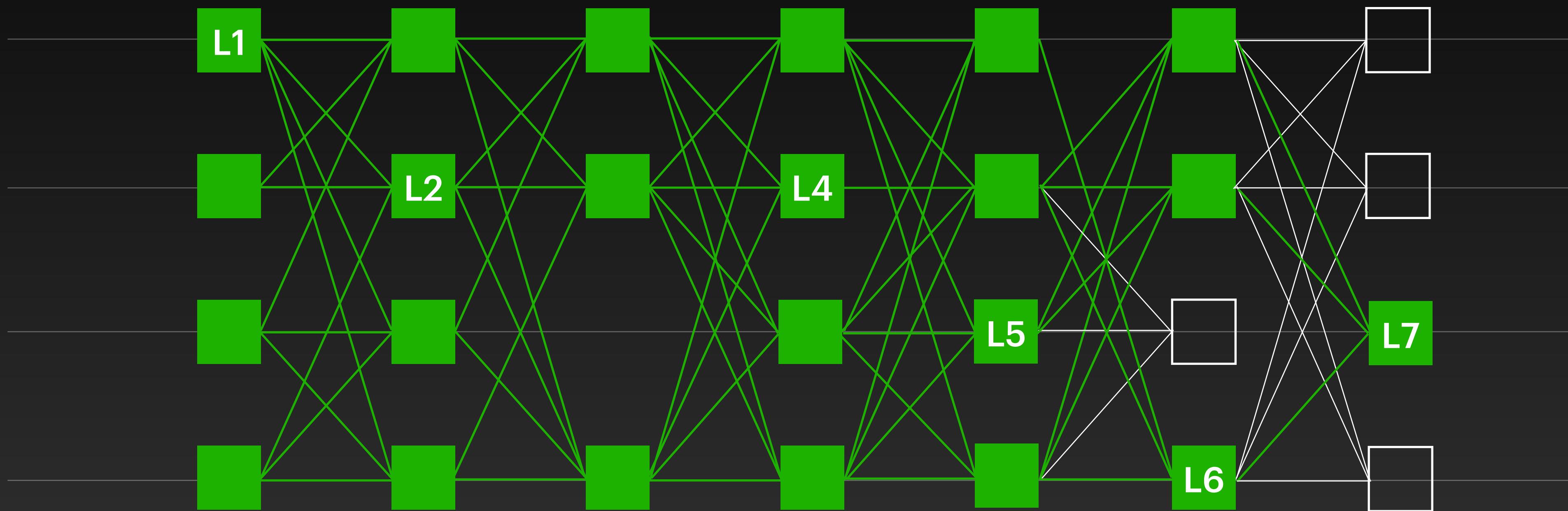
**output sequence:**



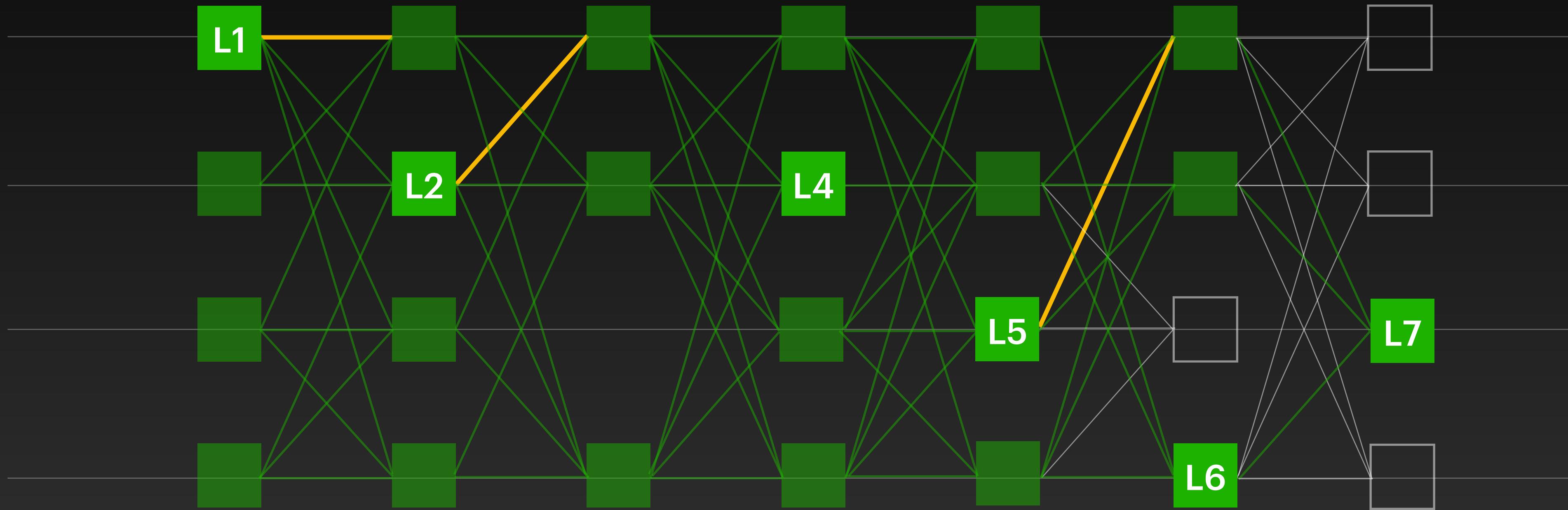
# HammerHead

Mitigating slow leaders

# Past Commits

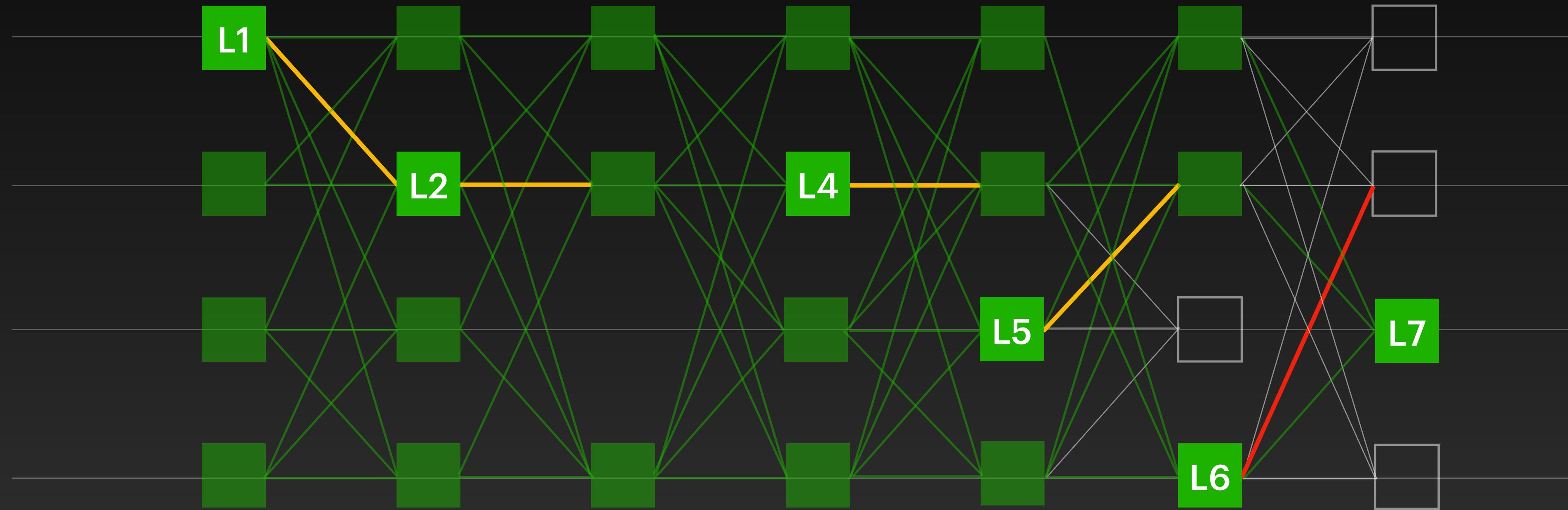


# Compute Reputation Scores



**node 1:** 3

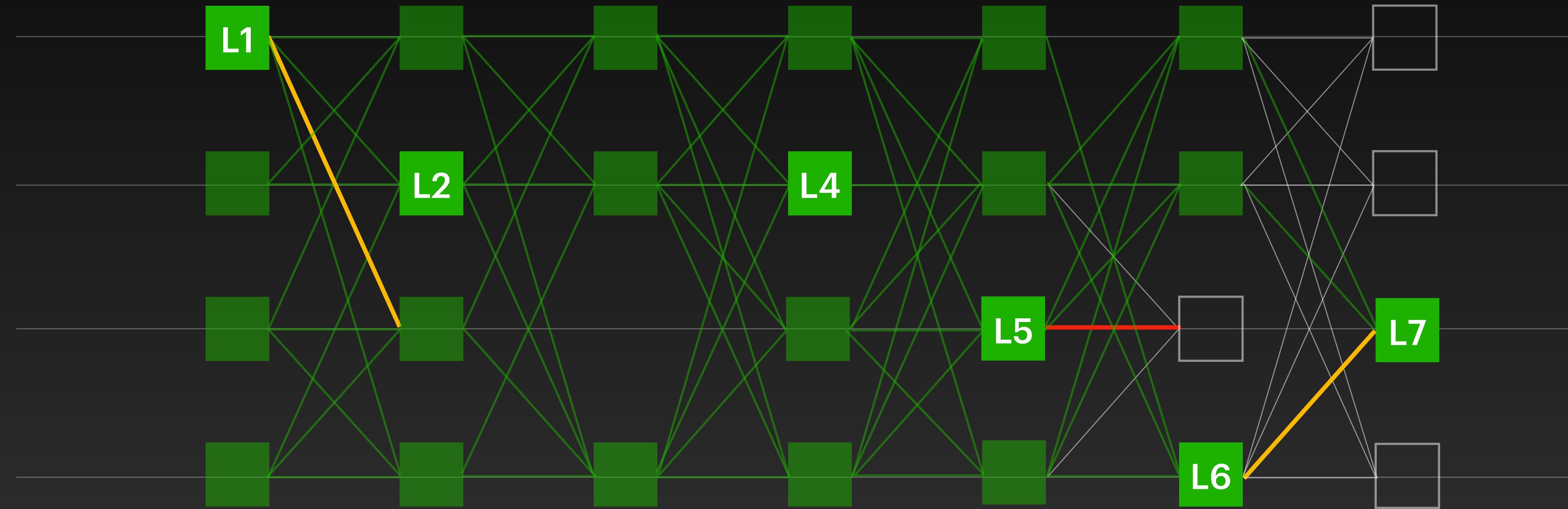
# Compute Reputation Scores



**node 1:** 3

**node 2:** 4

# Compute Reputation Scores

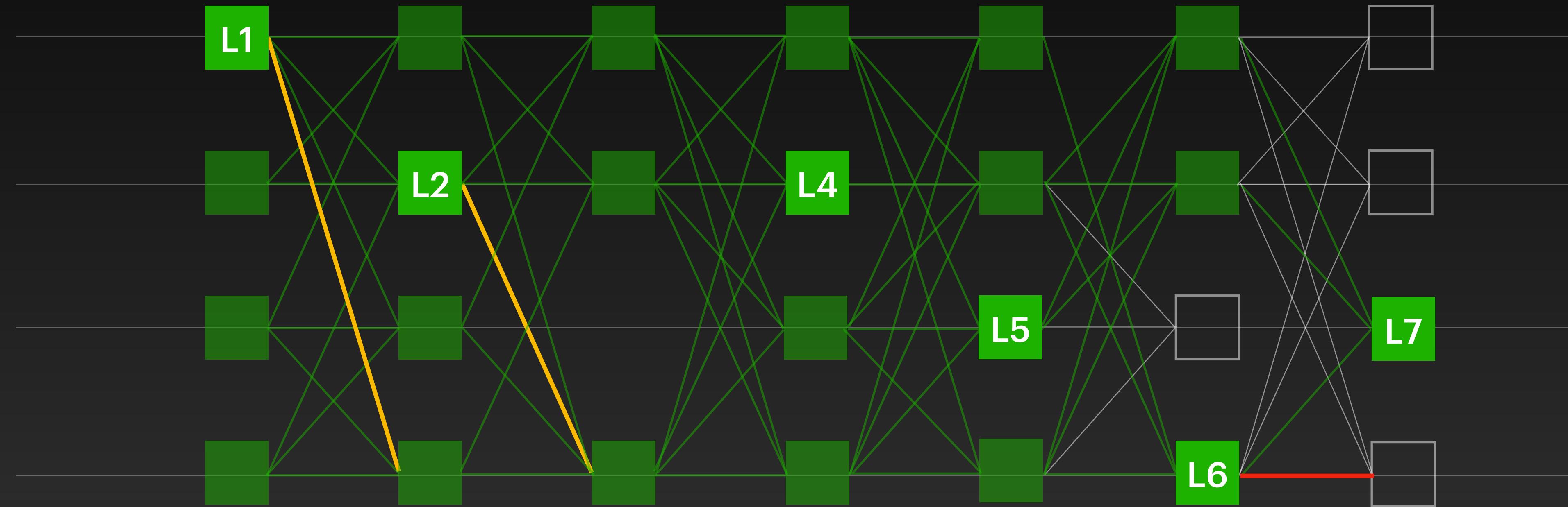


**node 1:** 3

**node 2:** 4

**node 3:** 2

# Compute Reputation Scores



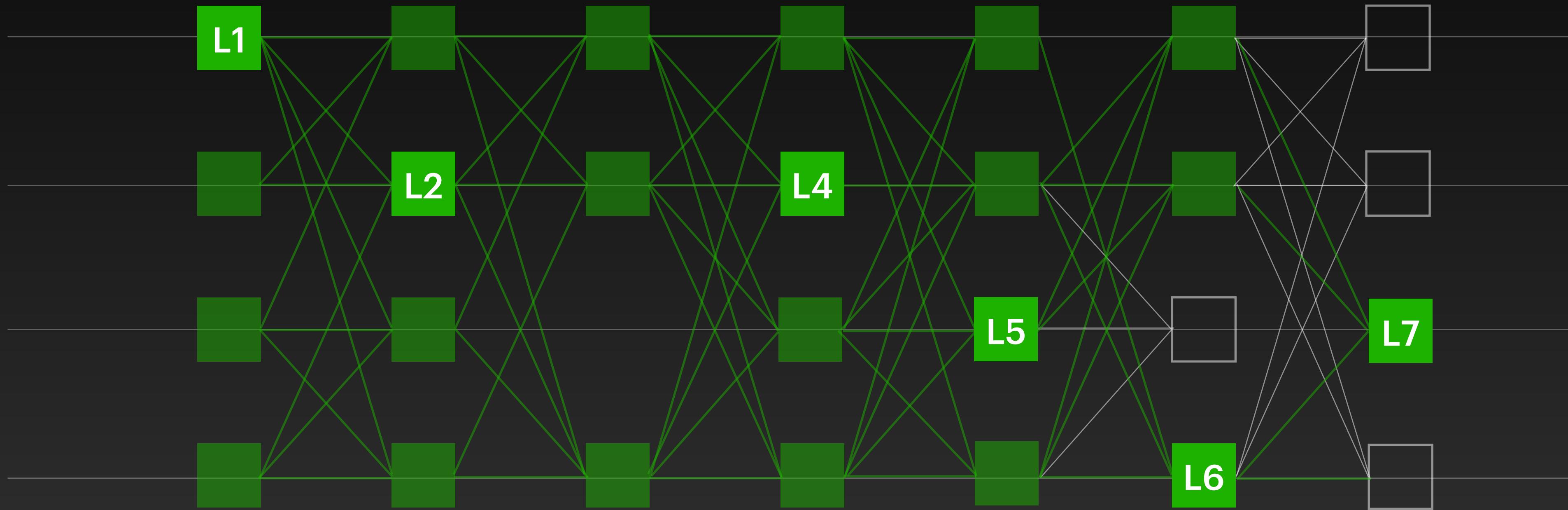
**node 1:** 3

**node 2:** 4

**node 3:** 2

**node 4:** 2

# Future Leaders



node 1: 3

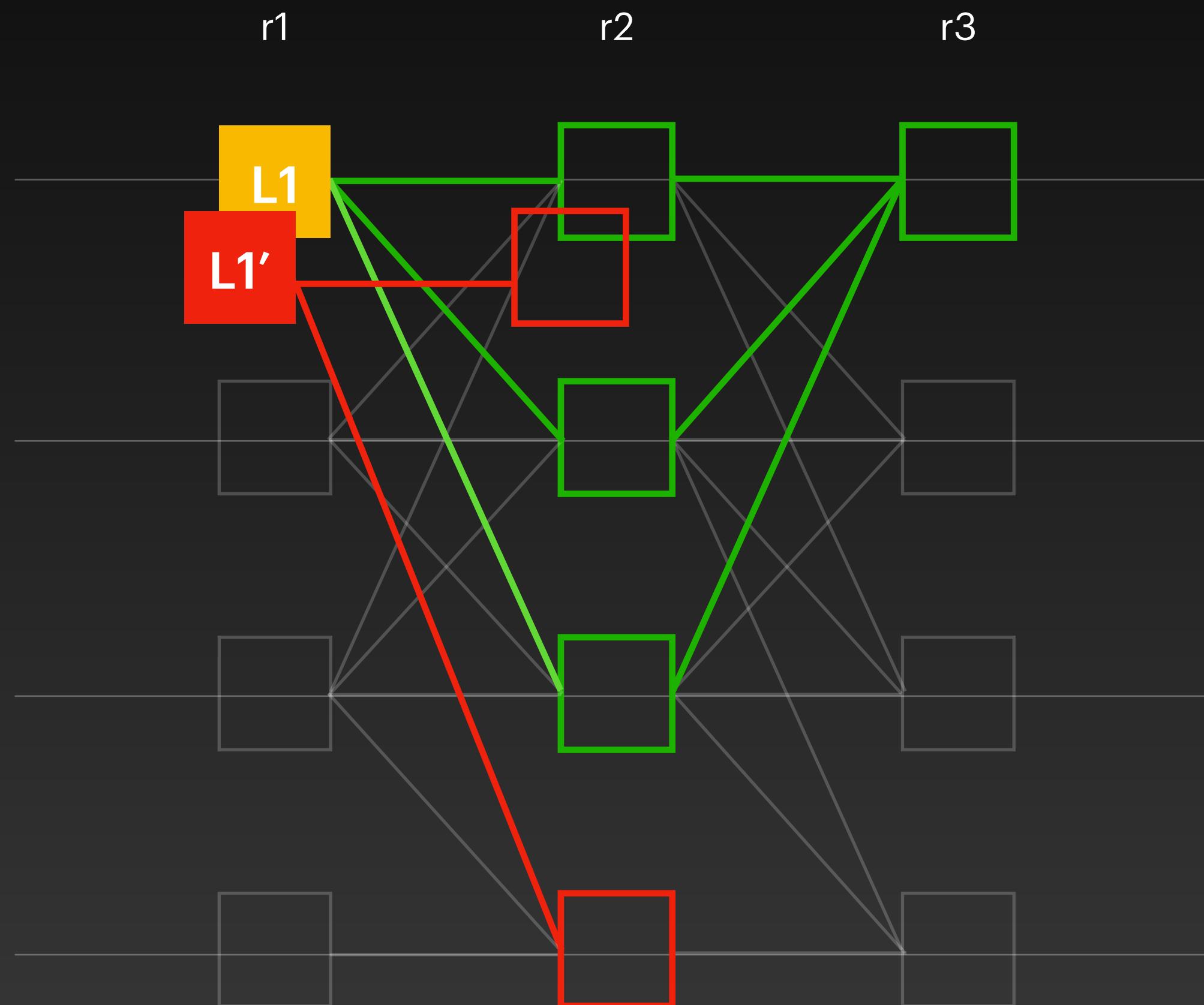
node 2: 4

node 3: 2

node 4: 2

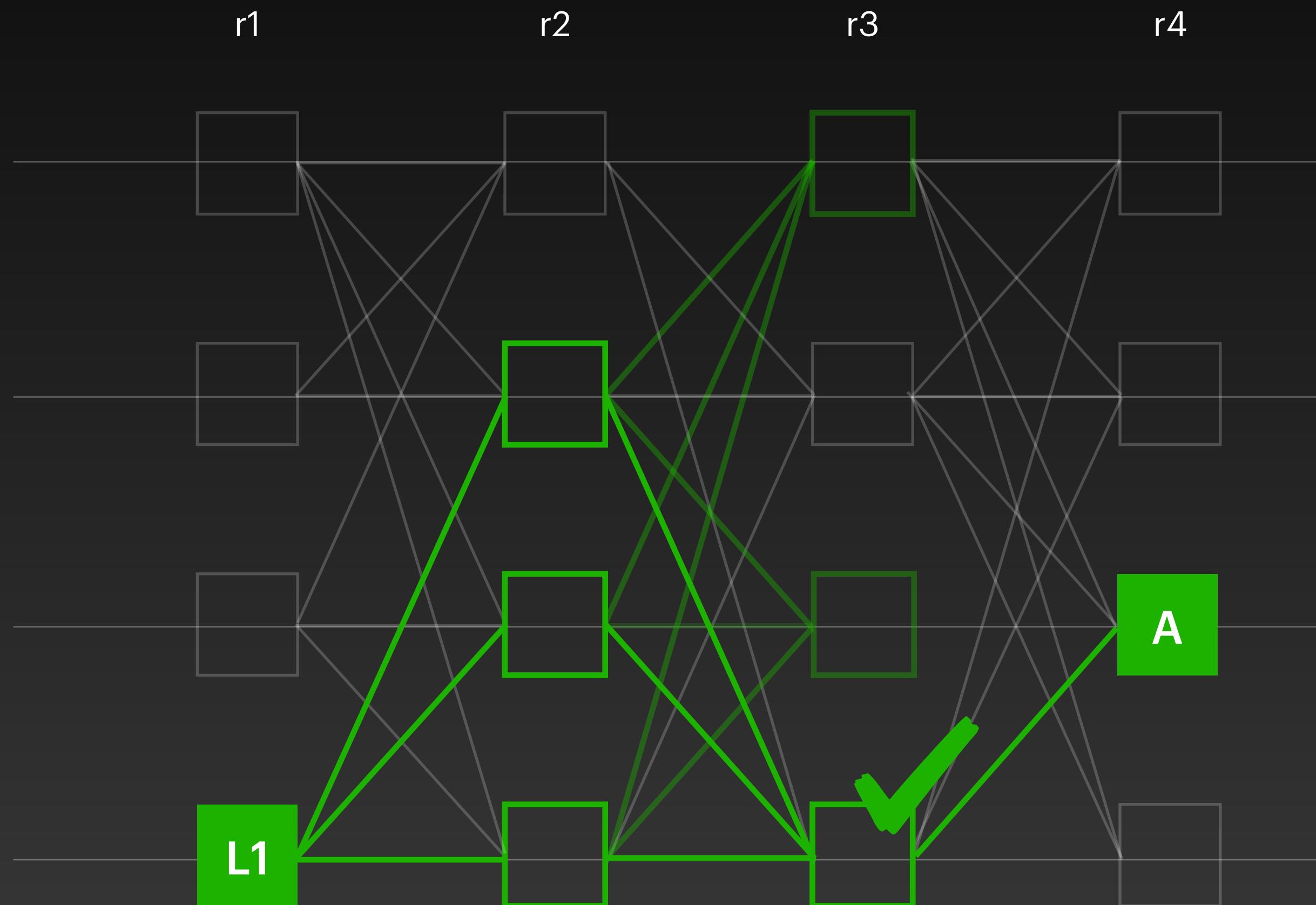
# Security Intuition

# Security Intuition



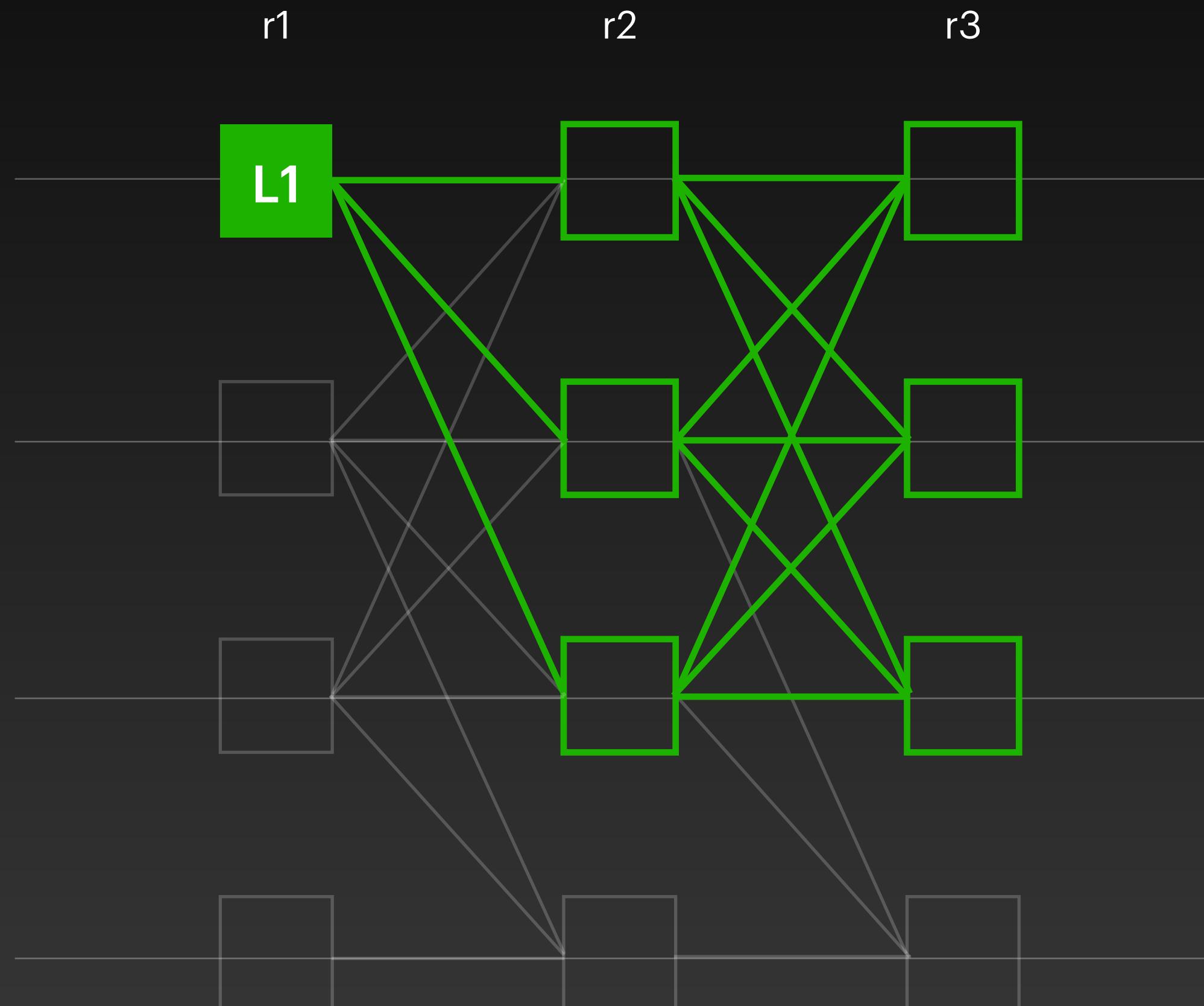
- At most **L1** or **L1'** can have a certificate pattern (quorum intersection)

# Security Intuition



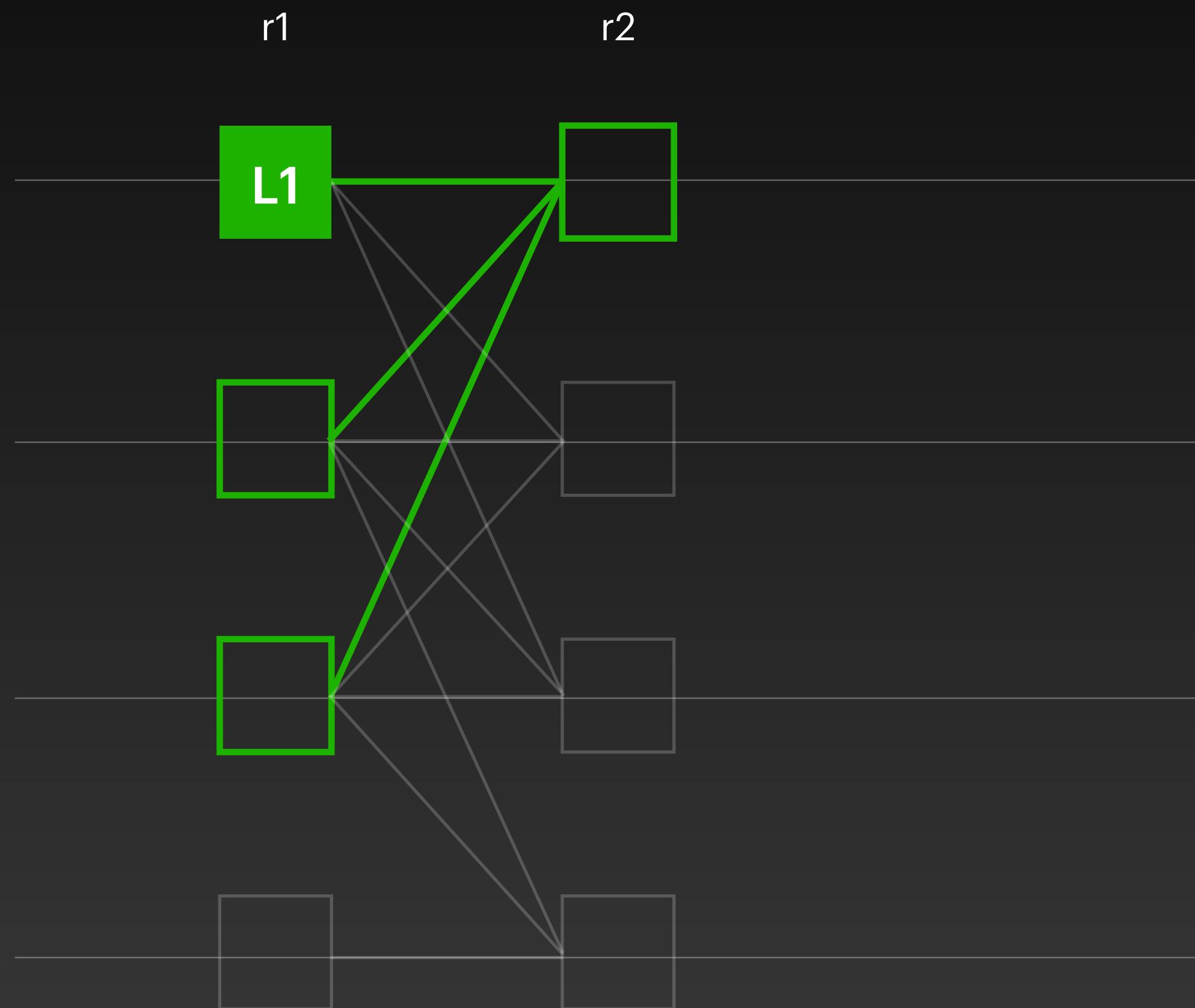
- At most **L1** or **L1'** can have a certificate pattern (quorum intersection)
- If **L1** has  $2f+1$  certificate patterns, **A** always has a certified link to **L1**

# Security Intuition



- At most **L1** or **L1'** can have a certificate pattern (quorum intersection)
- If **L1** has  $2f+1$  certificate patterns, **A** always has a certified link to **L1**
- After GST, the direct decision rule **commits** a block

# Security Intuition



**Leader Timeout:**

Wait for  $2f+1$  parents + 250 ms

# Mysticeti-FPC

Adding a fast commit path

# Consensus Not Required

Coins, balances, and transfers

NFTs creation and transfers

Game logic allowing users to combine assets

Inventory management for games / metaverse

Auditable 3rd party services not trusted for safety

...

# Consensus Required

Increment a publicly-accessible counter

Auctions

Market places

Collaborative in-game assets

...

# Object Type

## Owned Objects

- Objects that can be mutated by a single entity
- e.g., My bank account
- **Do not need consensus**

## Shared Objects

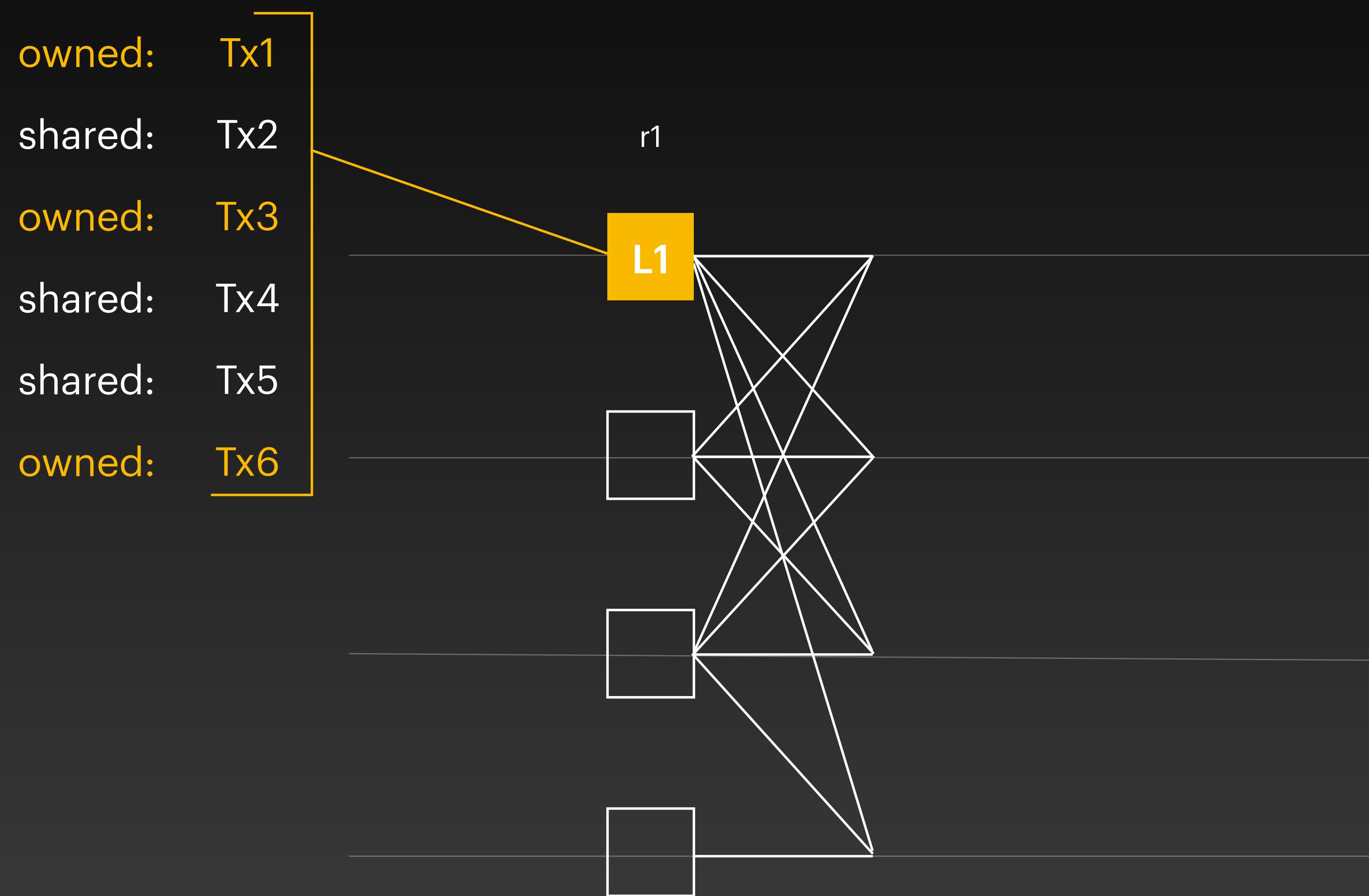
- Objects that can be mutated my multiple entities
- e.g., A global counter
- **Need consensus**

# System State

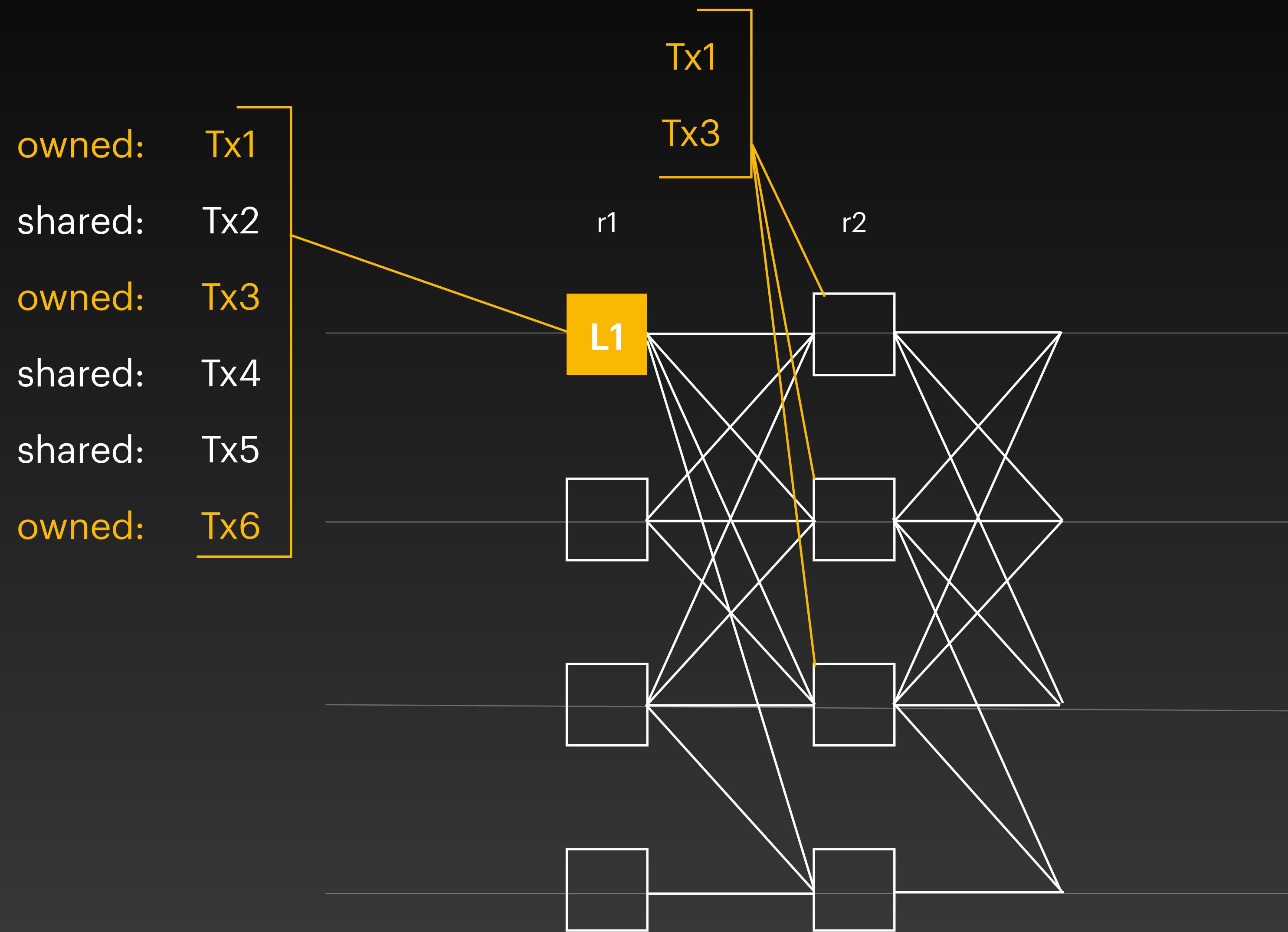
## Objects:

- Unique ID
- Version number
- Ownership Information
- Type (shared, owned)

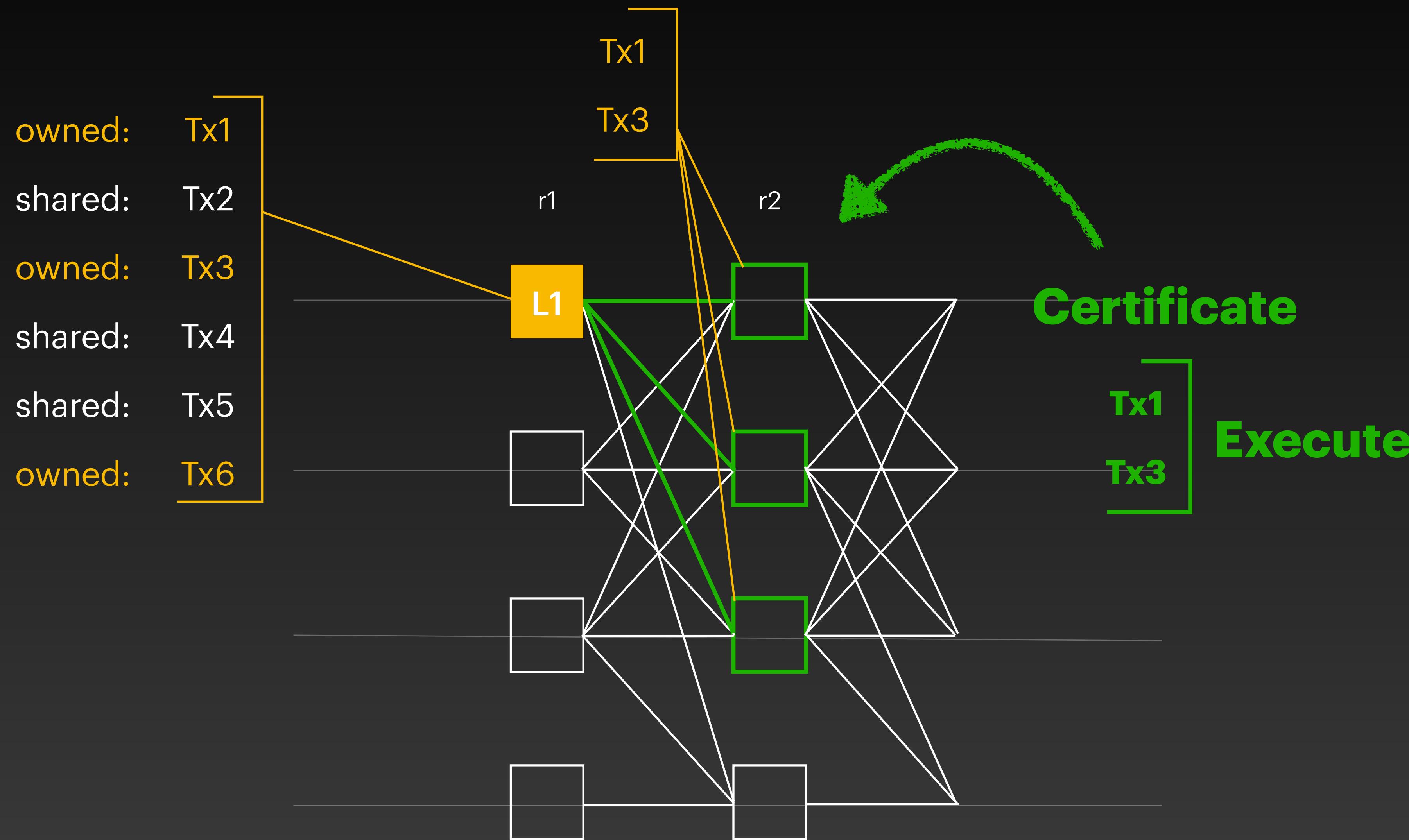
# Fast Execution



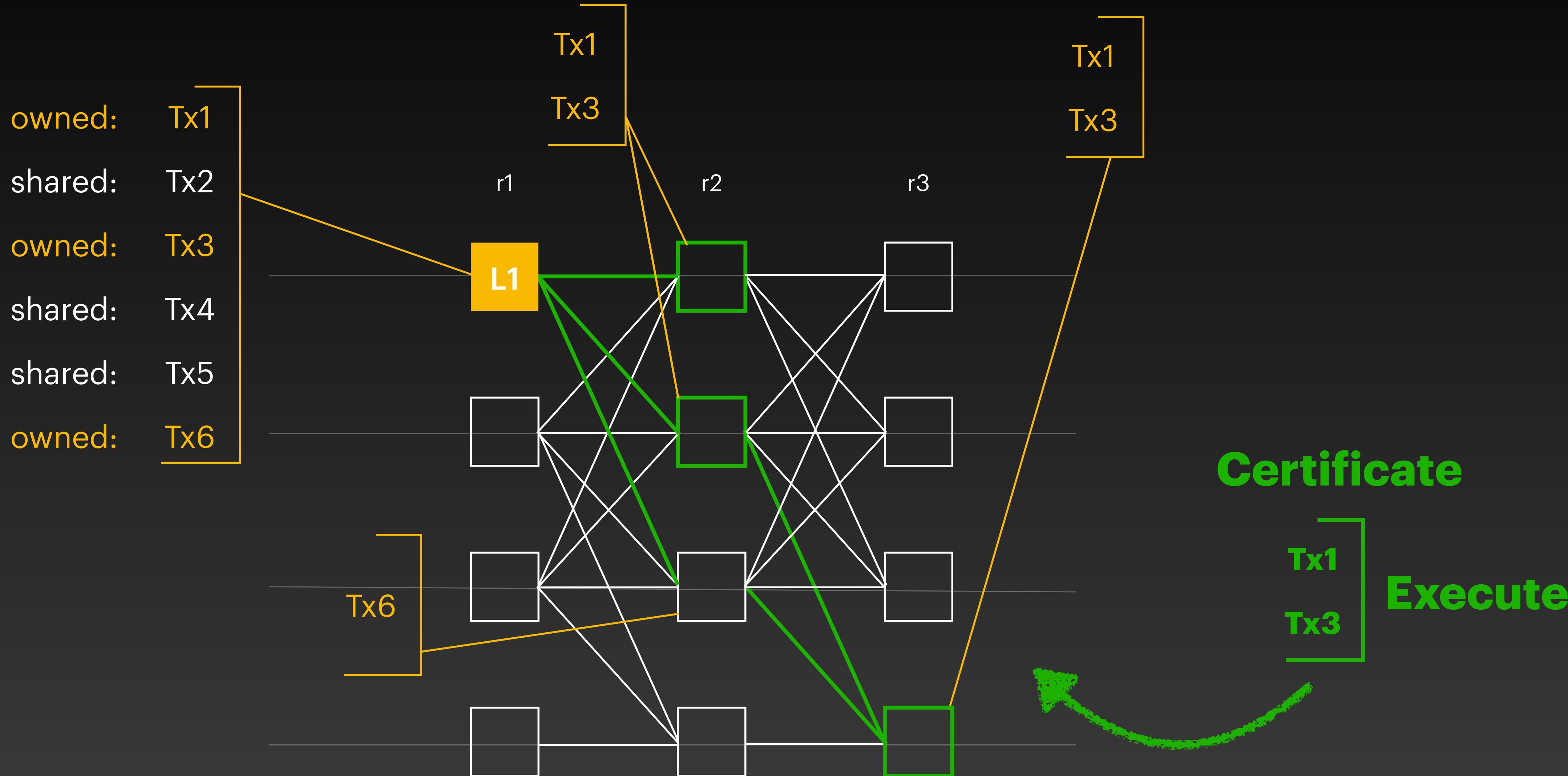
# Fast Execution



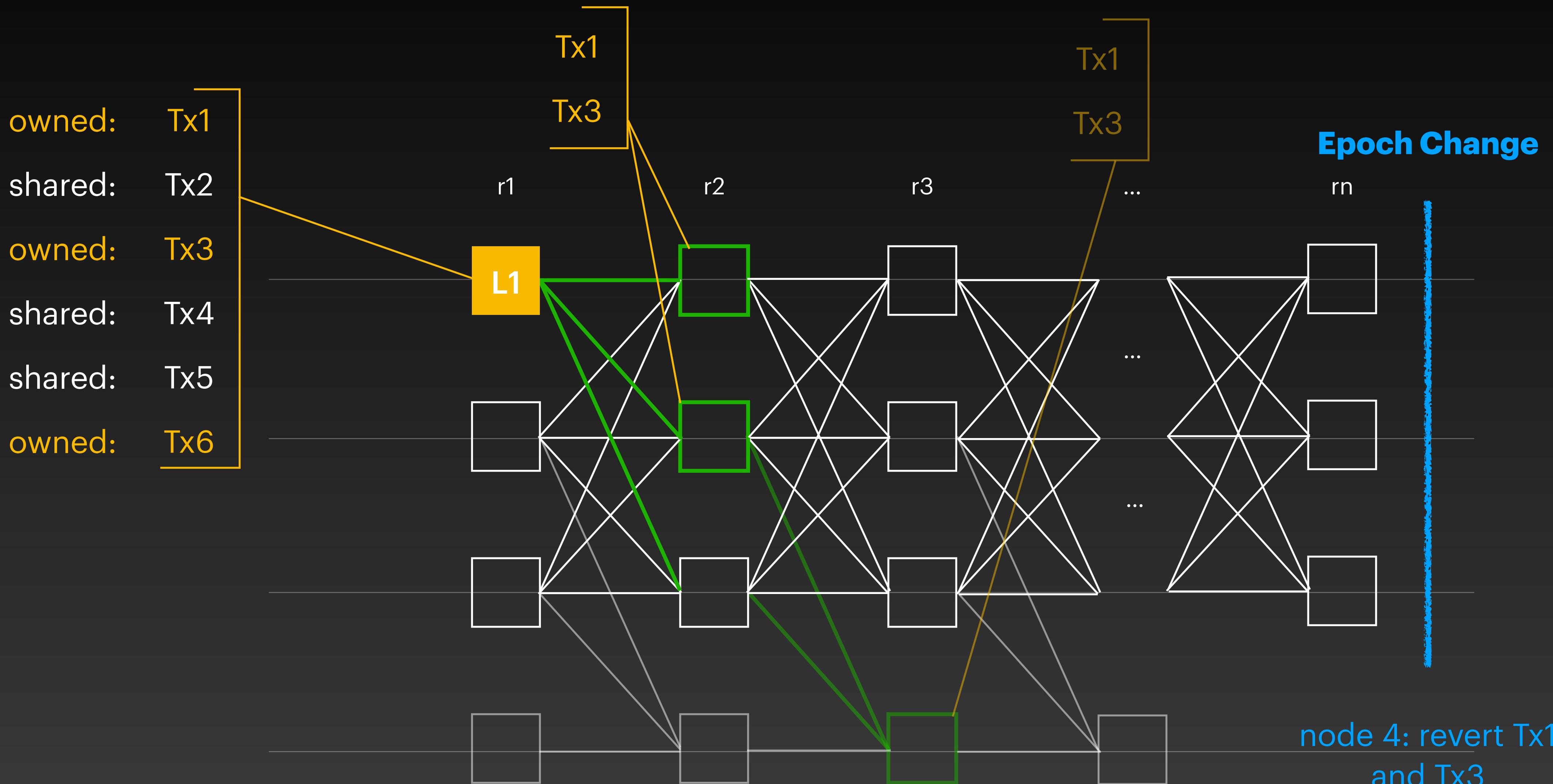
# Fast Execution



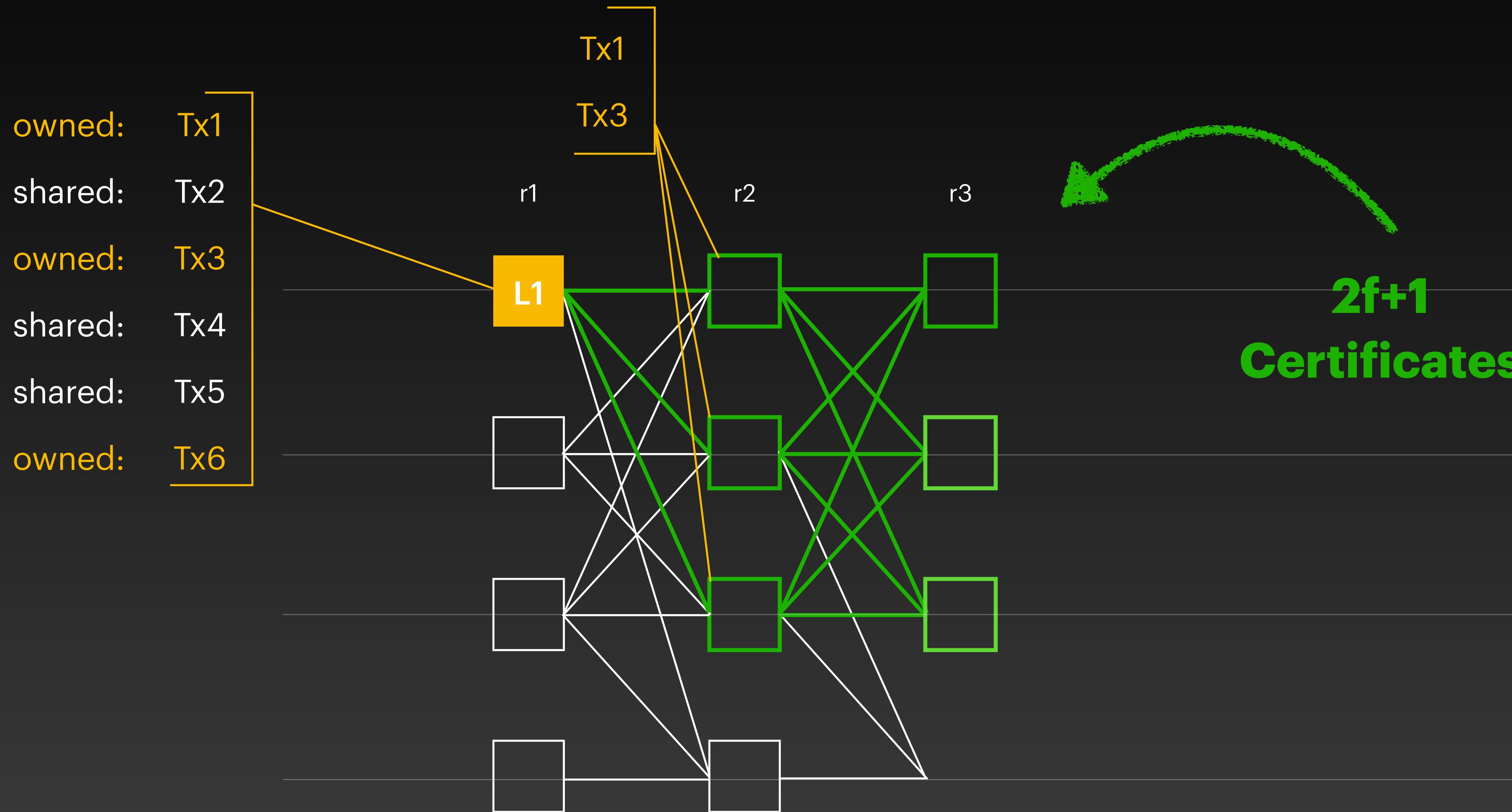
# Fast Execution



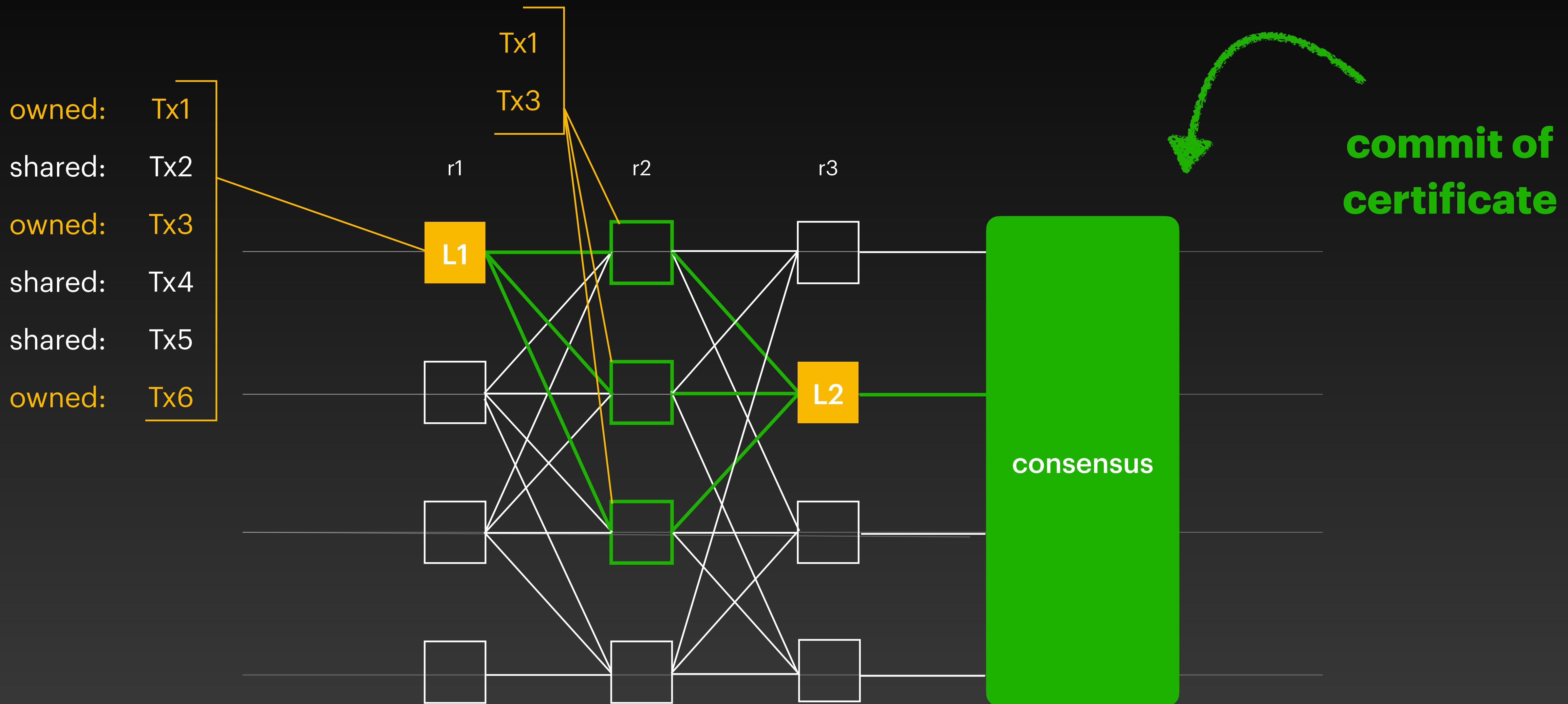
# No Finality



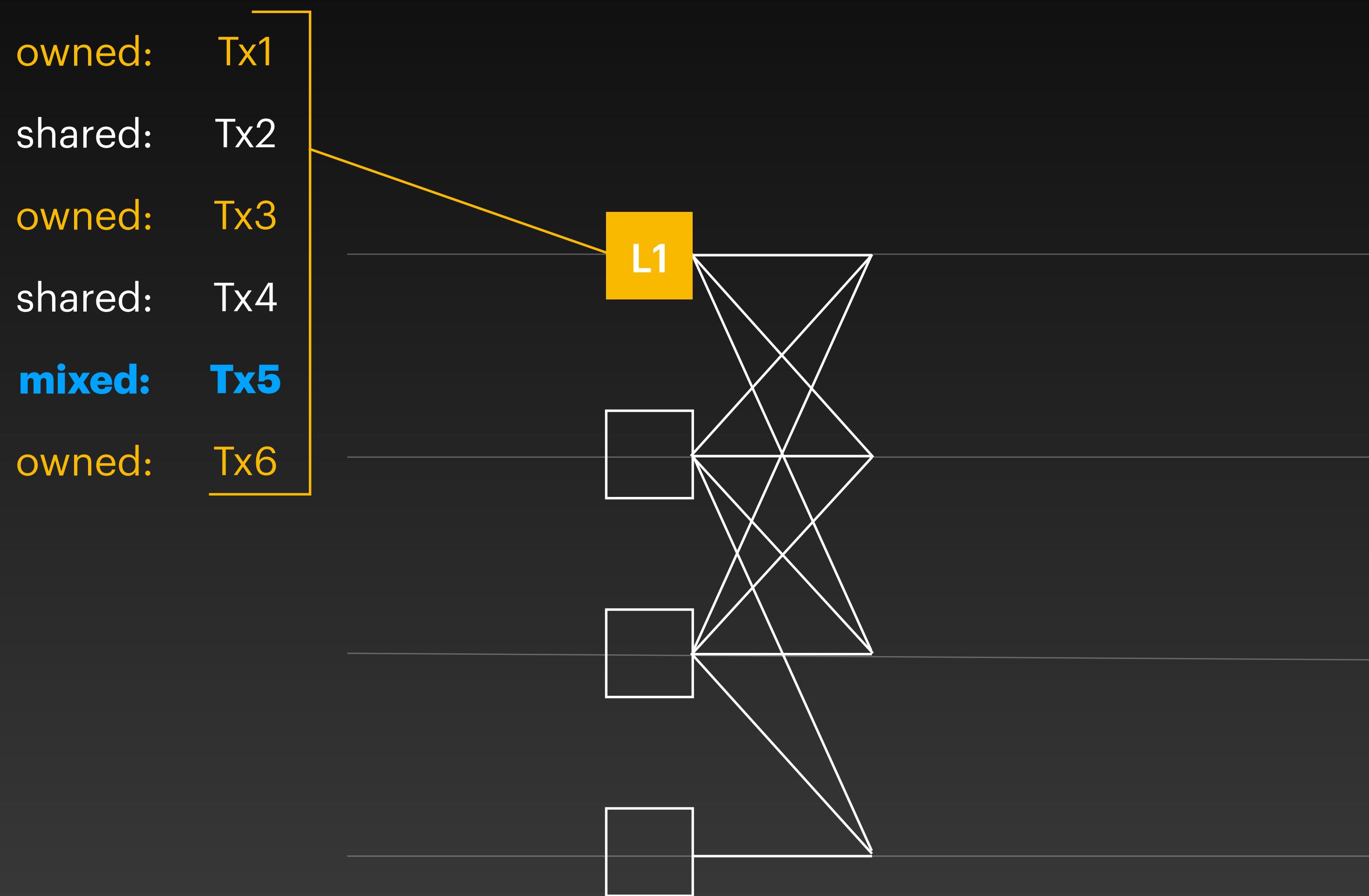
# Fast Path Finality (1)



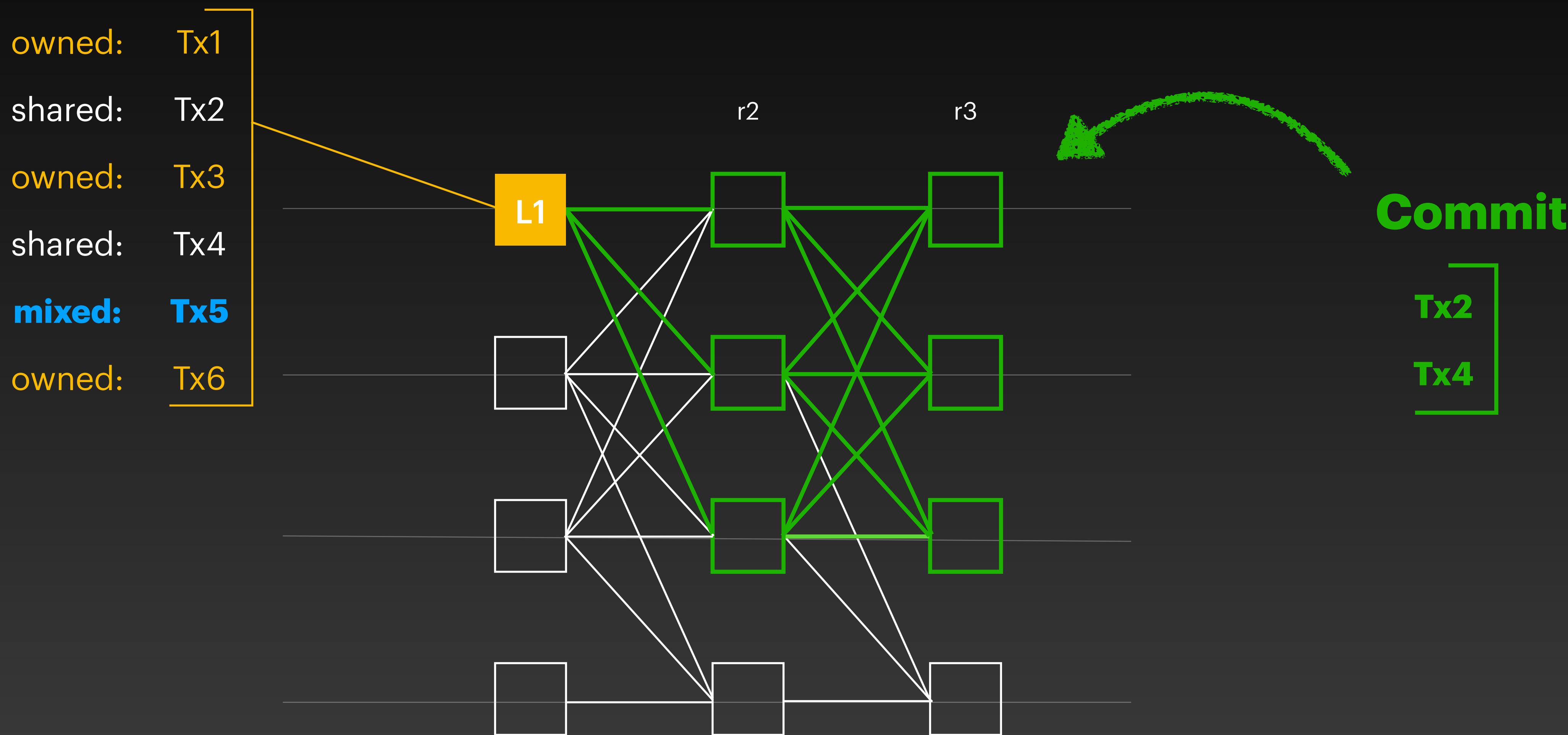
# Fast Path Finality (2)



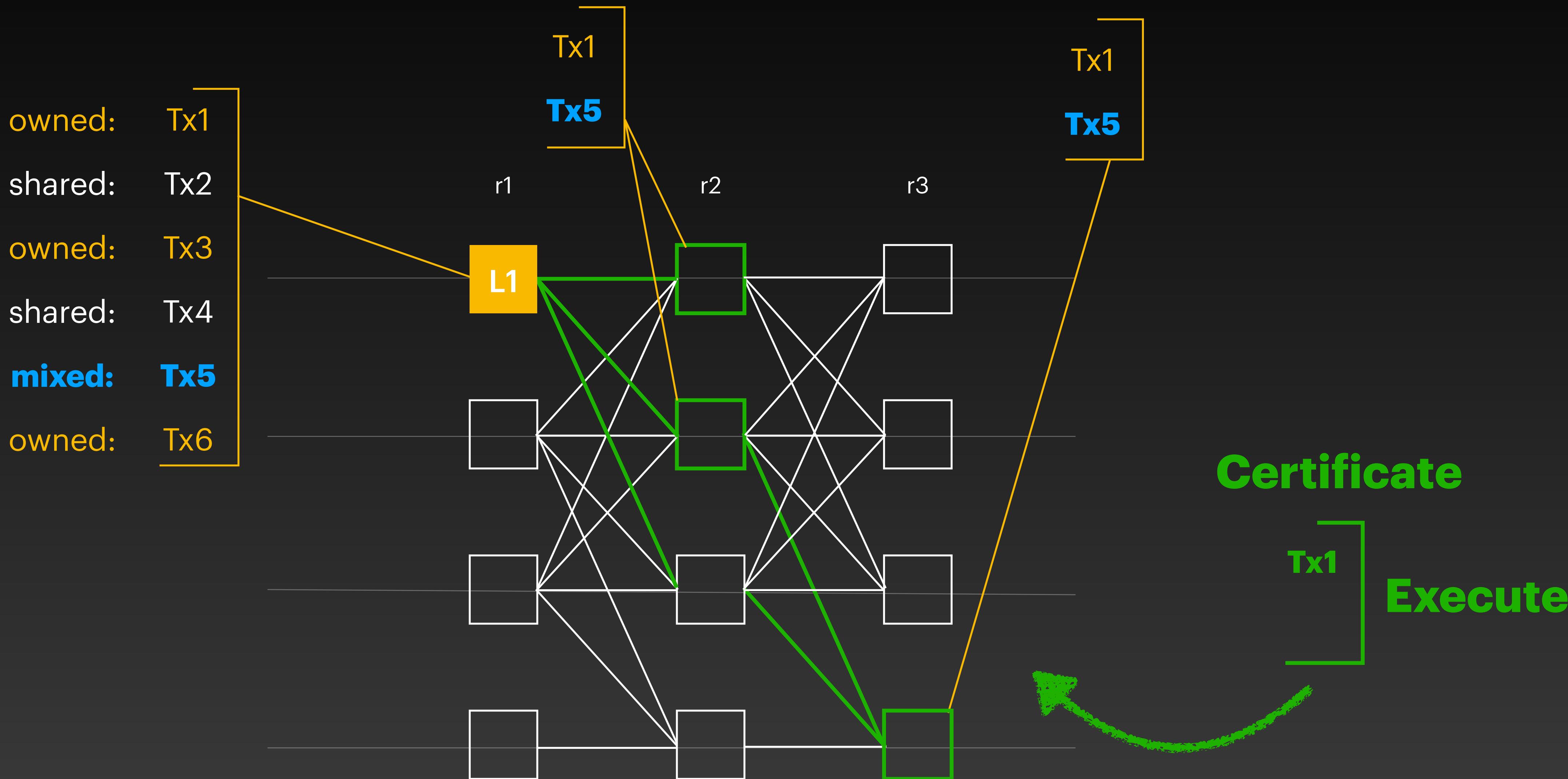
# Mixed-Objects Transactions



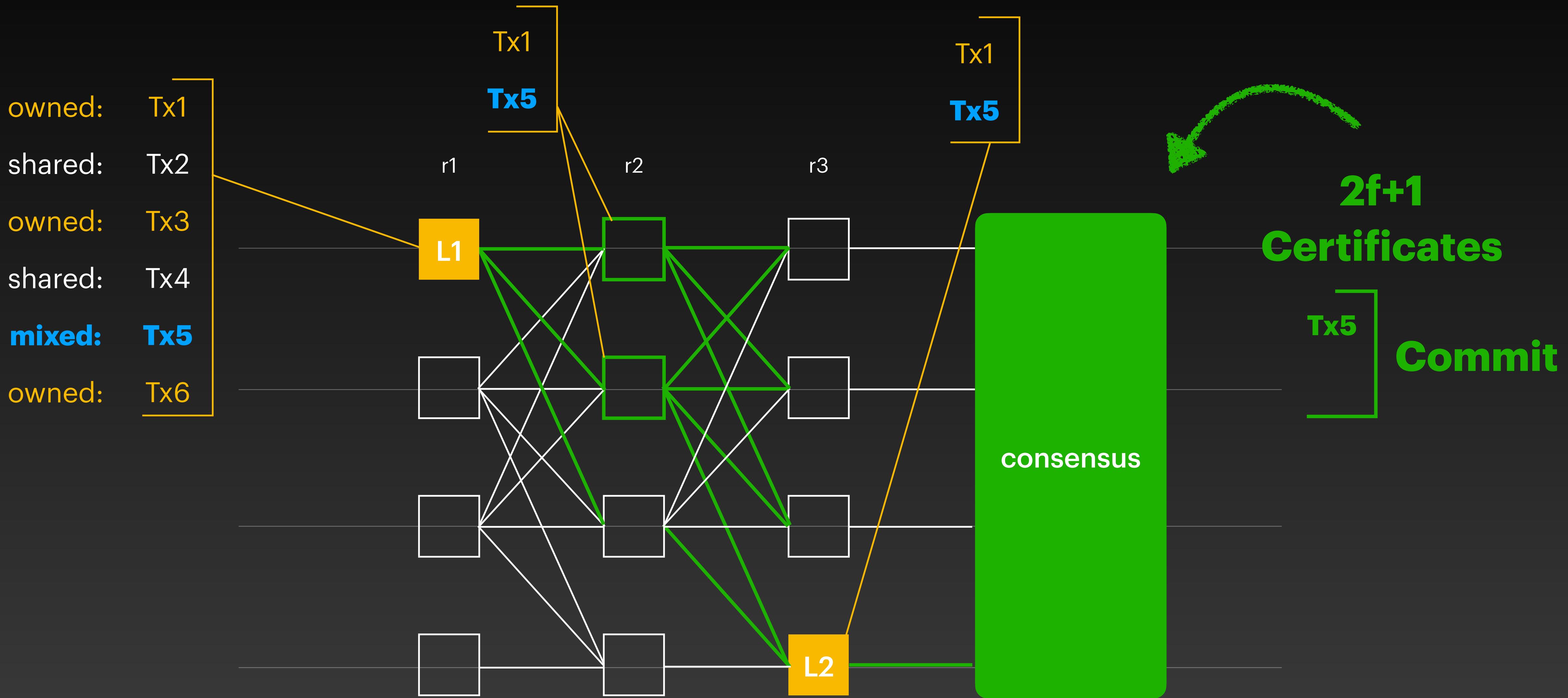
# Mixed-Objects Transactions



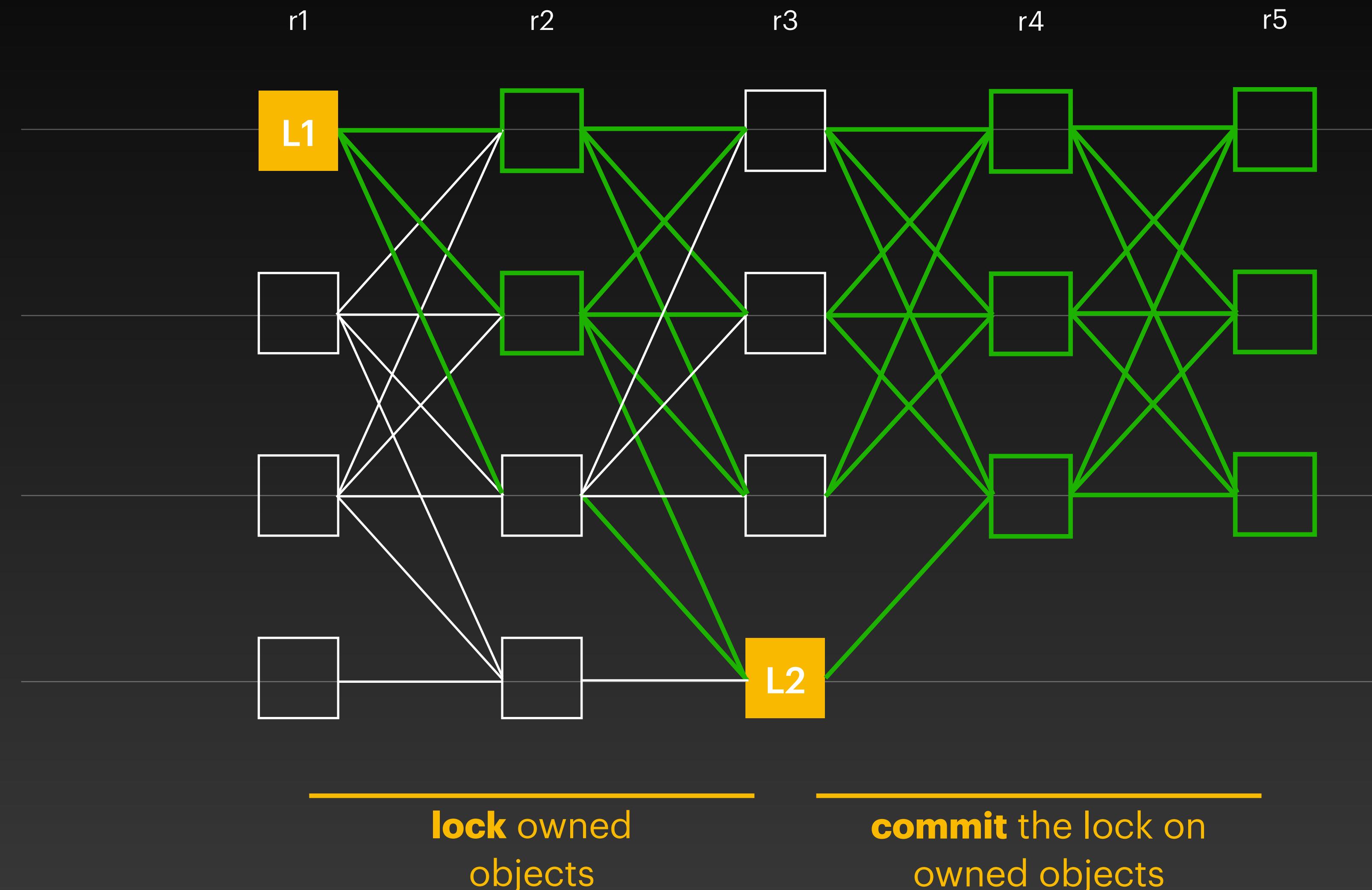
# Mixed-Objects Transactions



# Mixed-Objects Transactions



# Mixed-Objects Transactions



# Preliminary Benchmarks

More to come soon

# Implementation

- Written in Rust
- Networking: Tokio (TCP)
- Storage: custom WAL
- Cryptography: ed25519-consensus

<https://github.com/mystenlabs/mysticeti>

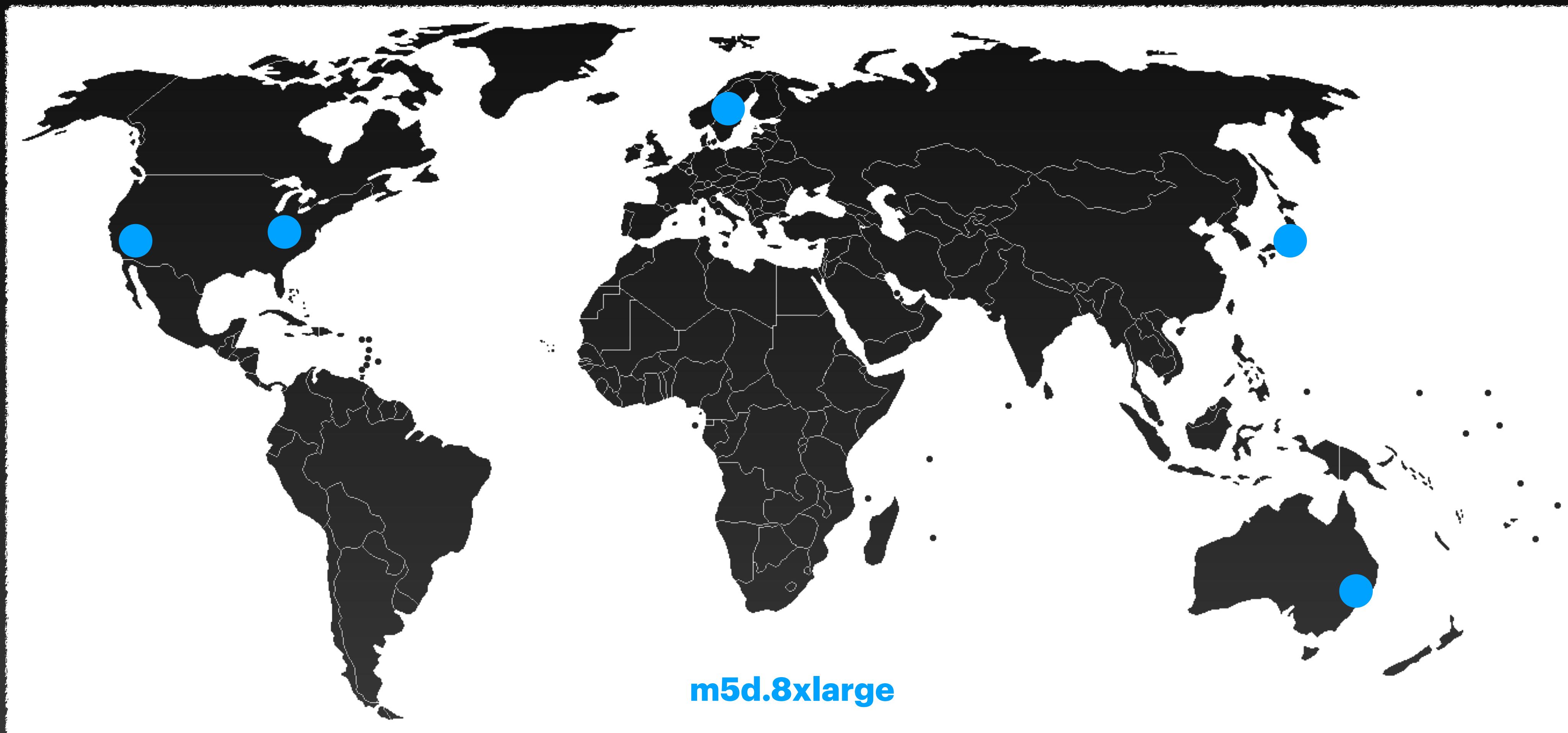
# Implementation

- Synchronous core
- One Tokio task per peer (limiting resource usage)
- DTE simulator

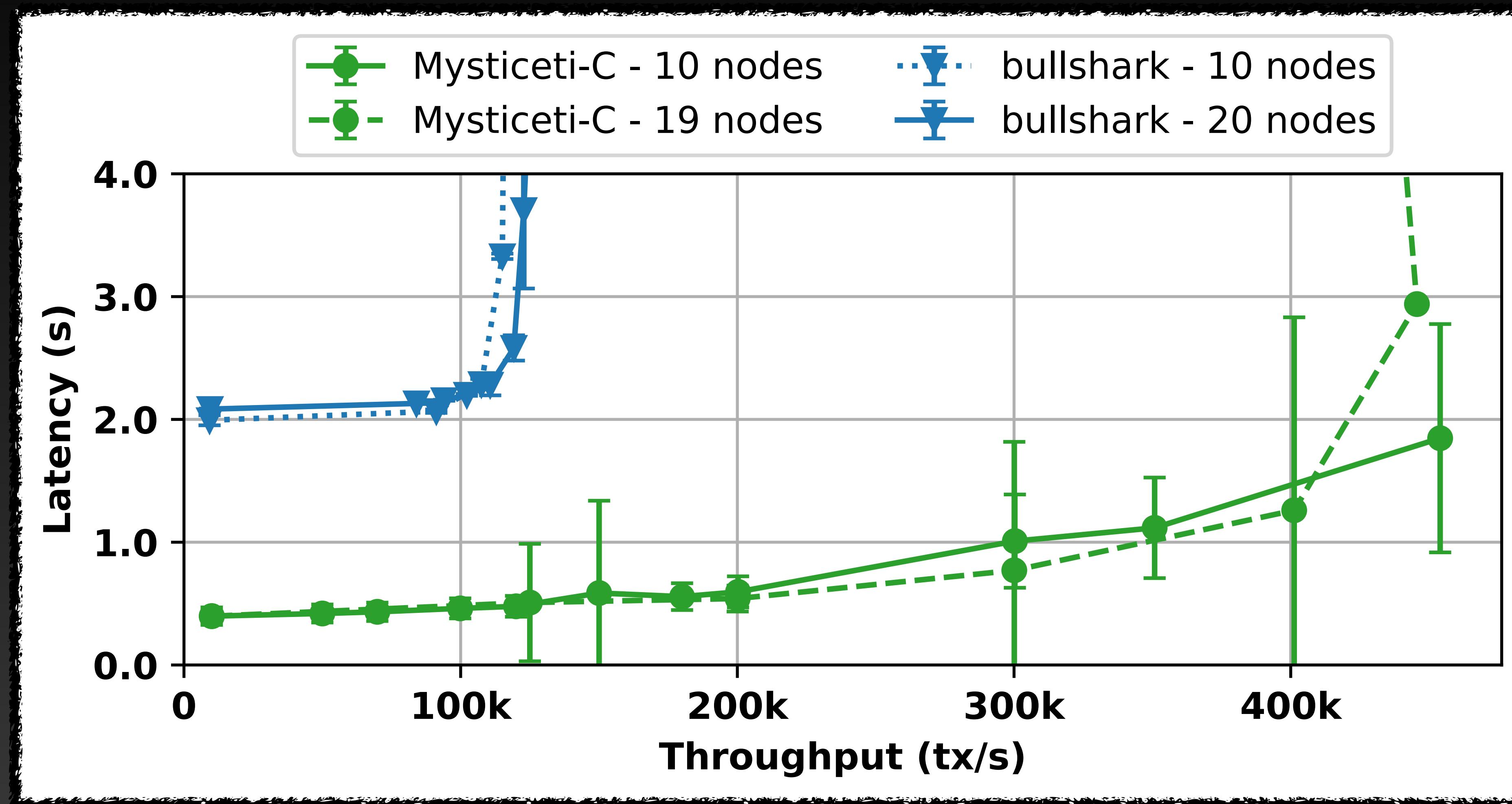
<https://github.com/mystenlabs/mysticeti>

# Evaluation

## Experimental setup on AWS



# Preliminary Results



# Engineering Benchmarks

Protocol	Committee	Load/TPS	P50	P95
Bullshark	137	5k	2.89 s	4.60 s
Mysticeti	137	5k	650 ms	975 ms

We ran it for 24h and it looks good 👍

# Testing Strategy



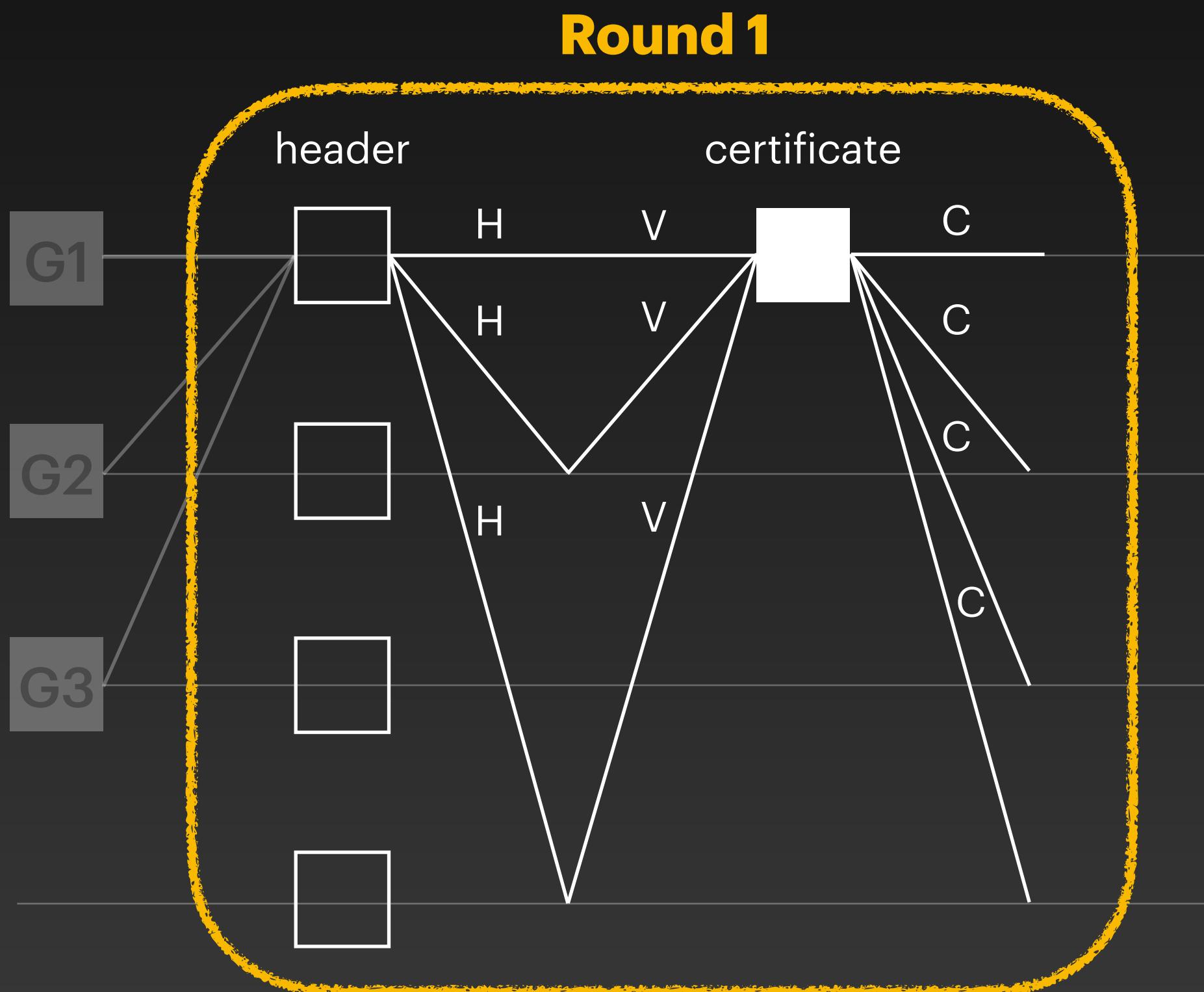
- Compare performance & robustness
- Test mainnet change bullshark -> mysticeti
- Prepare for the worst mysticeti -> bullshark

# Narwhal vs Mysticeti

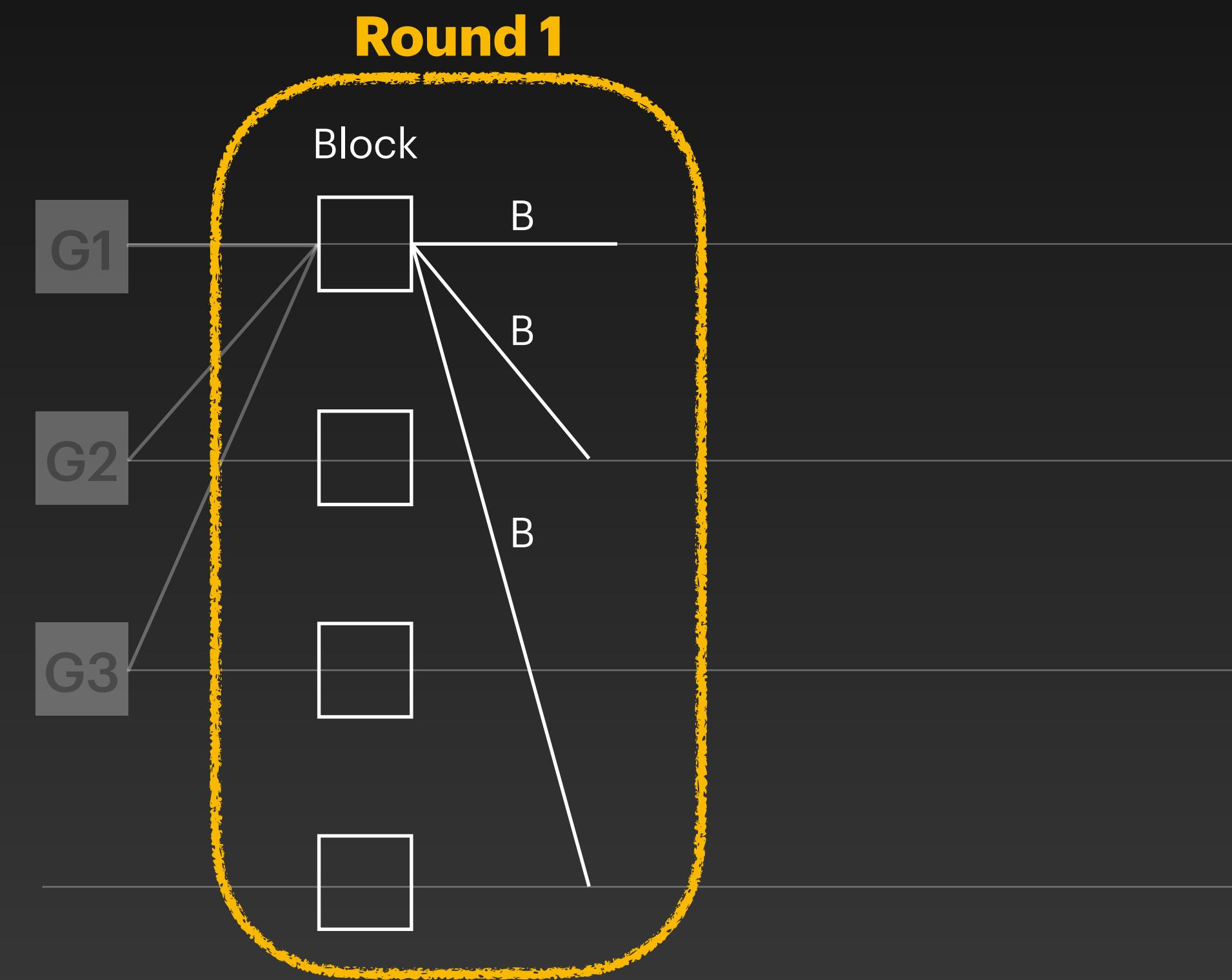
Key differences & Insight

# Narwhal vs Mysticeti

## Narwhal

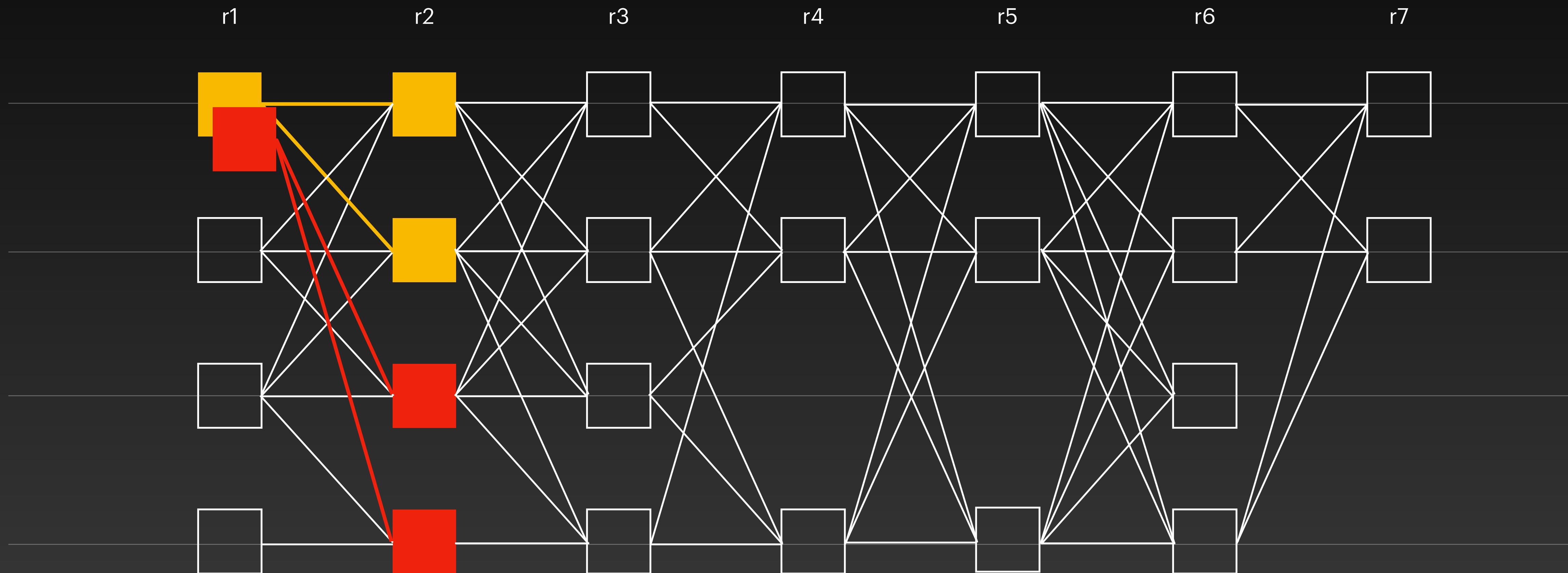


## Mysticeti



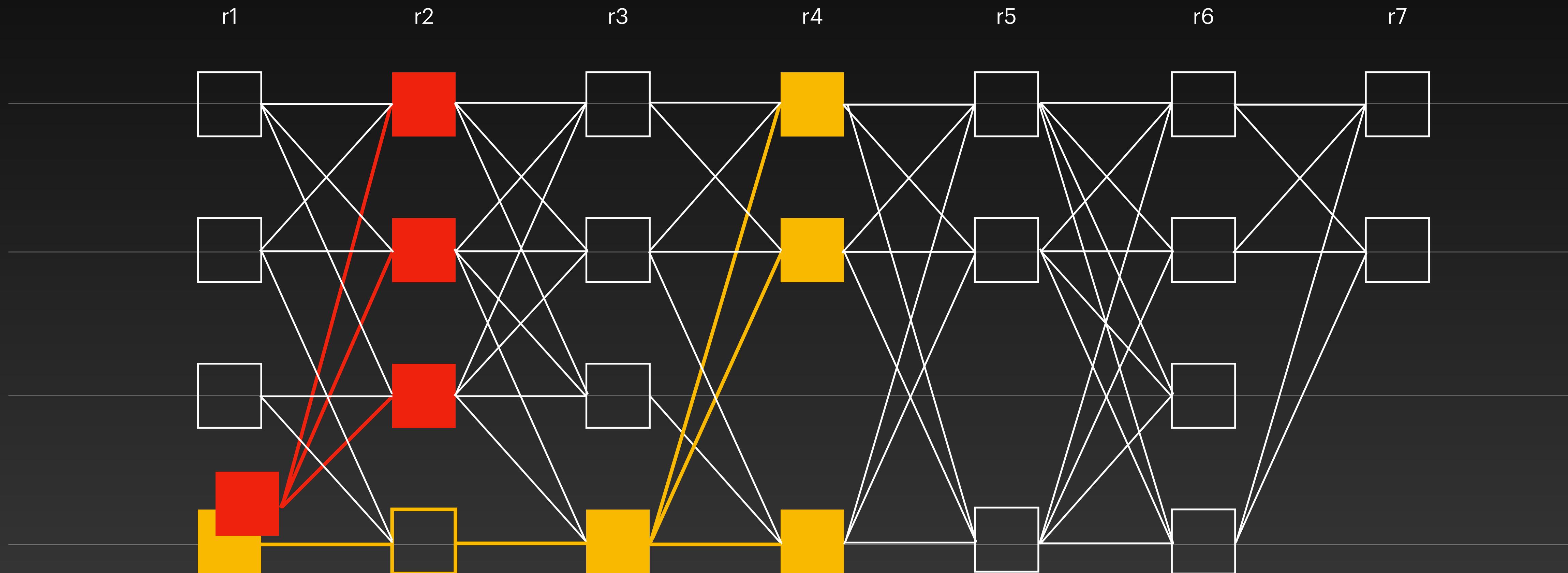
# Main Challenge

## Possible equivocations



# Main Challenge

## Possible equivocations (even with $2f+1$ support)



# Decision Rules

Upon interpreting the DAG...

## Bullshark

- A leader is **Commit** or not
- Either directly or indirectly  
(recursion)

## Mysticeti

- A leader is **Commit**, **Skip**, or  
**Undecided**
- Either directly or indirectly  
(recursion)

# Linear Chain vs DAG

# Quorum-Based Consensus

## Linear-Chain

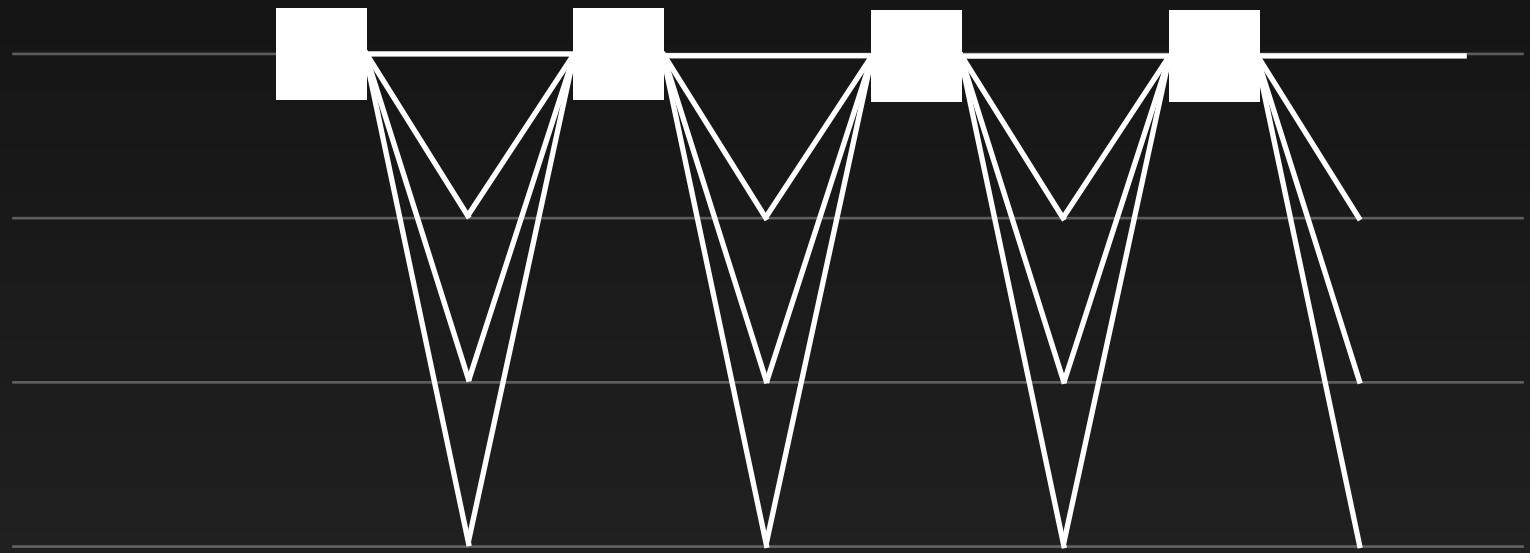
- Low latency
- Fragile to faults
- Complex leader-change

## DAG-Based

- High latency
- Robust against faults
- No/Simple leader-change

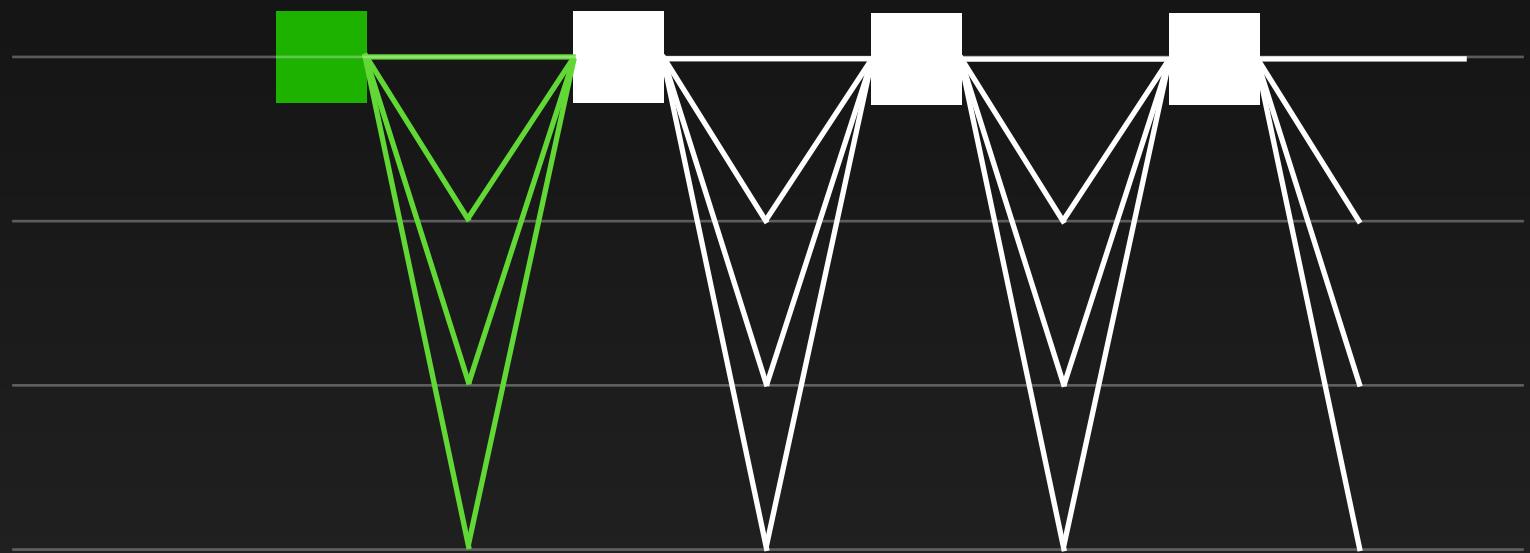
# Linear-Chain Consensus

## Rough overview



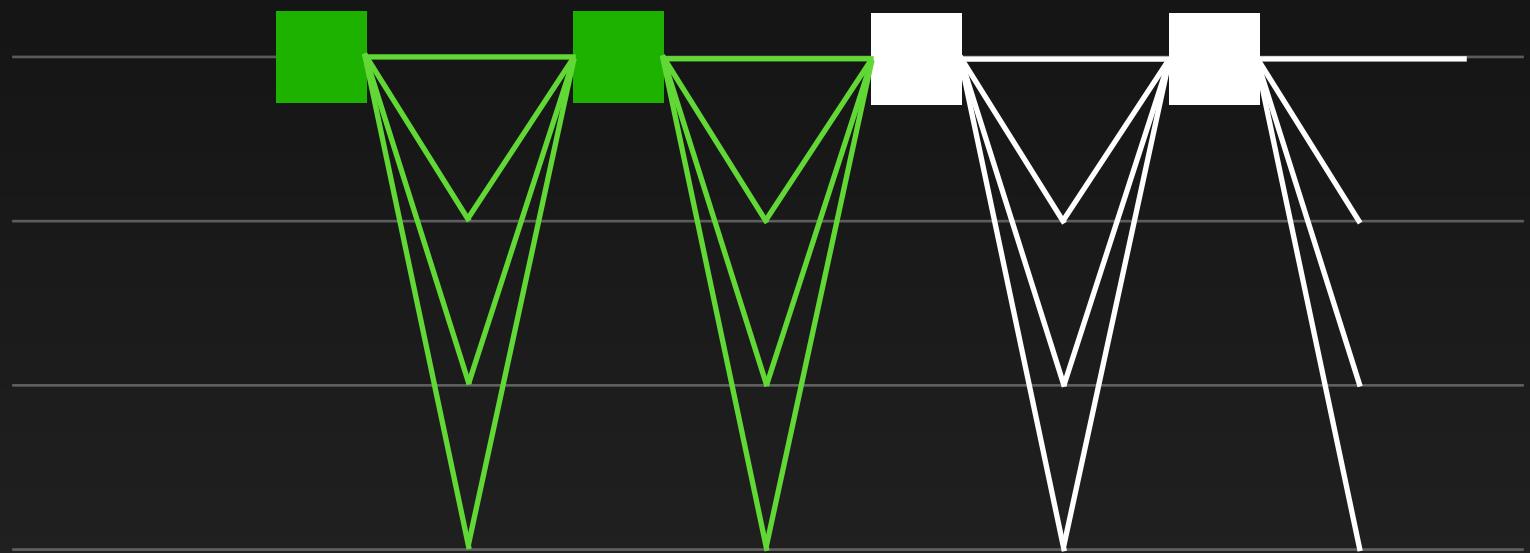
# Linear-Chain Consensus

## Rough overview



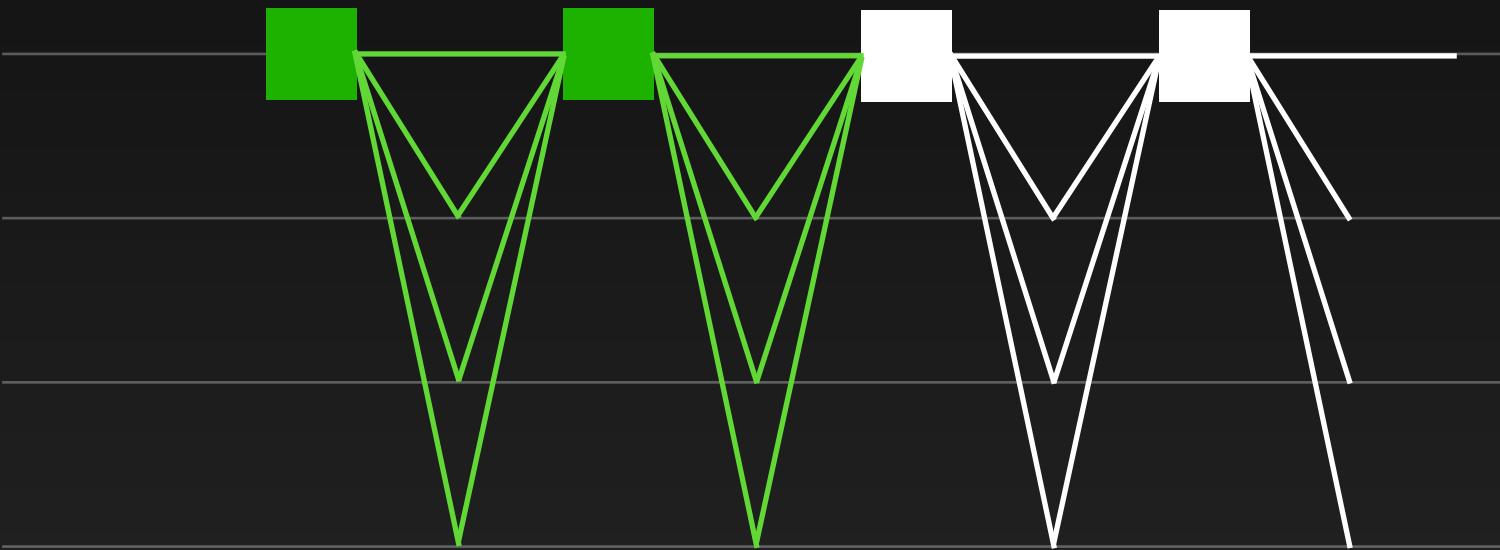
# Linear-Chain Consensus

## Rough overview



# Linear-Chain Consensus

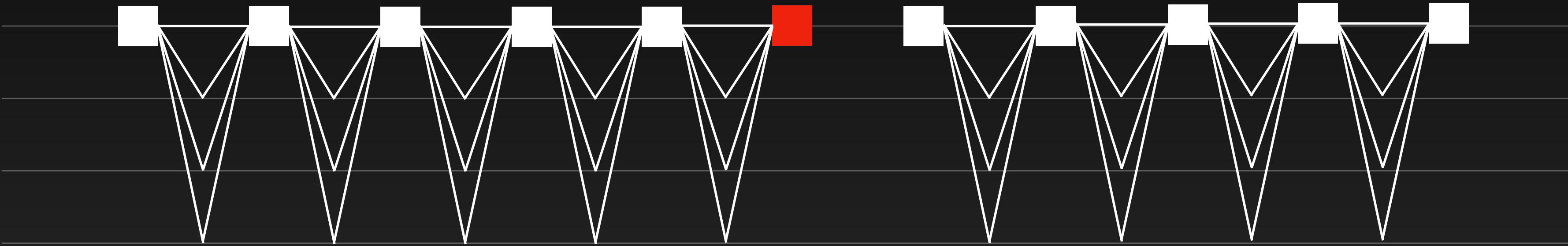
## Rough overview



- The leader does all the work

# Linear-Chain Consensus

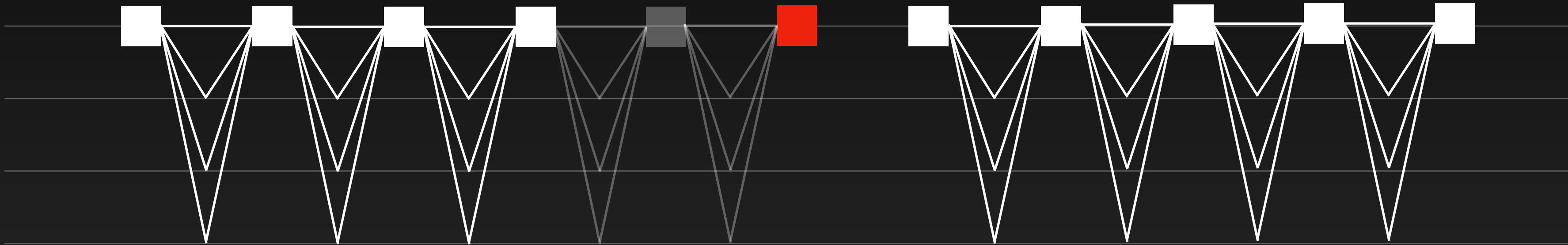
## Rough overview



- The leader does all the work
- Complex leader-change

# Linear-Chain Consensus

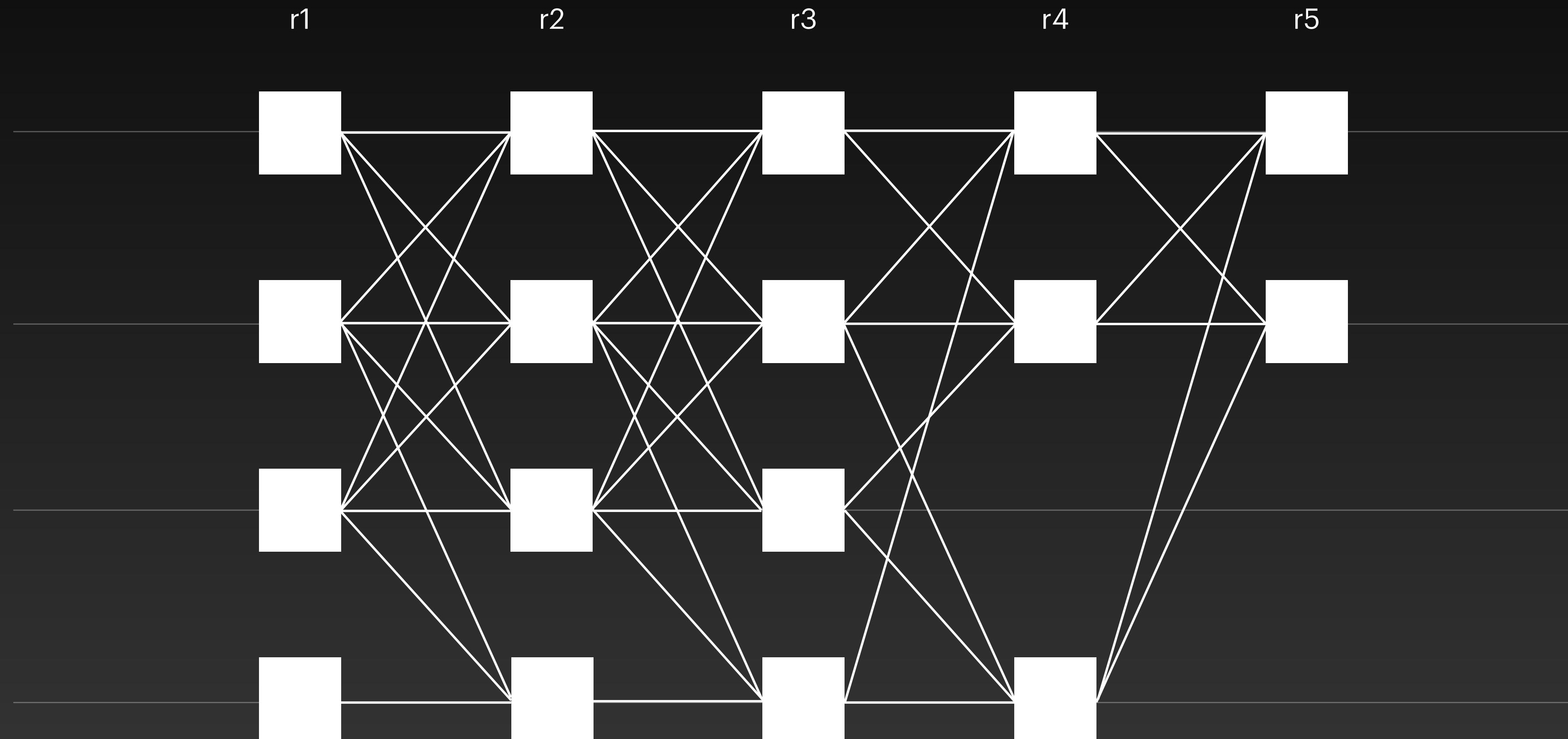
## Rough overview



- The leader does all the work
- Complex leader-change

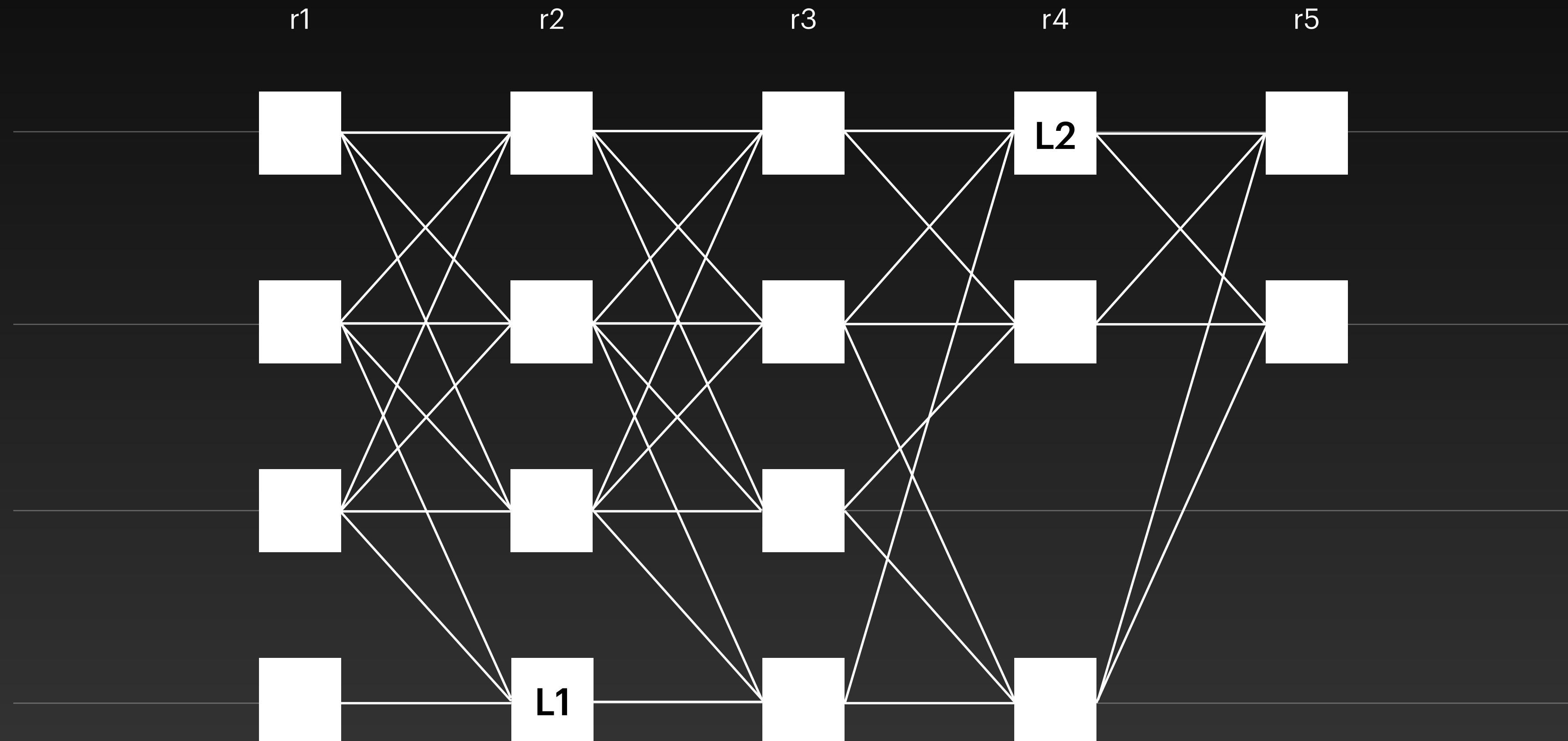
# DAG-Based Consensus

## Rough overview



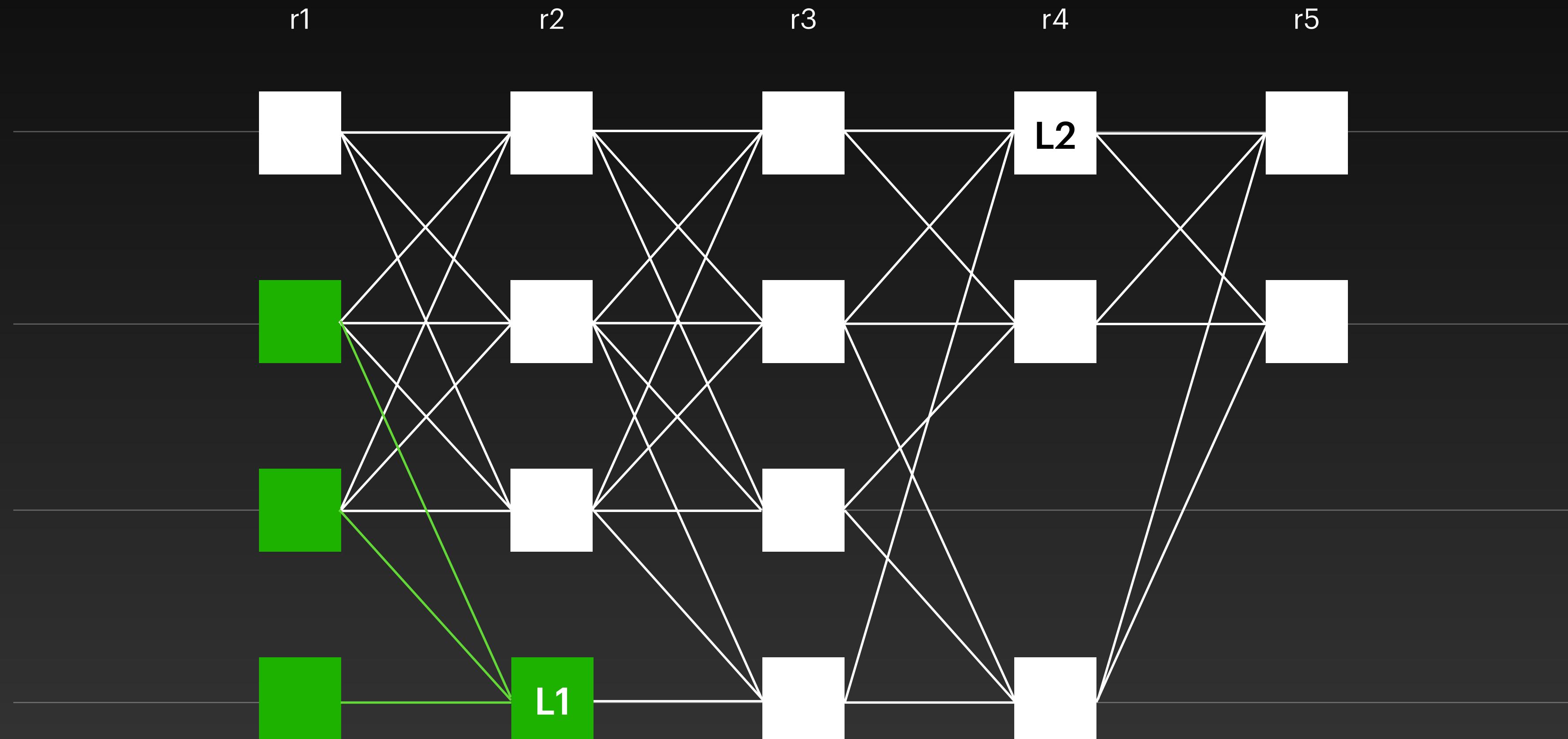
# DAG-Based Consensus

## Rough overview



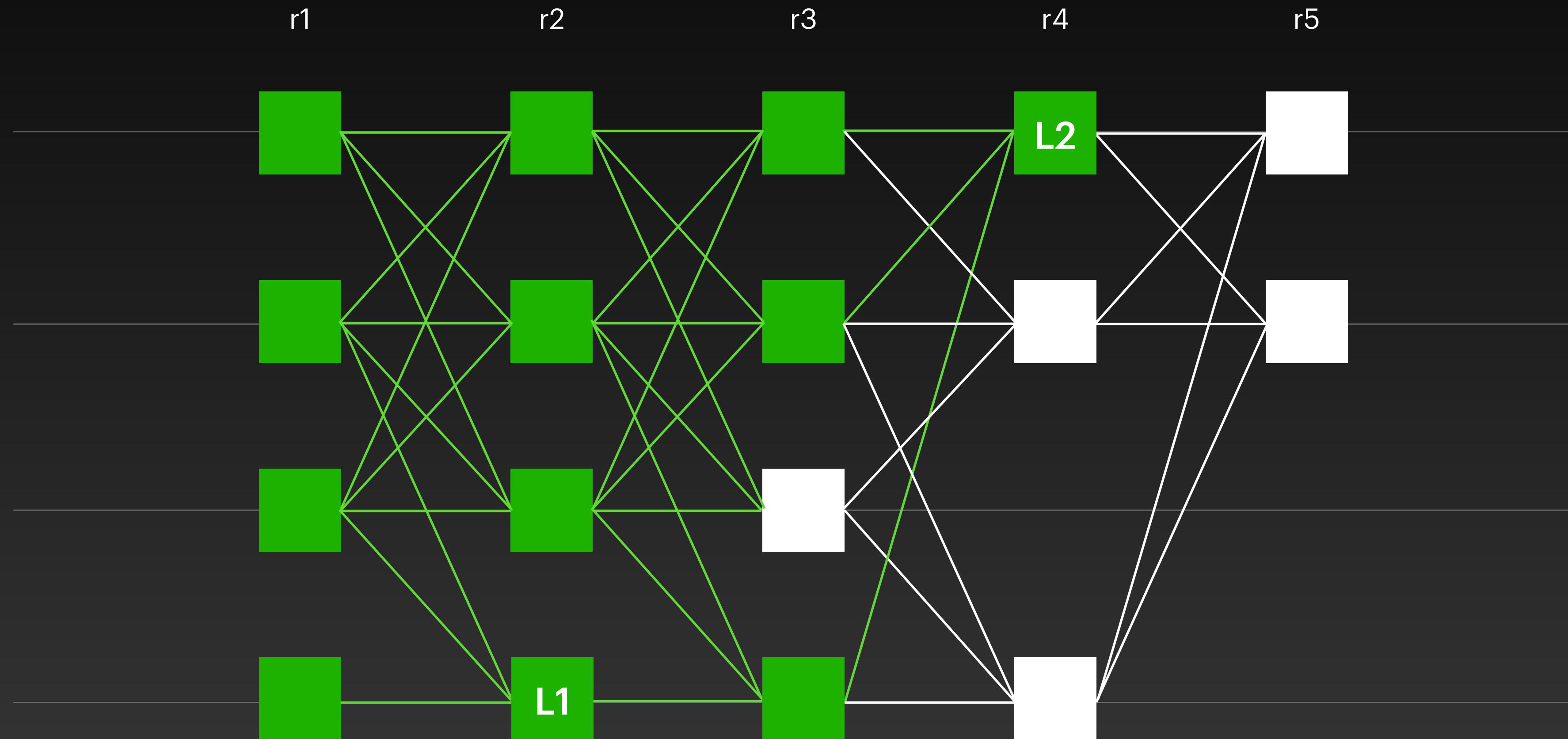
# DAG-Based Consensus

## Rough overview



# DAG-Based Consensus

## Rough overview



# Summary

## Mysticeti

- A single message type
- Interpret patterns on the DAG
- **Paper:** <https://sonnino.com/papers/mysticeti.pdf>
- **Code:** <https://github.com/mystenlabs/mysticeti>