

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



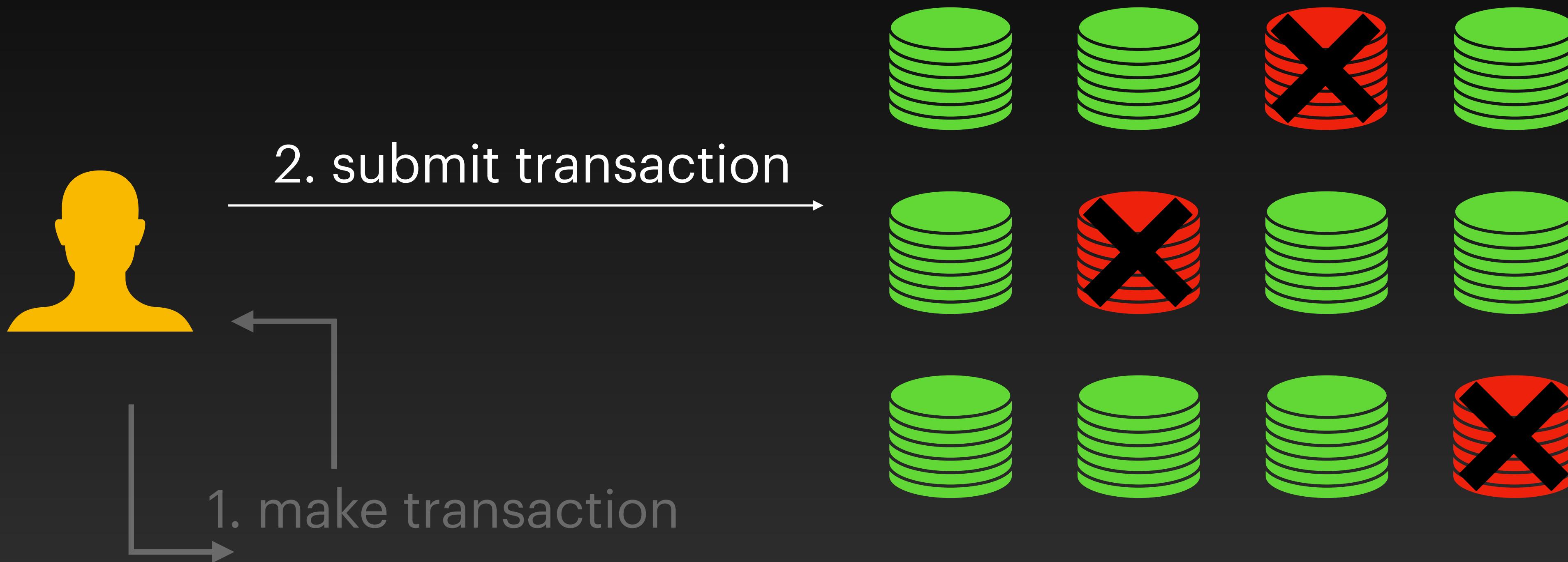
Blockchains



1. make transaction



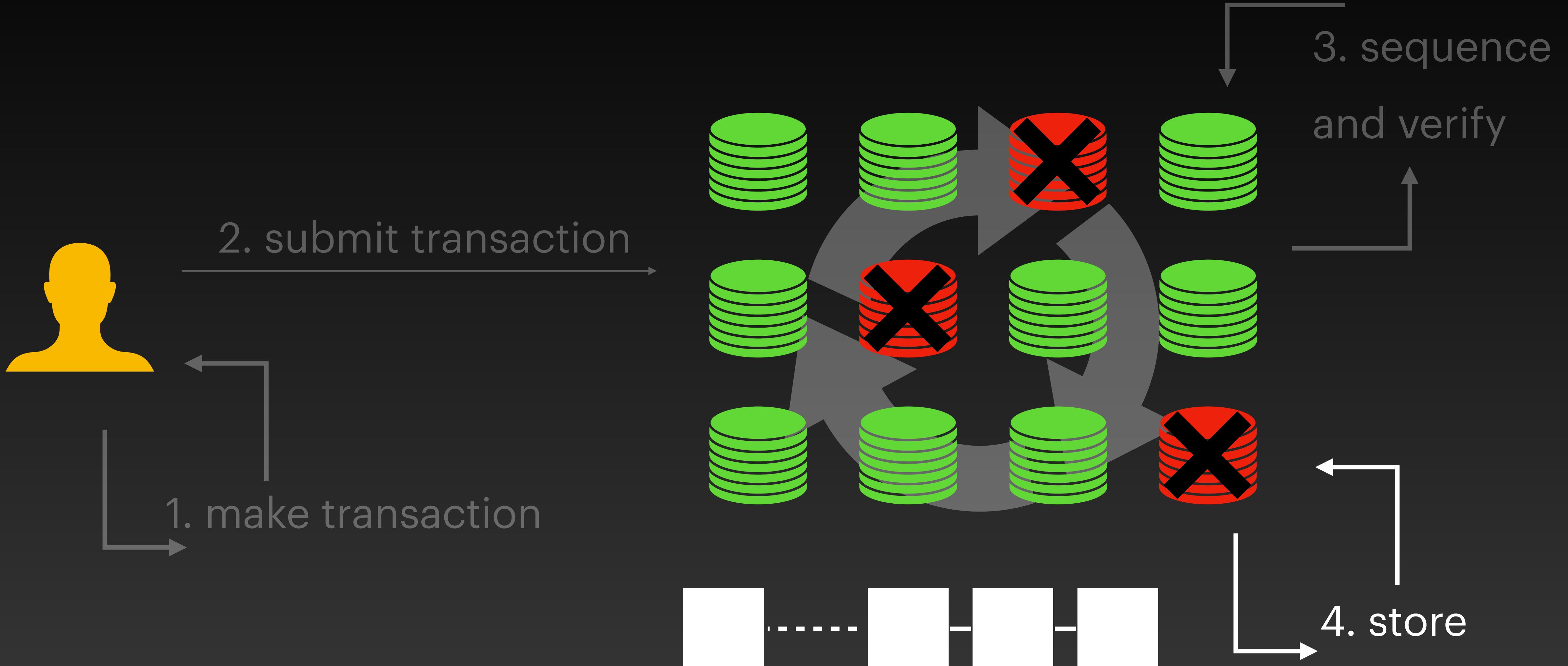
Blockchains



Blockchains



Blockchains



Keeping the Talk Short

In scope

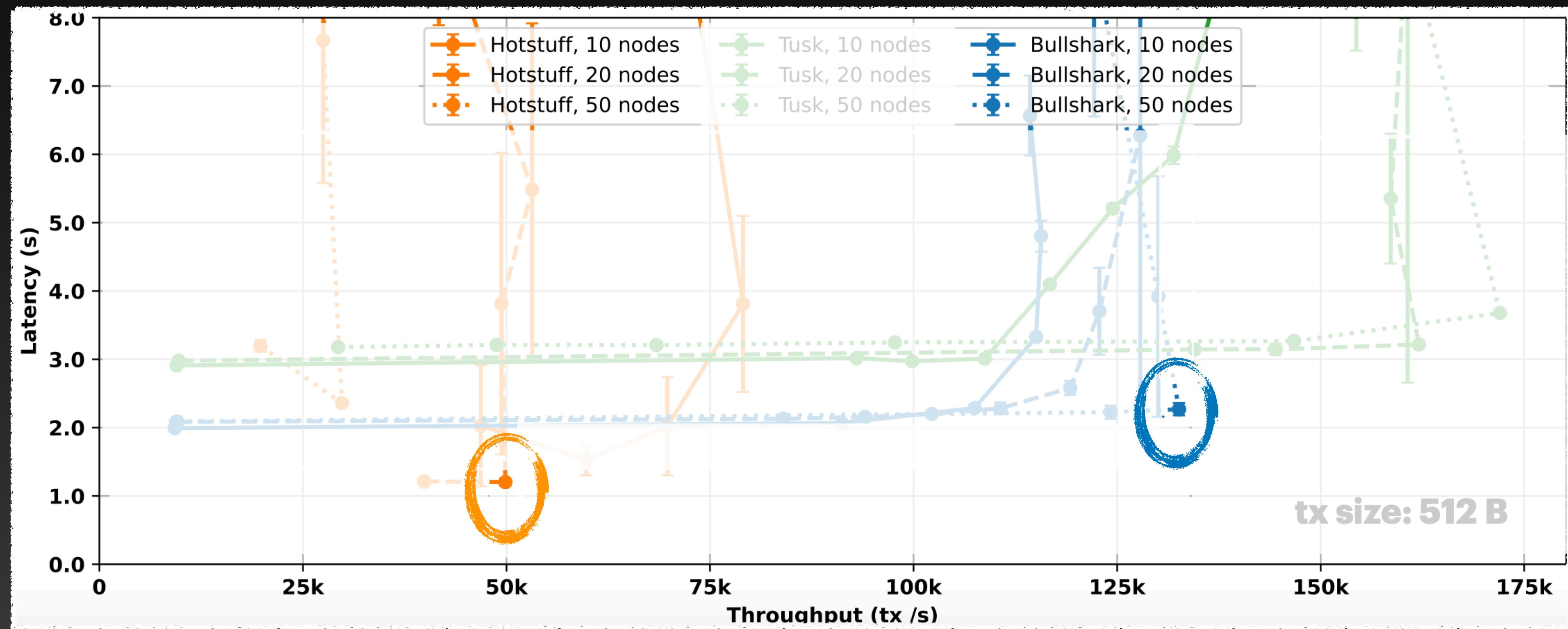
- Ordering (quorum-based)



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:

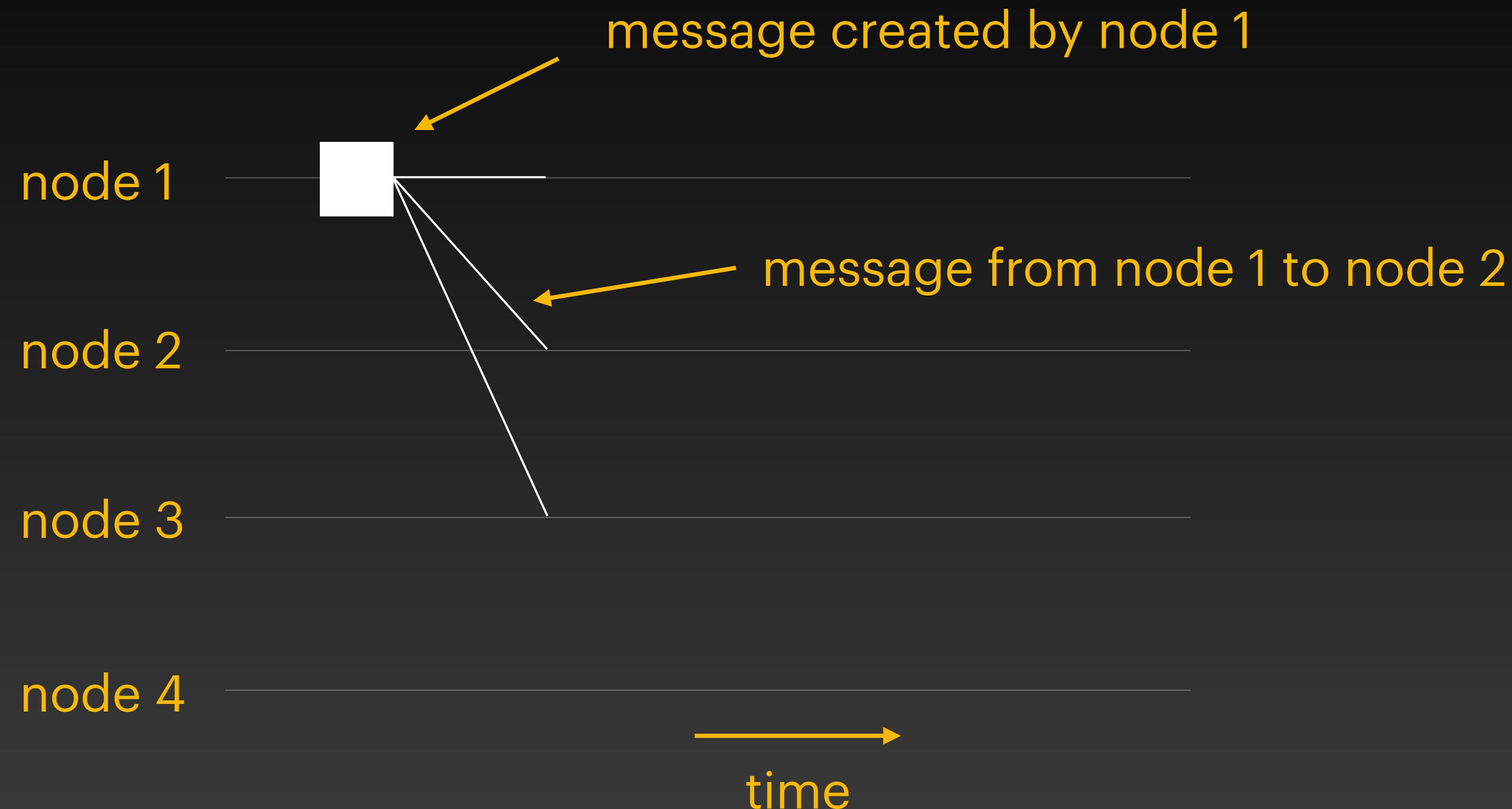
- How many Byzantine faults? 0
- How many Crash faults?

Why? Crash Faults

In a year of running Sui:

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

Lamport Diagram

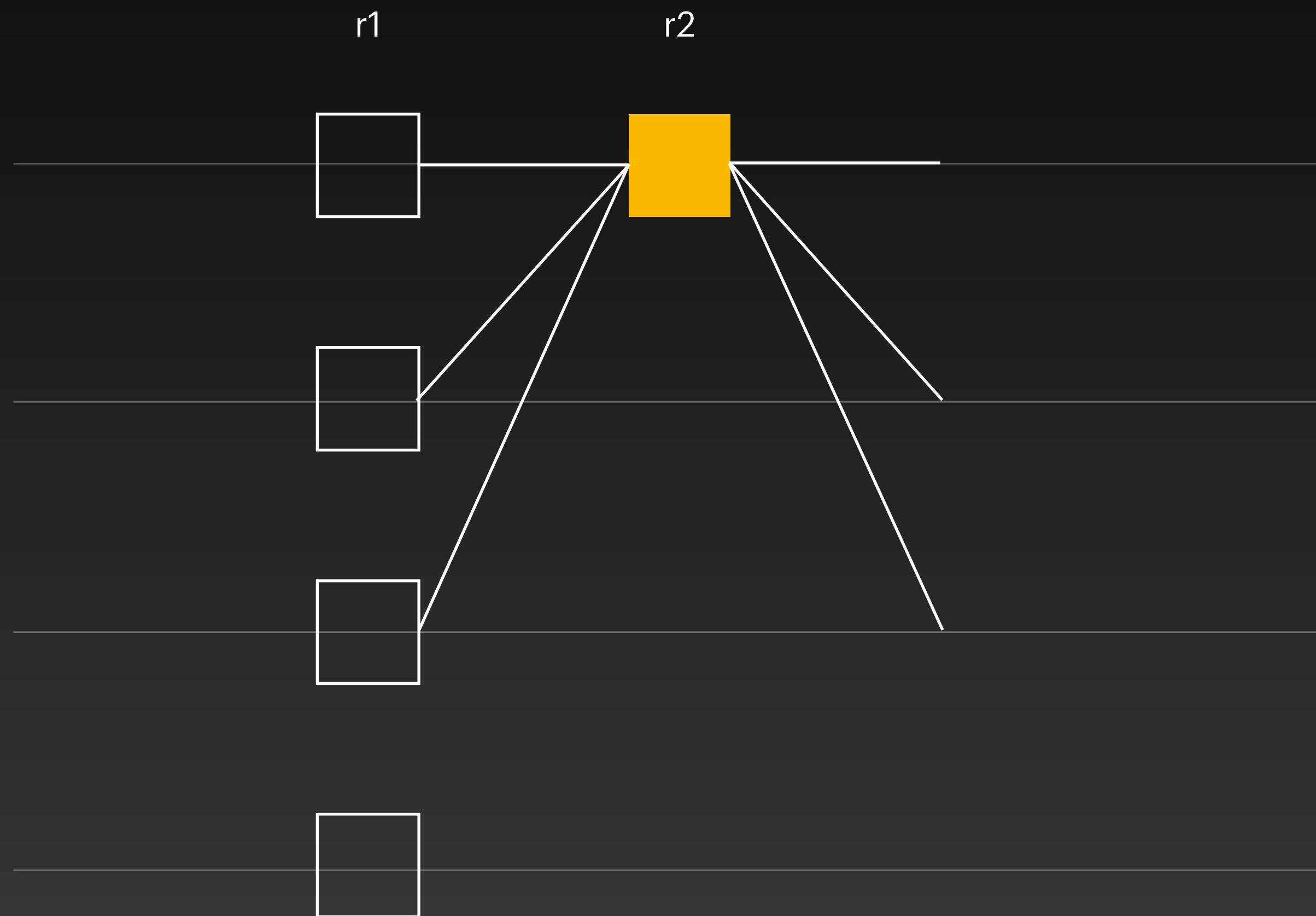


The Mysticeti DAG

Uncertified DAG

The Mysticeti DAG

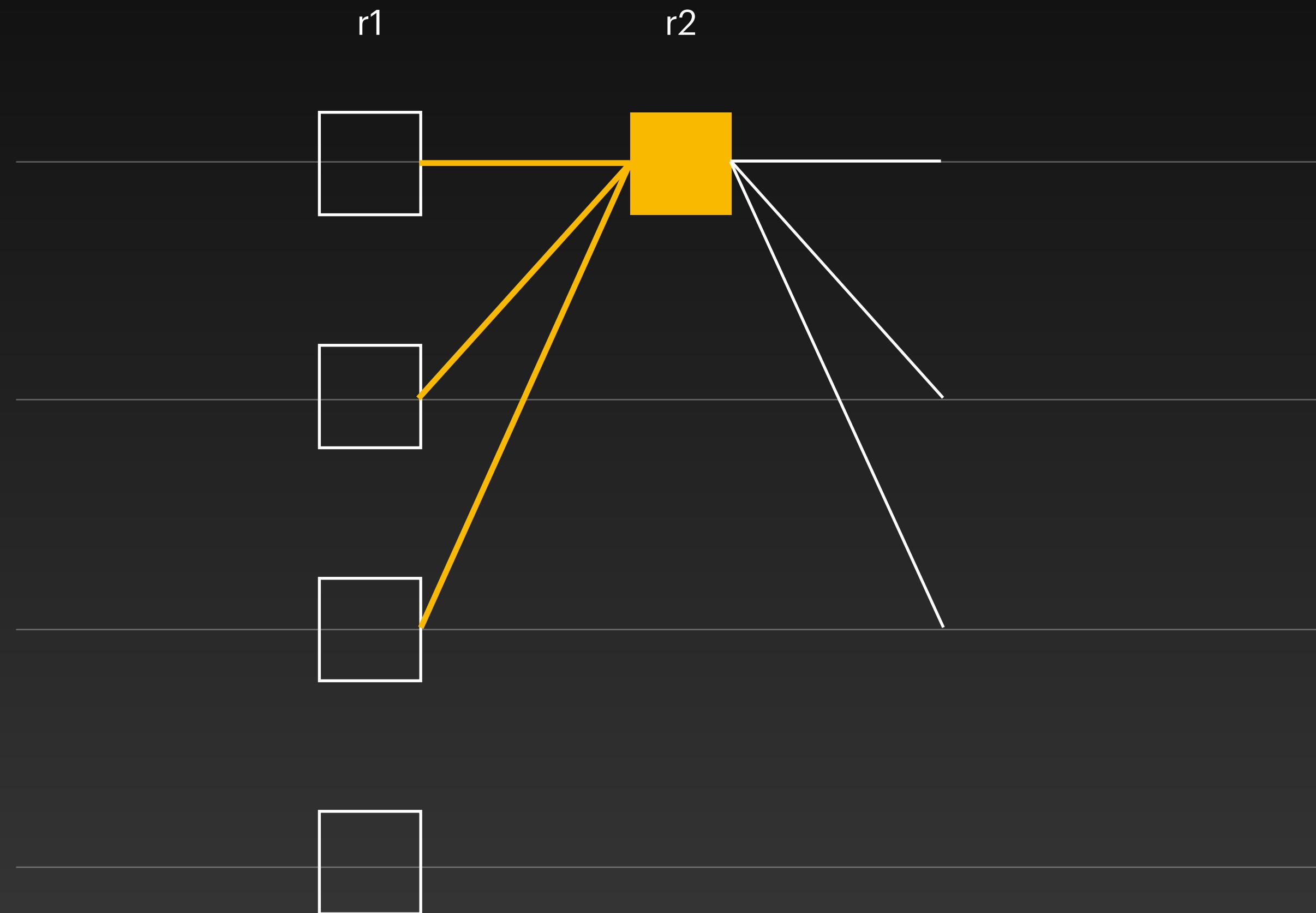
Block Creation



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

The Mysticeti DAG

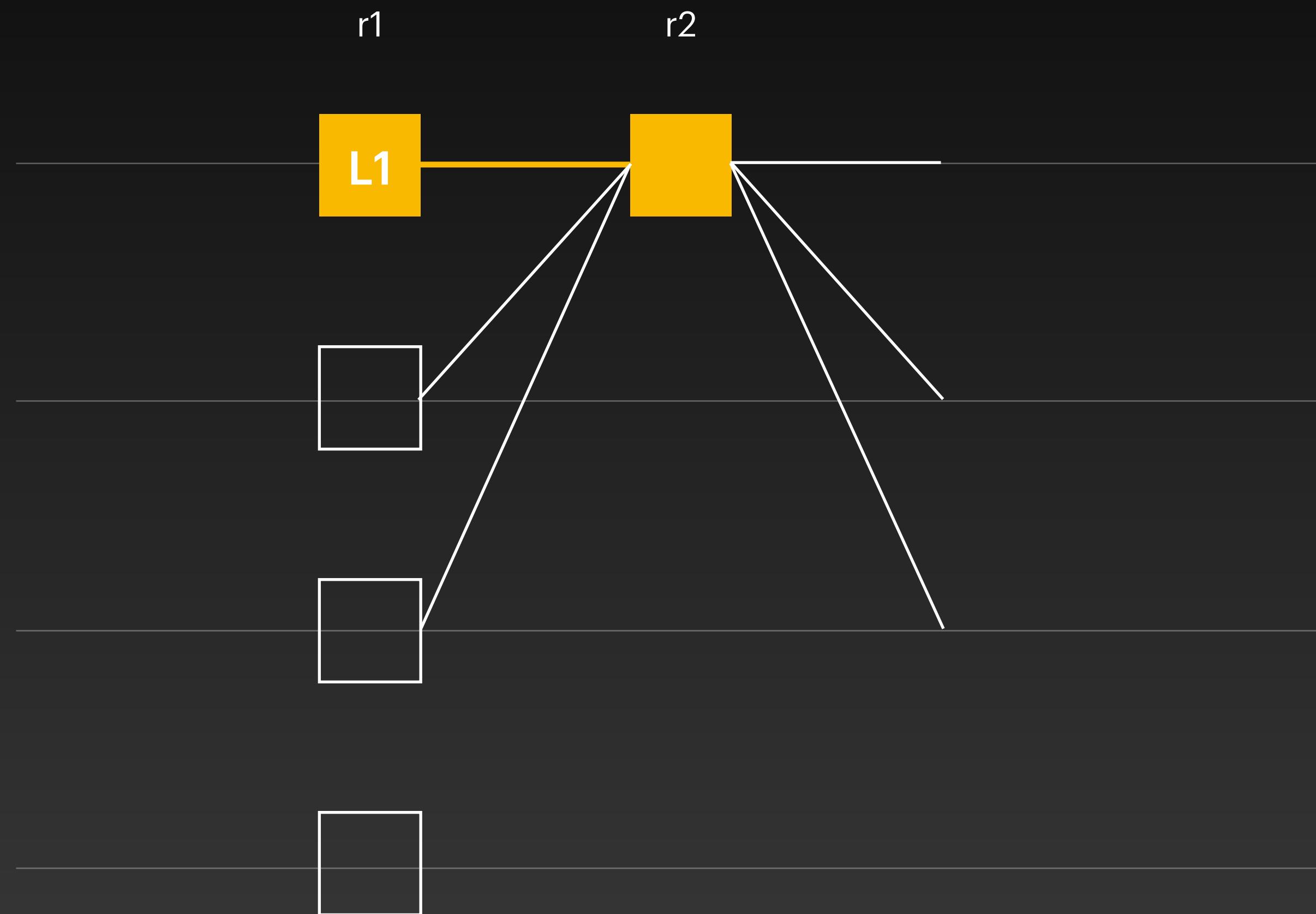
Rule 1: Link to $2f+1$ parents



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

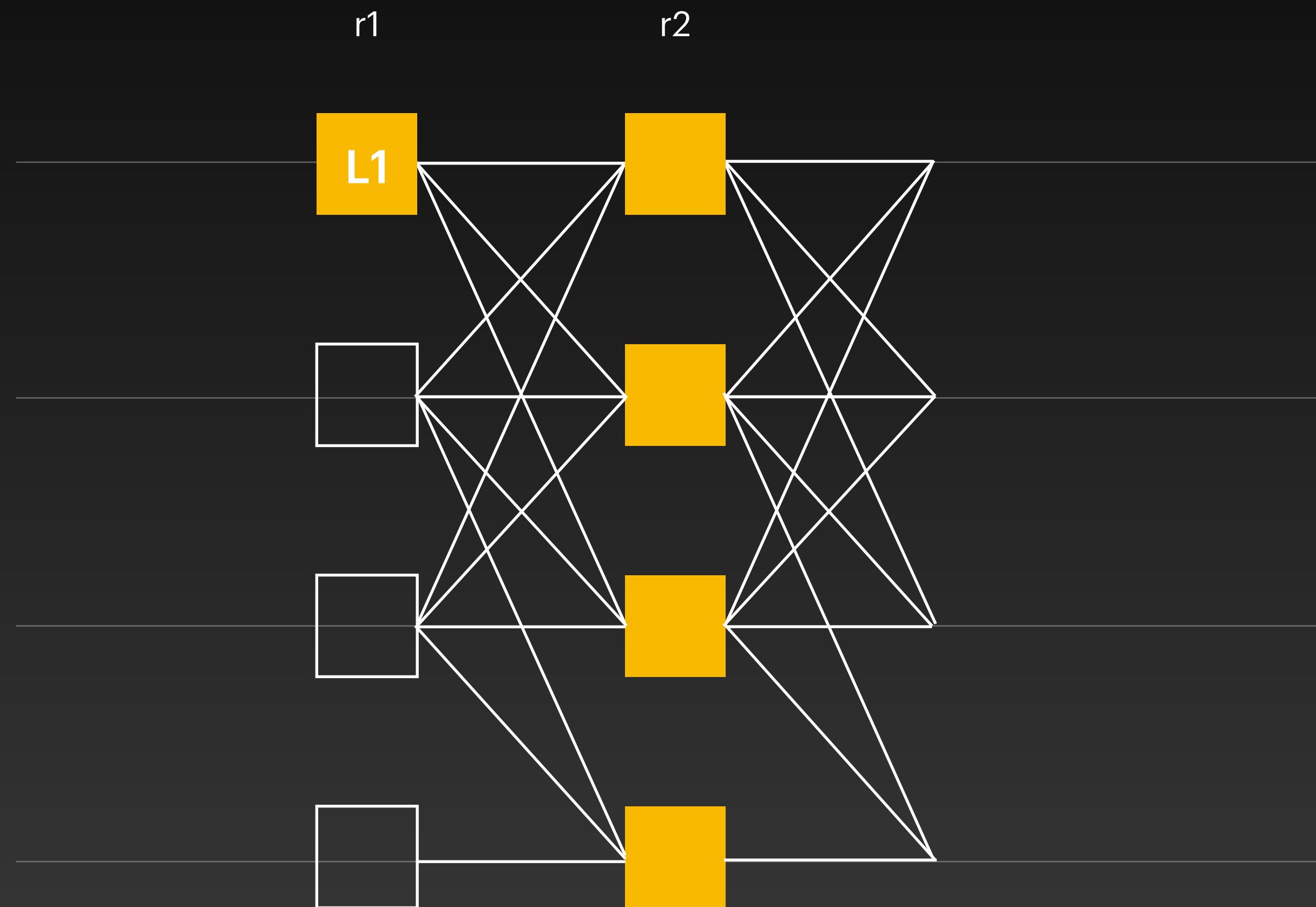
The Mysticeti DAG

Rule 2: Every node waits and links to leaders

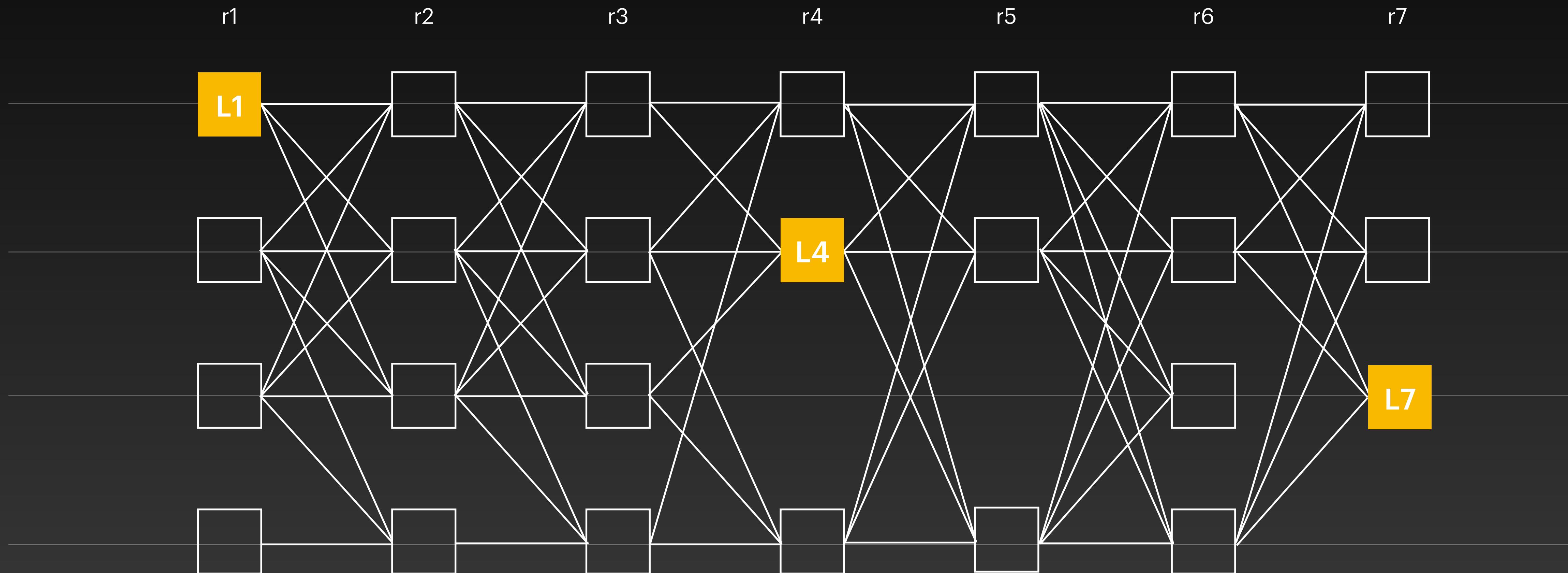


The Mysticeti DAG

Rule 3: All node run in parallel



The Mysticeti DAG

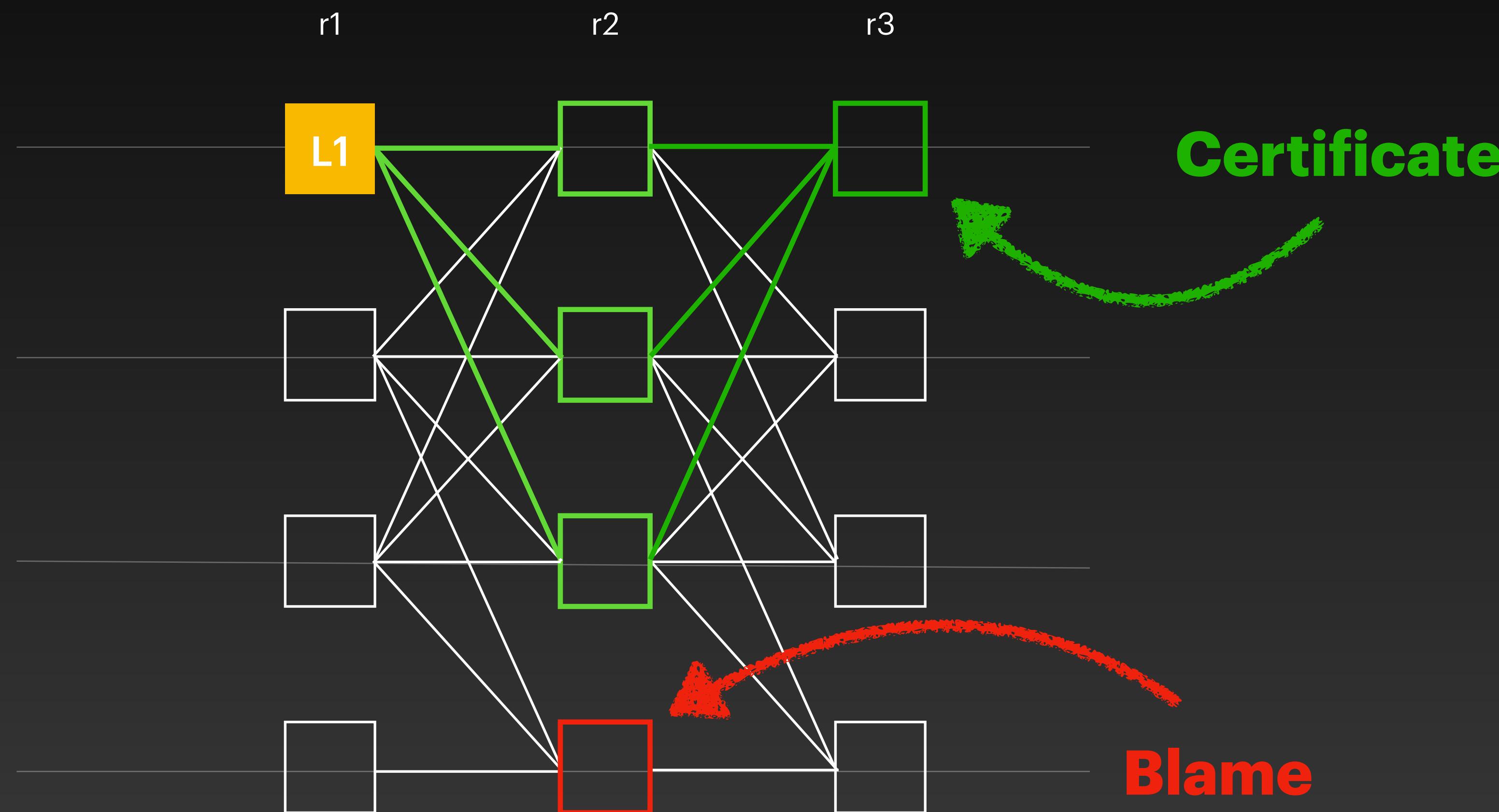


Main Ingredient:

All messages embedded in the DAG

- Fewer signatures
- Simpler synchronisation
- 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

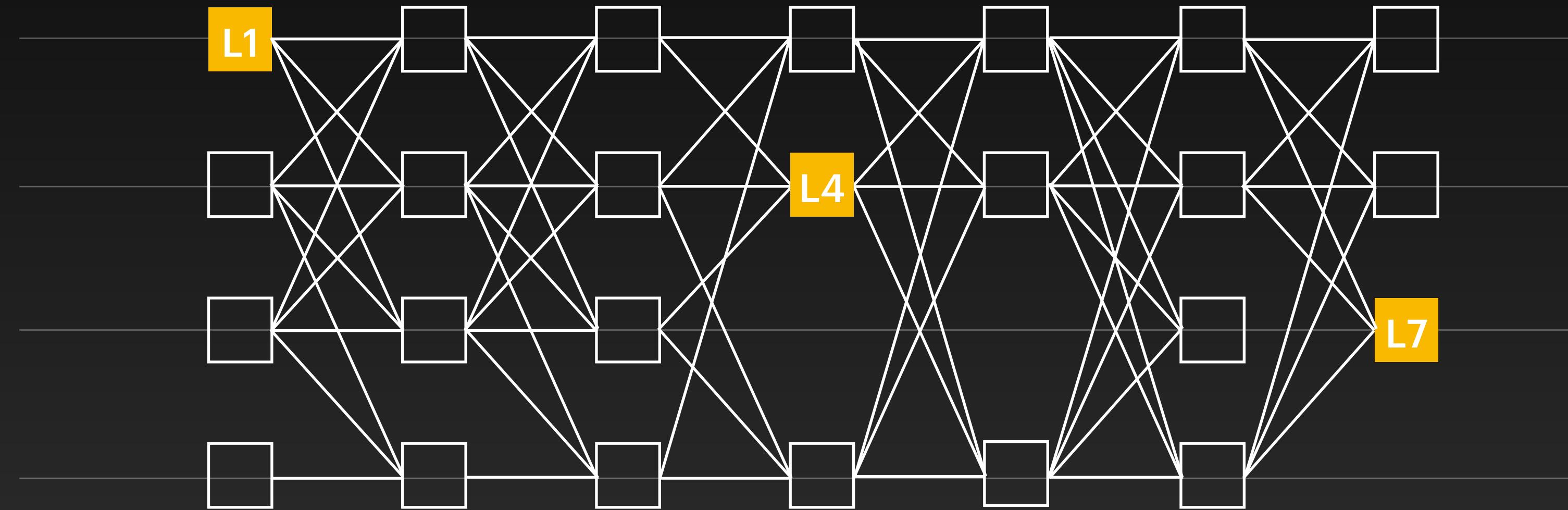
- Interpret BCB on DAG

Mysticeti-C

The consensus protocol

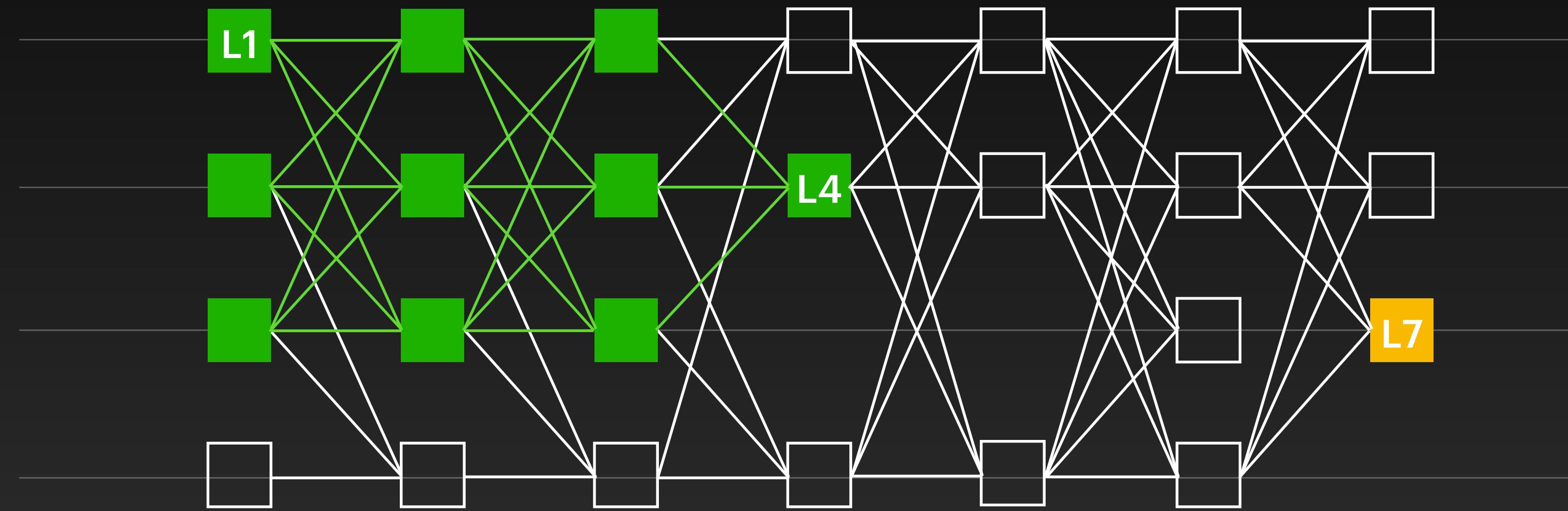
End Goal

Ordering leaders



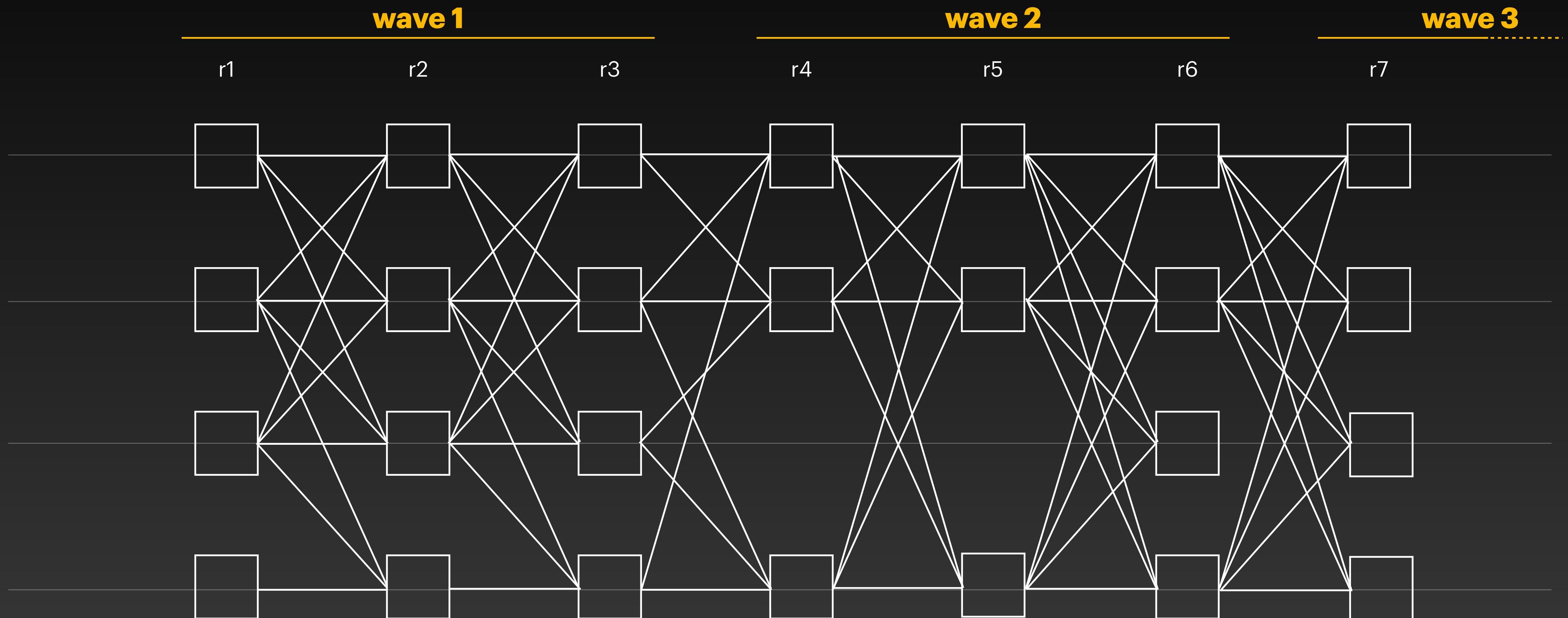
- We focus on ordering leaders: L1 L4 L7

End Goal Ordering leaders

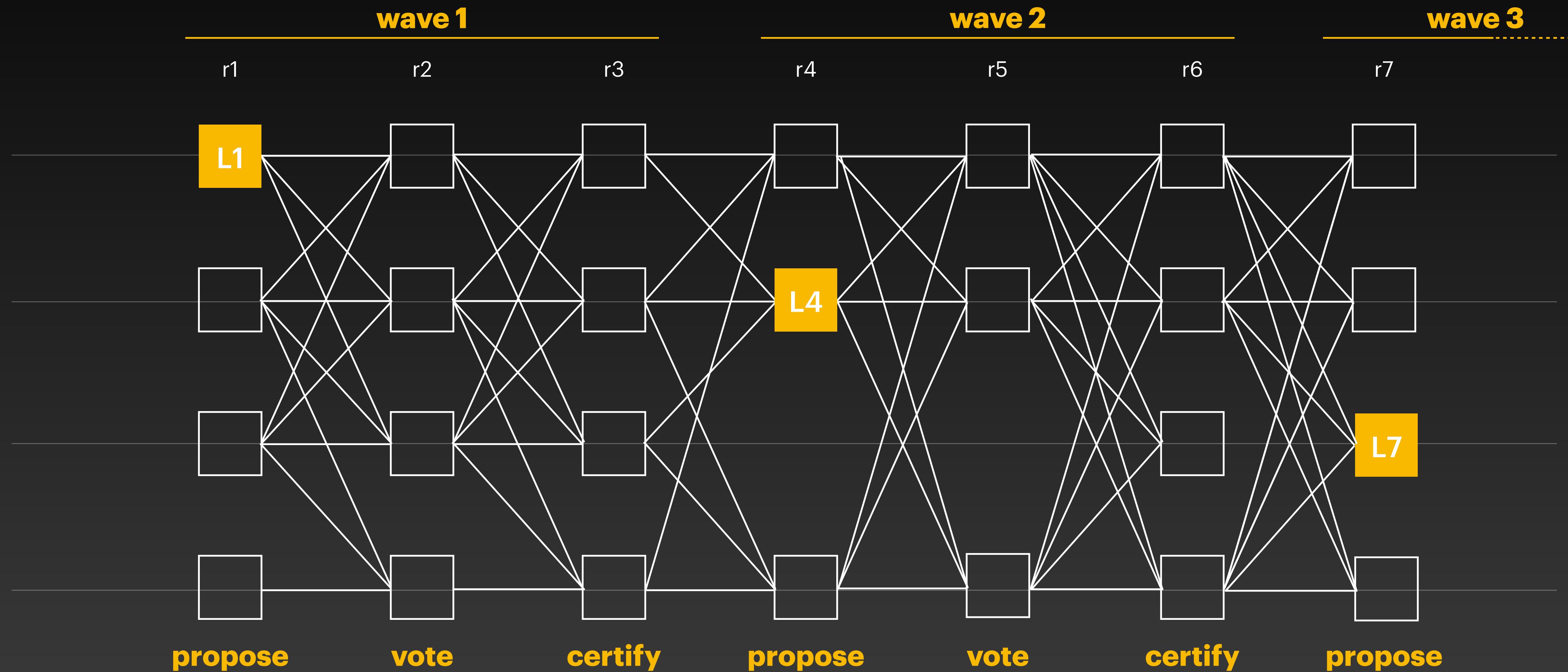


- We focus on ordering leaders: L1 L4 L7
 - Linearising the sub-DAG is simple

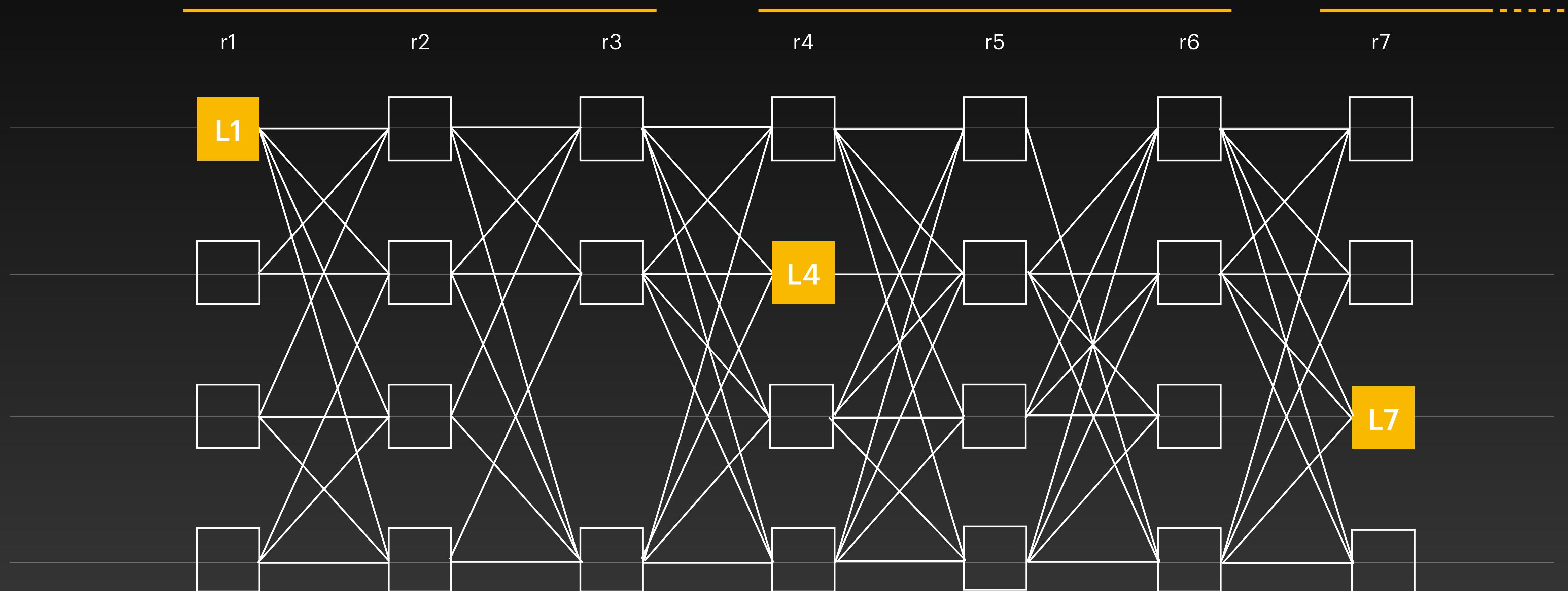
DAG Structure



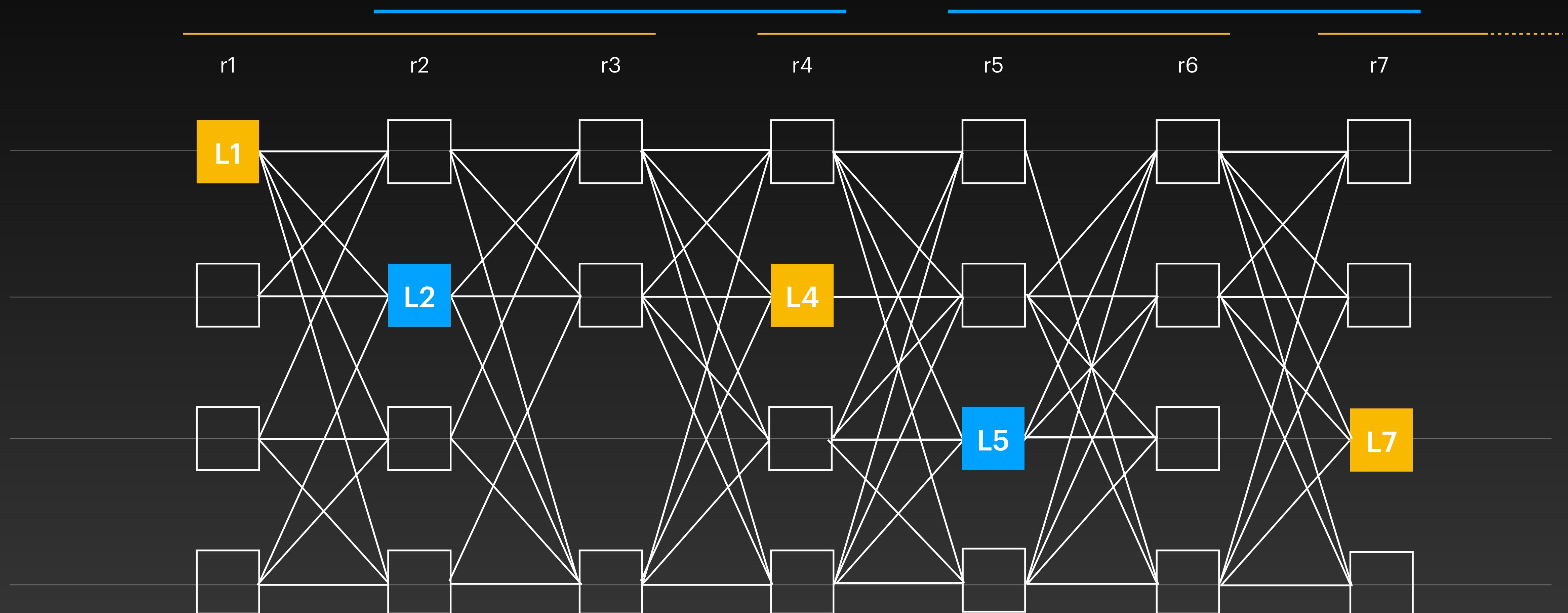
DAG Structure



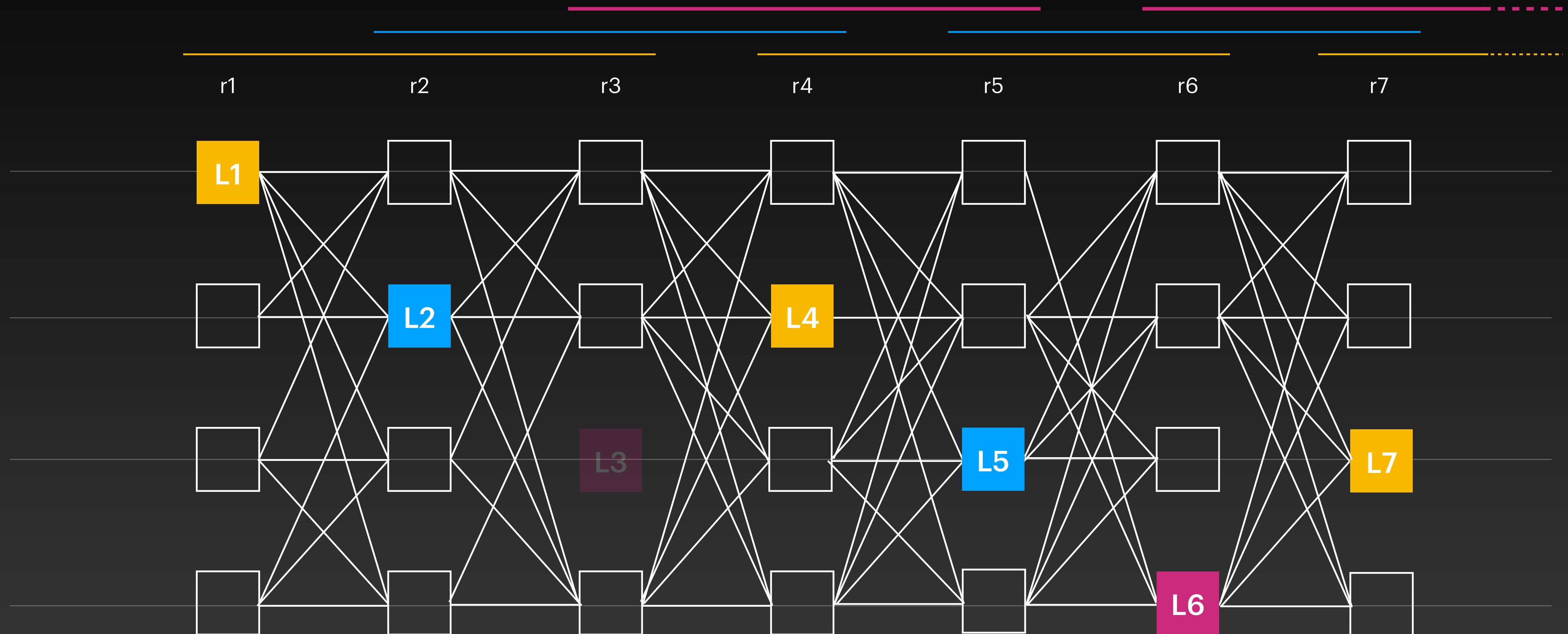
DAG Structure



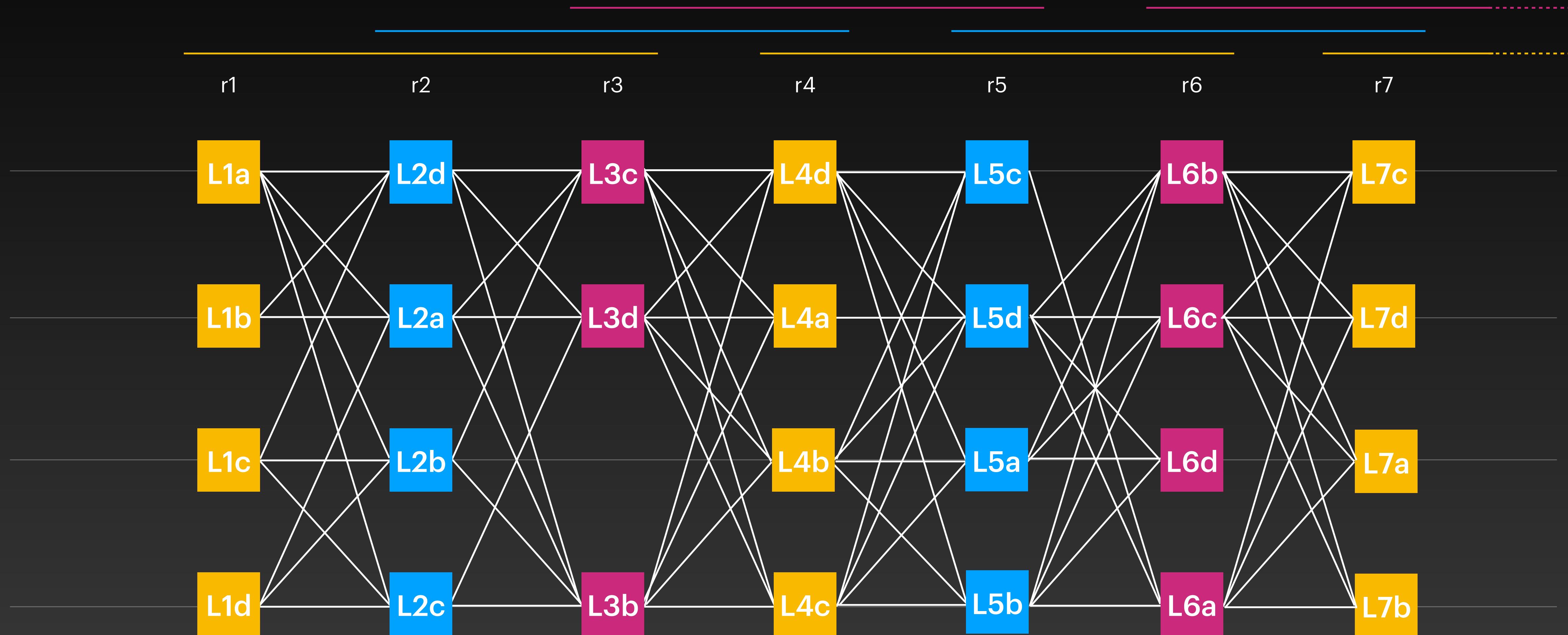
DAG Structure



DAG Structure

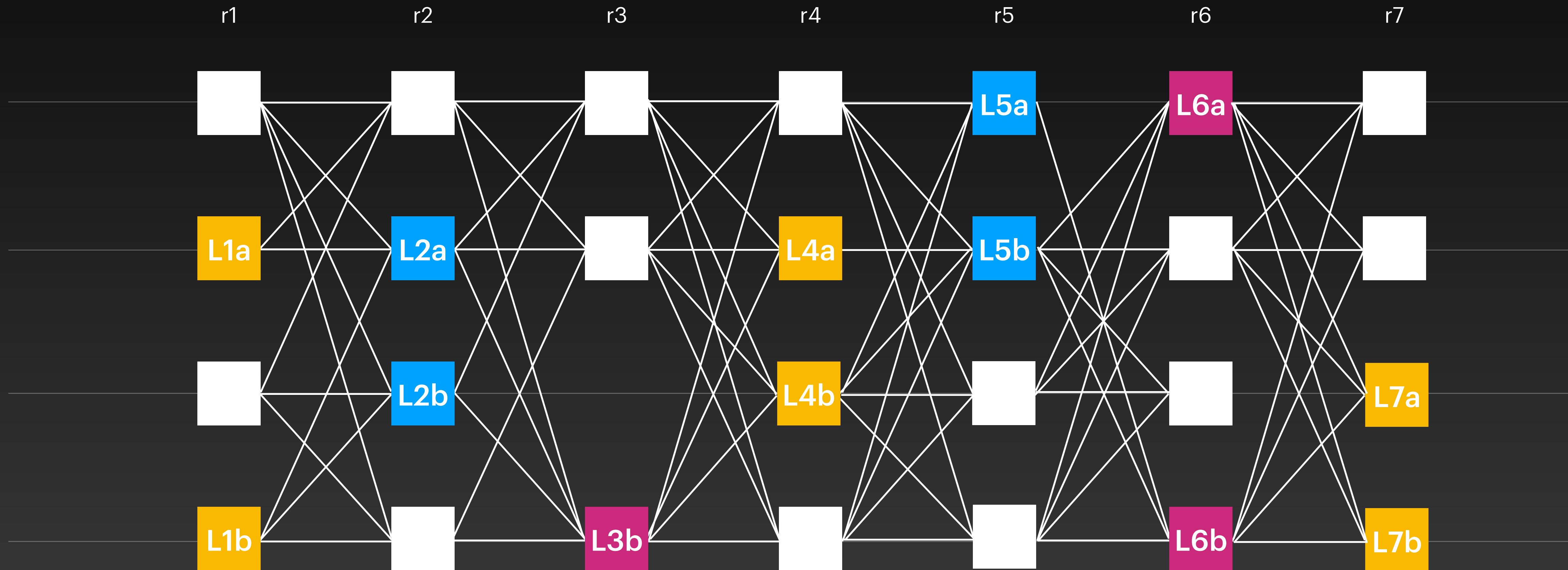


DAG Structure



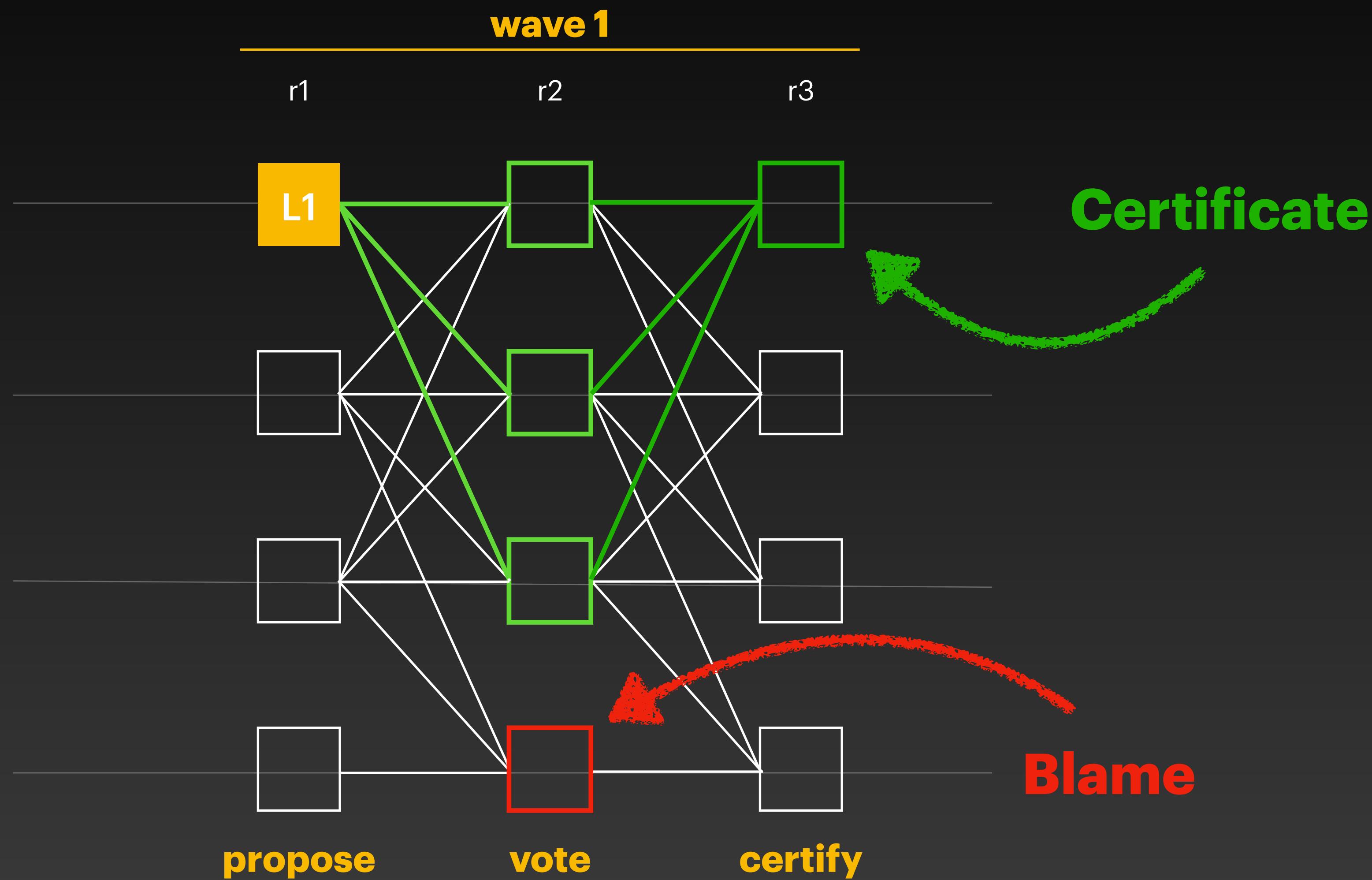
Practical Implementation

Select only 2 leaders per round



Interpreting DAG Patterns

Reminder



Direct Decision Rule

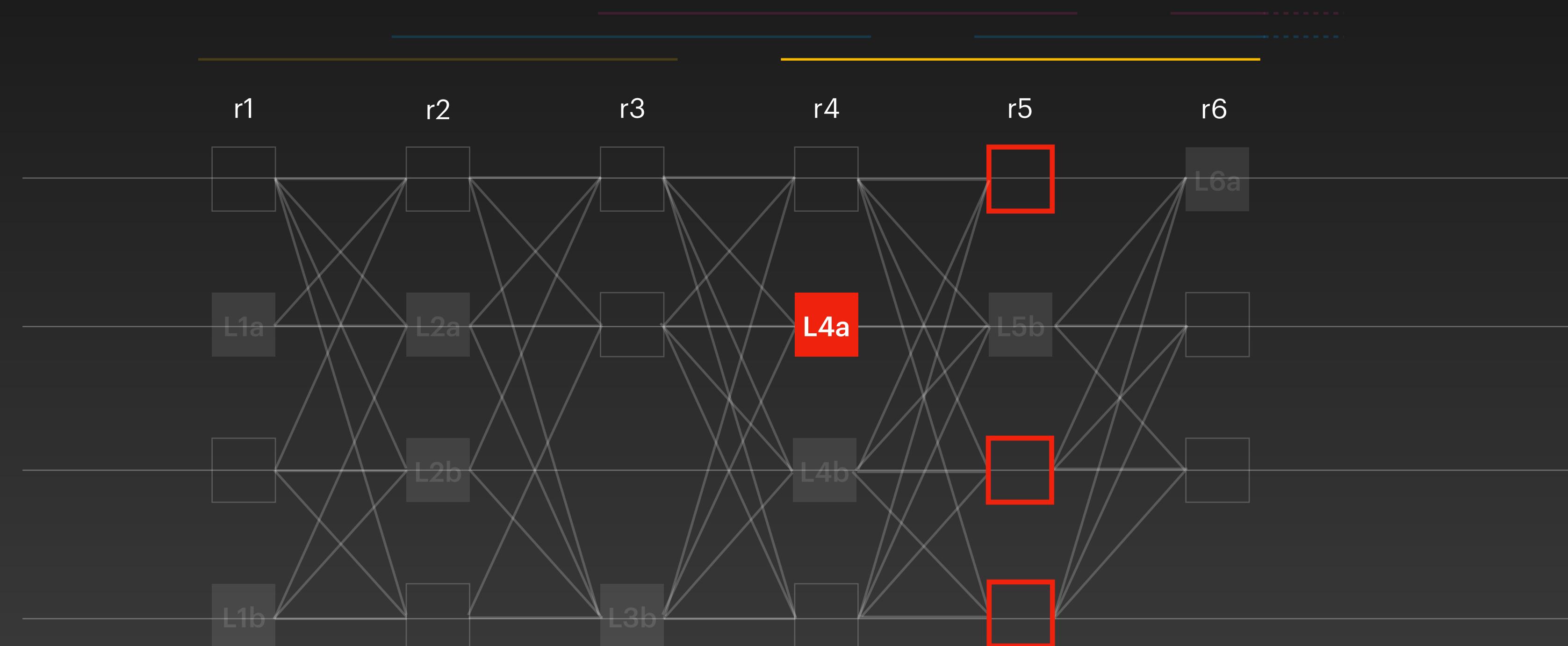
On each leader starting from highest round:

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

Direct Decision Rule

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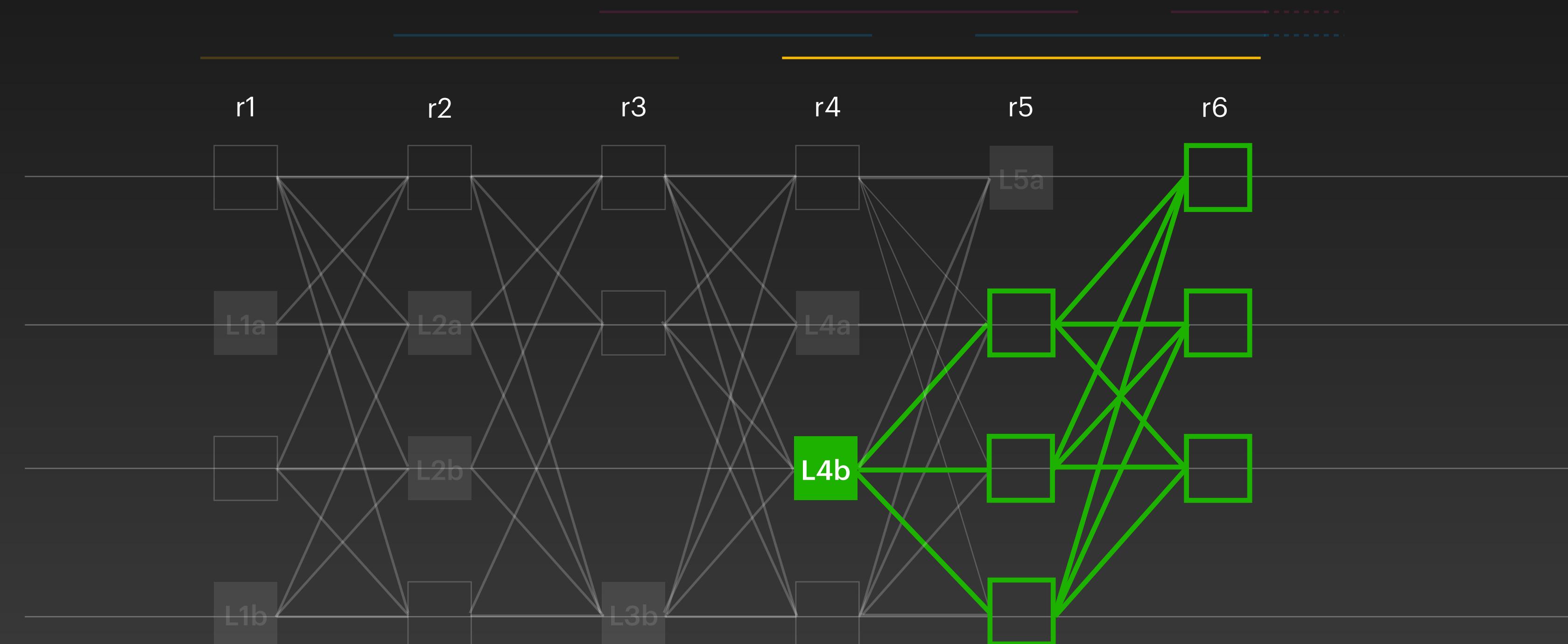
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Direct Decision Rule

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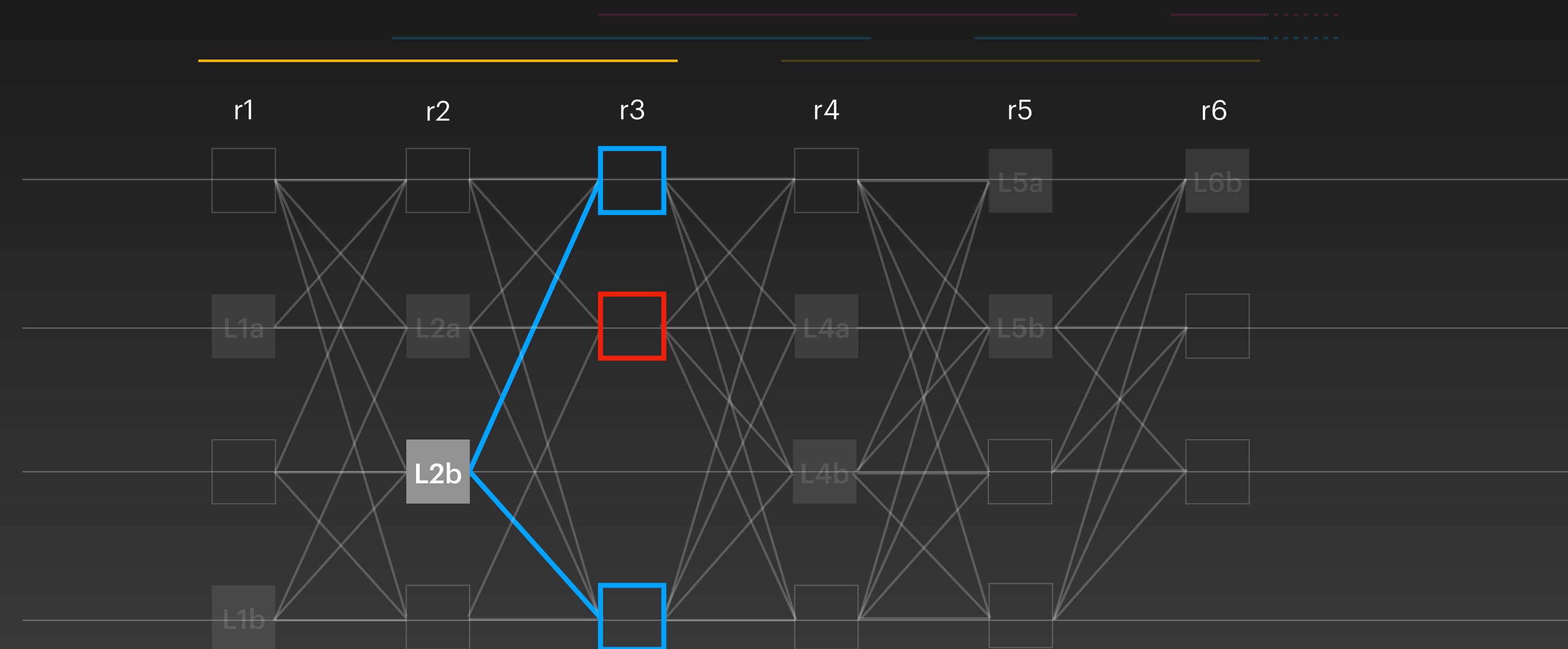
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Direct Decision Rule

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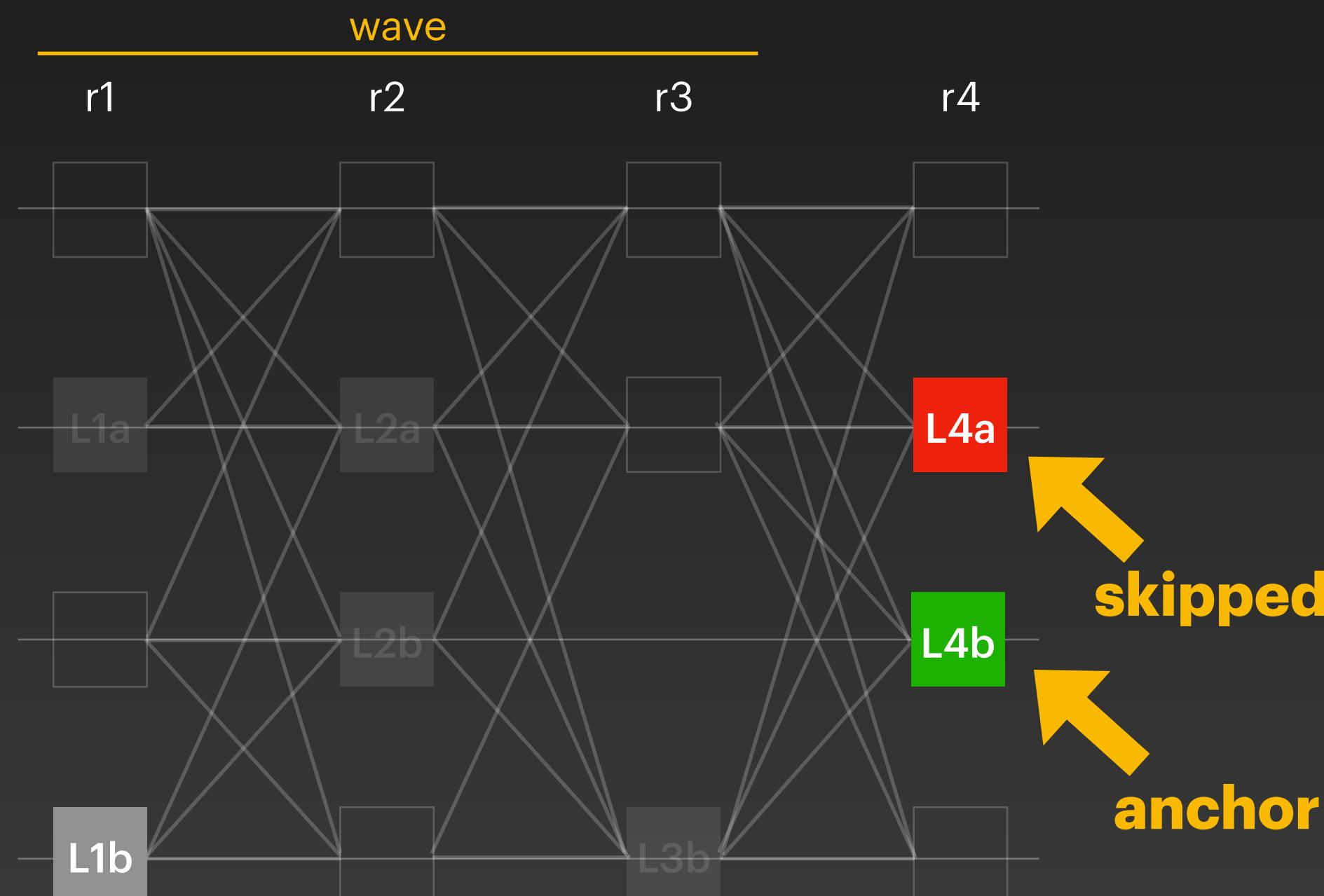


Indirect Decision Rule

Indirect Decision Rule

1. Find Anchor

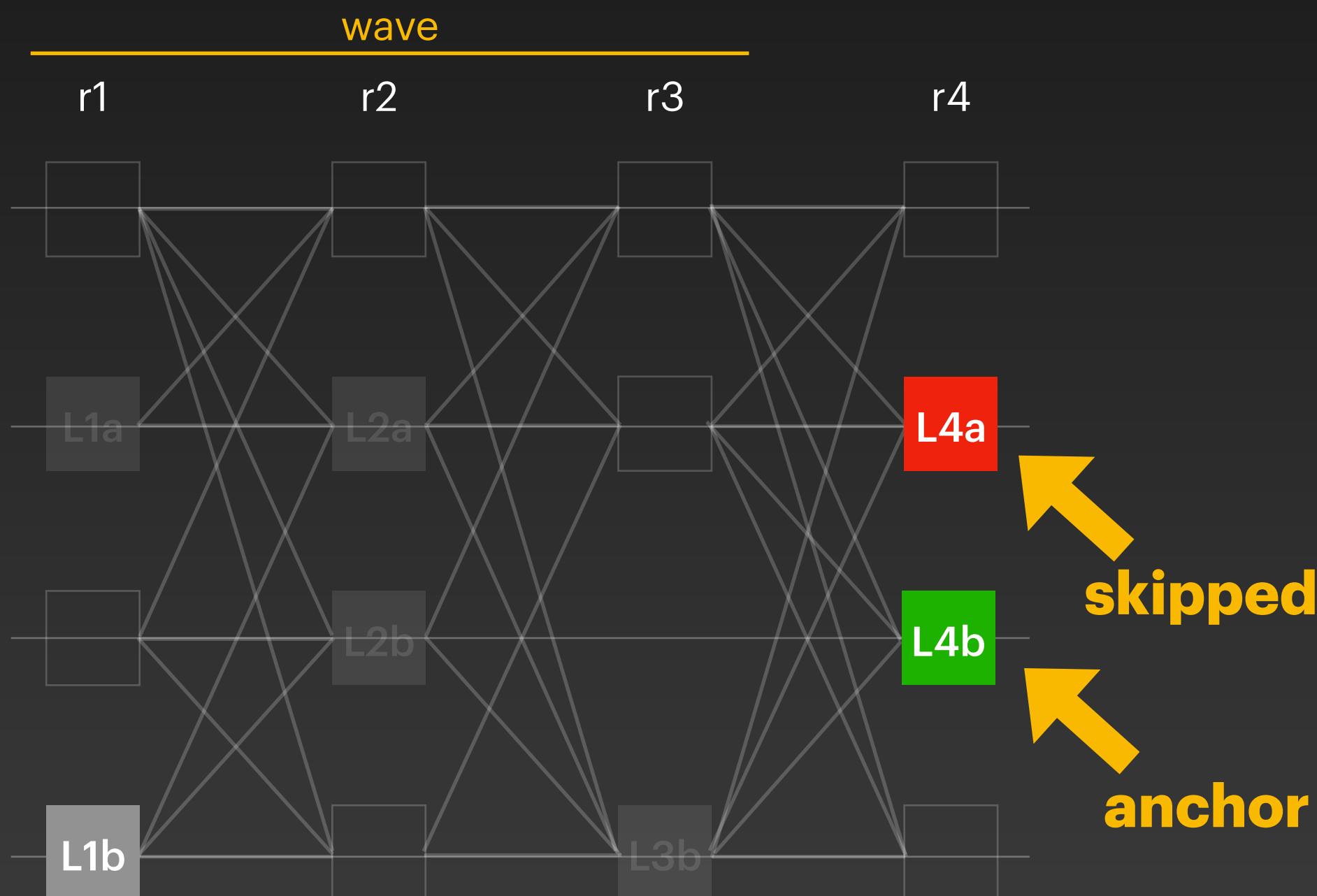
- First block with round $> r+2$ that is **Commit** or **Undecided**



Indirect Decision Rule

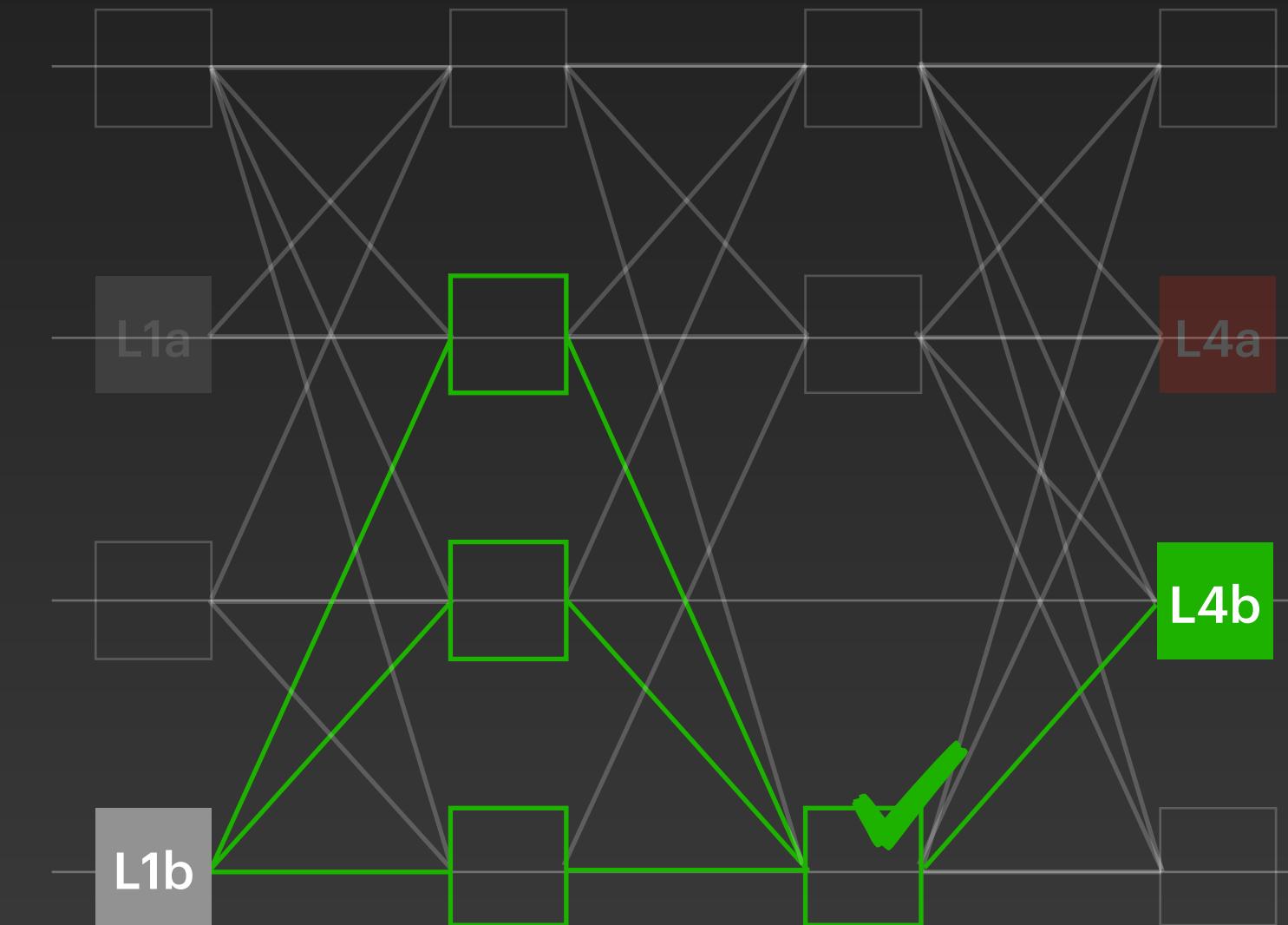
1. Find Anchor

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

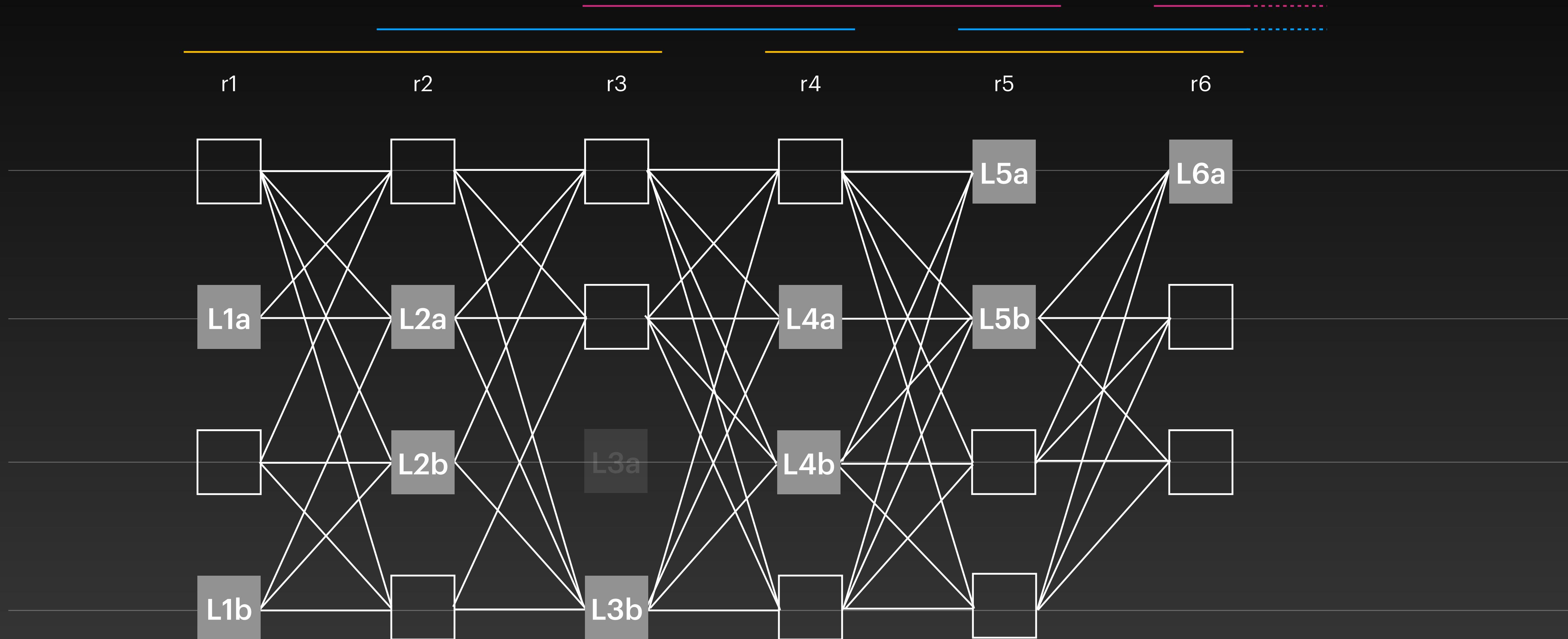


2. Certified link

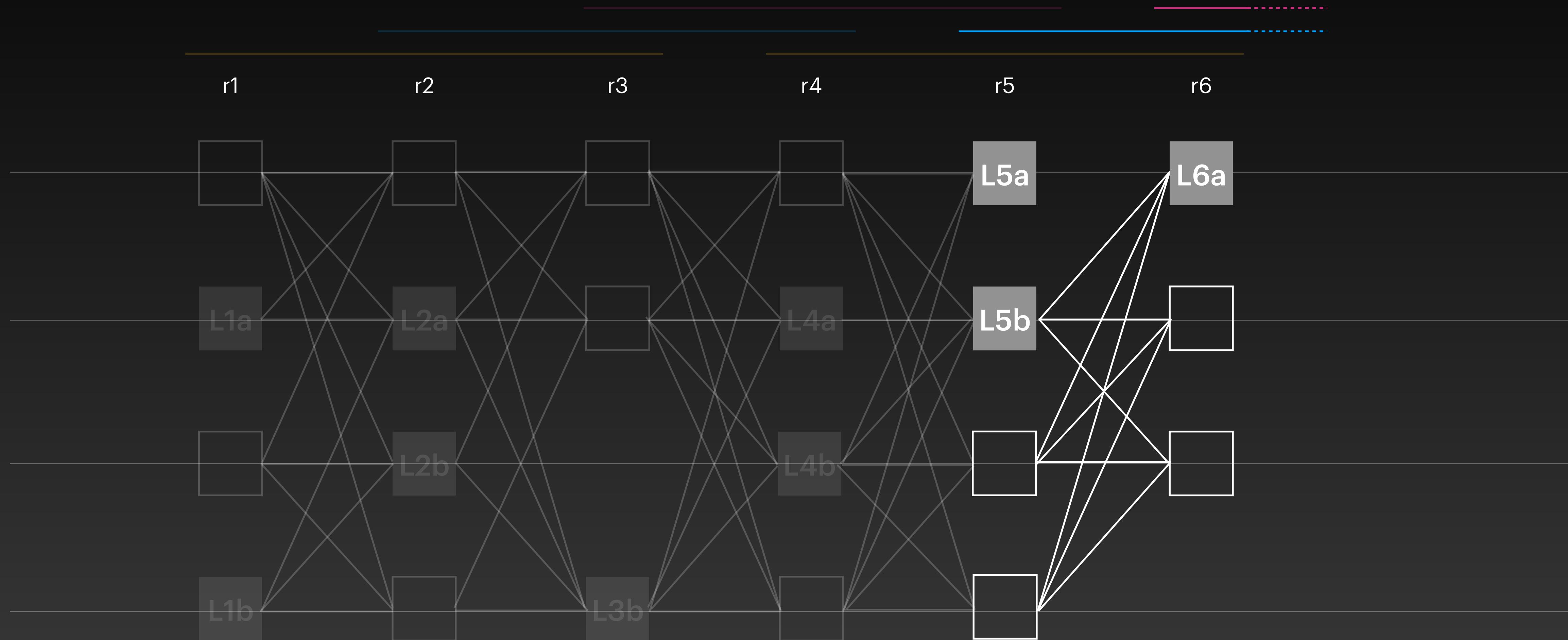
- Commit** if $B <->$ certified link $<->$ A
otherwise **Skip**



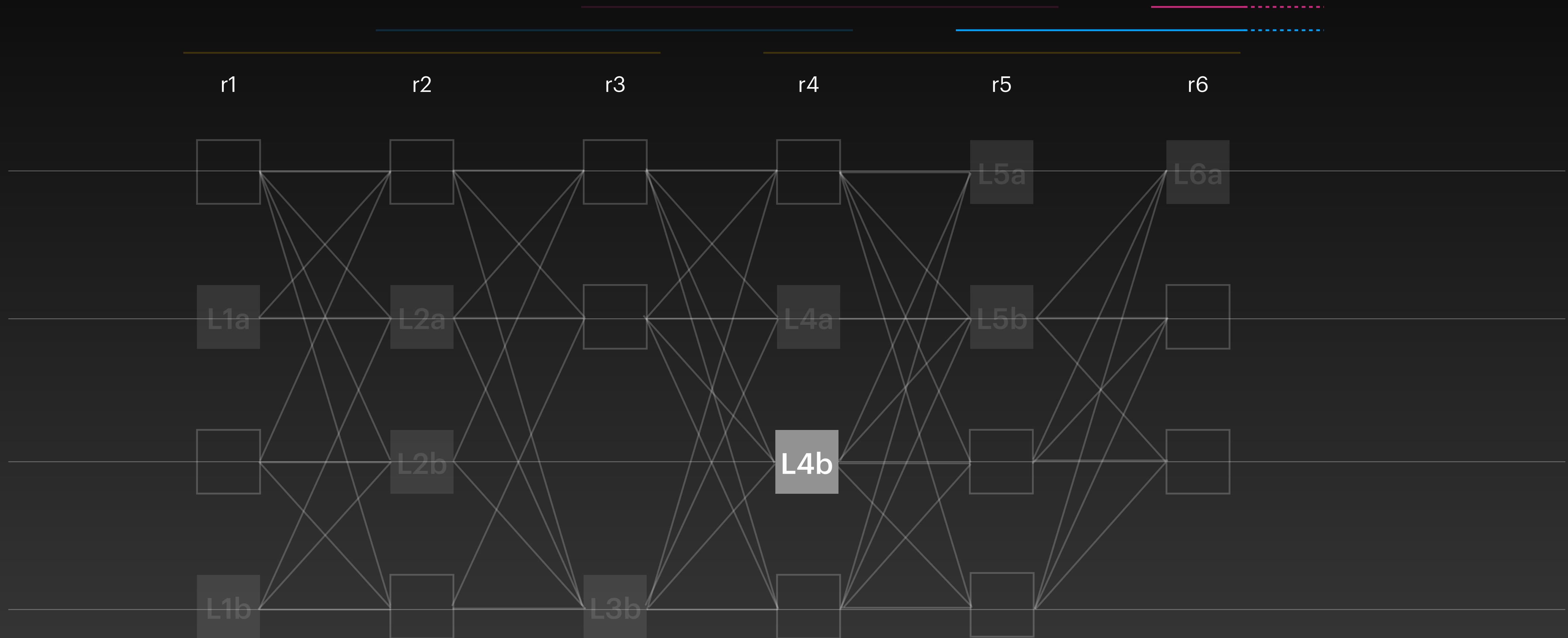
All Start at Undecided



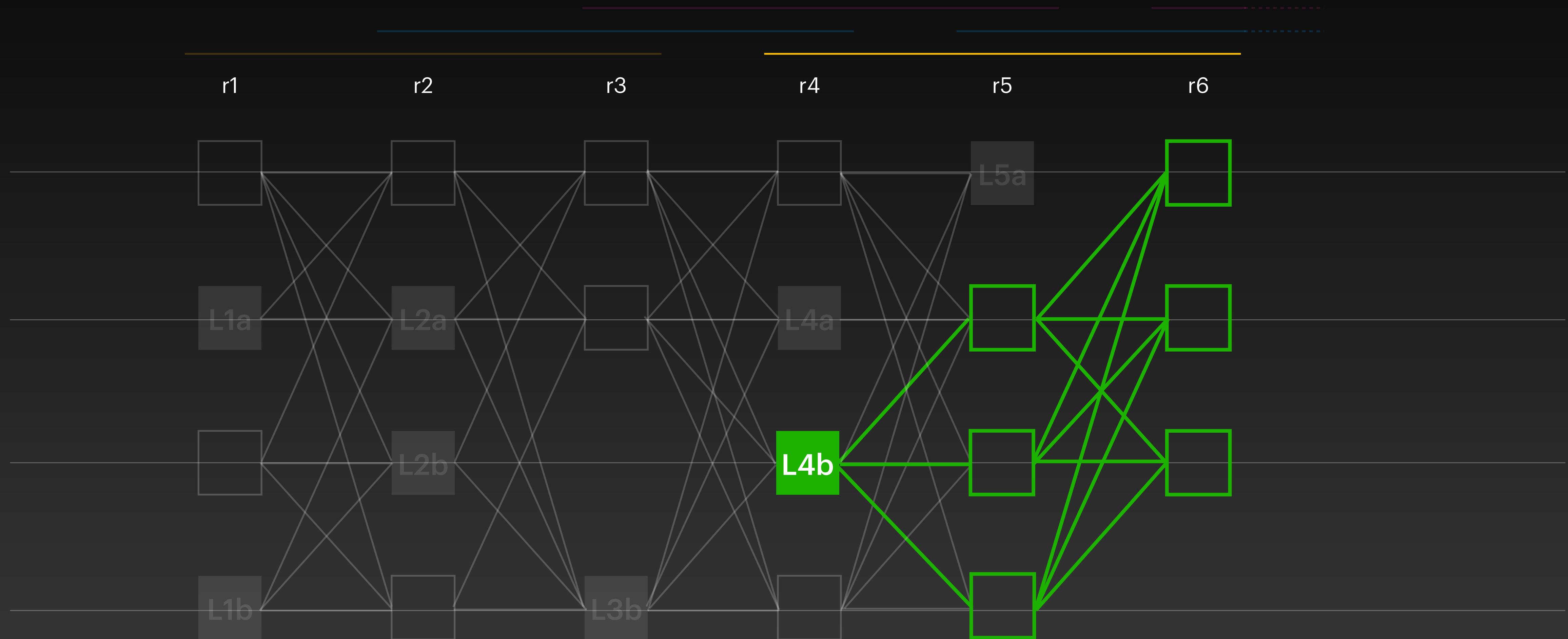
Ignore Incomplete Waves



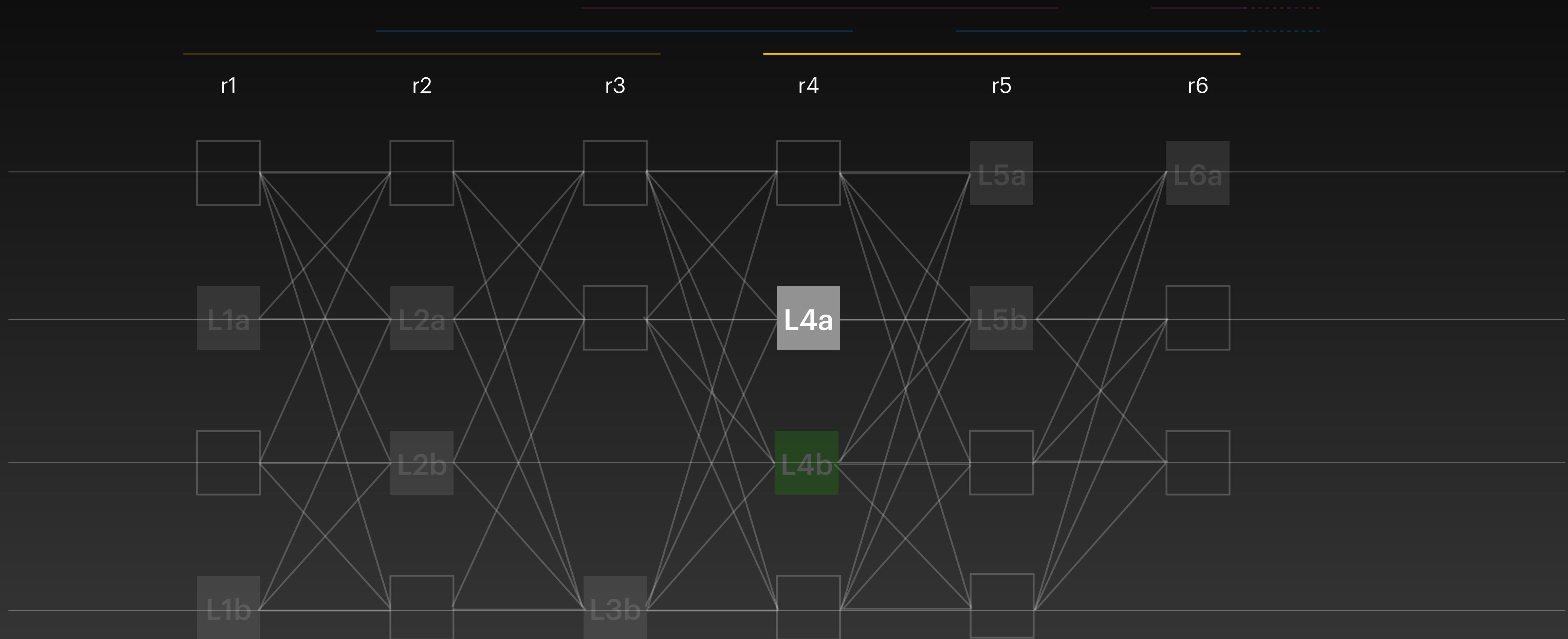
Apply Direct Rule



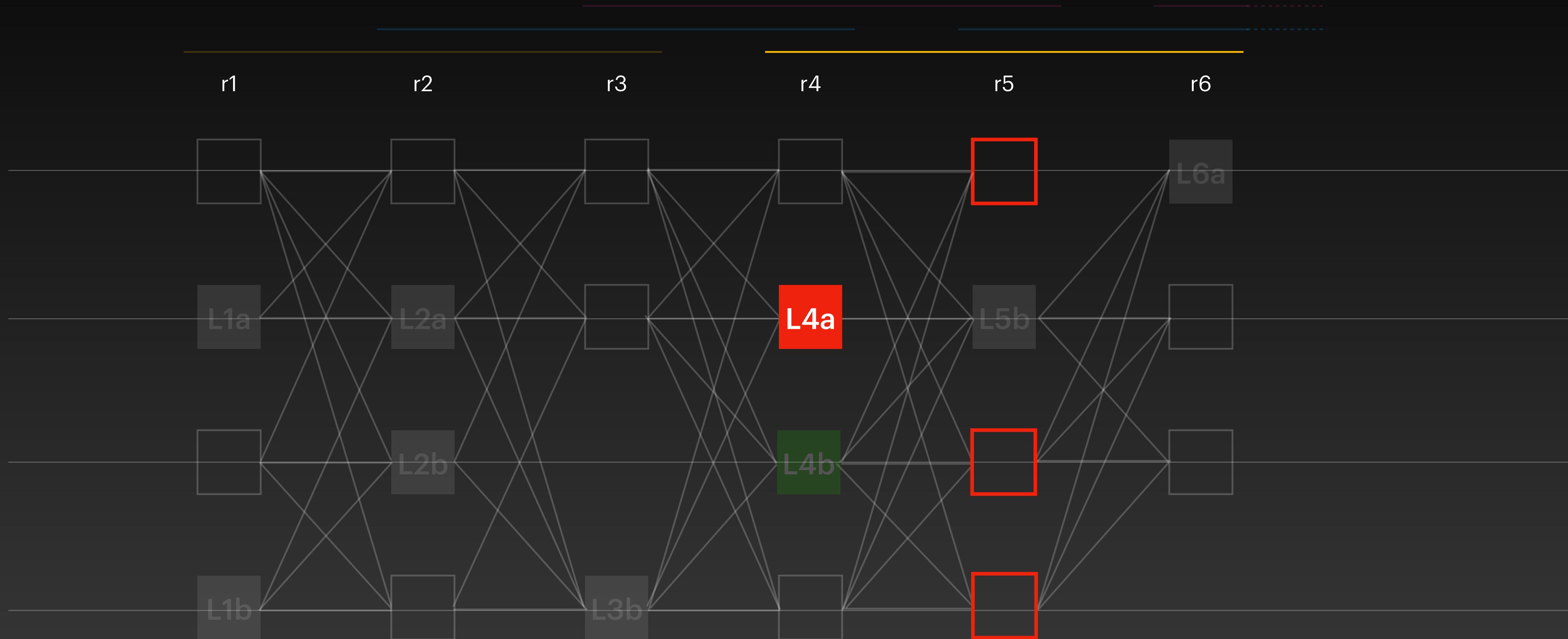
Apply Direct Rule



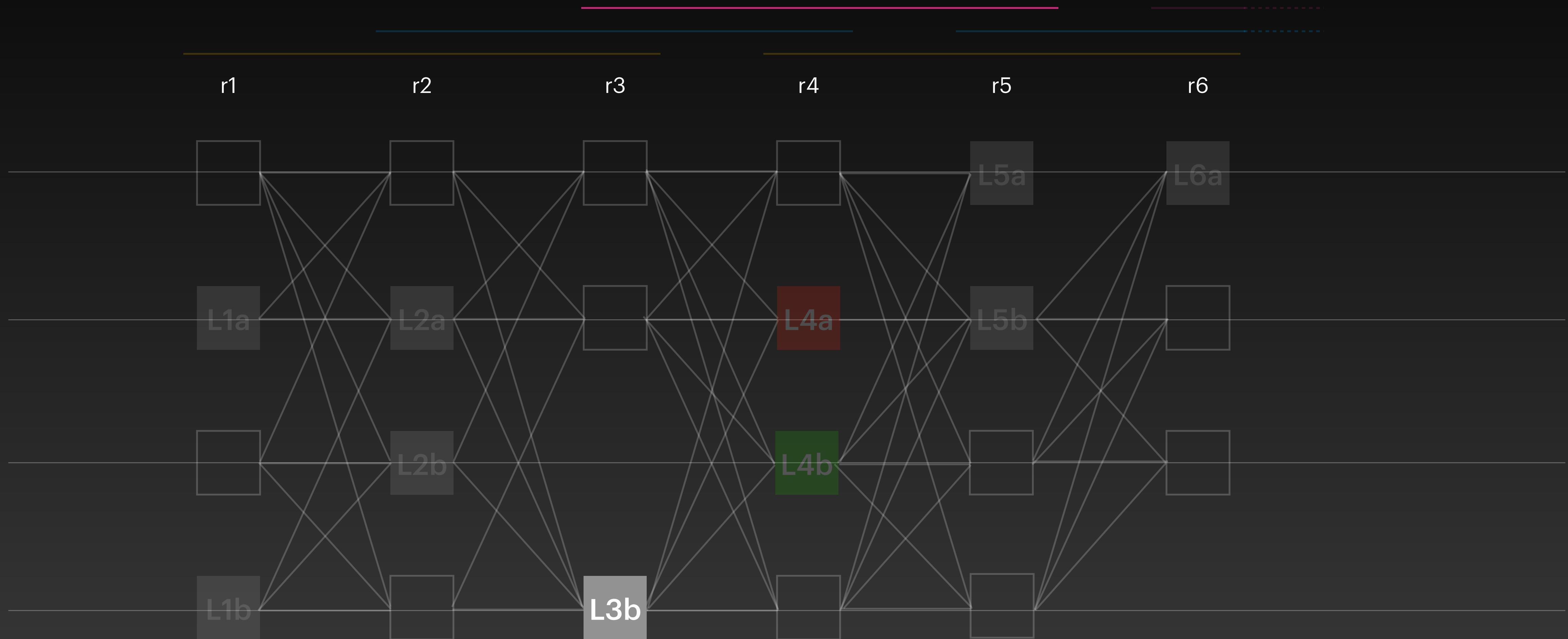
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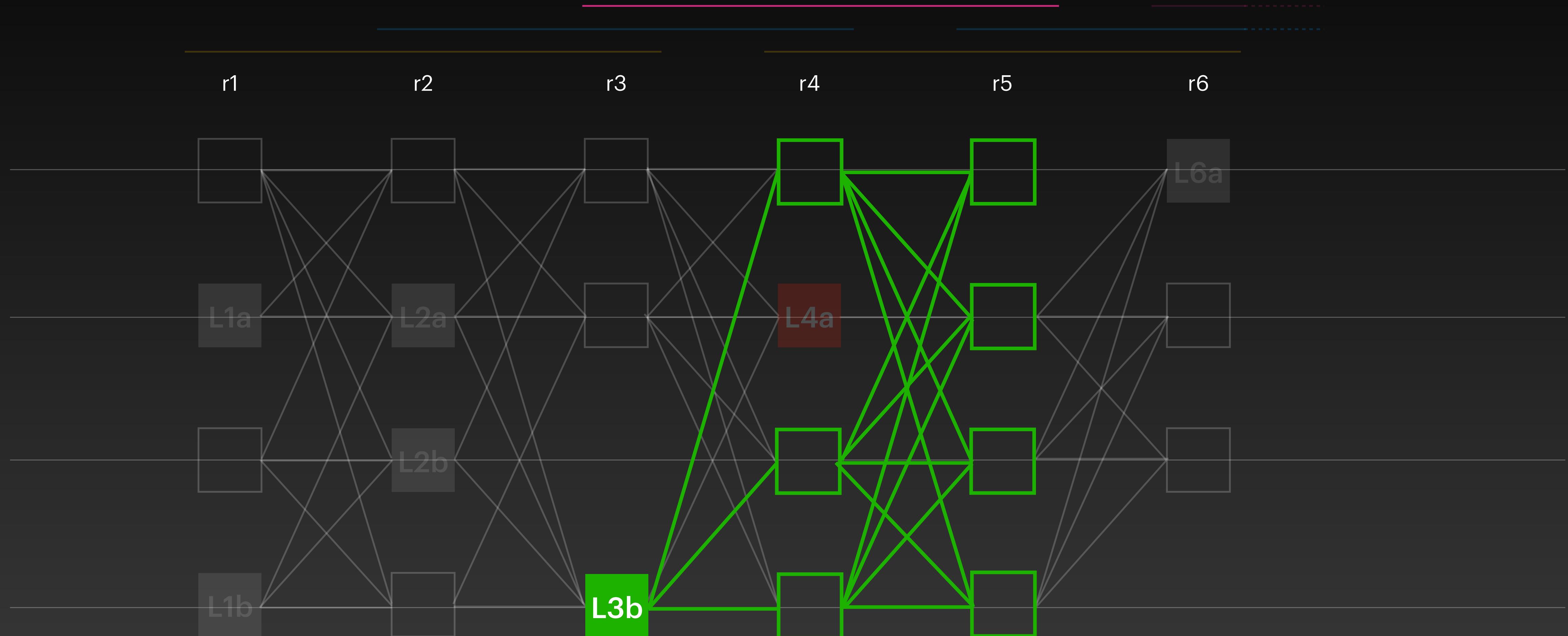
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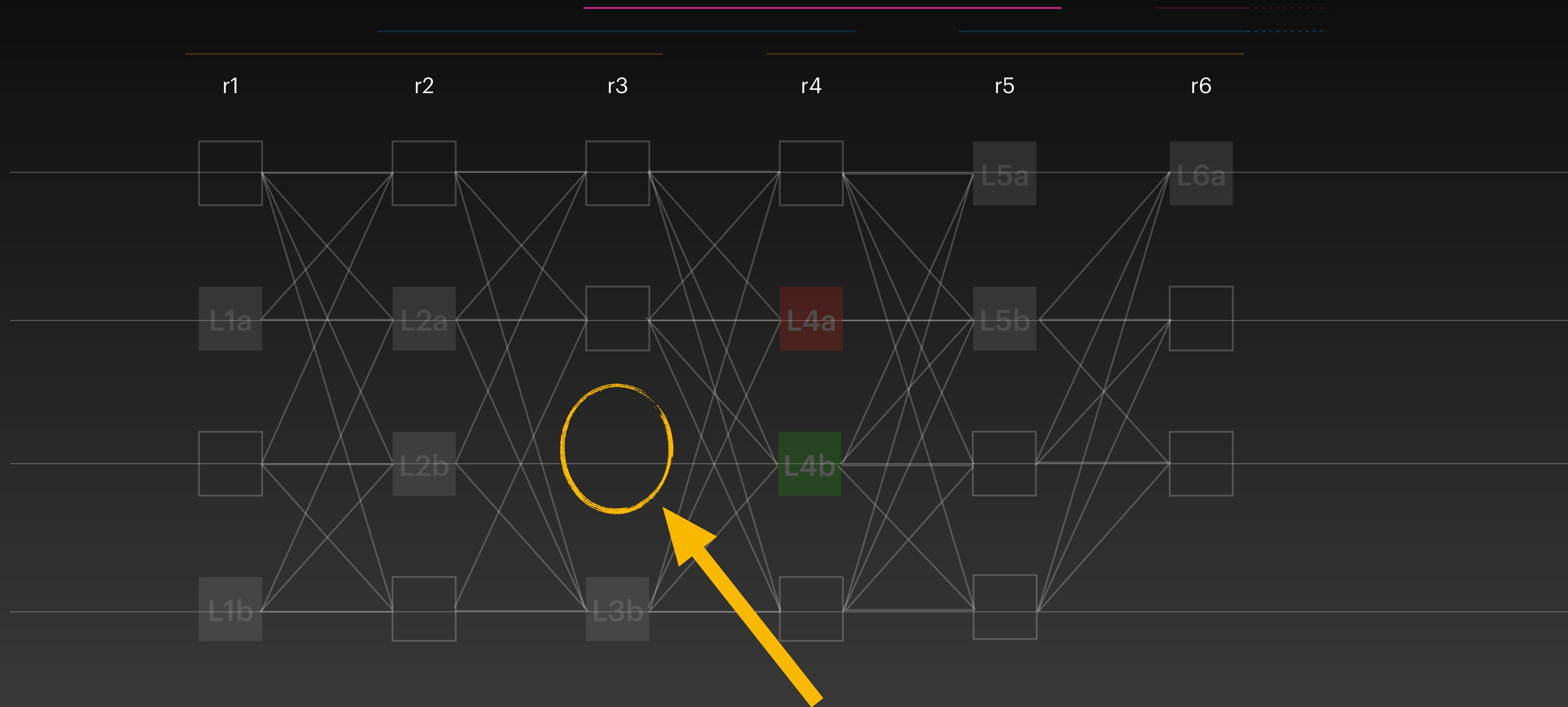
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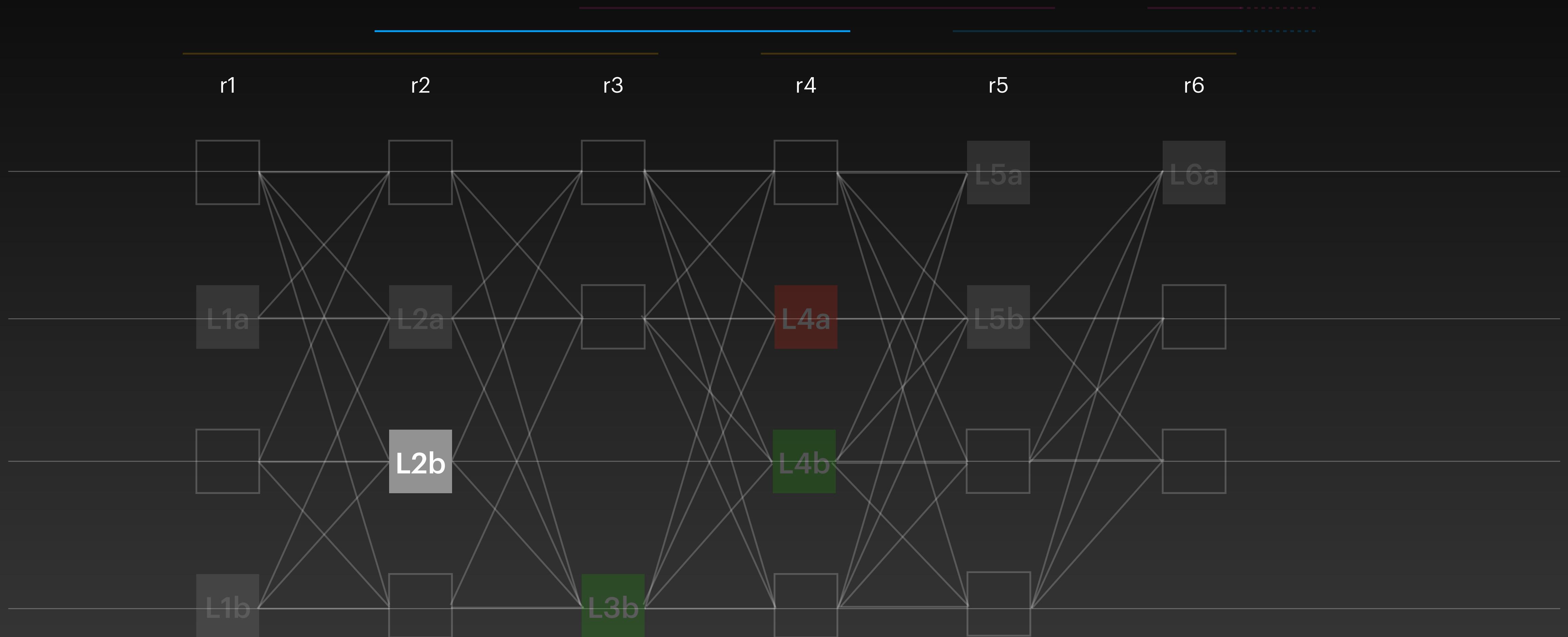
Apply Direct Rule



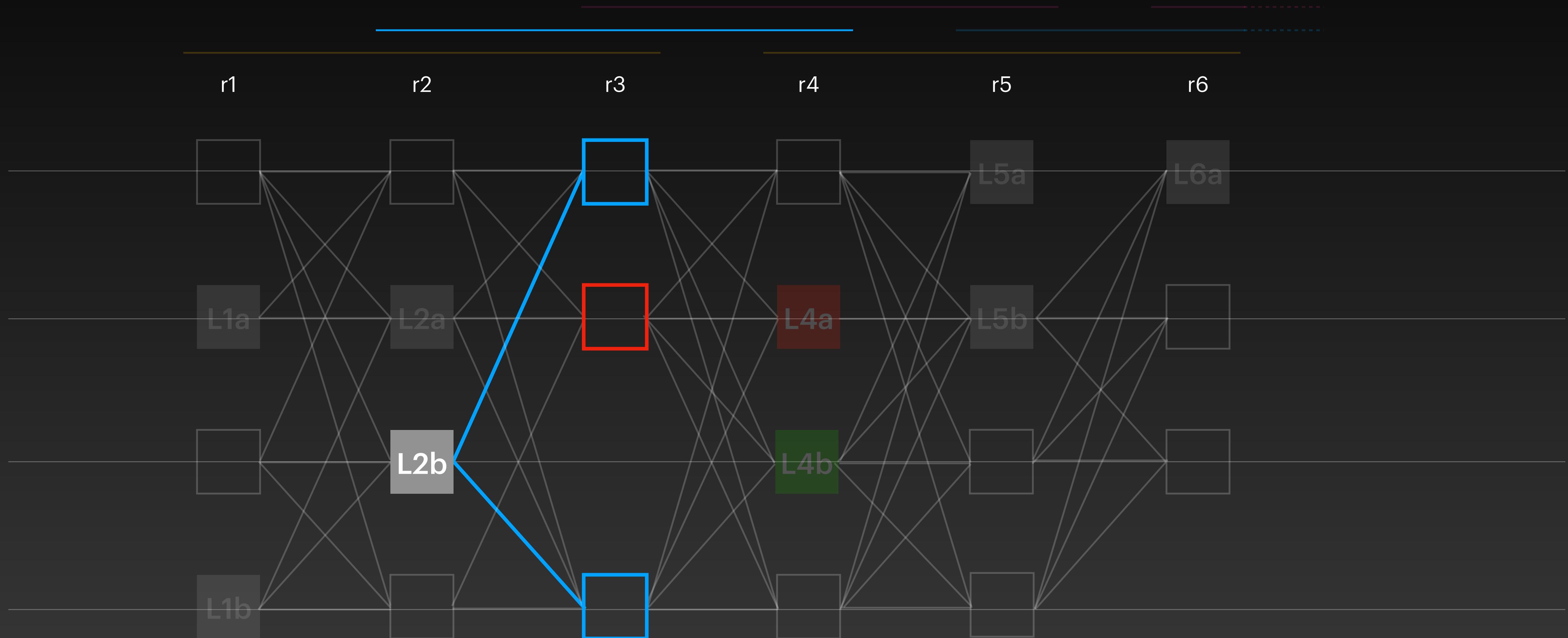
Ignore Missing Leader



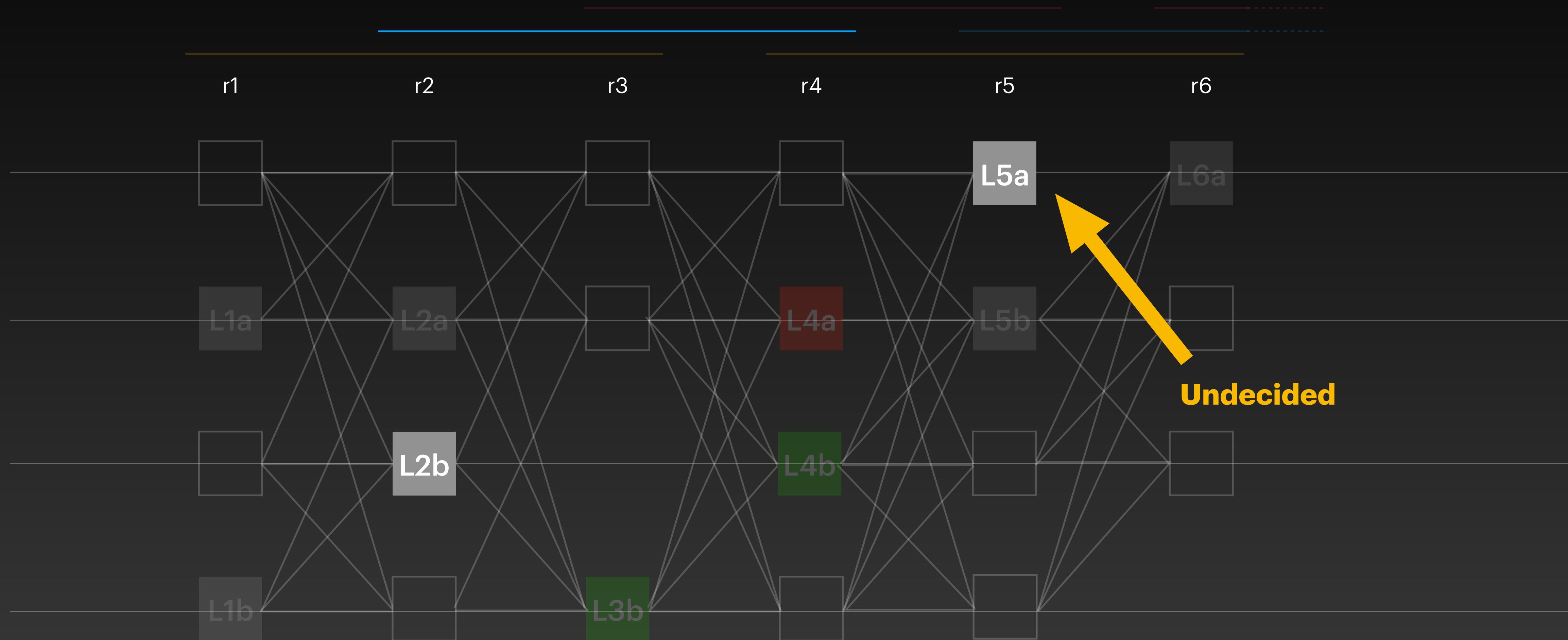
Apply Direct Rule



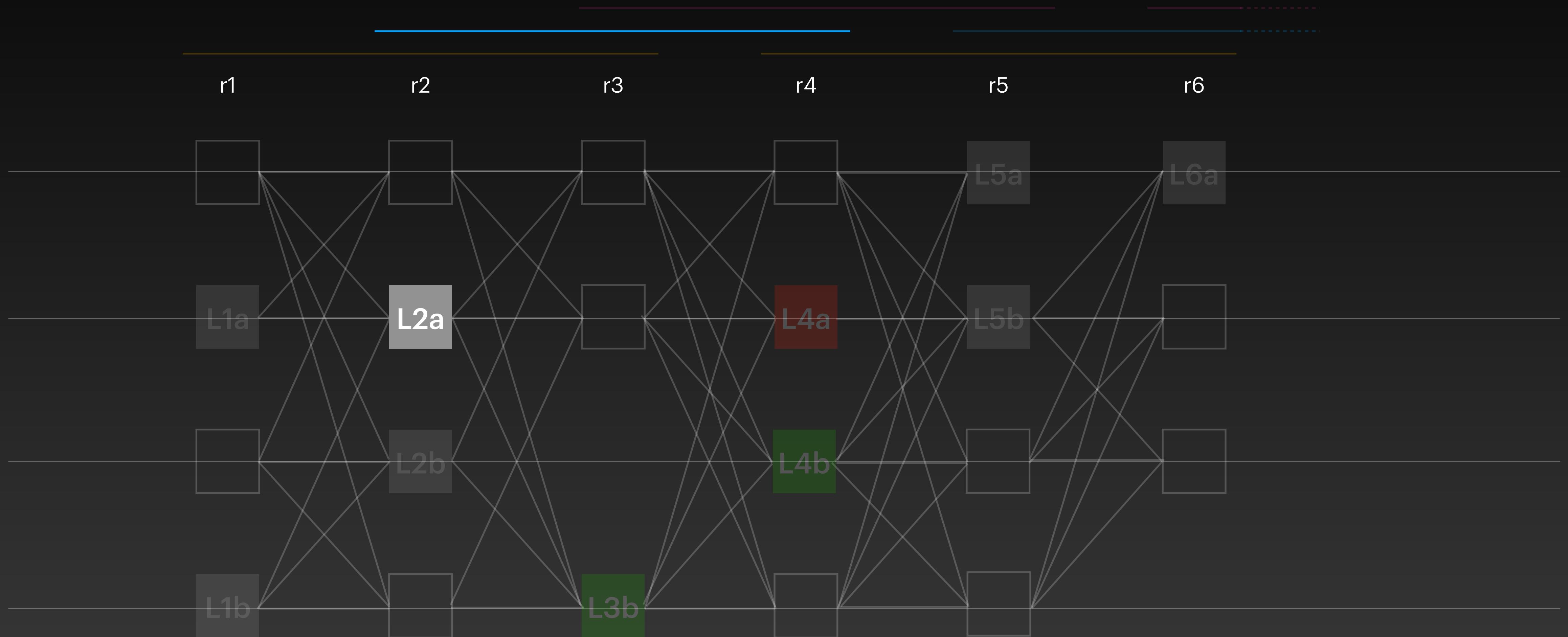
Apply Direct Rule



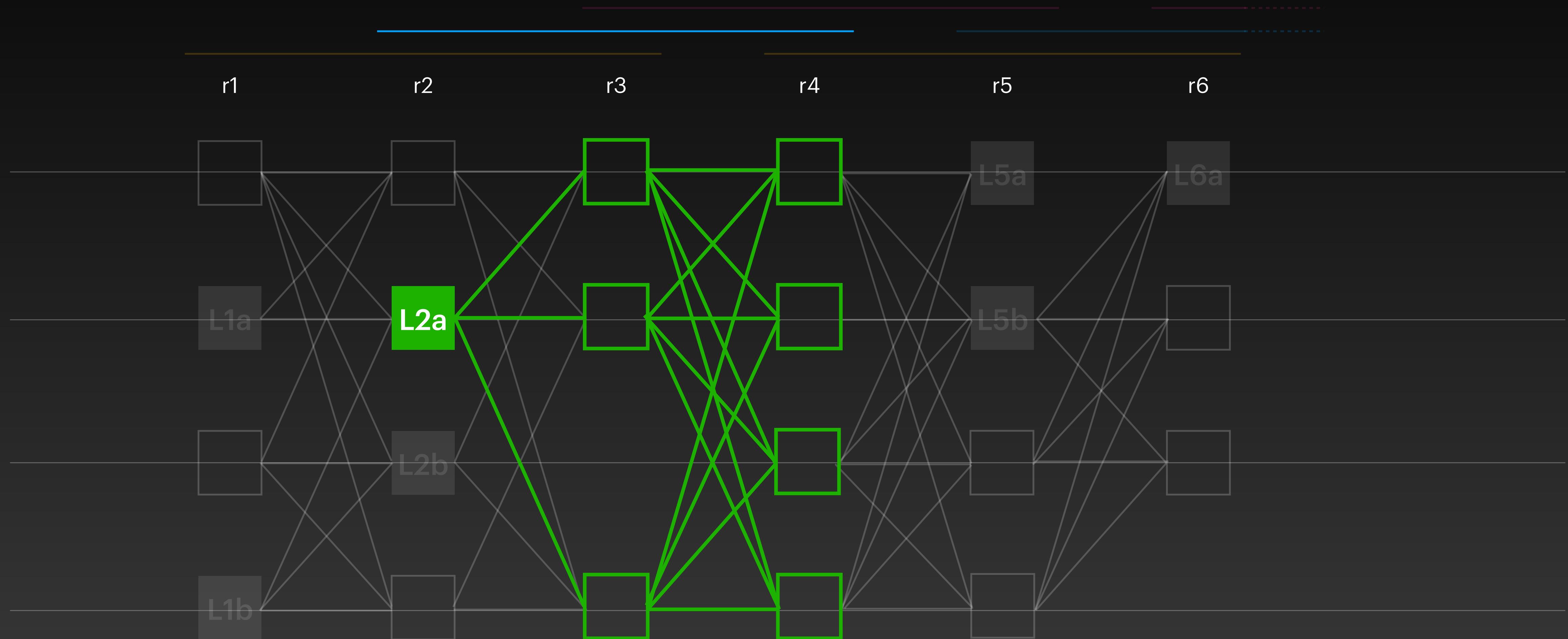
Apply Indirect Rule



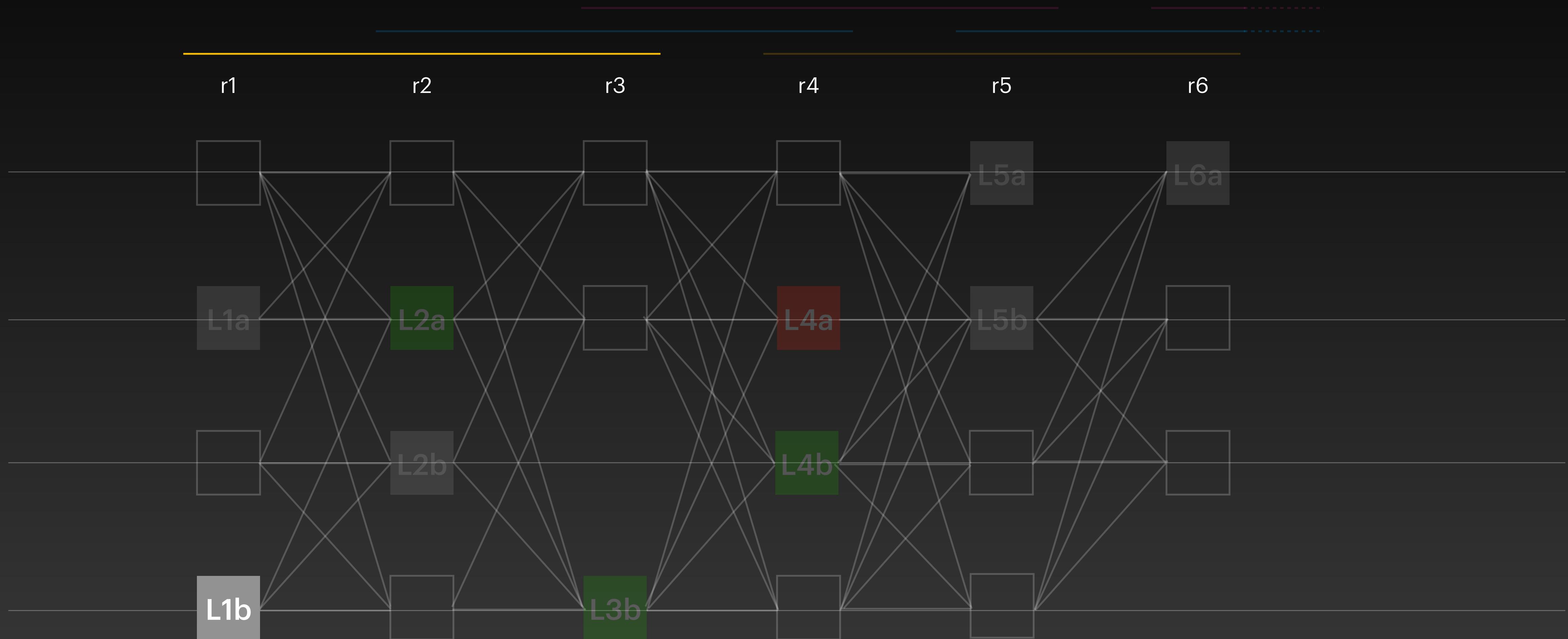
Apply Direct Rule



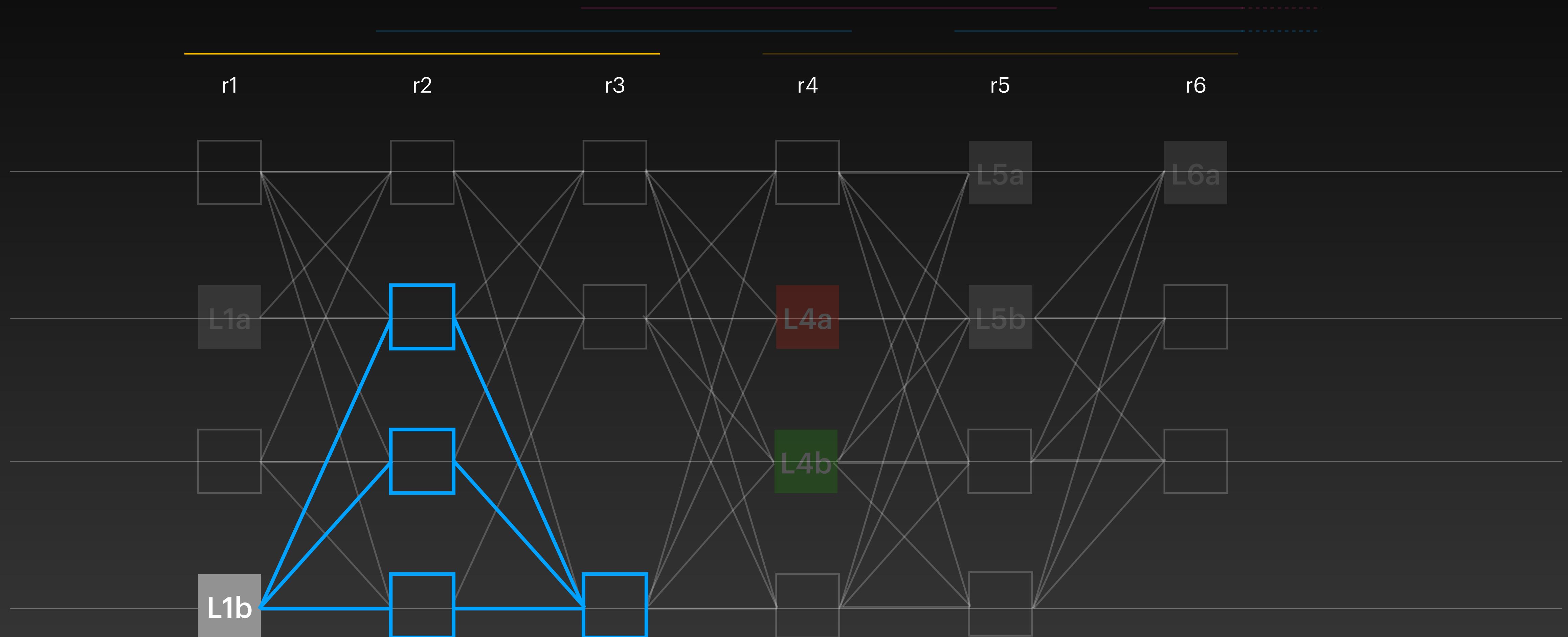
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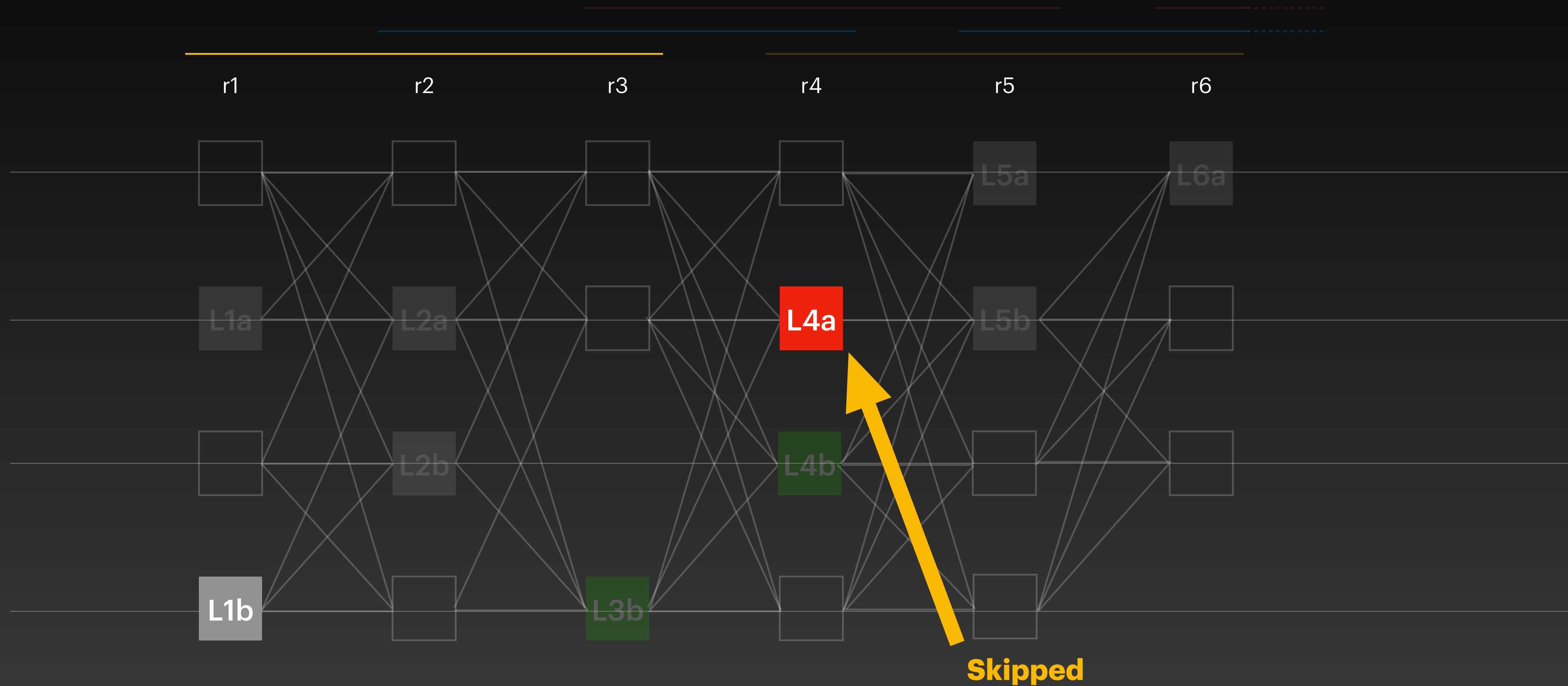
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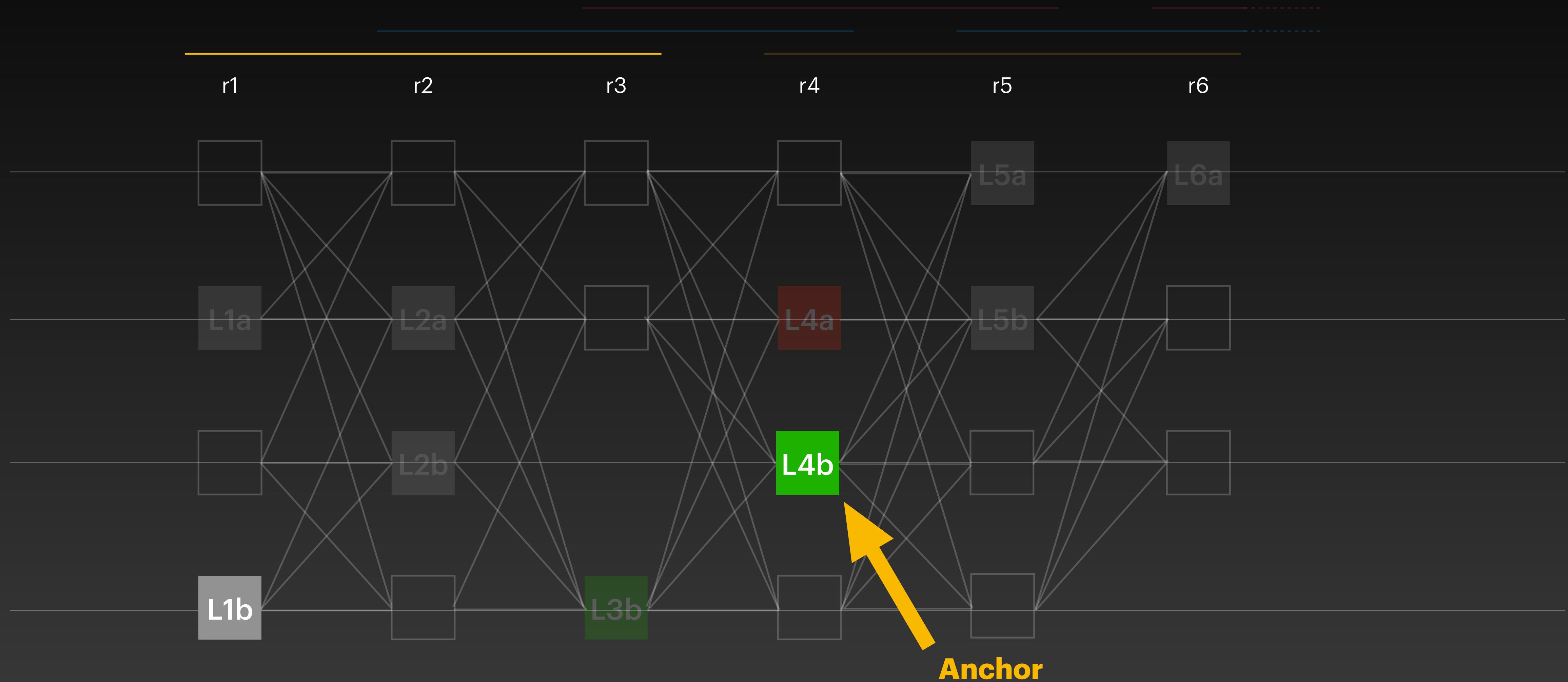
Apply Direct Rule



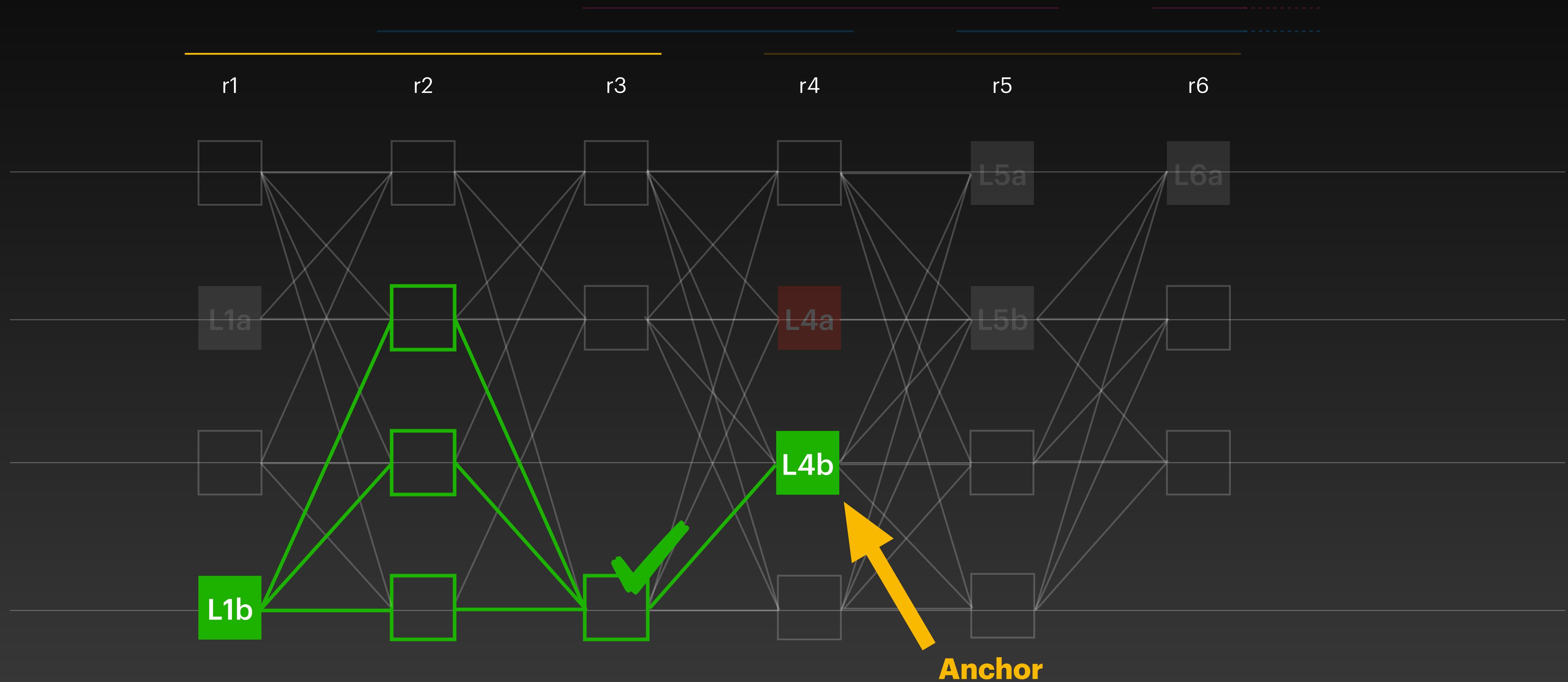
Apply Indirect Rule



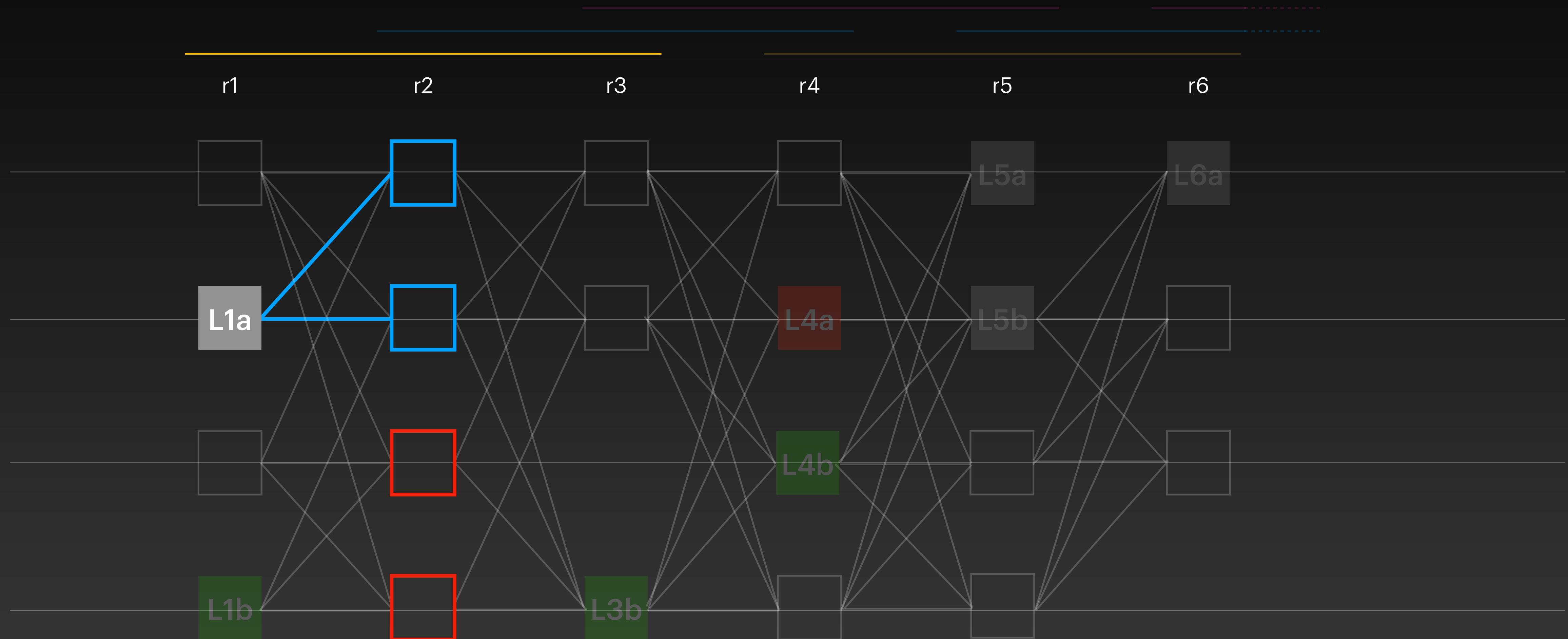
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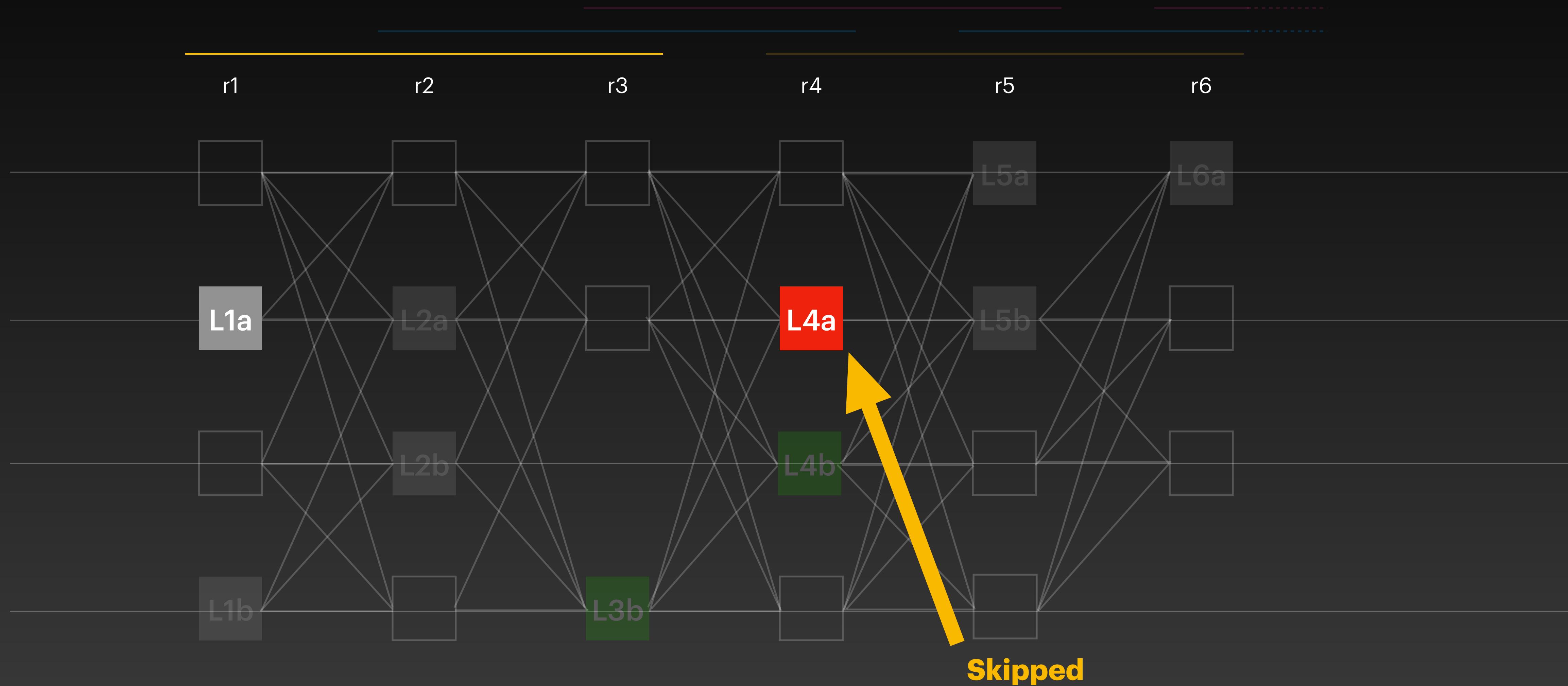
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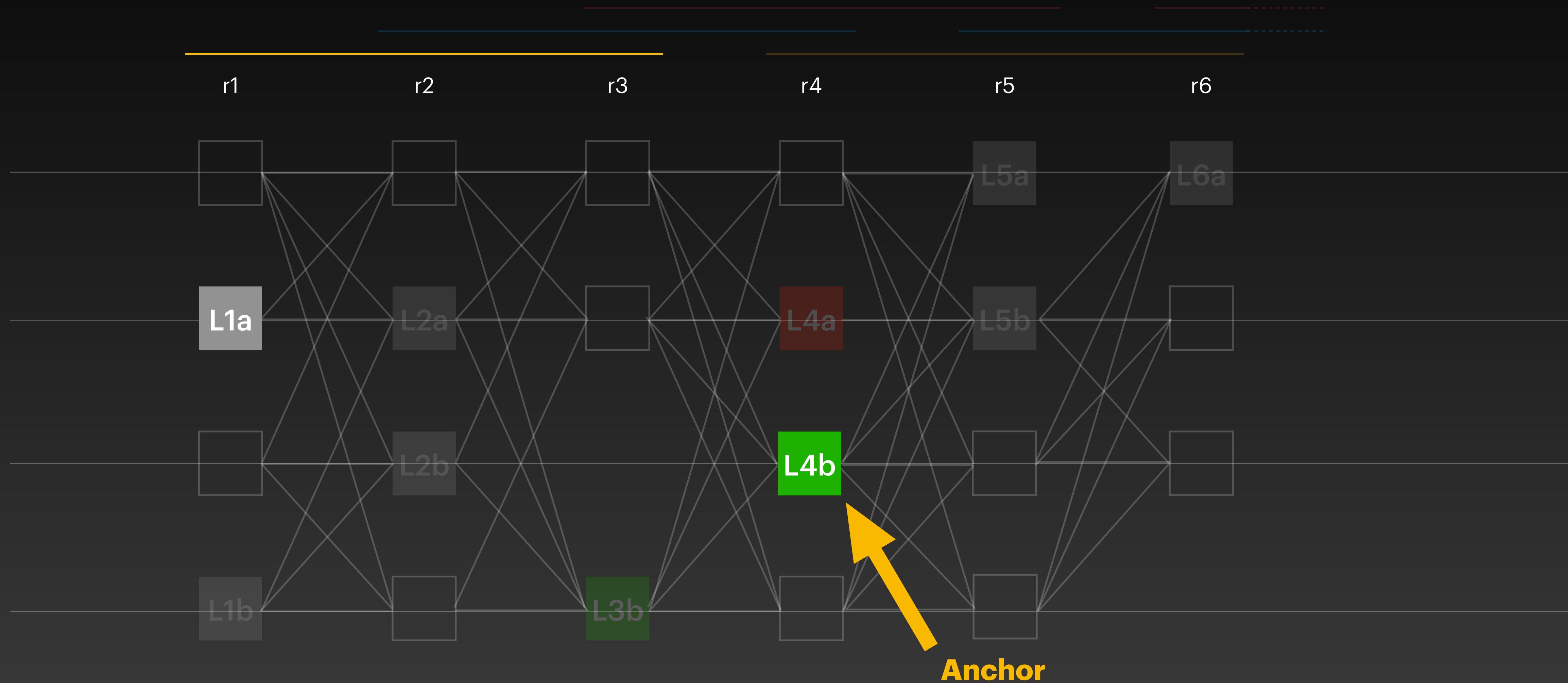
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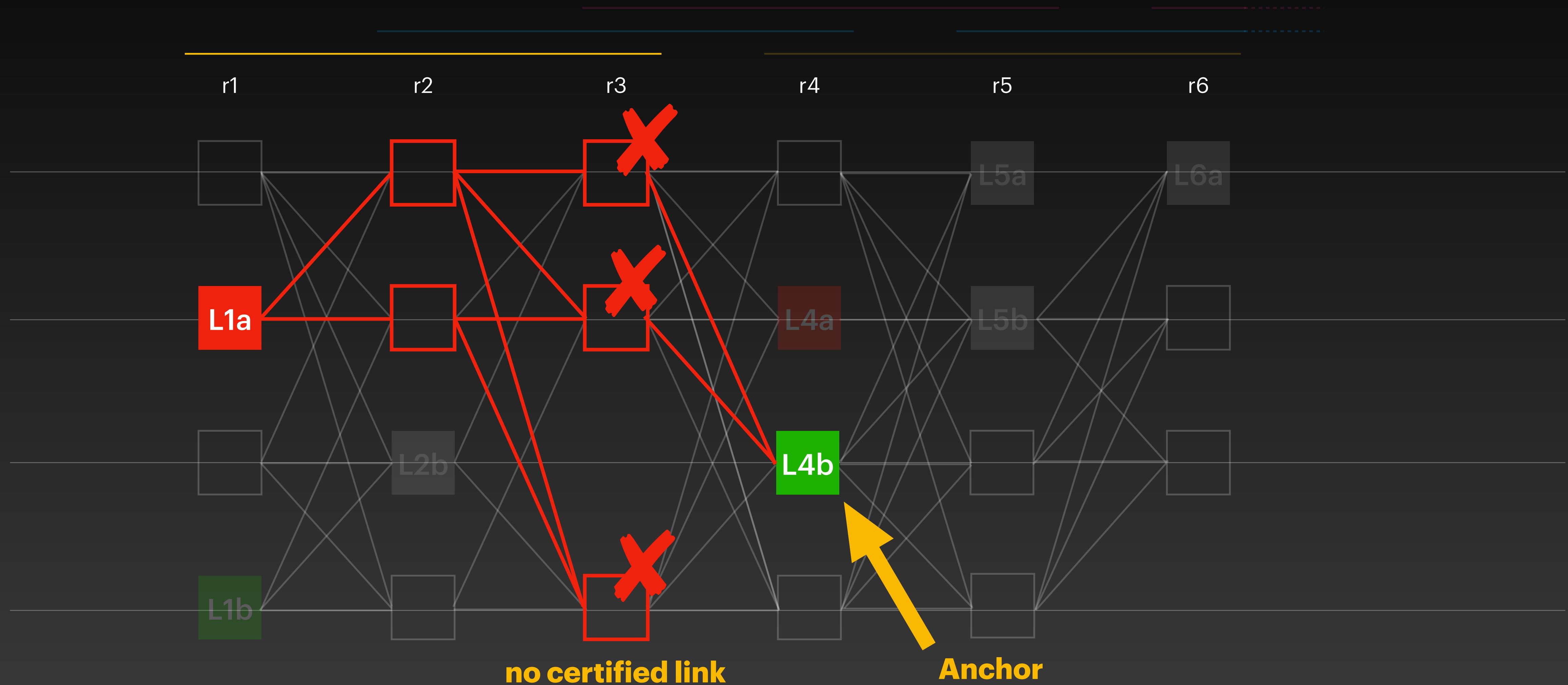
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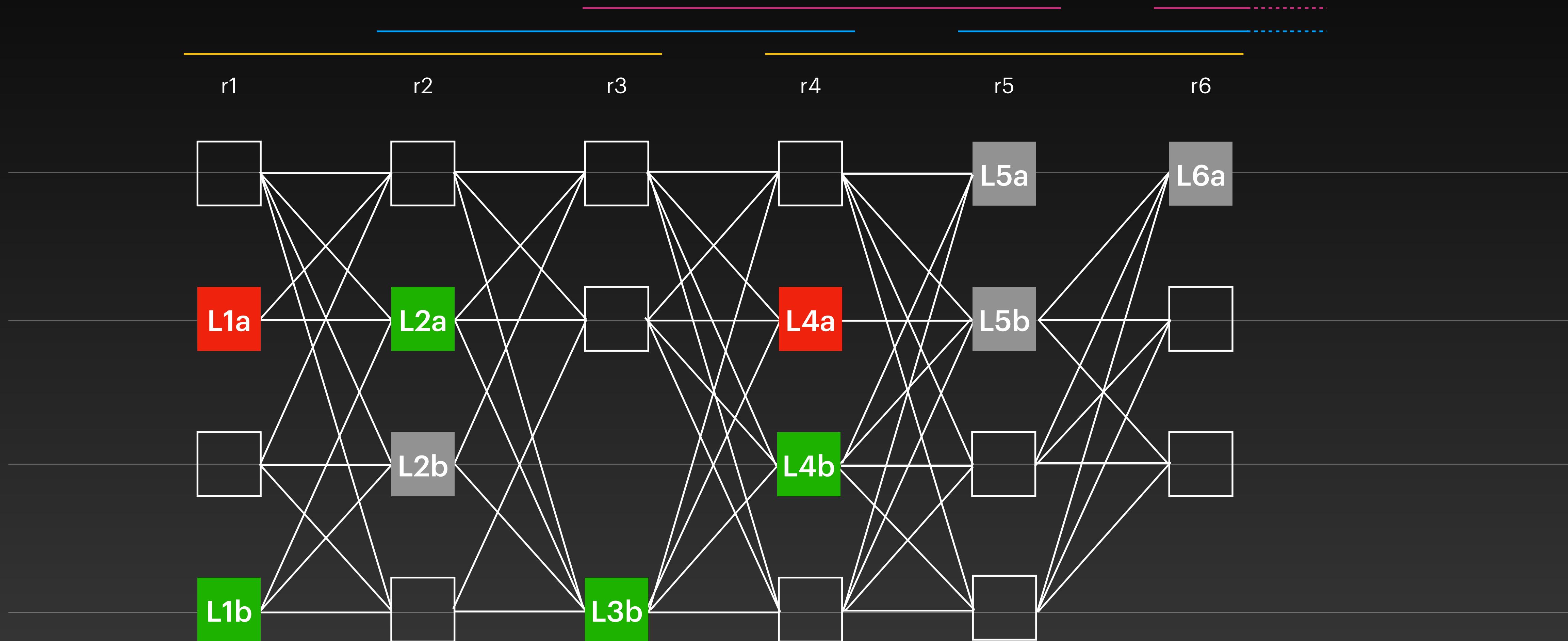
Apply Indirect Rule



Apply Indirect Rule

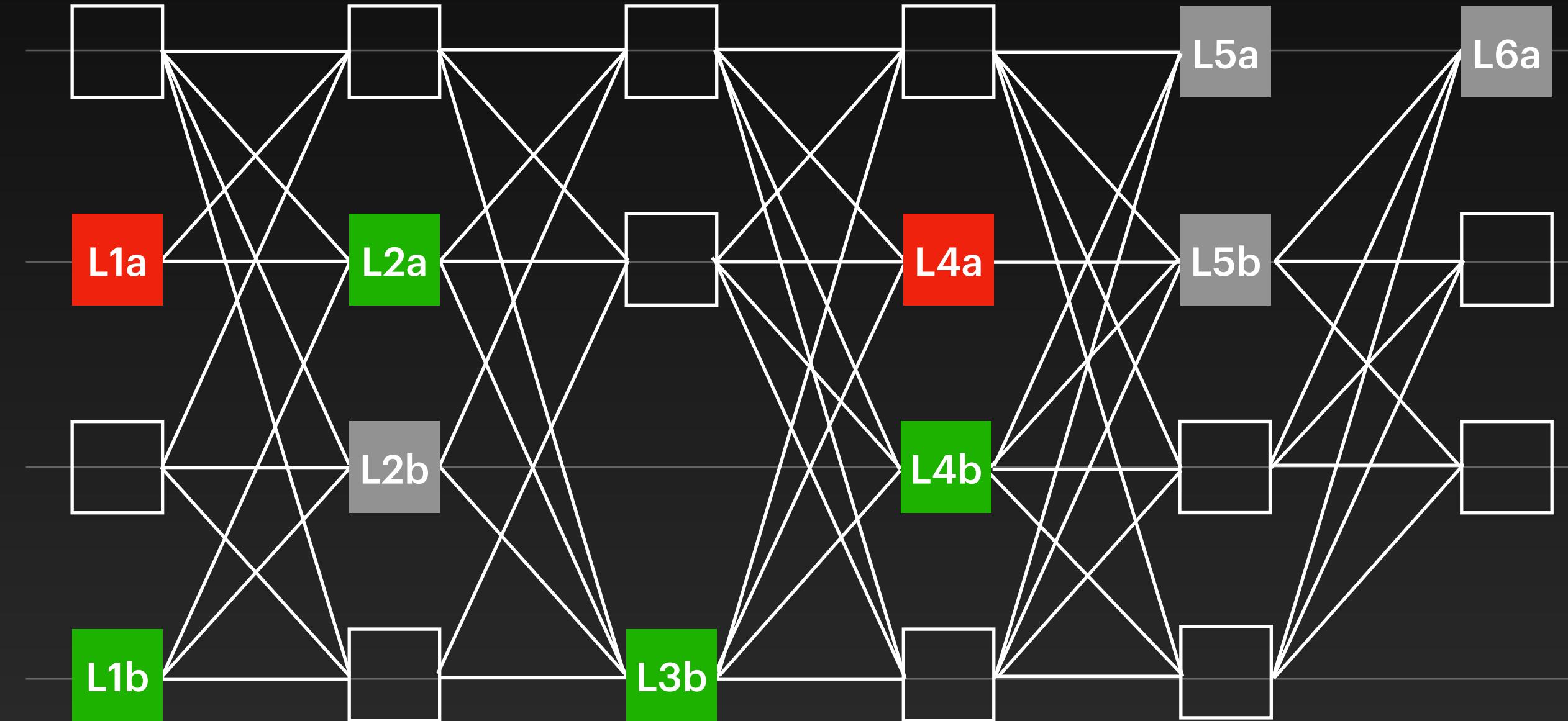


Current Status



Commit Sequence

Take all leaders in order

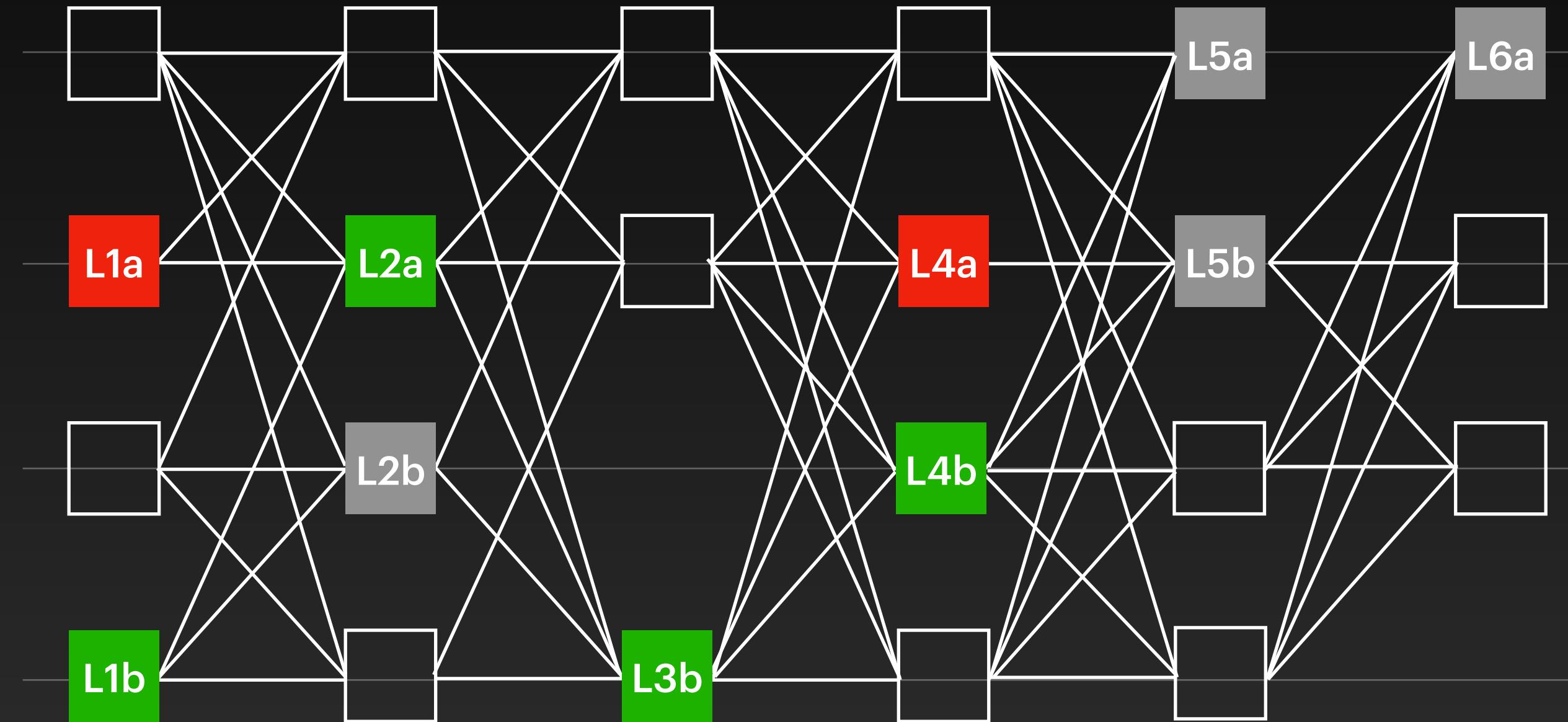


leaders sequence:

L1a L1b L2a L2b L3a L3b L4a L4b

Commit Sequence

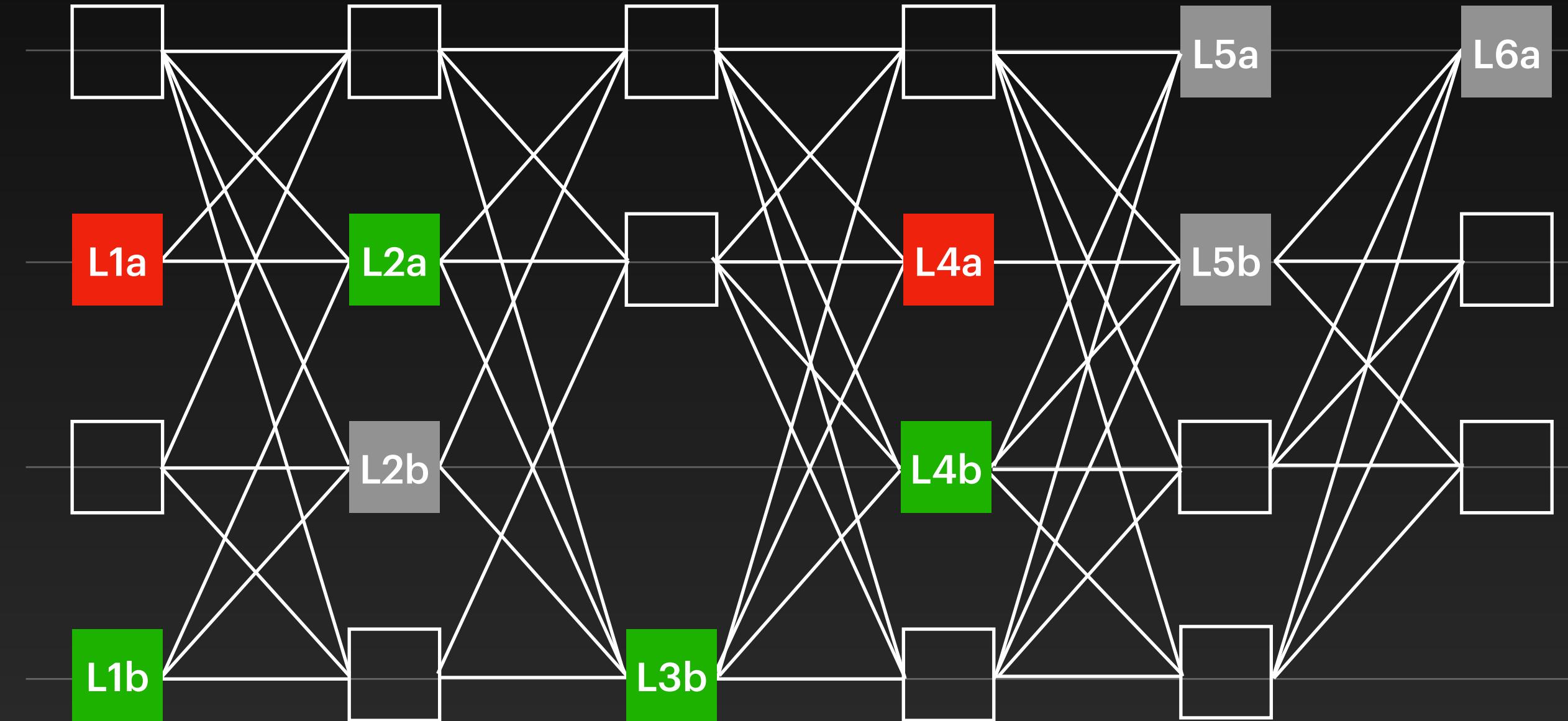
Stop at the first Undecided leader



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

Commit Sequence

Remove skipped leaders

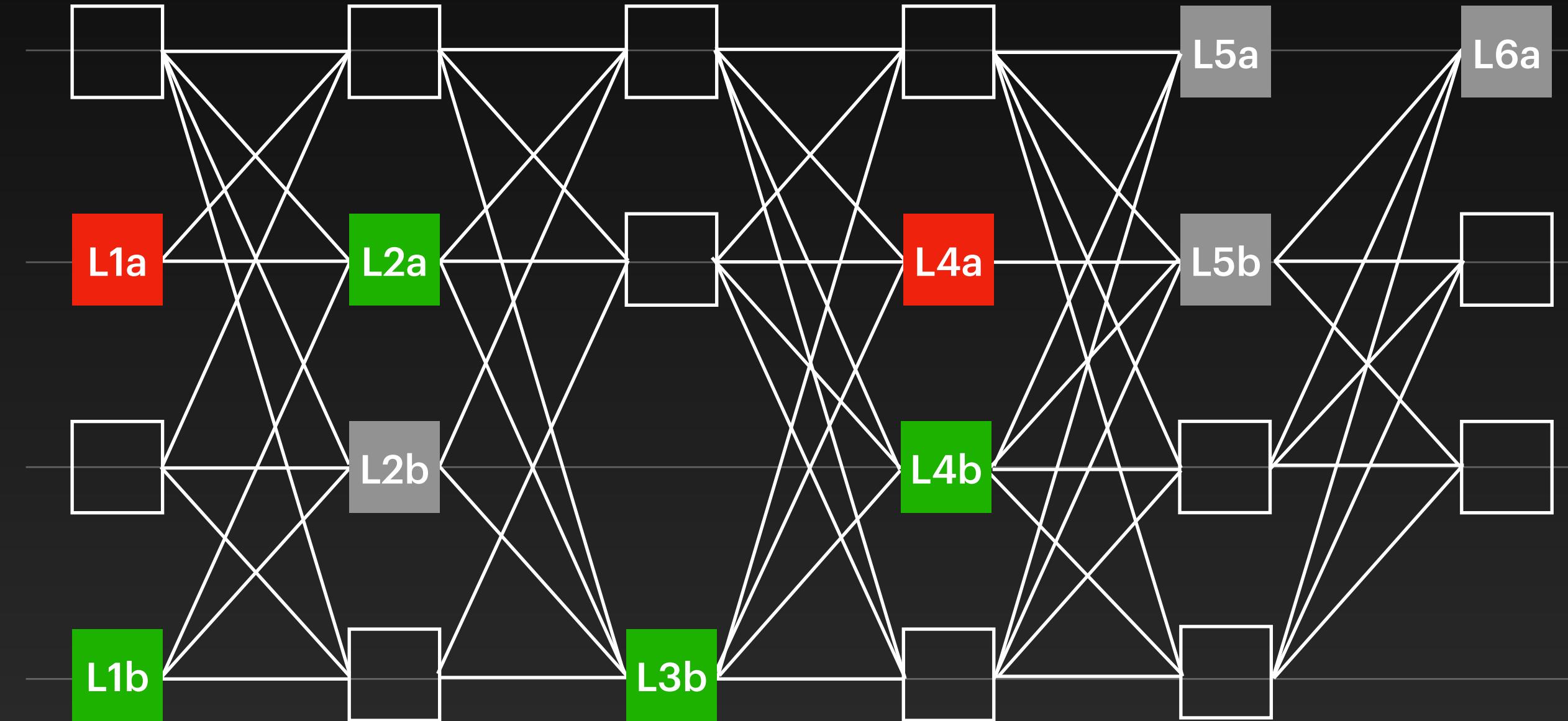


leaders sequence:

L1a L1b L2a L2b L3a L3b L4a L4b

Commit Sequence

Final leader sequence

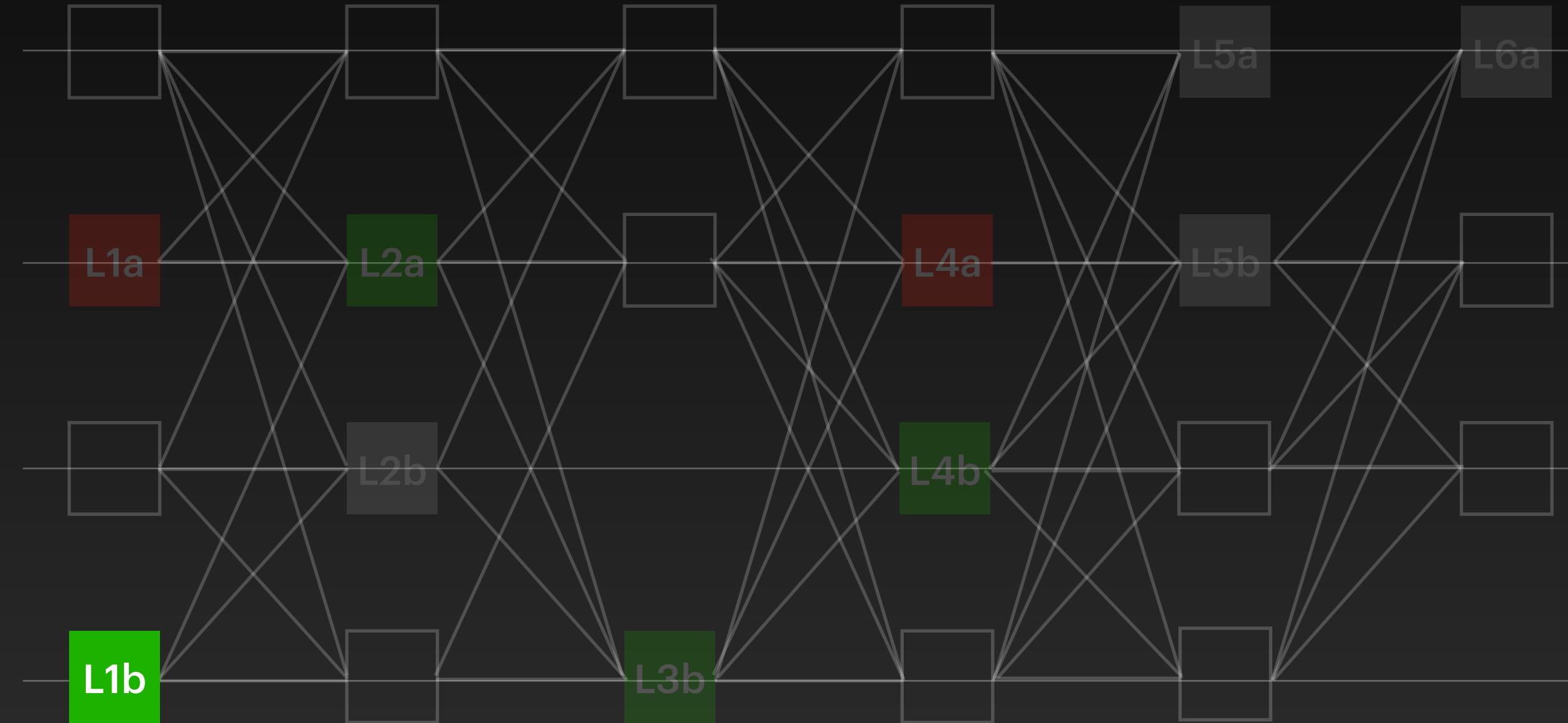


leaders sequence:

L1b L2a

Commit Sequence

Commit sub-dag



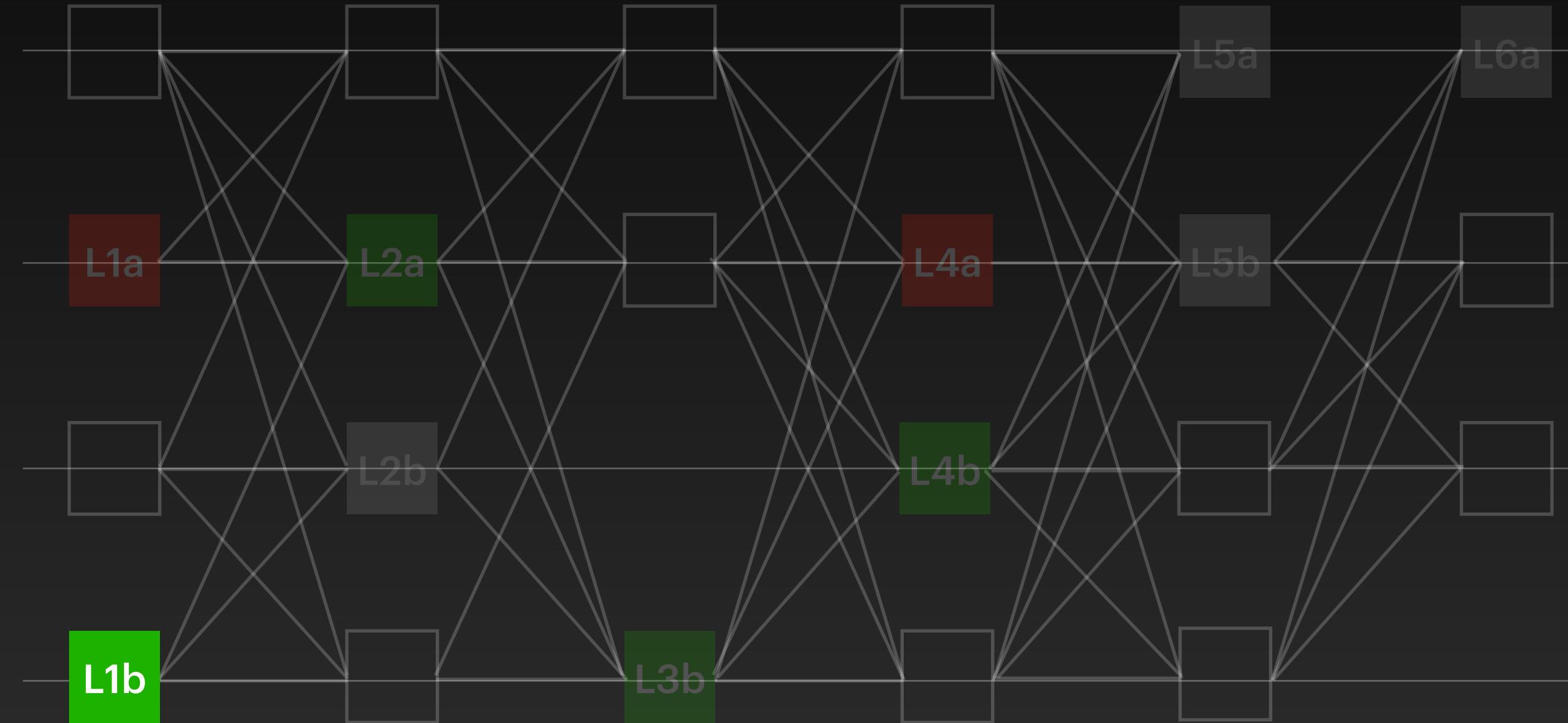
leaders sequence:



output sequence:

Commit Sequence

Commit sub-dag



leaders sequence:

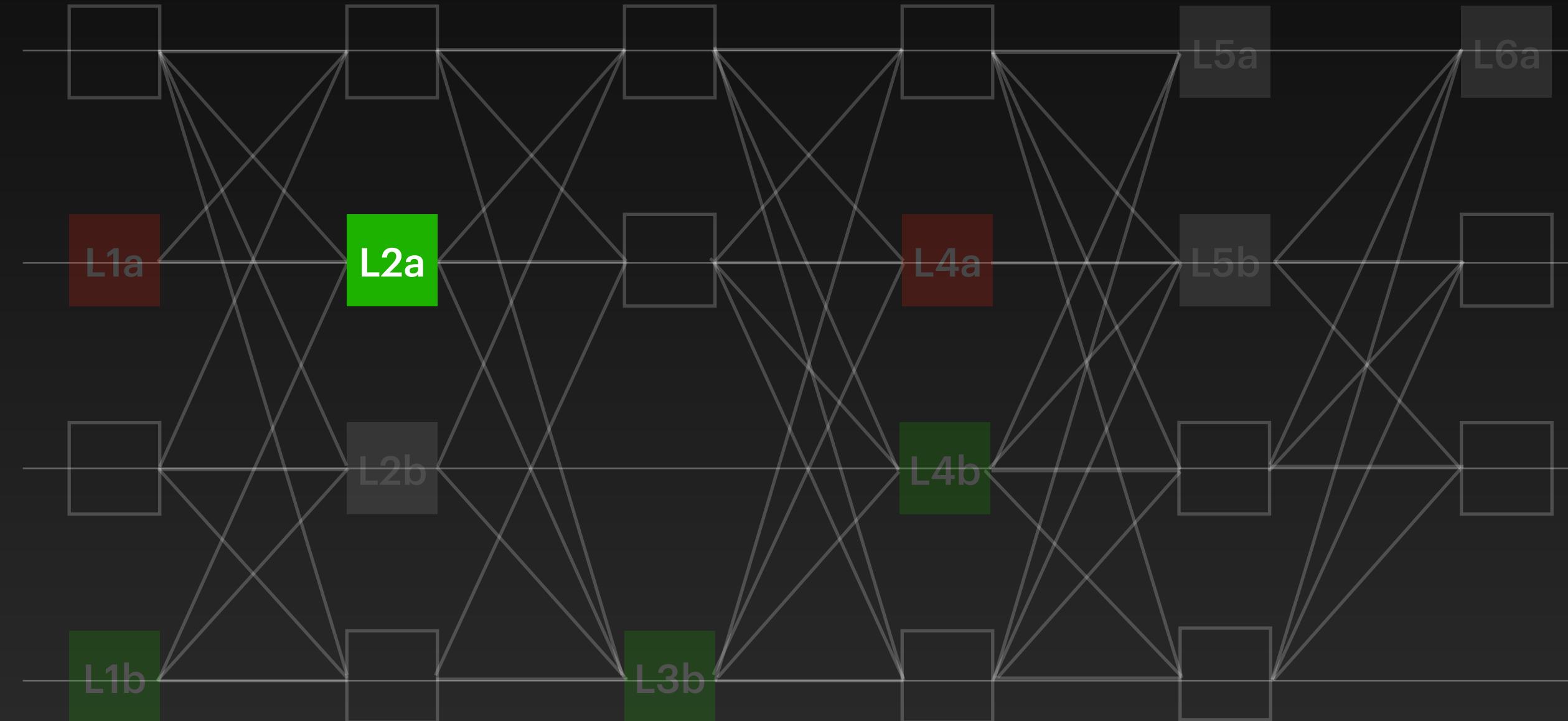
L2a

output sequence:

L1b

Commit Sequence

Commit sub-dag



leaders sequence:

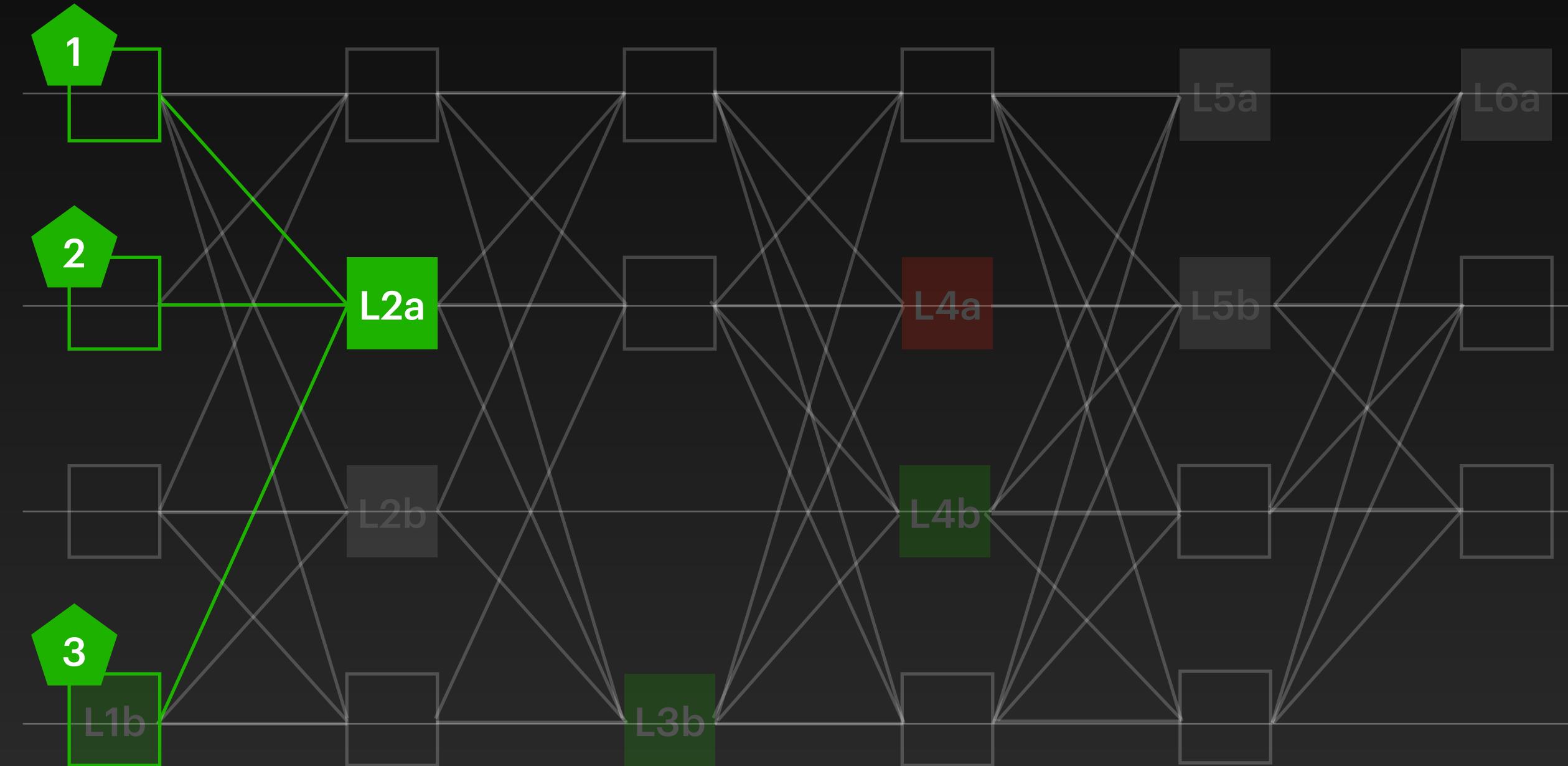
L2a

output sequence:

L1b

Commit Sequence

Commit sub-dag



leaders sequence:

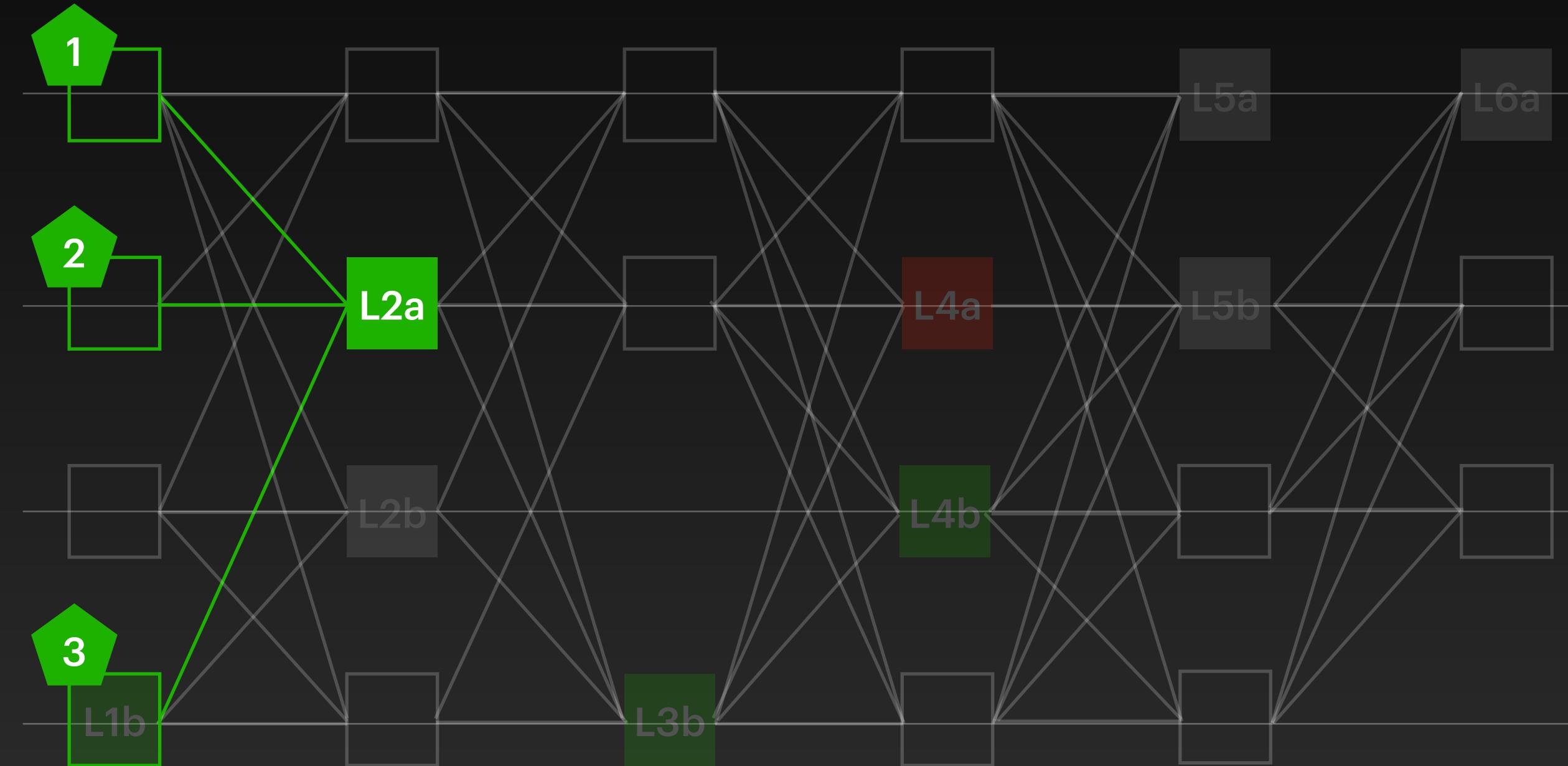
L2a

output sequence:

L1b

Commit Sequence

Commit sub-dag



leaders sequence:

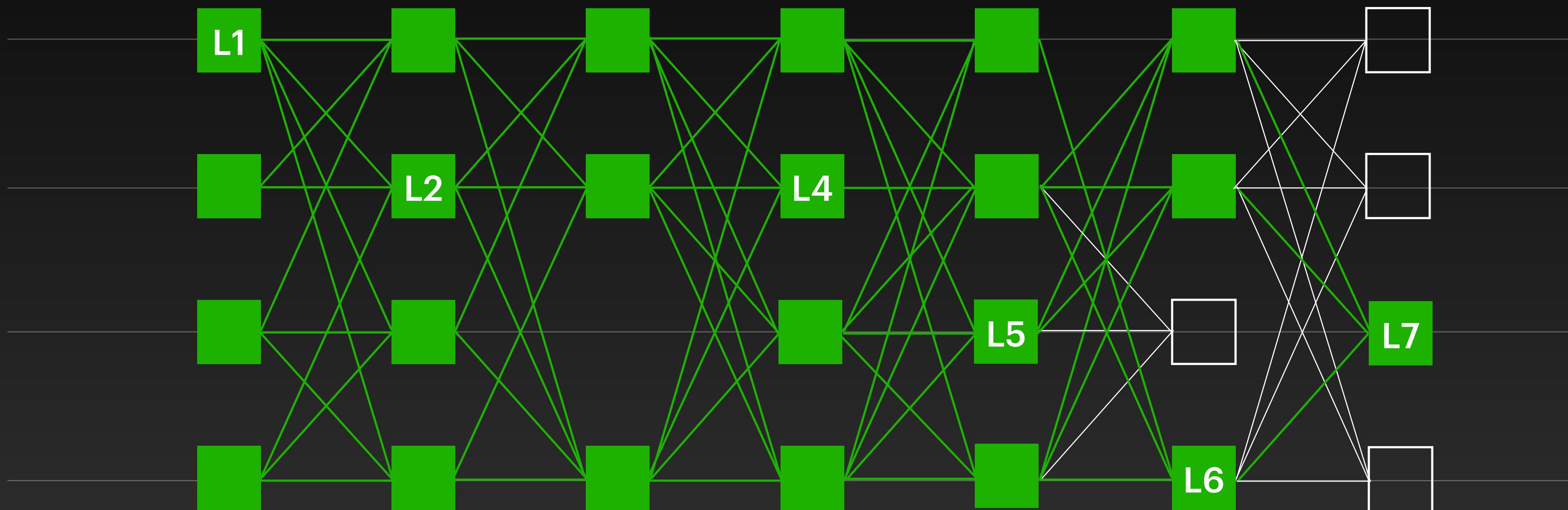
output sequence:



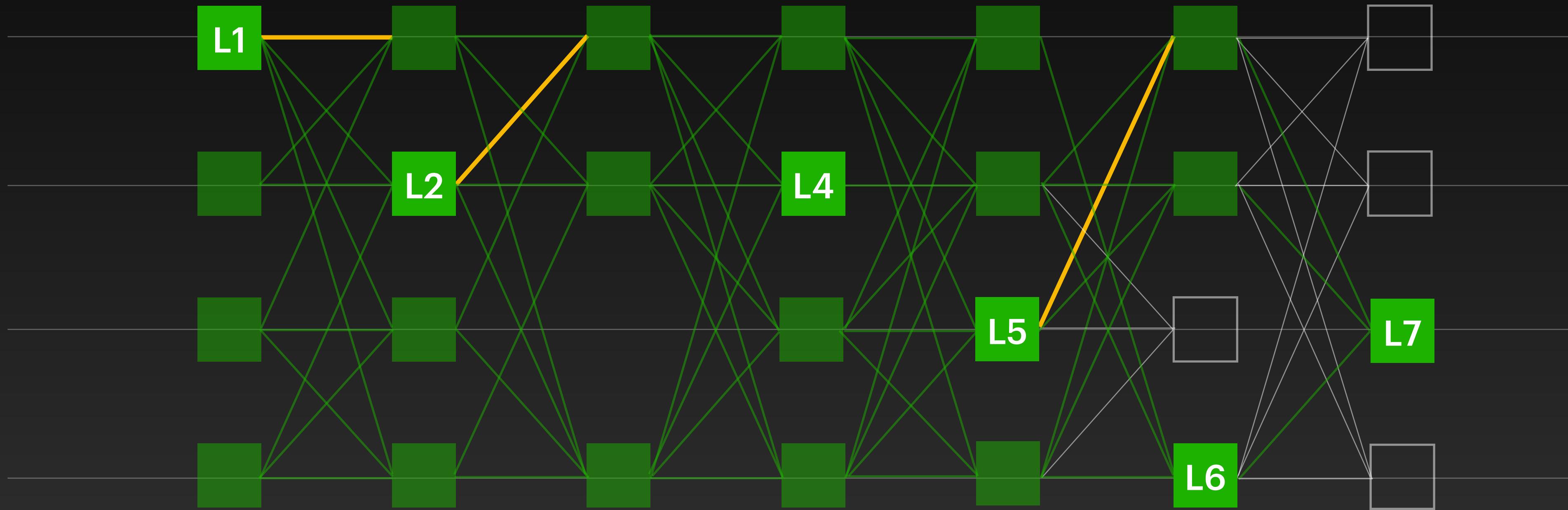
HammerHead

Mitigating slow leaders

Past Commits

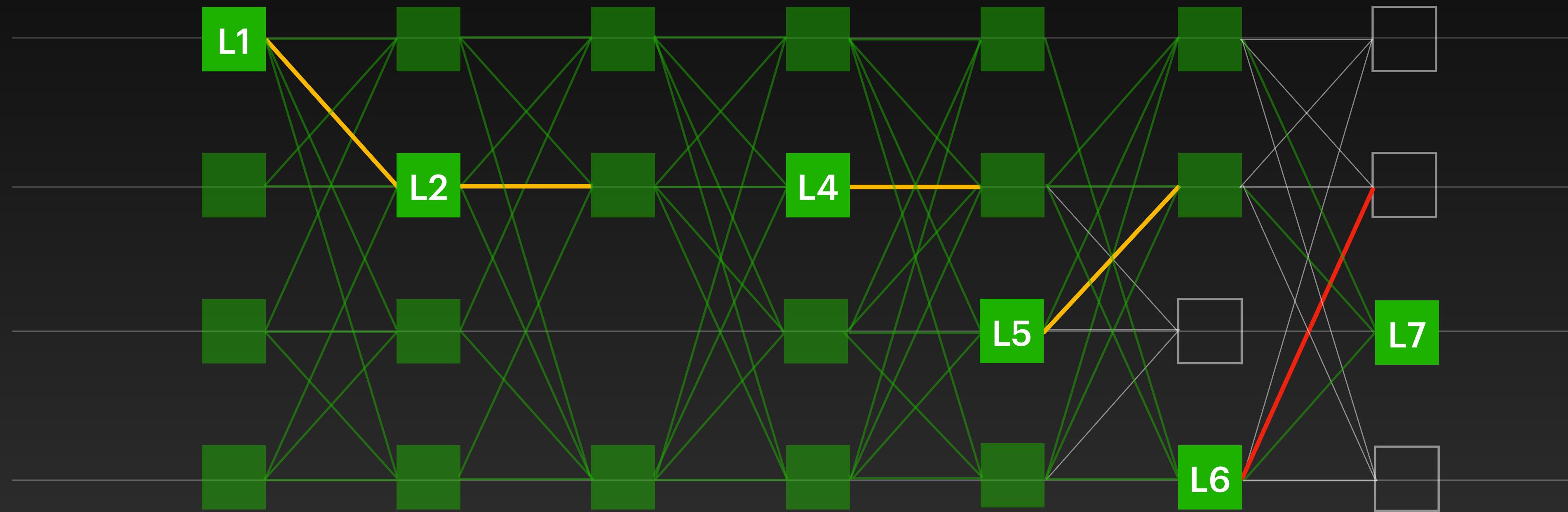


Compute Reputation Scores



node 1: 3

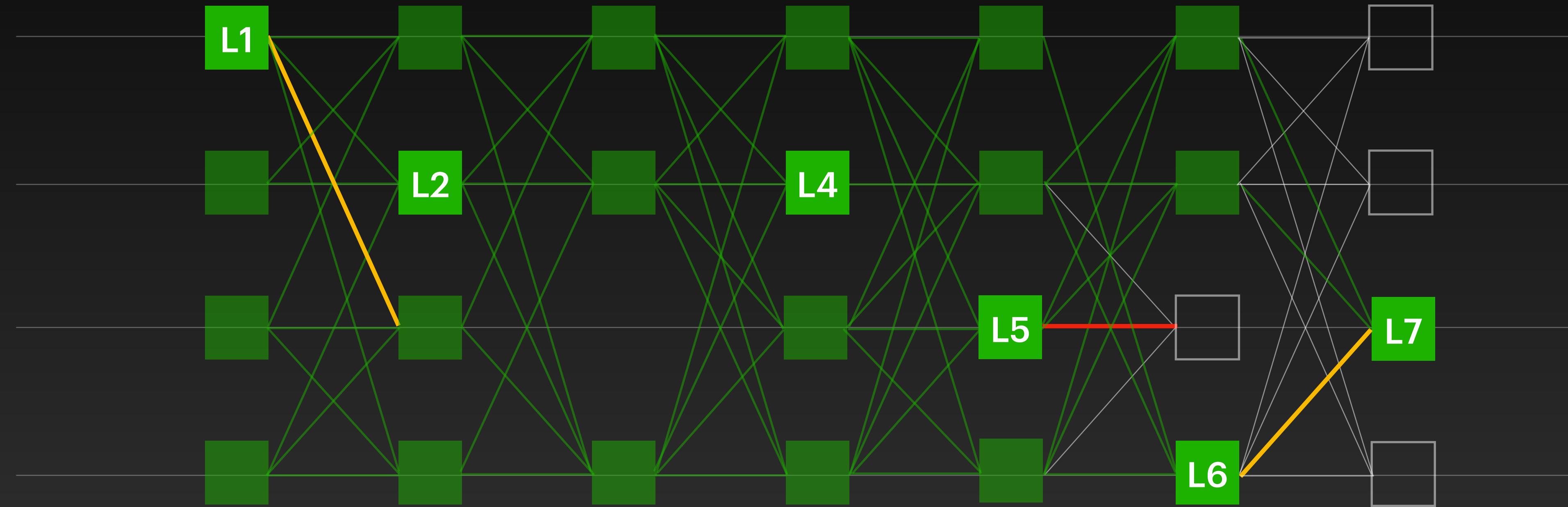
Compute Reputation Scores



node 1: 3

node 2: 4

Compute Reputation Scores

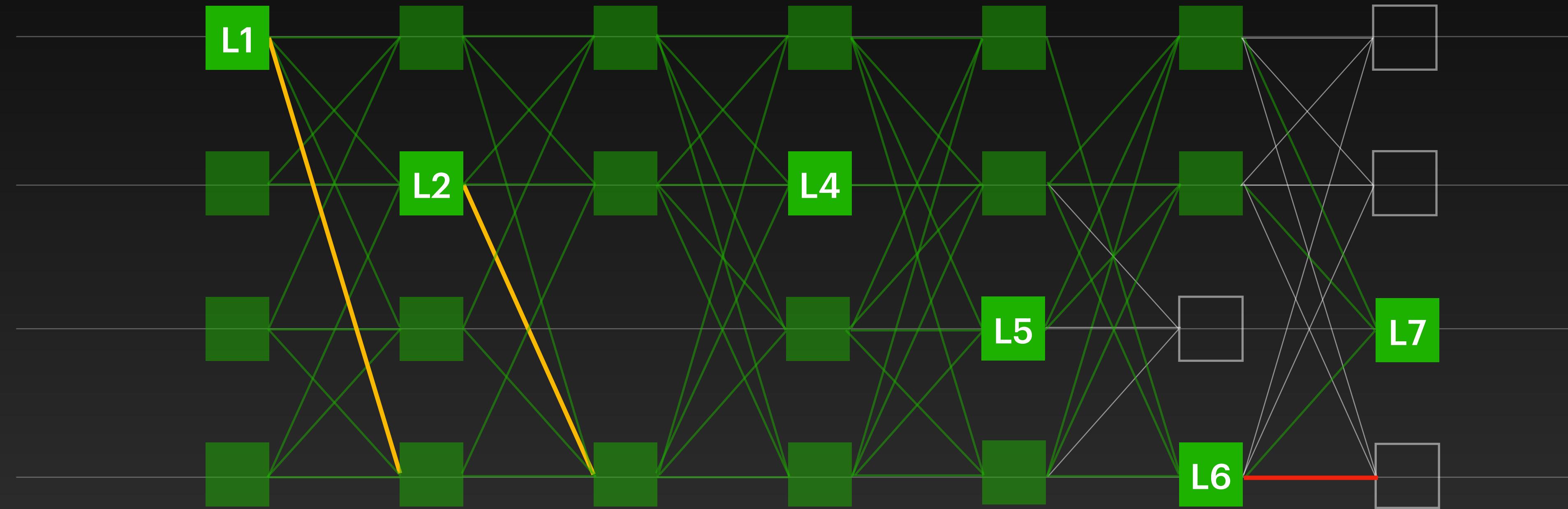


node 1: 3

node 2: 4

node 3: 2

Compute Reputation Scores



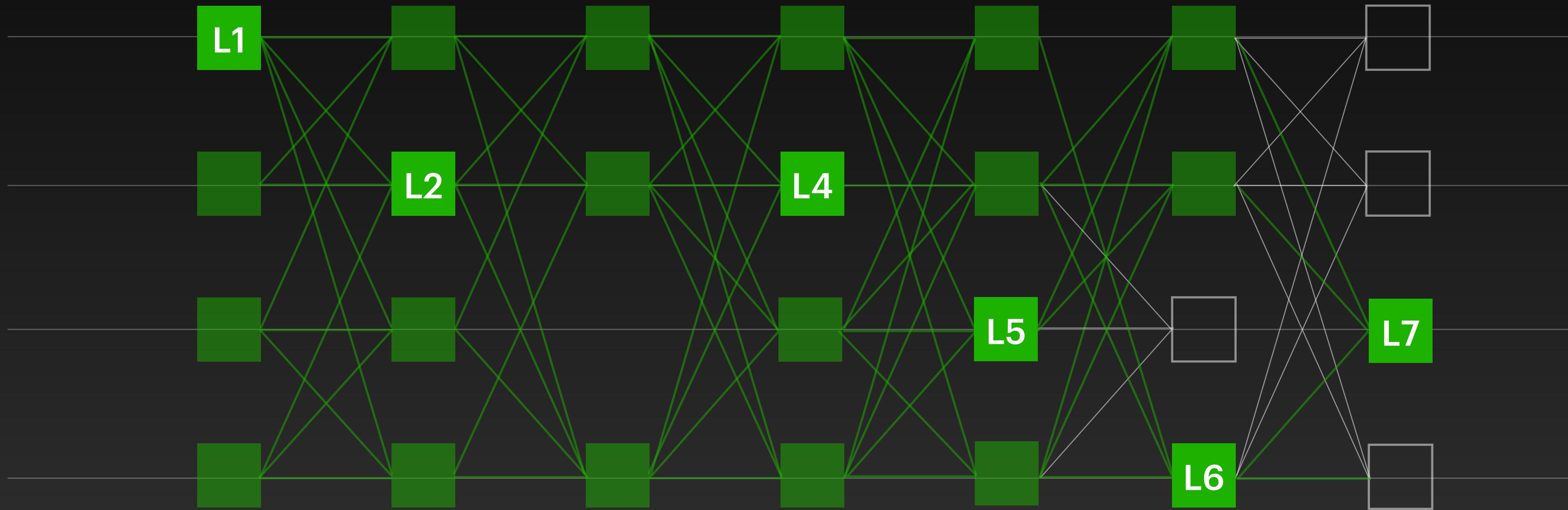
node 1: 3

node 2: 4

node 3: 2

node 4: 2

Future Leaders



node 1: 3

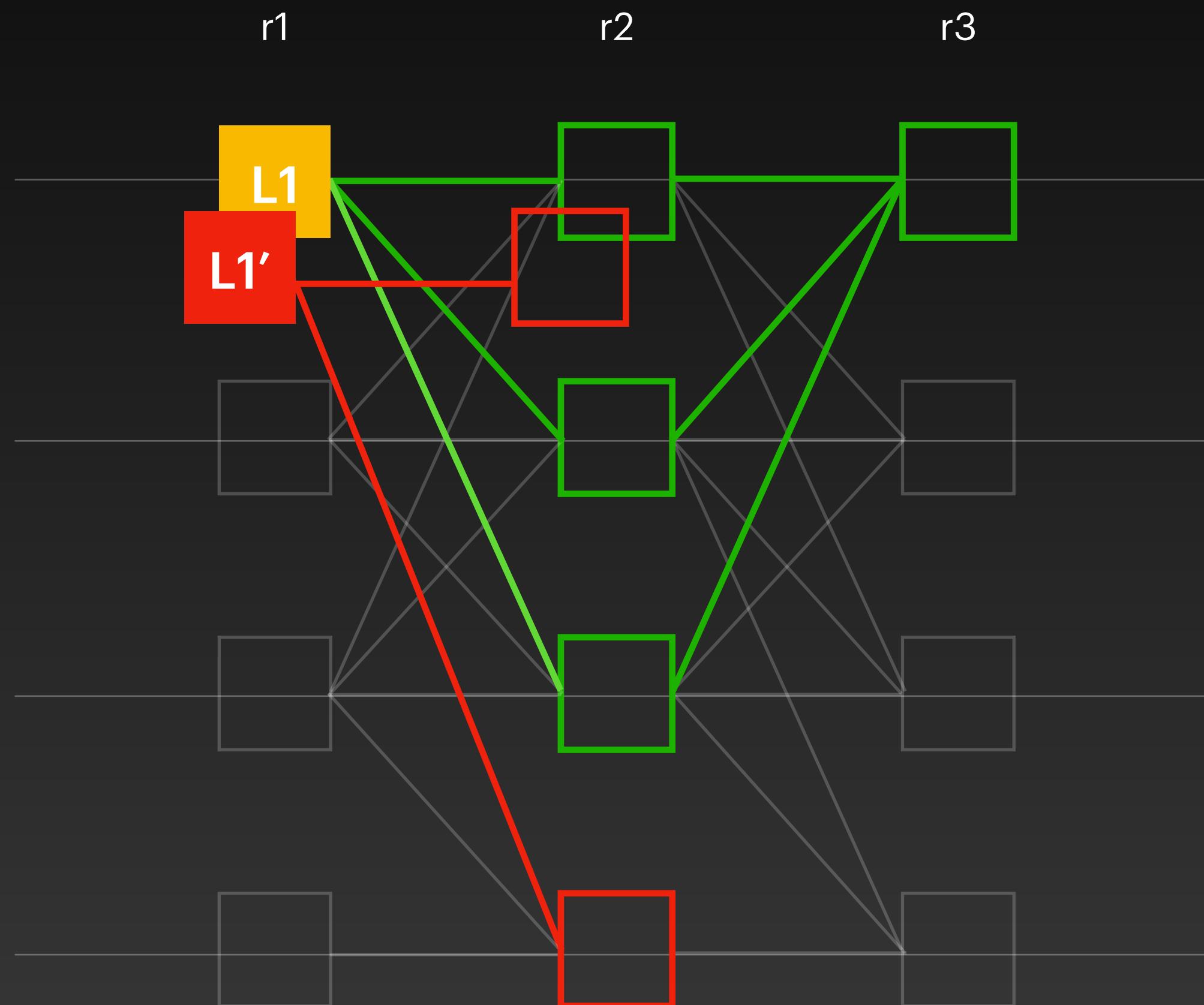
node 2: 4

node 3: 2

node 4: 2

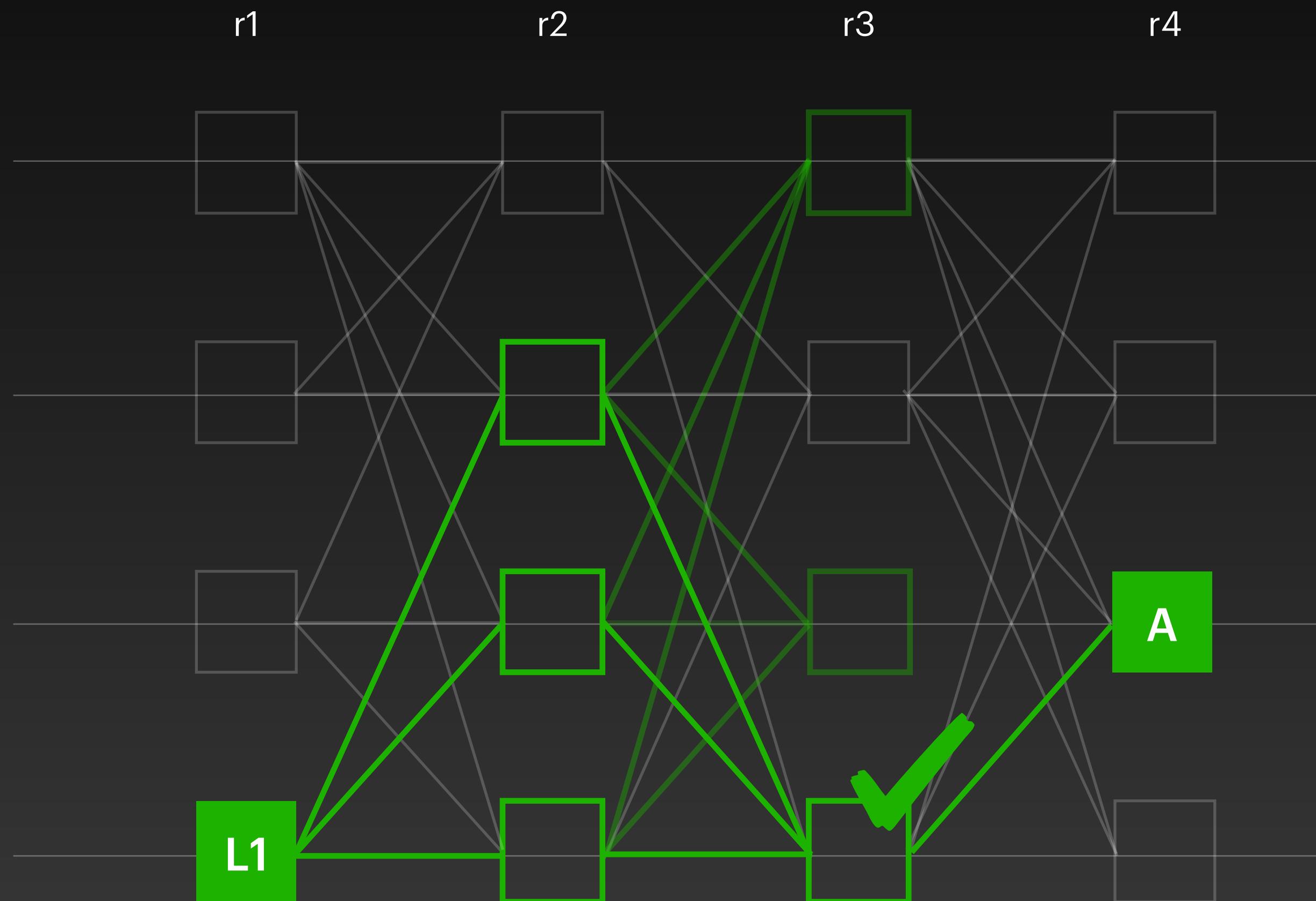
Security Intuition

Security Intuition



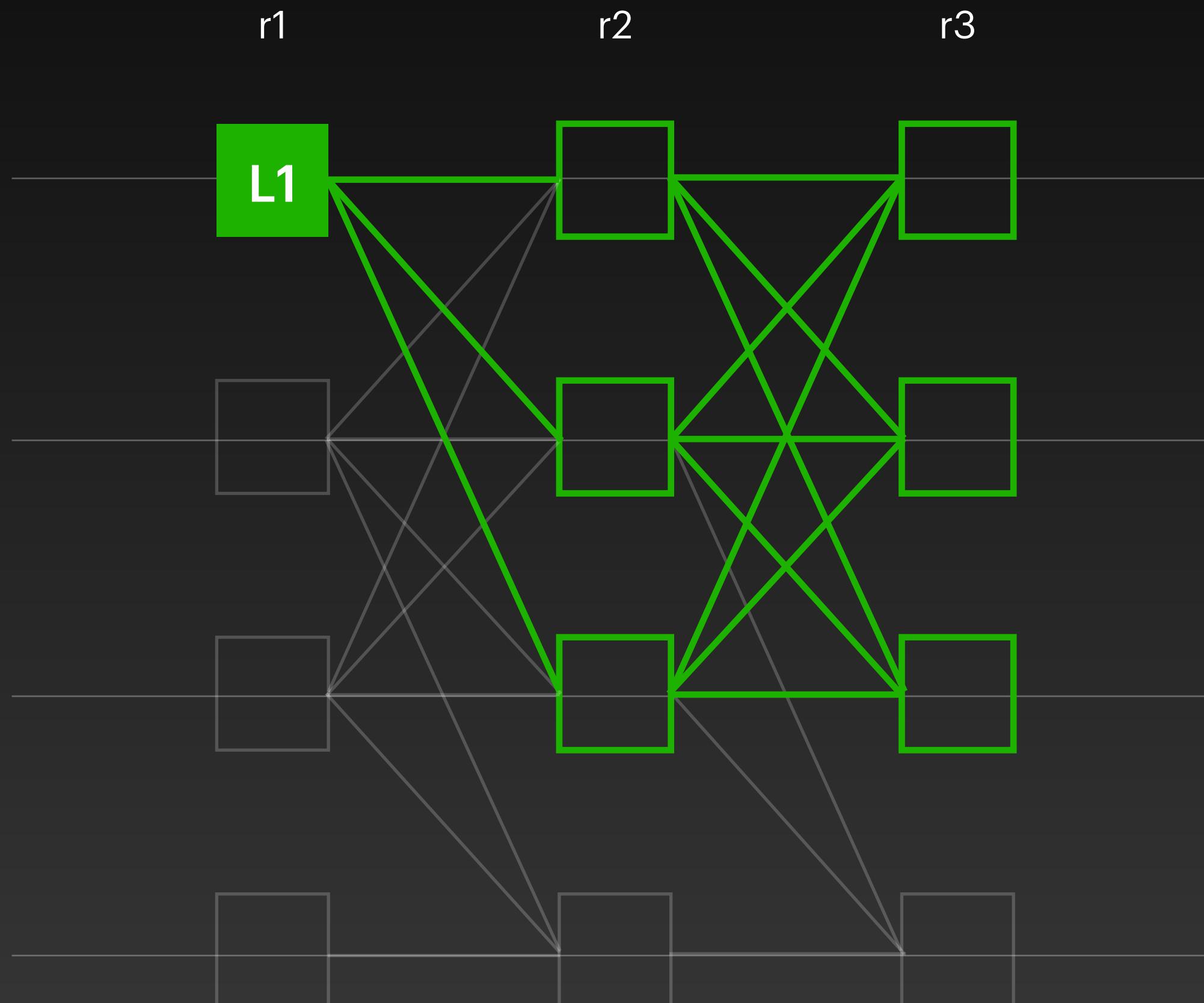
- At most **L1** or **L1'** can have a certificate pattern (quorum intersection)

Security Intuition



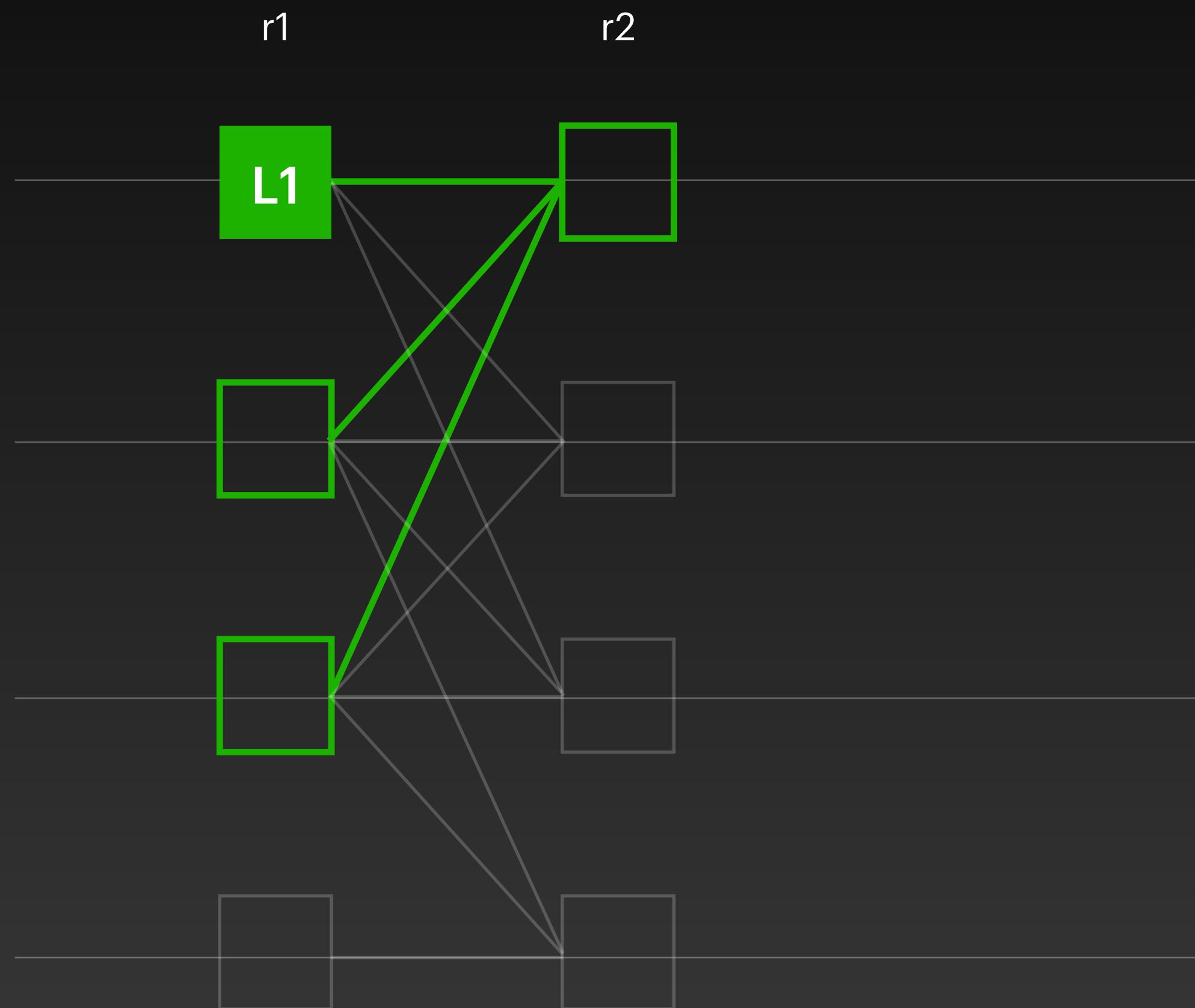
- At most **L1** or **L1'** can have a certificate pattern (quorum intersection)
- If **L1** has $2f+1$ certificate patterns, **A** always has a certified link to **L1**

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

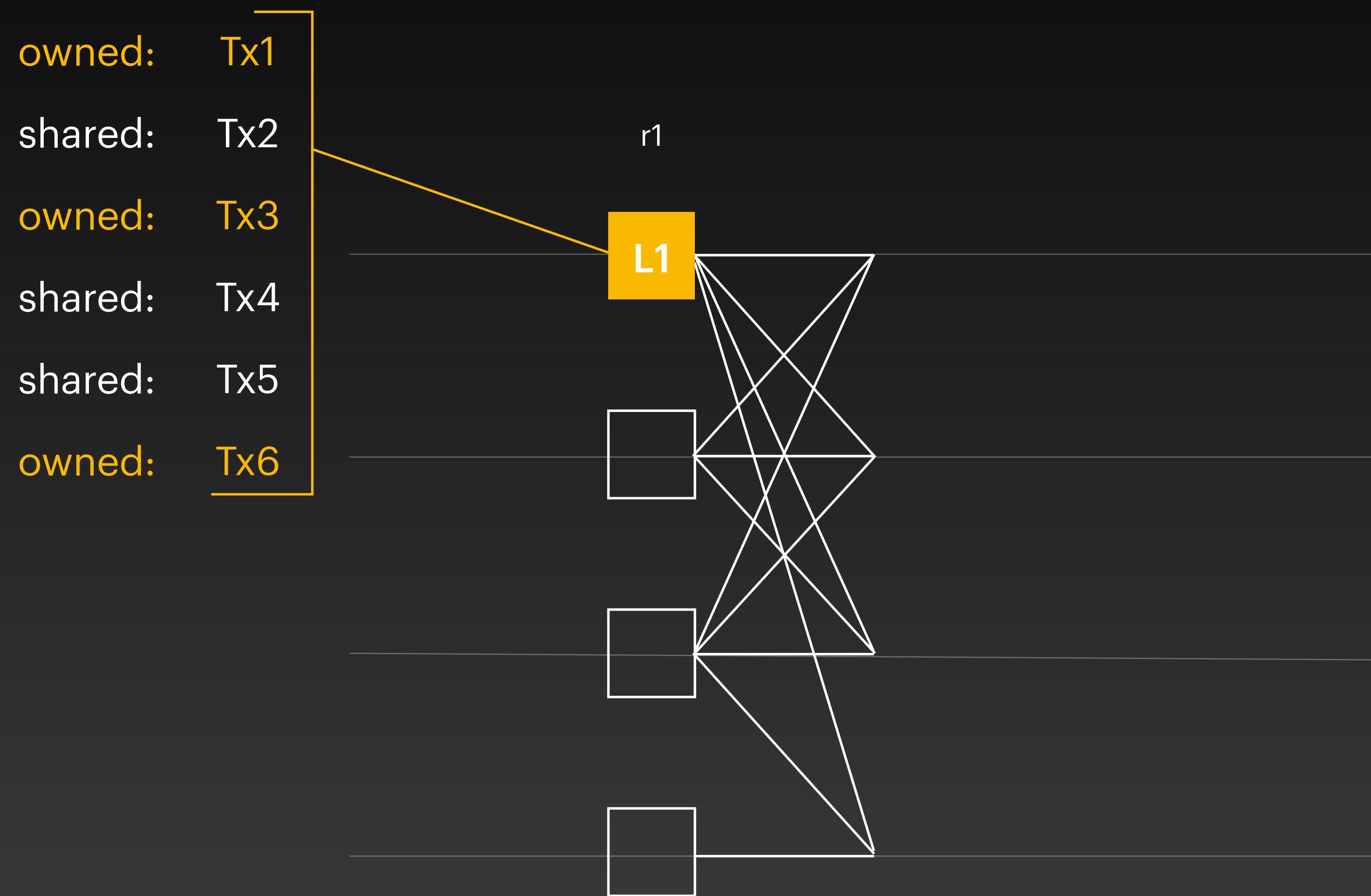
- Objects that can be mutated my multiple entities
- e.g., A global counter
- **Need consensus**

System State

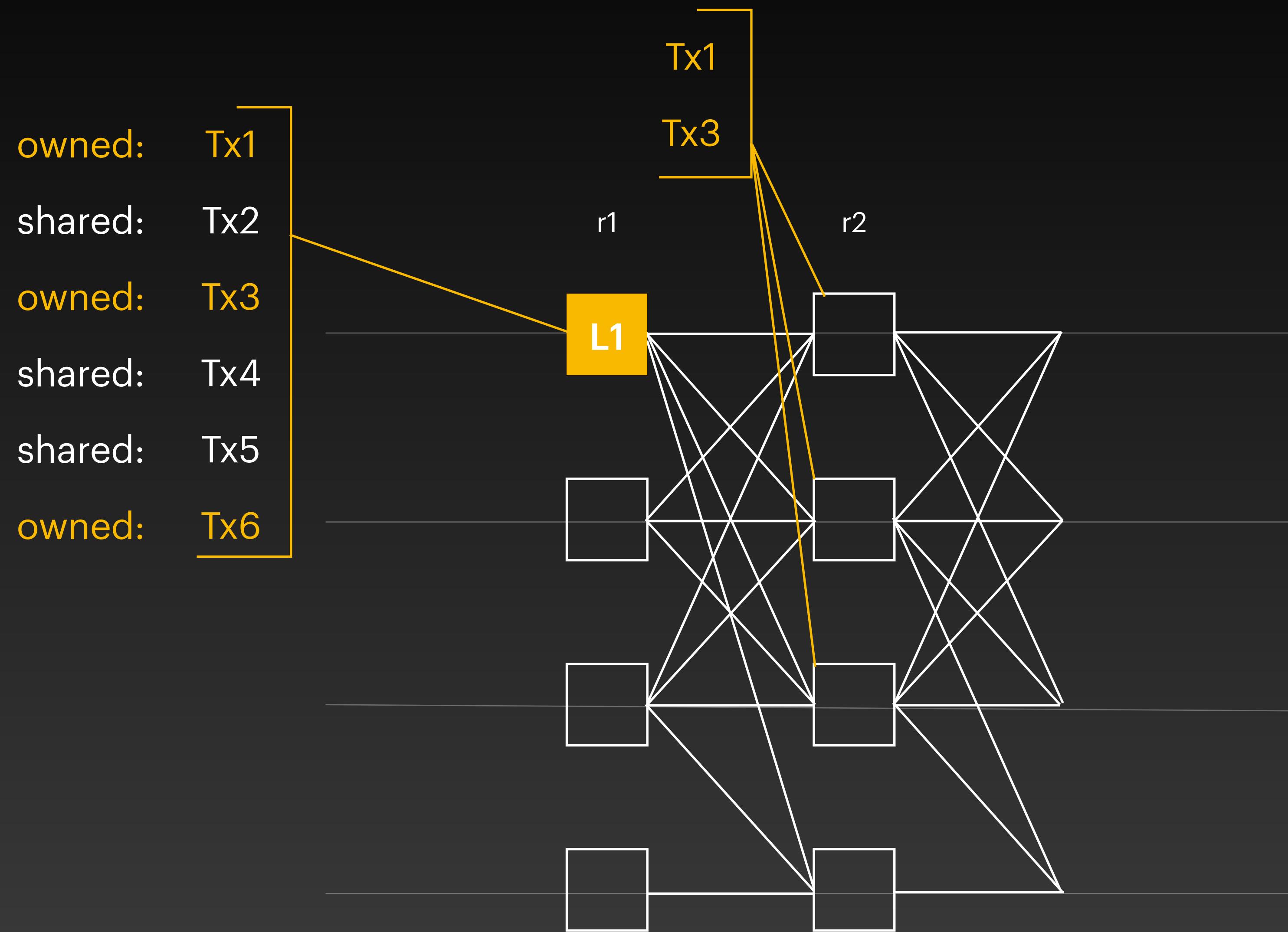
Objects:

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

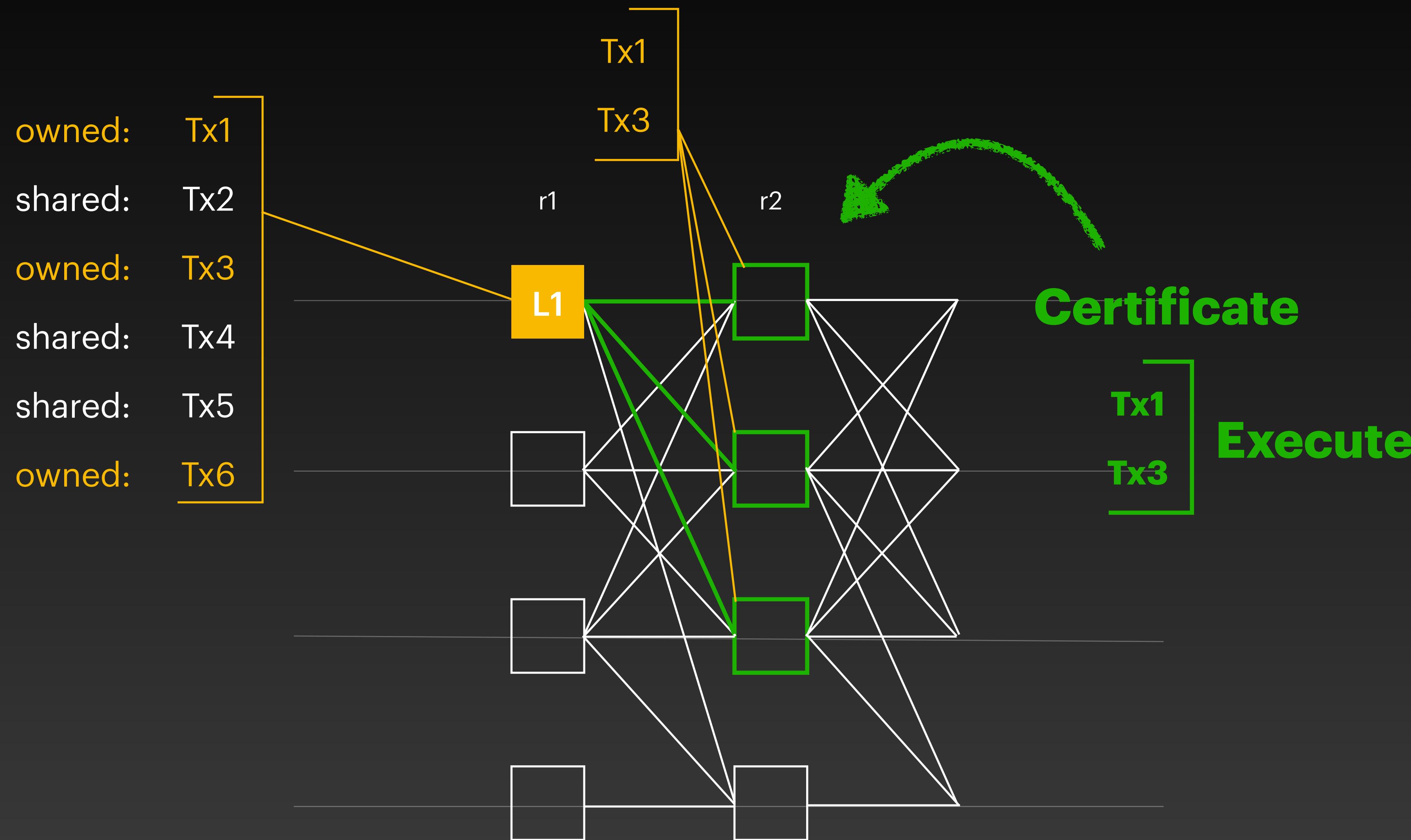
Fast Execution



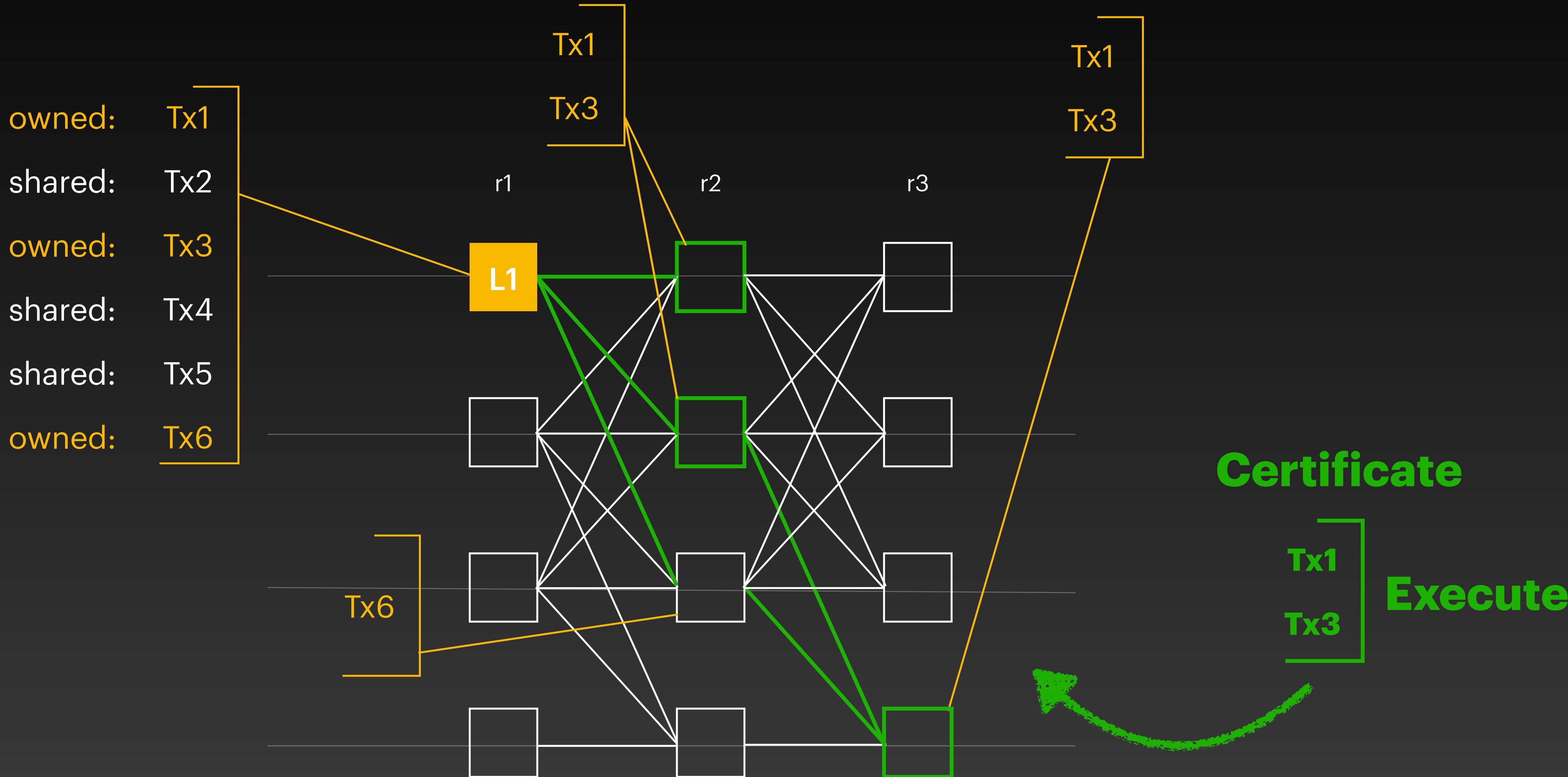
Fast Execution



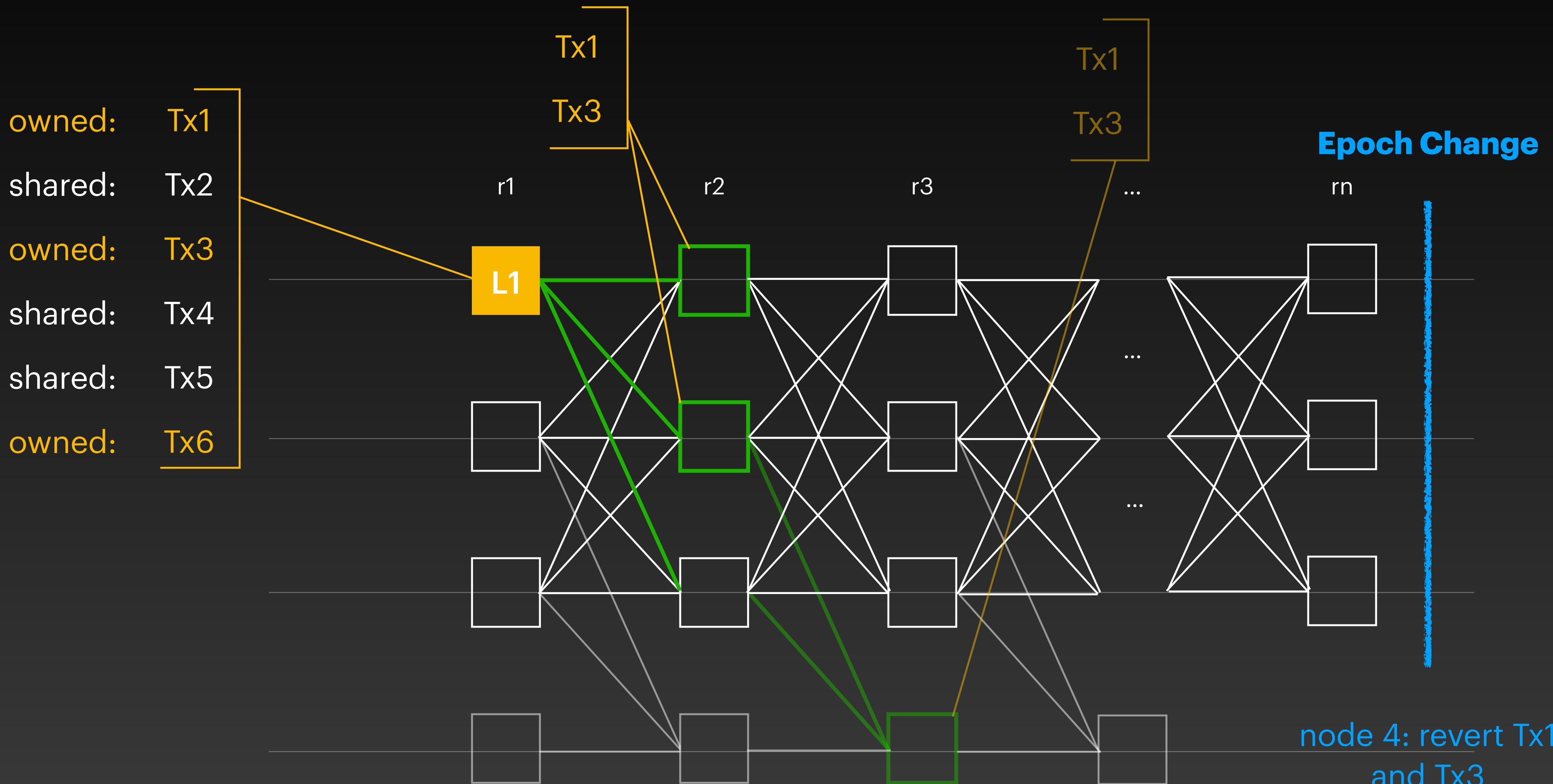
Fast Execution



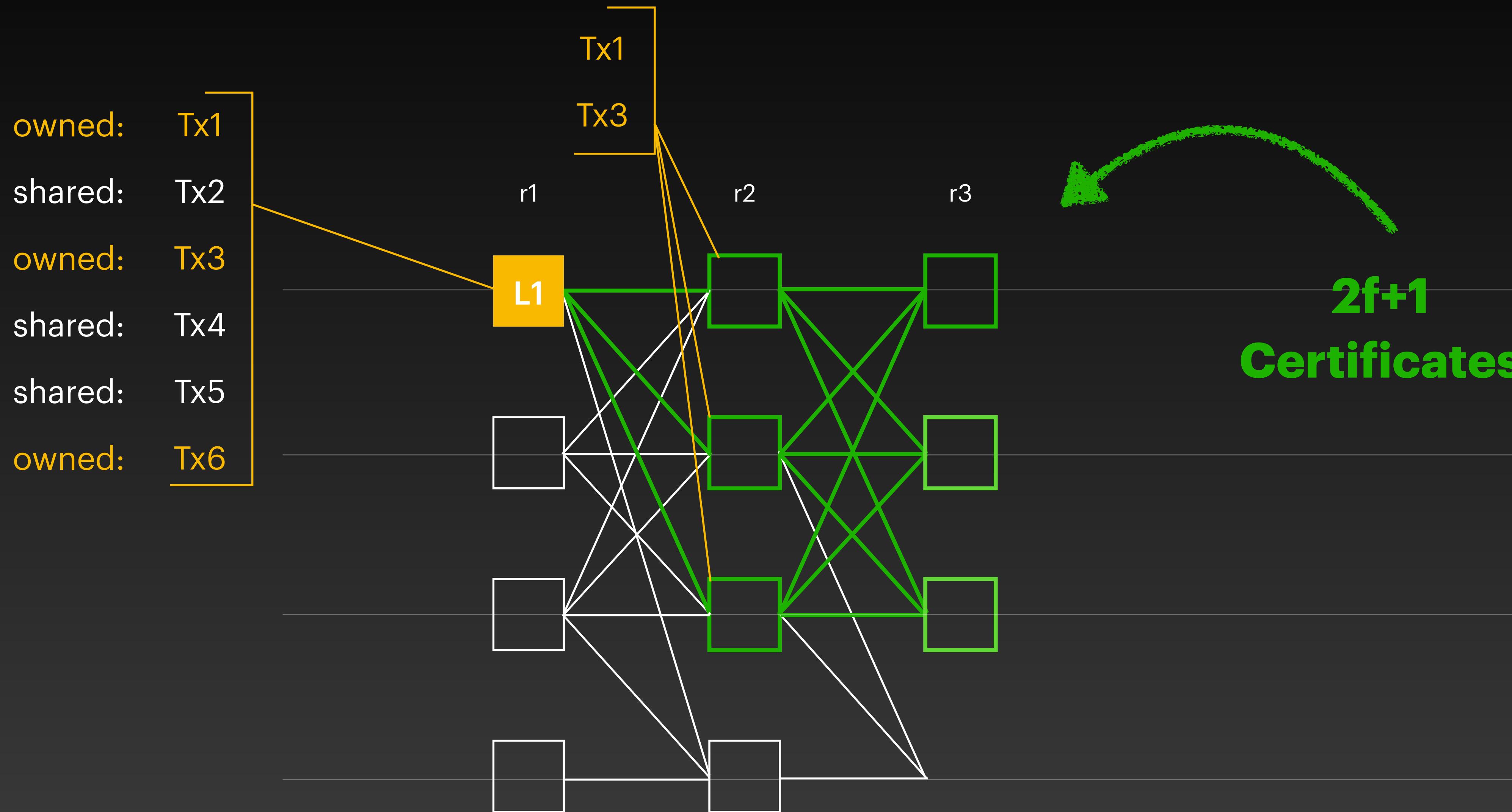
Fast Execution



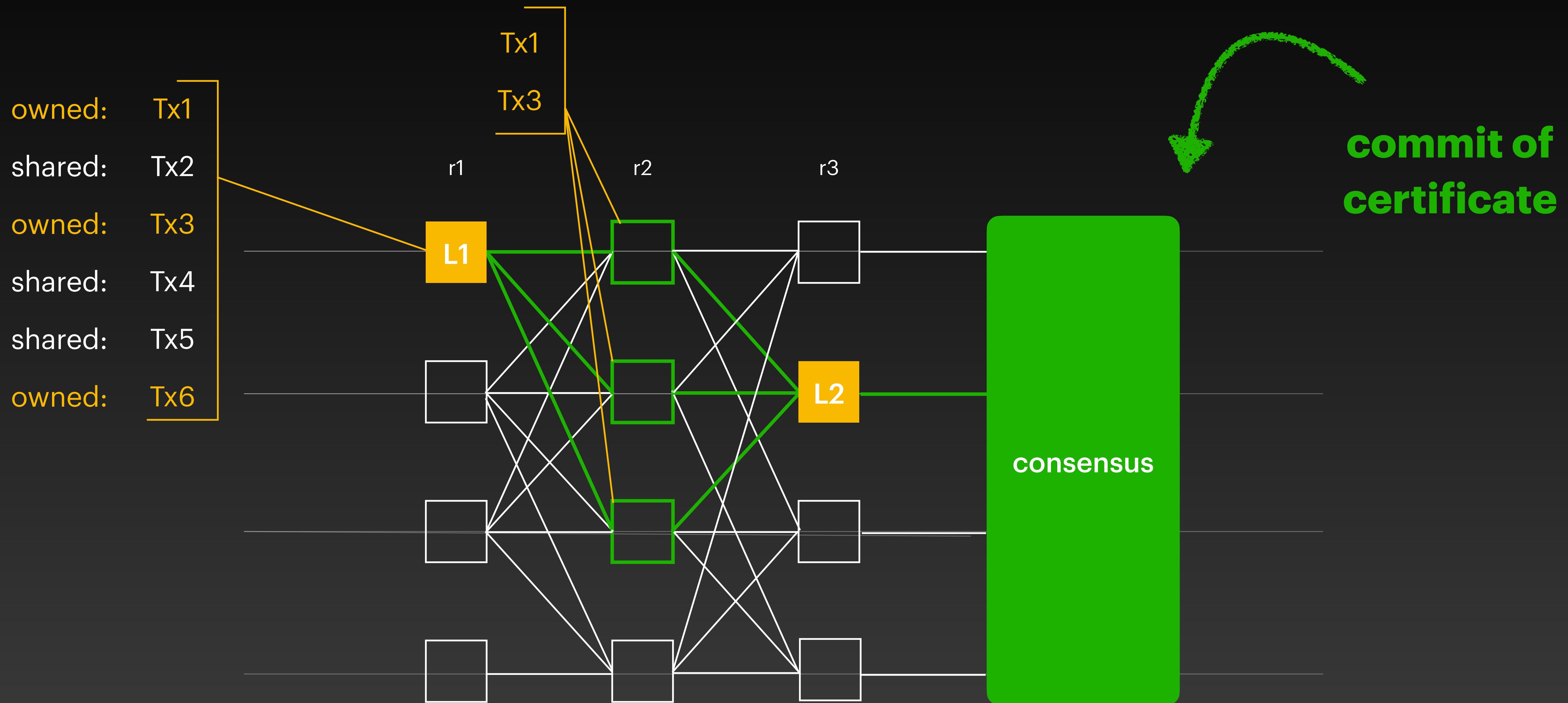
No Finality



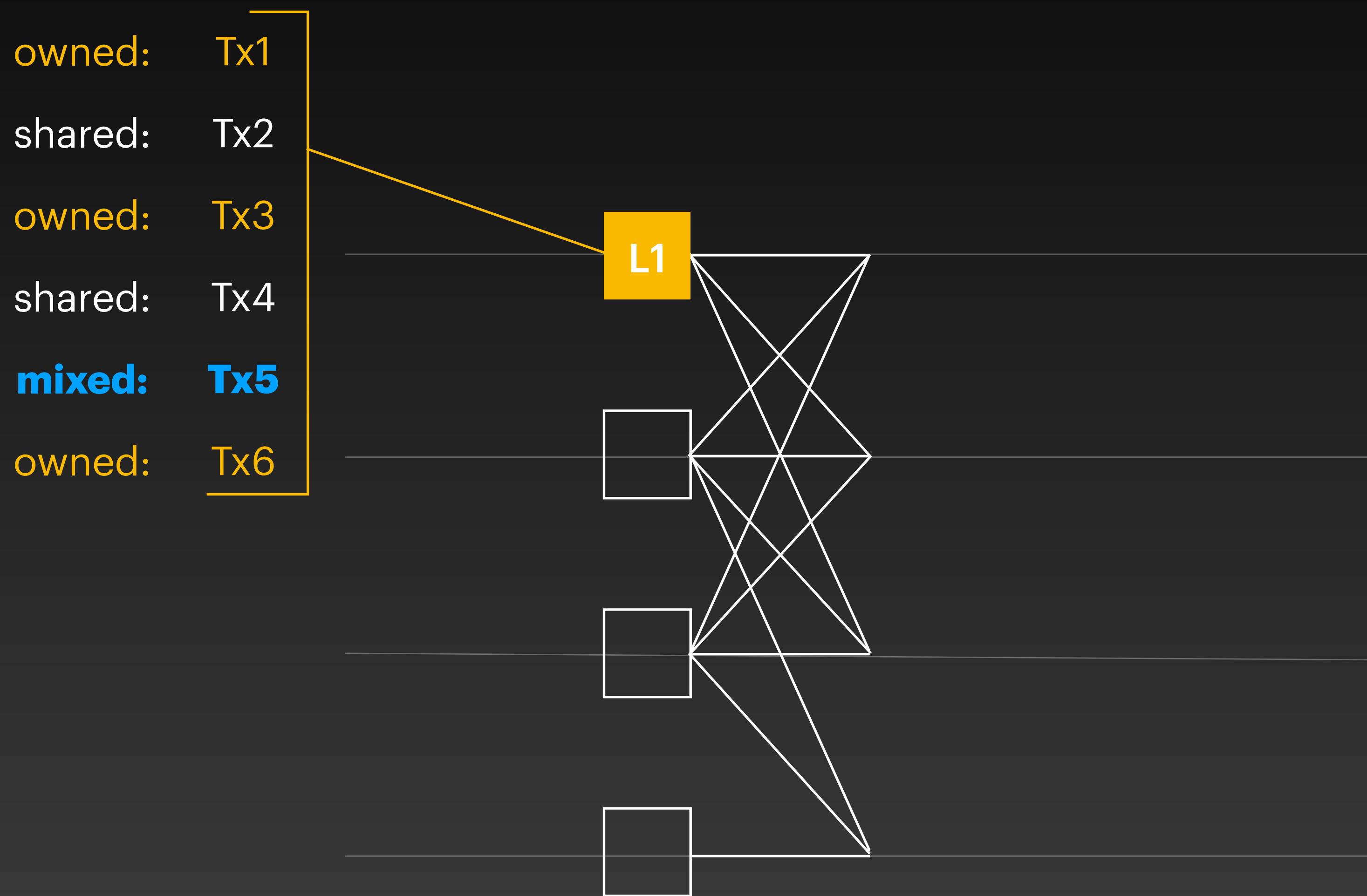
Fast Path Finality (1)



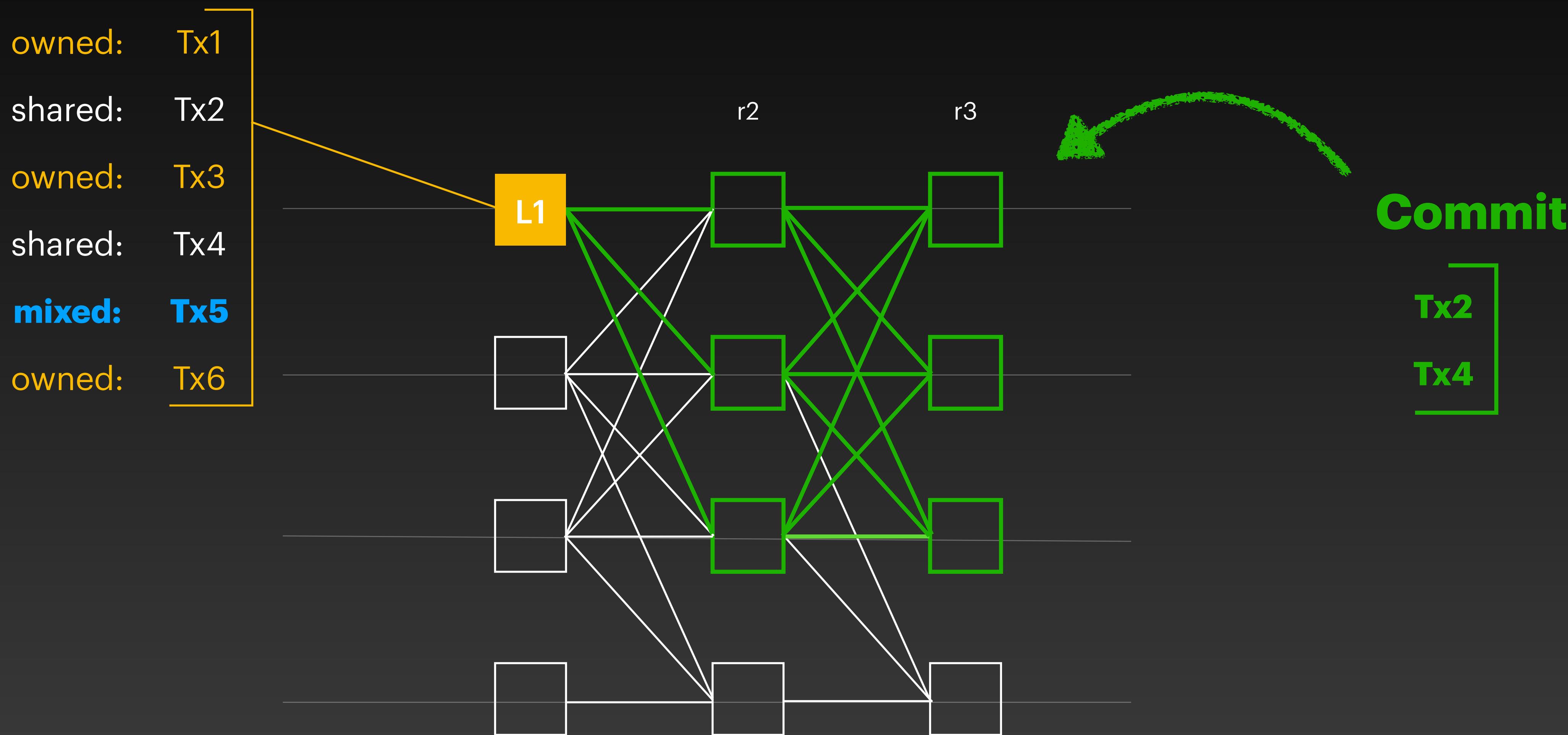
Fast Path Finality (2)



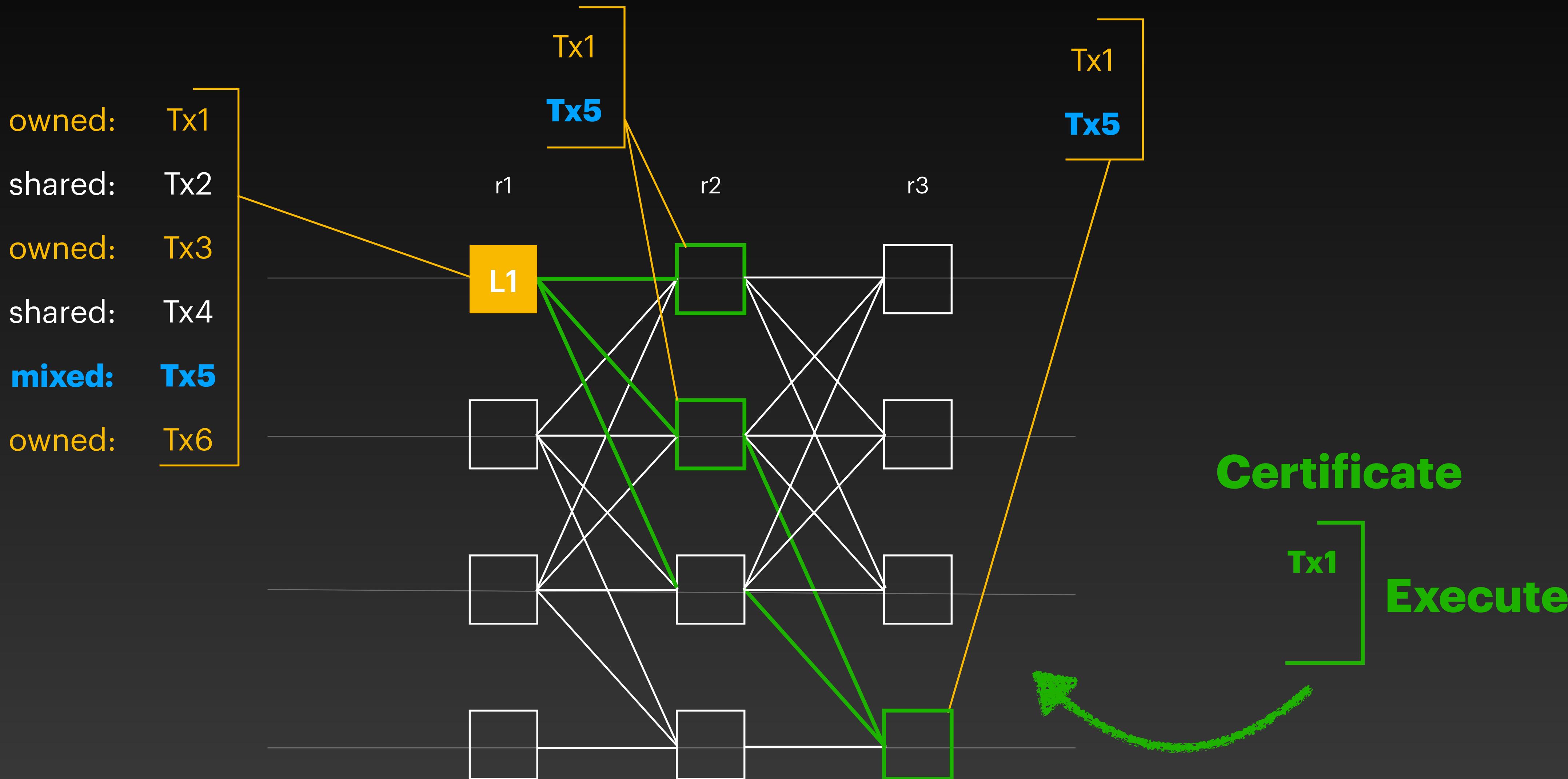
Mixed-Objects Transactions



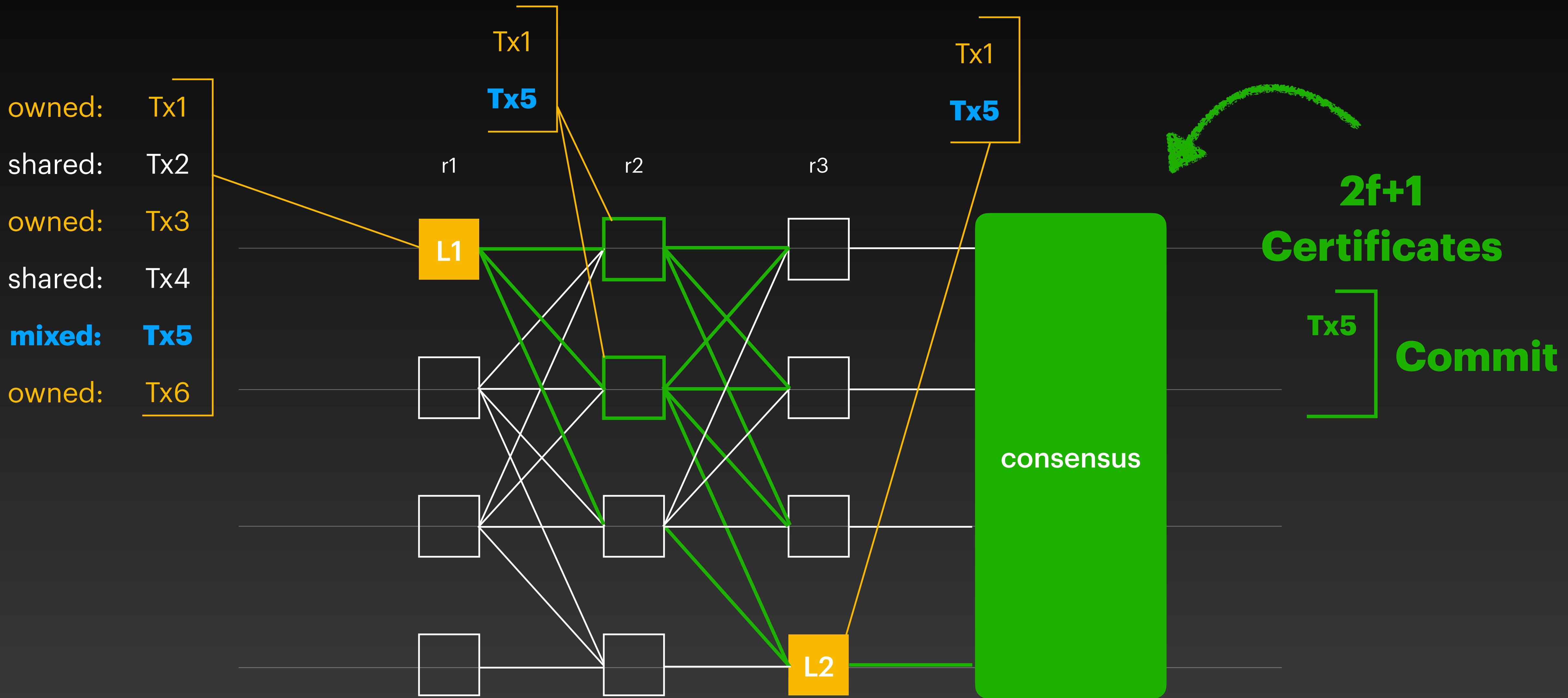
Mixed-Objects Transactions



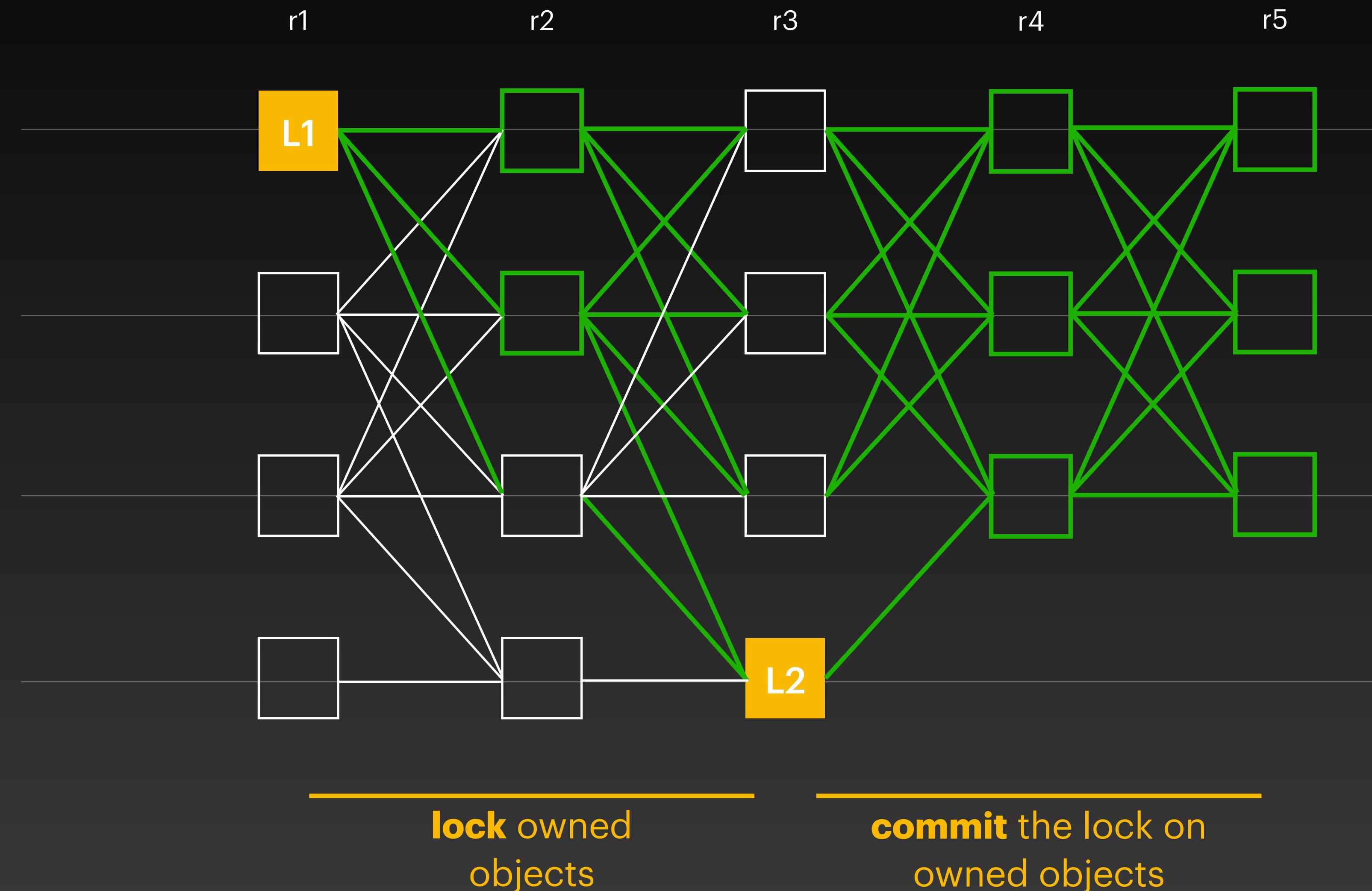
Mixed-Objects Transactions



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>

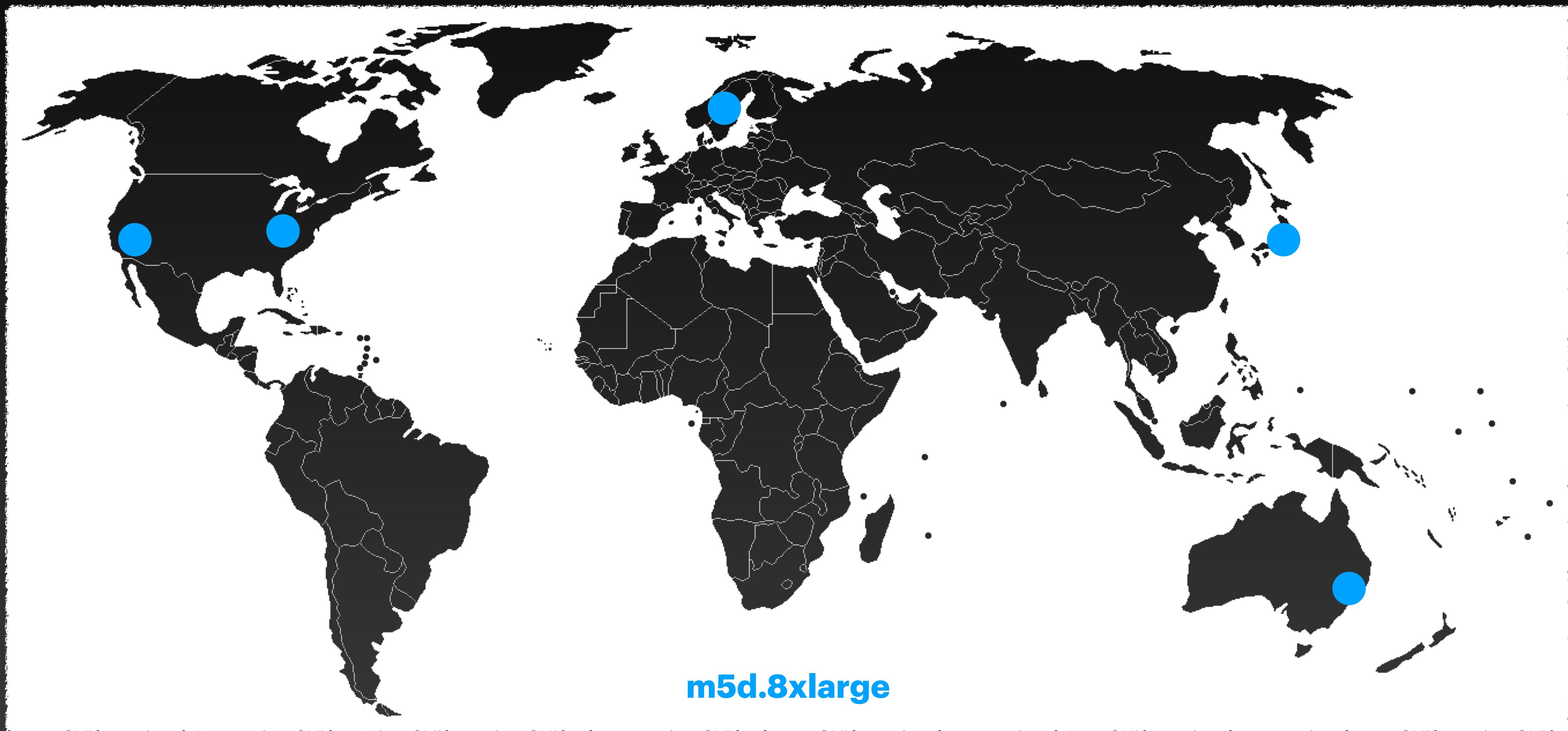
Implementation

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

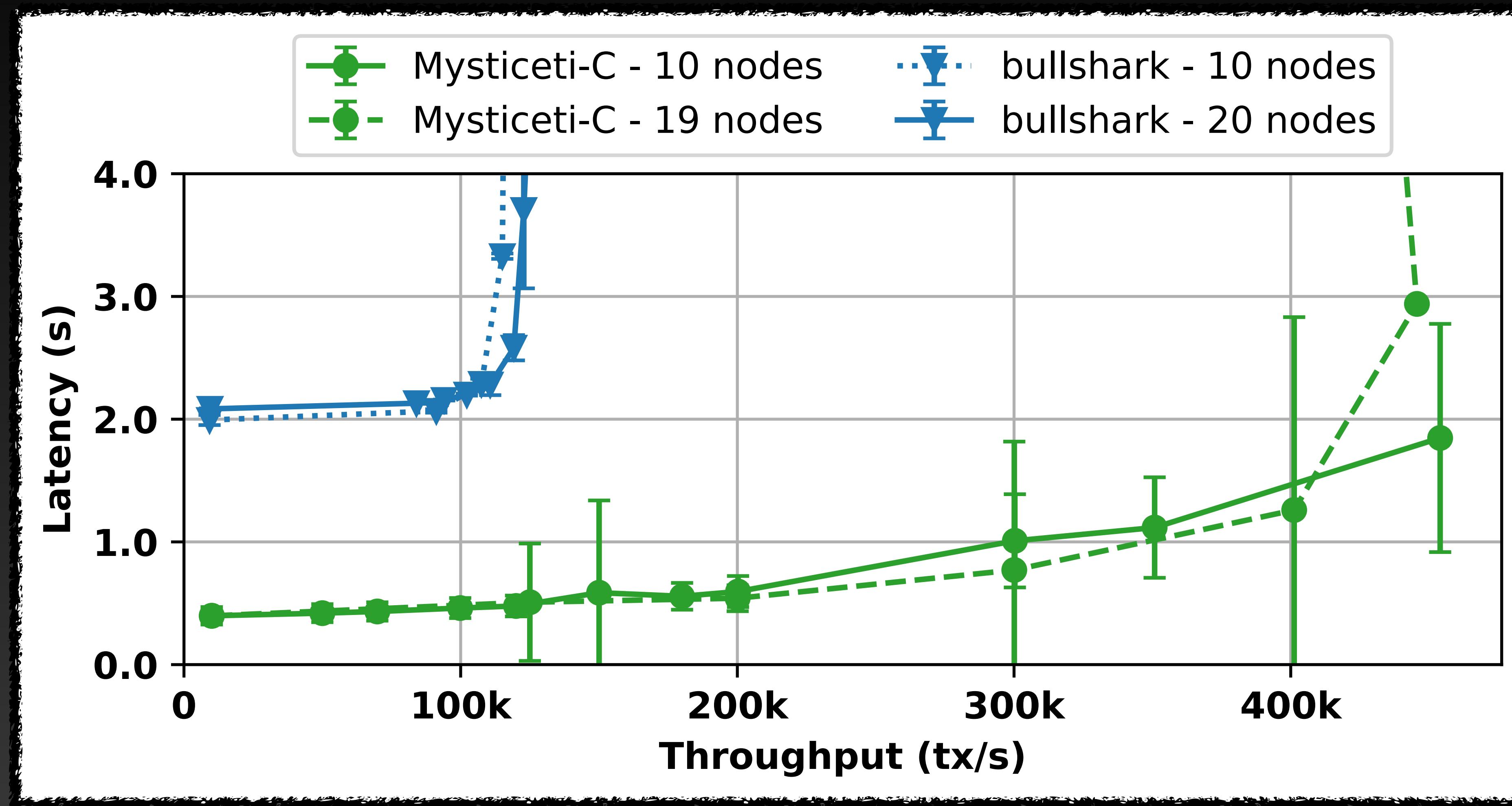
<https://github.com/mystenlabs/mysticeti>

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

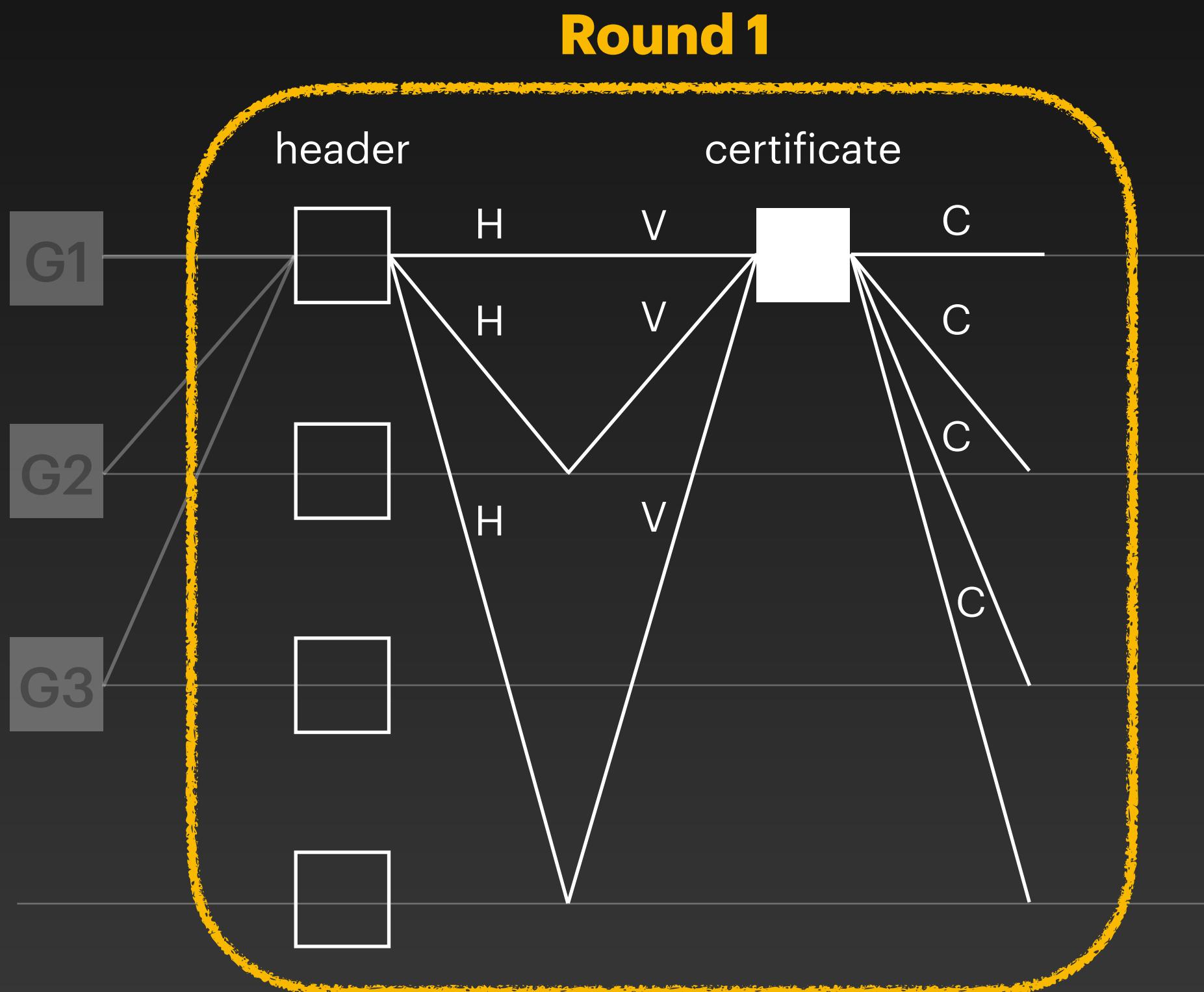
We run it at max load for 24h 

Narwhal vs Mysticeti

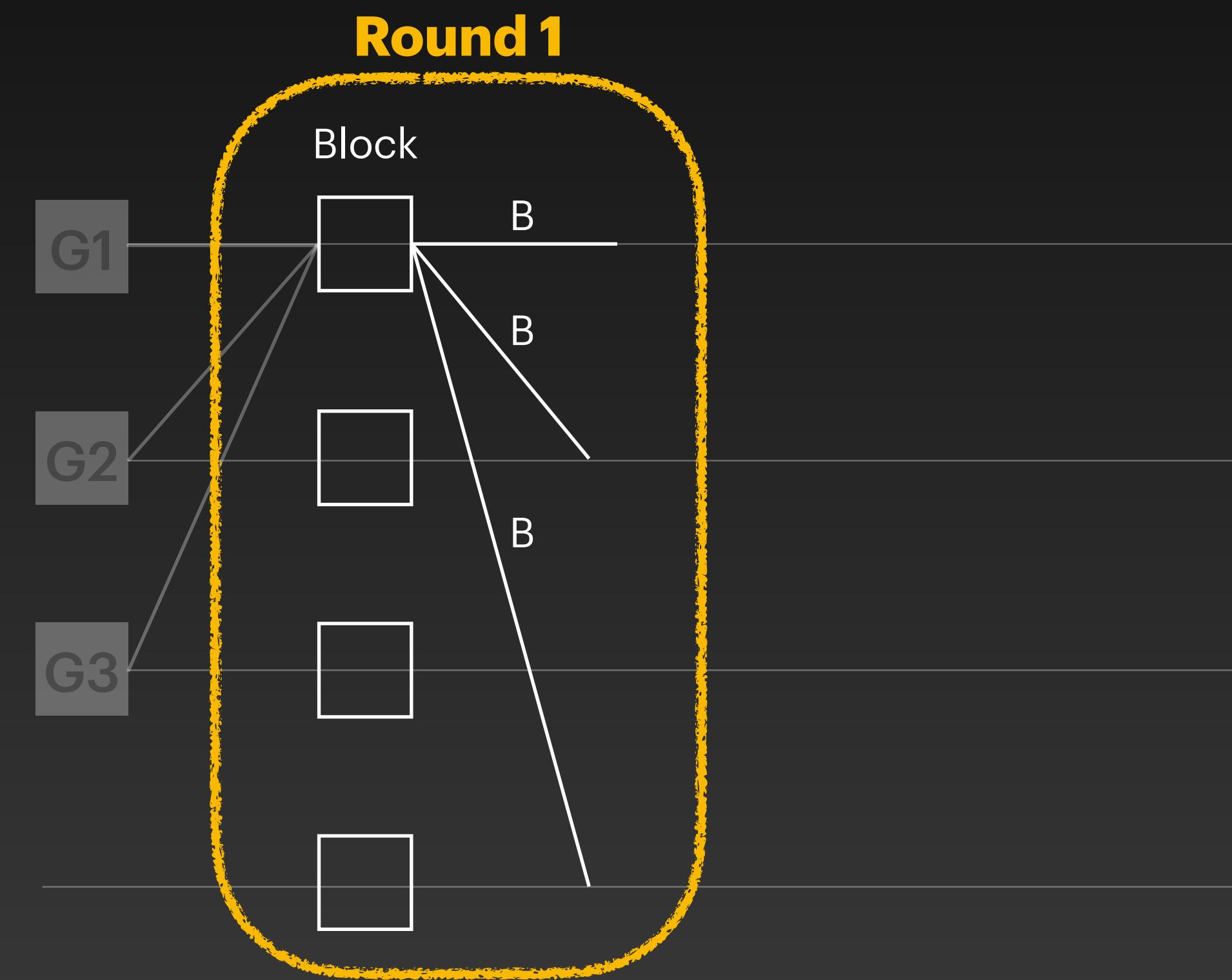
Key differences & Insight

Narwhal vs Mysticeti

Narwhal

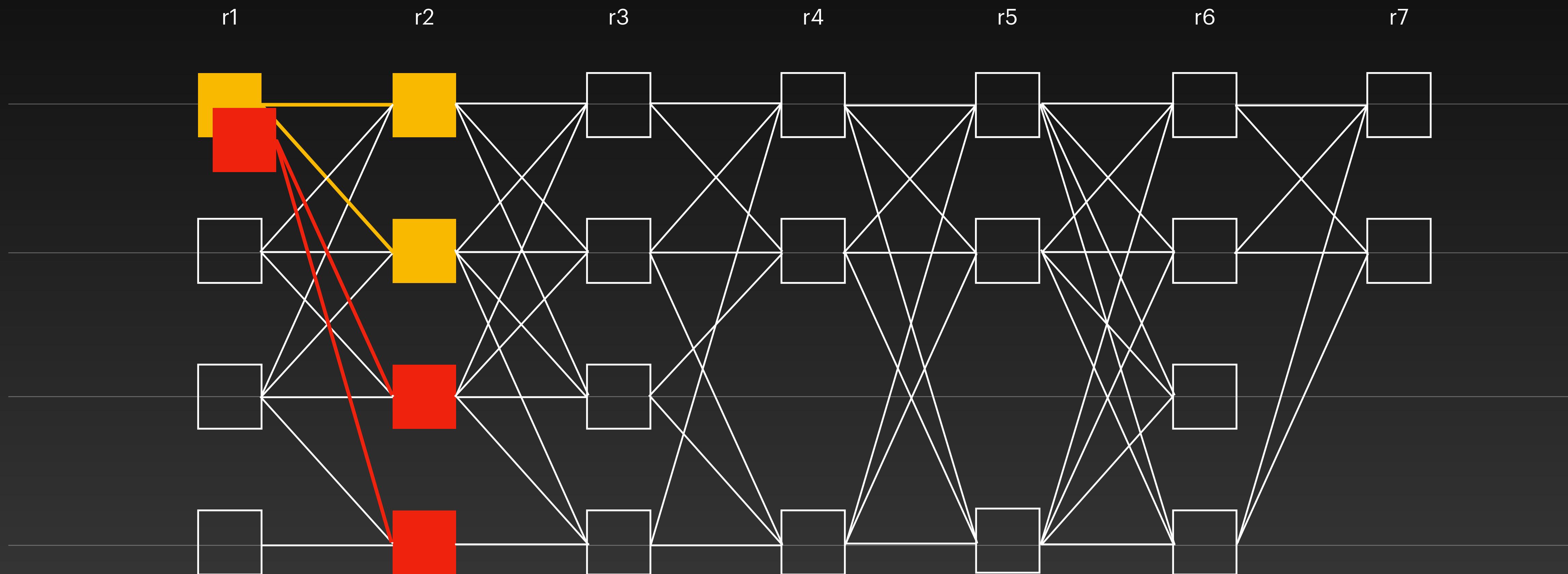


Mysticeti



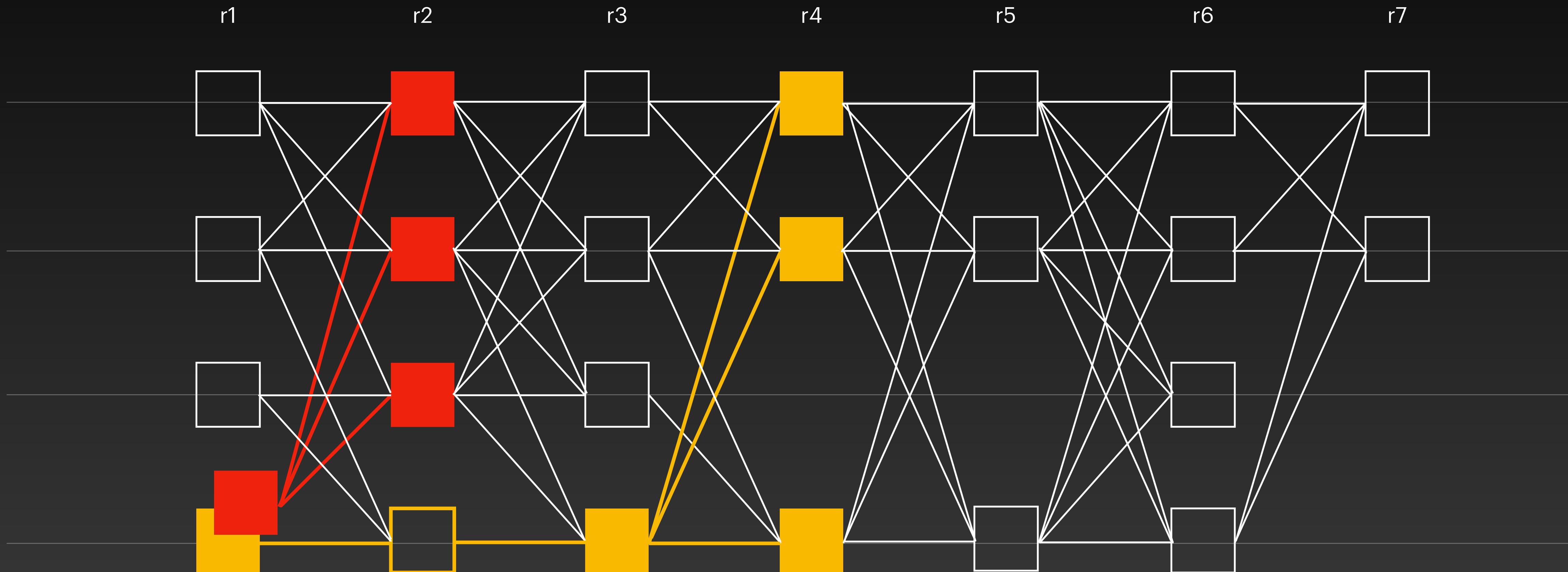
Main Challenge

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

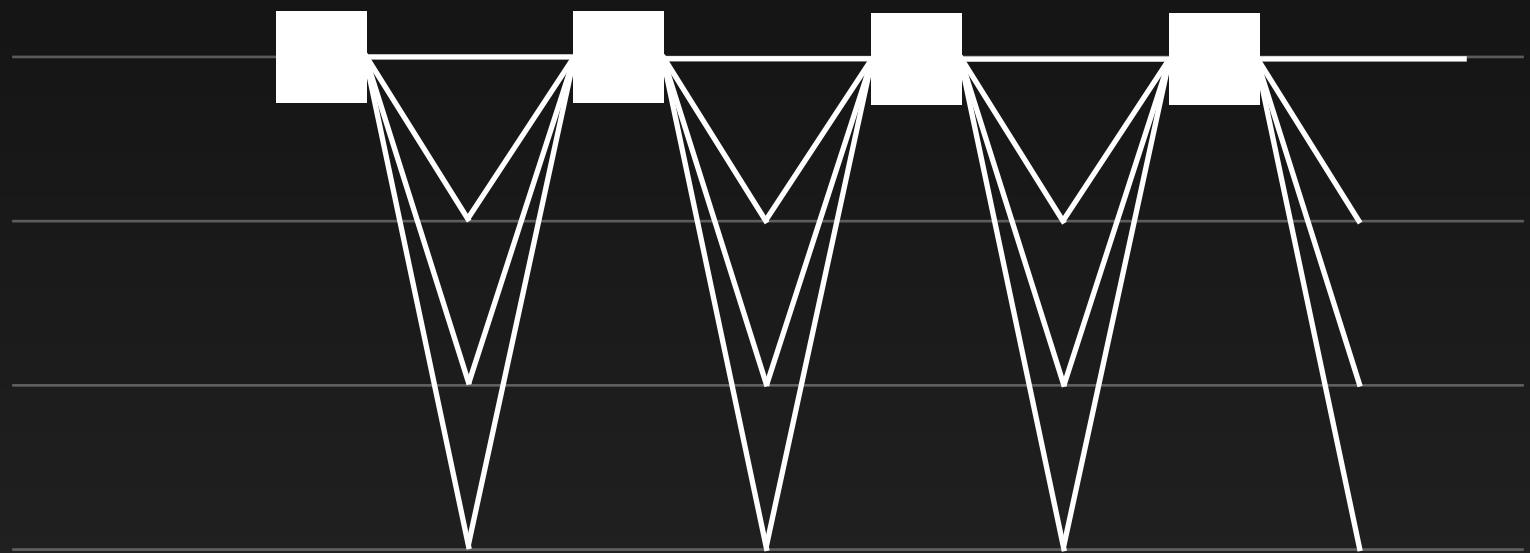
- Low latency
- Fragile to faults
- Complex leader-change

DAG-Based

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

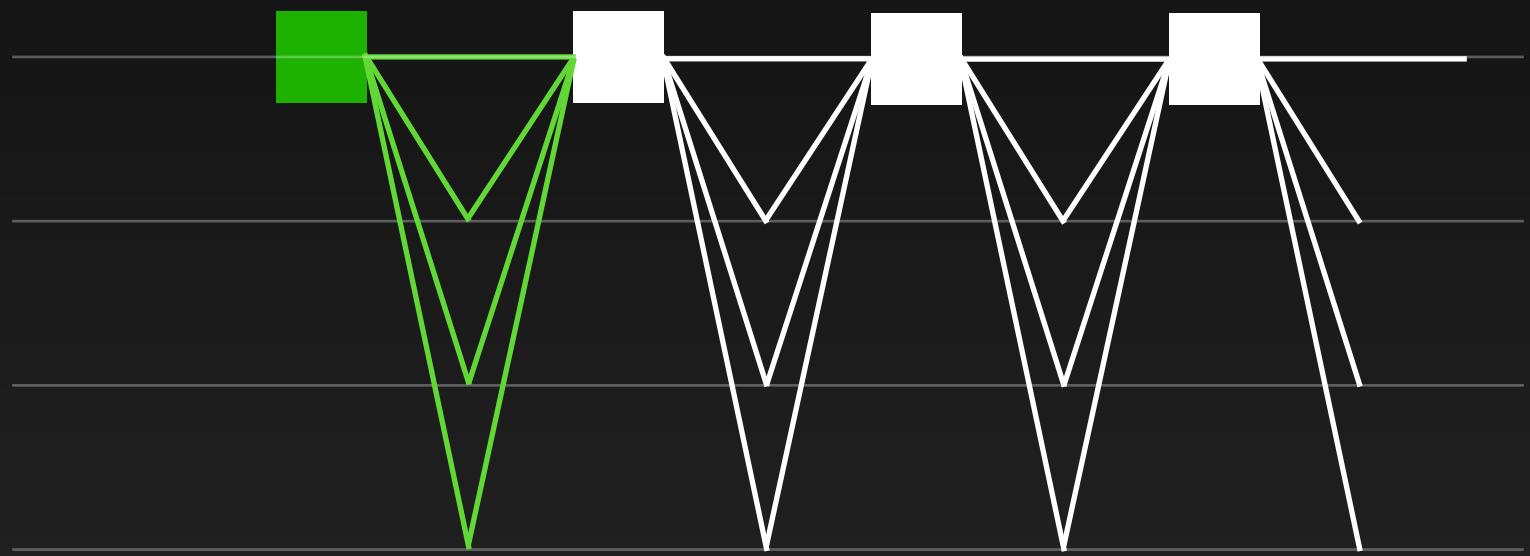
Linear-Chain Consensus

Rough overview



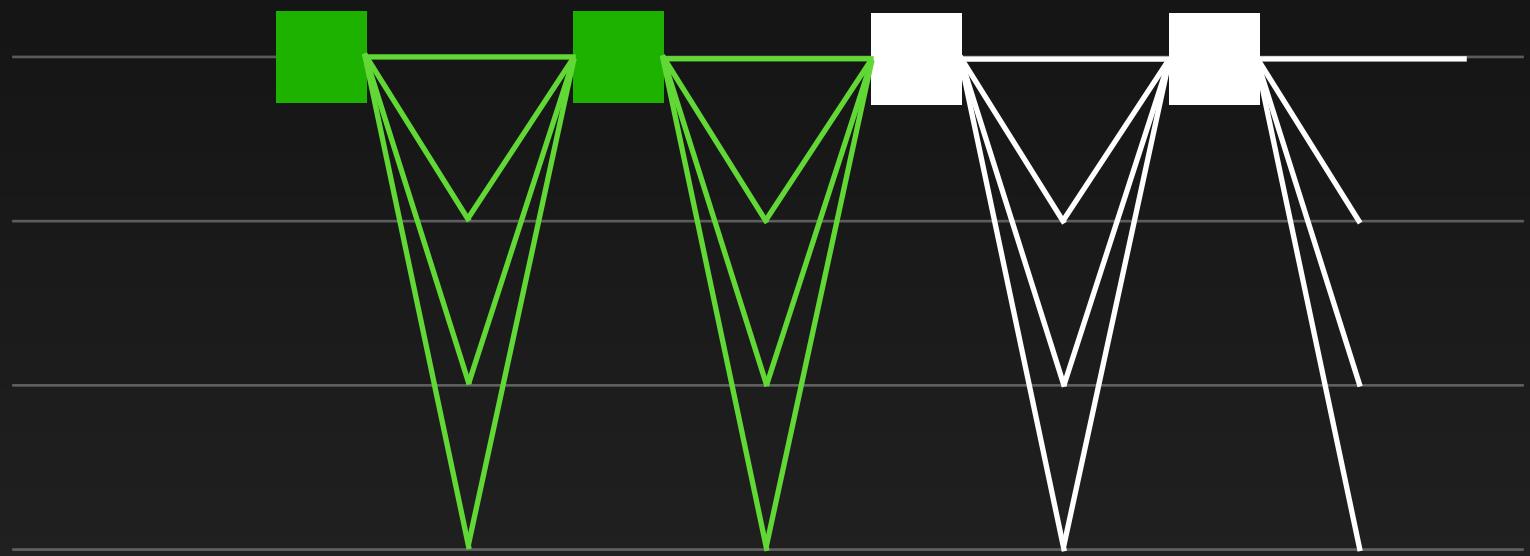
Linear-Chain Consensus

Rough overview



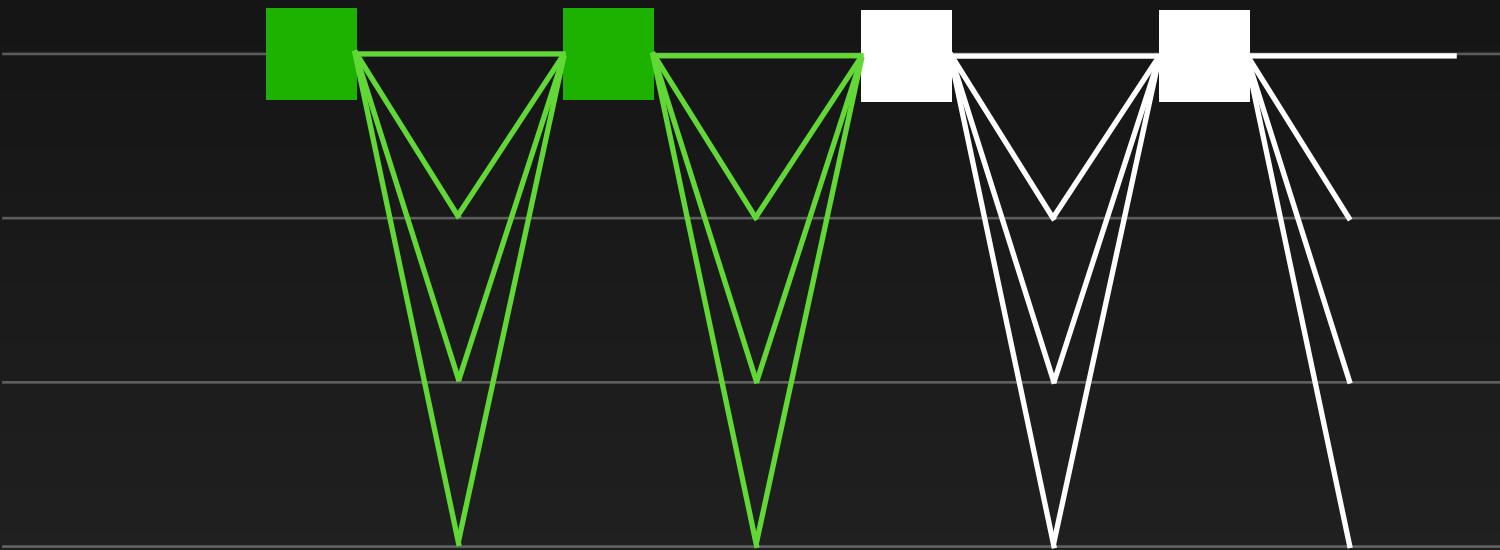
Linear-Chain Consensus

Rough overview



Linear-Chain Consensus

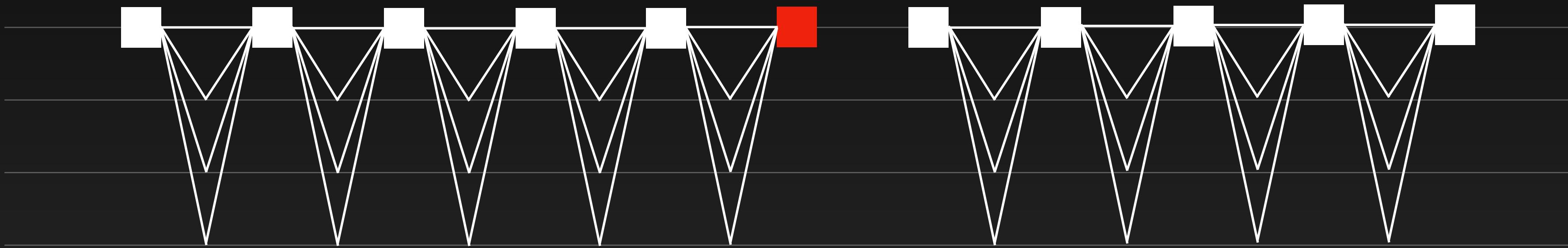
Rough overview



- The leader does all the work

Linear-Chain Consensus

Rough overview



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

Linear-Chain Consensus

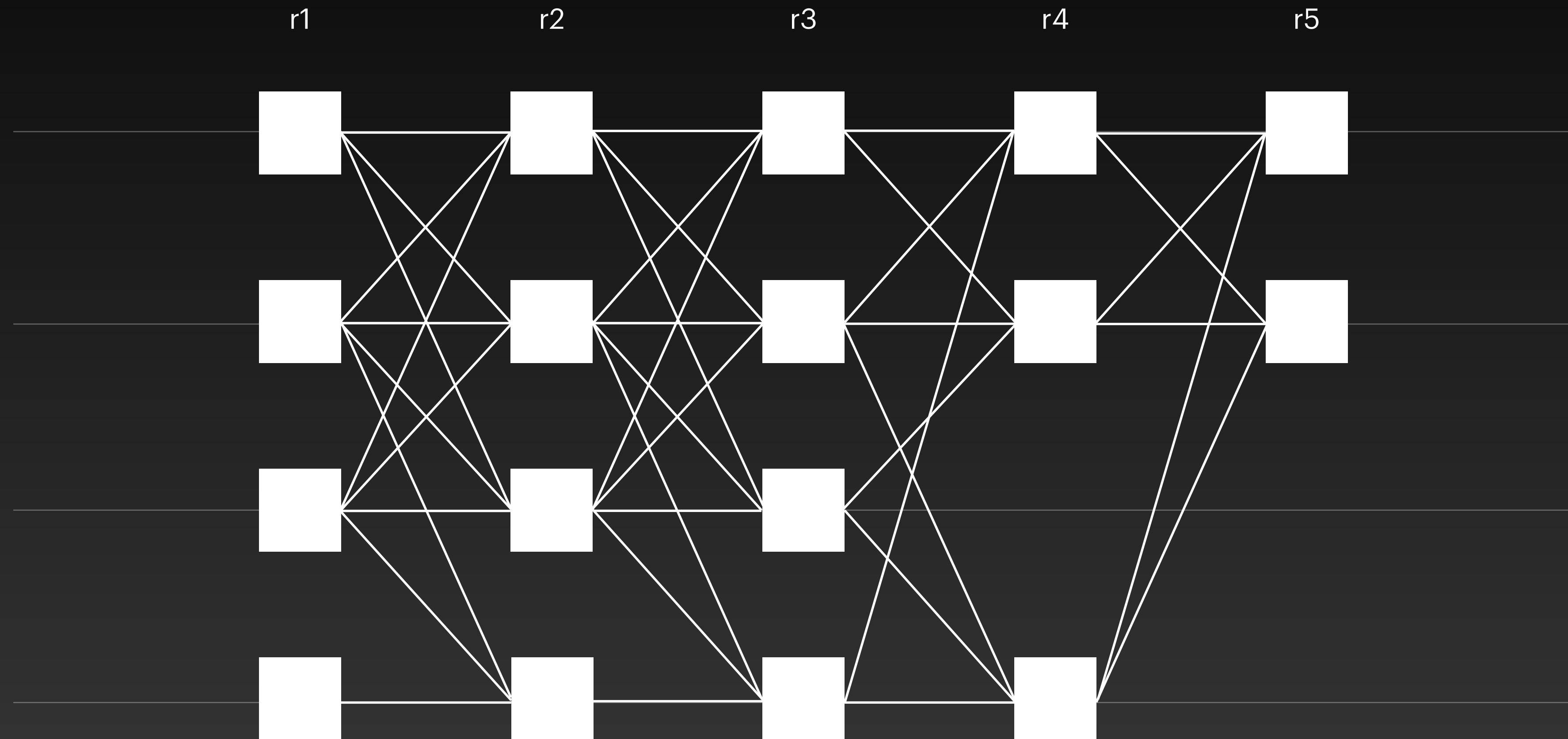
Rough overview



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

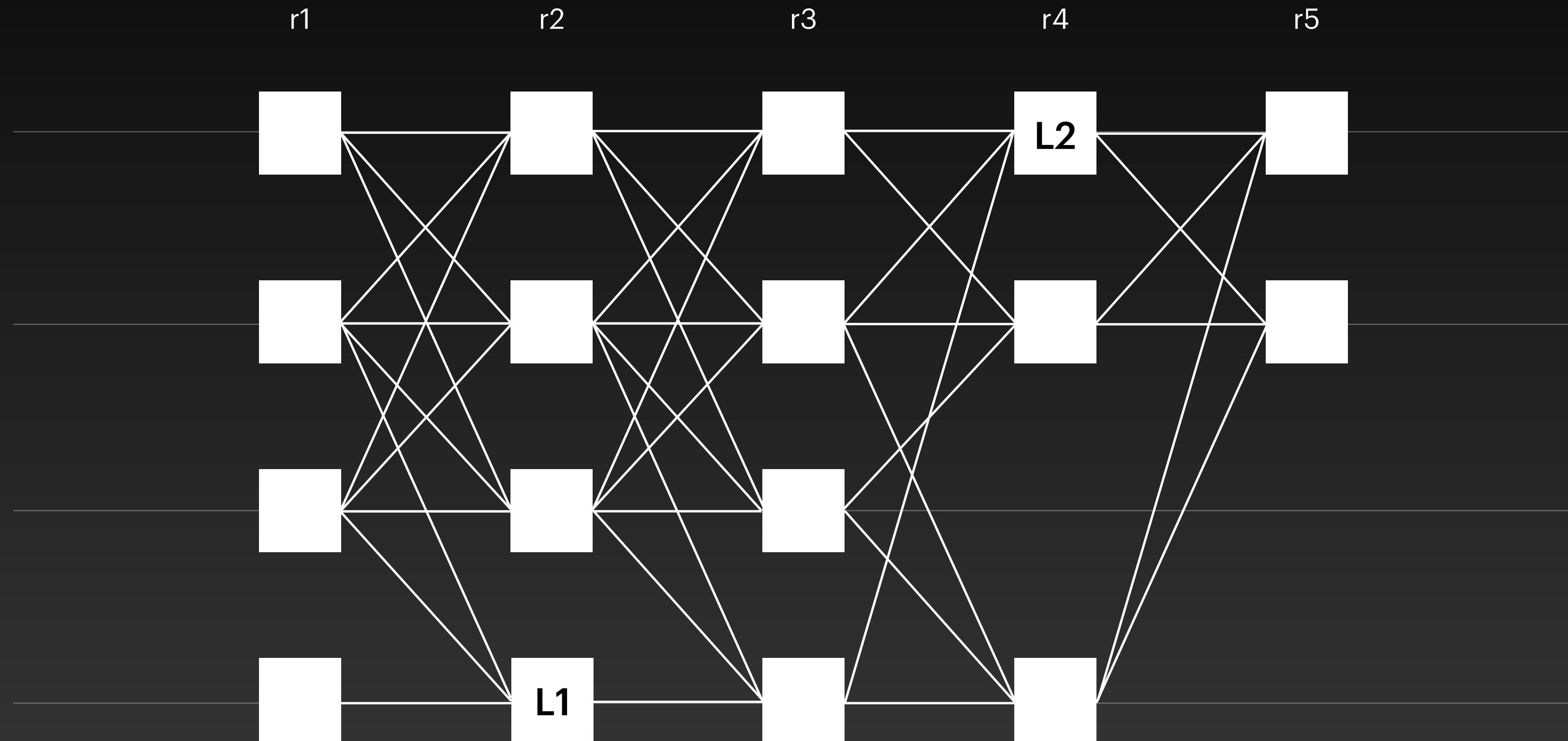
DAG-Based Consensus

Rough overview



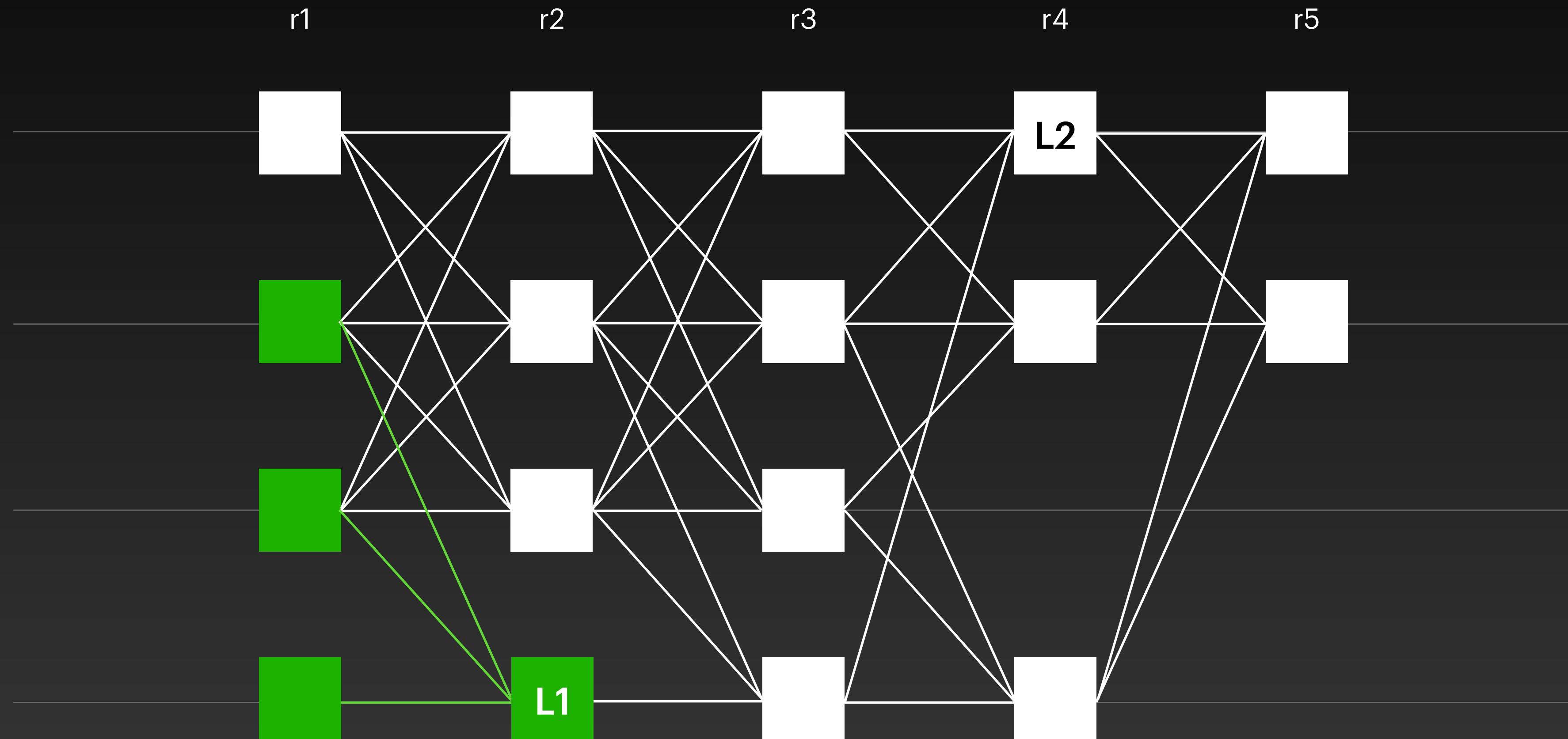
DAG-Based Consensus

Rough overview



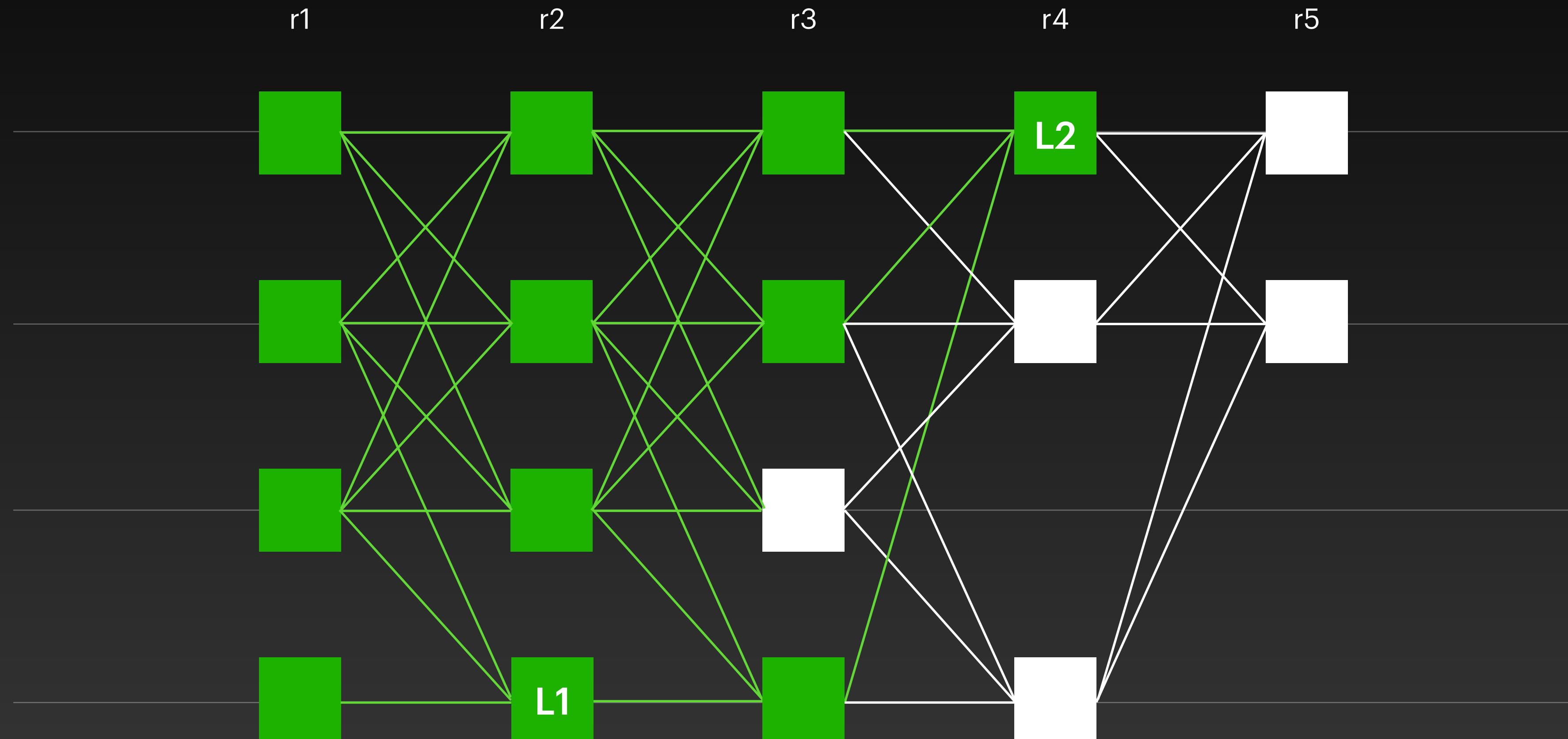
DAG-Based Consensus

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>