

Mysticeti

The new core of the Sui blockchain

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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



Byzantine Fault Tolerance



$$3f+1$$

Partial Synchrony



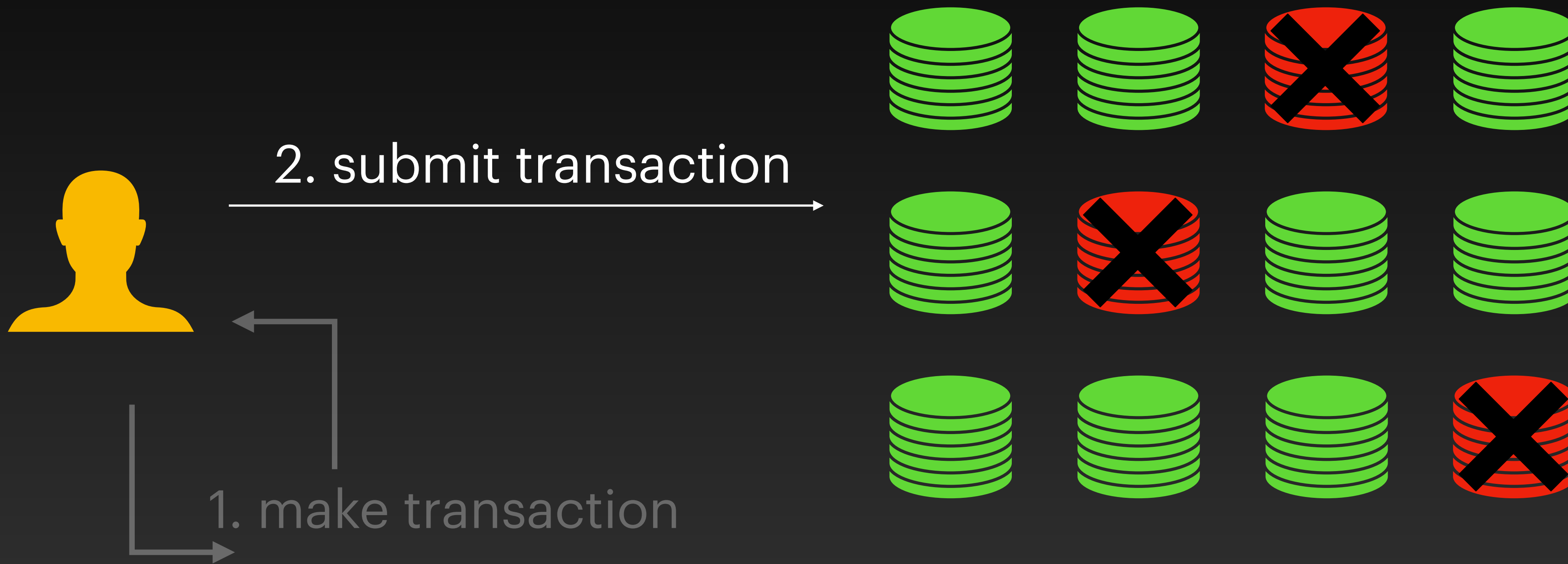
Blockchains



1. make transaction



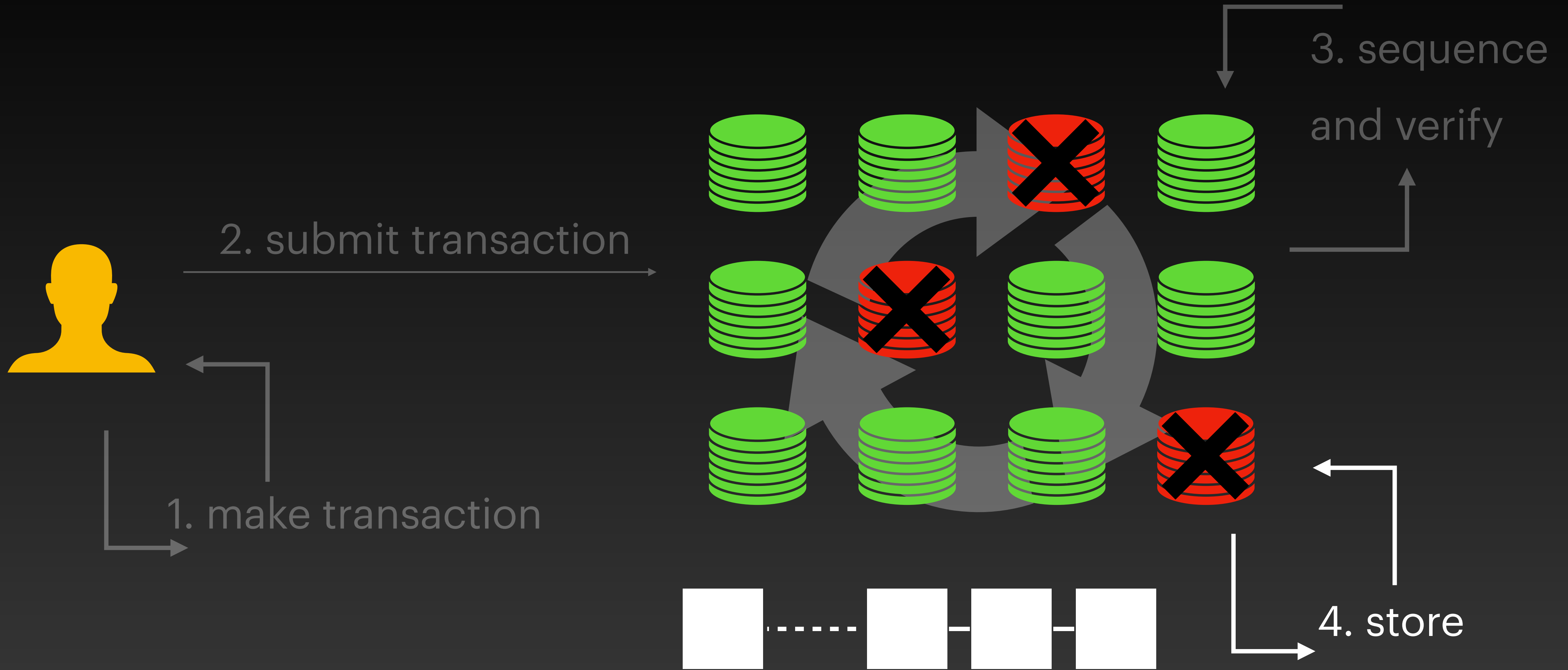
Blockchains



Blockchains



Blockchains



Keeping the Talk Short

In scope

- Ordering (quorum-based)

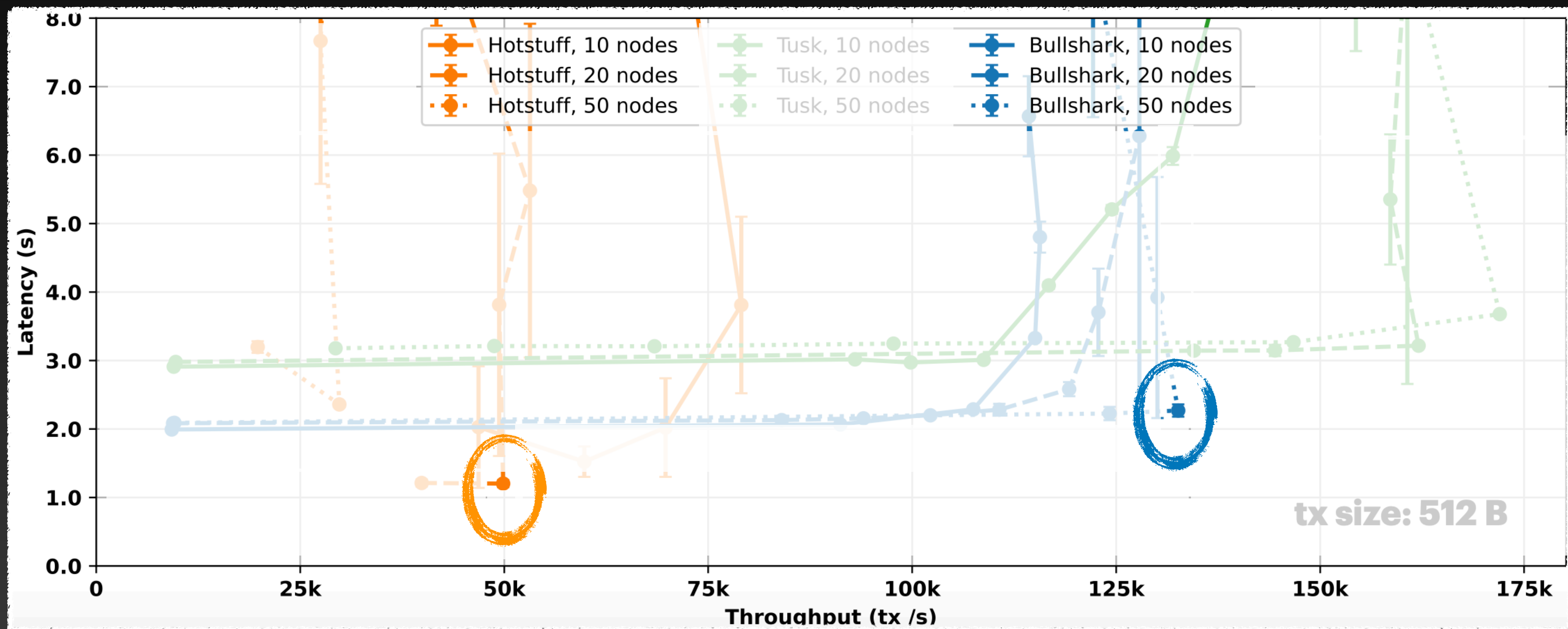


Not in scope

- 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?

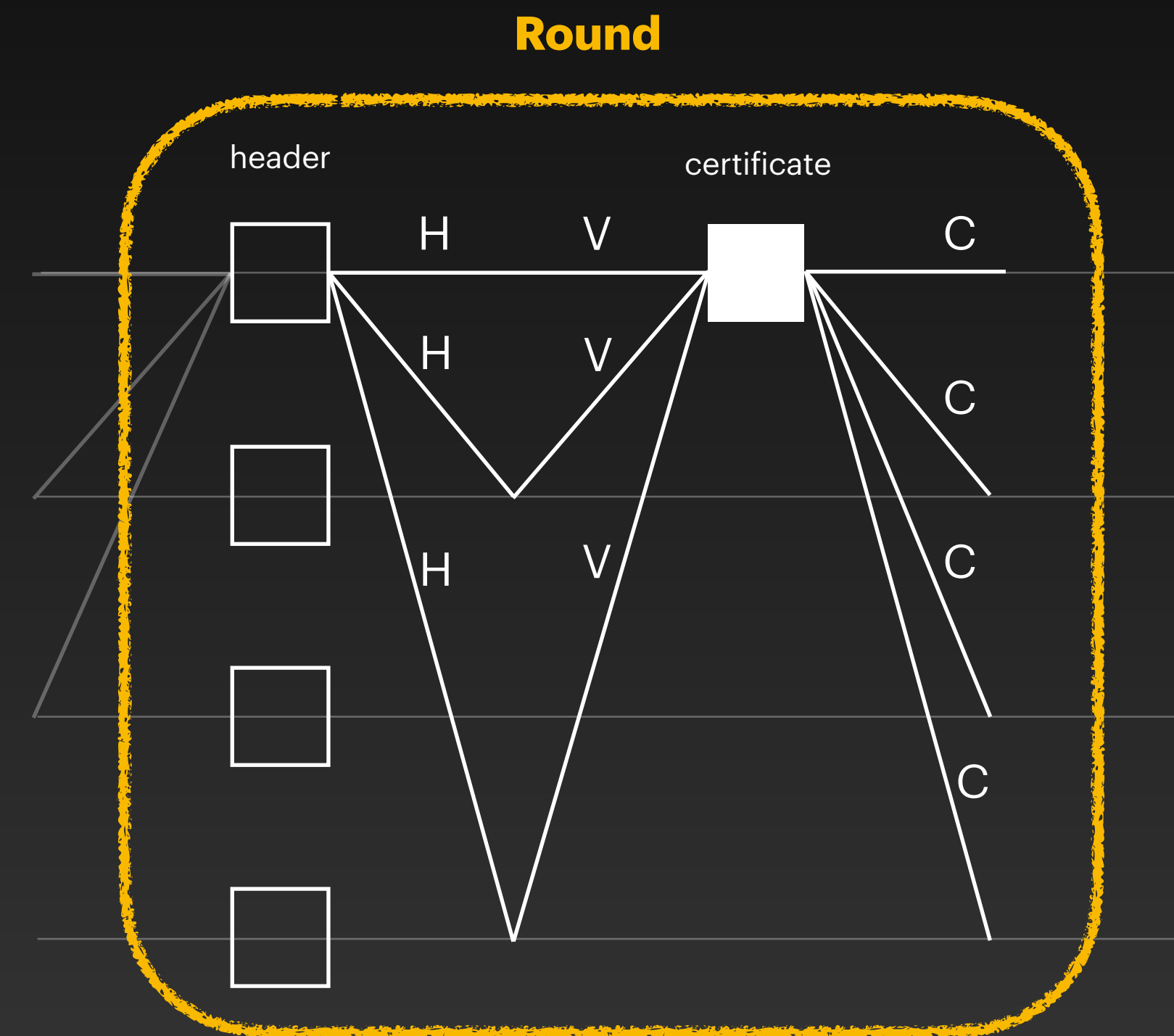
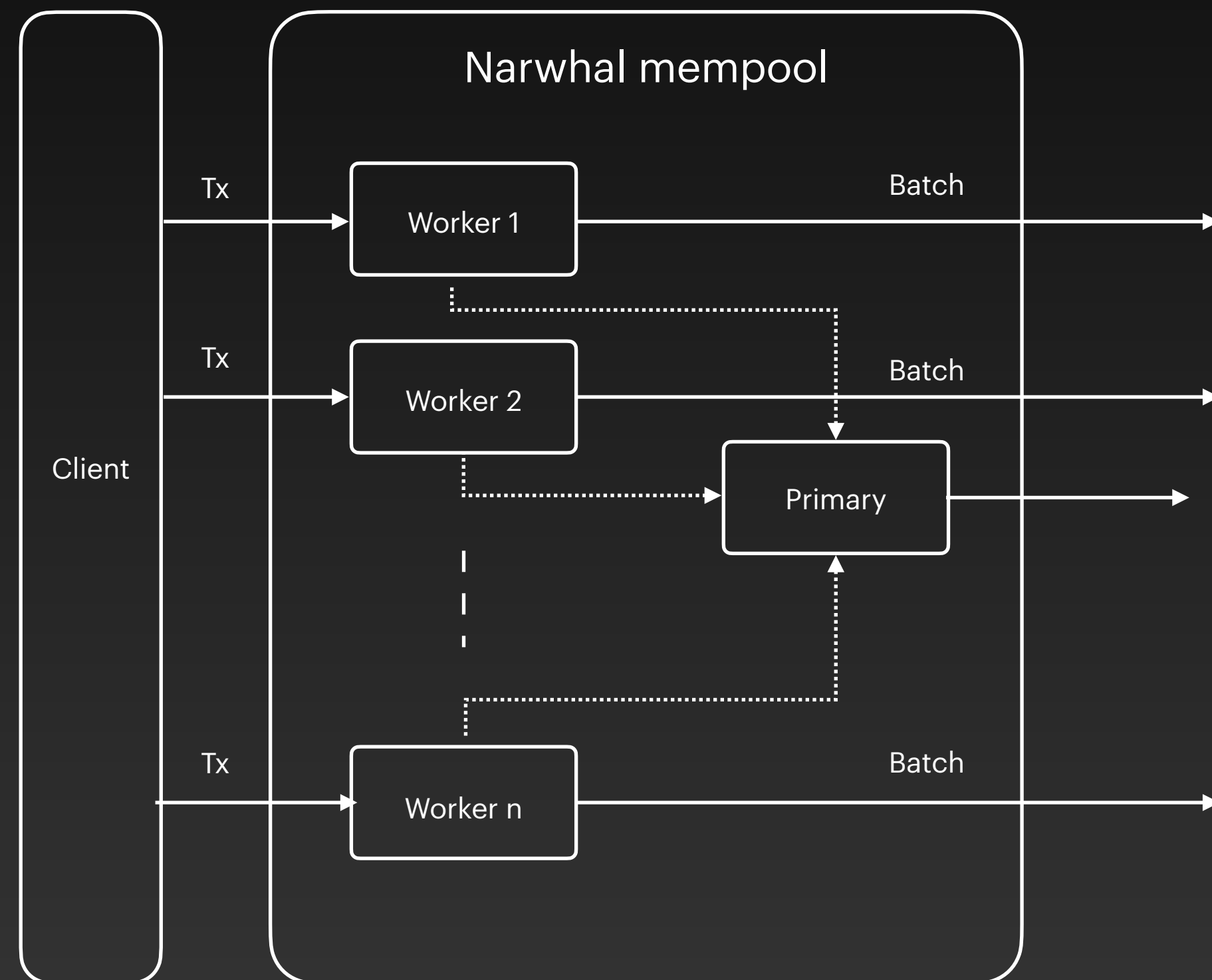
Crash Faults

In a year of running Sui:

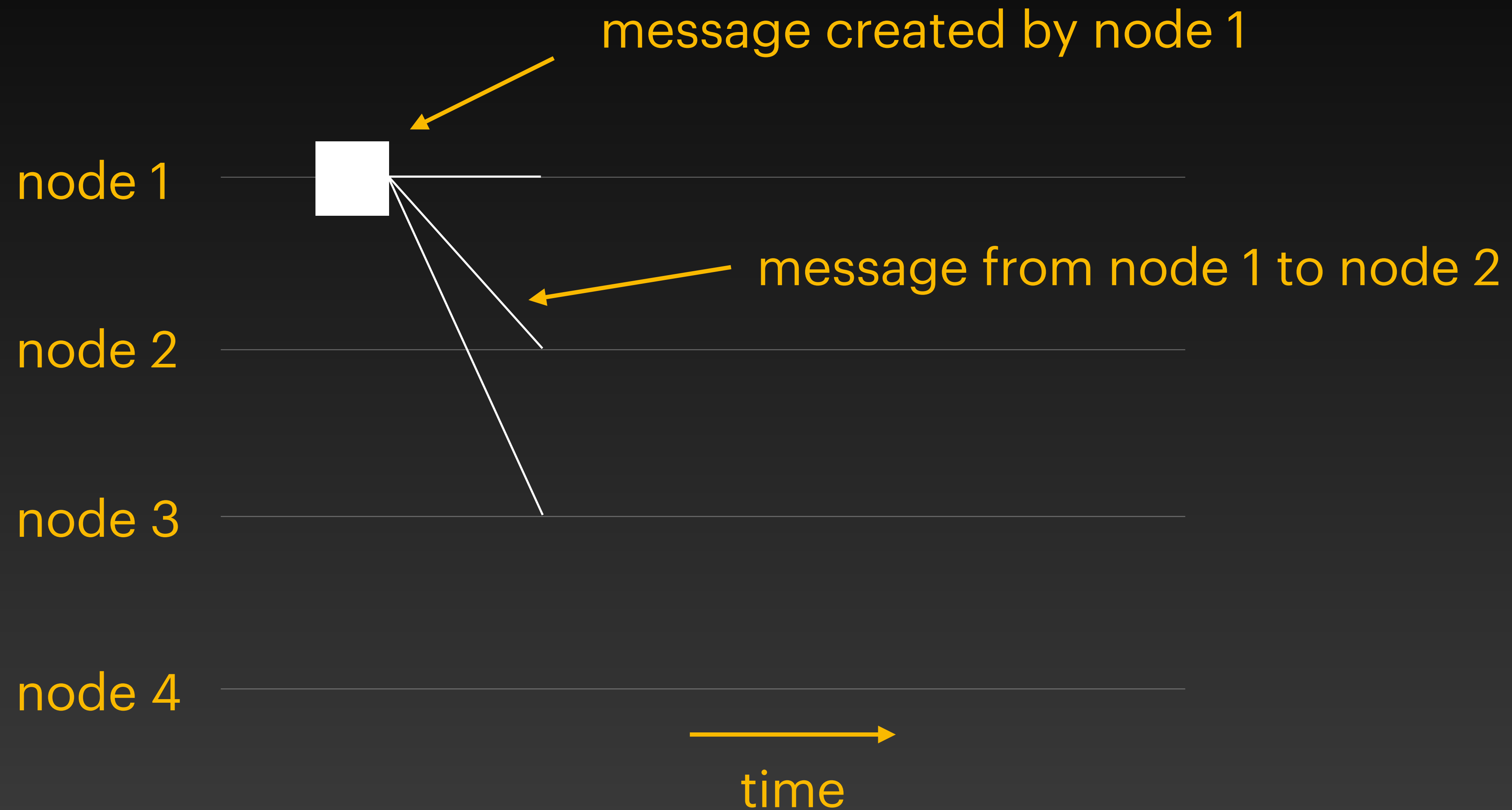
- How many Byzantine faults? 0
- How many Crash faults? 🥲

Why?

Engineering Complexity



Lamport Diagram

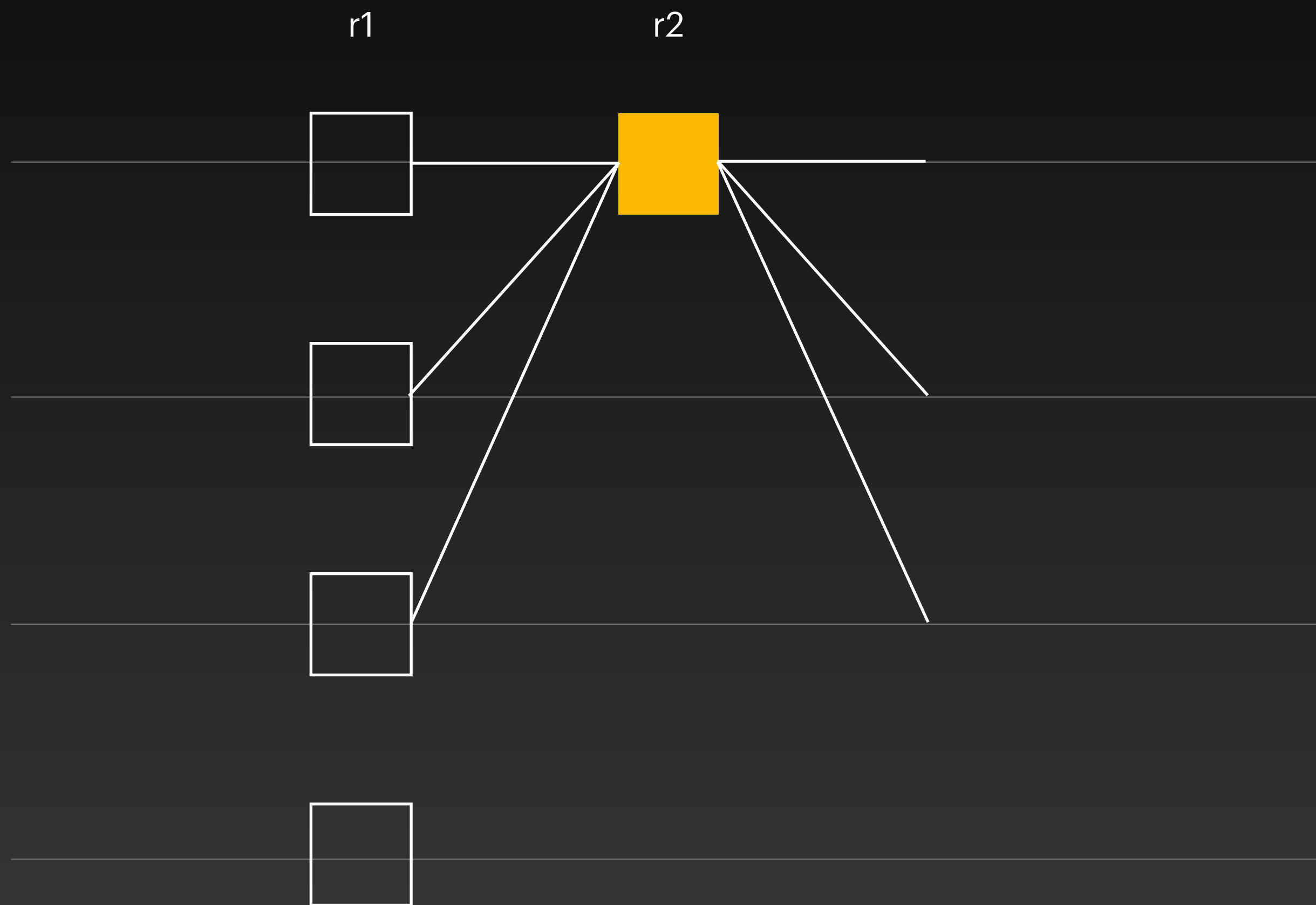


The Mysticeti DAG

Uncertified DAG

The MystiCeti DAG

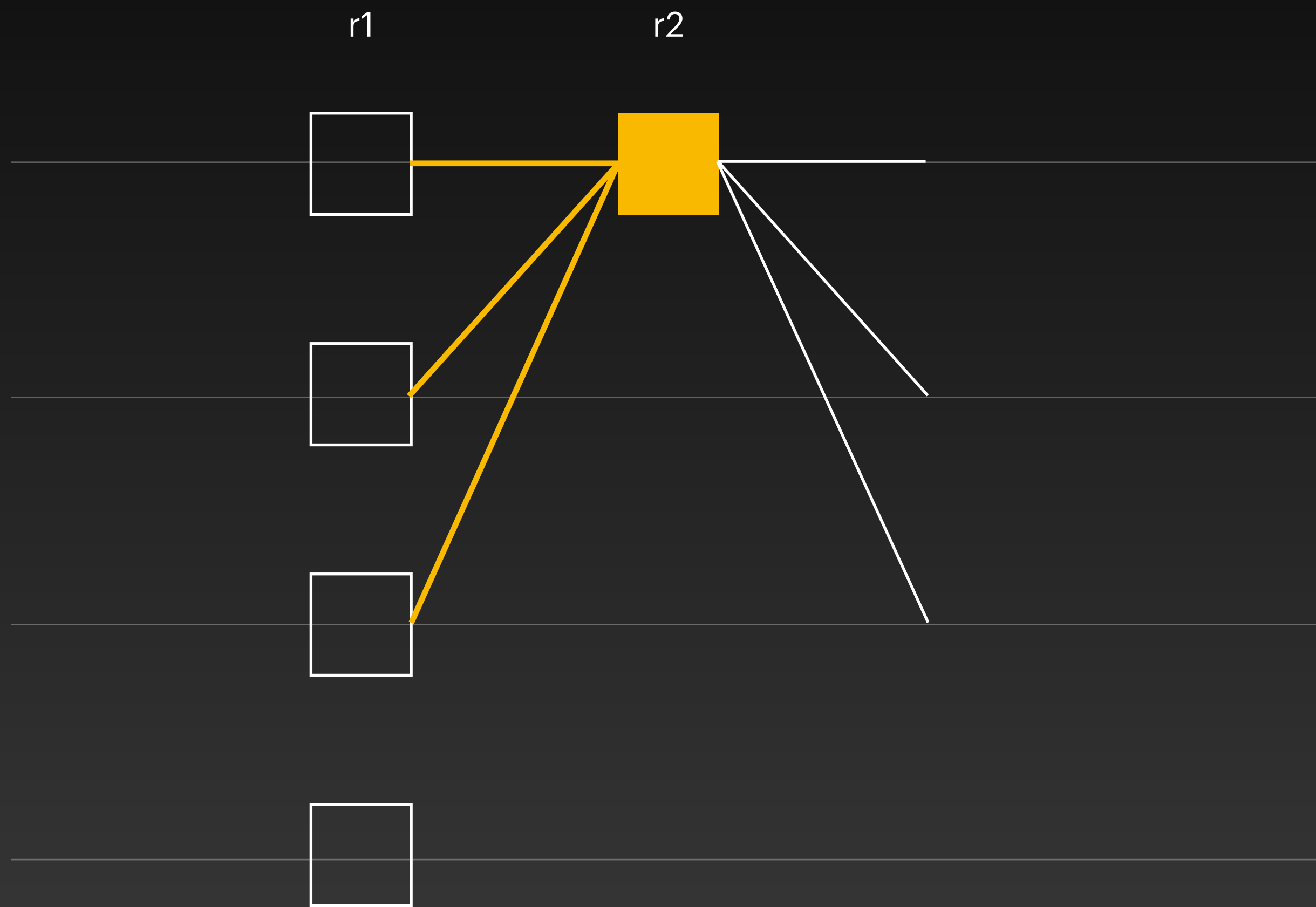
Block Creation



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

The Mysticeti DAG

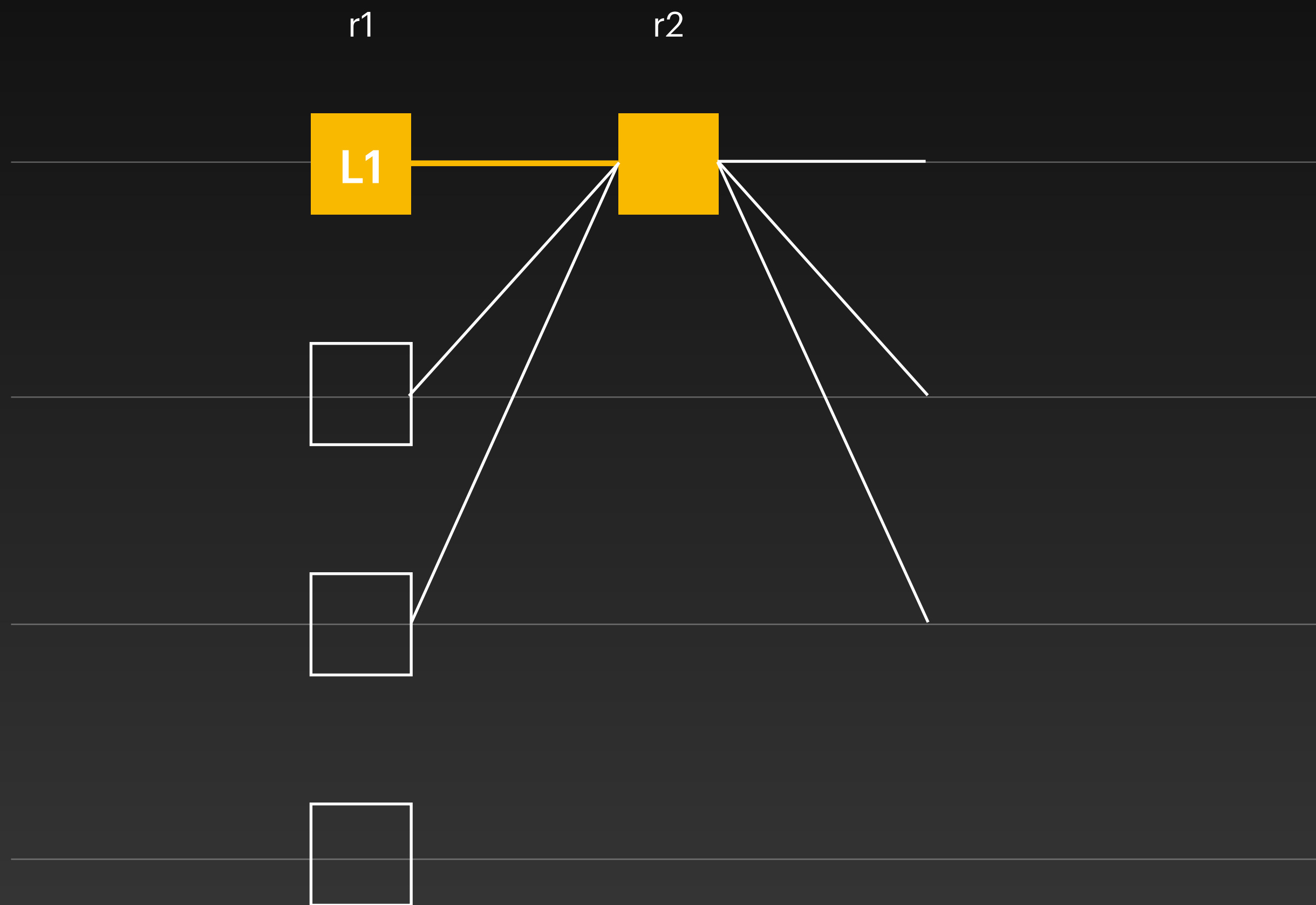
Rule 1: Link to $2f+1$ parents



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

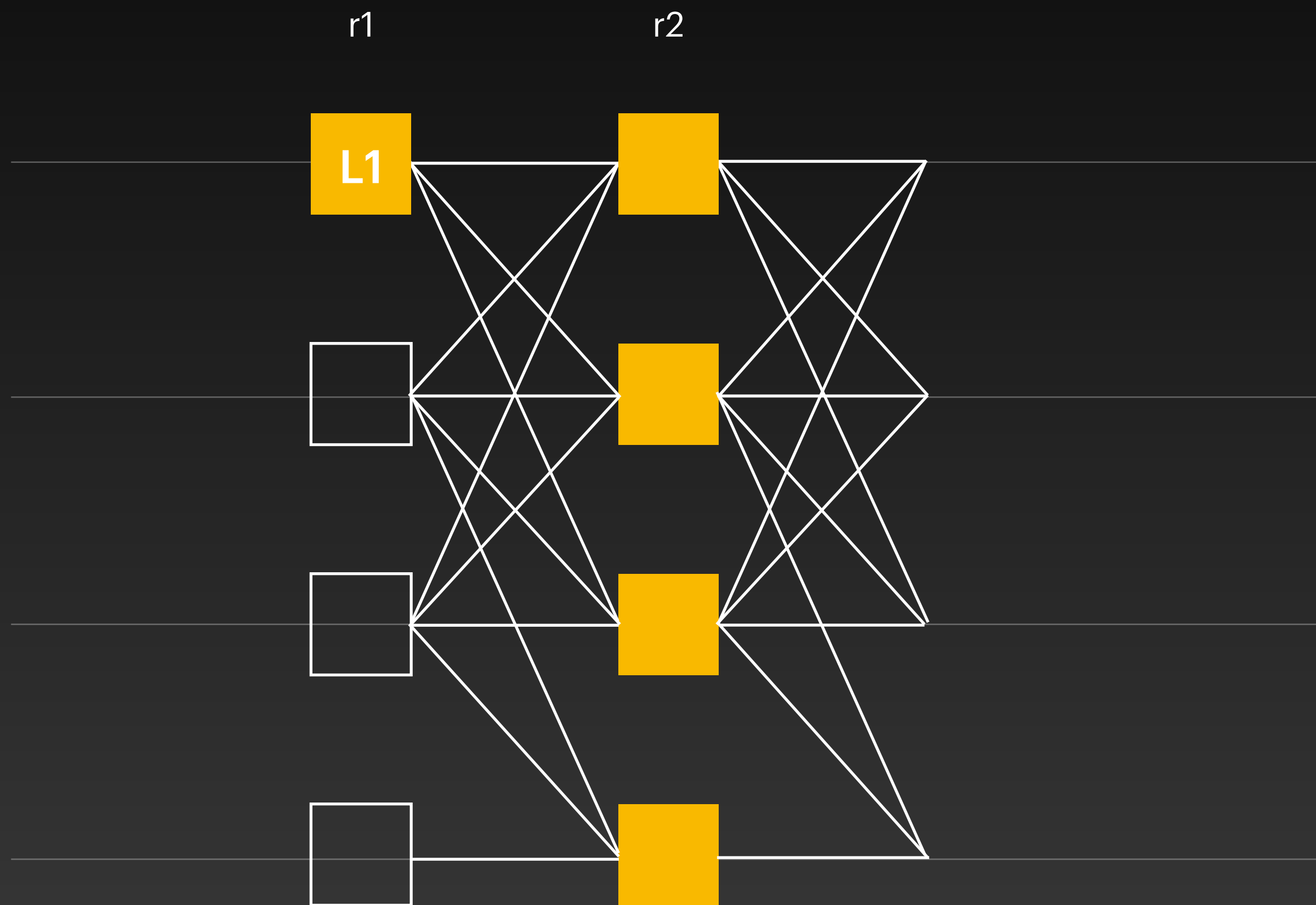
The Mysticieti DAG

Rule 2: Every node waits and links to leaders

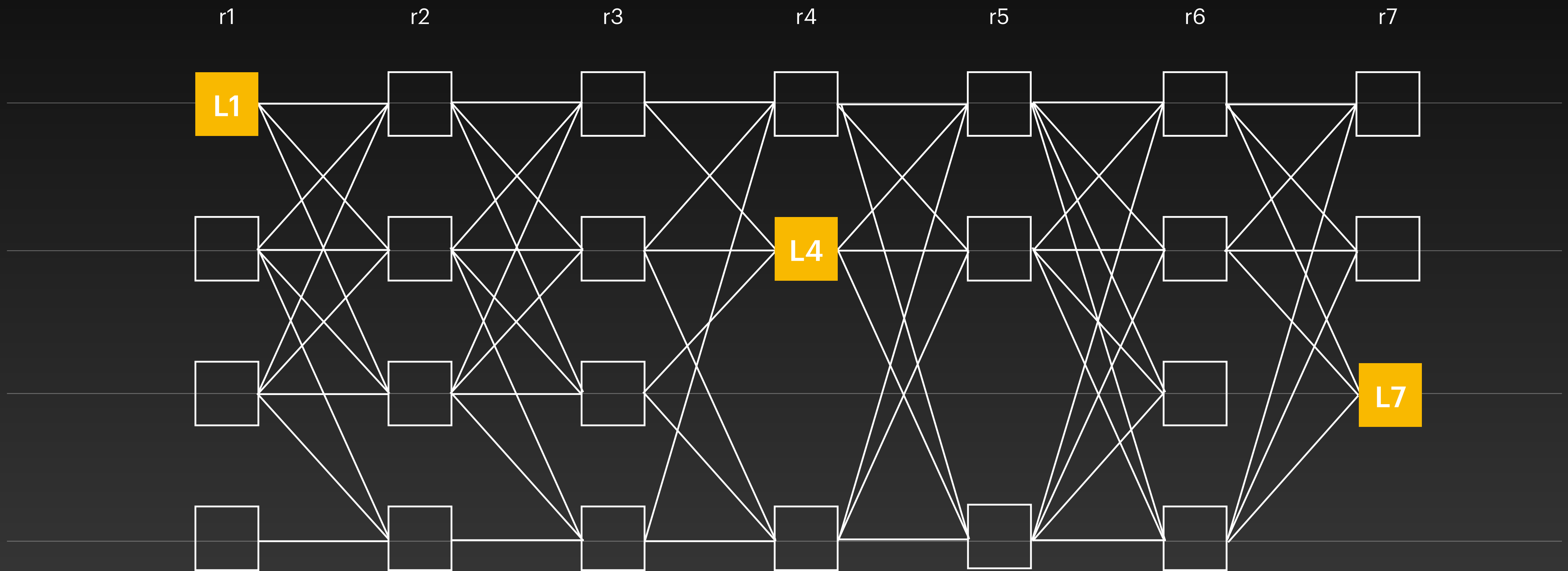


The Mysticeti DAG

Rule 3: All node run in parallel



The Mysticeti DAG

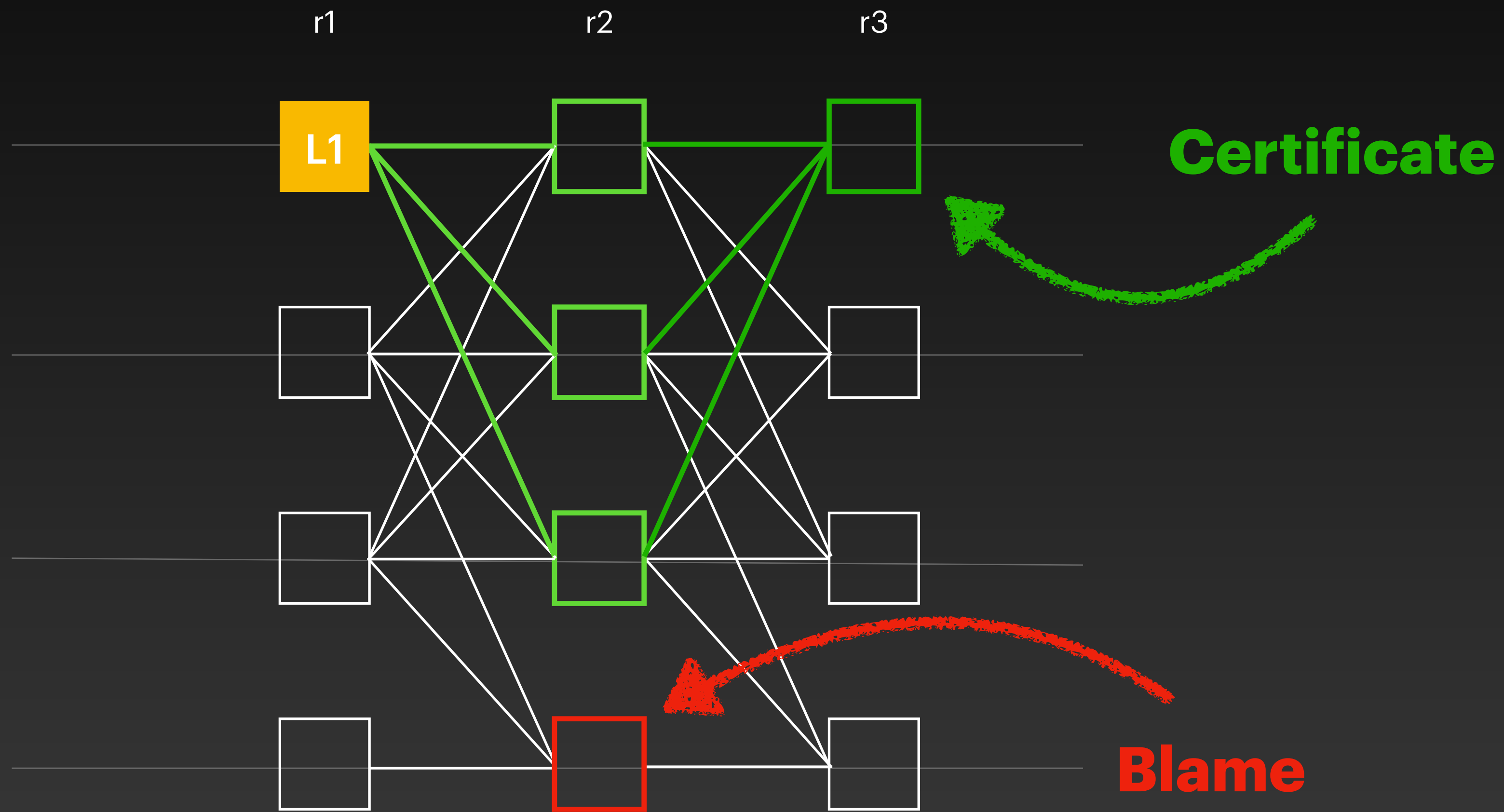


Main Ingredient:

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

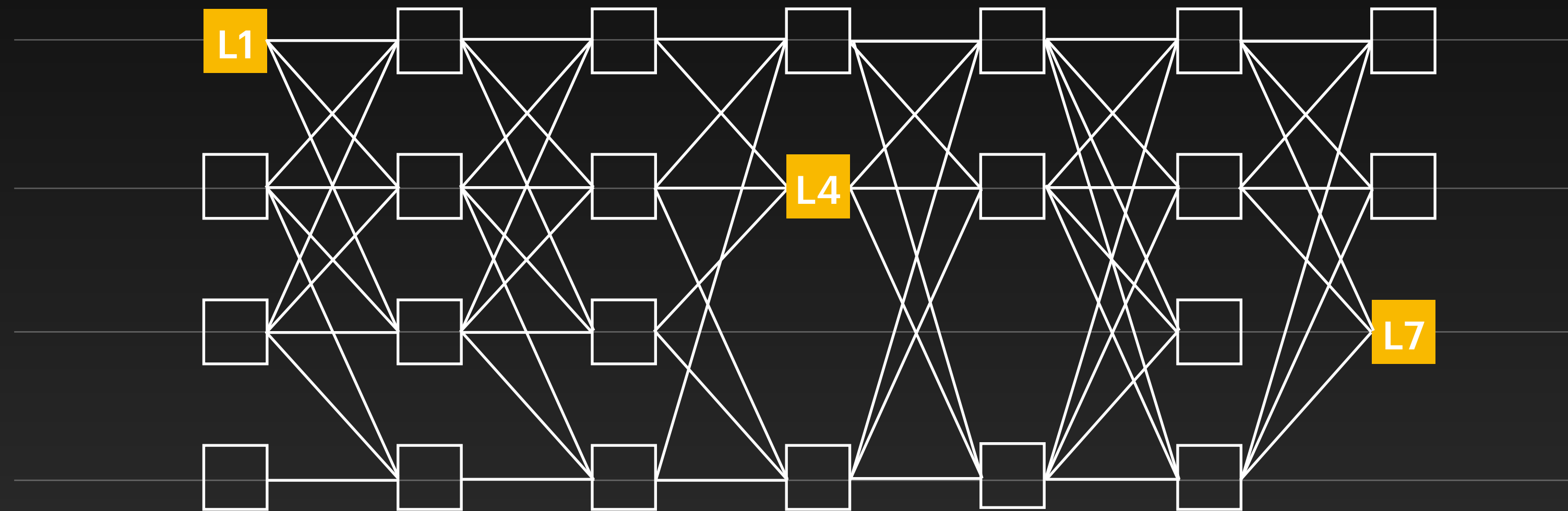
- Interpret BCB on DAG

Mysticeti-C

The consensus protocol

End Goal

Ordering leaders



- We focus on ordering leaders:

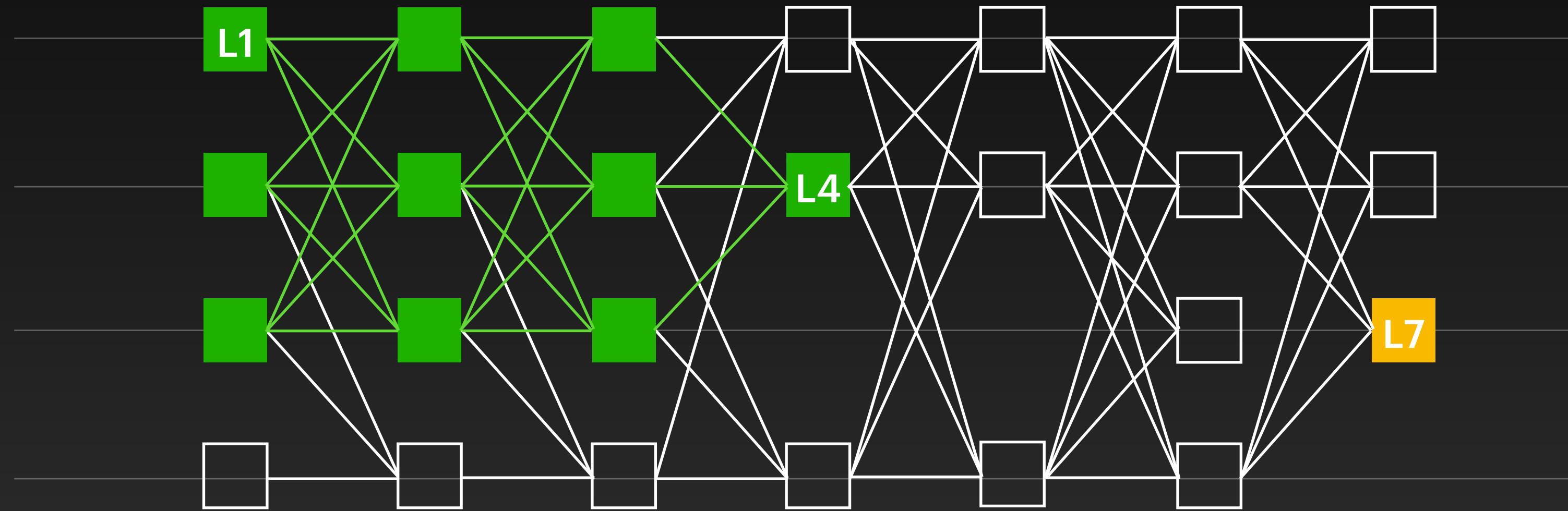
L1

L4

L7

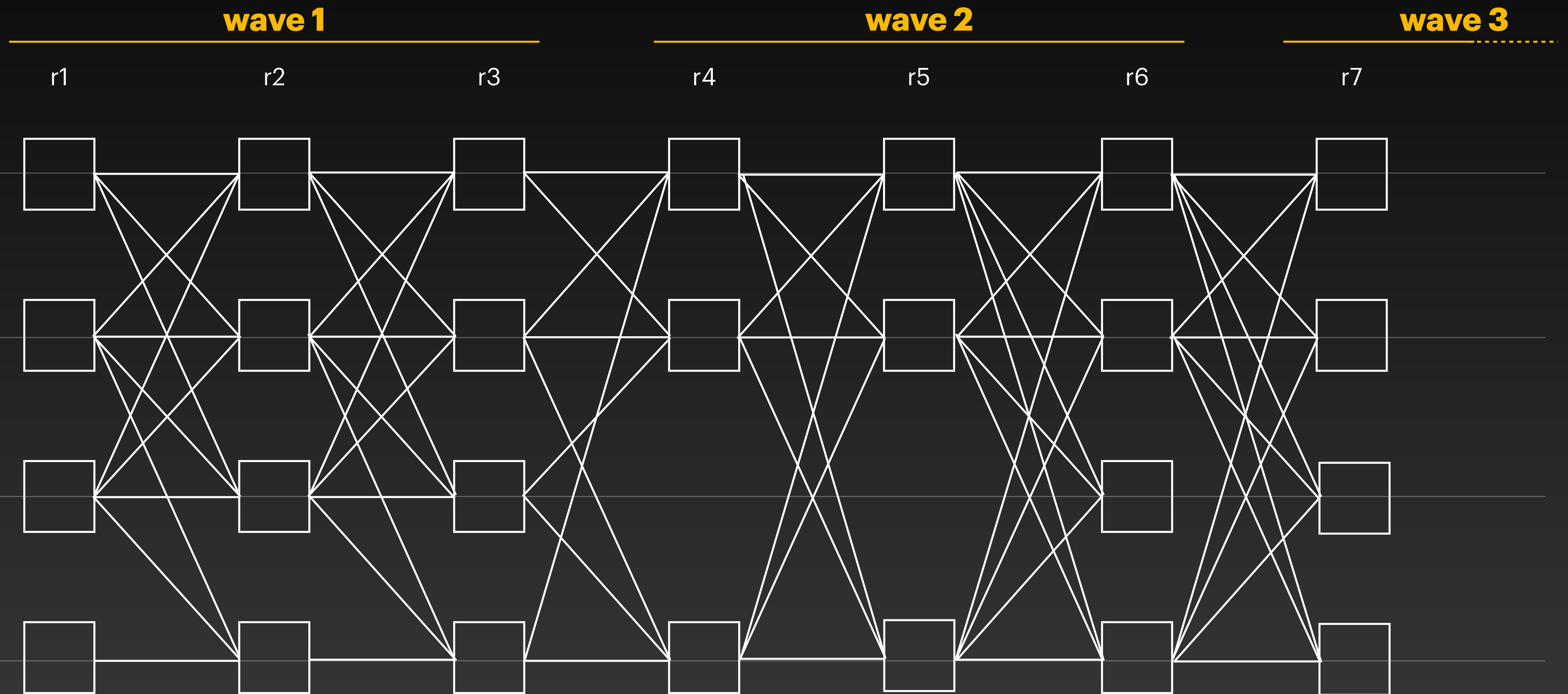
End Goal

Ordering leaders

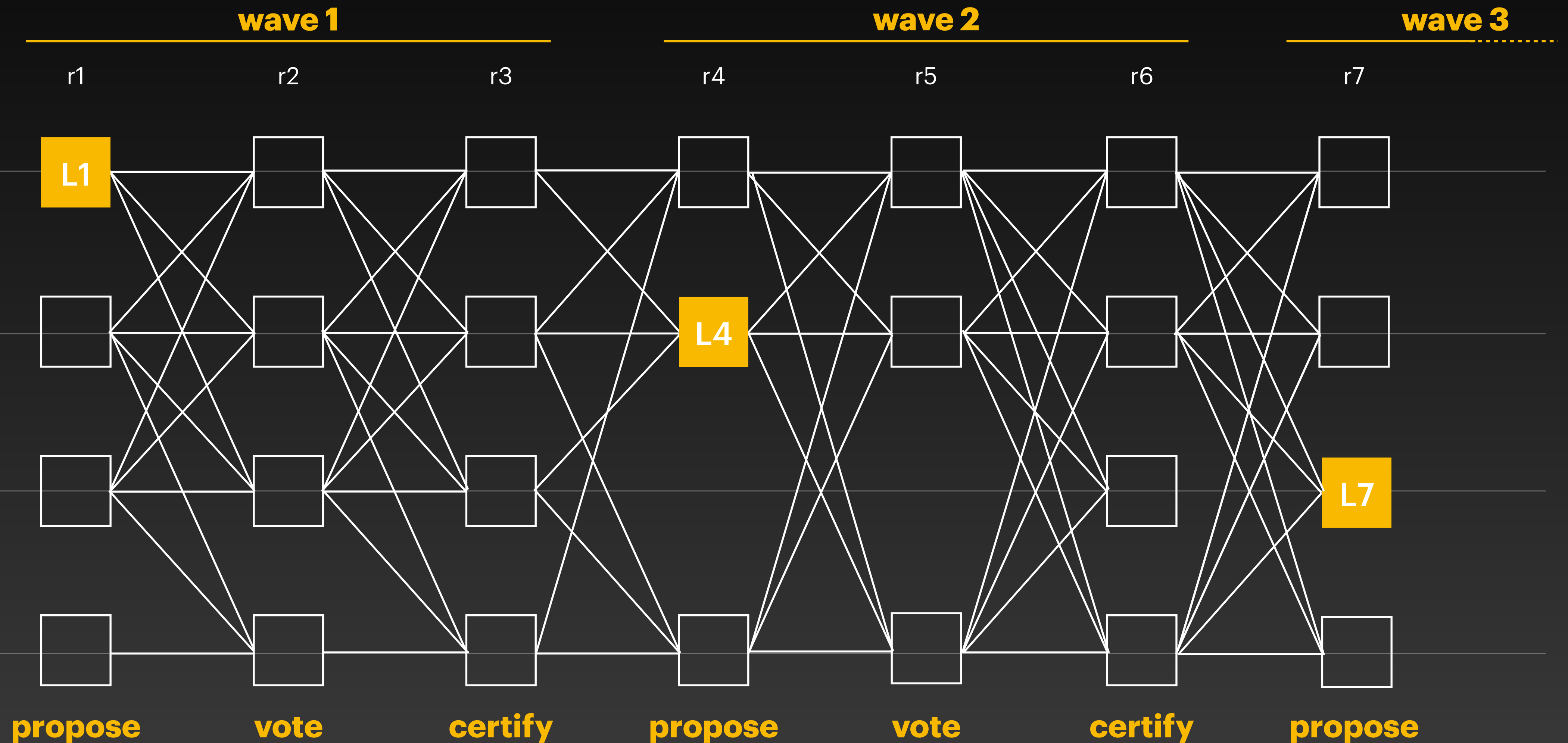


- We focus on ordering leaders: L1 L4 L7
- Linearising the sub-DAG is simple

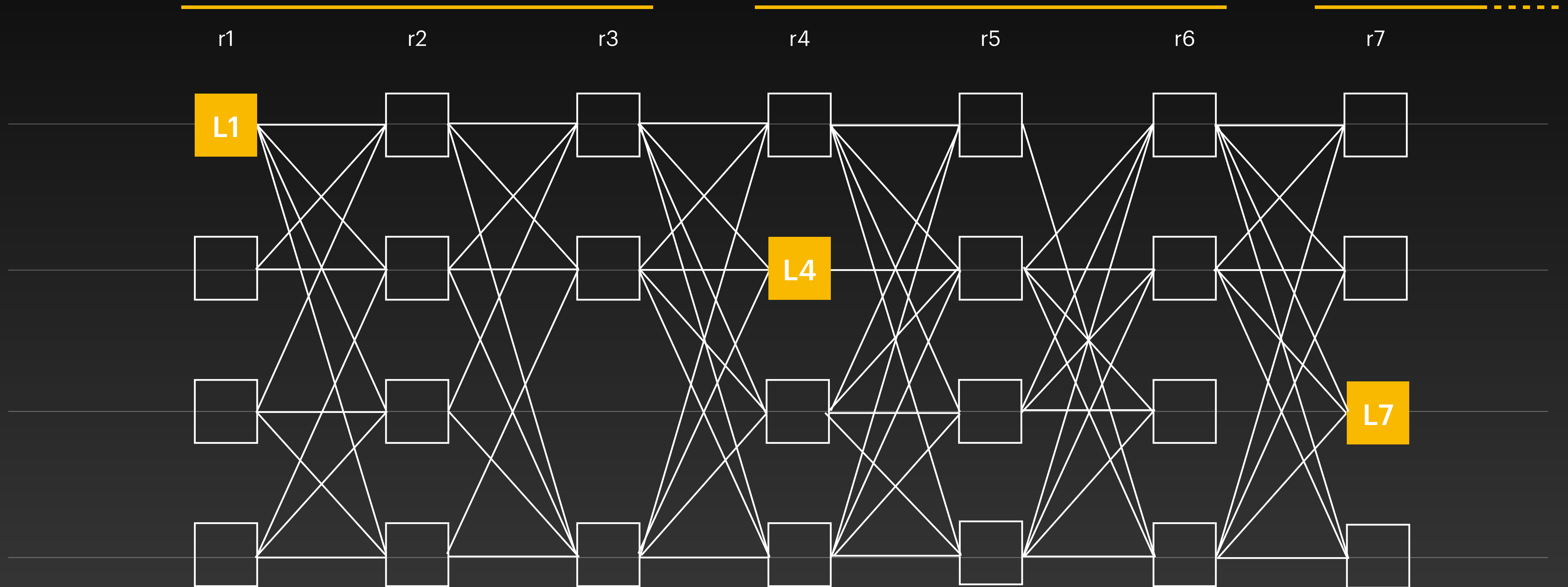
DAG Structure



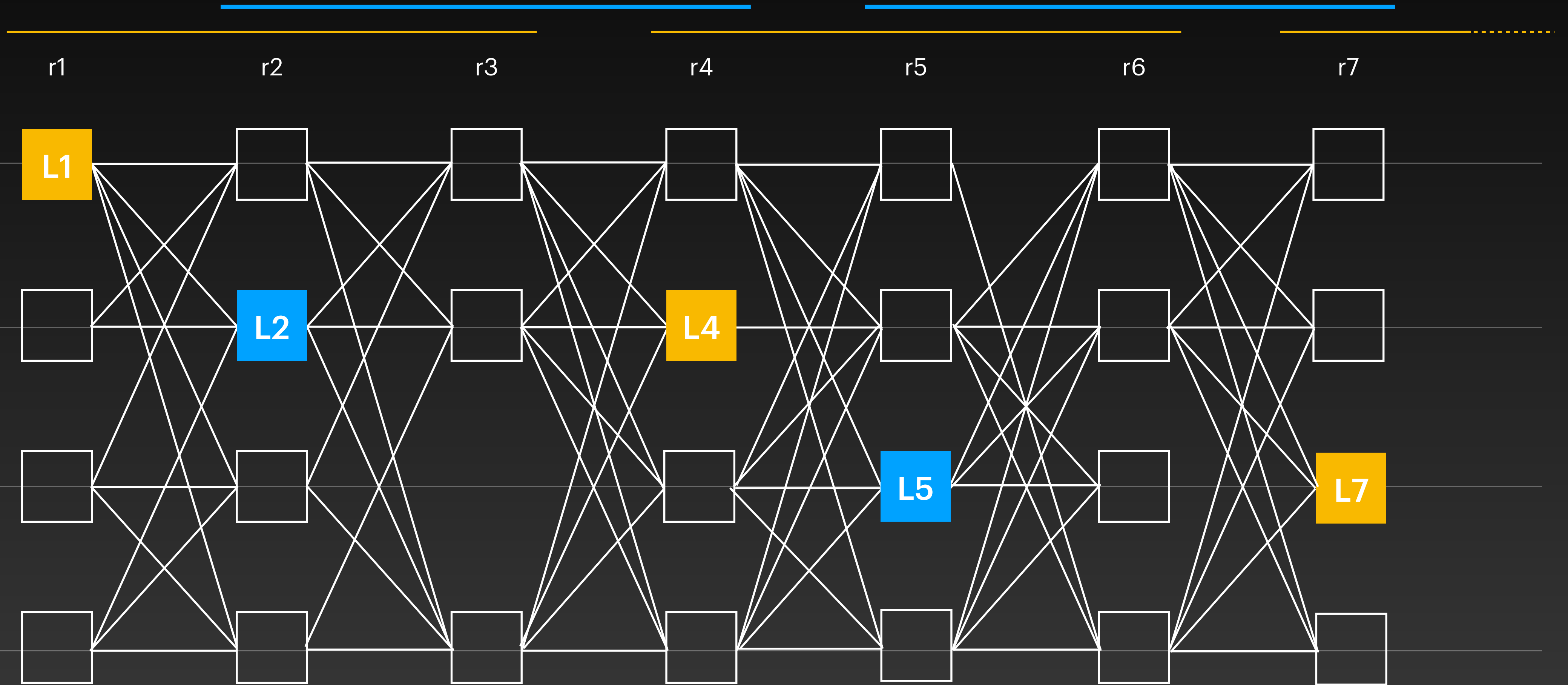
DAG Structure



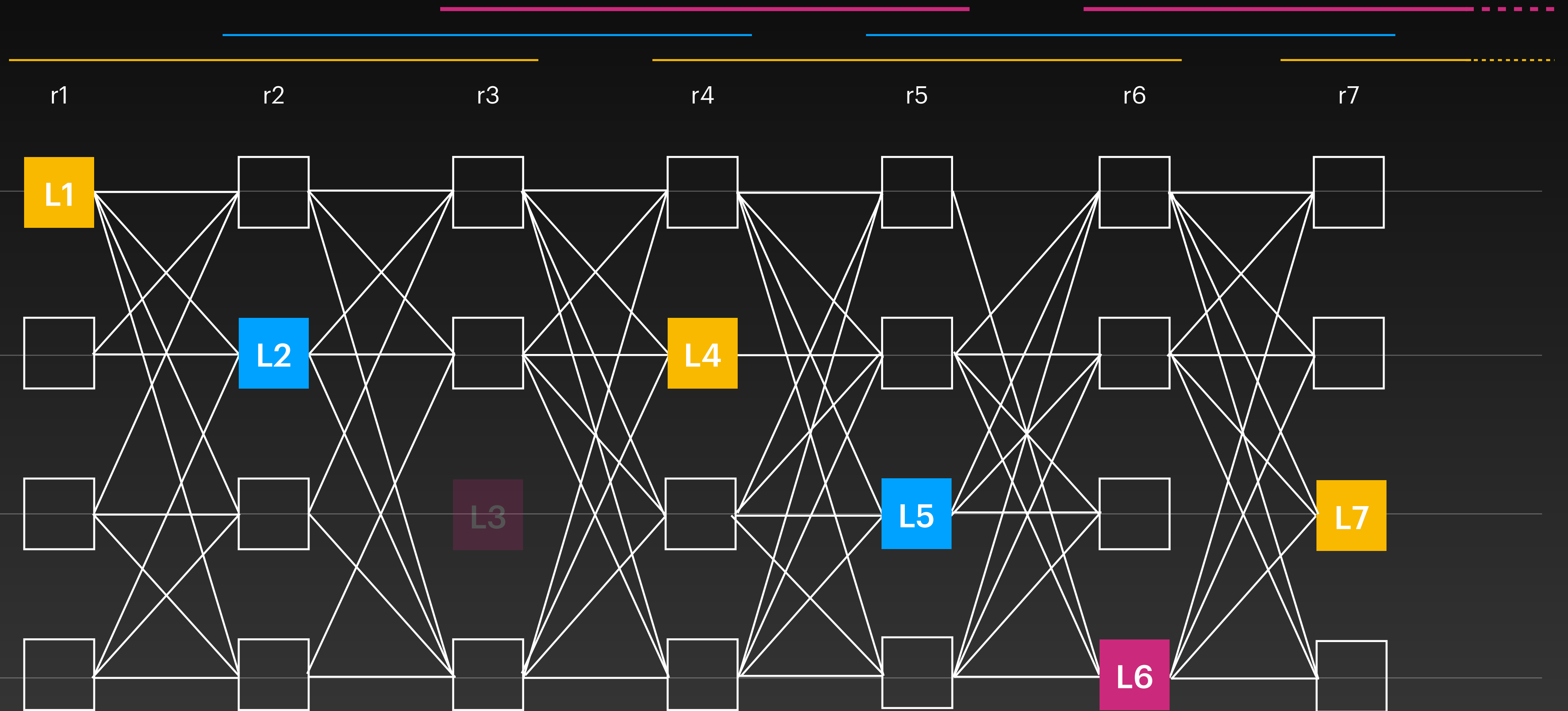
DAG Structure



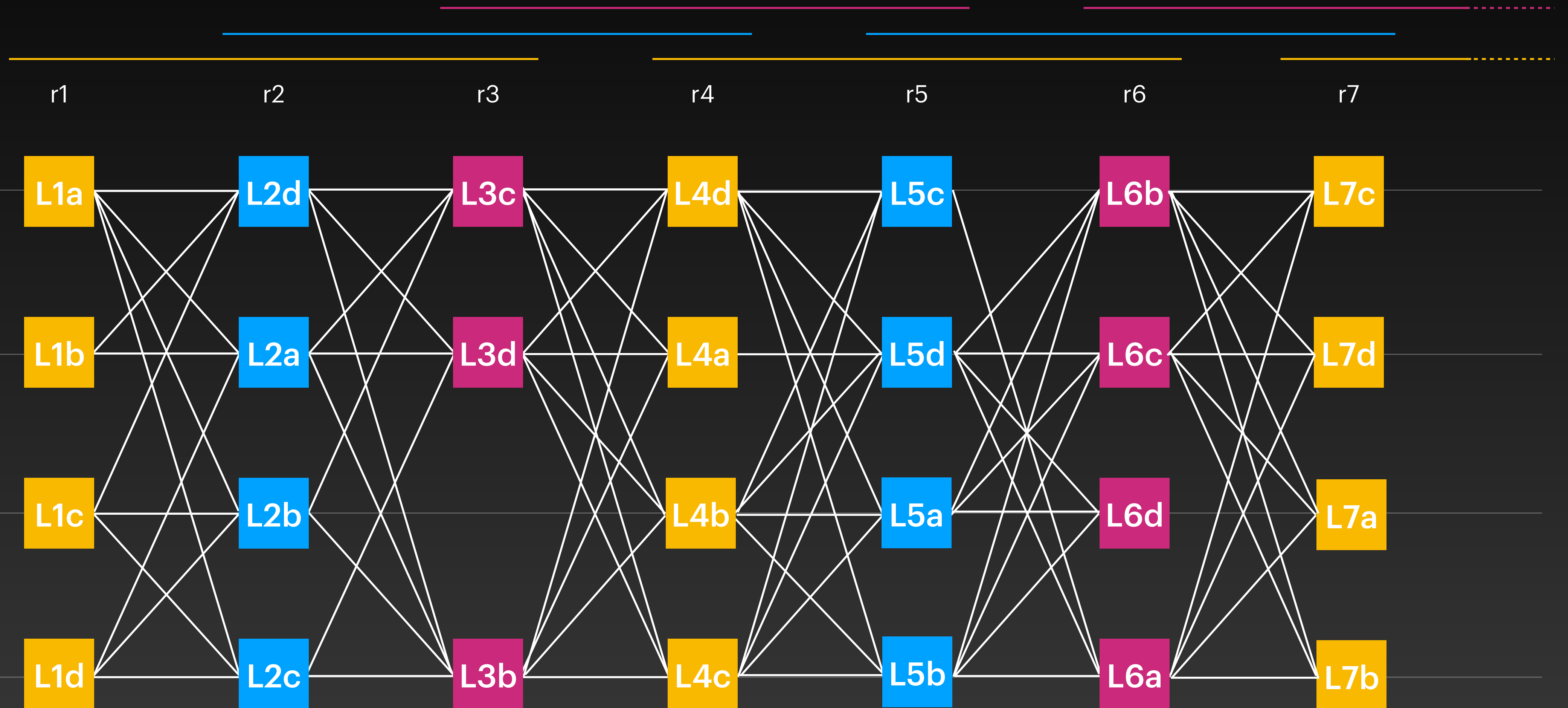
DAG Structure



DAG Structure

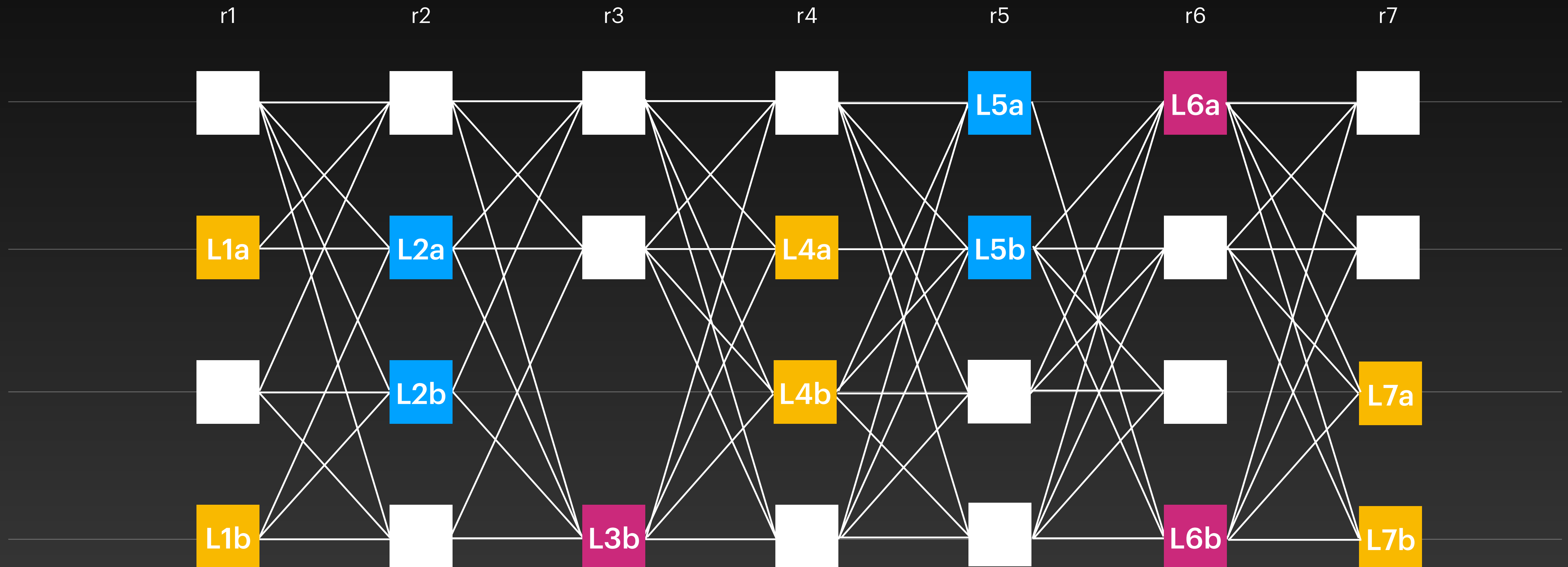


DAG Structure



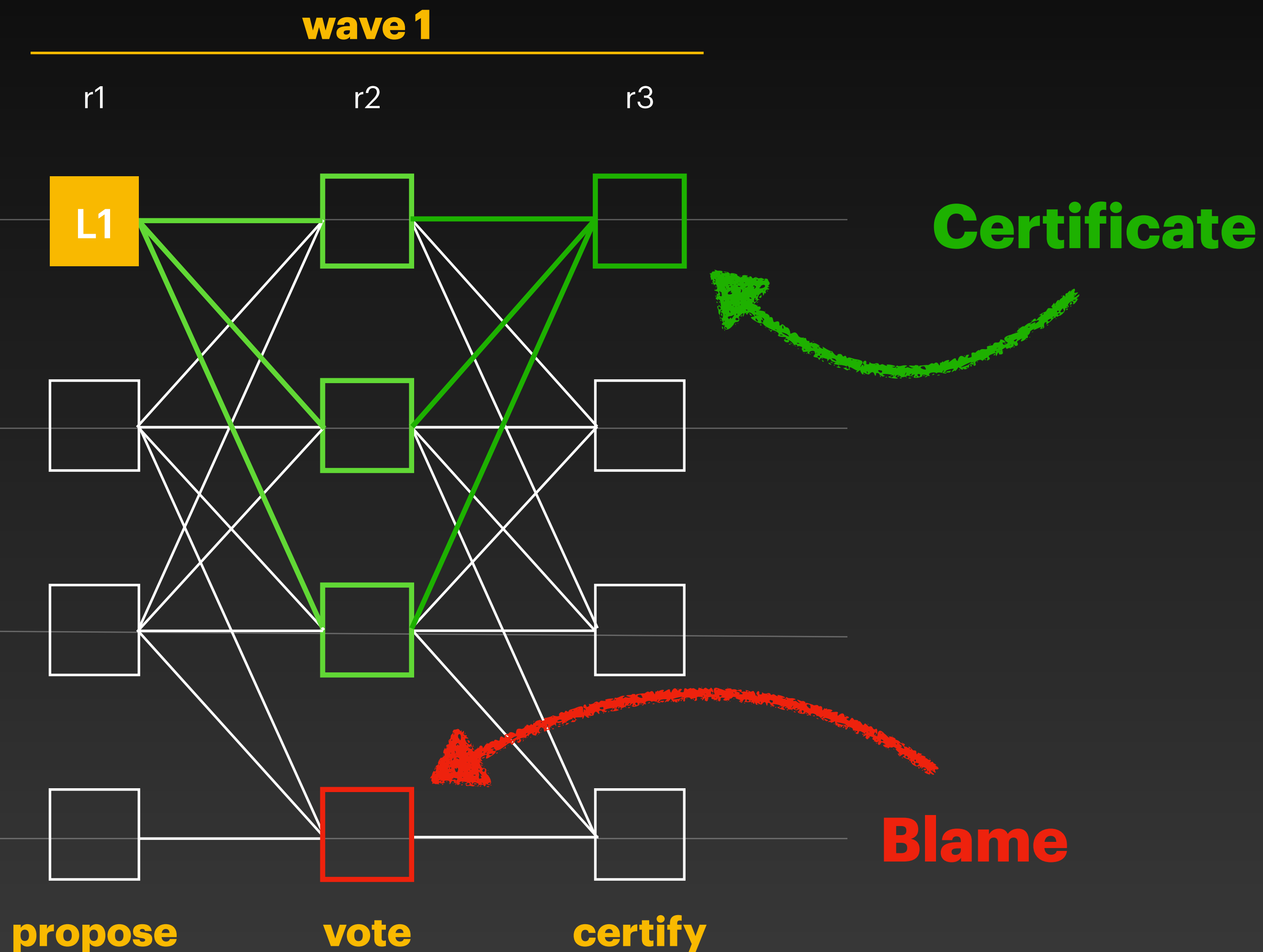
Practical Implementation

Select only 2 leaders per round



Interpreting DAG Patterns

Reminder



Direct Decision Rule

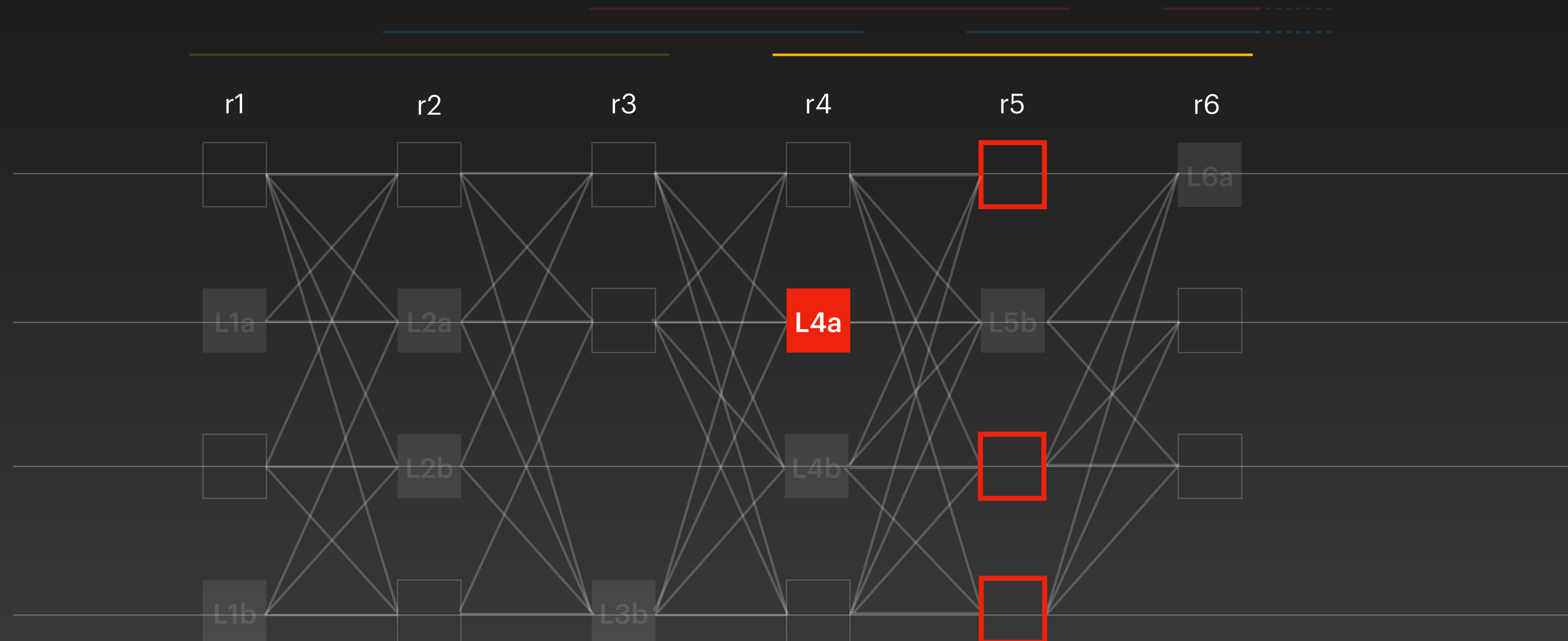
On each leader starting from highest round:

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

Direct Decision Rule

On each leader starting from highest round:

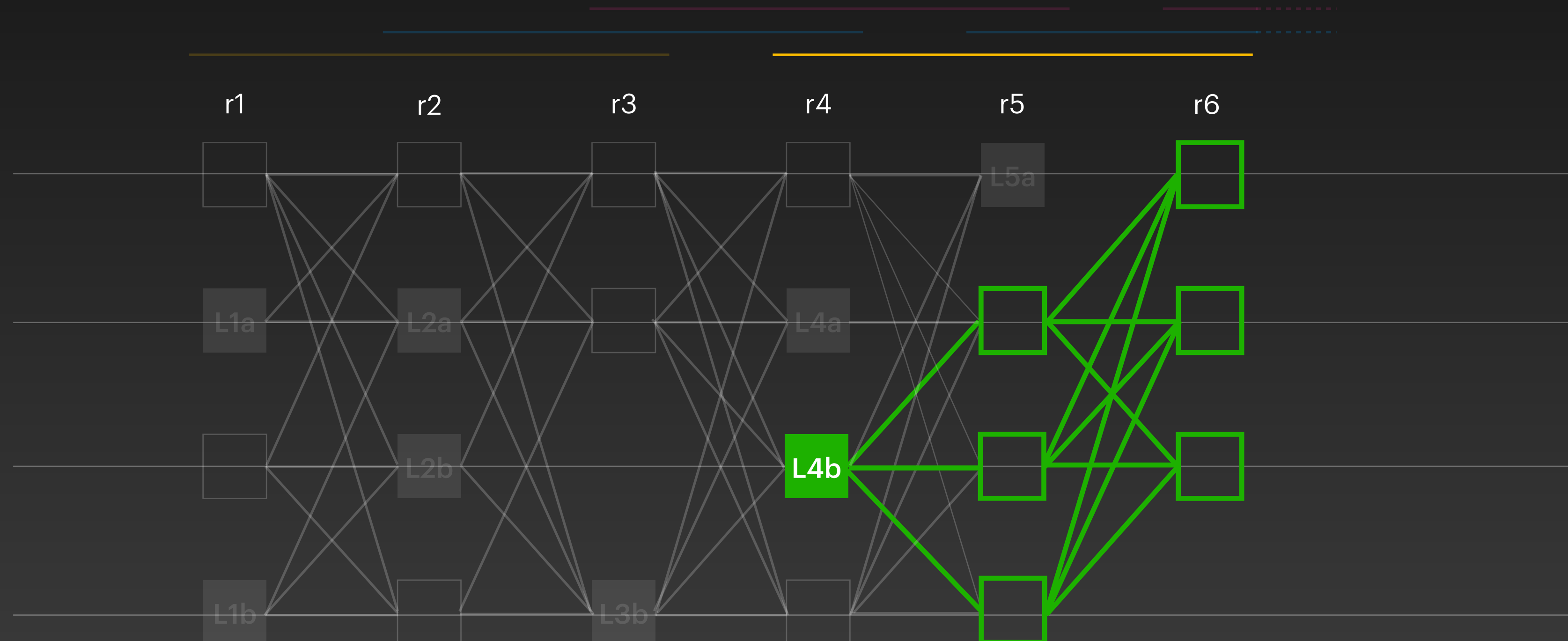
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Direct Decision Rule

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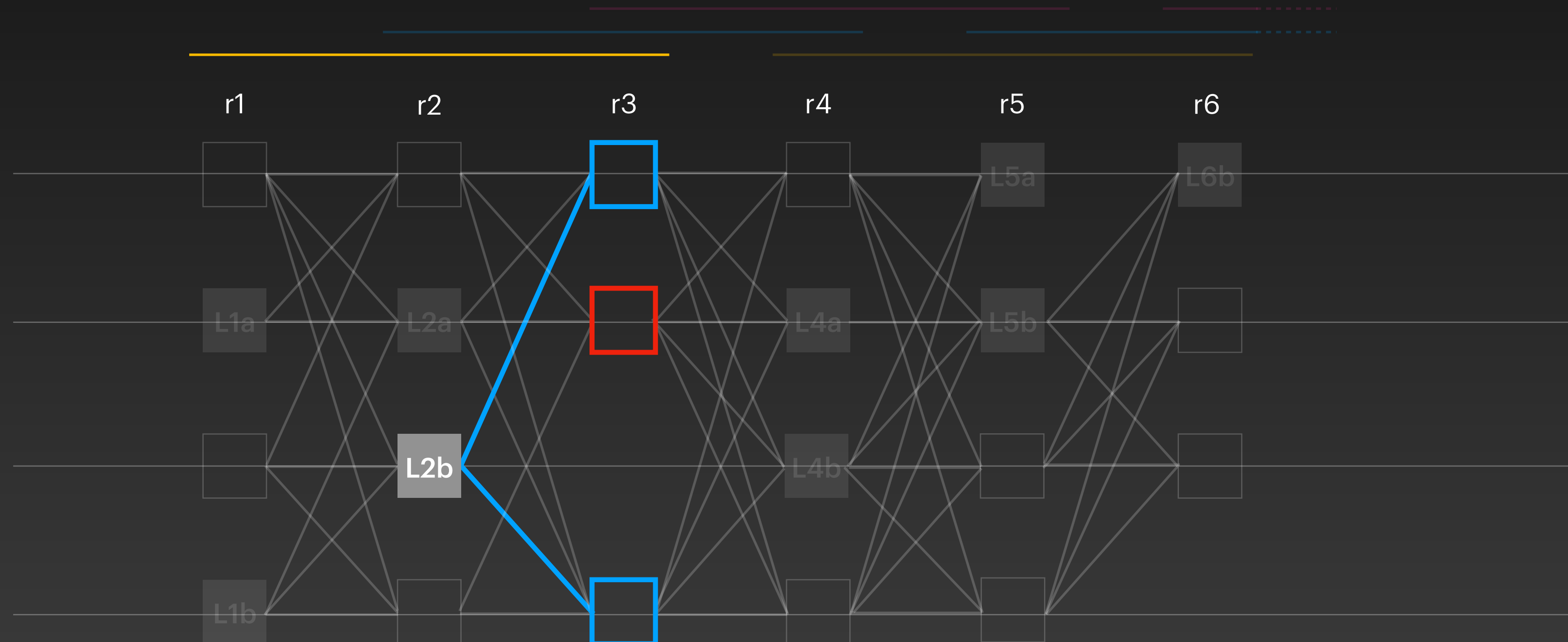
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Direct Decision Rule

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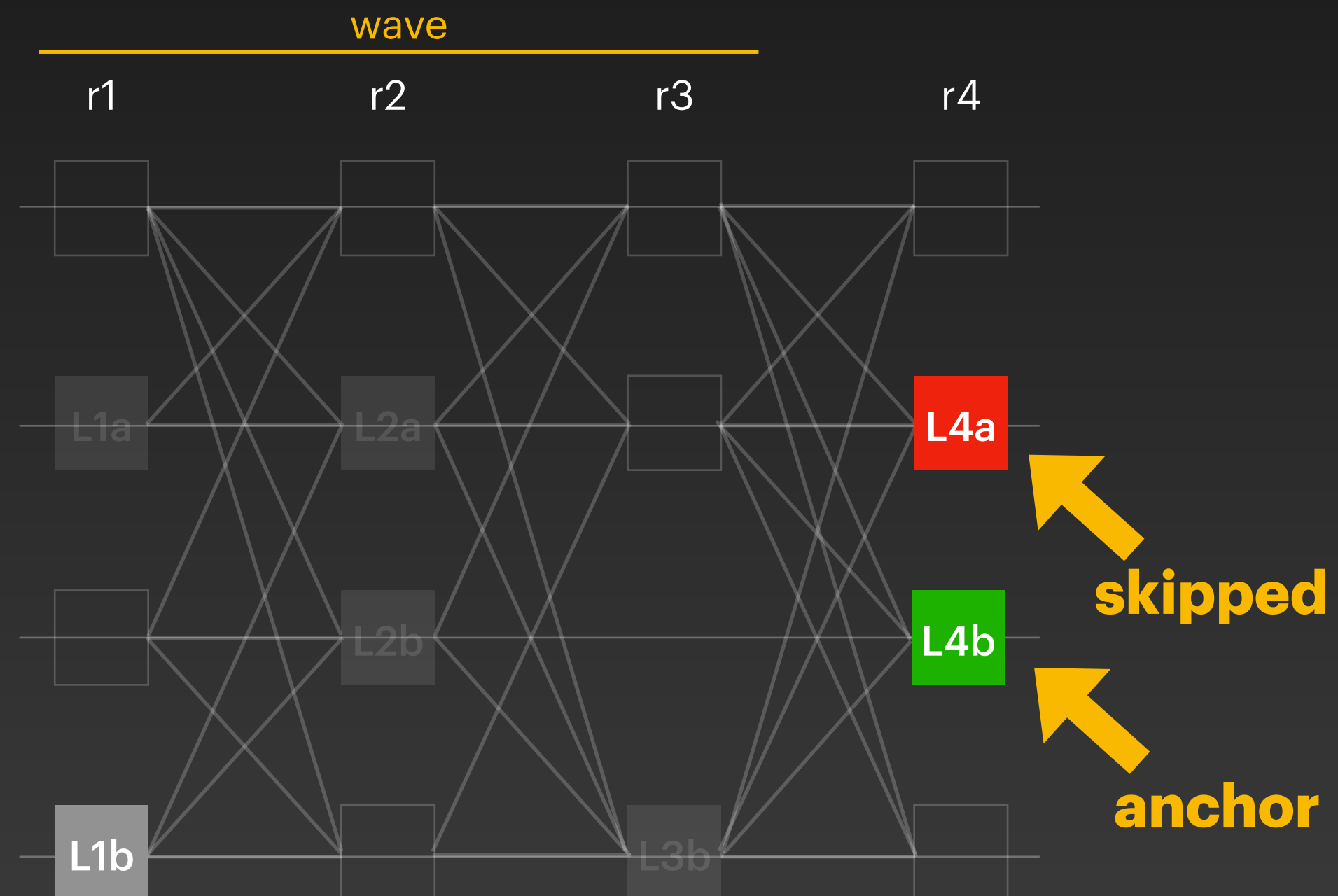


Indirect Decision Rule

Indirect Decision Rule

1. Find Anchor

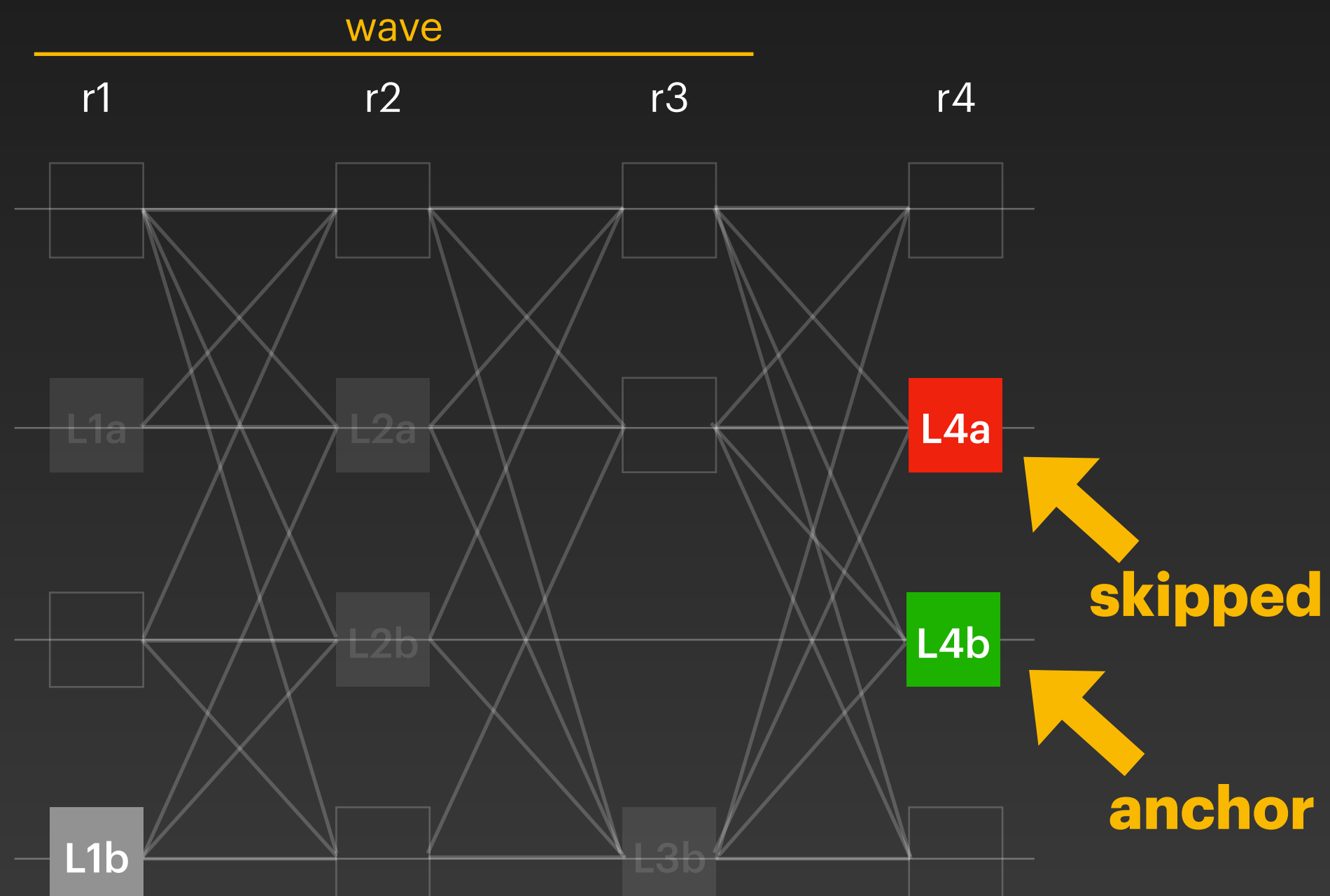
- First block with round $> r+2$ that is **Commit** or **Undecided**



Indirect Decision Rule

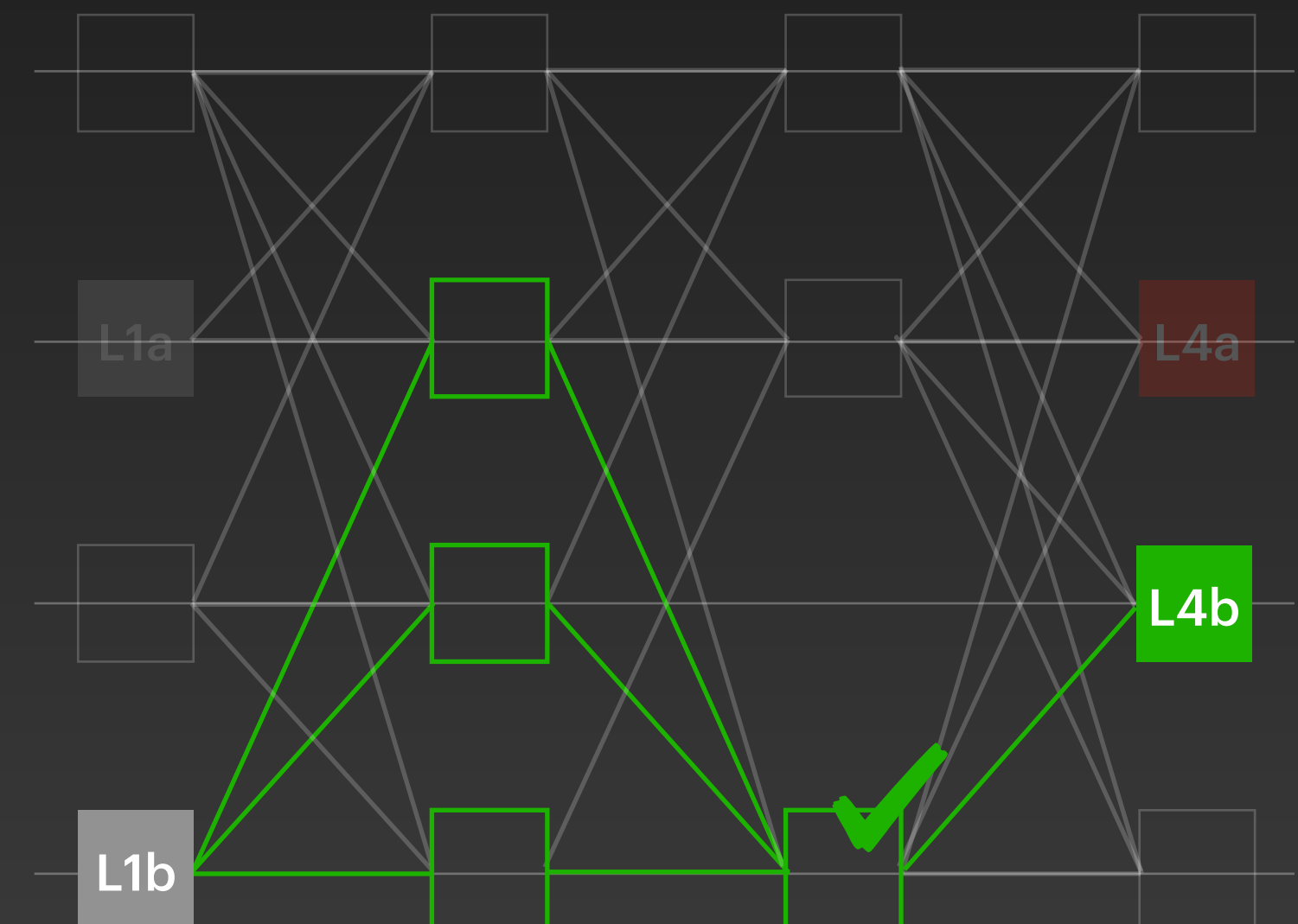
1. Find Anchor

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

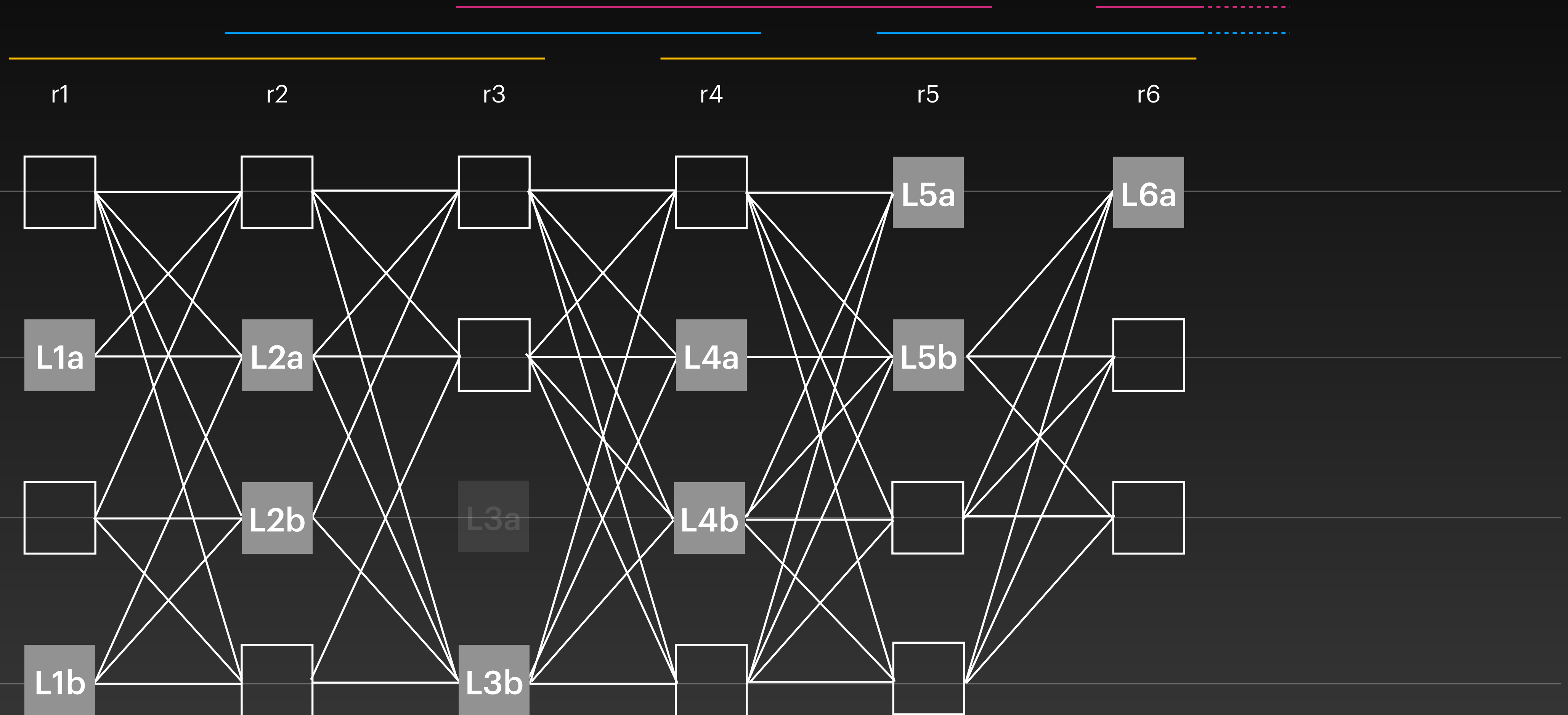


2. Certified link

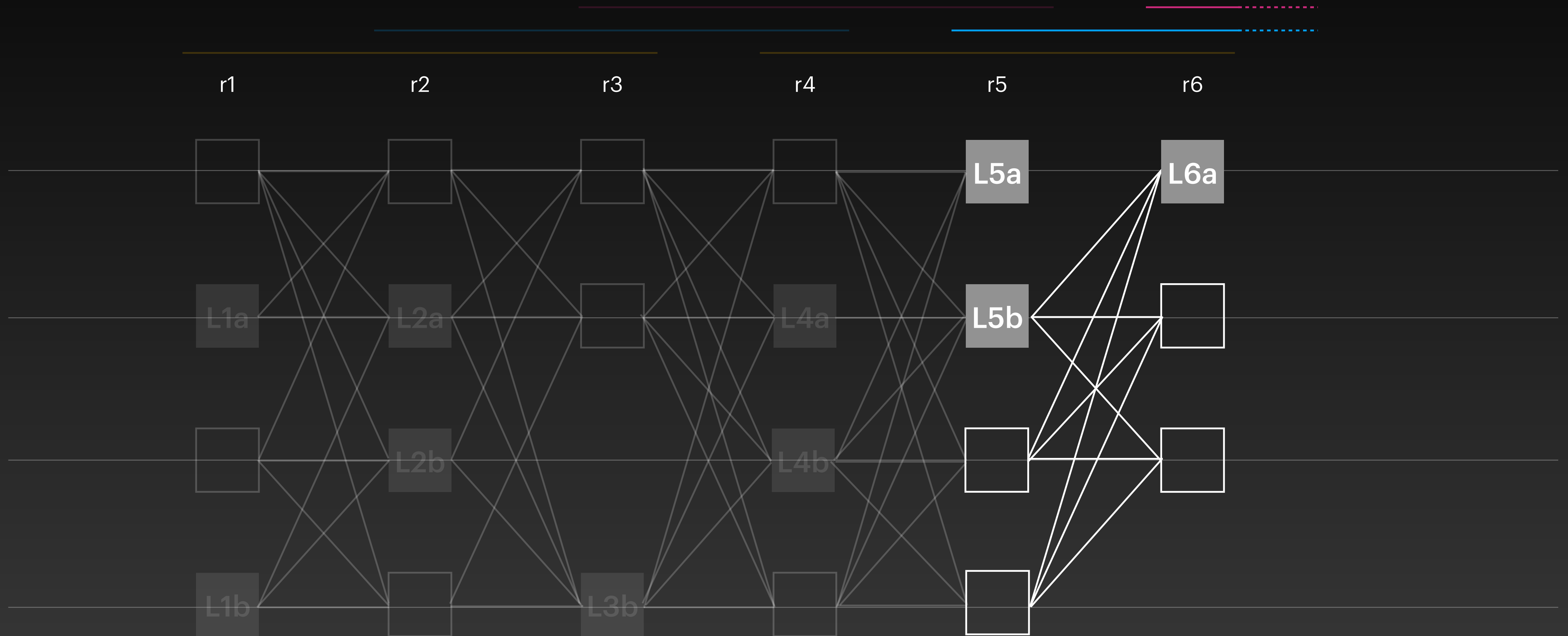
- Commit** if
 $B \leftrightarrow \text{certified link} \leftrightarrow A$
otherwise **Skip**



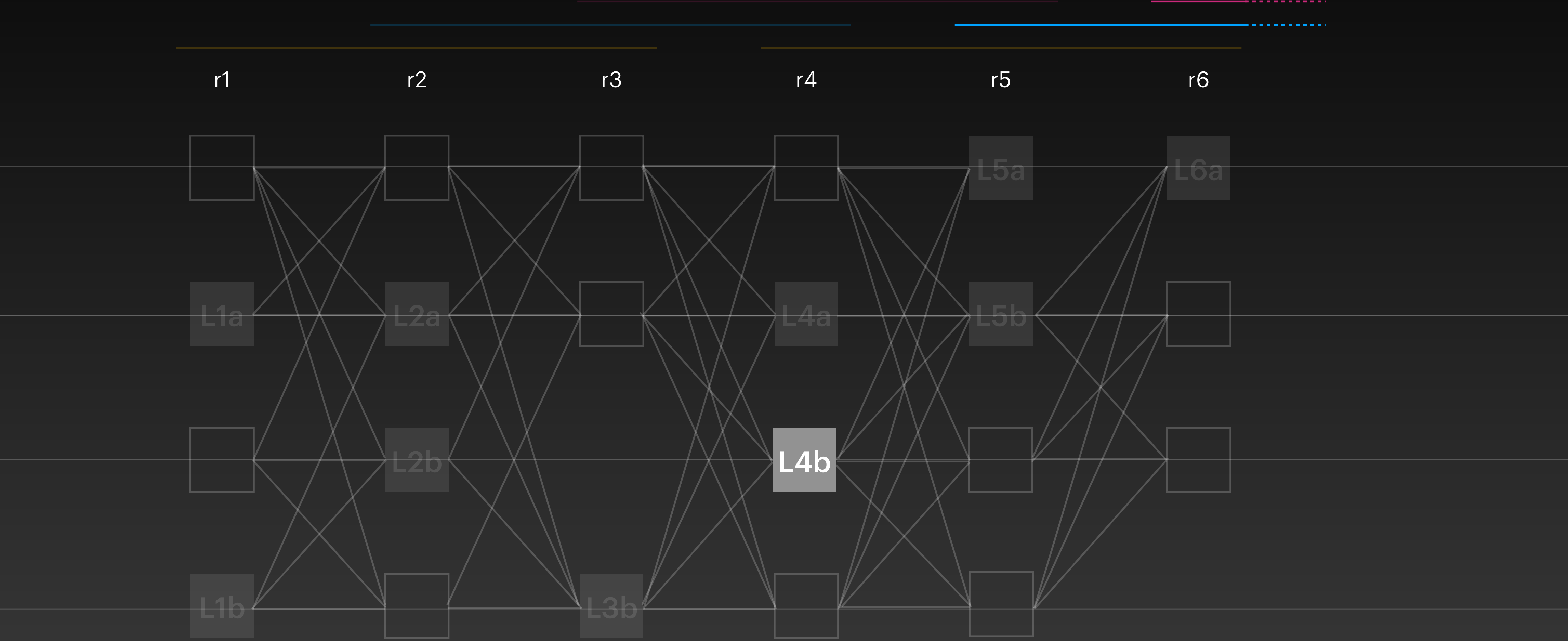
All Start at Undecided



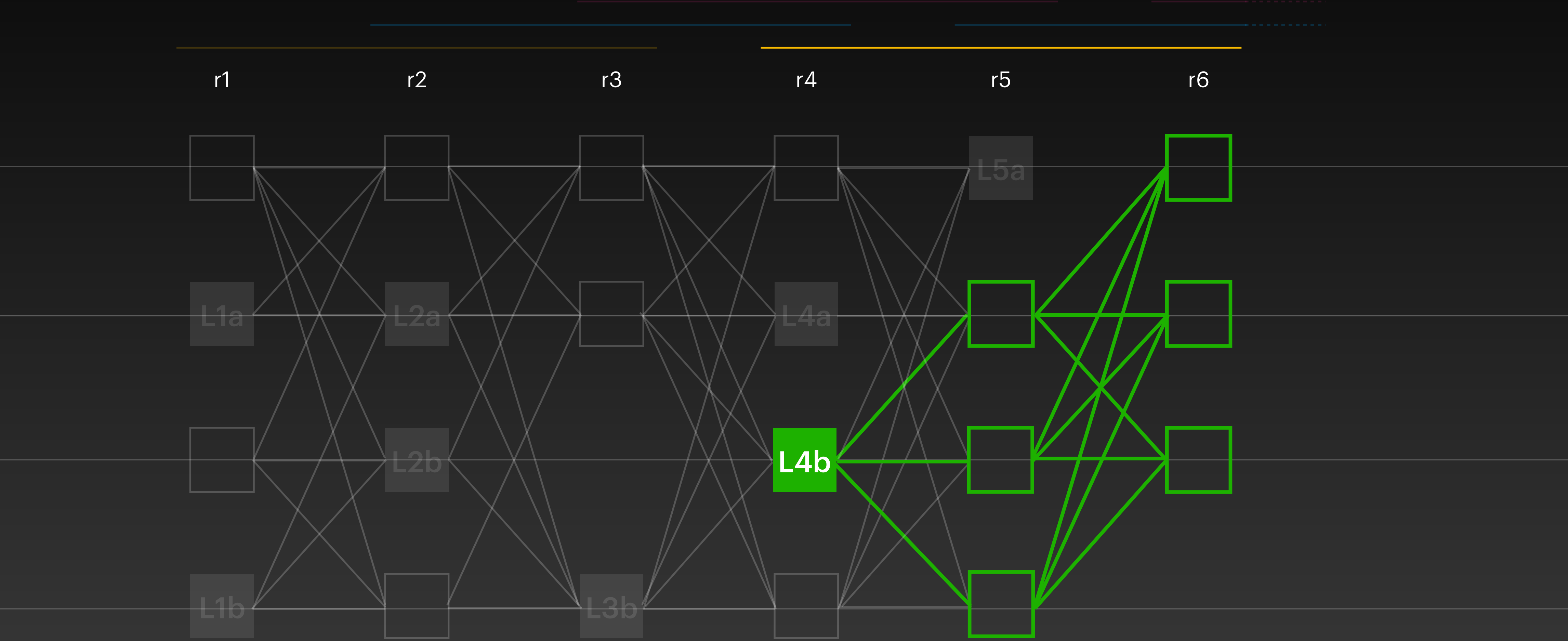
Ignore Incomplete Waves



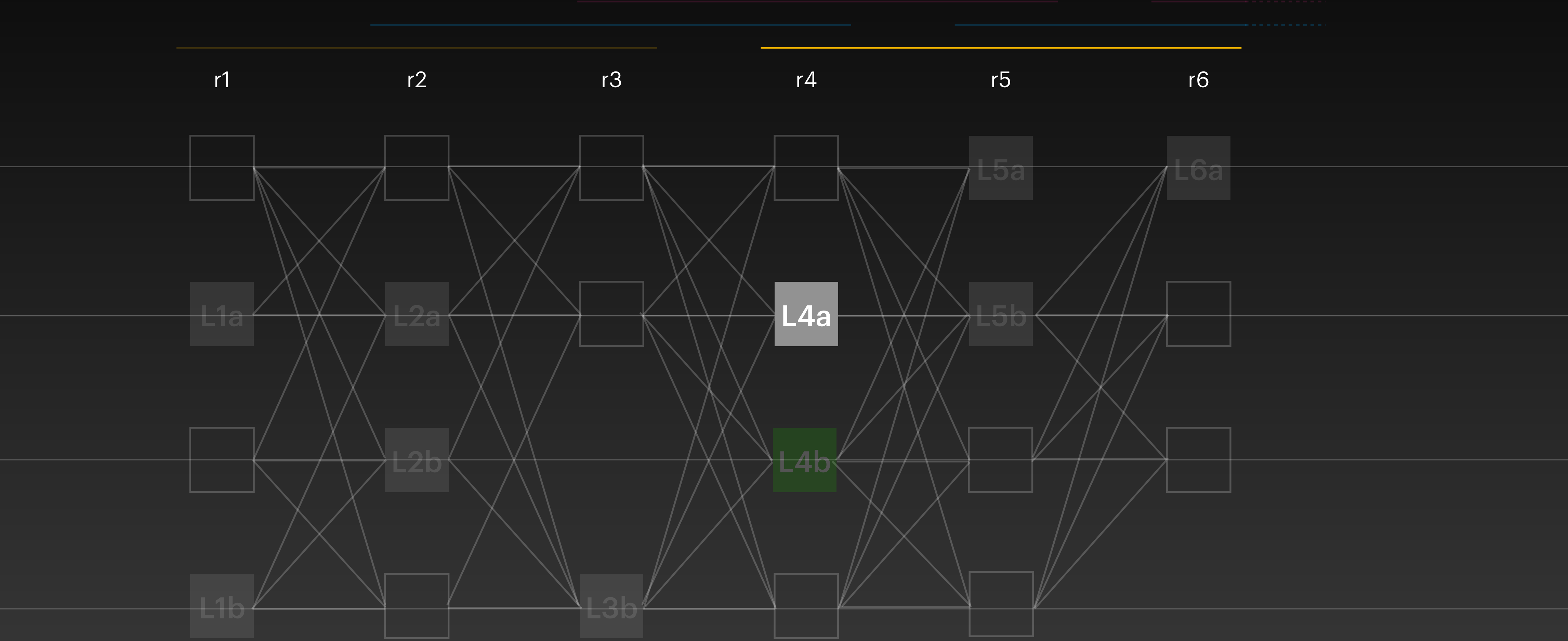
Apply Direct Rule



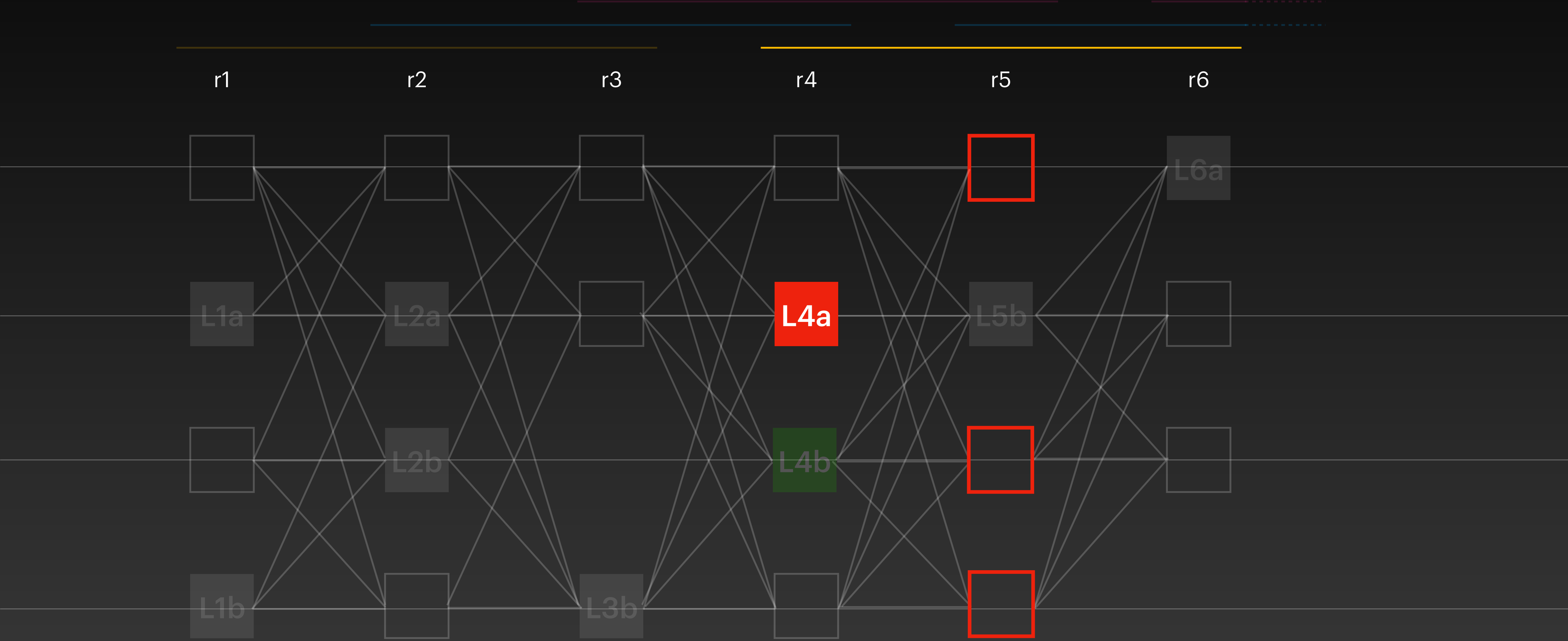
Apply Direct Rule



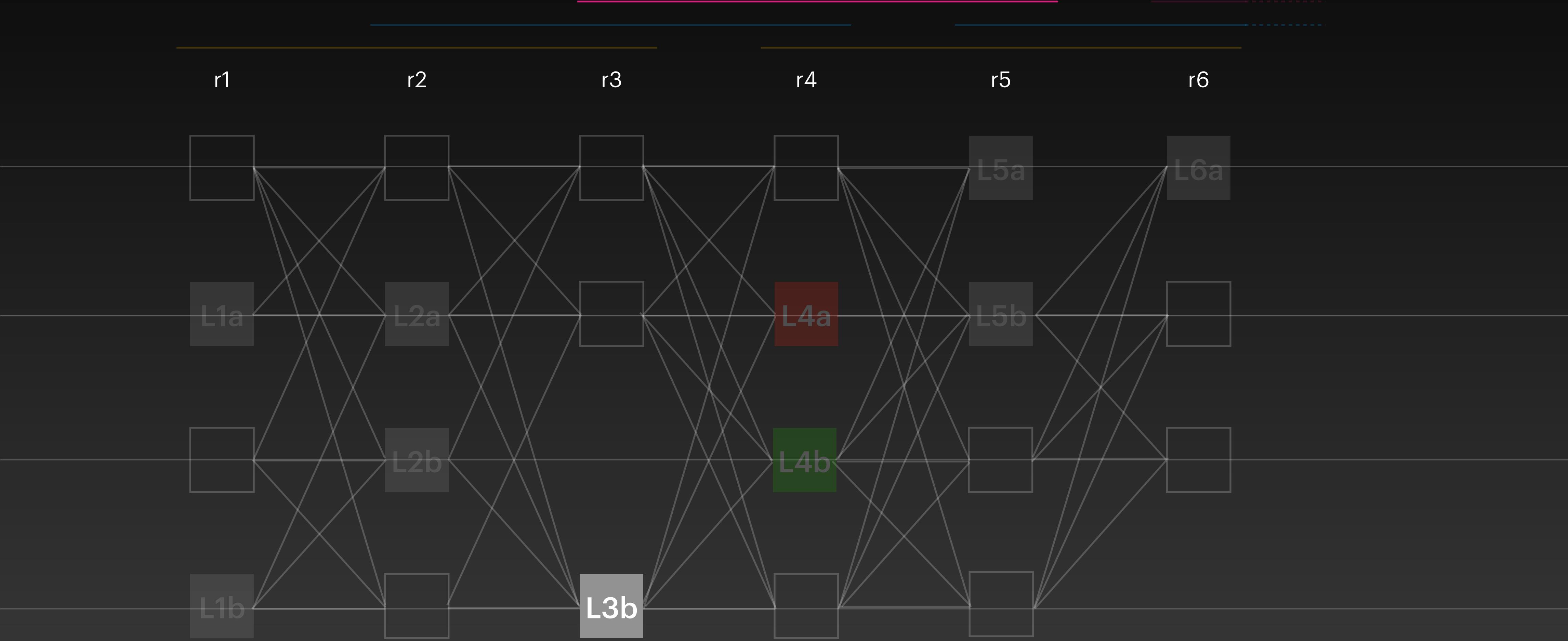
Apply Direct Rule



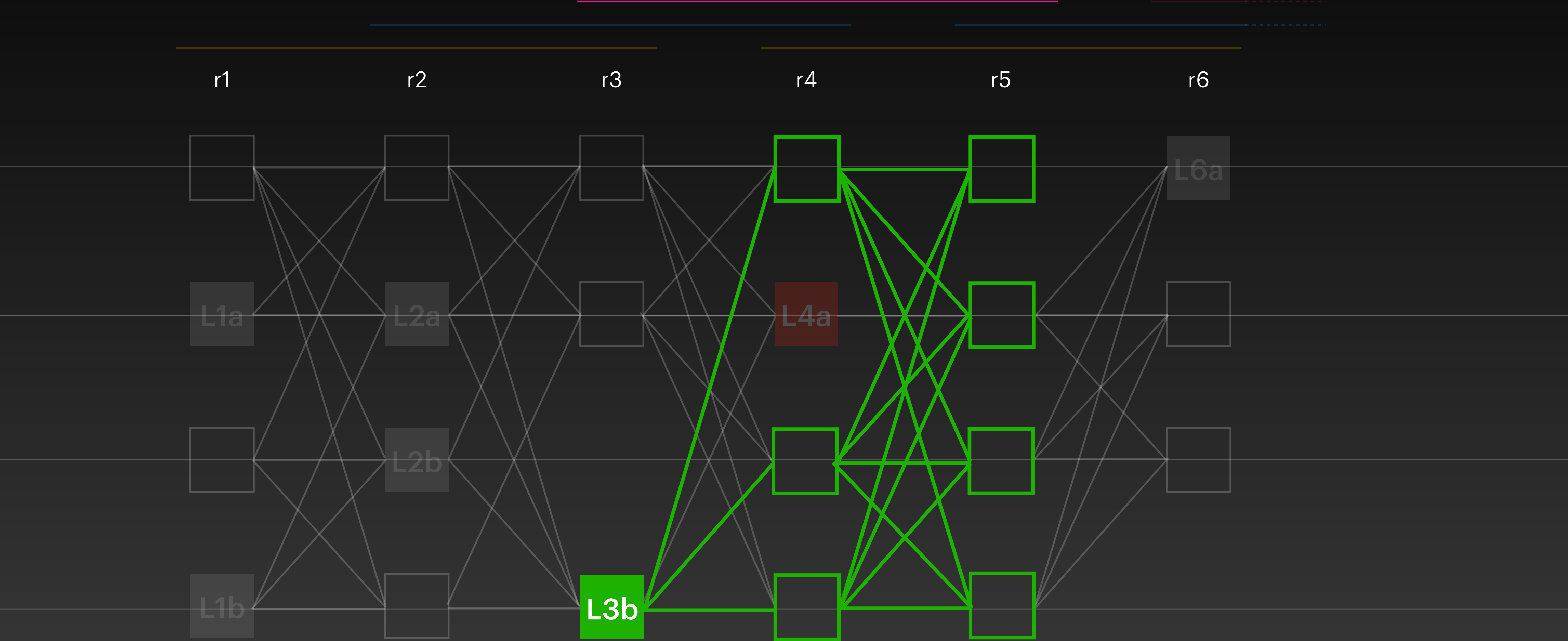
Apply Direct Rule



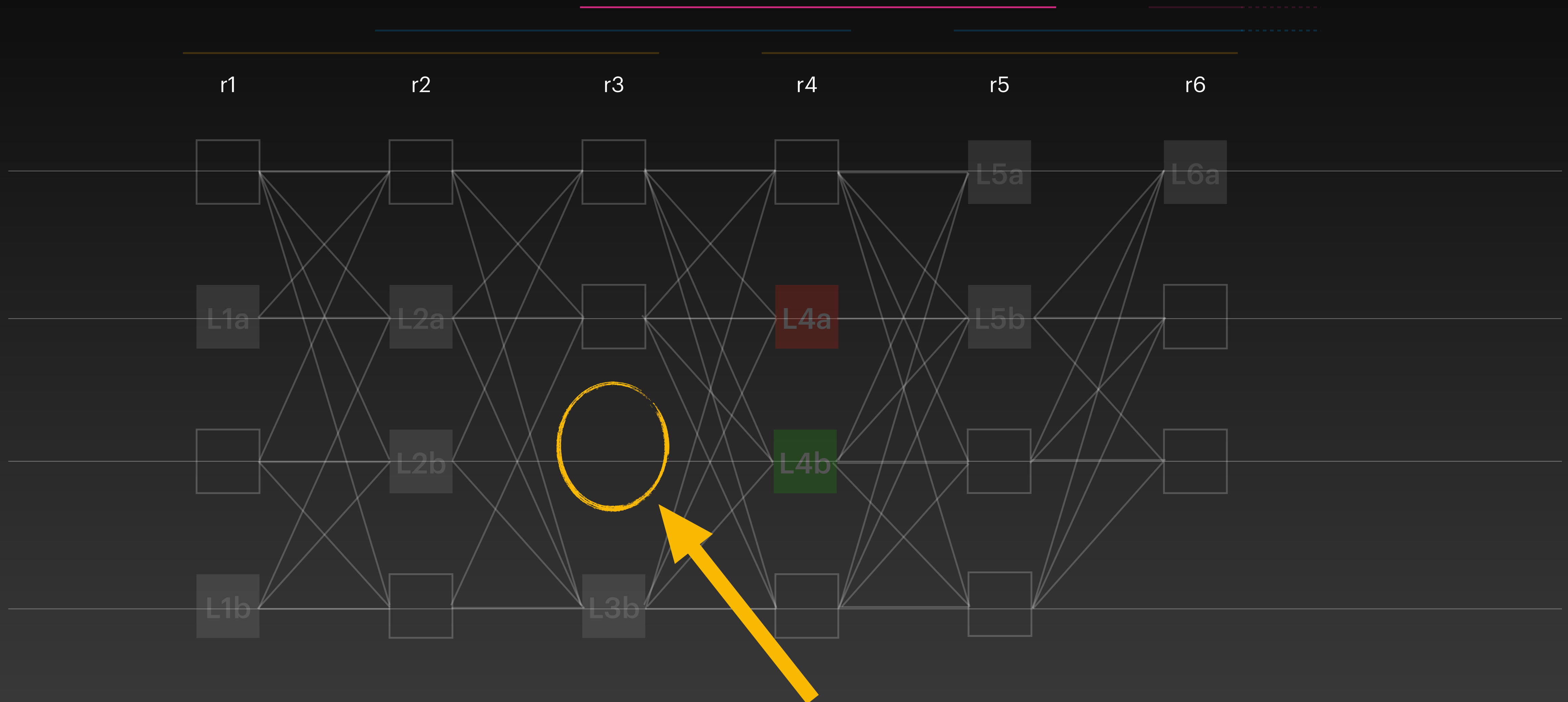
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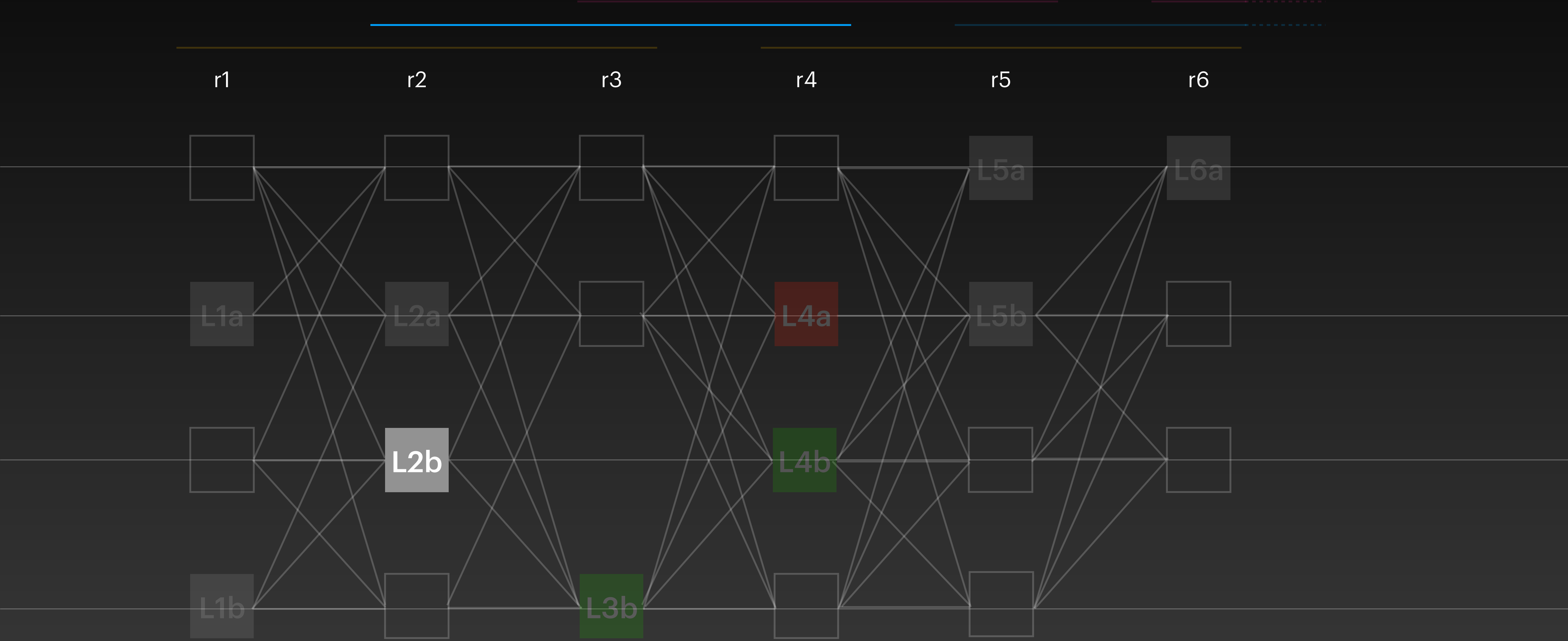
Apply Direct Rule



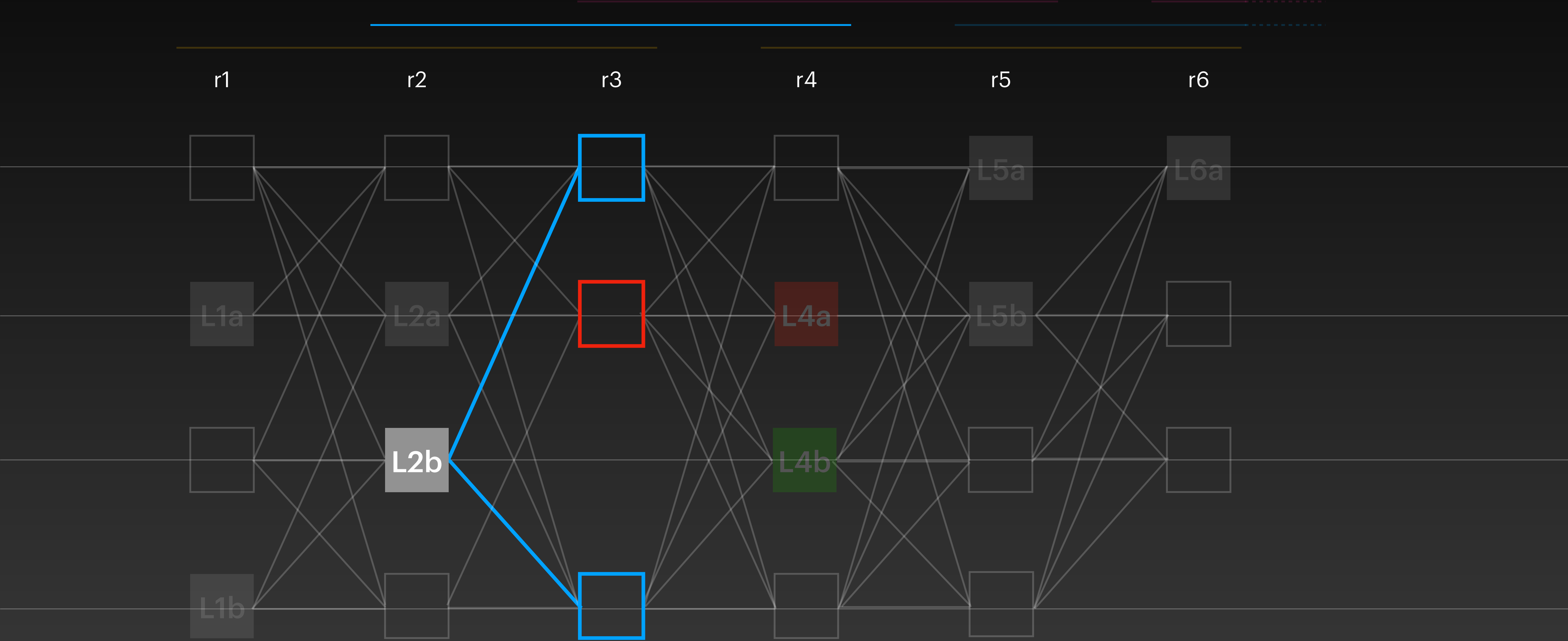
Ignore Missing Leader



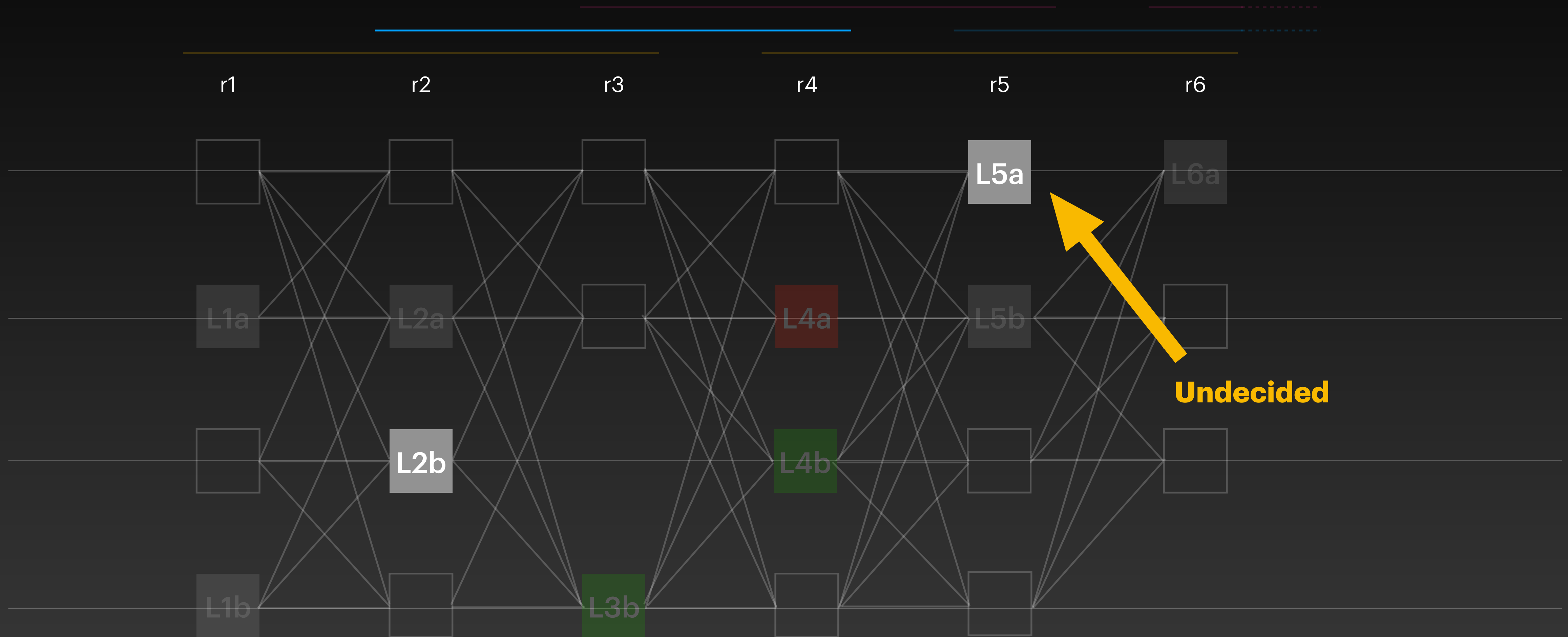
Apply Direct Rule



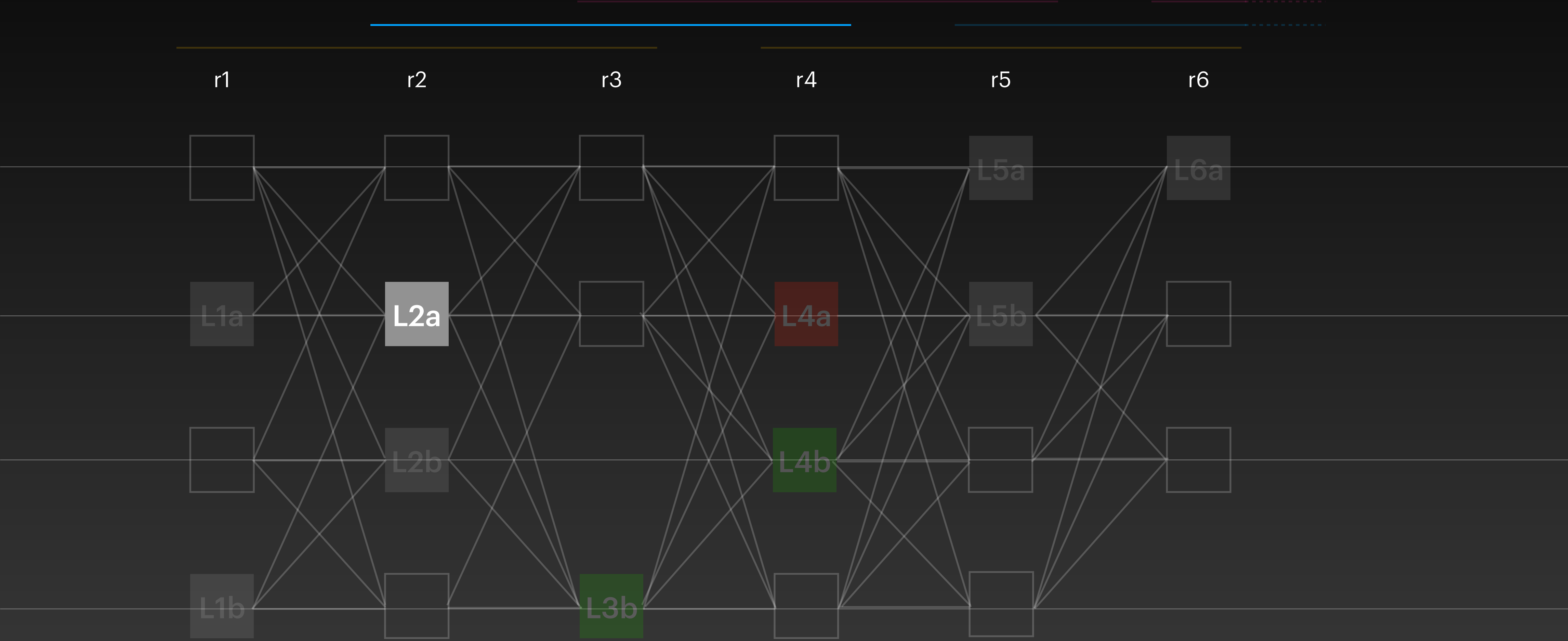
Apply Direct Rule



Apply Indirect Rule

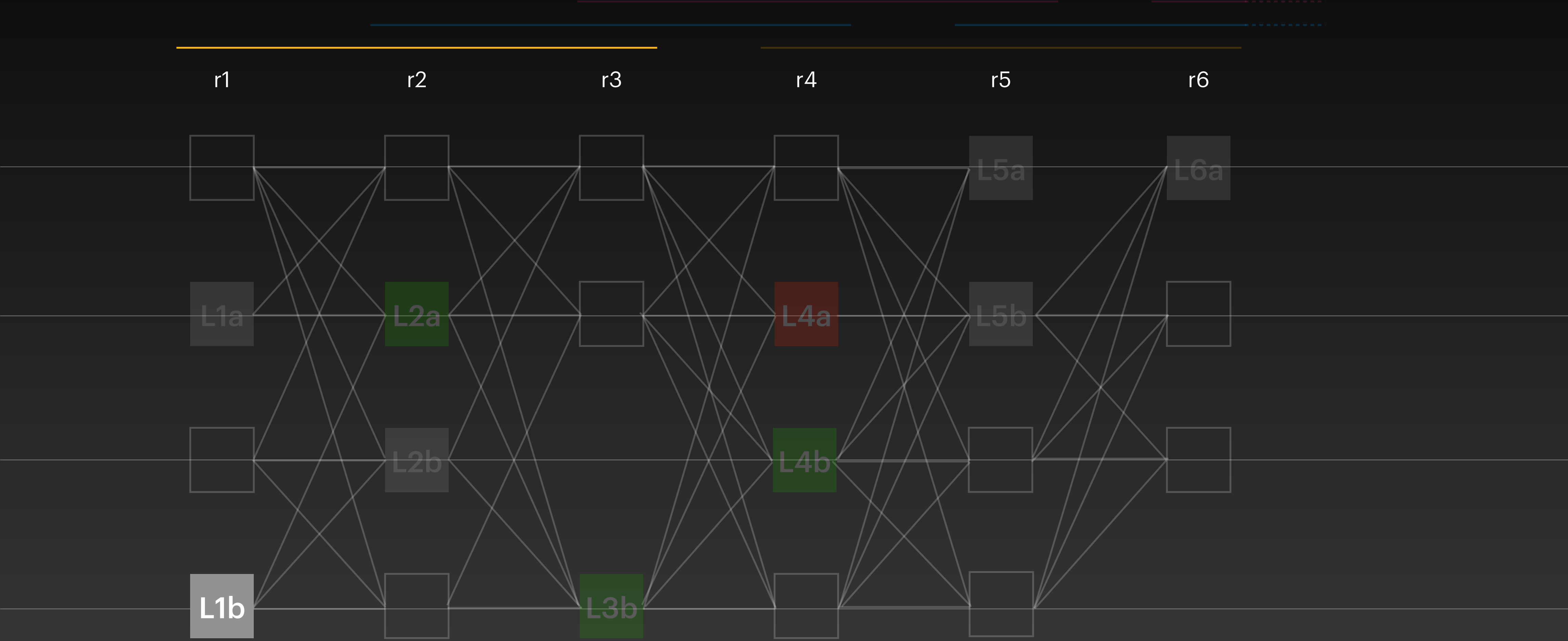


Apply Direct Rule

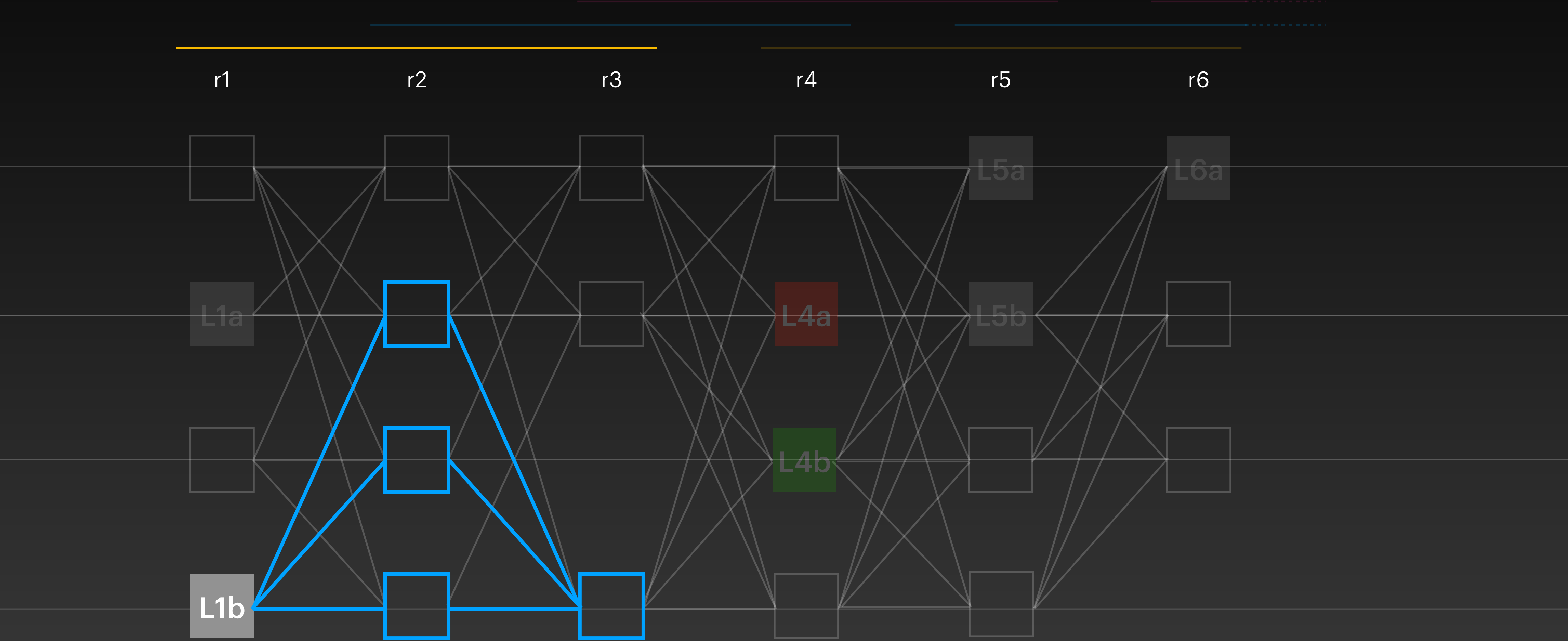


Apply Direct Rule

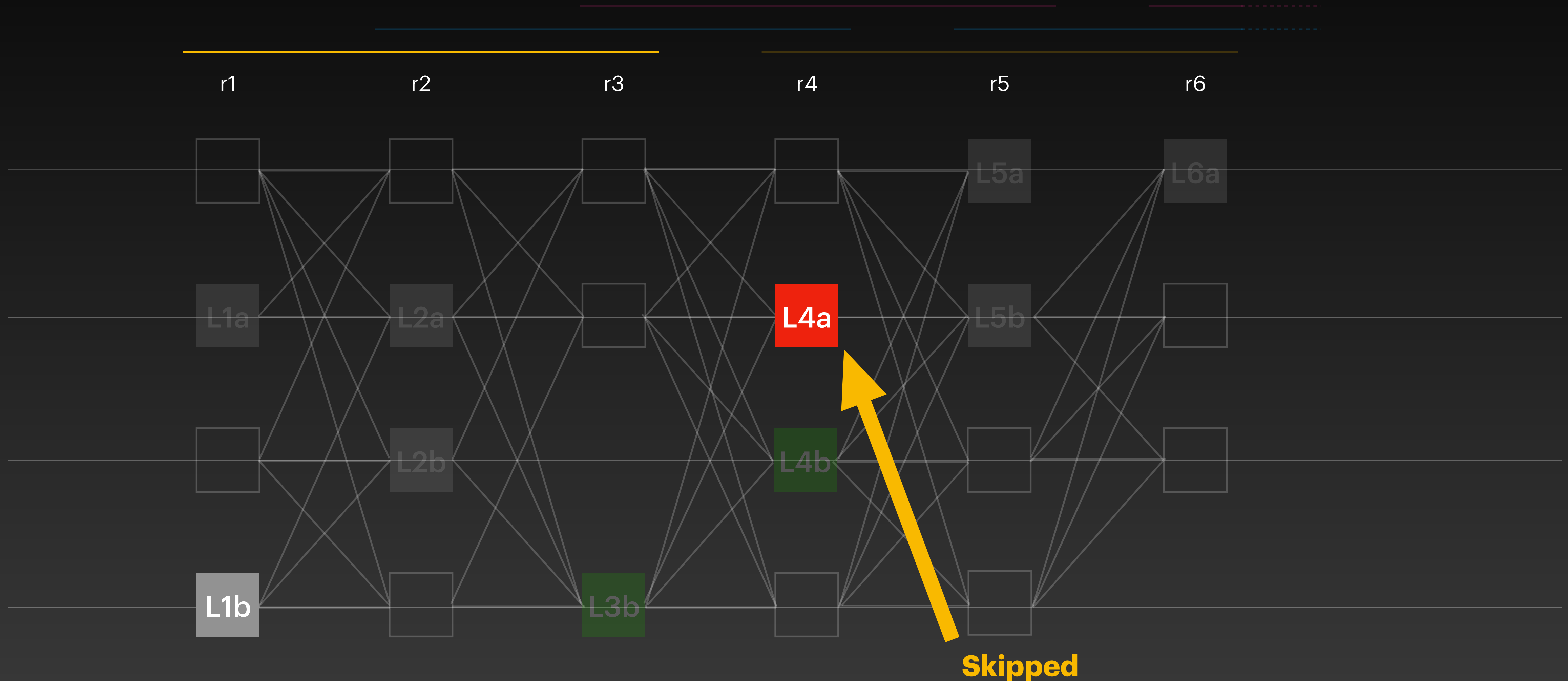
Apply Direct Rule



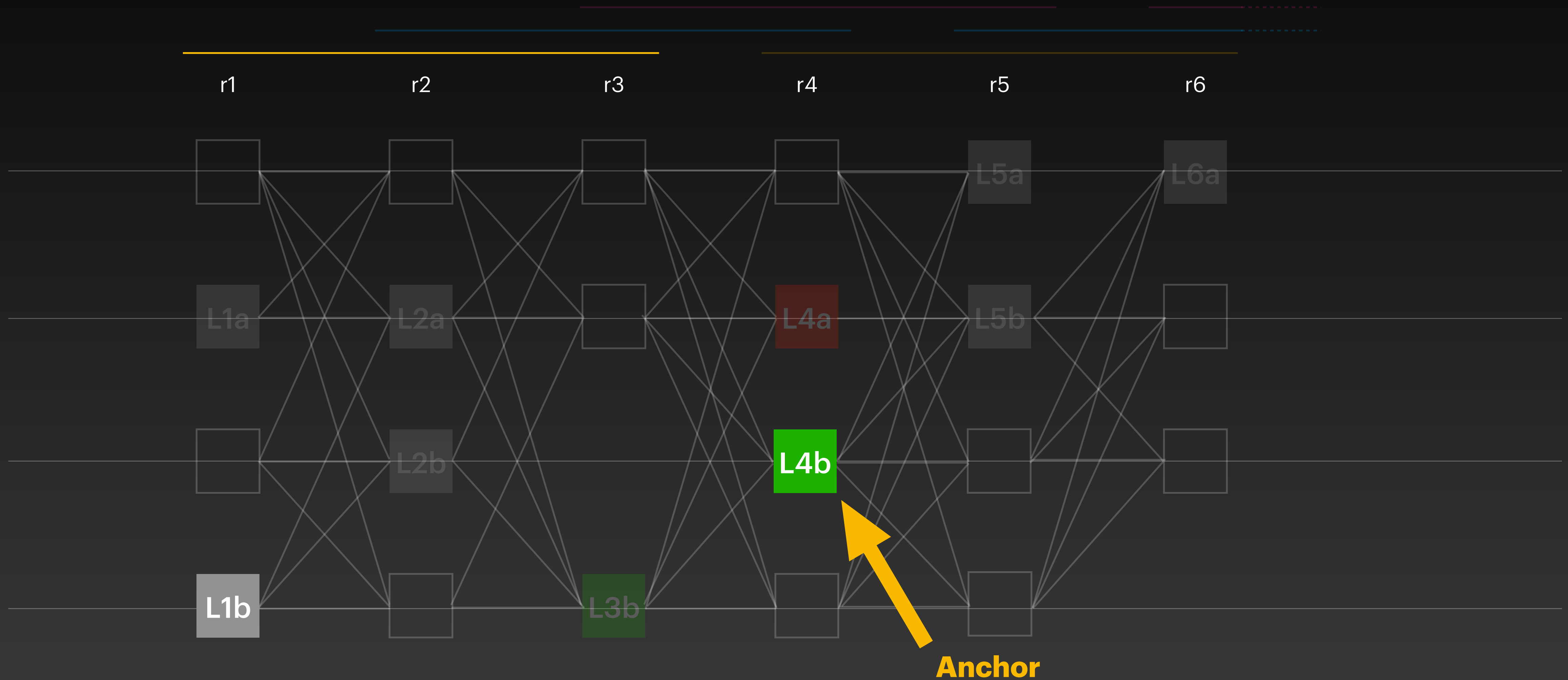
Apply Direct Rule



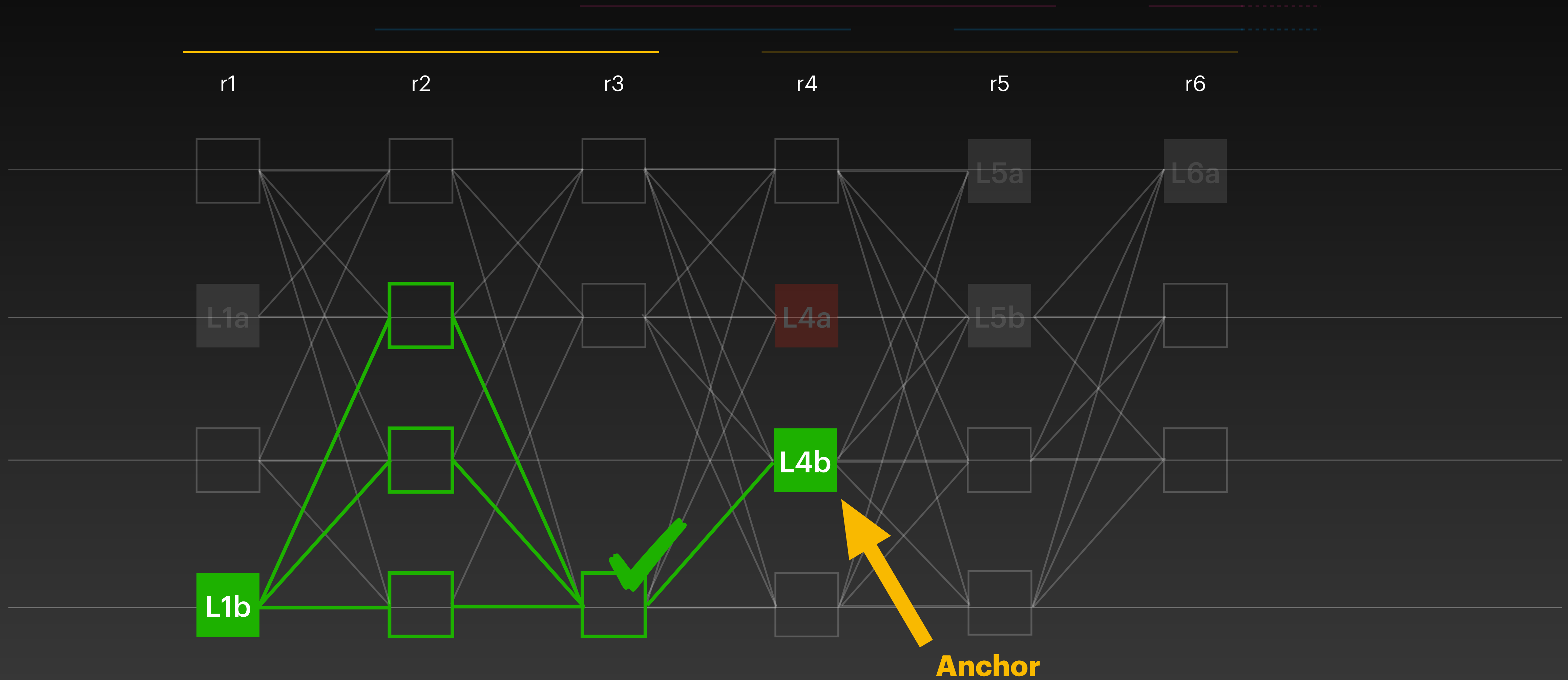
Apply Indirect Rule



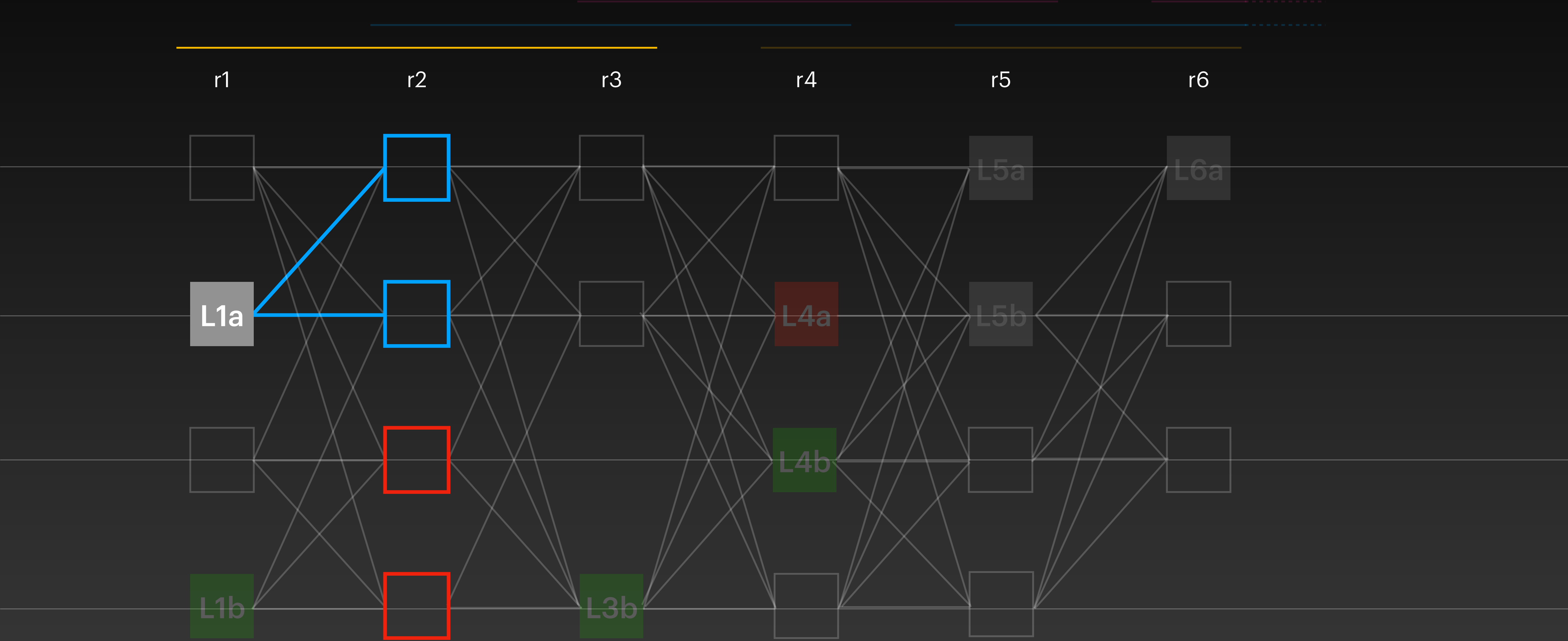
Apply Indirect Rule



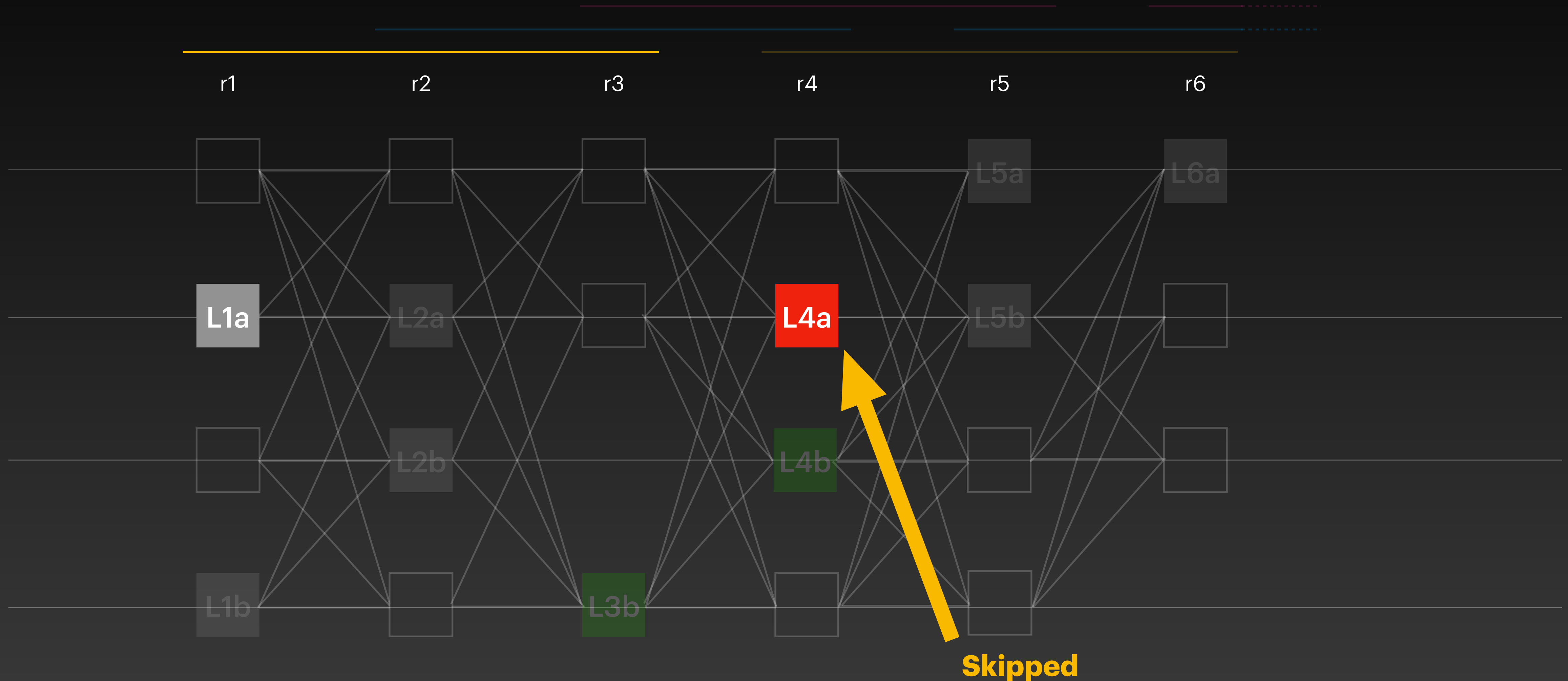
Apply Indirect Rule



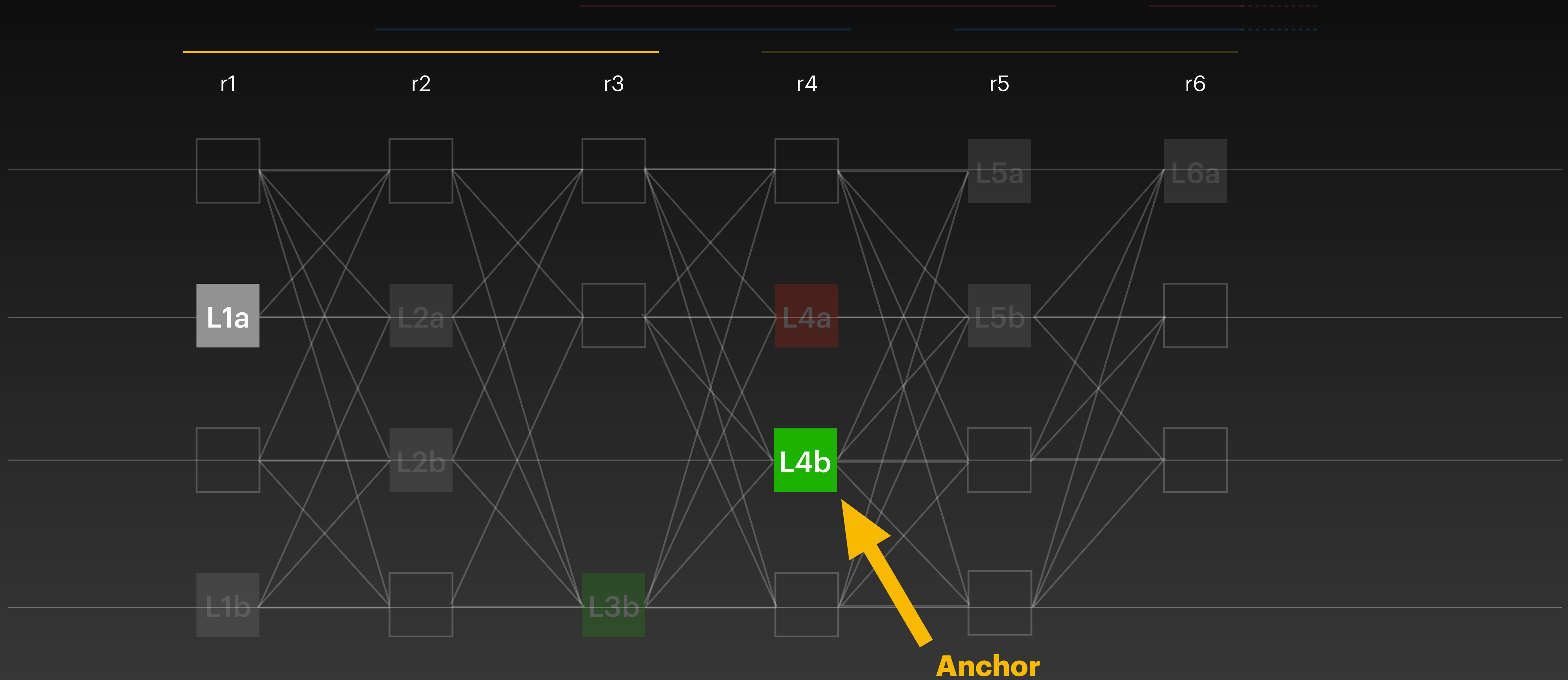
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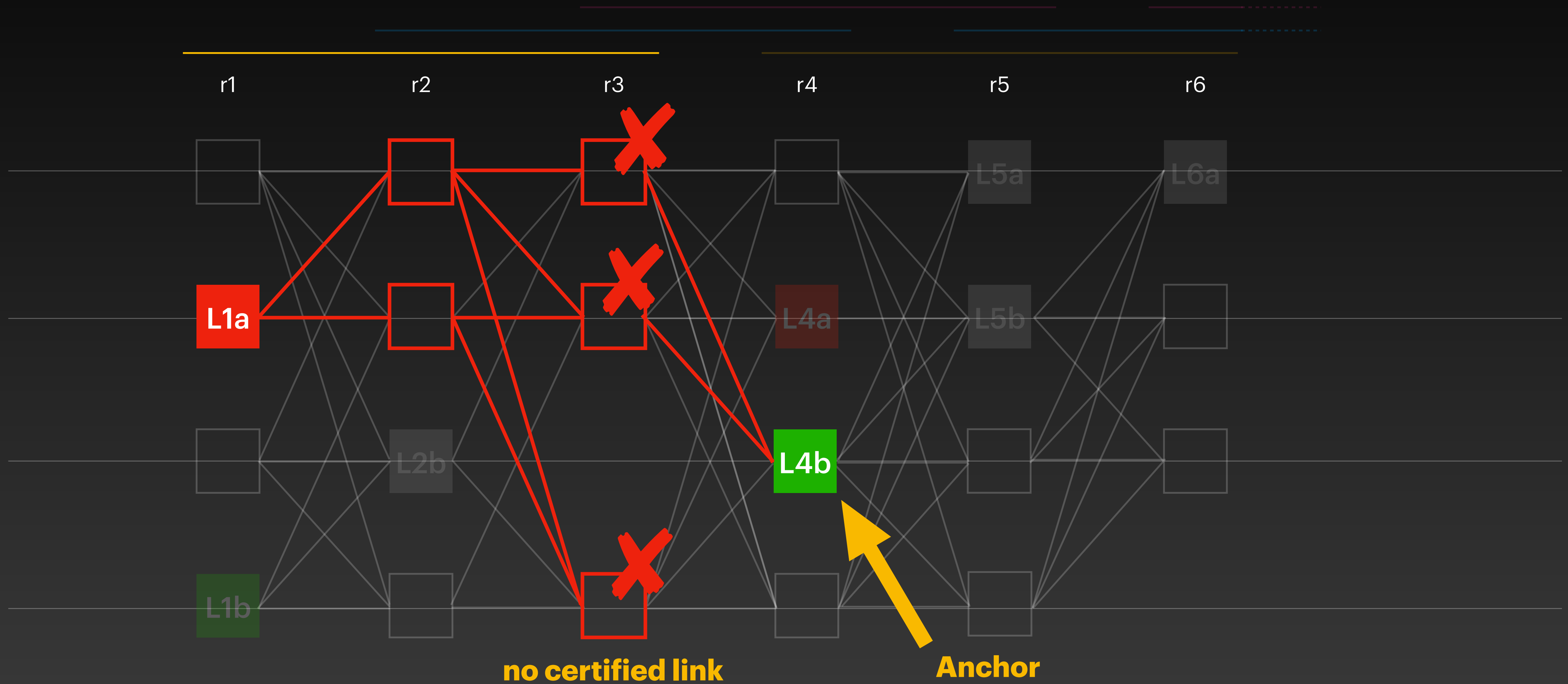
Apply Indirect Rule



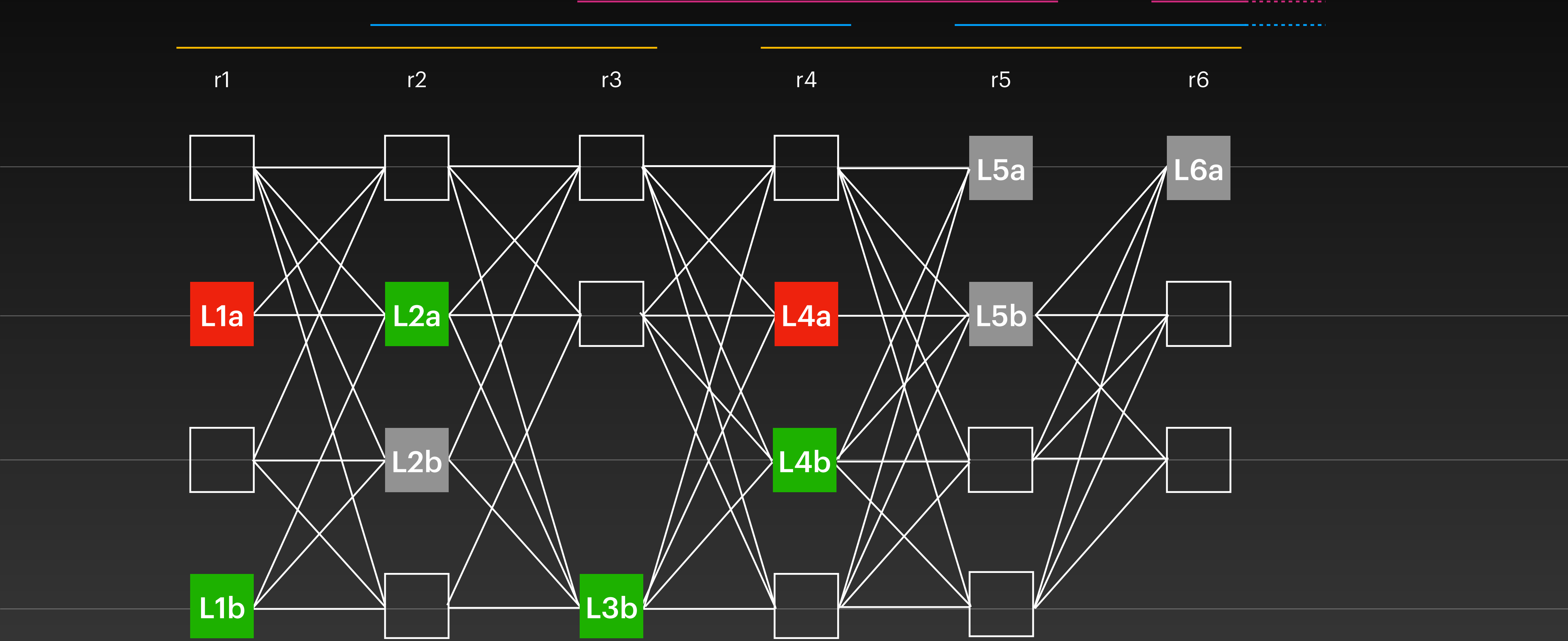
Apply Indirect Rule



Apply Indirect Rule

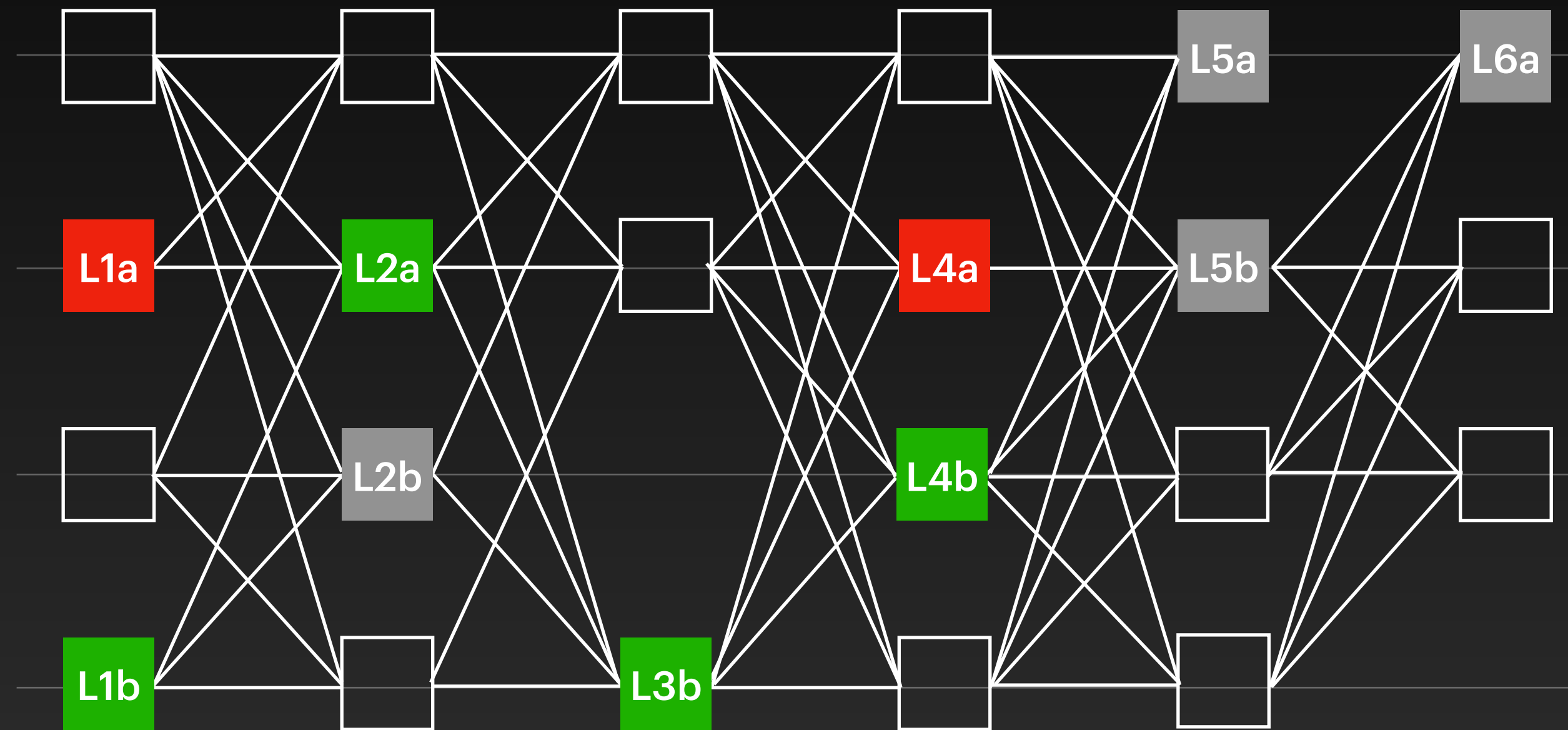


Current Status



Commit Sequence

Take all leaders in order

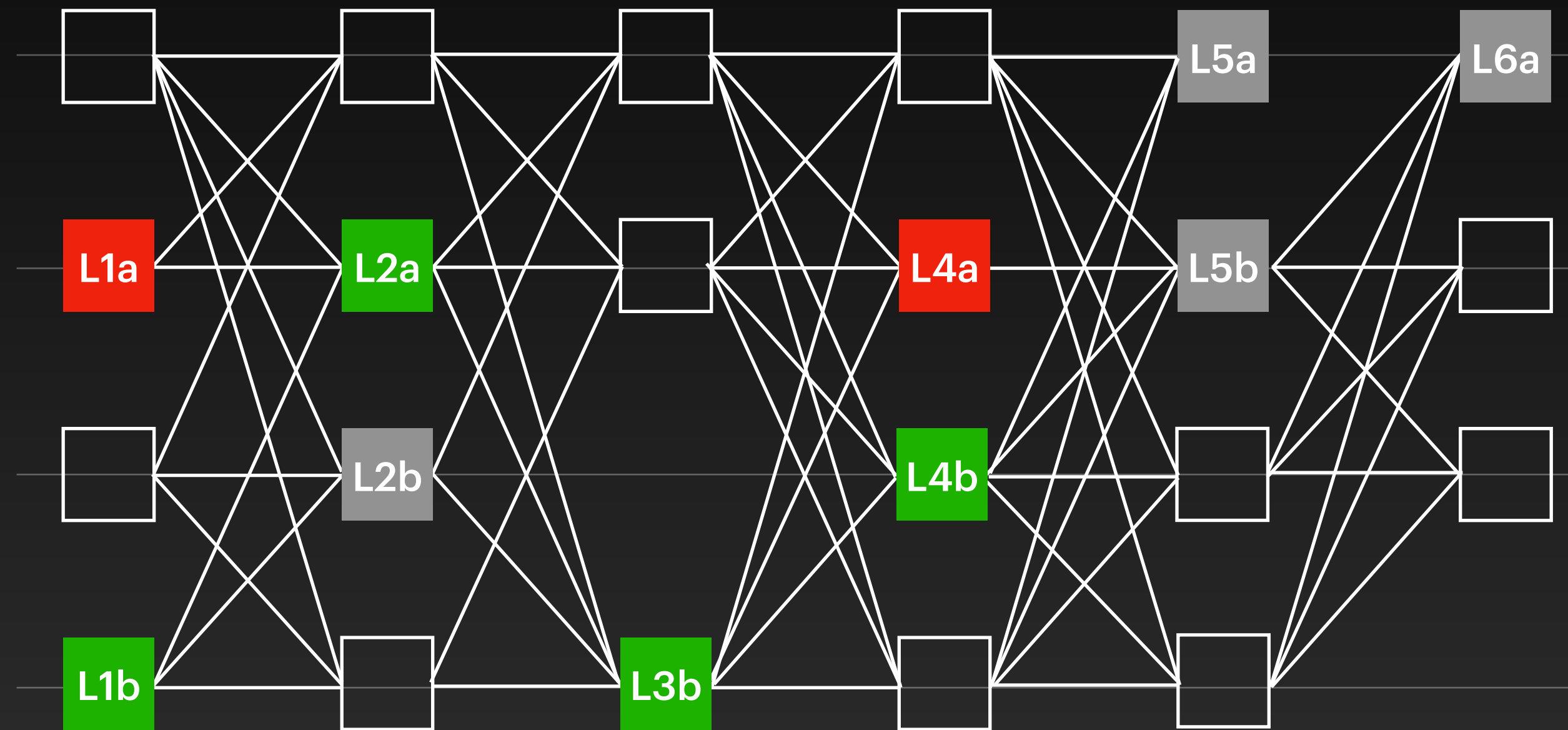


leaders sequence:



Commit Sequence

Stop at the first Undecided leader

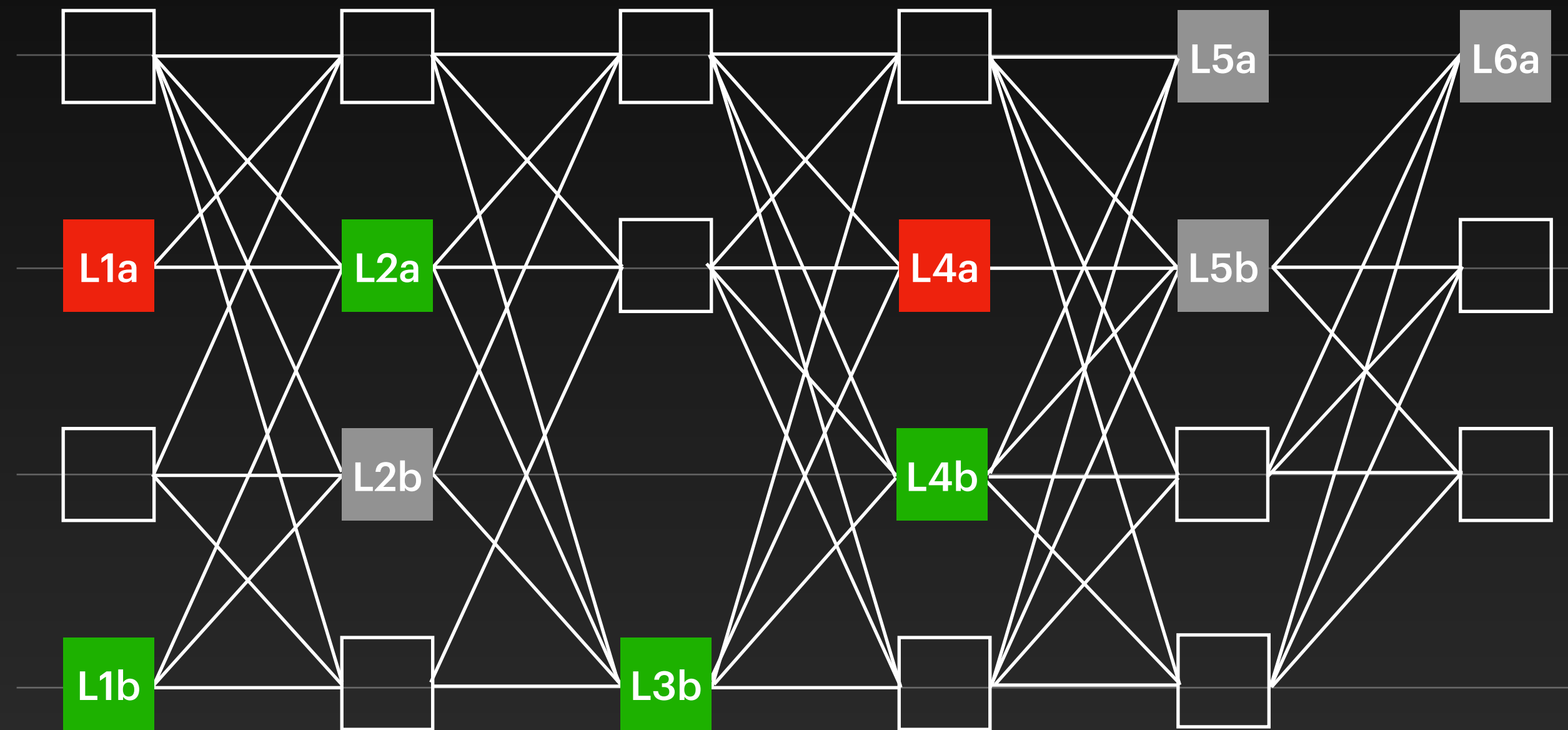


leaders sequence:



Commit Sequence

Remove skipped leaders

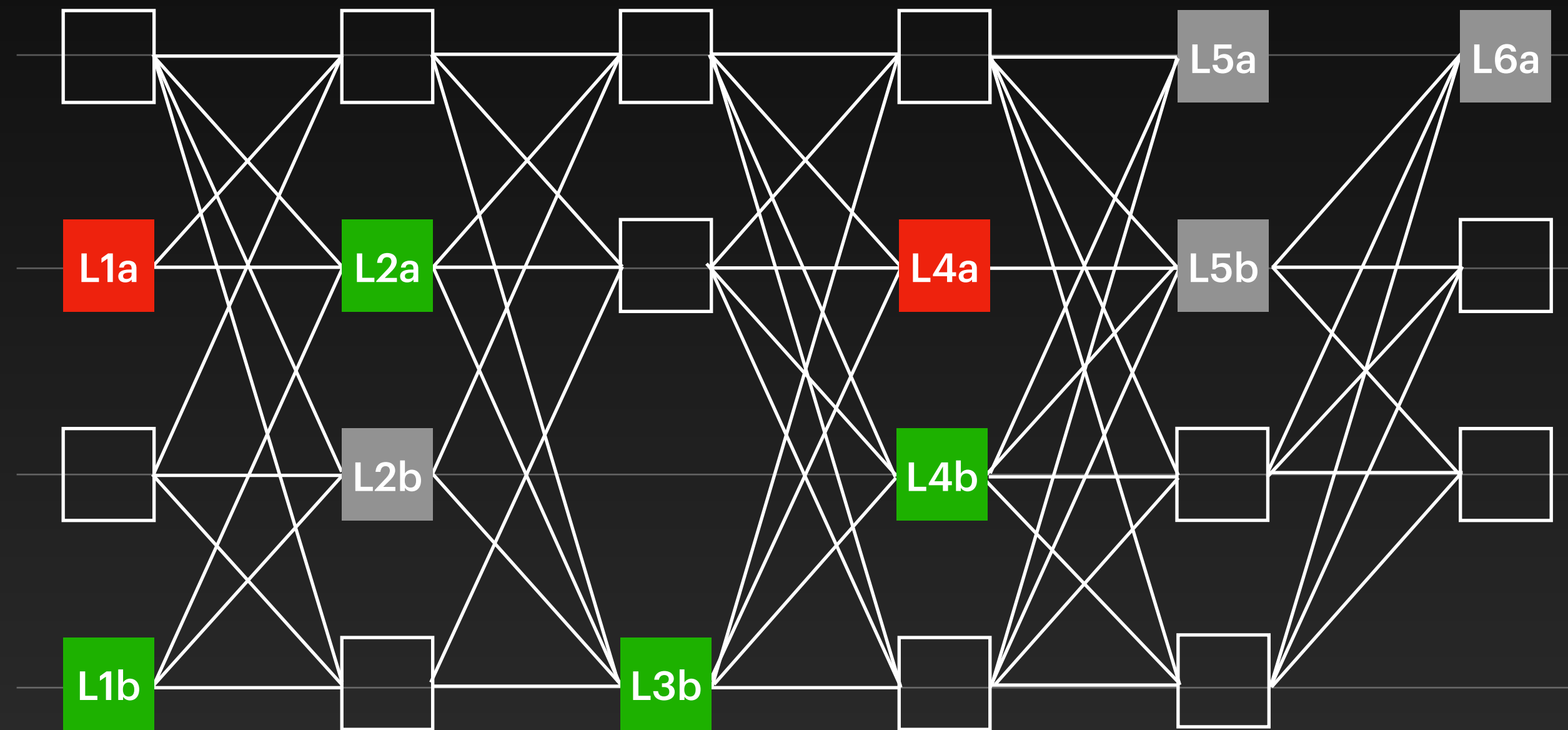


leaders sequence:



Commit Sequence

Final leader sequence



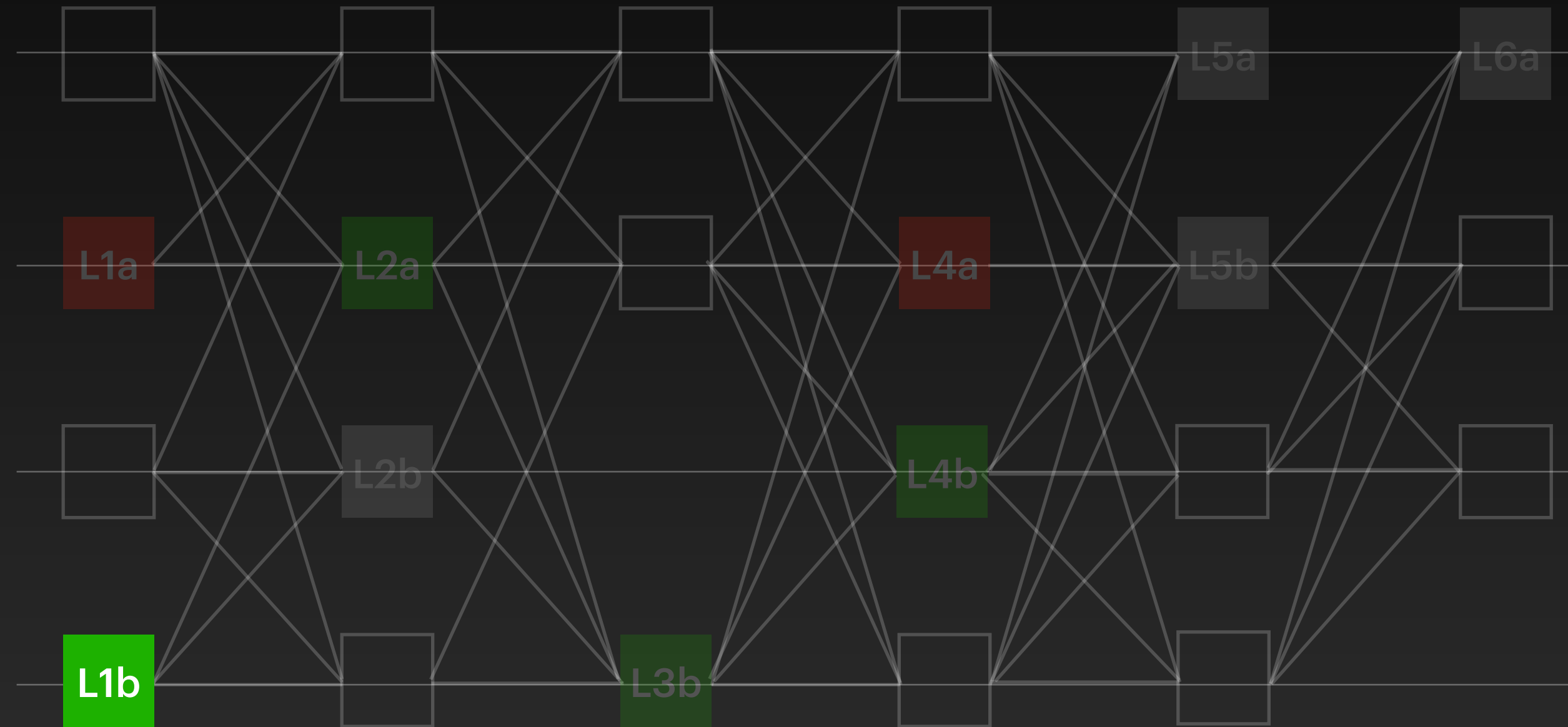
leaders sequence:

L1b

L2a

Commit Sequence

Commit sub-dag



leaders sequence:

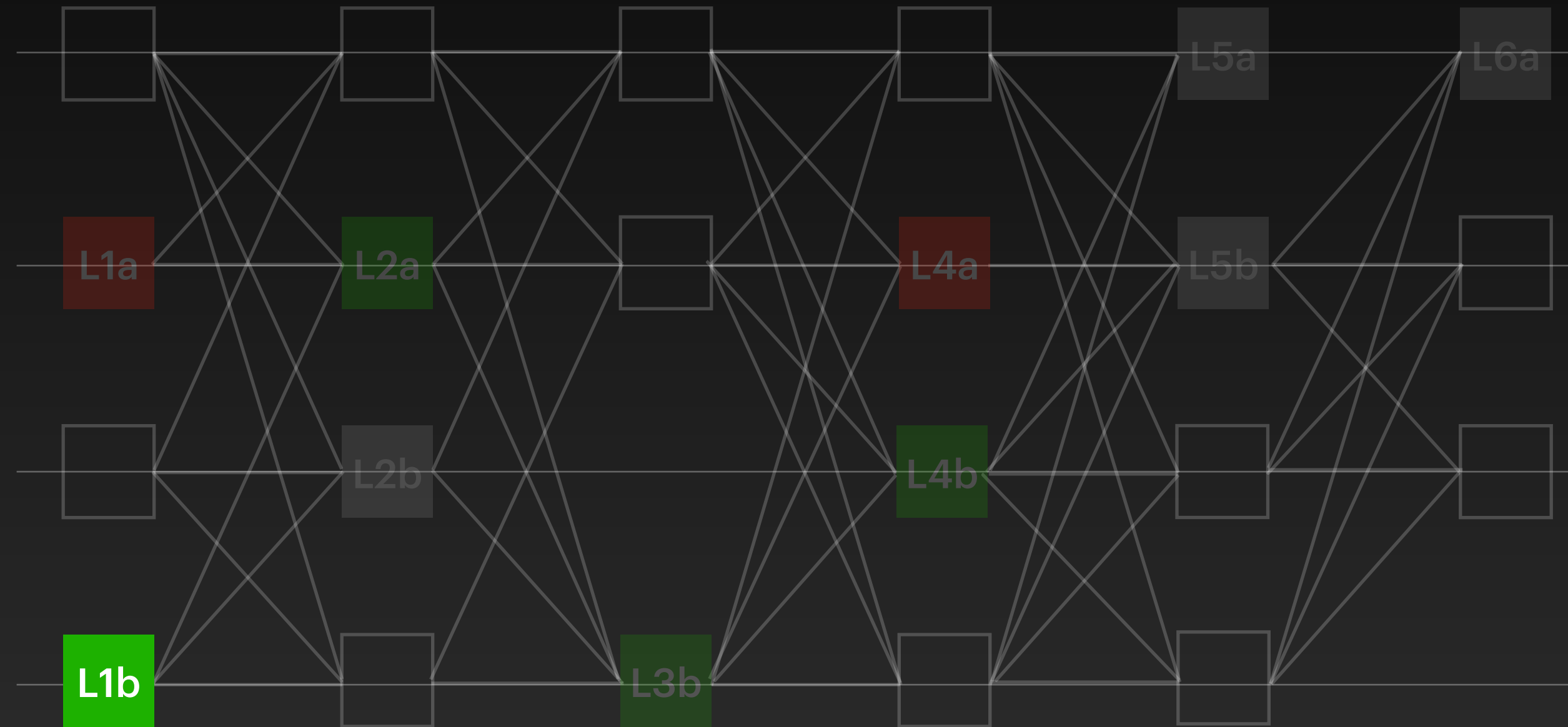
L1b

L2a

output sequence:

Commit Sequence

Commit sub-dag



leaders sequence:

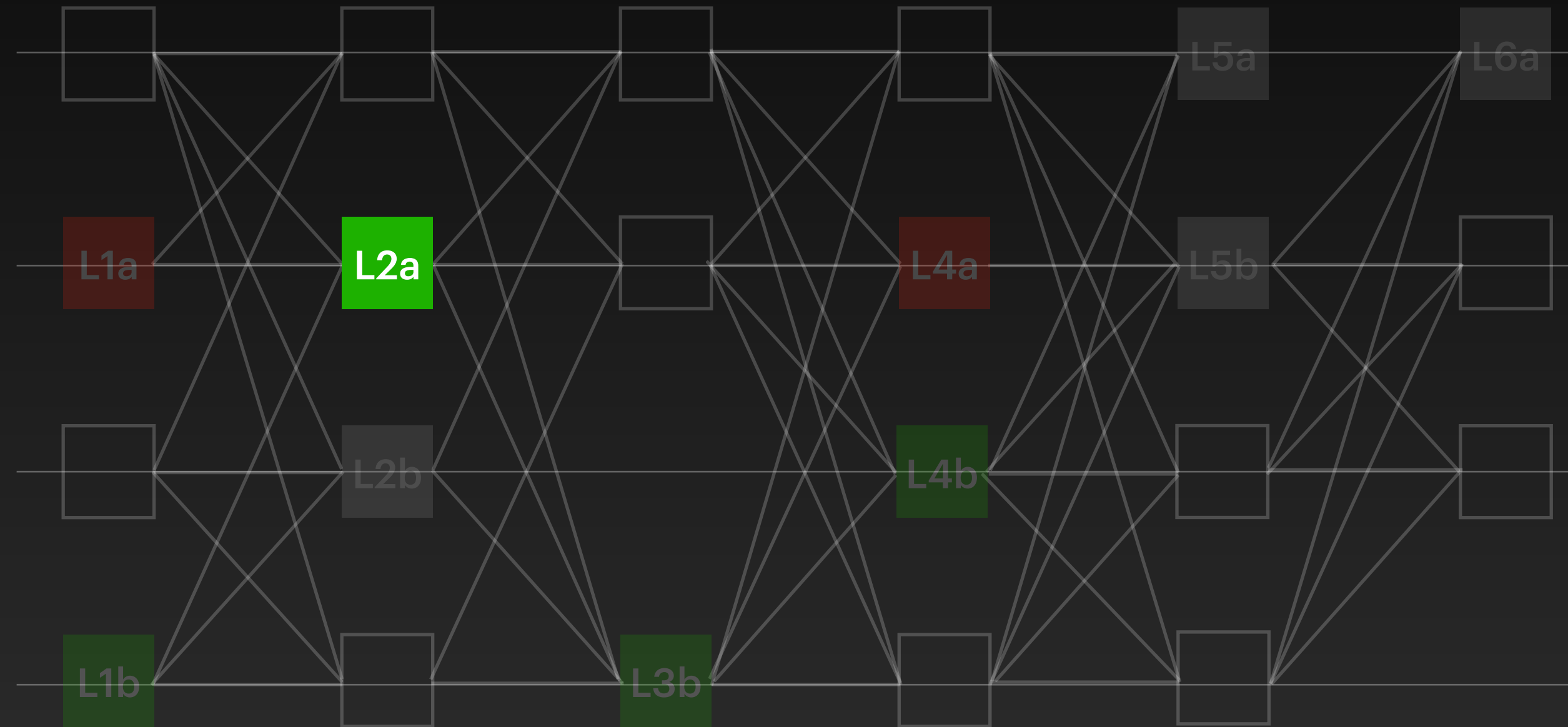
L2a

output sequence:

L1b

Commit Sequence

Commit sub-dag



leaders sequence:

L2a

output sequence:

L1b

Commit sub-dag

leaders sequence:

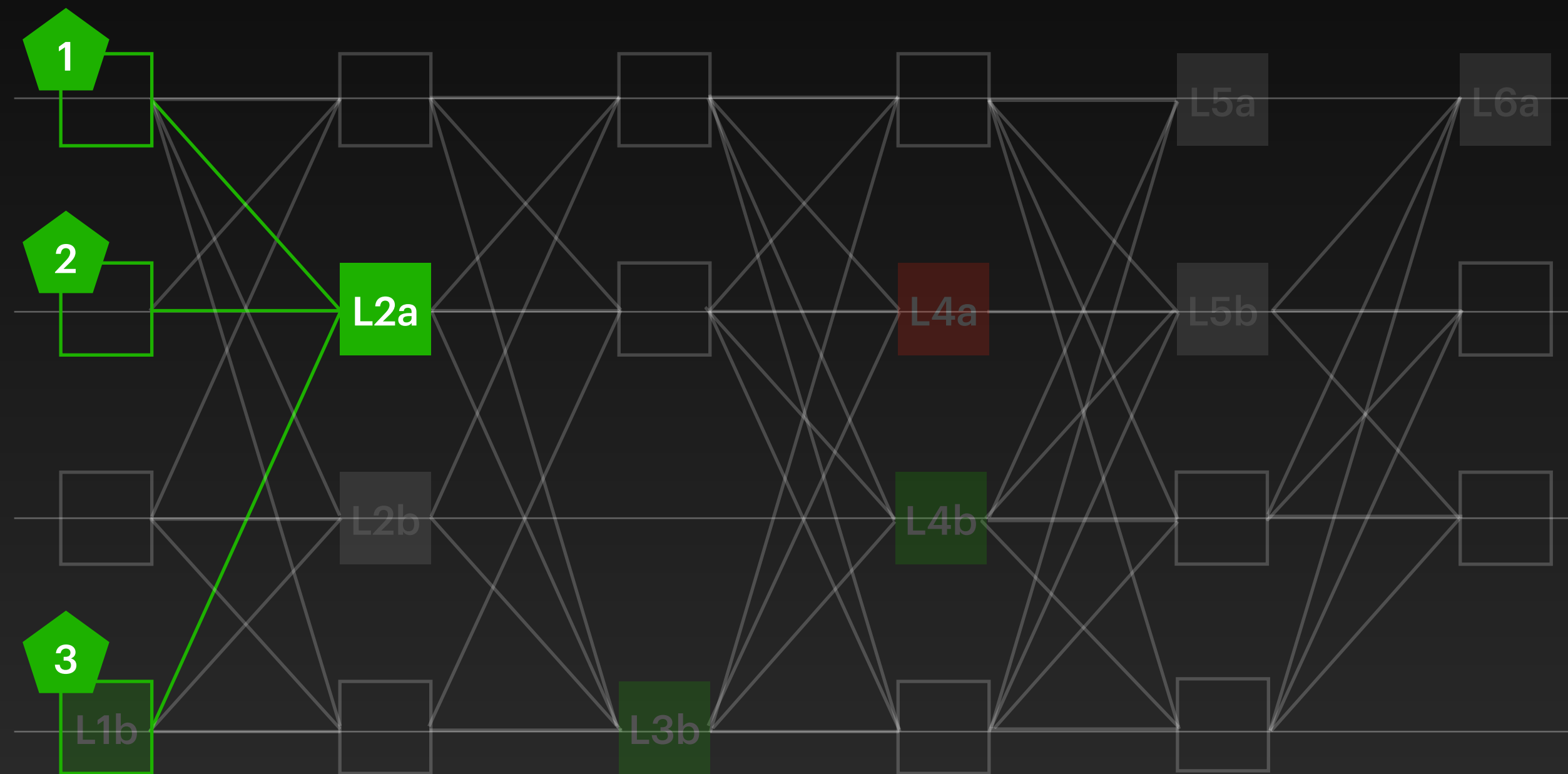
L2a

output sequence:

L1b

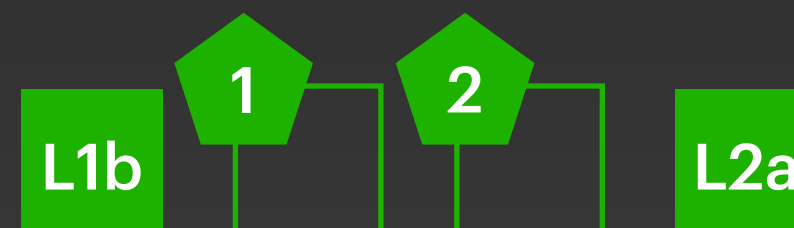
Commit Sequence

Commit sub-dag



leaders sequence:

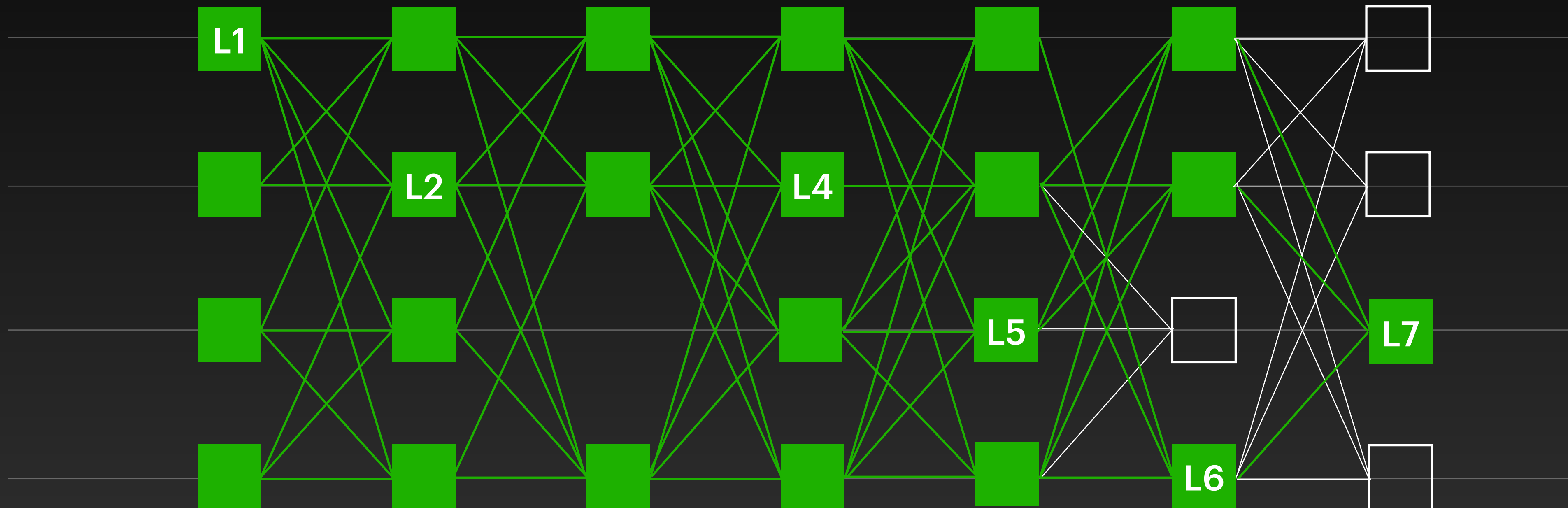
output sequence:



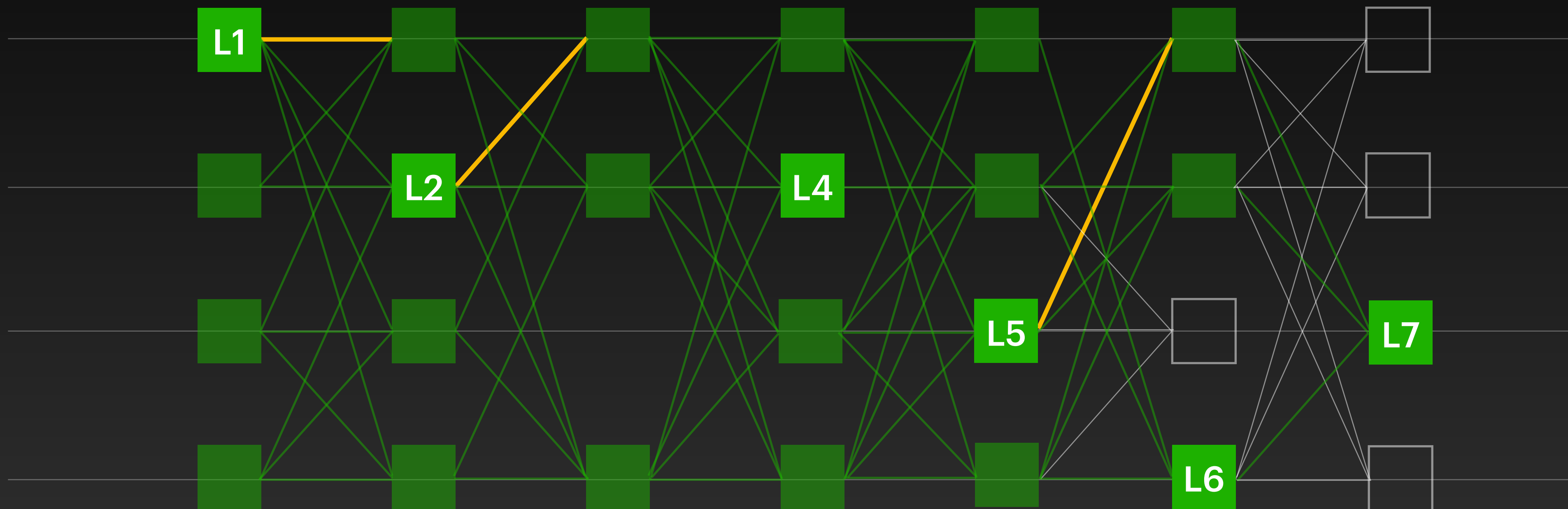
HammerHead

Mitigating slow leaders

Past Commits

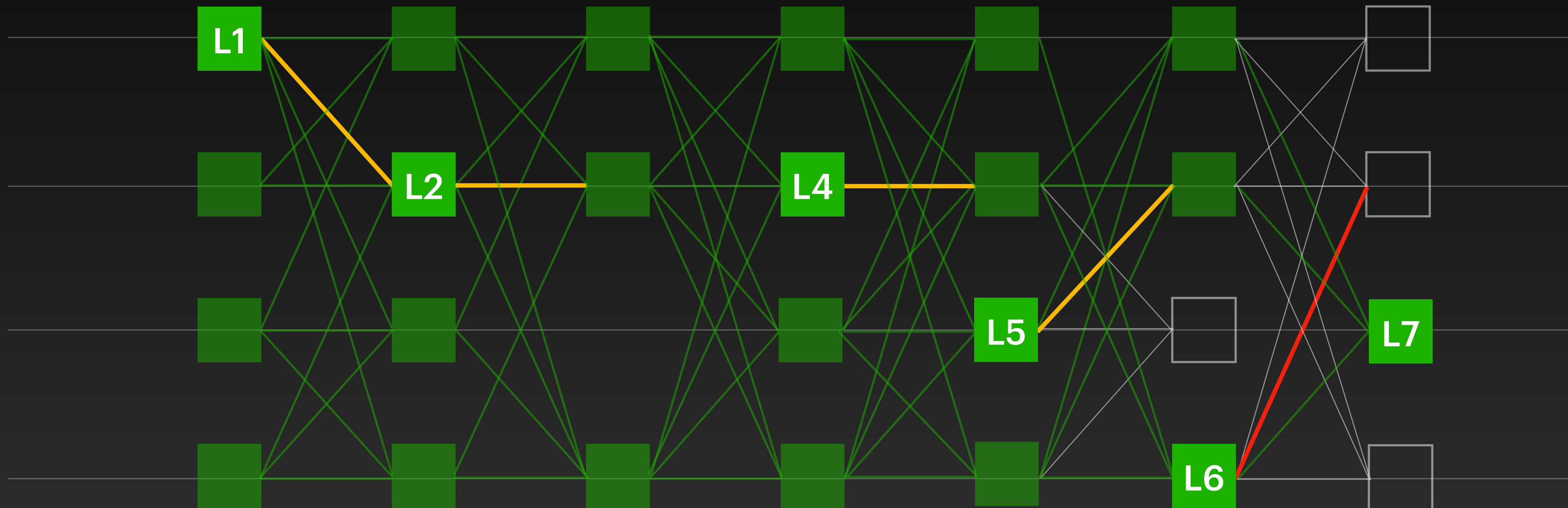


Compute Reputation Scores



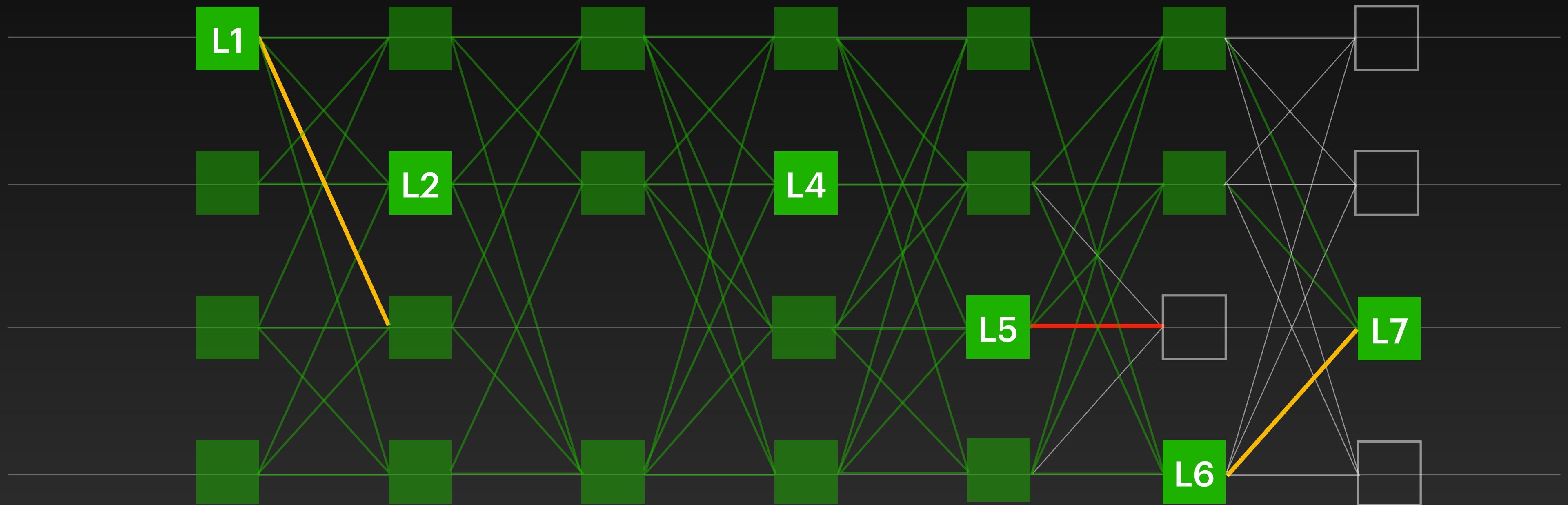
node 1: 3

Compute Reputation Scores



node 1: 3 node 2: 4

Compute Reputation Scores

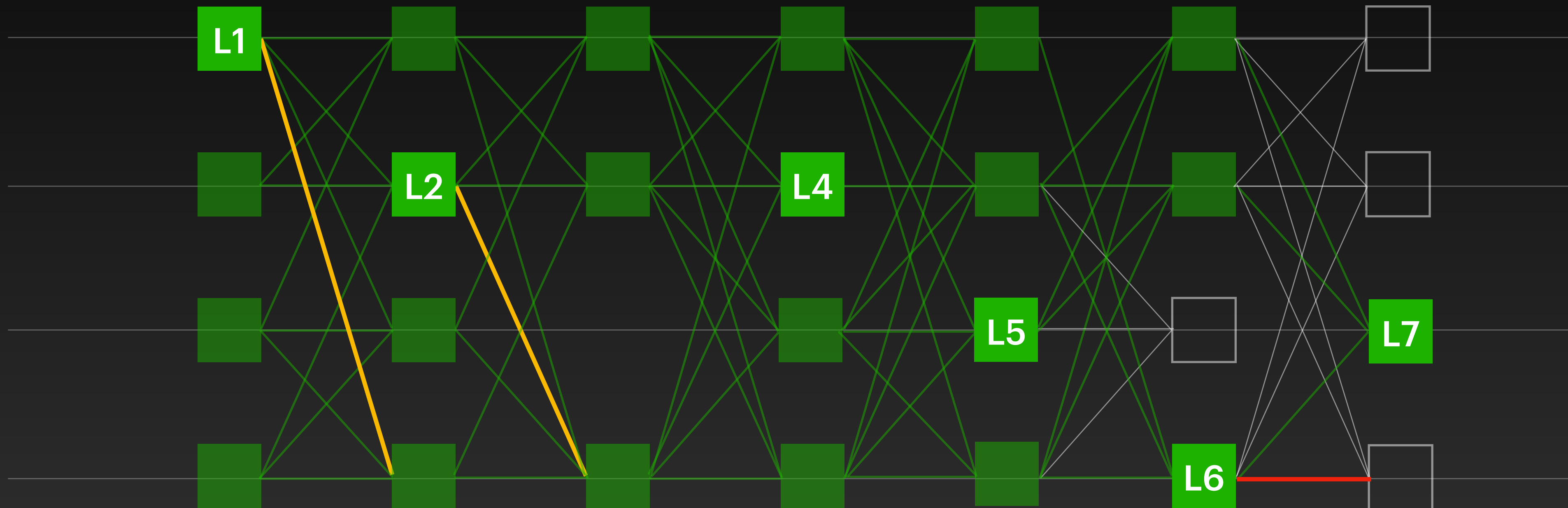


node 1: 3

node 2: 4

node 3: 2

Compute Reputation Scores



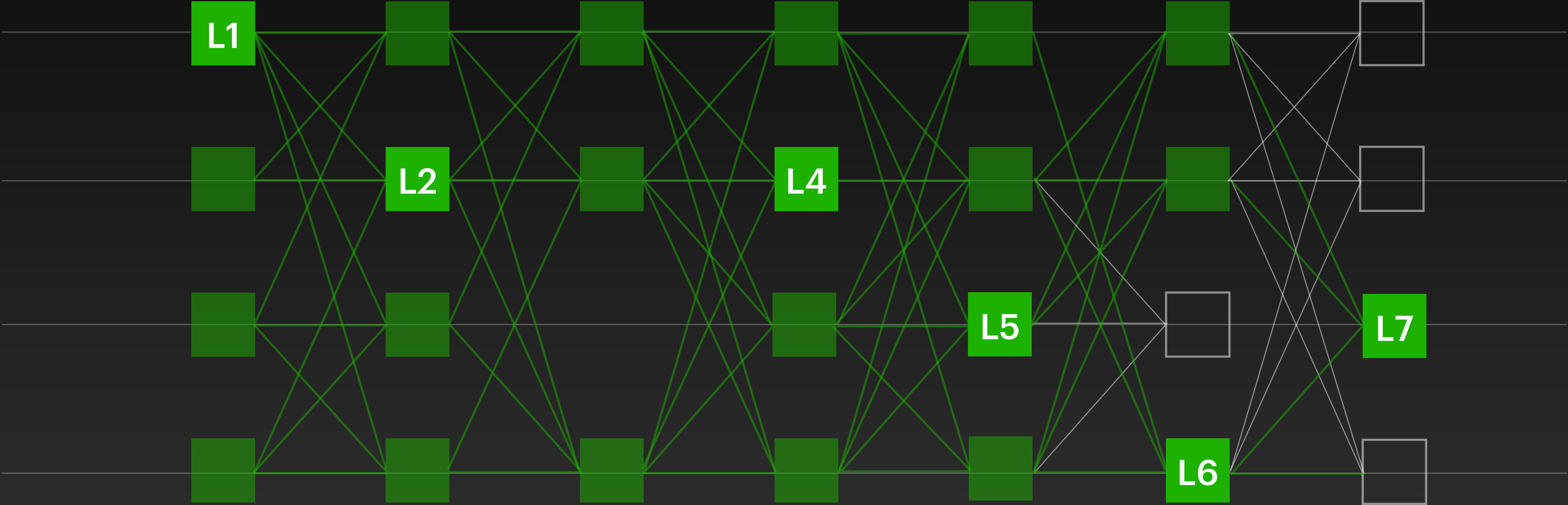
node 1: 3

node 2: 4

node 3: 2

node 4: 2

Future Leaders



node 1: 3

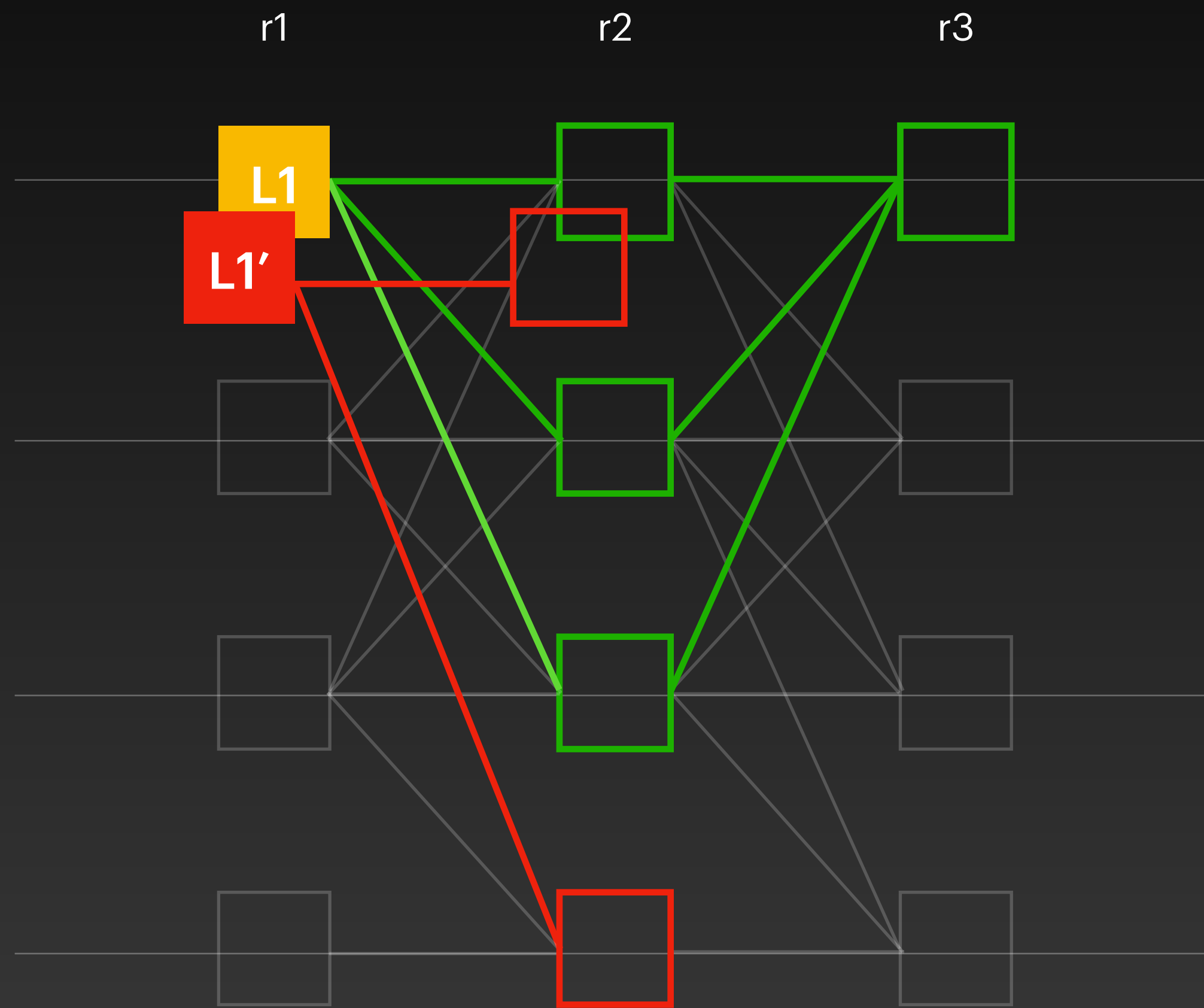
node 2: 4

node 3: 2

node 4: 2

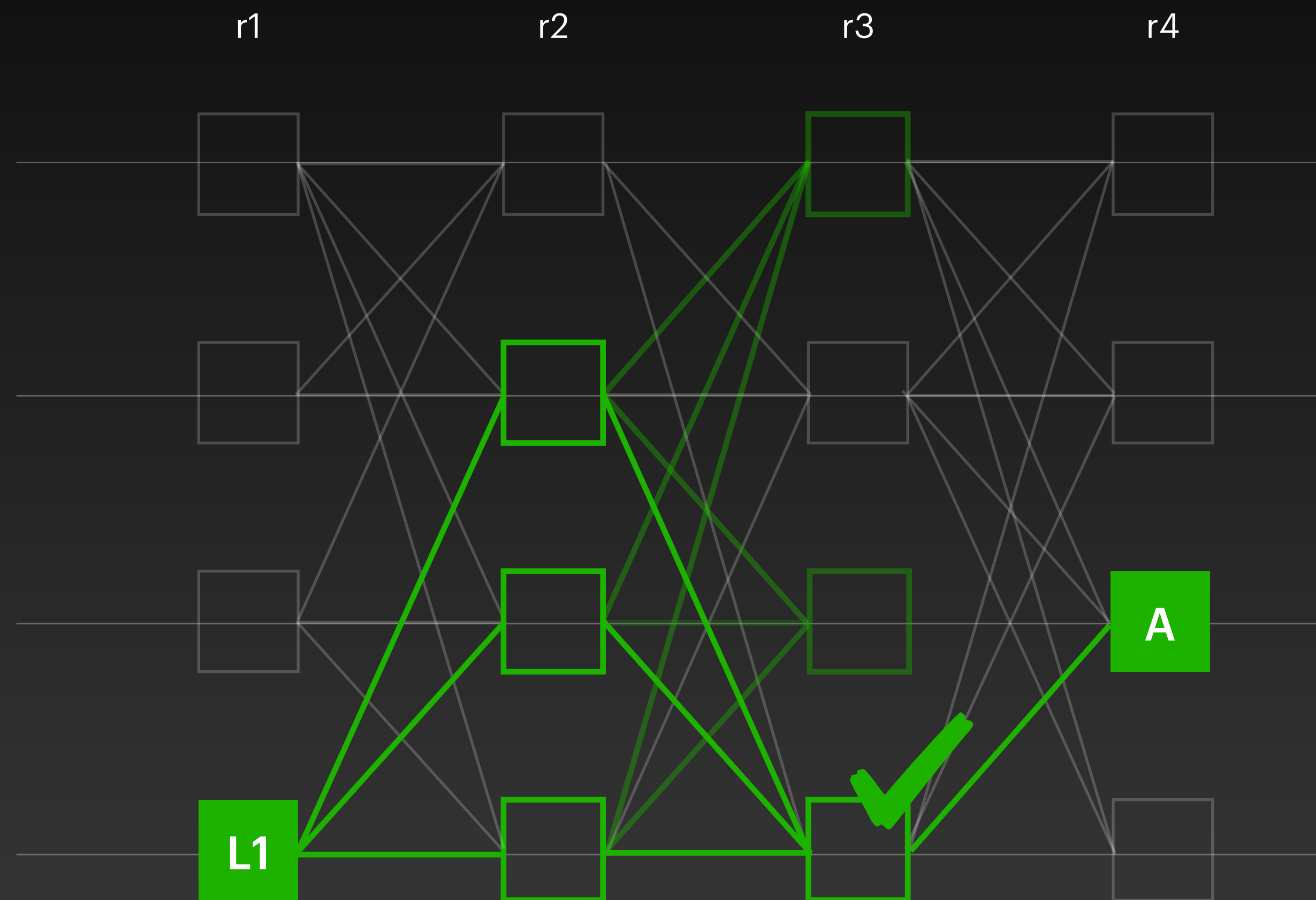
Security Intuition

Security Intuition



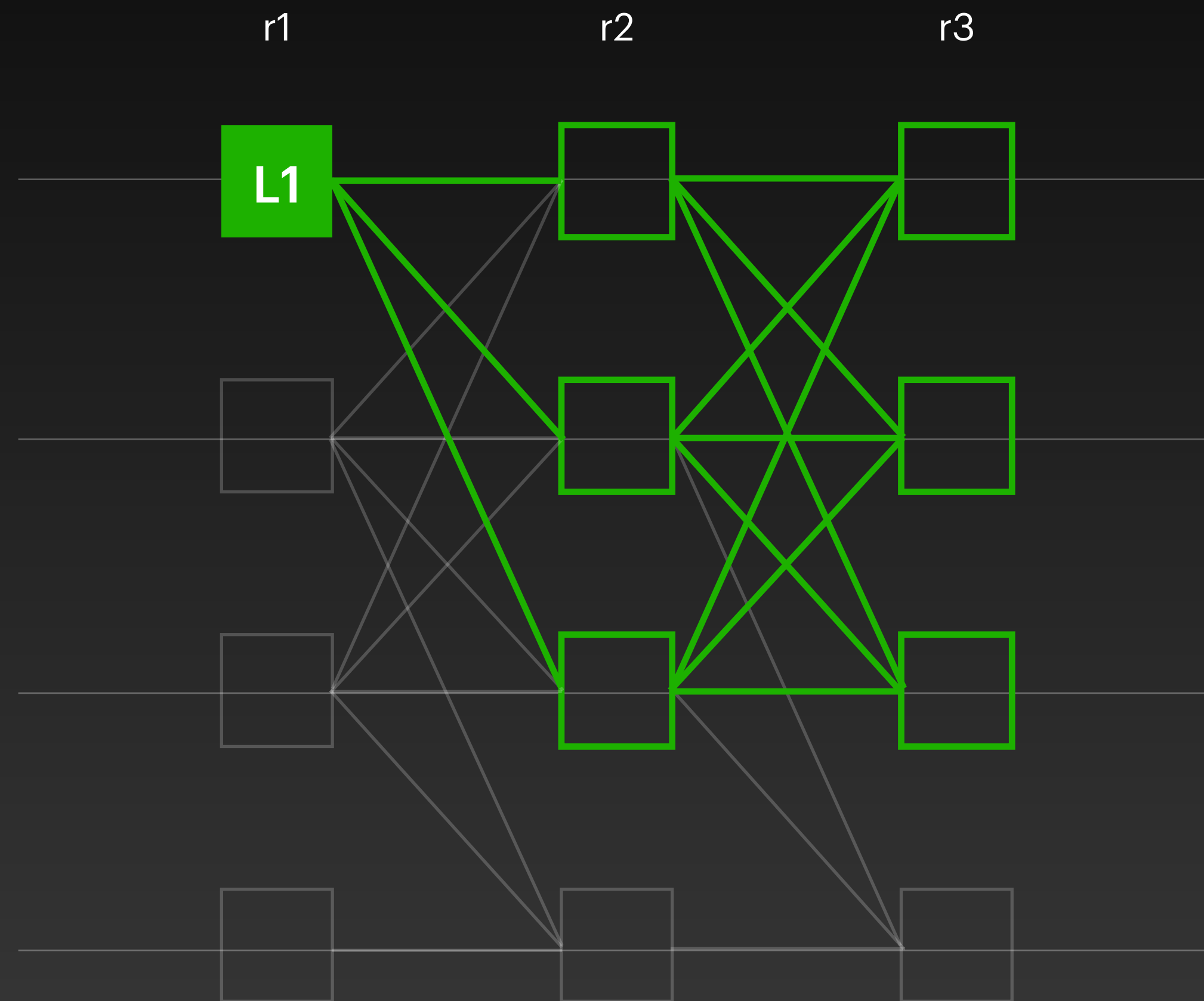
- At most **L1** or **L1'** can have a certificate pattern (quorum intersection)

Security Intuition



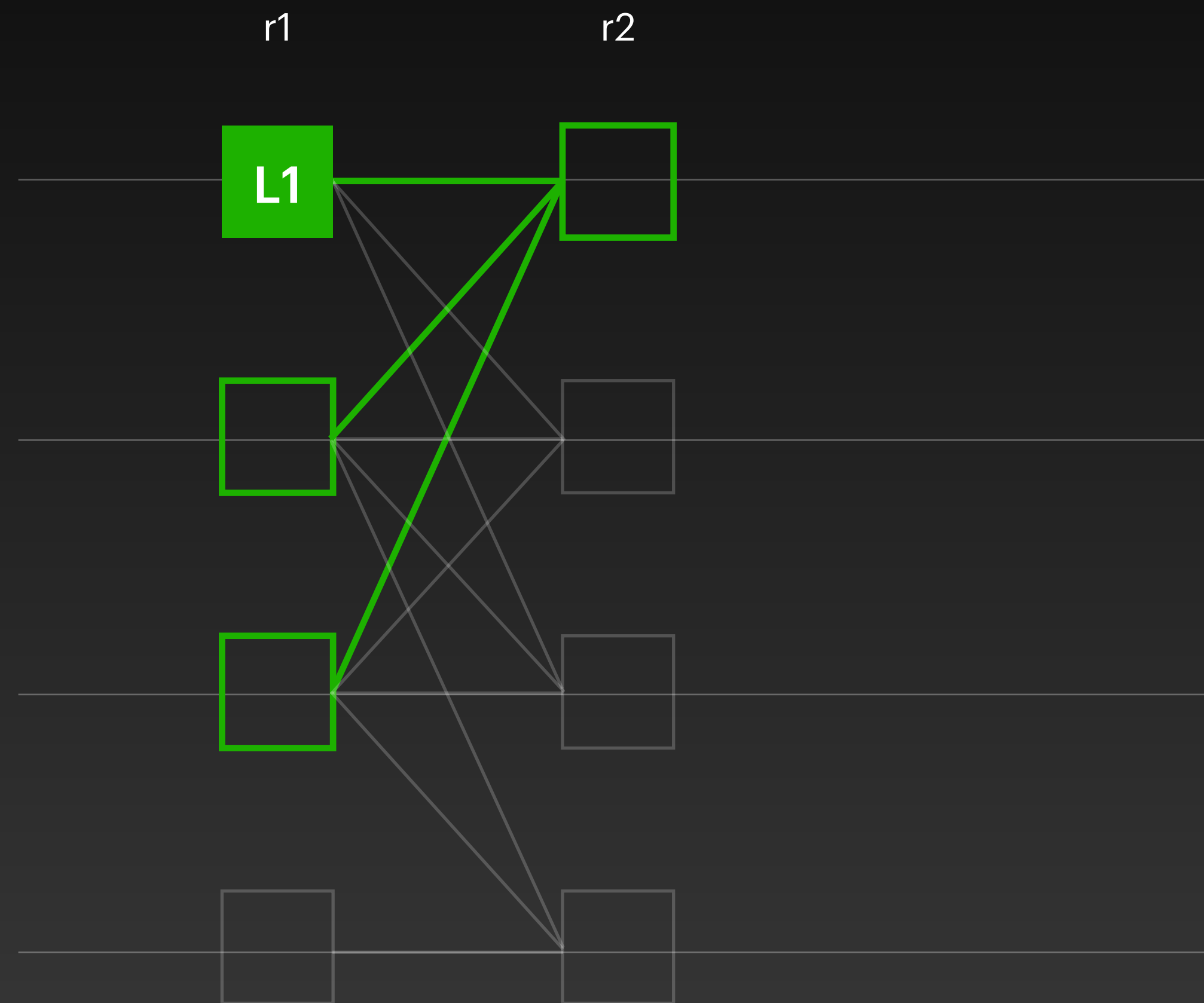
- At most **L1** or **L1'** can have a certificate pattern (quorum intersection)
- If **L1** has $2f+1$ certificate patterns, **A** always has a certified link to **L1**

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

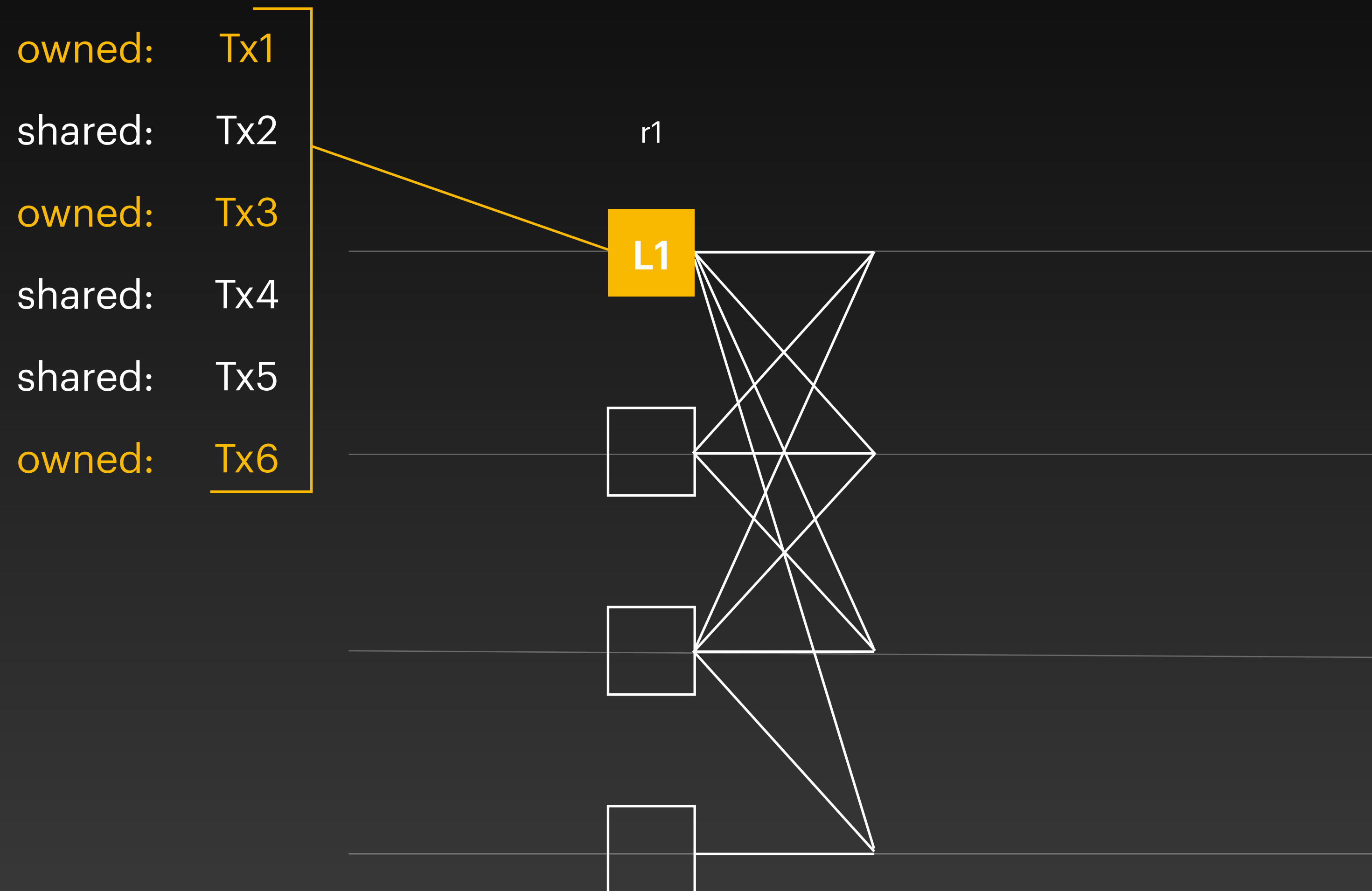
- Objects that can be mutated by multiple entities
- e.g., A global counter
- **Need consensus**

System State

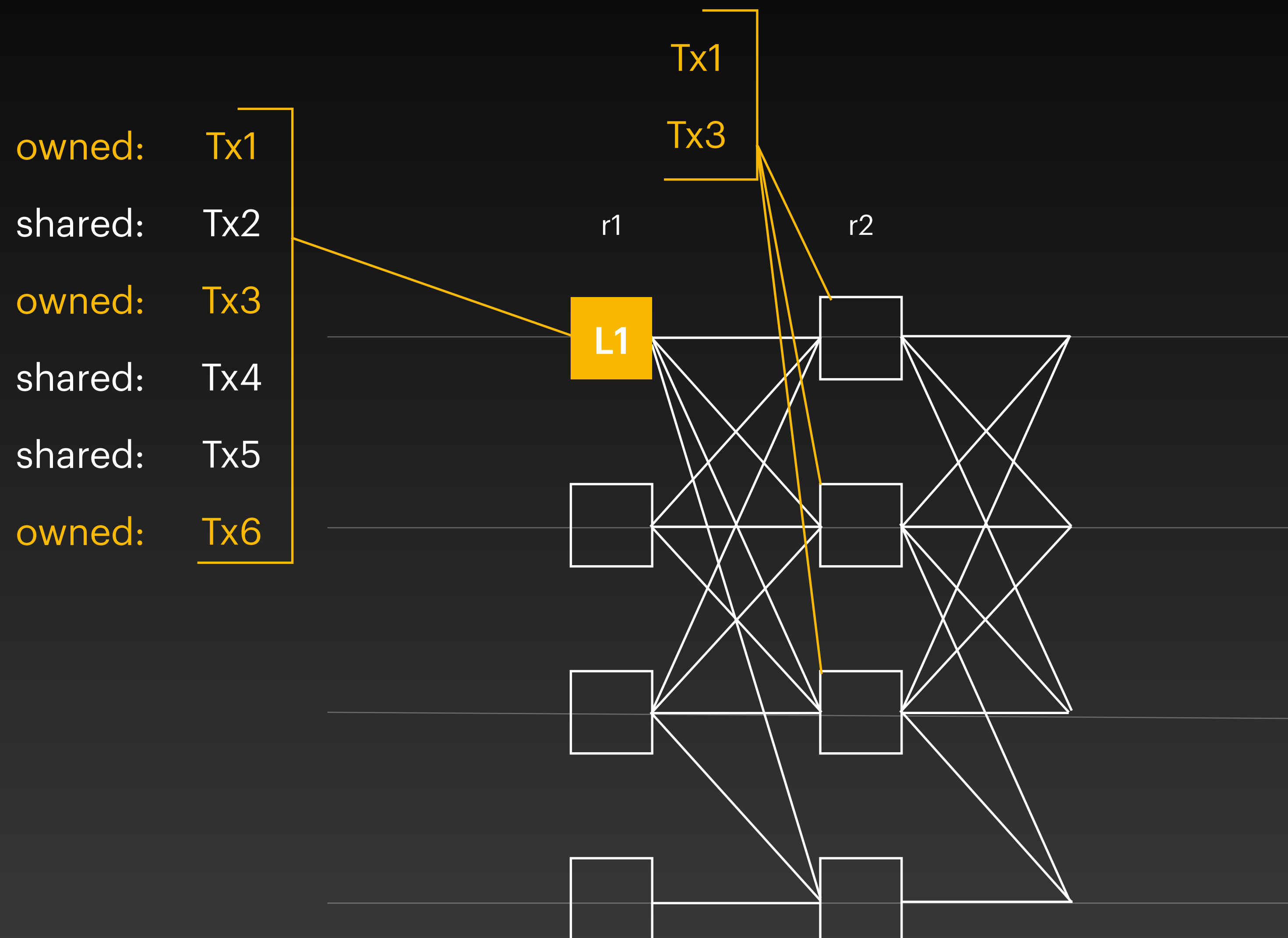
Objects:

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

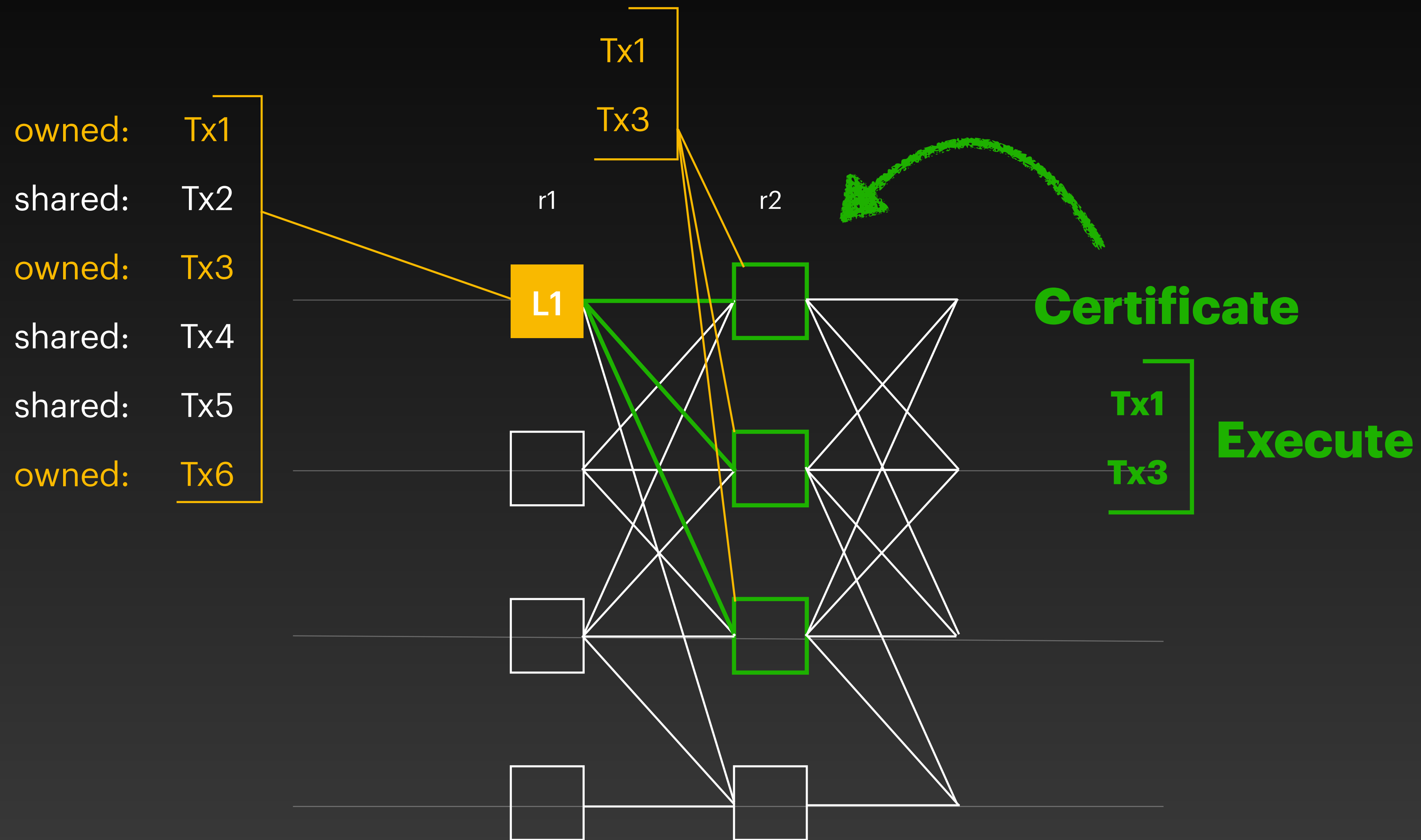
Fast Execution



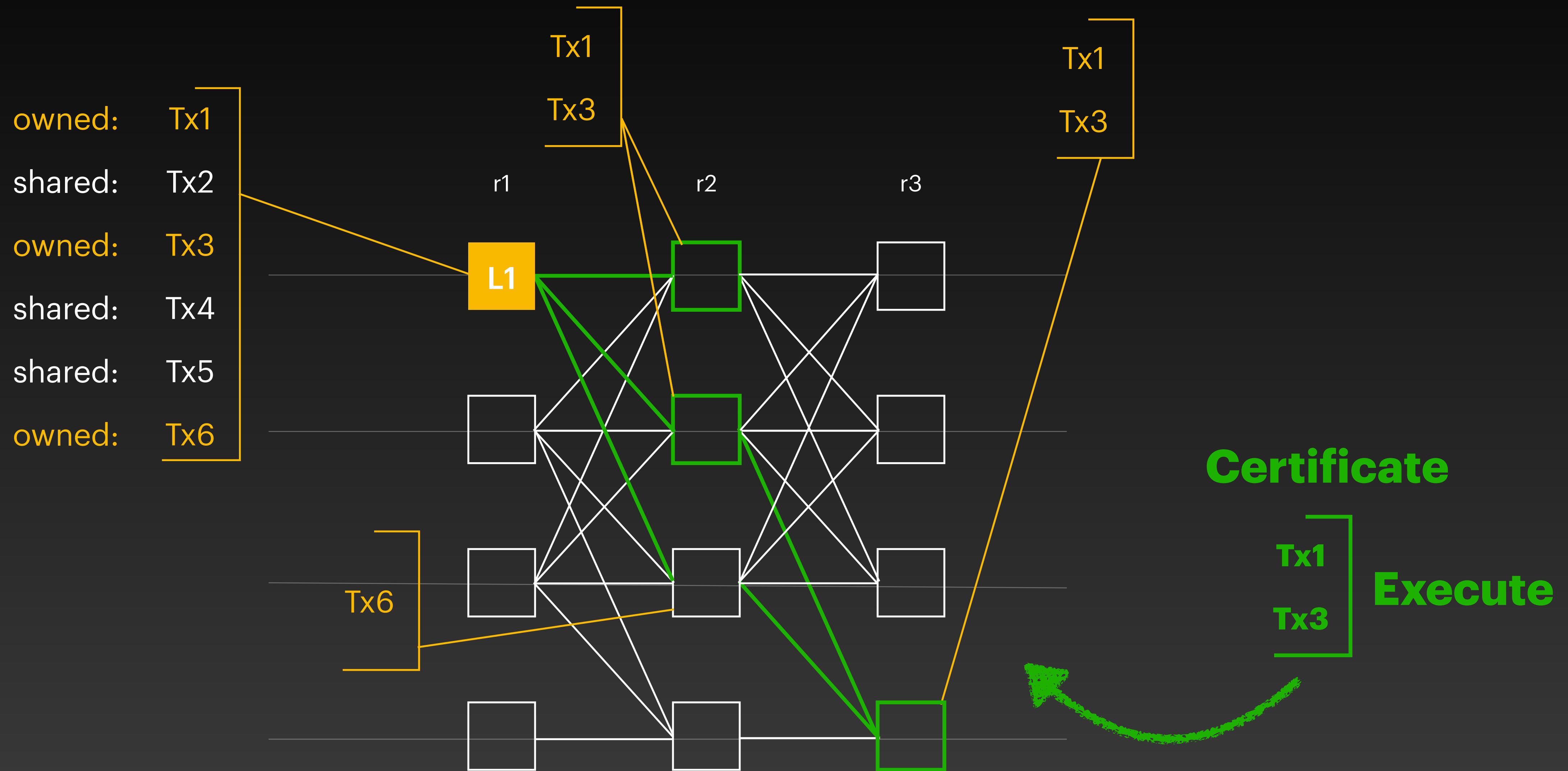
Fast Execution



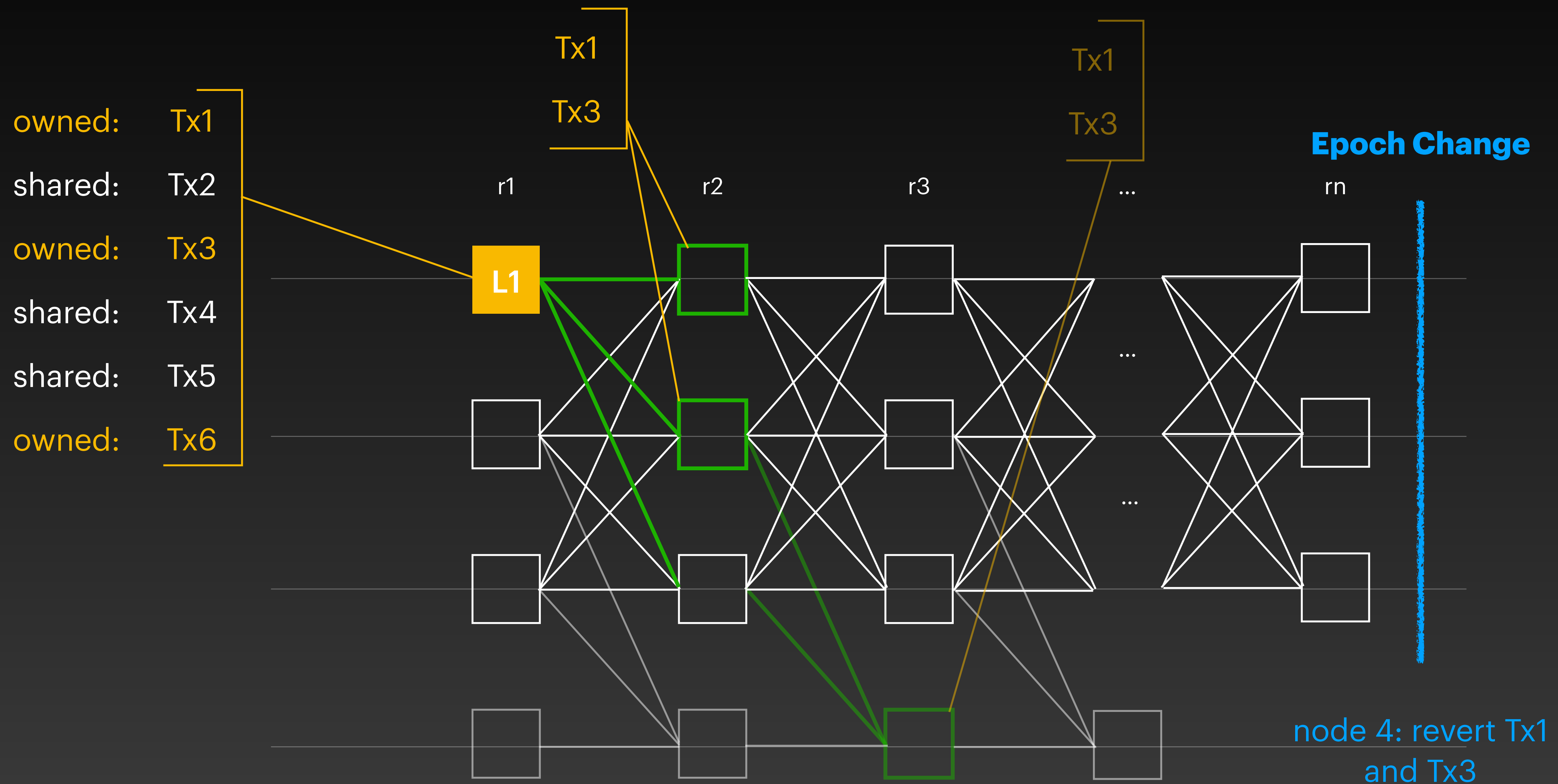
Fast Execution



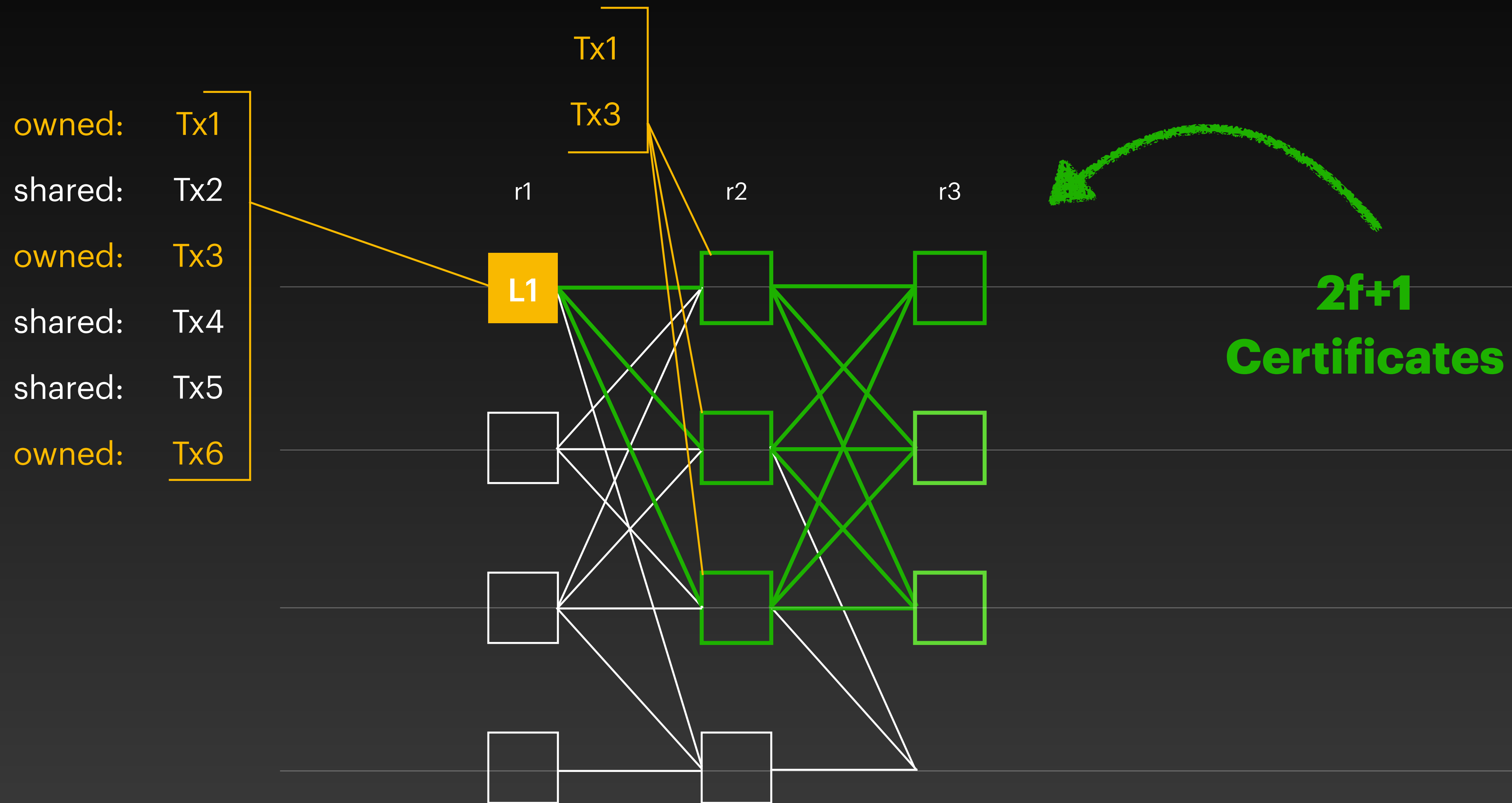
Fast Execution



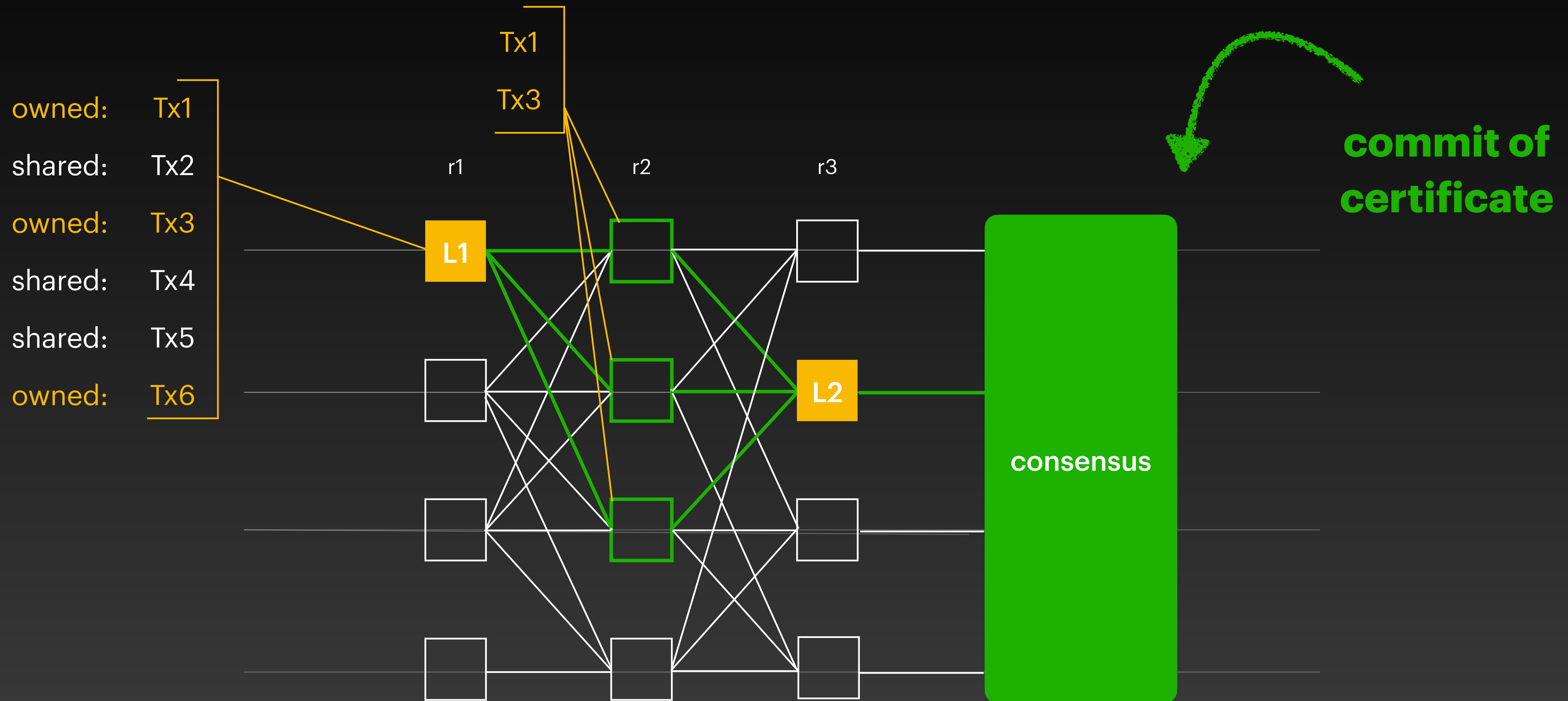
No Finality



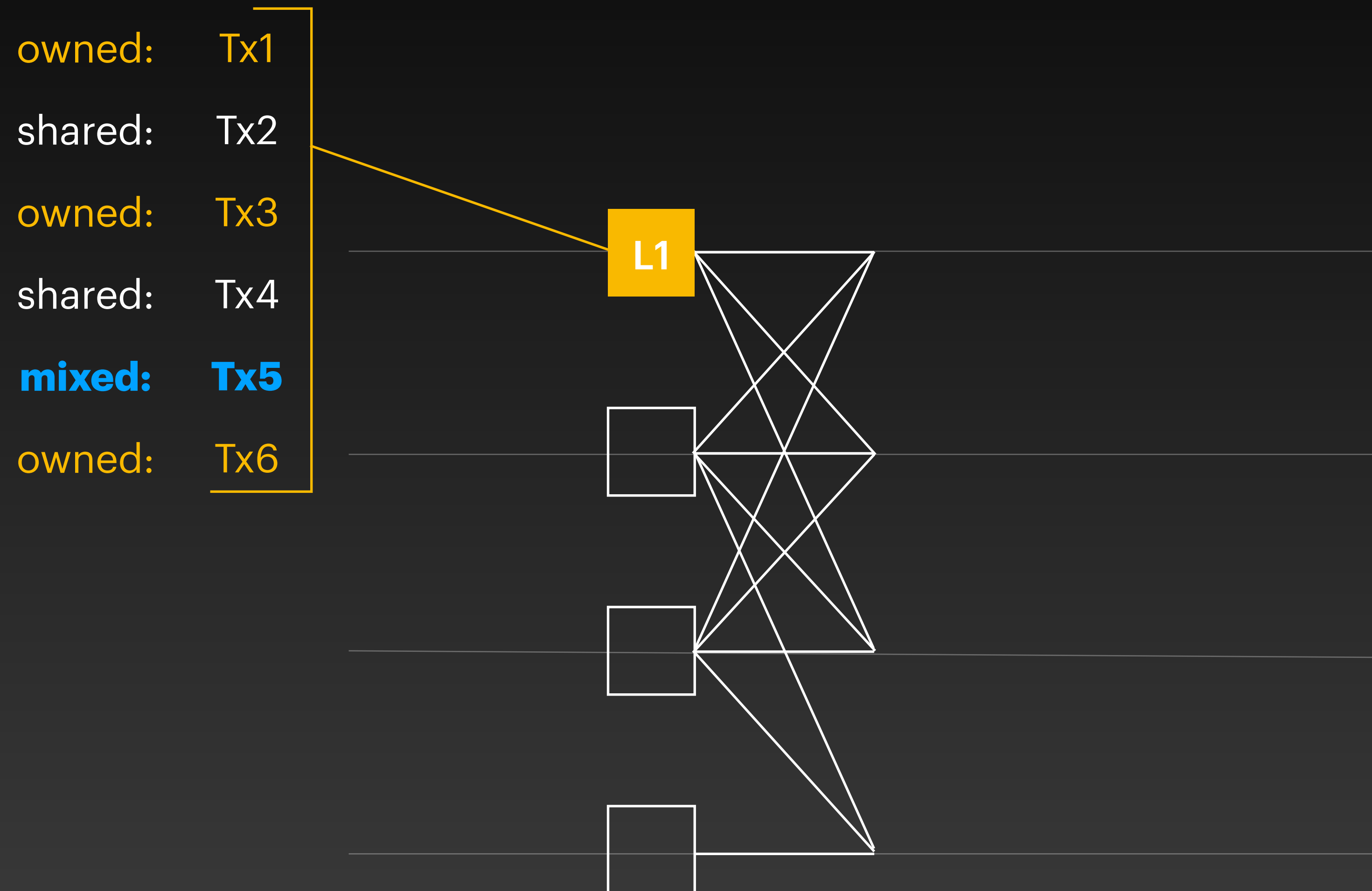
Fast Path Finality (1)



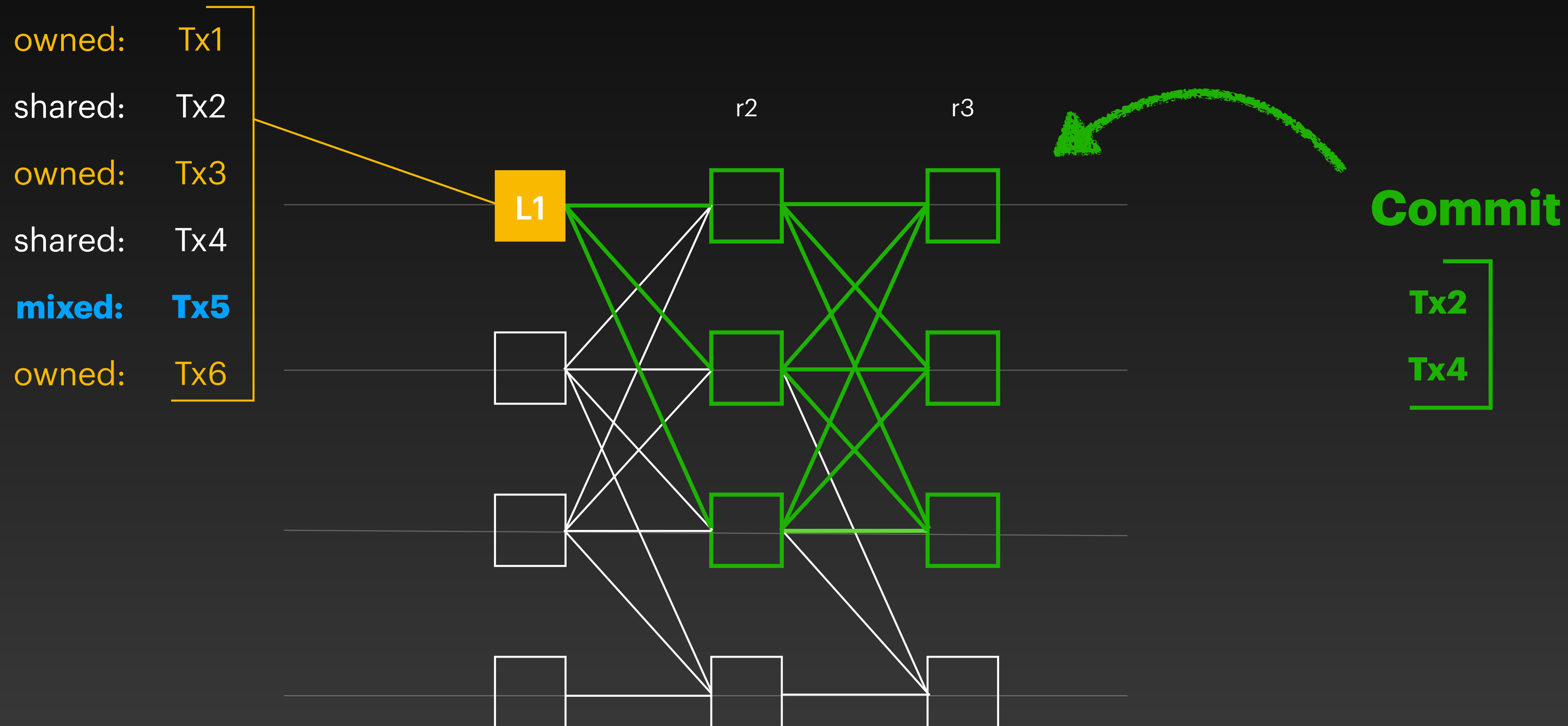
Fast Path Finality (2)



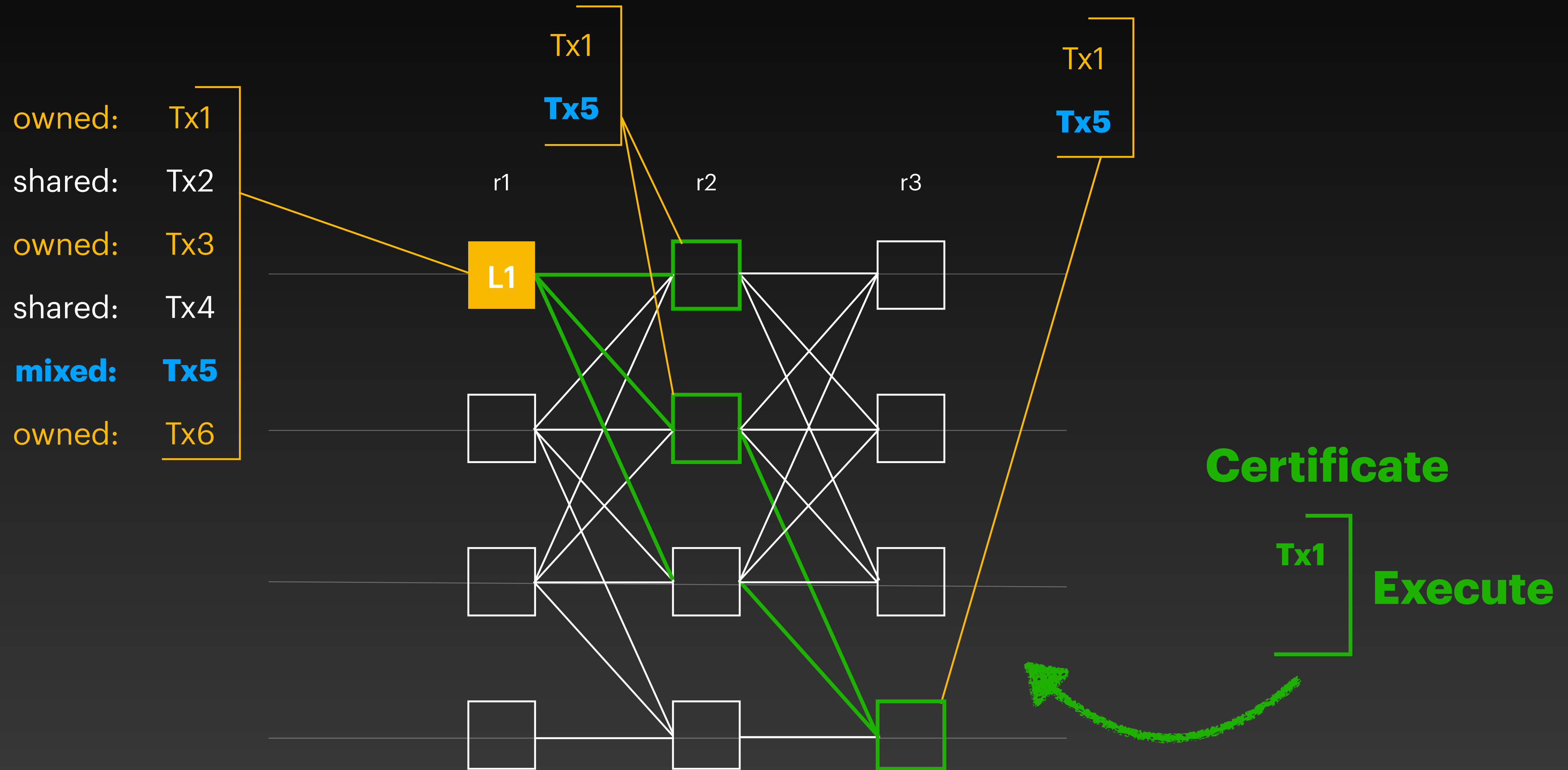
Mixed-Objects Transactions



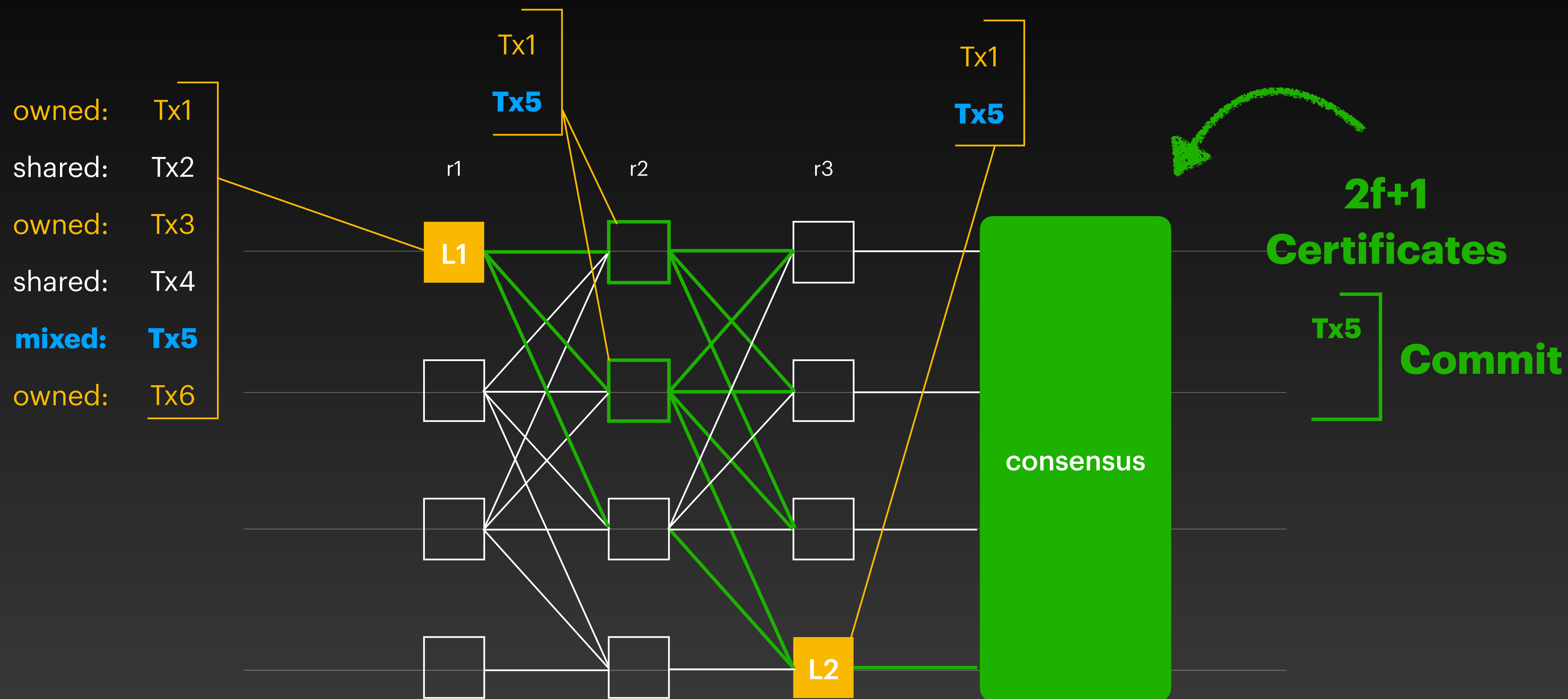
Mixed-Objects Transactions



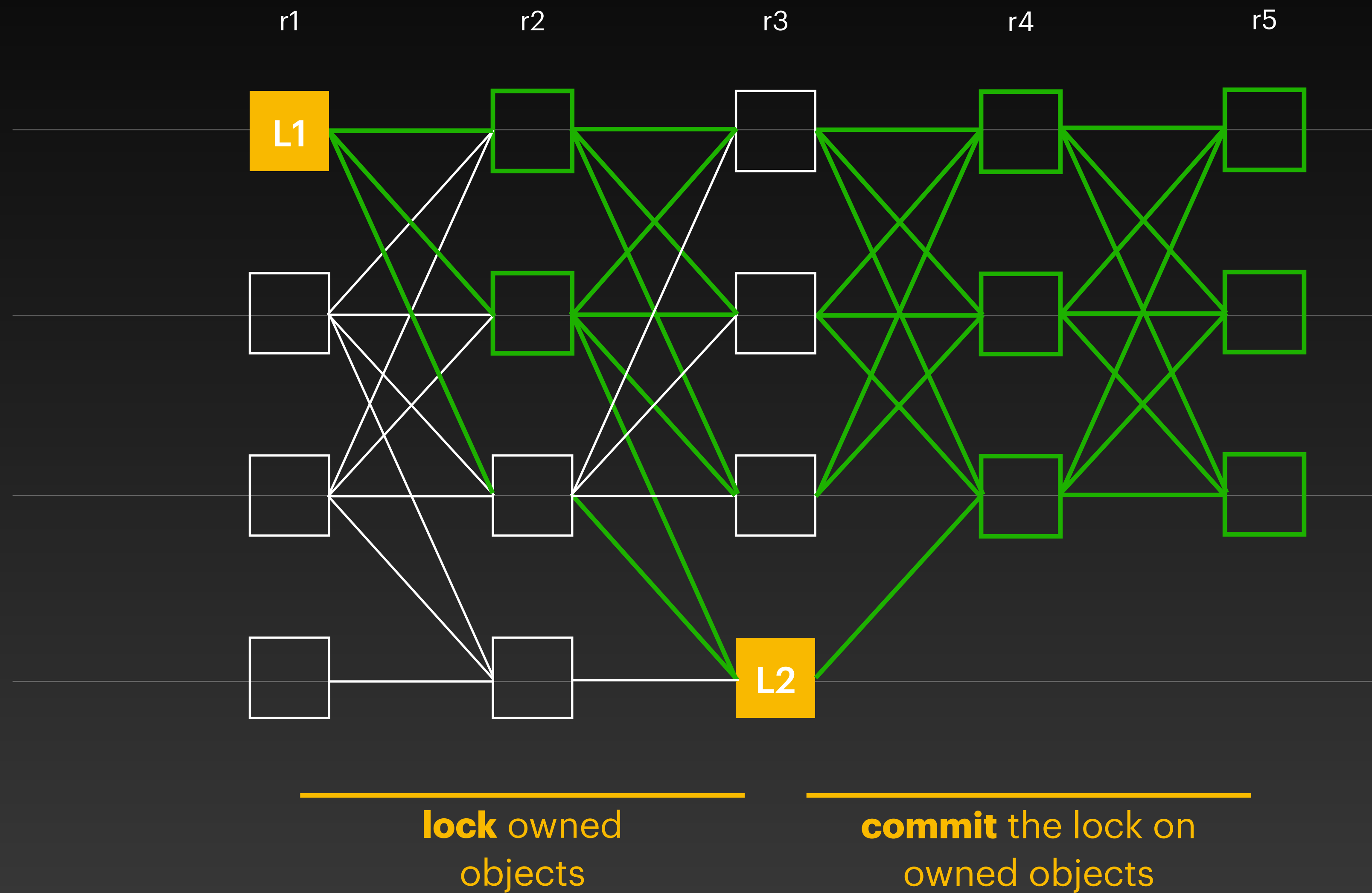
Mixed-Objects Transactions



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>

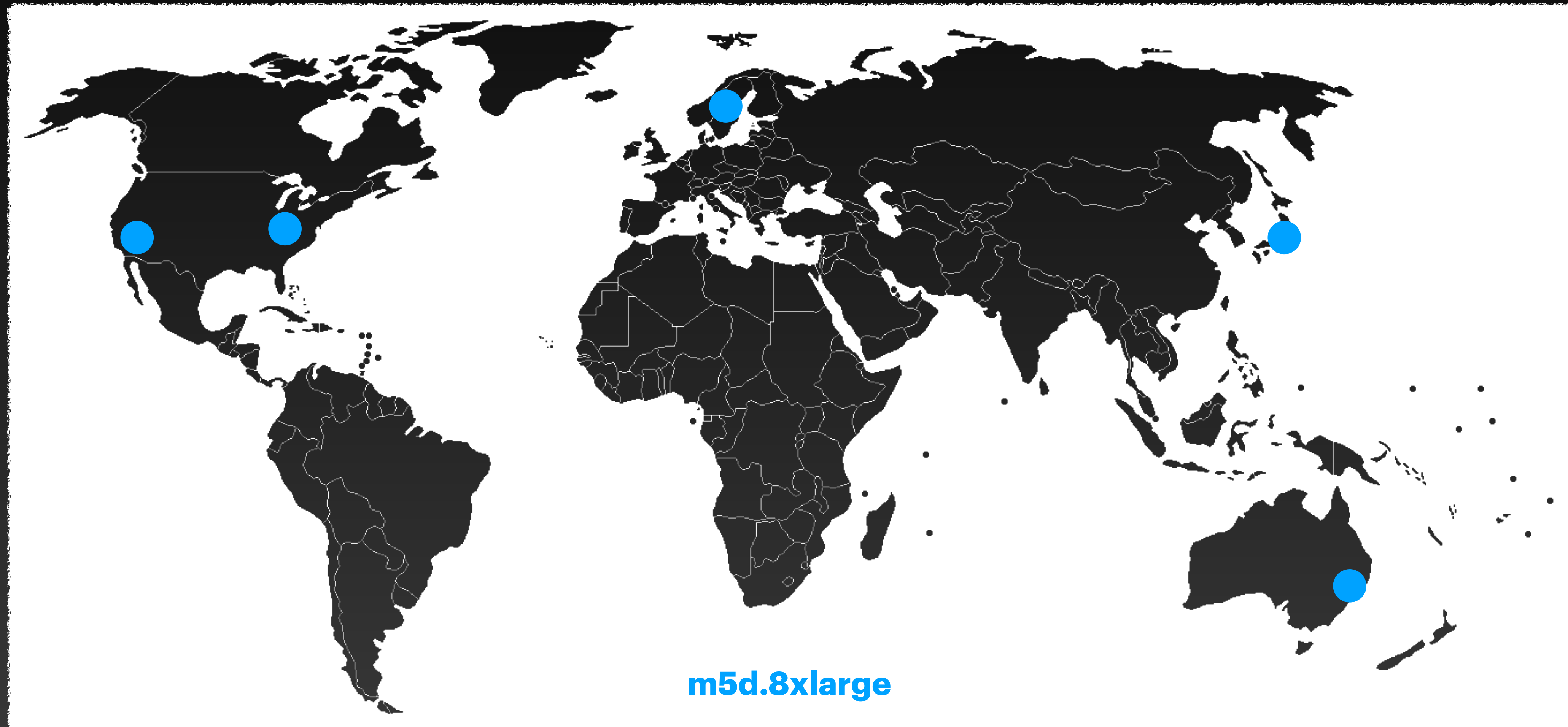
Implementation

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

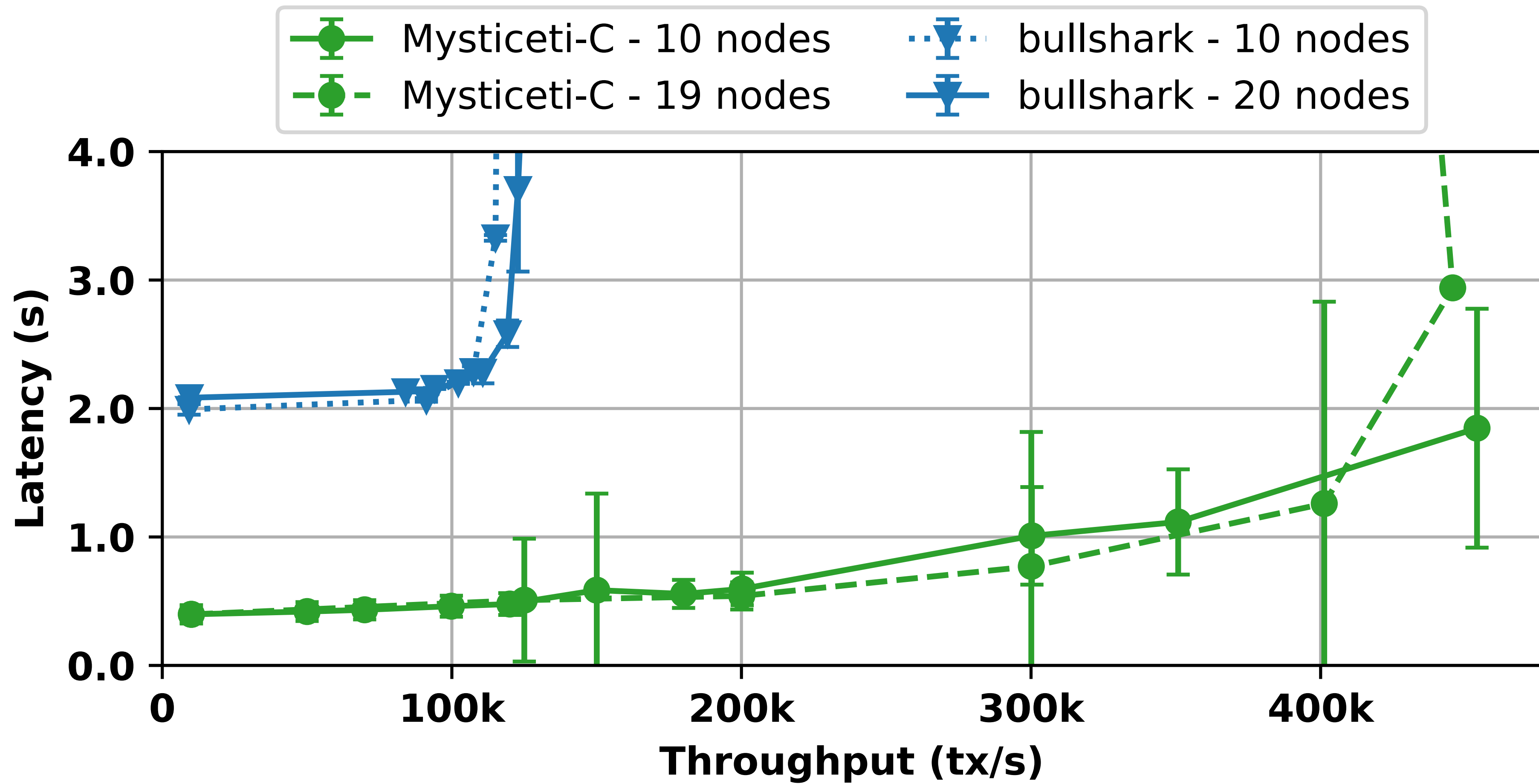
<https://github.com/mystenlabs/mysticeti>

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 \rightarrow mysticeti
- Prepare for the worst mysticeti \rightarrow bullshark

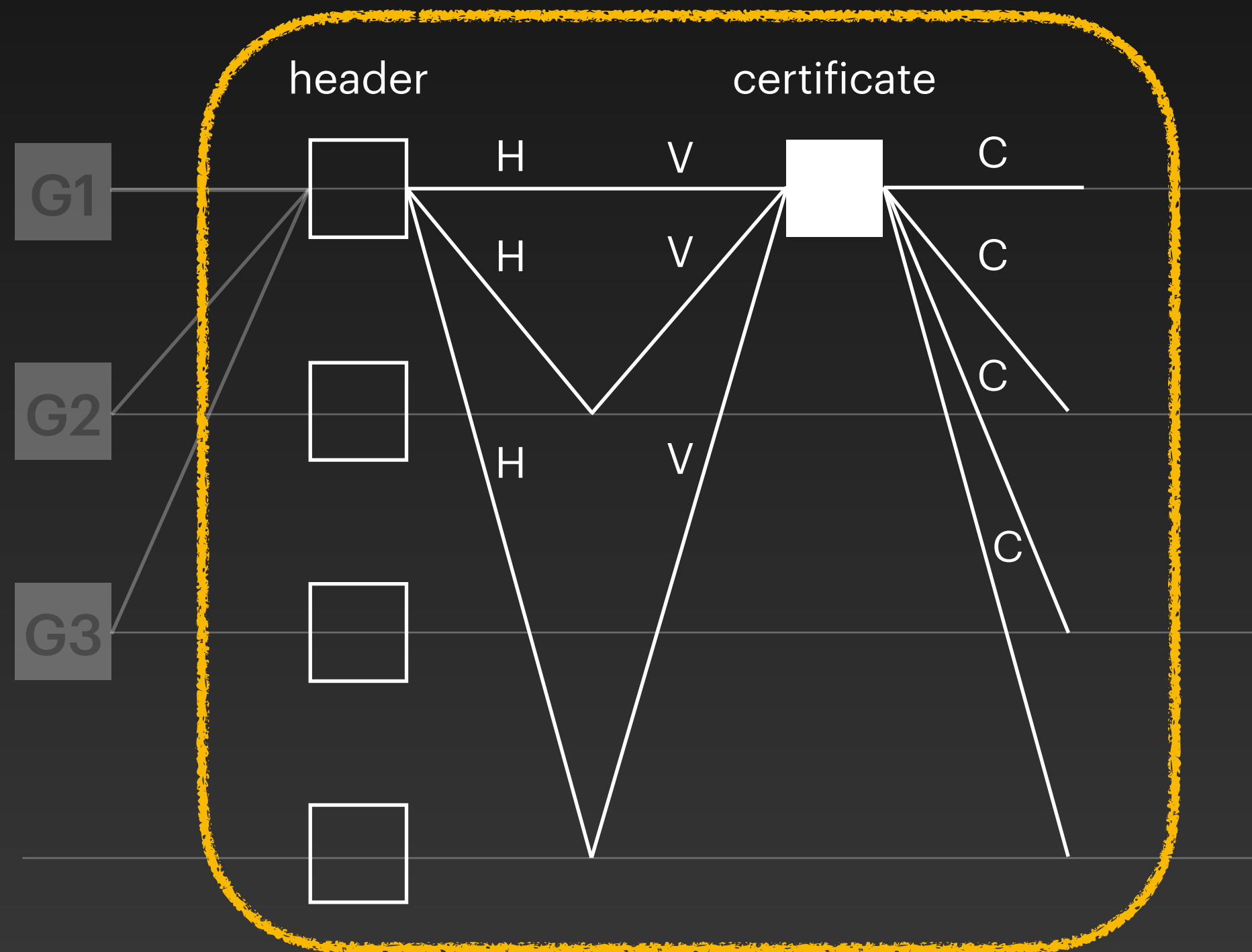
Narwhal vs Mysticeti

Key differences & Insight

Narwhal vs Mysticeti

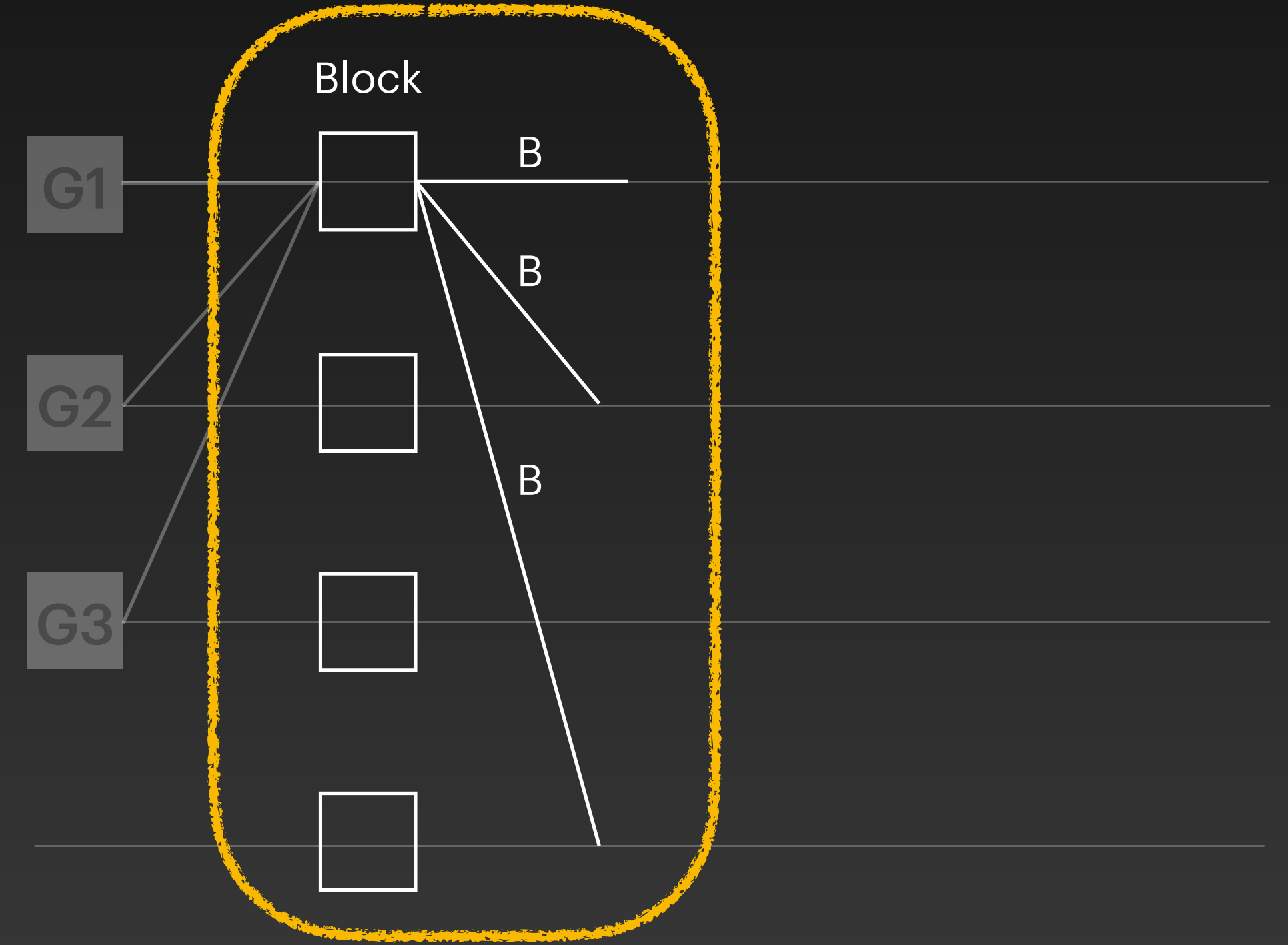
Narwhal

Round 1



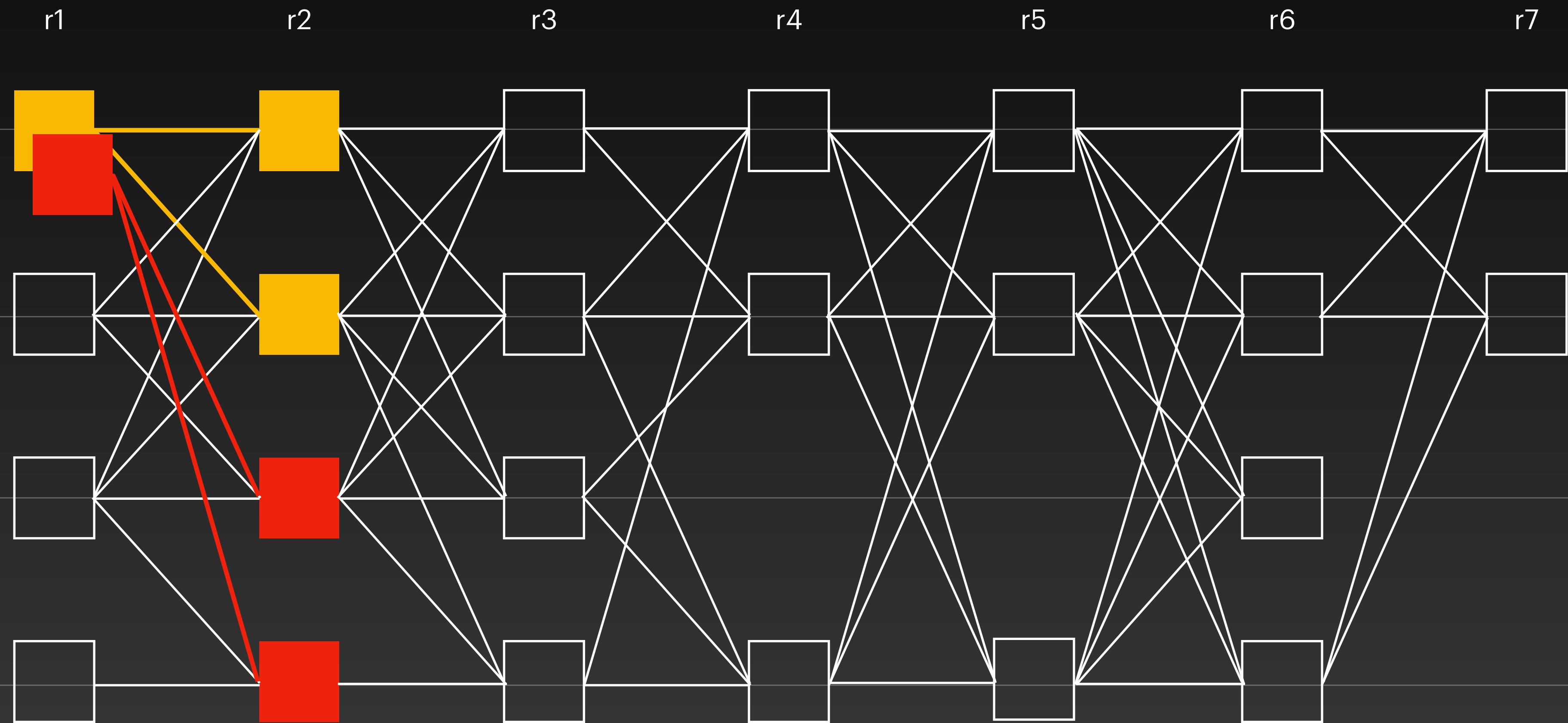
Mysticeti

Round 1



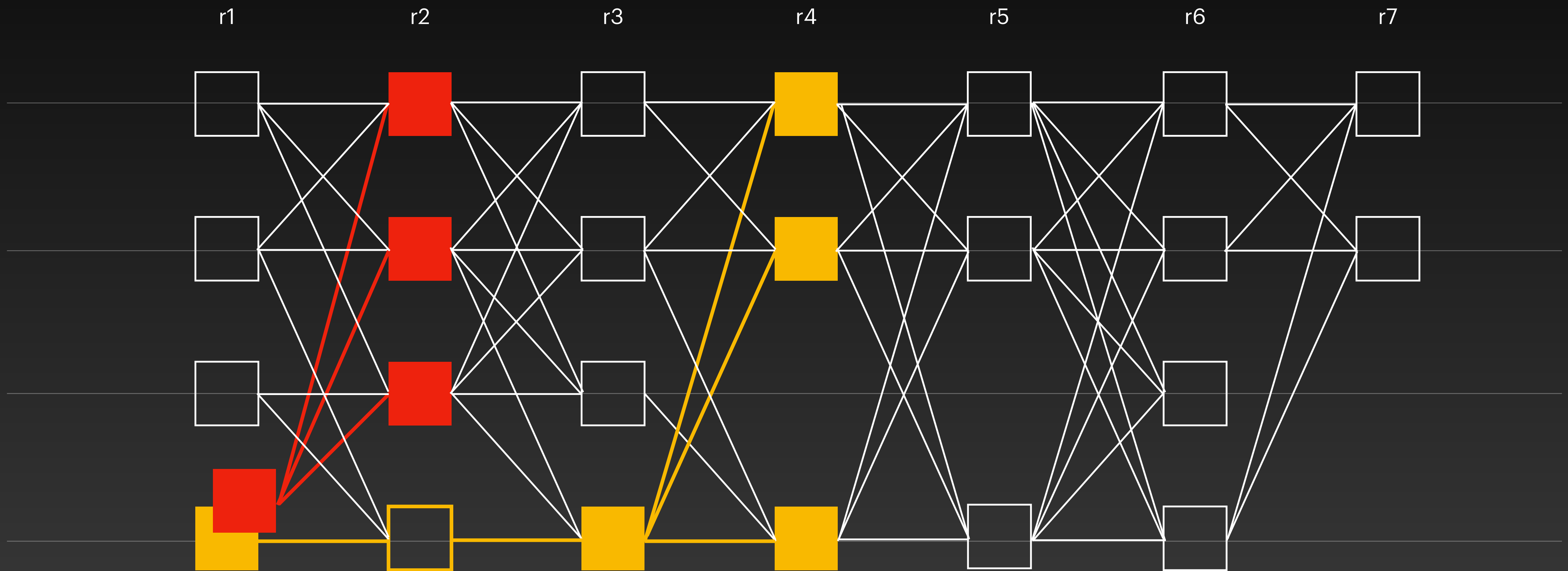
Main Challenge

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

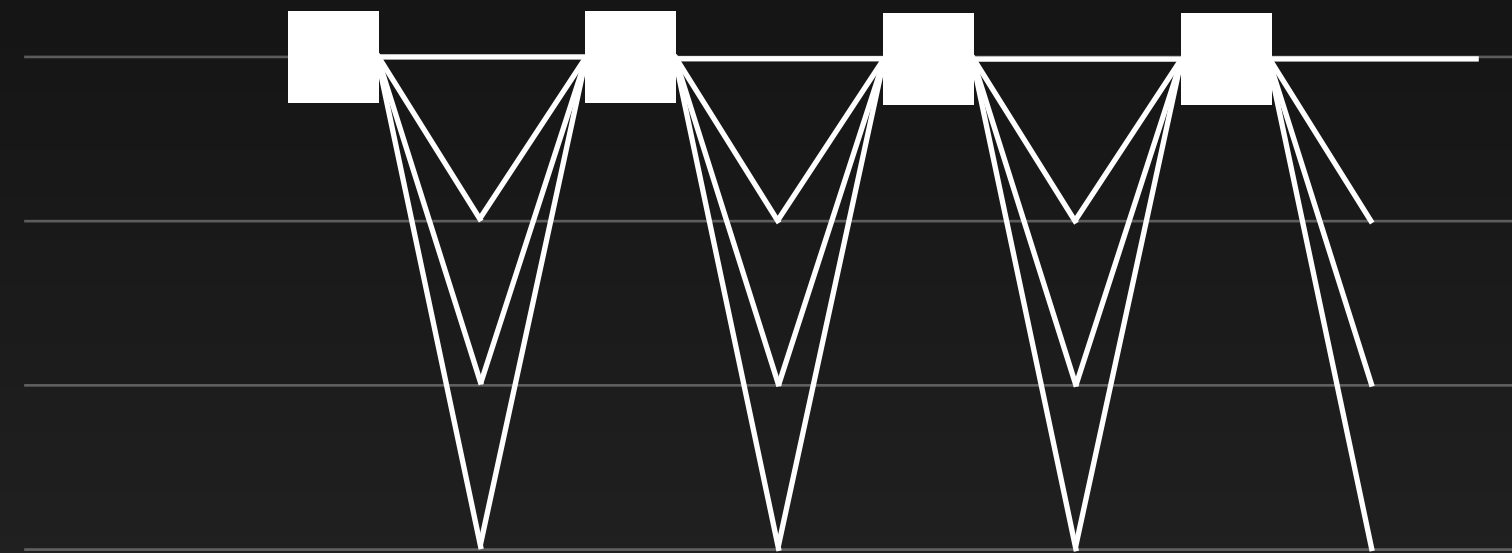
- Low latency
- Fragile to faults
- Complex leader-change

DAG-Based

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

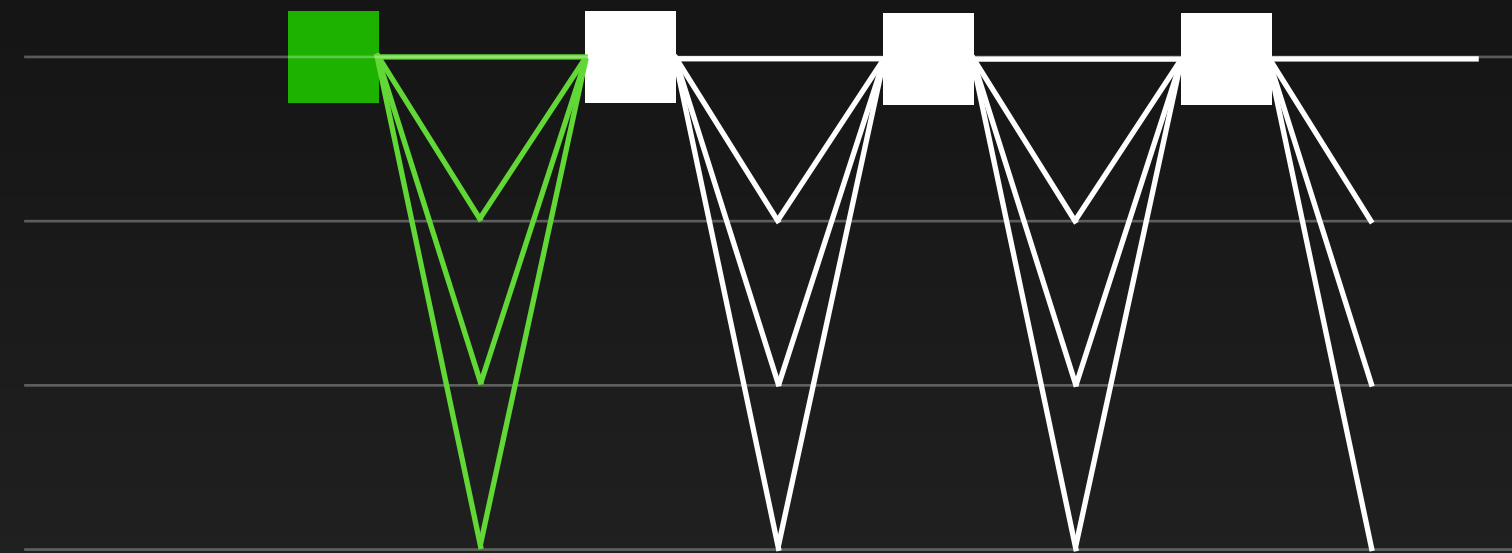
Linear-Chain Consensus

Rough overview



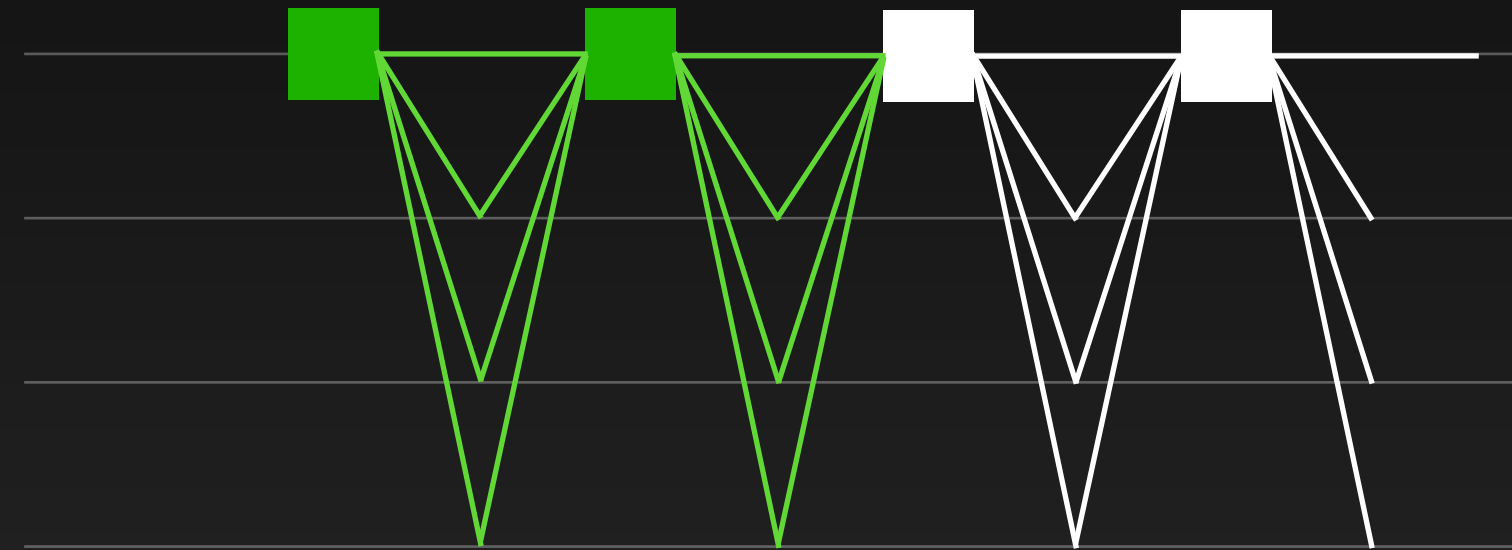
Linear-Chain Consensus

Rough overview



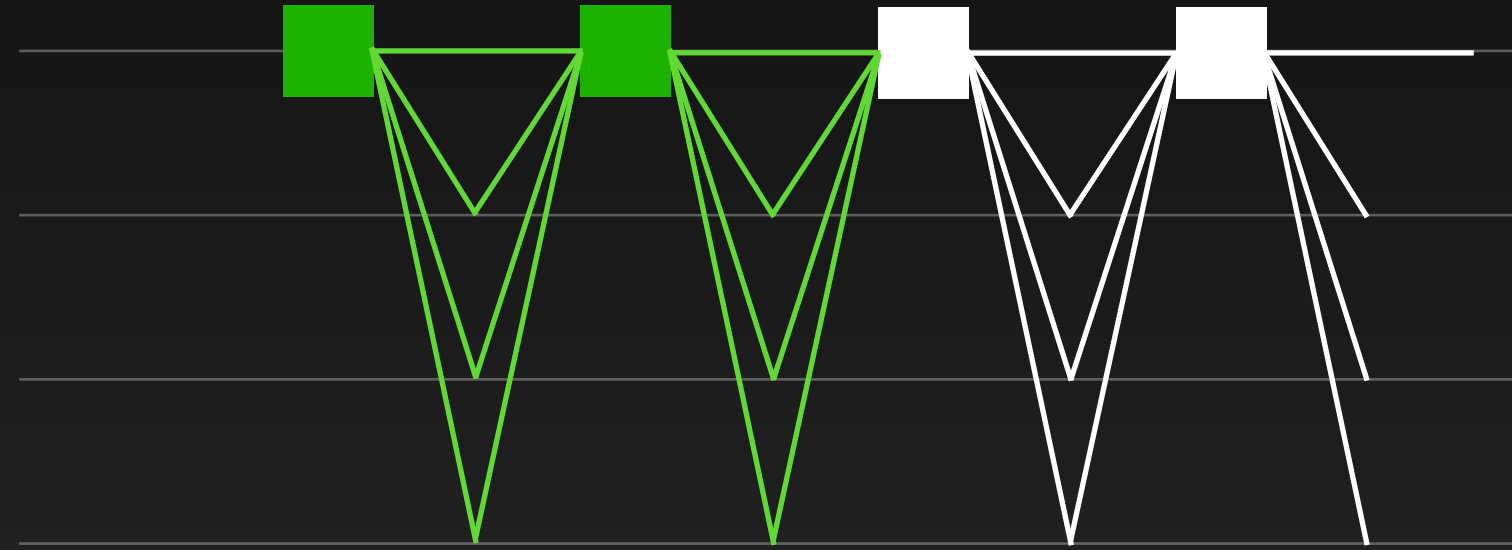
Linear-Chain Consensus

Rough overview



Linear-Chain Consensus

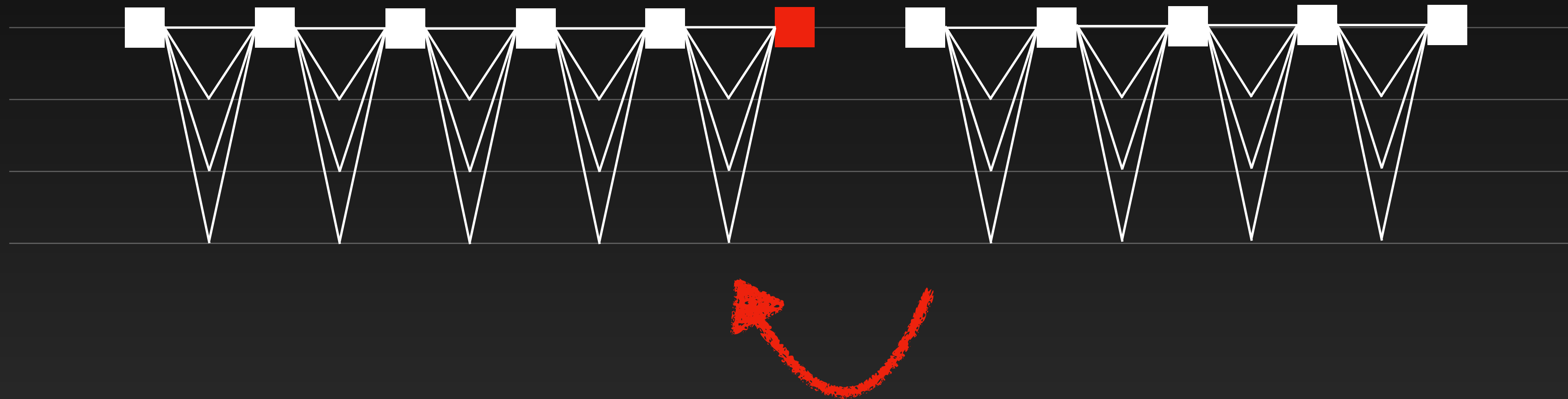
Rough overview



- The leader does all the work

Linear-Chain Consensus

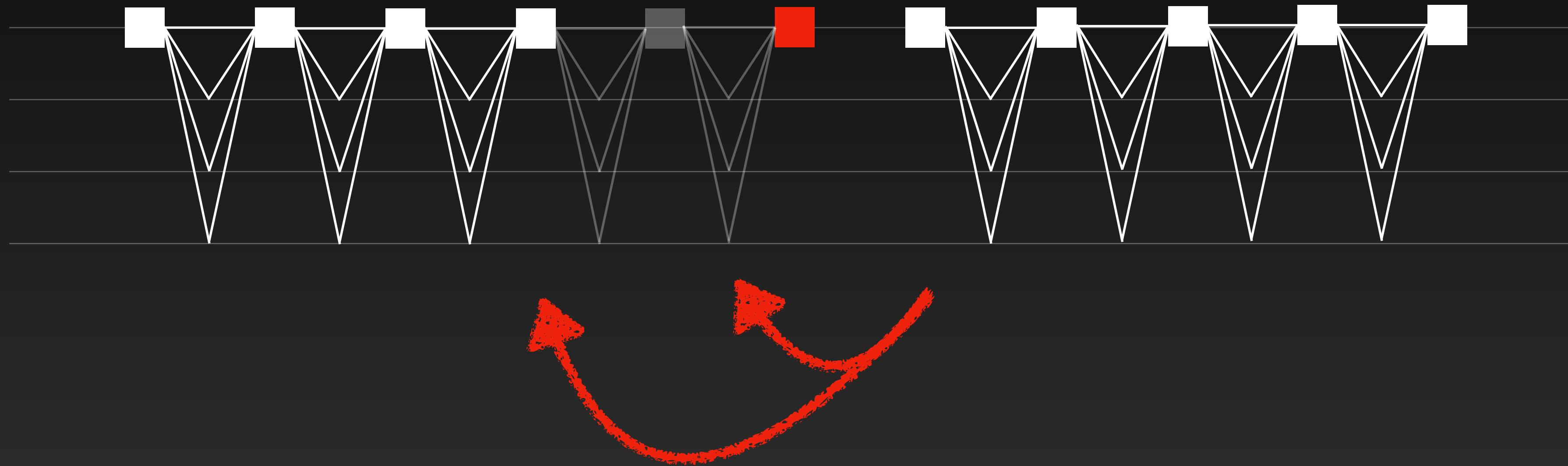
Rough overview



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

Linear-Chain Consensus

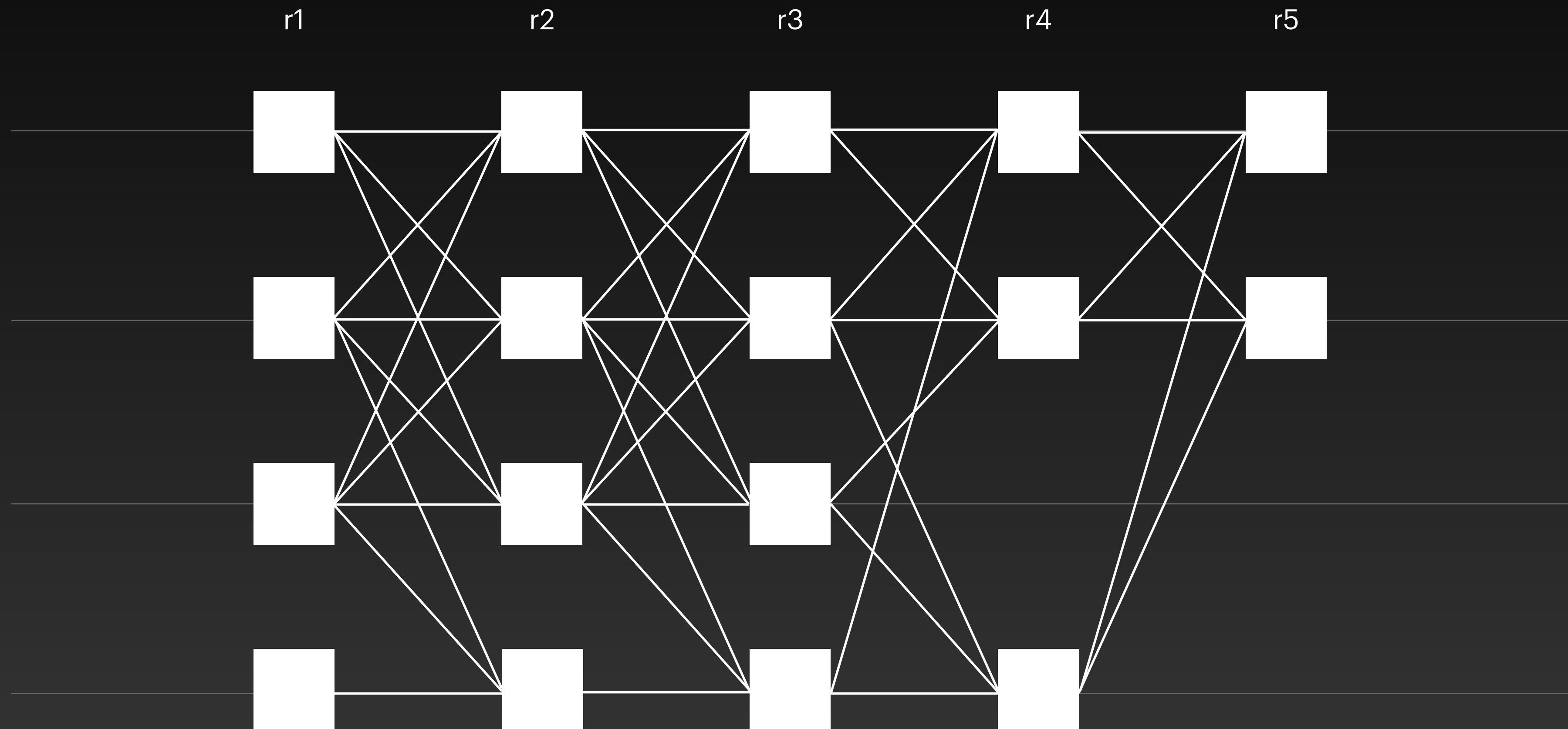
Rough overview



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

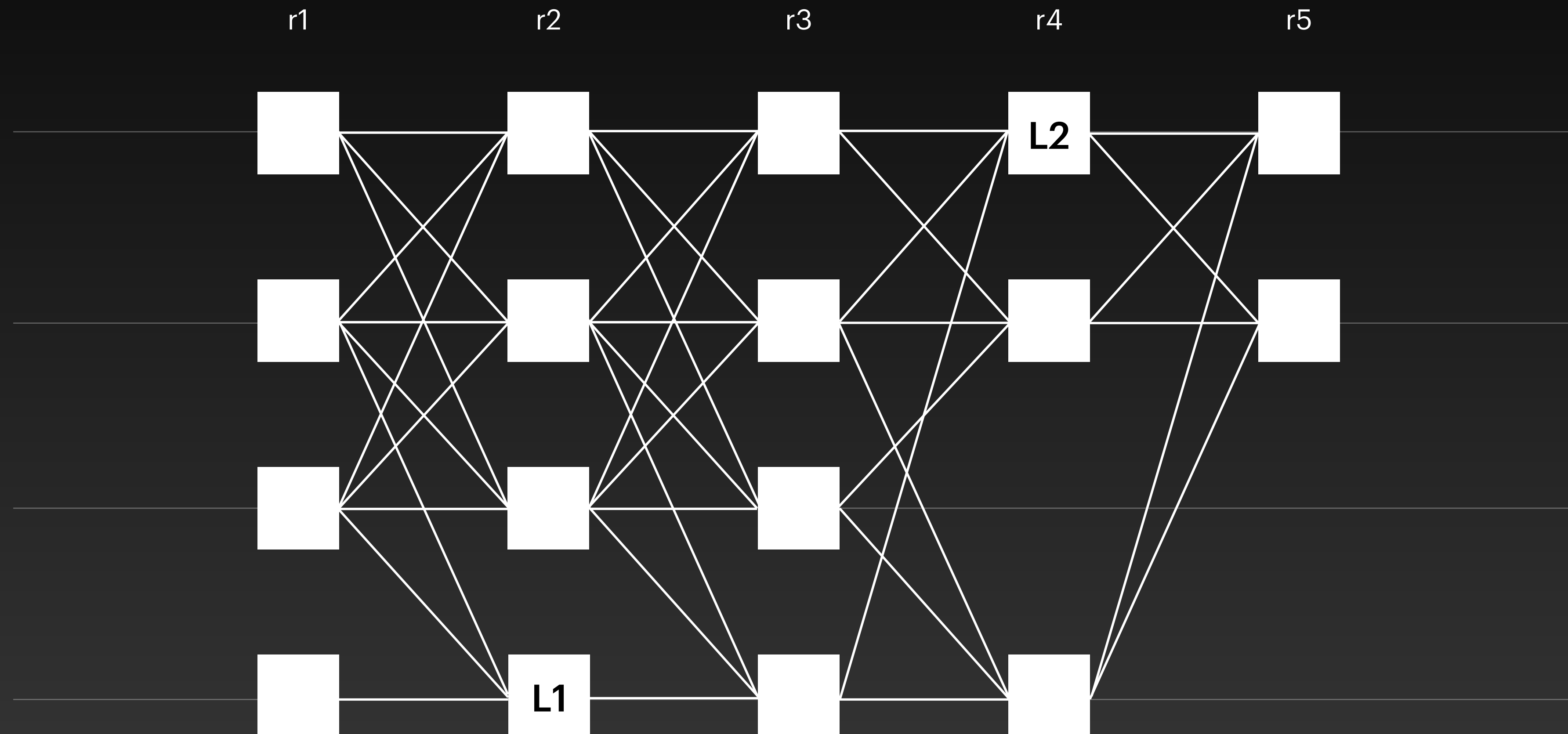
DAG-Based Consensus

Rough overview



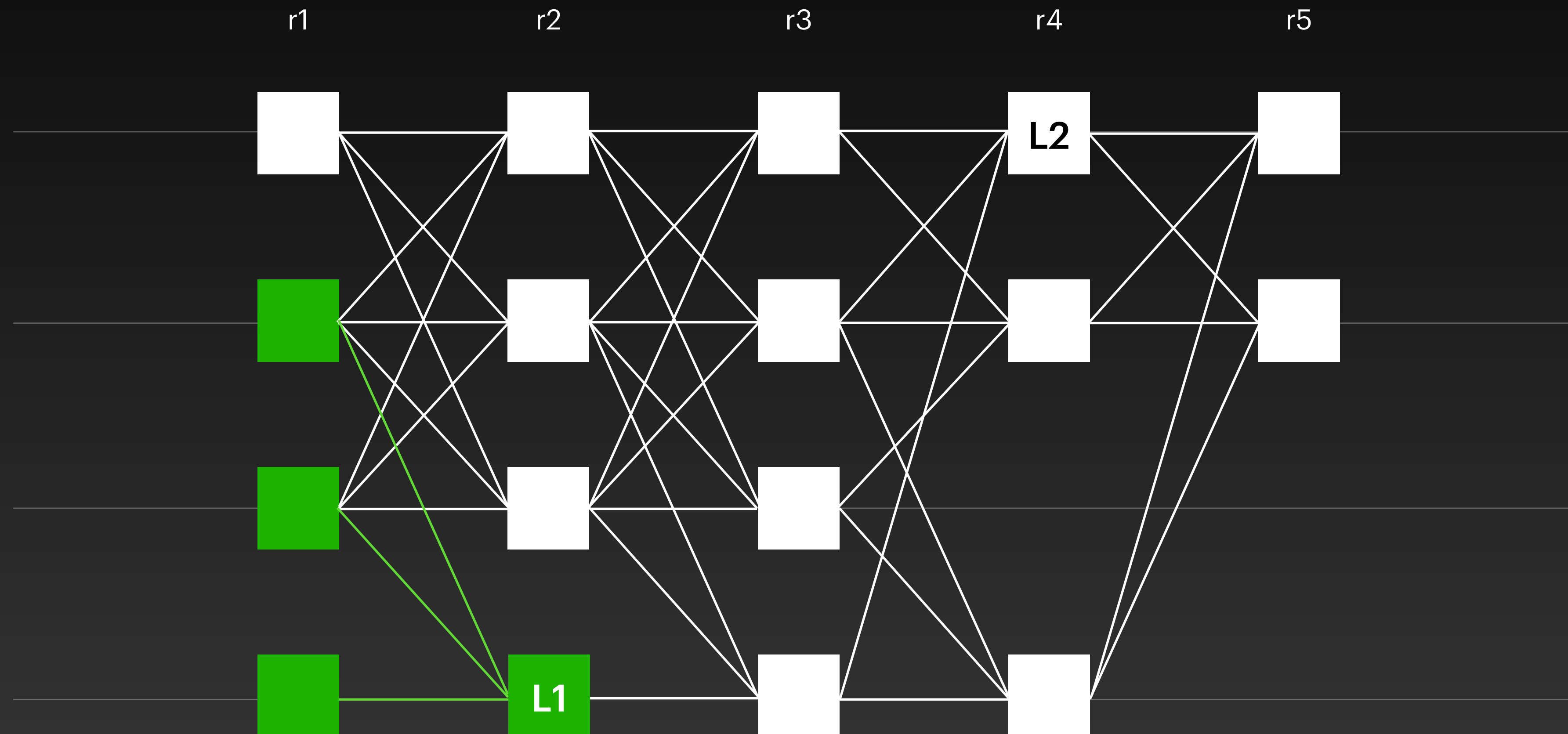
DAG-Based Consensus

Rough overview



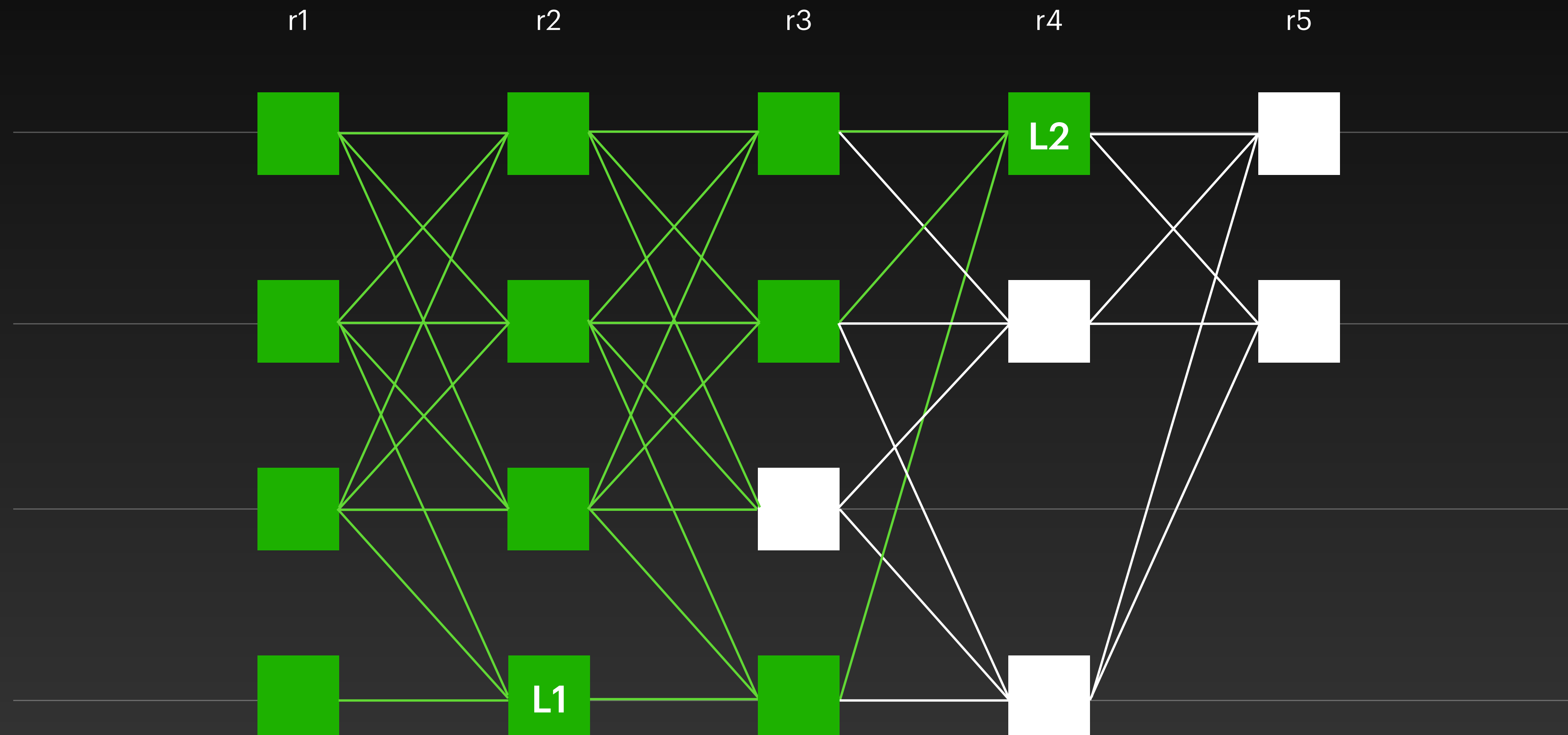
DAG-Based Consensus

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>