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

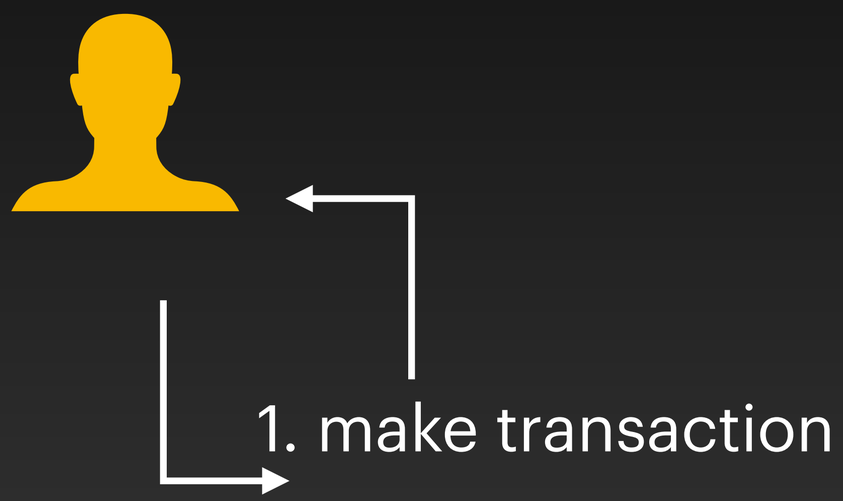
Byzantine Fault Tolerance

>= 2f+1

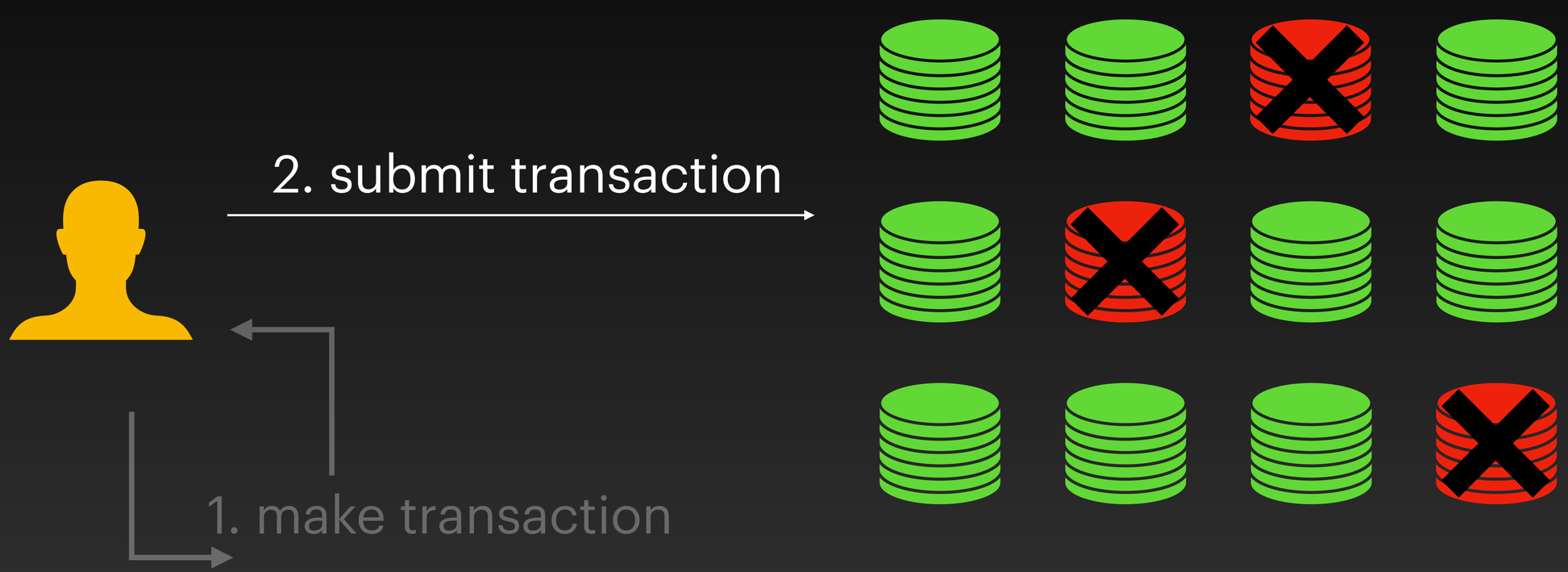
3f+1

Partial Synchrony

Blockchains



Blockchains



Blockchains

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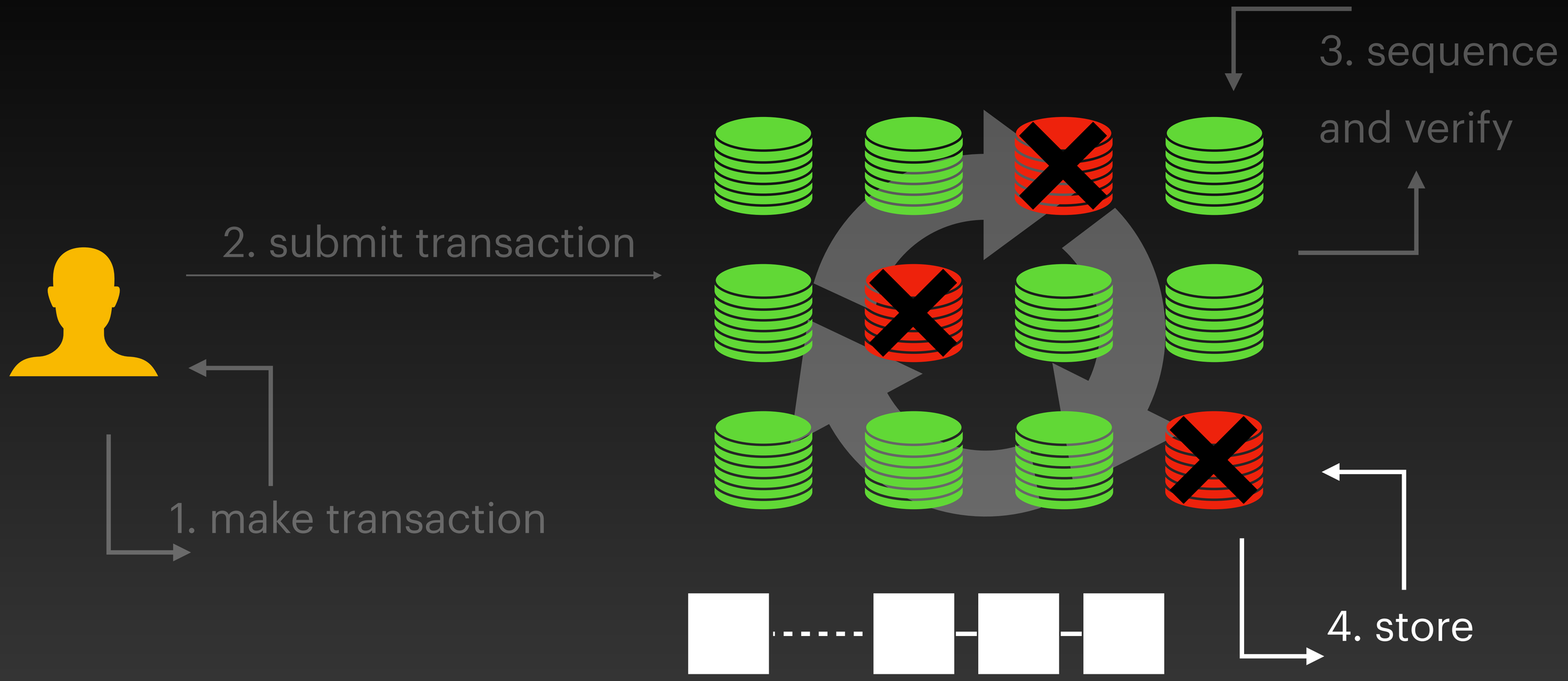


Keeping the Talk Short

In scope

- Ordering (quorum-based)

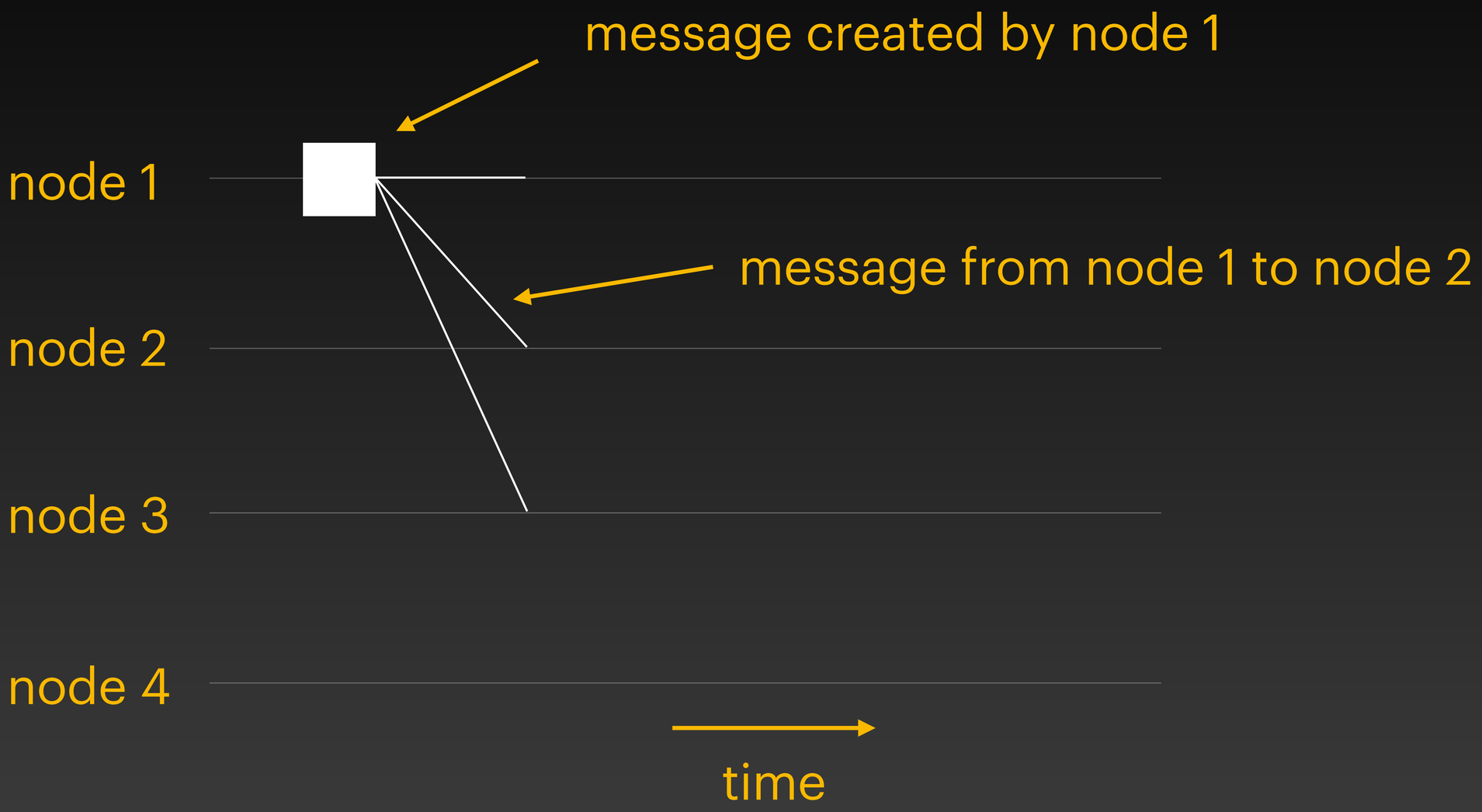
Not in scope

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

Mysticeti

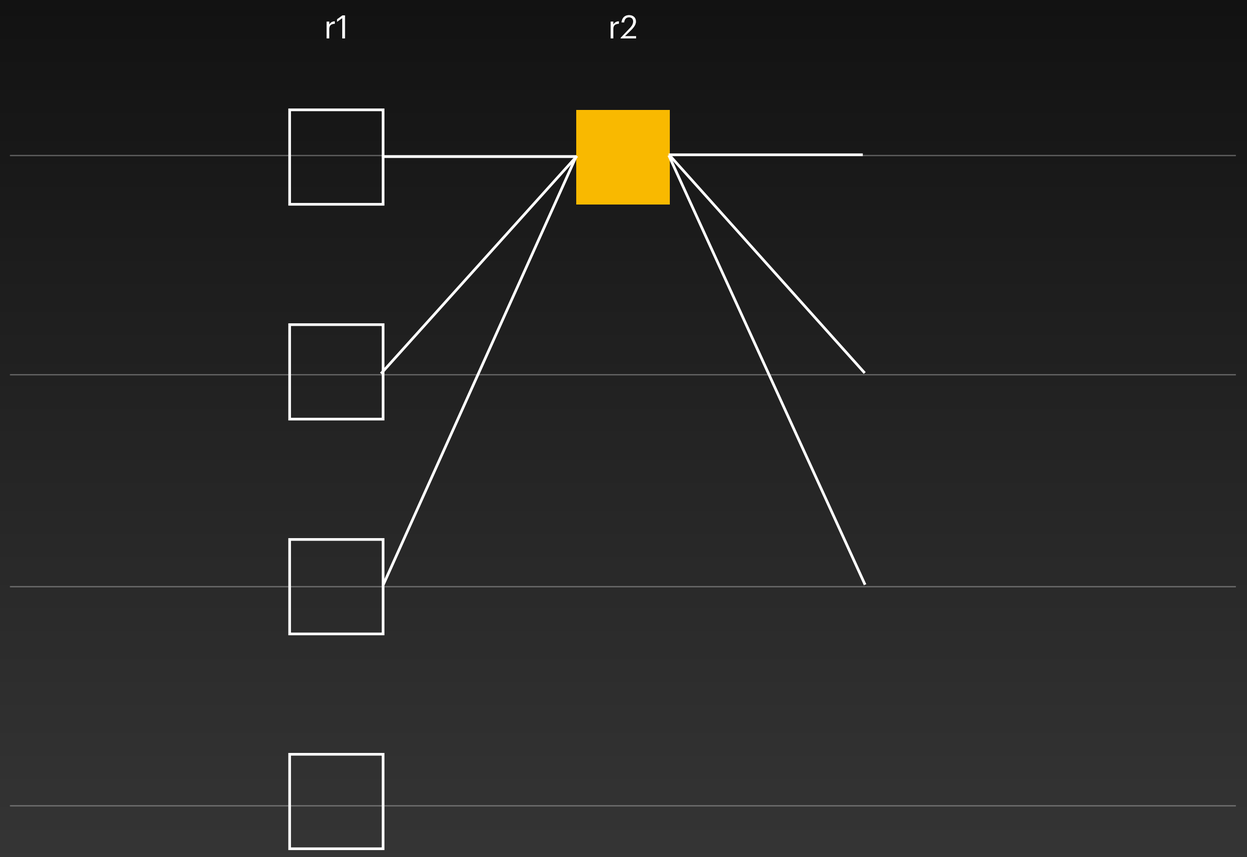
Low-latency DAG consensus with fast commit path

Lamport Diagram



The Mysticeti DAG

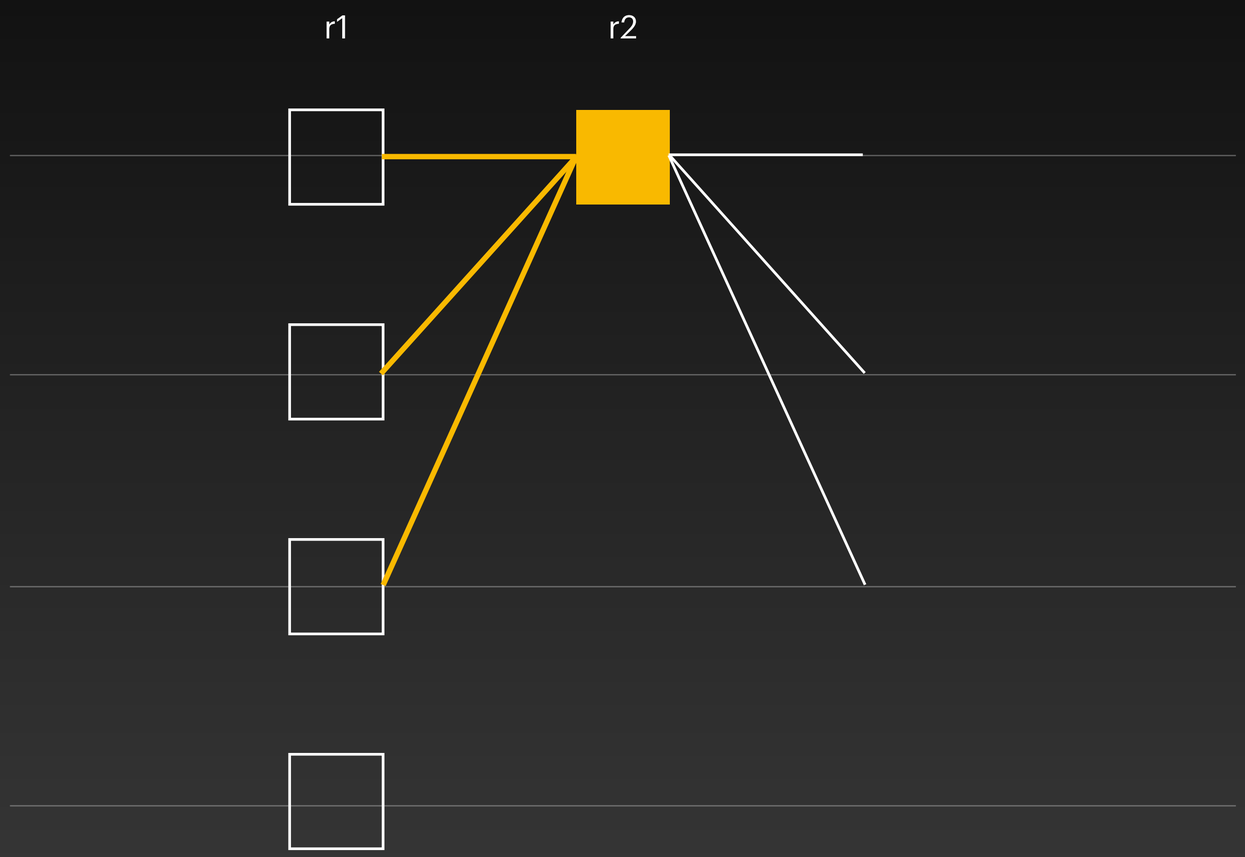
Block Creation



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

The Mysticeti DAG

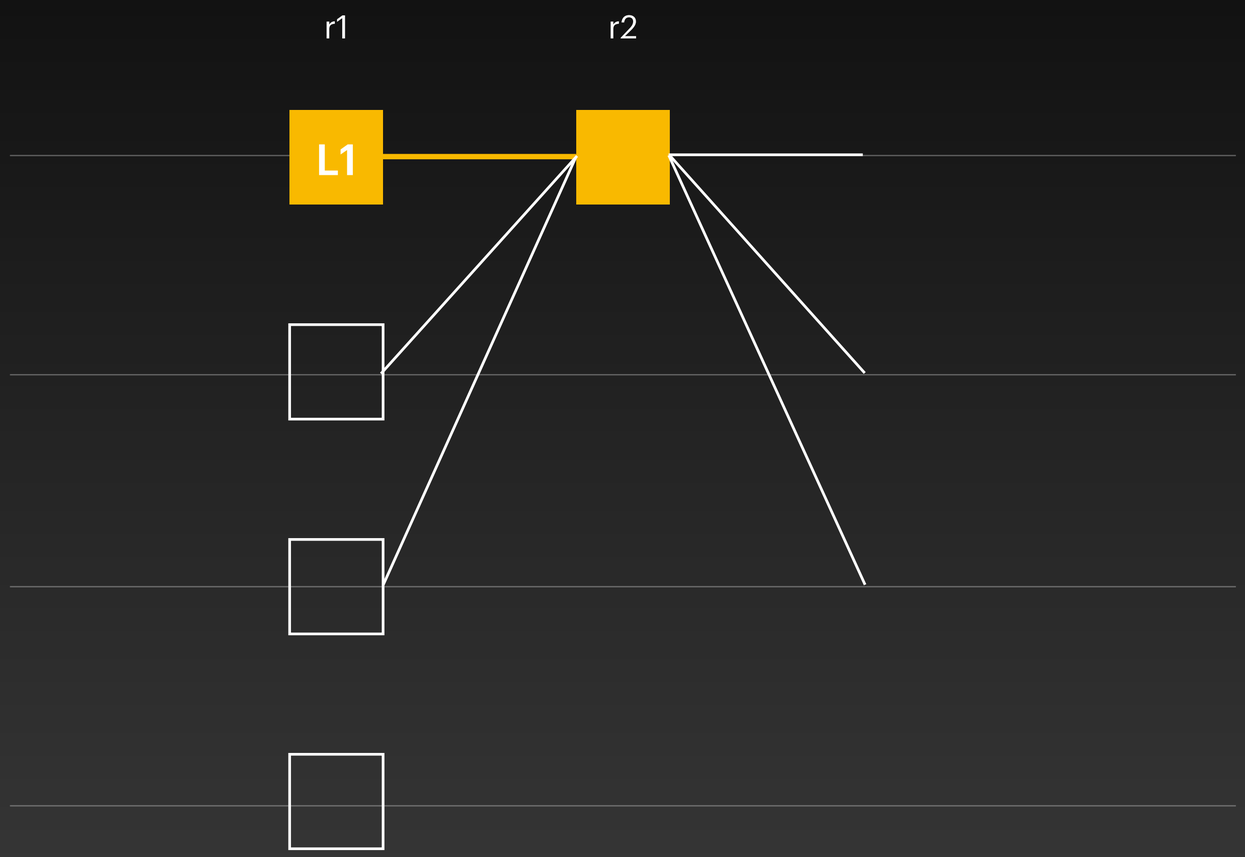
Rule 1: Link to 2f+1 parents



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

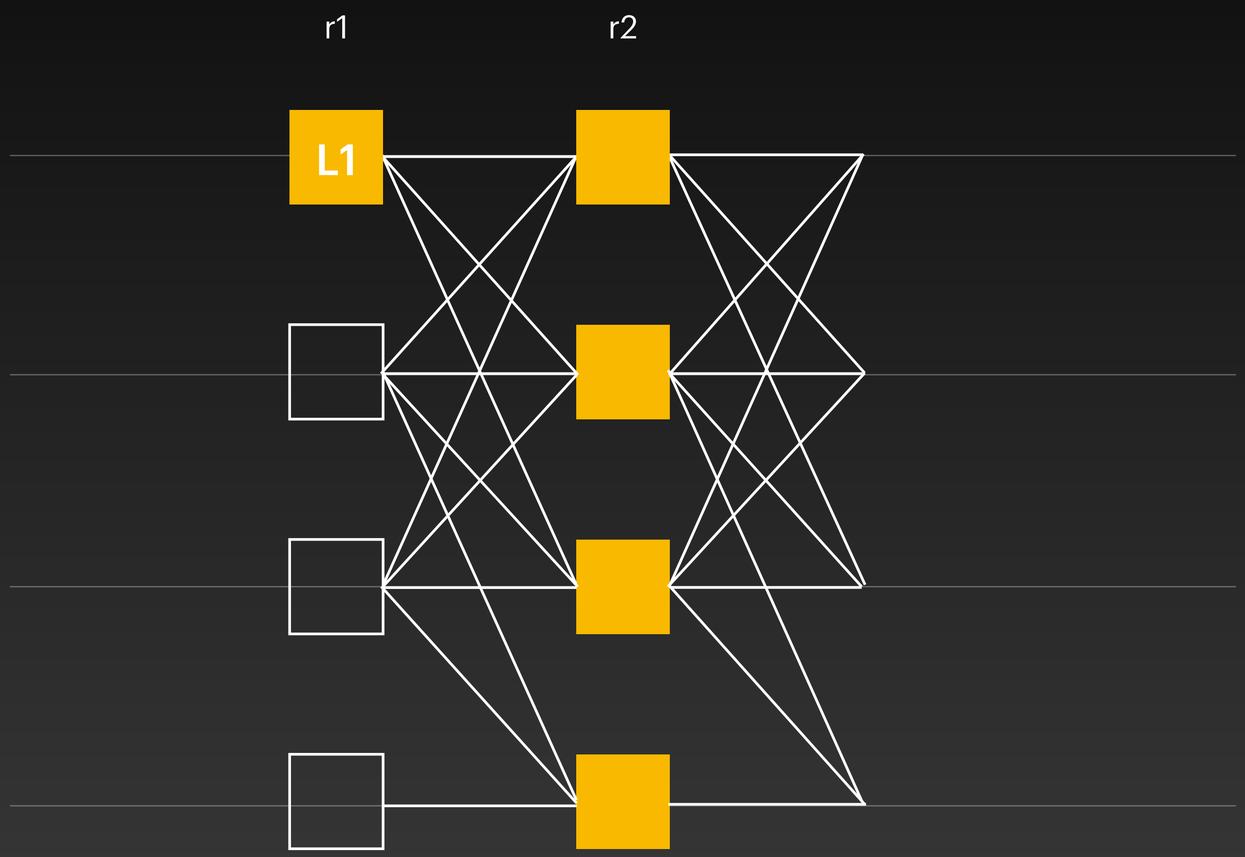
The Mysticeti DAG

Rule 2: Every node waits and links to leaders

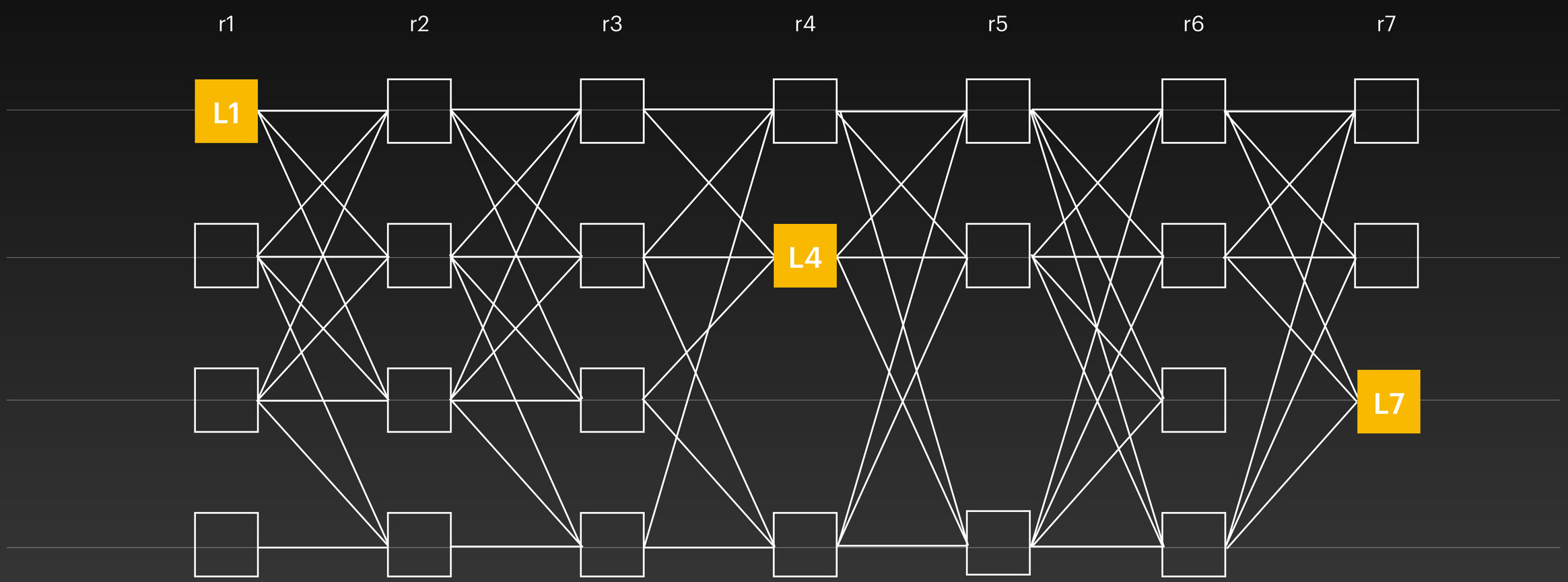


The Mysticeti DAG

Rule 3: All node run in parallel



The Mysticeti DAG

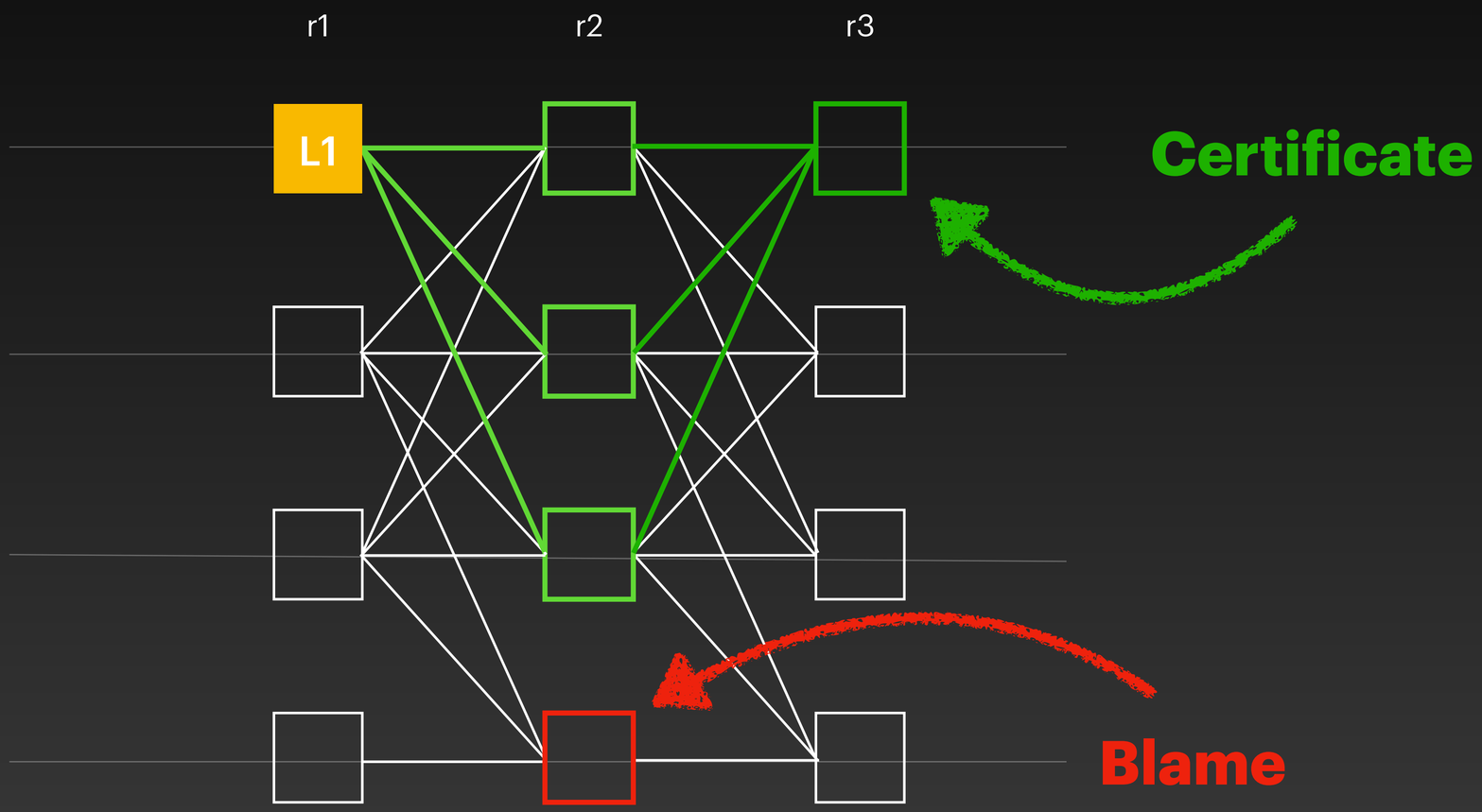


Main Ingredient:

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

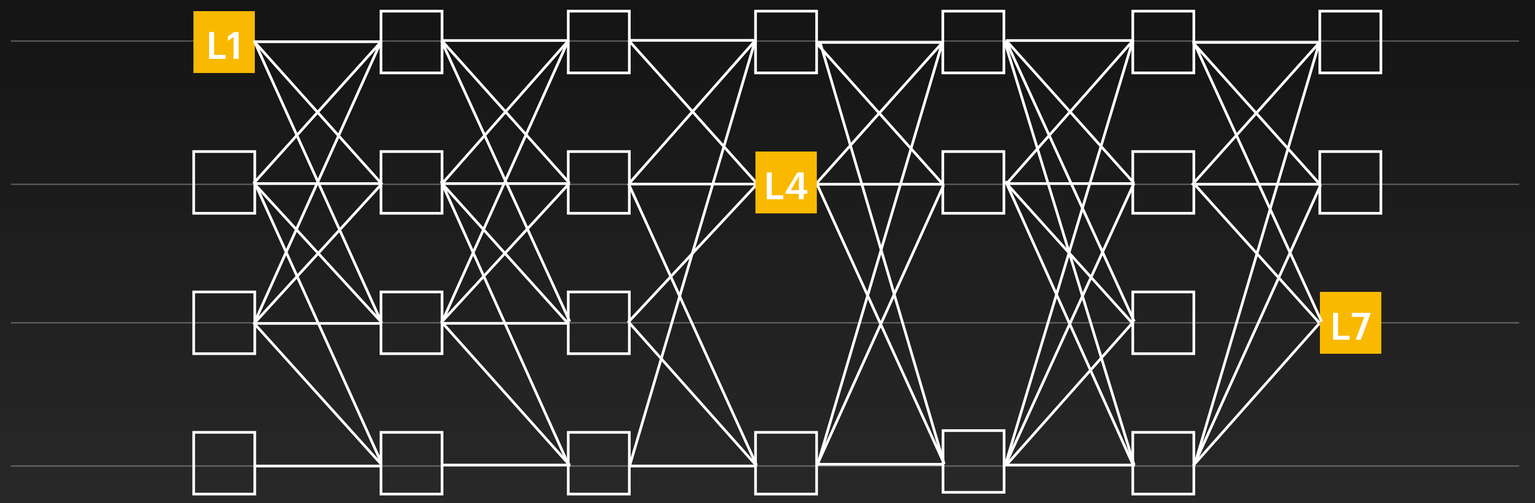
- Interpret BCB on DAG

Mysticeti-C

The consensus protocol

End Goal

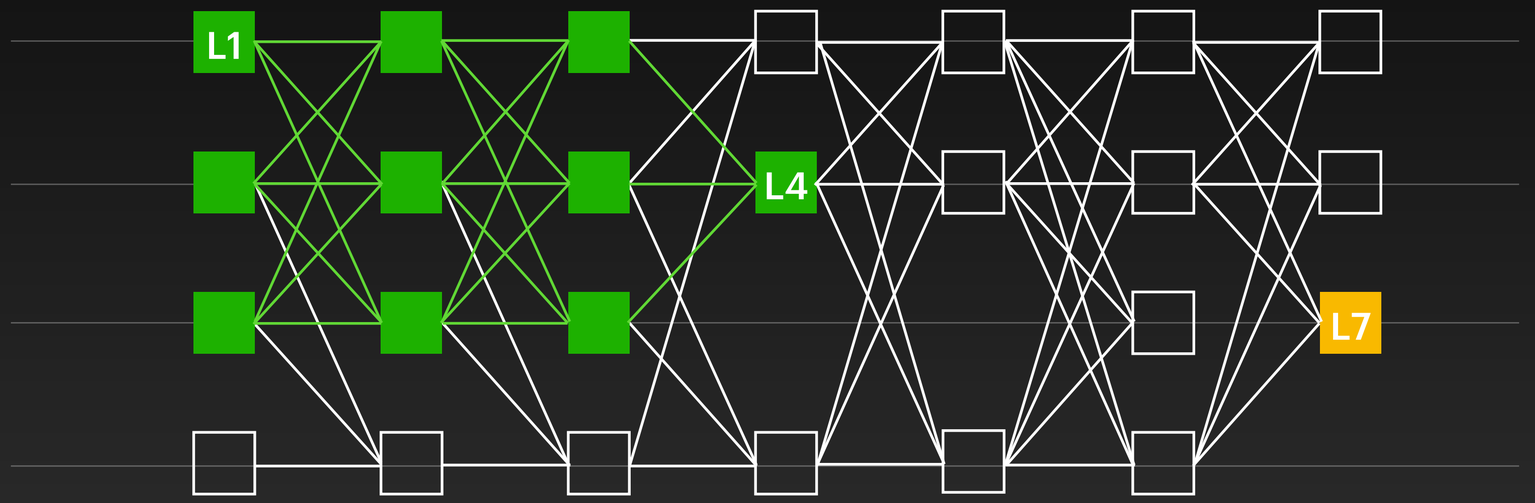
Ordering leaders



- We focus on ordering leaders: L1 L4 L7

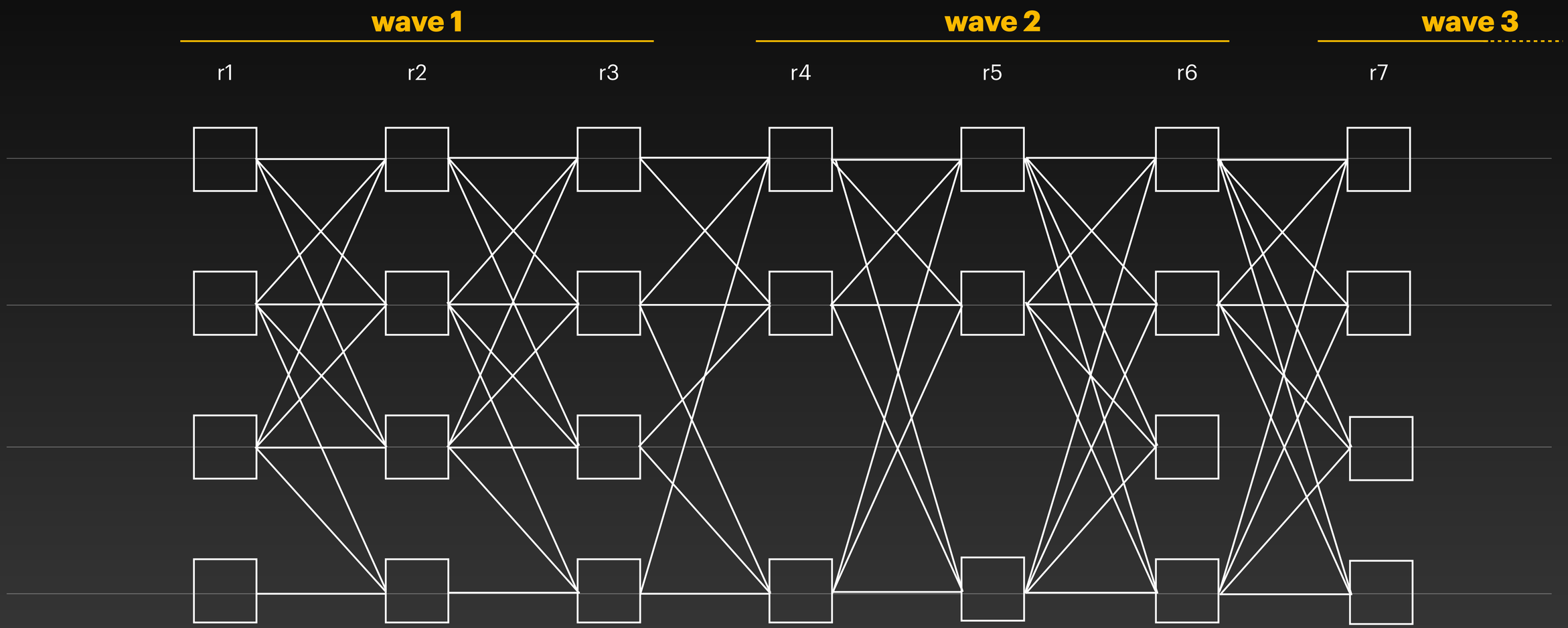
End Goal

Ordering leaders



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

DAG Structure



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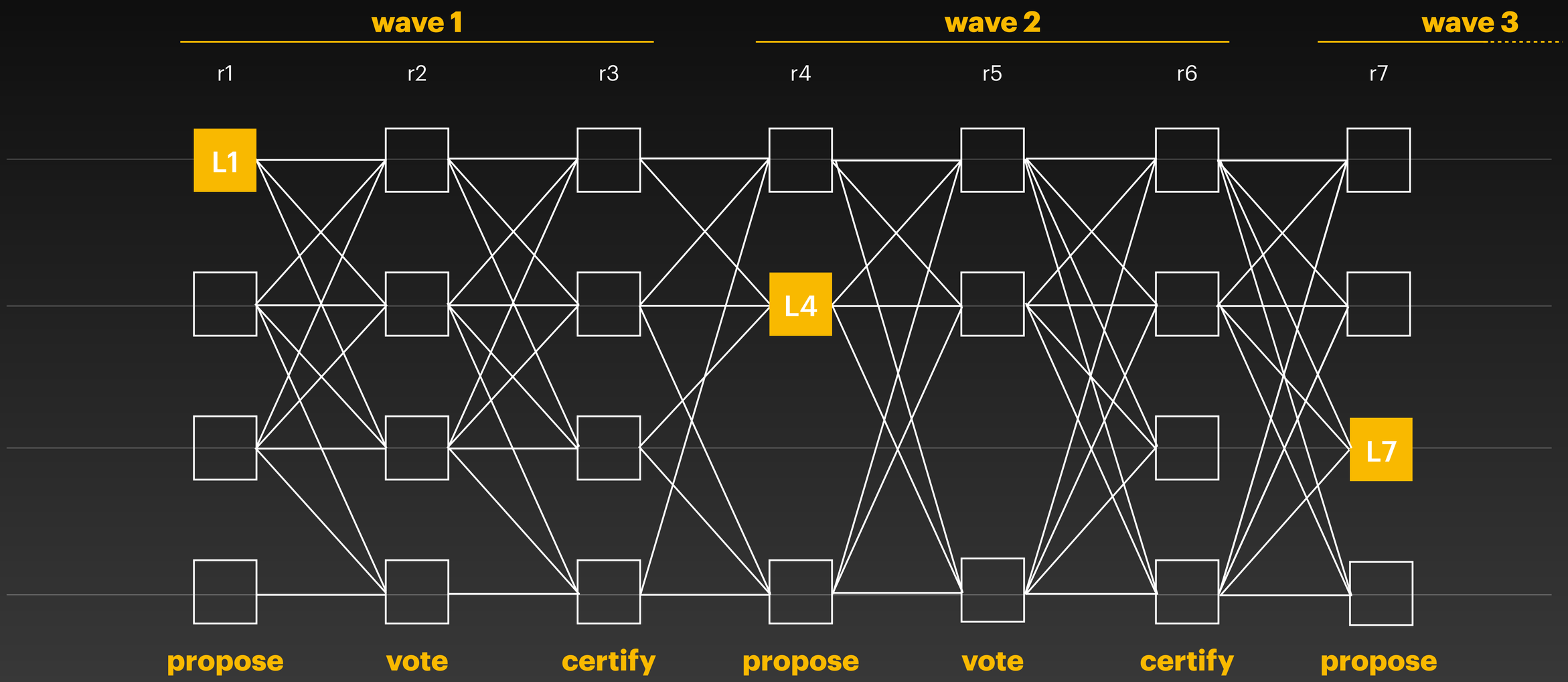

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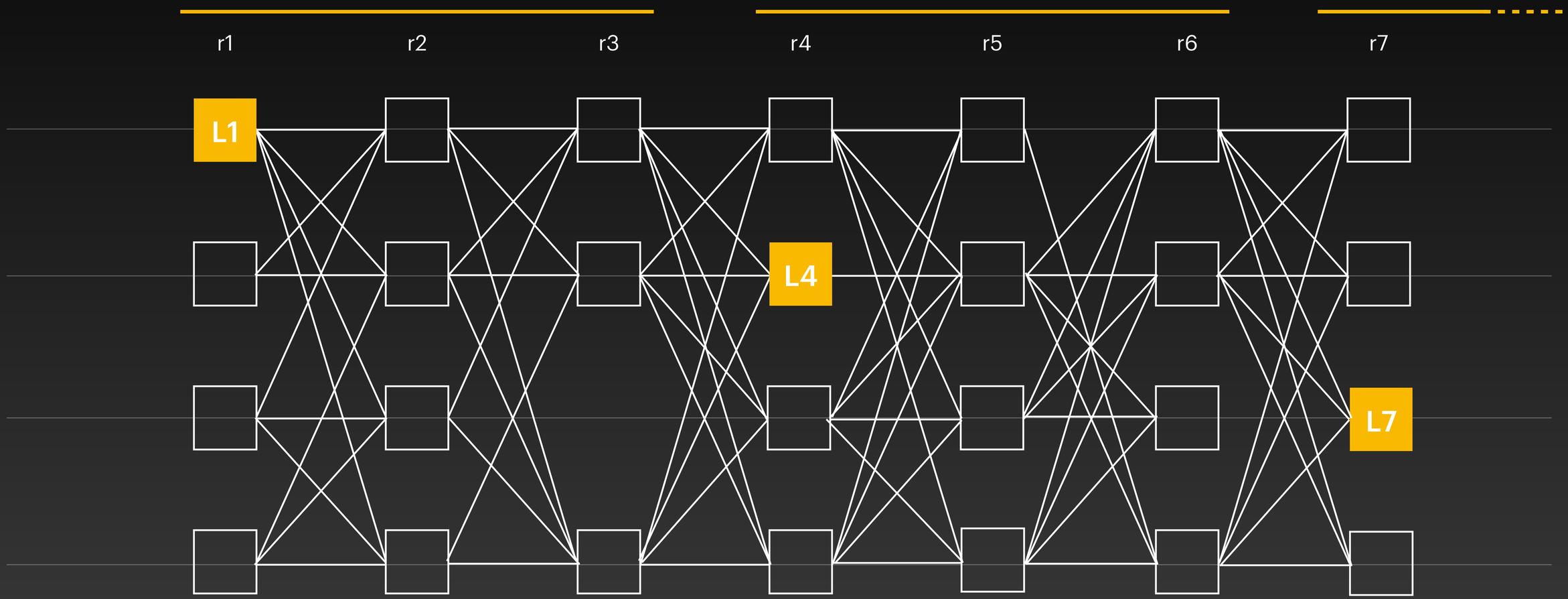
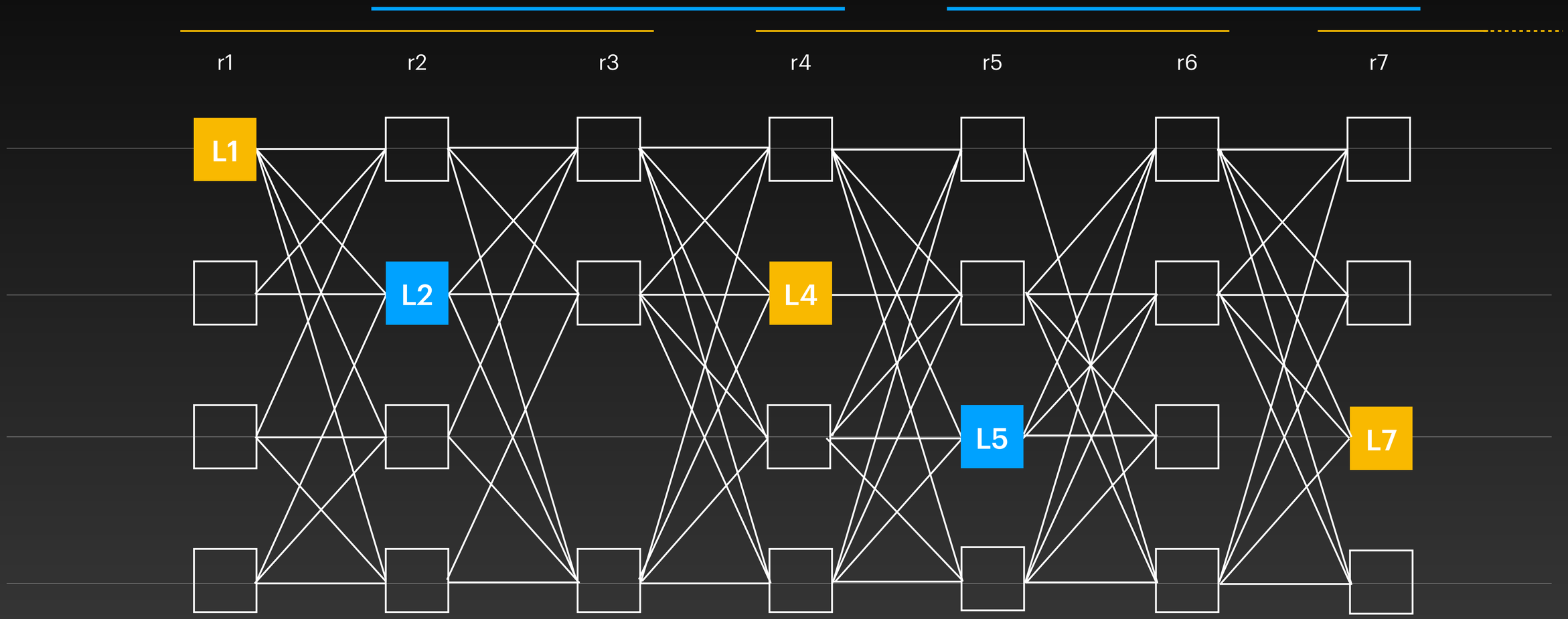


DAG Structure



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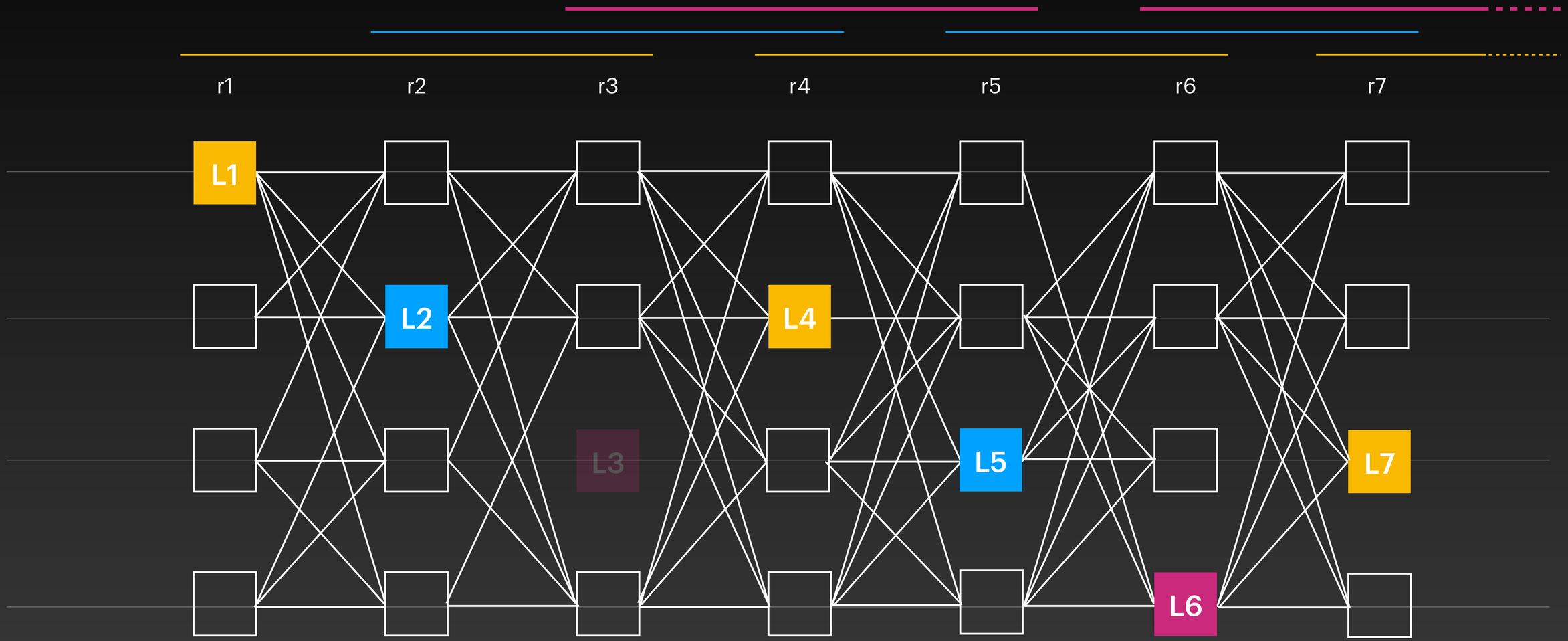
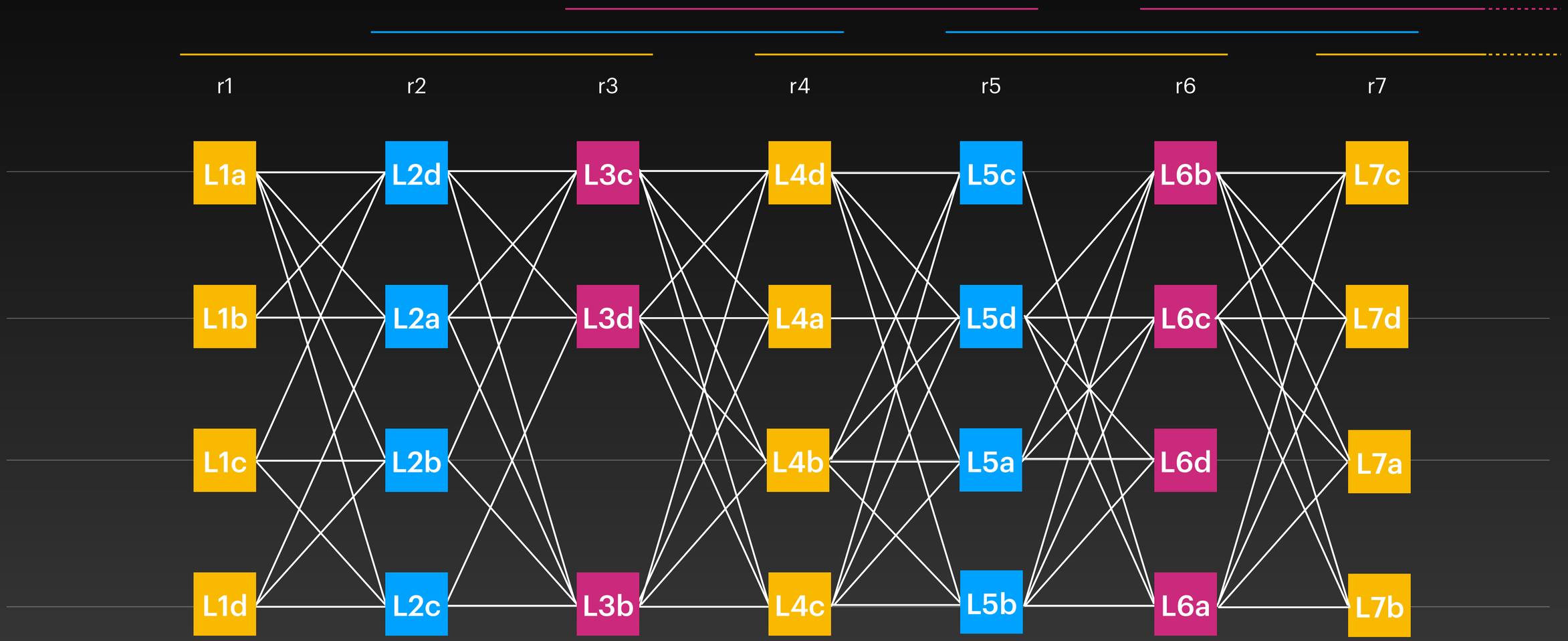
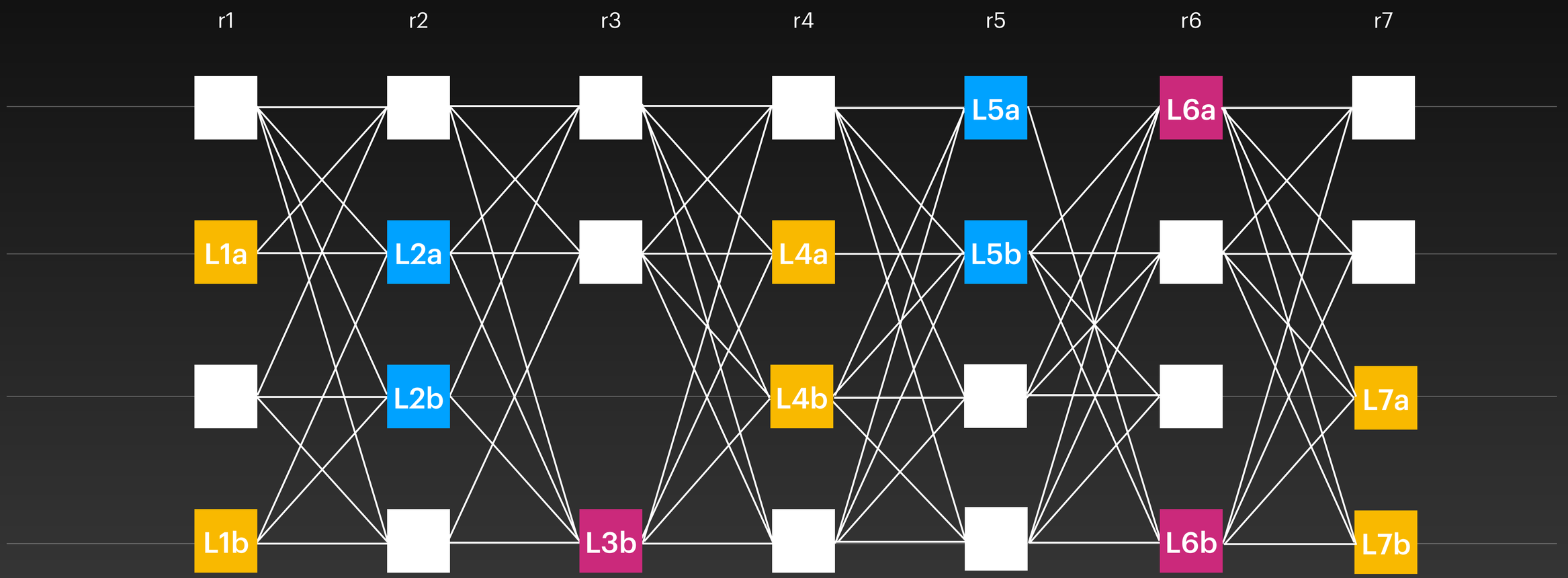


DAG Structure



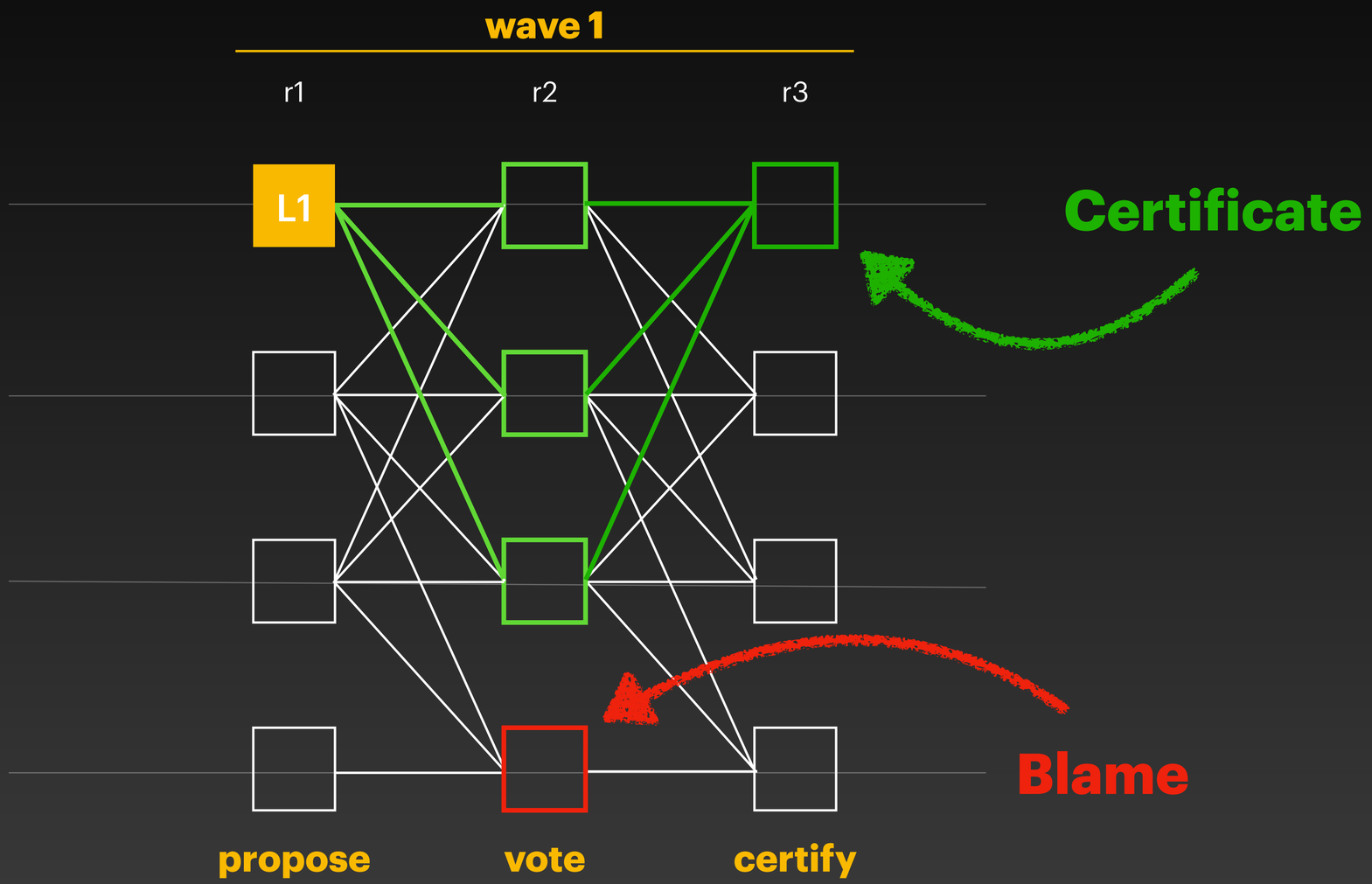
Practical Implementation

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

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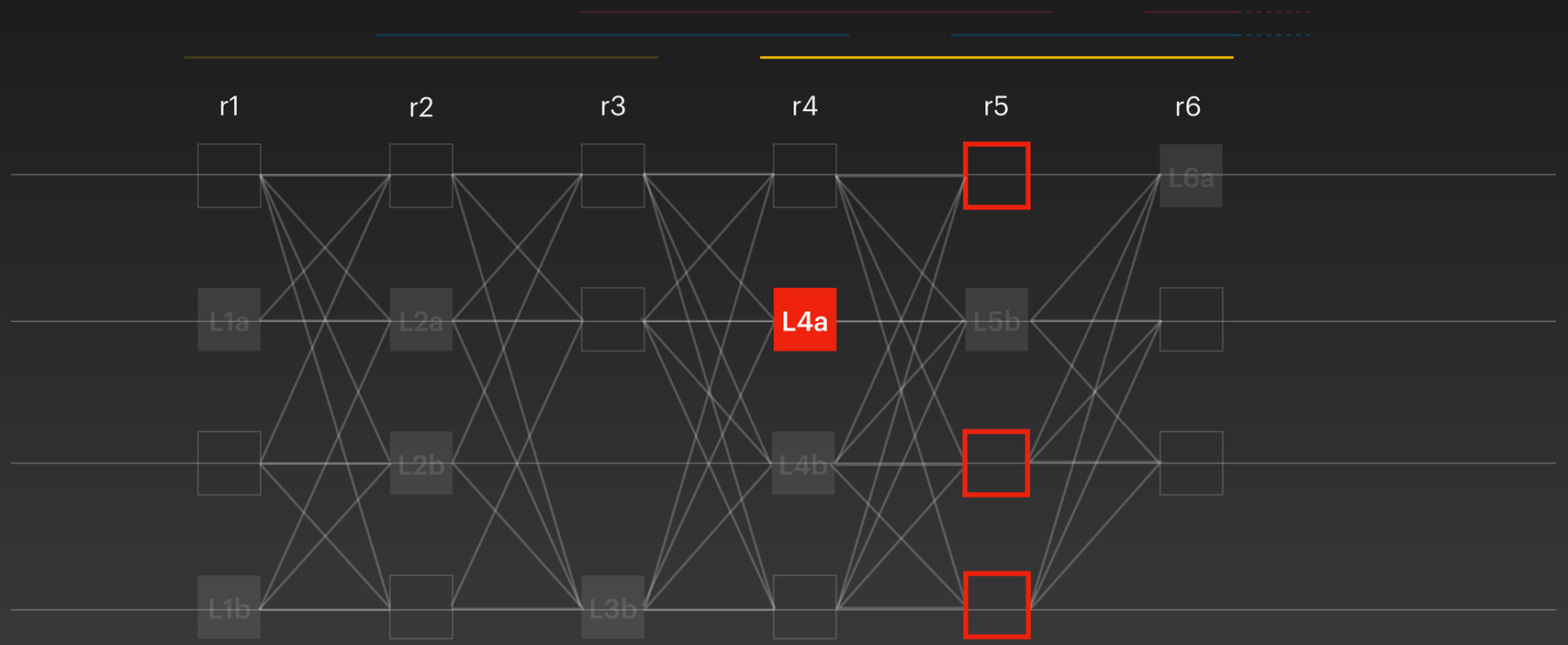

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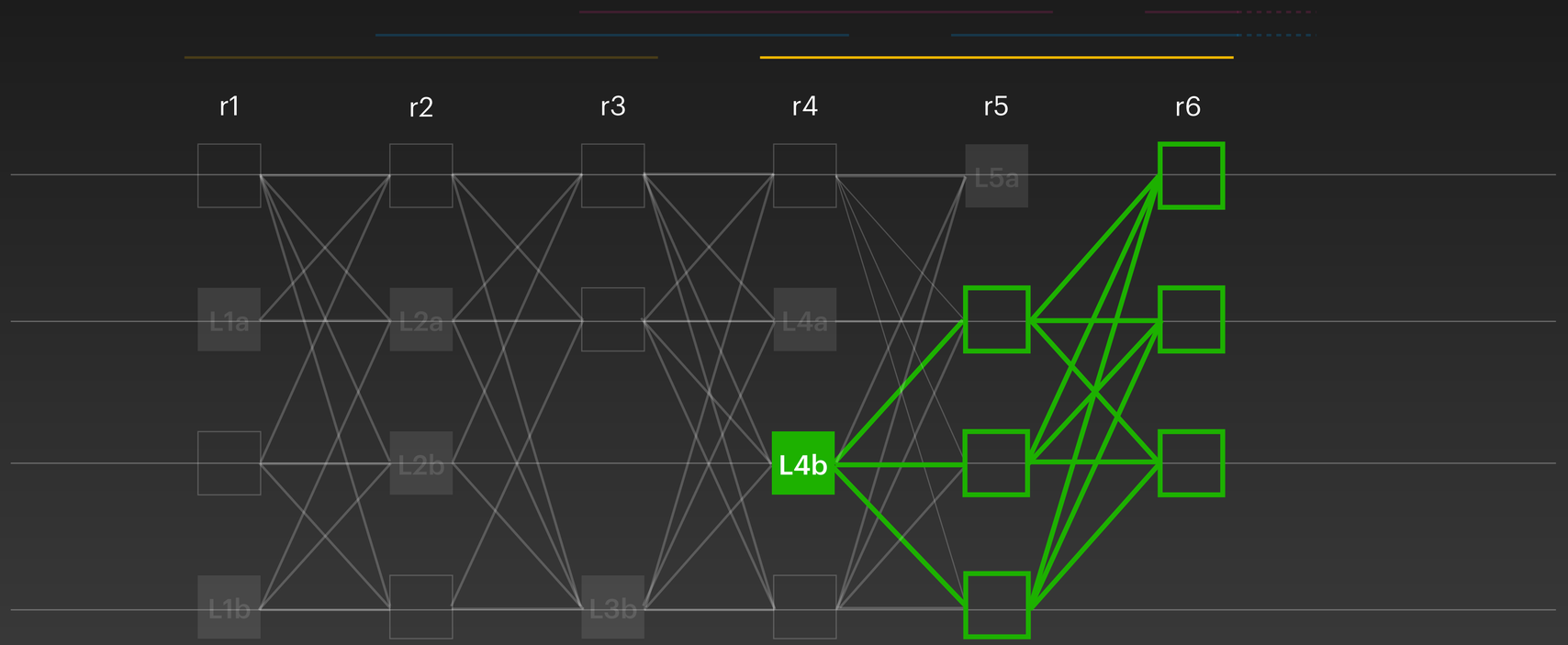

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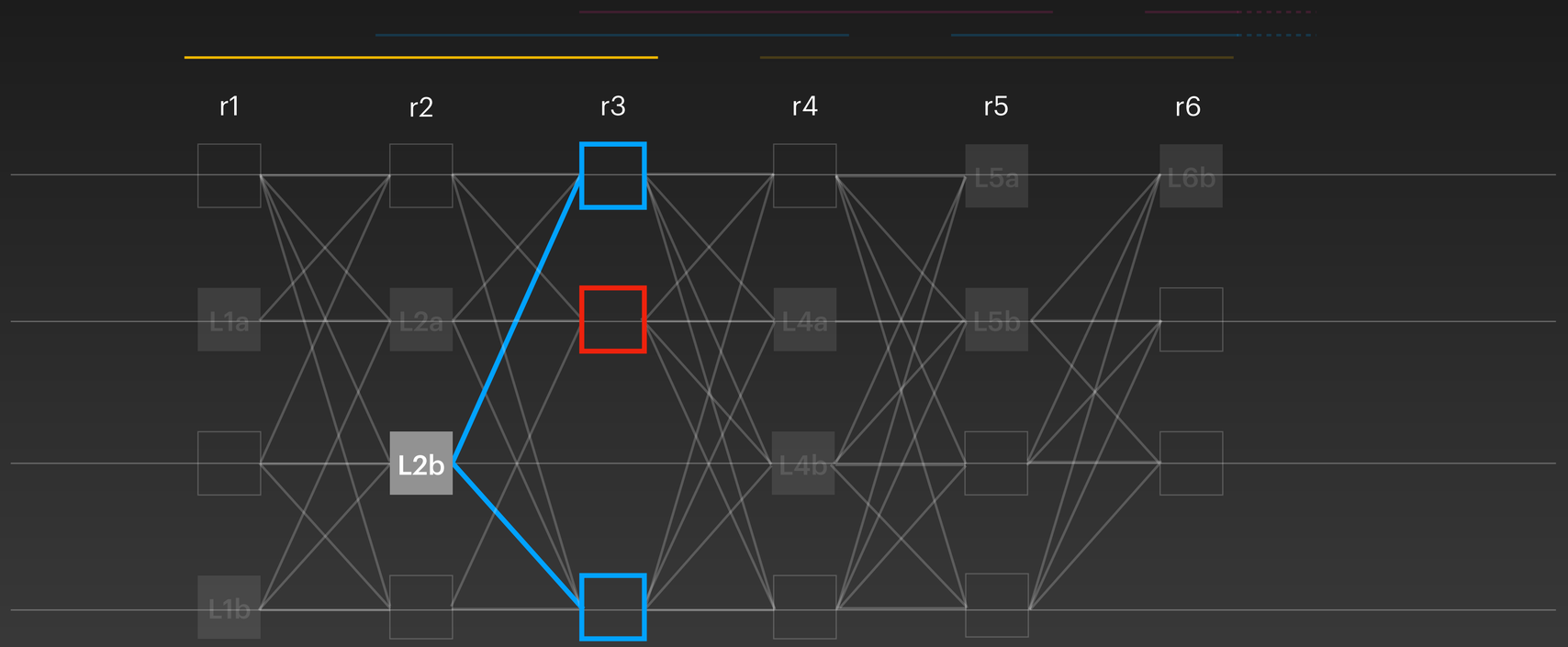
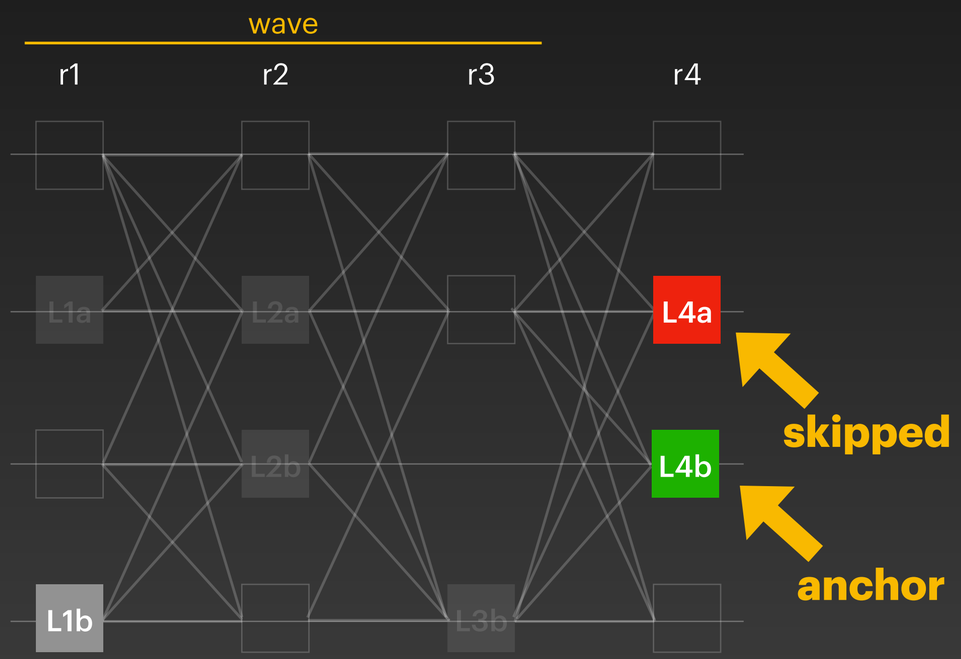


Indirect Decision Rule

Indirect Decision Rule

1. Find Anchor

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



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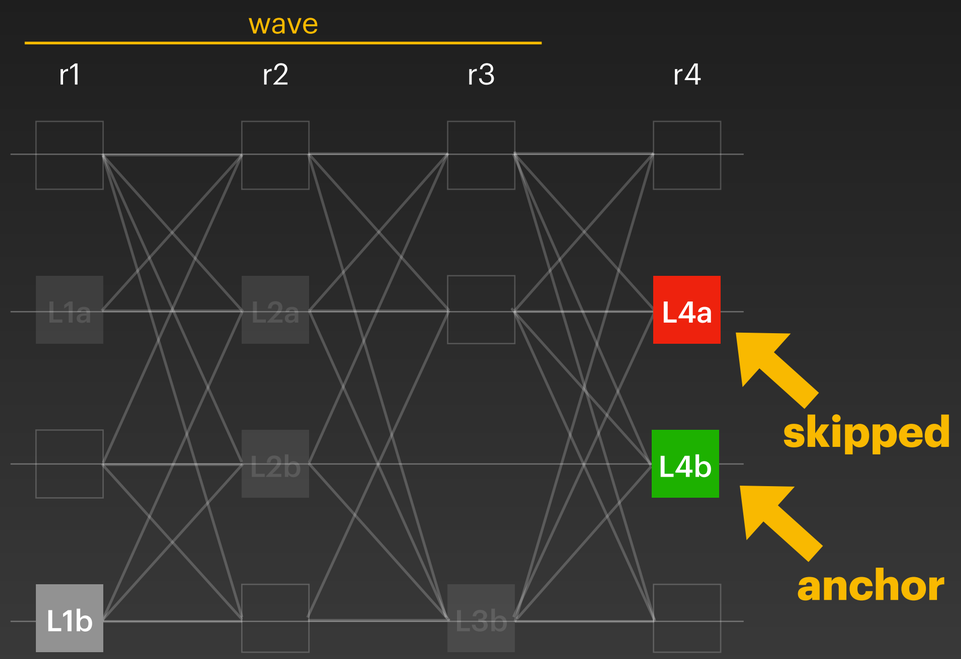
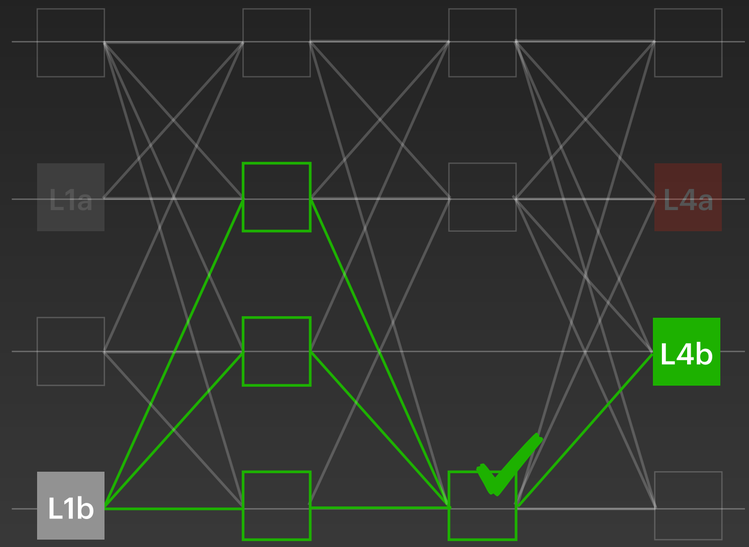
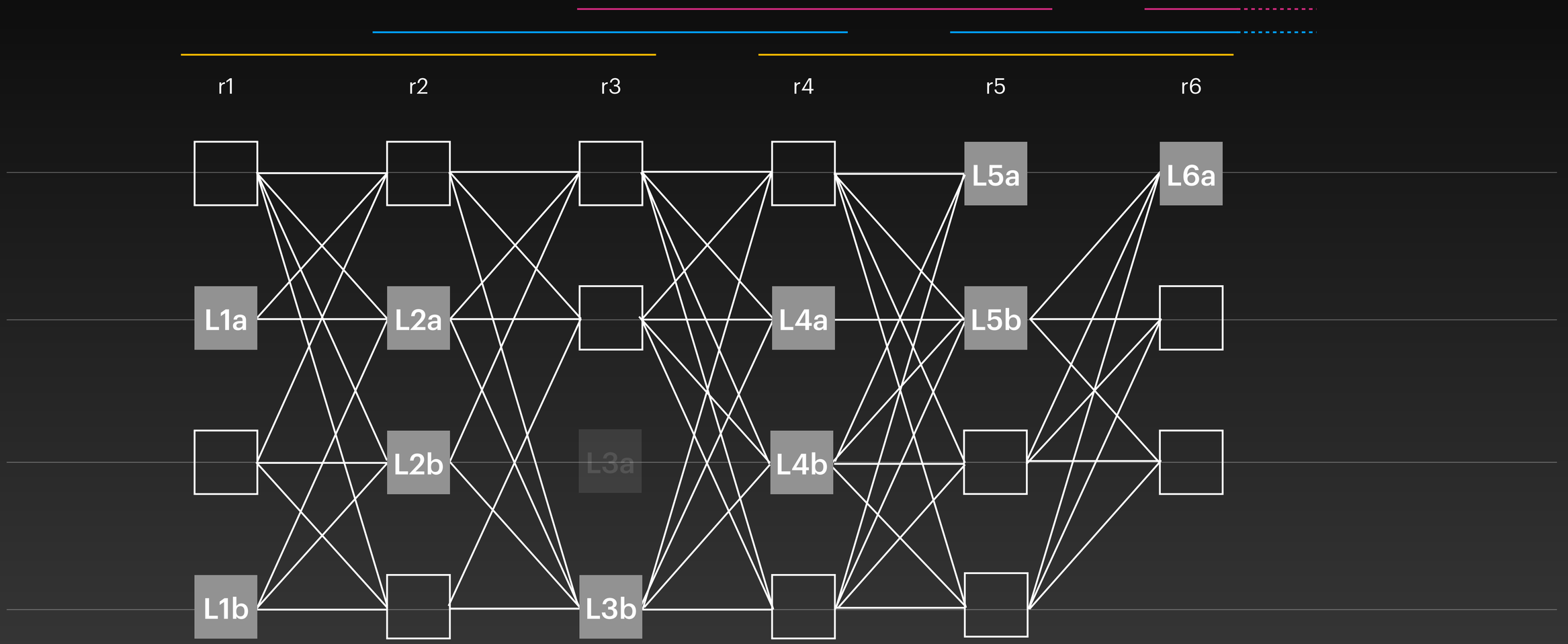


2. Certified link

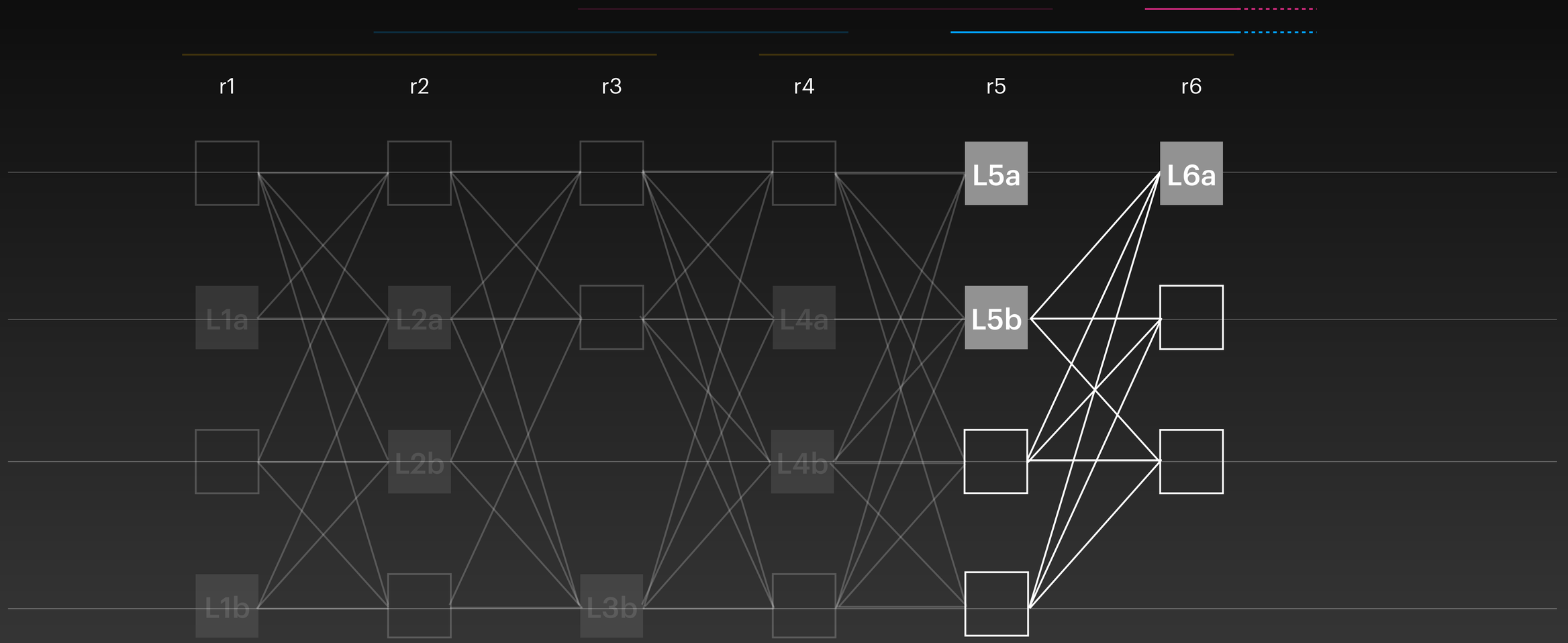
- **Commit** if `B <-> certified link <-> A` otherwise **Skip**



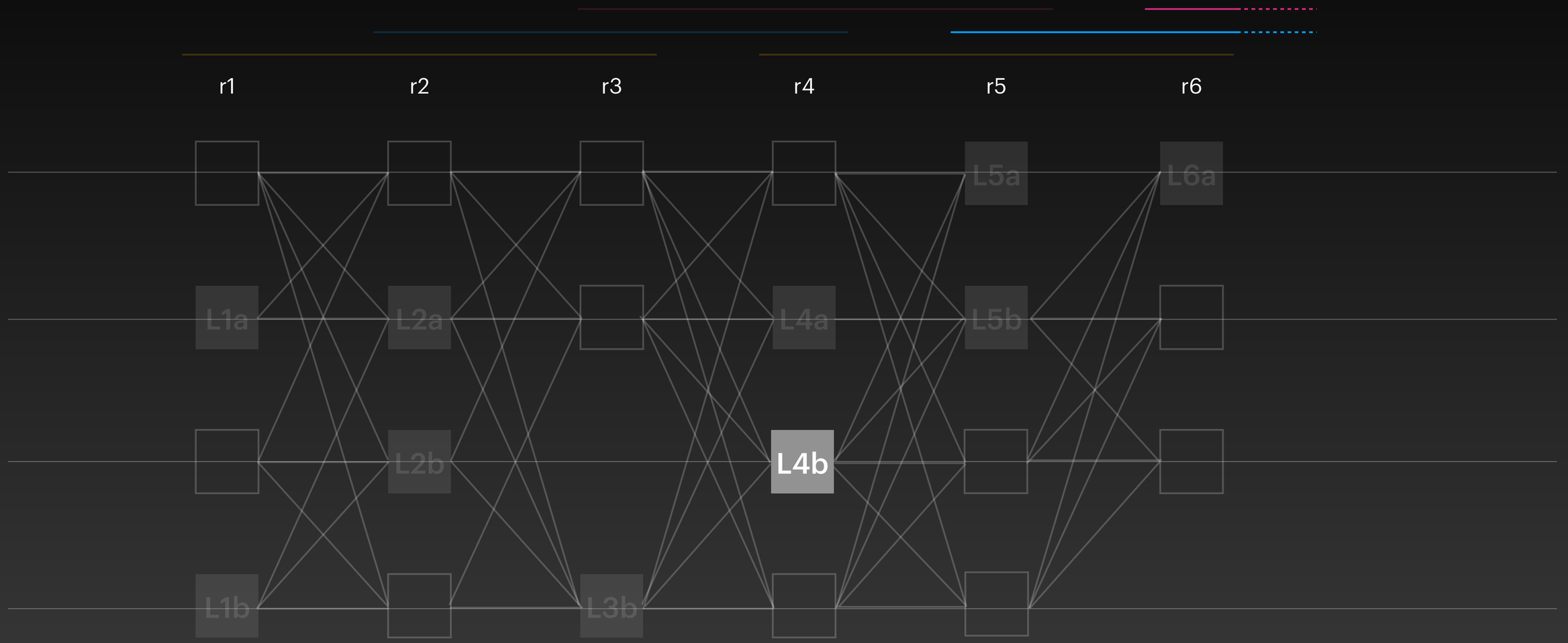
All Start at Undecided



Ignore Incomplete Waves



Apply Direct Rule



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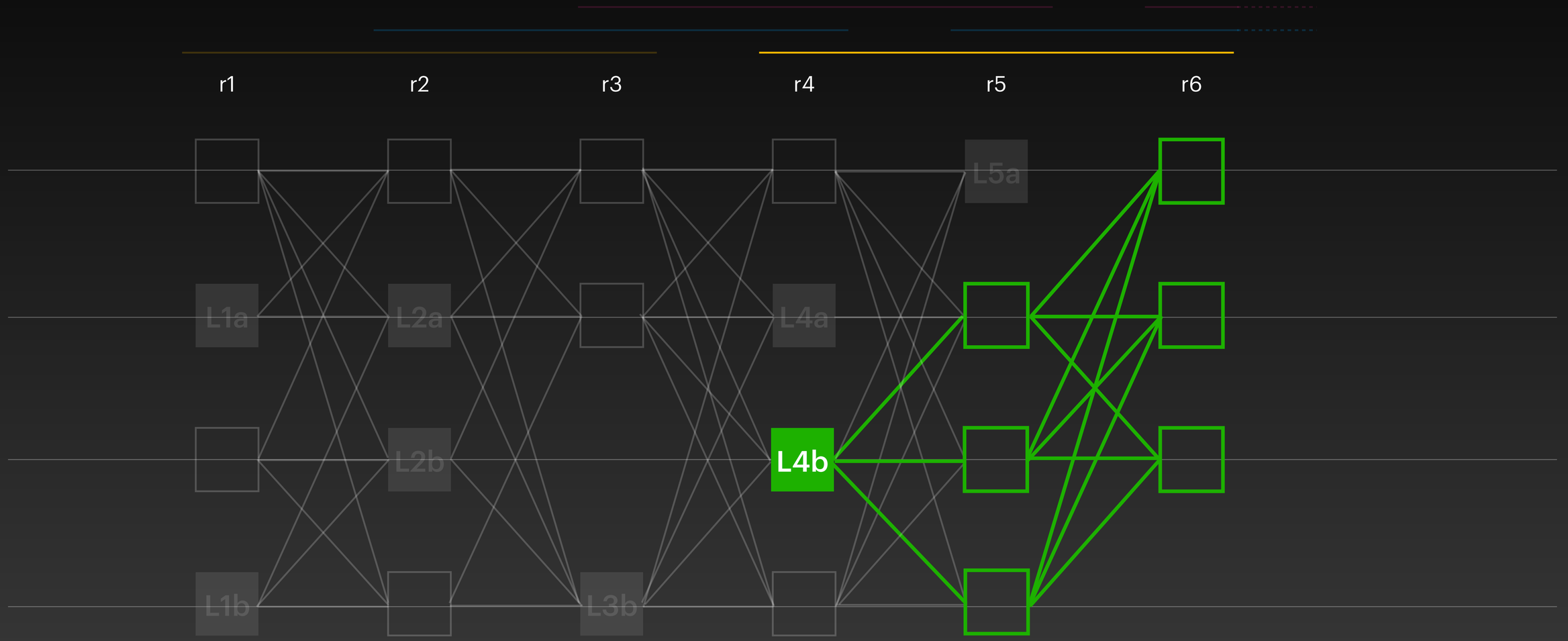

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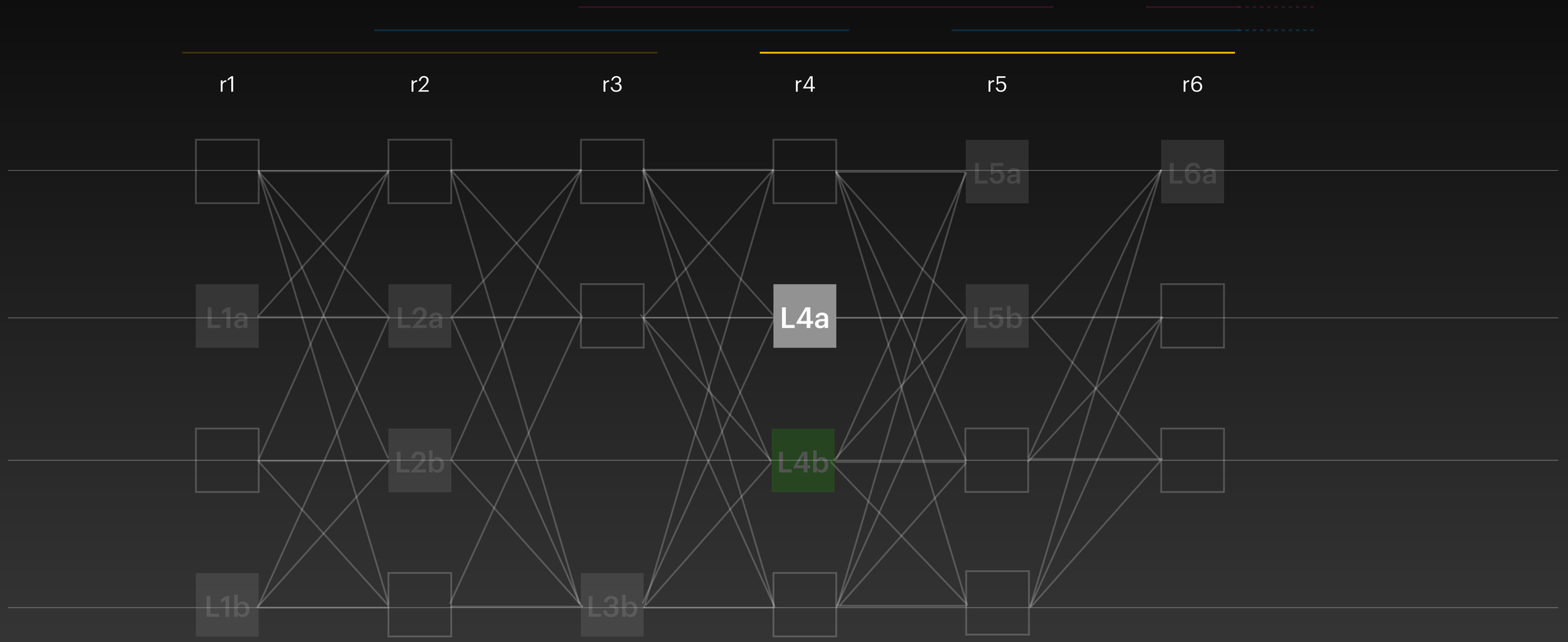

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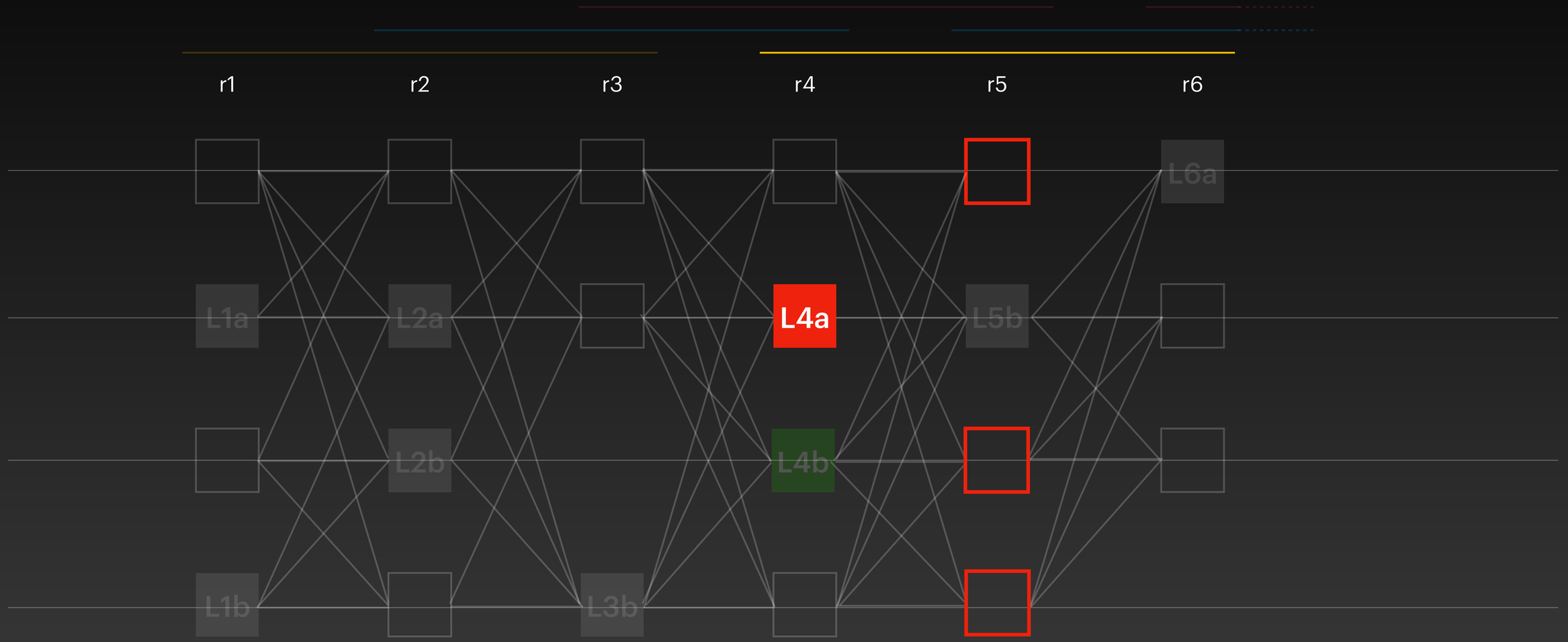

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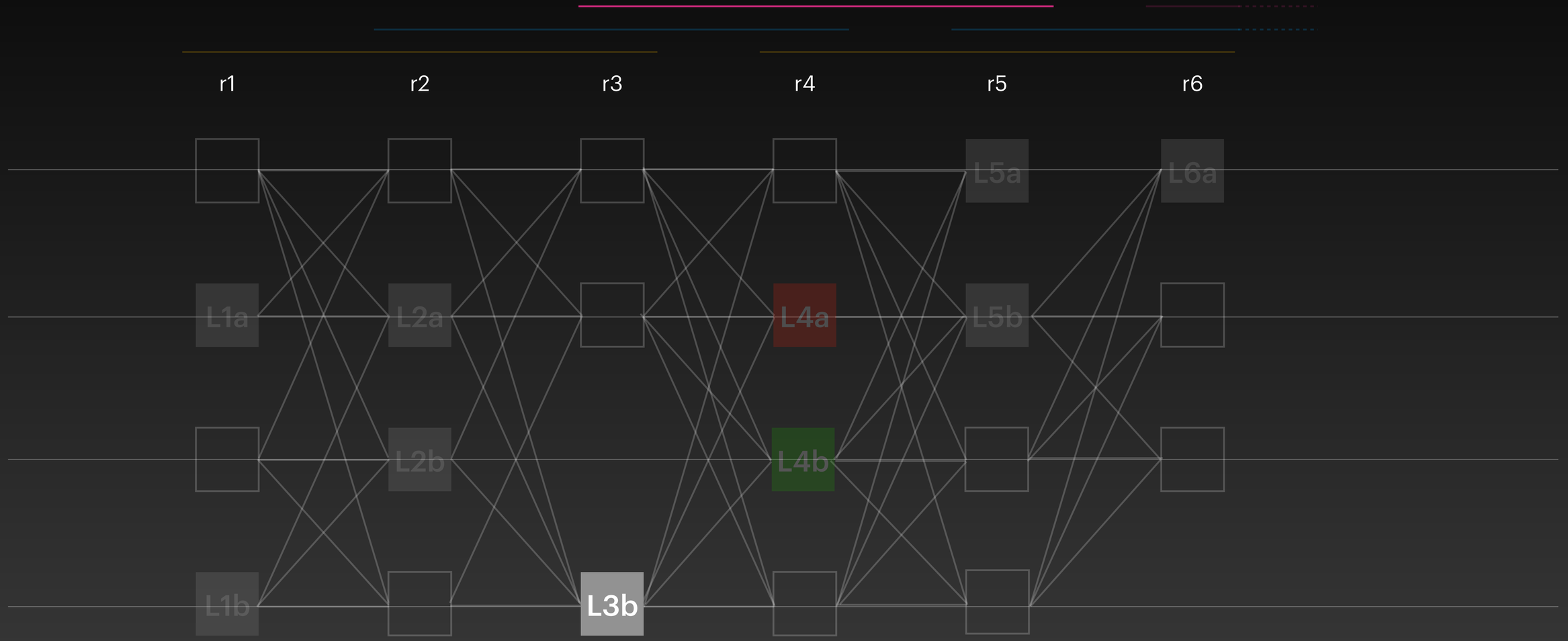

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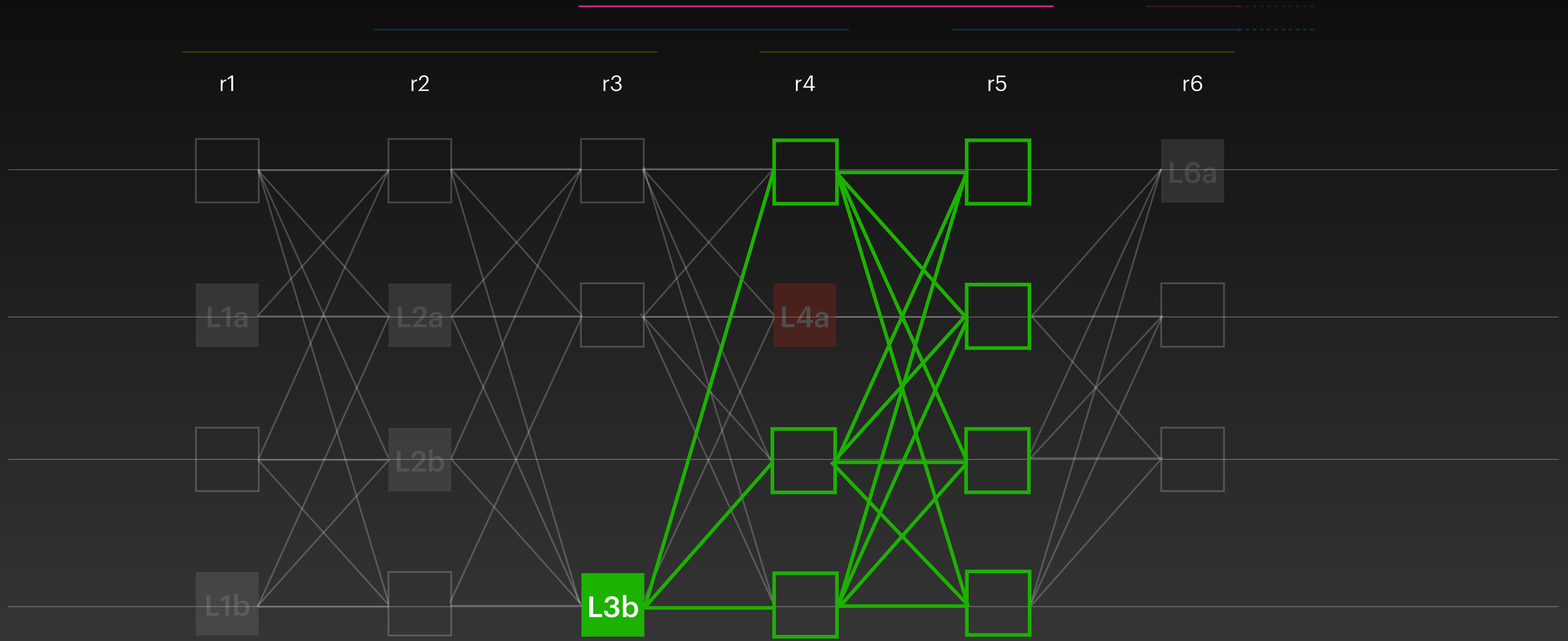
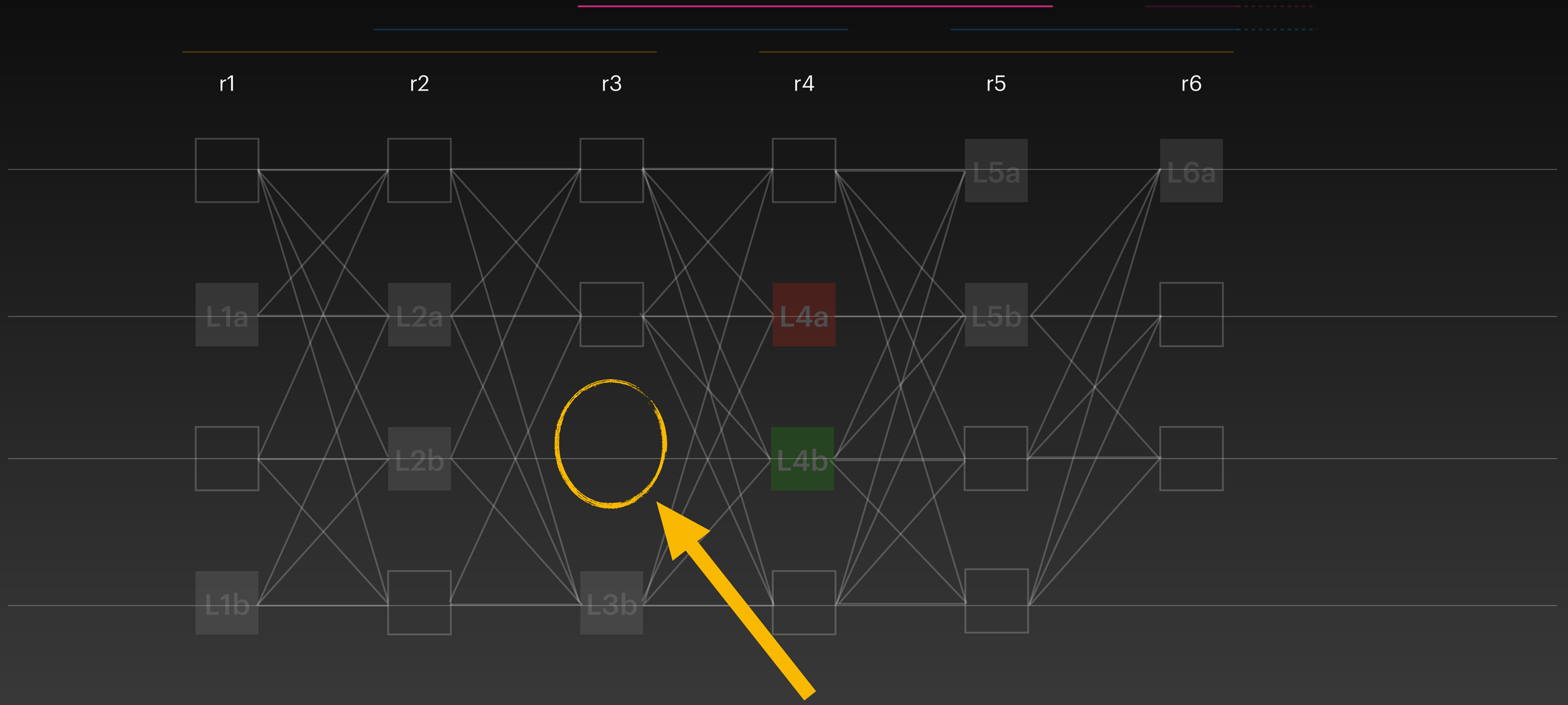


Ignore Missing Leader



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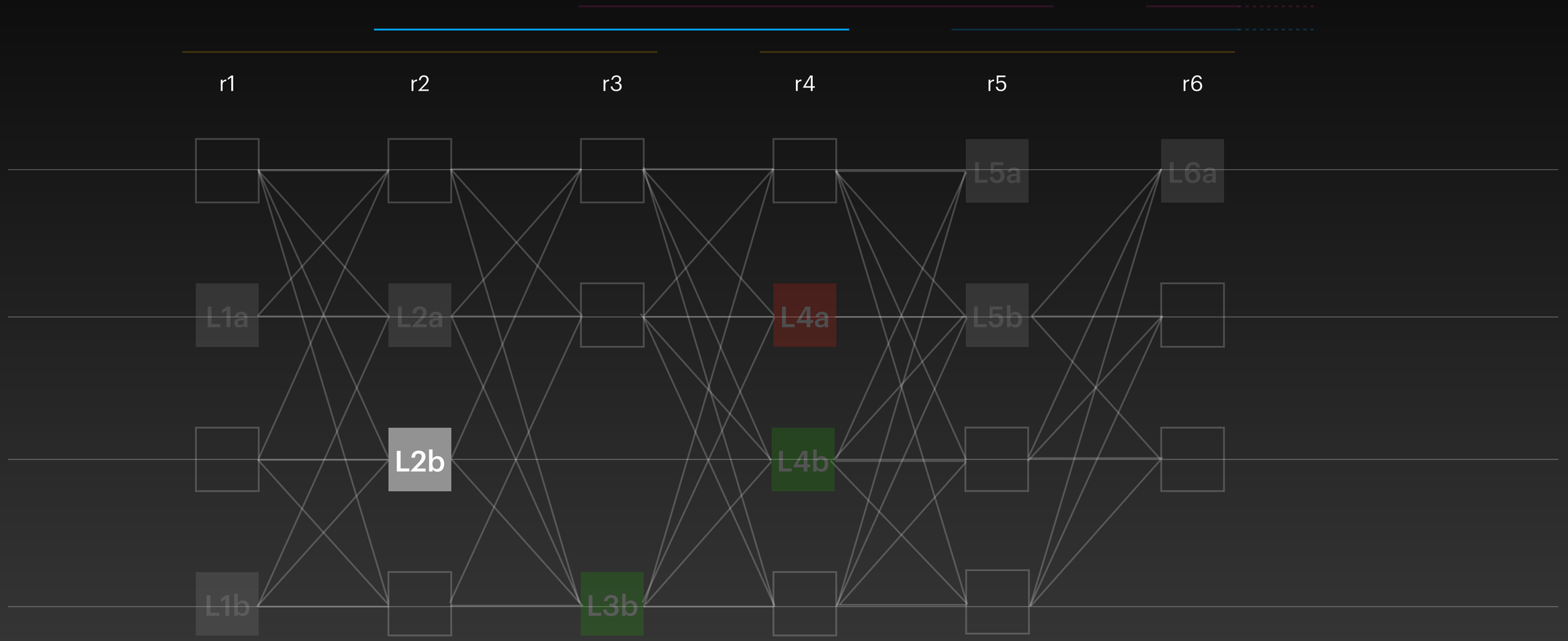

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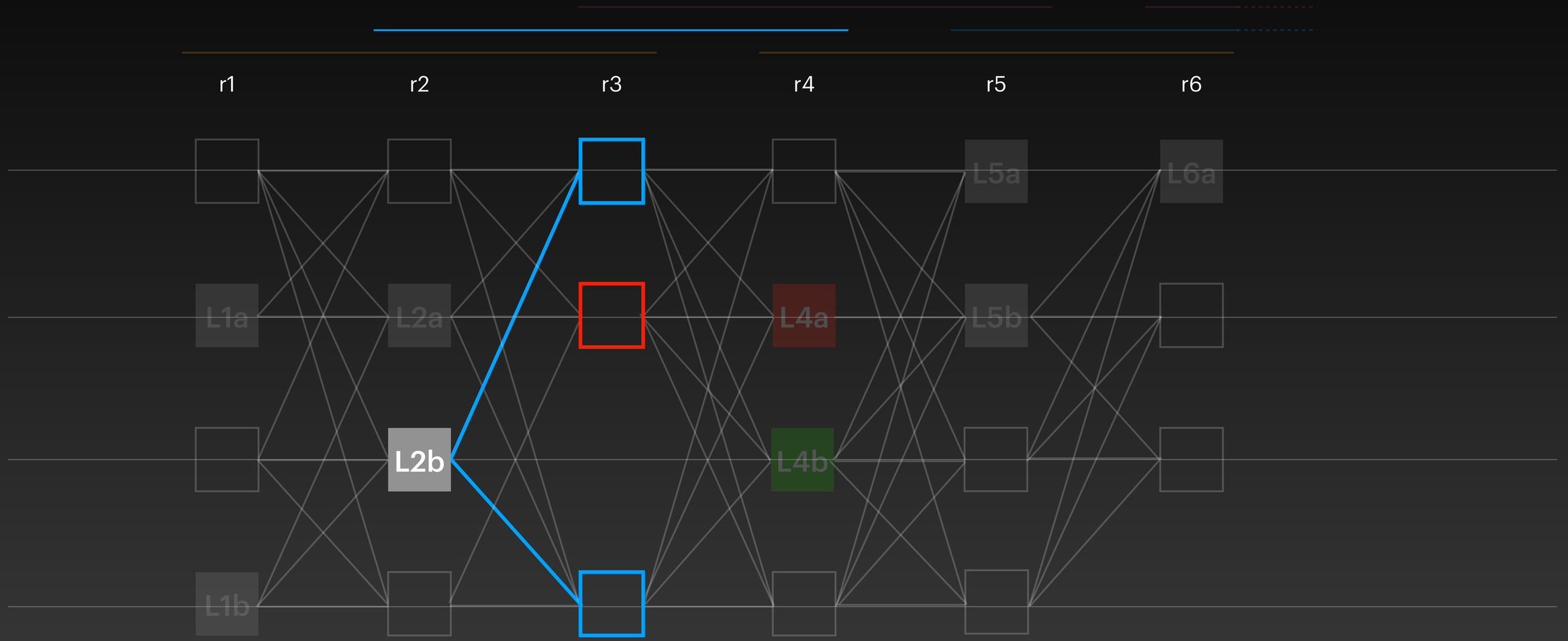

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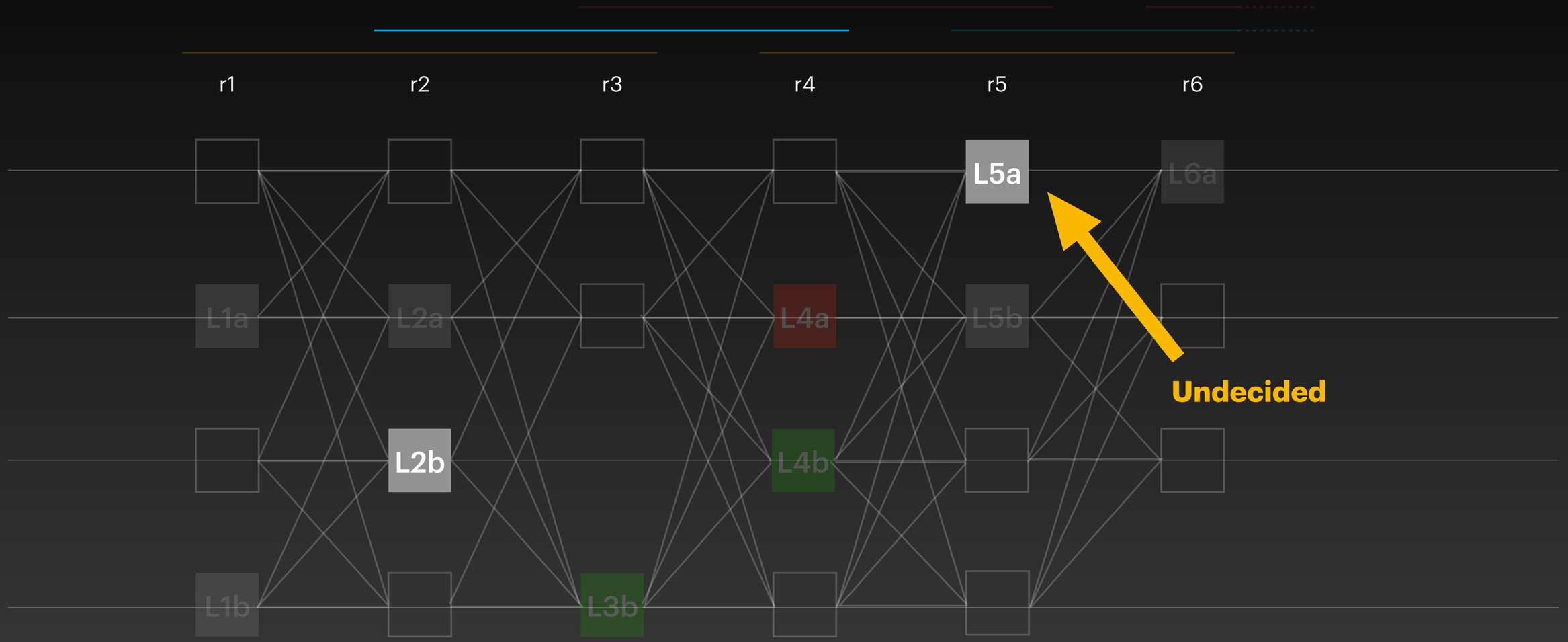

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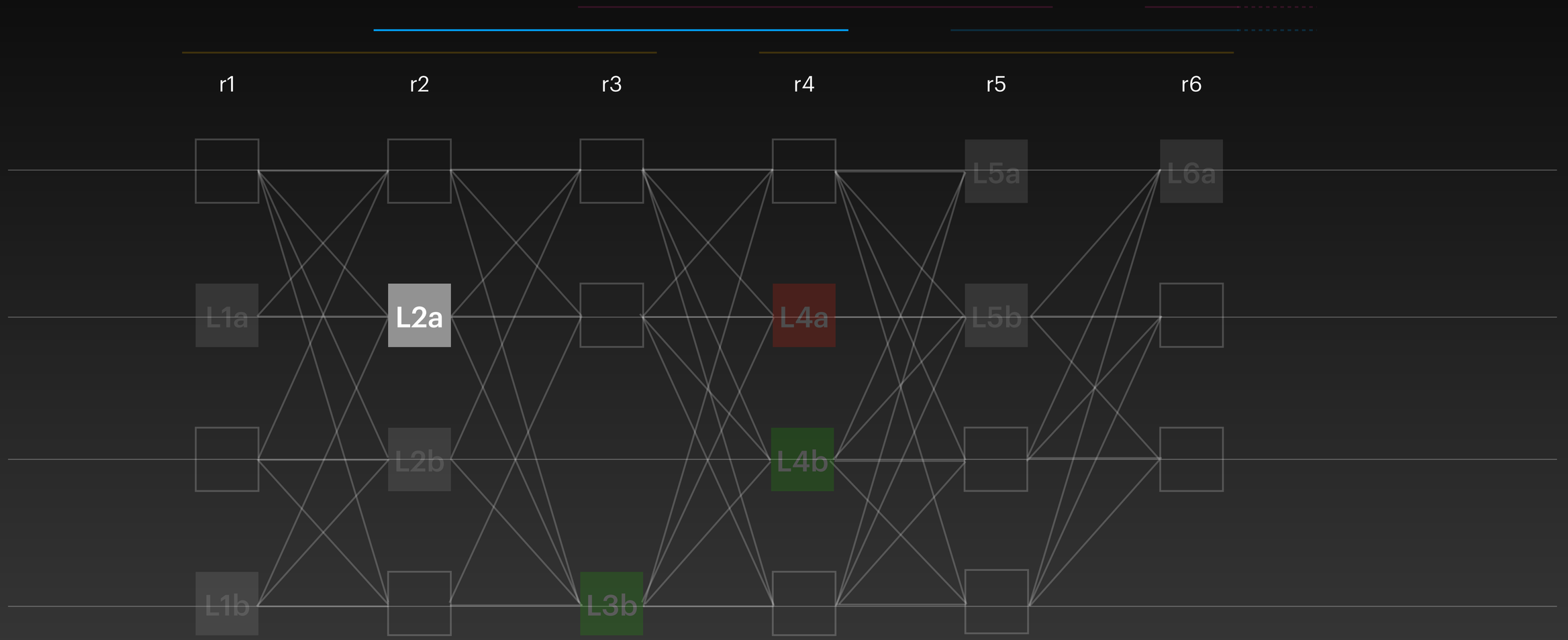

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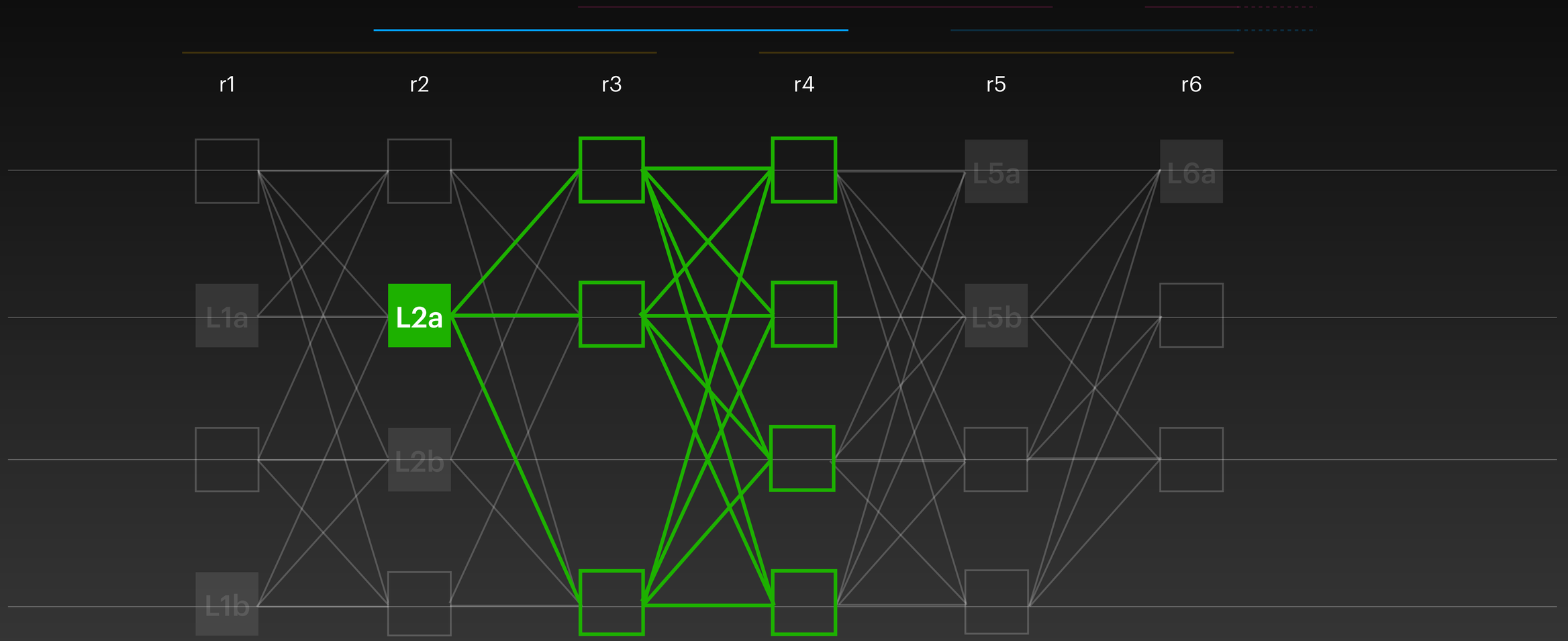

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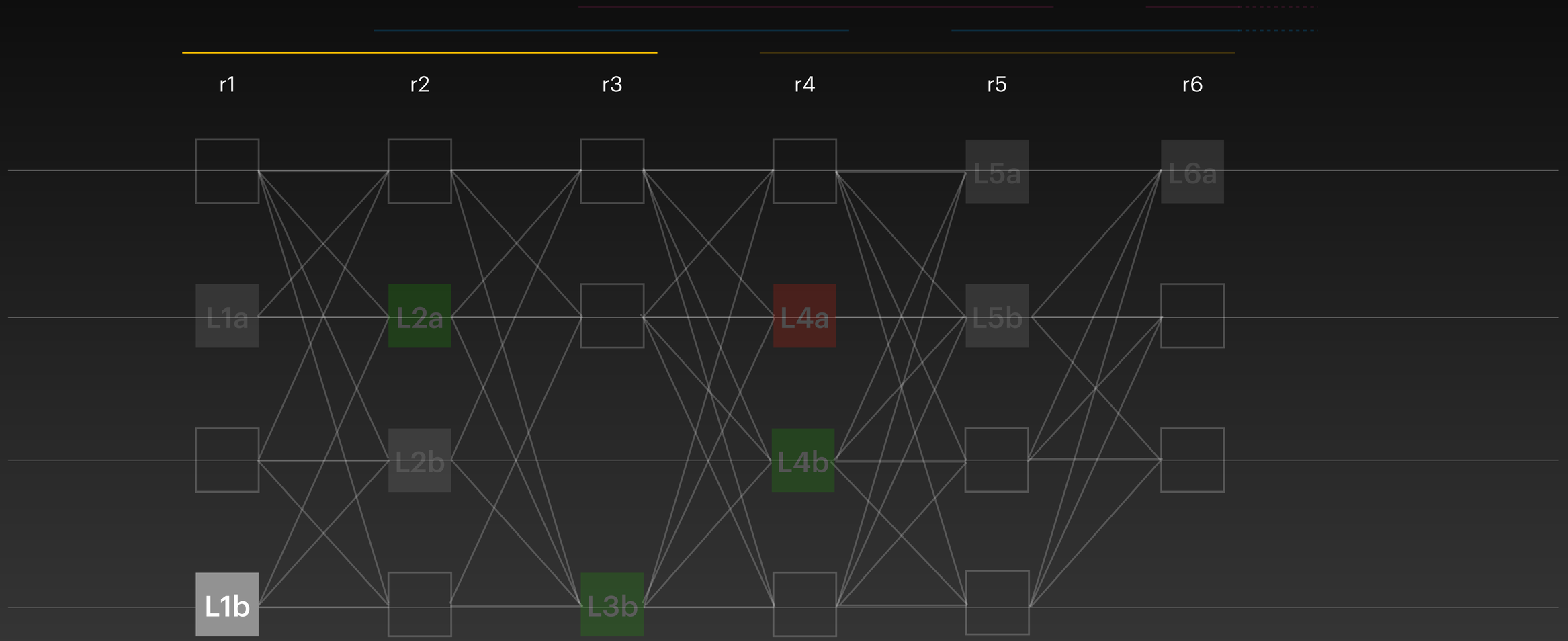

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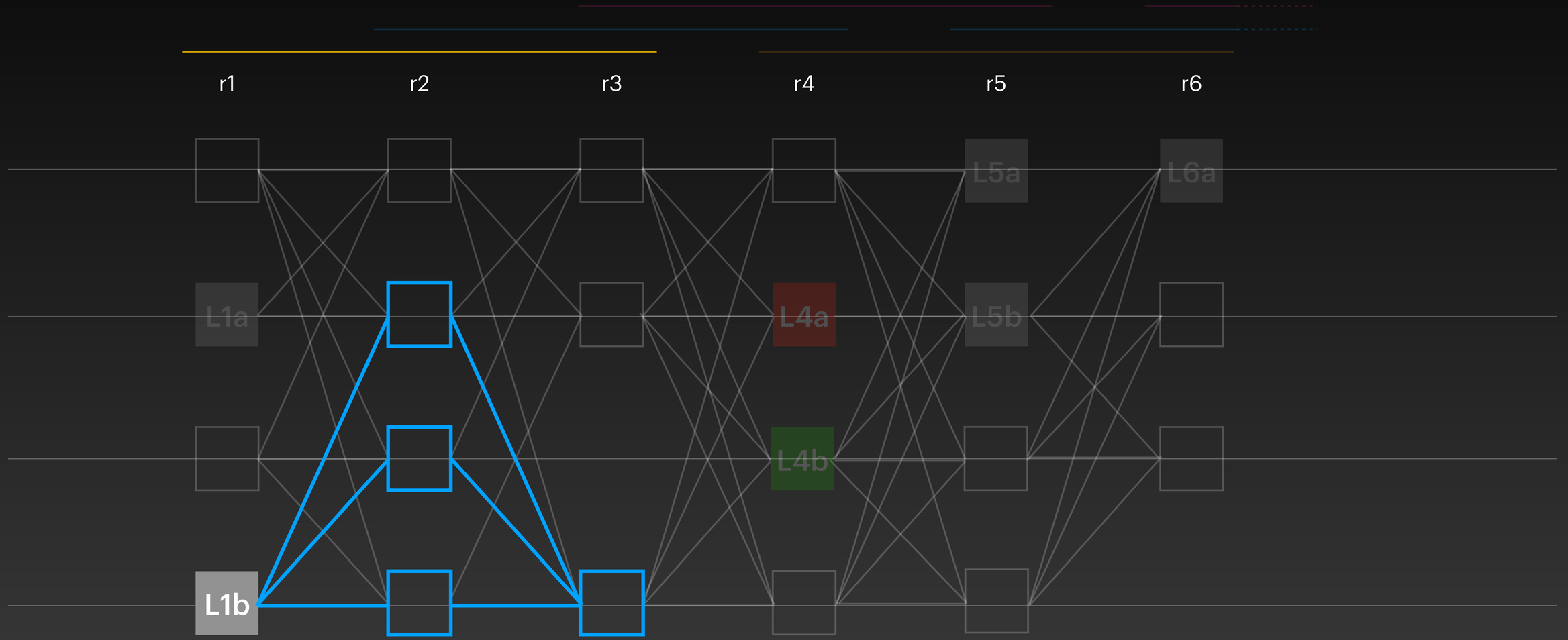

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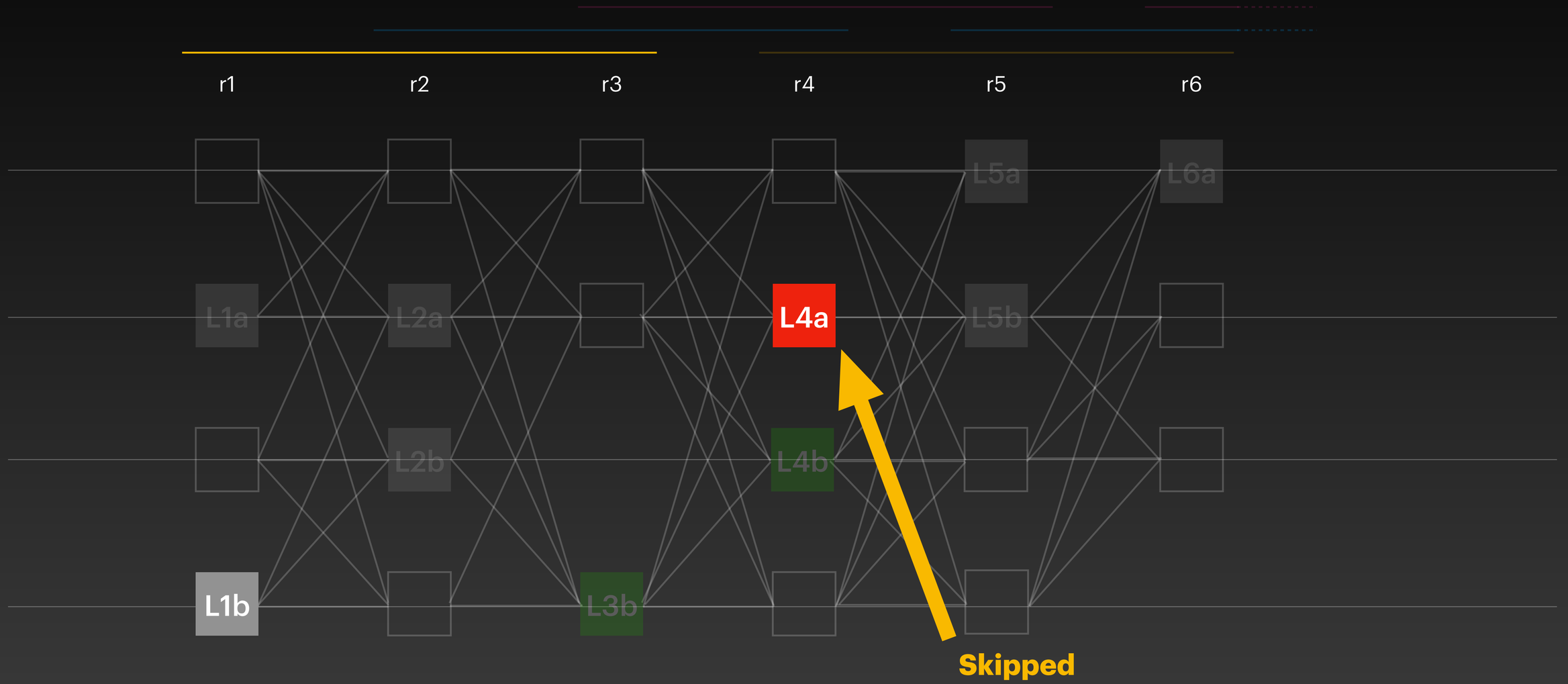

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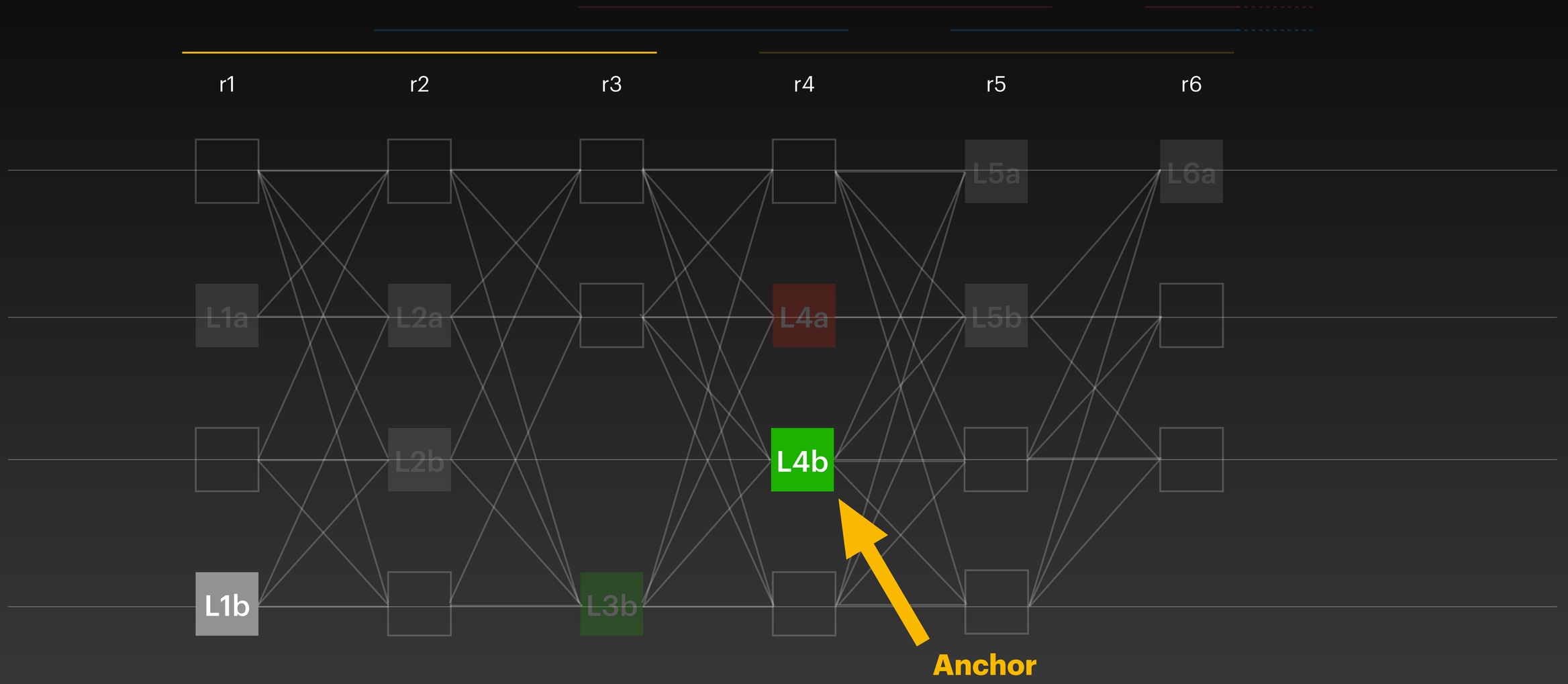

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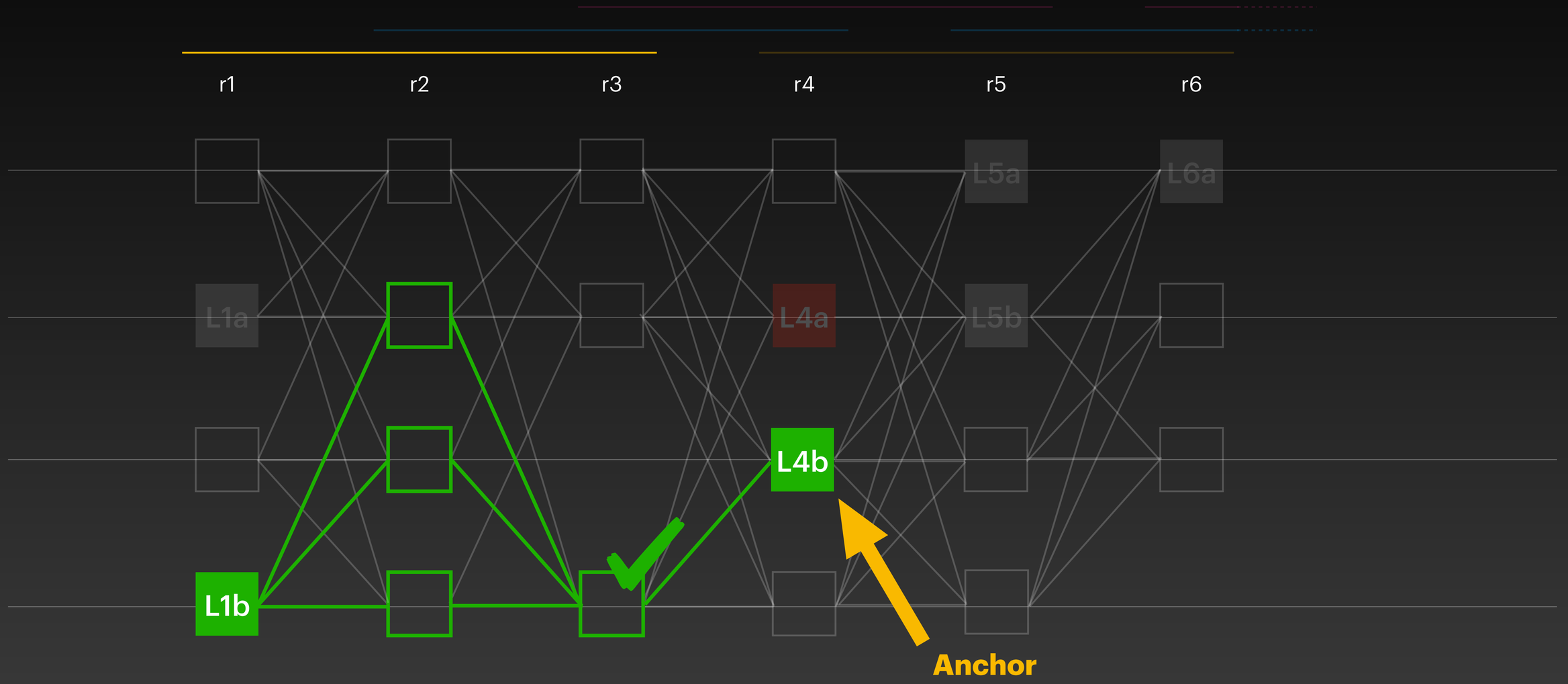

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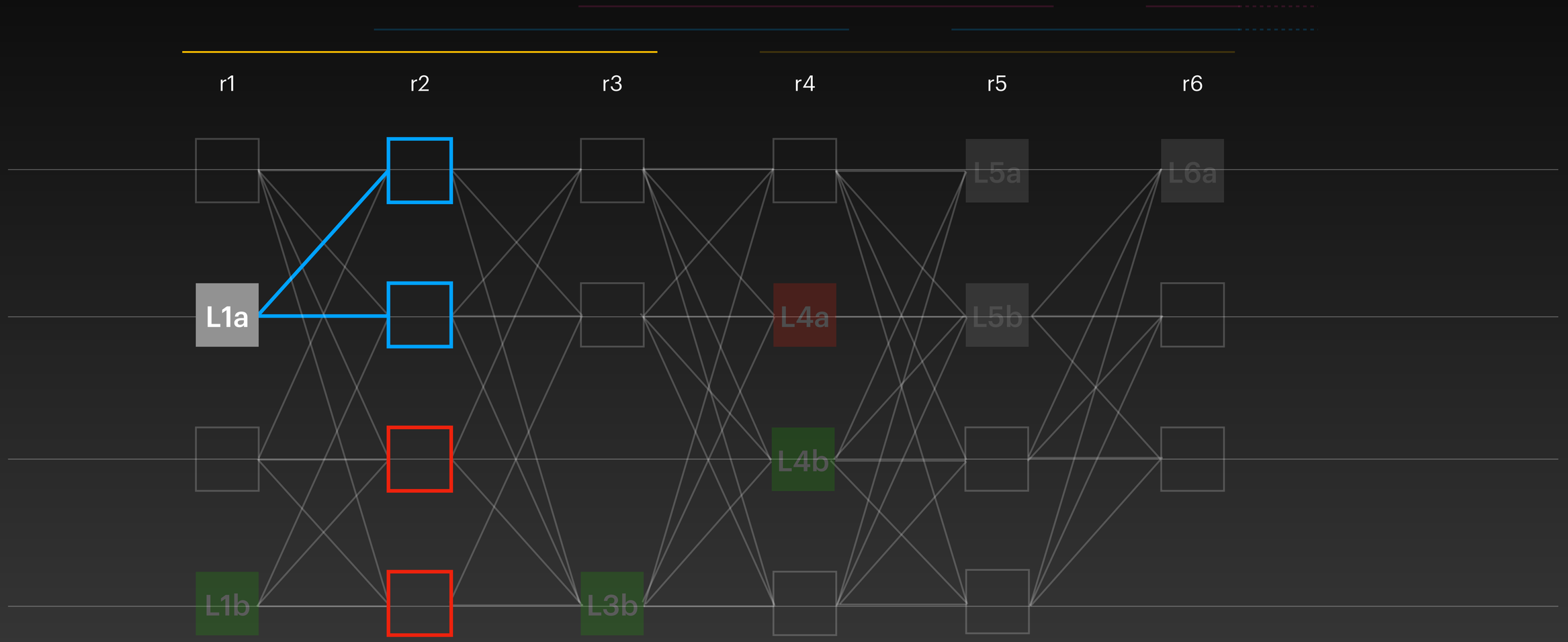

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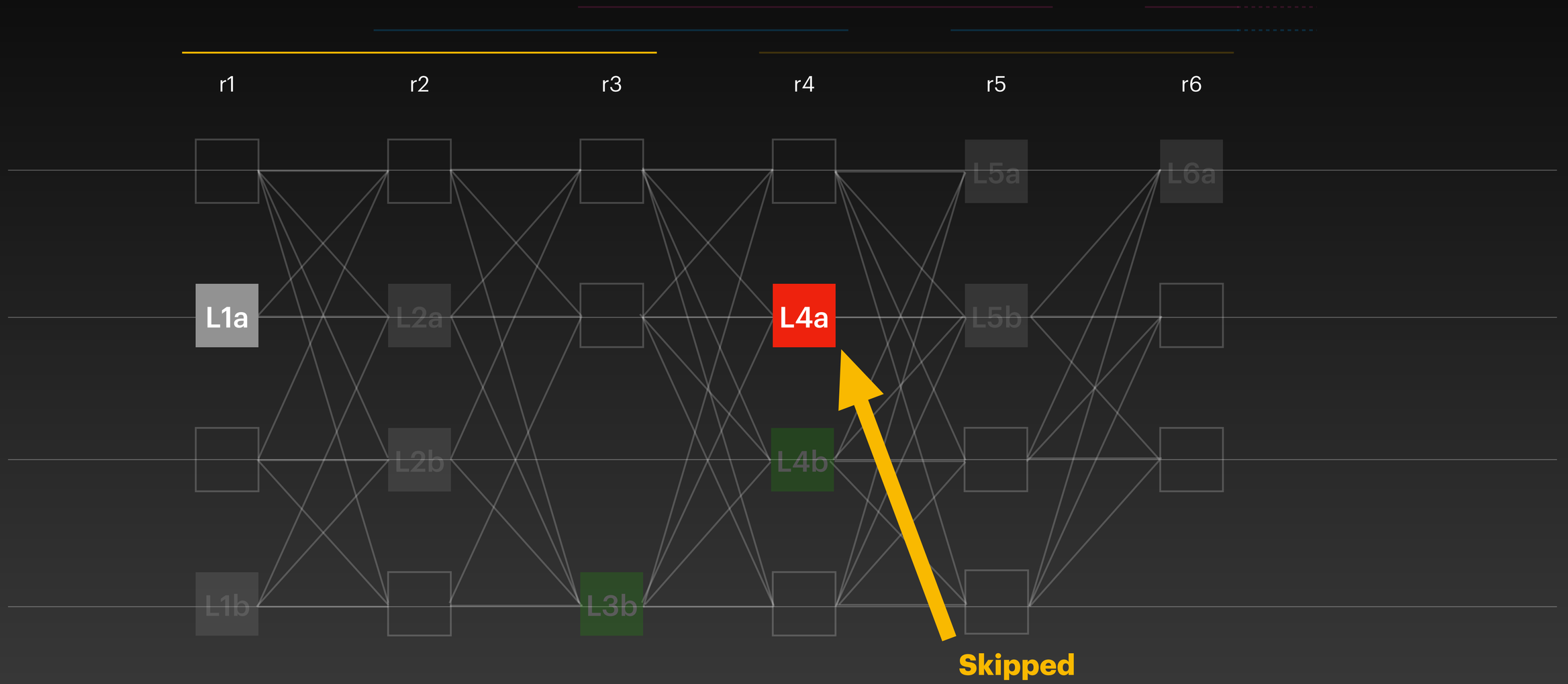

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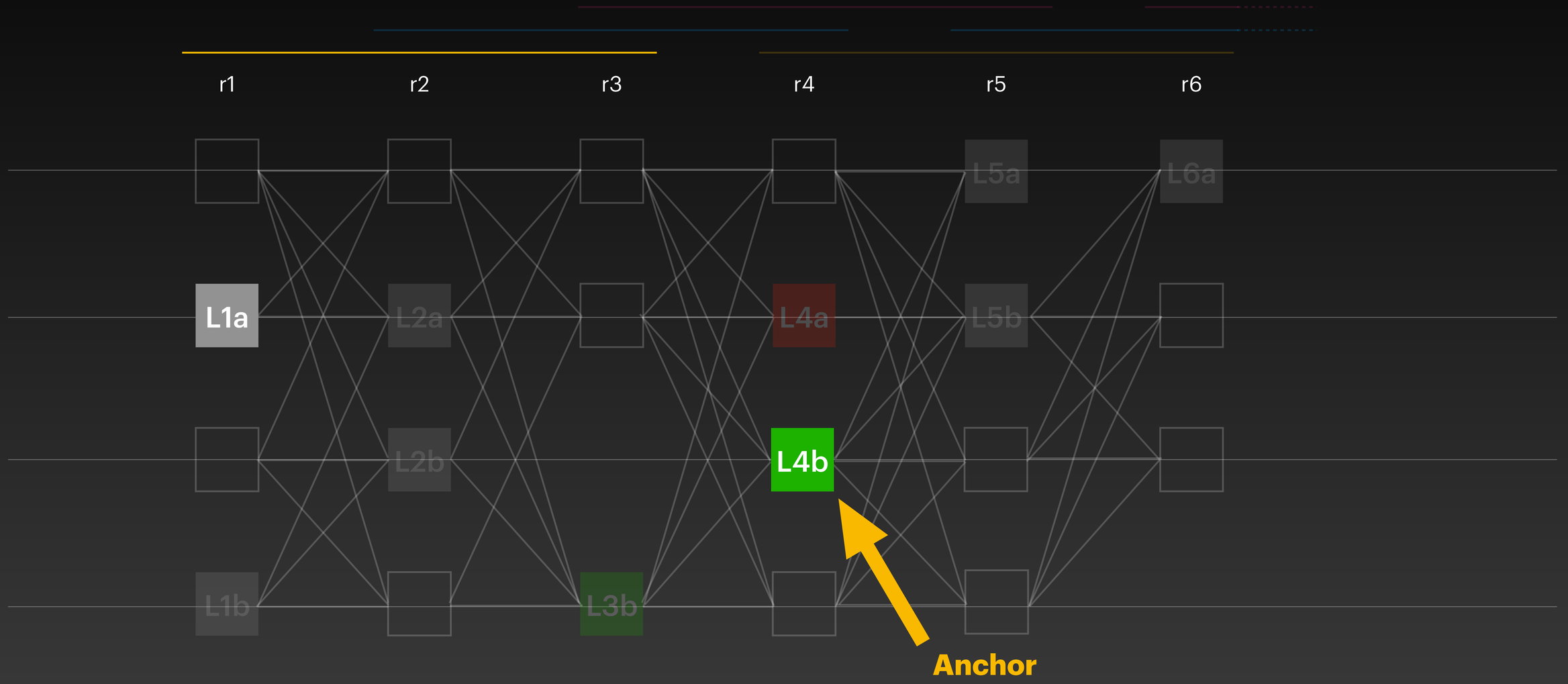
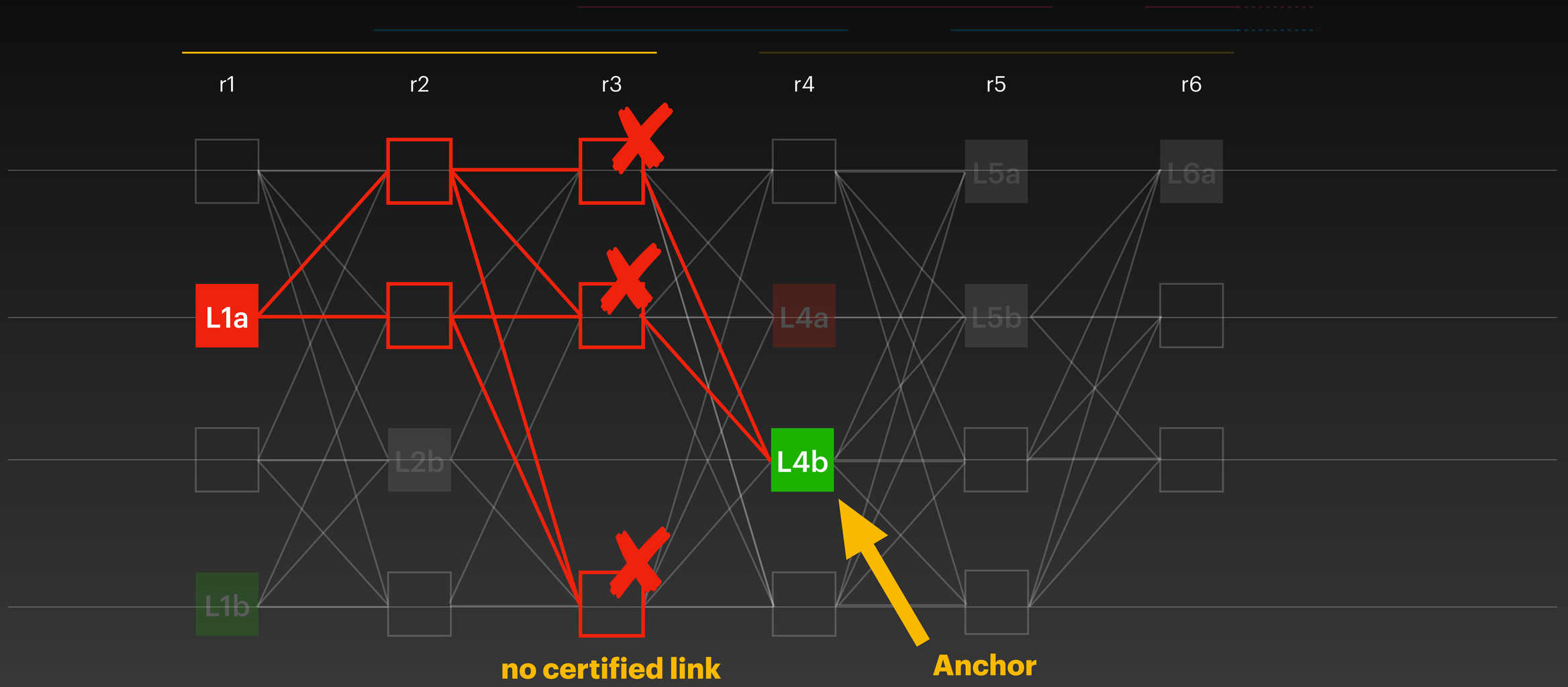
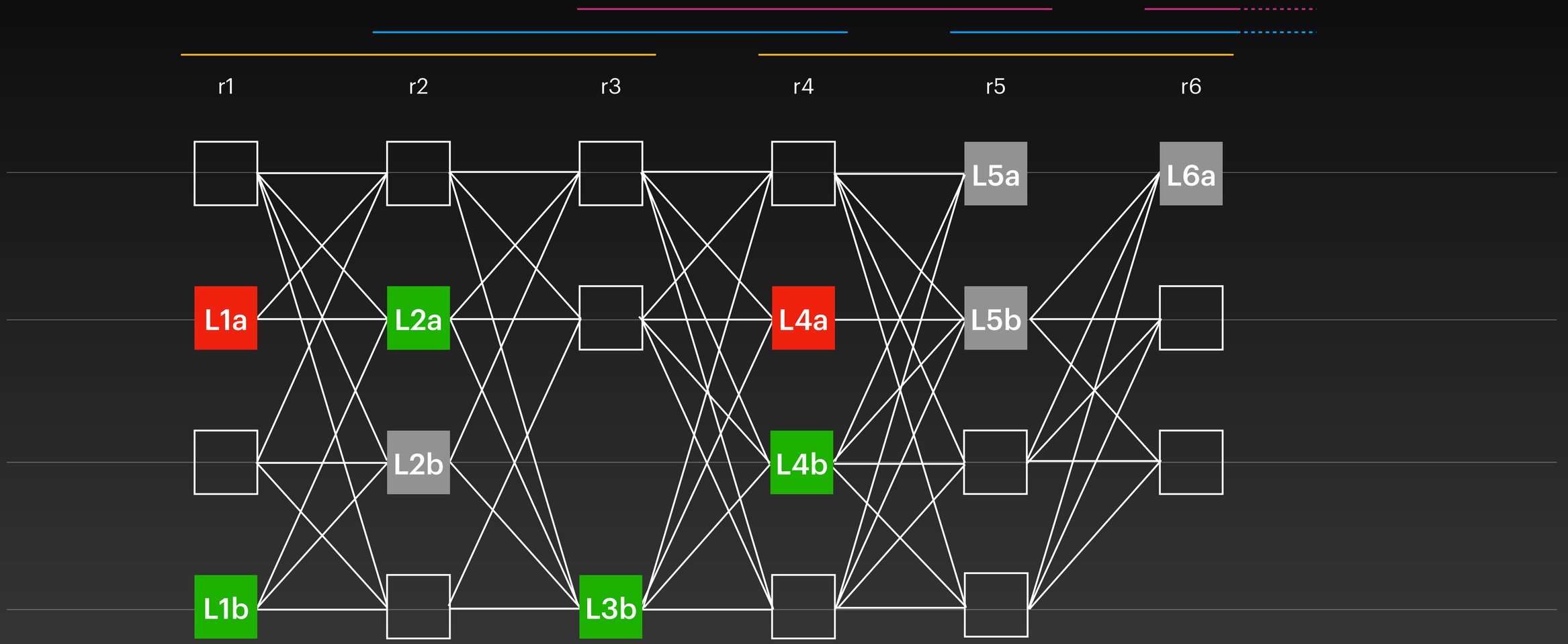


Apply Indirect Rule

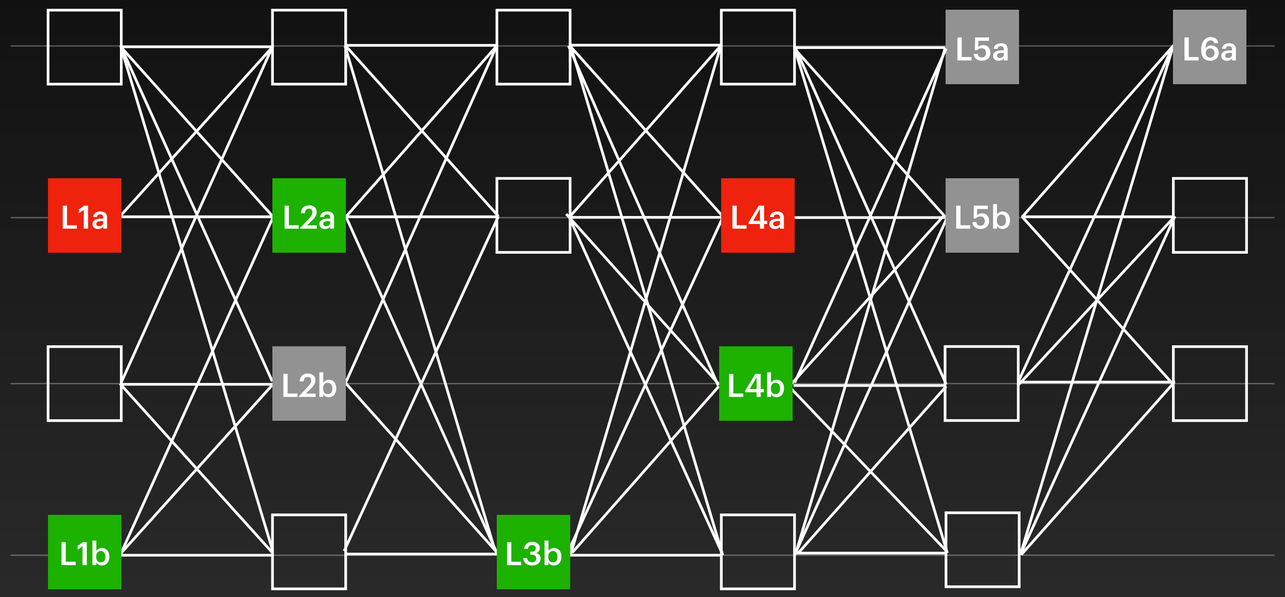


Current Status



Commit Sequence

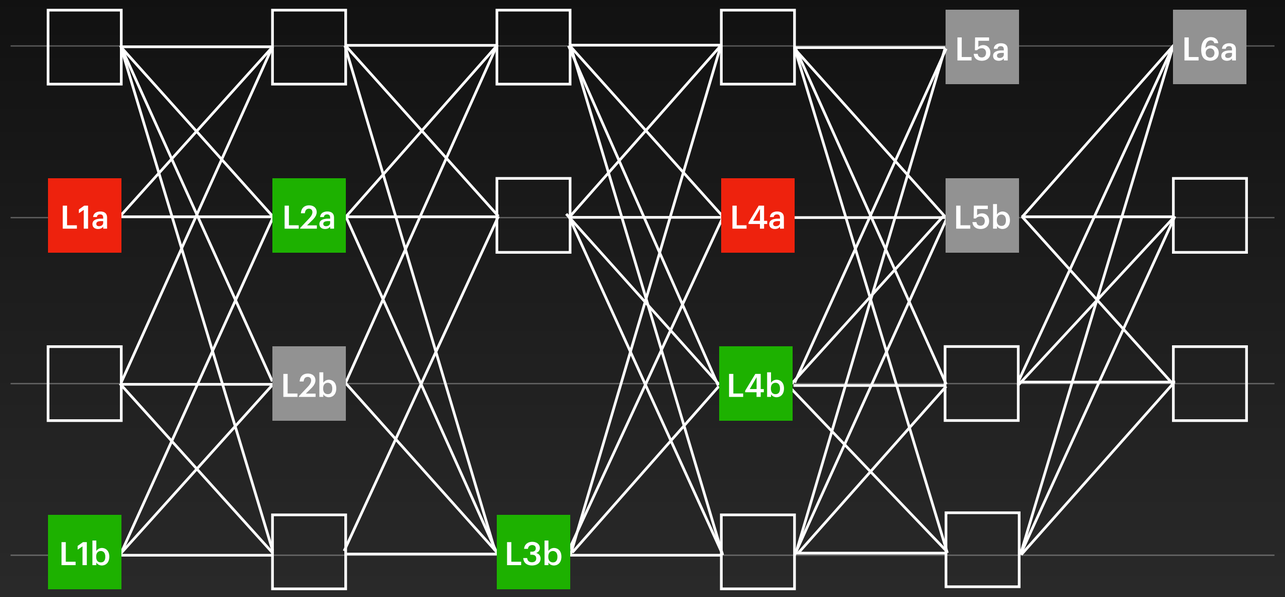
Take all leaders in order



leaders sequence: L1a L1b L2a L2b L3a L3b L4a L4b

Commit Sequence

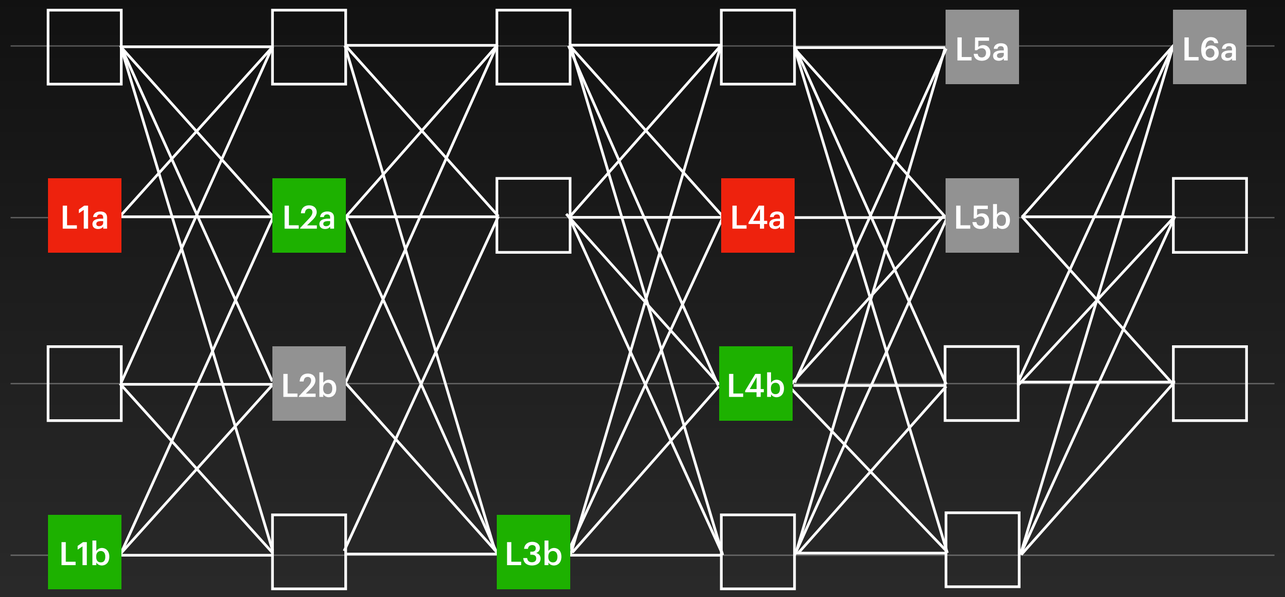
Stop at the first Undecided leader



leaders sequence: L1a L1b L2a L2b L3a L3b L4a L4b

Commit Sequence

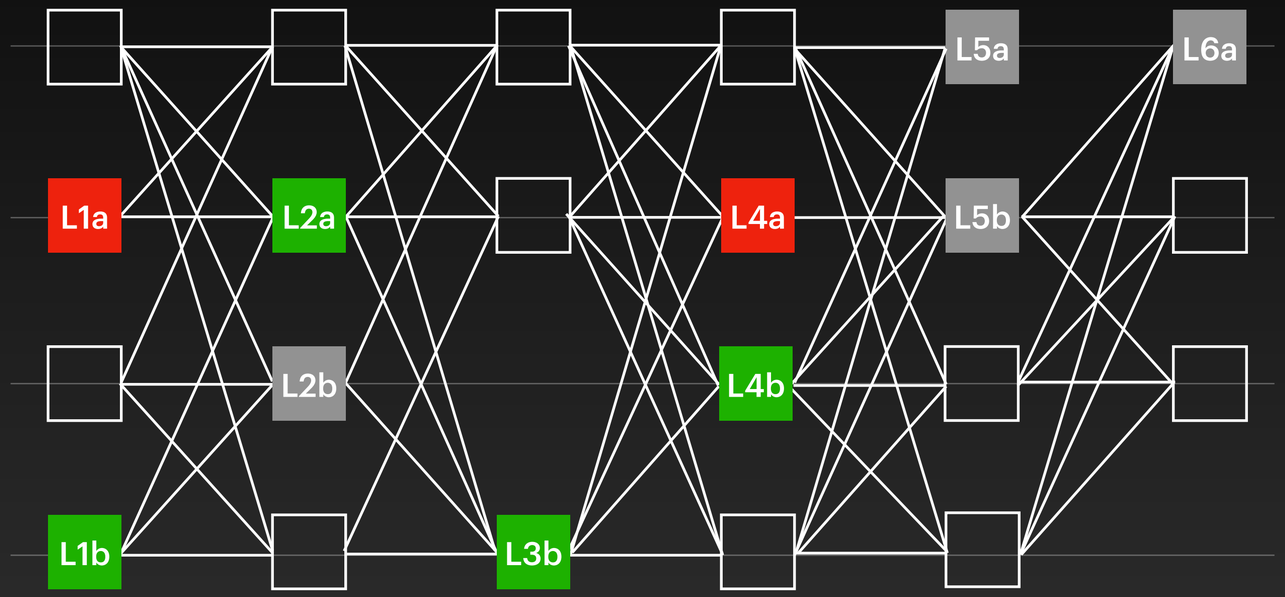
Remove skipped leaders



leaders sequence: L1a L1b L2a L2b L3a L3b L4a L4b

Commit Sequence

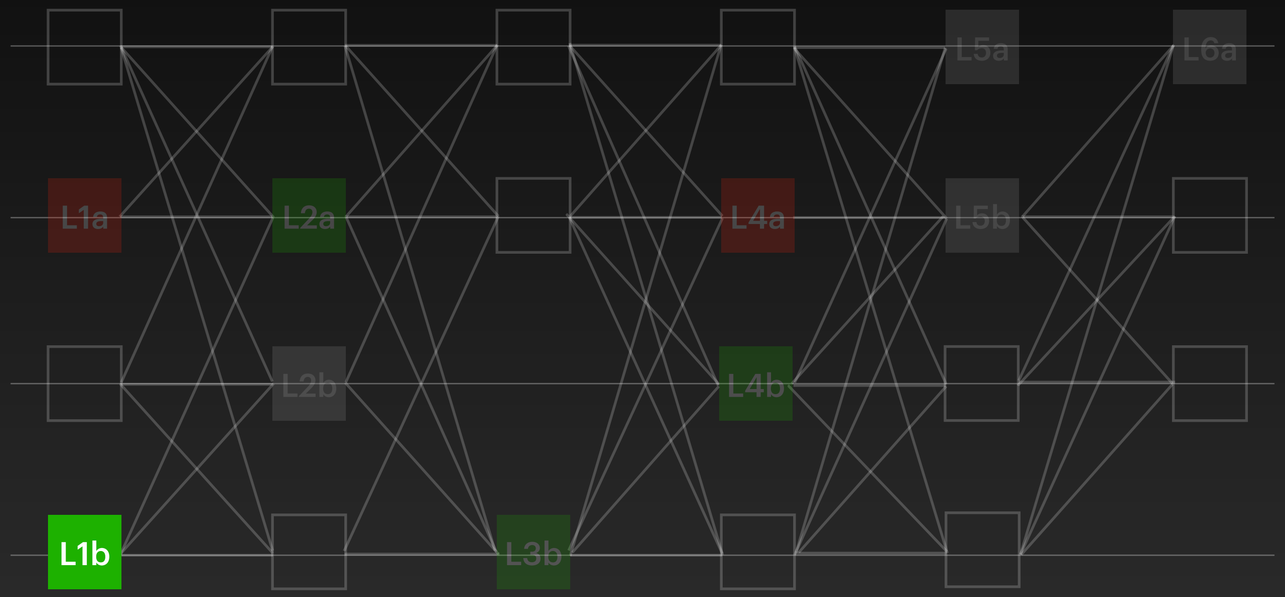
Final leader sequence



leaders sequence: L1b L2a

Commit Sequence

Commit sub-dag

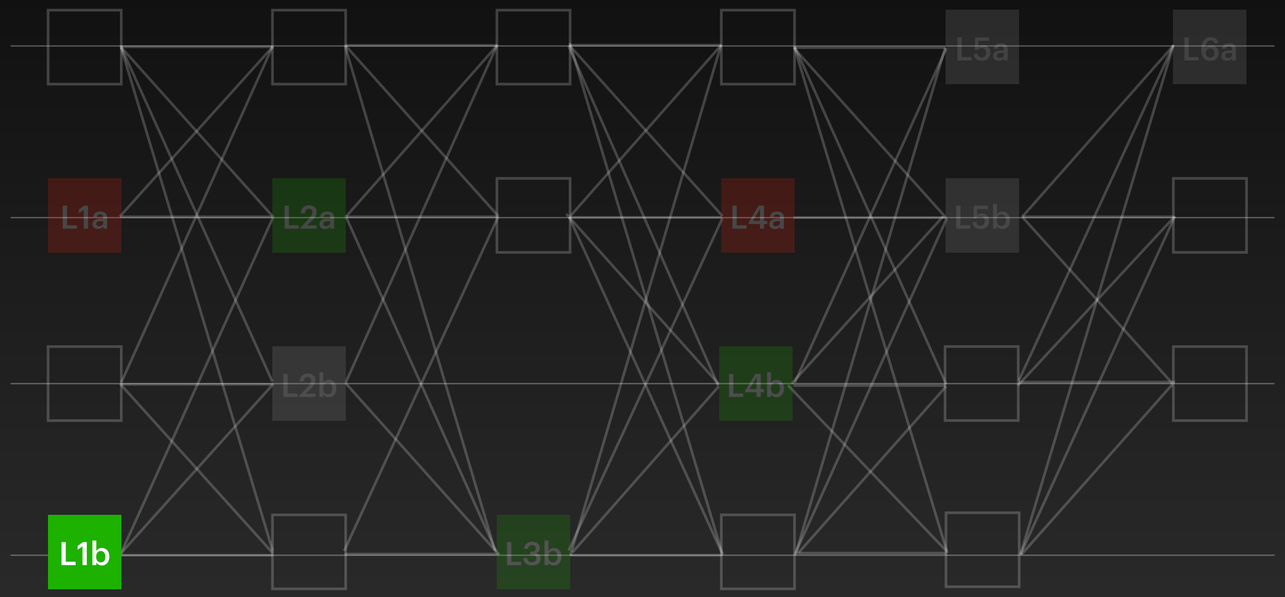


leaders sequence: L1b L2a

output sequence:

Commit Sequence

Commit sub-dag

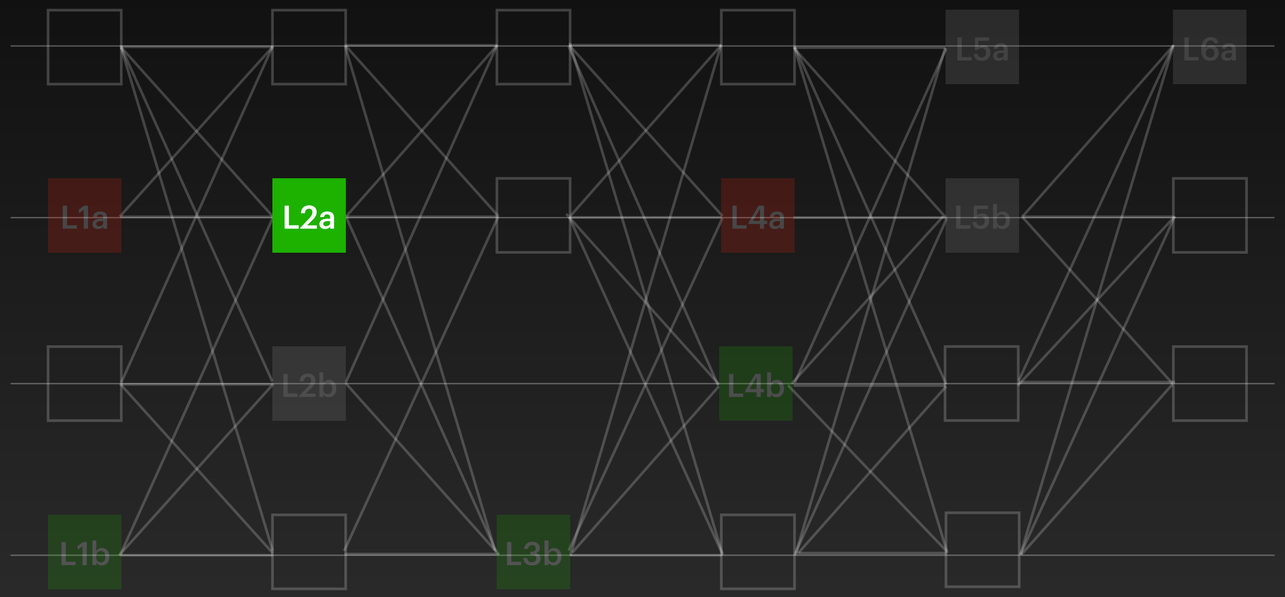


leaders sequence: L2a

output sequence: L1b

Commit Sequence

Commit sub-dag

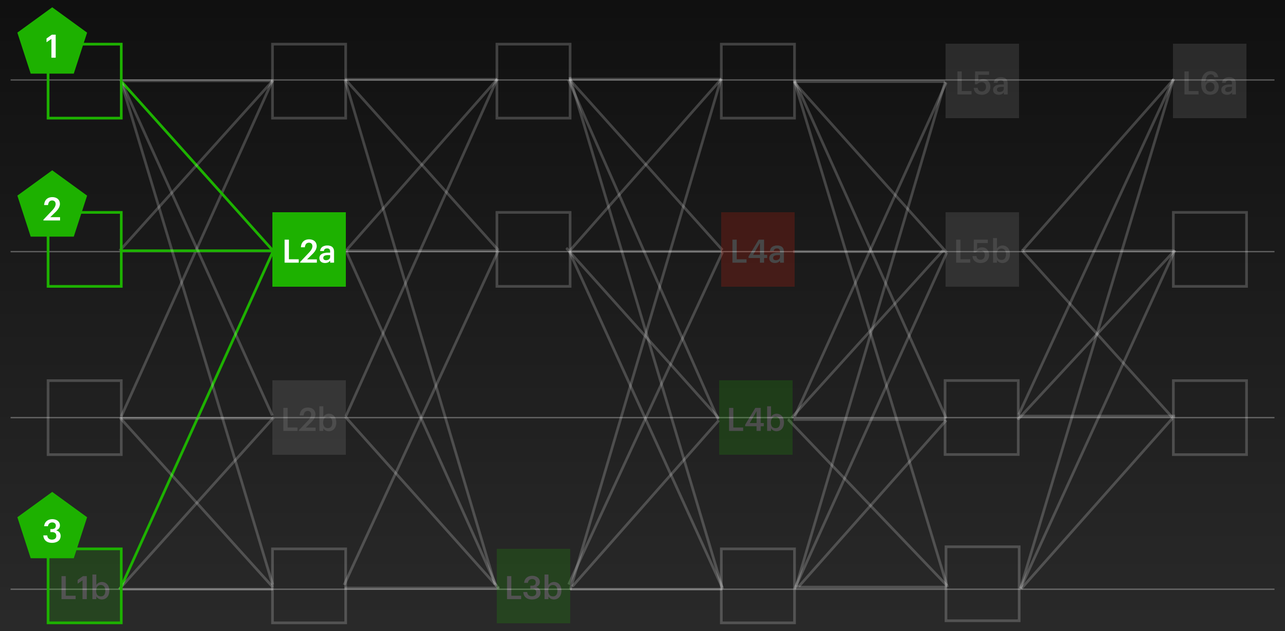


leaders sequence: L2a

output sequence: L1b

Commit Sequence

Commit sub-dag

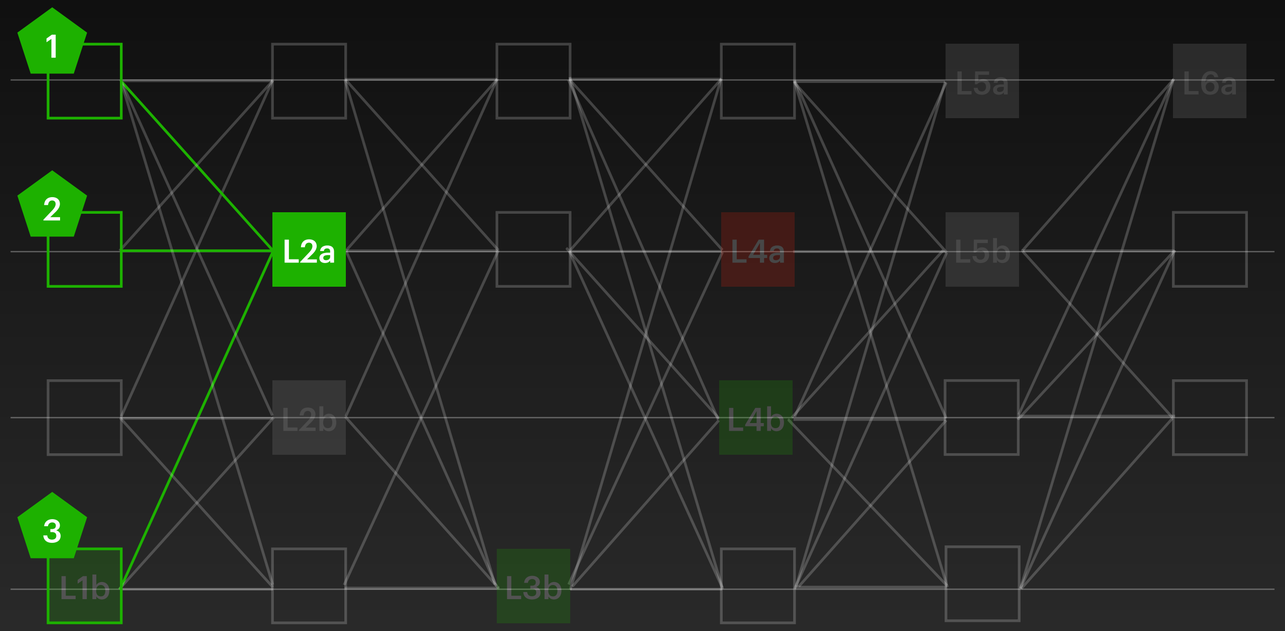


leaders sequence: L2a

output sequence: L1b

Commit Sequence

Commit sub-dag



leaders sequence:

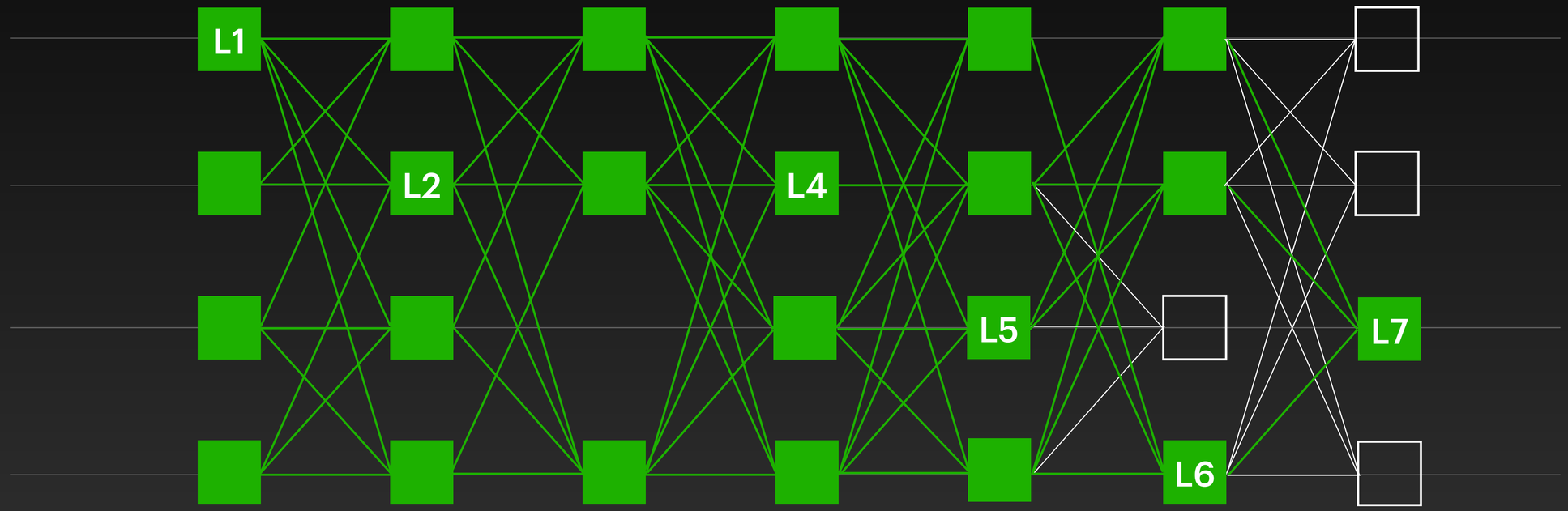
output sequence: L1b, 1, 2, L2a

Slow Leaders are Annoying

Suffer from them only when under attack or bad network

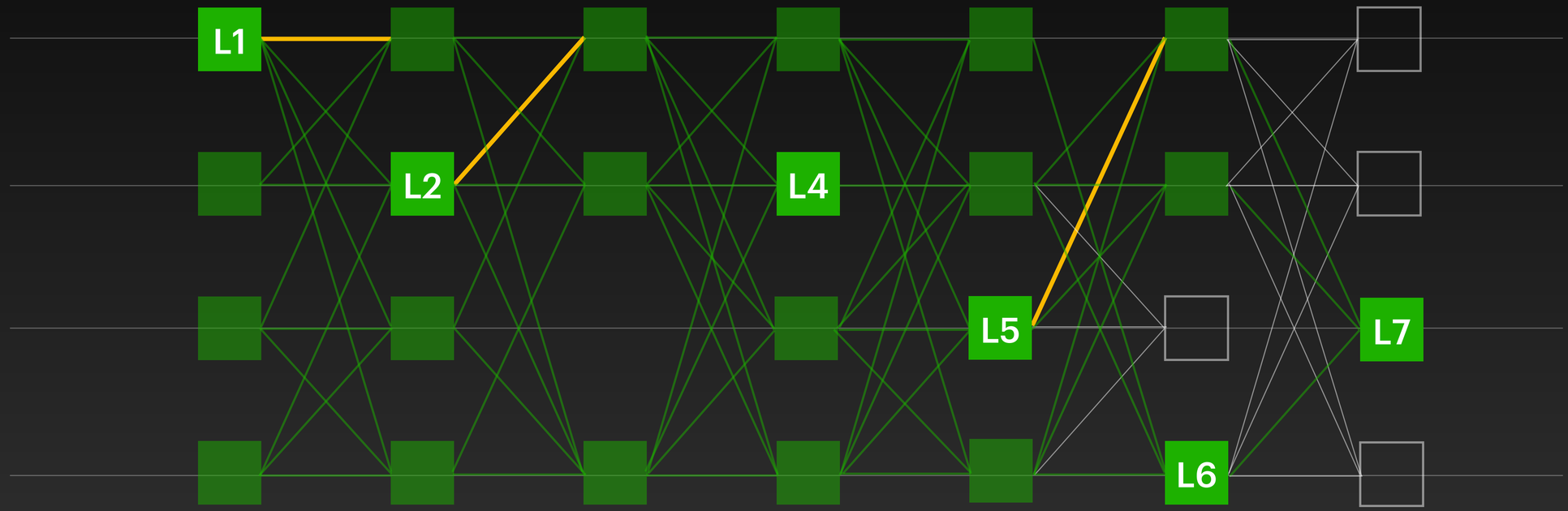
HammerHead

Compute Reputation Scores



HammerHead

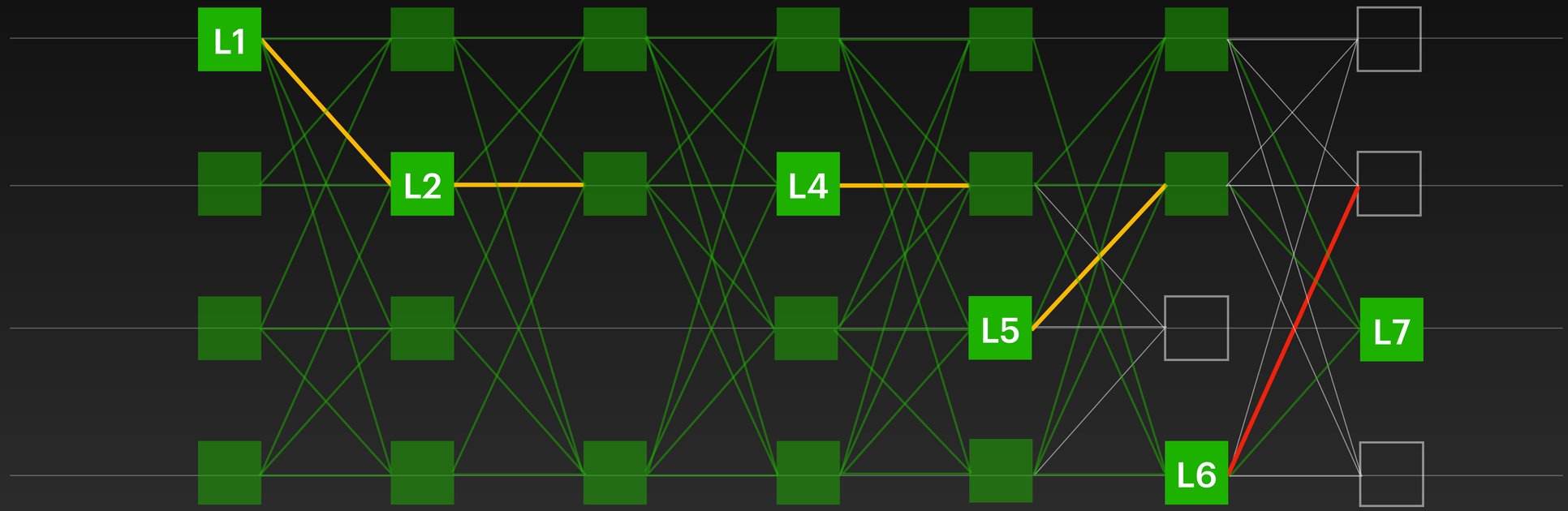
Compute Reputation Scores



node 1: 3

HammerHead

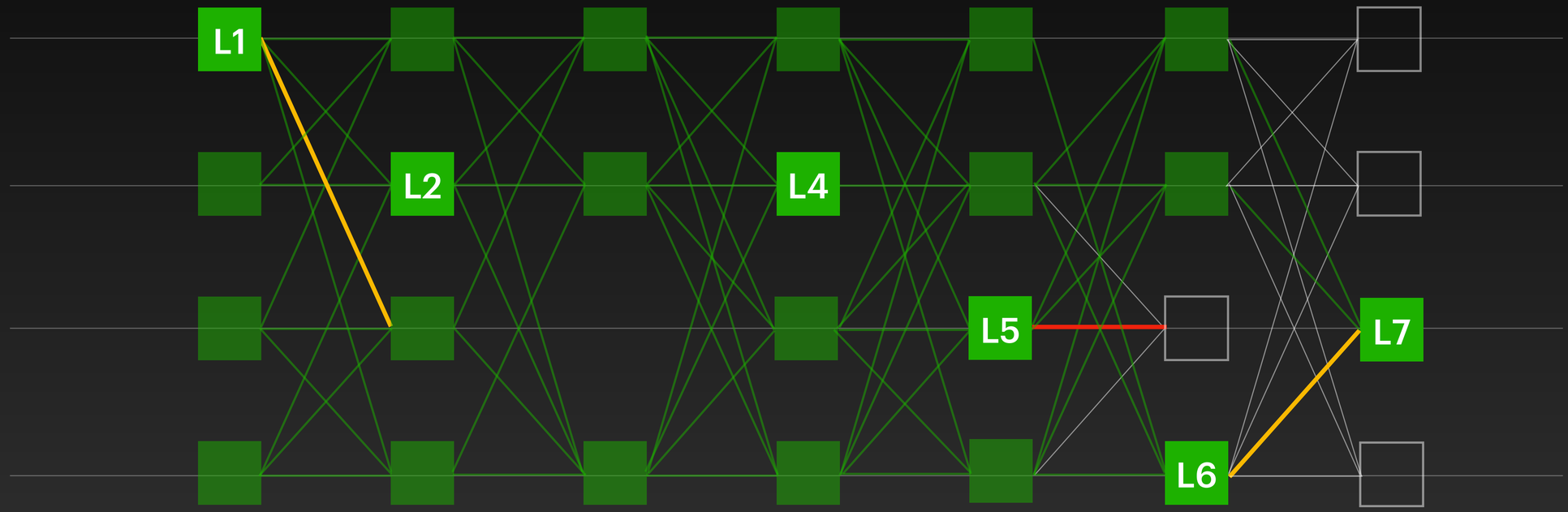
Compute Reputation Scores



node 1: 3 **node 2:** 4

HammerHead

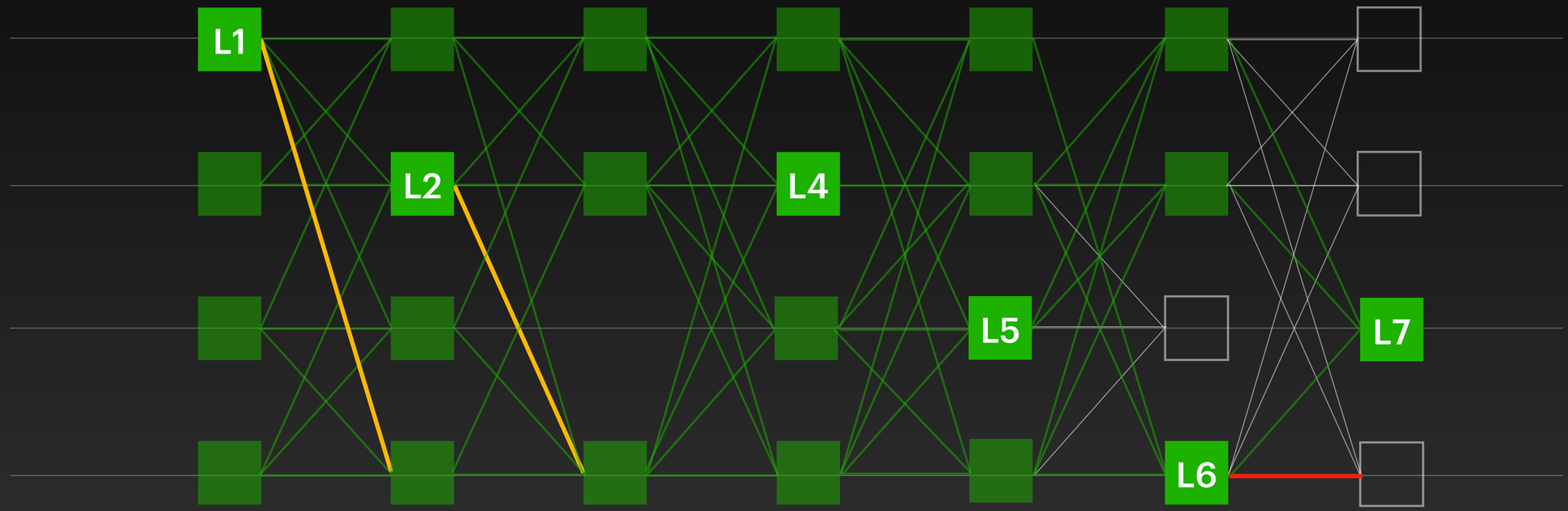
Compute Reputation Scores



node 1: 3 **node 2:** 4 **node 3:** 2

HammerHead

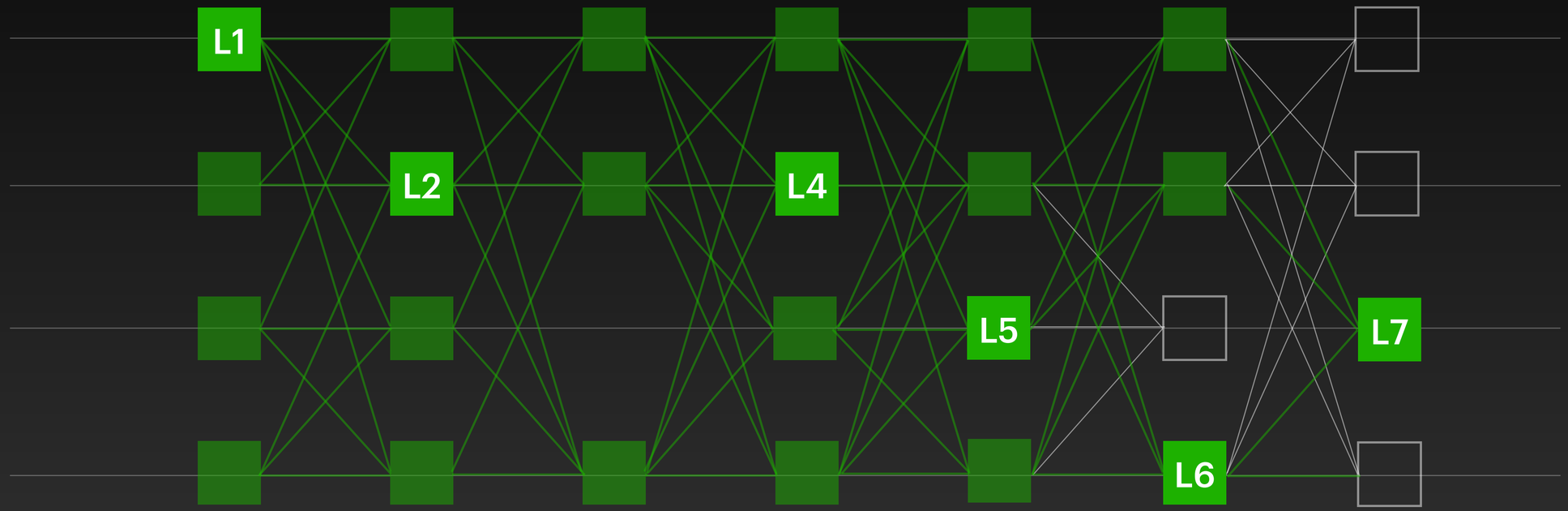
Compute Reputation Scores



node 1: 3 **node 2:** 4 **node 3:** 2 **node 4:** 2

HammerHead

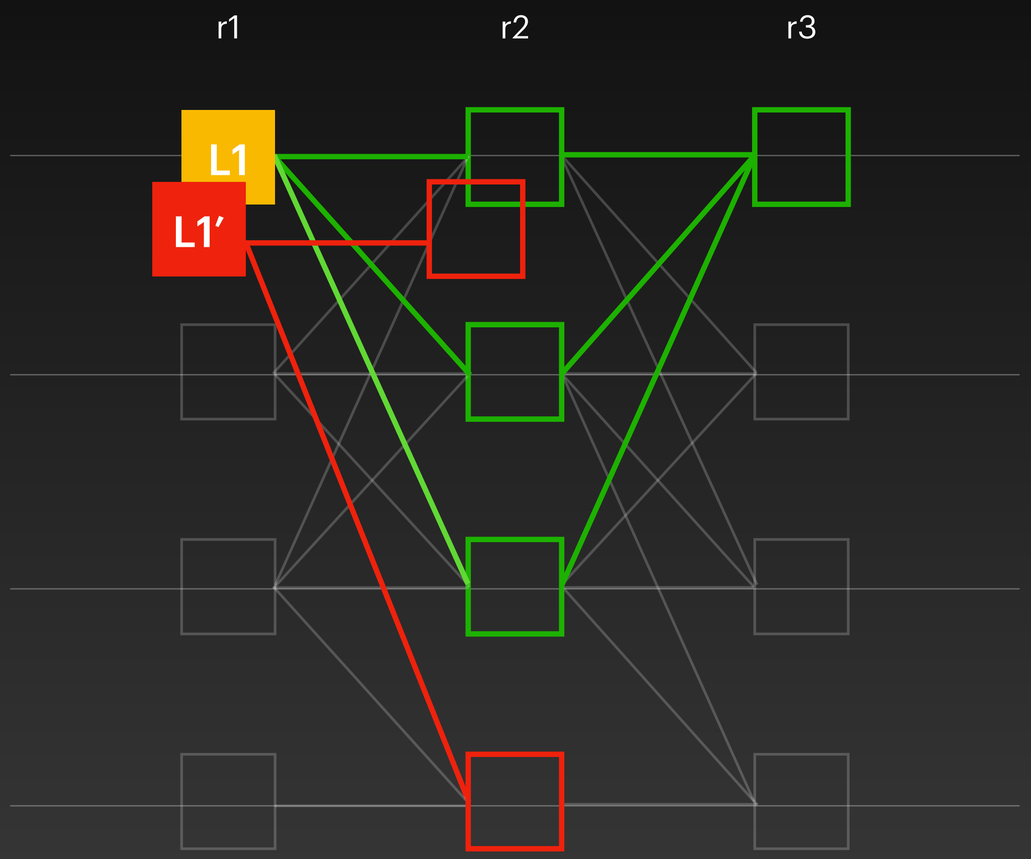
Future Leaders



node 1: 3 node 2: 4 node 3: 2 node 4: 2

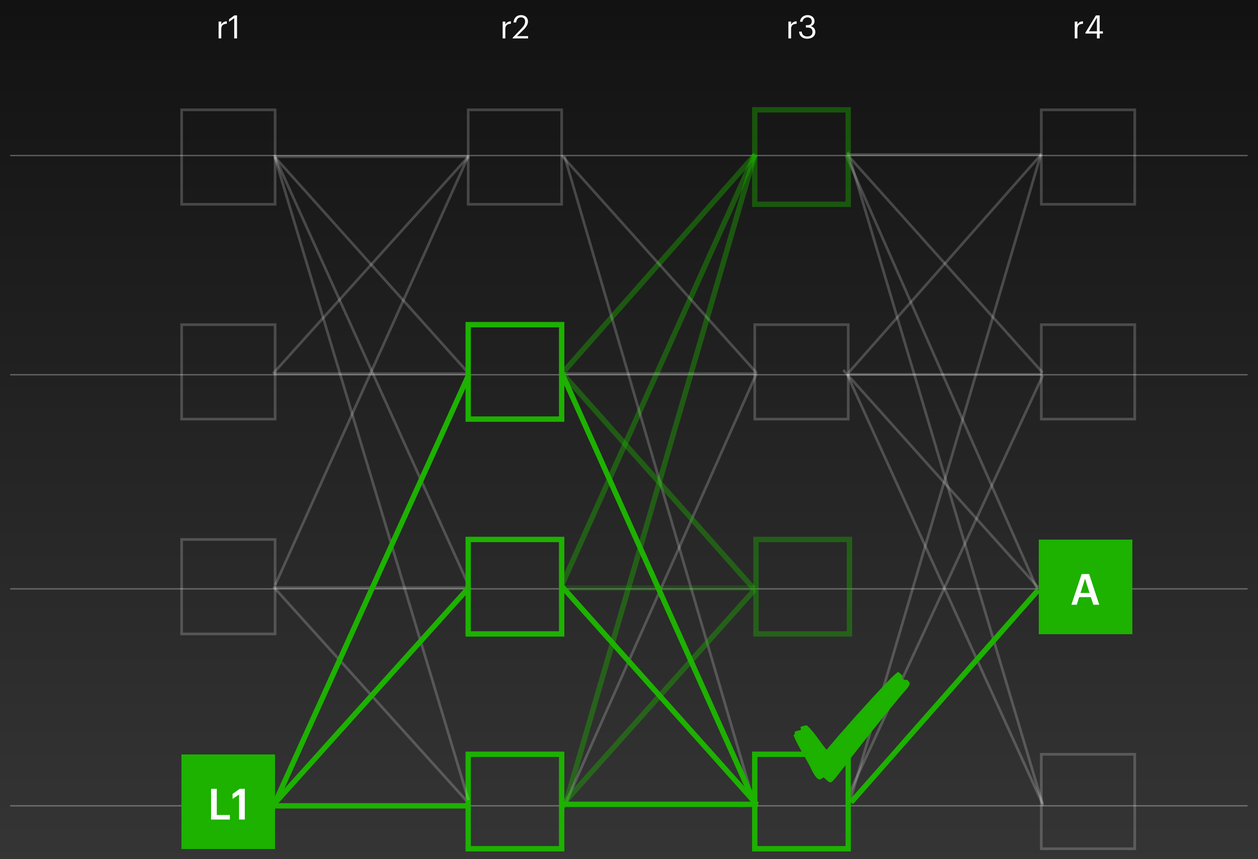
Security Intuition

Security Intuition



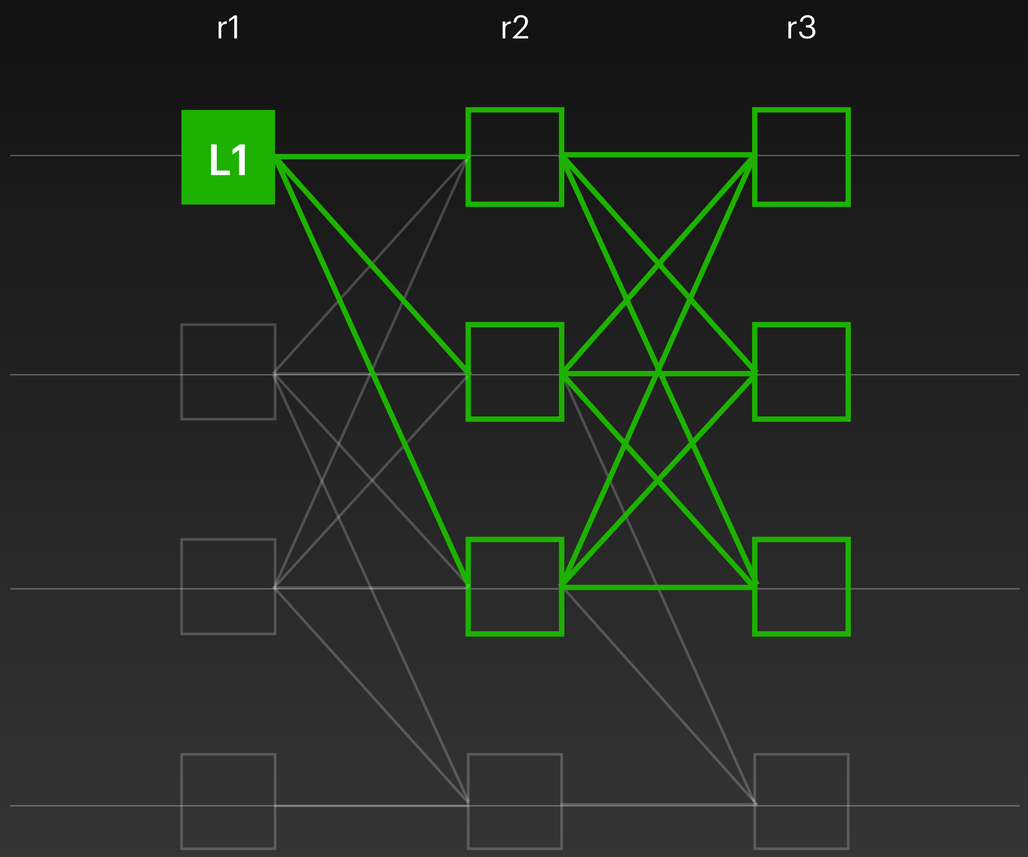
- At most **L1** or **L1’** can have a certificate pattern (quorum intersection)

Security Intuition



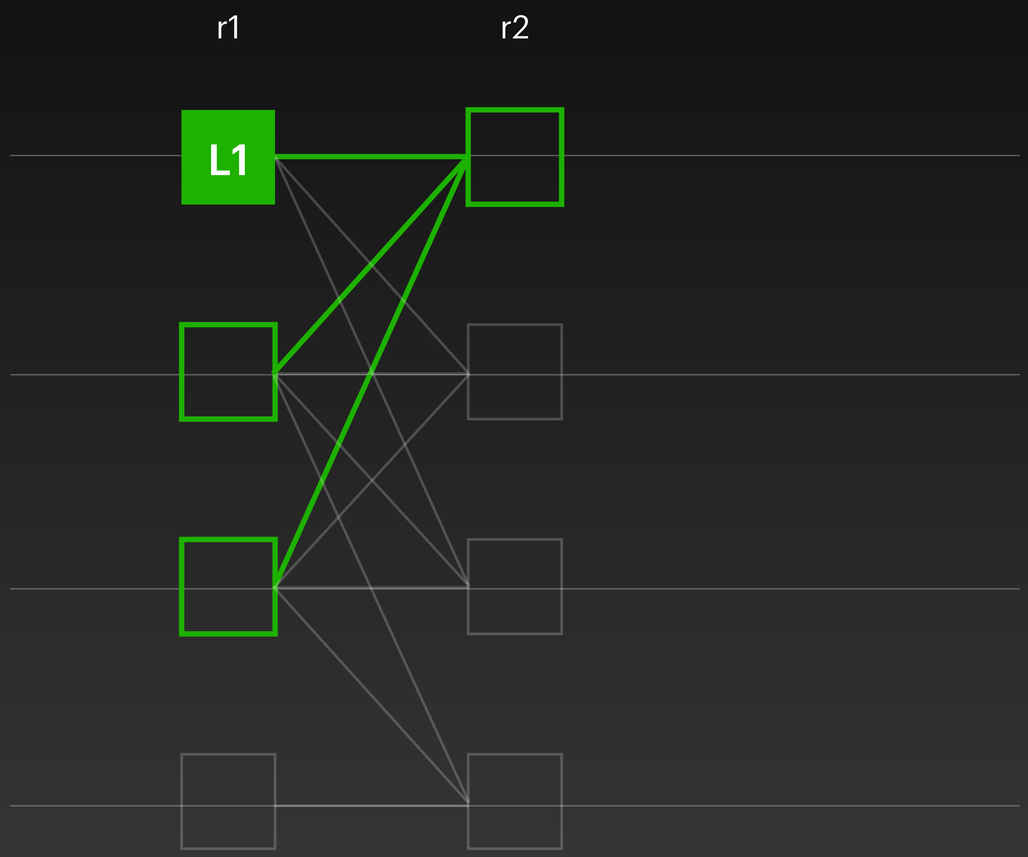
- At most **L1** or **L1'** can have a certificate pattern (quorum intersection
- If **L1** has 2f+1 certificate patterns, **A** always has a certified link to **L1**

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

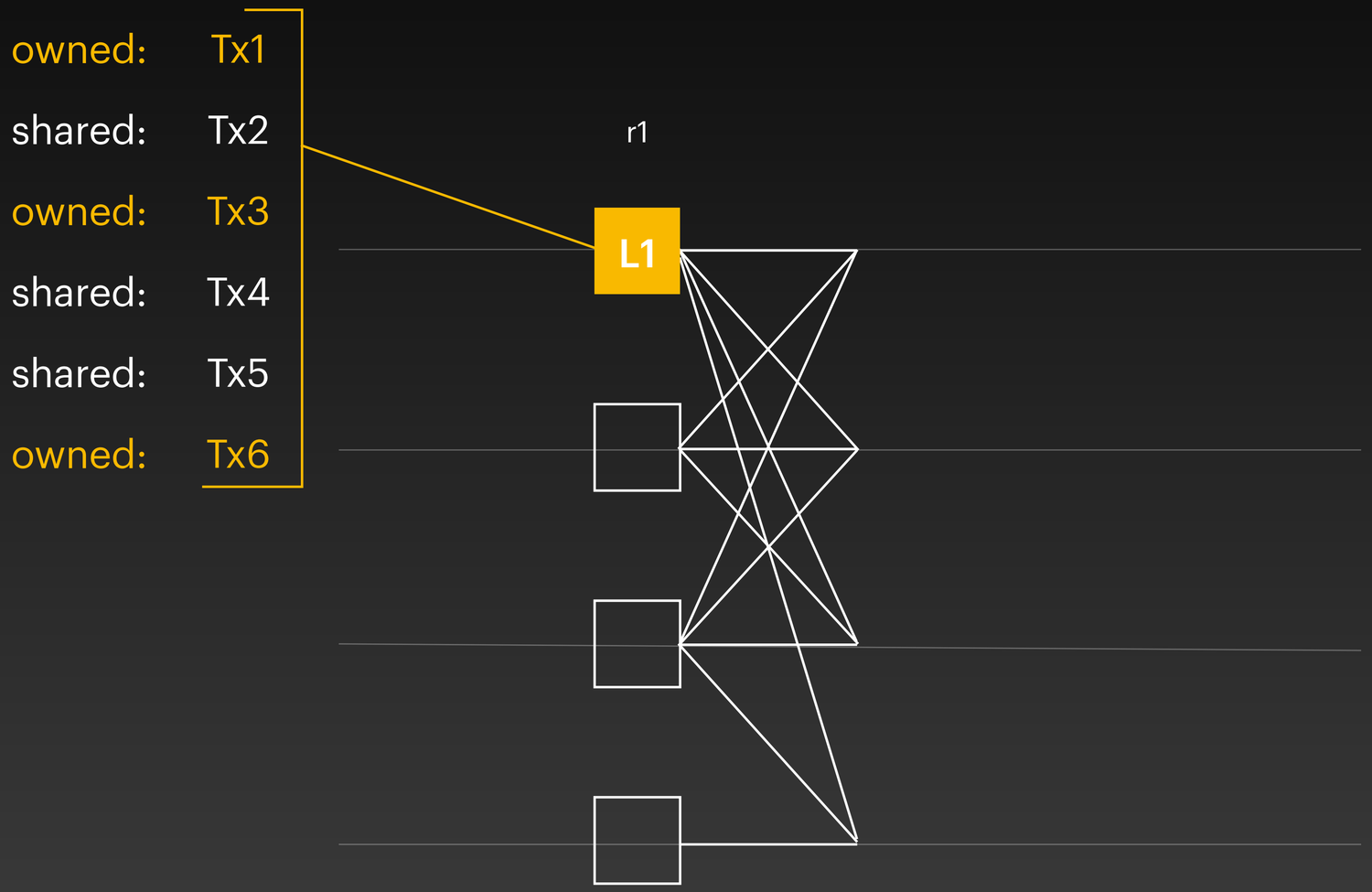
- Objects that can be mutated my multiple entities
- e.g., A global counter
- **Need consensus**

System State

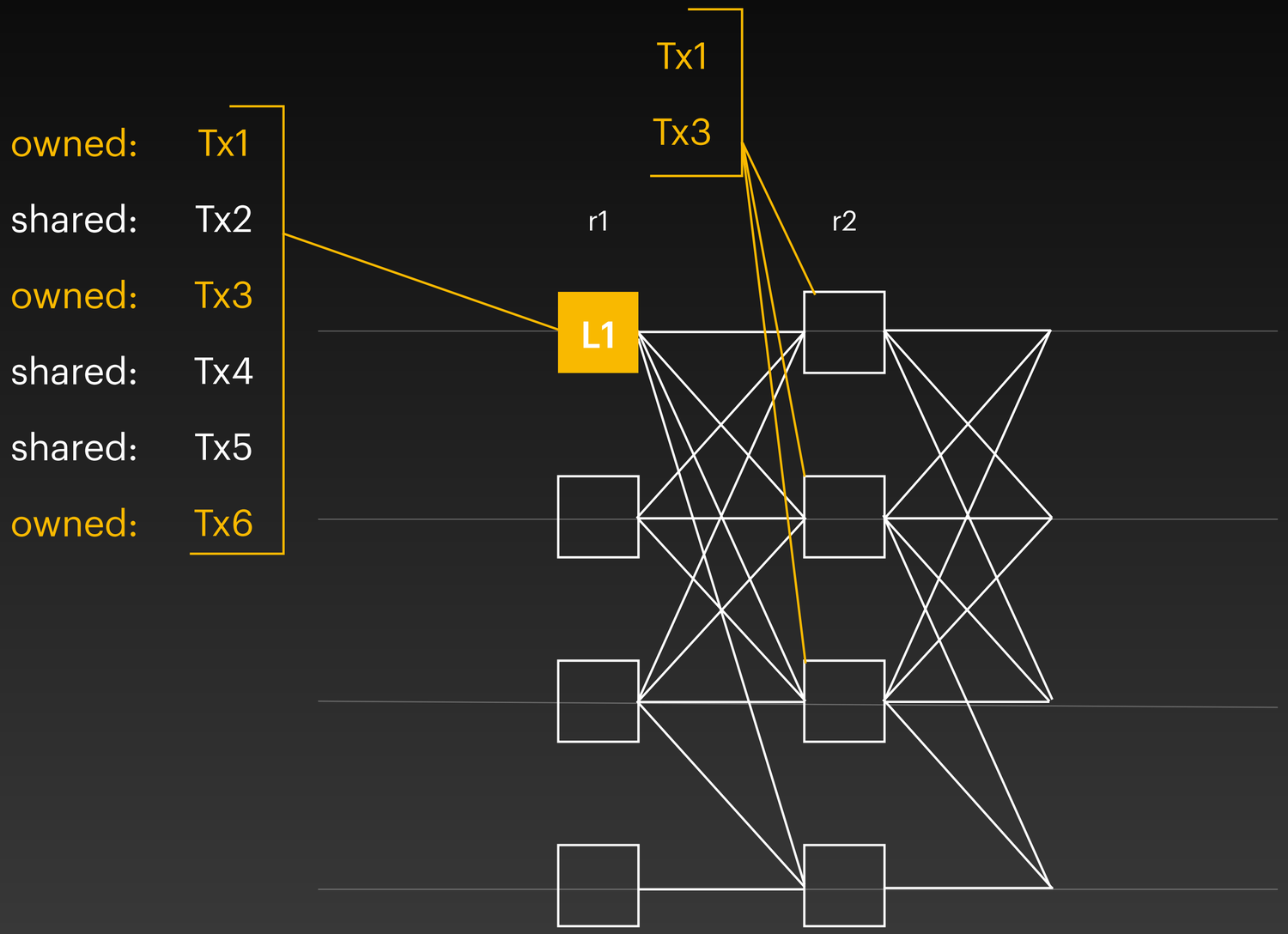
Objects:

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

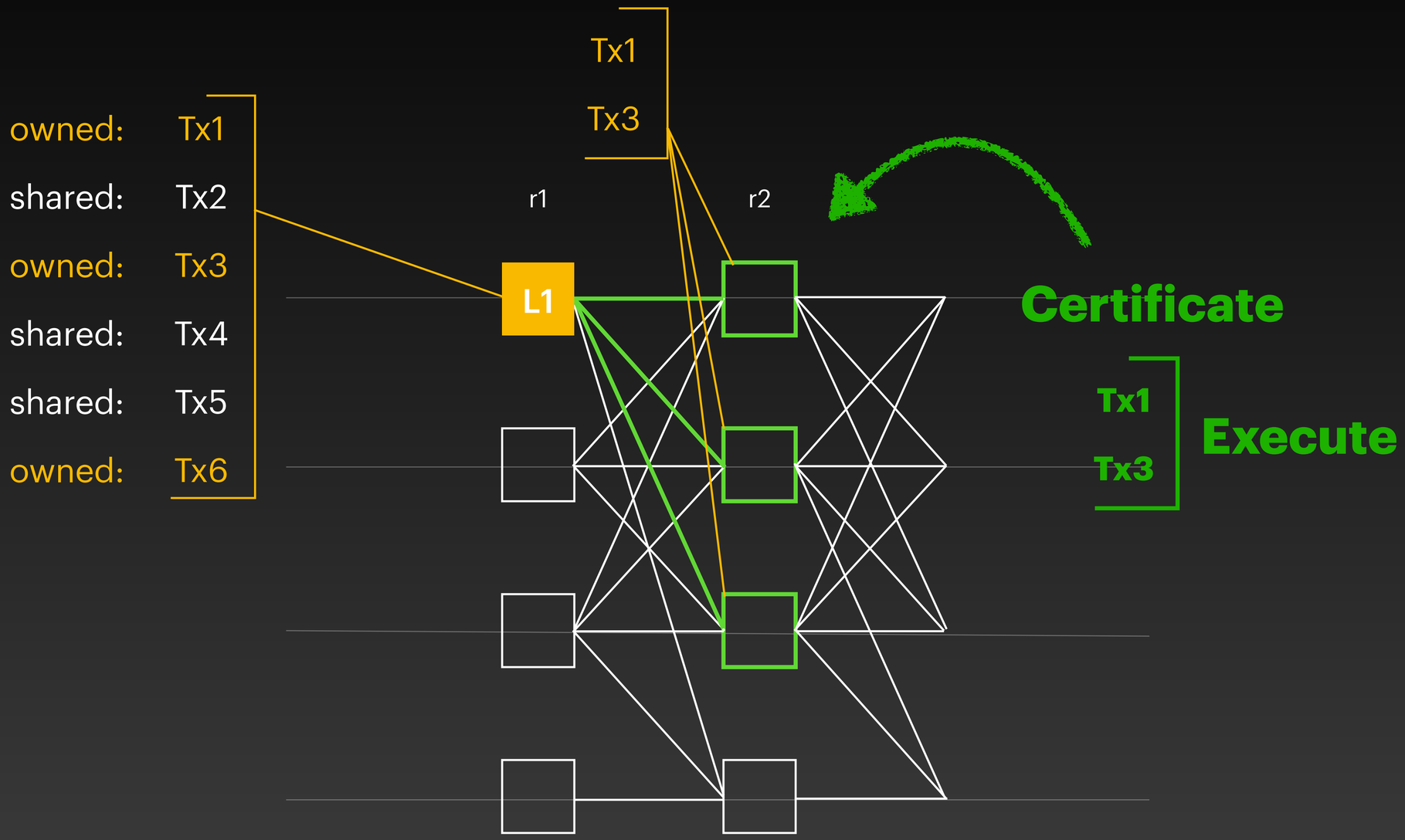
Fast Execution



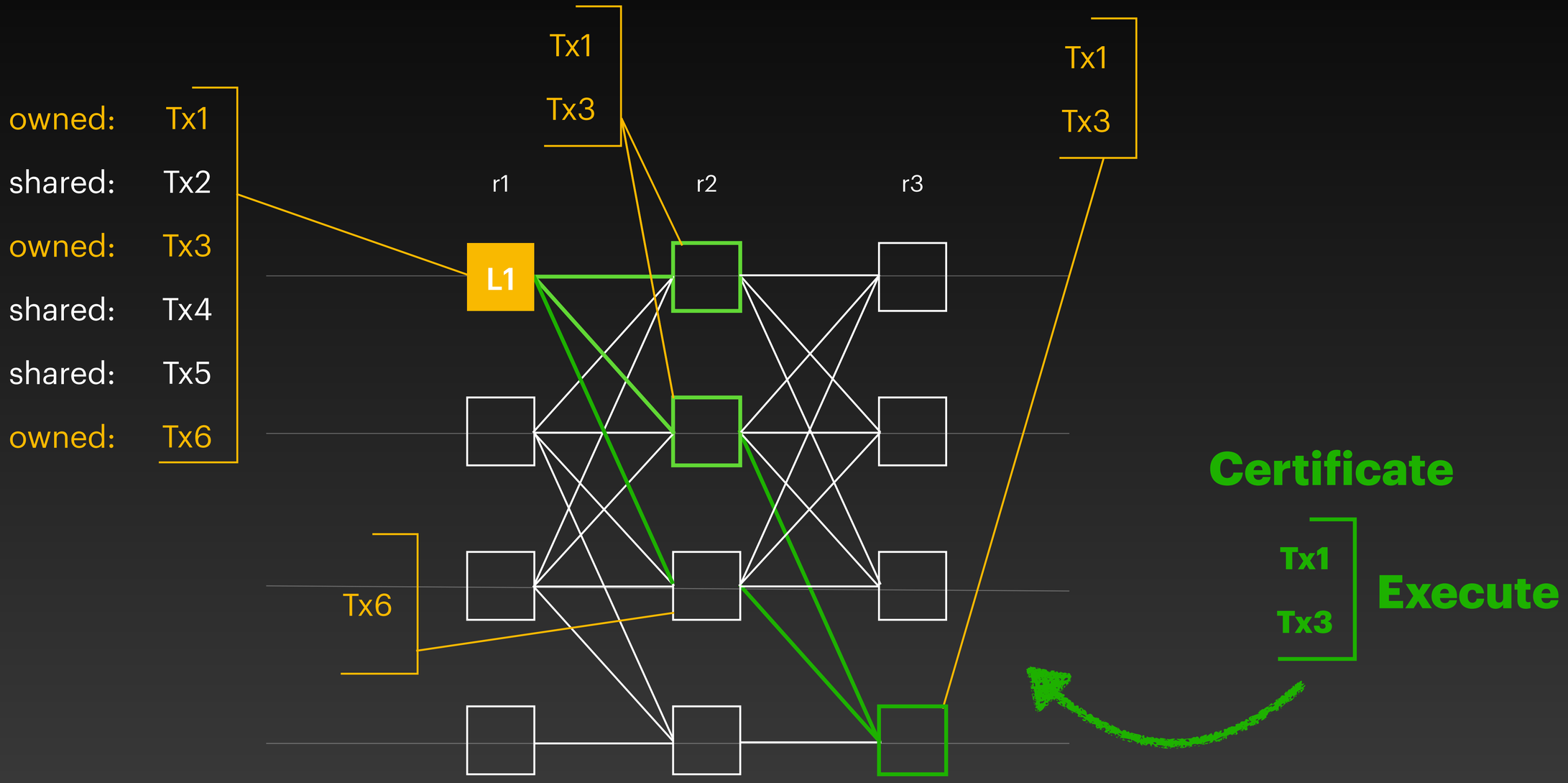
Fast Execution



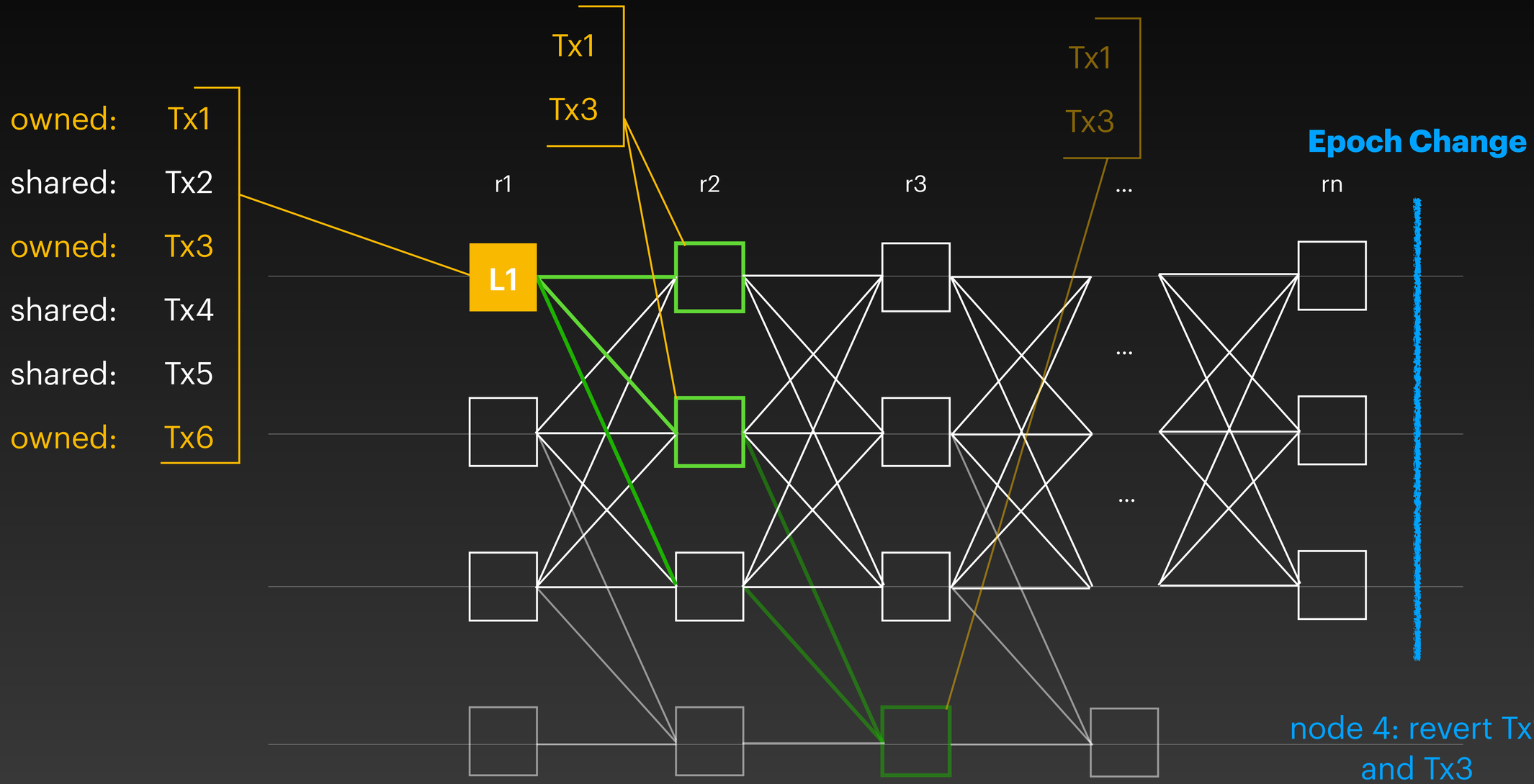
Fast Execution



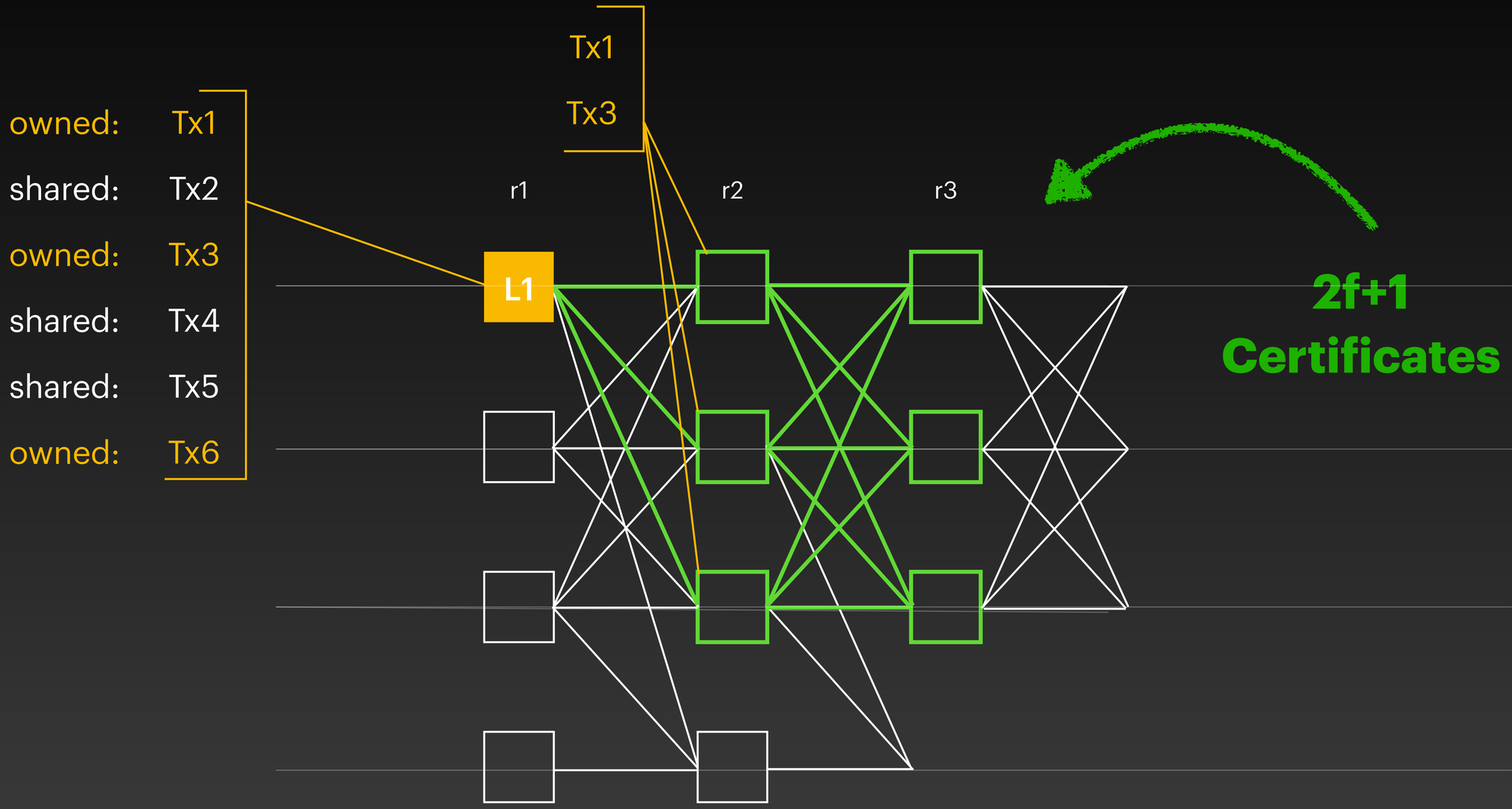
Fast Execution



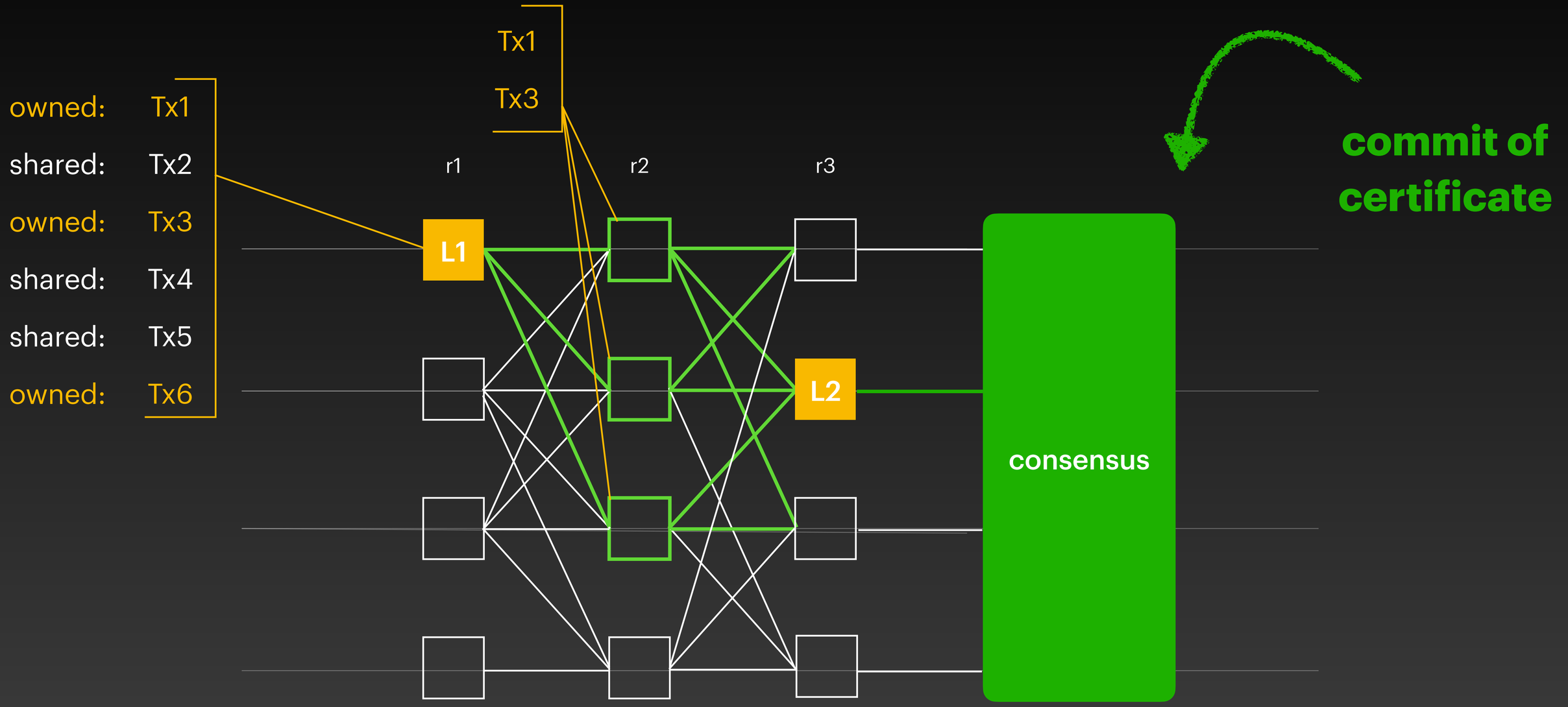
No Finality


owned: Tx1
shared: Tx2
owned: Tx3
shared: Tx4
shared: Tx5
owned: Tx6
Tx1
Tx3
Tx1
Tx3
r1
r2
r3
...
rn
L1
...
...
Epoch Change
node 4: revert Tx1 and Tx3

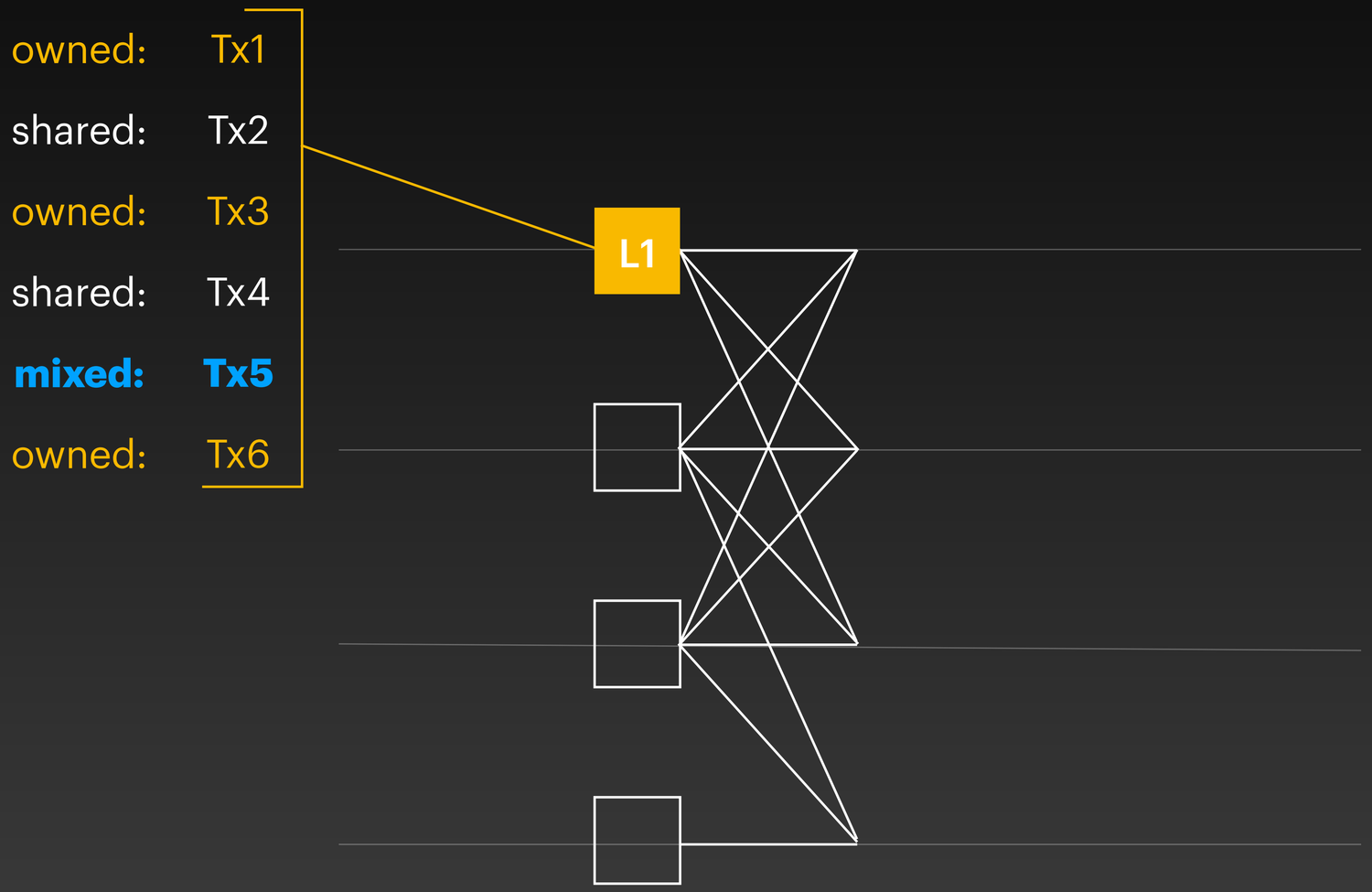
Fast Path Finality (1)



Fast Path Finality (2)

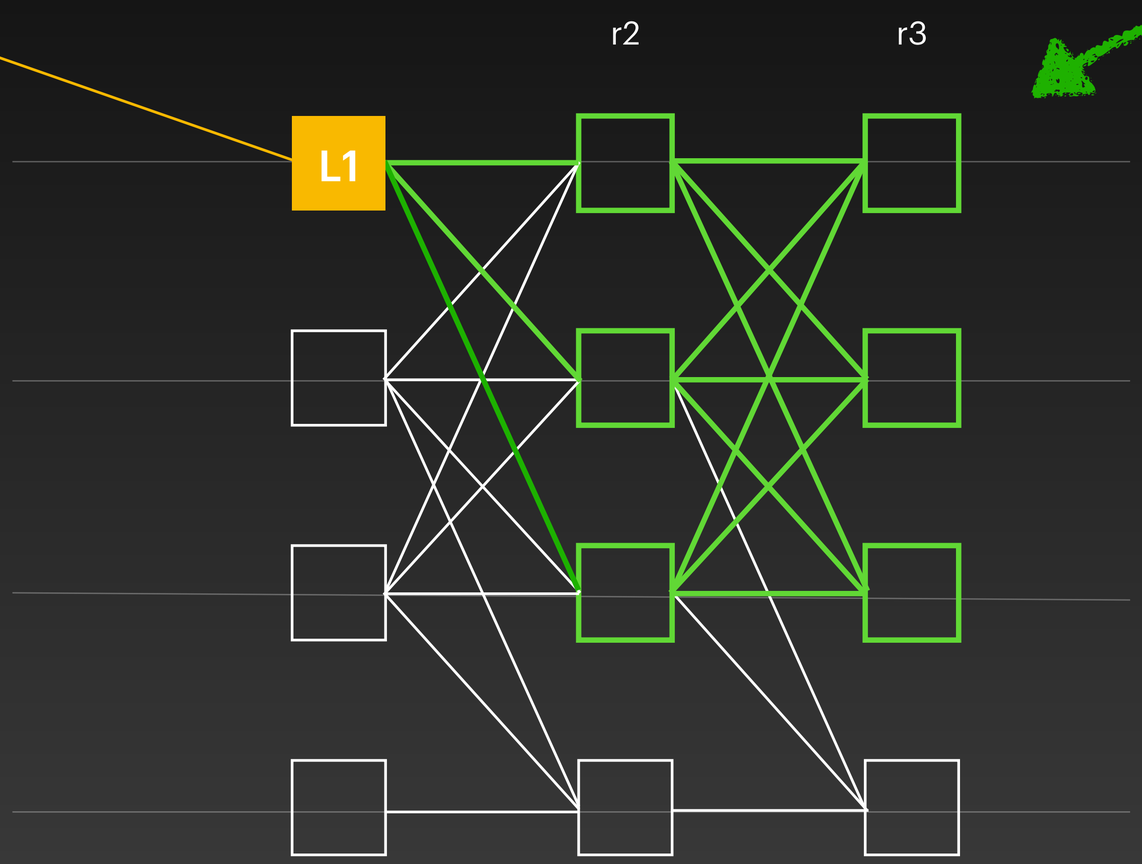


Mixed-Objects Transactions



Mixed-Objects Transactions

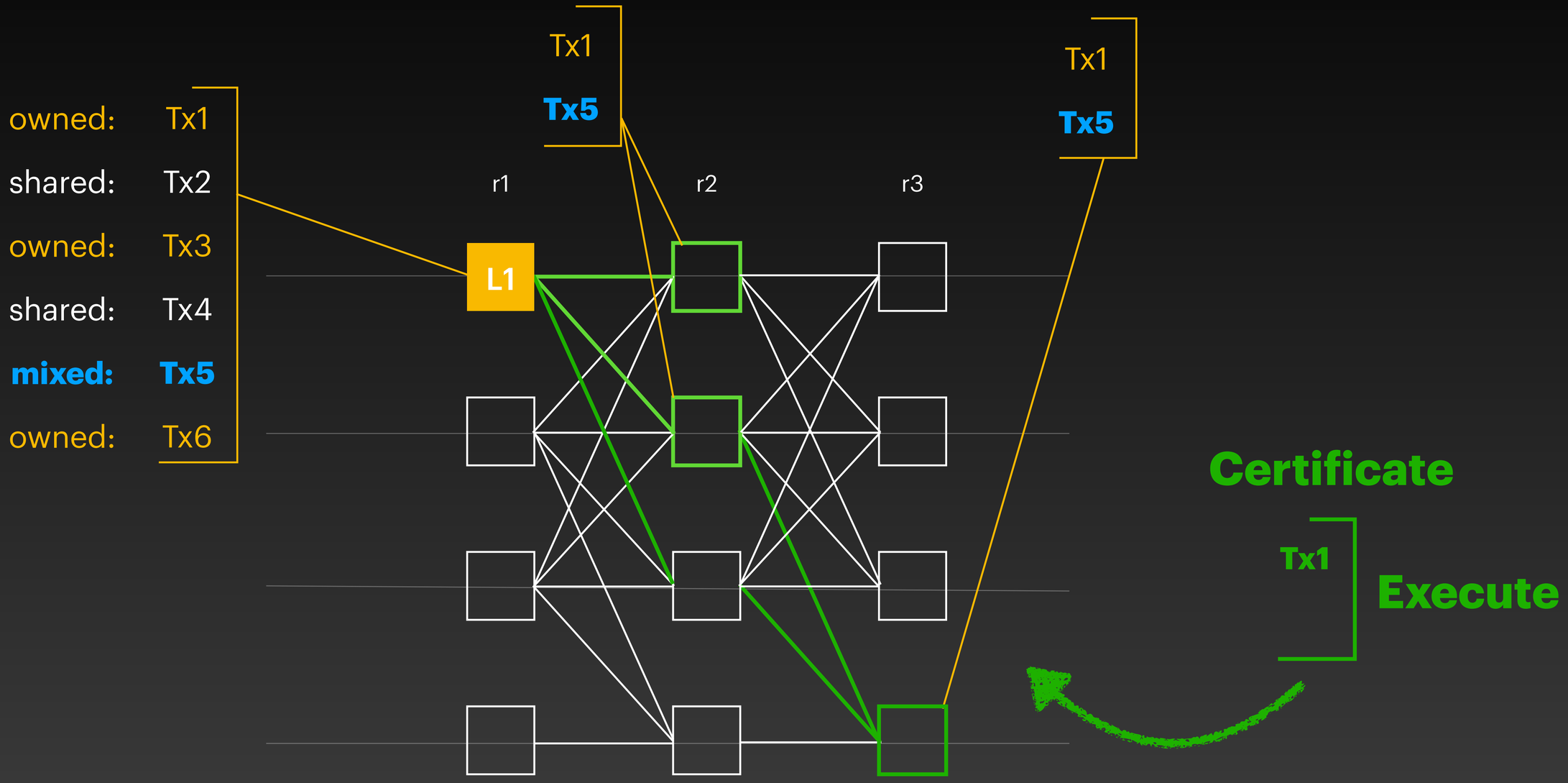
owned: Tx1
shared: Tx2
owned: Tx3
shared: Tx4
mixed: Tx5
owned: Tx6



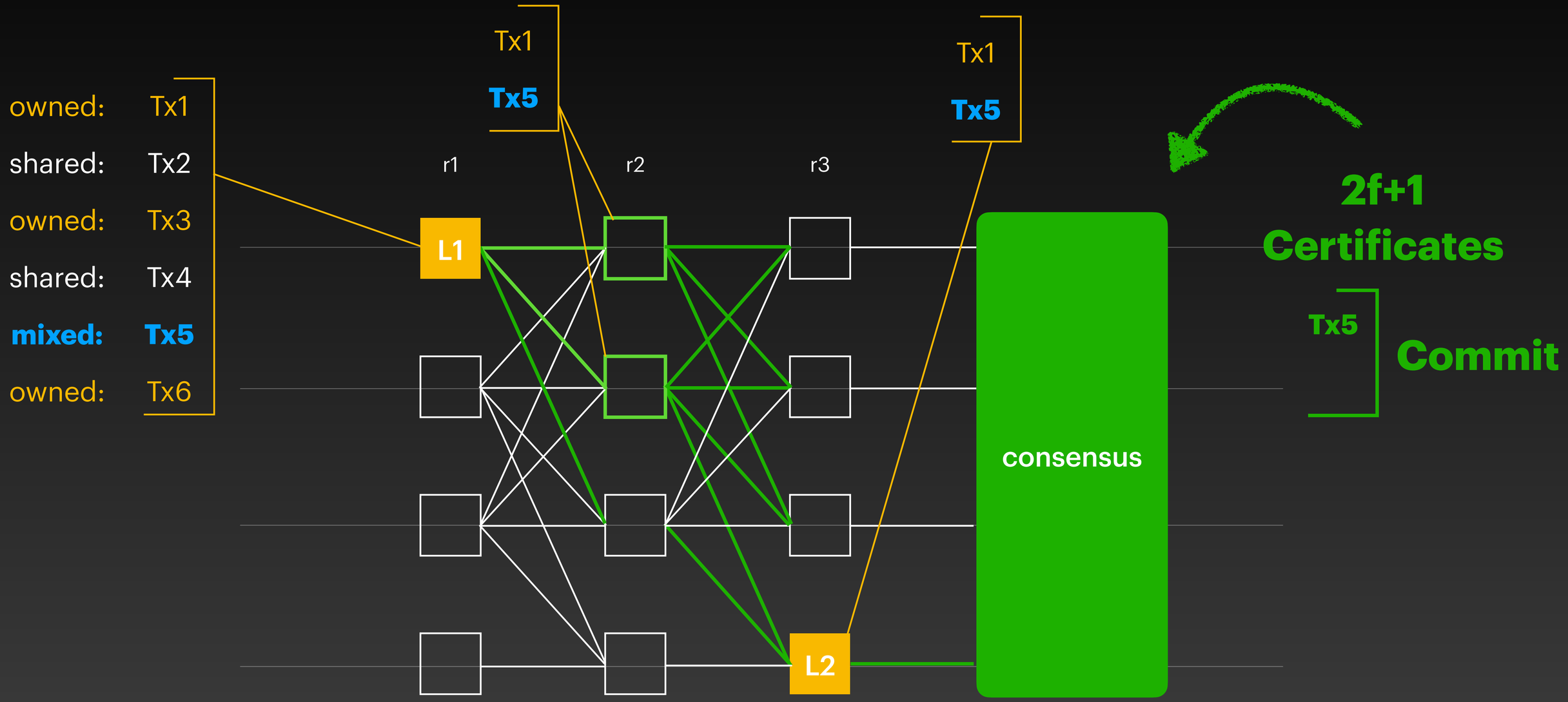
Commit

Tx2
Tx4

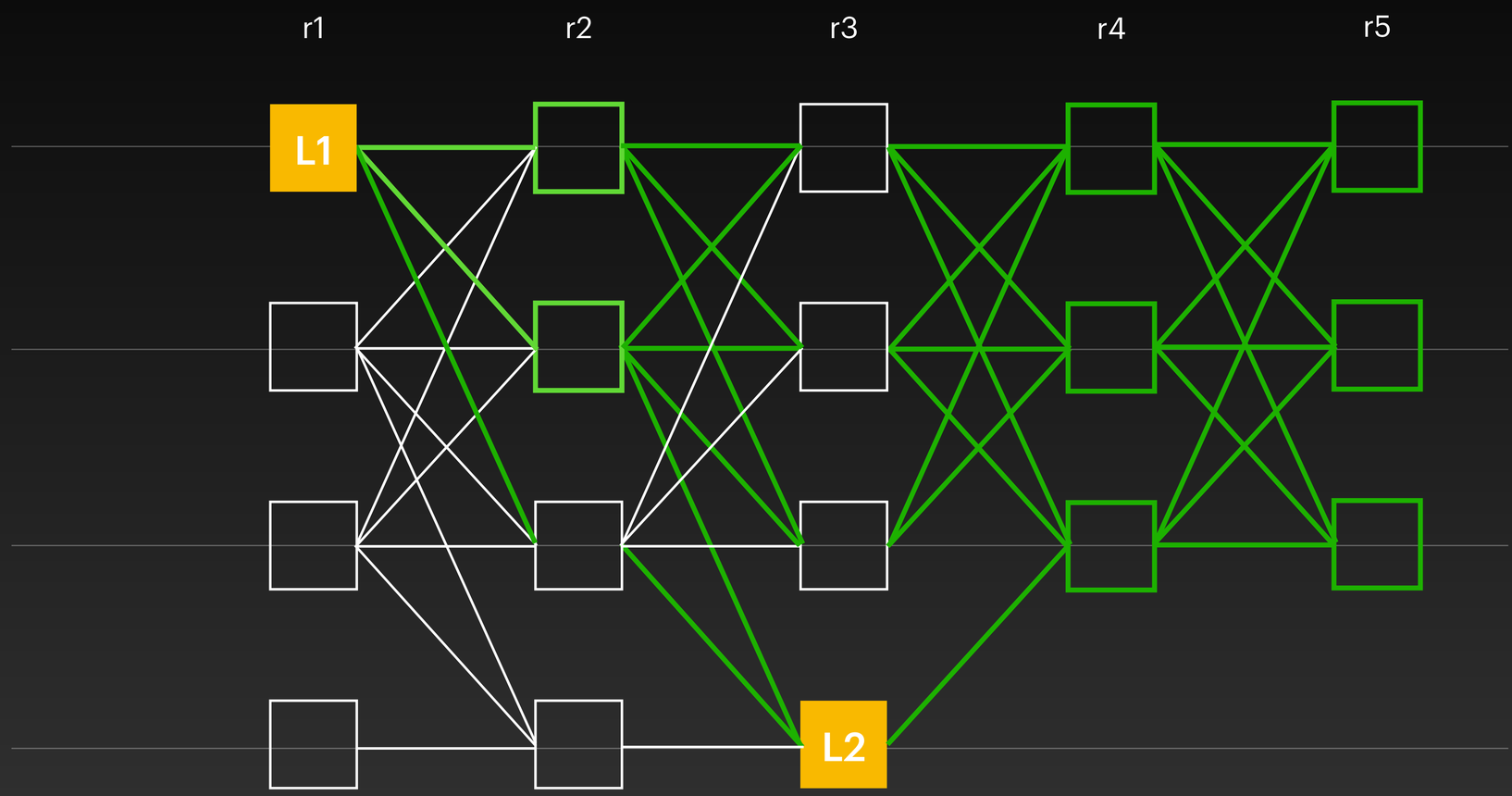
Mixed-Objects Transactions



Mixed-Objects Transactions



Mixed-Objects Transactions



lock owned objects

commit the lock on owned objects

Summary

Mysticeti

- A single message type
- Interpret patterns on the DAG

- **Paper:** https://sonnino.com/papers/mysticeti.pdf
- **Code:** https://github.com/mystenlabs/mysticeti

EXTRA

Preliminary Benchmarks

Implementation

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

https://github.com/mystenlabs/mysticeti

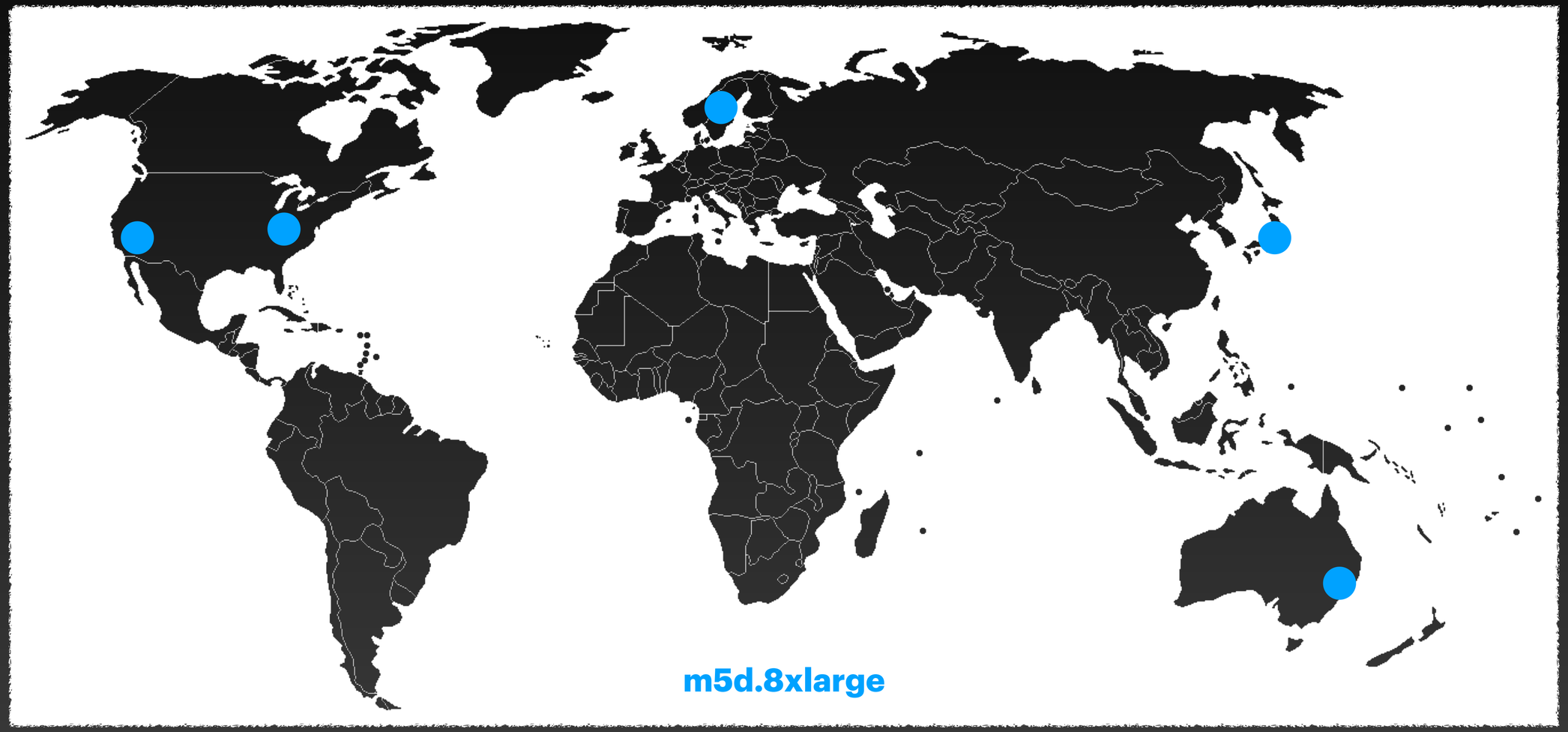
Implementation

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

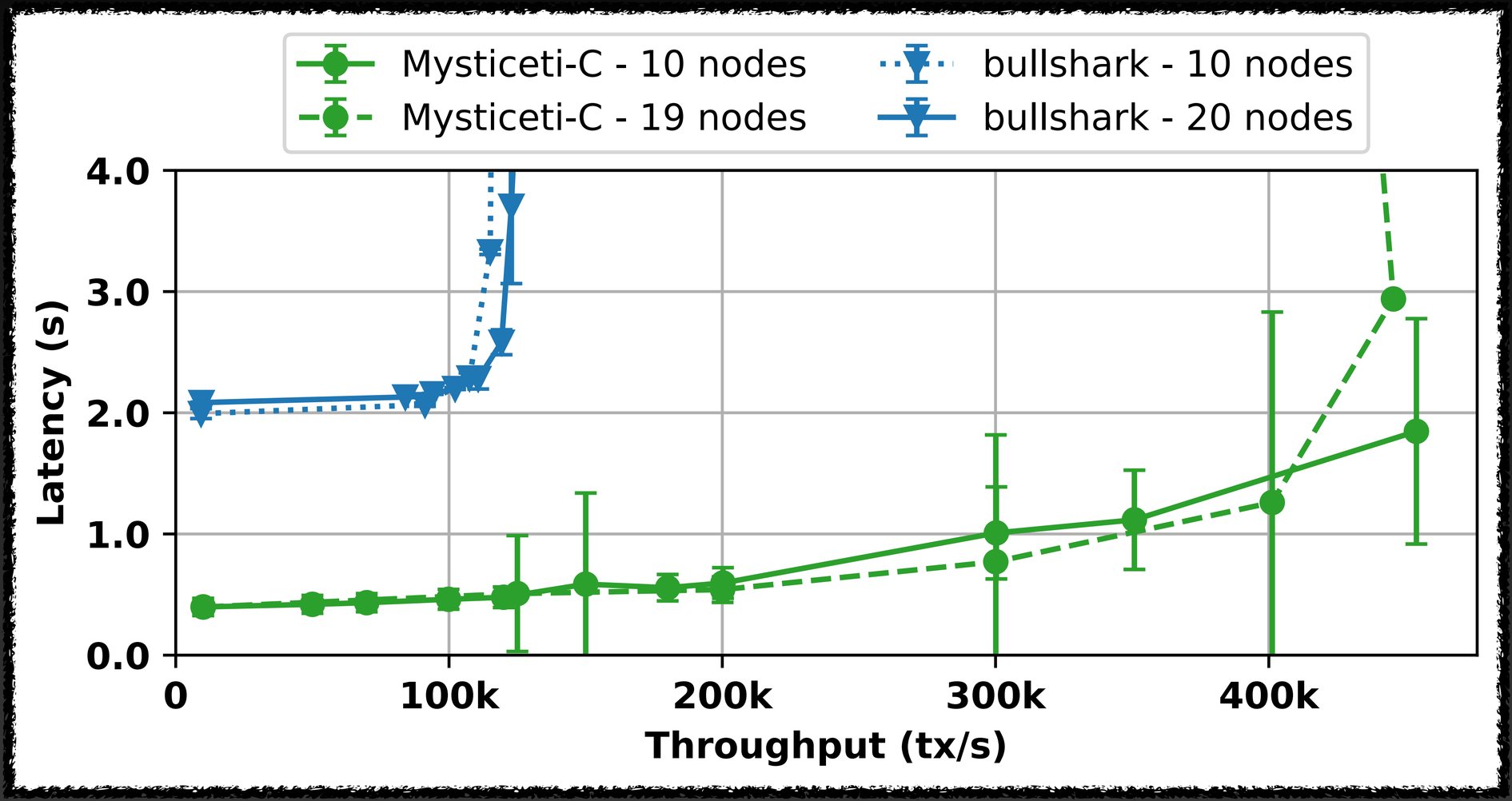
https://github.com/mystenlabs/mysticeti

Evaluation

Experimental setup on AWS



Preliminary Results



Engineering Benchmarks

Protocol	Committee	P50	P95
Bullshark	137	2.89 s	4.60 s
Mysticeti	137	650 ms	975 ms

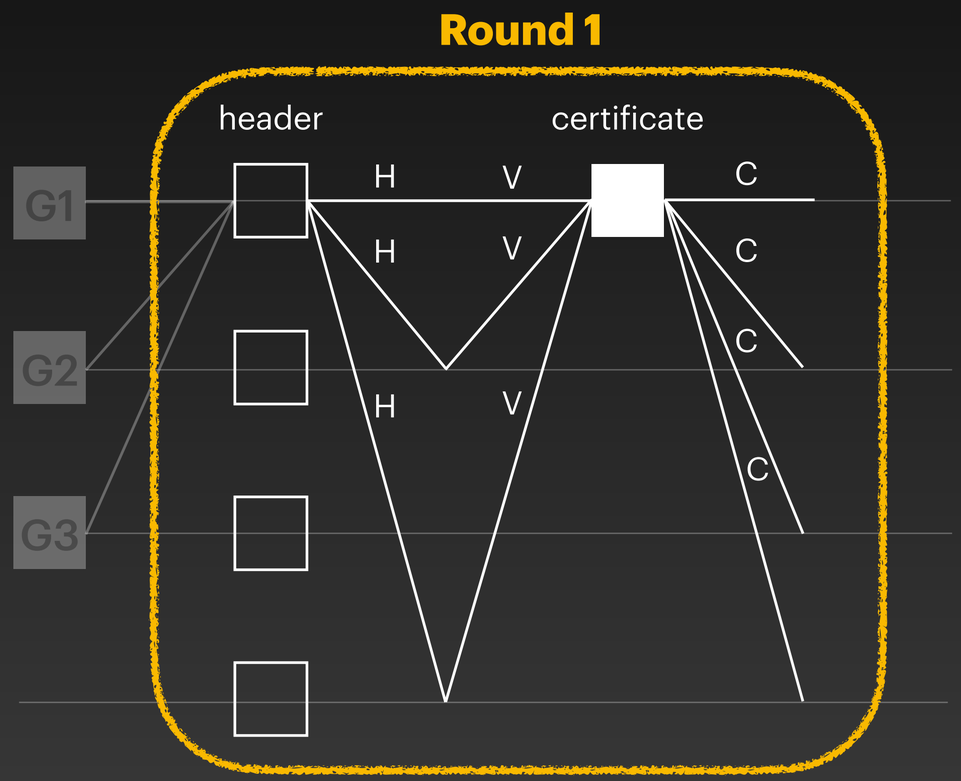
We run it at max load for 24h 👍

EXTRA

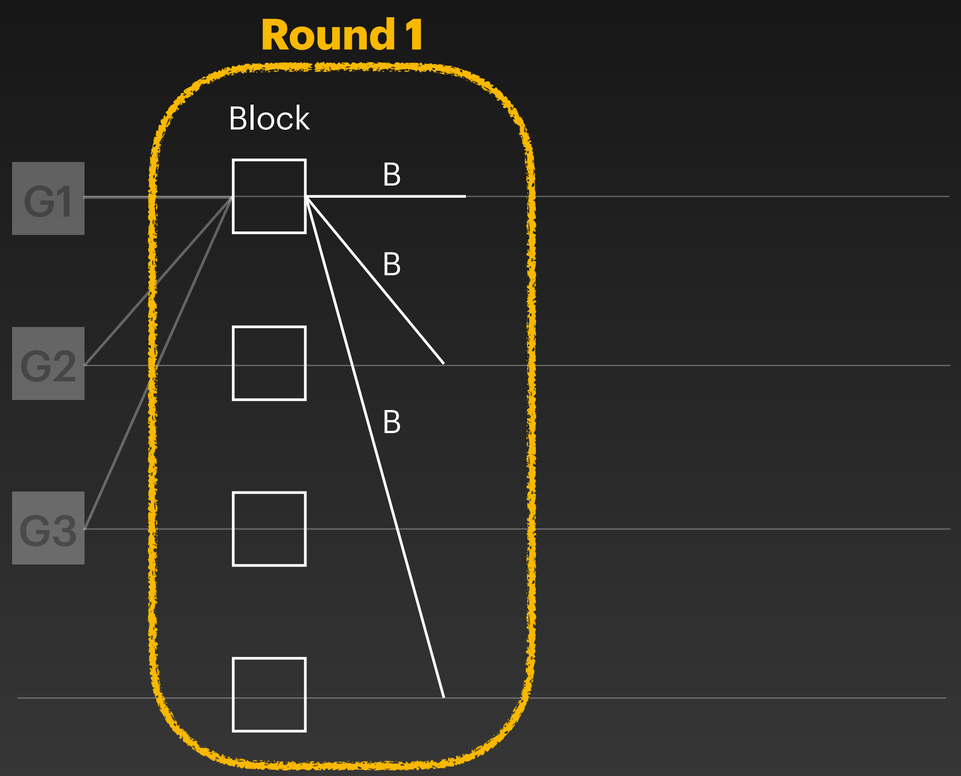
Narwhal vs Mysticeti

Narwhal vs Mysticeti

Narwhal

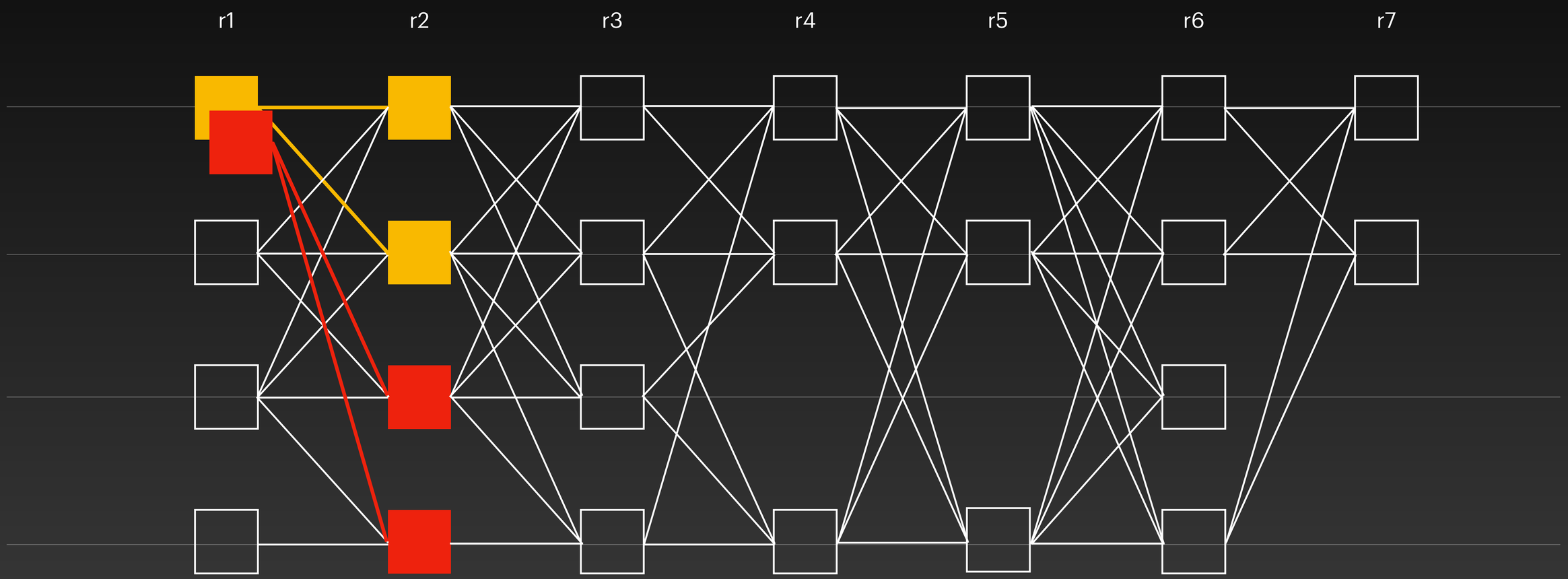


Mysticeti



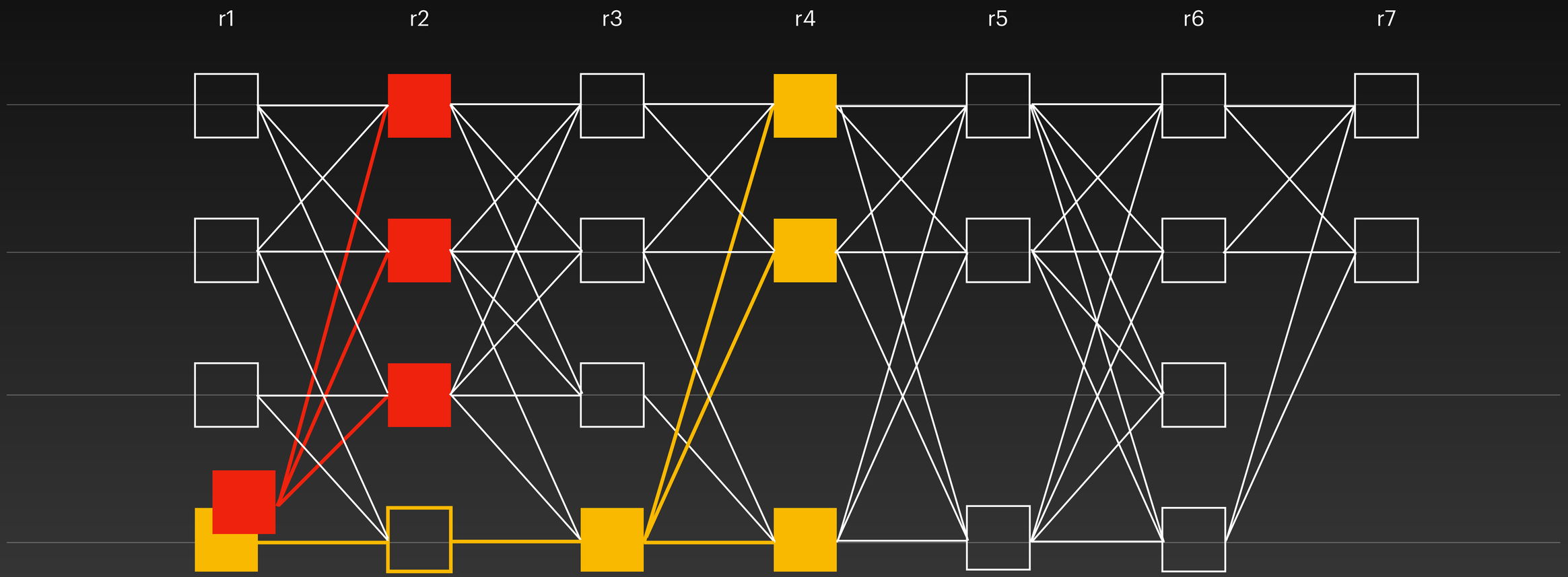
Main Challenge

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)

EXTRA

Linear vs DAG

Quorum-Based Consensus

Linear-Chain

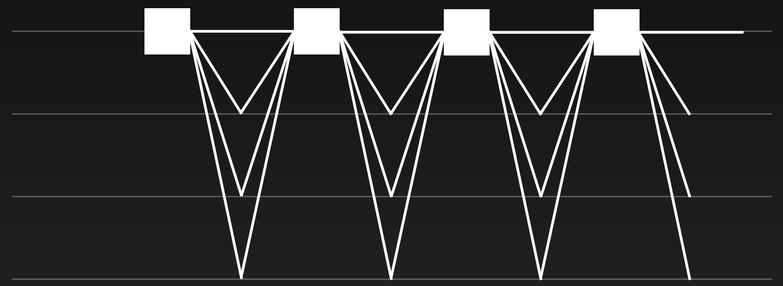
- Low latency
- Fragile to faults
- Complex leader-change

DAG-Based

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

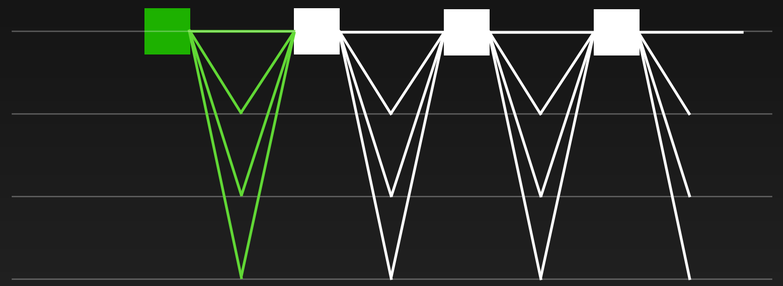
Linear-Chain Consensus

Rough overview



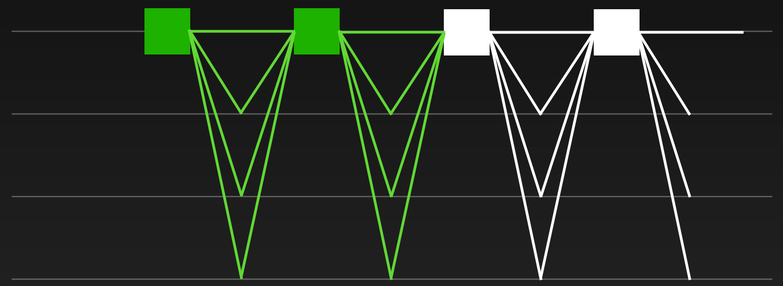
Linear-Chain Consensus

Rough overview



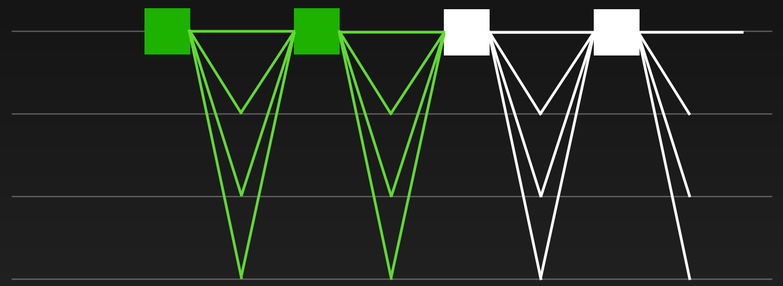
Linear-Chain Consensus

Rough overview



Linear-Chain Consensus

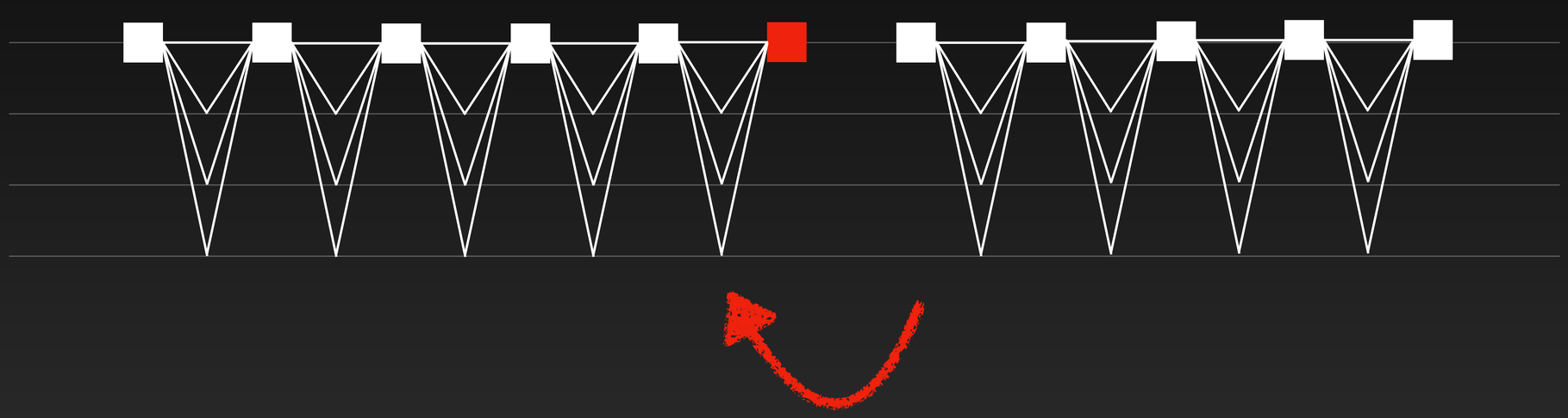
Rough overview



- The leader does all the work

Linear-Chain Consensus

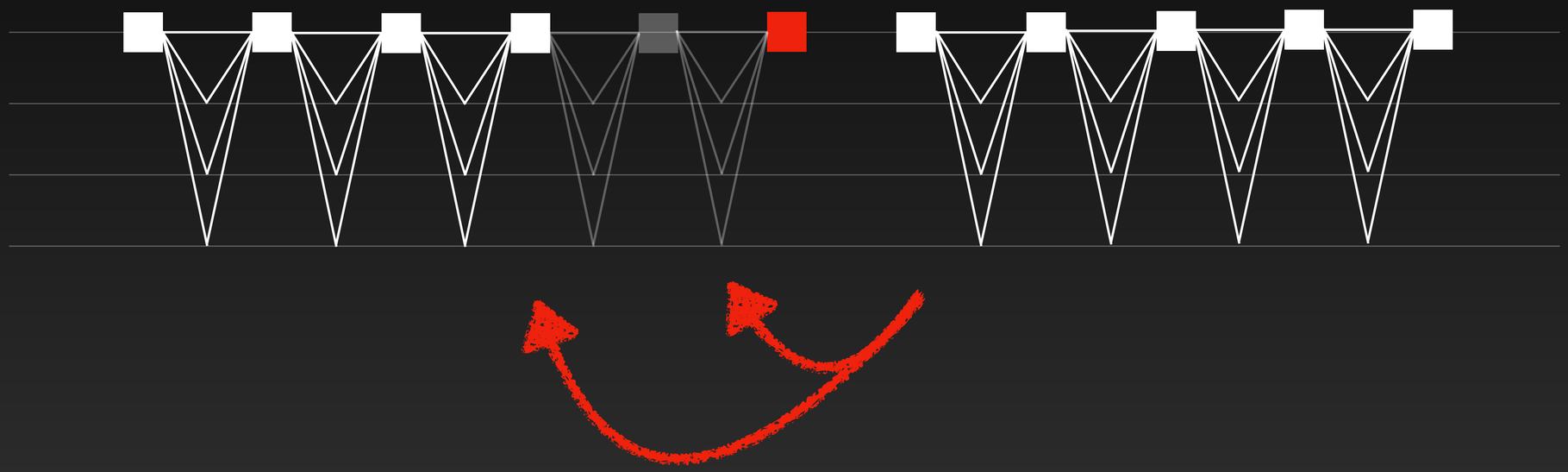
Rough overview



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

Linear-Chain Consensus

Rough overview



- The leader does all the work
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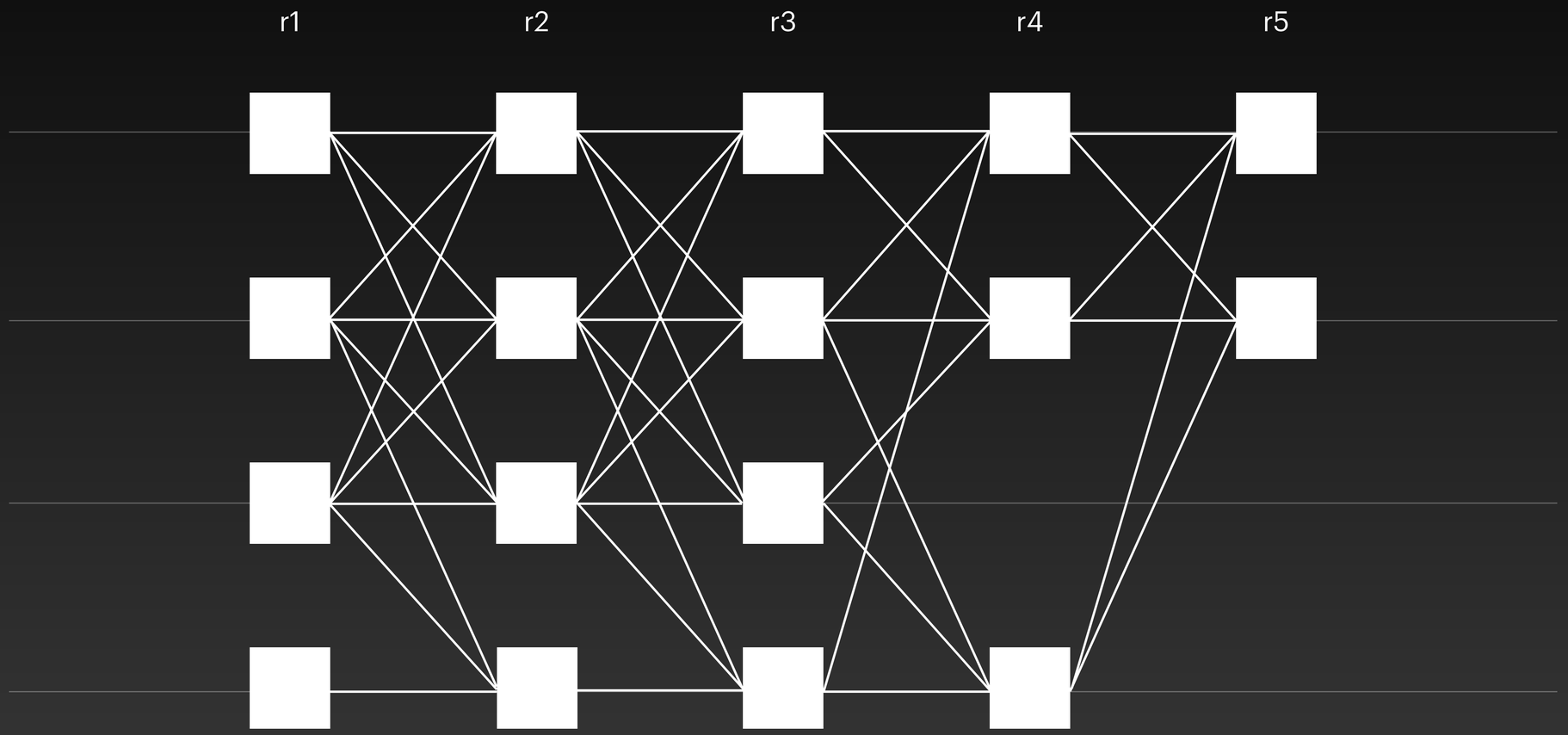
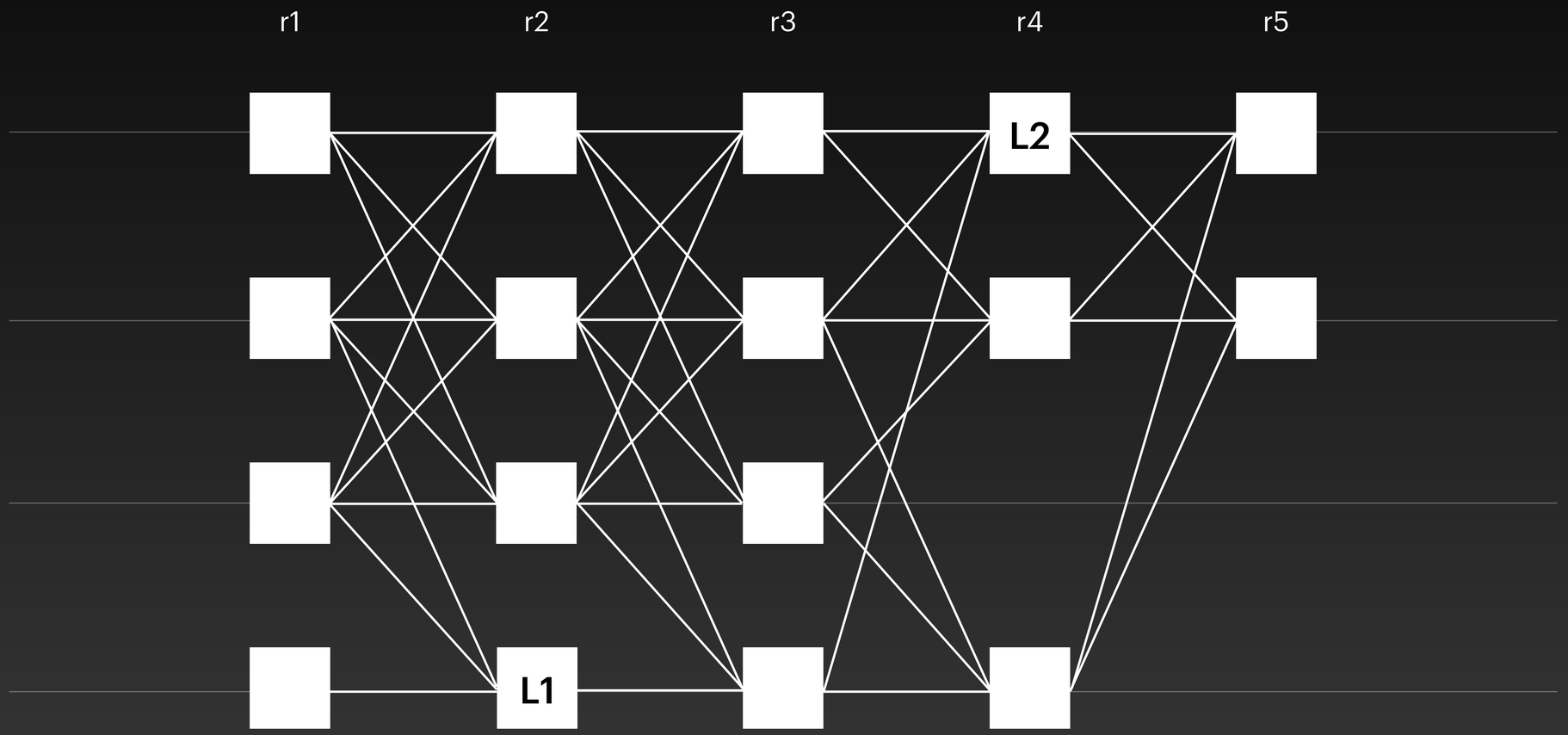
DAG-Based Consensus

Rough overview



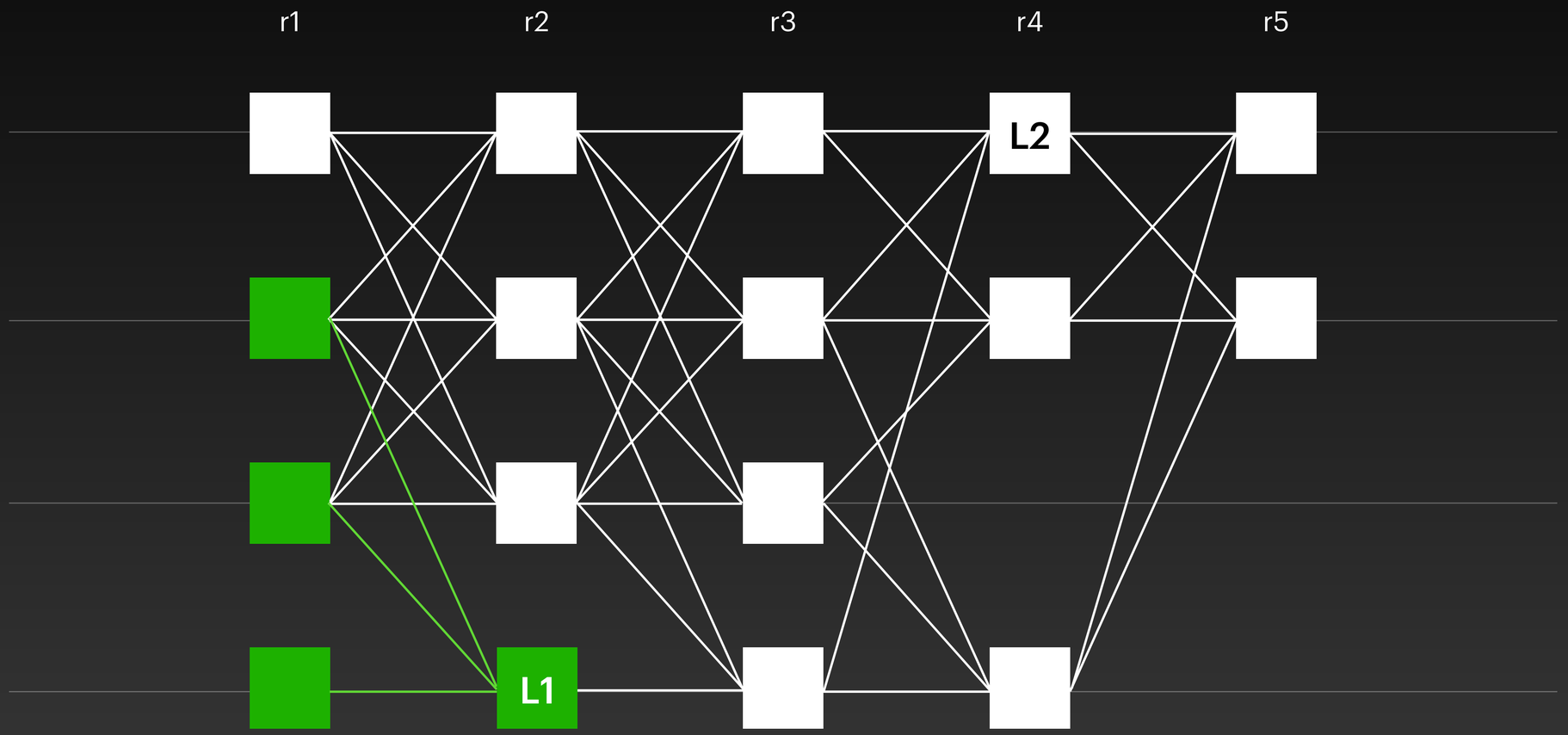
DAG-Based Consensus

Rough overview



DAG-Based Consensus

Rough overview



DAG-Based Consensus

Rough overview