Mysticeti

The new core of the Sui blockchain

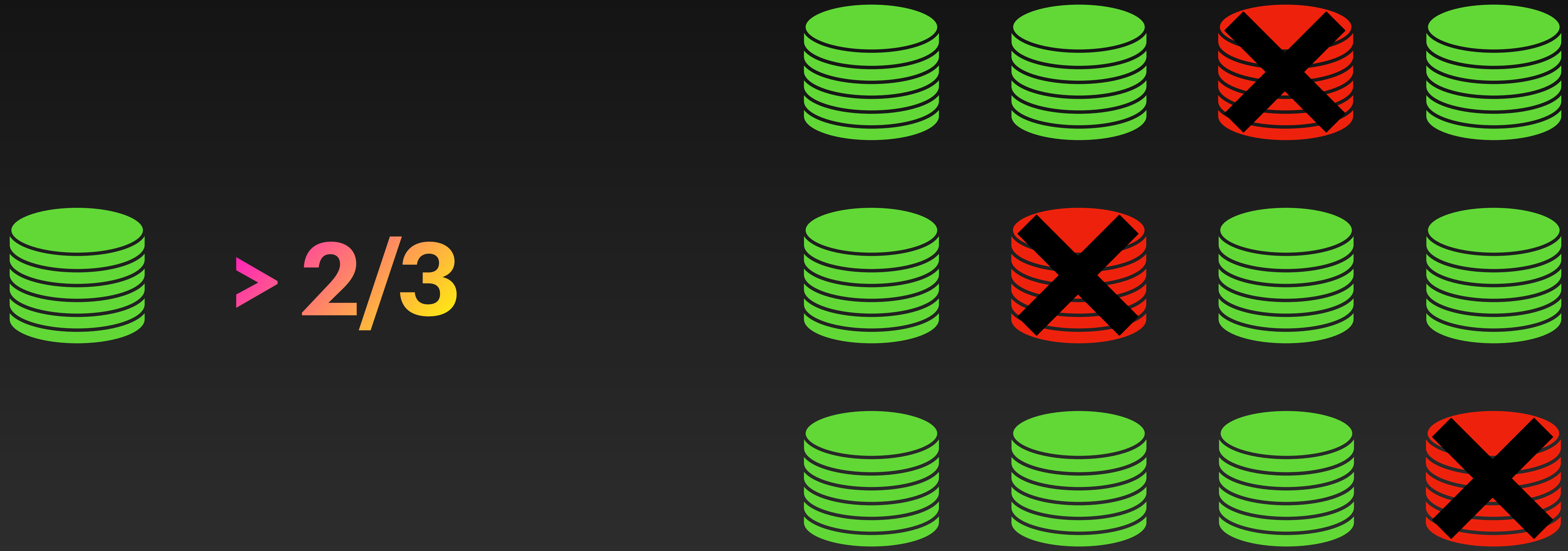
Alberto Sonnino

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)?

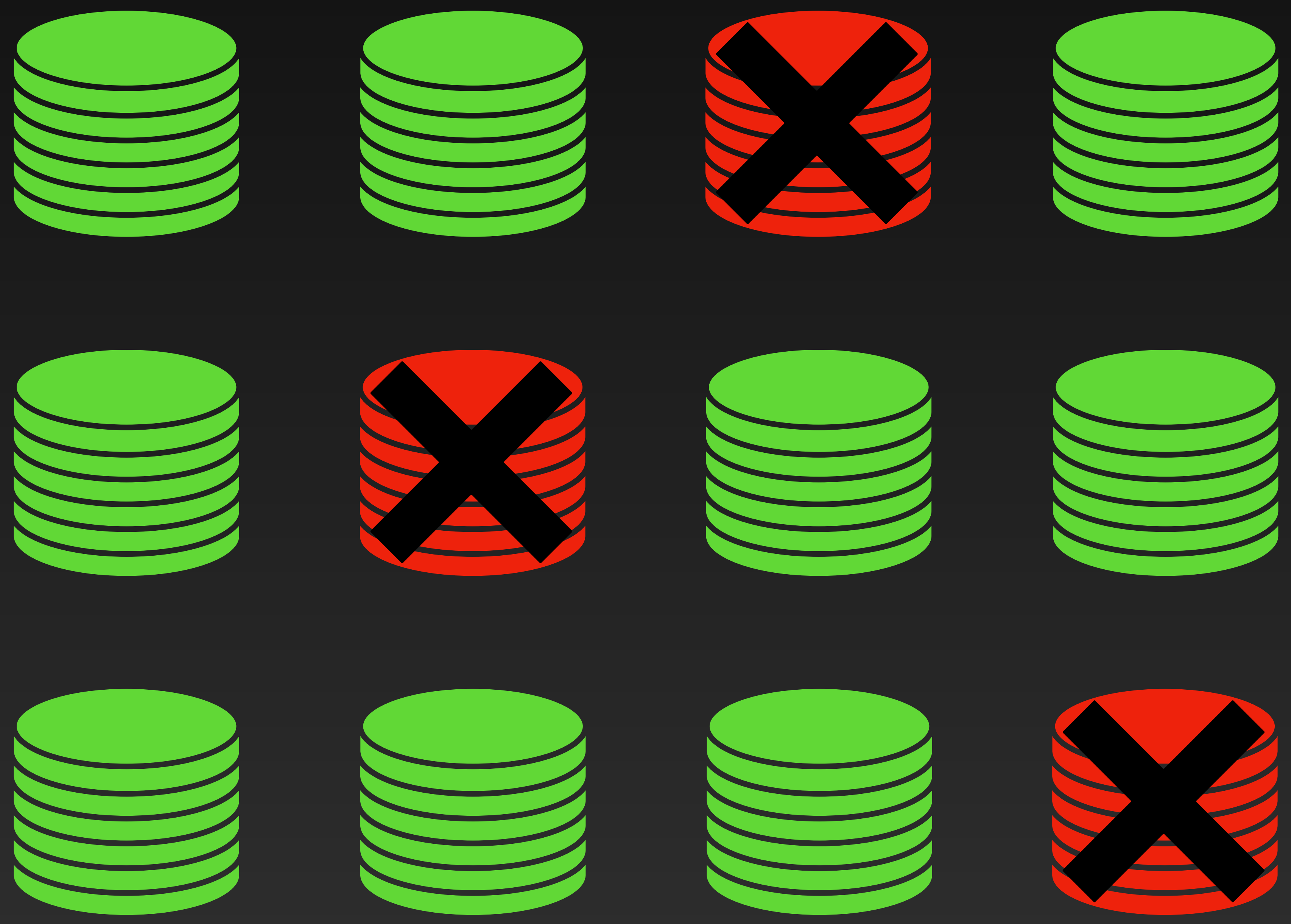
Byzantine Fault Tolerance



> 2/3

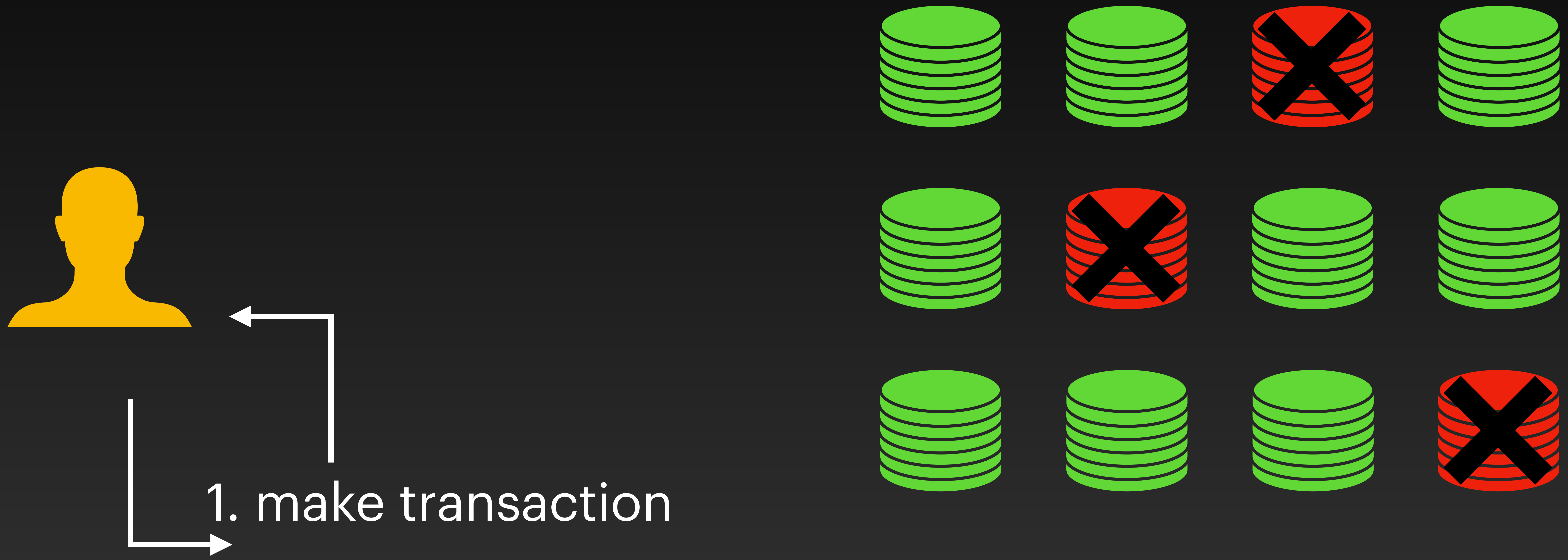
Byzantine Fault Tolerance

>= 2f+1



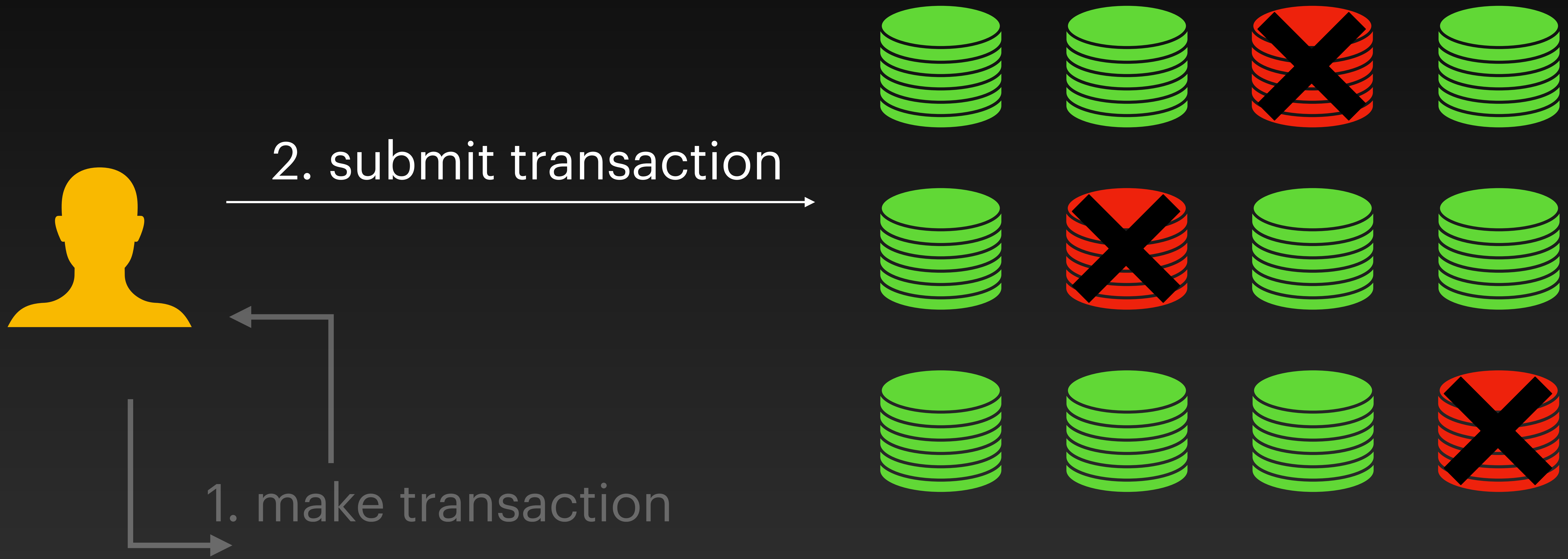
3f+1

Blockchains



1. make transaction

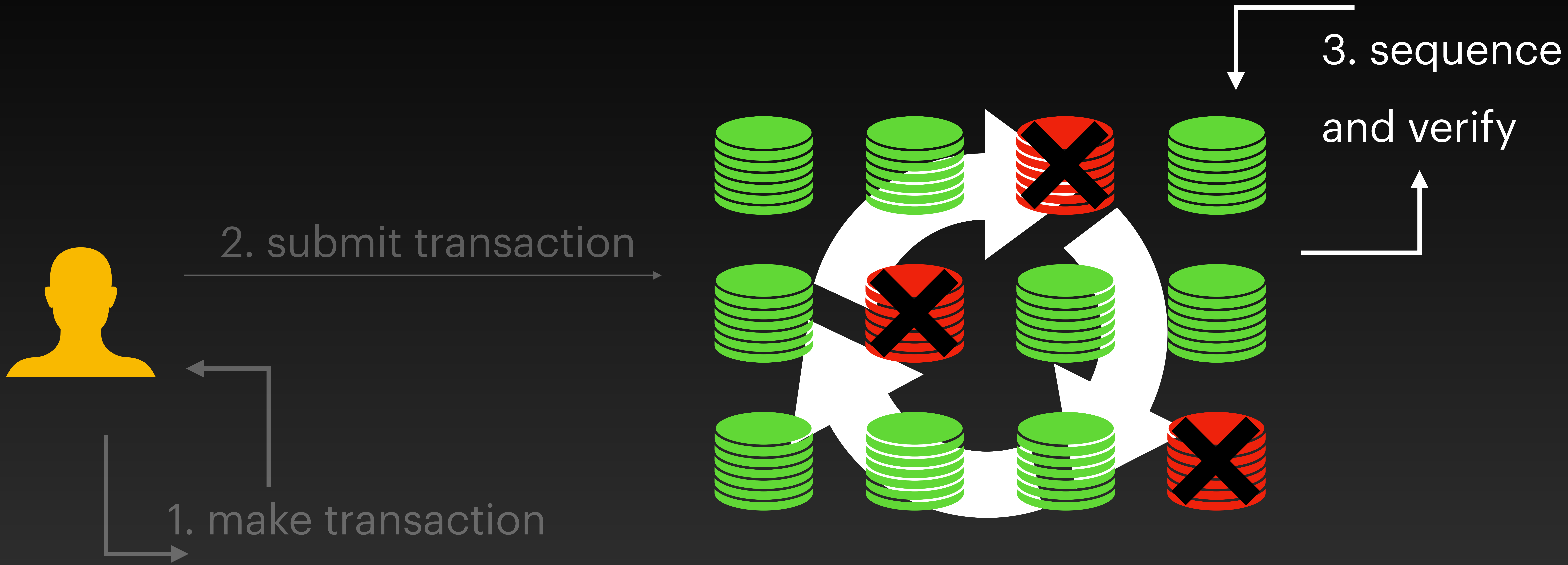
Blockchains



2. submit transaction

1. make transaction

Blockchains

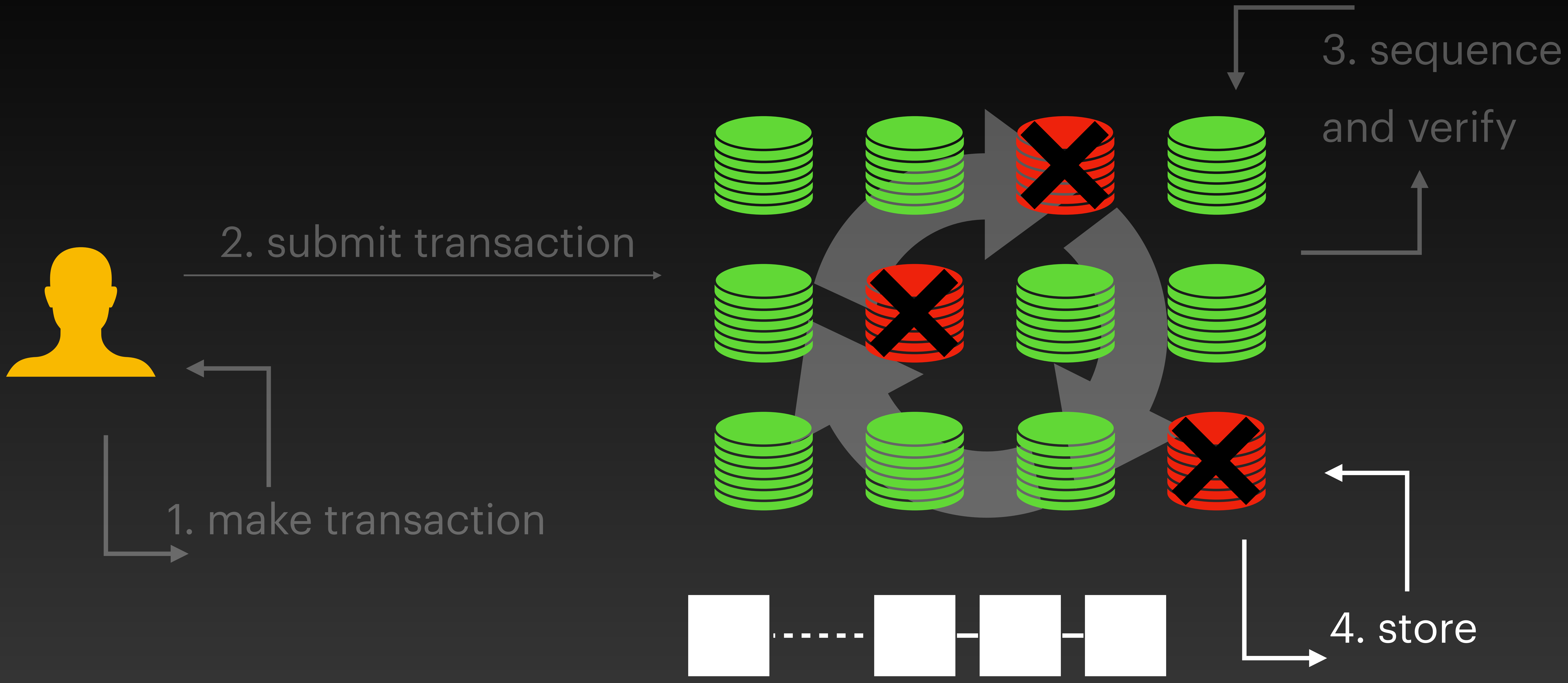


3. sequence and verify

2. submit transaction

1. make transaction

Blockchains



1. make transaction

2. submit transaction

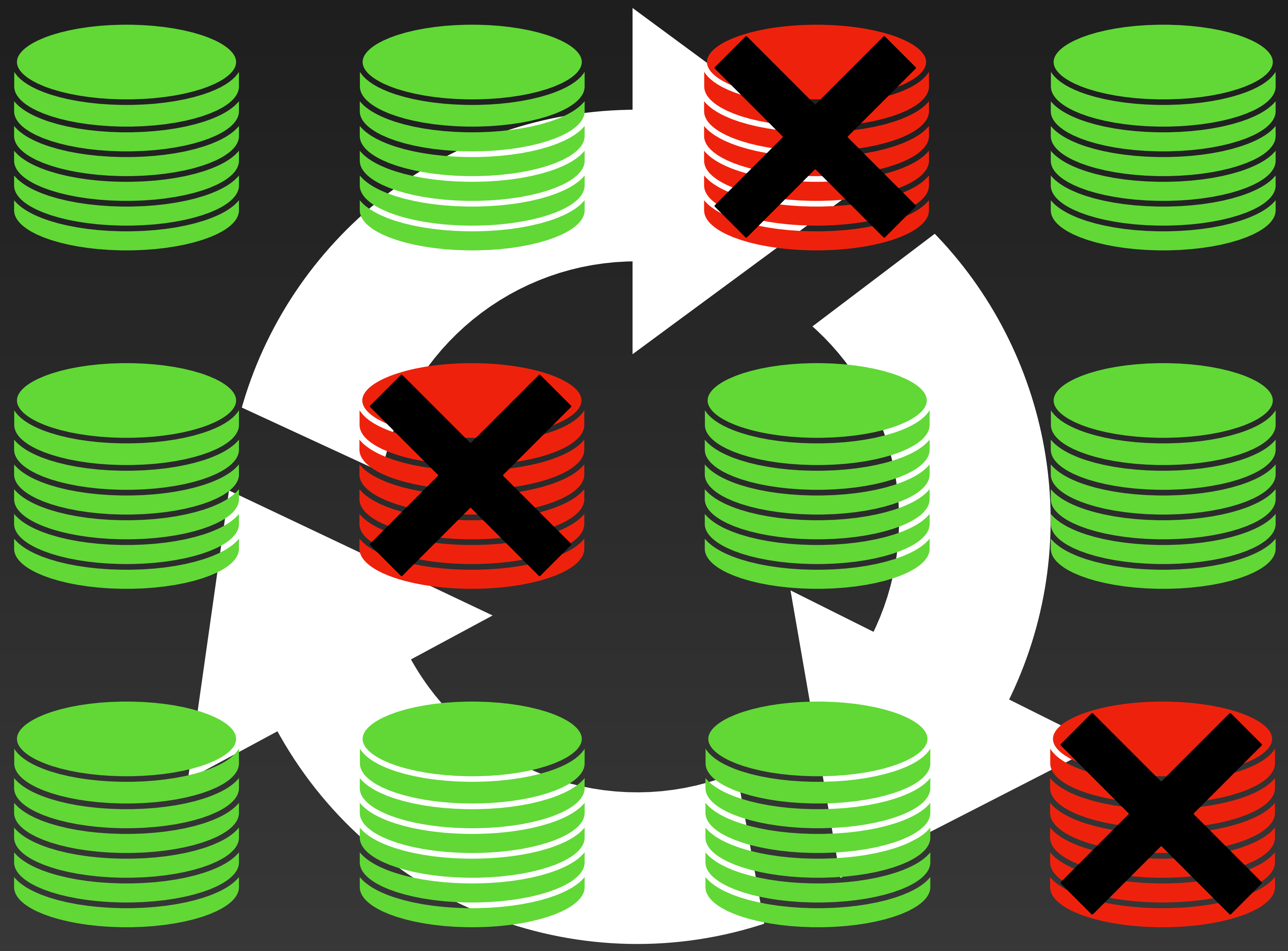
3. sequence and verify

4. store

Keeping the Talk Short

In scope

- Ordering (quorum-based)



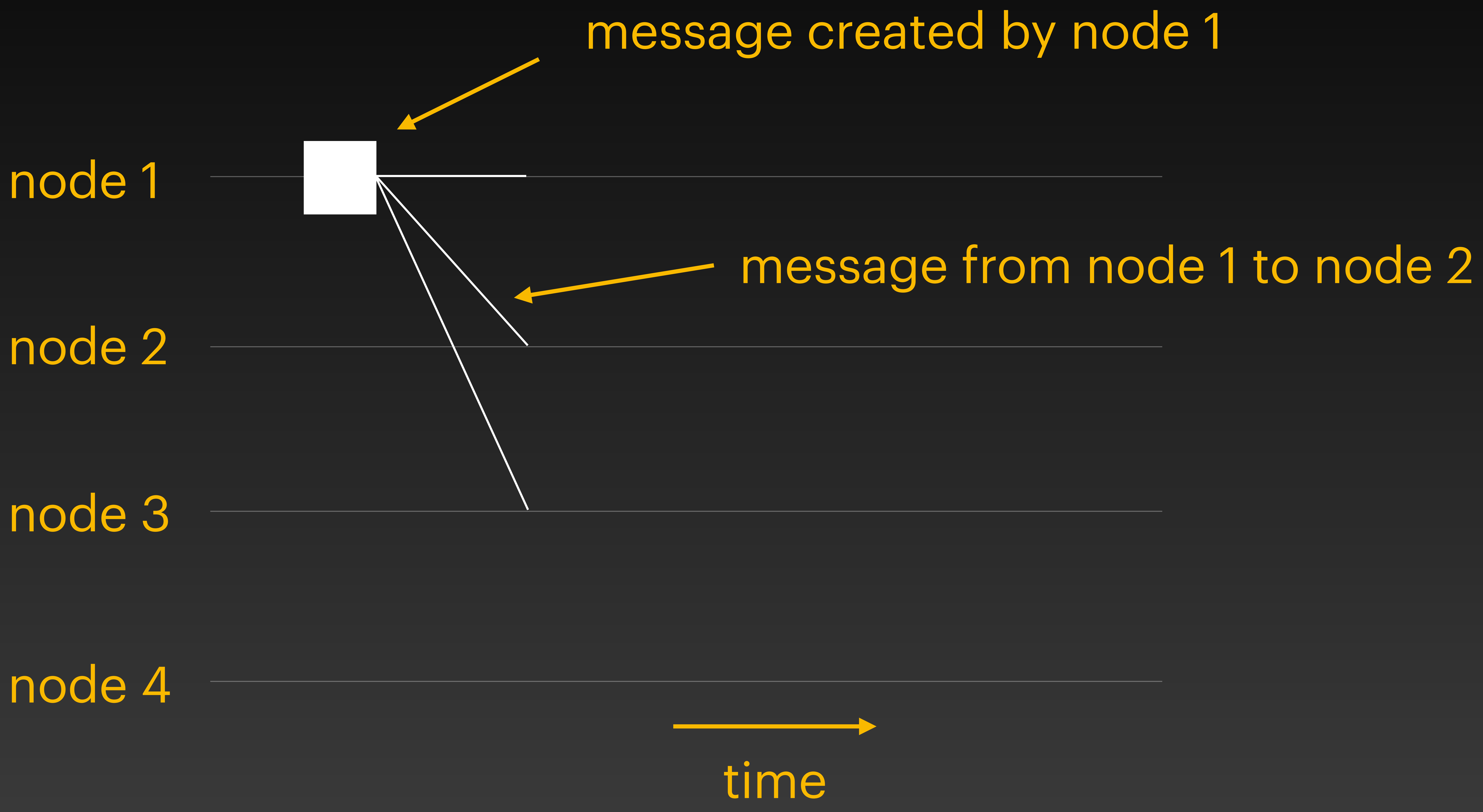
Not in scope

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

Mysticeti

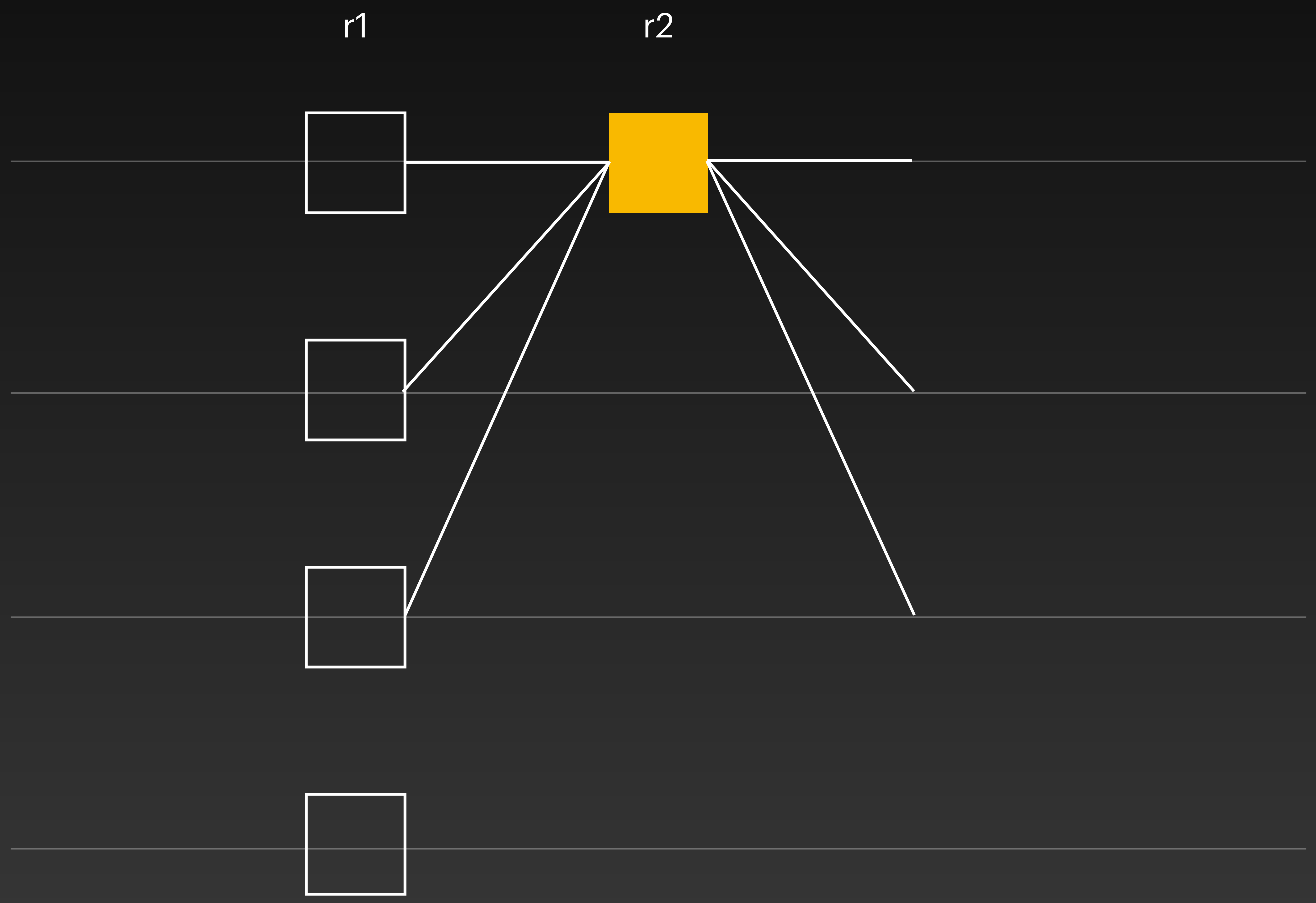
Low-latency DAG consensus with fast commit path

Lamport Diagram



The Mysticeti DAG

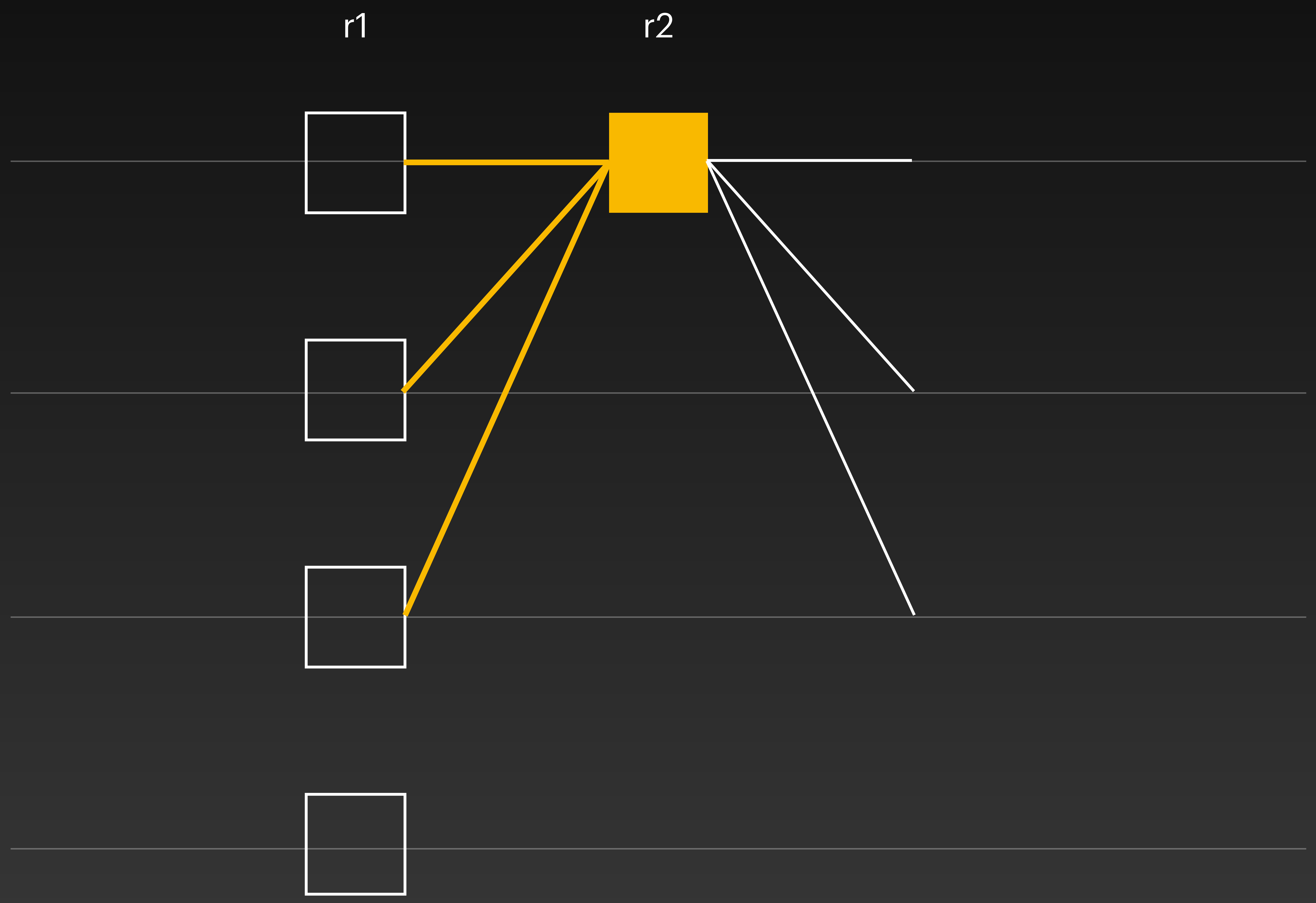
Block Creation



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

The Mysticeti DAG

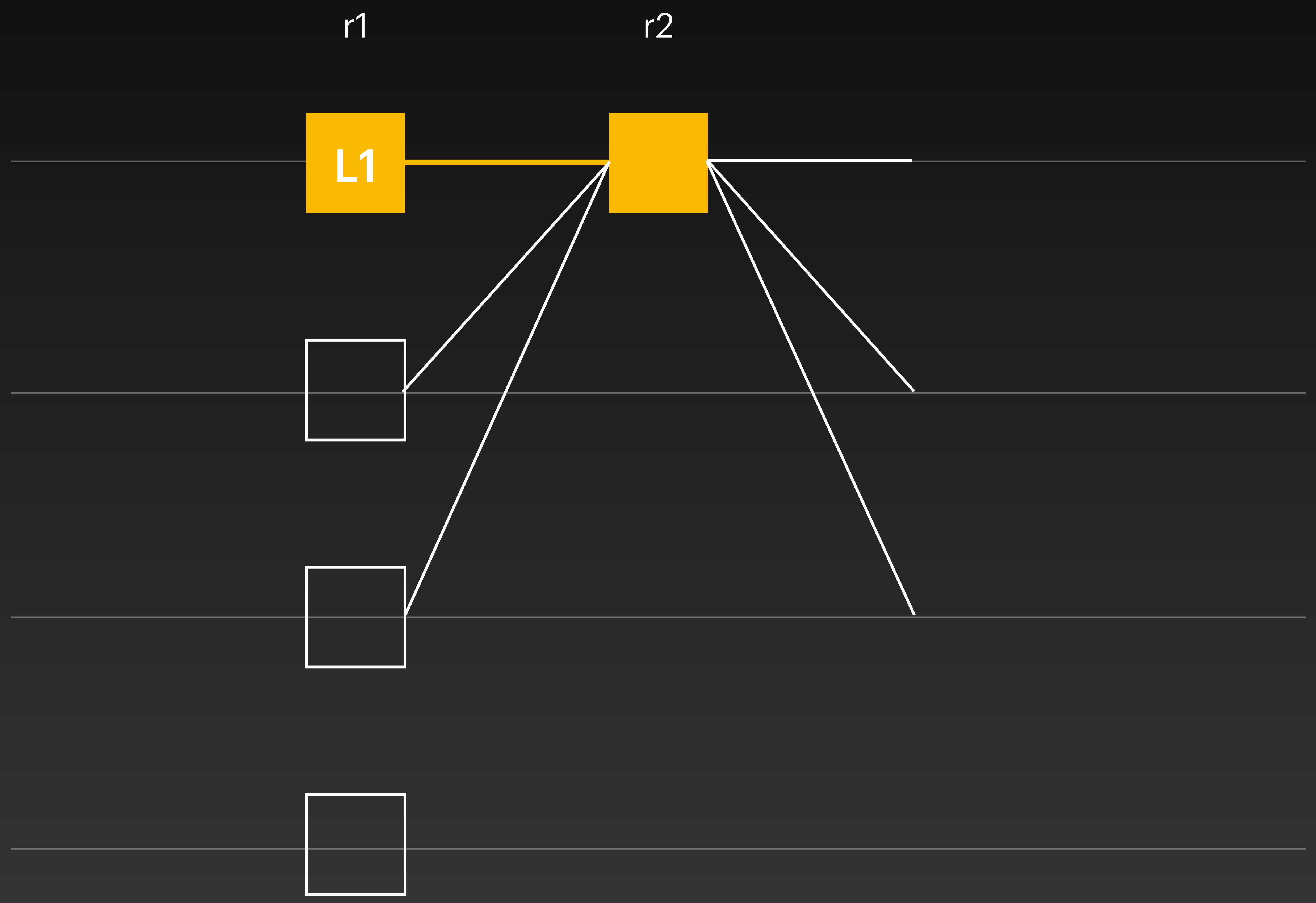
Rule 1: Link to 2f+1 parents



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

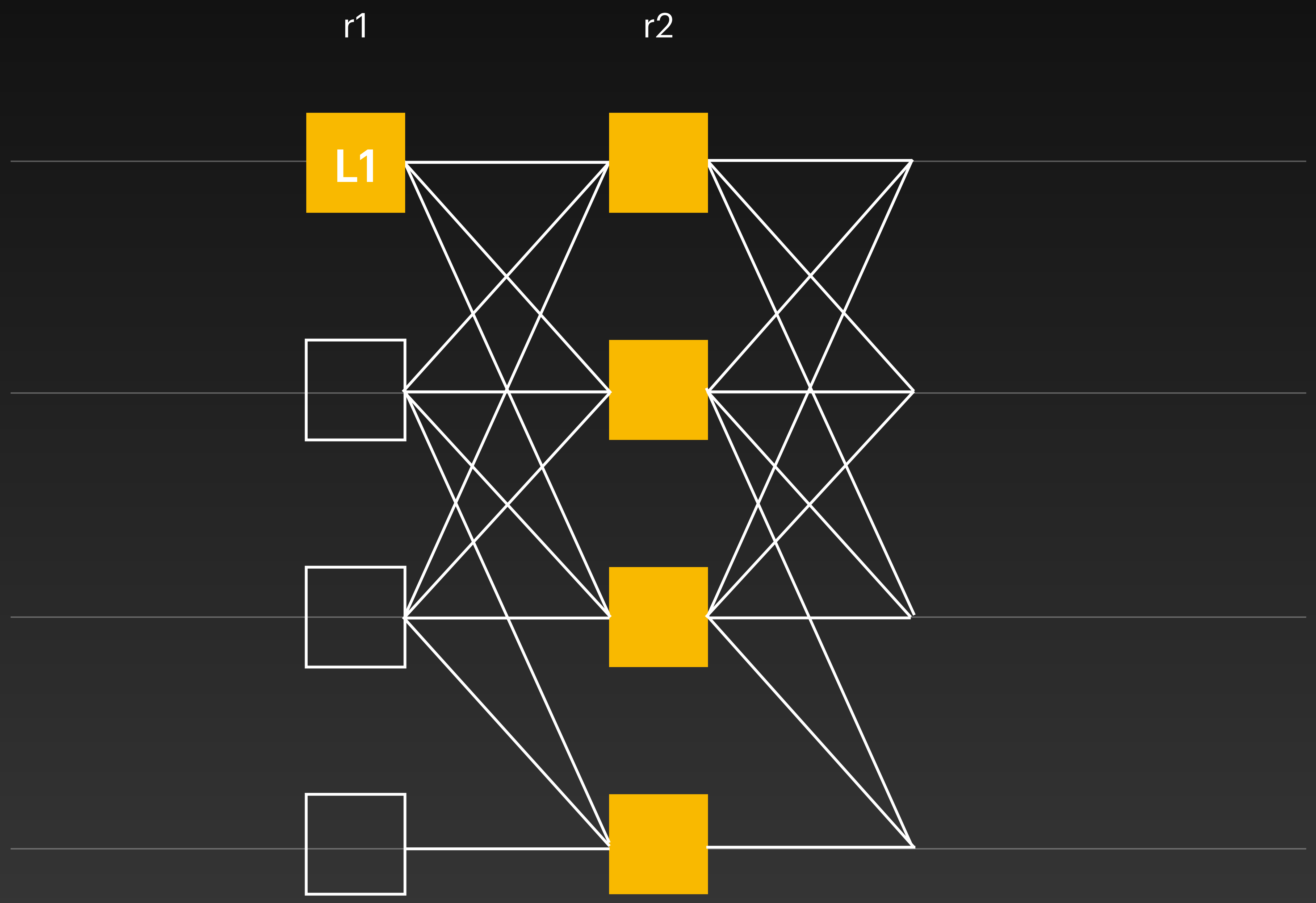
The Mysticeti DAG

Rule 2: Every node waits and links to leaders

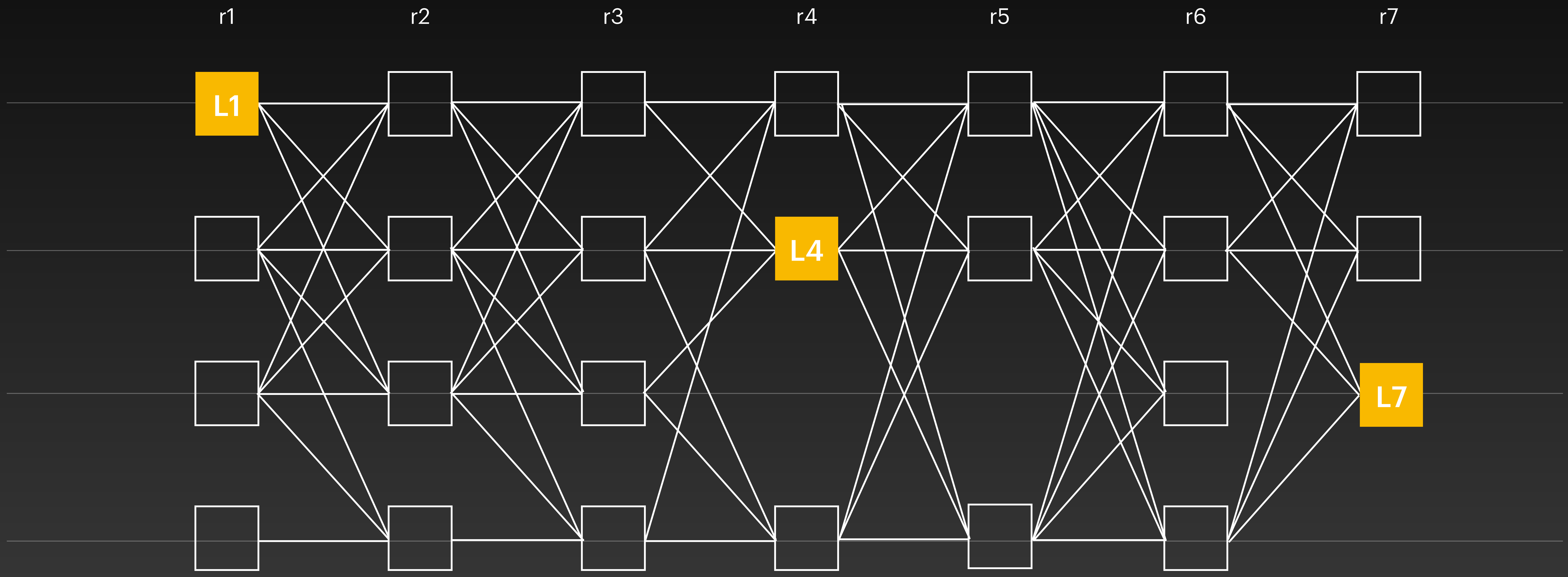


The Mysticeti DAG

Rule 3: All node run in parallel



The Mysticeti DAG

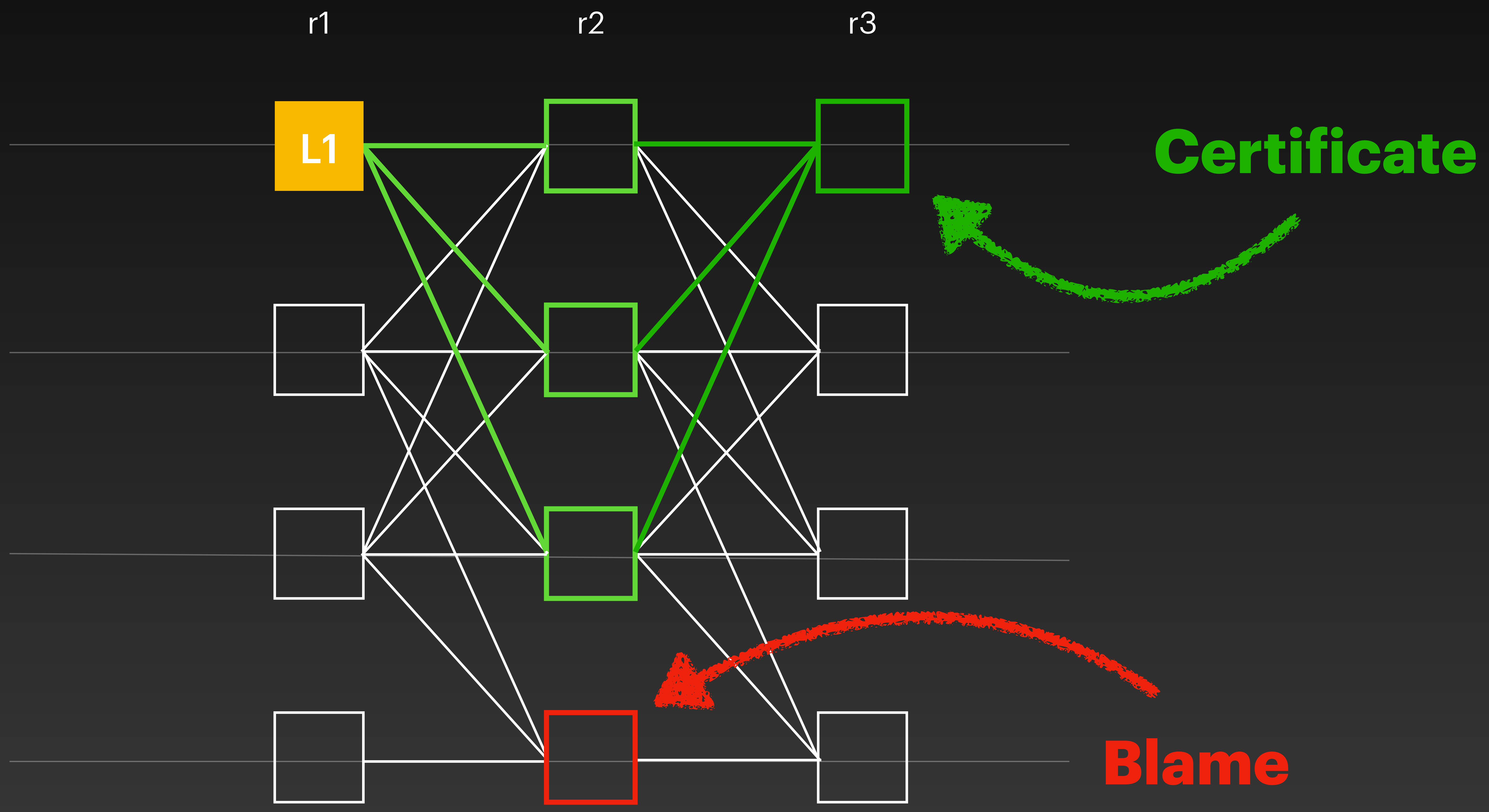


Main Ingredient:

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

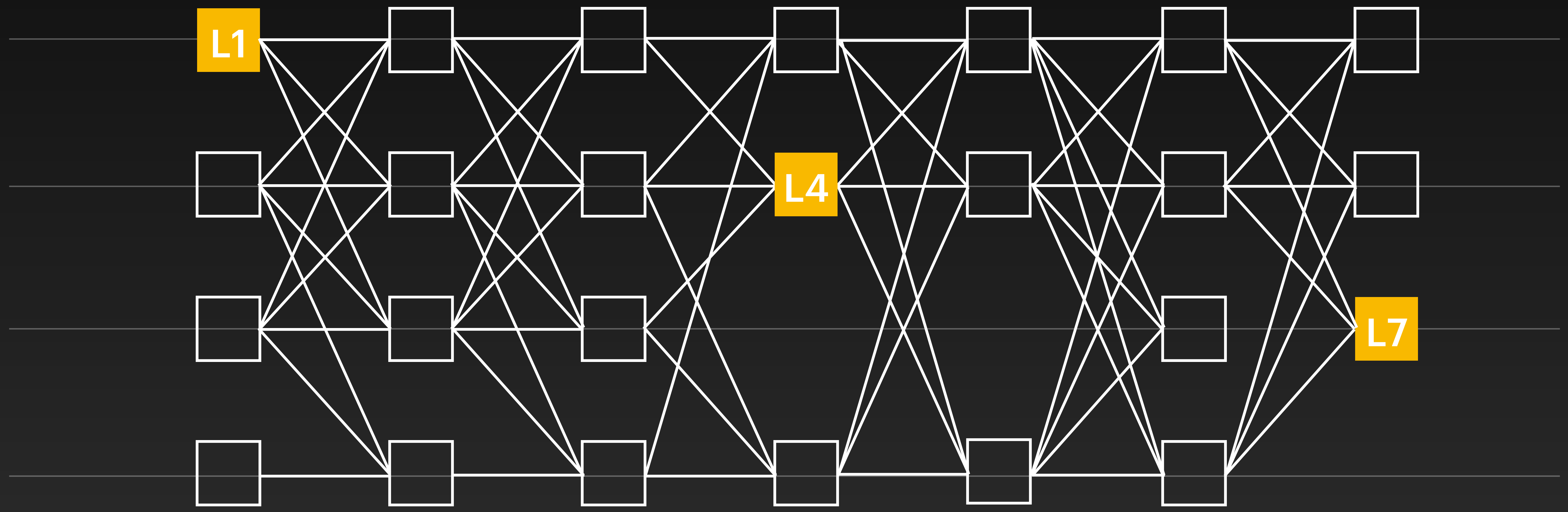
- Interpret BCB on DAG

Mysticeti-C

The consensus protocol

End Goal

Ordering leaders



- We focus on ordering leaders: L1 L4 L7

End Goal

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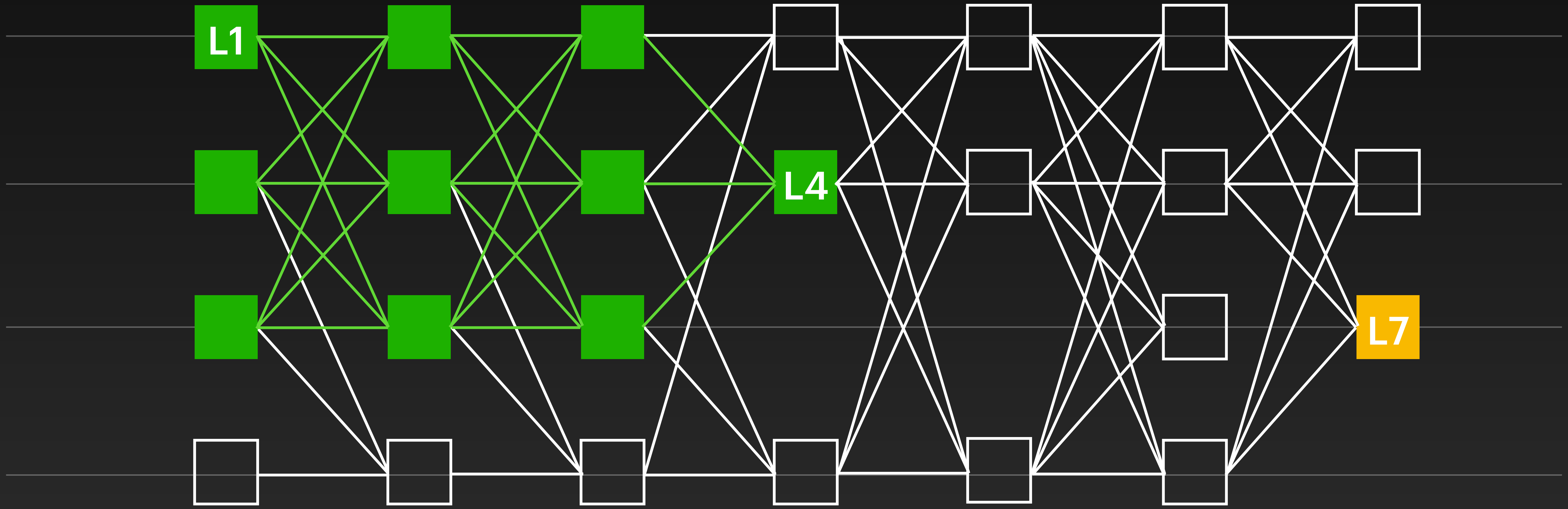
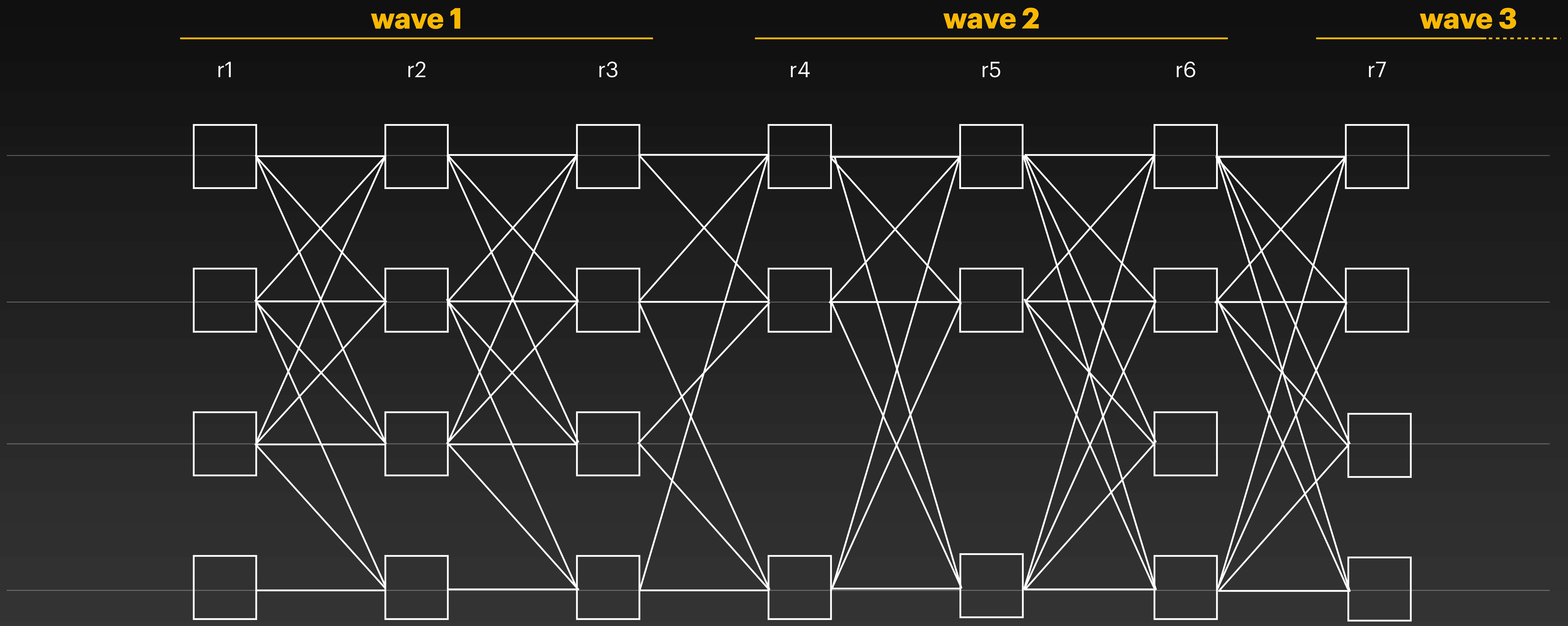


- We focus on ordering leaders: L1 L4 L7
- Linearising the sub-DAG is simple

DAG Structure



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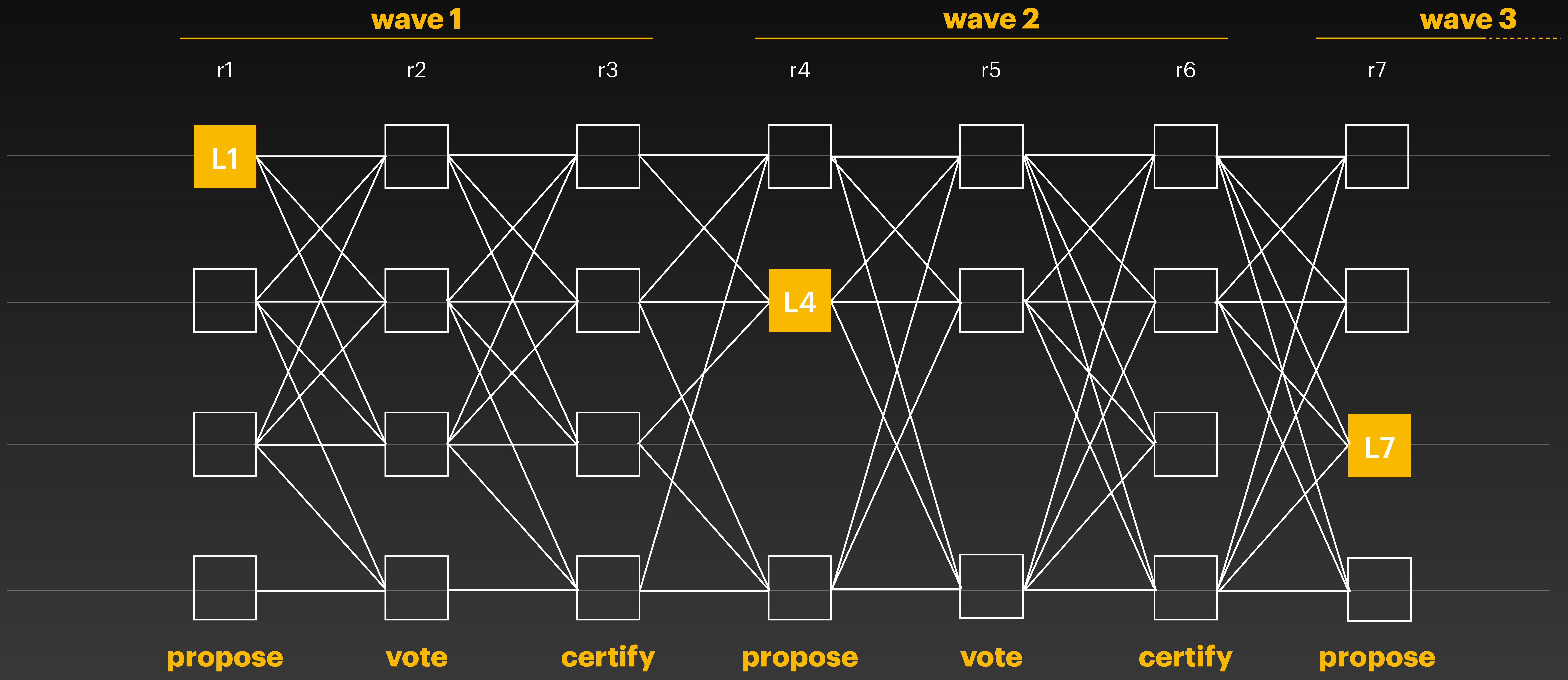

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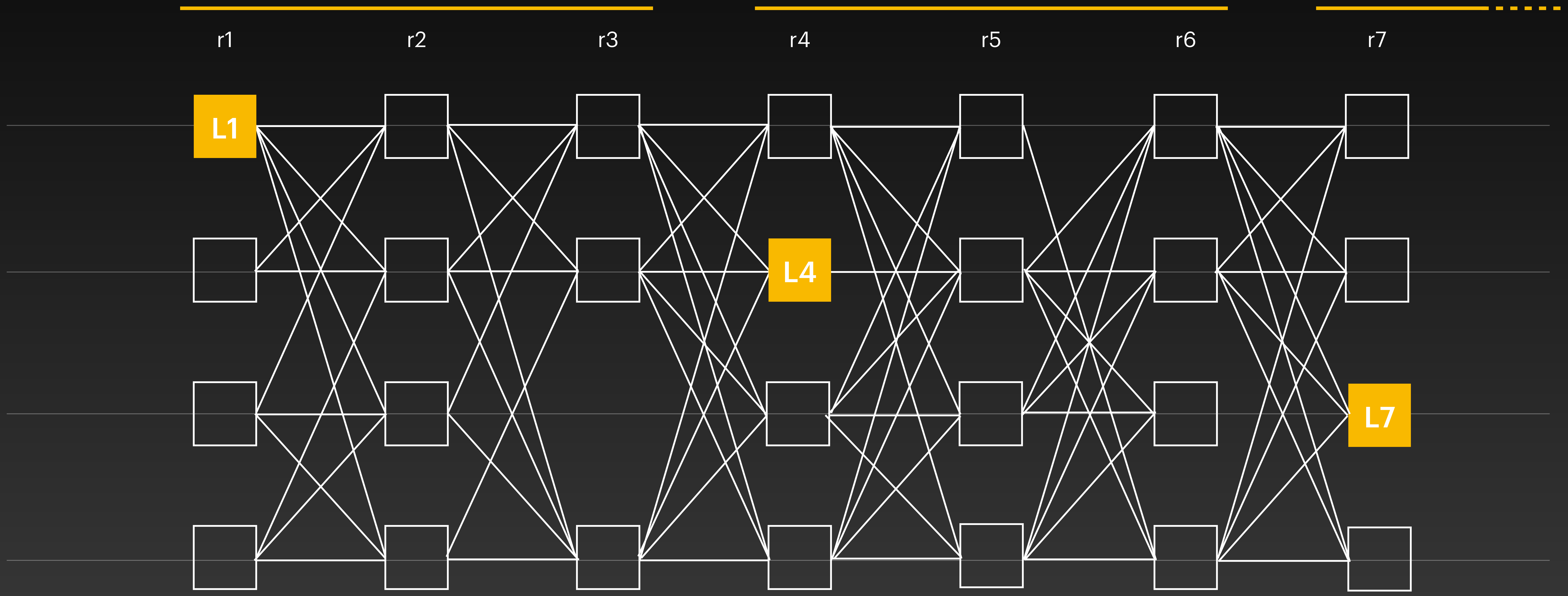

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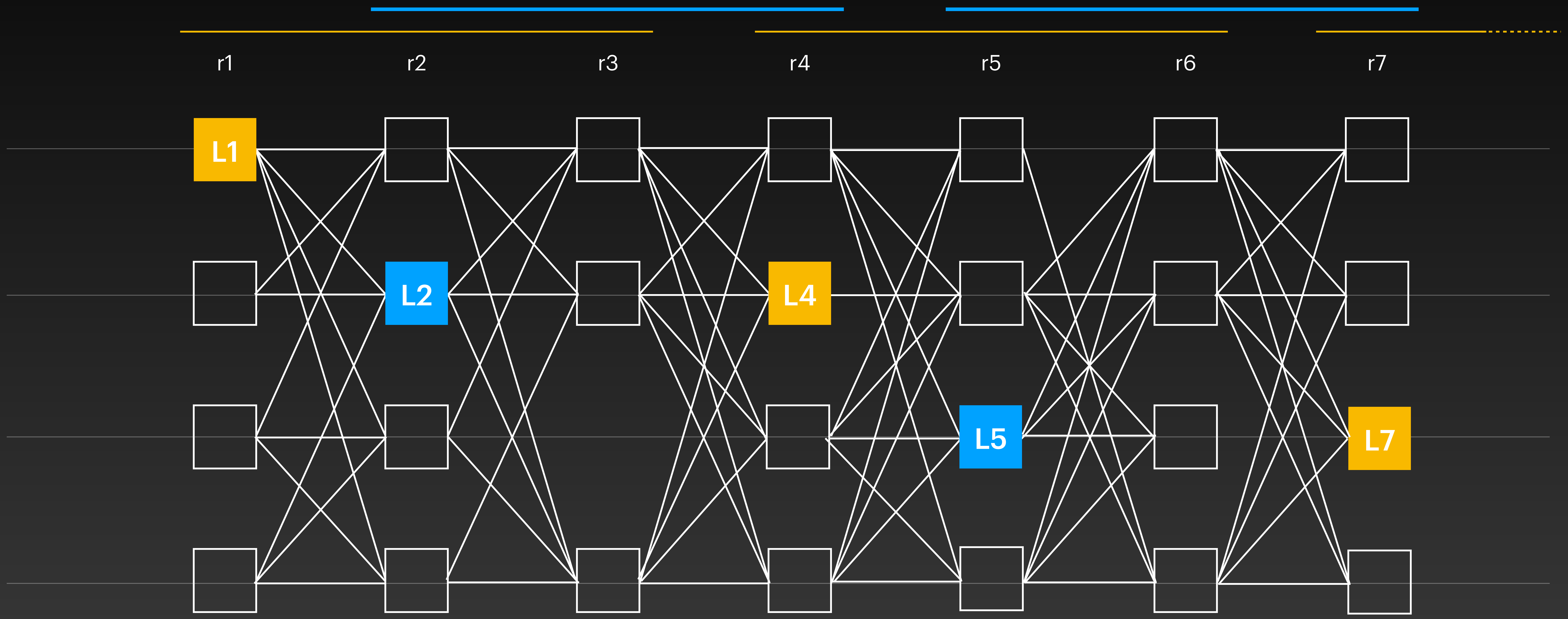

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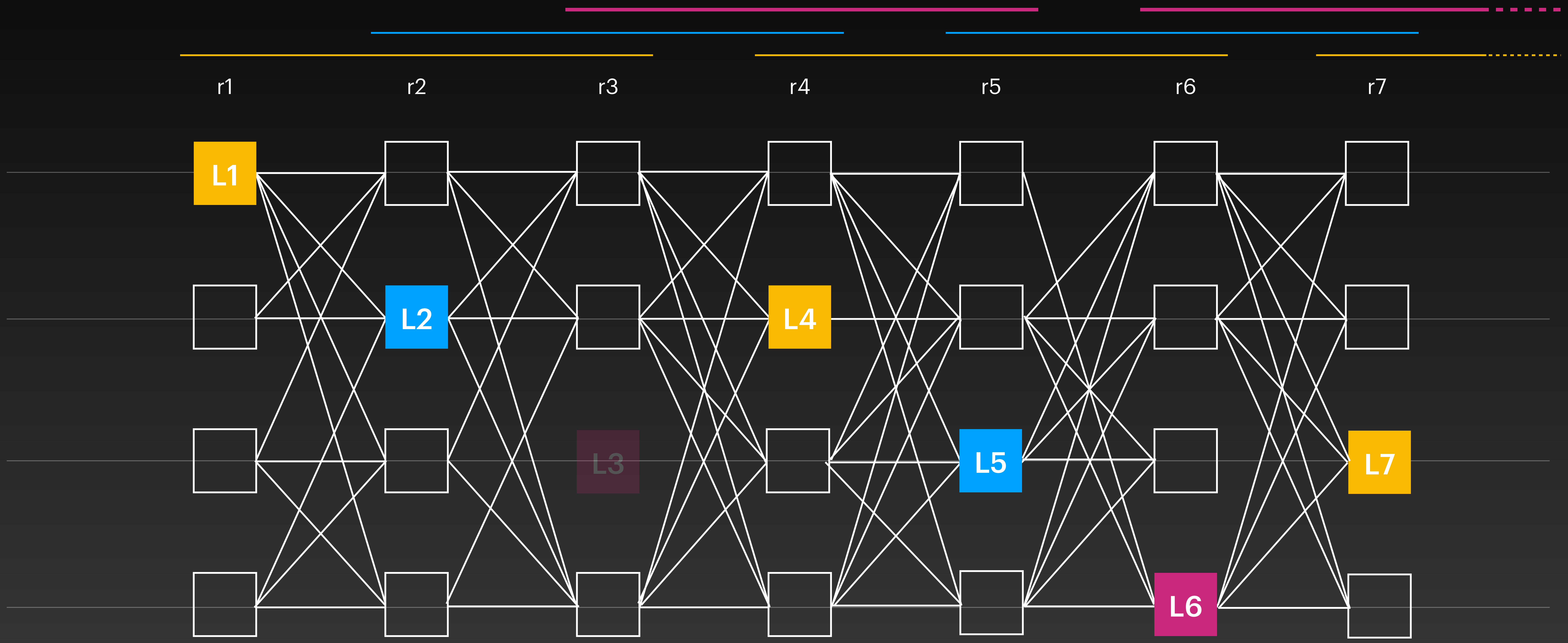

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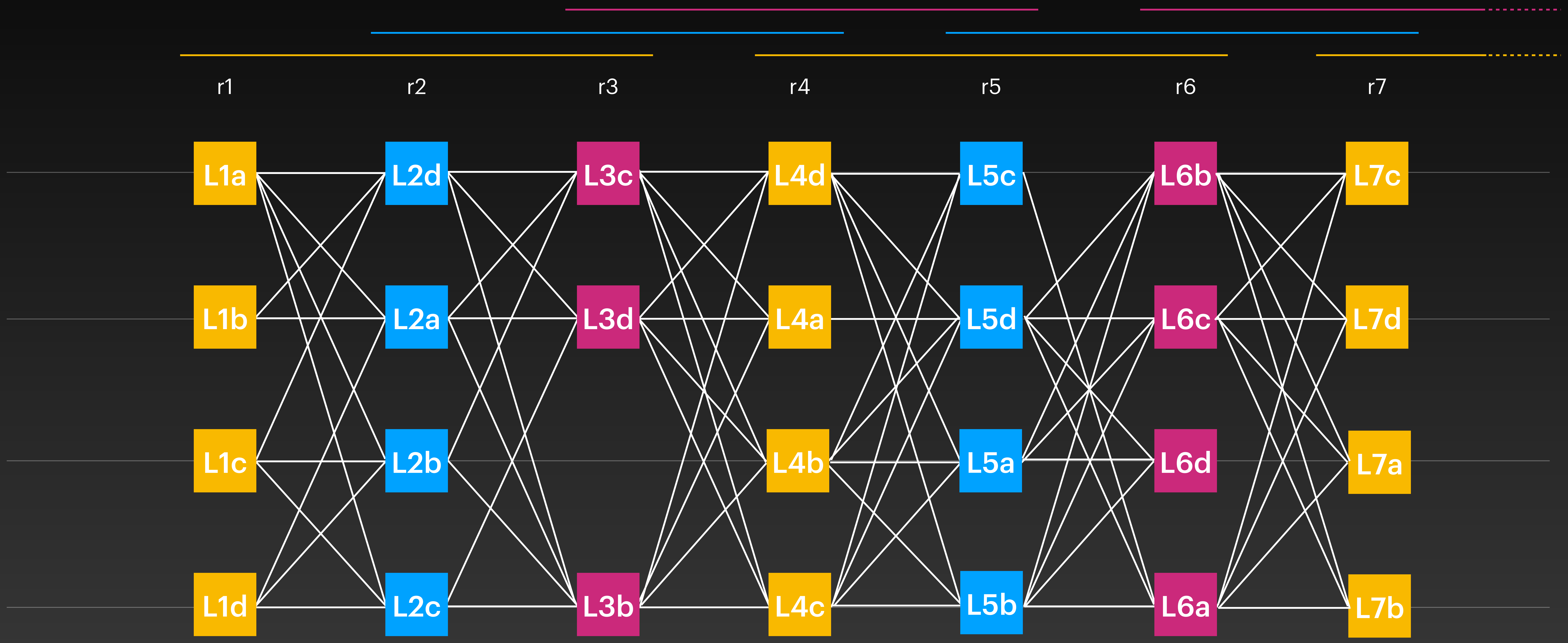
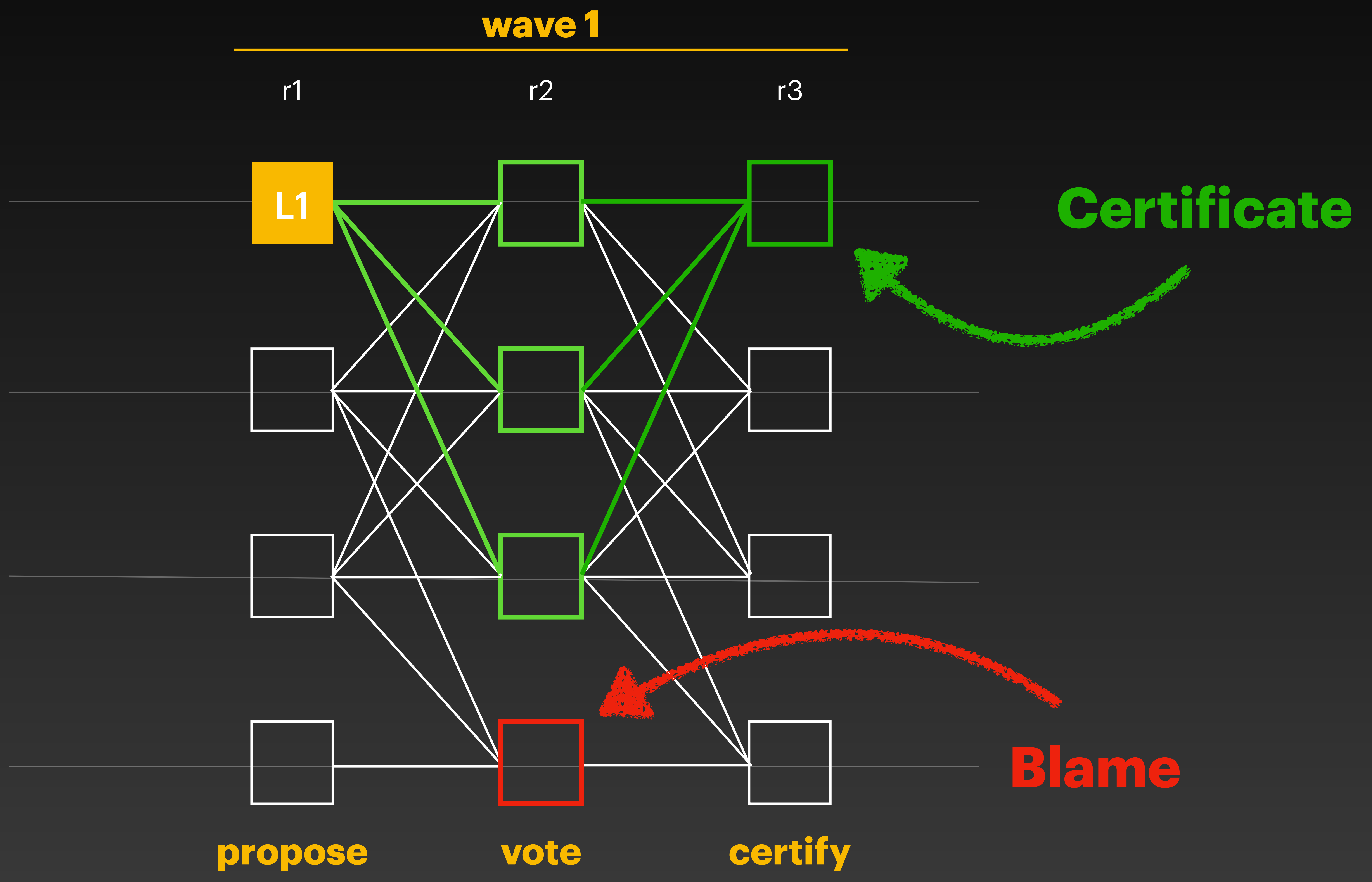


Interpreting DAG Patterns

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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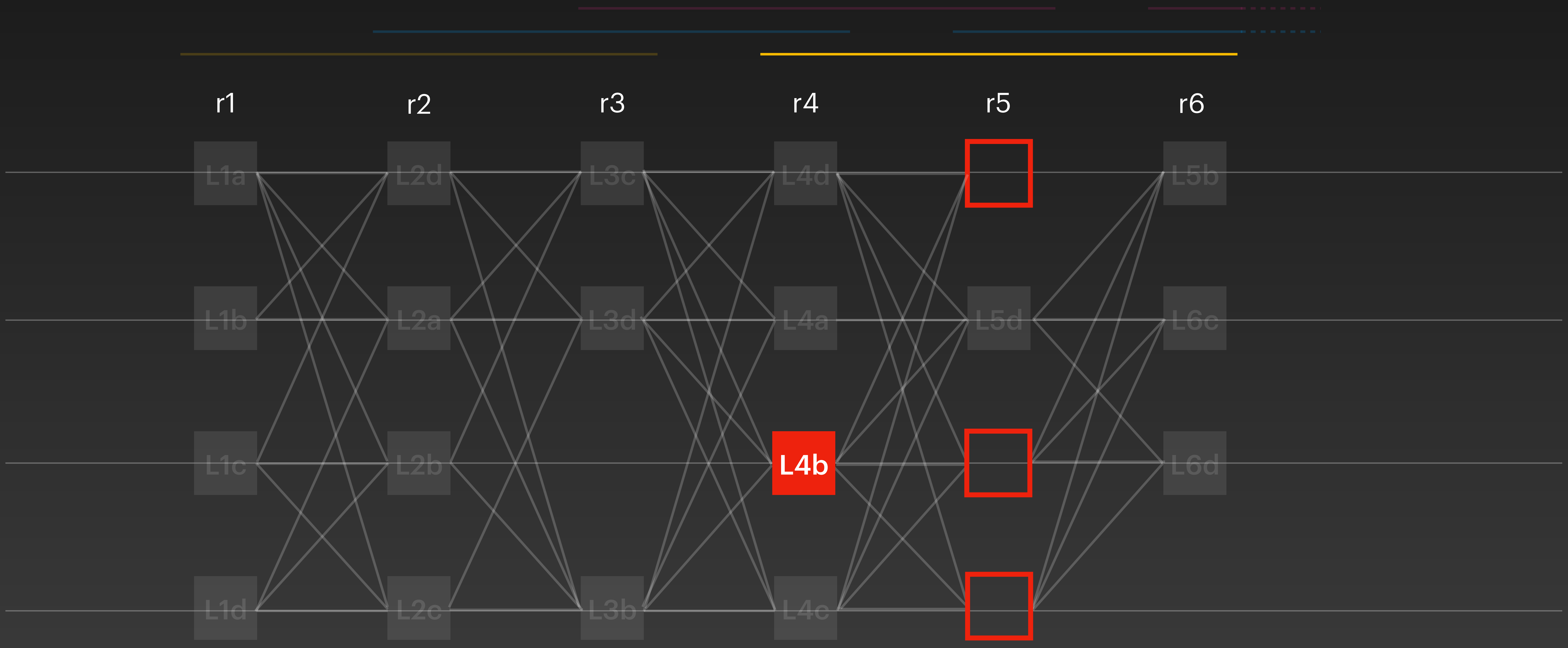

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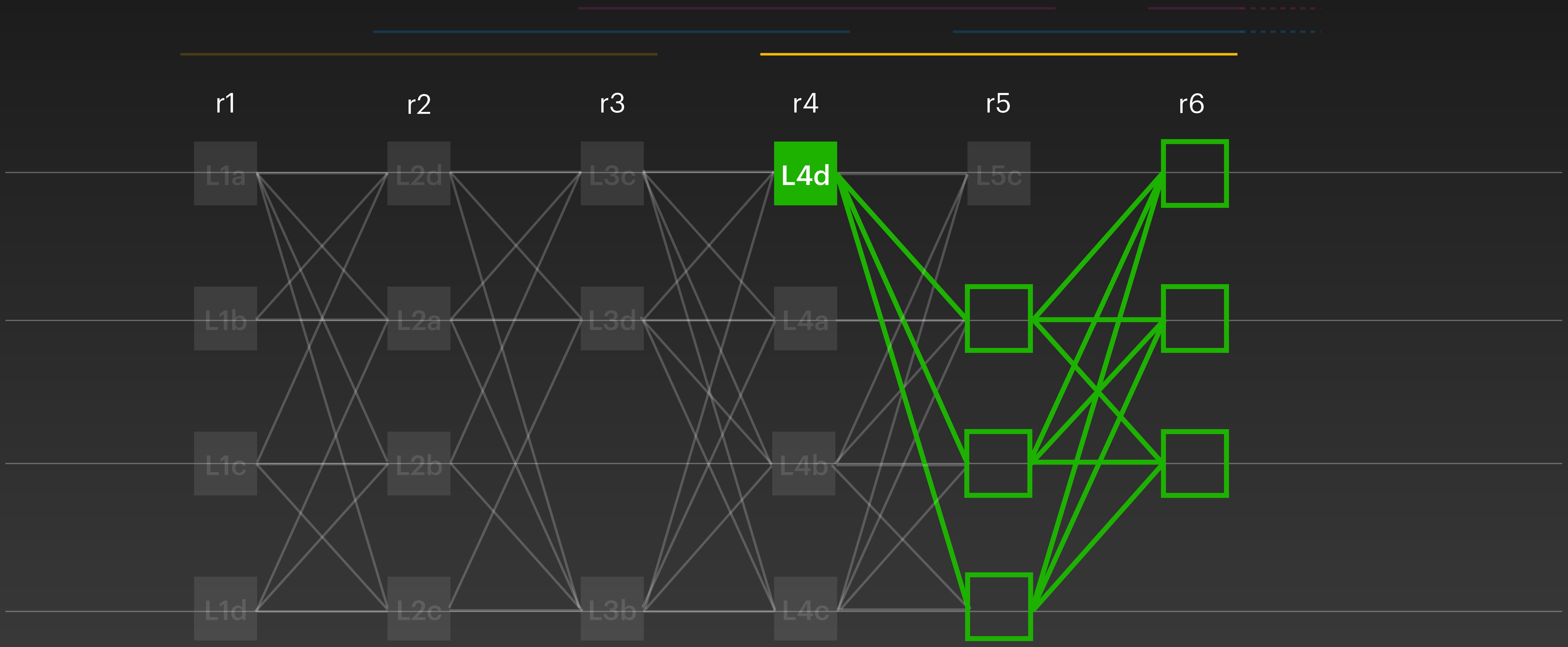

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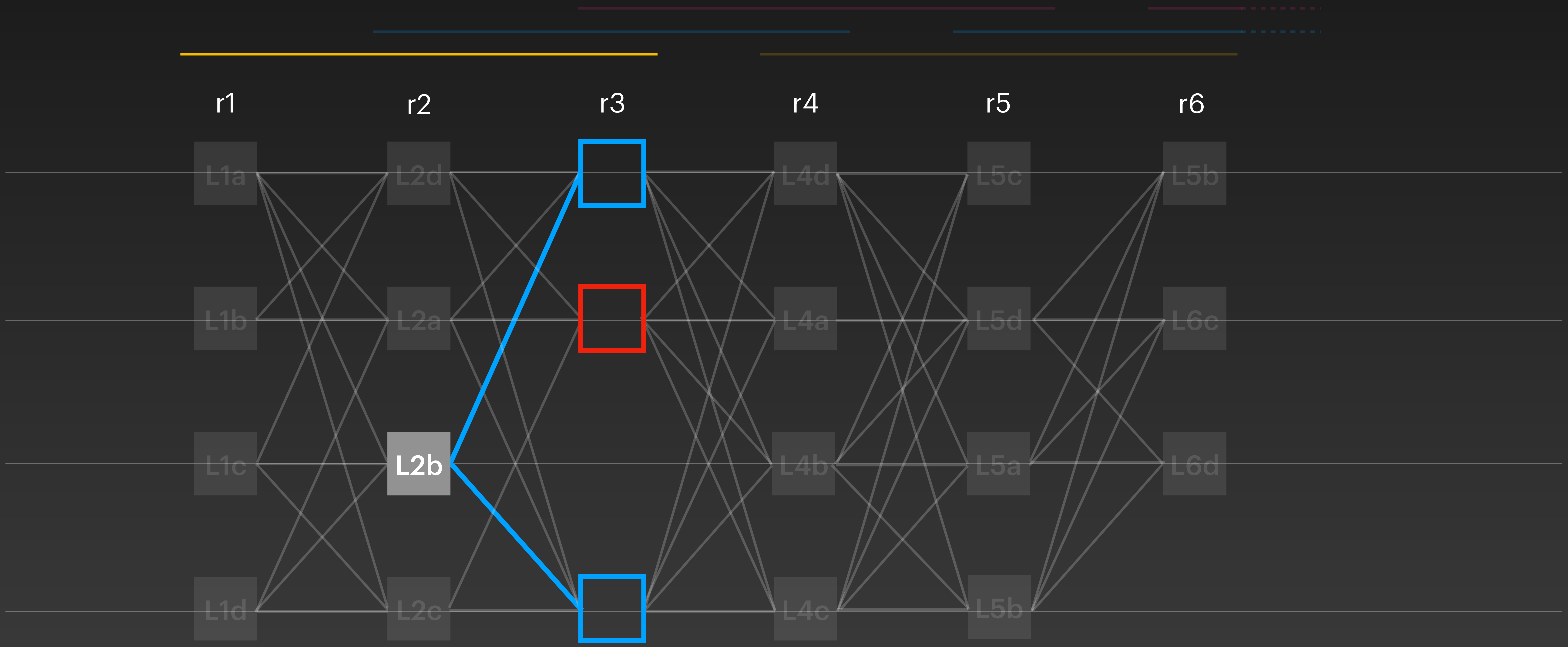
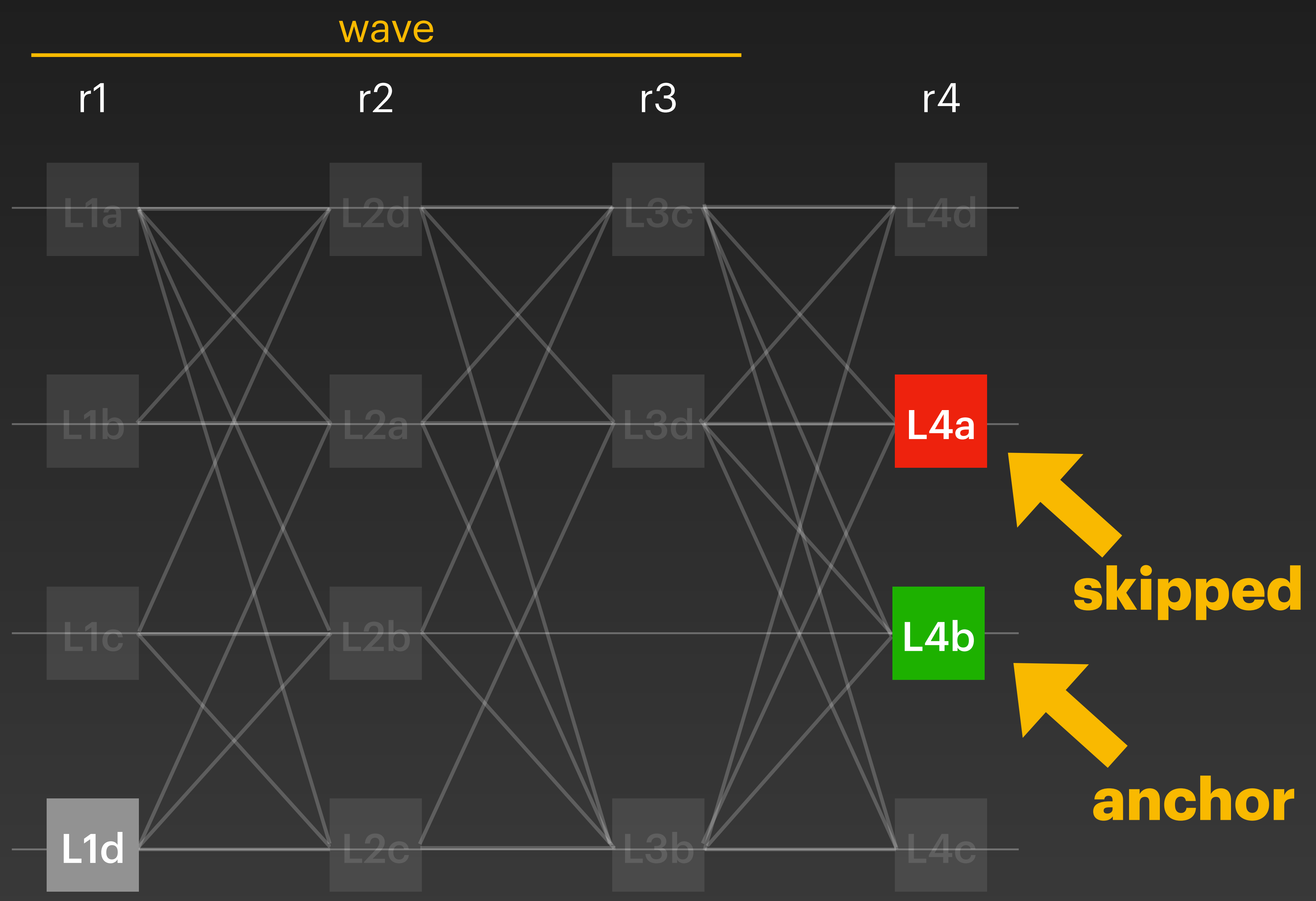


Indirect Decision Rule

Indirect Decision Rule

1. Find Anchor

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



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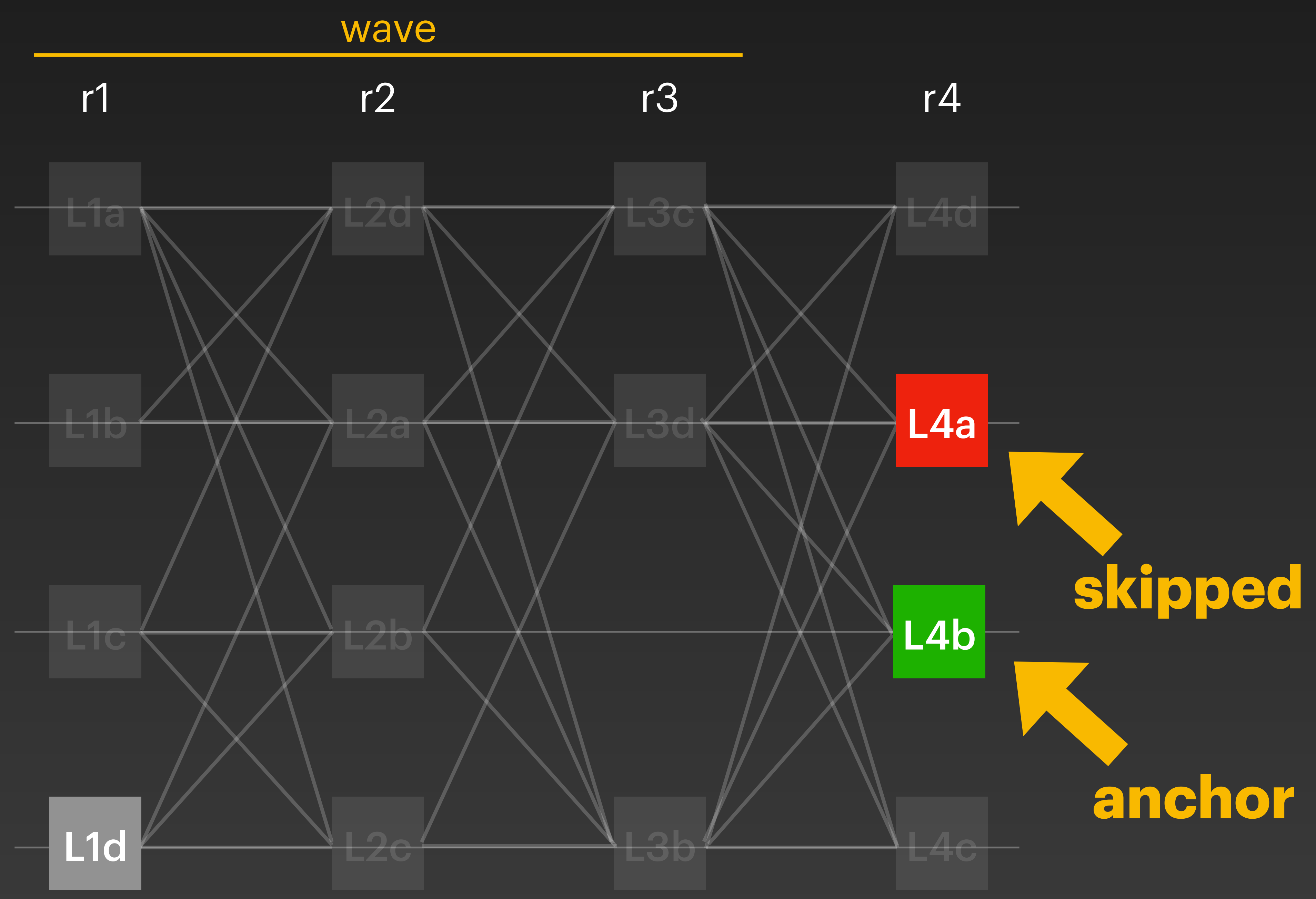
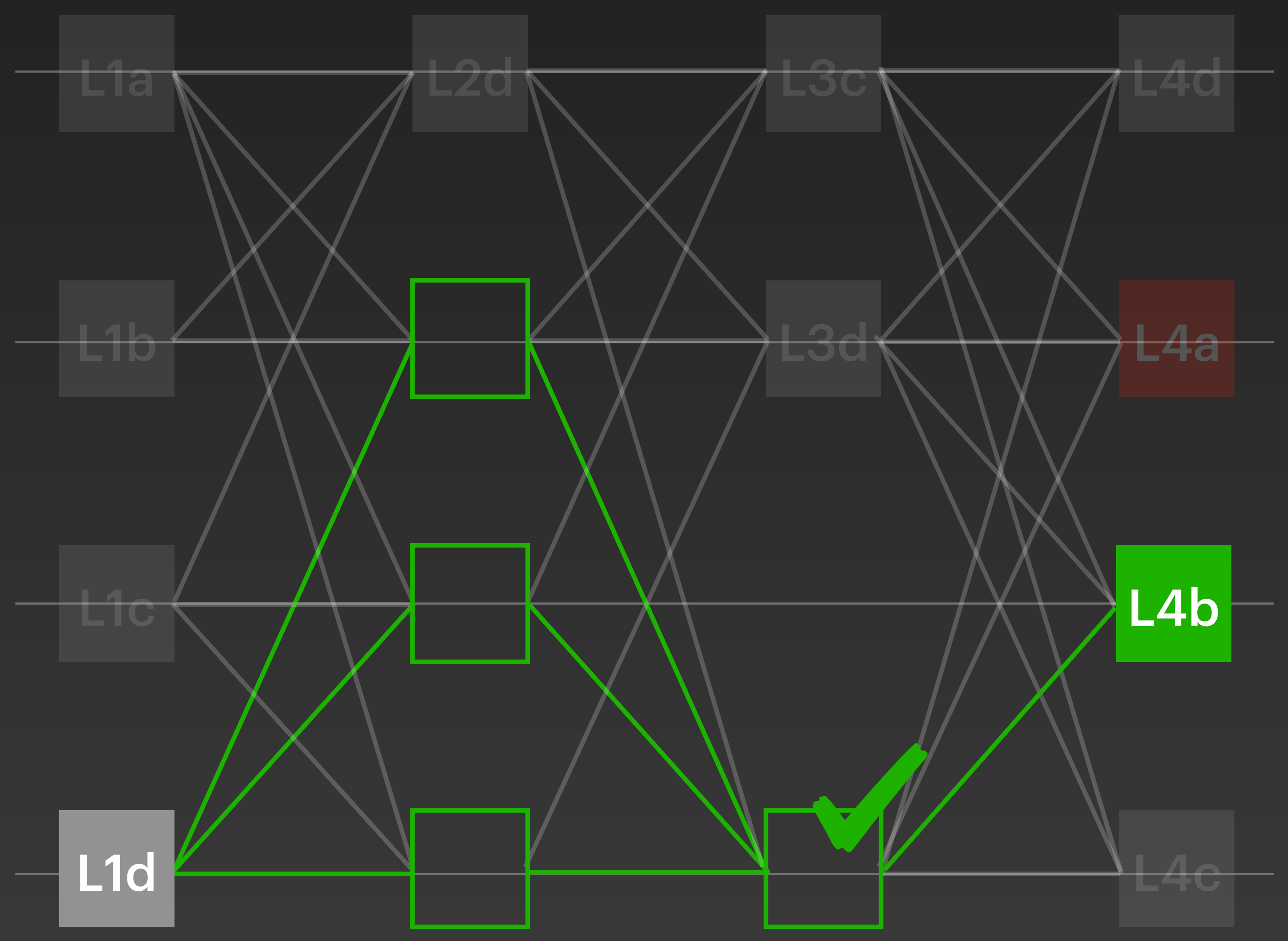


2. Certified link

- **Commit** if

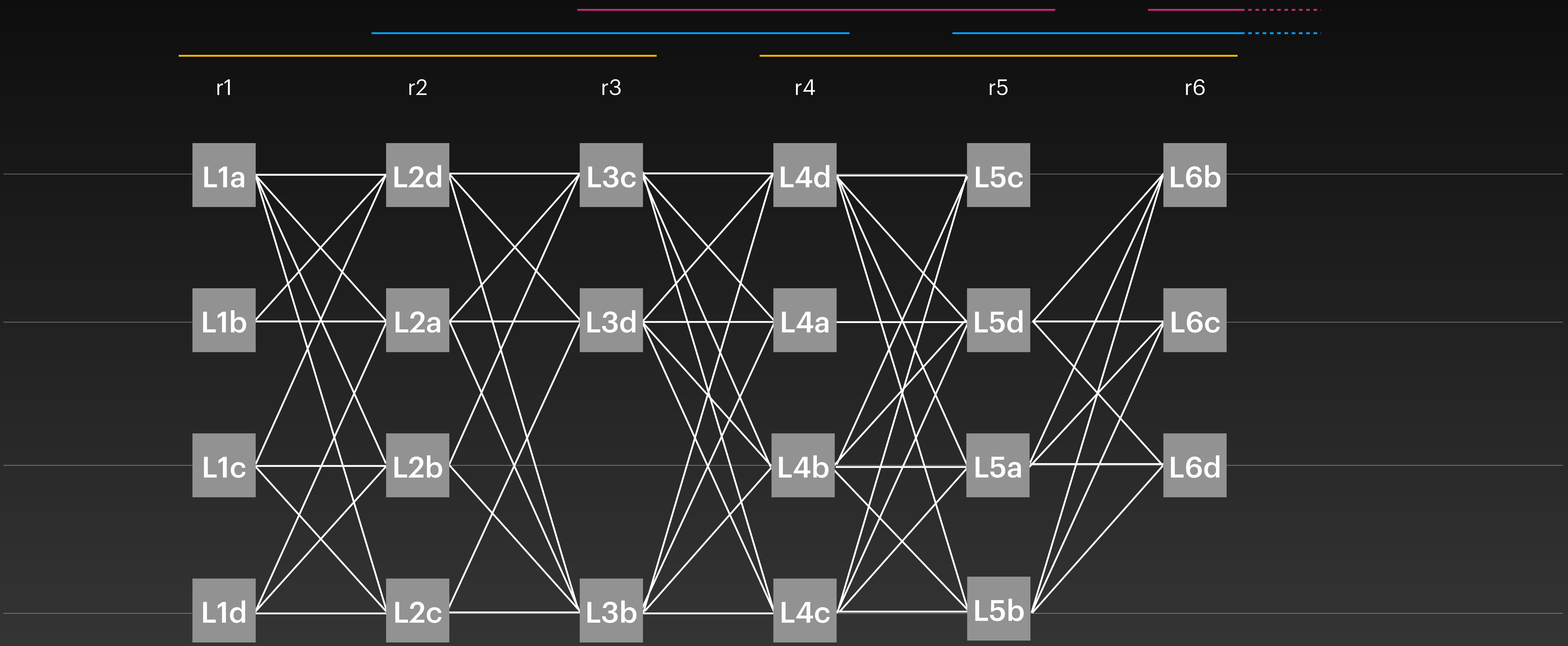
`B <-> certified link <-> A`

otherwise **Skip**



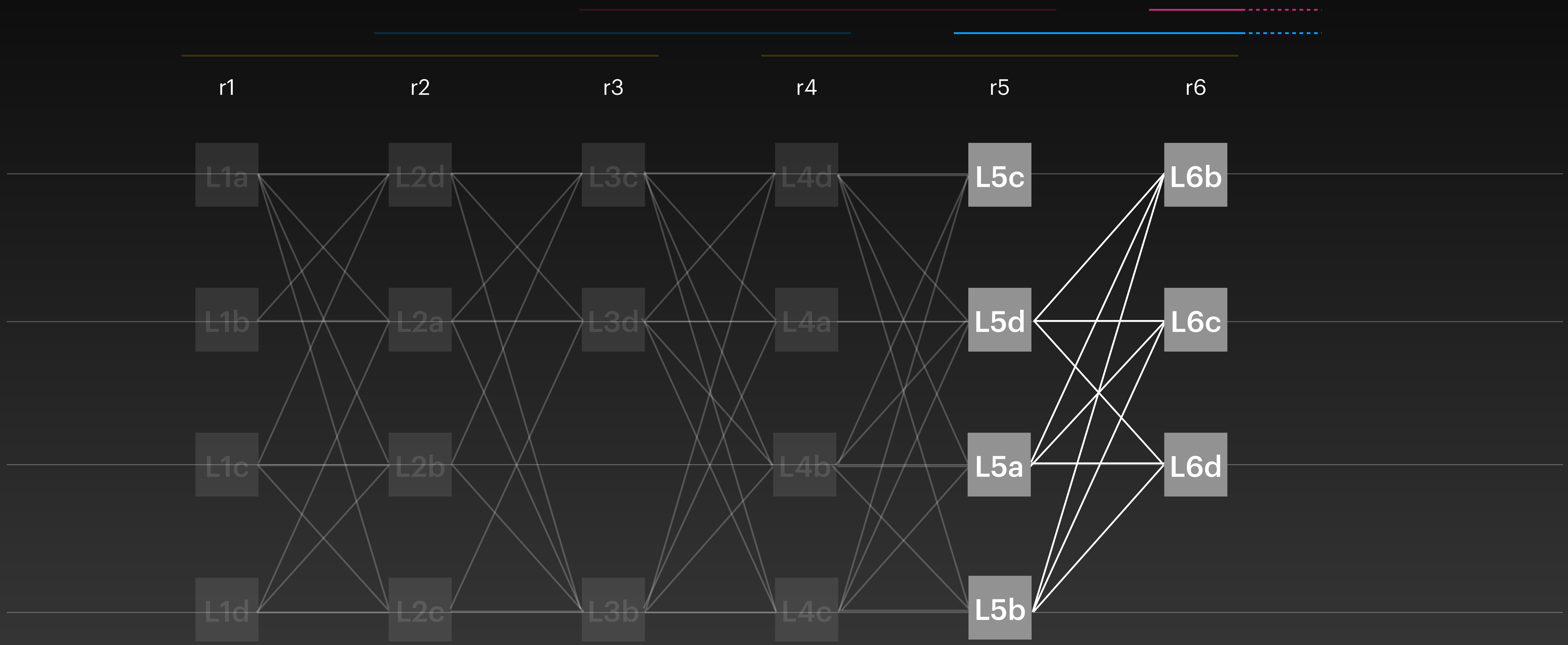
Apply Direct Rule

Mark all leaders as Undecided



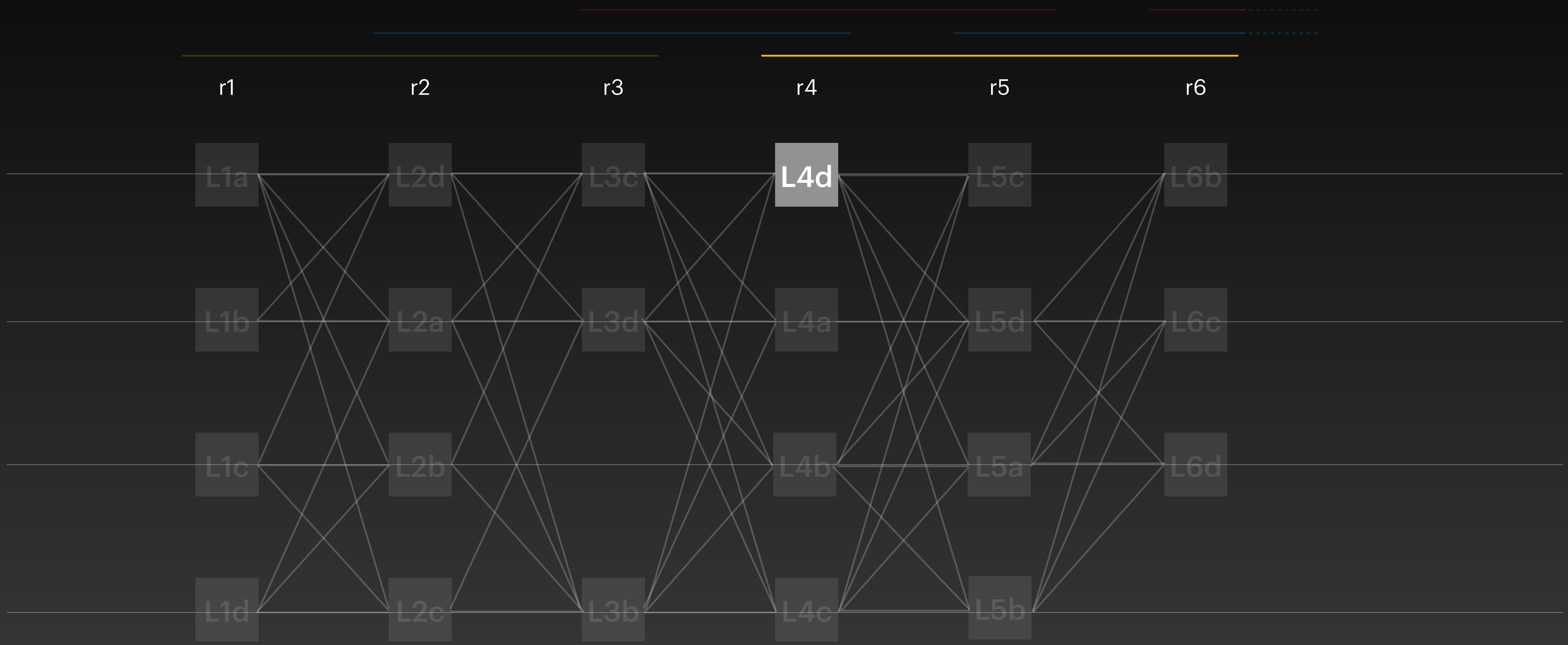
Apply Direct Rule

Cannot decide incomplete waves



Apply Direct Rule

Start with latest block and go backward



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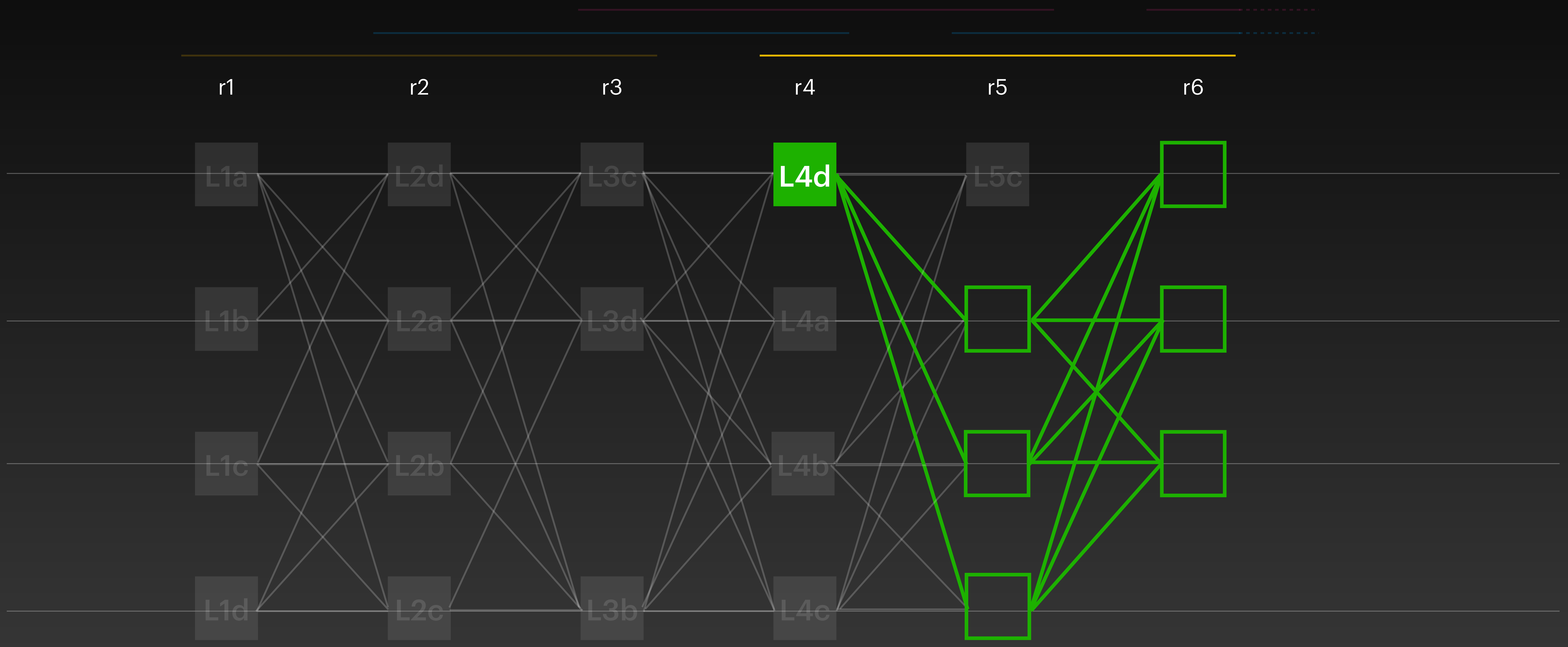

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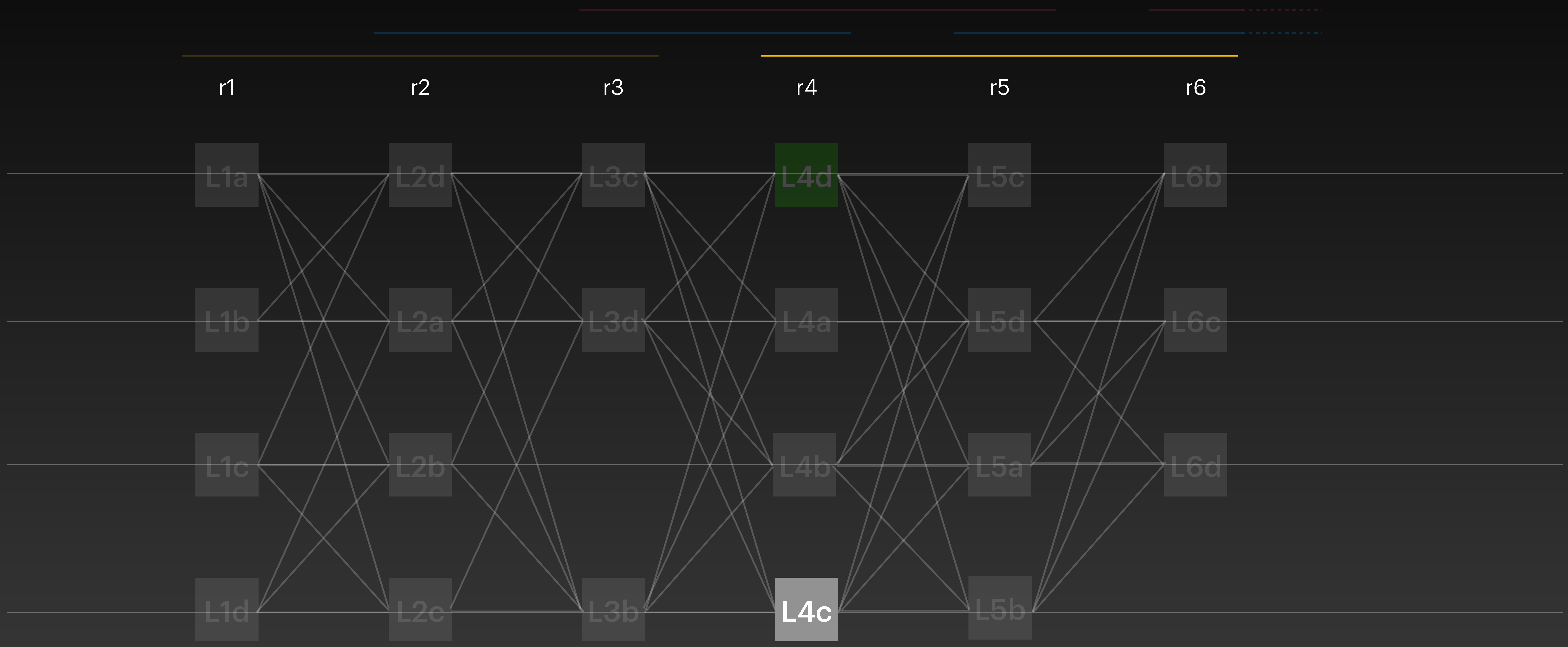

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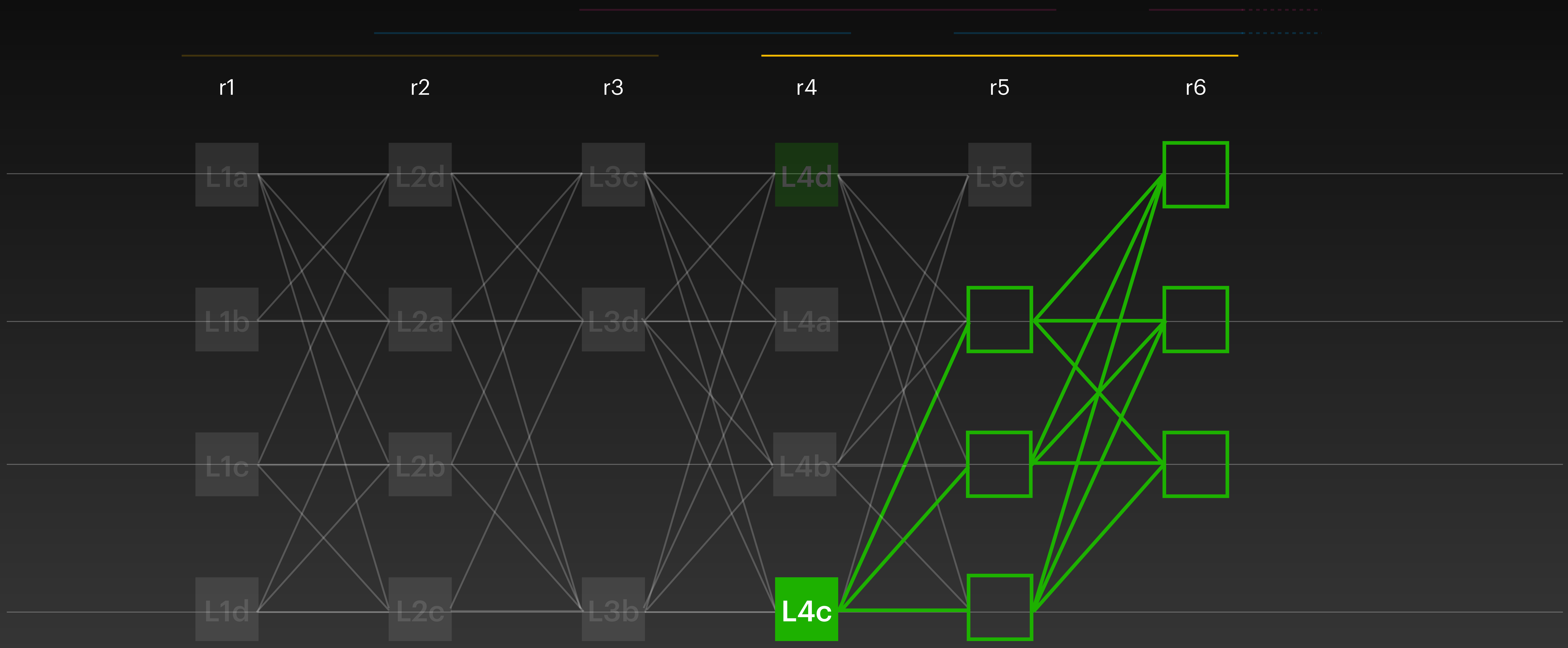

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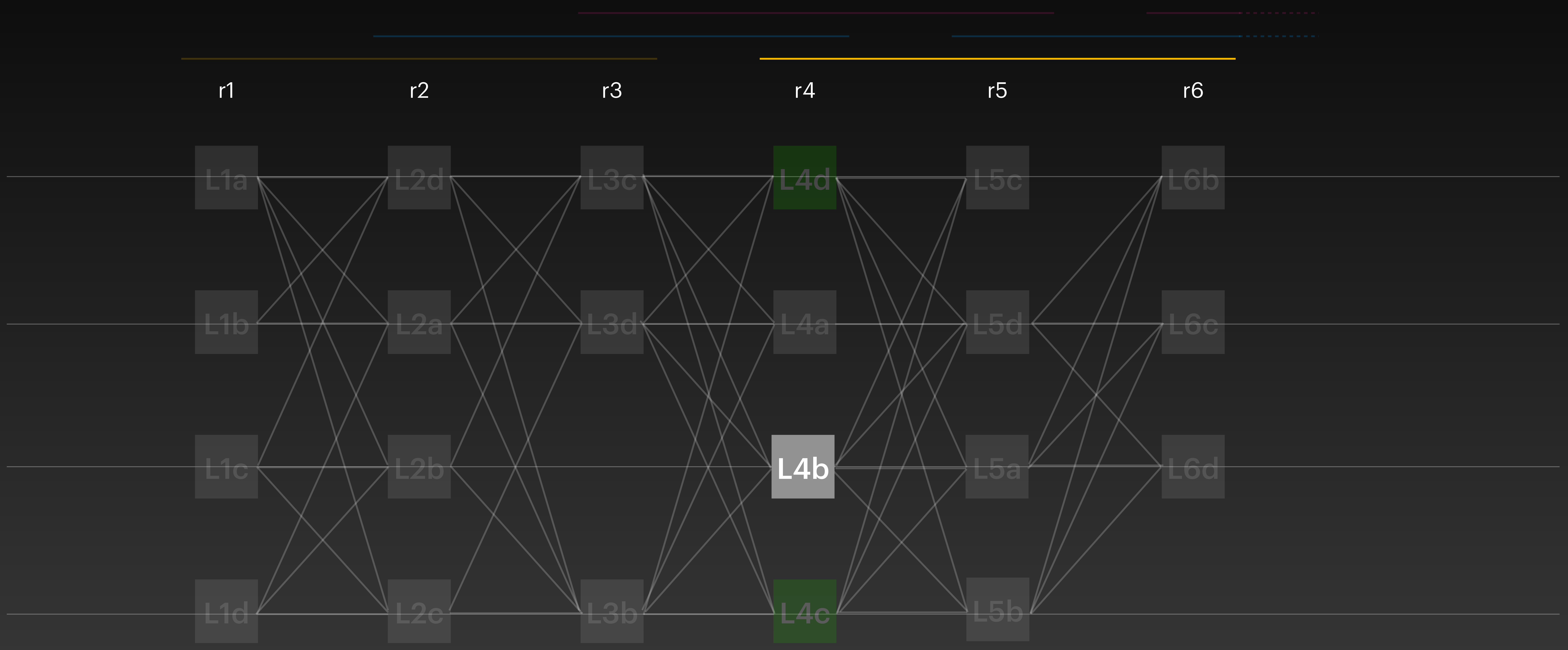

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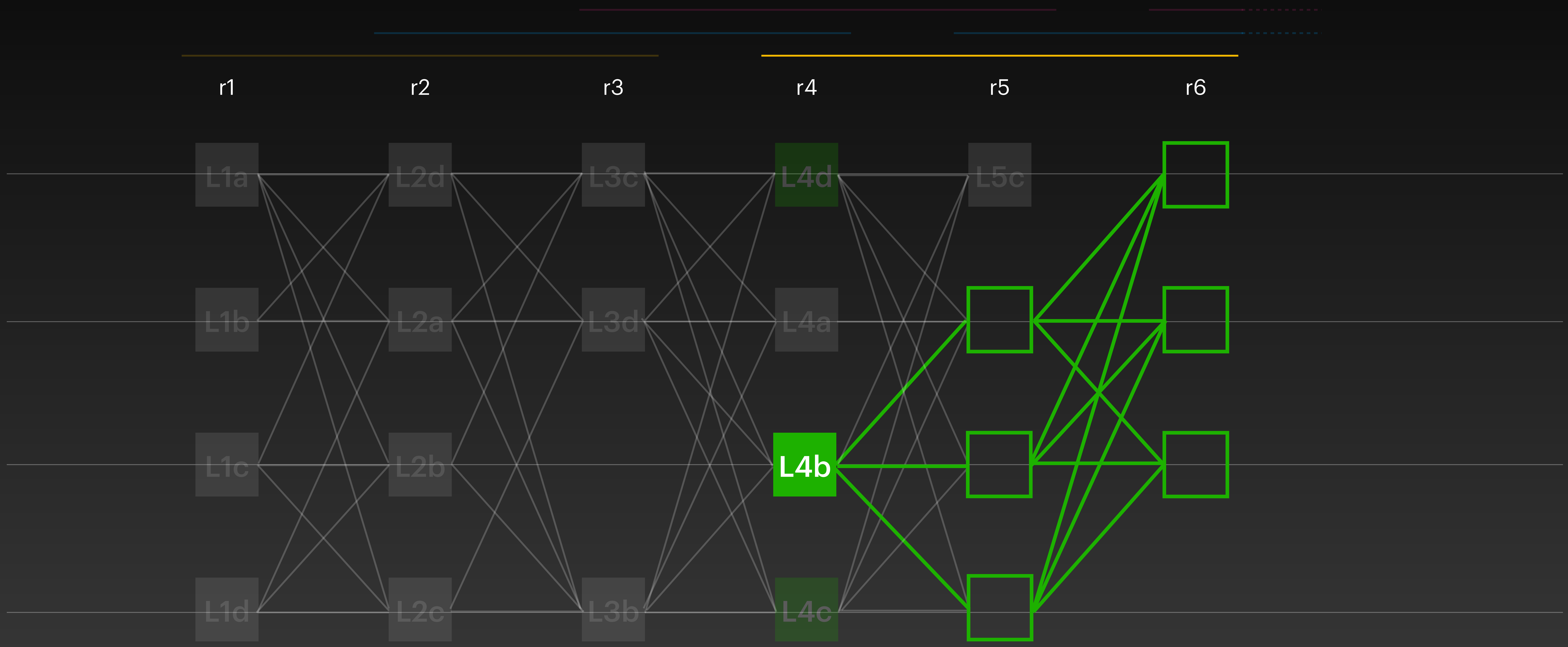

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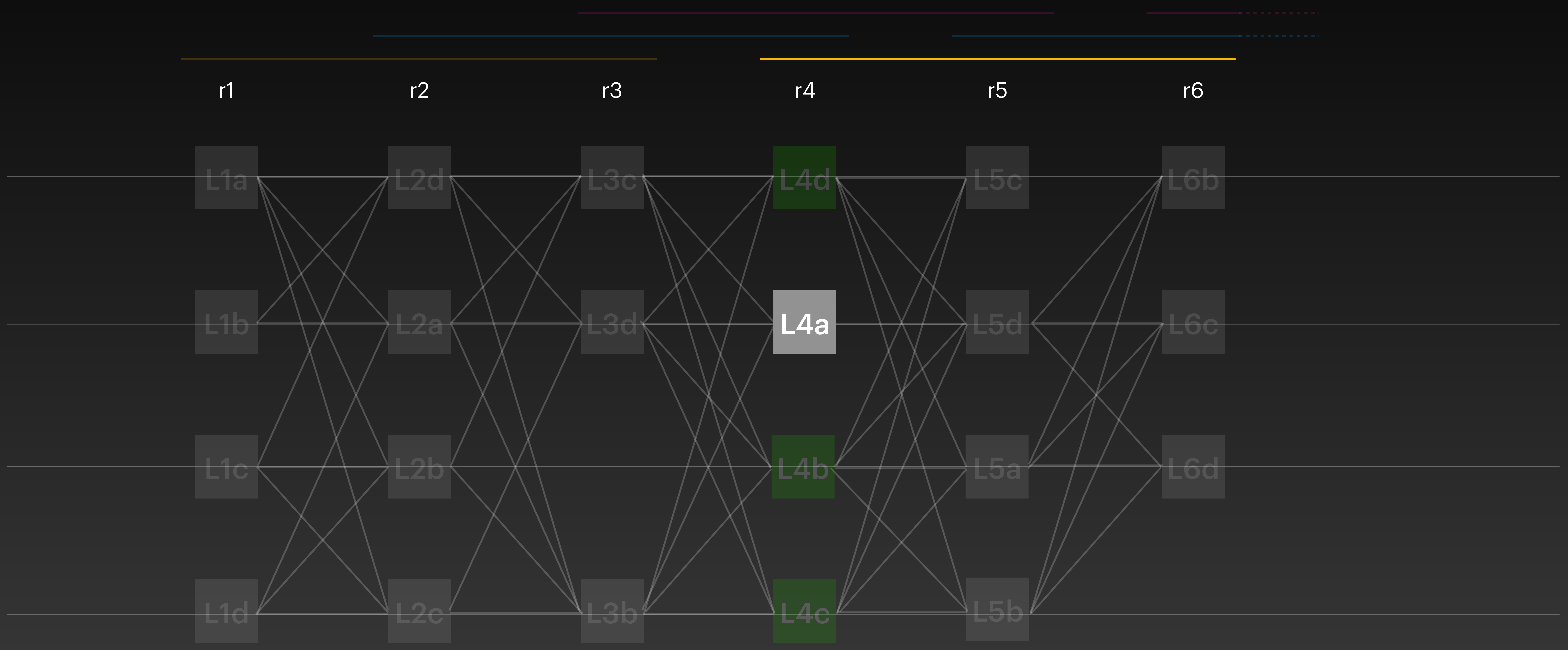

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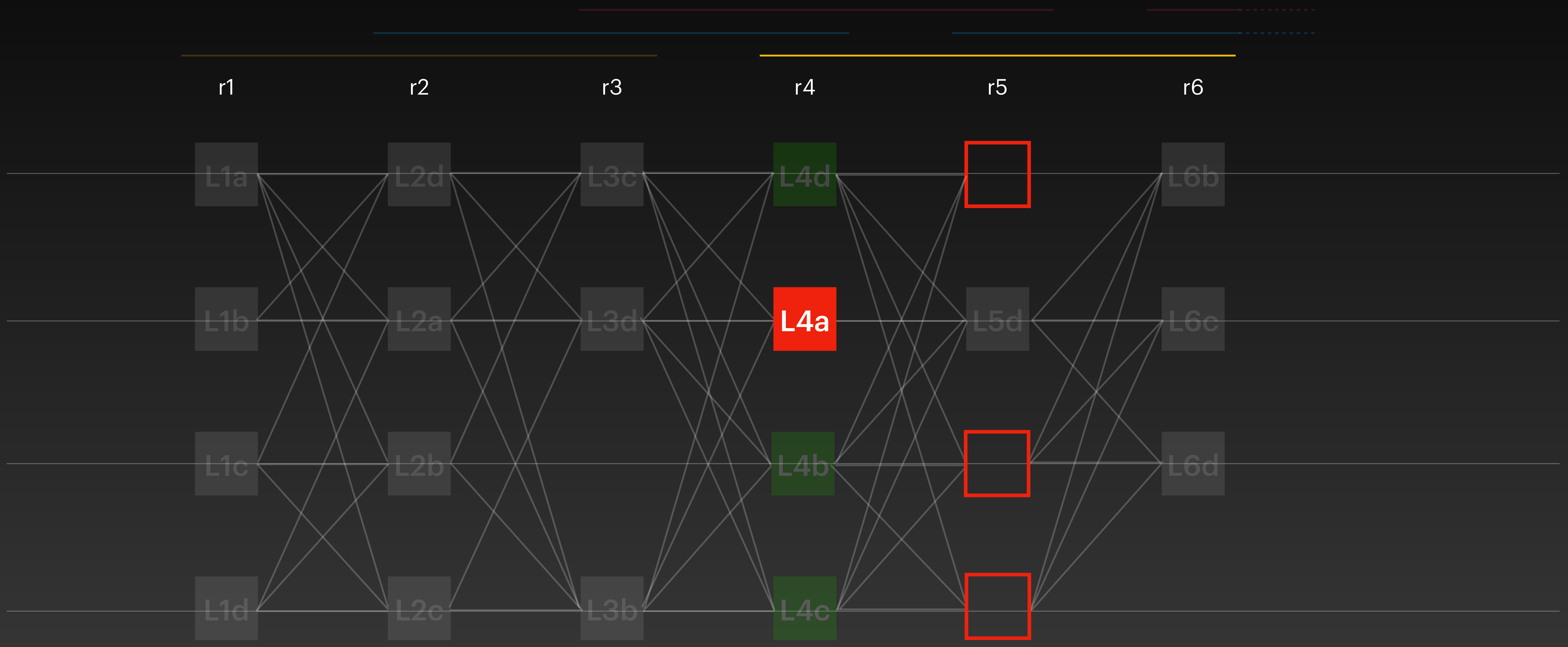

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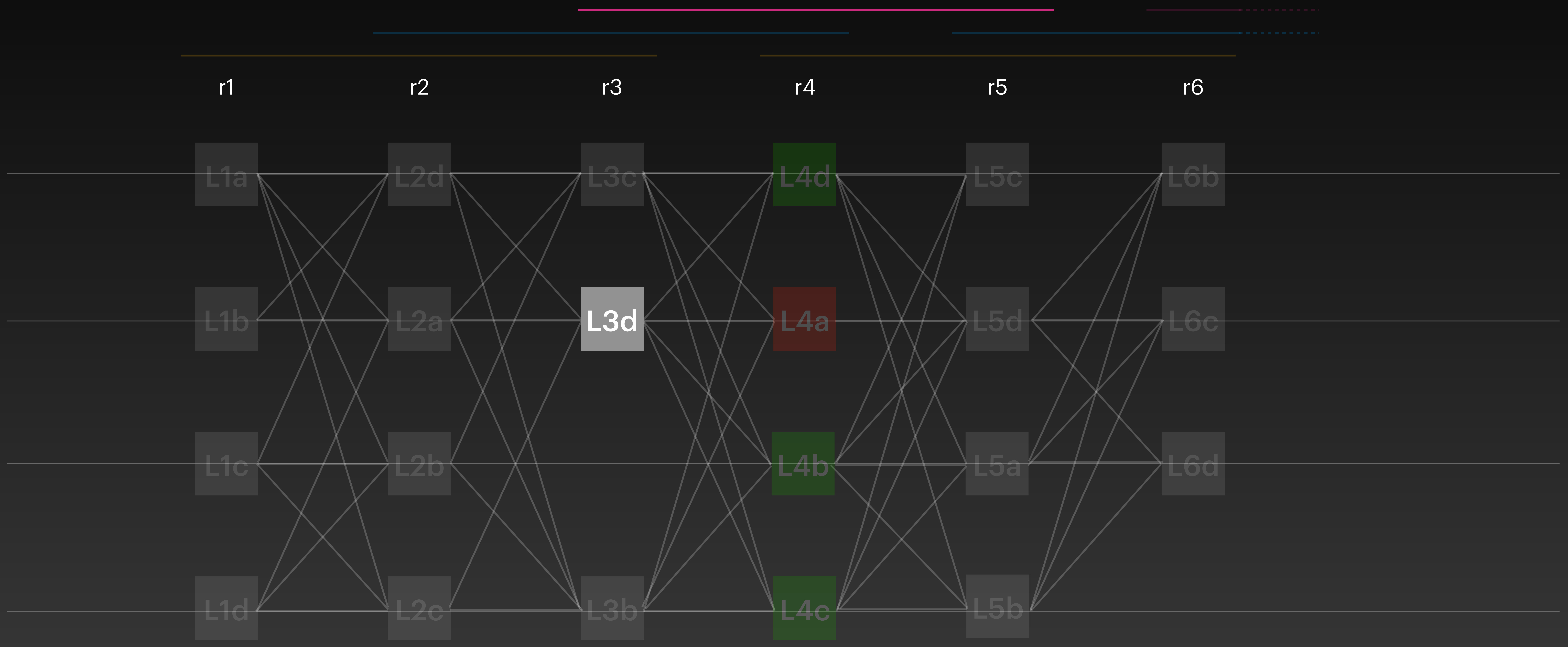

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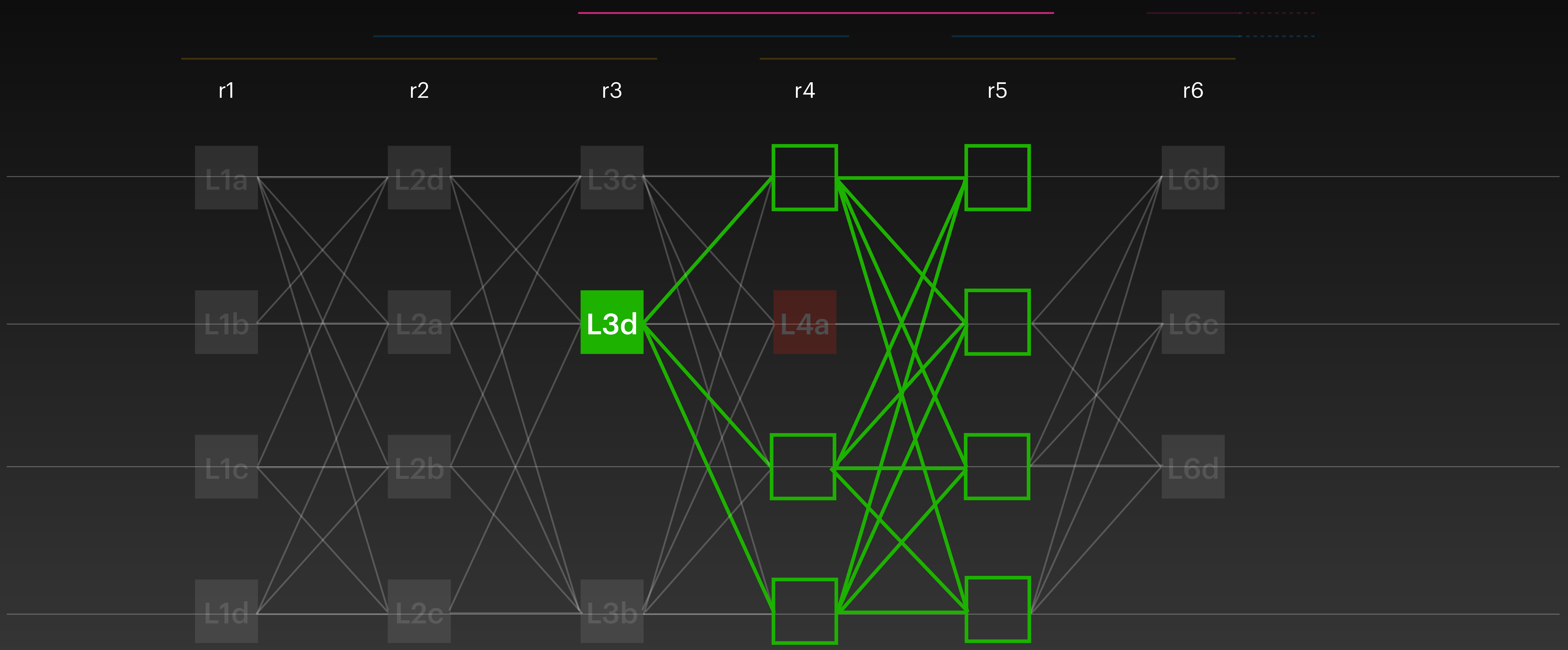

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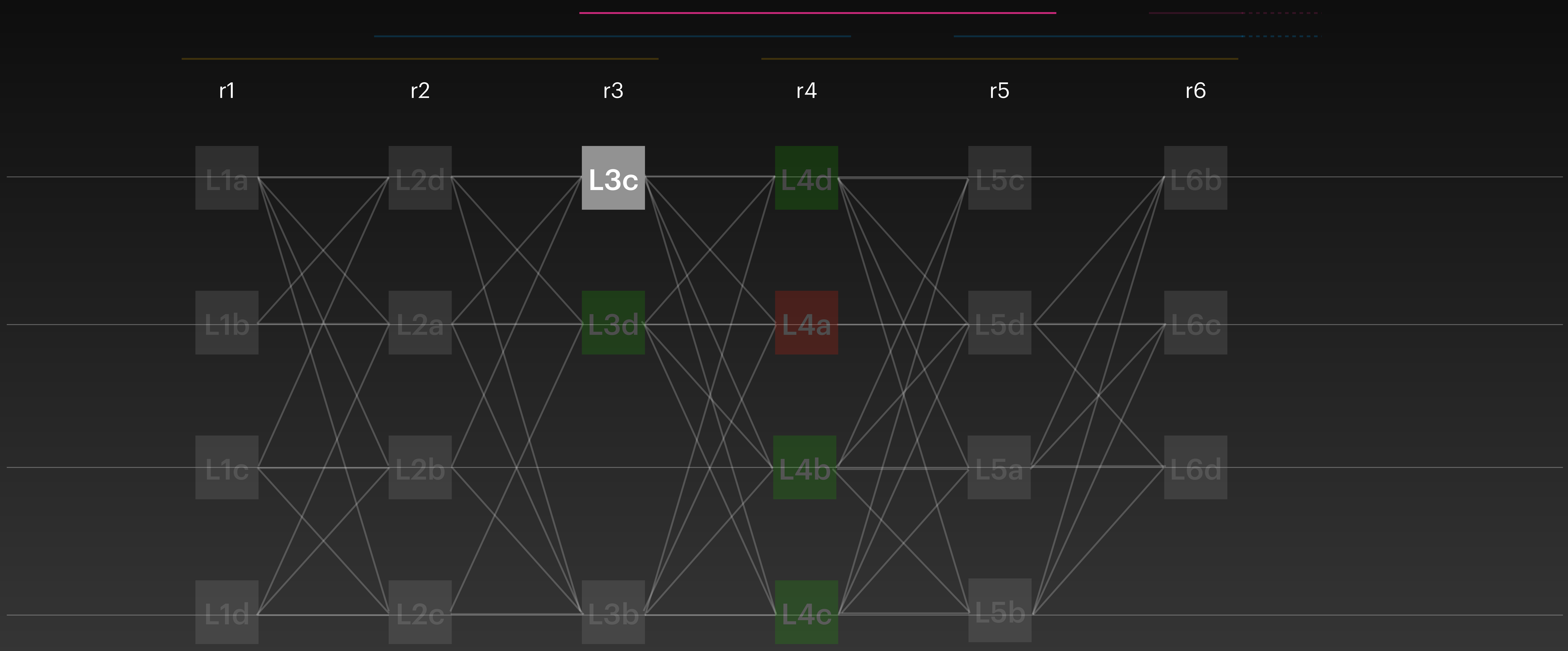

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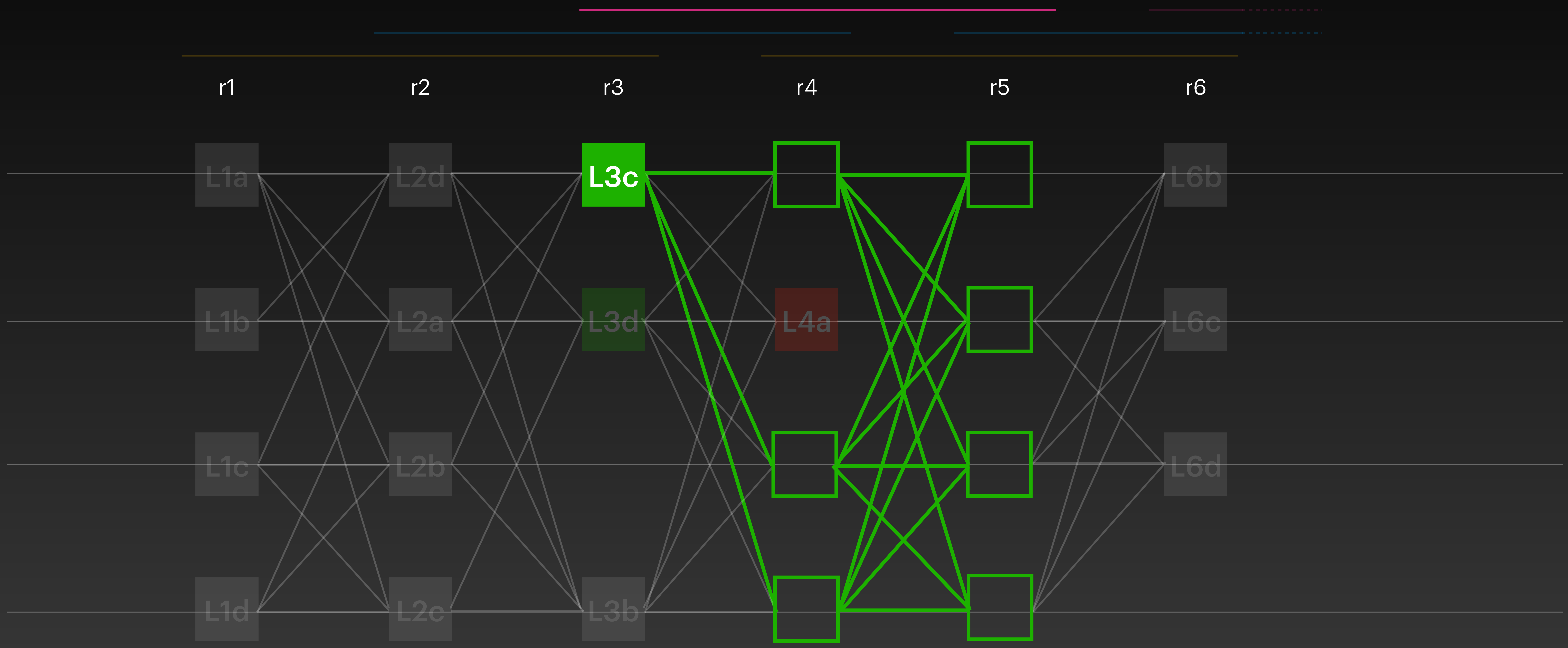

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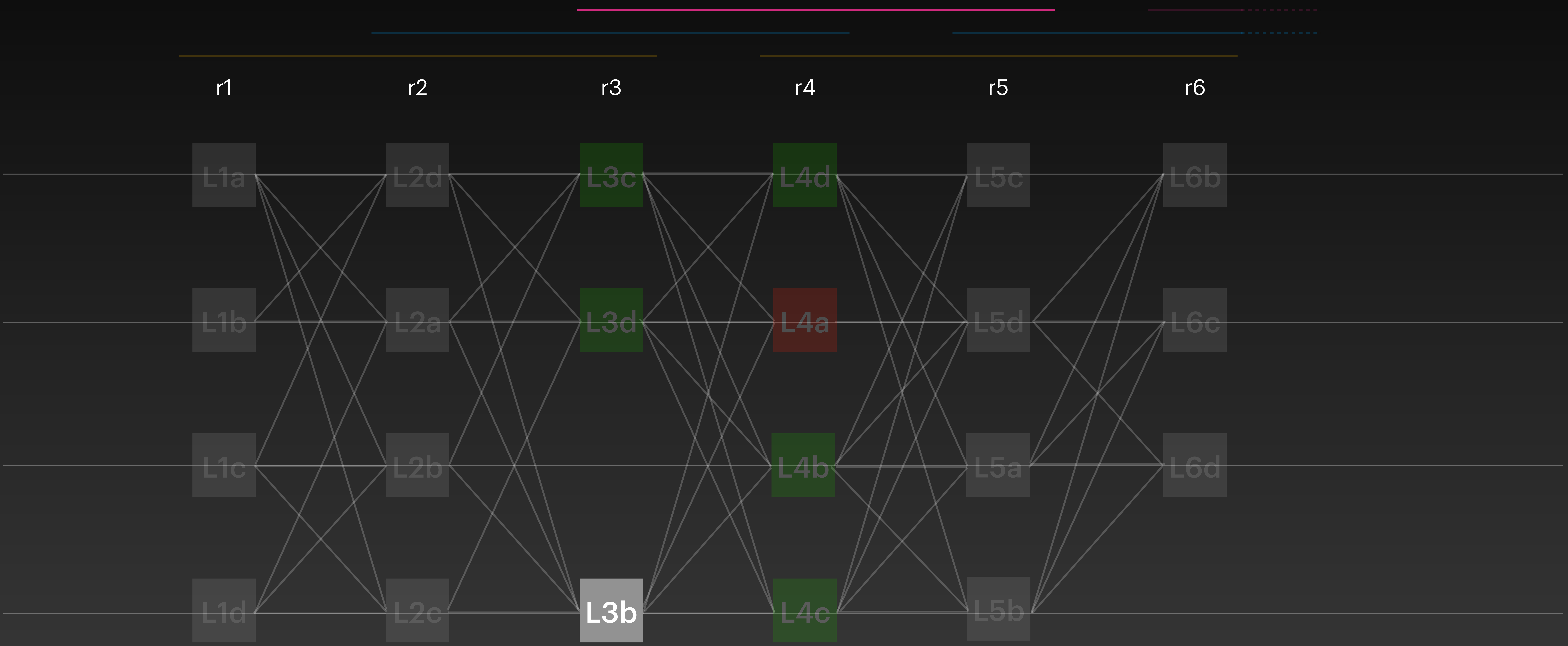

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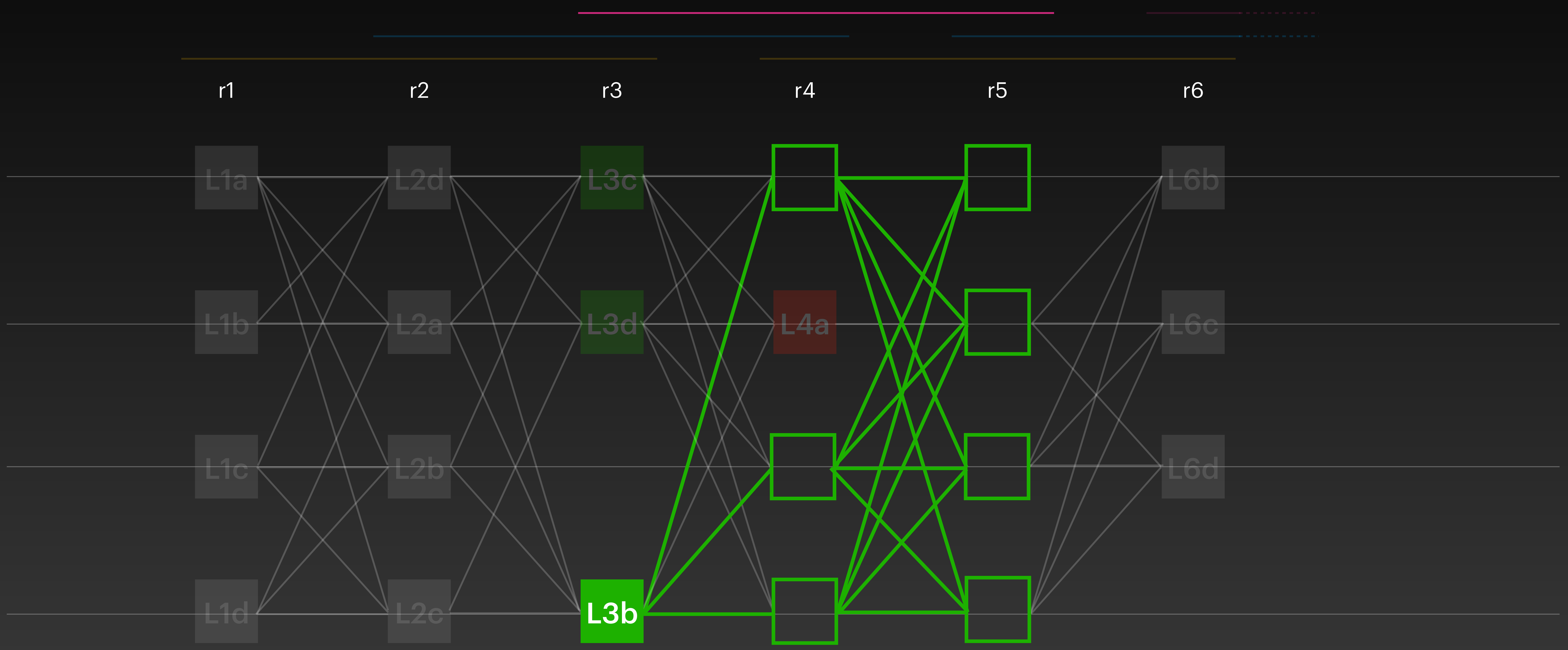

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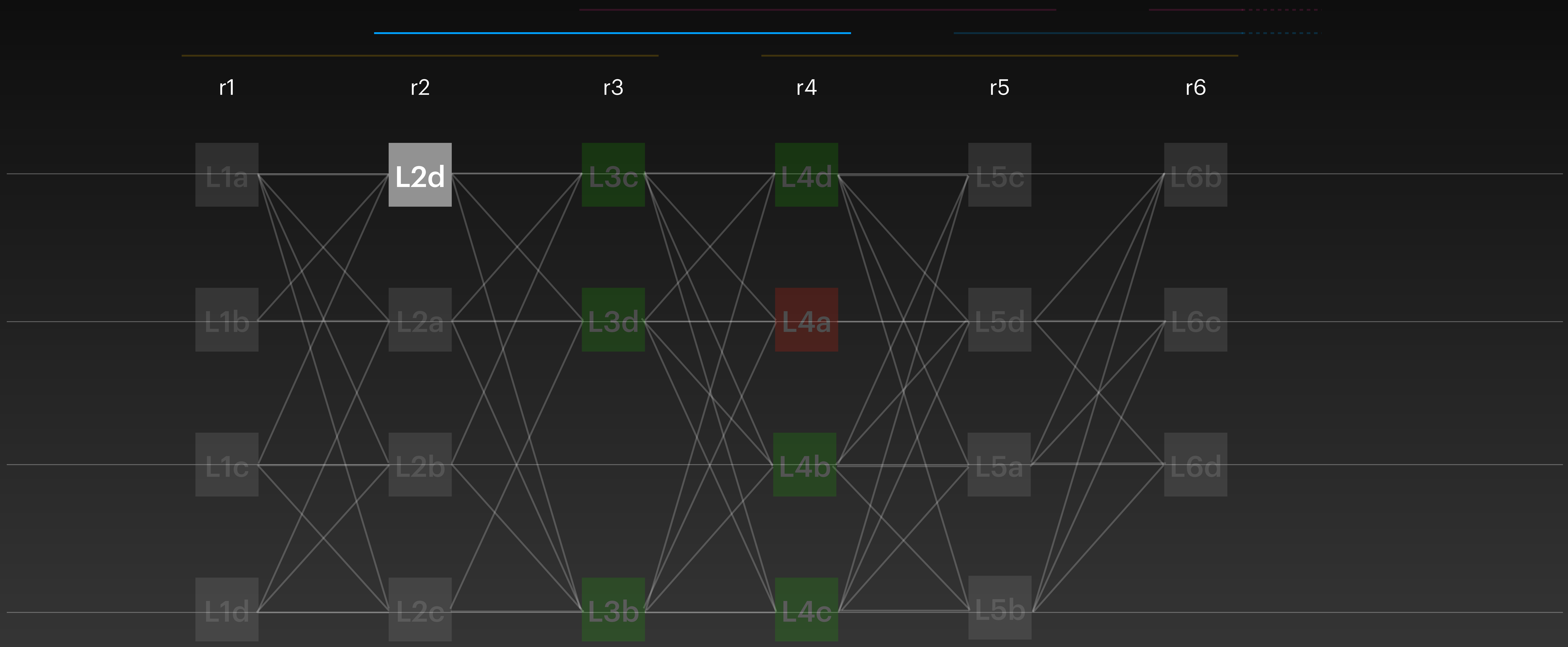

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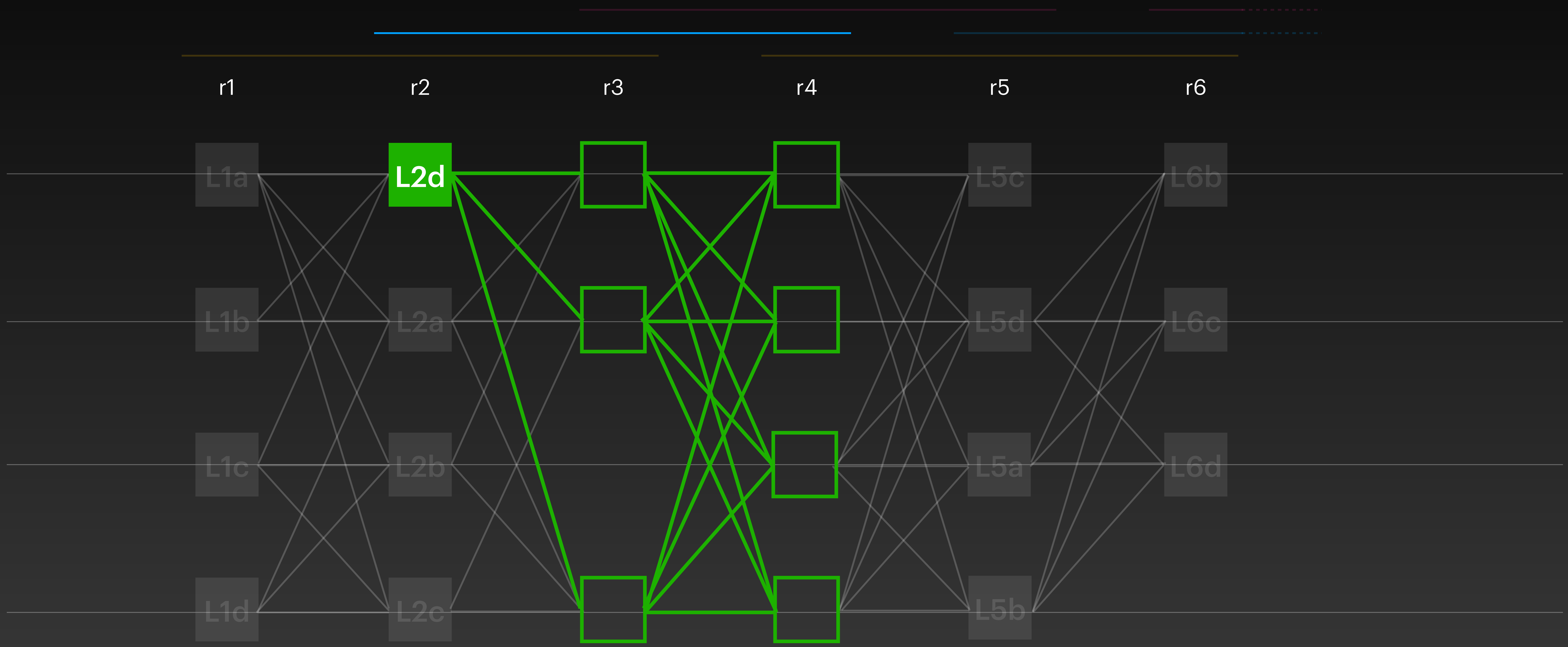

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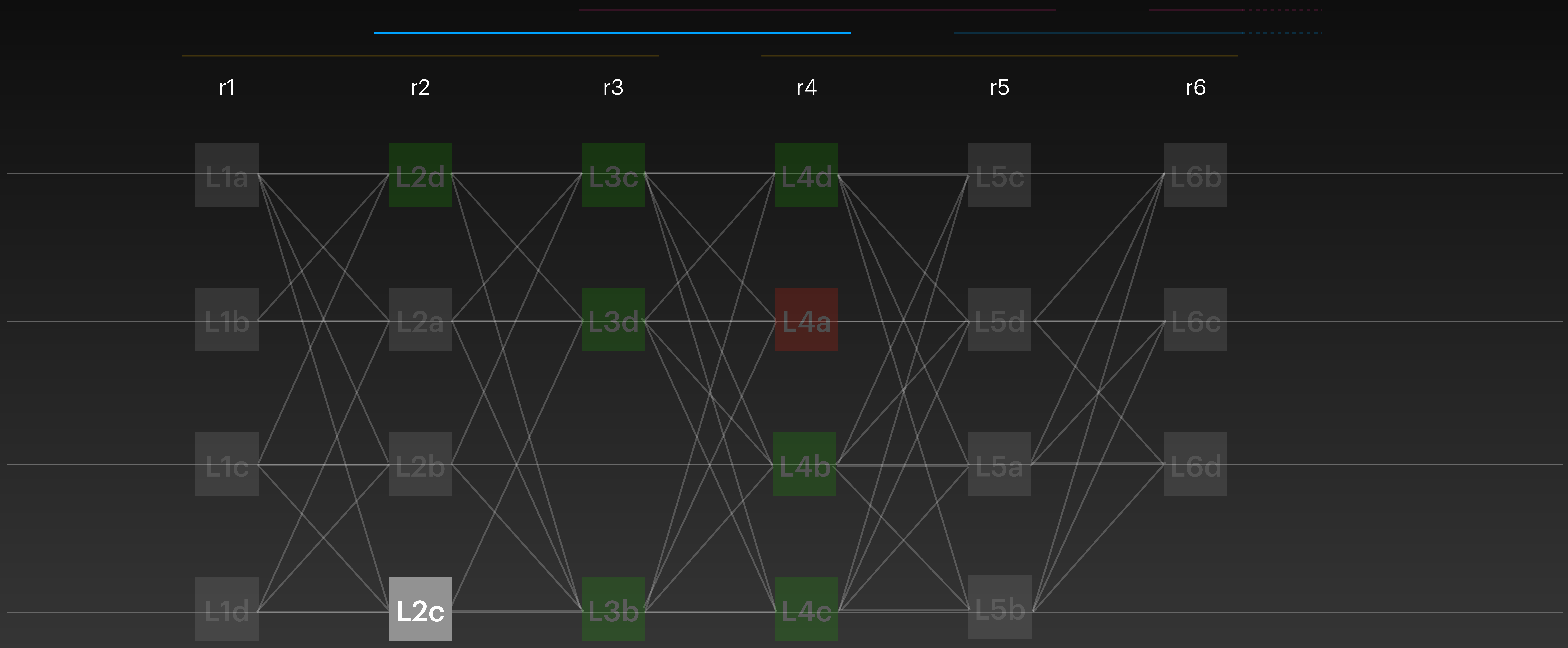
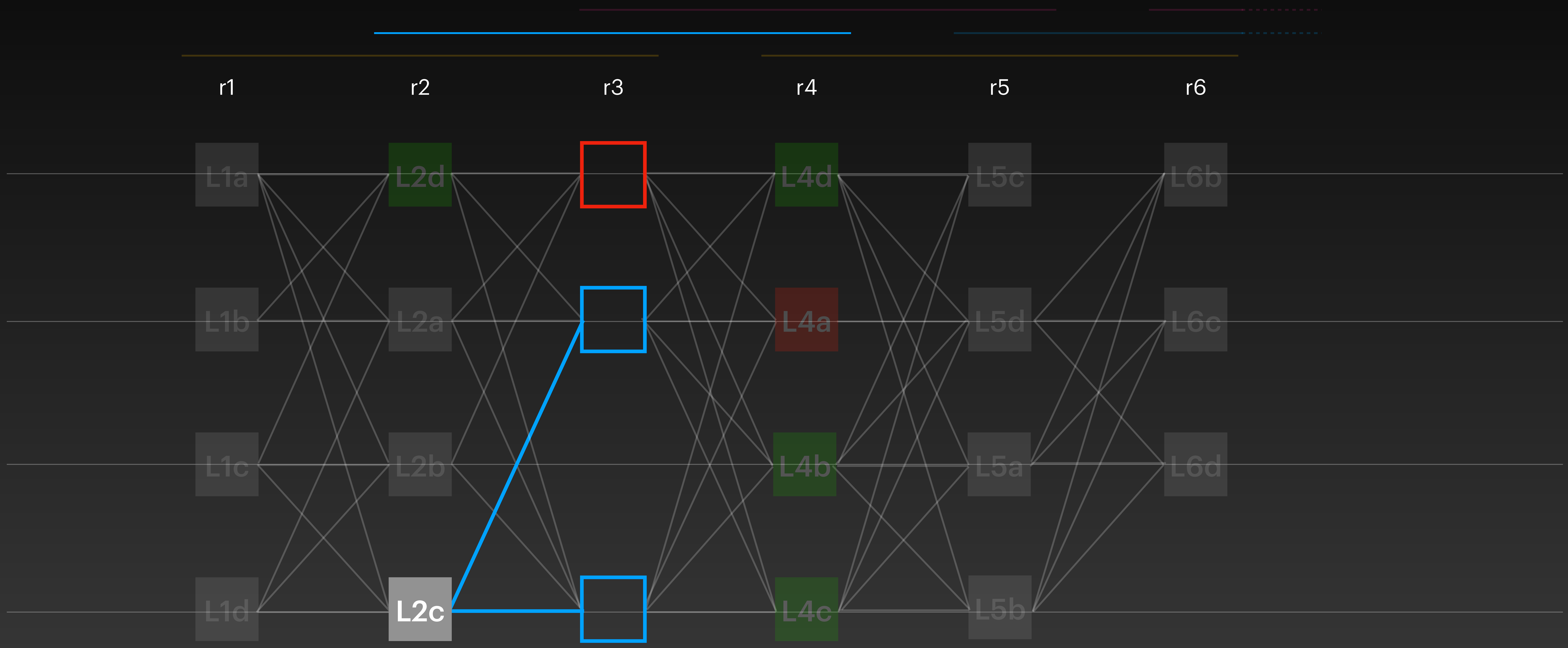


Apply Direct Rule

Direct rule cannot decide



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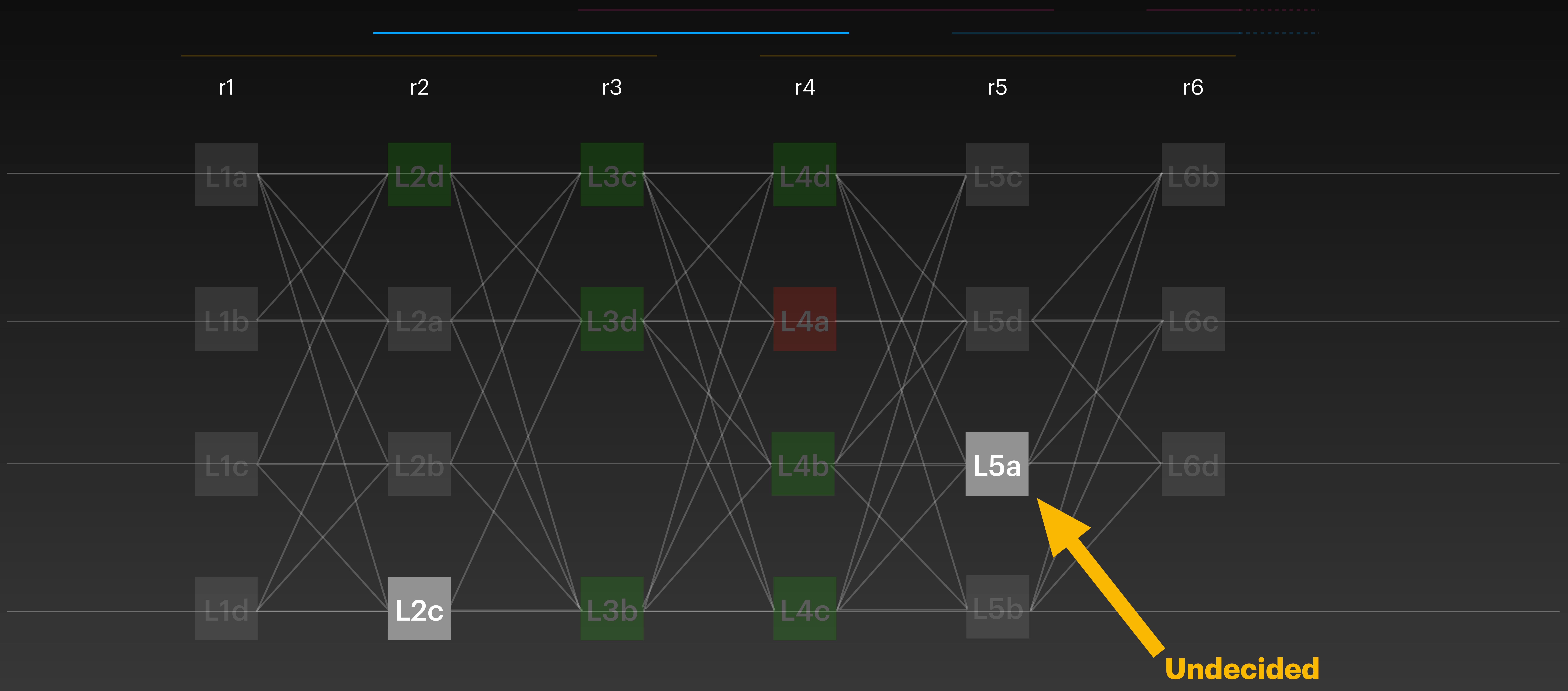
Find anchor & Check certified links



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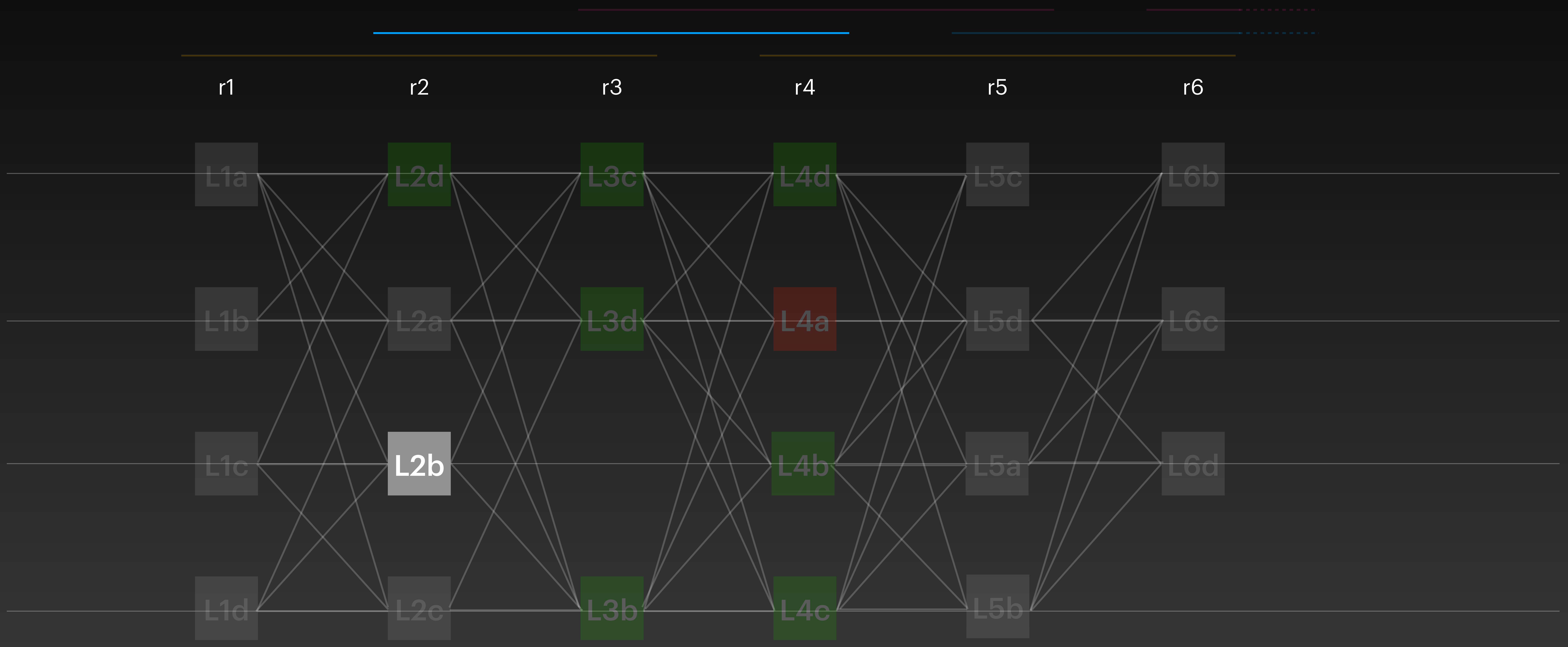

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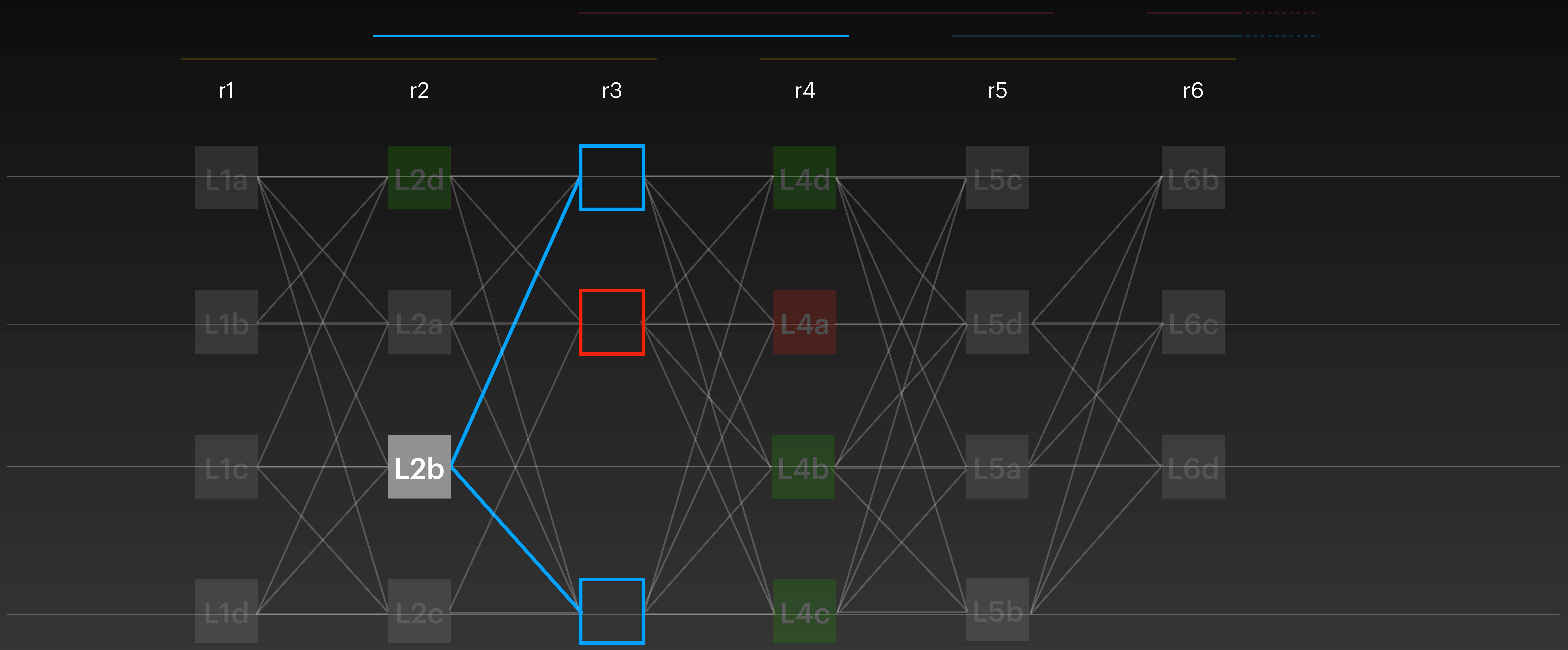

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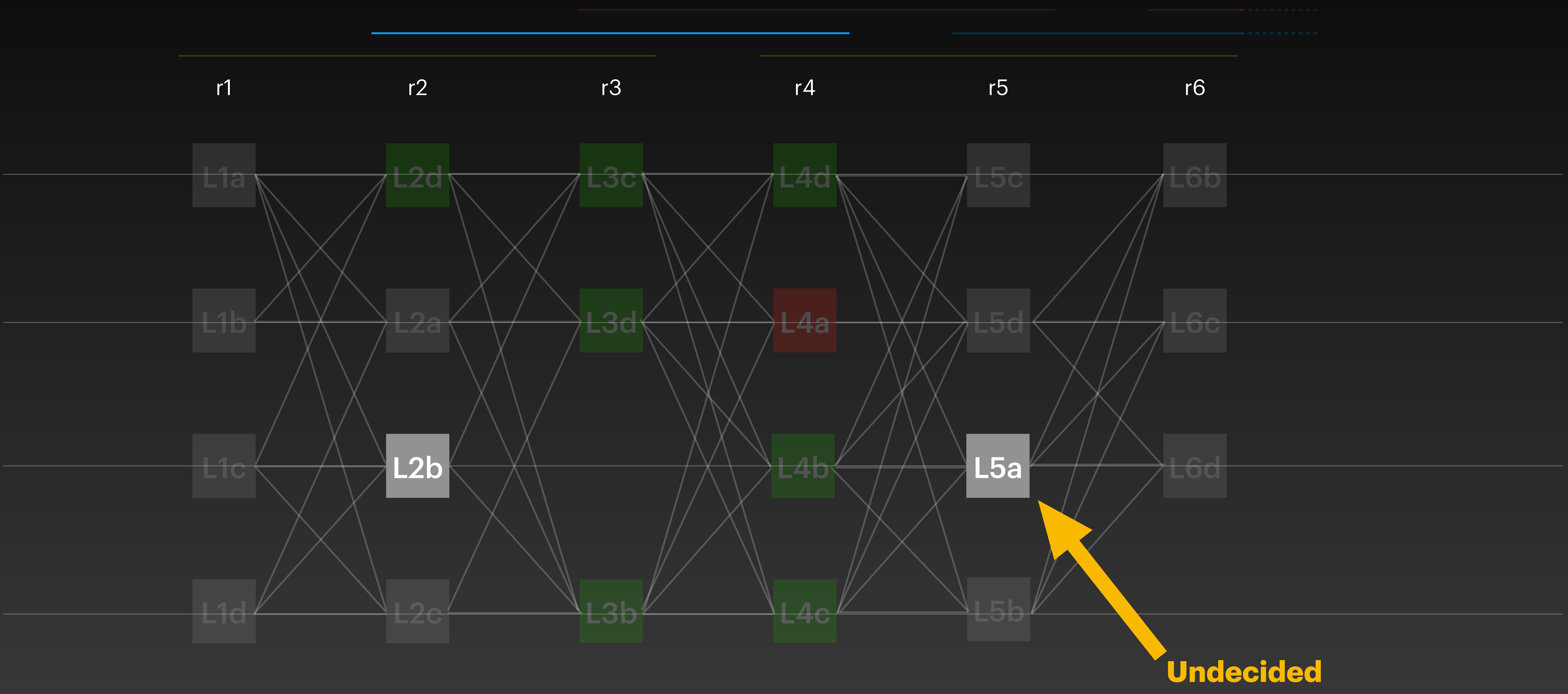

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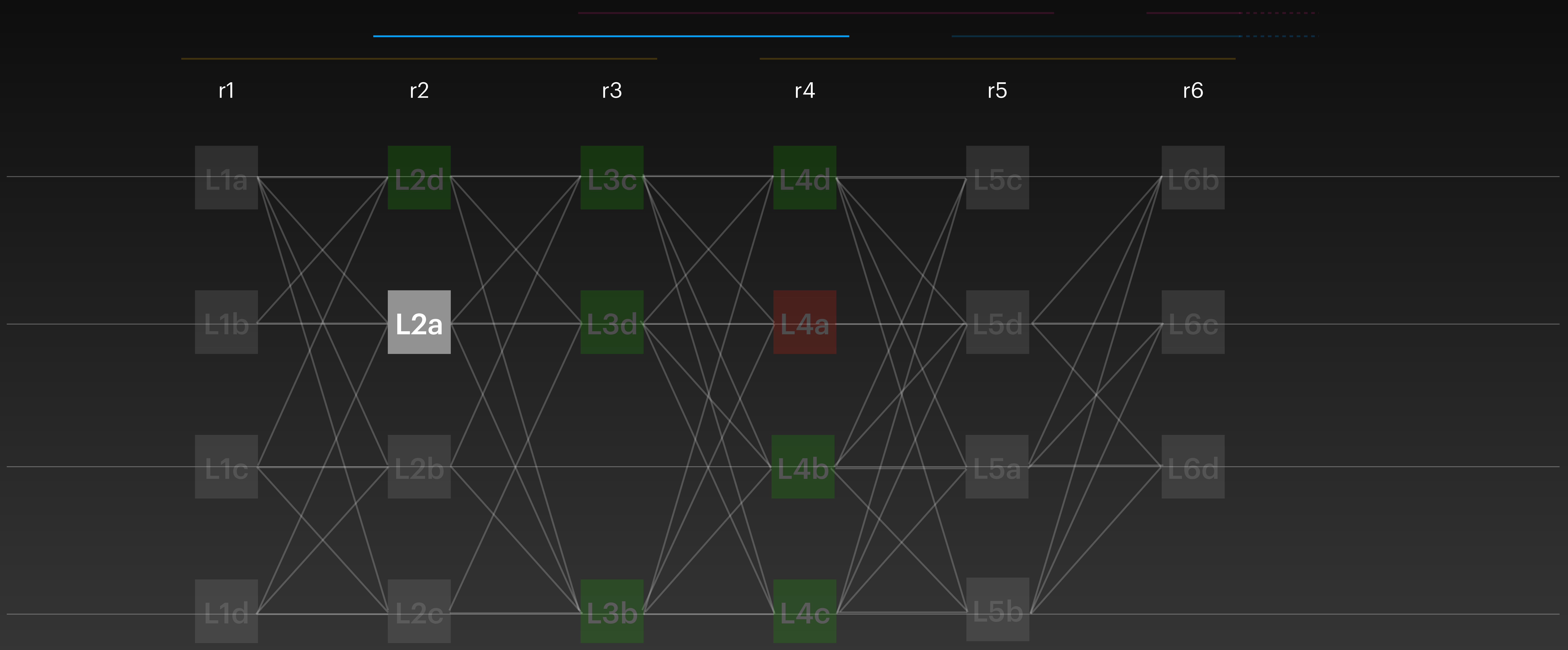

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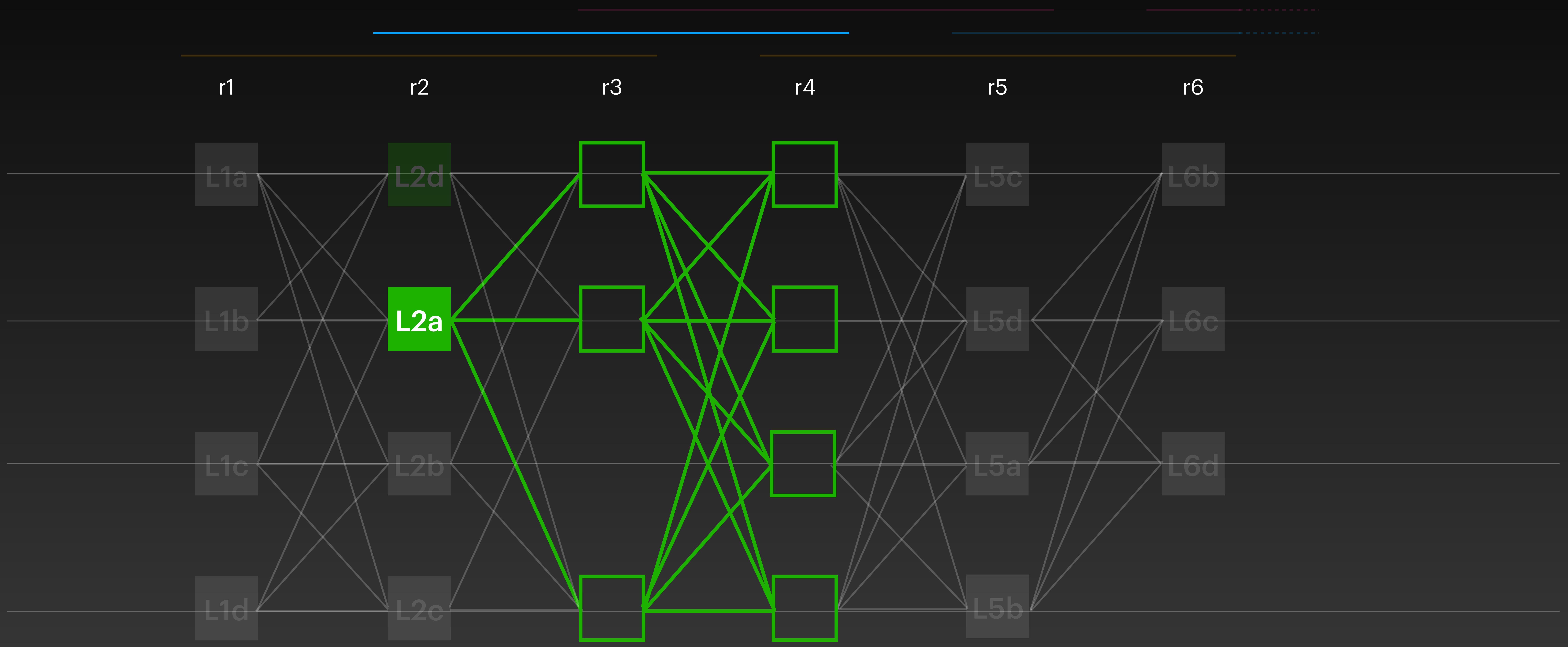

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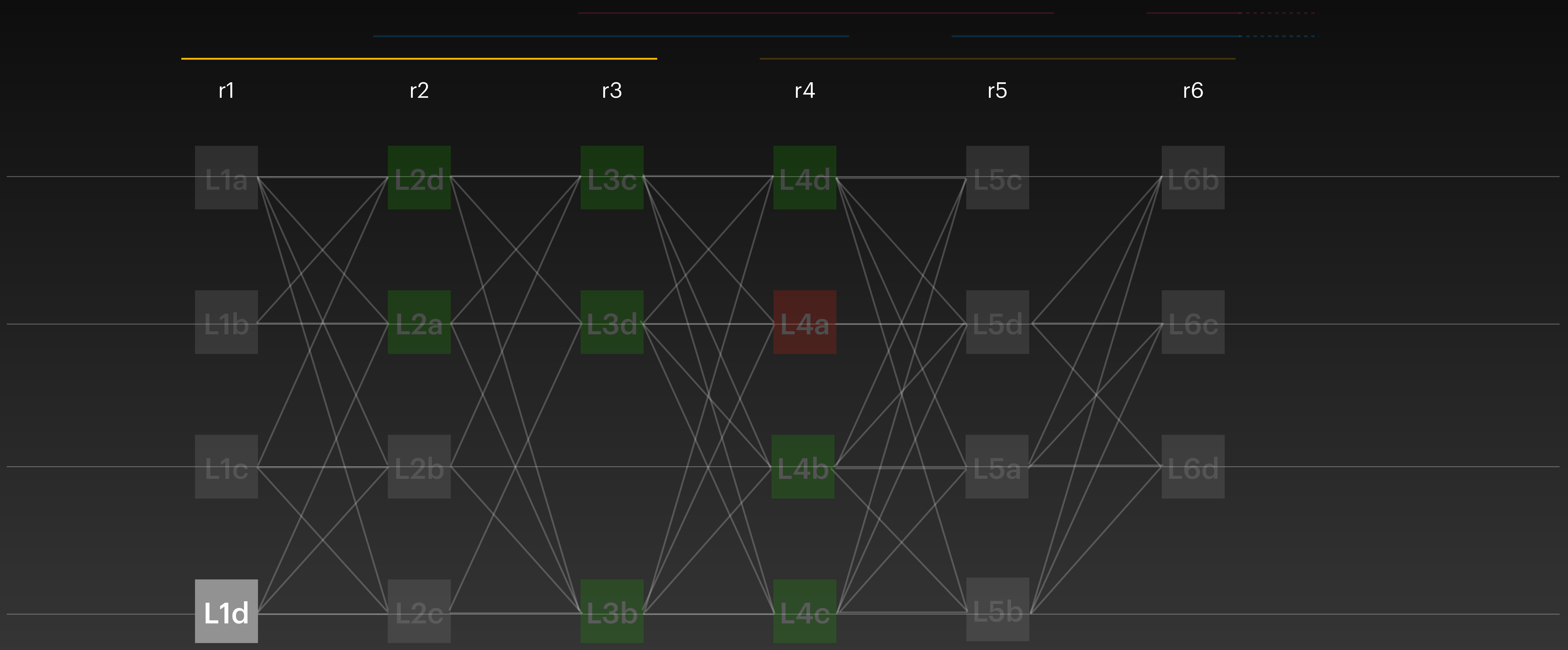

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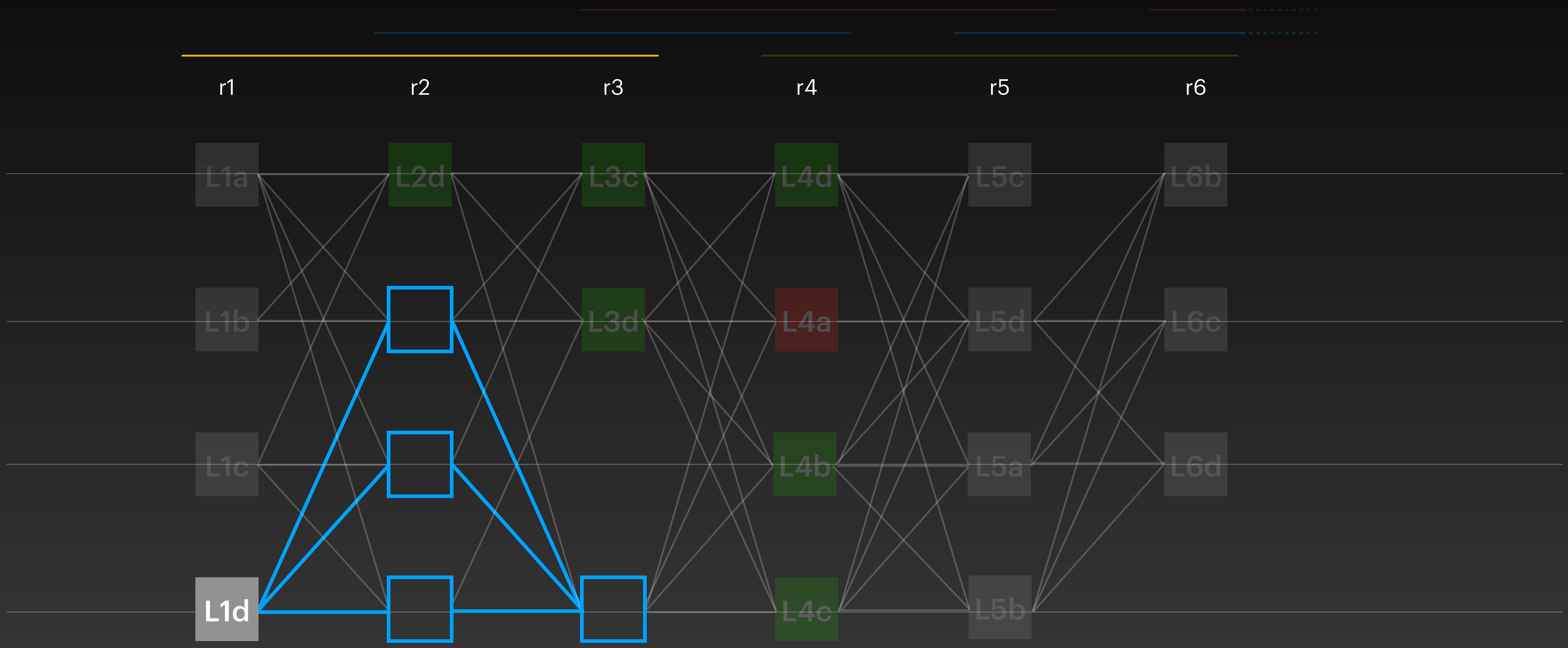

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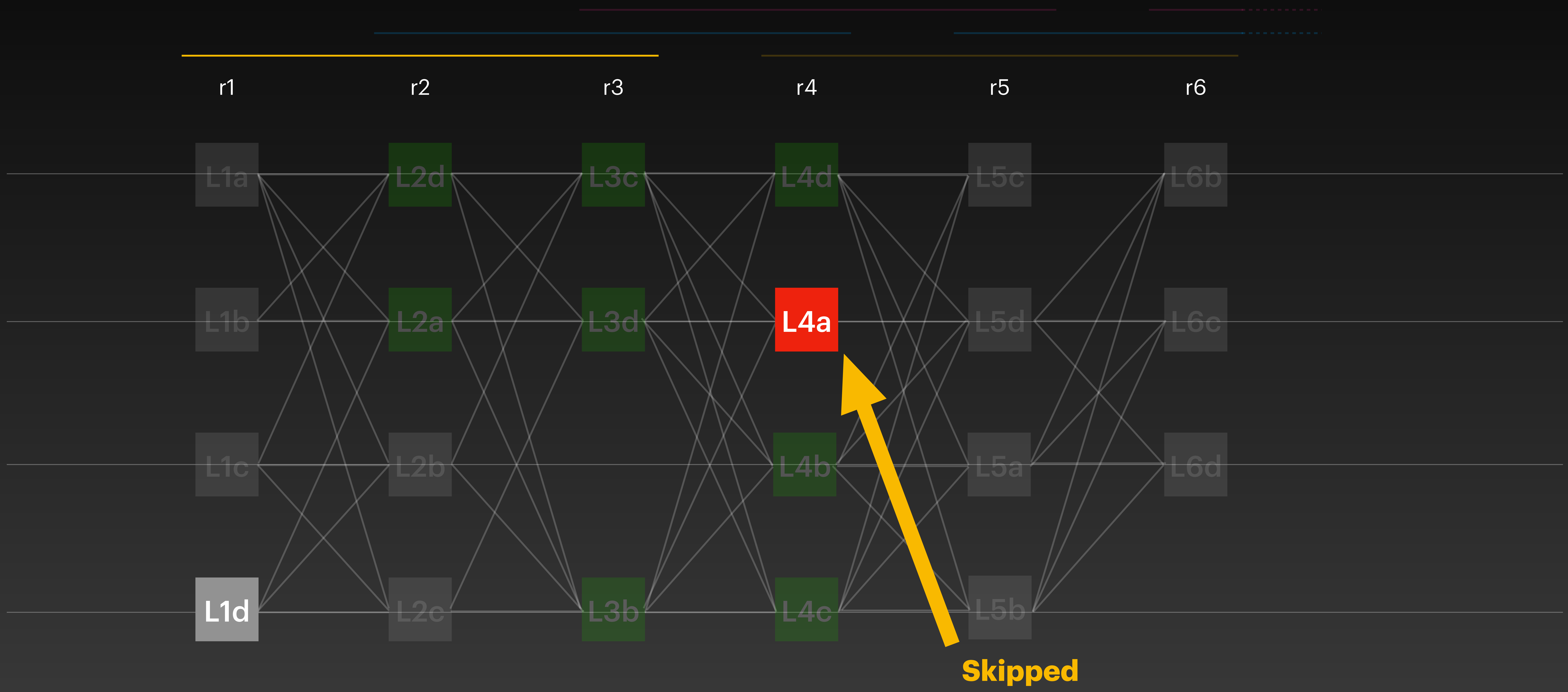

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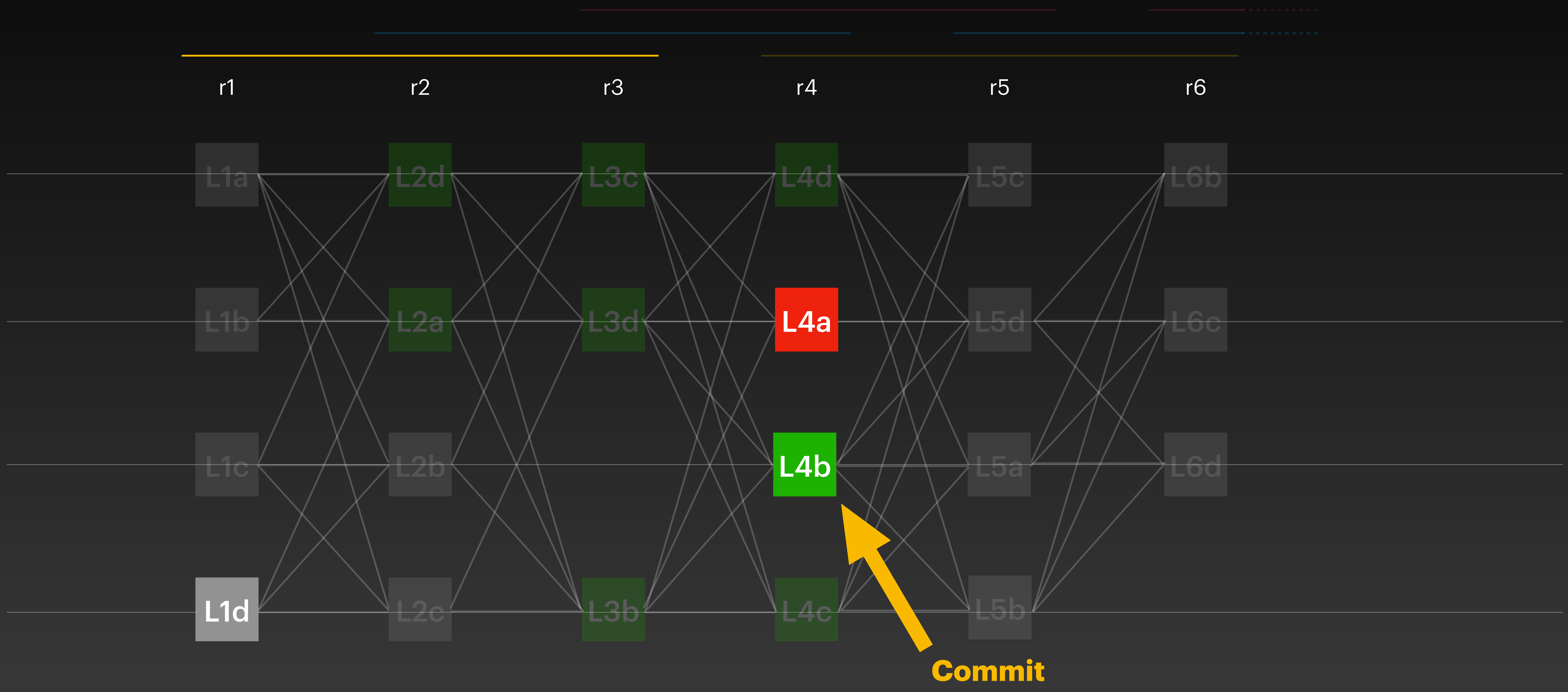

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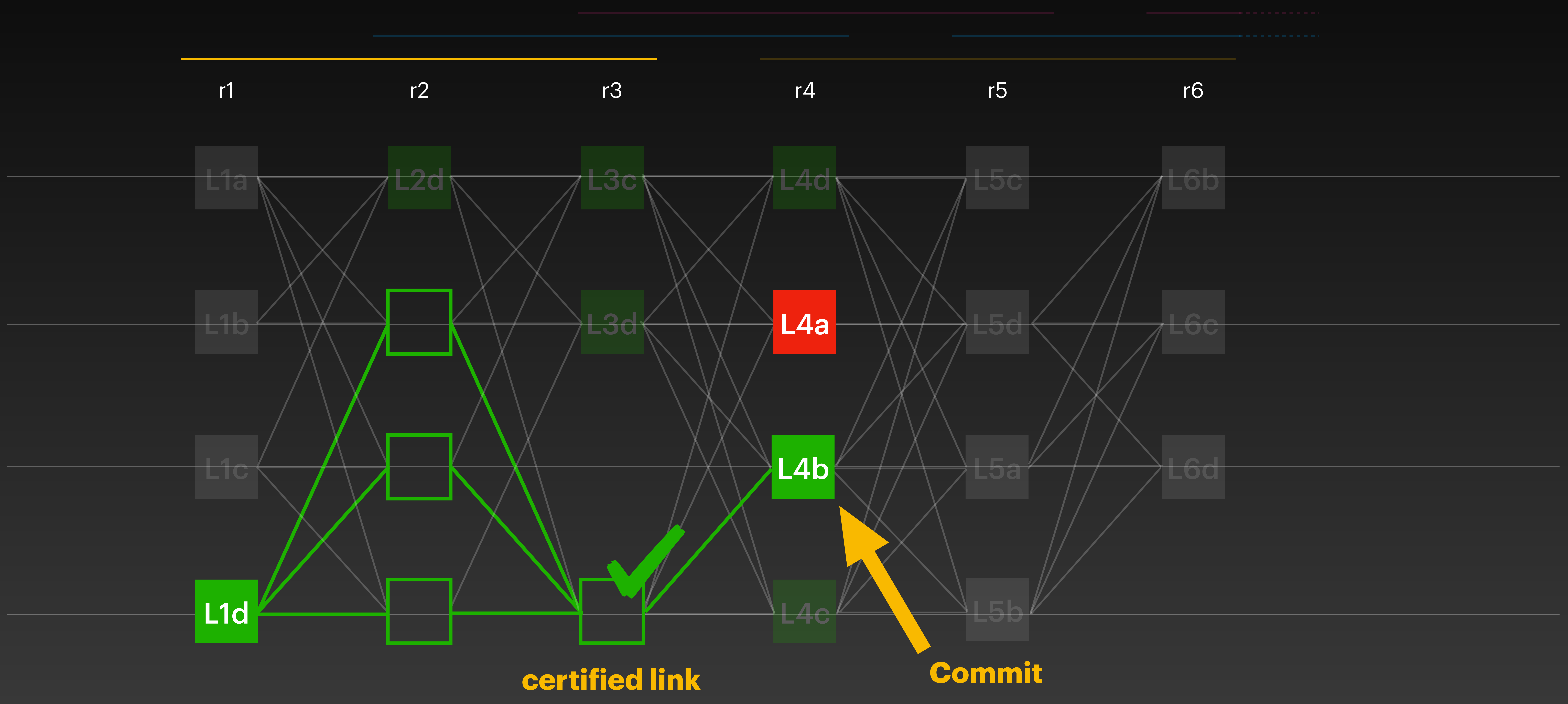

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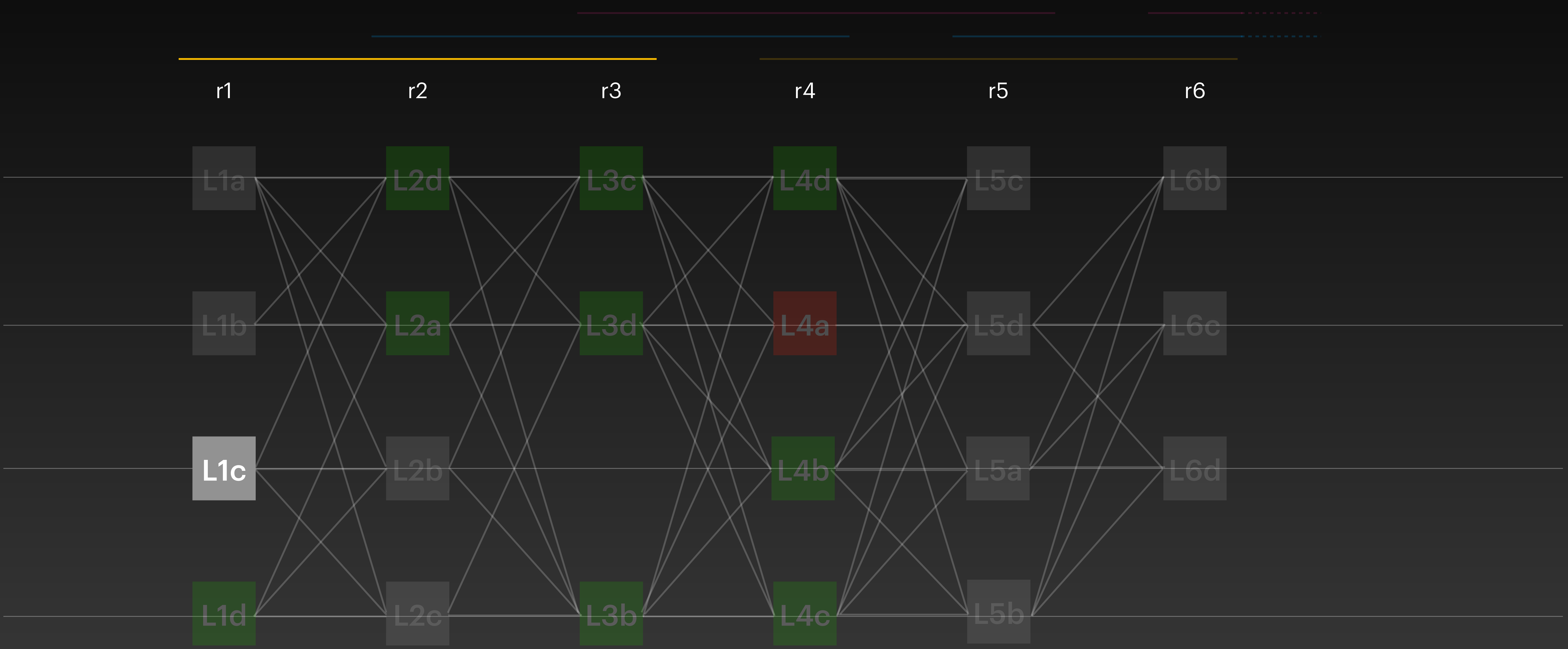

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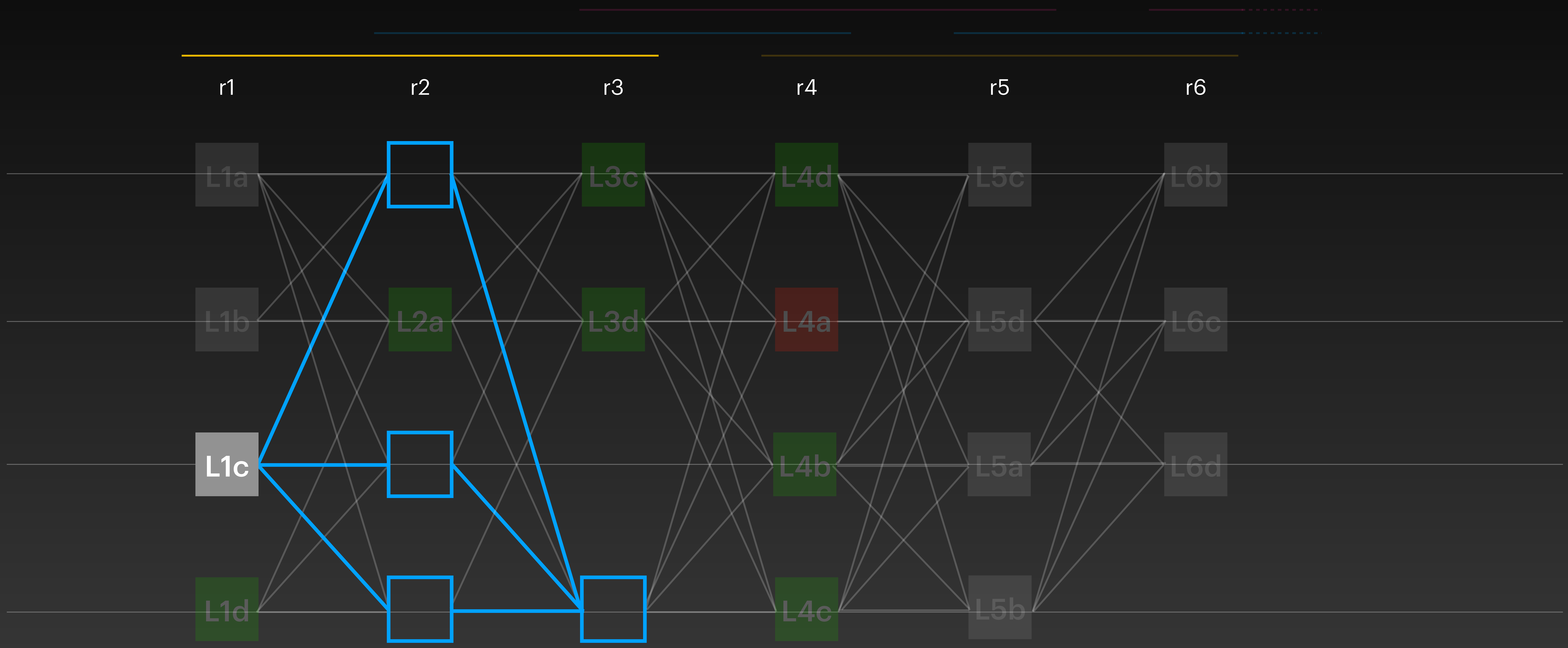

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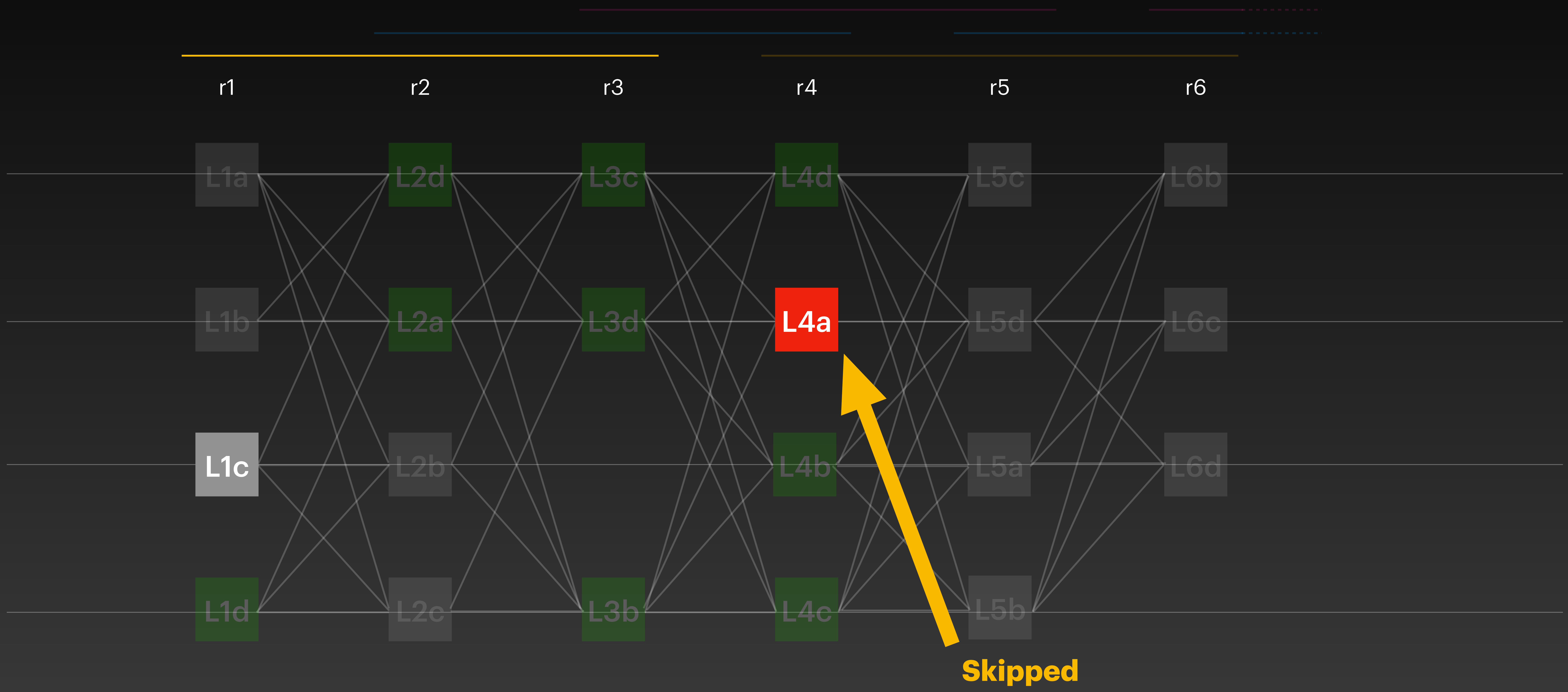

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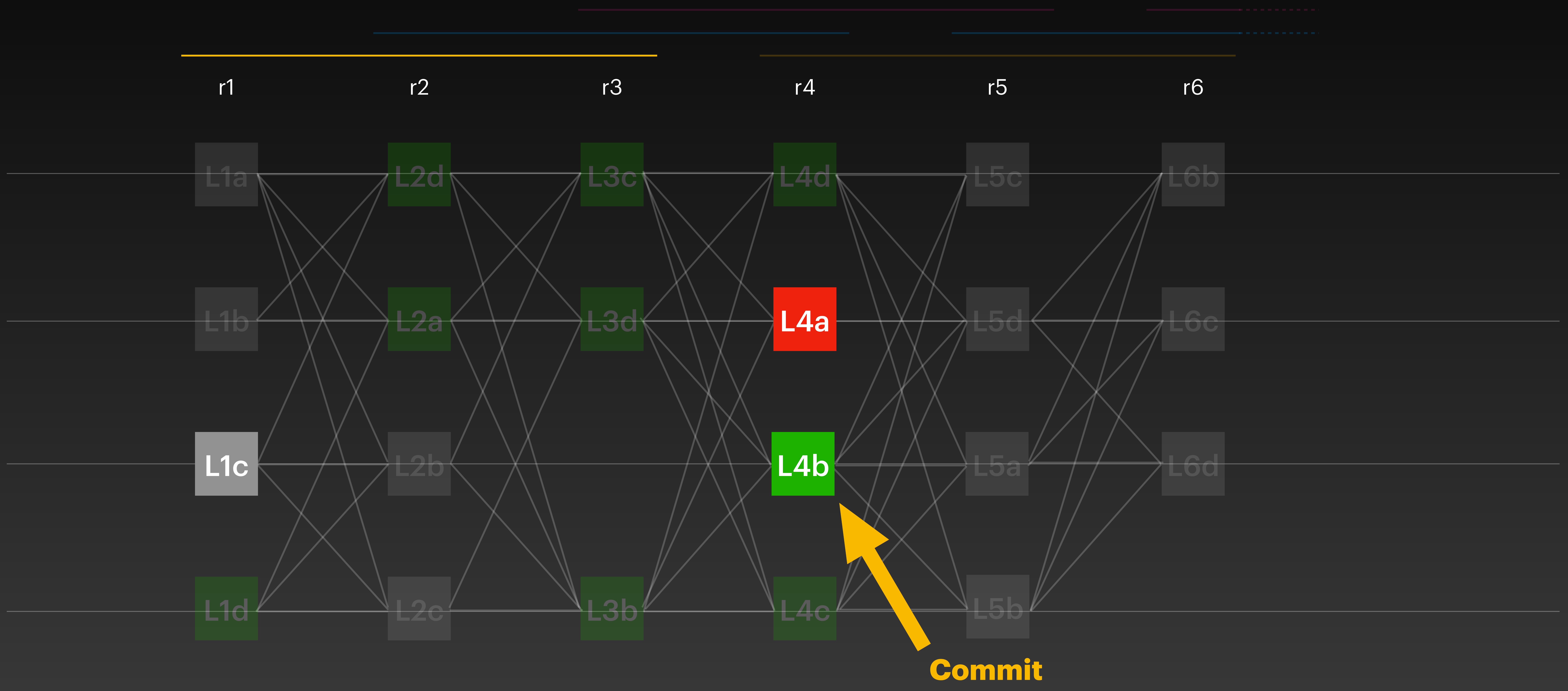

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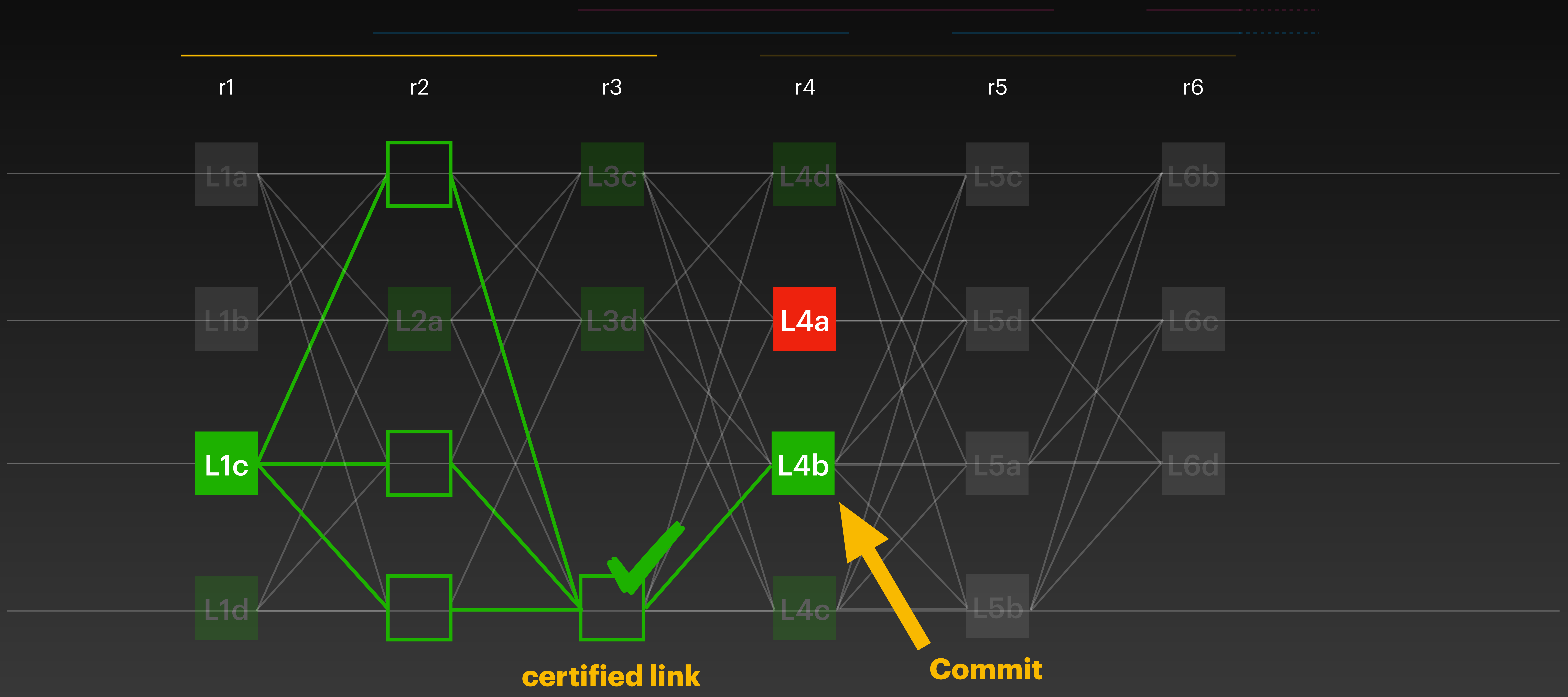

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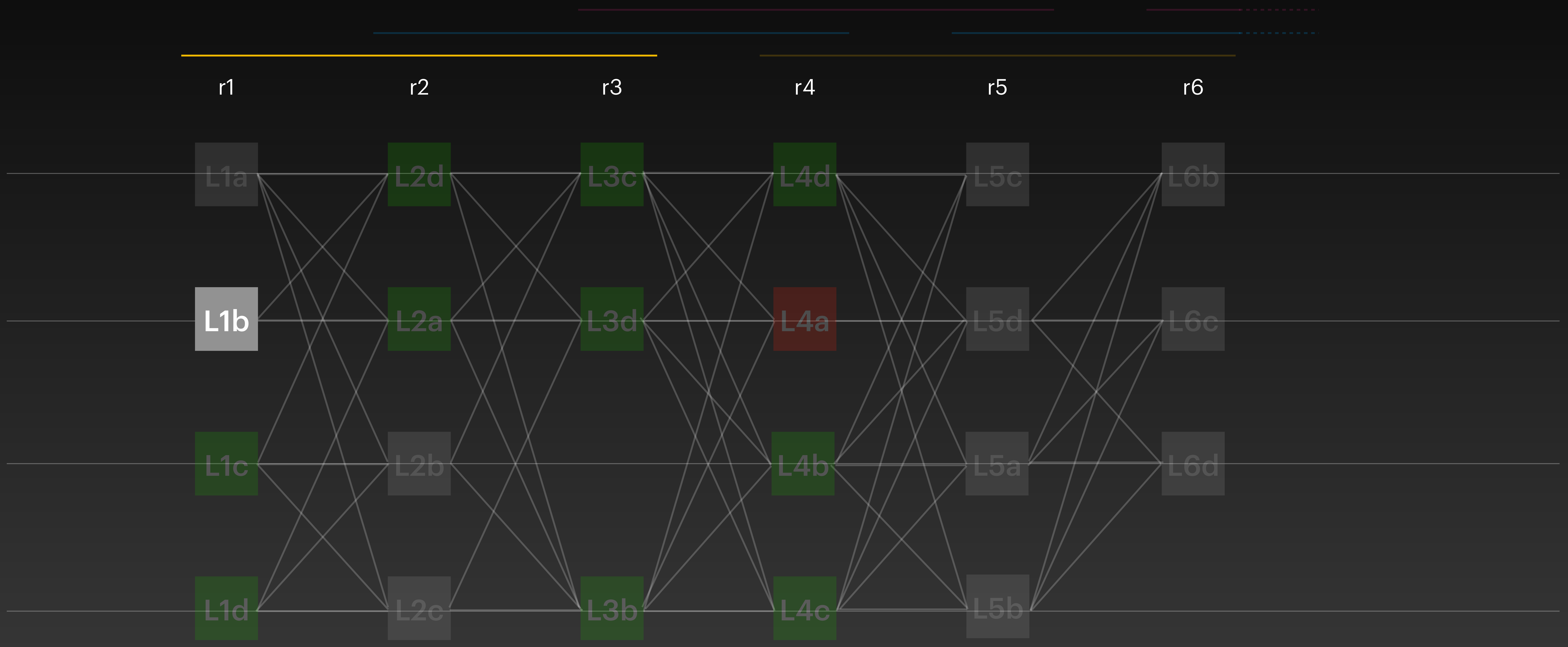
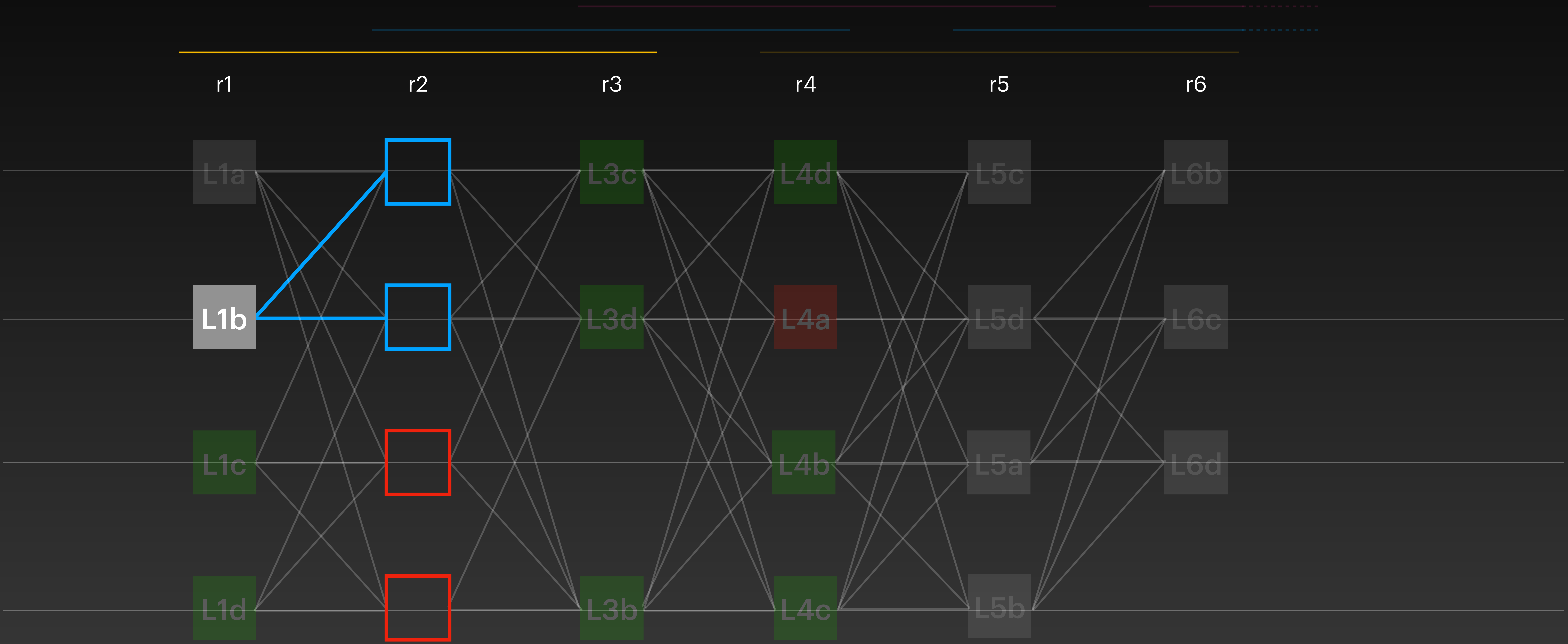
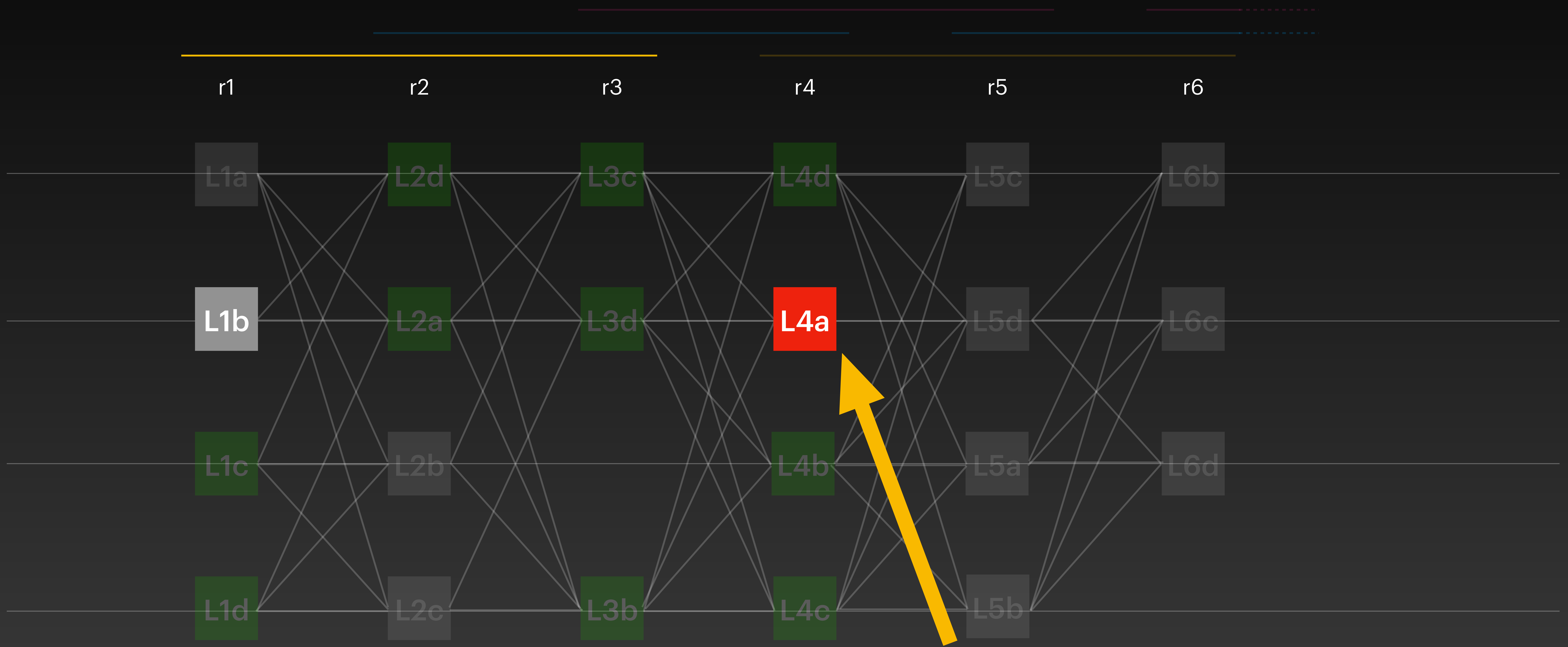


Apply Direct Rule



Apply Indirect Rule

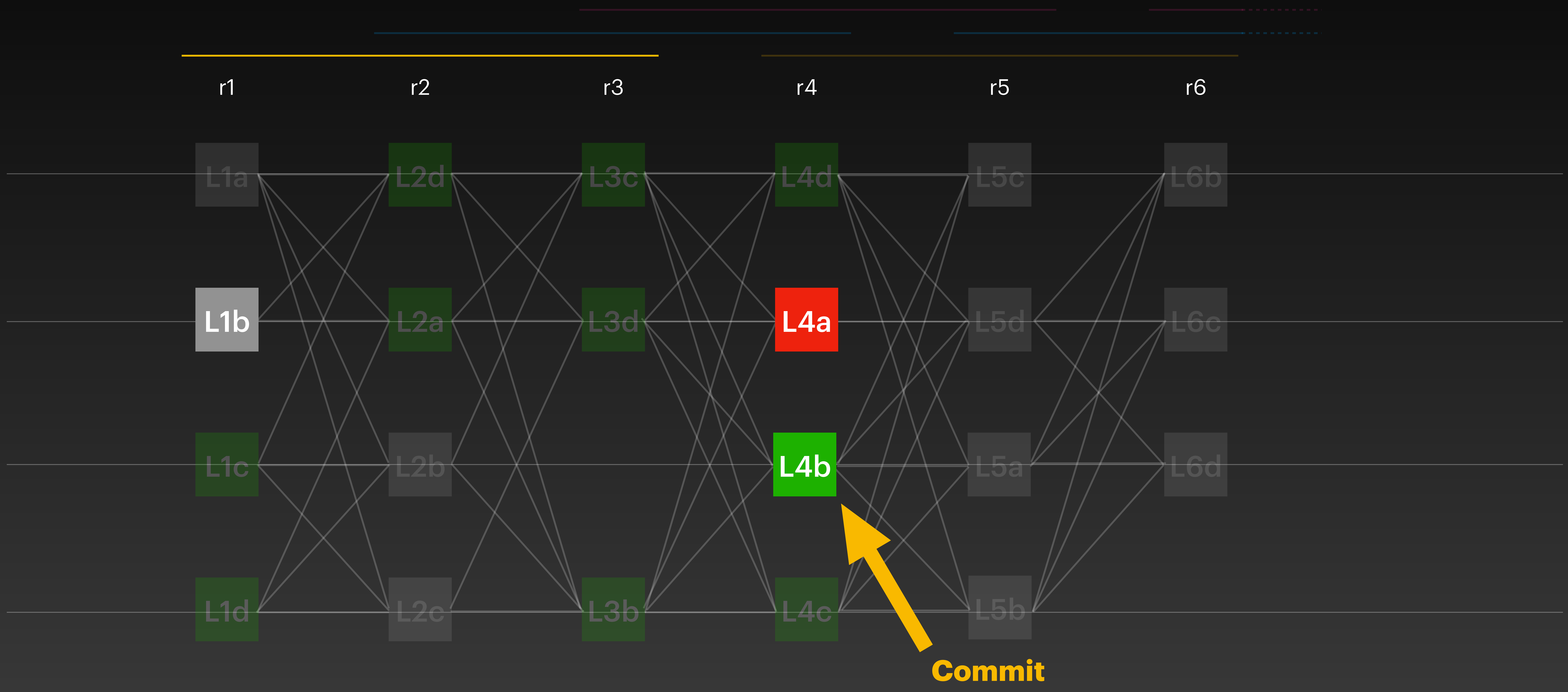
Find anchor & Check certified links



Skipped

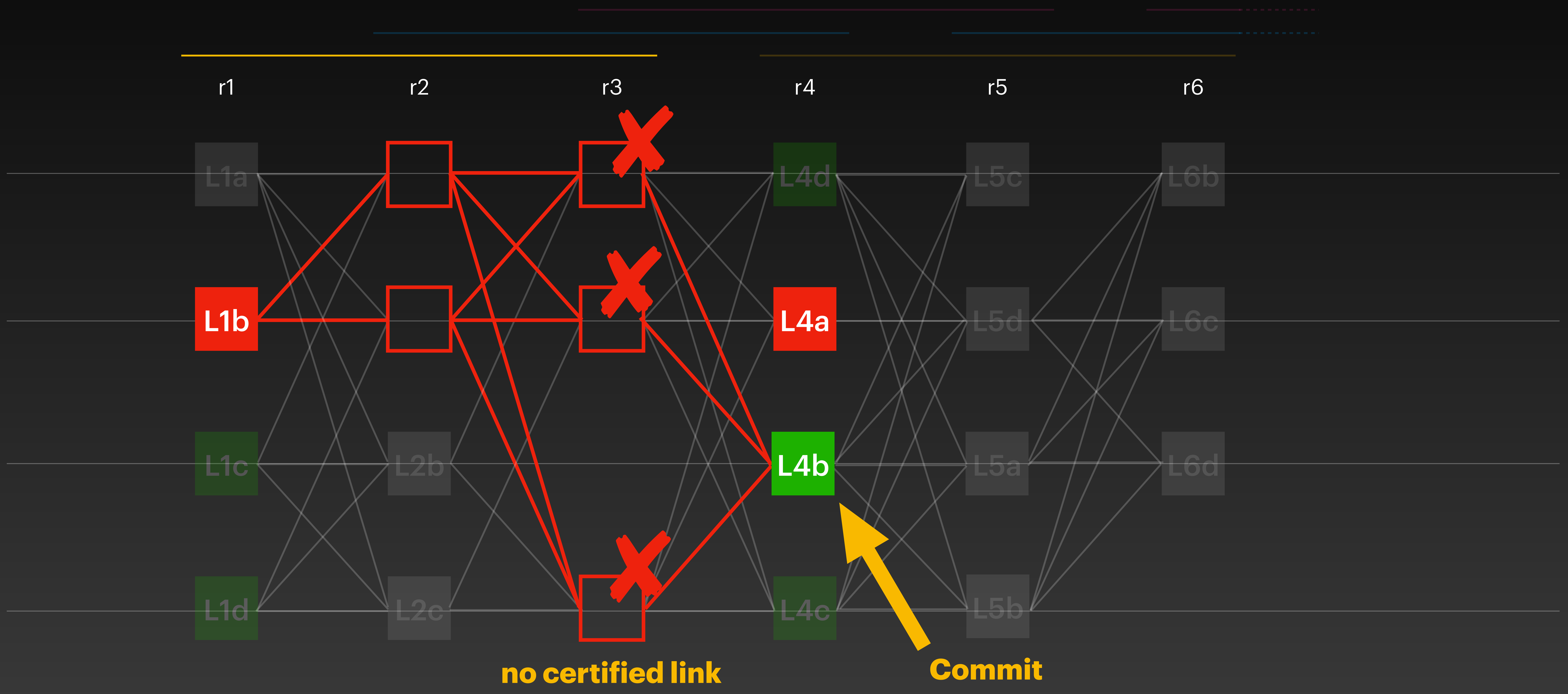
Apply Indirect Rule

Find anchor & Check certified links

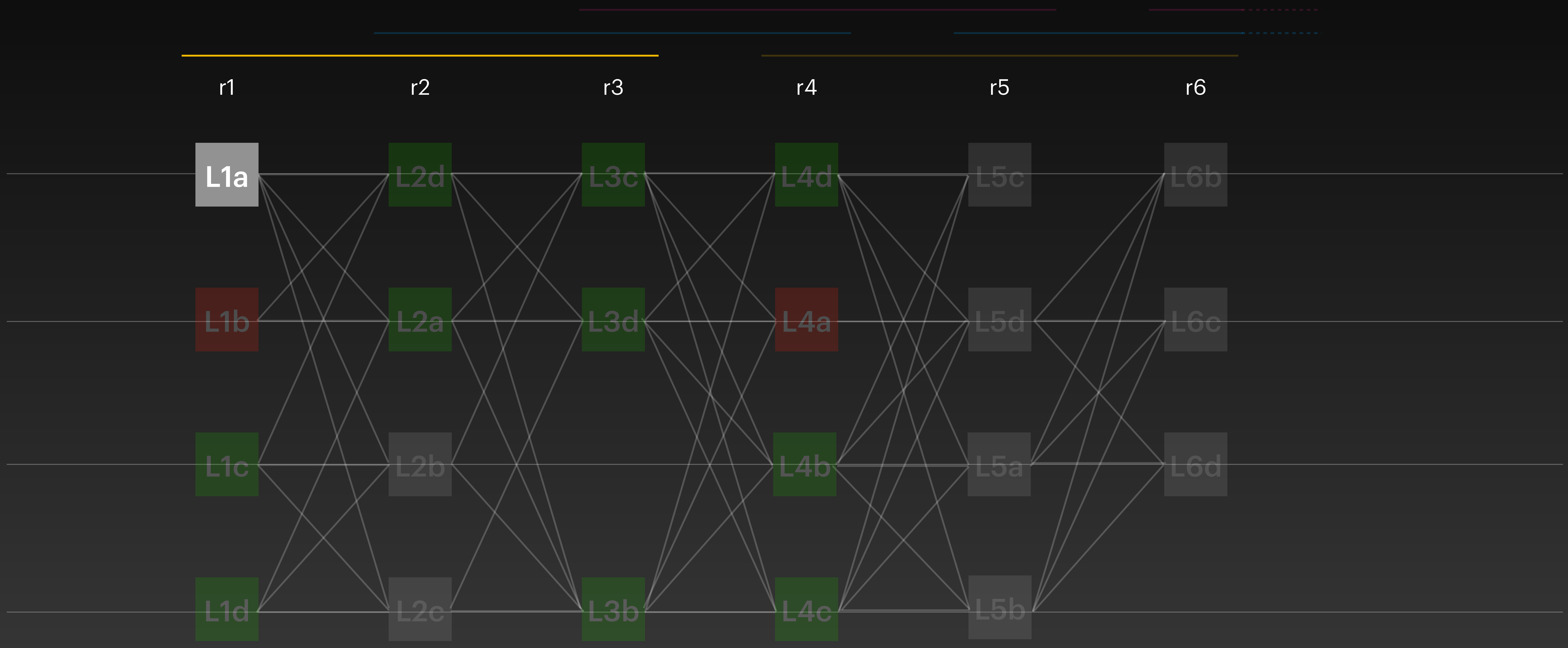


Apply Indirect Rule

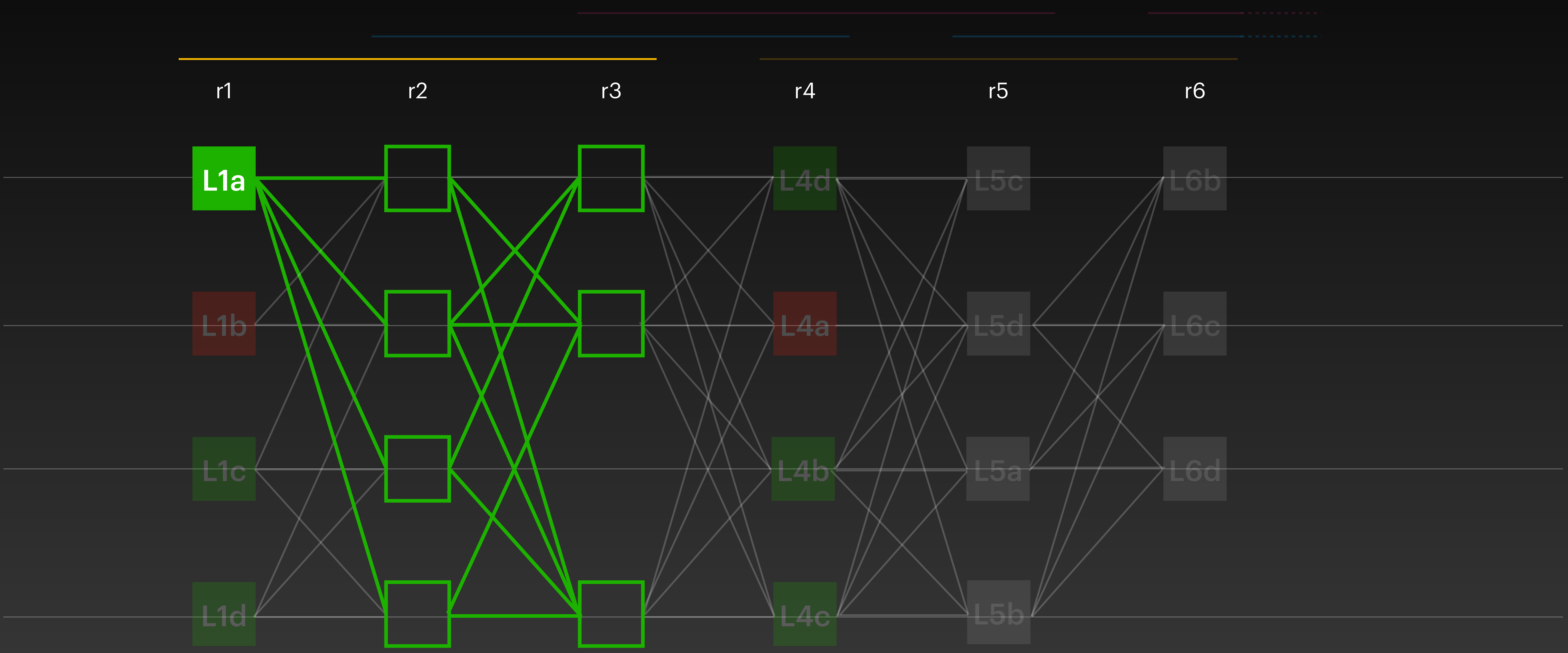
Find anchor & Check certified links



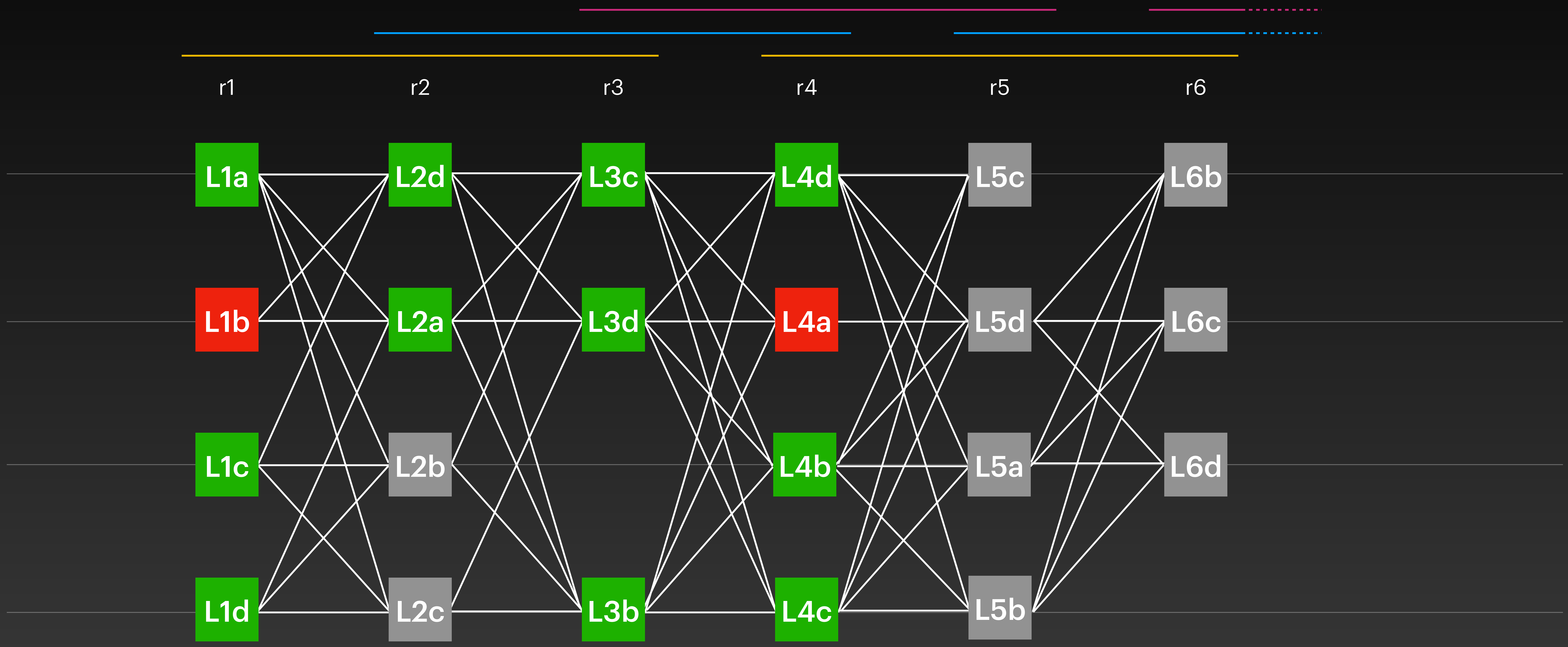
Apply Direct Rule



Apply Direct Rule

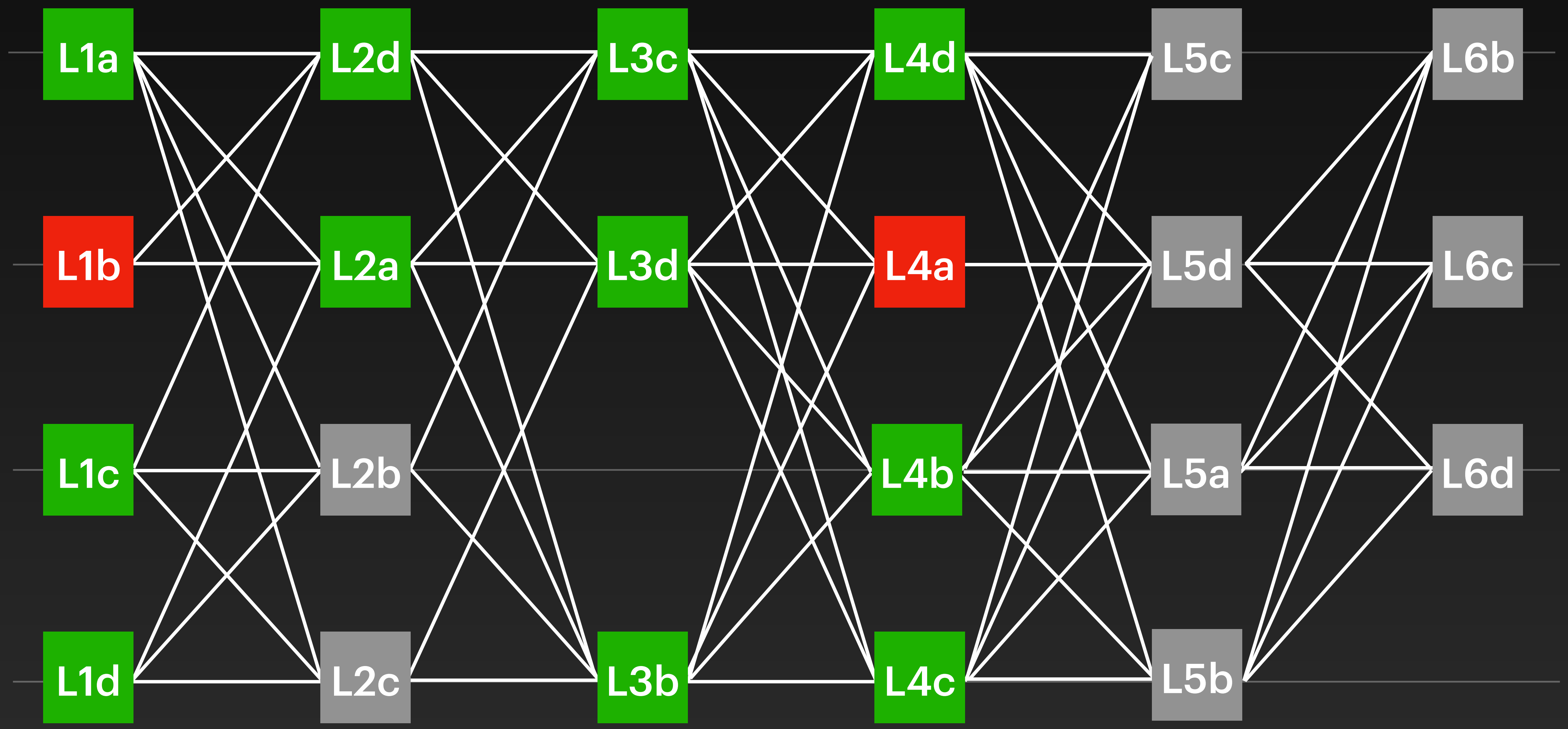


Current Status



Commit Sequence

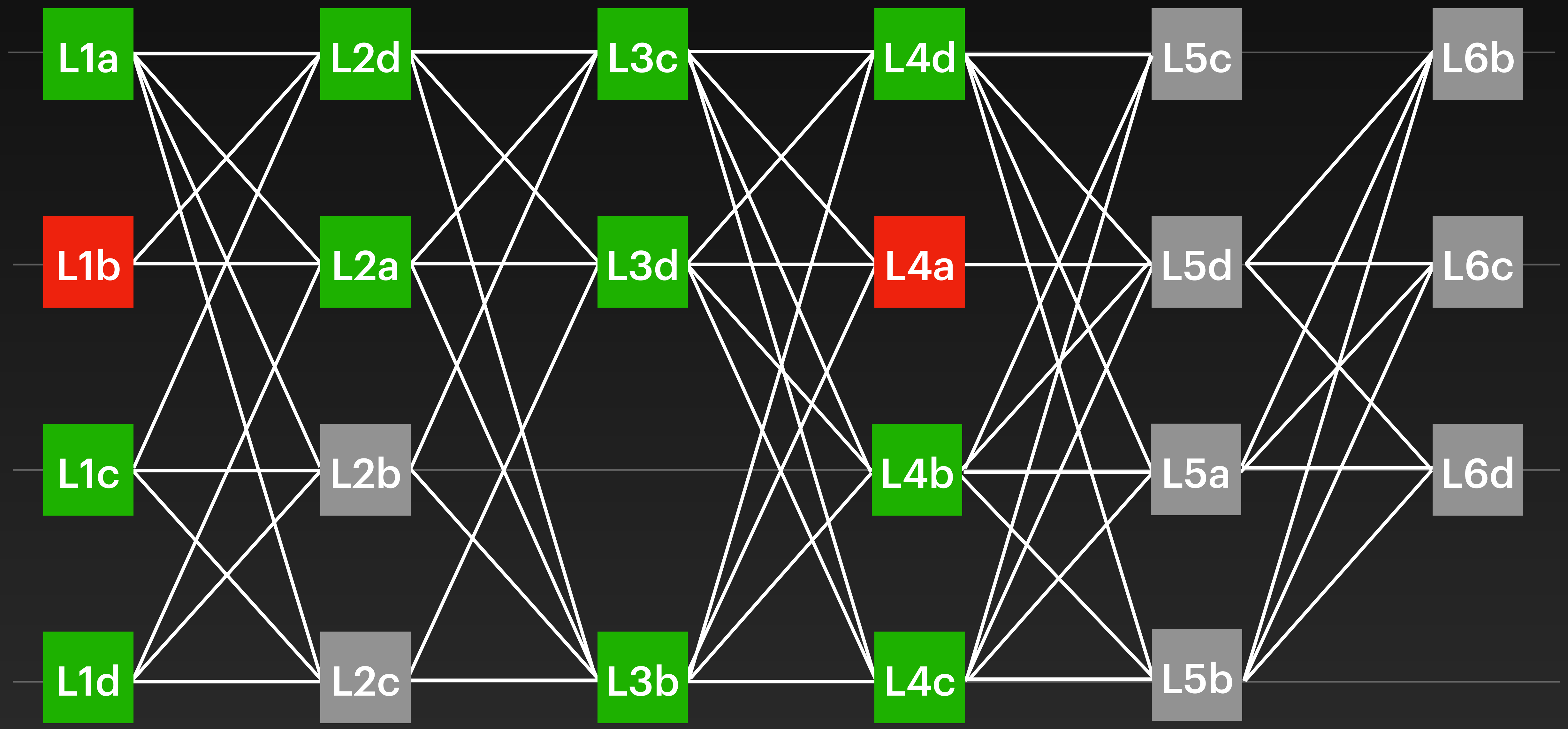
Take all leaders in order

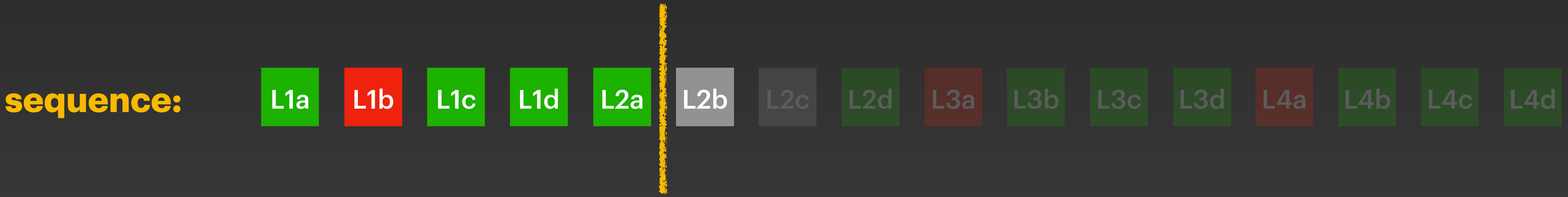


sequence: L1a L1b L1c L1d L2a L2b L2c L2d L3a L3b L3c L3d L4a L4b L4c L4d

Commit Sequence

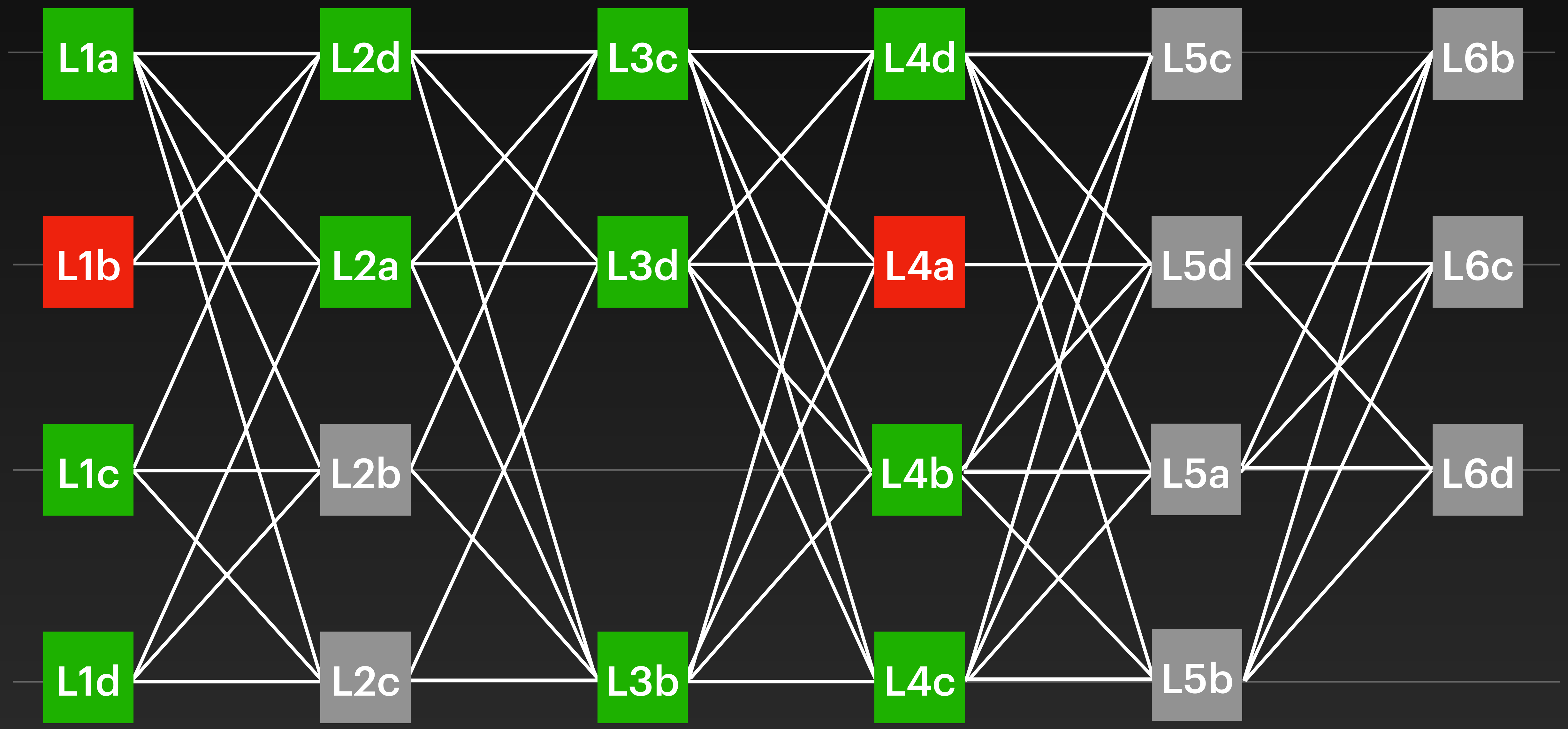
Stop at the first Undecided leader





Current Status

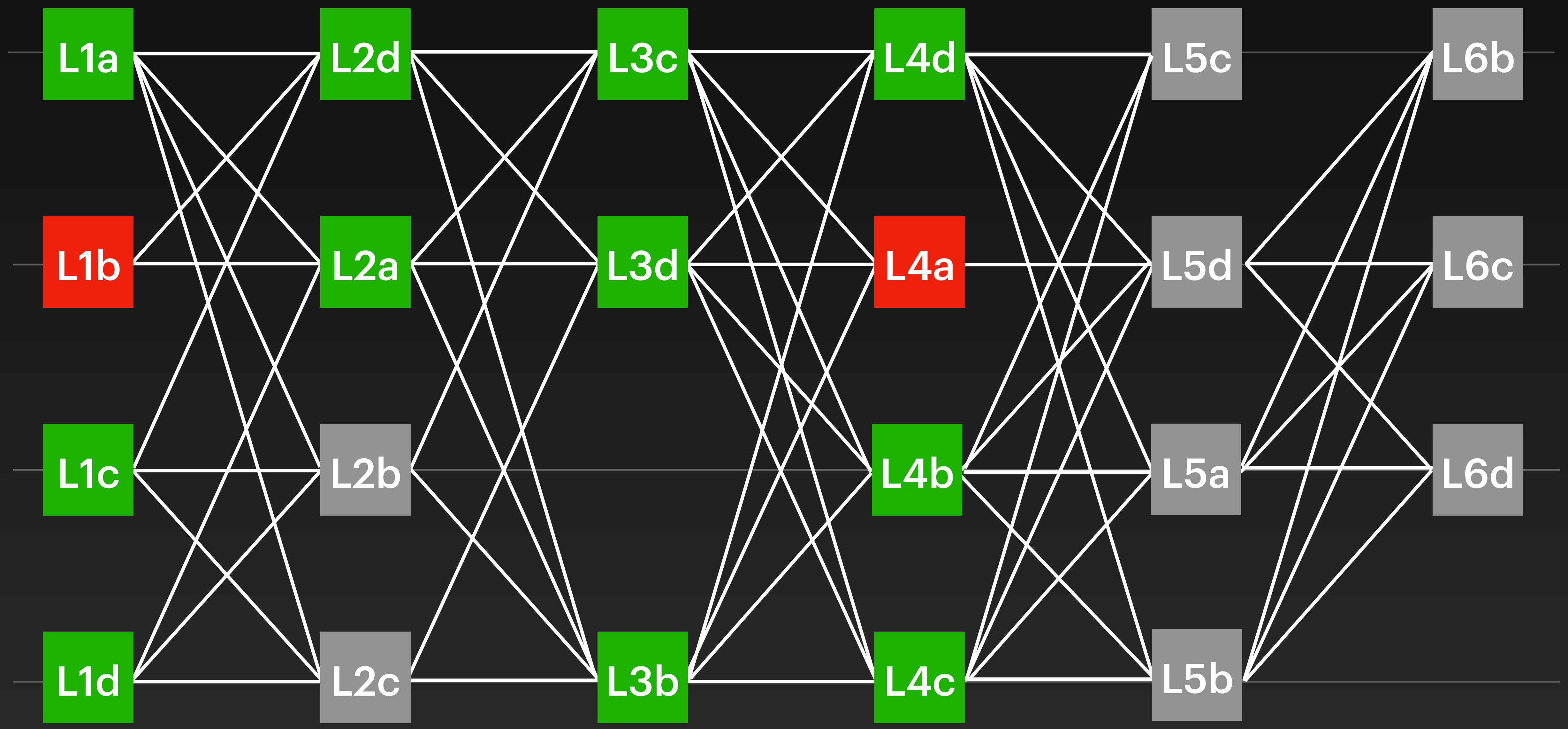
Remove skipped leaders



sequence: L1a L1b L1c L1d L2a | L2b L2c L2d L3a L3b L3c L3d L4a L4b L4c L4d

Current Status

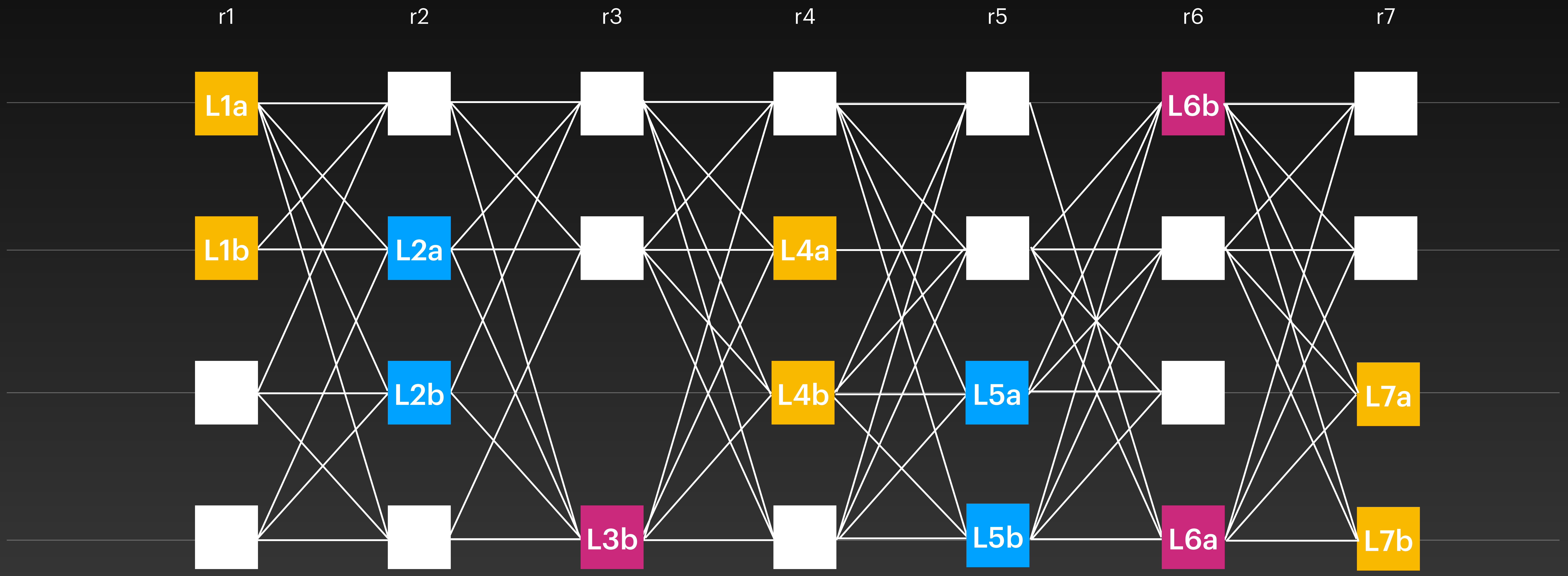
Remove skipped leaders



sequence: L1a L1c L1d L2a

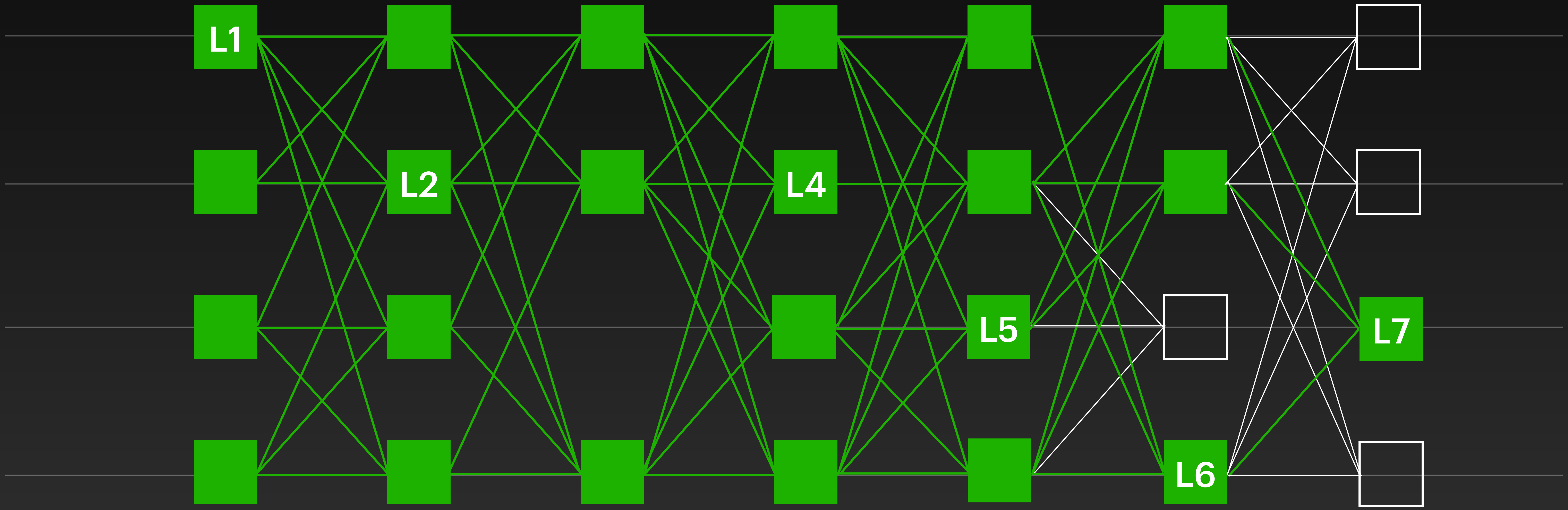
Practical Implementation

Select only 2 leaders per round



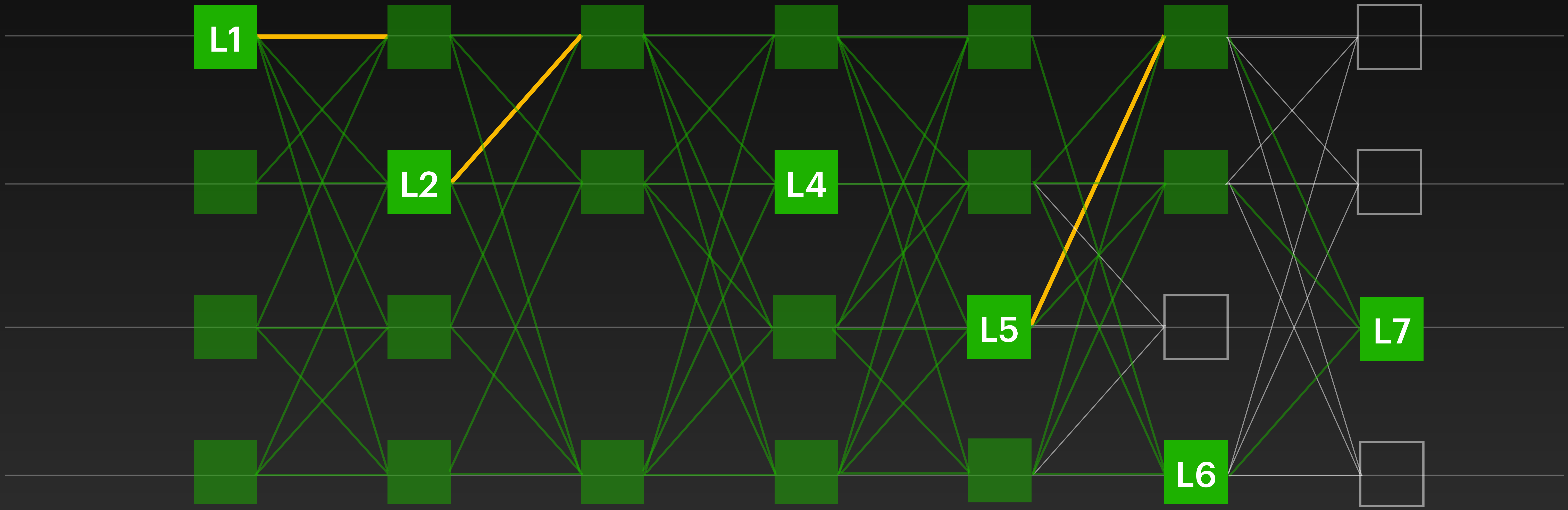
HammerHead

Compute Reputation Scores



HammerHead

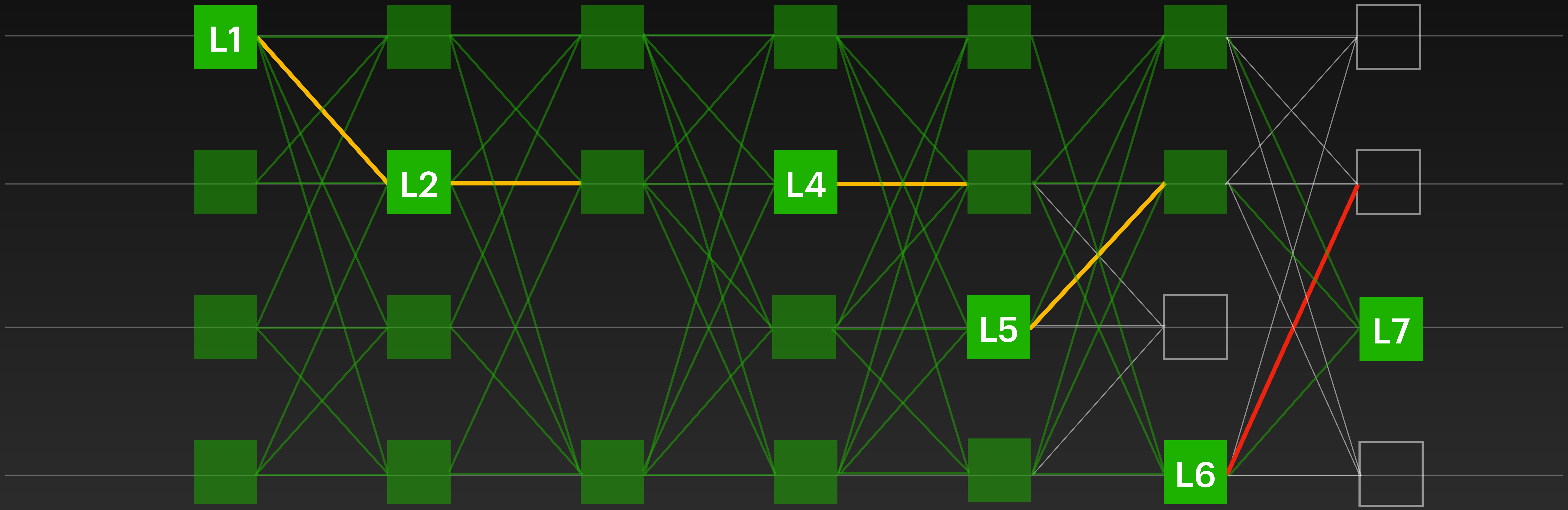
Compute Reputation Scores



node 1: 3

HammerHead

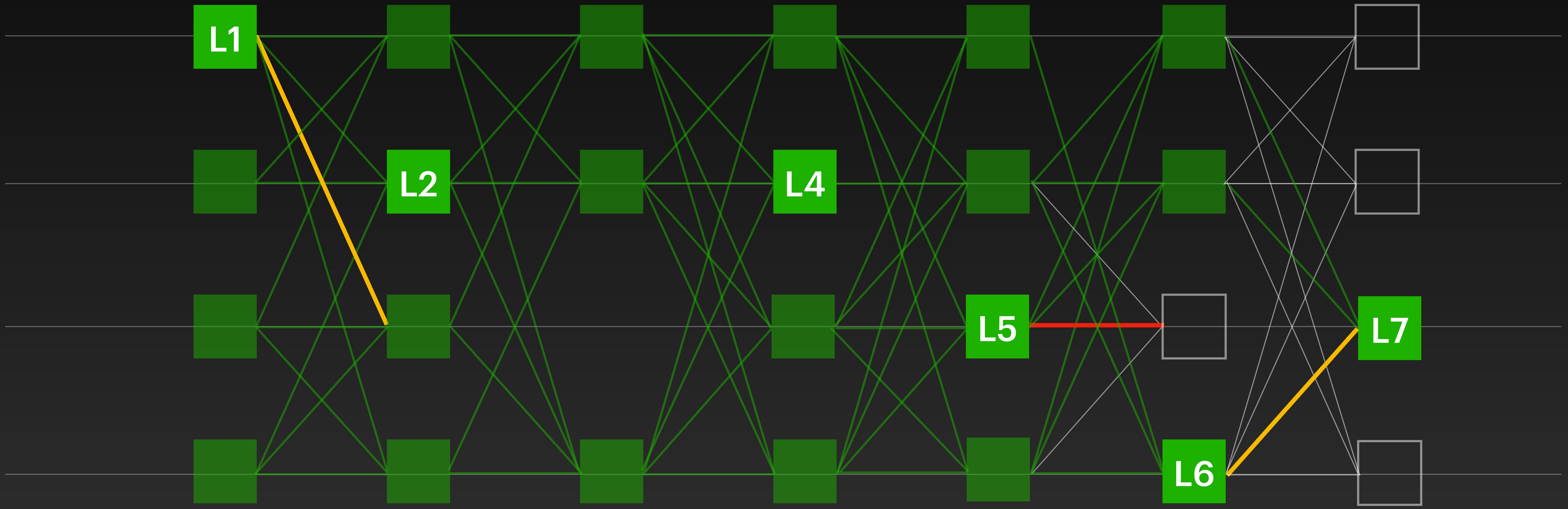
Compute Reputation Scores



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

HammerHead

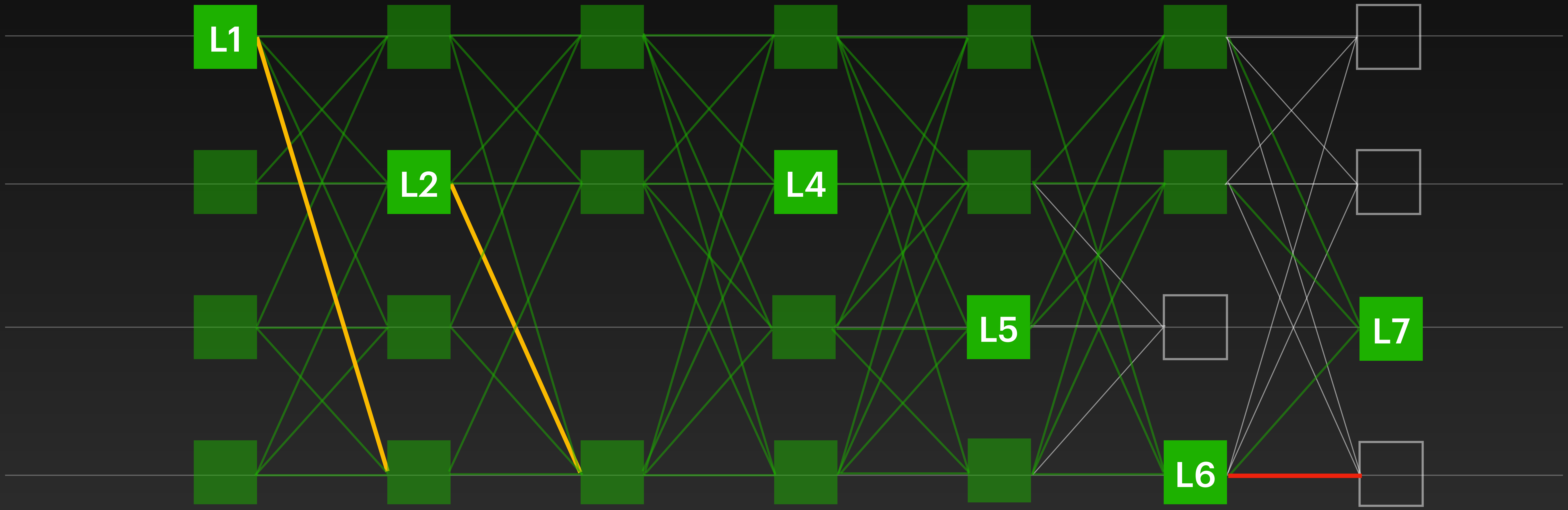
Compute Reputation Scores



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

HammerHead

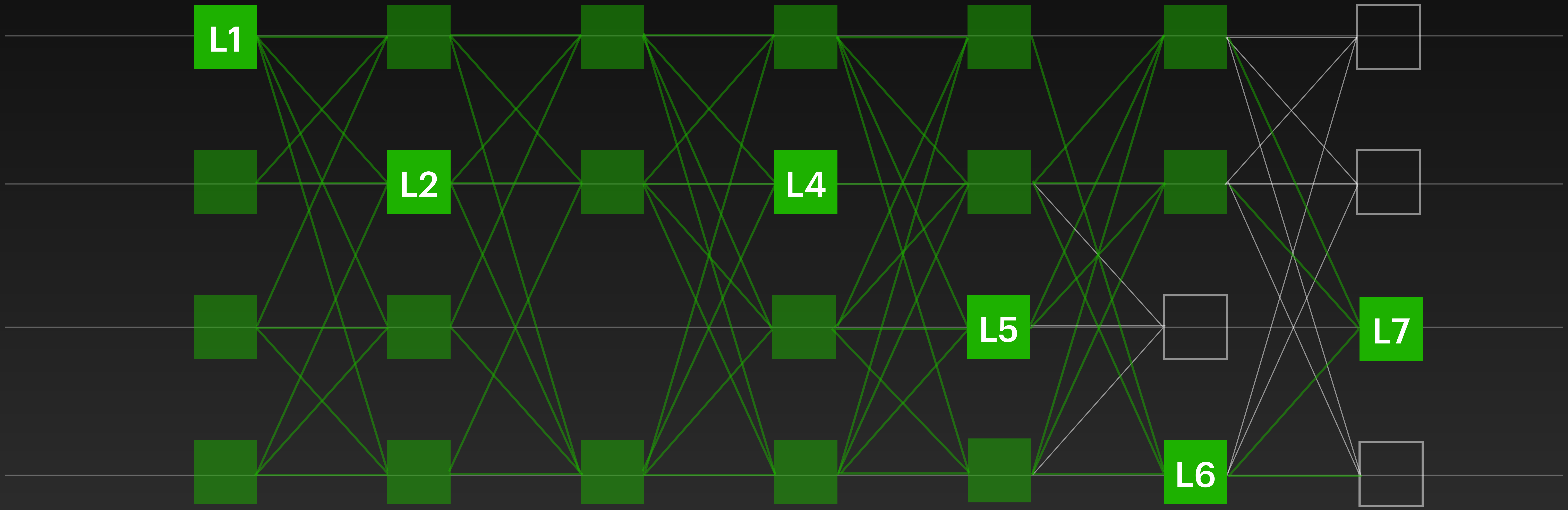
Compute Reputation Scores



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

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

owned: Tx1

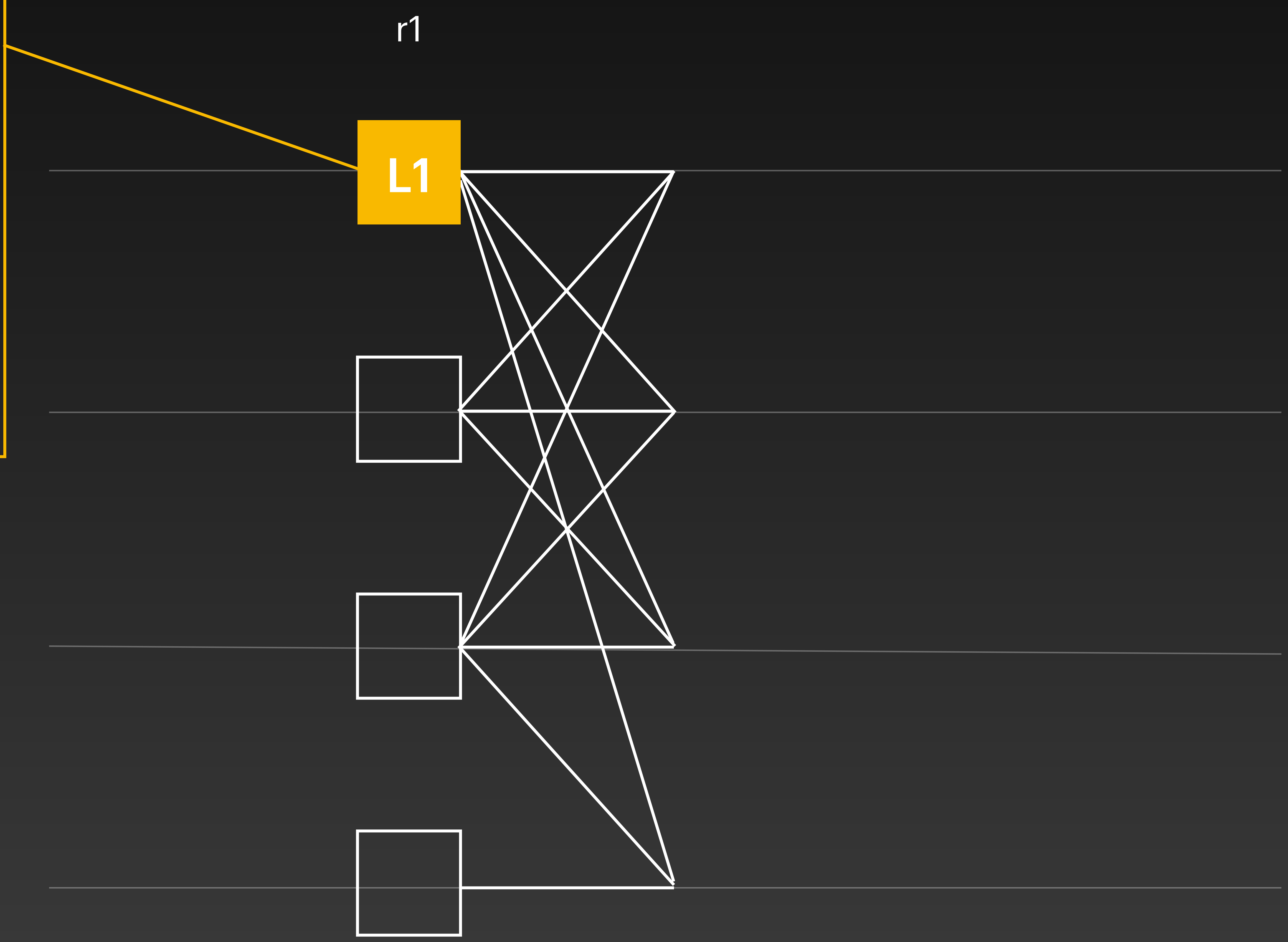
shared: Tx2

owned: Tx3

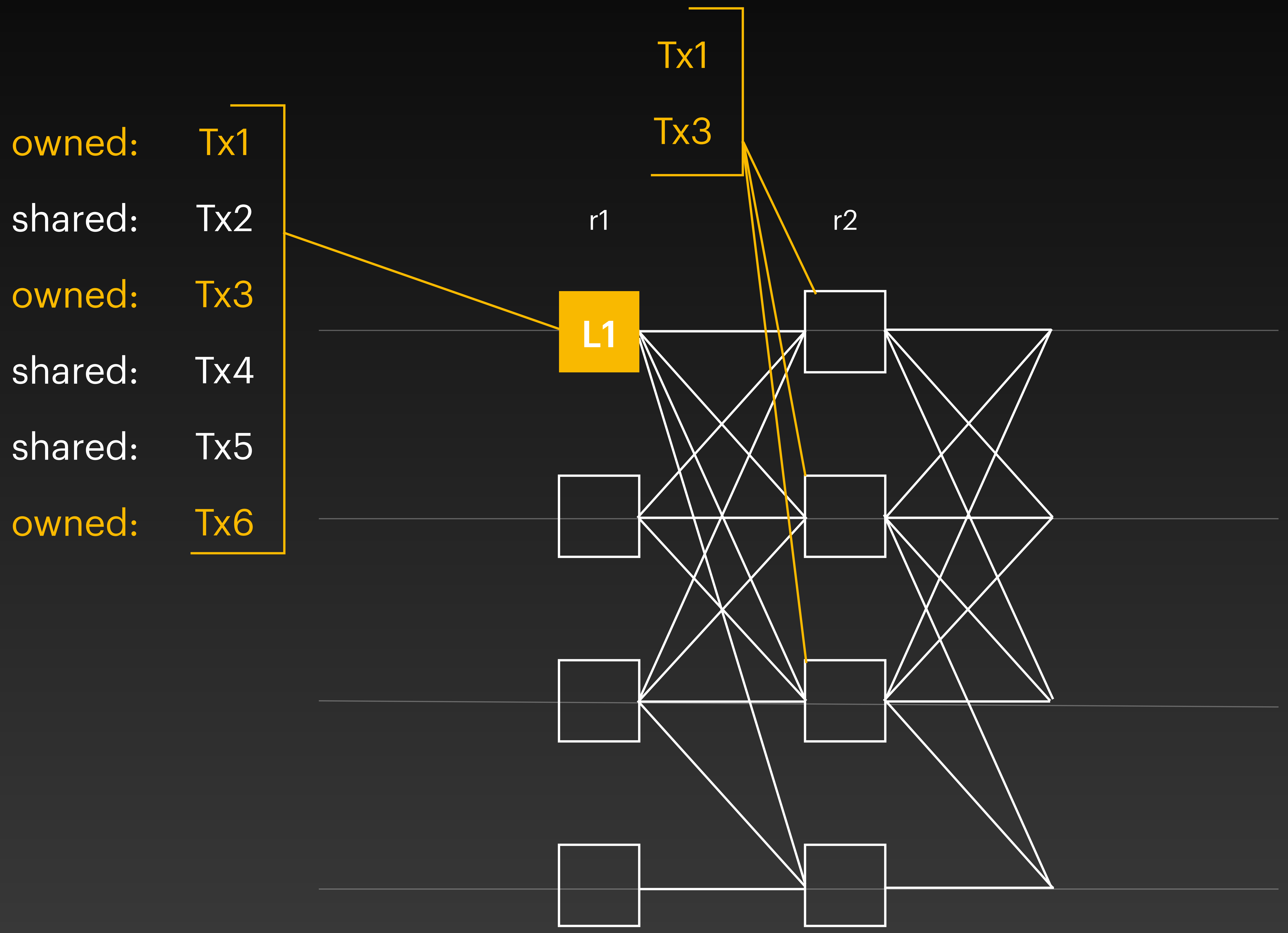
shared: Tx4

shared: Tx5

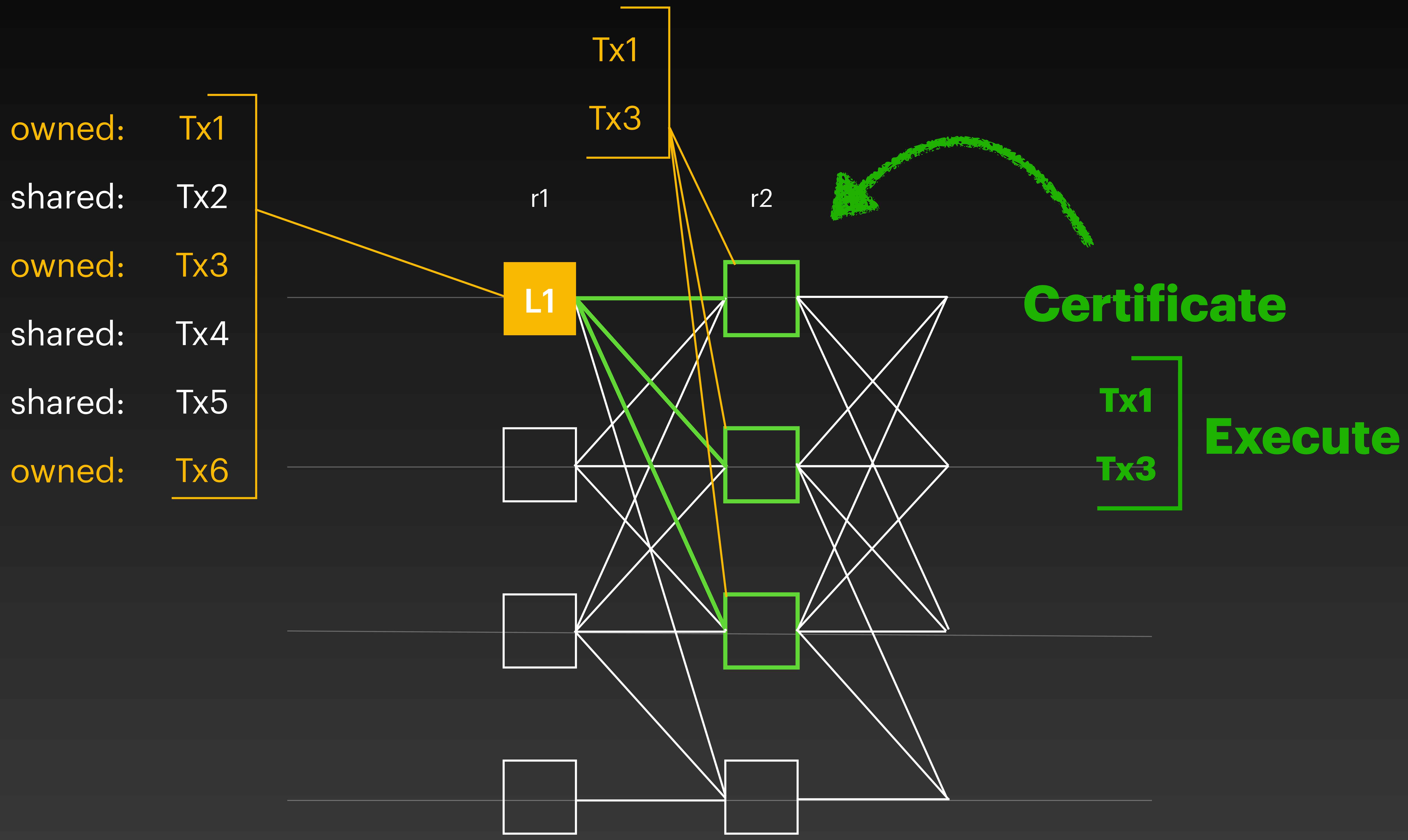
owned: Tx6



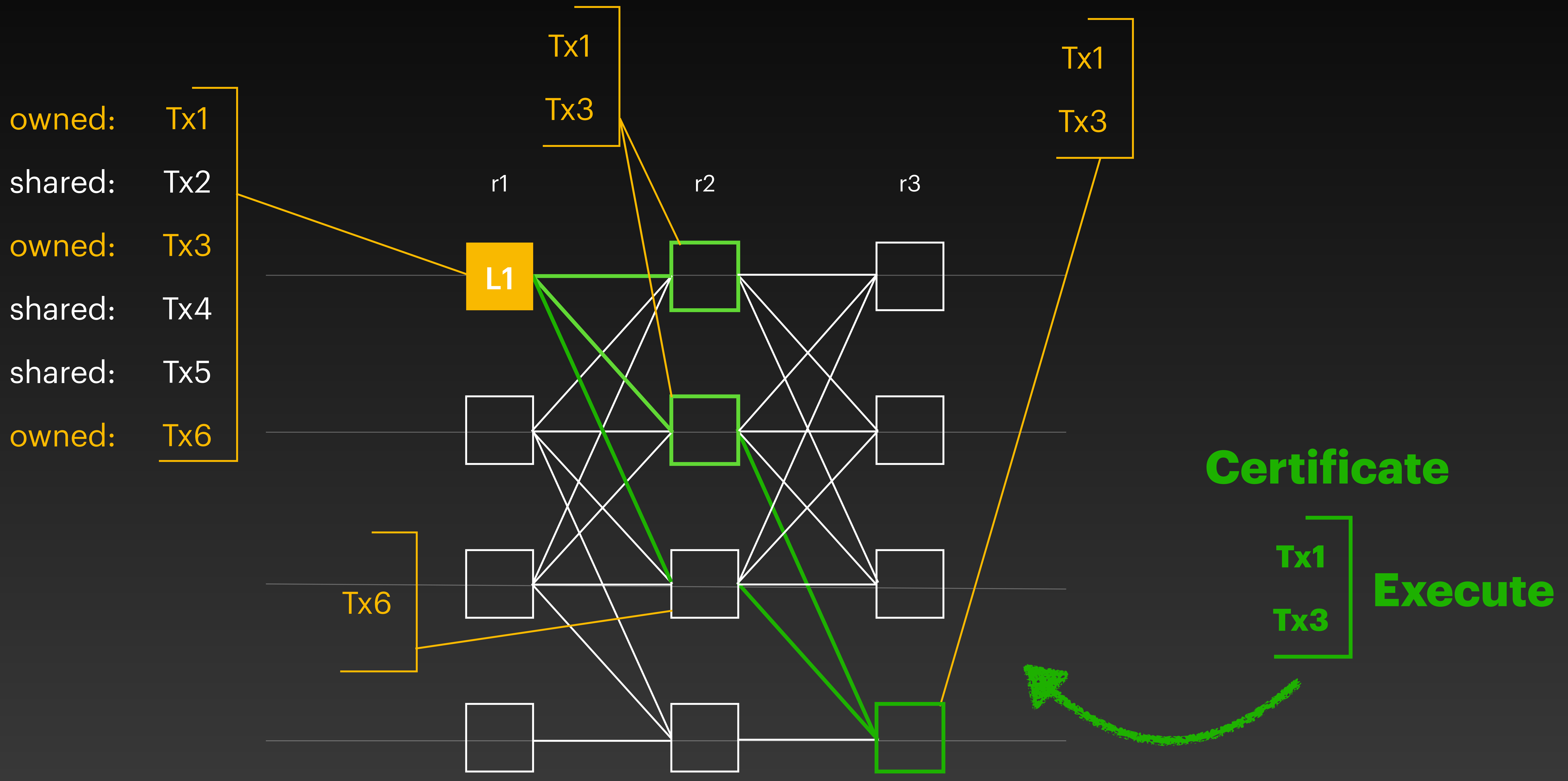
Fast Execution



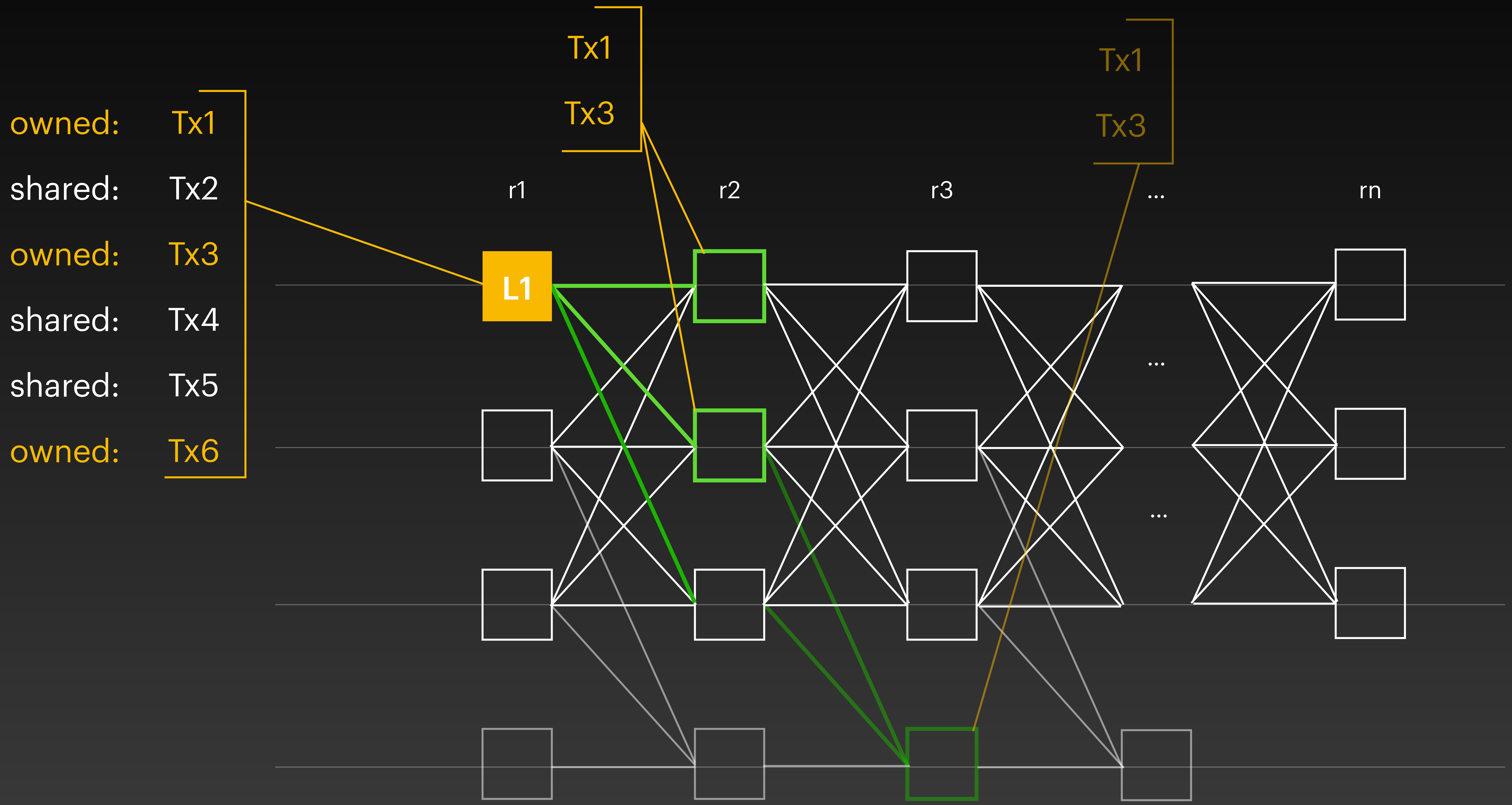
Fast Execution



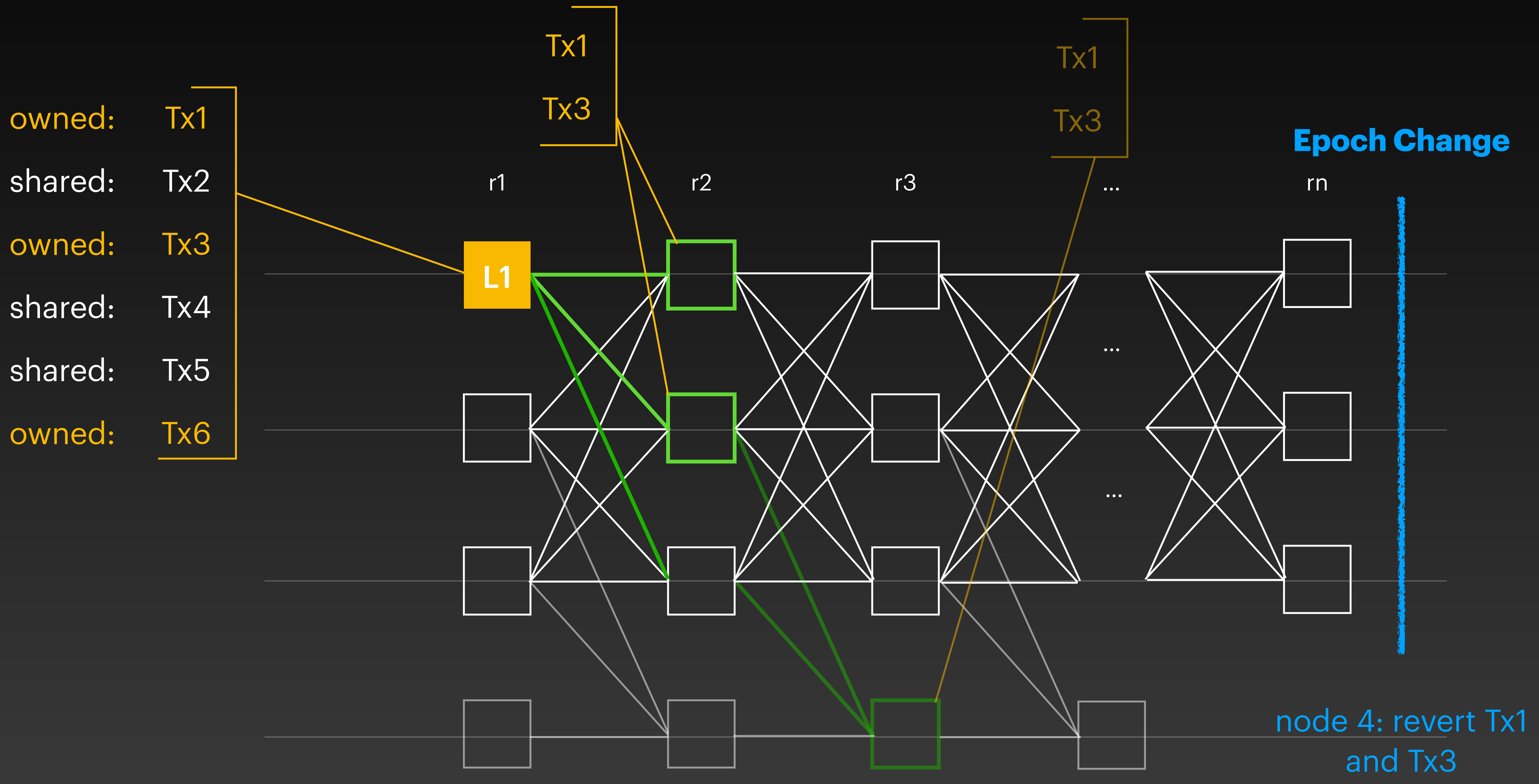
Fast Execution



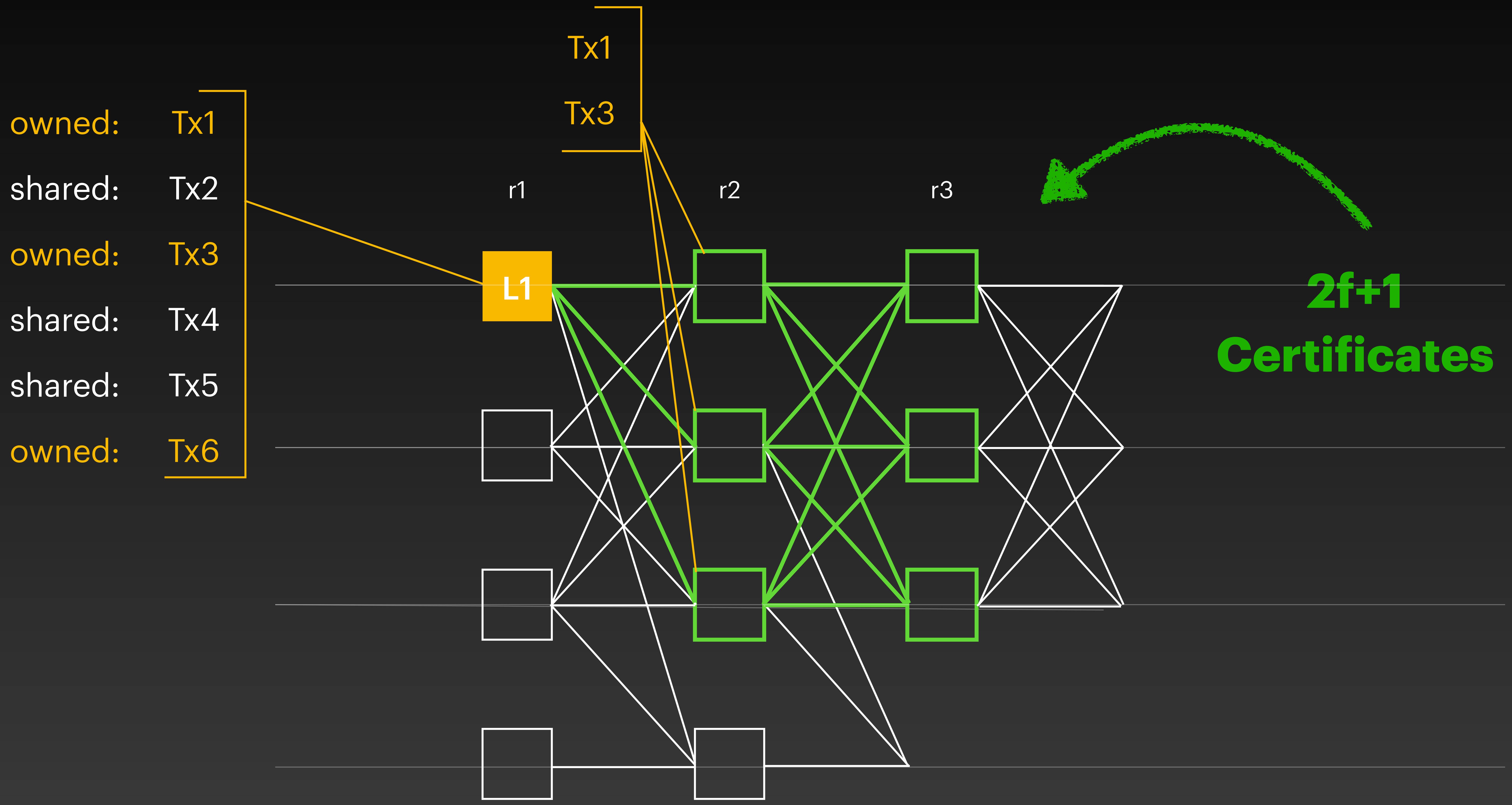
No Finality


owned: Tx1
shared: Tx2
owned: Tx3
shared: Tx4
shared: Tx5
owned: Tx6
Tx1
Tx3
Tx1
Tx3
r1
r2
r3
...
rn
L1
...
...

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

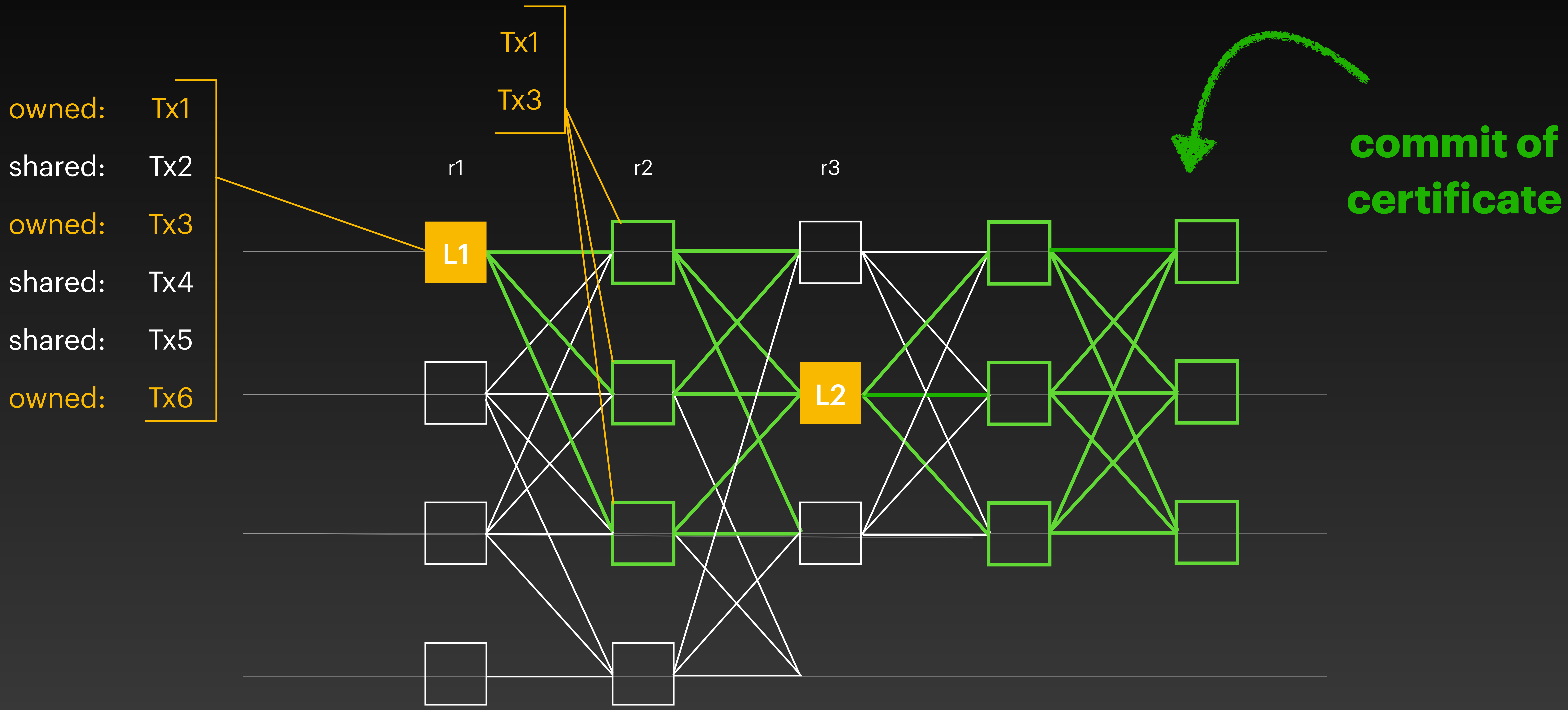
Fast Path Finality



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

2f+1
Certificates

Fast Path Finality



owned: Tx1

shared: Tx2

owned: Tx3

shared: Tx4

shared: Tx5

owned: Tx6

Tx1

Tx3

r1

r2

r3

L1

L2

commit of certificate

Mixed-Objects Transactions

owned: Tx1

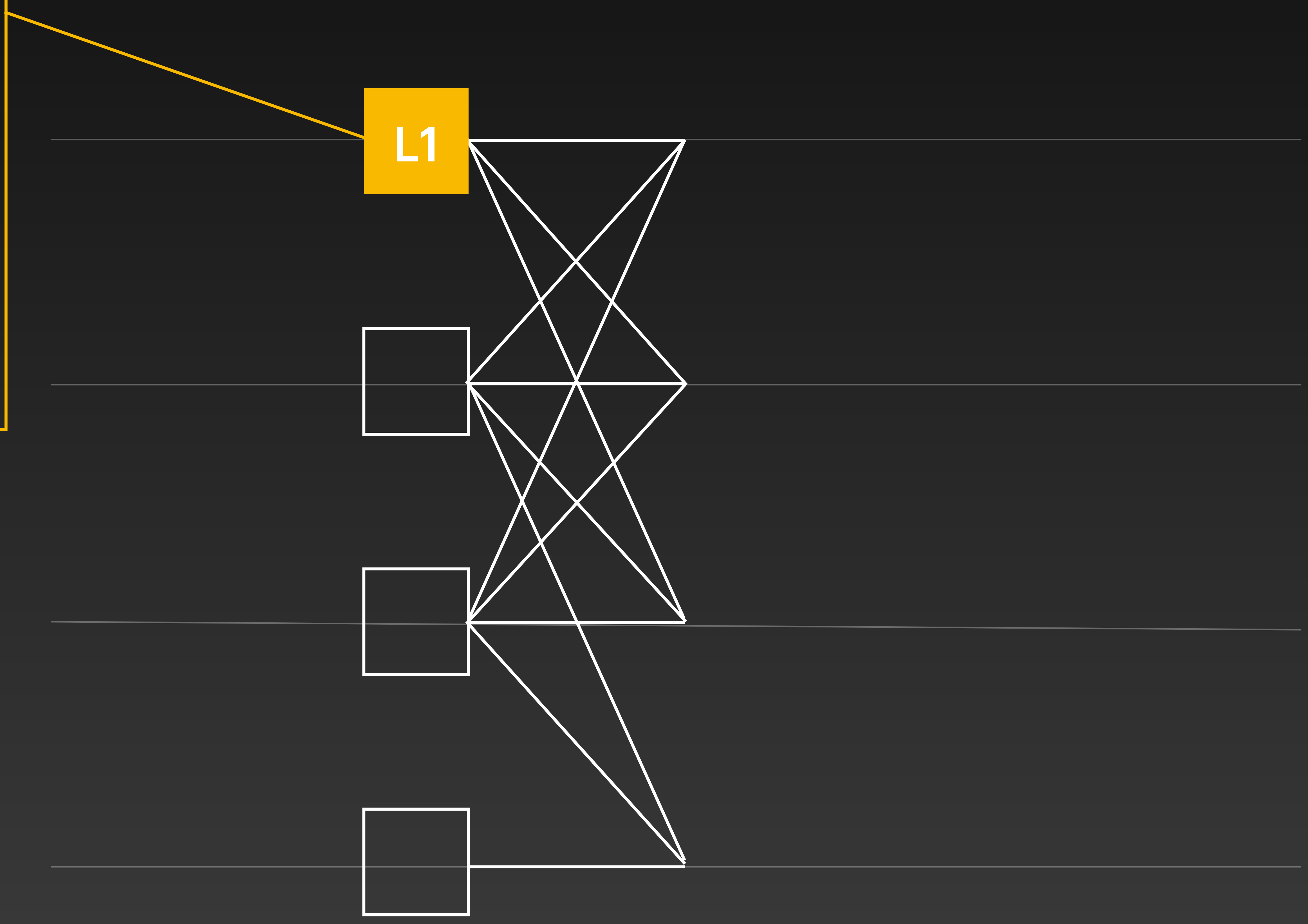
shared: Tx2

owned: Tx3

shared: Tx4

mixed: Tx5

owned: Tx6



Mixed-Objects Transactions

owned: Tx1

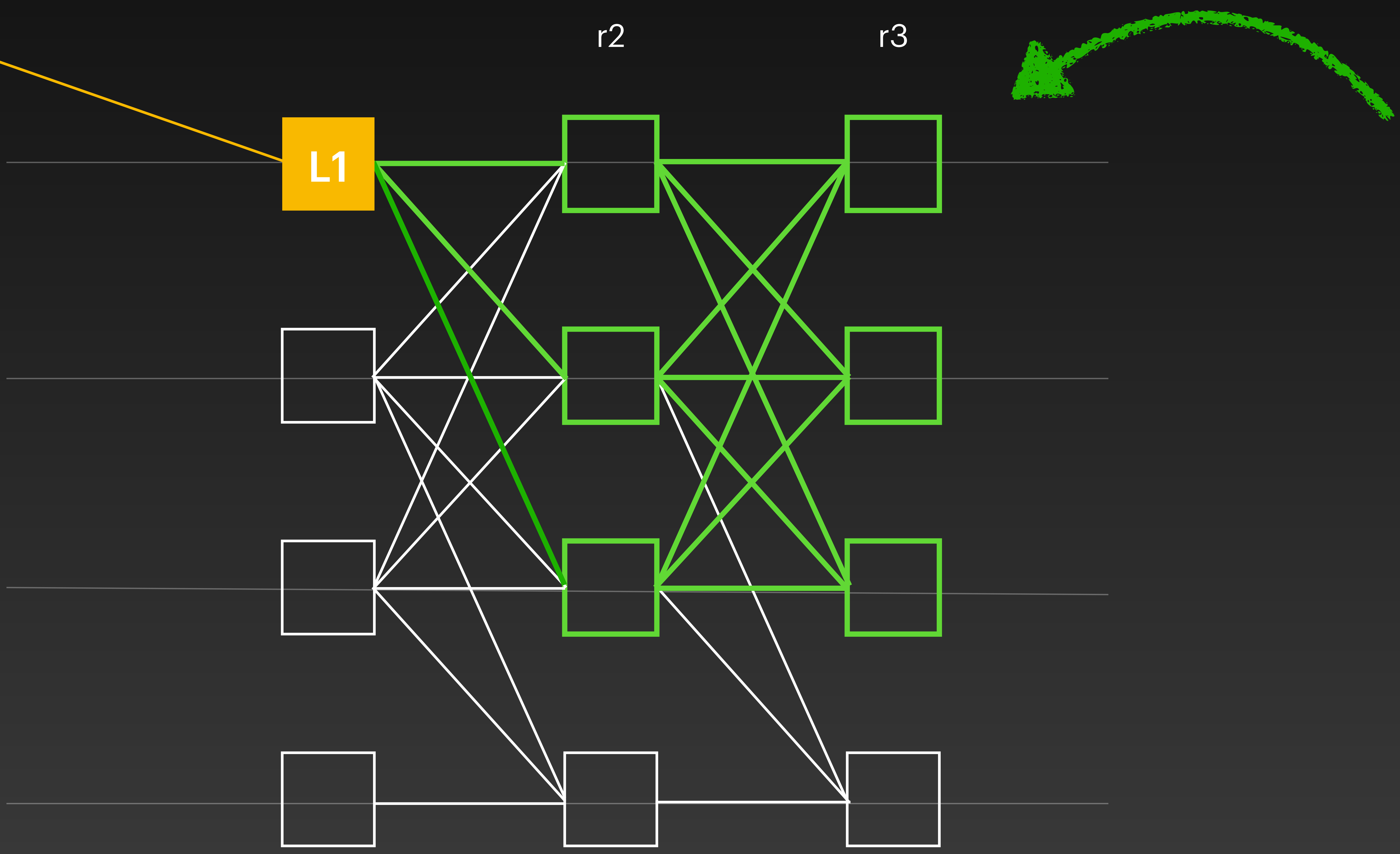
shared: Tx2

owned: Tx3

shared: Tx4

mixed: Tx5

owned: Tx6

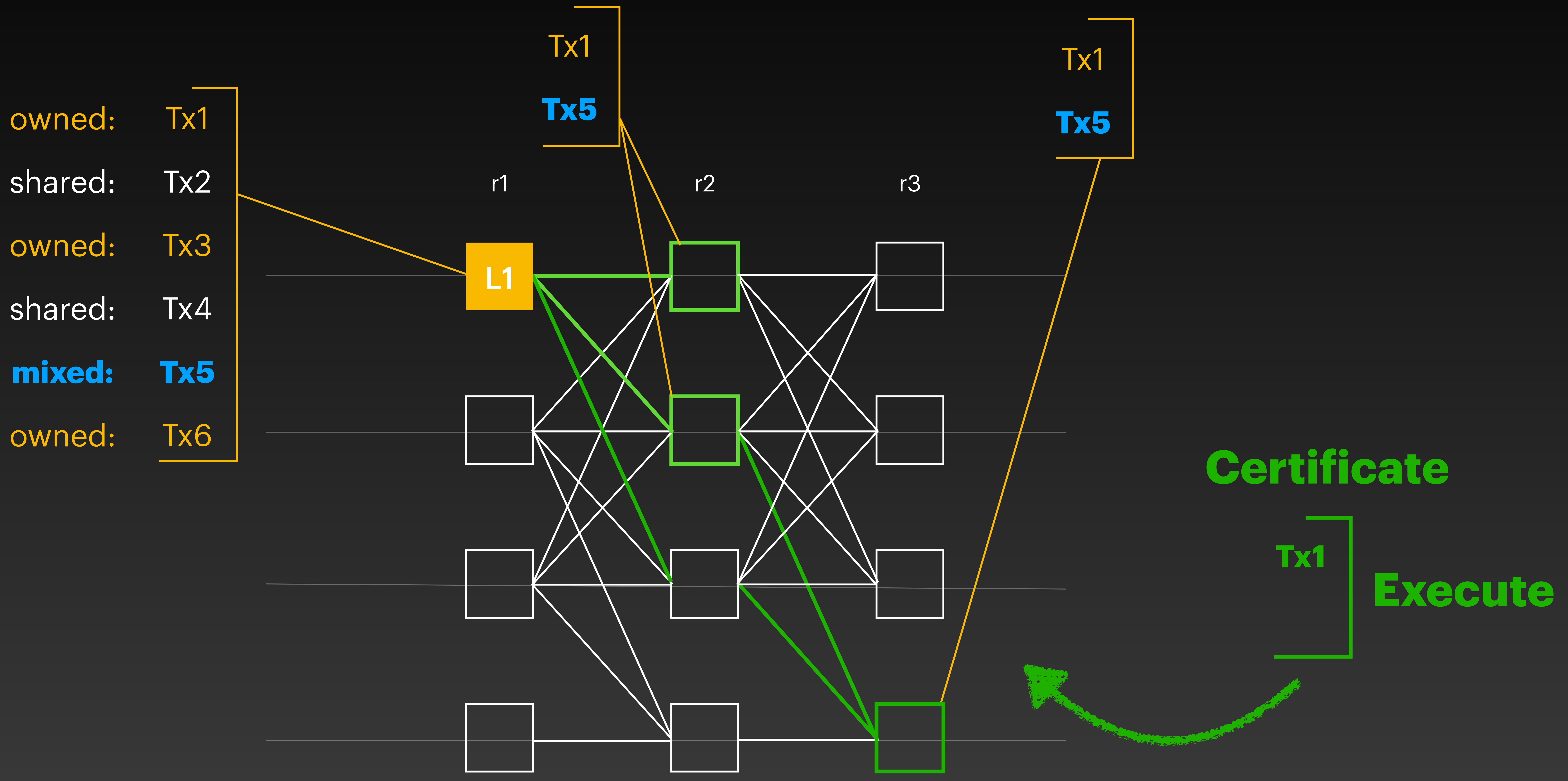


Commit

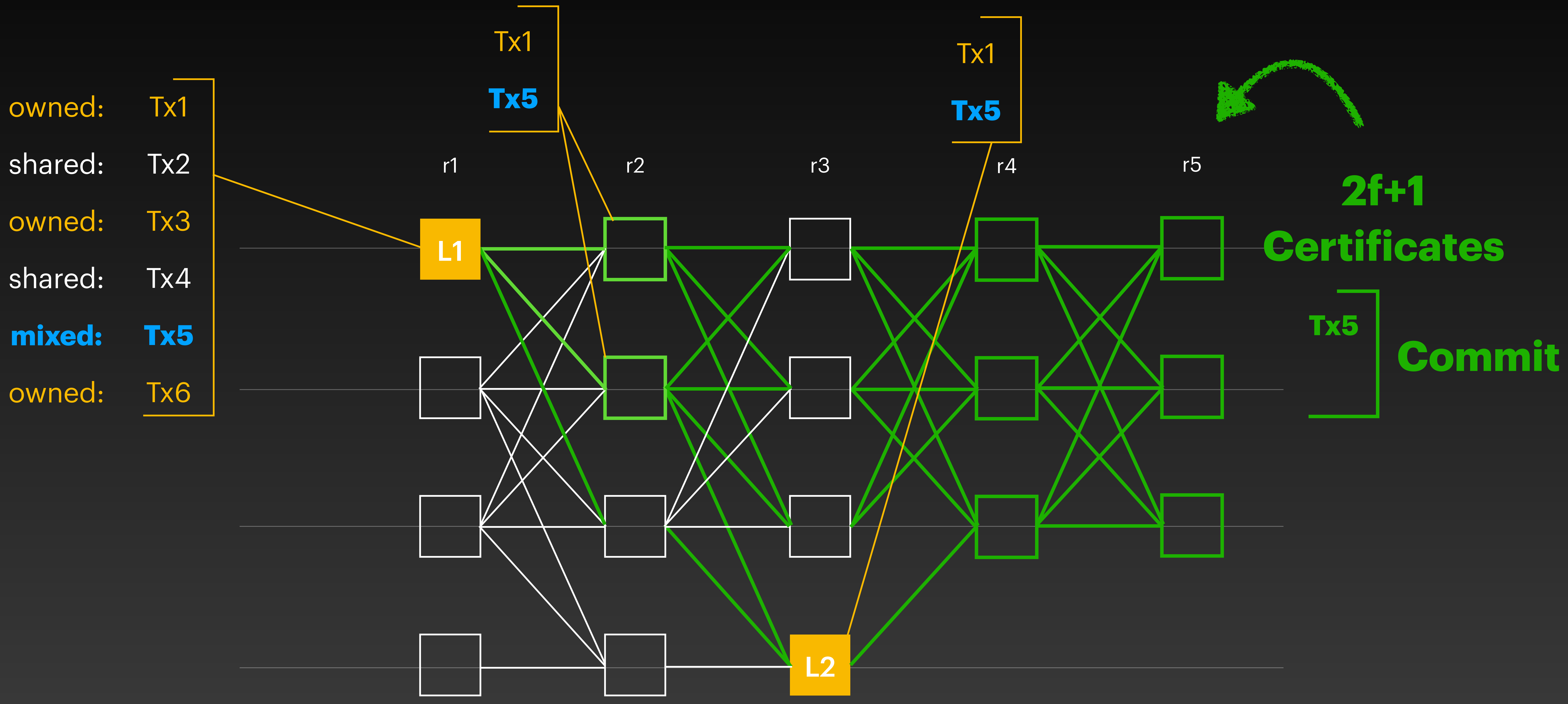
Tx2

Tx4

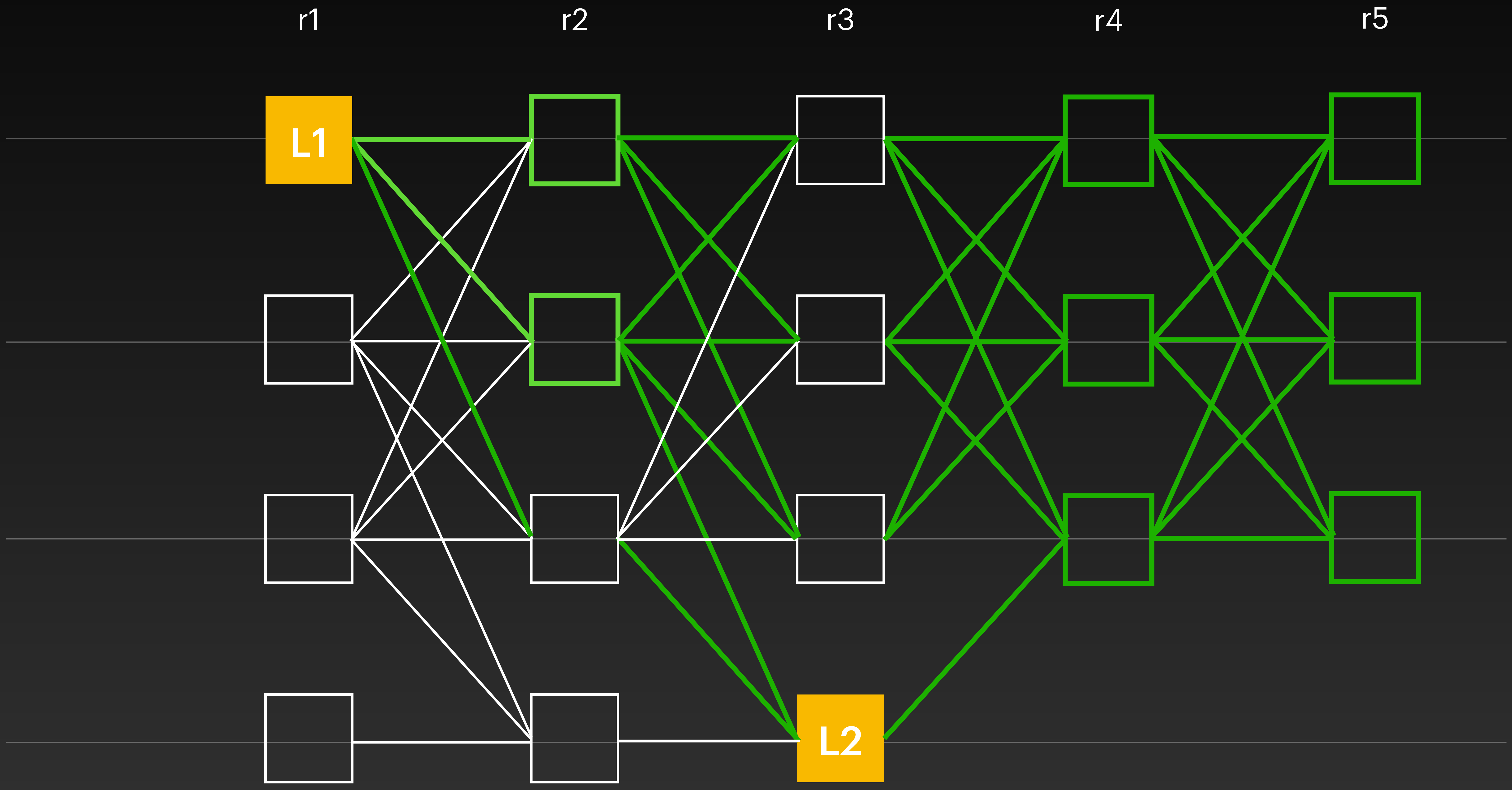
Mixed-Objects Transactions



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

Open Questions

Questions

- Anything obviously wrong?
- Is the protocol simple enough?
- What engineering challenges do you foresee?
- Suggested improvements?
- Is the fast path worth its complexity?

EXTRA

Preliminary Benchmarks

Implementation

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

https://github.com/mystenlabs/mysticeti

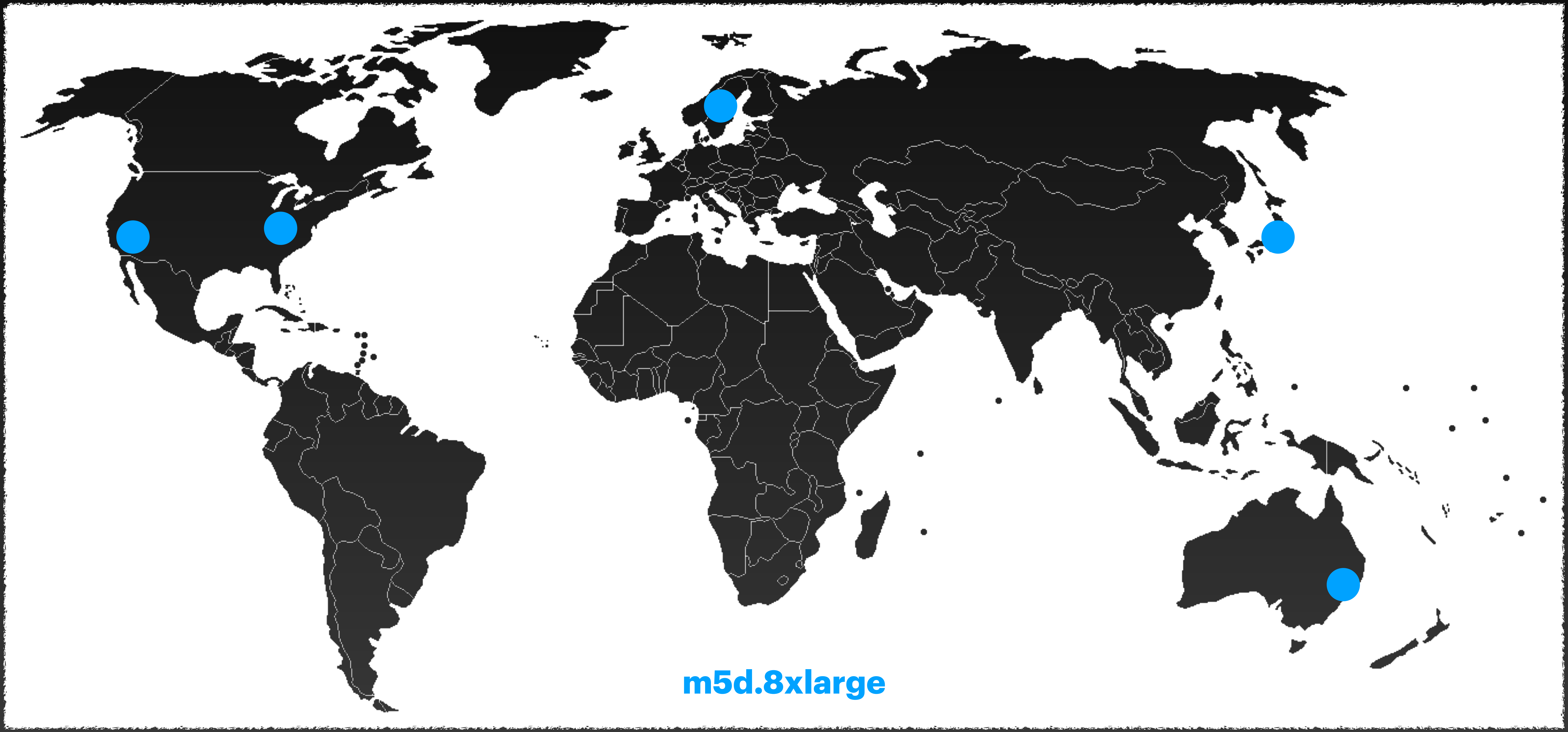
Implementation

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

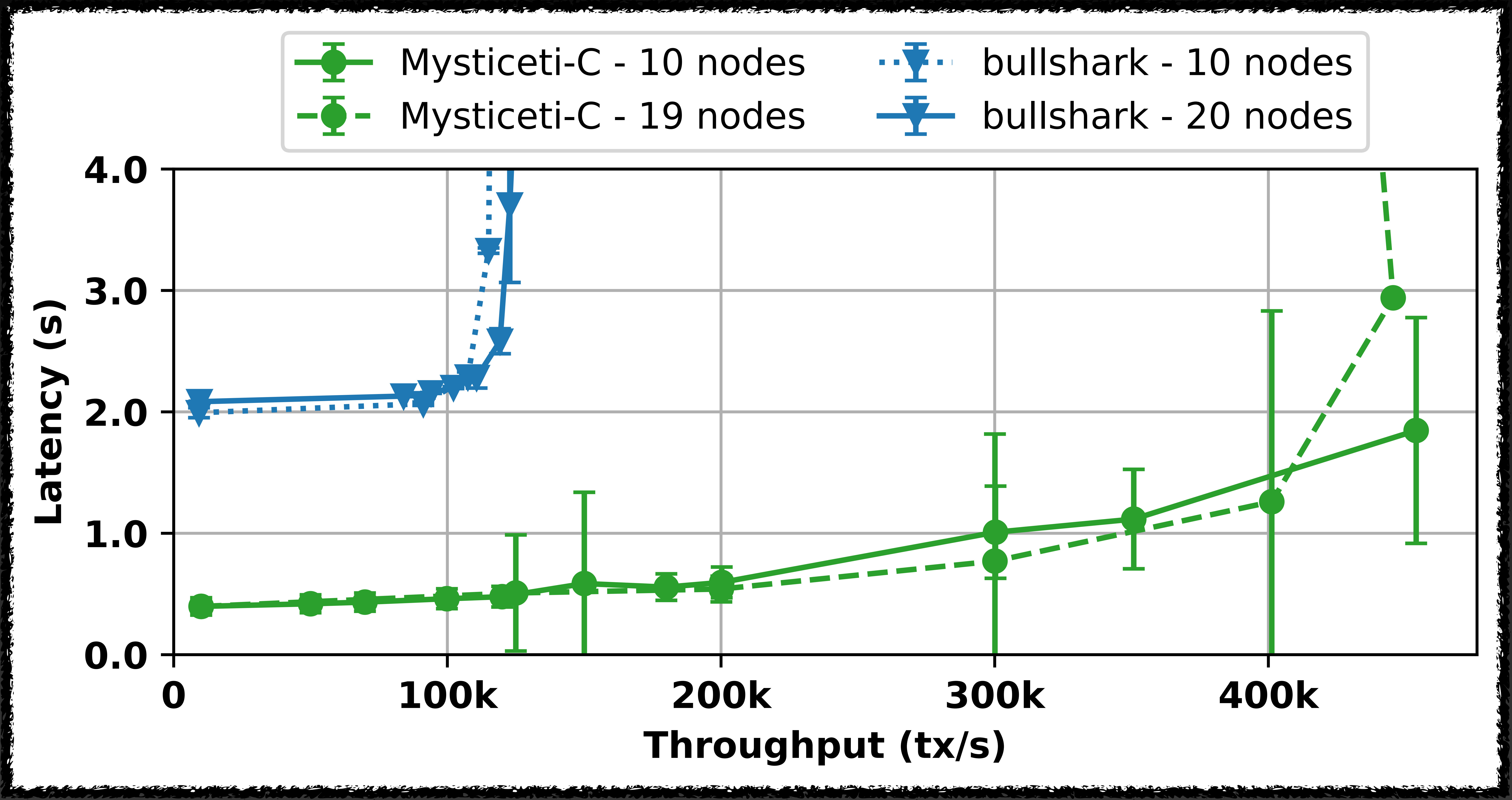
https://github.com/mystenlabs/mysticeti

Evaluation

Experimental setup on AWS



Preliminary Results

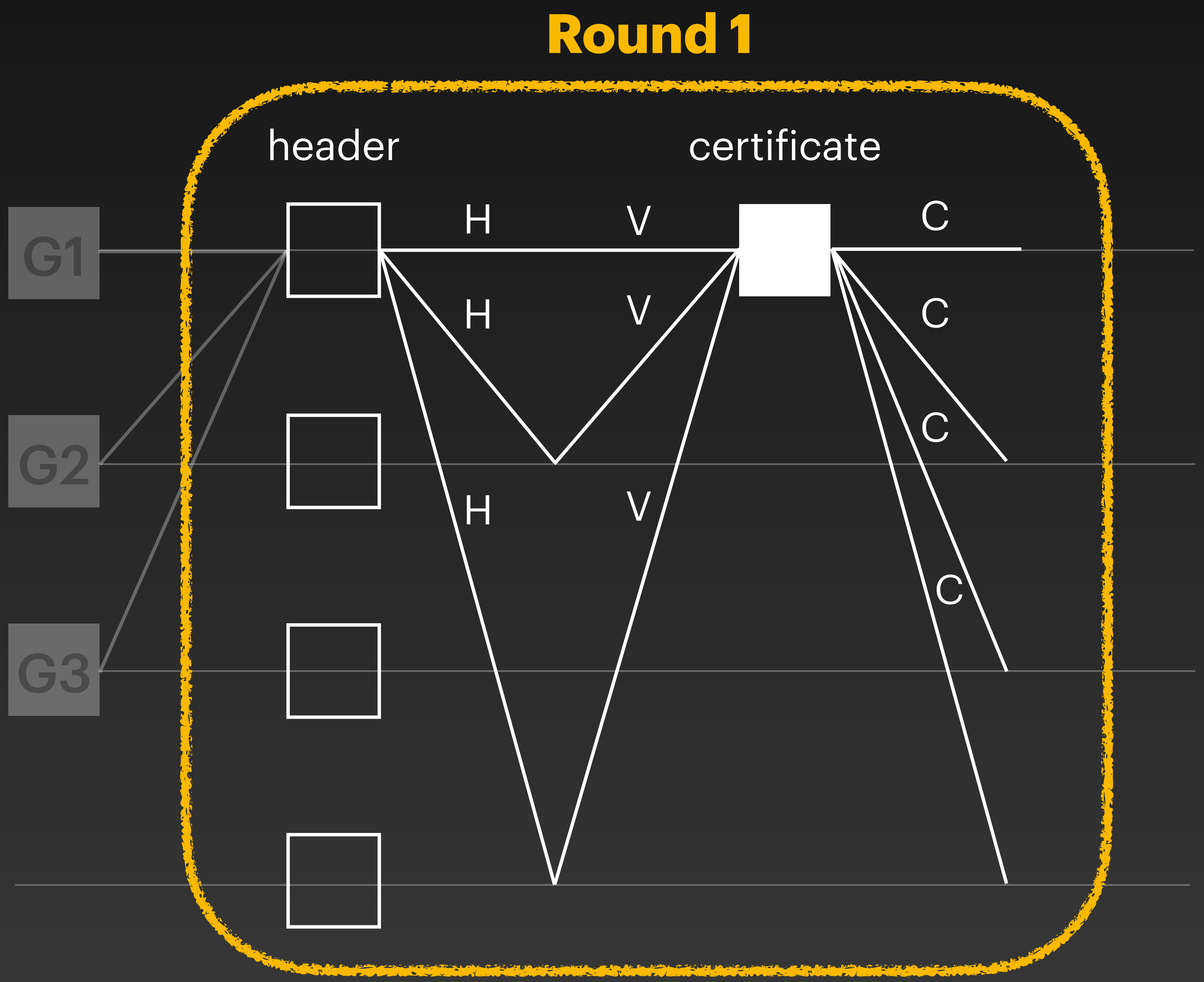


EXTRA

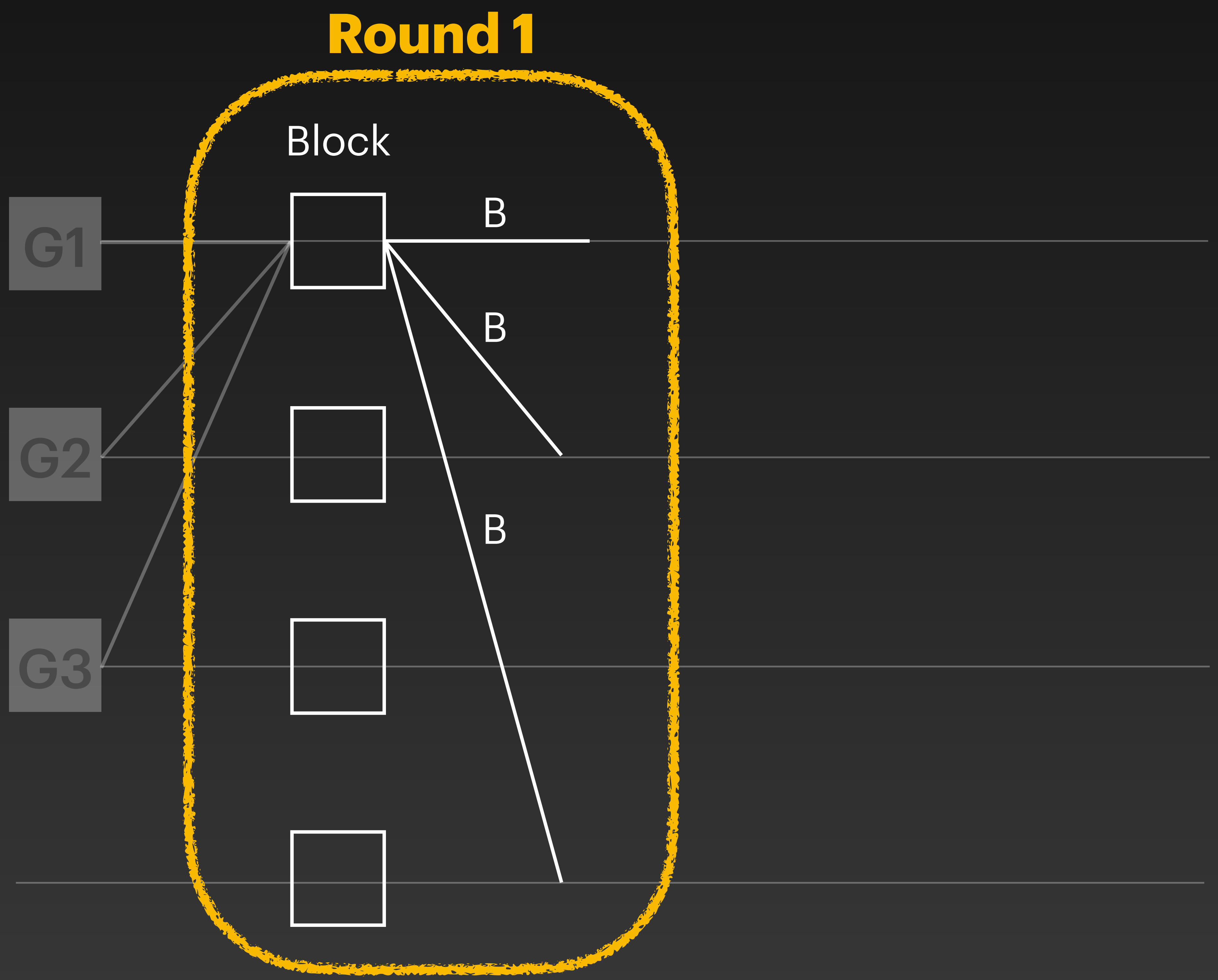
Narwhal vs Mysticeti

Narwhal vs Mysticeti

Narwhal

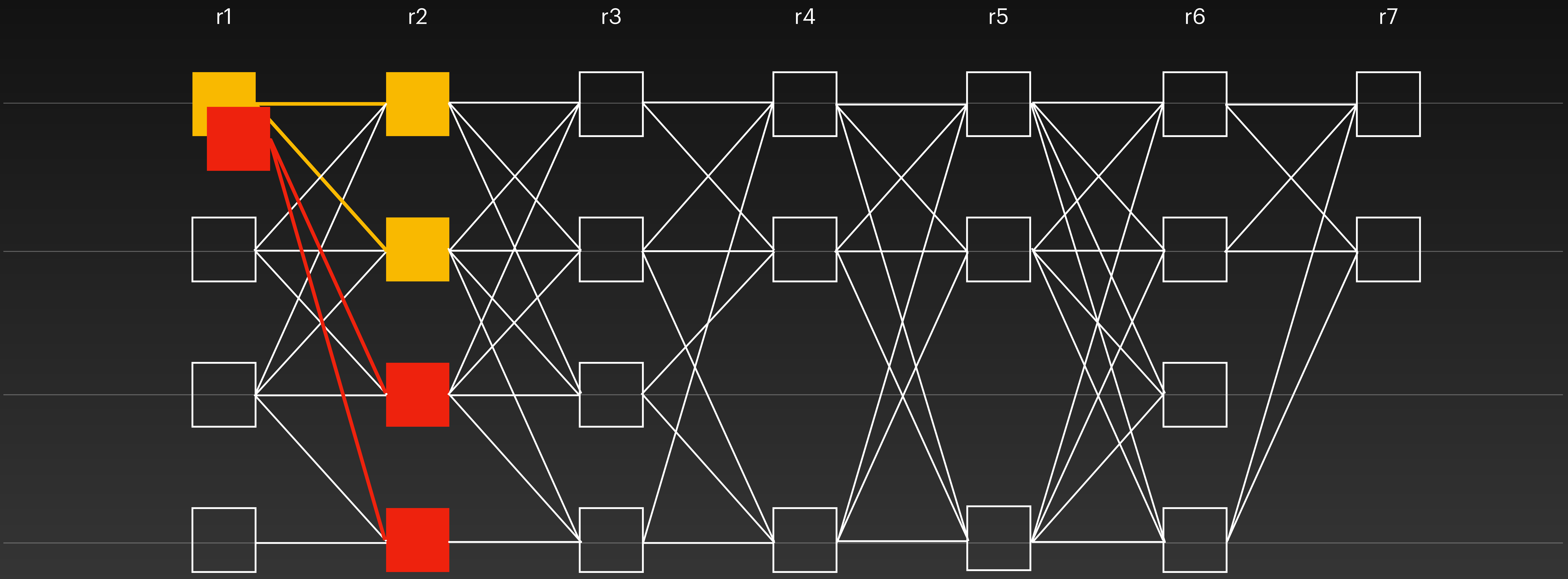


Mysticeti



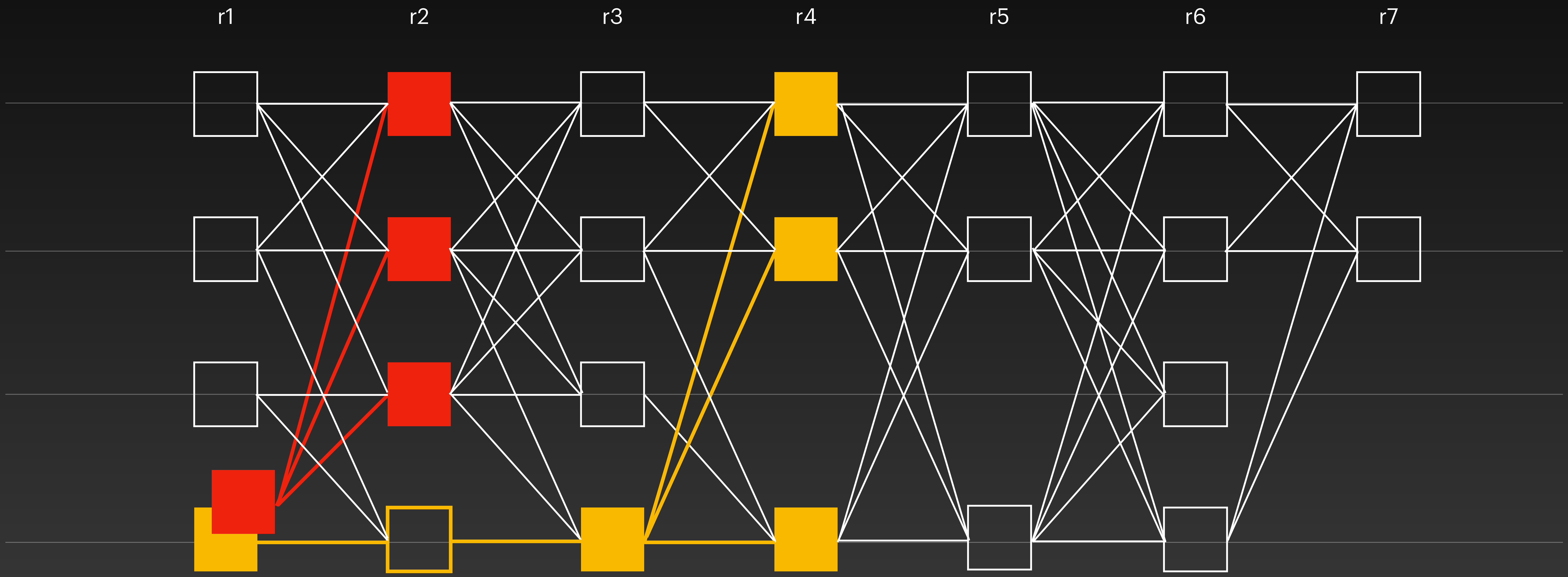
Main Challenge

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

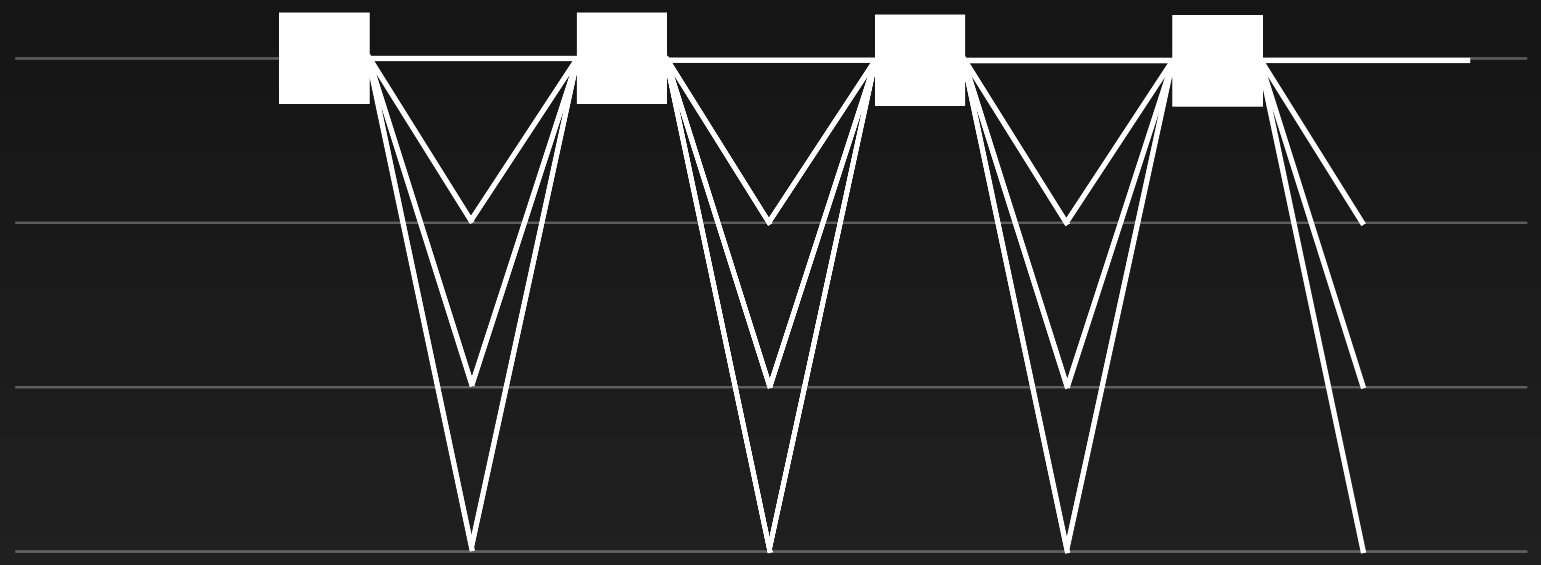
- Low latency
- Fragile to faults
- Complex leader-change

DAG-Based

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

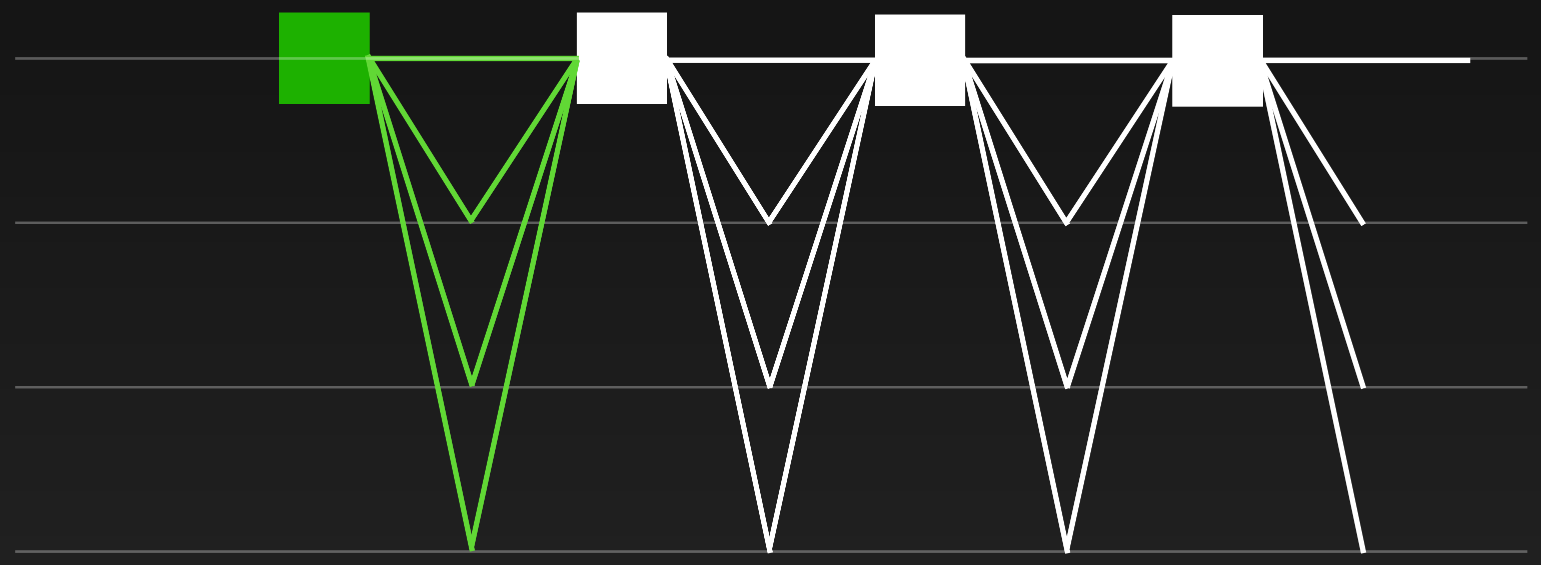
Linear-Chain Consensus

Rough overview



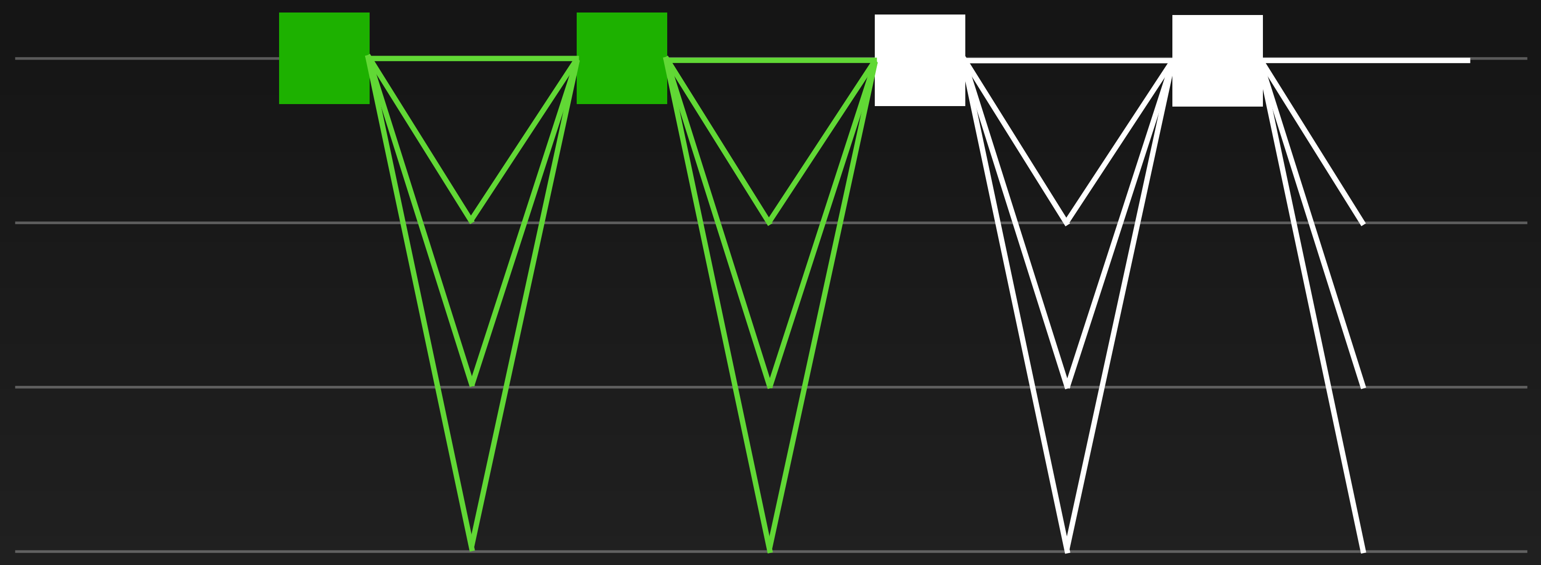
Linear-Chain Consensus

Rough overview



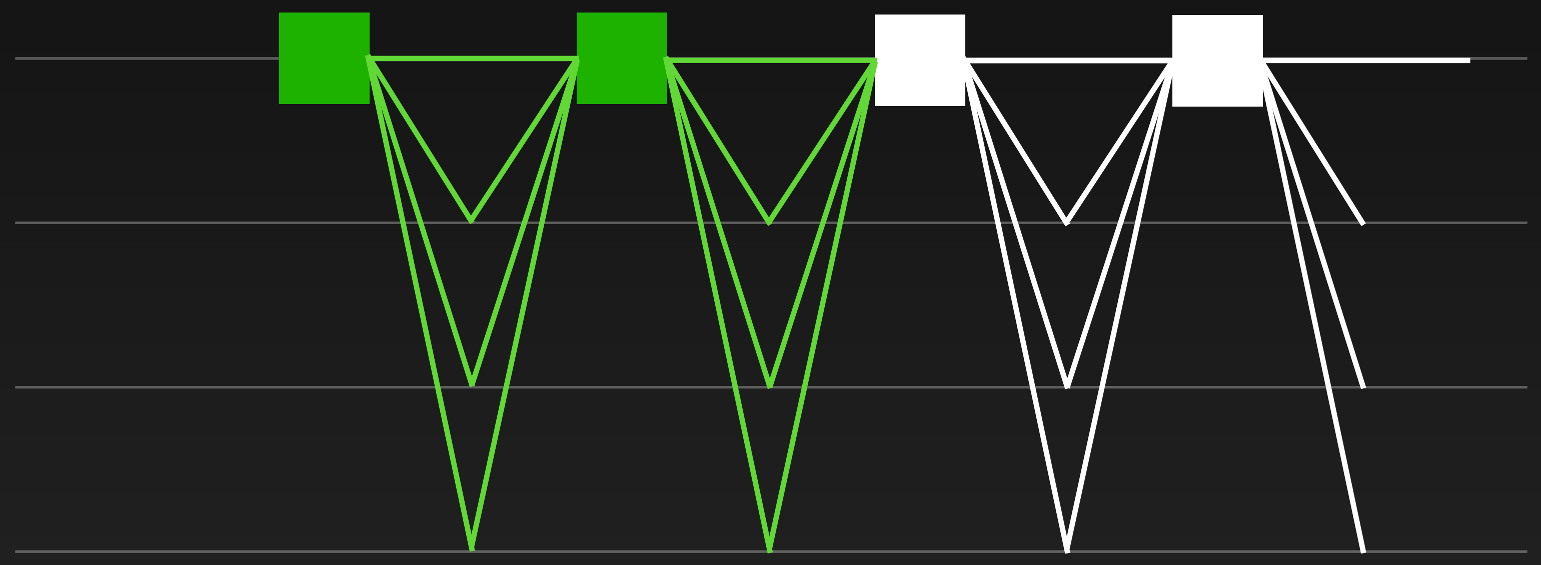
Linear-Chain Consensus

Rough overview



Linear-Chain Consensus

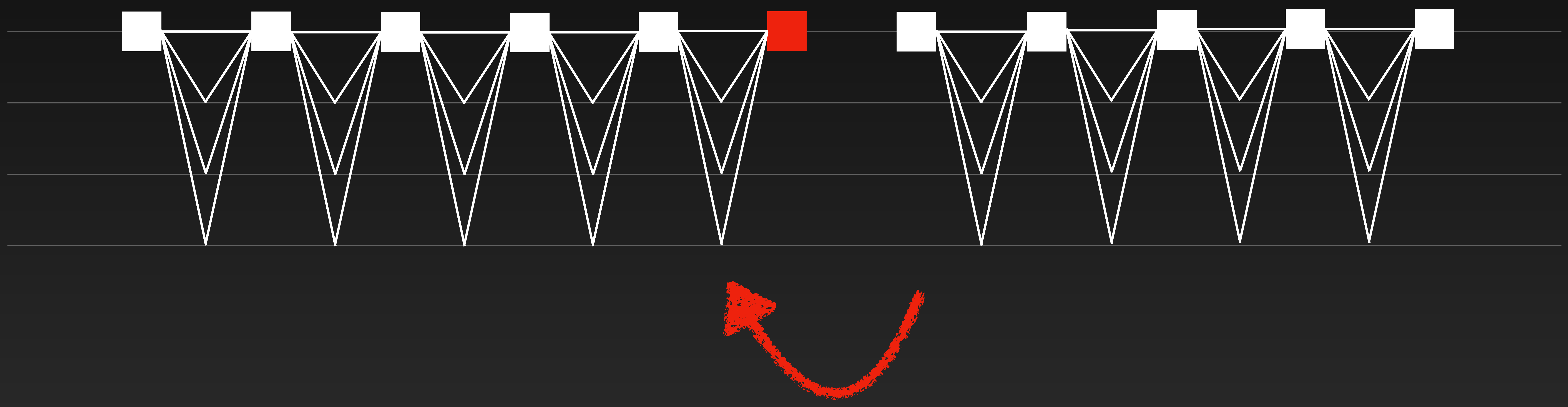
Rough overview



- The leader does all the work

Linear-Chain Consensus

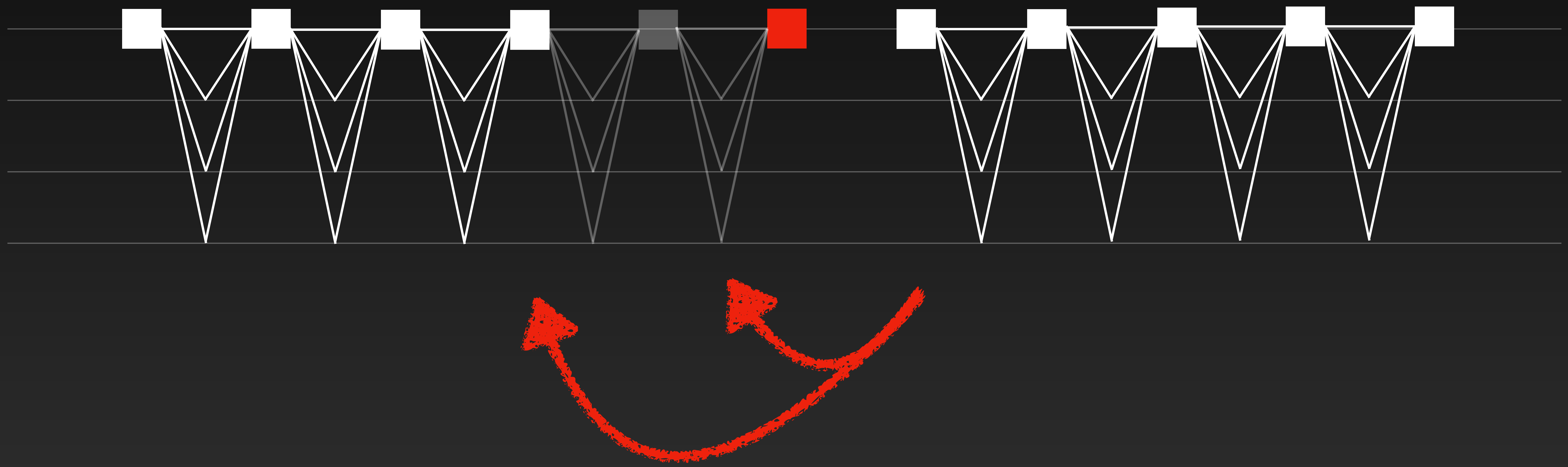
Rough overview



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

Linear-Chain Consensus

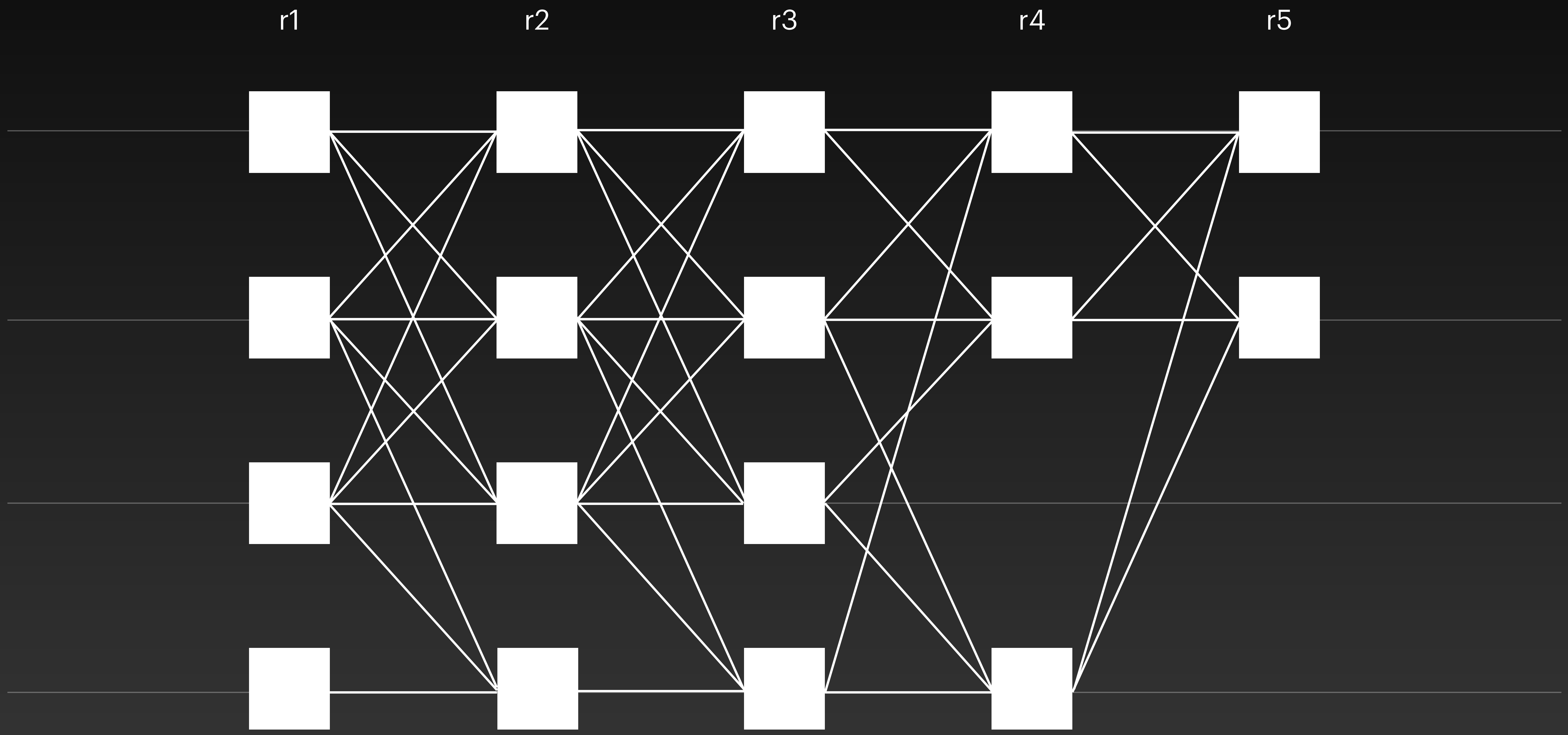
Rough overview



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

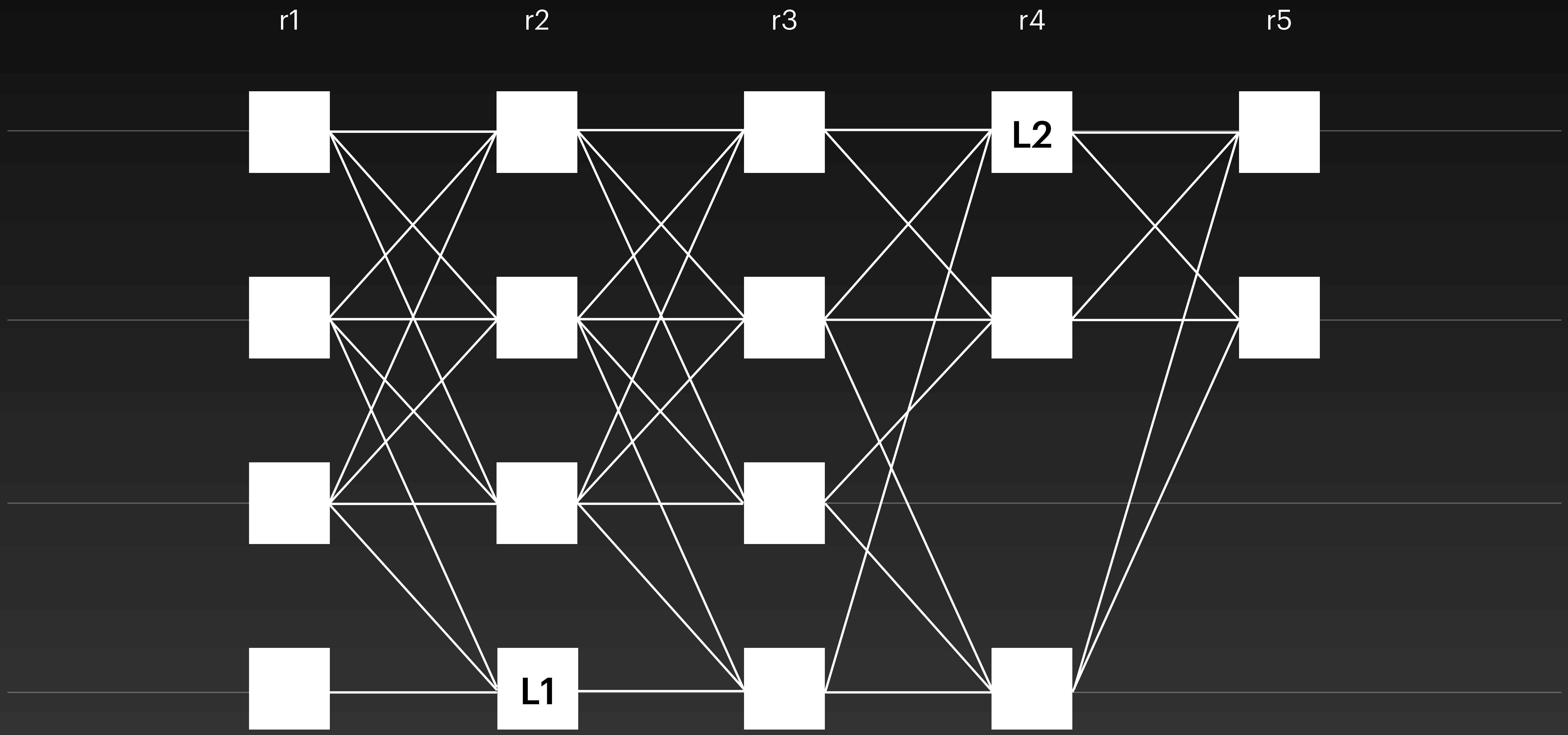
DAG-Based Consensus

Rough overview



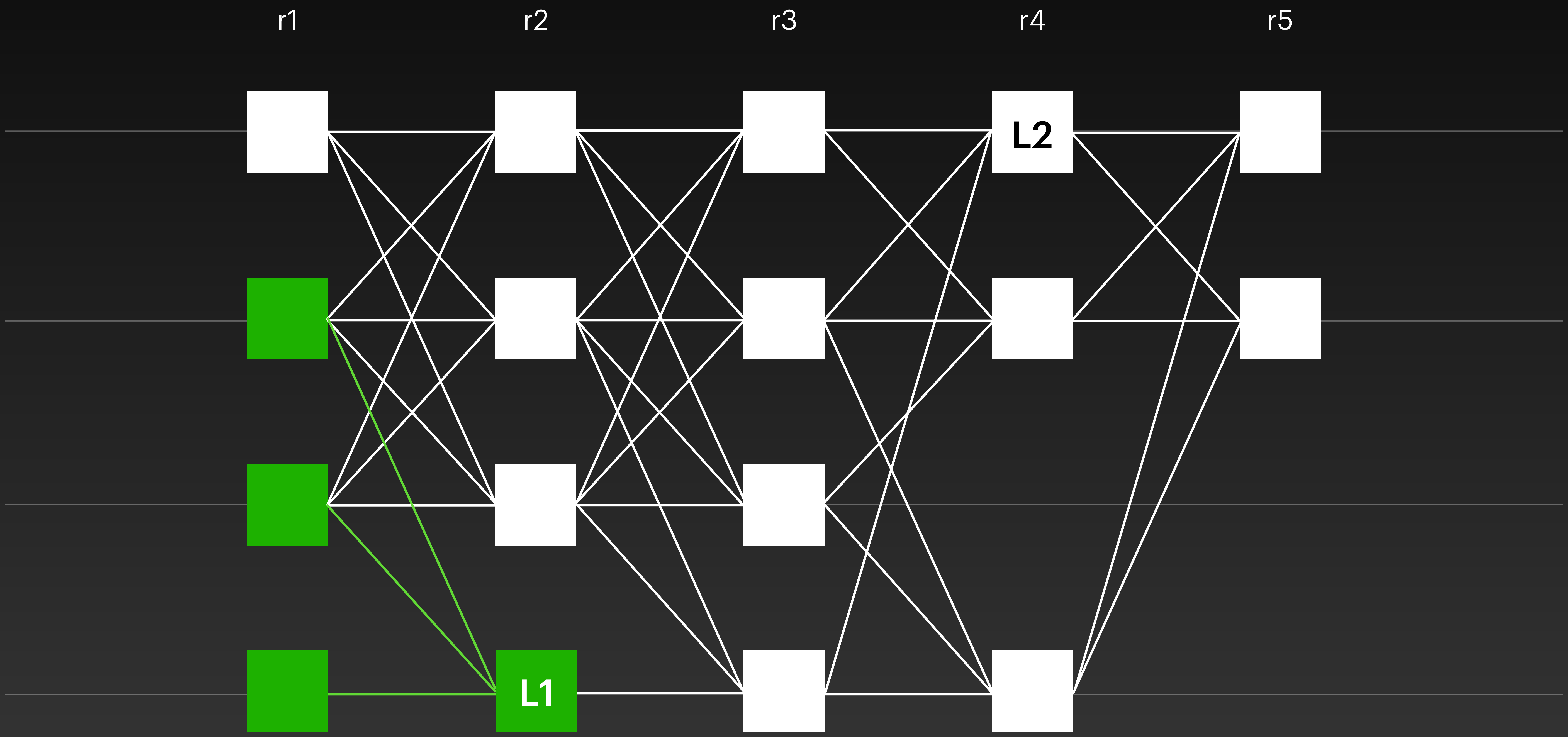
DAG-Based Consensus

Rough overview



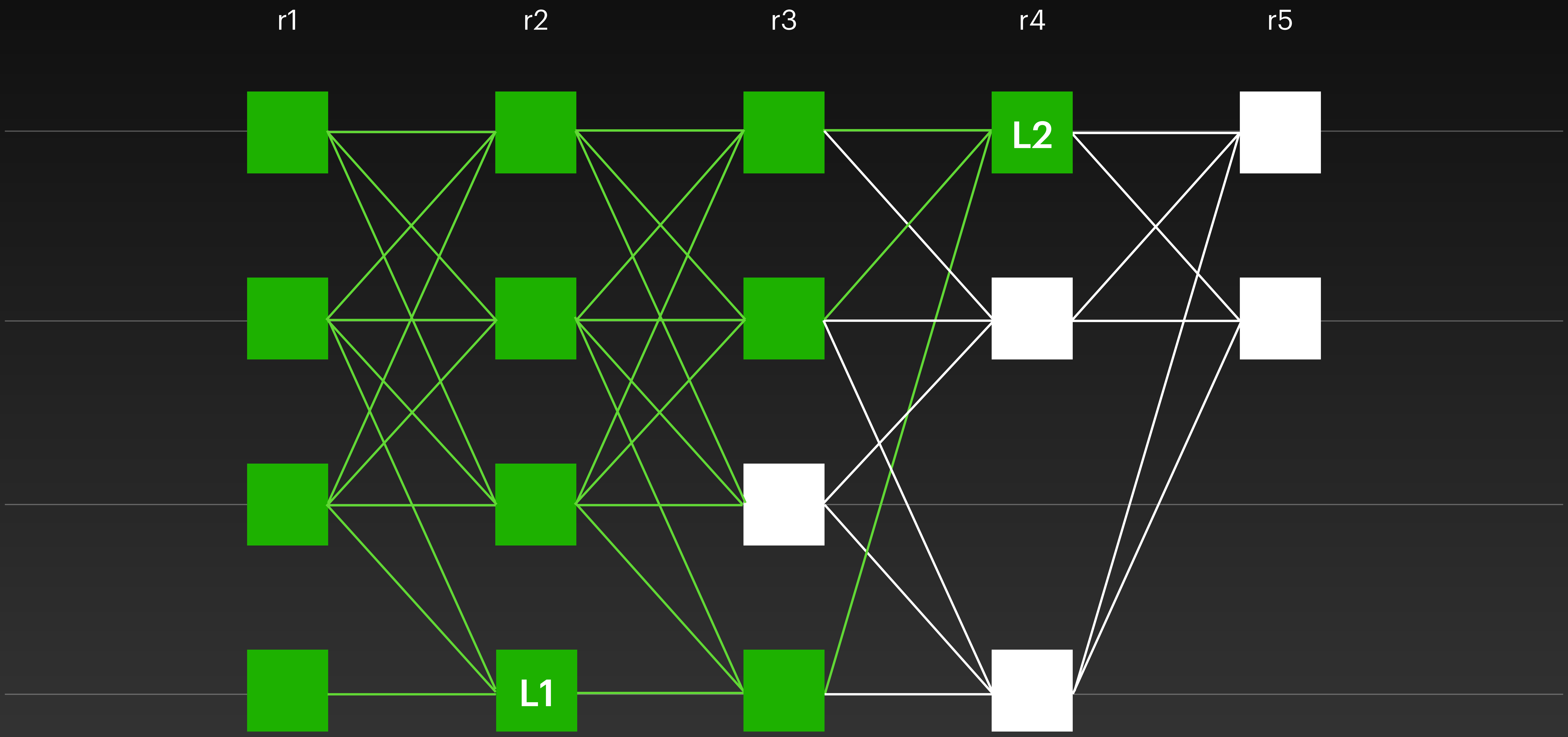
DAG-Based Consensus

Rough overview



DAG-Based Consensus

Rough overview


r1
r2
r3
r4
r5
L2
L1