Mysticeti

The consensus protocol

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The Mysticeti Consensus
In 45 minutes

In scope

• Consensus rule

Out of scope

• System design
• Fast path
All messages are in the DAG

Few signatures & Earlier decisions
The DAG

Narwhal

Mysticeti

Round 1

header certificate

Round 1

Block
Uncertified DAG... took you 3 years?
The Mysticeti DAG
Possible equivocations
The Mysticeti DAG
Possible equivocations (even with 2f+1 support)
Baseline Mysticeti
The Mysticeti DAG

wave 1

r1
r2
r3

wave 2

r4
r5
r6

wave 3

r7
The Mysticeti DAG

wave 1

wave 2

wave 3

r1       r2       r3

r4       r5       r6

r7

propose  vote  certify

propose  vote  certify

propose
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)
Direct Commit

wave 1

r1  r2  r3

L1

propose
Direct Commit
2f+1 votes

wave 1

r1   r2   r3

L1

propose  vote
Direct Commit

wave 1

r1  r2  r3

L1

propose  vote  certify
Direct Commit
2f+1 certificates

wave 1

r1  r2  r3

L1

propose  vote  certify
Direct Skip
2f+1 blames

wave 1

r1    r2    r3

L1

propose    vote
Undecided

<2f+1 blames and <2f+1 certificates
Undecided

<2f+1 blames and <2f+1 certificates

wave 1

r1  r2  r3

L1

propose  vote  certify
Indirect Commit

Wave 1:
- r1
- r2
- r3

L1
- propose
- vote
- certify

Wave 2:
- r4
- r5
- r6

L2
- propose
- vote
- certify
Indirect Commit

Certified link to next commit

wave 1
r1 r2 r3

wave 2
r4 r5 r6

propose vote certify propose vote certify

L1 L2

Certi

ifed link to next commit
Indirect Commit
Certified link to next commit

Wave 1
- r1
- r2
- r3

Wave 2
- r4
- r5
- r6

L1
- propose
- vote
- certify

L2
- propose
- vote
- certify

Certiﬁed link to next commit
Indirect Skip

wave 1

r1

propose

L1

certify

r2

vote

r3

propose

wave 2

r4

certify

r5

r6

propose

vote

certify
Indirect Skip
No certified link to next commit

Wave 1
- r1
- r2
- r3

Wave 2
- r4
- r5
- r6

Propose
- L1
- vote
- certify

Propose
- L2
- vote
- certify
Universal Mysticeti Committter
Pipelined Mysticeti
Pipelined Mysticeti
Pipelined Multi-Leader Mysticeti
Direct Decision Rule

On each leader starting from highest round:
- **Skip** if 2f+1 blames
- **Commit** if 2f+1 certifies
- **Undecided** otherwise
1. **Find Anchor**

- First block with round > r+2 that is **Commit** or **Undecided**.
Indirect Decision Rule

1. Find Anchor
   - First block with round > r+2 that is
     - Commit or Undecided

2. Certified link
   - Commit if
     B <-> certified link <-> A
   - Otherwise Skip
Apply Direct Rule
Mark all leaders as Undecided
Apply Direct Rule
Cannot decide incomplete waves
Apply Direct Rule

Start with highest round and go backward
Apply Direct Rule
Start with highest round and go backward
Apply Direct Rule
Start with highest round and go backward
Apply Direct Rule
Start with highest round and go backward
Apply Direct Rule
Start with highest round and go backward
Apply Direct Rule
Start with highest round and go backward
Apply Direct Rule

Start with highest round and go backward
Apply Direct Rule
Start with highest round and go backward

- Apply Direct Rule
- Start with highest round and go backward

Diagram showing the application of the Direct Rule with nodes and connections labeled from L1a to L6c, with specific nodes highlighted in red.
Apply Direct Rule

Start with highest round and go backward
Apply Direct Rule
Start with highest round and go backward
Apply Direct Rule
Start with highest round and go backward
Apply Direct Rule
Start with highest round and go backward
Apply Direct Rule
Start with highest round and go backward
Apply Direct Rule
Start with highest round and go backward
Apply Direct Rule
Start with highest round and go backward
Apply Direct Rule
Start with highest round and go backward
Apply Direct Rule
Start with highest round and go backward
Apply Direct Rule
Start with highest round and go backward
Apply Indirect Rule
Find anchor & Check certified links
Apply Direct Rule
Start with highest round and go backward

<table>
<thead>
<tr>
<th>r1</th>
<th>r2</th>
<th>r3</th>
<th>r4</th>
<th>r5</th>
<th>r6</th>
</tr>
</thead>
<tbody>
<tr>
<td>L1a</td>
<td>L2d</td>
<td>L3c</td>
<td>L4d</td>
<td>L5c</td>
<td>L6b</td>
</tr>
<tr>
<td>L1b</td>
<td>L2a</td>
<td>L3d</td>
<td>L4a</td>
<td>L5d</td>
<td>L6c</td>
</tr>
<tr>
<td>L1c</td>
<td>L2b</td>
<td></td>
<td>L4b</td>
<td>L5a</td>
<td>L6d</td>
</tr>
<tr>
<td>L1d</td>
<td>L2c</td>
<td>L3b</td>
<td>L4c</td>
<td>L5b</td>
<td></td>
</tr>
</tbody>
</table>
Apply Direct Rule
Start with highest round and go backward
Apply Indirect Rule
Find anchor & Check certified links

Undecided
Apply Direct Rule
Start with highest round and go backward
Apply Direct Rule
Start with highest round and go backward
Apply Direct Rule
Start with highest round and go backward
Apply Direct Rule
Start with highest round and go backward
Apply Indirect Rule
Find anchor & Check certified links

[Diagram with nodes and arrows showing connections between nodes labeled r1, r2, r3, r4, r5, r6, L1a, L1b, L1c, L1d, L2a, L2b, L2c, L2d, L3a, L3b, L3c, L3d, L4a, L4b, L4c, L4d, L5a, L5b, L5c, L5d, L6a, L6b, L6c, L6d, with an arrow pointing to L4a and a note indicating 'Skipped']
Apply Indirect Rule
Find anchor & Check certified links
Apply Indirect Rule
Find anchor & Check certified links

Certified link
Commit
Apply Direct Rule
Start with highest round and go backward
Apply Direct Rule
Start with highest round and go backward
Apply Indirect Rule
Find anchor & Check certified links
Apply Indirect Rule
Find anchor & Check certified links

Commit
Apply Indirect Rule
Find anchor & Check certified links

certified link

Commit
Apply Direct Rule

Start with highest round and go backward
Apply Direct Rule
Start with highest round and go backward
Apply Indirect Rule

Find anchor & Check certified links
Apply Indirect Rule
Find anchor & Check certified links
Apply Indirect Rule
Find anchor & Check certified links

no certified link
Commit
Apply Direct Rule
Start with highest round and go backward
Apply Direct Rule
Start with highest round and go backward
Commit Sequence
Take all leaders in order

sequence:
L1a  L1b  L1c  L1d  L2a  L2b  L2c  L3a  L3b  L3c  L3d  L4a  L4b  L4c  L4d
Commit Sequence
Stop at the first Undecided leader

sequence: L1a L1b L1c L1d L2a L2b L2c L2d L3a L3b L3c L3d L4a L4b L4c L4d L5a L5b L5c L5d L6a L6b L6c L6d
Current Status
Remove skipped leaders

sequence:
L1a  L1b  L1c  L1d  L2a  L2b  L2c  L2d  L3a  L3b  L3c  L3d  L4a  L4b  L4c  L4d  L5a  L5b  L5c  L5d  L6a  L6b  L6c  L6d
Preliminary Results

![Graph showing latency vs. throughput for different configurations of Mysticeti-C and bullshark. The graph displays two sets of data points for Mysticeti-C with 10 and 19 nodes, and two sets for bullshark with 10 and 20 nodes. The latency on the y-axis ranges from 0 to 4 seconds, and the throughput on the x-axis ranges from 0 to 400k transactions per second (tx/s). The graph illustrates increasing latency with higher throughput for both configurations.](image-url)