# Tyr: Finding Consensus Failure Bugs in Blockchain System with Behaviour Divergent Model

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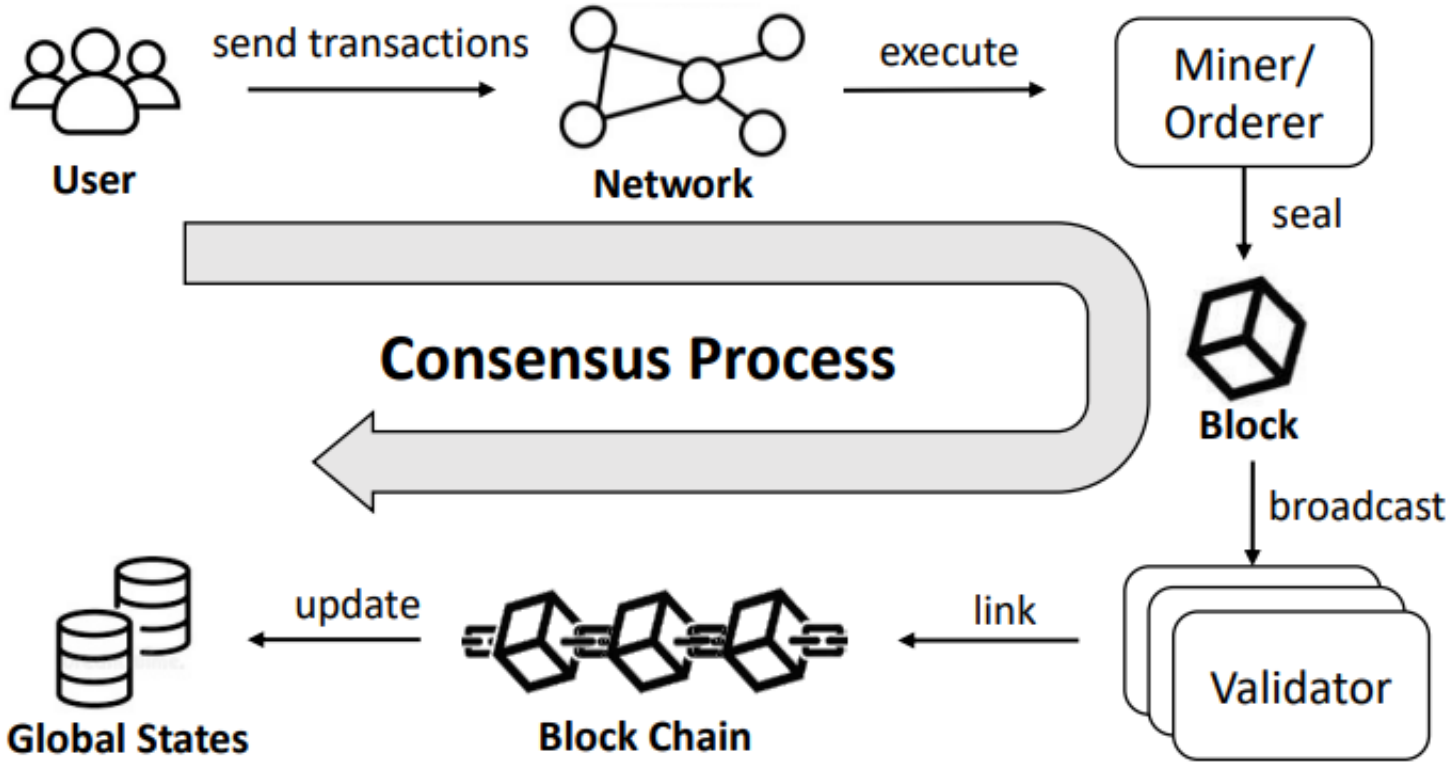
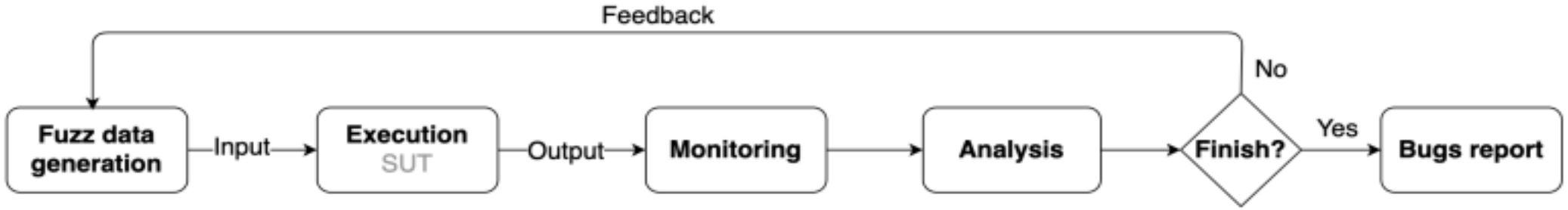
# Blockchain Consensus




- Public Blockchain: Ethereum、Bitcoin.
  - Nakamoto Consensus: POW & POS
- Consortium Chain: Fabric、FISCO-BCOS、Quorum、Diem.
  - Committee-based Consensus: PBFT
- Message
  - Node Communication

# Fuzzing Technology




generate a with 2^n

```
1. a= Input()
2. if a=1:
3.         func1()
4. else if a=2:
5.         func2()
6. ...
7. ...
8. else if a=1024:
9.         bug()
```

No Bug

report Bug

- Metric:
  - Find bug&Flaw
  - branch coverage

# Previous Work

- **Fluffy**[ SOSP‘21]
  - Differential testing is used to detect formula vulnerabilities in blockchain clients of different progrem languages. ( e.g.,Ethereum geth(golang)，Parity（rust).)
  - Fabric , FISCOBCOS have only one implementation.

- **Peach**[industry]
  - Mutating network protocol field.
  - Only detect the target program exits normally.

- **Twins**[industry]
  - Detects byzantine behaviors in a mock environment.
  - Ignoring the runtime behaviors

# Contributions

- **Four consensus property** are constructed to detect bugs of the consensus system.
  - Liveness、Safety、Integrity、Fairness.
- Construct the **behavior divergent model** to diverge the behaviors of nodes and trigger the bug oracles.
- Tyr Framwork
  - Compatible with **six blockchain platforms**.
  - High branch coverage
  - 20 serious previously unknown bugs(**5 CVEs**)

# Main Idea

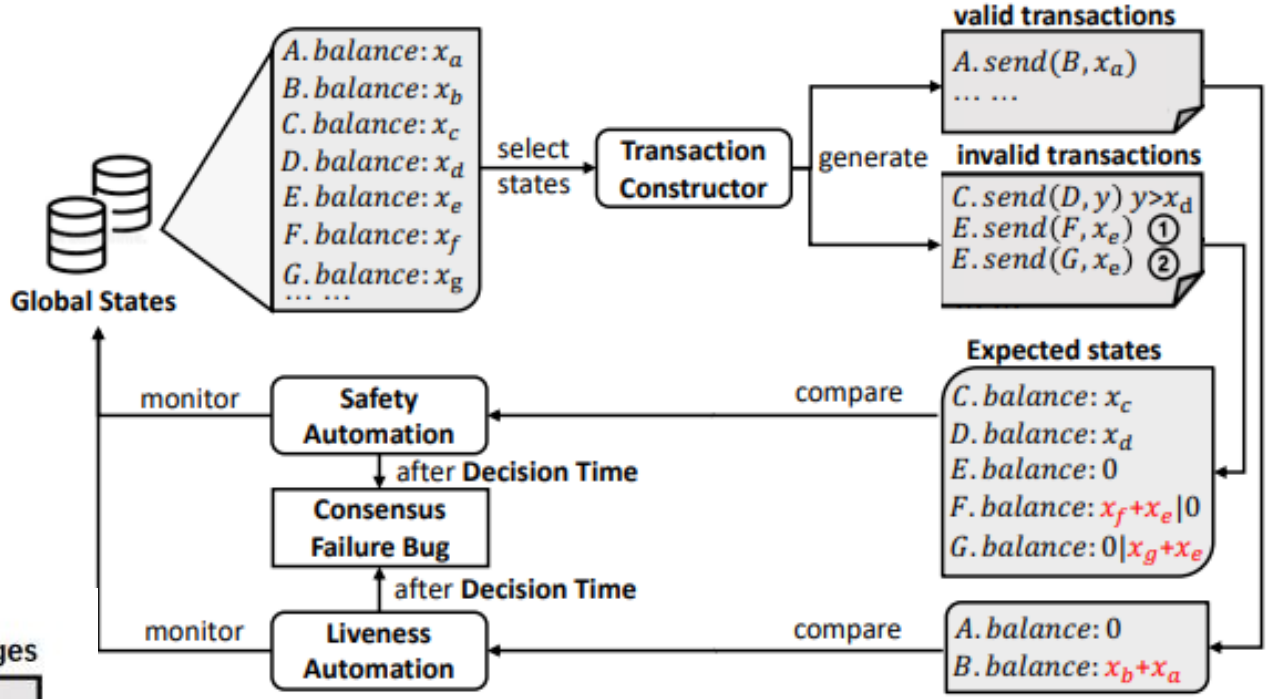
- **Four consensus property**
  - Proposed the rules of anomaly detection for fuzzer.

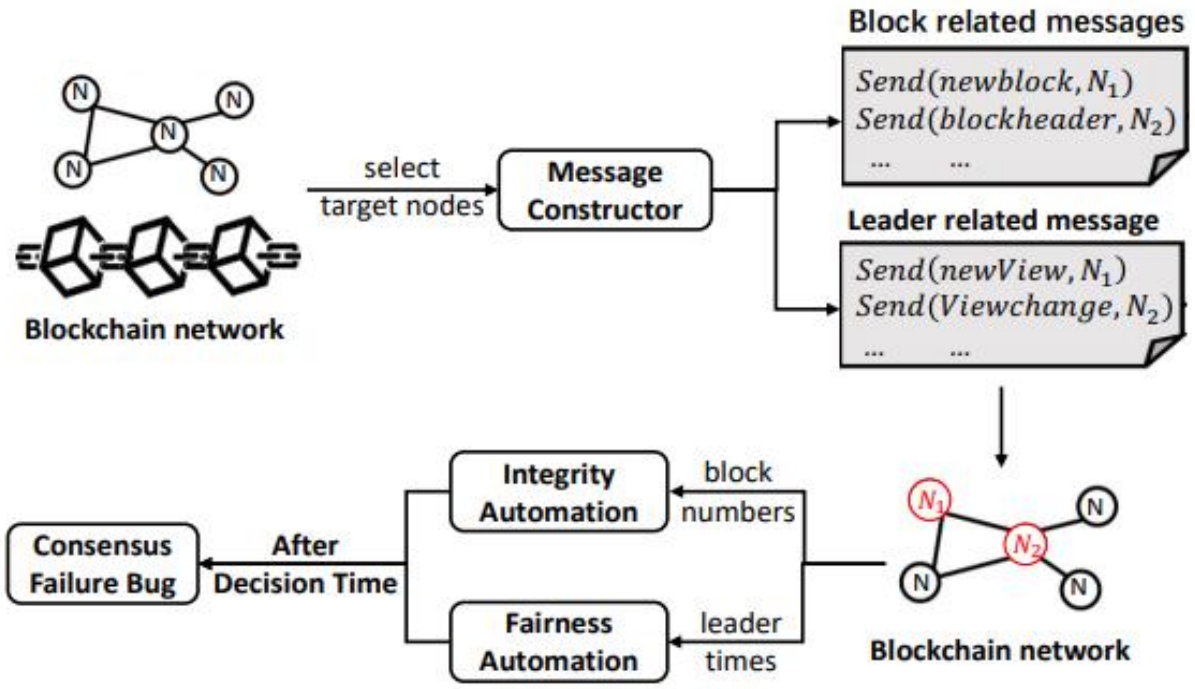
- **behavior divergent model**
  - Guide the blockchain system to violate the consensus property.

# Design

- **Four consensus property**
  - **Liveness**
    - all valid transactions must be executed, committed and stored in a specific block eventually.
  - **Safety**
    - Any invalid transactions are not allowed to be executed, committed, or stored in any blocks.
  - **Integrity**
    - any block with the same block height should be equivalent to each other in all nodes.
    - block syncing mechanism should work normally. There is no node isolation in this network.
  - **Fairness.**
    - all nodes should have a fair possibility to be elected as the leader node or miner node

Safety and Liveness




Integrity

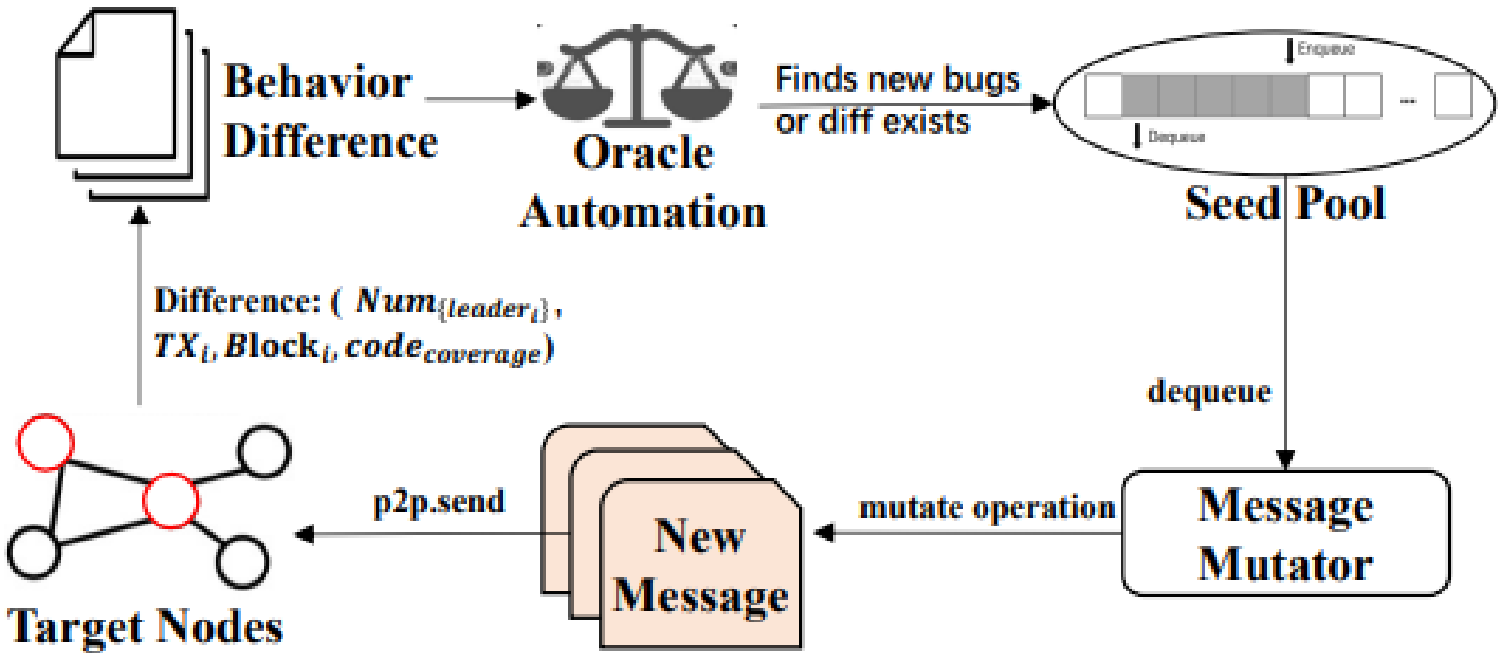
$$(diff_{ij} = |Height_{block_i} - Height_{block_j}|/Height_{block_i})$$

Fairness

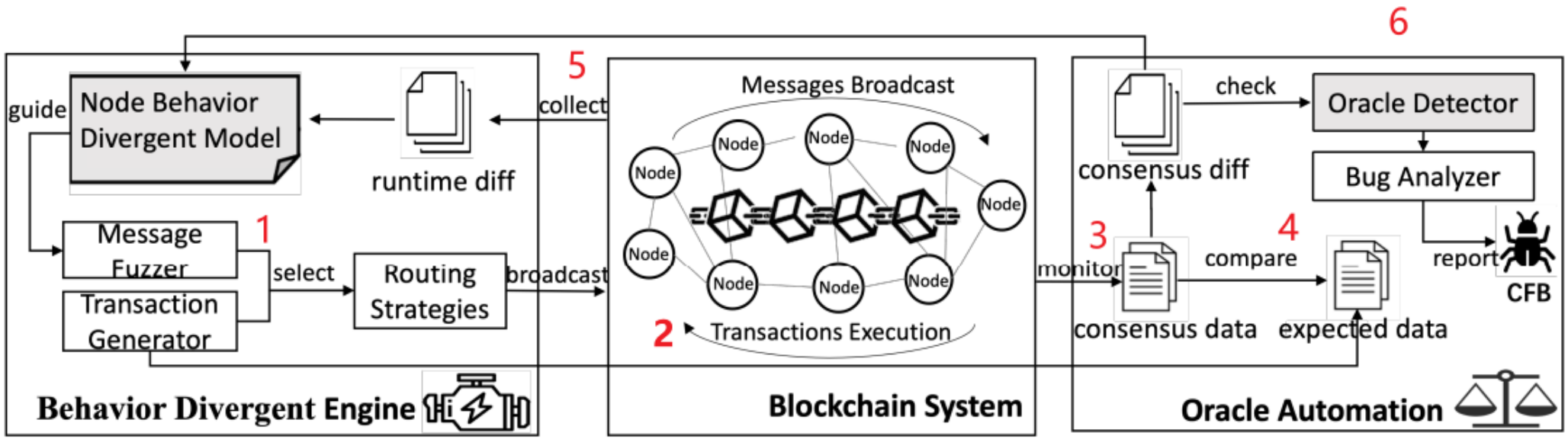
$$(diff_{ij} = |Num_{leader_i} * P_j - Num_{leader_j} * P_i|/Num_{leader_i} * P_j)$$

# Behavior Divergent Engien

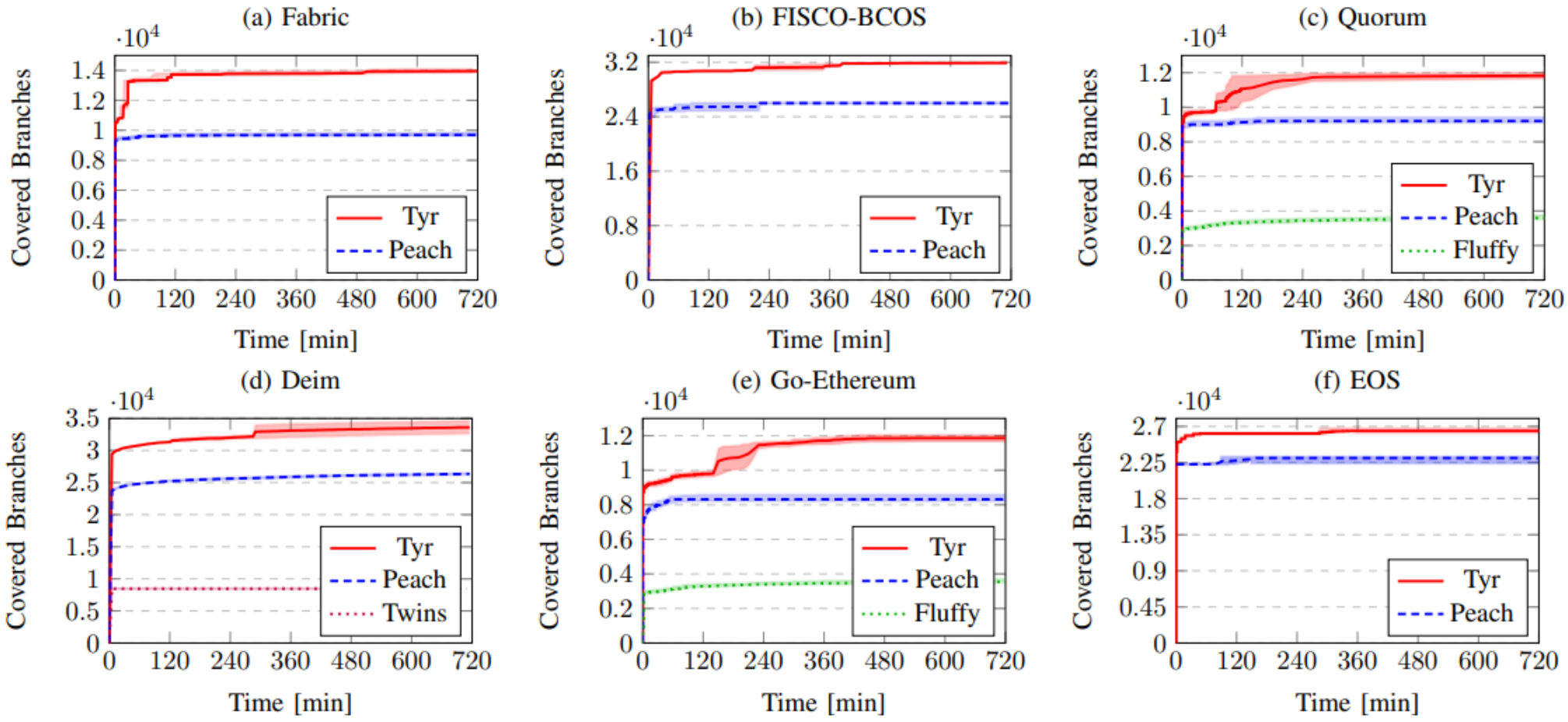
- heuristic insight
  - the ultimate consensus failure is the cumulative result of many transient inconsistencies in the consensus process.



# Implemataion



# Expriment

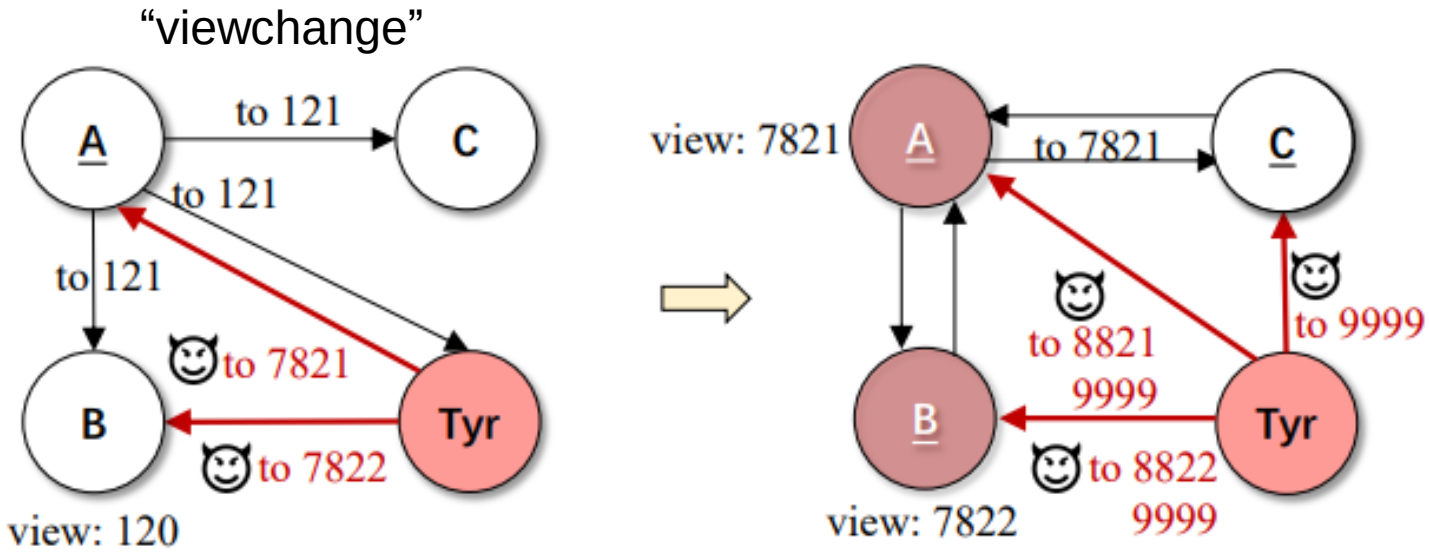

(a) Fabric
(b) FISCO-BCOS
(c) Quorum
(d) Deim
(e) Go-Ethereum
(f) EOS
Covered Branches
Time [min]
·10^4
Tyr
Peach
Fluffy
Twins

# Expriments

| # | Platform | Bug Type | Bug Description | Identifier |
|---|---|---|---|---|
| 1 | Fabric | Integrity | Missing Deletion of in-flight when syncing past the in-flight sequence. | CVE-2022-26297 |
| 2 | Fabric | Safety | Asynchronous sync procedures cause some proposals to be double processed. | CVE-2022-26298 |
| 3 | Fabric | Integrity | Repeat malicious consensus messages makes some honest nodes to be disconnected. | Bug#18167 |
| 4 | Fabric | Fairness | Various viewchange message sequences make some nodes always skip leader. | Bug#17950 |
| 5 | Fabric | Liveness | Random newView causes abnormal high-frequent viewchange and chaos in the network. | Bug#17875 |
| 6 | FISCO-BCOS | Liveness | The nodes change view frequently and stop generating blocks. | CVE-2022-26534 |
| 7 | FISCO-BCOS | Liveness | Transaction handling process is stuck after confusing nodes with different transaction headers. | Bug#2206 |
| 8 | FISCO-BCOS | Liveness | Multi-thread bugs cause some transactions cannot to be executed anymore. | Bug#2204 |
| 9 | FISCO-BCOS | Liveness | Some transactions cannot be processed correctly due to a deadlock. | Bug#2133 |
| 10 | FISCO-BCOS | Liveness | Lack of the verification of the packet header and the view-change is continuously triggered. | Bug#2448 |
| 11 | FISCO-BCOS | Safety | A malicious leader may fake a proposal's header and transactions cannot be processed . | Bug#2307 |
| 12 | FISCO-BCOS | Fairness | A malicious node can always be the leader, thus stop producing new blocks.. | CVE-2022-28937 |
| 13 | Quorum | Liveness | Transactions get stuck in a pending state after receiving incorrect gas from a malicious node. | Bug#1371 |
| 14 | Quorum | Integrity | Serial of malicious sync messages cause repeated "Full sync failed ", isolate normal node. | Bug#1107 |
| 15 | Diem | Fairness | Malicious nodes affect the QC commit and the leader's reputation and cause unfair leader selection. | Bug#10362 |
| 16 | Go-Ethereum | Integrity | Geth nodes no longer sync with Parity nodes after keep receiving malicious sync messages. | Bug#25243 |
| 17 | Go-Ethereum | Integrity | Keep rejecting blocks and stopping the block syncing procedure, leading to node isolation. | Bug#24448 |
| 18 | Go-Ethereum | Liveness | The client stopped transaction processing after receiving plenty of re-connection requests. | Bug#24832 |
| 19 | EOS | Liveness | The producer node crashes when generating a test account through the txn_test_gen_plugin. | CVE-2022-26300 |
| 20 | EOS | Integrity | Isolation occurs when multiple nodes produce blocks with the same index at the same time. | Bug#11063 |

# CVE-2022-26534

- Platform: FISCO-BCOS
- Implication: Dos to make node off line.




```
uint64_t greaterViewWeight = 0;
ViewType viewToReach = 0;
for (auto const& it : m_viewChangeCache) {
    ...
    // check the viewchange weight
    auto viewChangeCache = it.second;
    for (auto const& cache : viewChangeCache){
        auto fromIdx = cache.first;
        auto nodeInfo = m_config->
            getConsensusNodeByIndex(fromIdx);
        if (!nodeInfo){ continue;
// BUG: weight in cache should be clear to 0.
        greaterViewWeight += nodeInfo->weight();
    }
}
if (greaterViewWeight <
     (m_config->maxFaultyQuorum() +1)) return 0;
if (m_config->toView()>=viewToReach) return 0;
if (viewToReach > 0)
{  m_config->setToView(viewToReach - 1)};
```

# Conclusion

- These paper proposes Tyr, an automatic testing tool for detecting Consensus bug in blockchain systems based on the behavior divergent model.
- Tyr designs four properties to analyzing the violation of consensus.
- Fabric, FISCO-BCOS, Quorum, Diem, Go-Ethereum, and EOS.
  - Tyr is compatible with six platforms, has higher code coverage, and finds 20 consensus bugs (5 CVEs).