The SNOW Theorem and Latency-Optimal Read-Only Transactions

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Web Services Are Huge

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[1][2]

2.5 B – content items shared

2.7 B – “likes”

300 M – photos uploaded

105 TB – data scanned

500 TB – new data ingested

[1] Facebook data science. https://www.facebook.com/data
[2] “How Big Is Facebook’s Data?” https://goo.gl/bBN2ch

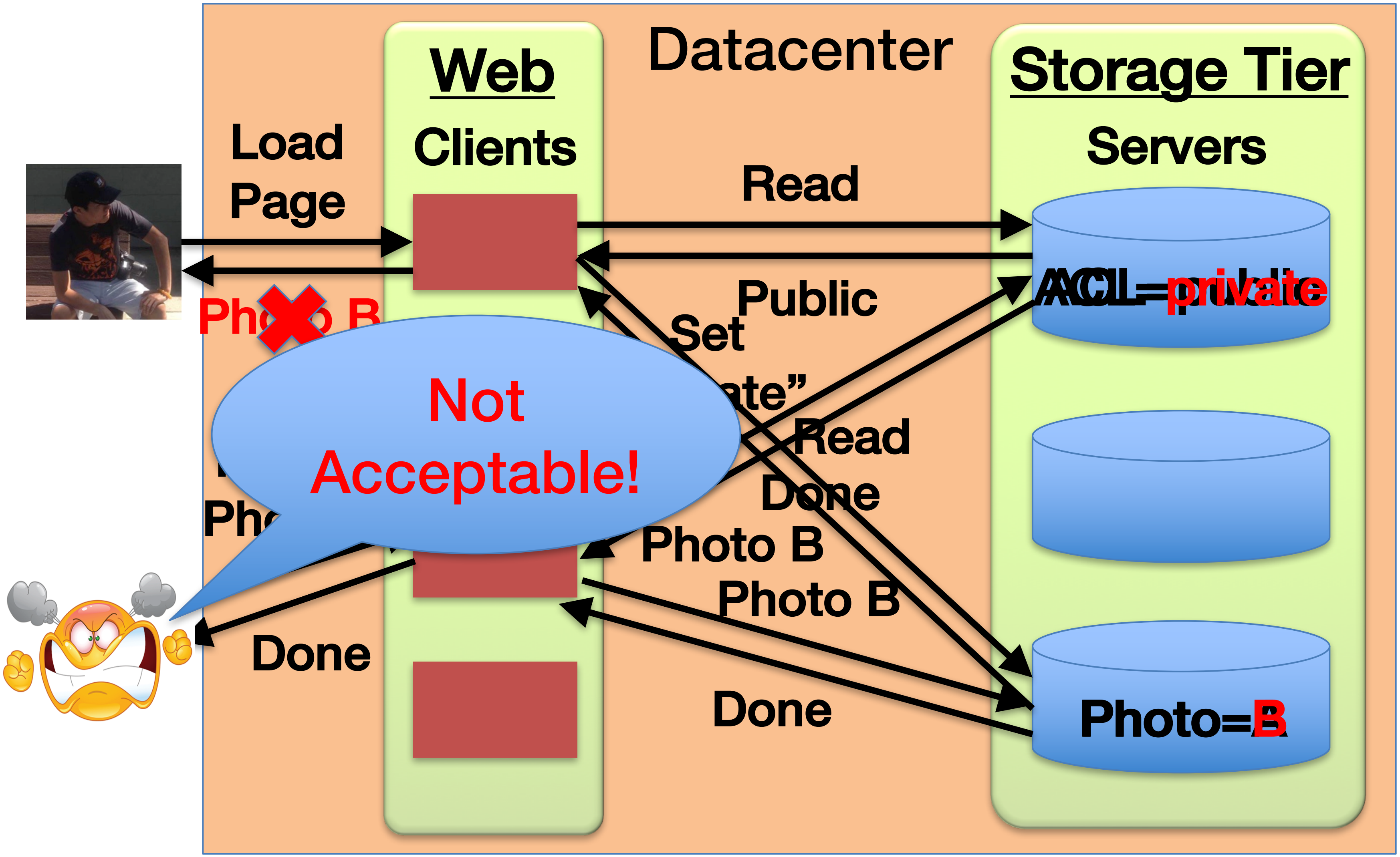
Huge Web Services Shard Data

Massive amount of data

→ must be distributed across servers

Reads dominate the workloads
– need to be as fast as possible!

Simple Reads Are Insufficient



Read-Only Transactions

- Transactions that do not modify data
- Consistently read data across servers

The Power of Read-Only Txn

- Consistency restricts what can be read
  - Eliminates unacceptable combinations
- Compatibility enables write transactions
  - Write transactions atomically update data
- Higher power → more useful
  - Stronger consistency → higher power
  - Compatibility → higher power

Fundamental Tradeoff

High Power	VS	Low Latency

- Reduces anomalies
  (the ACL – Photo example)
- Easier to reason about

- Better user experience
- Higher revenue

Our study proves:
highest power + lowest latency is impossible

The SNOW Properties

[S]trict serializability

[N]on-blocking operations

Highest Power

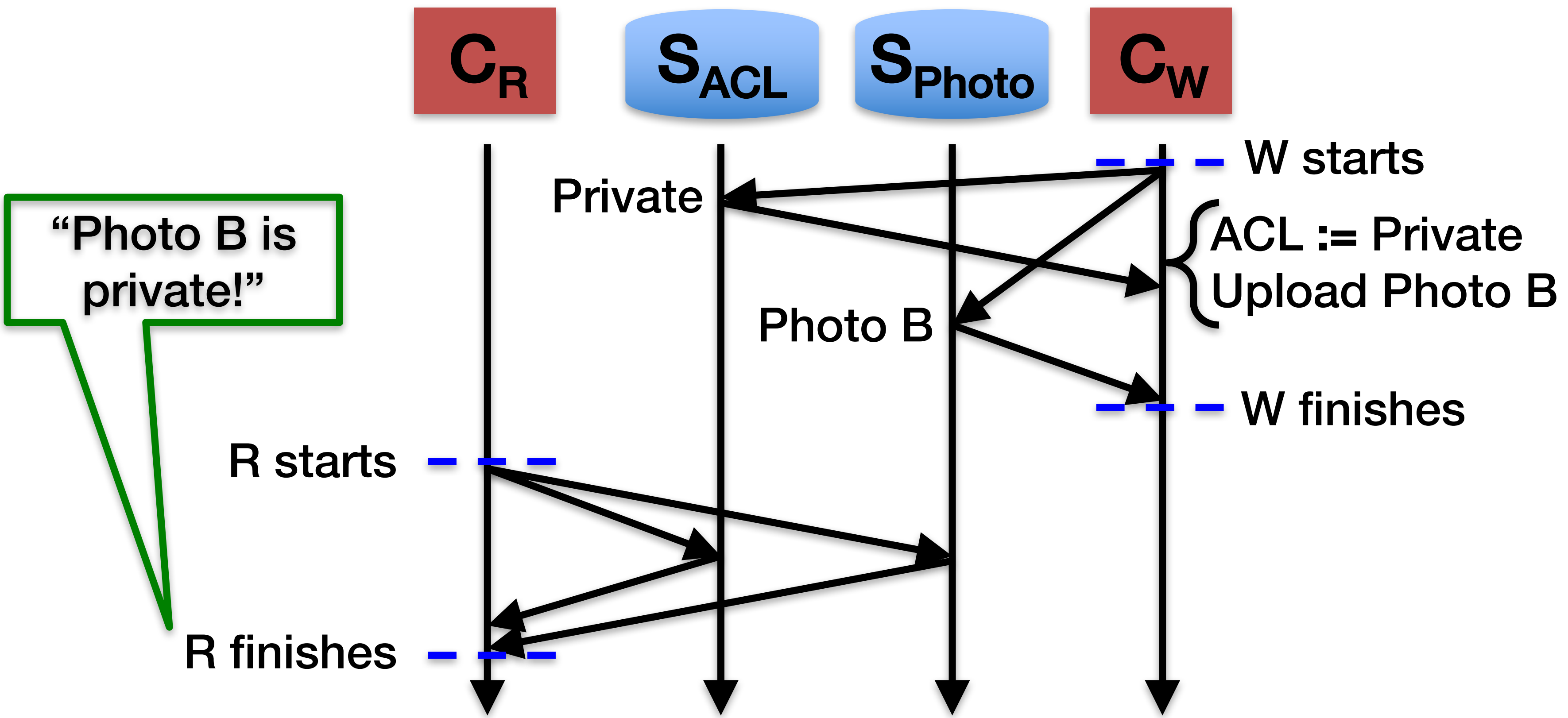
[O]ne response per read

[W]rite transactions that conflict

Lowest Latency

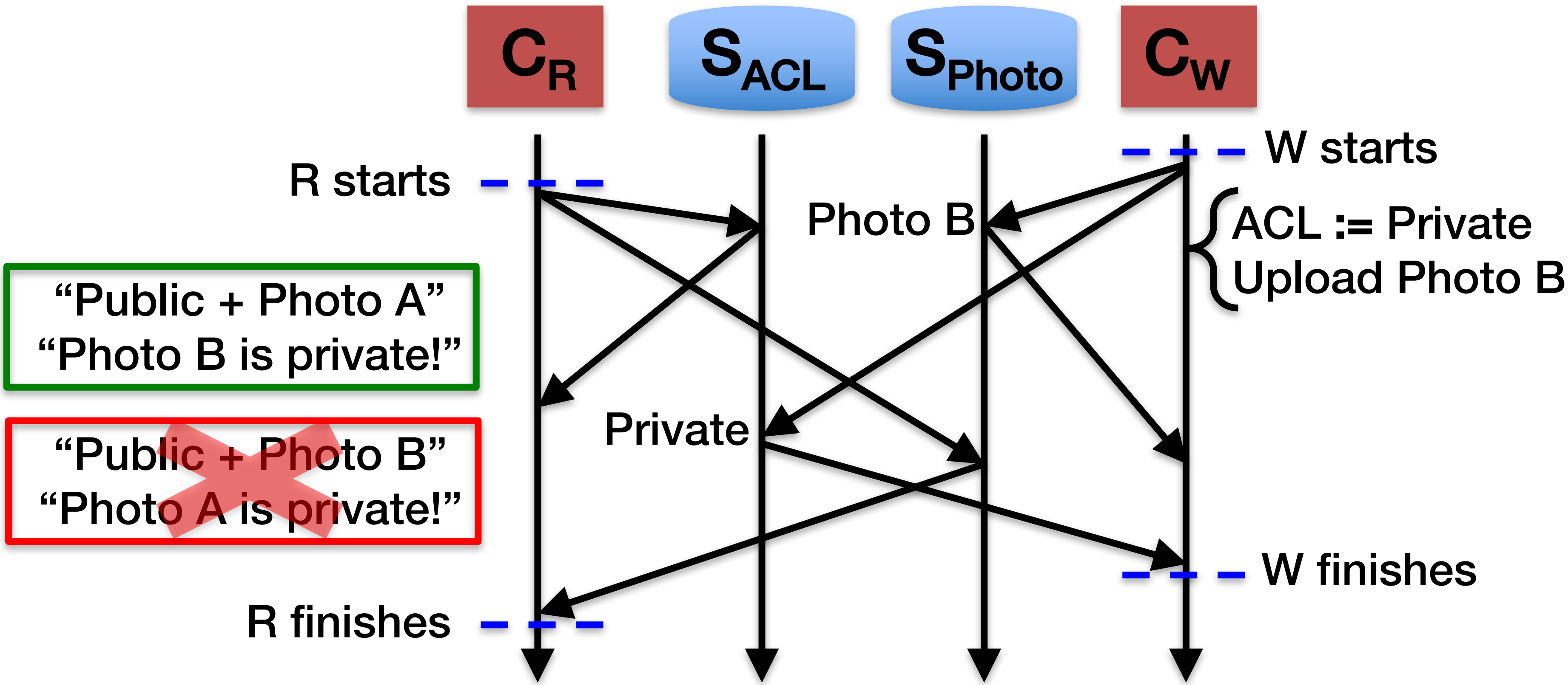
[S]trict Serializability

- Strongest model: real-time + total order



[S]trict Serializability

- Strongest model: real-time + total order



[N]on-blocking Operations

- Do not wait on external events
  - Locks, timeouts, messages, etc.
- Lower latency
  - Save the time spent blocking

[O]ne Response

- One round-trip
  - No message redirection
    - Centralized components: coordinator, etc.
  - No retries
  - Save the time for extra round-trips

- One value per response
  - Less time for transmitting, marshaling, etc.

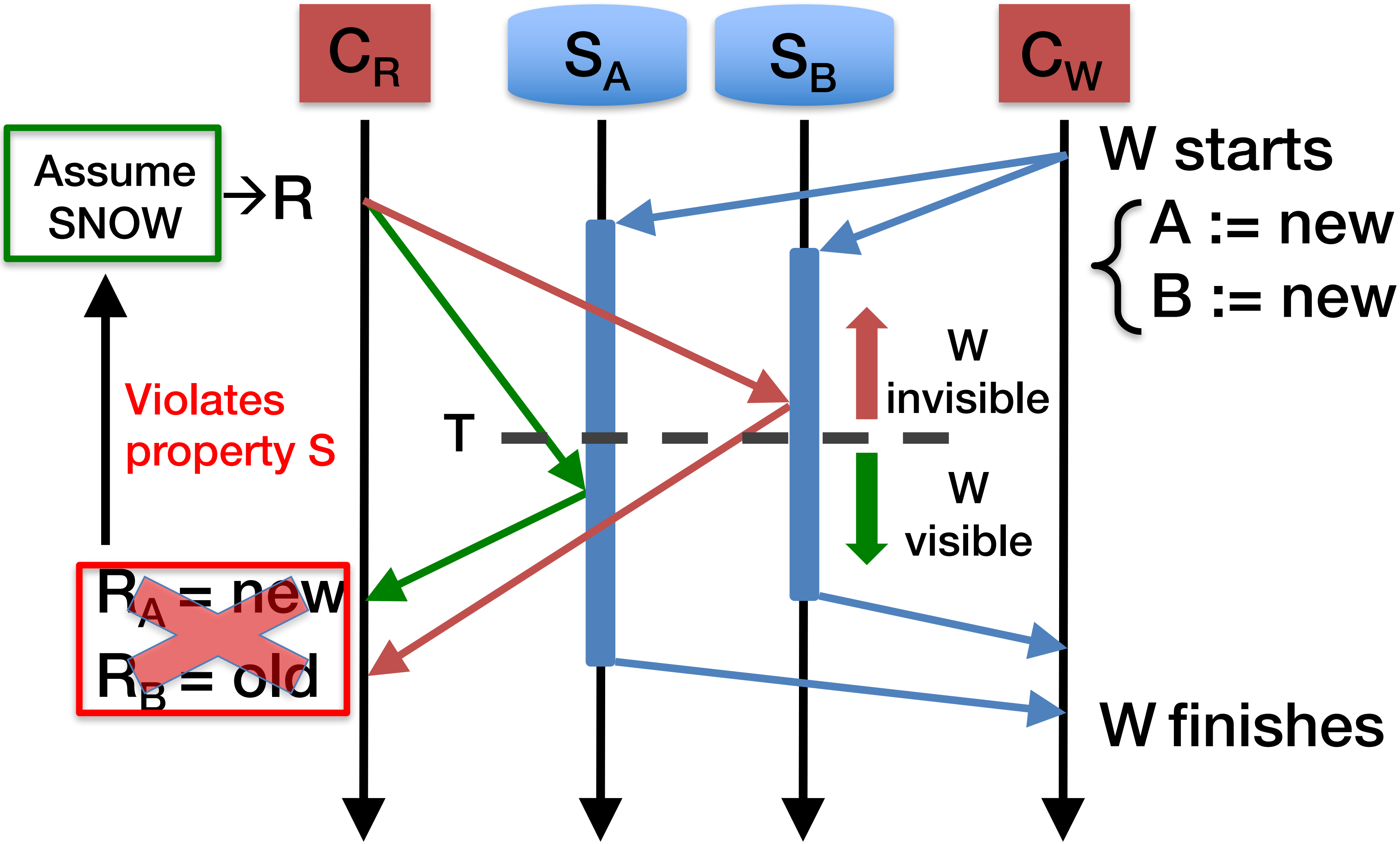
[W]rite Transactions That Conflict

- Compatible with write transactions
  - Richer system model
  - Easier to program

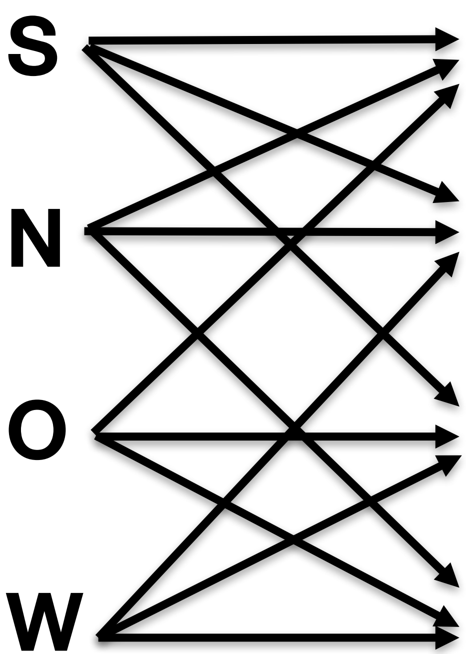
The SNOW Theorem:

Impossible for read-only transaction algorithms to have all SNOW properties

Why SNOW Is Impossible



SNOW Is Tight



S+N+O : COPS-DW

S+N+W: Eiger

S+O+W: Spanner-RO

N+O+W: Spanner-Snap

SNOW-optimal: have any 3 properties
Latency-optimal: have N and O

Study Existing Systems with SNOW

SNOW-optimal and latency-optimal

System	S	N	O	W
Spanner-Snap [OSDI '12]	✖	✔	✔	✔
Yesquel [SOSP '15]	✖	✔	✔	✔
MySQL Cluster	✖	✔	✔	✔

Study Existing Systems with SNOW

SNOW-optimal

System	S	N	O	W
Eiger [NSDI '13]	✔	✔	≤ 3	✔
DrTM [SOSP '15]	✔	✔	≥ 1	✔
RIFL [SOSP '15]	✔	✔	≥ 2	✔
Sinfonia [SOSP '07]	✔	✔	≥ 2	✔
Spanner-RO [OSDI '12]	✔	✖	✔	✔

Study Existing Systems with SNOW

Candidates for Improvement

System	S	N	O	W
COPS	✖	✔	≤ 2	✖
Rococo	✔	✖	> 1	✔

Many more

⋮

Improve Existing Systems
with the SNOW Theorem

- COPS [SOSP ’11]
  - Geo-replicated
  - Causally consistent
  - Read-only txn: ~~S~~ N ~~O~~ ~~W~~

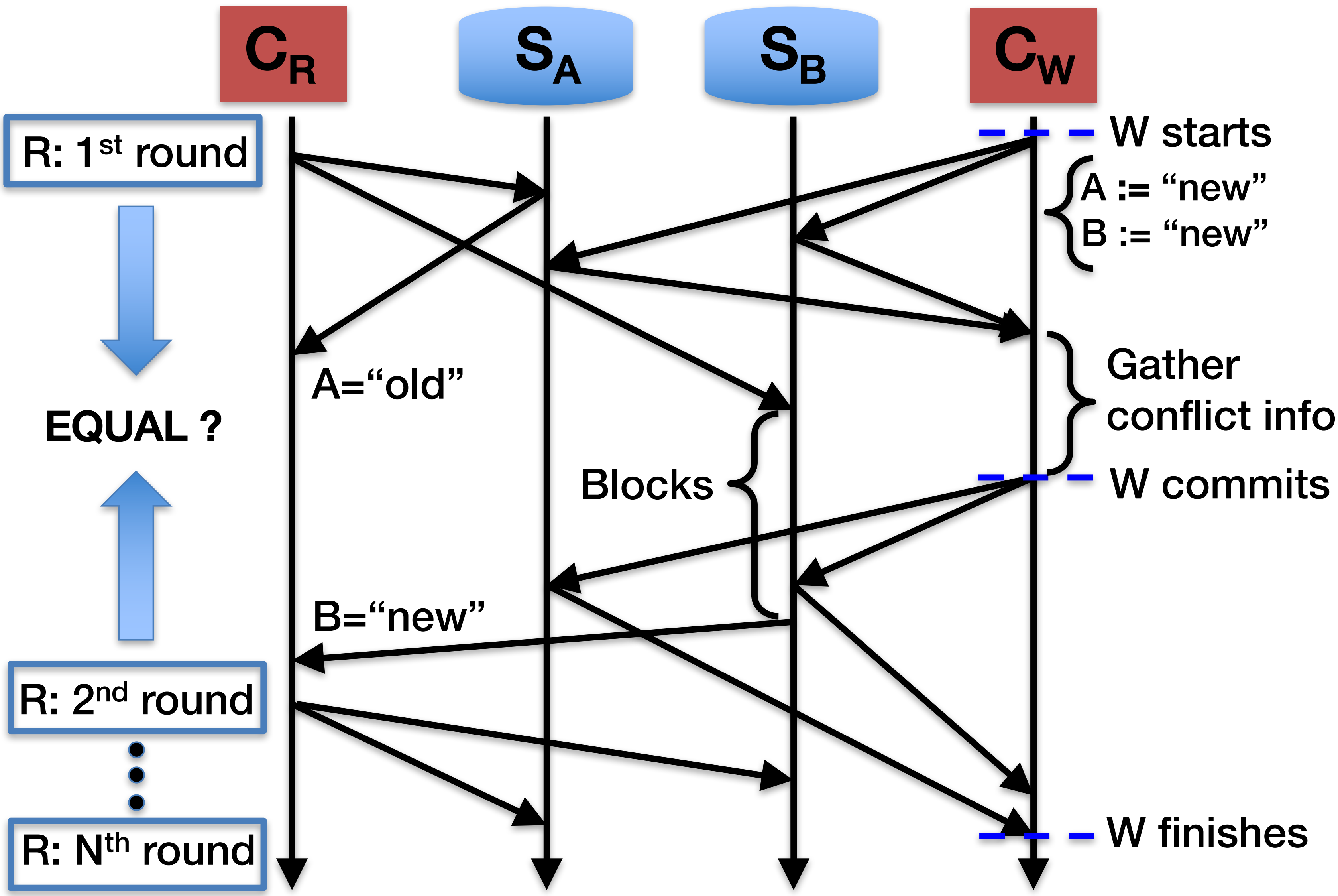
- Rococo [OSDI ’14]
  - Supports general transactions
  - Strictly serializable
  - Read-only txn: S ~~N~~ ~~O~~ W

New Algorithm Designs

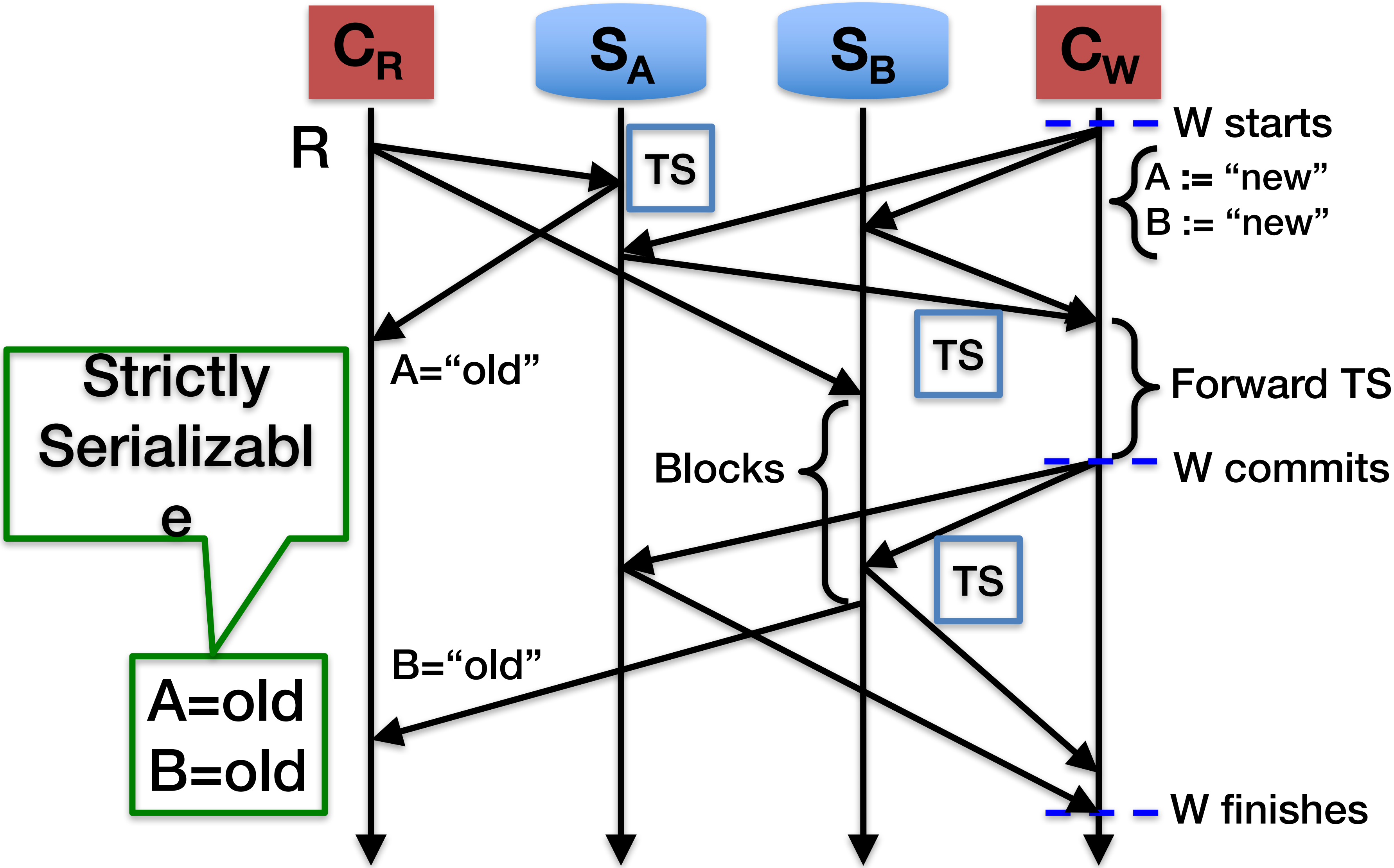
- COPS-SNOW
  - Latency-optimal (N + O)
- Rococo-SNOW
  - SNOW-optimal (S + O + W)

Design insight for optimizing reads: shift the overhead to writes

Rococo's Read-Only Txn (S + W)



Rococo-SNOW (S+O+W)



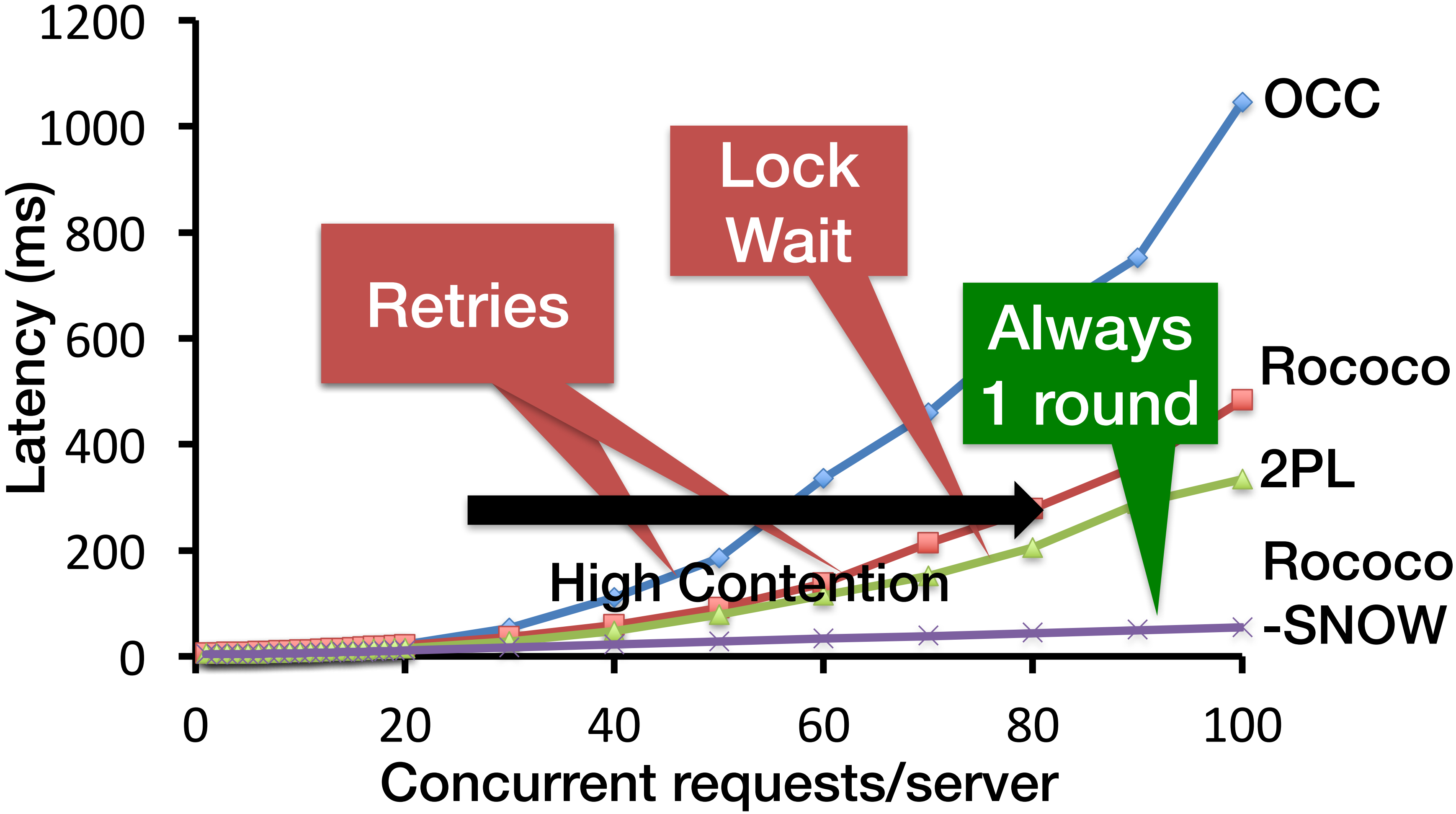
Evaluation of Rococo-SNOW

- To understand
  - Latency of read-only transactions
  - Throughput of other types of transactions

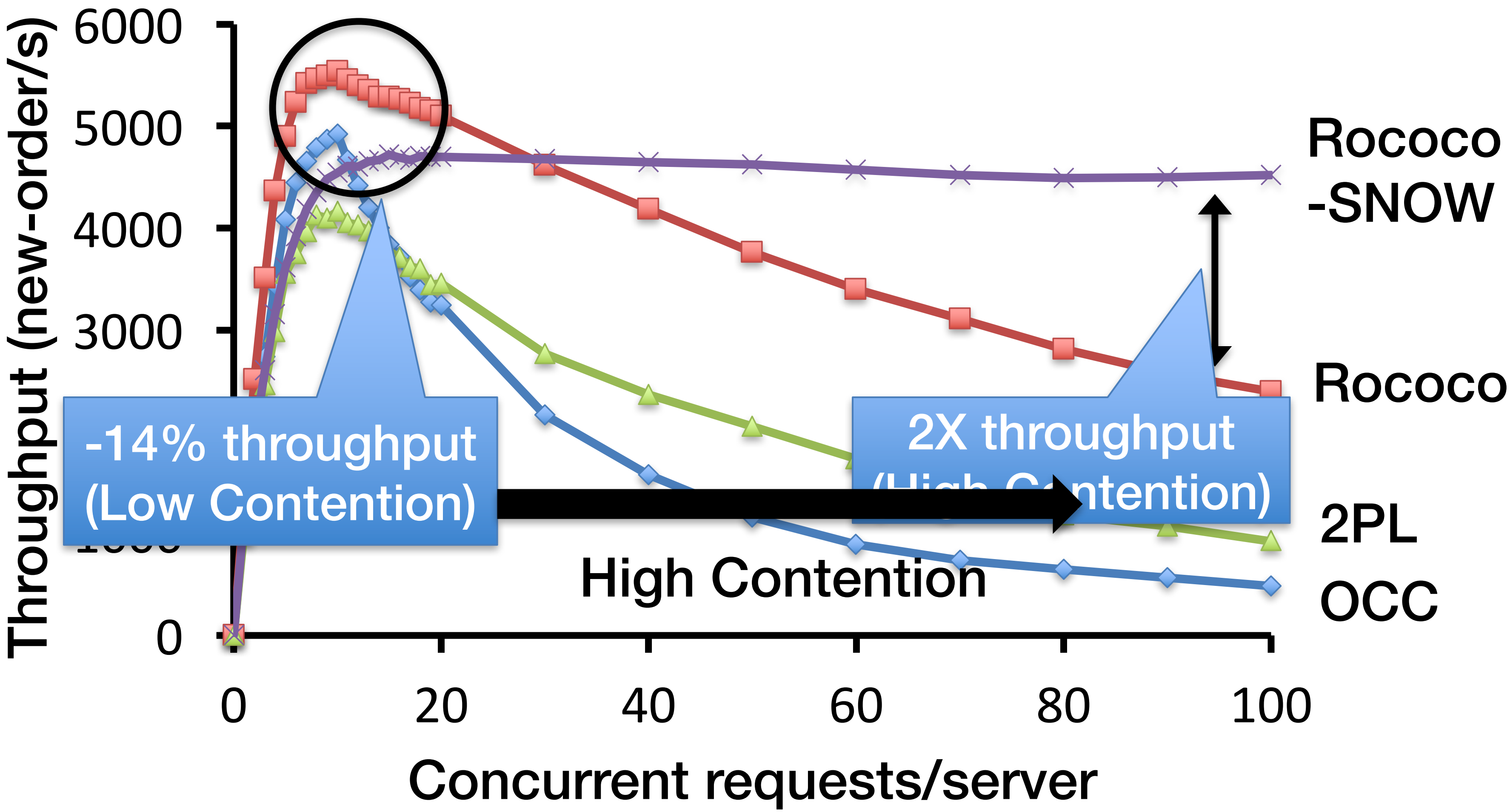
- Experiment configuration
  - Identical to Rococo's
  - TPC-C workloads

- https://github.com/USC-NSL/Rococo-SNOW

Significantly Lower Latency
for Read-Only Txn



Higher Throughput
under High Contention



Conclusion

- The SNOW Theorem for read-only txns
  - Impossible to have all of the SNOW properties
  - The SNOW Theorem is tight
  - Understands what is possible
- SNOW helps understand existing systems
  - Many are not yet optimal
- Rococo-SNOW
  - SNOW Theorem guided SNOW-optimal design
  - Significantly higher throughput and lower latency under high contention