ΠΑΝΕΠΙΣΤΗΜΙΟ ΚΡΗΤΗΣ
UNIVERSITY OF CRETE

HY590.45
Modern Topics in Scalable Storage Systems

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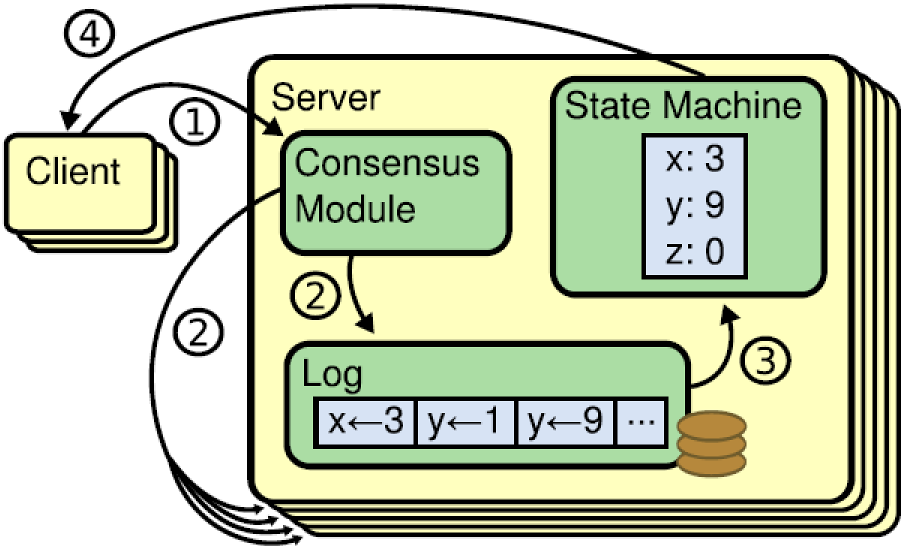
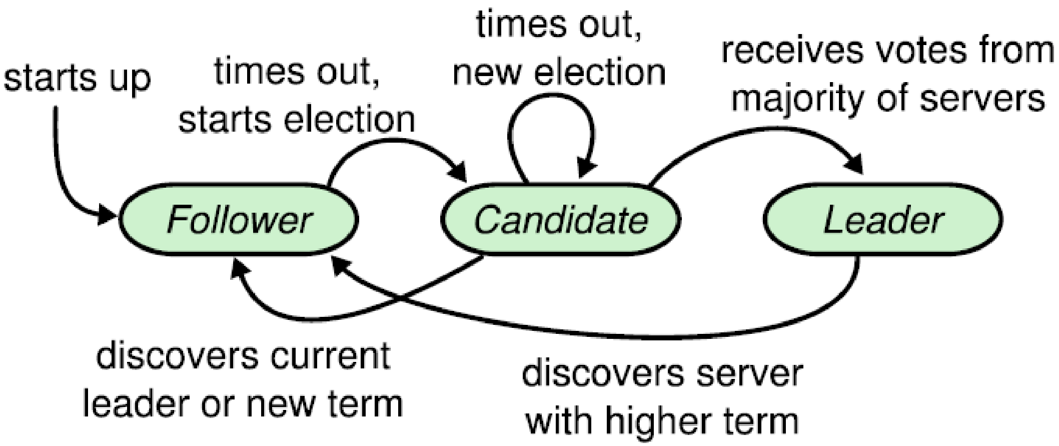
Raft

- Consensus algorithm for log replication
- Easier to understand compared to Multi-Paxos

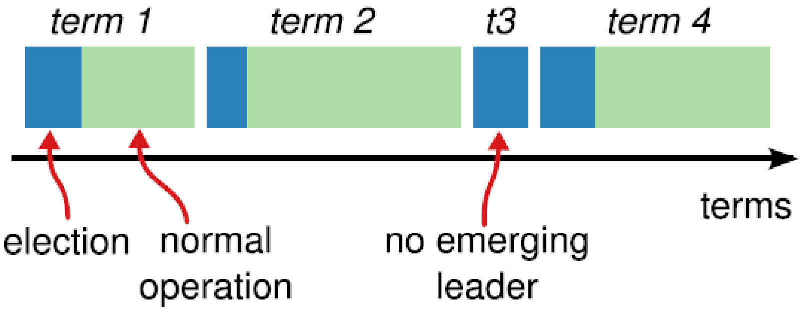
Replicated state machine architecture



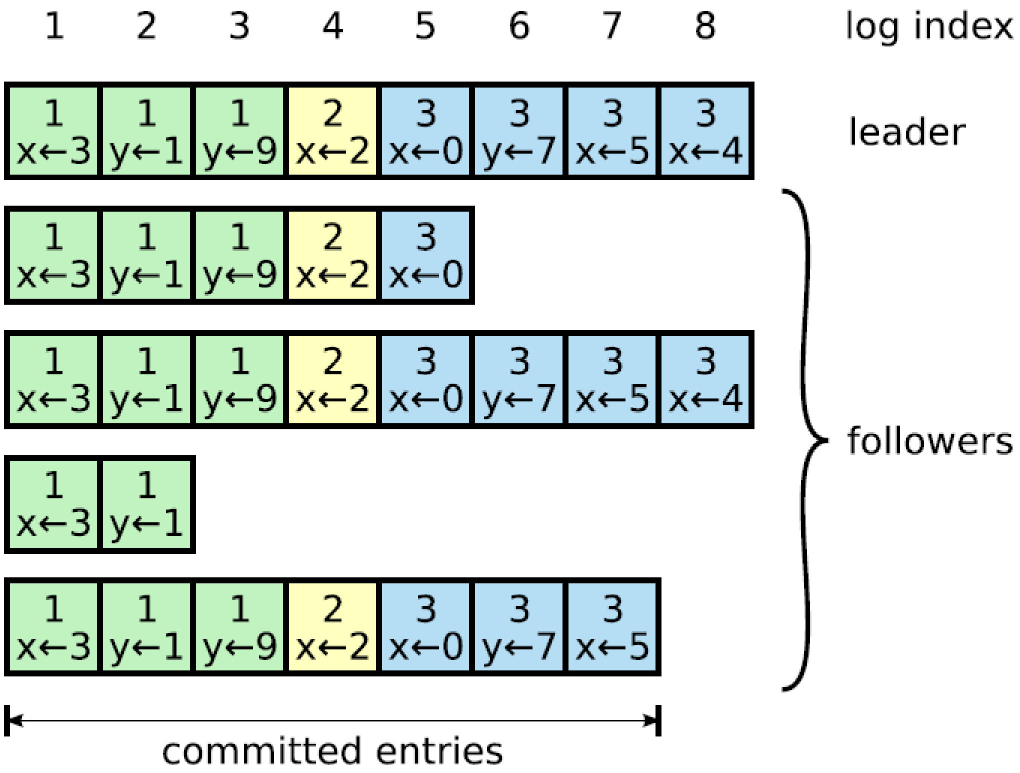
Server states



Terms (epochs)

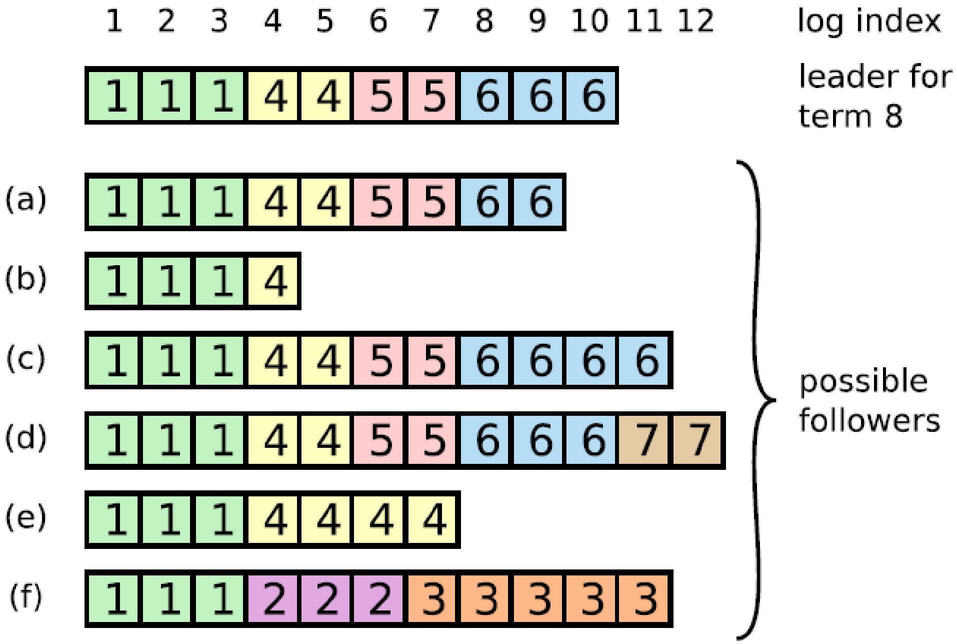


Log entries



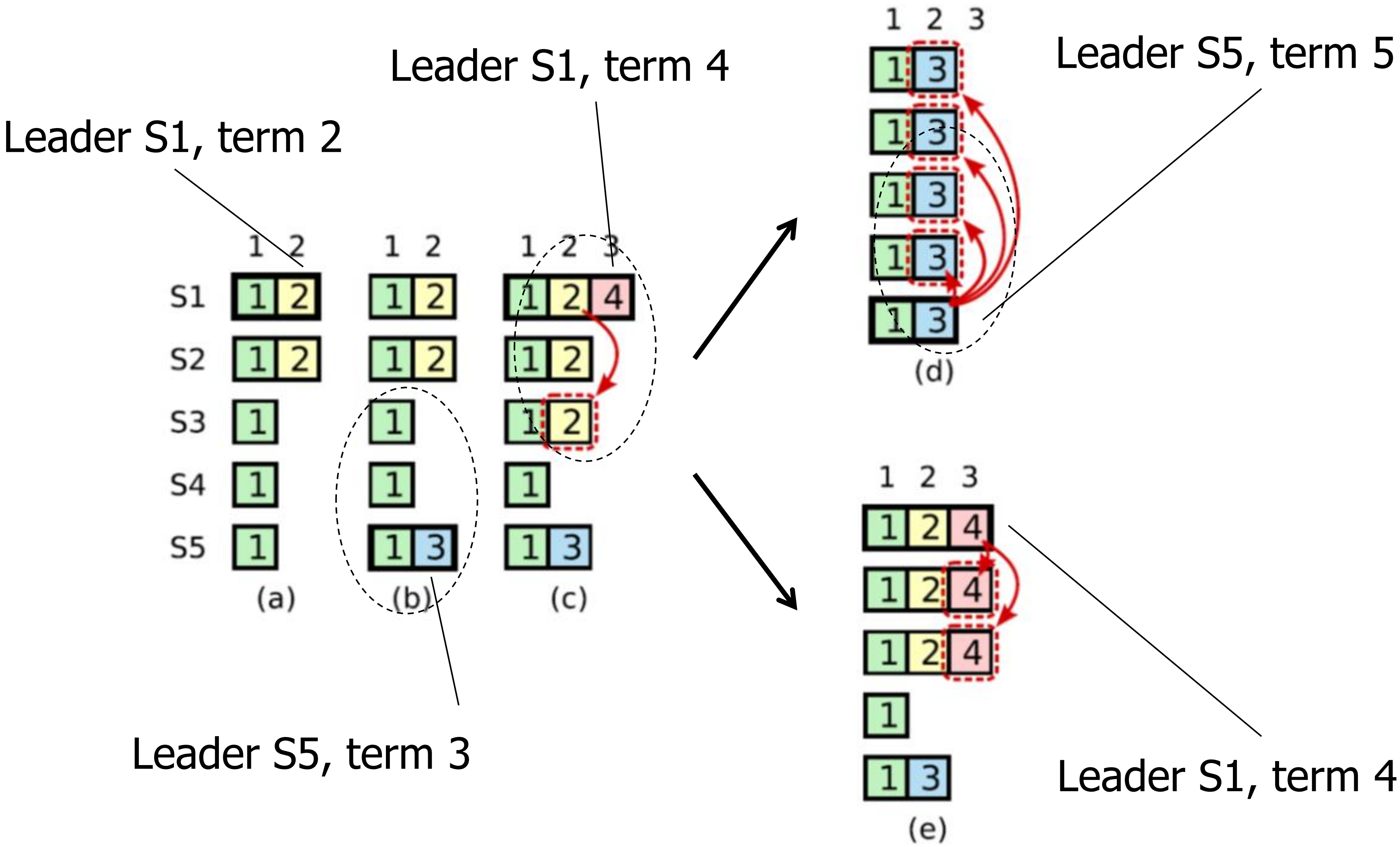
log index	1	2	3	4	5	6	7	8
leader	1 x←3	1 y←1	1 y←9	2 x←2	3 x←0	3 y←7	3 x←5	3 x←4
followers	1 x←3	1 y←1	1 y←9	2 x←2	3 x←0			
	1 x←3	1 y←1	1 y←9	2 x←2	3 x←0	3 y←7	3 x←5	3 x←4
	1 x←3	1 y←1						
	1 x←3	1 y←1	1 y←9	2 x←2	3 x←0	3 y←7	3 x←5	

Possible states of followers



	1	2	3	4	5	6	7	8	9	10	11	12	log index
	1	1	1	4	4	5	5	6	6	6			leader for term 8
(a)	1	1	1	4	4	5	5	6	6				possible followers
(b)	1	1	1	4									
(c)	1	1	1	4	4	5	5	6	6	6	6		
(d)	1	1	1	4	4	5	5	6	6	6	7	7	
(e)	1	1	1	4	4	4	4						
(f)	1	1	1	2	2	2	3	3	3	3	3		

When is an entry committed?



Leader S1, term 2

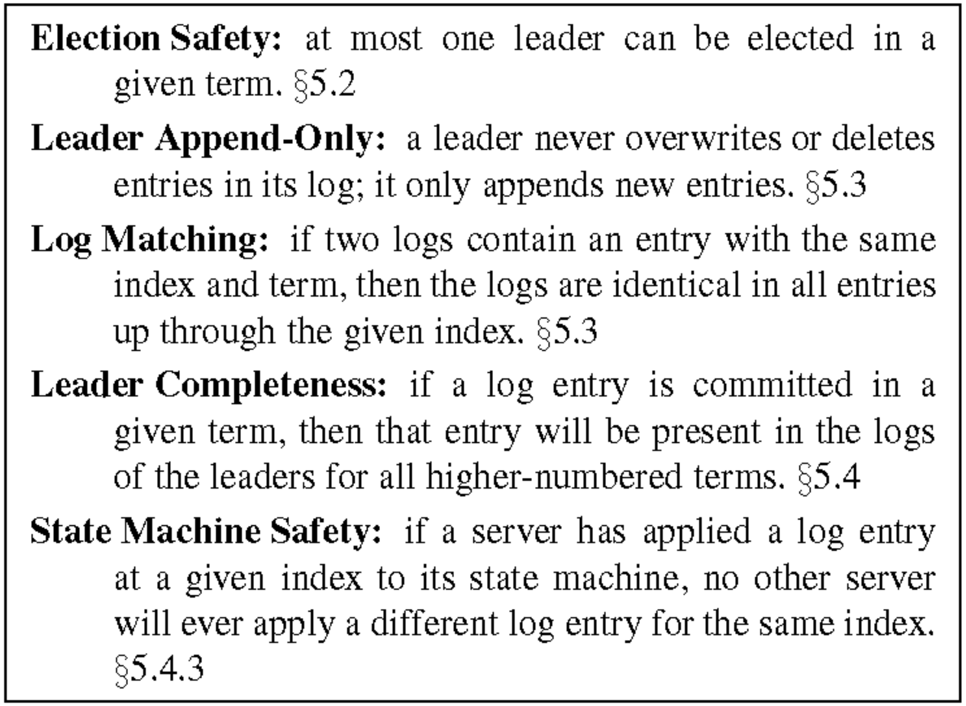
Leader S1, term 4

Leader S5, term 5

Leader S5, term 3

Leader S1, term 4

Properties



Election Safety: at most one leader can be elected in a given term. §5.2

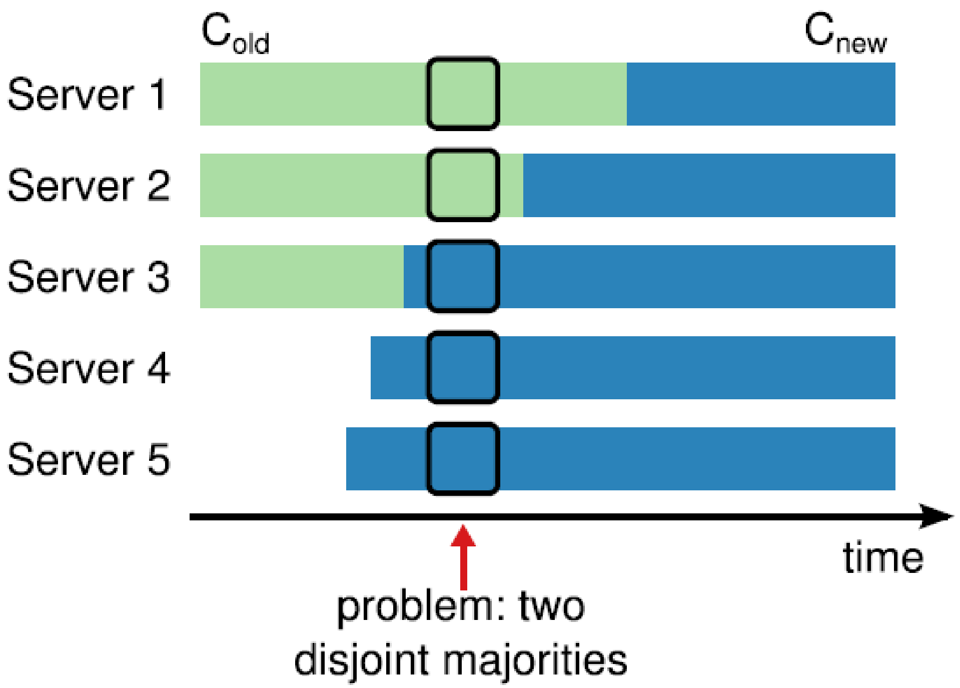
Leader Append-Only: a leader never overwrites or deletes entries in its log; it only appends new entries. §5.3

Log Matching: if two logs contain an entry with the same index and term, then the logs are identical in all entries up through the given index. §5.3

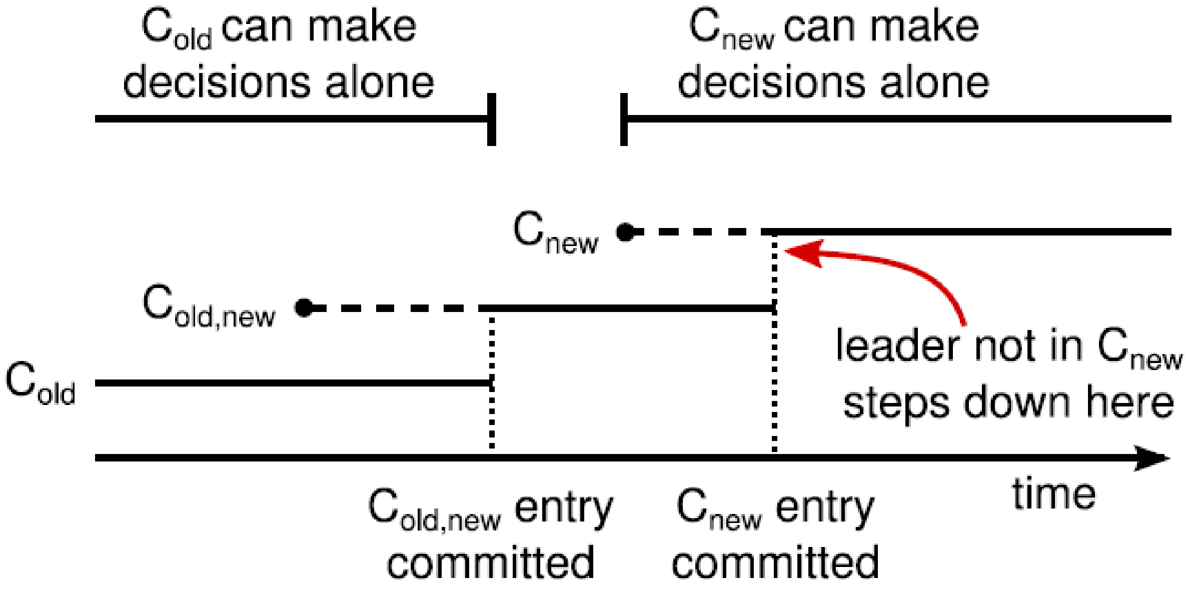
Leader Completeness: if a log entry is committed in a given term, then that entry will be present in the logs of the leaders for all higher-numbered terms. §5.4

State Machine Safety: if a server has applied a log entry at a given index to its state machine, no other server will ever apply a different log entry for the same index. §5.4.3

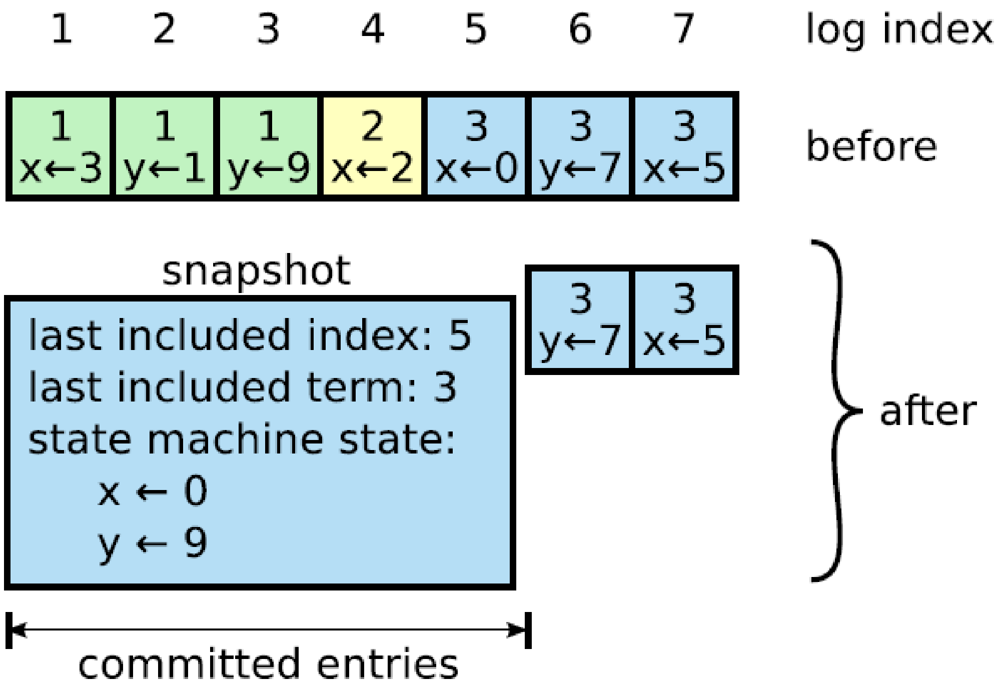
Reconfiguration



Joint consensus


C_{old} can make decisions alone
C_{new} can make decisions alone
C_{new}
$C_{old,new}$
C_{old}
leader not in C_{new} steps down here
time
$C_{old,new}$ entry committed
C_{new} entry committed

Log compaction - snapshots



1	2	3	4	5	6	7	log index
1 x←3	1 y←1	1 y←9	2 x←2	3 x←0	3 y←7	3 x←5	before

snapshot

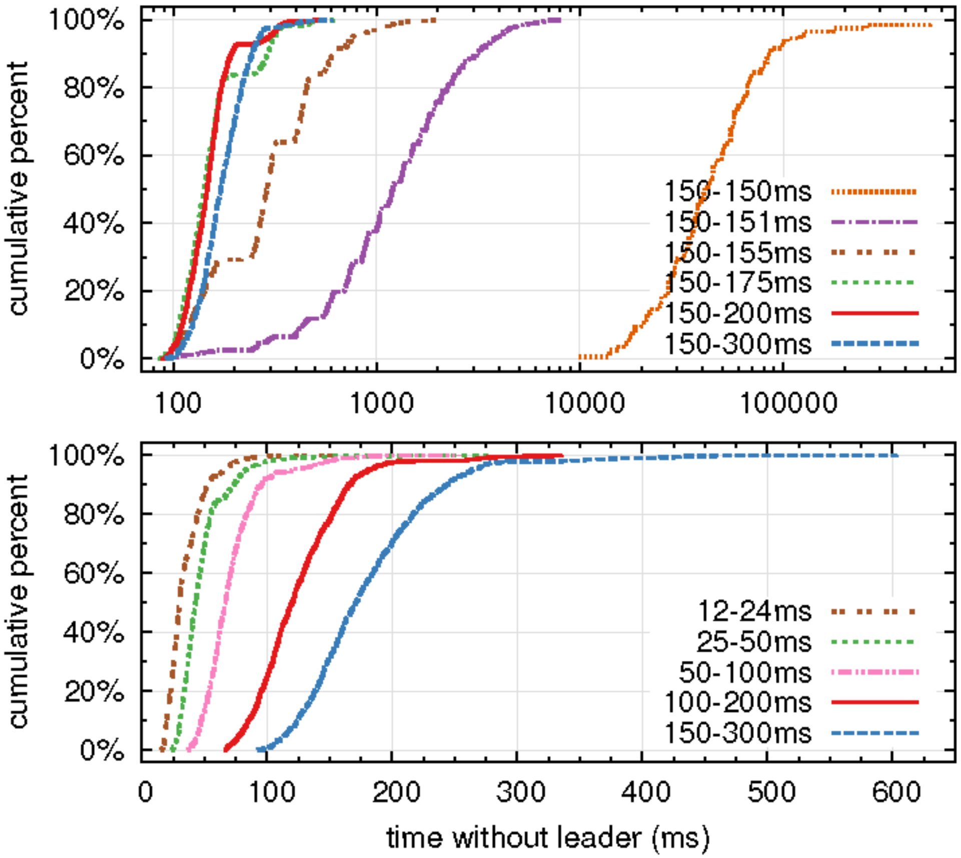
last included index: 5
last included term: 3
state machine state:
x ← 0
y ← 9

3 y←7	3 x←5

after

committed entries

Time to detect and replace crashed leader



Timing requirement

$$broadcastTime \ll electionTimeout \ll MTBF$$

Raft