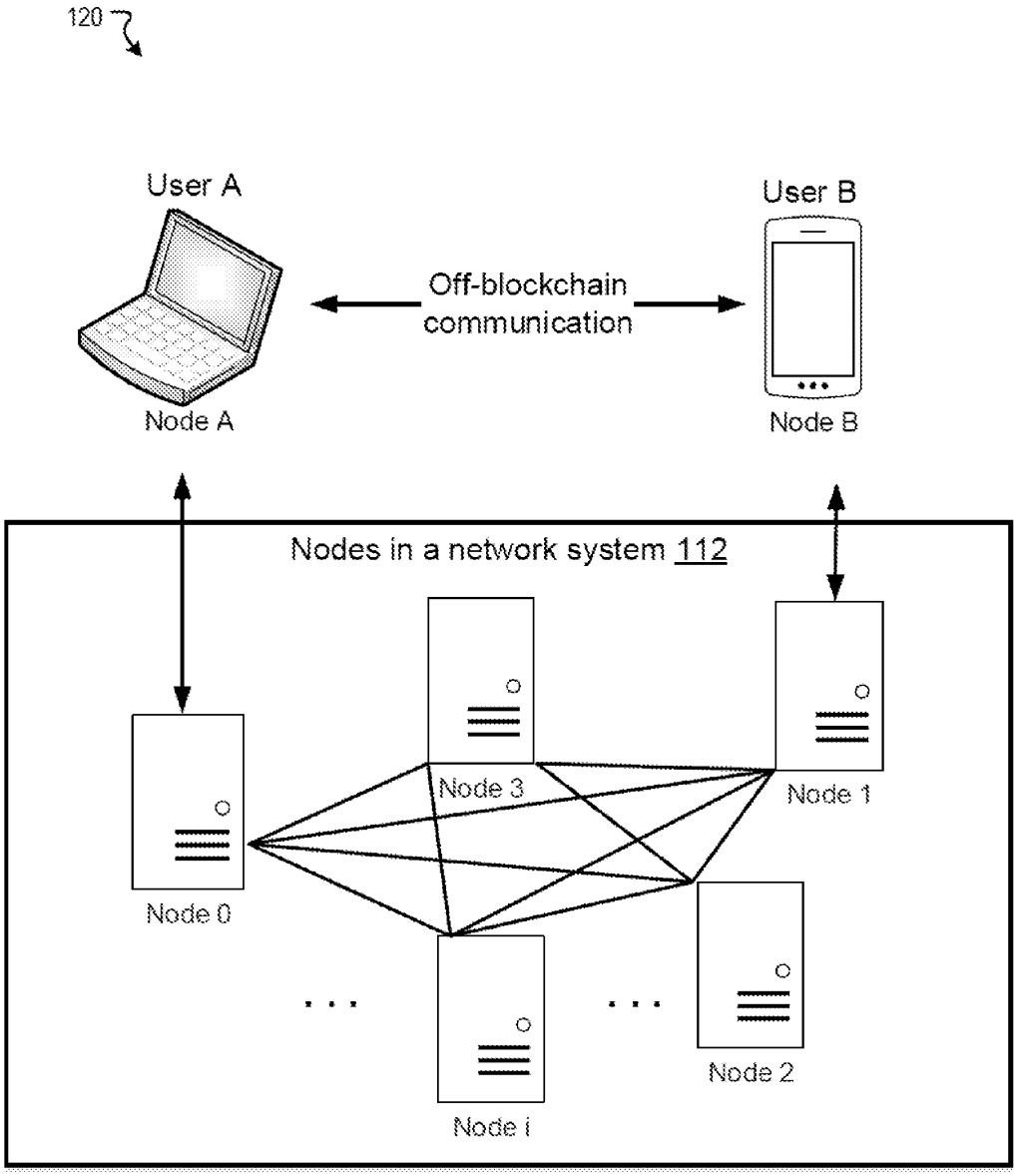
120
User A
User B
Off-blockchain communication
Node A
Node B
Nodes in a network system 112
Node 3
Node 1
Node 0
Node 2
Node i

FIG. 1

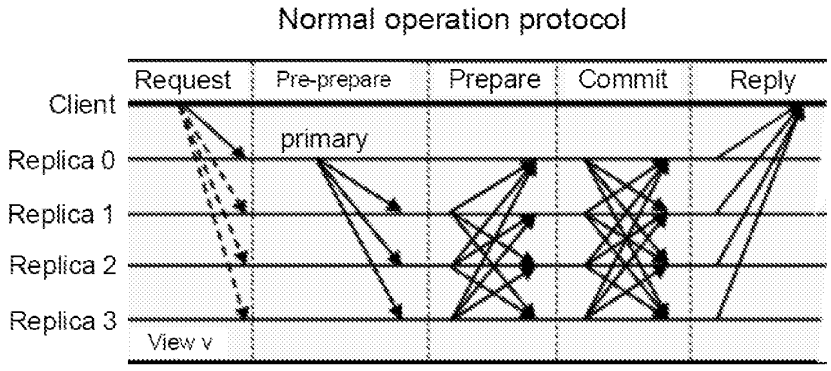

FIG. 2A

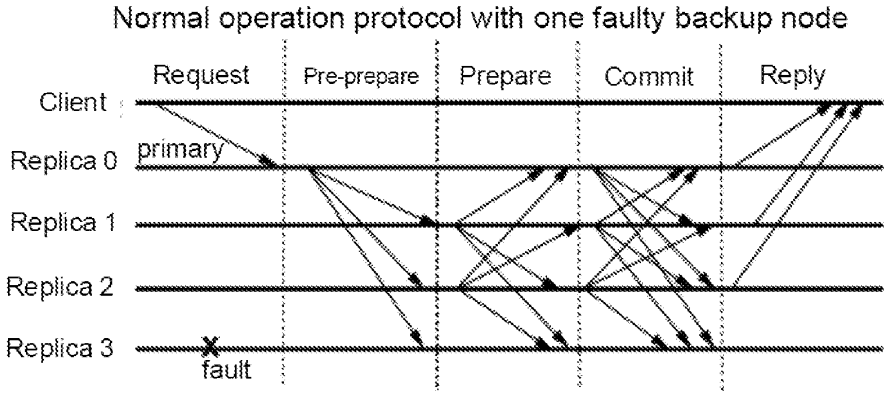

FIG. 2B

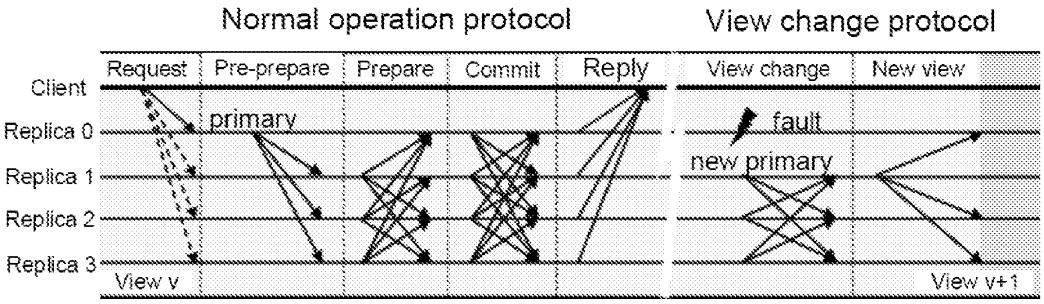

FIG. 2C

Normal operation protocol

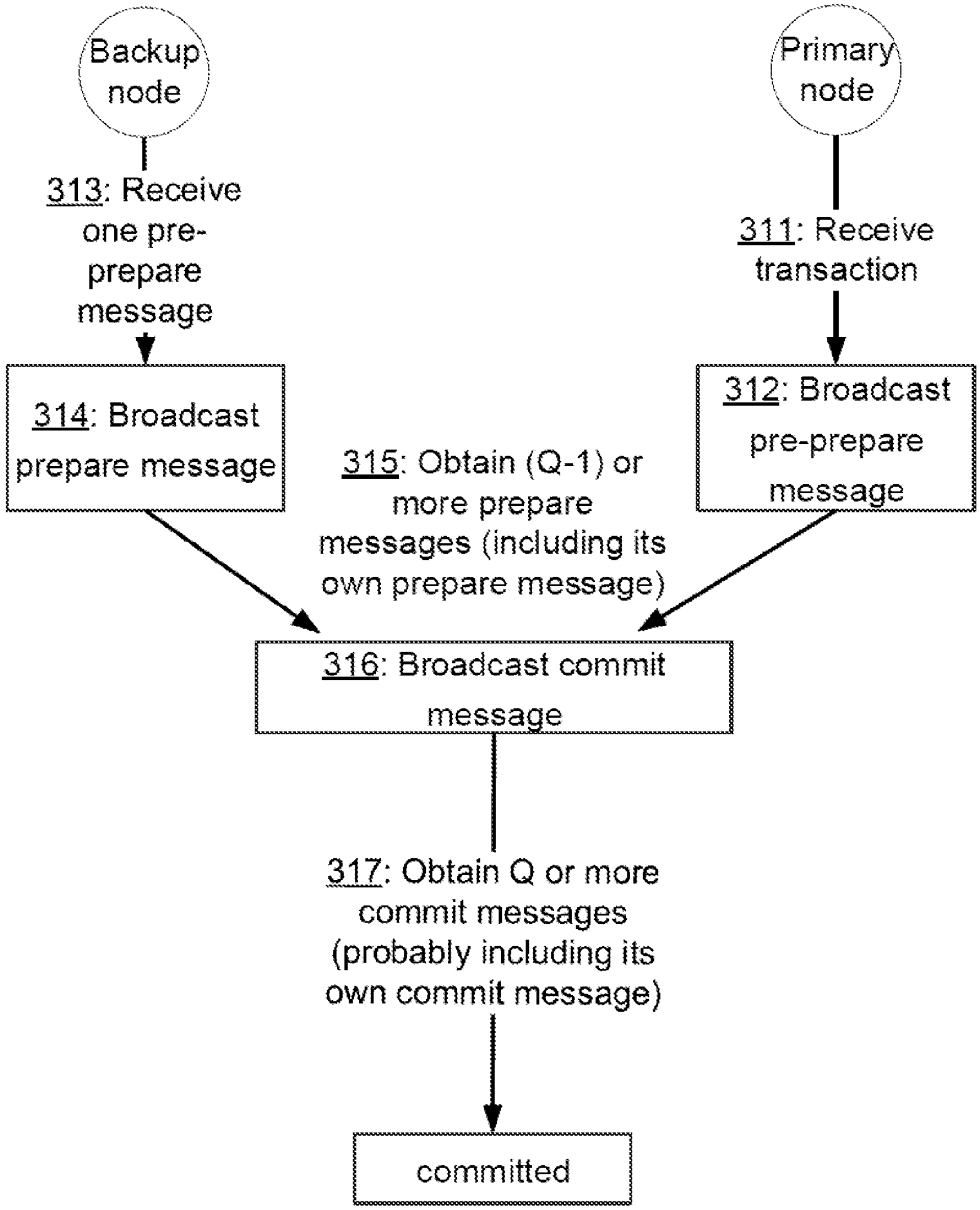

FIG. 3A

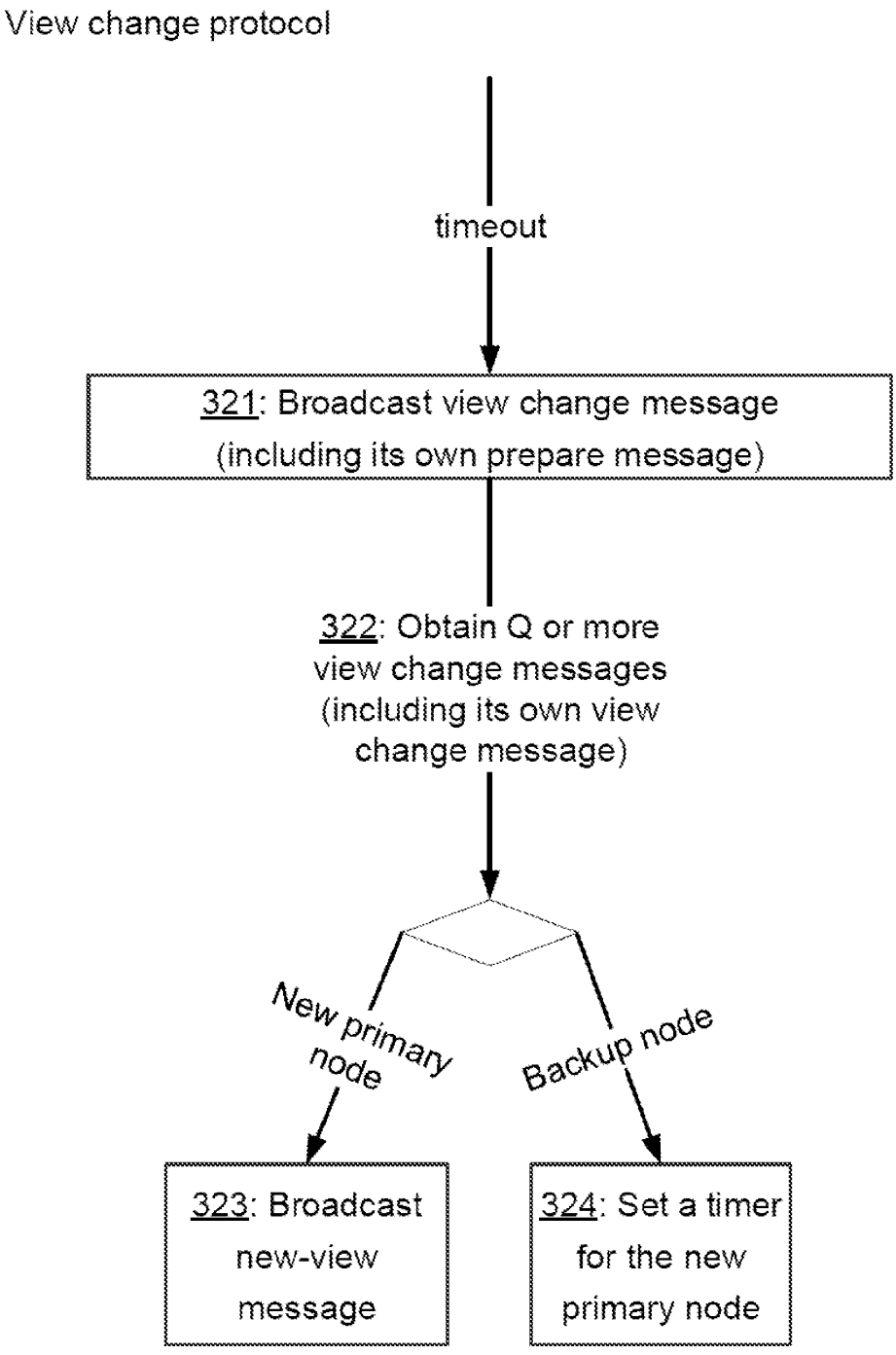
View change protocol
timeout
321: Broadcast view change message (including its own prepare message)
322: Obtain Q or more view change messages (including its own view change message)
New primary node
Backup node
323: Broadcast new-view message
324: Set a timer for the new primary node

FIG. 3B

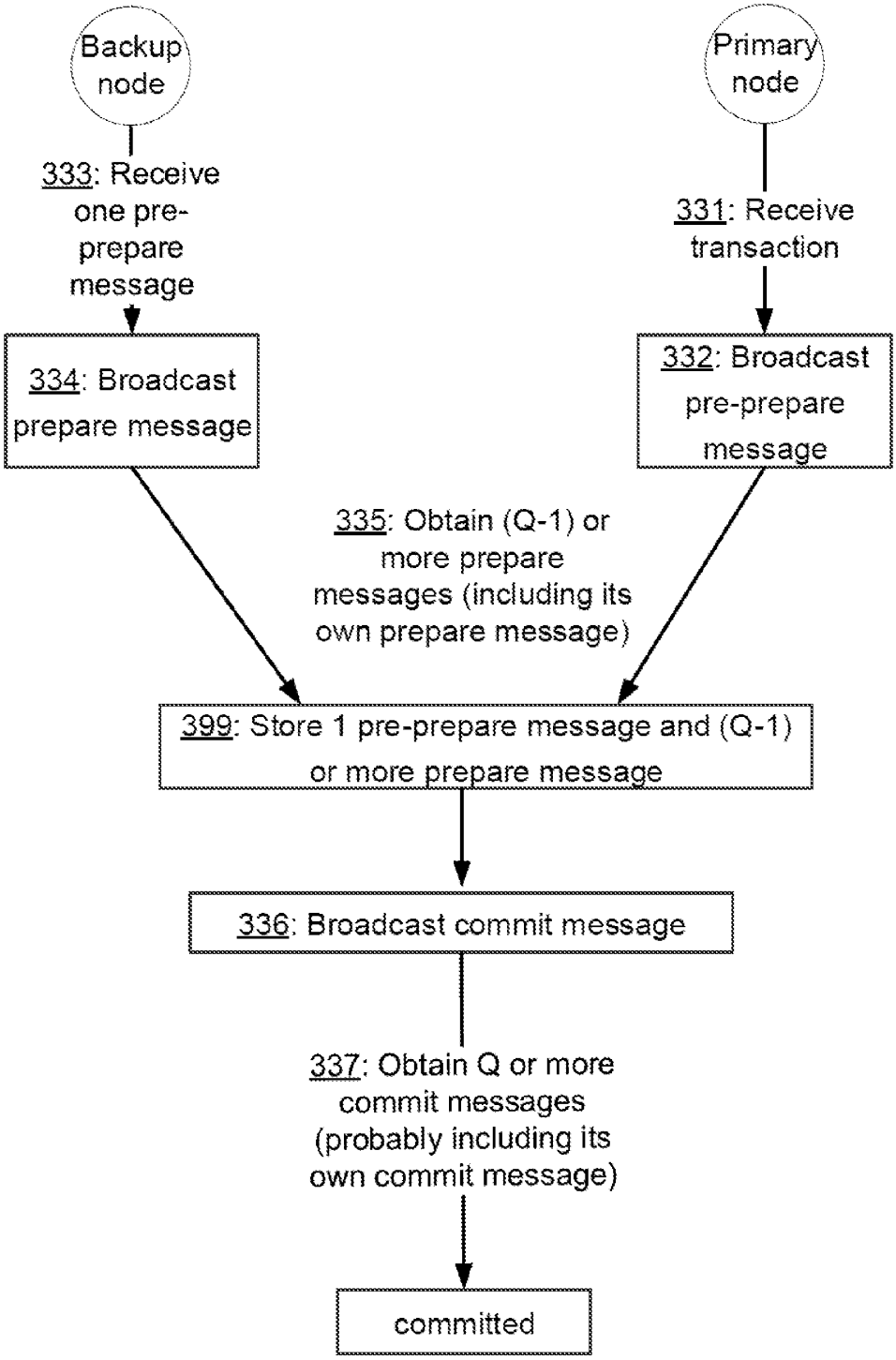
Backup node
Primary node
333: Receive one pre-prepare message
331: Receive transaction
334: Broadcast prepare message
332: Broadcast pre-prepare message
335: Obtain (Q-1) or more prepare messages (including its own prepare message)
399: Store 1 pre-prepare message and (Q-1) or more prepare message
336: Broadcast commit message
337: Obtain Q or more commit messages (probably including its own commit message)
committed

FIG. 3C

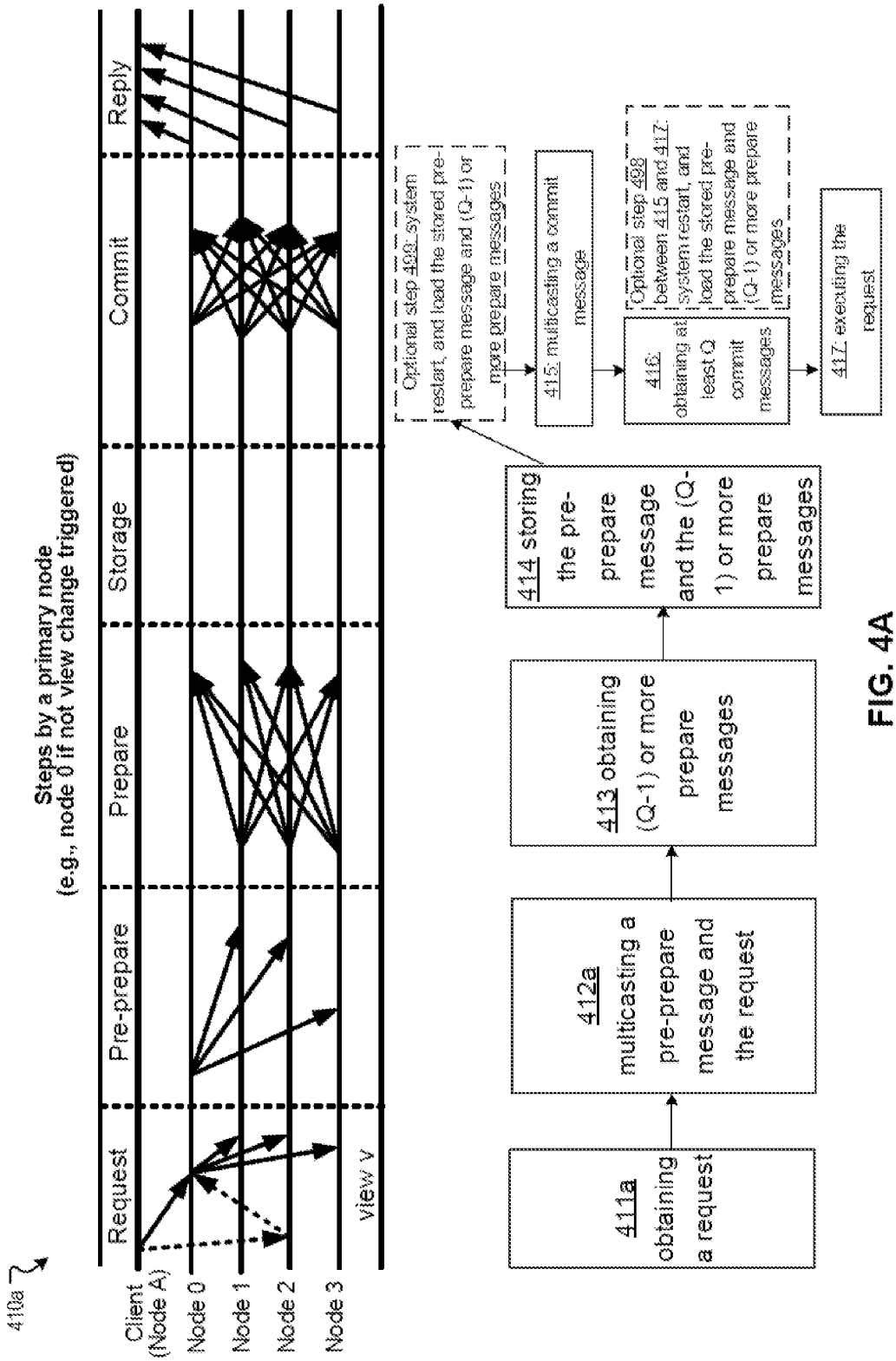
410a
Steps by a primary node
(e.g., node 0 if not view change triggered)
Request
Pre-prepare
Prepare
Storage
Commit
Reply
Client (Node A)
Node 0
Node 1
Node 2
Node 3
view v
411a obtaining a request
412a multicasting a pre-prepare message and the request
413 obtaining (Q-1) or more prepare messages
414 storing the pre-prepare message and the (Q-1) or more prepare messages
Optional step 498: system restart, and load the stored pre-prepare message and (Q-1) or more prepare messages
415: multicasting a commit message
416: obtaining at least Q commit messages
Optional step 498 between 415 and 417: system restart, and load the stored pre-prepare message and (Q-1) or more prepare messages
417: executing the request

FIG. 4A

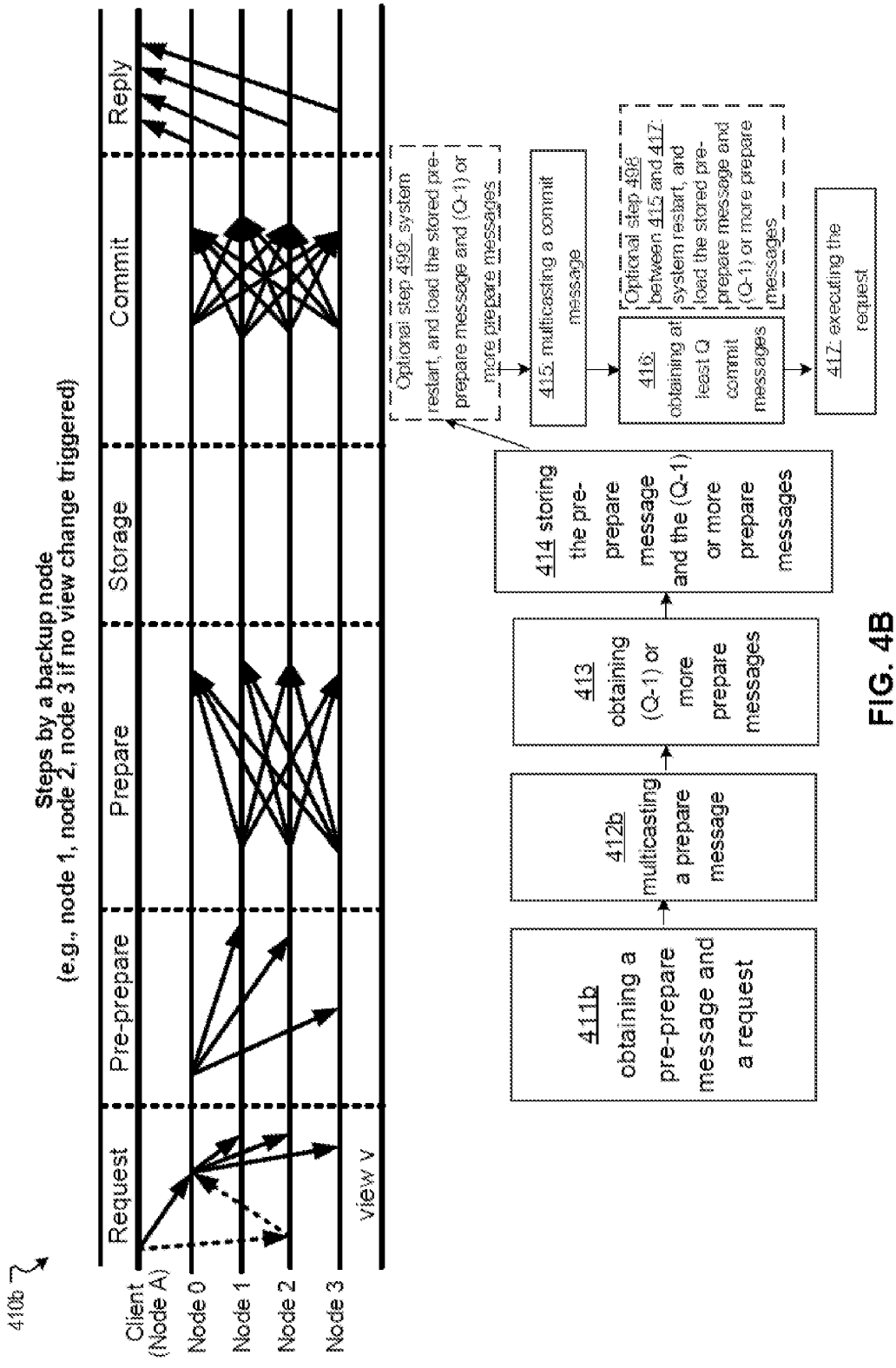
410b
Steps by a backup node
(e.g., node 1, node 2, node 3 if no view change triggered)
Request
Pre-prepare
Prepare
Storage
Commit
Reply
Client (Node A)
Node 0
Node 1
Node 2
Node 3
View V
411b obtaining a pre-prepare message and a request
412b multicasting a prepare message
413 obtaining (Q-1) or more prepare messages
414 storing the pre-prepare message and the (Q-1) or more prepare messages
Optional step 498: system restart, and load the stored pre-prepare message and (Q-1) or more prepare messages
415: multicasting a commit message
416: obtaining at least Q commit messages
Optional step 496 between 415 and 417: system restart, and load the stored pre-prepare message and (Q-1) or more prepare messages
417: executing the request

FIG. 4B

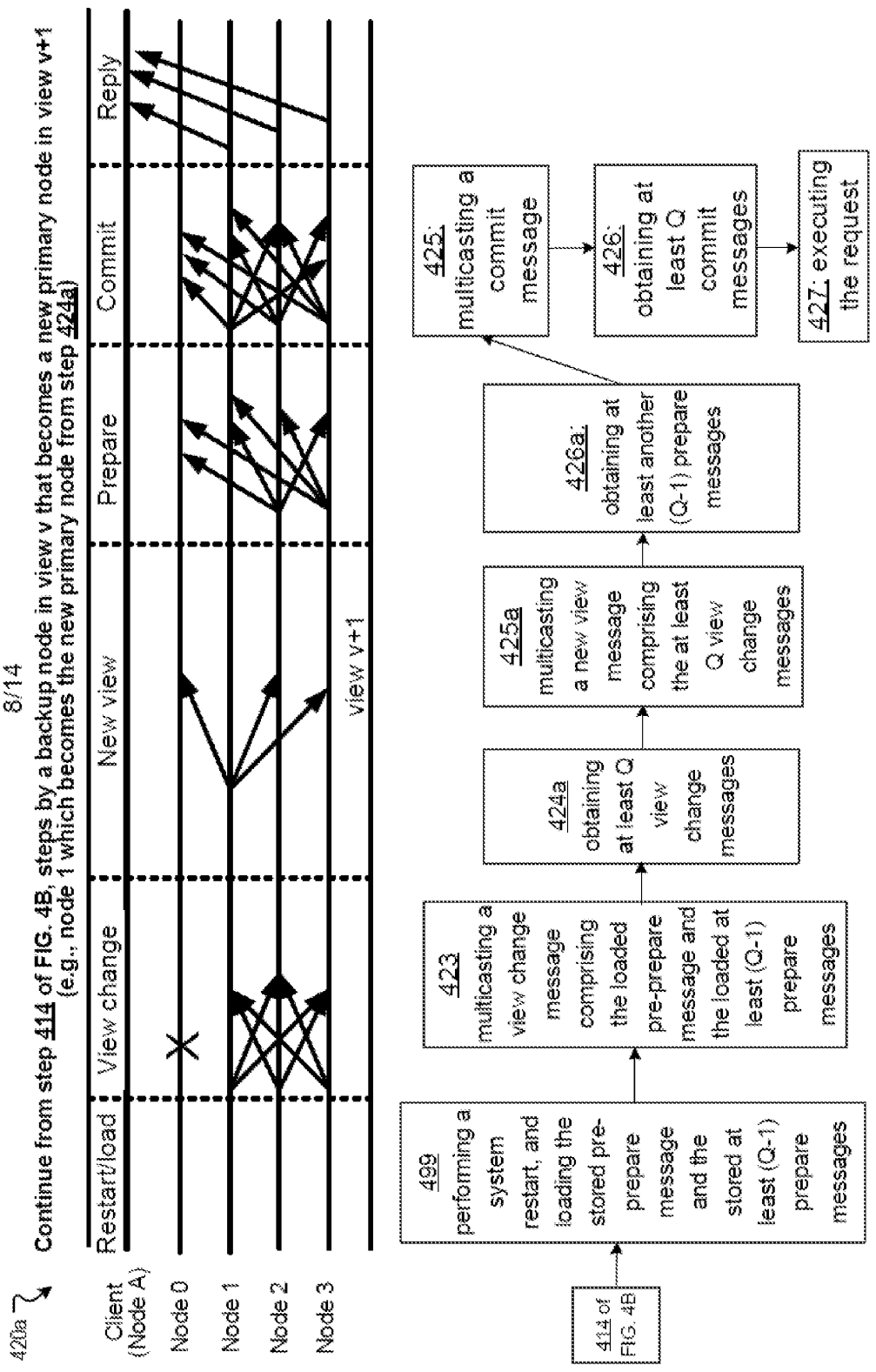
8/14
420a
Continue from step 414 of FIG. 4B, steps by a backup node in view v that becomes a new primary node in view v+1 (e.g., node 1 which becomes the new primary node from step 424a)
Restart/load
View change
New view
Prepare
Commit
Reply
Client (Node A)
Node 0
Node 1
Node 2
Node 3
view v+1
414 of FIG. 4B
499 performing a system restart, and loading the stored pre-prepare message and the stored at least (Q-1) prepare messages
423 multicasting a view change message comprising the loaded pre-prepare message and the loaded at least (Q-1) prepare messages
424a obtaining at least Q view change messages
425a multicasting a new view message comprising the at least Q view change messages
426a: obtaining at least another (Q-1) prepare messages
425: multicasting a commit message
426: obtaining at least Q commit messages
427: executing the request

FIG. 4C

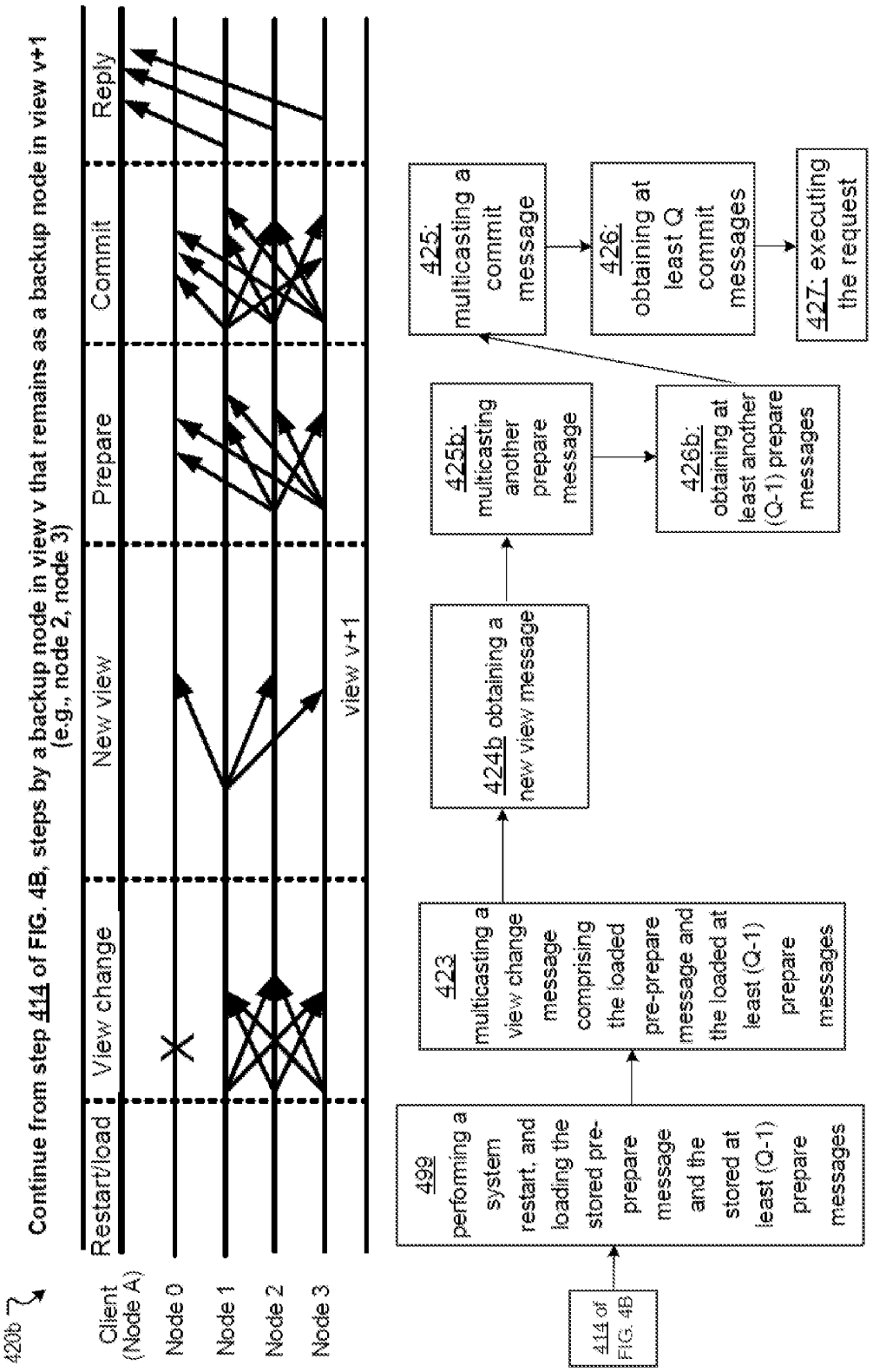
420b
Continue from step 414 of FIG. 4B, steps by a backup node in view v that remains as a backup node in view v+1 (e.g., node 2, node 3)
Restart/load
View change
New view
Prepare
Commit
Reply
Client (Node A)
Node 0
Node 1
Node 2
Node 3
view v+1
414 of FIG. 4B
499 performing a system restart, and loading the stored pre-prepare message and the stored at least (Q-1) prepare messages
423 multicasting a view change message comprising the loaded pre-prepare message and the loaded at least (Q-1) prepare messages
424b obtaining a new view message
425b: multicasting another prepare message
426b: obtaining at least another (Q-1) prepare messages
425: multicasting a commit message
426: obtaining at least Q commit messages
427: executing the request

FIG. 4D

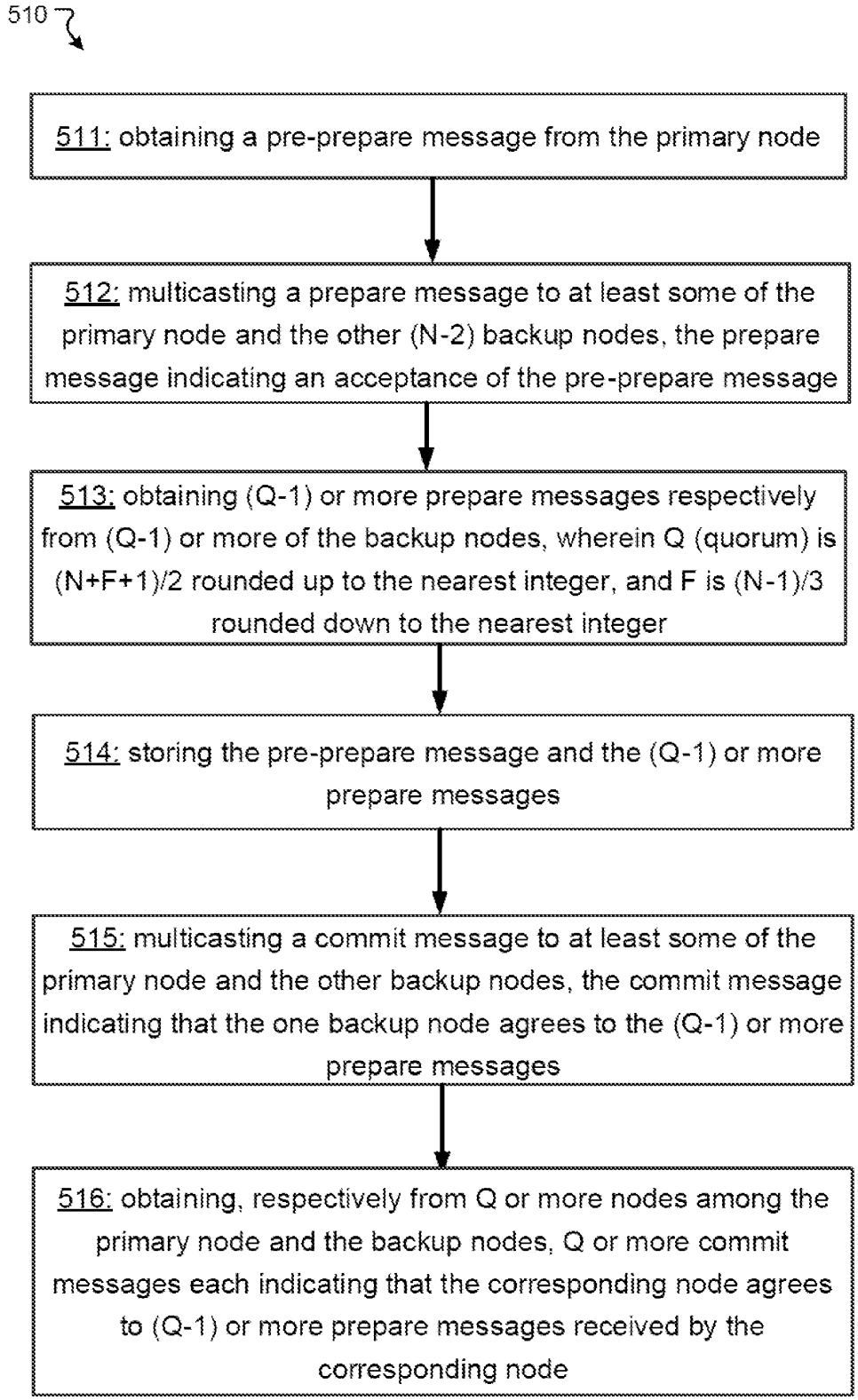
510
511: obtaining a pre-prepare message from the primary node
512: multicasting a prepare message to at least some of the primary node and the other (N-2) backup nodes, the prepare message indicating an acceptance of the pre-prepare message
513: obtaining (Q-1) or more prepare messages respectively from (Q-1) or more of the backup nodes, wherein Q (quorum) is (N+F+1)/2 rounded up to the nearest integer, and F is (N-1)/3 rounded down to the nearest integer
514: storing the pre-prepare message and the (Q-1) or more prepare messages
515: multicasting a commit message to at least some of the primary node and the other backup nodes, the commit message indicating that the one backup node agrees to the (Q-1) or more prepare messages
516: obtaining, respectively from Q or more nodes among the primary node and the backup nodes, Q or more commit messages each indicating that the corresponding node agrees to (Q-1) or more prepare messages received by the corresponding node

FIG. 5A

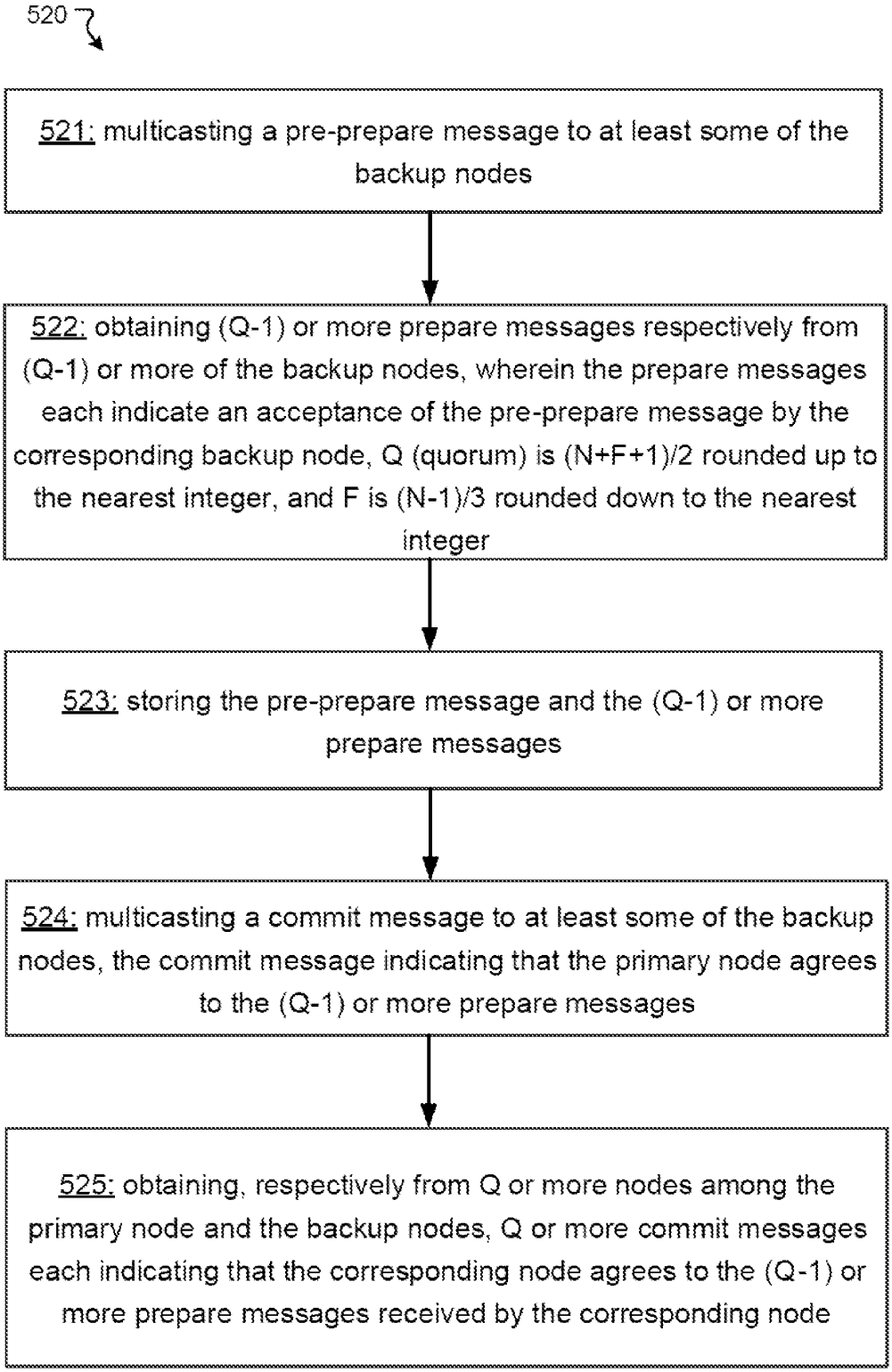
520
521: multicasting a pre-prepare message to at least some of the backup nodes
522: obtaining (Q-1) or more prepare messages respectively from (Q-1) or more of the backup nodes, wherein the prepare messages each indicate an acceptance of the pre-prepare message by the corresponding backup node, Q (quorum) is (N+F+1)/2 rounded up to the nearest integer, and F is (N-1)/3 rounded down to the nearest integer
523: storing the pre-prepare message and the (Q-1) or more prepare messages
524: multicasting a commit message to at least some of the backup nodes, the commit message indicating that the primary node agrees to the (Q-1) or more prepare messages
525: obtaining, respectively from Q or more nodes among the primary node and the backup nodes, Q or more commit messages each indicating that the corresponding node agrees to the (Q-1) or more prepare messages received by the corresponding node

FIG. 5B

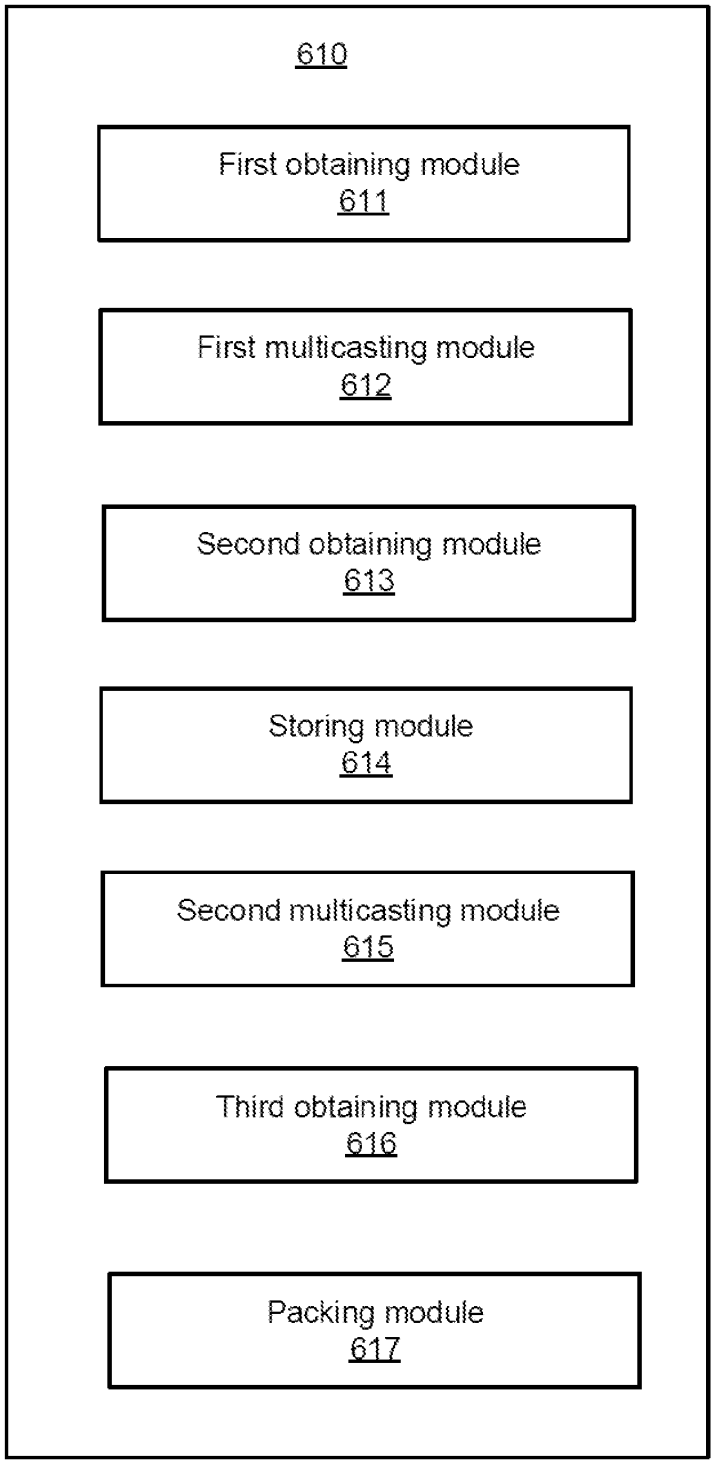
610
First obtaining module
611
First multicasting module
612
Second obtaining module
613
Storing module
614
Second multicasting module
615
Third obtaining module
616
Packing module
617

FIG. 6A

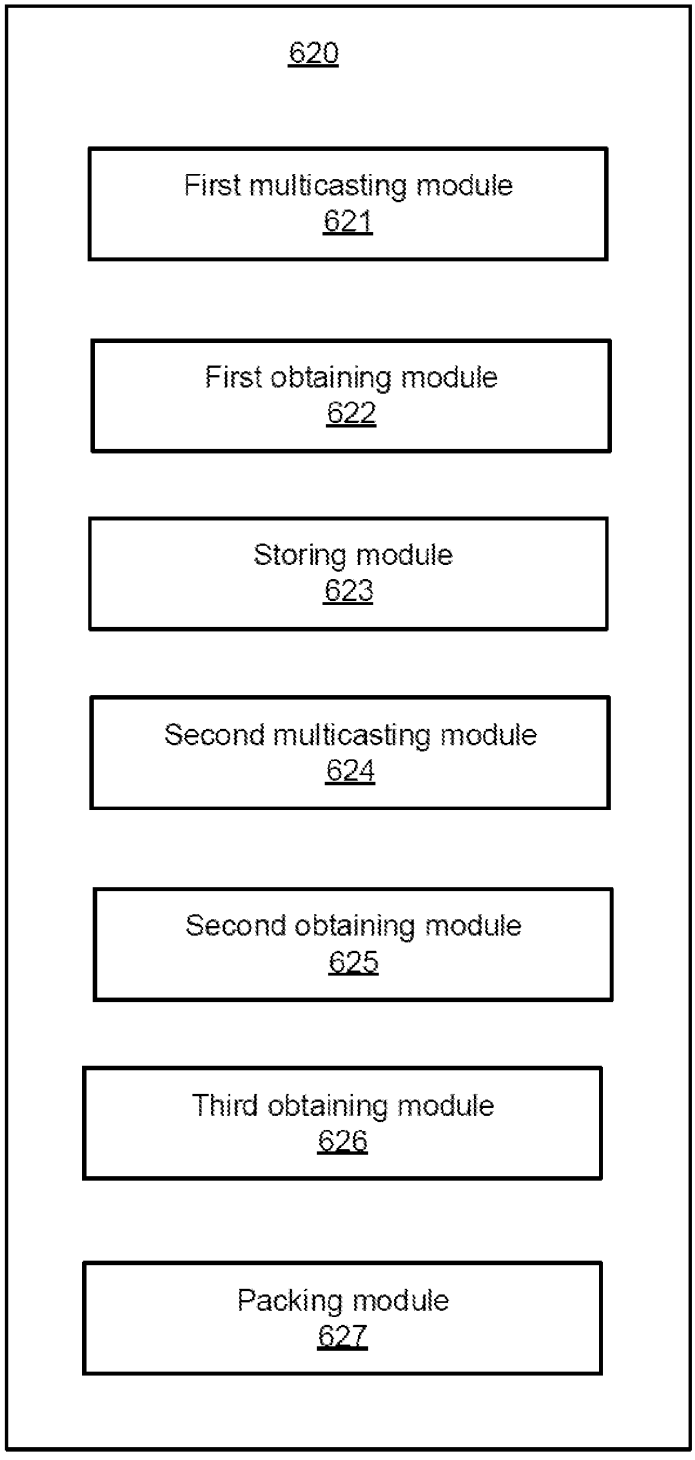
620
First multicasting module
621
First obtaining module
622
Storing module
623
Second multicasting module
624
Second obtaining module
625
Third obtaining module
626
Packing module
627

FIG. 6B

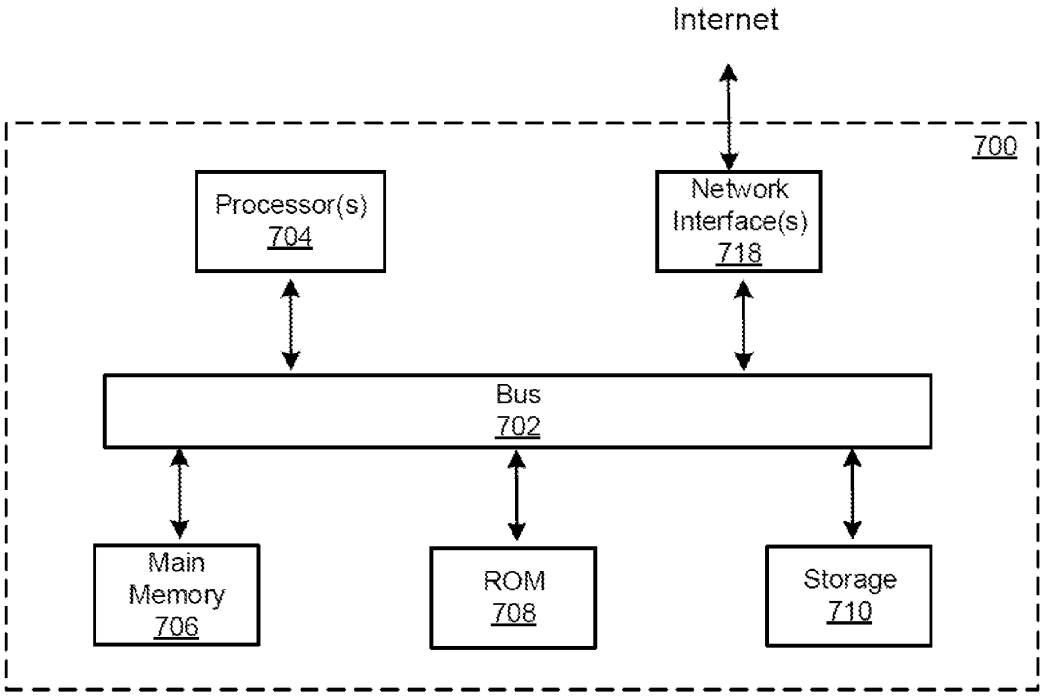
Internet
700
Processor(s)
704
Network
Interface(s)
718
Bus
702
Main
Memory
706
ROM
708
Storage
710

FIG. 7