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(12) **United States Patent**  
Alpert et al.

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- (54) **DISTRIBUTED PARALLEL DETERMINATION OF SINGLE AND MULTIPLE SOURCE SHORTEST PATHS IN LARGE DIRECTED GRAPHS**
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- (75) **Inventors:** Jesse Louis Alpert, Berkeley, CA (US); Nissan Hajaj, San Mateo, CA (US)
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- (73) **Assignee:** Google Inc., Mountain View, CA (US)
- (\* ) **Notice:** Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 713 days.

\* cited by examiner

*Primary Examiner* — Kevin Bates  
*Assistant Examiner* — Tom Y Chang  
 (74) *Attorney, Agent, or Firm* — Fish & Richardson P.C.

- (21) **Appl. No.:** 12/537,681
- (22) **Filed:** Aug. 7, 2009

**Related U.S. Application Data**

- (60) **Provisional application No.** 61/087,623, filed on Aug. 8, 2008.
- (51) **Int. Cl.**
  - G06F 15/16 (2006.01)
  - G06F 7/00 (2006.01)
  - G06F 17/00 (2006.01)
  - G06F 17/30 (2006.01)
- (52) **U.S. Cl.**
  - USPC ..... 709/219; 707/631; 707/637; 707/798
- (58) **Field of Classification Search**
  - USPC ..... 709/219
  - See application file for complete search history.

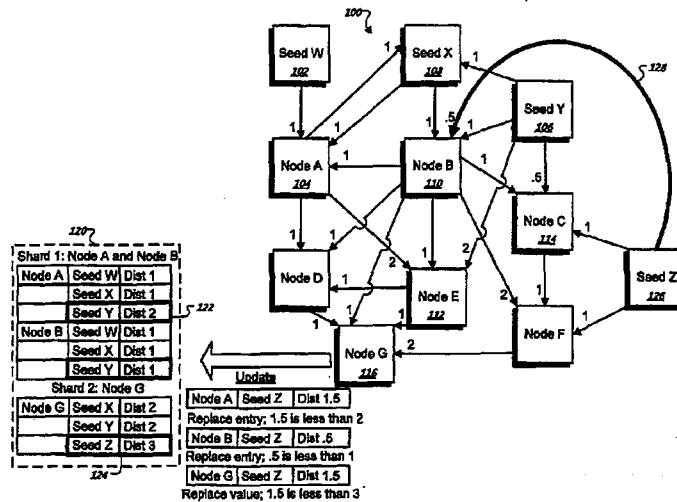
(57) **ABSTRACT**

Systems and methods for checkpointing a computation distributed over multiple peer servers. On each server, sequentially storing checkpoints collectively representing a current state of the computation on that server as of a most recent checkpoint, each checkpoint having a checkpoint timestamp. When restarting a first server, rebuilding a most recent state of the first server from the checkpoints written by the first server through a most recent checkpoint having a most recent checkpoint timestamp, and requesting from each of the other peer servers updates from the most recent checkpoint timestamp time of the first server. On each server, in response to a first request for updates as of a particular time, deriving the requested updates from the state data in the server uncommitted to a checkpoint and the state data in checkpoints of the server that have a timestamp no earlier than the particular time of the first request, and providing the requested updates to the first server.

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19 Claims, 8 Drawing Sheets



**EXHIBIT 2085**  
 Facebook, Inc. et al.  
 v.

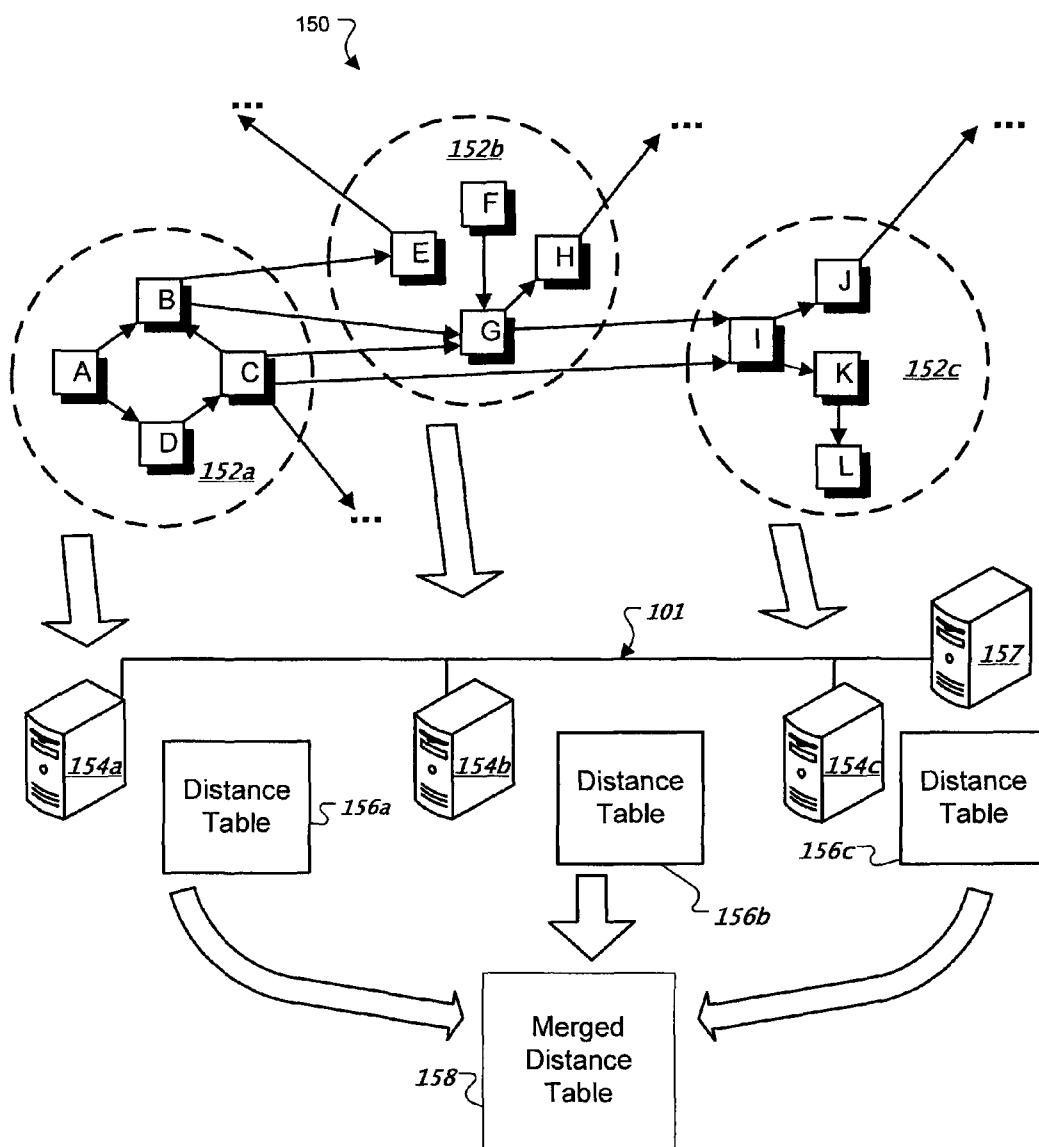


FIG. 1A

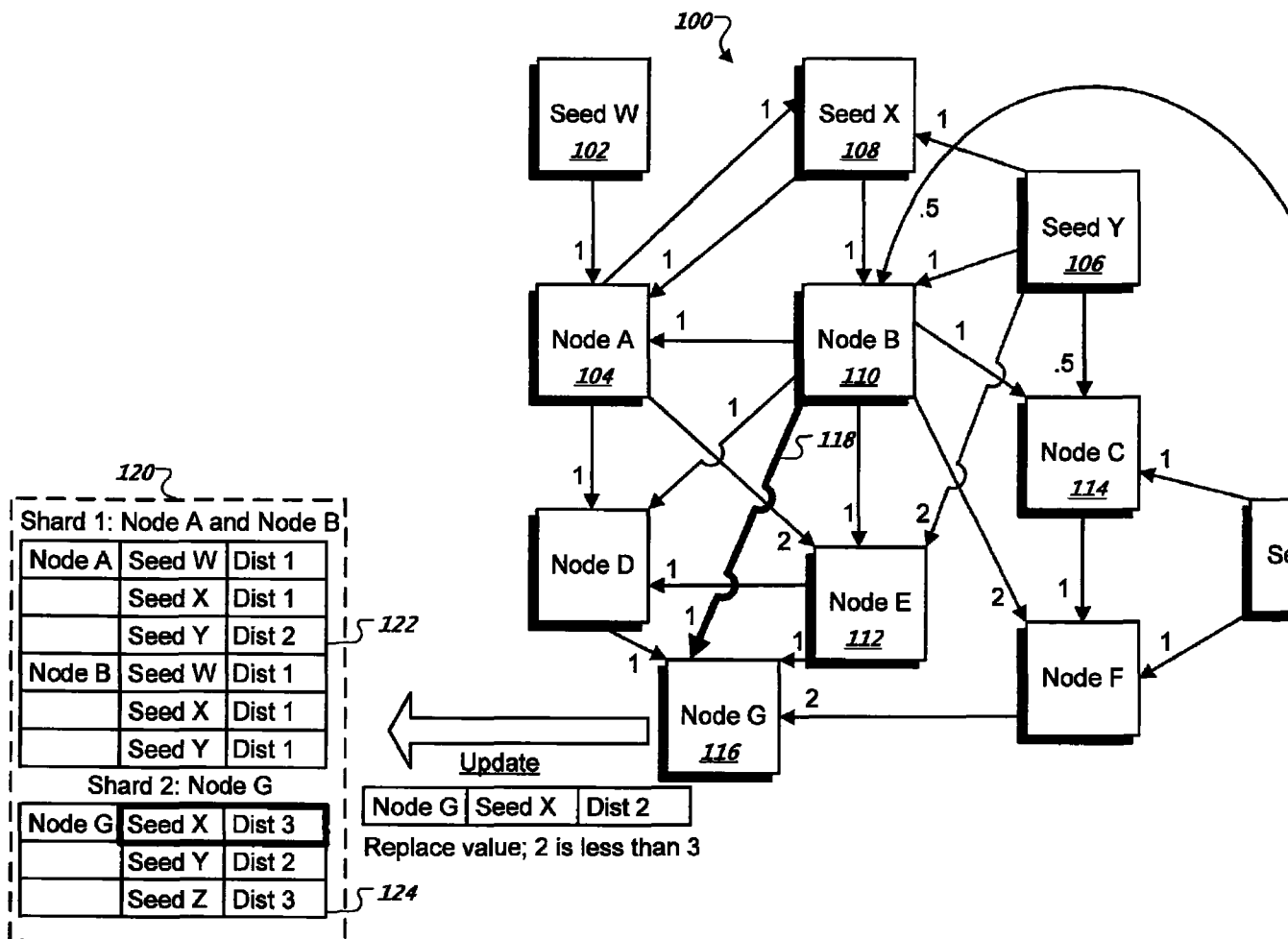


FIG. 1B

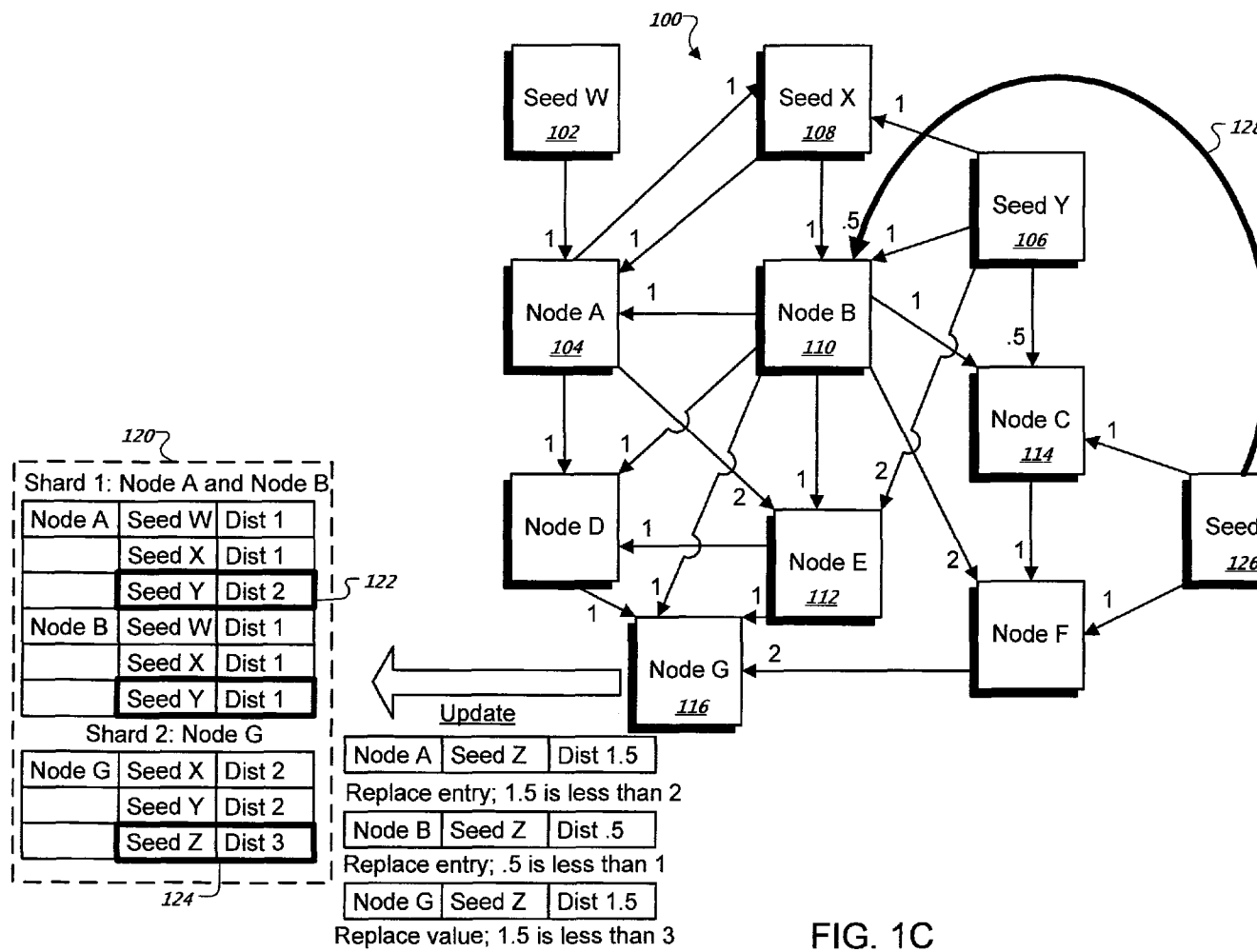


FIG. 1C

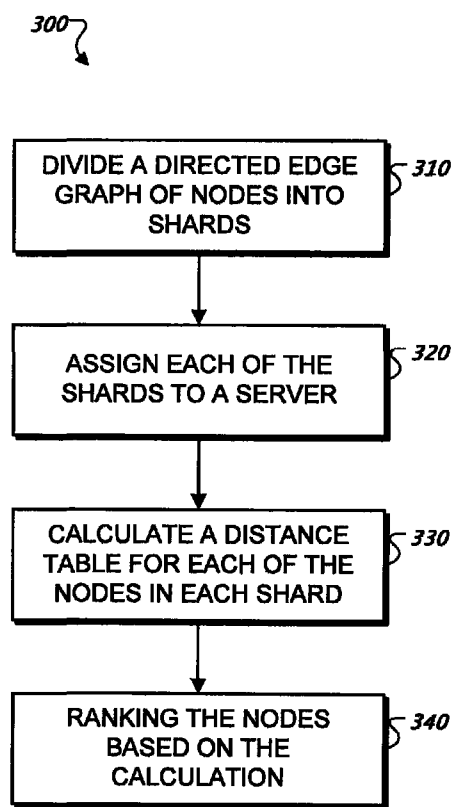


FIG. 2

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