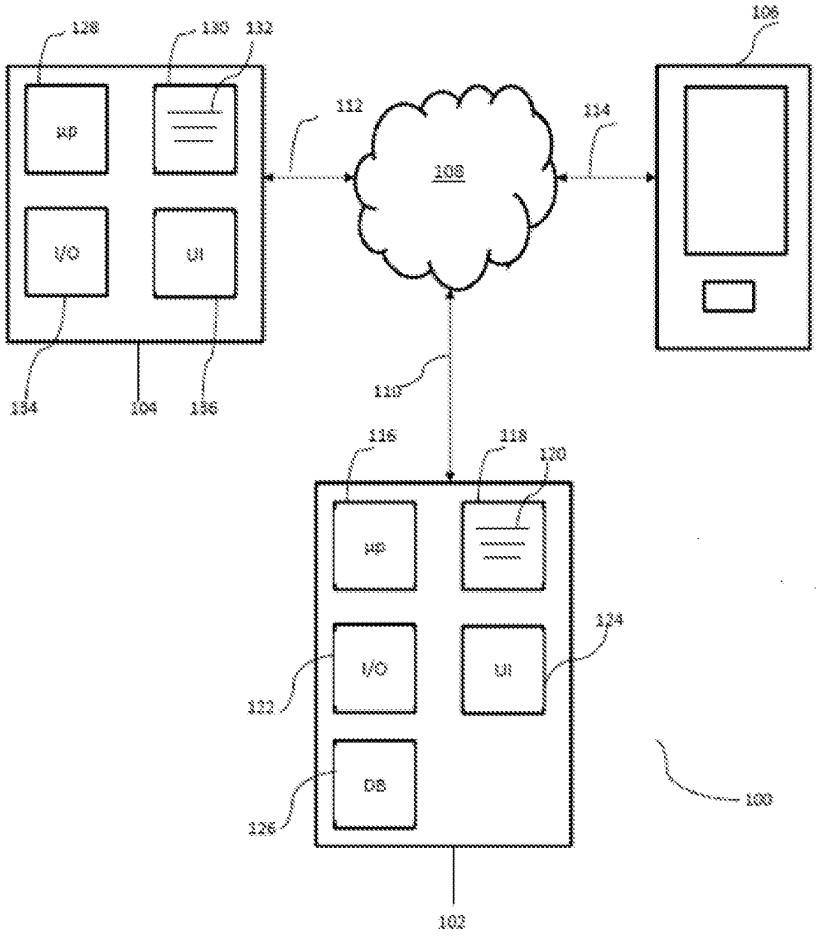

128
130
132
106
112
114
108
I/O
UI
134
104
136
110
116
118
120
122
124
DB
126
100
102

Fig. 1

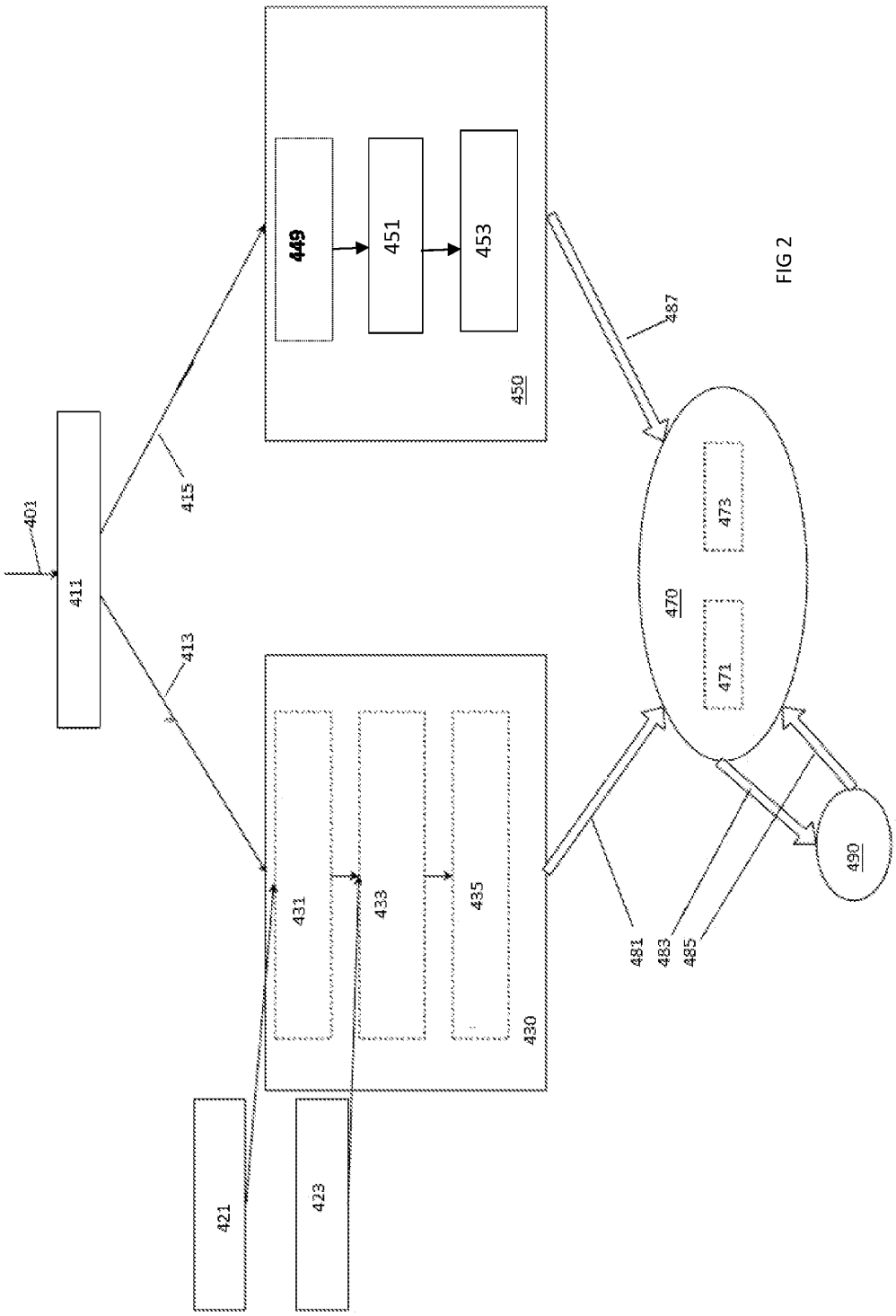

401
411
415
413
449
451
453
450
487
470
473
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481
483
485
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435
430
421
423

FIG 2

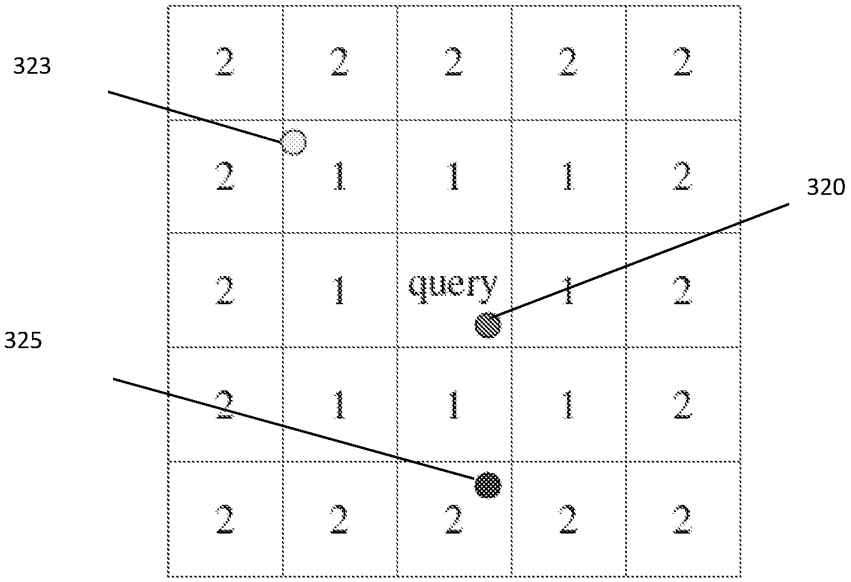


Fig 3

Input: K, loc
Output: the K nearest Objects
Initialization
result $\leftarrow$ priority queue of size K
min_iter $\leftarrow$ MAX
i = 0 // current iteration
1: cell_list.add(index(loc))
2: **while** len(cell_list) > 0 **do**
3: neighbours $\leftarrow \emptyset$
4: **for** cell in cell_list **do**
5: **if** cell.visited **then**
6: **continue**
7: **end if**
8: cell.visited $\leftarrow$ true
9: nearest_objects $\leftarrow$ KNearest_InCell(K, loc, cell)
// on node sharding(cell)
10: result, min_iter $\leftarrow$ Merge(result, nearest_objects)
11: neighbours.add(neighbour(cell))
12: **end for**
13: **if** i$\geq \lceil \sqrt{2} * (\text{min_iter}+1) + 1 \rceil$ && result.size==K **then**
14: **break**
15: **end if**
16: i $\leftarrow$ i+1
17: cell_list $\leftarrow$ neighbours
18: **end while**
19: **return** *result*

Algorithm 1: Naive_BFS(K, loc)

FIG 4

Input: K, loc
Output: the K nearest Objects
Initialization
result ← priority queue of size K
1: shard_list ← FindNearbyCrossingShards(loc)
2: **for** shard_id in shard_list **do**
3: nearest_objects ← Naive_BFS(K, loc) on node=sharding(shard_id)
4: result ← Merge(result, nearest_objects)
5: **end for**
6: **return** *result*

Algorithm 2: Optimised_KNearest(K, loc)

Fig 5

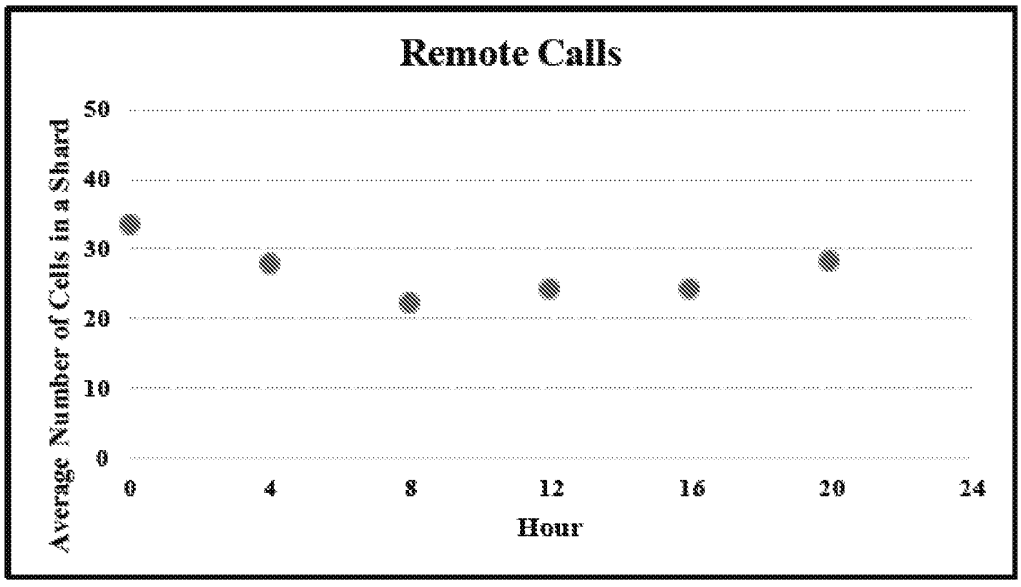
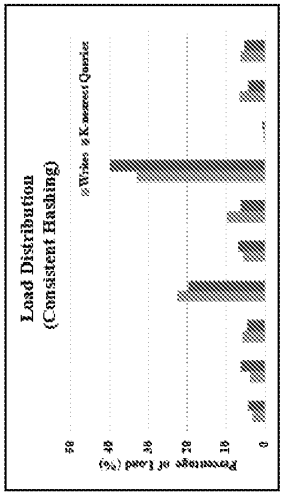
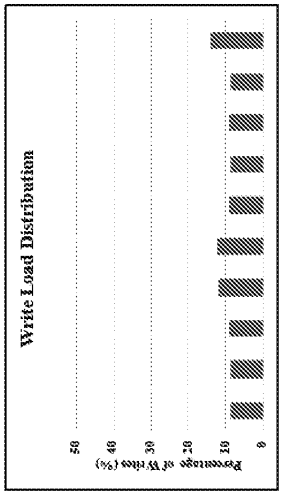


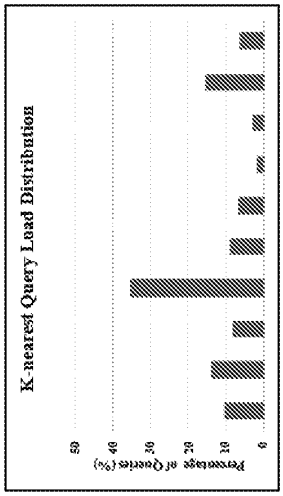
Figure 6



(a) Imbalanced write and query load



(b) Balanced write load



(c) Imbalanced query load

Figure 7

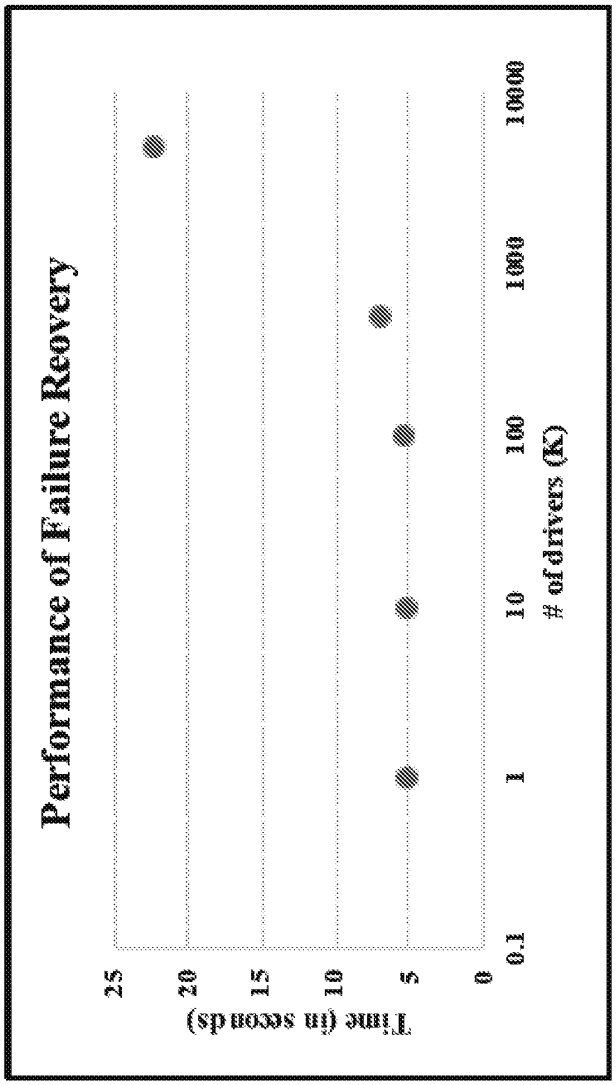

Performance of Failure Reovery
Time (in seconds)
25
20
15
10
5
0
0.1
1
10
100
1000
10000
# of drivers (K)

Figure 8

geospatial index	performance (ns/op)
Embodiment	0.57
Geohash	108
S2	784
H3	2084

Fig.9

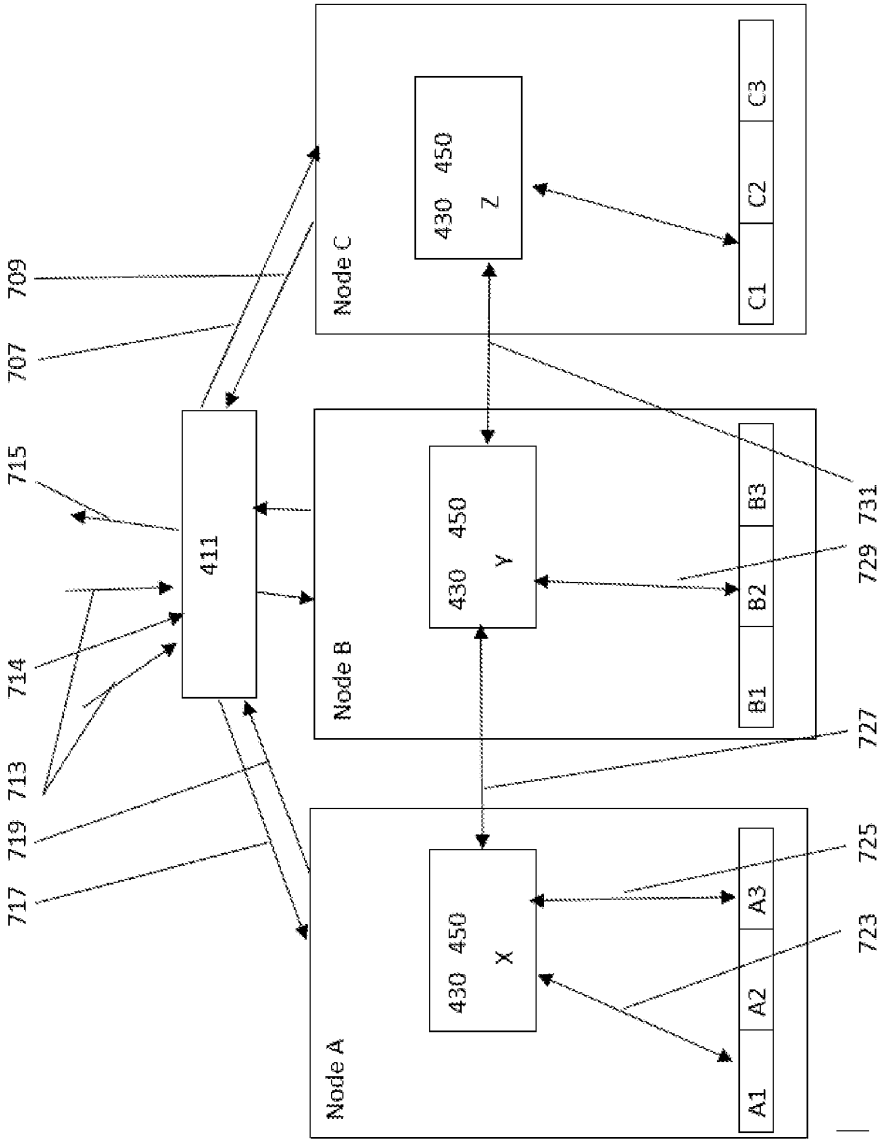

709
707
715
714
713
719
717
411
Node C
430 450
Z
C1
C2
C3
Node B
430 450
Y
B1
B2
B3
729
731
727
Node A
430 450
X
A1
A2
A3
725
723

Figure 10