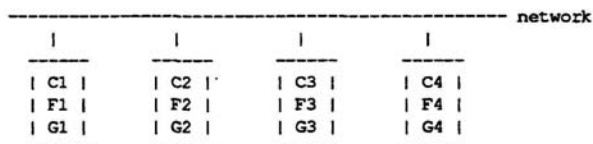From: Hector Garcia-Molina <hector@DB.Stanford.EDU>
X-Authentication-Warning: Coke.Stanford.EDU: Host localhost [127.0.0.1] didn't use HELO protocol
To: shankle@ee.stanford.edu (Diane Shankle)
Subject: Re: Quals Questions 1996
Date: Sat, 27 Jan 96 09:29:24 -0800
X-Mts: smtp

> Send a copy of your Quals Question & Answer to
> Diane Shankle
Here is my question...
hector

EE QUALIFYING EXAM 1996
Hector Garcia-Molina

You have four computers, C1, C2, C3, C4, connected by a network.
Each computer Ci has a file Fi containing 1000 records.
Each record is 1000 bytes long, including an 8 byte key.
(Example: 1000 byte employee record, with 8 byte employee number as key.)
The keys range from 1 through 1,000,000.
Each computer has an unlimited amount of main memory.

We want to sort the records, so that we end up with four files,
G1, G2, G3, G4. File G1 is located at C1 and will contain the 1000
records with smallest keys. File G2 will be at C2 and will contain the
1000 records with the next 1000 smallest keys, and so on.

```
----------------------------------------------------- network
      |              |              |              |
    ------        ------        ------        ------
    | C1 |        | C2 |        | C3 |        | C4 |
    | F1 |        | F2 |        | F3 |        | F4 |
    | G1 |        | G2 |        | G3 |        | G4 |
    ------        ------        ------        ------
```

(1) Suggest one or more efficient algorithms for sorting the files.

(a) A simple solution is to send all records to one computer, say C1,
and sort them all there. Then the records are distributed to the
appropriate computers.

(b) Another solution is to only send the 8 byte keys to C1.
C1 sorts the keys and determines the three breakpoints, b1, b2, b3.
(That is, the three records with keys less than b1 must go to C1;
the ones with keys between b1 and b2 go to C2, and so on.)
The breakpoints are sent to all computers, which then distribute the records
accordingly.

(c) A third solution is to determine the breakpoints without transmitting
all the keys. For instance, each computer can sort its records locally,
and determine three breakpoints that separate its own records into
four groups. All computers send their local breakpoints to say C1,
and C1 can determine "roughly" where the global b1, b2, b3 breakpoints are.
At this point C1 can either perform more iterations with the other computers
to refine the breakpoints, or it can go ahead and initiate the record
transfers. (If the breakpoints are not known exactly, some records may go to
the wrong computer, but when this is discovered, they can be routed
to the correct place.) Another variation is for computers to initially
send more than three breakpoints, e.g., they send a "histogram"
that more accurately reflects the key ranges it has. With these
histograms, C1 can more accurately determine the true global breakpoints.