TE WHARE WĀNANGA O TE ŪPOKO O TE IKA A MĀUI
VICTORIA
UNIVERSITY OF WELLINGTON

EXAMINATIONS – 2016

TRIMESTER 1

SWEN432

Advanced Database Design and Implementation

Time allowed: TWO HOURS

Instructions: Closed Book
Answer all questions
Non-electronic foreign language to English dictionaries are permitted
No other reference material is allowed
No Calculators permitted

Question	Topic	Marks
Section 1. NoSQL Databases		**[32 marks]**
1.	NoSQL Database Properties	[15 marks]
2.	Membership Changes	[17 marks]
Section 2. Cassandra		**[34 marks]**
3.	Basic Terms and Properties	[16.5 marks]
4.	Meeting Availability Requirements	[7.5 marks]
5.	Extreme Write Availability	[10 marks]
Section 3. MongoDB		**[30 marks]**
6.	Basic Terms and Properties	[22.5 marks]
7.	A Composite `_id` Field	[3 marks]
8.	An `aggregate` Query	[4.5 marks]
Section 4. Data Warehousing		**[24 marks]**
9.	OLAP Specific Queries	[12 marks]
10.	Query Rewriting	[12 marks]

Student ID:_____

Section 1. NoSQL Databases [32 marks]

Question 1. NoSQL Database Properties [15 marks]

Given the words/phrases below:

a) Availability	f) Network Partition Tolerance
b) Partitioning	g) Versioning
c) Scalability	h) Eventual Consistency
d) CAP Theorem	i) Consistent Hashing
e) Replication	j) Gossip Protocol

Select the word or phrase from the list above that best matches each of the following descriptions. Write the letter of your answer for each description in the answer box. Each word/phrase should be used only once.

1. Any networked, shared data system can have at most two of the following three properties: Consistency, Availability, and Network Partition Tolerance.
2. A property of networked shared services that is satisfied if it allows read and write operations a high proportion of time (even in the case of a node crash or some hardware or software parts being down due to upgrades).
3. An ability of a system to increase total throughput under an increased load when resources (typically hardware) are added.
4. An inter node way of communication involving periodic, pair wise inter node interactions with the information exchange of a limited size.
5. Storing several copies of the same data on different servers (nodes) to increase availability.
6. The ability of a distributed, shared service to perform expected operations even if two or more “islands” of networked nodes cannot connect to each other.
7. A data partitioning technique where each node and each data object are mapped to a ring of tokens.
8. Splitting the space of data object key values into non-overlapping ranges and storing each key range and corresponding data objects on a different server (node).
9. A property of a distributed shared system that is satisfied when at least *1* server (node) in each partition is available for writing and reading.
10. Appending such information to data objects that allows reasoning about the precedence of updates applied to objects in different time moments.

ANSWER

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10.					

Question 2. Membership Changes [17 marks]

Consider a consistent hashing ring containing 10 physical nodes and applying remapping of data objects in the case of a node leaving the ring. Assume a replication factor of 3. Designate nodes by upper case letters A, B,..., J.

a) Assume the node A leaves the ring. Give a detailed description of the operations that the other nodes will perform aiming to redistribute data according to the new ring structure. **[12 marks]**

Hint: You may find it useful to draw the part of the ring containing the nodes affected.

ANSWER

b) Assume:

- There are *N* data objects stored on nodes of the consistent hashing ring and each replicated three times, and
- The distribution of data object among nodes was even before the node A left the ring.

Calculate the percentage *p*(*leave*) of data objects copied between different nodes since the node A left the ring. **[5 marks]**

ANSWER

Section 2. Cassandra [34 marks]

Question 3. Basic Terms and Properties [16.5 marks]

Given the words/phrases below:

a) Keyspace	g) Bloom Filter
b) Network Topology Strategy	h) Compaction
c) Snitch	i) Partitioning Key
d) Read Repair	j) Seed Node
e) Merkle Tree	k) Coordinator Node
f) Light Weight Transaction	

Select the word or phrase from the list above that best matches each of the following descriptions. Write the letter of your answer for each description in the answer box. Each word/phrase should be used only once.

1. A background mechanism to bring a column of a table row on all replica nodes to the same state.
2. When a node first starts up, it looks at its `cassandra.yaml` configuration file to determine which node(s) to contact to obtain information about the other nodes in the cluster.
3. The node that receives a client's read or write request.
4. The part of the primary key used to compute the token.
5. A file that informs Cassandra about the network topology.
6. The process of defragmenting table rows, deleting tombstoned columns and obsolete updates to columns.
7. A probabilistic data structure used to compare and discover differences in data stored on different replica nodes during anti entropy node repair.
8. A probabilistic data structure used during read to check whether a SSTable may contain a given row key.
9. A named data container of an application that contains a set of tables (column families) having the same replication requirements.
10. A mechanism that provides lineariazable consistency.
11. A replication strategy that recognizes the cluster topology in terms of data centers and racks.

ANSWER

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SPARE PAGE FOR EXTRA ANSWERS

Cross out the rough working that you do not want marked.

Specify the question number for work you do want marked.

Question 4. Meeting Availability Requirements **[7.5 marks]**

A cluster spans two data centers dc1 and dc2. In both data centers, the cluster contains five nodes. Nodes in data center dc1 are node1, node2, … , node5, and nodes in data center dc2 are node6, node7,… , node10. In both data centers, nodes are placed in racks. Assume the partitioning is done by consistent hashing and a partitioner assigns the same initial tokens to nodes nodei, $i \in \{1, 2, \ldots, 5\}$, and node(i + 5). Assume further, the replication factor is 3. The availability requirements are:

1. The database must provide for the strong consistency if 2 nodes are down, and
2. The database must provide for the strong consistency if 2 racks are down.

Consider physical nodes only. In your answer, show the distribution of nodes among racks in both data centers. Justify your claim that availability requirements have been met using the formulae for strong consistency.

ANSWER

Question 5. Extreme Write Availability [10 marks]

As a Cassandra database designer, you are asked to provide for extreme write availability of a database. A statement like the following:

```
insert into driver (driver_name, password) values ('adam', 'a99a');
```

where `driver_name` is the primary key of the table `driver`, has to succeed even if all replica nodes for the partition key `adam` are down, providing that at least one cluster node is still up.

a) Use CQL and sqlsh commands to show how you will satisfy the extreme availability request. **[3 marks]**

ANSWER

b) Name the Cassandra mechanism that will be used behind the scene to achieve the extreme write availability request. **[2 marks]**

ANSWER

c) Briefly describe how the extreme availability request will be satisfied and when the inserted data will be available for reading. **[5 marks]**

ANSWER

Section 3. MongoDB [30 marks]

Question 6. Basic Terms and Properties [22.5 marks]

Given the words/phrases below:

a) Shard Key	i) mongod
b) Shard	j) Master Server
c) Chunk	k) Slave Server
d) Sharded Cluster	l) Failover
e) Query Router	m) Write Concern: Acknowledged
f) Config Server	n) Write Concern: Journaled
g) Replica Set	o) Write Concern: Replica Acknowledged
h) Sharding	

Select the word or phrase from the list above that best matches each of the following descriptions. Write the letter of your answer for each description in the answer box. Each word/phrase should be used only once.

1. A database architecture that partitions data by key ranges and distributes the data among two or more replica sets. It enables horizontal scaling.
2. MongoDB confirms to a client that it has applied a write command in the master's main memory.
3. A contiguous range of shard key values within a particular shard.
4. A `mongod` instance that stores all the metadata associated with a sharded cluster.
5. The process that allows a secondary member of a replica set to become primary in the event of a failure.
6. A server that receives all writes in a MongoDB replica set.
7. MongoDB confirms a client that it has committed a write command on master's disk.
8. The process that starts the MongoDB server as a daemon. The MongoDB server manages data requests and formats and manages background operations.
9. MongoDB confirms a client that it has applied a write command in a slave's main memory.
10. The routing and load balancing process that acts as an interface between an application and a MongoDB sharded cluster.
11. A replica set member that replicates the contents of the master database.
12. A single replica set that stores some portion of a sharded cluster's total data set. The same term is also used for a portion of the total data set
13. The field MongoDB uses to distribute documents among members of a sharded cluster.
14. The set of nodes comprising a sharded MongoDB deployment. It consists of config servers, shards, and one or more mongos routing processes.

15. A cluster of MongoDB servers that implements master-slave replication and automated failover.

ANSWER

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10.		11.		12.	
13.		14.		15.	

Question 7. A Composite `_id` Field [3 marks]

Consider the `class` document describing the SWEN432 class given in the ANSWER box to this question. All document field names are having assigned values except the `_id` field. You are asked to assign a unique natural value to the `_id` field and not to leave to MongoDB to assign it an artificial value of the `ObjectId` type. Your natural `_id` value should contain data already present in the document. When deciding on the `_id` value, consider the following business rules:

- The field `code` uniquely identifies each course (paper),
- Each course may be offered each `year`, and
- There is only one stream of a course offered in each `term`.

ANSWER

```
{
 _id:
 code: "SWEN432",
 title: "Advanced Databases",
 prerequisites: [“NWEN304”, “SWEN304”],
 year: 2016,
 term: 1,
 no_of_stud: 12
 }
```

Question 8. An `aggregate` Query [4.5 marks]

Consider the `aggregate()` method applied to the `myclasses` collection containing `class` documents structured the same way as the document in Question 7 above. The `aggregate()` method is given in the box below.

```
db.myclasses.aggregate( [
{$match: {year: 2016}},
{$unwind: "$prerequisites"},
{$group: {_id: "$prerequisites", number: {$sum : 1}}},
{$sort: {number: -1}},
{$limit: 1},
{$project: {course_code: "$_id", number: "$number", _id: 0}}
  ] )
```

Use plain English to describe the query answered by the `aggregate()` method above.

ANSWER

Section 3. Data Warehousing [24 marks]

Question 9. OLAP Specific Queries [12 marks]

Given the words/phrases below:

a) Roll–up	e) WINDOW
b) Pivoting	f) Ranking
c) CUBE	g) Drill–down
d) TopN	h) ROLLUP

Select the word or phrase from the list above that best matches each of the following descriptions. Write the letter of your answer for each description in the answer box. Each word/phrase should be used only once.

1. An OLAP query that takes the current aggregation level of a Data Warehouse fact table and performs a further aggregation using either an attribute hierarchy or by dropping some dimensions.
2. An OLAP query that looks for more detailed data using an attribute hierarchy of one (or more) dimension, or even uses operational data.
3. An OLAP query that is performed on a fact table by selecting two dimensions, aggregating the measure, and representing the aggregated measure in a grid having two selected dimensions as coordinates.
4. An OLAP query that returns only the top N items within each partition.
5. An extension to the SQL GROUP BY clause that computes aggregates of (n + 1) sublists of a grouping attribute list. It starts with the whole list and then successively omits the last attribute in the current sublist.
6. An extension to the SQL GROUP BY clause that computes aggregates of all subsets of a set of attributes in the grouping list.
7. An aggregate function.
8. An extension to the SQL SELECT statement that computes aggregates like “moving average for a given time interval” for each row of the result set.

ANSWER

1.		2.		3.	
4.		5.		6.	
7.		8.			

Question 10. Query Rewriting [12 marks]

Consider the following star schema:

```
{
 Sales ({ TimeId, ProdId, ShopId, Amnt }, { TimeId + ProdId +
 ShopId }),
 Time ({ TimeId, Day, Week, MonthId, Month_Name, Year },
 { TimeId }),
 Product ({ ProdId, Prod_Name, TypeId, Type_Name, Industry },
 { ProdId }),
 Location ({ ShopId, CityId, City_Name, Country },
 { ShopId })
}
```

Suppose attribute hierarchies are defined using the following sets of functional dependencies:

Product hierarchy:

ProdId→Prod_Name,

ProdId→TypeId, *TypeId→Type_Name*,

TypeId→Industry.

Time hierarchy:

TimeId→Day, *TimeId→Week*, *TimeId→MonthId*, *MonthId→Month_Name*, *MonthId→Year*

Location hierarchy:

ShopId→CityId, *CityId→City_Name*, *CityId→Country*.

Suppose the following view has been materialized:

```
CREATE MATERIALIZED VIEW V AS
SELECT TypeId, CityId, Month_Name, SUM(Amnt) AS Total
FROM Sales NATURAL JOIN Product NATURAL JOIN Location
NATURAL JOIN Time
GROUP BY TypeId, CityId, Month_Name;
```

and a clever OLAP query processor realizes that the following query can be answered using the view V:

```
SELECT Industry, Country, Month_Name, SUM(Amnt)
FROM Sales NATURAL JOIN Product NATURAL JOIN Location NATURAL
JOIN Time
GROUP BY Industry, Country, Month_Name;
```

Show how the query processor will rewrite the query above.

ANSWER

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