CS535 BIG DATA

PART 0. INTRODUCTION
2. A PARADIGM FOR BIG DATA

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FAQs

- Wait list
- Term project topics

This material is built based on

- Nathan Marz and James Warren, “Big Data, Principles and Best Practices of Scalable Real-Time Data System”, 2015, Manning Publications, ISBN 9781617290343

Lambda Architecture

Typical problems for scaling traditional databases

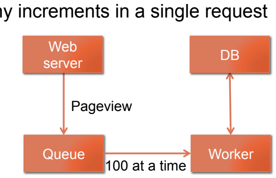
- Suppose that the application should track the number of page views for any URL a customer wishes to track
  - The customer’s web page pings the application’s web server with its URL every time a pageview is received
  - Application tells you top 100 URLs by number of pageviews

Id (integer)	User_id (integer)	url (varchar(255)	Pageviews(bigint)

Scaling with a queue

- Direct access from Web server to the backend DB cannot handle the large amount of frequent write requests
  - Timeout errors

- Batch many increments in a single request



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Scaling by sharding the database

- What if your data amount increases even more?
  - Your worker cannot keep up with the writes
- What if you add more workers?
  - Again, the Database will be overloaded
- **Horizontal partitioning or sharding of database**
  - Uses multiple database servers and spreads the table across all the servers
  - Chooses the shard for each key by taking the hash of the key modded by the number of shards
- What if your current number of shards cannot handle your data?
  - Your mapping script should cope with new set of shards
  - Application and data should be re-organized

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Other issues

- Fault-tolerance issues
  - What if one of the database machines is down?
  - A portion of the data is unavailable
- Corruption issues
  - What if your worker code accidentally generated a bug and stored the wrong number for some of the data portions

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How will Big Data techniques help?

- The databases and computation systems used in Big Data applications are aware of their distributed nature
  - Sharding and replications will be considered as a fundamental component in the design of Big Data systems
- Data is dealt as immutable
  - Users will mutate data continuously
    - The raw pageview information is **not modified**
- **Applications will be designed in different ways**

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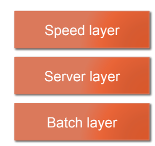
Lambda Architecture

- Big Data systems as a series of layers
  - Batch layer
  - Serving layer
  - Speed layer
- Batch view
  - Precomputed query function
  - Quick access to the values you need
  - *batch view = function(all data)*
  - *query = function(batch view)*



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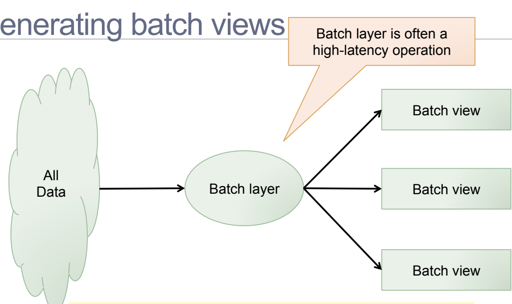
Generating batch views



e.g. A function on all the pageviews to precompute an index from a key of [url, day] to count the number of pageviews for that URL for that day
This index can be used to sum up the counts to get the results

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Batch layer

- Batch layer
  - Stores the master copy of the dataset
  - Precomputes batch views
    - The component that performs the batch view processing
- Stores an immutable, constantly growing master dataset
- Computes arbitrary functions on that dataset
  - Batch-processing systems
  - e.g. Hadoop, Spark, TensorFlow

```
Api.execute(Api.hfsSeqfile("/tmp/pageview-counts"),
       new Subquery("?uri", "?count")
               .predicate(Api.hfsSeqfile("/data/pageviews"),
                    "?uri", "?user", "?timestamp")
               .predicate(new Count(), "?count");
```

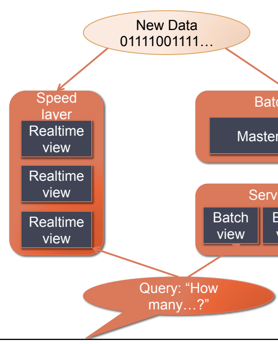
Serving layer

- The batch layer emits batch view as the result of its functions
  - These views should be loaded somewhere and queried
- Specialized distributed database that loads in a batch view and makes it possible to do random reads on it
- Batch update and random reads should be supported
  - e.g. BigQuery, ElephantDB, Dynamo, MongoDB

Speed layer

- Is there any data not represented in the batch view?
- Data came while the precomputation was running
  - With fully real-time data system
- Speed layer looks only at recent data
  - Whereas the batch layer looks at all the data at once
- *realtime view= function(realtime view, new data)*

Lambda architecture



How long should the real time view be maintained?

- Once the data arrives at the serving layer, the corresponding results in the real-time views are no longer needed
  - You can discard pieces of the realtime views

Extended example with Lambda architecture

- Web analytics application tracking the number of pageviews over a range of days
  - The speed layer keeps its own separate view of [url, day]
    - Updates its views by incrementing the count in the view whenever it receives new data
  - The batch layer recomputes its views by counting the pageviews
  - To resolve the query, you query both the batch and realtime views
    - With satisfying ranges
    - Sum up the results

What if the algorithm is not incremental?

- **Brain Storming Quiz**
- What are the examples of non-incremental algorithms?
- How can the lambda architecture handle the non-incremental analysis?

What if the algorithm is not incremental?

- The batch/speed layer will split your data
  - The exact algorithm on the batch layer
  - An approximate algorithm on the speed layer
- The batch layer repeatedly overrides the speed layer
  - The approximation gets corrected
  - Eventual accuracy

Example of a non-incremental algorithm

- Cardinality estimation
  - Count-distinct problem: finding number of distinct elements
  - Counting **exact unique counts** in the batch layer
  - **A Hyper-LogLog** as an approximation in the speed layer
  - Batch layer corrects what's computed in the speed layer
    - Eventual accuracy

Recent trends in technology (1/3)

- Physical limits of how fast a single CPU can go
  - Parallelize computation to scale to more data
  - **Scale-out** solution
- Elastic clouds
  - Infrastructure as a Service (IaaS)
  - Rent hardware on demand rather than owning your hardware
  - Increase and decrease the size of your cluster nearly instantaneously
  - Simplifies system administration

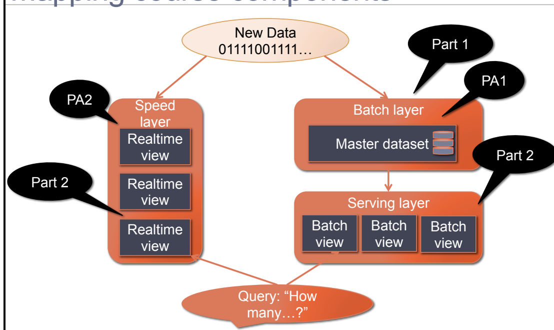
Recent trends in technology (2/3)

- Open source ecosystem for Big Data
  - Batch computation systems
    - Hadoop, HDFS
    - Spark, RDD
  - Serialization frameworks
    - Serializes an object into a byte array from any language
    - Deserialize that byte array into an object in any language
    - Thrift, Protocol Buffers, and Avro

Recent trends in technology (3/3)

- Open source ecosystem for Big Data- cont.
  - Random-access NoSQL databases
    - Sacrifice the full expressiveness of SQL
    - Specializes in certain kinds of operations
    - Cassandra, Hbase, MongoDB, etc.
  - Messaging/queuing systems
    - Sends and consumes messages between processes in a fault-tolerant manner
    - Apache Kafka
  - Real-time computation system
    - High throughput, low latency, stream-processing systems
    - Apache Storm

Mapping course components



CS535 BIG DATA

PART 0. INTRODUCTION
3. DATA MODEL FOR BIG DATA
: APACHE THRIFT

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This material is built based on

- Mark Slee, Aditya Agarwal and Marc Kwiatkowski, “Thrift: Scalable Cross-Language Services Implementation” https://thrift.apache.org/static/files/thrift-20070401.pdf

- Nathan Marz, and James Warren, “Big Data, Principles and Best Practices of Scalable Real-Time Data System”, 2015, Manning Publications, ISBN 9781617290343

Why we are looking at Thrift

- Applications and services involve multiple, distributed components
  - Possibly developed in different languages
  - Communicate very intensively with each other
  - The wire formats used for data interchange may evolve over time

- Goal
  - Support this interoperability and evolution of wire formats
  - But without compromising on performance (i.e., speed)

Apache Thrift

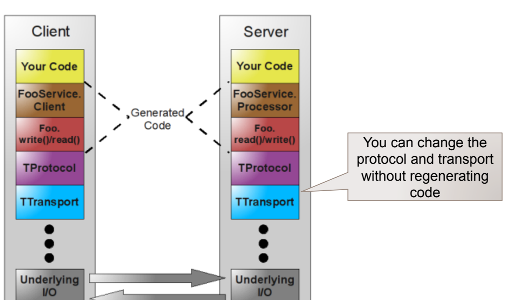
- A framework for creating interoperable and scalable services
  - Data serialization framework

- Originally developed at Facebook
  - Now an Apache project

- Users can create their services via a simple Interface definition language (IDL)
  - Consumable and serviceable by numerous languages
  - Codes for clients and servers are automatically generated

- Binary communication protocol
  - Compact size

Thrift Architecture



Source: http://jnb.ociweb.com/jnb/jnbJun2009.html

Types

https://thrift.apache.org/docs/types

Base types

Note the absence of unsigned integer type.
- This is due to the fact that there are no native unsigned integer types in many programming languages.

- `bool`
  - A boolean value, true or false
- `byte`
  - A signed byte
- `i16`
  - A 16-bit signed integer
- `i32`
  - A 32-bit signed integer
- `i64`
  - A 64-bit signed integer
- `double`
  - A 64-bit floating point number
- `string`
  - A text string encoded using UTF-8 encoding

Special Types

- Binary: a sequence of unencoded bytes
  - Added to provide better interoperability with java

Structs

- Defines a common object to be used across languages
- Equivalent to a class in object oriented programming languages
  - But without inheritance
- Contains a set of strongly typed fields
  - With a unique name identifier within the struct

```
Struct Example {
  1:i32 number=10,
  2:i64 bigNumber,
  3:double decimals,
  4:string name="thrifty"
}
```


Containers (1/2)

- Strongly typed data-type that maps to commonly used and commonly available container types in most programming languages.
- `List`
  - An ordered list of elements
  - e.g. translated to Java `ArrayList`
- `Set`
  - An unordered set of unique elements
  - e.g. translated to Java `HashSet`, `set` in Python, etc.
- `List map`
  - A map of strictly unique keys to values
  - e.g. translated to Java `HashMap`, Python/Ruby `dictionary`

Containers (2/2)

- Container elements may be any valid Thrift Type
- The `key` type for map should be a basic type rather than a `struct` or `container` type
  - There are some languages that do not support more complex `key` types in their native map types

Exceptions

- Functionally equivalent to `structs`
  - Except that they inherit from the native exception base class as appropriate in each target programming language

Services

- Defined using Thrift types
- Consists of a set of named functions
  - With a list of parameters and return types

```
service <name> {
 <returntype><name>(<arguments>)
   [throws (<exceptions>)}
…
}
```

```
service StringCache{
 void set(1:i32 key, 2:string value),
 string get(1:i32 key) throws (1:KeyNotFound knf),
 void delete(1:i32 key)
}
```


Transport

`TTransport` Interface (1/2)

- Describes “how” the data is transmitted
- Thrift decouples the transport layer from the code generation layer
- Needs to know how to read and write data
  - The origin and destination of the data are irrelevant
  - It may be a socket, a segment of shared memory, or a file on the local disk

`TTransport` Interface (2/2)

- `open` opens the transport
- `close` closes the transport
- `isOpen` indicates whether the transport is open
- `read` reads from the transport
- `write` writes to the transport
- `flush` forces any pending writes

`TServerTransport` interface

- `TServerTrasnport` interface accepts or creates primitive transport objects
- `Open` opens the transport
- `listen` begins listening for connections
- `accept` returns a new client transport
- `close` closes the transport

`TSocket`

- Implementation of `TServerTransport` interface
- Provides a common, simple interface for a TCP/IP stream socket
  - Implemented across all target languages

TFileTransport

- Abstraction of an on-disk file to a data stream
  - It can be used to write out a set of incoming Thrift requests to a file on disk