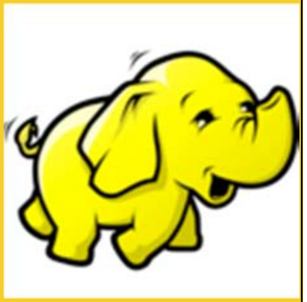
HBase Overview

Originals of slides and source code for examples: http://www.coreservlets.com/hadoop-tutorial/

Also see the customized Hadoop training courses (onsite or at public venues) – http://courses.coreservlets.com/hadoop-training.html



Agenda

- Overview
- Data Model
- Architecture
- Resources

HBase

- Column-Oriented data store, known as "Hadoop Database"
- Supports random real-time CRUD operations (unlike HDFS)
- Distributed – designed to serve large tables
  - Billions of rows and millions of columns
- Runs on a cluster of commodity hardware
  - Server hardware, not laptop/desktops
- Open-source, written in Java
- Type of "NoSQL" DB
  - Does not provide a SQL based access
  - Does not adhere to Relational Model for storage

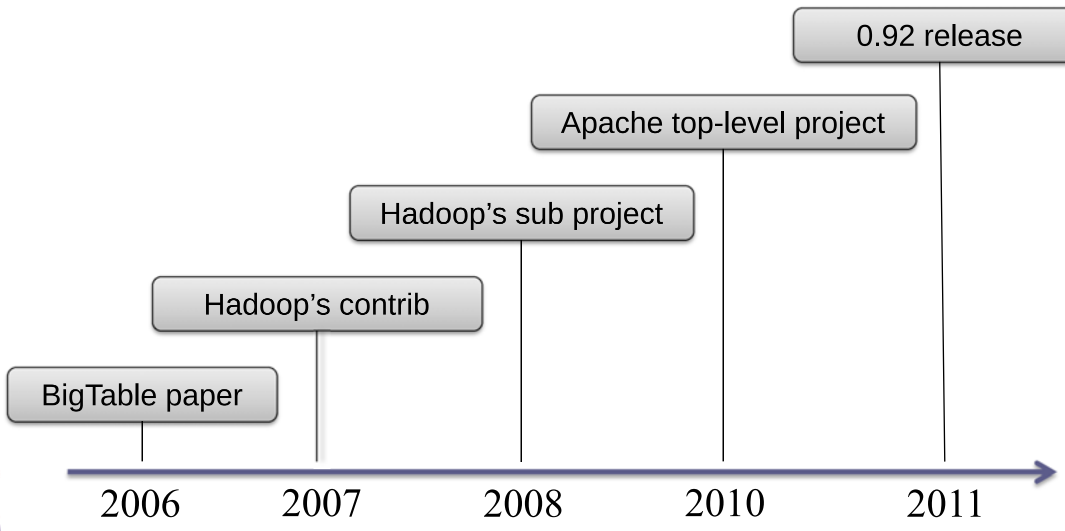
HBase

- **Horizontally scalable**
  - Automatic sharding
- **Strongly consistent reads and writes**
- **Automatic fail-over**
- **Simple Java API**
- **Integration with Map/Reduce framework**
- **Thrift, Avro and REST-ful Web-services**

HBase

- **Based on Google's Bigtable**
  - http://labs.google.com/papers/bigtable.html
- **Just like BigTable is built on top of Google File System (GFS), HBase is implemented on top of HDFS**

HBase History



Source: Lars, George. HBase The Definitive Guide. O'Reilly Media. 2011

Who Uses HBase?

- Here is a very limited list of well known names
  - Facebook
  - Adobe
  - Twitter
  - Yahoo!
  - Netflix
  - Meetup
  - Stumbleupon
  - You????

When To Use HBase

- **Not suitable for every problem**
  – Compared to RDBMs has VERY simple and limited API
- **Good for large amounts of data**
  – 100s of millions or billions of rows
  – If data is too small all the records will end up on a single node leaving the rest of the cluster idle

When To Use HBase

- **Have to have enough hardware!!**
  – At the minimum 5 nodes
    - There are multiple management daemon processes: Namenode, HBaseMaster, Zookeeper, etc....
    - HDFS won't do well on anything under 5 nodes anyway; particularly with a block replication of 3
    - HBase is memory and CPU intensive
- **Carefully evaluate HBase for mixed work loads**
  – Client Request vs. Batch processing (Map/Reduce)
    - SLAs on client requests would need evaluation
  – HBase has intermittent but large IO access
    - May affect response latency!!!

When to Use HBase

- **Two well-known use cases**
  - Lots and lots of data (already mentioned)
  - Large amount of clients/requests (usually cause a lot of data)
- **Great for single random selects and range scans by key**
- **Great for variable schema**
  - Rows may drastically differ
  - If your schema has many columns and most of them are null

When NOT to Use HBase

- **Bad for traditional RDBMs retrieval**
  - Transactional applications
  - Relational Analytics
    - 'group by', 'join', and 'where column like', etc....
- **Currently bad for text-based search access**
  - There is work being done in this arena
    - HBasene: https://github.com/akkumar/hbasene/wiki
    - HBASE-3529: 100% integration of HBase and Lucene based on HBase' coprocessors
  - Some projects provide solution that use HBase
    - Lily=HBase+Solr http://www.lilyproject.org

HBase Data Model

- **Data is stored in Tables**
- **Tables contain rows**
  - Rows are referenced by a unique key
    - Key is an array of bytes – good news
    - Anything can be a key: string, long and your own serialized data structures
- **Rows made of columns which are grouped in column families**
- **Data is stored in cells**
  - Identified by row x column-family x column
  - Cell's content is also an array of bytes

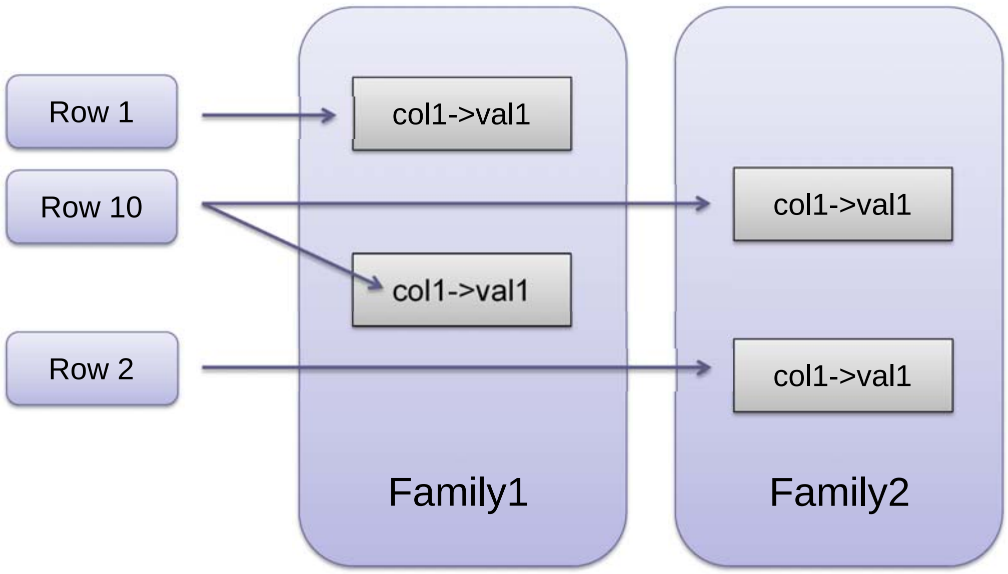
HBase Families

- **Rows are grouped into families**
  - Labeled as “family:column”
    - Example “user:first_name”
  - A way to organize your data
  - Various features are applied to families
    - Compression
    - In-memory option
    - Stored together - in a file called HFile/StoreFile
- **Family definitions are static**
  - Created with table, should be rarely added and changed
  - Limited to small number of families
    - unlike columns that you can have millions of

HBase Families

- **Family name must be composed of printable characters**
  - Not bytes, unlike keys and values
- **Think of family:column as a tag for a cell value and NOT as a spreadsheet**
- **Columns on the other hand are NOT static**
  - Create new columns at run-time
  - Can scale to millions for a family

Rows Composed Of Cells Stored In Families:Columns

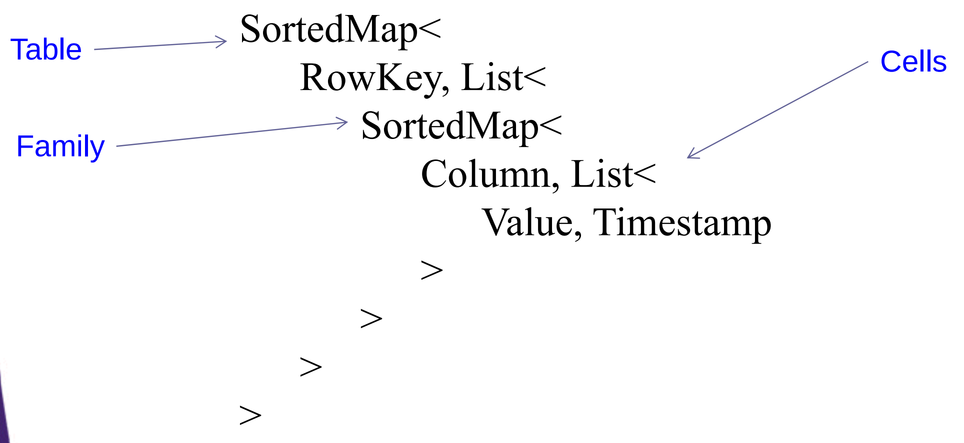


HBase Timestamps

- **Cells' values are versioned**
  - For each cell multiple versions are kept
    - 3 by default
  - Another dimension to identify your data
  - Either explicitly timestamped by region server or provided by the client
    - Versions are stored in decreasing timestamp order
    - Read the latest first – optimization to read the current value
- **You can specify how many versions are kept**
  - More on this later....

HBase Cells

- **Value = Table+RowKey+Family+Column+Timestamp**
- **Programming language style:**



```
SortedMap<
    RowKey, List<
        SortedMap<
            Column, List<
                Value, Timestamp
            >
        >
    >
>
```

HBase Row Keys

- **Rows are sorted lexicographically by key**
  - Compared on a binary level from left to right
  - For example keys 1,2,3,10,15 will get sorted as
    - 1, 10, 15, 2, 3
- **Somewhat similar to Relational DB primary index**
  - Always unique
  - Some but minimal secondary indexes support

HBase Cells

An example - Logical representation of how values are stored

Row Key	Time stamp	Name Family		Address Family	
		first_name	last_name	number	address
row1	t1	**Bob**	**Smith**		
	t5			10	First Lane
	t10			30	Other Lane
	t15			**7**	**Last Street**
row2	t20	**Mary**	Tompson		
	t22			**77**	**One Street**
	t30		**Thompson**		

Source: Lars, George. HBase The Definitive Guide. O'Reilly Media. 2011

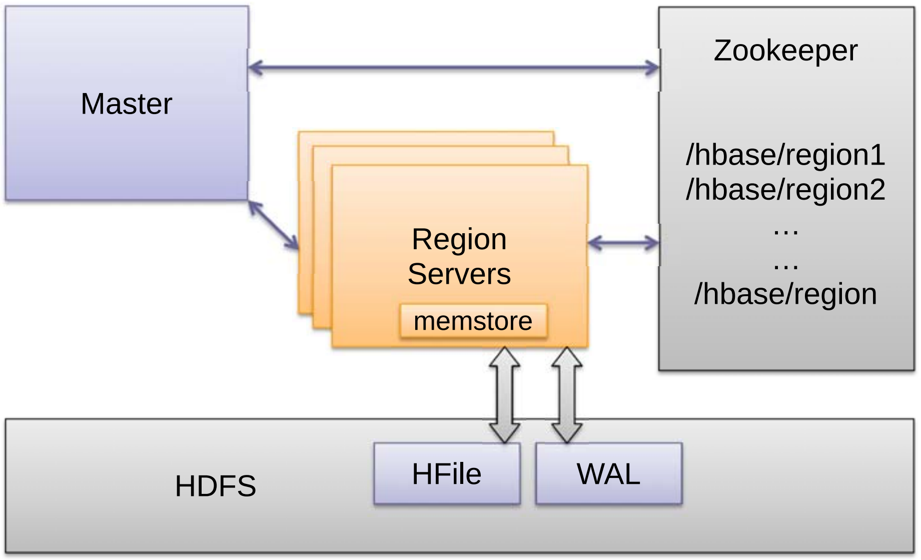
HBase Cells

- **Can ask for**
  - Most recent value (default)
  - Specific timestamp
  - Multiple values such as range of timestamps
  - More on this later....

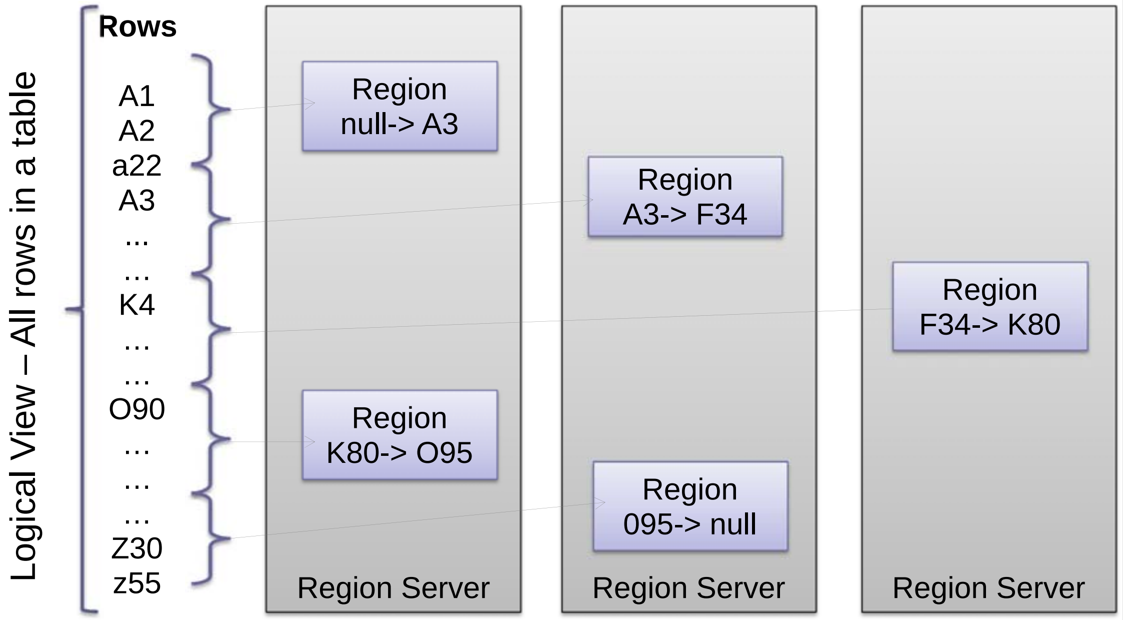
HBase Architecture

- **Table is made of regions**
- **Region – a range of rows stored together**
  - Single shard, used for scaling
  - Dynamically split as they become too big and merged if too small
- **Region Server- serves one or more regions**
  - A region is served by only 1 Region Server
- **Master Server – daemon responsible for managing HBase cluster, aka Region Servers**
- **HBase stores its data into HDFS**
  - relies on HDFS's high availability and fault-tolerance features
- **HBase utilizes Zookeeper for distributed coordination**

HBase Components



Rows Distribution Between Region Servers



Source: Lars, George. HBase The Definitive Guide. O'Reilly Media. 2011

HBase Regions

- **Region is a range of keys**
  - start key → stop key (ex. k3cod → odiekd)
  - start key inclusive and stop key exclusive
- **Addition of data**
  - At first there is only 1 region
  - Addition of data will eventually exceed the configured maximum → the region is split
    - Default is 256MB
  - The region is split into 2 regions at the middle key
- **Regions per server depend on hardware specs, with today's hardware it's common to have:**
  - 10 to 1000 regions per Region Server
  - Managing as much as 1GB to 2 GB per region

HBase Regions

- **Splitting data into regions allows**
  - Fast recovery when a region fails
  - Load balancing when a server is overloaded
    - May be moved between servers
  - Splitting is fast
    - Reads from an original file while asynchronous process performs a split
  - All of these happen automatically without user's involvement

Data Storage

- **Data is stored in files called HFiles/StoreFiles**
  - Usually saved in HDFS
- **HFile is basically a key-value map**
  - Keys are sorted lexicographically
- **When data is added it's written to a log called Write Ahead Log (WAL) and is also stored in memory (memstore)**
- **Flush: when in-memory data exceeds maximum value it is flushed to an HFile**
  - Data persisted to HFile can then be removed from WAL
  - Region Server continues serving read-writes during the flush operations, writing values to the WAL and memstore

Data Storage

- **Recall that HDFS doesn't support updates to an existing file therefore HFiles are immutable**
  - Cannot remove key-values out of HFile(s)
  - Over time more and more HFiles are created
- **Delete marker is saved to indicate that a record was removed**
  - These markers are used to filter the data - to “hide” the deleted records
  - At runtime, data is merged between the content of the HFile and WAL

Data Storage

- **To control the number of HFiles and to keep cluster well balanced HBase periodically performs data compactions**
  - Minor Compaction: Smaller HFiles are merged into larger HFiles (n-way merge)
    - Fast - Data is already sorted within files
    - Delete markers are not applied
  - Major Compaction:
    - For each region merges all the files within a column-family into a single file
    - Scan all the entries and apply all the deletes as necessary

HBase Master

- **Responsible for managing regions and their locations**
  - Assigns regions to region servers
  - Re-balanced to accommodate workloads
  - Recovers if a region server becomes unavailable
  - Uses Zookeeper – distributed coordination service
- **Doesn't actually store or read data**
  - Clients communicate directly with Region Servers
  - Usually lightly loaded
- **Responsible for schema management and changes**
  - Adding/Removing tables and column families

HBase and Zookeeper

- **HBase uses Zookeeper extensively for region assignment**

"Zookeeper is a centralized service for maintaining configuration information, naming, providing distributed synchronization, and providing group services" - zookeeper.apache.org

- **HBase can manage Zookeeper daemons for you or you can install/manage them separately**
- **Learn More at http://zookeeper.apache.org**

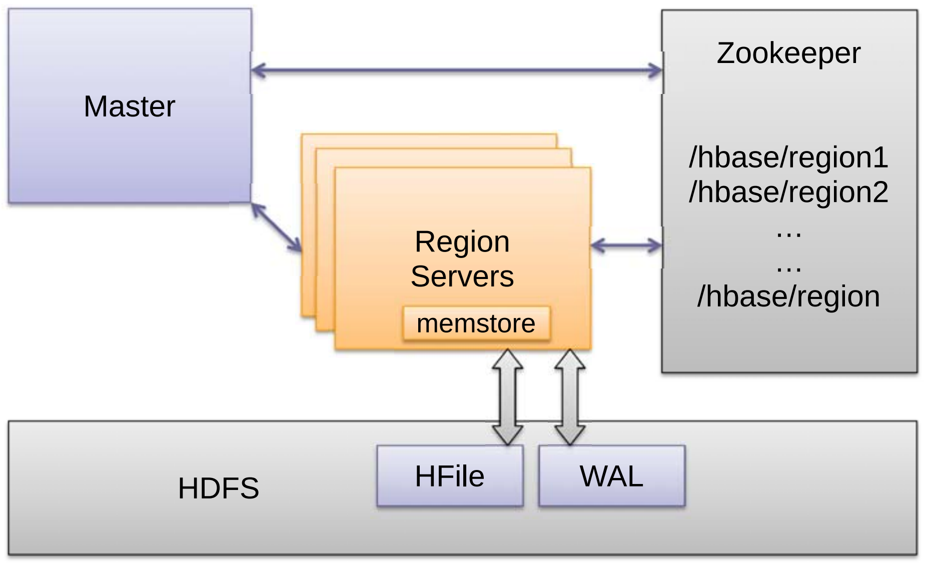
HBase and Zookeeper

- **Zookeeper crash course**
  - Very simple file-like API, written in Java
  - Operations on directories and files (called Znodes)
  - CRUD ZNodes and register for updates
    - Supports PERSISTENT and EPHERMAL Znodes
  - Clients connect with a session to Zookeeper
    - Session is maintained via heartbeat, if client fails to report then the session is expired and all the EPHERMAL nodes are deleted
    - Clients listening for updates will be notified of the deleted nodes as well as new nodes

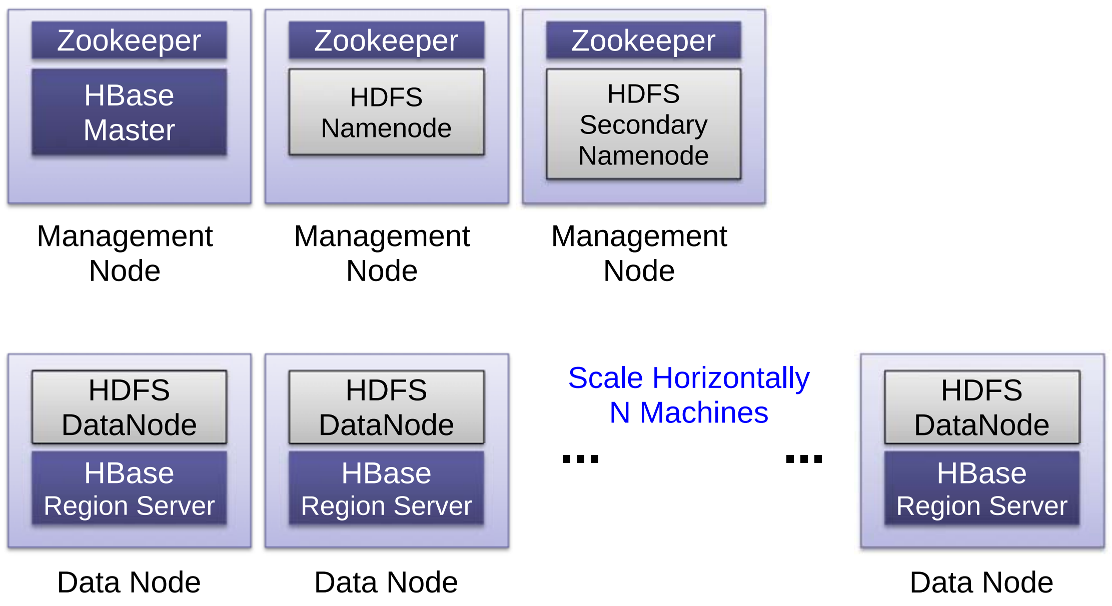
HBase and Zookeeper

- **Each Region Server creates an ephemeral node**
  - Master monitors these nodes to discover available region servers
  - Master also tracks these nodes for server failures
- **Uses Zookeeper to make sure that only 1 master is registered**
- **HBase cannot exist without Zookeeper**

HBase Components



HBase Deployment



HBase Access

- **HBase Shell**
- **Native Java API**
  - Fastest and very capable options
- **Avro Server**
  - Apache Avro is also a cross-language schema compiler
  - http://avro.apache.org
  - Requires running Avro Server
- **HBql**
  - SQL like syntax for HBase
  - http://www.hbql.com

HBase Access

- **PyHBase**
  - python client for HBase Avro interface
  - https://github.com/hammer/pyhbase
- **AsyncHBase**
  - asynchronous, non-blocking, thread-safe, HBase client
  - https://github.com/stumbleupon/asynchbase
- **JPA/JPO access to HBase via DataNucleous**
  - http://www.datanucleus.org
- **HBase-DSL**
  - Java Library that helps you build queries
  - https://github.com/nearinfinity/hbase-dsl

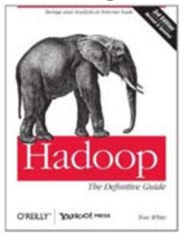
HBase Access

- **Native API is not the only option**
  - REST Server
    - Complete client and admin APIs
    - Requires a REST gateway server
    - Supports many formats: text, xml, json, protocol buffers, raw binary
  - Thrift
    - Apache Thrift is a cross-language schema compiler
    - http://thrift.apache.org
    - Requires running Thrift Server

Resources: Books

- **HBase: The Definitive Guide by Lars George**
  – Publication Date: September 20, 2011

- **Apache HBase Reference Guide**
  – Comes packaged with HBase
  – http://hbase.apache.org/book/book.html
- **Hadoop: The Definitive Guide by Tom White**
  – Publication Date: May 22, 2012
  – Chapter about HBase



Resources

- **Home Page**
  – http://hbase.apache.org
- **Mailing Lists**
  – http://hbase.apache.org/mail-lists.html
  – Subscribe to User List
- **Wiki**
  – http://wiki.apache.org/hadoop/Hbase
- **Videos and Presentations**
  – http://hbase.apache.org/book.html#other.info

Wrap-Up

Summary

- **Presented**
  – HBase Overview
  – HBase Architecture
- **Learned about**
  – Data Model
  – Available Resources

Questions?

More info:
http://www.coreservlets.com/hadoop-tutorial/ – Hadoop programming tutorial
http://courses.coreservlets.com/hadoop-training.html – Customized Hadoop training courses, at public venues or onsite at *your* organization
http://courses.coreservlets.com/Course-Materials/java.html – General Java programming tutorial
http://www.coreservlets.com/java-8-tutorial/ – Java 8 tutorial
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