Hadoop 簡介：源起與術語

Introduction to Hadoop : History and Terminology

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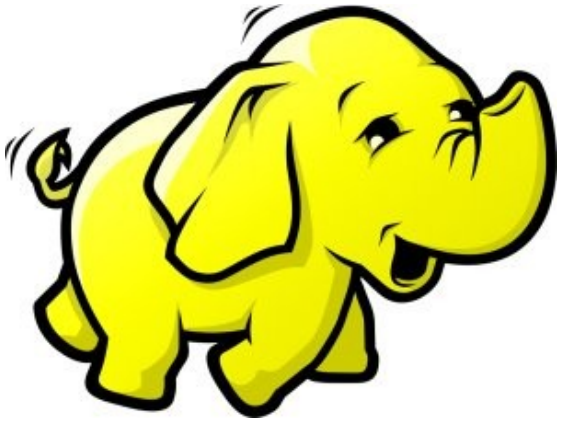


What is Hadoop ?

用一句話解釋 Hadoop 是什麼 ??

Hadoop is a software platform that lets one easily write and run applications that process vast amounts of data.

Hadoop 是一個讓使用者簡易撰寫並執行處理海量資料應用程式的軟體平台。

亦可以想像成一個處理海量資料的生產線，只須學會定義 **map** 跟 **reduce** 工作站該做哪些事情。

Features of Hadoop …

Hadoop 這套軟體的特色是 …

- **海量 Vast Amounts of Data**
  - 擁有儲存與處理大量資料的能力
  - Capability to STORE and PROCESS vast amounts of data.
- **經濟 Cost Efficiency**
  - 可以用在由一般 PC 所架設的叢集環境內
  - Based on large clusters built of commodity hardware.
- **效率 Parallel Performance**
  - 透過分散式檔案系統的幫助，以致得到快速的回應
  - With the help of HDFS, Hadoop have better performance.
- **可靠 Robustness**
  - 當某節點發生錯誤，能即時自動取得備份資料及佈署運算資源
  - Robustness to add and remove computing and storage resource without shutdown entire system.

Founder of Hadoop – Doug Cutting

Hadoop 這套軟體的創辦人 Doug Cutting

Doug Cutting Talks About The Founding Of Hadoop

http://www.youtube.com/watch?v=qxC4urJOchs

History of Hadoop ... 2002~2004

Hadoop 這套軟體的歷史源起 ... 2002~2004

- Lucene
  - http://lucene.apache.org/
  - 用Java 設計的高效能文件索引引擎API
  - a high-performance, full-featured **text search engine library** written entirely in **Java**.
  - 索引文件中的每一字，讓搜尋的效率比傳統逐字比較還要高的多
  - Lucene create an inverse index of every word in different documents. It enhance performance of text searching.

History of Hadoop … 2002~2004

Hadoop 這套軟體的歷史源起 … 2002~2004

- Nutch
  - http://nutch.apache.org/
  - Nutch 是基於開放原始碼所開發的網站搜尋引擎
  - Nutch is open source web-search software.
  - 利用Lucene 函式庫開發
  - It builds on Lucene and Solr, adding web-specifics, such as a crawler, a link-graph database, parsers for HTML and other document formats, etc.

Three Gifts from Google ....

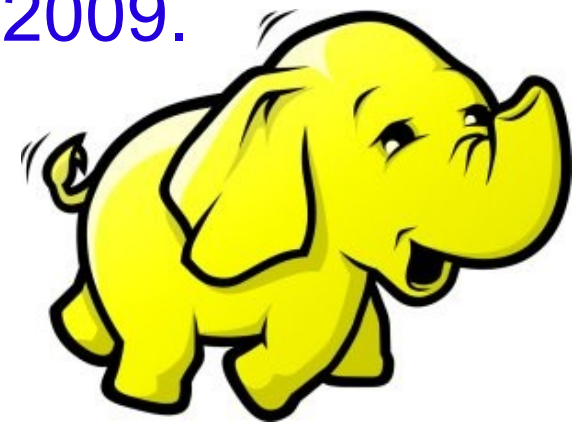
來自 Google 的三個禮物 ....

- Nutch 後來遇到儲存大量網站資料的瓶頸
- Nutch encounter storage issue
- Google 在一些會議分享他們的三大關鍵技術
- Google shared their design of web-search engine
  - SOSP 2003 : “The Google File System”
  - http://labs.google.com/papers/gfs.html
  - OSDI 2004 : “MapReduce : Simplifed Data Processing on Large Cluster”
  - http://labs.google.com/papers/mapreduce.html
  - OSDI 2006 : “Bigtable: A Distributed Storage System for Structured Data”
  - http://labs.google.com/papers/bigtable-osdi06.pdf

History of Hadoop ... 2004 ~ Now

Hadoop 這套軟體的歷史源起 ... 2004 ~ Now

- Dong Cutting reference from Google's publication
- Added DFS & MapReduce implement to Nutch
- According to user feedback on the mail list of Nutch ....
- Hadoop became separated project since Nutch 0.8
- Nutch DFS → Hadoop Distributed File System (HDFS)
- Yahoo hire Dong Cutting to build a team of web search engine at year 2006.
  - Only 14 team members (engineers, clusters, users, etc.)
- Doung Cutting joined Cloudera at year 2009.



Who Use Hadoop ??

有哪些公司在用 Hadoop 這套軟體 ??

- Yahoo is the key contributor currently.
- IBM and Google teach Hadoop in universities …
- http://www.google.com/intl/en/press/pressrel/20071008_ibm_univ.html
- The New York Times used 100 Amazon EC2 instances and a Hadoop application to process 4TB of raw image TIFF data (stored in S3) into 11 million finished PDFs in the space of 24 hours at a computation cost of about $240 (not including bandwidth)

  – from http://en.wikipedia.org/wiki/Hadoop
- http://wiki.apache.org/hadoop/AmazonEC2
- http://wiki.apache.org/hadoop/PoweredBy

- A9.com
- ADSDAQ by Contextweb
- EHarmony
- Facebook
- Fox Interactive Media
- IBM
- ImageShack
- ISI
- Joost
- Last.fm
- Powerset
- The New York Times
- Rackspace
- Veoh
- Metaweb

Performance improvement of Hadoop
Hadoop 過去幾年的效能改進 (from Yahoo)

年份	日期	節點數	耗時（小時）
2006	四月	188	47.9
2006	五月	500	42
2006	十一月	20	1.8
2006	十一月	100	3.3
2006	十一月	500	5.2
2006	十一月	900	7.8
2007	七月	20	1.2
2007	七月	100	1.3
2007	七月	500	2
2007	七月	900	2.5

Sort benchmark, every nodes with terabytes data.

Hadoop in production run ....
商業運轉中的 Hadoop 應用 ....

- February 19, 2008
- Yahoo! Launches World's Largest Hadoop Production Application
- http://developer.yahoo.net/blogs/hadoop/2008/02/yahoo-worlds-largest-production-hadoop.html

Number of links between pages in the index	roughly 1 trillion links
Size of output	over 300 TB, compressed!
Number of cores used to run single Map-Reduce job	over 10,000
Raw disk used in the production cluster	over 5 Petabytes

Hadoop in production run ....
商業運轉中的 Hadoop 應用 ....

- September 30, 2008
- Scaling Hadoop to 4000 nodes at Yahoo!
- http://developer.yahoo.net/blogs/hadoop/2008/09/scaling_hadoop_to_4000_nodes_a.html

Total Nodes	**4000**
Total cores	**30000**
Data	**16PB**

	500-node cluster		**4000-node cluster**	
	write	**read**	**write**	**read**
number of files	990	990	14,000	14,000
file size (MB)	320	320	360	360
total MB processes	316,800	316,800	5,040,000	5,040,000
tasks per node	2	2	4	4
avg. throughput (MB/s)	**5.8**	**18**	**40**	**66**

Comparison between Google and Hadoop
Google 與 Hadoop 的比較表

Develop Group	Google	Apache
Sponsor	Google	Yahoo, Amazon
Algorithm Method	MapReduce	MapReduce
Resource	open document	open source
File System (MapReduce)	GFS	HDFS
Storage System (for structure data)	big-table	HBase
Search Engine	Google	Nutch
OS	Linux	Linux / GPL

Why should we learn Hadoop ?
為何需要學習 Hadoop ??

Search Jobs | Browse Jobs | Local Jobs | Salaries | Employment Trends

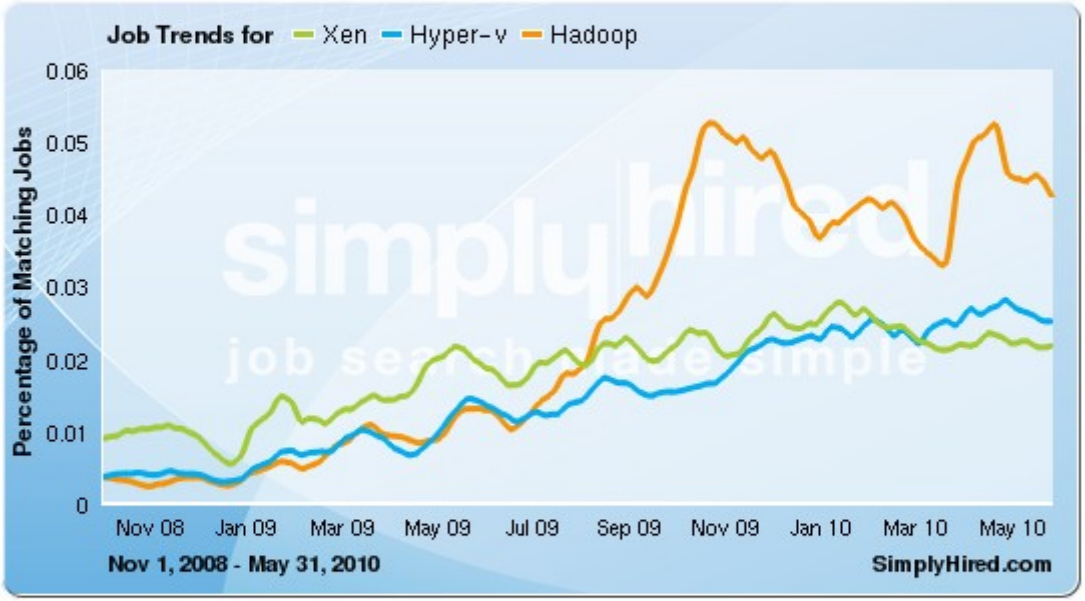
simplyhired®
job search made simple

Employment Trends

Xen, Hyper-V, Hadoop

Tip: You can compare trends by separating them with commas.

Xen, Hyper-v, Hadoop Trends



Xen, Hyper-v, Hadoop Job Trends

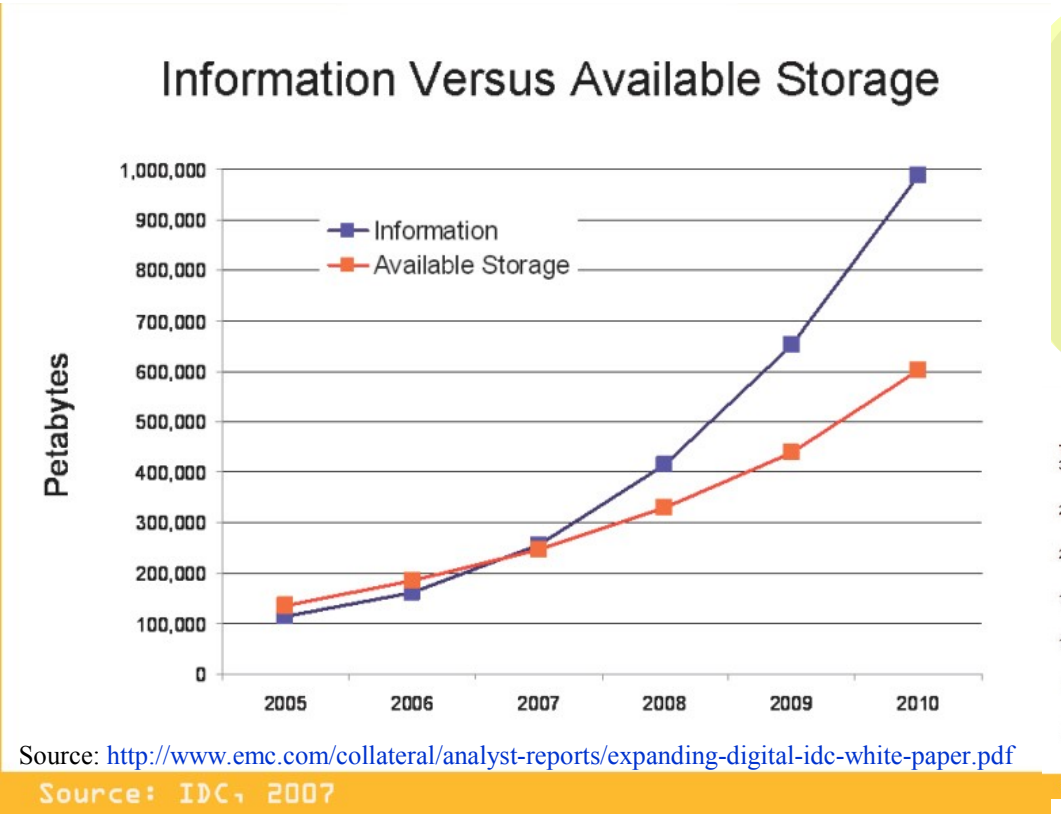
This graph displays the percentage of jobs with your search terms anywhere in the job listing. Since November 2008, the following has occurred:

- Xen jobs increased 141%
- Hyper-v jobs increased 551%
- Hadoop jobs did not change or there is no data available

1. Data Explore
資訊大爆炸

2. Data Mining Tool
方便作資料探勘的工作

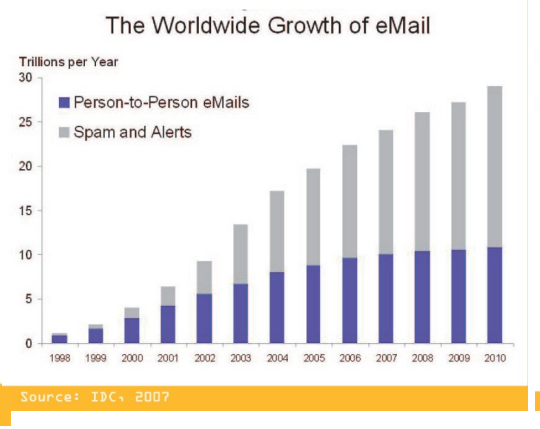
3. Looking for Jobs
好找工作 !!

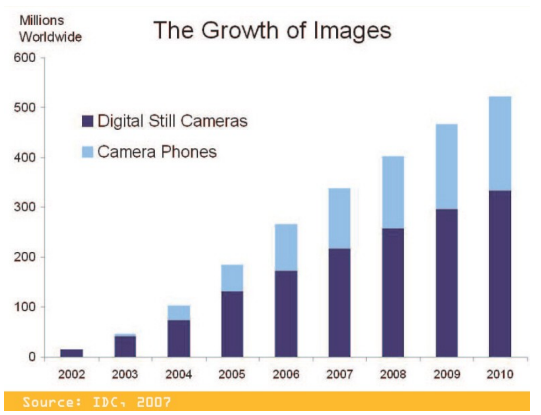


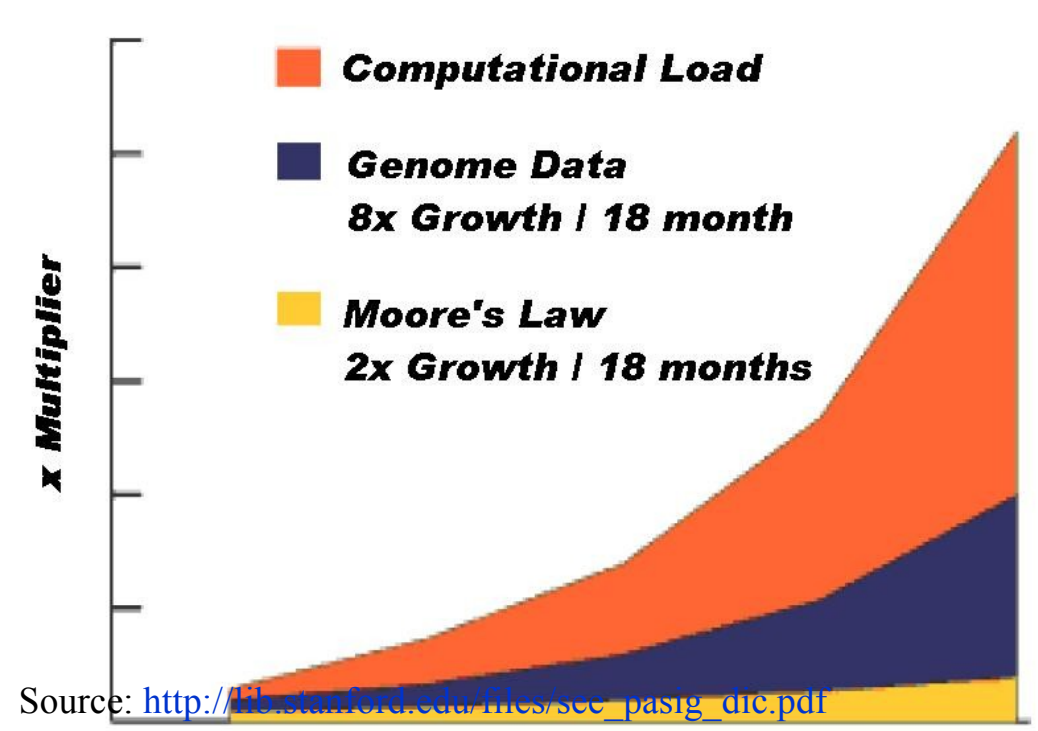
Source: http://www.emc.com/collateral/analyst-reports/expanding-digital-idc-white-paper.pdf

2007 Data Explore

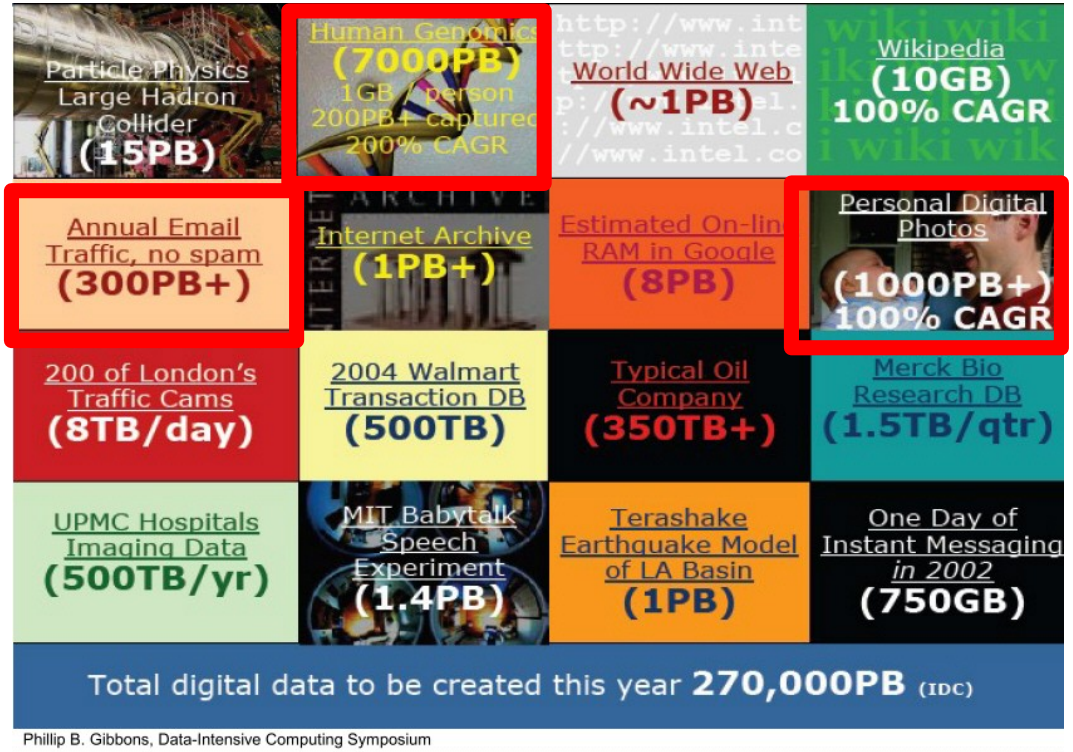
Top 1 : Human Genomics – 7000 PB / Year
Top 2 : Digital Photos – 1000 PB+/ Year
Top 3 : E-mail (no Spam) – 300 PB+ / Year







Source: http://lib.stanford.edu/files/see_pasig_dic.pdf



Phillip B. Gibbons, Data-Intensive Computing Symposium

Hadoop 專業術語

Introduction to Hadoop Terminology

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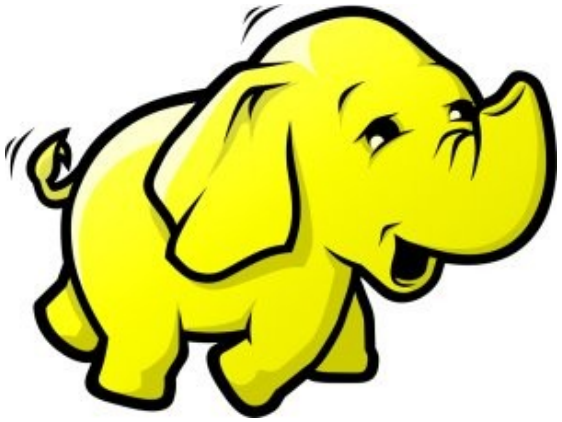


Two Key Elements of Operating System
作業系統兩大關鍵組成元素

Scheduler
程序排程

File System
檔案系統

Terminologies of Hadoop

Hadoop 文件中的專業術語

- Job
  - 任務
- Task
  - 小工作
- JobTracker
  - 任務分派者
- TaskTracker
  - 小工作的執行者
- Client
  - 發起任務的客戶端
- Map
  - 應對
- Reduce
  - 總和

- Namenode
  - 名稱節點
- Datanode
  - 資料節點
- Namespace
  - 名稱空間
- Replication
  - 副本
- Blocks
  - 檔案區塊 (64M)
- Metadata
  - 屬性資料

Two Key Roles of HDFS
HDFS 軟體架構的兩種關鍵角色

名稱節點 NameNode

- Master Node
- Manage NameSpace of HDFS
- Control Permission of Read and Write
- Define the policy of Replication
- Audit and Record the NameSpace
- Single Point of Failure

資料節點 DataNode

- Worker Nodes
- Perform operation of Read and Write
- Execute the request of Replication
- Multiple Nodes

Two Key Roles of Job Scheduler
程序排程的兩種關鍵角色

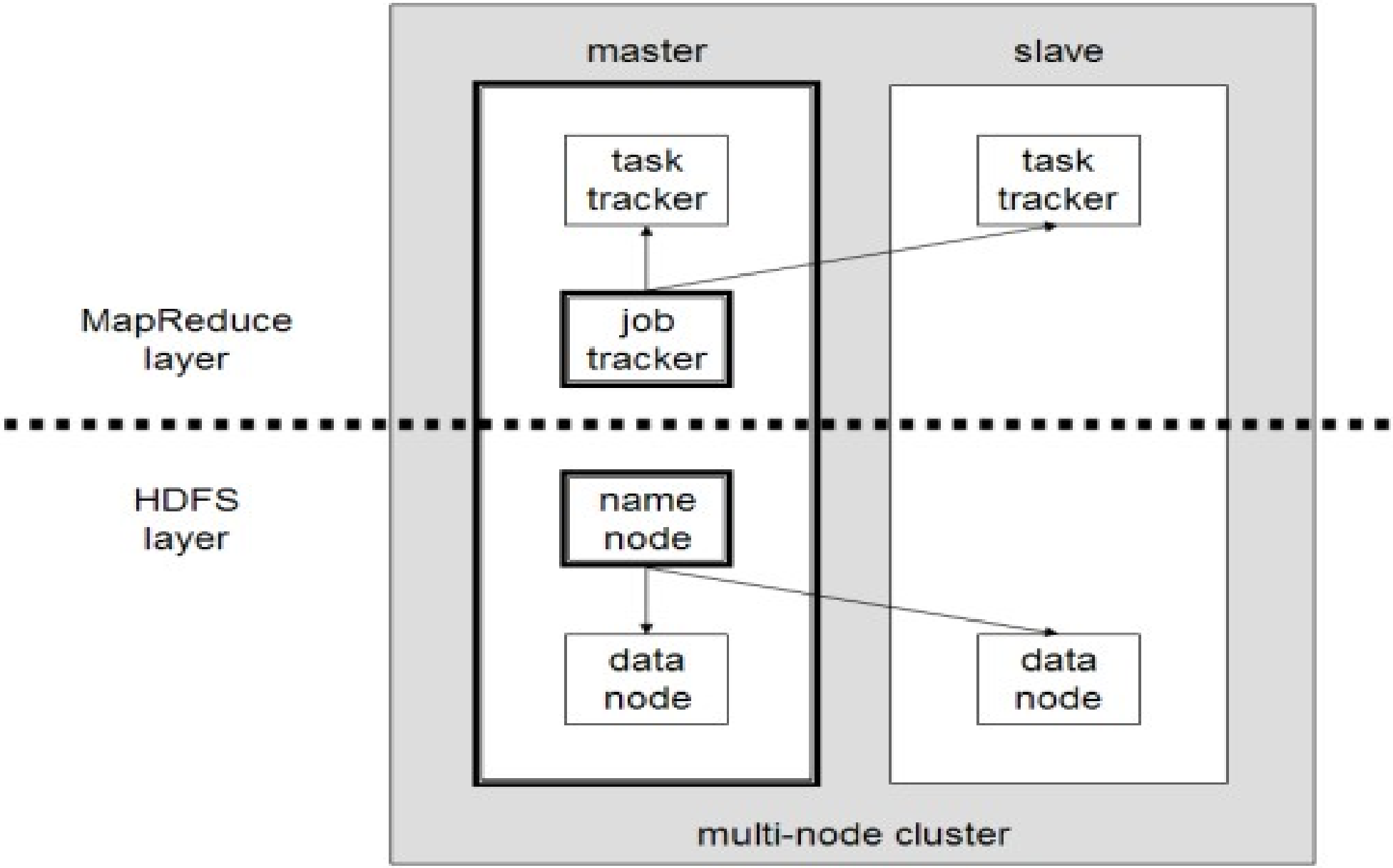
JobTracker

- Master Node
- Receive Jobs from Hadoop Clients
- Assigned Tasks to TaskTrackers
- Define Job Queuing Policy, Priority and Error Handling
- Single Point of Failure

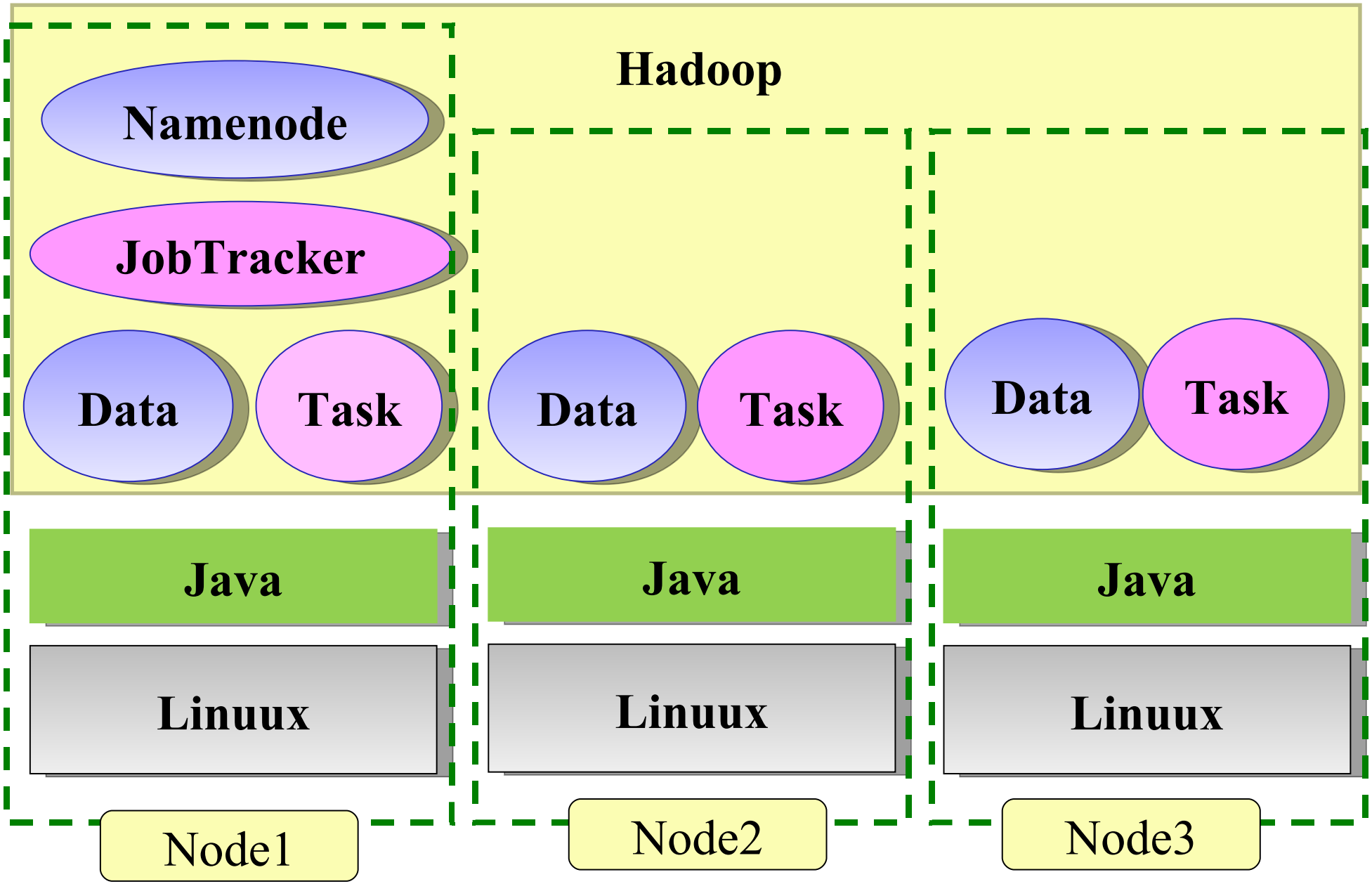
TaskTracker

- Worker Nodes
- Excute Mapper and Reducer Tasks
- Save Results and report task status
- Multiple Nodes

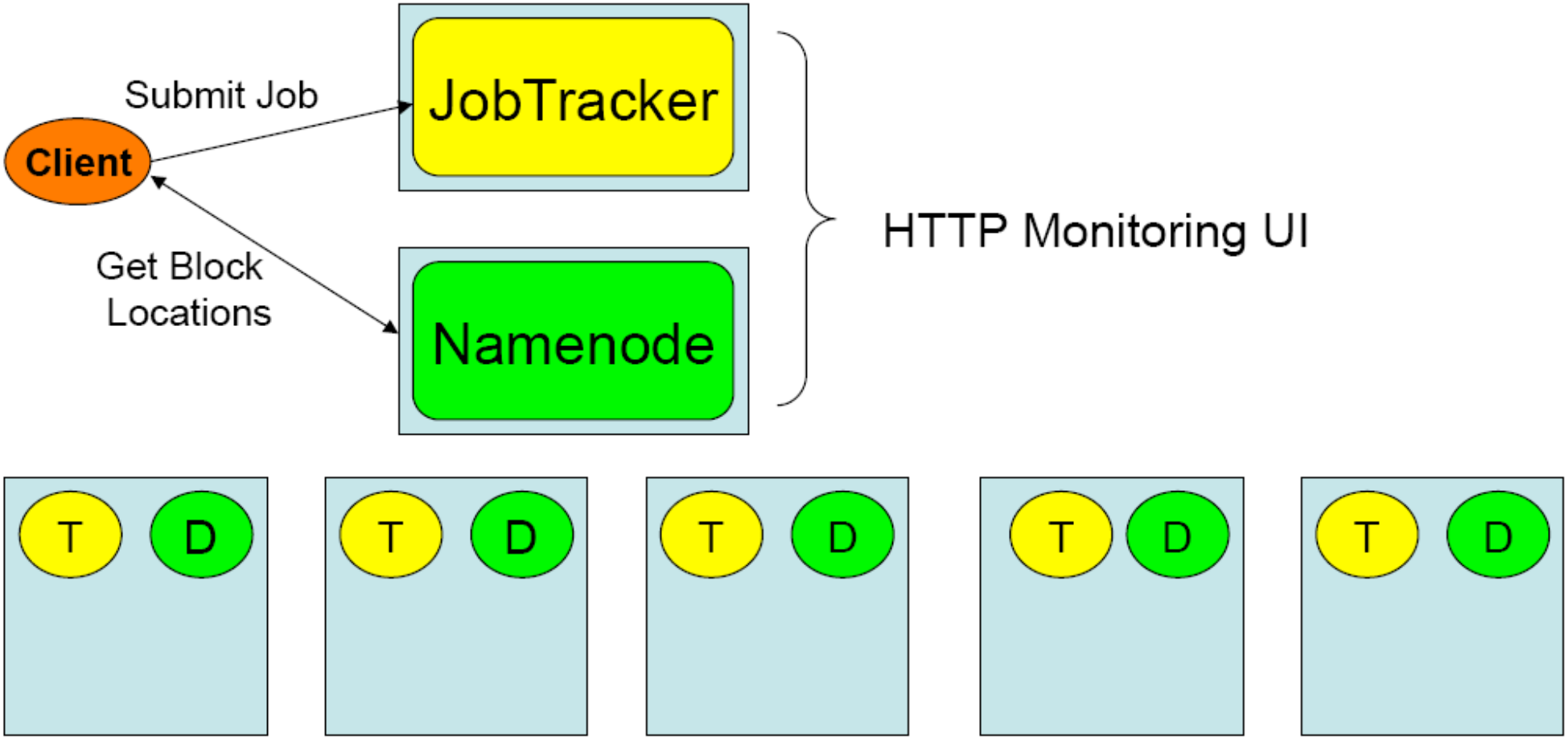
Different Roles of Hadoop Architecture
Hadoop 軟體架構中的不同角色



Distributed Operating System of Hadoop
Hadoop 建構成一個分散式作業系統



About Hadoop Client ...
不在雲裡的 Hadoop Client



What we learn today ?

WHAT	Hadoop 是運算海量資料的軟體平台 !! hadoop is a software platform to process vast amount of data!!
WHO	始祖是 Doug Cutting ， Apache 社群支持， Yahoo 贊助 From Doug Cutting to Apache Community, Yahoo and more !
WHEN	Hadoop 是 2004 年從 Nutch 分裂出來的專案 !! Hadoop became separate project since year 2004 !!
WHY	資料大爆炸、資料探勘、找工作 ***Data Explore, Data Mining, Jobs !!***
HOW	採用自由軟體也能打造私有雲端 Install on large clusters built of commodity hardware !!

Questions?

Slides - http://trac.nchc.org.tw/cloud

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HDFS 簡介

Introduction to Hadoop Distributed File System

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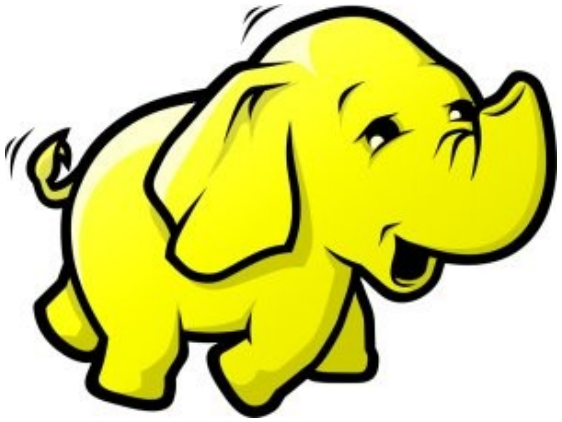


What is HDFS ??

什麼是 HDFS ??

- **Hadoop Distributed File System**
  - 實現類似 Google File System 分散式檔案系統
  - Reference from Google File System.
  - 一個易於擴充的分散式檔案系統，目的為對大量資料進行分析
  - A scalable distributed file system for large data analysis .
  - 運作於廉價的普通硬體上，又可以提供容錯功能
  - based on commodity hardware with high fault-tolerant.
  - 給大量的用戶提供總體性能較高的服務
  - It have better overall performance to serve large amount of users.

Features of HDFS ...

HDFS 的特色是 ...

- **硬體錯誤容忍能力 Fault Tolerance**
  - 硬體錯誤是正常而非異常
  - Failure is the norm rather than exception
  - 自動恢復或故障排除
  - automatic recovery or report failure
- **串流式的資料存取 Streaming data access**
  - 批次處理多於用戶交互處理
  - Batch processing rather than interactive user access.
  - 高 Throughput 而非低 Latency
  - High aggregate data bandwidth (throughput)

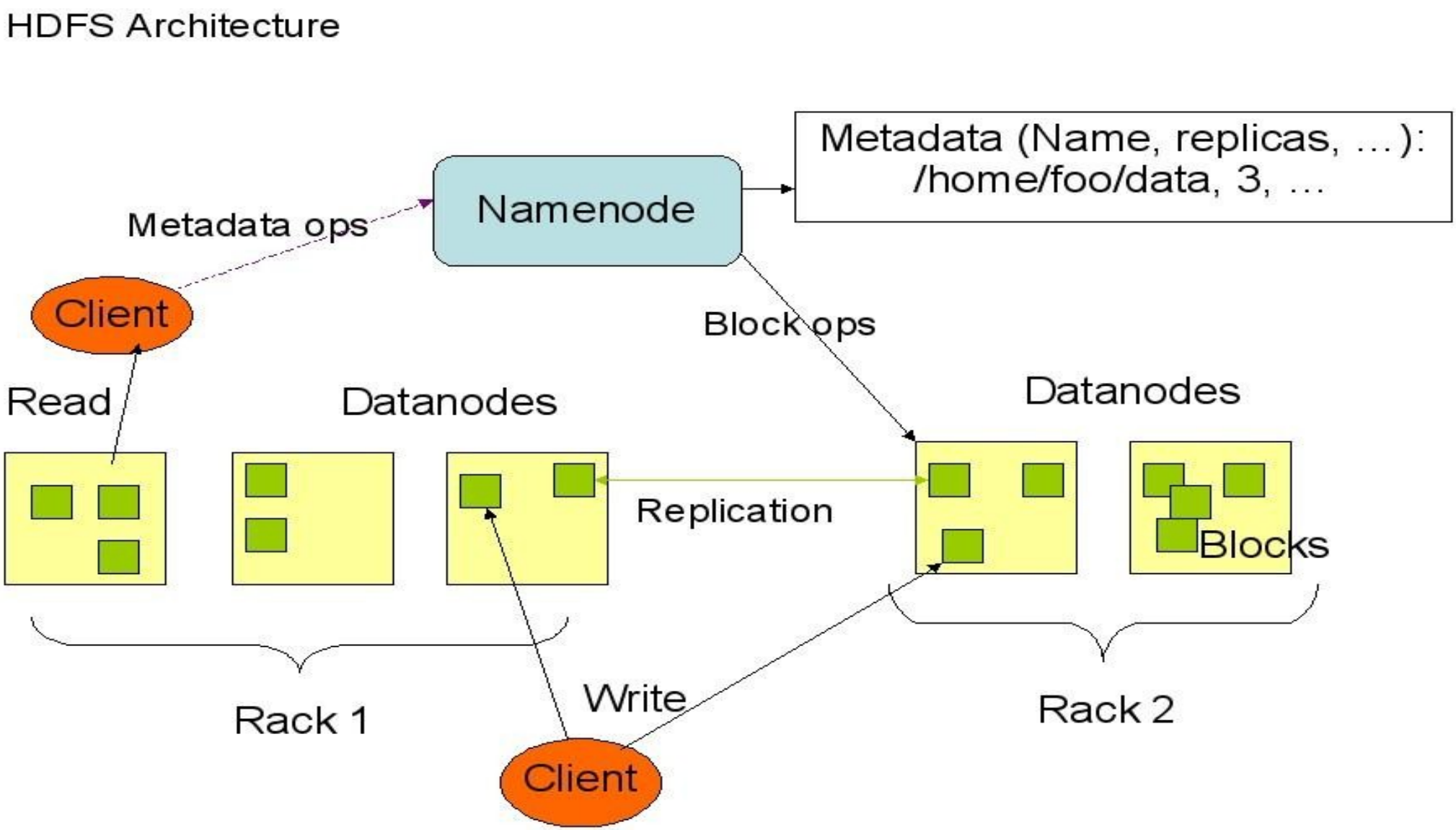
Features of HDFS …

HDFS 的特色是 …

- **大規模資料集 Large data sets and files**
  - 支援 Petabytes 等級的磁碟空間
  - Support Petabytes size
- **一致性模型 Coherency Model**
  - 一次寫入，多次存取 Write-once-read-many
  - 簡化一致性處理問題 This assumption simplifies coherency
- **在地運算 Data Locality**
  - 到資料的節點上計算 > 將資料從遠端複製過來計算
  - “move compute to data” > “move data to compute”
- **異質平台移植性 Heterogeneous**
  - 即使硬體不同也可移植、擴充
  - HDFS could be deployed on different hardware

How HDFS manage data …

HDFS 如何管理資料 …



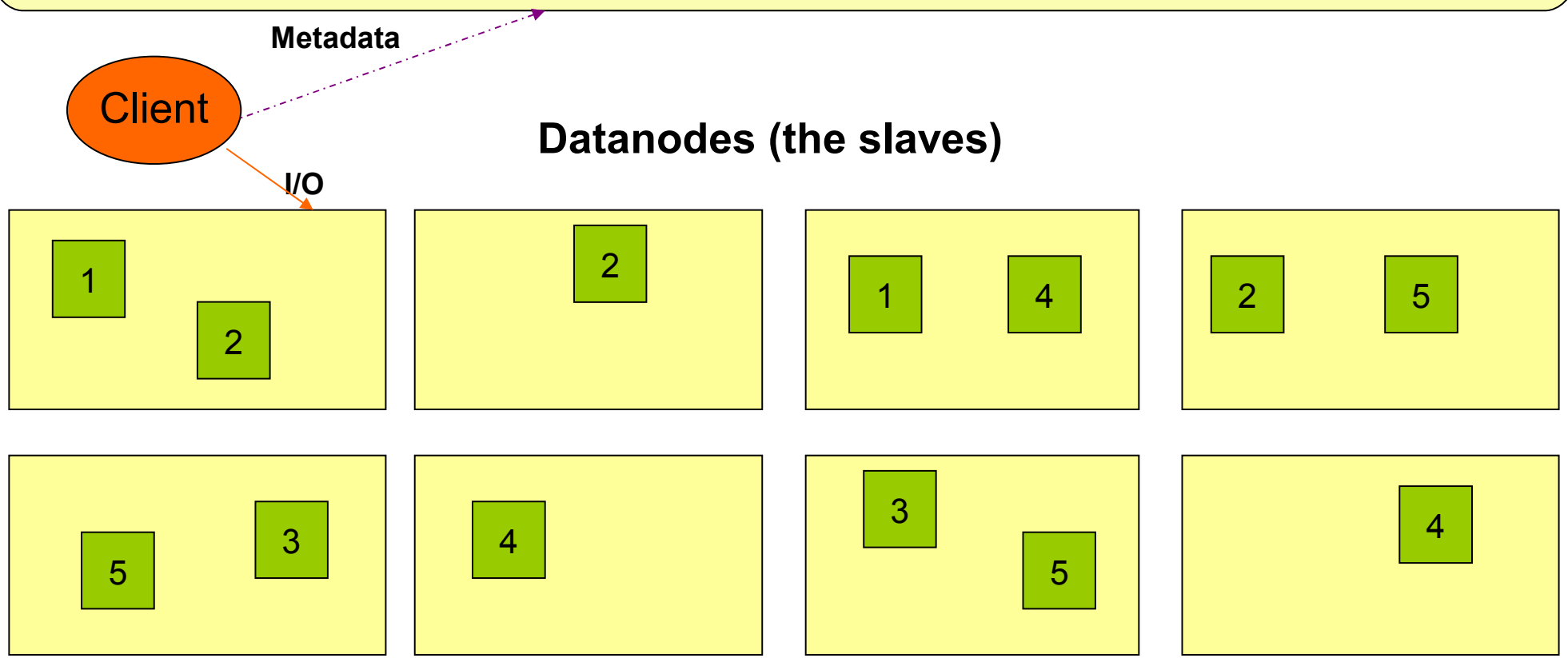
How does HDFS work ...

HDFS 如何運作 ...

Namenode (the master)

Path and Filename – Replication , blocks

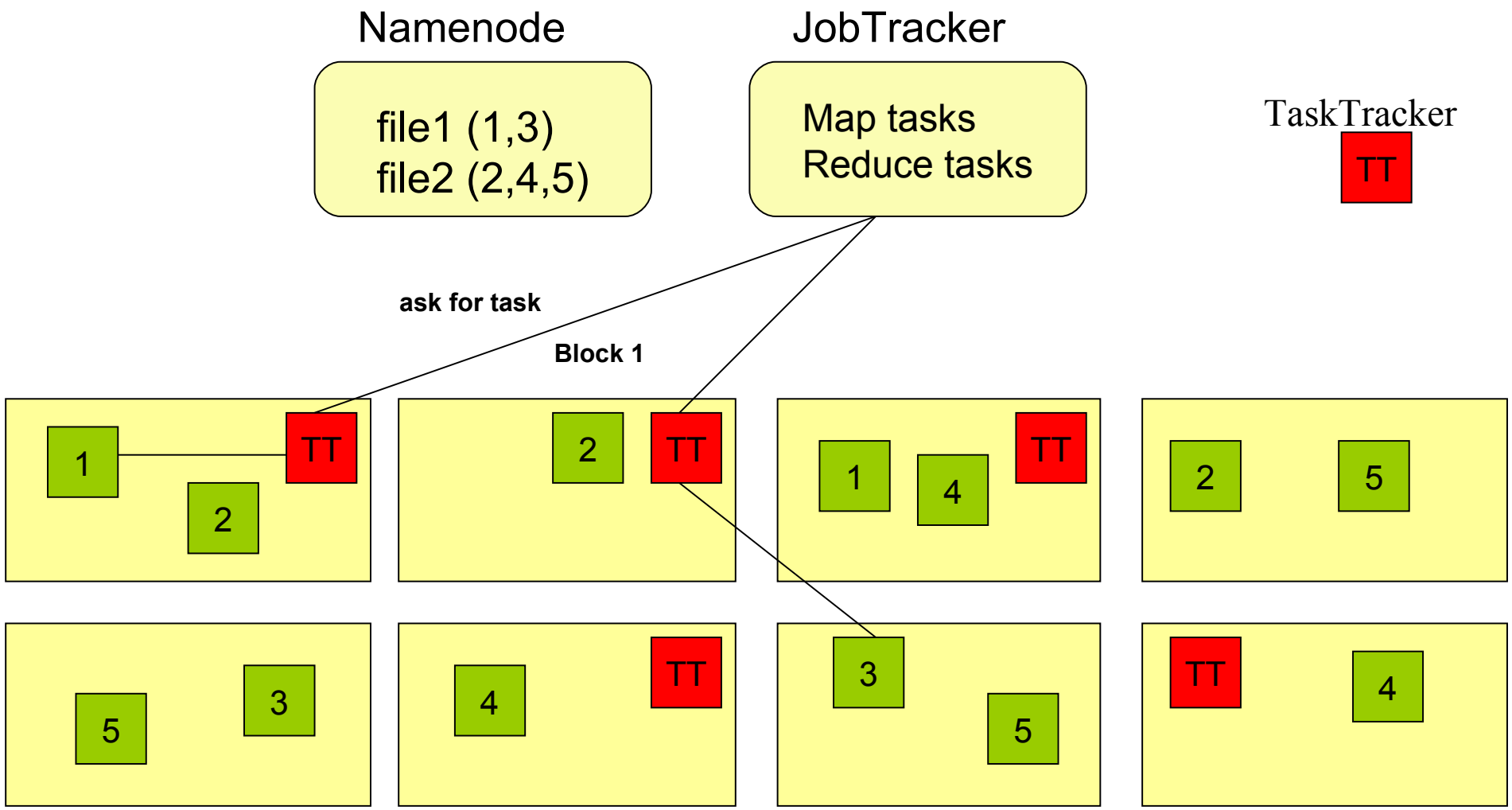
name:/users/joeYahoo/myFile - copies:2, blocks:{1,3}
name:/users/bobYahoo/someData.gzip, copies:3, blocks:{2,4,5}



About Data locality ...

HDFS 如何達成在地運算 ...

- Increase reliability and read bandwidth
  - robustness ： read replication while found any failure
  - High read bandwith ： distribute read （ but increase write bottlenet ）



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About Fault Tolerance …
HDFS 如何達成容錯機制 …

資料崩毀
Data Corrupt

網路或資料
節點失效
Network Fault
DataNode Fault

名稱節點錯誤
NameNode Fault

- 資料完整性 Data integrity
  - checked with CRC32
  - 用副本取代出錯資料
  - Replcae corrupt block with replication one
- Heartbeat
  - Datanode send heartbeat to Namenode
- Metadata
  - FSImage 、 Editlog 為核心印象檔及日誌檔
  - FSImage – core file system mapping image
  - Editlog – like. SQL transaction log
  - 多份儲存，當名稱節點故障時可以手動復原
  - Multiple backups of FSImage and Editlog
  - Manually recovery while NameNode Fault

8

Coherency Model and Performance of HDFS
HDFS 的一致性機制與效能 ...

- **檔案一致性機制 Coherency model of files**
  - 刪除檔案╲新增寫入檔案╲讀取檔案皆由名稱節點負責
  - NameNode handle the operation of write, read and delete.
- **巨量空間及效能機制 Large Data Set and Performance**
  - 預設每個區塊大小以 64MB 為單位
  - By default, the block size is 64MB
  - 大區塊可提高存取效率
  - Bigger block size will enhance read performance
  - 檔案有可能大過一顆磁碟
  - Single file stored on HDFS might be larger than single physical disk of DataNode.
  - 區塊均勻散佈各節點以分散讀取流量
  - Fully distributed blocks increase throughput of reading.

POSIX like HDFS commands

與 POSIX 相似的操作指令 ...

```
jazz@hadoop:~$ hadoop fs
Usage: java FsShell
           [-ls <path>]
           [-lsr <path>]
           [-du <path>]
           [-dus <path>]
           [-count[-q] <path>]
           [-mv <src> <dst>]
           [-cp <src> <dst>]
           [-rm <path>]
           [-rmr <path>]
           [-expunge]
           [-put <localsrc> ... <dst>]
           [-copyFromLocal <localsrc> ... <dst>]
           [-moveFromLocal <localsrc> ... <dst>]
           [-get [-ignoreCrc] [-crc] <src> <localdst>]
           [-getmerge <src> <localdst> [addnl]]
           [-cat <src>]
           [-text <src>]
           [-copyToLocal [-ignoreCrc] [-crc] <src> <localdst>]
           [-moveToLocal [-crc] <src> <localdst>]
           [-mkdir <path>]
           [-setrep [-R] [-w] <rep> <path/file>]
           [-touchz <path>]
           [-test -[ezd] <path>]
           [-stat [format] <path>]
           [-tail [-f] <file>]
           [-chmod [-R] <MODE[,MODE]... | OCTALMODE> PATH...]
           [-chown [-R] [OWNER][:[GROUP]] PATH...]
           [-chgrp [-R] GROUP PATH...]
           [-help [cmd]]
```

Questions?

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MapReduce 簡介

Introduction to MapReduce

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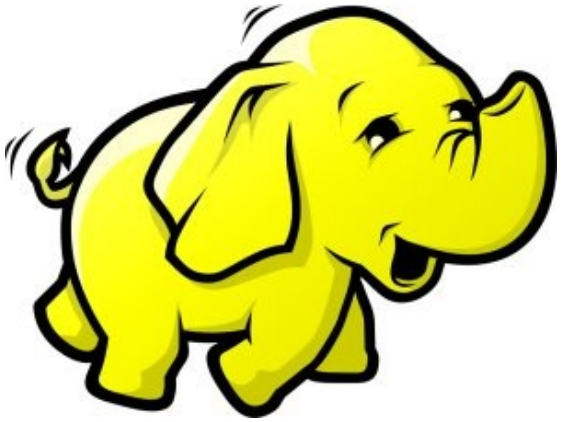
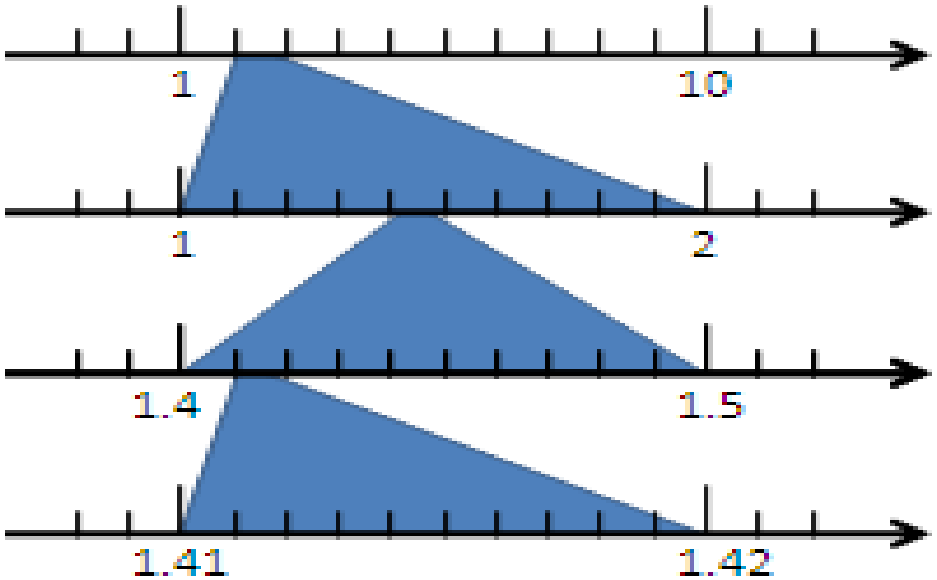


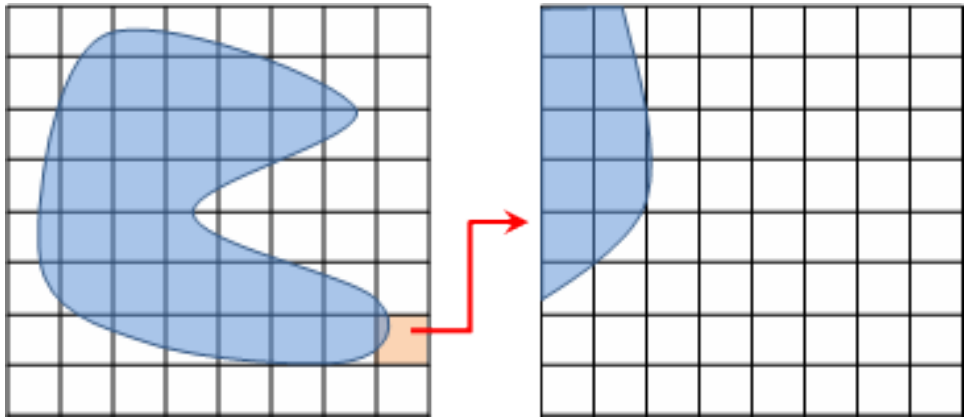
Divide and Conquer Algorithms
分而治之演算法

Example 1:

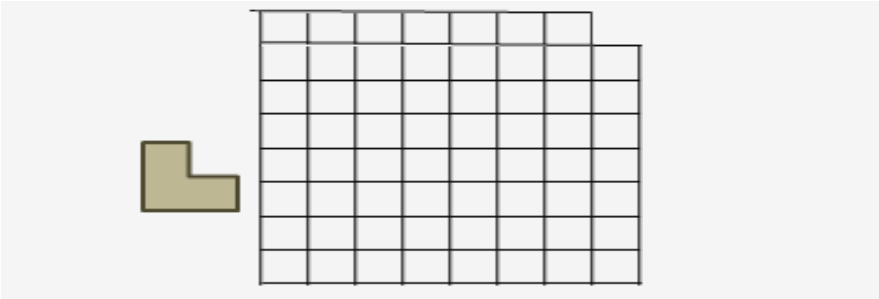


sqrt(2)

Example 2:



Example 3:



Example 4: The way to climb 5 steps stair within 2 steps each time. 眼前有五階樓梯，每次可踏上一階或踏上兩階，那麼爬完五階共有幾種踏法？

Ex : (1,1,1,1,1) or (1,2,1,1)

What is MapReduce ??

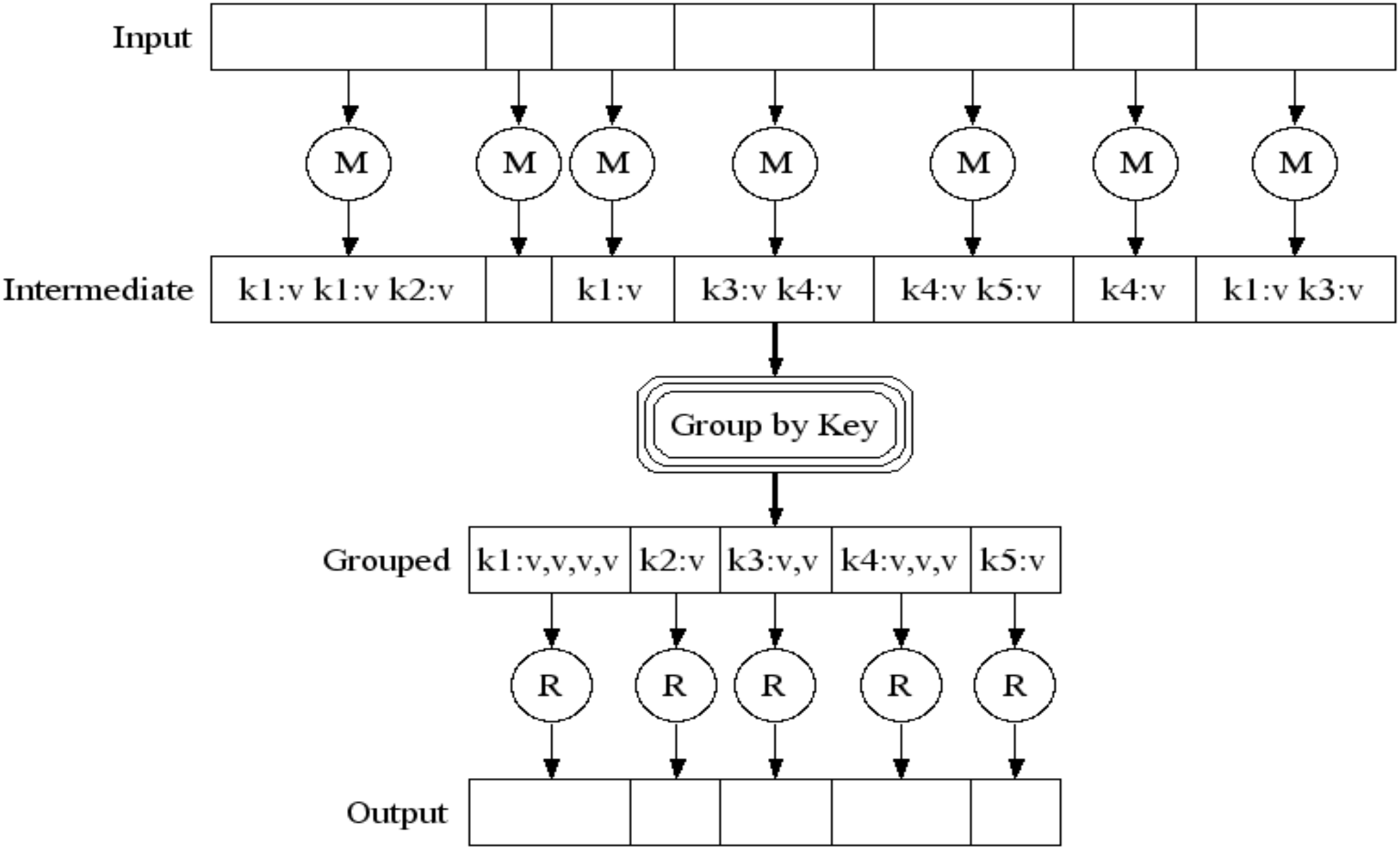
什麼是 MapReduce ??

- MapReduce 是 Google 申請的軟體專利，主要用來處理大量資料
- MapReduce is a patented software framework introduced by Google to support distributed computing on large data sets on clusters of computers.
- 啟發自函數編程中常用的 map 與 reduce 函數。
- The framework is inspired by map and reduce functions commonly used in functional programming, although their purpose in the MapReduce framework is not the same as their original forms
  - Map(...) : N → N
    - Ex. [1,2,3,4] – (*2) -> [2,4,6,8]
  - Reduce(...): N → 1
    - [1,2,3,4] - (sum) -> 10
- Logical view of MapReduce
    - Map(k1,v1) -> list(k2,v2)
    - Reduce(k2, list (v2)) -> list(v3)

Source: http://en.wikipedia.org/wiki/MapReduce

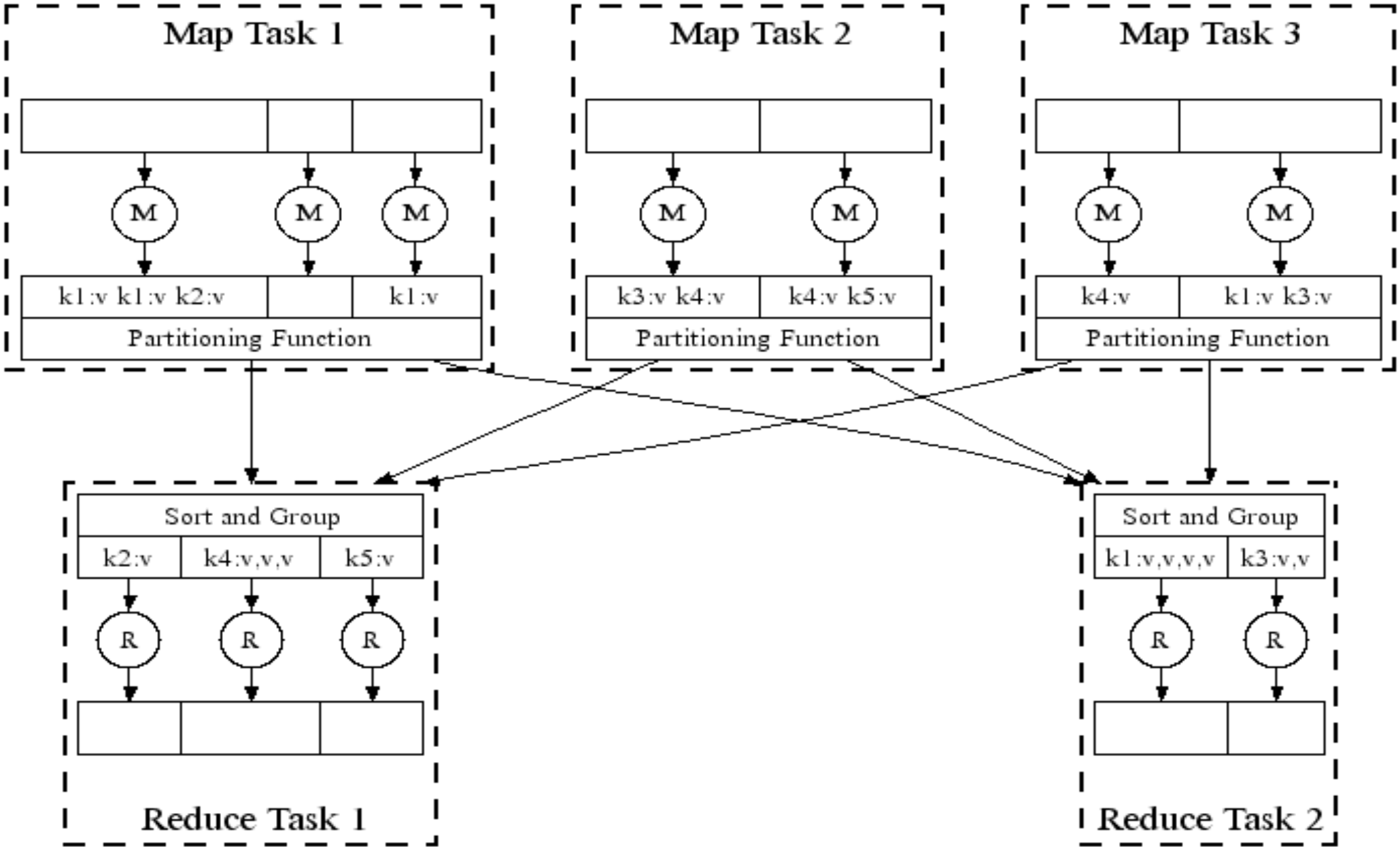
Google's MapReduce Diagram

Google 的 MapReduce 圖解



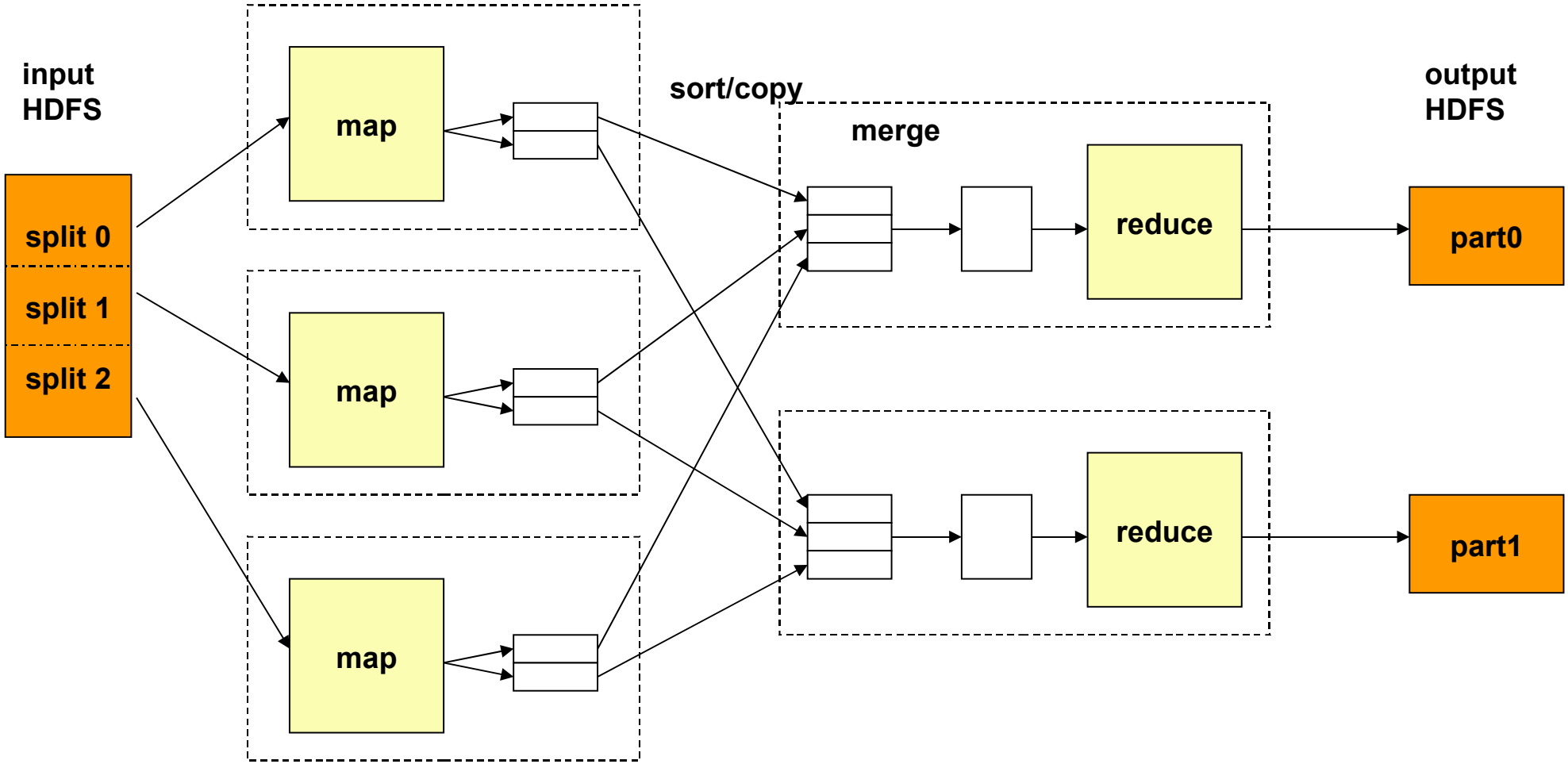
Google's MapReduce in Parallel

Google 的 MapReduce 平行版圖解



How does MapReduce work in Hadoop

Hadoop MapReduce 運作流程



JobTracker 跟 NameNode 取得需要運算的 blocks

JobTracker 選數個 TaskTracker 來作 Map 運算，產生些中間檔案

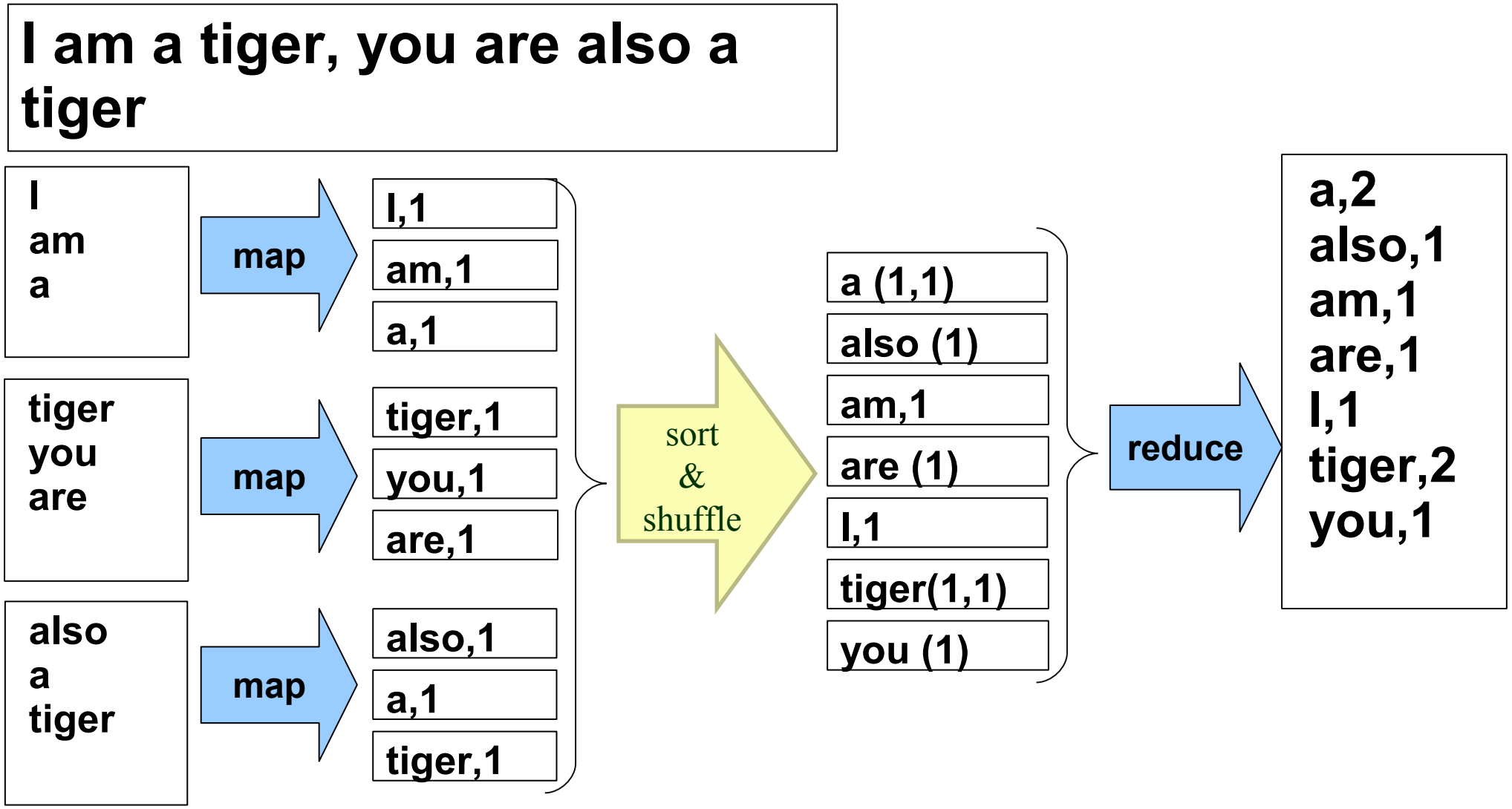
JobTracker 將中間檔案整合排序後，複製到需要的 TaskTracker 去

JobTracker 派遣 TaskTracker 作 reduce

reduce 完後通知 JobTracker 與 Namenode 以產生 output

MapReduce by Example (1)

MapReduce 運作實例 (1)



JobTracker 先選了三個 Tracker 做 map

Map 結束後，hadoop 進行中間資料的重組與排序

JobTracker 再選一個 TaskTracker 作 reduce

MapReduce by Example (2)

MapReduce 運作實例 (2)

$$\begin{bmatrix} a & b \\ c & d \end{bmatrix} \Rightarrow \begin{bmatrix} \text{sqrt}(a+b) \\ \text{sqrt}(c+d) \end{bmatrix}$$

$$\begin{bmatrix} 1.0 & 0.0 & 3.0 \\ 3.2 & 0.8 & 32.0 \\ 1.0 & 14.0 & 1.0 \end{bmatrix} \Rightarrow ?$$

```
(0,sqrt(1.0 +  0.0 +  3.0))
(1,sqrt(3.2 +  0.8 + 32.0))
(2,sqrt(1.0 + 14.0 +  1.0))
```

Input File

```
0 0 1.0  // A[0][1] = 1.0
0 1 0.0  // A[0][1] = 0.0
0 2 3.0  // A[0][2] = 3.0
1 0 3.2  // A[1][0] = 3.2
1 1 0.8  // A[1][1] = 0.8
```

map

```
(0,1.0)
(0,0.0)
(0,3.0)
(1,3.2)
(1,0.8)
```

```
1 2 32.0 // A[1][2] = 32.0
2 0 1.0  // A[2][0] = 1.0
2 1 14.0 // A[2][1] = 14.0
2 2 1.0  // A[2][2] = 1.0
```

map

```
(1,32.0)
(2,1.0)
(2,14.0)
(2,1.0)
```

sort / merge

```
(0,{1.0,0.0,3.0})
(1,{3.2,0.8,32.0})
(2,{1.0,14.0,1.0})
```

reduce

MapReduce is suitable to ....
MapReduce 合適用於 ....

- 大規模資料集
- **Large Data Set**
- 可拆解
- **Parallelization**

- Text tokenization
- Indexing and Search
- Data mining
- machine learning
- …

- http://www.dbms2.com/2008/08/26/known-applications-of-mapreduce/
- http://wiki.apache.org/hadoop/PoweredBy

MapReduce 程式設計入門

MapReduce Programing 101

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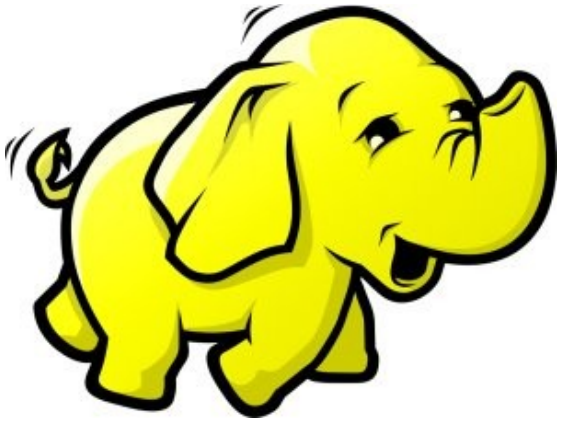


Program Prototype (v 0.20)

Map 區

Reduce 區

設定區

```
Class MR{
    static public Class Mapper …{
    }
    static public Class Reducer …{
    }
    main(){
        Configuration conf = new Configuration();
        Job job = new Job(conf, “job name");
        job.setJarByClass(thisMainClass.class);
        job.setMapperClass(Mapper.class);
        job.setReduceClass(Reducer.class);
        FileInputFormat.addInputPaths(job, new Path(args[0]));
        FileOutputFormat.setOutputPath(job, new Path(args[1]));
        Other configure 其他的設定參數程式碼
        job.waitForCompletion(true);
}}
```

Mapper 程式碼

Reducer 程式碼

Program Prototype (v 0.18)

Map 區

Reduce 區

設定區

```
Class MR{
    static public Class Mapper …{
    }
    static public Class Reducer …{
    }
    main(){
        JobConf conf = new JobConf( MR.class );
        conf.setMapperClass(Mapper.class);
        conf.setReduceClass(Reducer.class);
        FileInputFormat.setInputPaths(conf, new Path(args[0]));
        FileOutputFormat.setOutputPath(conf, new Path(args[1]));
        JobClient.runJob(conf);
}}
```

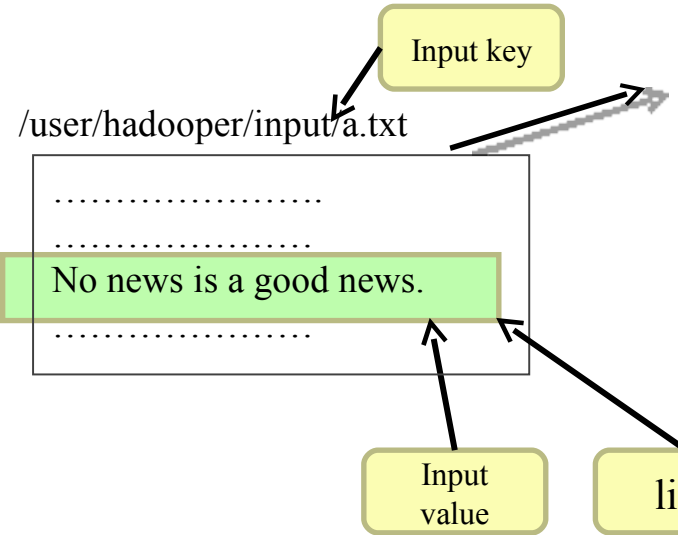
Map 程式碼

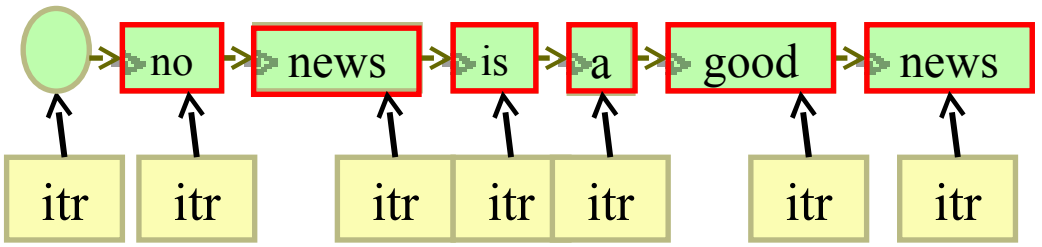
Reduce 程式碼

Other configure 其他的設定參數程式碼

Word Count - mapper

```
class MyMapper extends Mapper<LongWritable, Text, Text, IntWritable> {
        private final static IntWritable one = new IntWritable(1);
        private Text word = new Text();
        public void map( LongWritable key, Text value, Context context)
        throws IOException , InterruptedException {
                String line = ((Text) value).toString();
                StringTokenizer itr = new StringTokenizer(line);
                while (itr.hasMoreTokens()) {
                        word.set(itr.nextToken());
                        context.write(word, one);
}}}
```



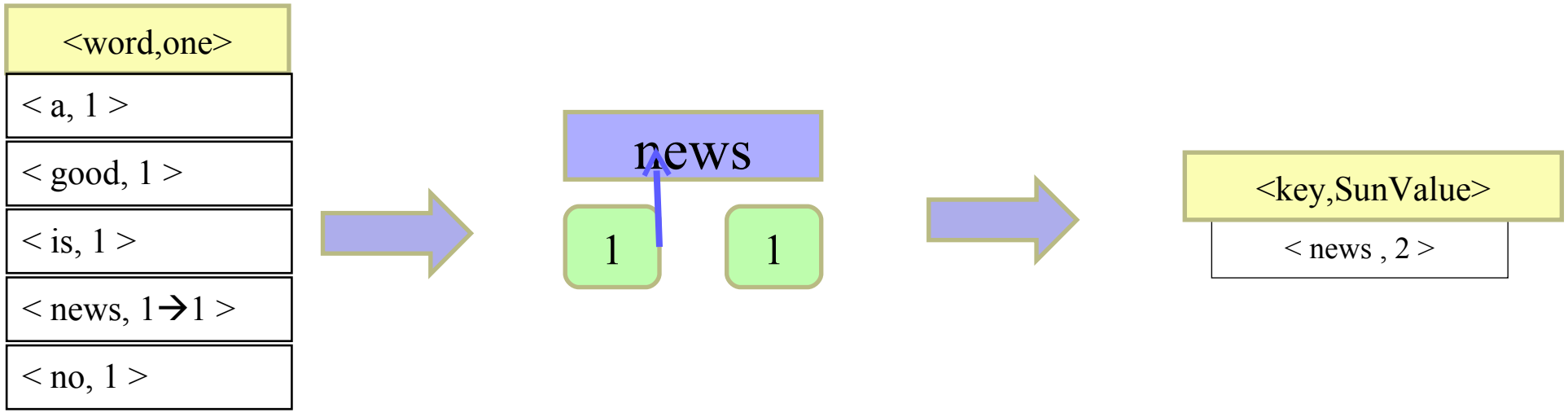


<word,one>
< no , 1 >
< news , 1 >
< is , 1 >
< a, 1 >
< good , 1 >
< news, 1 >

Word Count - reducer

```
class MyReducer extends Reducer< Text, IntWritable, Text, IntWritable> {
        IntWritable result = new IntWritable();
        public void reduce( Text key, Iterable <IntWritable> values, Context context)
        throws IOException, InterruptedException {
                int sum = 0;
                for ( IntWritable val : values )
                sum += val.get();
                result.set(sum);
                context.write ( key, result);
}}
```

```
for ( int i ; i < values.length ; i ++ ){
  sum += values[i].get()
}
```



Word Count – main program

```
Class WordCount{
    main()
        Configuration conf = new Configuration();
        Job job = new Job(conf, “job name” );
        job.setJarByClass(thisMainClass.class);
        job.setMapperClass(MyMapper.class);
        job.setReduceClass(MyReducer.class);
        FileInputFormat.addInputPaths(job, new Path(args[0]));
        FileOutputFormat.setOutputPath(job, new Path(args[1]));
        job.waitForCompletion(true);
}}
```

Questions?

Slides - http://trac.nchc.org.tw/cloud

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