Networking For
Big Data

Raj Jain
Washington University in Saint Louis
Saint Louis, MO 63130
Jain@cse.wustl.edu

IEEE CS Keynote at 19th Annual International Conference on
Advanced Computing and Communications (ADCOM) 2013,
Chennai, India, October 22, 2013

These slides and audio/video recordings of this talk are at:
http://www.cse.wustl.edu/~jain/talks/adcom13.htm
1. Why, What, and How of Big Data:
   It’s all because of advances in networking
2. Recent Developments in Networking and their role in Big Data (Virtualization, SDN, NFV)
3. Networking needs Big Data
What’s Big?

- “Big data” is data larger than what you can handle
- “Big Data” first appeared as a problem in October 1997
- Sudden burst of activity in Q2 2012. Why? Let’s ask Google…
What is Google Trends?

- A time series graph of number of searches on any term of your choice
- Includes geographical distribution of those searches
- Includes major news items
- Example: “Barack Obama”
  K: Nov 2008 election
  B: Nov 2012 election
  Popular in Africa

https://www.google.com/trends/explore#q=barack+obama
You are what you search!

- Internet users from countries with higher Gross Domestic Production (GDP) are more likely to search for future topics than about the past.
- Economic indicators are correlated to on-line behavior.

Ref: C. Johnston, “Google Trends reveals clues about the mentality of richer nations,”

©2013 Raj Jain
Big Data: Google Trends

- Near the peak (As in Gartner’s Hype cycle)
- Highest interest in India
- Followed by South Korea, Singapore, Taiwan, Hong Kong
- Knee on March 27, 2012 (Point G)

Snapshot: September 3, 2013
Recent News about Big Data

- NSF $80M, DoD $250M, DOE $25M

- ACCEL PARTNERS LAUNCHES $100MM BIG DATA FUND
  http://www.accel.com/bigdata

- MongoDB Raises $150M, Now the Most Funded Big Data Startup
  http://siliconangle.com/blog/2013/10/04/mongodb-raises-150m-now-the-most-funded-big-data-startup/

- Big Data Investment Keeps Climbing in 2013 – Funding Hits $1.28B Across 127 Deals

Washington University in St. Louis

Networking is the Basis of Big Data

- Networking is the “plumbing” of computing
- Almost all areas of computing are network-based.
  - Distributed computing
  - Distributed databases
  - Distributed storage
  - Distributed Games
MapReduce

- Software framework to process massive amounts of unstructured data by distributing it over a large number of inexpensive processors

- **Map**: Takes a set of data and divides it for computation

- **Reduce**: Takes the output from Map outputs the result


Hadoop

- An open source implementation of MapReduce
- Named by Doug Cutting at Yahoo after his son’s yellow plus elephant
- Hadoop File System (HDFS) requires data to be broken into blocks. Each block is stored on 2 or more data nodes on different racks.
- **Name node**: Manages the file system name space ⇒ keeps track of blocks on various Data Nodes.
Hadoop (Cont)

- **Job Tracker**: Assigns MapReduce jobs to task tracker nodes that are close to the data (same rack).
- **Task Tracker**: Keep the work as close to the data as possible.

DN = Data Node
TT = Task Tracker
NN = Name Node
Networking Requirements for Big Data

1. **Code/Data Collocation**: The data for map jobs should be at the processors that are going to map.

2. **Elastic bandwidth**: to match the variability of volume

3. **Fault/Error Handling**: If a processor fails, its task needs to be assigned to another processor.

4. **Security**: Access control (authorized users only), privacy (encryption), threat detection, all in real-time in a highly scalable manner

5. **Synchronization**: The map jobs should be comparables so that they finish together. Similarly reduce jobs should be comparable.
Recent Developments in Networking

1. High-Speed: 100 Gbps Ethernet
   ⇒ 400 Gbps ⇒ 1000 Gbps
   ⇒ Cheap storage access. Easy to move big data.

2. Virtualization

3. Software Defined Networking

4. Network Function Virtualization
“Virtualization means that Applications can use a resource without any concern for where it resides, what the technical interface is, how it has been implemented, which platform it uses, and how much of it is available.”

-Rick F. Van der Lans

in Data Virtualization for Business Intelligence Systems
Virtualization (Cont)

- Recent networking technologies and standards allow:
  1. Virtualizing Computation
  2. Virtualizing Storage
  3. Virtualizing Rack Storage Connectivity
  4. Virtualizing Data Center Storage
  5. Virtualizing Metro and Global Storage
1. Virtualizing Computation

- Initially data centers consisted of multiple IP subnets
  - Each subnet = One Ethernet Network
  - Ethernet addresses are globally unique and do not change
  - IP addresses are locators and change every time you move
  - If a VM moves inside a subnet ⇒ No change to IP address ⇒ Fast
  - If a VM moves from one subnet to another ⇒ Its IP address changes ⇒ All connections break ⇒ Slow ⇒ Limited VM mobility

- IEEE 802.1ad-2005 Ethernet Provider Bridging (PB), IEEE 802.1ah-2008 Provider Backbone Bridging (PBB) allow Ethernets to span long distances ⇒ Global VM mobility
2. Virtualizing Storage

- Initially data centers used Storage Area Networks (Fibre Channel) for server-to-storage communications and Ethernet for server-to-server communication.

- IEEE added 4 new standards to make Ethernet offer low loss, low latency service like Fibre Channel:
  - Priority-based Flow Control (IEEE 802.1Qbb-2011)
  - Enhanced Transmission Selection (IEEE 802.1Qaz-2011)
  - Congestion Control (IEEE 802.1Qau-2010)
  - Data Center Bridging Exchange (IEEE 802.1Qaz-2011)

- Result: Unified networking $\Rightarrow$ Significant CapEx/OpEx saving
3. Virtualizing Rack Storage Connectivity

- MapReduce jobs are assigned to the nodes that have the data.
- Job tracker assigns jobs to task trackers in the rack where the data is.
- High-speed Ethernet can get the data in the same rack.
- Peripheral Connect Interface (PCI) Special Interest Group (SIG)’s Single Root I/O virtualization (SR-IOV) allows a storage to be virtualized and shared among multiple VMs.

![Diagram of rack storage connectivity]

Washington University in St. Louis  
http://www.cse.wustl.edu/~jain/talks/adcom13.htm  
©2013 Raj Jain
Multi-Root IOV

- PCI-SIG Multi-Root I/O Virtualization (MR-IOV) standard allows one or more PCIe cards to serve multiple servers and VMs in the same rack.
- Fewer adapters ⇒ Less cooling. No adapters ⇒ Thinner servers.
4. Virtualizing Data Center Storage

- IEEE 802.1BR-2012 Virtual Bridgeport Extension (VBE) allows multiple switches to combine into a very large switch.
- Storage and computers located anywhere in the data center appear as if connected to the same switch.
5. Virtualizing Metro Storage

- Data center Interconnection standards:
  - Virtual Extensible LAN (VXLAN),
  - Network Virtualization using GRE (NVGRE), and
  - Transparent Interconnection of Lots of Link (TRILL)

⇒ data centers located far away to appear to be on the same Ethernet

Virtualizing the Global Storage

- Energy Science Network (ESNet) uses virtual switch to connect members located all over the world
- Virtualization ⇒ Fluid networks ⇒ The world is flat ⇒ You draw your network ⇒ Every thing is virtually local

Ref: I. Monga, “Software Defined Networking for Big-data Science,”
http://www.es.net/assets/pubs_presos/Monga-WAN-Switch-SC12SRS.pdf
Software Defined Networking

- Centralized Programmable Control Plane
- Allows automated orchestration (provisioning) of a large number of virtual resources (machines, networks, storage)
- Large Hadoop topologies can be created on demand
Network Function Virtualization (NFV)

- Fast standard hardware ⇒ Software based Devices
  Virtual networking modules (DHCP, Firewall, DNS, …) running on standard processors
- Modules can be combined to create any combination of function for data privacy, access control, …
- Virtual Machine implementation ⇒ Quick provisioning
- Standard Application Programming Interfaces (APIs)
  ⇒ Networking App Market
  ⇒ Privacy and Security for Big data in the multi-tenant clouds

Router =

- DHCP
- NAT
- Forwarding
- QoS

VM VM VM

Hypervisor

Washington University in St. Louis
http://www.cse.wustl.edu/~jain/talks/adcom13.htm
©2013 Raj Jain
Big Data for Networking

- Today’s data center:
  - Tens of tenants
  - Hundreds of switches and routers
  - Thousands of servers
  - Hundreds of administrators

- Tomorrow:
  - 1k of clients
  - 10k of pSwitches
    - $\Rightarrow$ 100k of vSwitches
  - 1M of VMs
  - Tens of Administrators

- Need to monitor traffic patterns and rearrange virtual networks connecting millions of VMs in real-time
  - $\Rightarrow$ Managing clouds is a real-time big data problem.

- Internet of things $\Rightarrow$ Big Data generation and analytics
Summary

1. Virtualization has made networking, computing, and storage to be liquid. You can shape it (virtually) in any way you like.

2. I/O virtualization allows all storage in the rack to appear local to any VM in that rack ⇒ Solves the co-location problem of MapReduce

3. Network virtualization allows storage anywhere in the data center or even other data centers to appear local

4. Software defined networking allows orchestration of a large number of resources ⇒ Dynamic creation of Hadoop clusters

5. Network function virtualization will allow these clusters to have special functions and security in multi-tenant clouds.
References