1. REPORT DATE (DD-MM-YYYY)	2. REPORT TYPE	3. DATES COVERED (From - To)
17-04-2015	Final Report	1-Feb-2014 - 31-Jan-2015

4. TITLE AND SUBTITLE	5a. CONTRACT NUMBER
Final Report: Building a Cloud Computing and Big Data Infrastructure for Cybersecurity Research and Education	W911NF-14-1-0045
	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
	206022

6. AUTHORS	5d. PROJECT NUMBER
Chung-Chu (George) Hsieh	
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAMES AND ADDRESSES	8. PERFORMING ORGANIZATION REPORT NUMBER
Norfolk State University 700 Park Avenue McDemmond Center for Applied Research, Suite 601 Norfolk, VA 23504 -8060	

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS (ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
U.S. Army Research Office P.O. Box 12211 Research Triangle Park, NC 27709-2211	ARO
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)
	64713-CS-REP.2

12. DISTRIBUTION AVAILIBILITY STATEMENT

Approved for Public Release; Distribution Unlimited

13. SUPPLEMENTARY NOTES

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14. ABSTRACT

The main objective of this instrumentation grant is to acquire the essential equipment for developing a new, mid-range, cloud computing and big data infrastructure to support the cybersecurity research, education, and outreach programs at Norfolk State University. During the project's period of performance (2/1/2014 to 1/31/2015), all proposed equipment was successfully acquired, installed, configured, and operational. The acquired equipment has been used by faculty and students in research. Its use will grow and expand rapidly to support the research, education, outreach, and workforce development activities not only for NSU, but also for two new five-year, multi-

15. SUBJECT TERMS

Big data, cloud computing, infrastructure

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	15. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			Chung-Chu (George) Hsieh
UU	UU	UU	UU		19b. TELEPHONE NUMBER 757-823-8313

Report Title

Final Report: Building a Cloud Computing and Big Data Infrastructure for Cybersecurity Research and Education

ABSTRACT

The main objective of this instrumentation grant is to acquire the essential equipment for developing a new, mid-range, cloud computing and big data infrastructure to support the cybersecurity research, education, and outreach programs at Norfolk State University. During the project's period of performance (2/1/2014 to 1/31/2015), all proposed equipment was successfully acquired, installed, configured, and operational. The acquired equipment has been used by faculty and students in research. Its use will grow and expand rapidly to support the research, education, outreach, and workforce development activities not only for NSU, but also for two new five-year, multi-institution cybersecurity related initiatives funded recently by DoD and DoE, respectively.

Enter List of papers submitted or published that acknowledge ARO support from the start of the project to the date of this printing. List the papers, including journal references, in the following categories:

(a) Papers published in peer-reviewed journals (N/A for none)

Received   Paper

TOTAL:

Number of Papers published in peer-reviewed journals:

(b) Papers published in non-peer-reviewed journals (N/A for none)

Received   Paper

TOTAL:

Number of Papers published in non peer-reviewed journals:

(c) Presentations

Title: Big Data and Data Science @ NSU. Conference: Tidewater Big Data Event, December 9, 2014, Newport News, VA.

Non Peer-Reviewed Conference Proceeding publications (other than abstracts):

Received   Paper

TOTAL:

Number of Non Peer-Reviewed Conference Proceeding publications (other than abstracts):

Peer-Reviewed Conference Proceeding publications (other than abstracts):

Received   Paper

04/17/2015   1.00 Chung-Chu (George) Hsieh, Raymond Sye, Shontae Vincent, Wallace Hendricks. Lessons Learned:
                   Building a Big Data Research and Education Infrastructure,
                   ABDa'14. 24-JUL-14, . : ,

TOTAL: **1**

Number of Peer-Reviewed Conference Proceeding publications (other than abstracts):

(d) Manuscripts

Received   Paper

TOTAL:

Number of Manuscripts:

Books

Received   Book

  TOTAL:

Received   Book Chapter

  TOTAL:

Patents Submitted

Patents Awarded

Awards

Graduate Students

NAME	PERCENT_SUPPORTED
FTE Equivalent:	
Total Number:	

Names of Post Doctorates

NAME	PERCENT_SUPPORTED
FTE Equivalent:	
Total Number:	

Names of Faculty Supported

NAME	PERCENT_SUPPORTED	National Academy Member
Dr. Chung-Chu (George) Hsieh	0.00	
FTE Equivalent:	**0.00**	
Total Number:	**1**	

Names of Under Graduate students supported

NAME	PERCENT_SUPPORTED
FTE Equivalent:	
Total Number:	

Student Metrics
This section only applies to graduating undergraduates supported by this agreement in this reporting period

The number of undergraduates funded by this agreement who graduated during this period: 0.00

The number of undergraduates funded by this agreement who graduated during this period with a degree in science, mathematics, engineering, or technology fields:...... 0.00

The number of undergraduates funded by your agreement who graduated during this period and will continue to pursue a graduate or Ph.D. degree in science, mathematics, engineering, or technology fields:...... 0.00

Number of graduating undergraduates who achieved a 3.5 GPA to 4.0 (4.0 max scale):...... 0.00

Number of graduating undergraduates funded by a DoD funded Center of Excellence grant for Education, Research and Engineering:...... 0.00

The number of undergraduates funded by your agreement who graduated during this period and intend to work for the Department of Defense 0.00

The number of undergraduates funded by your agreement who graduated during this period and will receive scholarships or fellowships for further studies in science, mathematics, engineering or technology fields:...... 0.00

Names of Personnel receiving masters degrees

NAME
Total Number:

Names of personnel receiving PHDs

NAME
Total Number:

Names of other research staff

NAME	PERCENT_SUPPORTED
Mr. Wallace T. Hendricks	0.00
Ms. Linda B. Winkfield	0.00
FTE Equivalent:	**0.00**
Total Number:	**2**

Sub Contractors (DD882)

Inventions (DD882)

Scientific Progress

Technology Transfer

REPORTING REQUIREMENTS FOR INSTRUMENTATION GRANTS

A. Equipment Actually Acquired (During the Performance Period: 02/01/2014 to 01/31/2015)

1. Financial:

   a. Budget: $497,725.00

   b. Expenses: $495,918.36

   c. Balance: $1,804.64

2. Vendors:

   a. Dell (hardware, engineering and installation)

   b. VMware (VMware software licenses) – included in the Dell orders

   c. Cloudera (Cloudera Manager subscription fees) – included in the Dell orders

3. Listing of all items acquired: See Attachment A for the detailed Dell orders

4. Status: All proposed equipment was acquired, installed, configured, and operational before 01/31/2015.

B. Equipment Use

1. Research projects on which equipment has been used:

   a. Graduate Independent Study research by Vivek Kanumuri of the M.S. in Computer Science program at Norfolk State University (NSU) under the supervision of the grant's PI (Dr. George Hsieh): Design, install, and configure the new Big Data Integration System using five of the newly acquired Dell converged servers. Installed everything from ground up.

   b. Graduate Independent Study research by Anuraag Jayaseela Vidyasagar of the M.S. in Computer Science program at NSU under the supervision of Dr. Hsieh: Design, install, and configure the new Big Data Integration System using five of the newly acquired Dell converged servers. Installed everything from ground up.

2. Research projects on which equipment will be used:

   a. Graduate and undergraduate capstone research (M.S. Thesis/Project and B.S. Seminar) and independent study research projects. Currently there are fourteen students who are learning or conducting research in big data and cloud computing for cybersecurity applications. Ten of these students will soon start using the acquired equipment as they progress further in their research.

   b. **CENTER OF EXCELLENCE IN CYBER SECURITY**. This project is funded through a Cooperative Agreement by DoD to establish a Center of Excellence in Cyber Security at Norfolk State University in partnership with the Air Force Research Laboratory. The total funding is $4,984,352 for a five-year period of performance (April 14, 2015 - April 14, 2020). The Center will be led by NSU and include two additional academic partners: Old Dominion University/Virginia Modeling, Simulation and Analysis Center and Tennessee State University. The main research objective of the Center is to develop a cloud-based, big-data analysis capable Cyber

Analysis, Simulation and Experimentation Environment to enhance situational awareness and decision support capabilities for cyber defense and cyber training. The Center will also perform research-related education, outreach, and workforce development activities. Dr. George Hsieh serves as the PI for this cooperative agreement. The equipment acquired through this grant will have a very prominent role in supporting the new Center's research, education, outreach, and workforce development activities.

c. **CONSORTIUH FOR K-20 CYBERSECURITY WORKFORCE PIPELINE**. This project is funded through a grant by U.S. Department of Energy to develop a K-20 workforce pipeline for the cybersecurity workforce. The total funding is $25 million for five years (October 1, 2014 - September 30, 2019) for a consortium consisted of thirteen colleges and universities, one public school district, two DoE national labs, and one DoD facility. NSU is the lead of the project and Dr. Hsieh serves as a co-PI with duties primarily in leading and coordinating consortium-wide research and capacity building activities. The equipment acquired through this grant will have a very prominent role in supporting the consortium project's research, education, outreach, and workforce development activities.

C. Presentations by Dr. George Hsieh

1. "Lessons Learned: Building a Big Data Research and Education Infrastructure", *2014 Int'l Conf. on Advances in Big Data Analytics* (*ABDA'14*), July 21-24, 2014, Las Vegas, NV. [Attachment B]

2. "Big Data and Data Science @ NSU", *Tidewater Big Data Event*, December 9, 2014, Newport News, VA. [Attachment C]

3. "Big Data and Data Science @ NSU - A Briefing for US Army TBOC", September 18, 2014, NSU, Norfolk, VA. [Attachment D]

4. "Center for Data Analytics - An Incubator Project Concept", February 27, 2014, NSU, Norfolk, VA. [Attachment E]

ATTACHMENT A – EQUIPMENT LIST/PERCHASE ORDERS

					Company	NORFOLK STATE UNIV

Proposal Date	Vendor PO	NSU PO	Received	2/25/2014		Customer #	11026148

Quote #				Product Description	QTY	Subtotal	Tax	Shipping	Extended	Application Description
676450142	DO1680559	P0005959	Yes	PowerEdge R720xd, Intel Xeon E-26XX Processors	5	$61,413.85	$0.00	$0.00	$61,413.85	**5 Extra Master Nodes**
678359756	DO1680562	P0005961	Yes	Dell UPS, Rack, 5600W, 4U, HEOnline, 208V, hardwire/electrician required	2	$6,507.20	$0.00	$0.00	$6,507.20	**Racks/ PDU's/ UPS**
678373154	DO1682908	P0006099	Yes	Force10, S4820T, 1U, 48 x 10GBase-T, 4 x 40GbE QSFP+, 1 x AC PSU, 2 x Fan Modules, IO to PSU Panels	3	$46,316.40	$0.00	$0.00	$46,316.40	**3 Switches**
676449298	DO1684274	P0006119	Yes	PowerEdge R720xd, Intel Xeon E-26XX Processors	12	$189,587.52	$0.00	$0.00	$189,587.52	**12 Slave Nodes**
676449296	DO1682966	P0006100	Yes	PowerEdge R720xd, Intel Xeon E-26XX Processors	5	$61,413.85	$0.00	$0.00	$61,413.85	**5 Server Master Nodes**
676395713	DO1682965	P0006101	Yes	PowerEdge VRTX Rack	1	$58,956.88	$0.00	$0.00	$58,956.88	**VRTX Converged Chassis**
				Software and Peripherals						
678032822	DO1684275	P0006124	Yes	1U 17IN LCD CONSOLE W/USB TOUCHPAD KEYB/PRE-MOUNTED AV3008	1	$1,241.10	$0.00	$0.00	$1,241.10	**KMM and cables**
675020138	DO1684276	P0006125	Yes	VLA VMWARE VCENTER SVR 5 STD VSPHERE5 INSTANCE	1	$21,666.19	$0.00	$0.00	$21,666.19	**VMWARE**
658283898	DO1684277	P0006131	Yes	Installation and Implementation of The Dell Cloud Hadoop Solution, w/ 8 Nodes	1	$17,879.22	$0.00	$0.00	$17,879.22	**INSTALL**
658283897	DO1684278	P0006132	Yes	Cloudera Community	1	$30,940.00	$0.00	$0.00	$30,940.00	**CLOUDERA**

Technical Sales Specialist
Rob Hall
rob_a_hall@dell.com
512-513-9177

ADVANCED SOLUTIONS GROUP

Project Totals	
Hardware	$424,195.70
Software and Peripherals	$70,485.41
Shipping	$0.00
Sales Tax	$0.00
Grand Total	**$495,922.21**

QUOTATION

Thanks for choosing Dell! Your quote is detailed below; please review the quote for product and informational accuracy. If you find errors or desire

Sales Professional Information

SALES REP:	DAVID MCCULLOUGH	**PHONE:**	1888 - 9773355
Email Address:	David_Mccullough@Dell.com	**Phone Ext:**	5139074

GROUP: 1   QUANTITY: 5   SYSTEM PRICE: $12,282.77   GROUP TOTAL: $61,413.85

Description	Quantity
PowerEdge R720xd, Intel Xeon E-26XX Processors (210-ABMY)	5
PowerEdge R720 Motherboard, TPM (591-BBBP)	5
Dell Hardware Limited Warranty Plus On Site Service Initial Year (936-0967)	5
ProSupport: Next Business Day Onsite Service After Problem Diagnosis, 2 Year Extended (936-7243)	5
ProSupport: 7x24 HW / SW Tech Support and Assistance, 3 Year (936-7263)	5
Dell Hardware Limited Warranty Plus On Site Service Extended Year (939-3398)	5
ProSupport: Next Business Day Onsite Service After Problem Diagnosis, Initial Year (989-2701)	5
Dell ProSupport. For tech support, visit http://support.dell.com/ProSupport or call 1-800-945-3355 (989-3439)	5
On-Site Installation Declined (900-9997)	5
Proactive Maintenance Service Declined (926-2979)	5
PowerEdge R720 Shipping (331-4437)	5
Intel Ethernet X540 DP 10GBASE-T Server Adapter (430-4440)	5
iDRAC7 Enterprise (421-5339)	5
Intel Ethernet X540 DP 10Gb BT + I350 1Gb BT DP Network Daughter Card (430-4448)	5
Chassis with up to 24, 2.5" Hard Drives (342-3566)	5
Bezel (318-1375)	5
Power Saving Dell Active Power Controller (330-5116)	5
RAID 10 for H710P/H710/H310 (4-24 HDDs in pairs) (331-4537)	5
PERC H710 Integrated RAID Controller, 512MB NV Cache (342-3529)	5

Heat Sink for PowerEdge R720 and R720xd (331-4508)	5
Intel Xeon E5-2695v2 2.4GHz, 30M Cache, 8.0GT/s QPI, Turbo, HT, 12C, 115W, Max Mem 1866MHz (338-BCUG)	5
DIMM Blanks for Systems with 2 Processors (317-8688)	5
Heat Sink for PowerEdge R720 and R720xd (331-4508)	5
Intel Xeon E5-2695v2 2.4GHz, 30M Cache, 8.0GT/s QPI, Turbo, HT, 12C, 115W, Max Mem 1866MHz, 2nd Proc	5
8GB RDIMM, 1600MT/s, Low Volt, Dual Rank, x4 Data Width (319-1811)	80
1600 MHz RDIMMS (331-4424)	5
Performance Optimized (331-4428)	5
600GB 10K RPM SAS 6Gbps 2.5in Hot-plug Hard Drive (342-0847)	30
Electronic System Documentation and OpenManage DVD Kit for R720 and R720xd (331-5914)	5
ReadyRails Sliding Rails With Cable Management Arm (331-4433)	5
Dual, Hot-plug, Redundant Power Supply (1+1), 750W (331-4605)	5
Power Cord, C13 to C14, PDU Style, 12 Amps, 2 meter, Qty 1 (330-3151)	10
No Operating System (420-6320)	5
No Media Required (421-5736)	5
CLOUD COMPUTE NODE,DCS, INFO MOD,HADOOP (331-3282)	5
CLOUD COMPUTE NODE,PEC,CROWBAR (331-3310)	5

*Total Purchase Price:	**$61,413.85**
Product Subtotal:	$61,413.85
Tax:	$0.00
Shipping & Handling:	$0.00
State Environmental Fee:	$0.00
Shipping Method:	LTL 5 DAY OR LESS
	(* Amount denoted in $)

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QUOTATION

Date: 3/20/2014

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Sales Professional Information

SALES REP:	DAVID MCCULLOUGH	**PHONE:**	1888 - 9773355
Email Address:	David_Mccullough@Dell.com	**Phone Ext:**	5139074

GROUP: 1   QUANTITY: 2   SYSTEM PRICE: $2,413.50   GROUP TOTAL: $4,827.00

Description	Quantity
Dell UPS, Rack, 5600W, 4U, HEOnline, 208V, hardware/electrician required (225-2368)	2
Dell UPS External Battery Module, Rack, 216V, 3U, for 5600W UPS (312-2226)	2
Dell Hardware Limited Warranty Initial Year (935-2447)	2
Dell Hardware Limited Warranty Extended Year(s) (938-8608)	2
Basic Hardware Services: Business Hours (5X10) Next Business Day Parts Delivery 2 Year Extended (995-3982)	2
Basic Hardware Services: Business Hours (5X10) Next Business Day Parts Delivery Initial Year (996-5860)	2
On-Site Installation Declined (900-9997)	2
Dell UPS Network Management Card (430-4100)	2

SOFTWARE & ACCESSORIES   GROUP TOTAL: $1,680.20

Product	Quantity	Unit Price	Total
DELL 42U NetShelter (A7545497)	1	$1,038.23	$1,038.23
PDU,30A,208V,(21)C13,(6)C19,Vertical, with L6-30P 3m attached input cord,CusKit (331-0031)	2	$241.19	$482.38
PDU,24A,208V,(14)C13,(2)C19,Half-Height,with L6-30P 3.7m attached input cord,CusKit (330-6438)	1	$159.59	$159.59

*Total Purchase Price:	**$6,507.20**
Product Subtotal:	$6,507.20
Tax:	$0.00
Shipping & Handling:	$0.00
State Environmental Fee:	$0.00
Shipping Method:	LTL 5 DAY OR LESS
	(* Amount denoted in $)

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For certain products shipped to end-users in California, a State Environmental Fee will be applied to your invoice. Dell encourages customers to dispose of electronic equipment properly.
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Sales Professional Information			
SALES REP:	DAVID MCCULLOUGH	**PHONE:**	1888 - 9773355
Email Address:	David_Mccullough@Dell.com	**Phone Ext:**	5139074

GROUP: 1	QUANTITY: 2	SYSTEM PRICE: $19,014.95	GROUP TOTAL: $38,029.90
Description			**Quantity**
Force10, S4820T, 1U, 48 x 10GBase-T, 4 x 40GbE QSFP+, 1 x AC PSU, 2 x Fan Modules, IO to PSU Panels			2
No Returns Allowed on Dell Networking Switches (331-9233)			2
ProSupport: Next Business Day Onsite Service After Problem Diagnosis, Initial Year (971-5033)			2
ProSupport: Next Business Day Onsite Service After Problem Diagnosis, 2 Year Extended (971-5062)			2
ProSupport: 7x24 HW / SW Tech Support and Assistance, 3 Years (971-5065)			2
Dell Hardware Limited Warranty Initial Year (971-5145)			2
Dell Hardware Limited Warranty Extended Year(s) (971-5153)			2
Dell ProSupport. For tech support, visit http://support.dell.com/ProSupport or call 1-800-945-3355 (989-3439)			2
Remote Implementation of a Layer 2 Ethernet Switch (923-2669)			2
Declined Remote Consulting Service (973-2426)			2
Force10, Software, L3 Latest Version, S4810T (421-9486)			2
Power Cord, 125V, 15A, 10 Feet, NEMA 5-15/C13, S-Series (331-5996)			2
Power Cord, 250V, 12A, 2 Meters, C13/C14, US (450-AASX)			2
Force10, Software, iSCSI-Optimized Configuration, S4810 (331-9460)			2
Force10,DOC,USER,S4820,DAO/BCC (331-9990)			2
ProSupport for, Force10,Layer 3 Enablement, 1 Year (996-3080)			2
CLOUD COMPUTE NODE,DCS, INFO MOD,HADOOP (331-3282)			2
CLOUD COMPUTE NODE,PEC,CROWBAR (331-3310)			2

GROUP: 2	QUANTITY: 1	SYSTEM PRICE: $8,286.50	GROUP TOTAL: $8,286.50
Description			**Quantity**
Dell Networking N4032, 24x 10GBASE-T Fixed Ports, 1x Hot Swap Modular Bay, 2x Power Supplies Included (210-			1
Dell Hardware Limited Warranty Initial Year (966-6411)			1
Dell Hardware Limited Warranty Extended Year(s) (966-6413)			1
Lifetime Limited Hardware Warranty with Basic Hardware Service Next Business Day Parts Only on Your Network			1
Software Support,NW,90 Day (966-6423)			1

ProSupport: Next Business Day Onsite Service After Problem Diagnosis, Initial Year (966-6424)	1
ProSupport: Next Business Day Onsite Service After Problem Diagnosis, 2 Year Extended (966-6428)	1
ProSupport: 7x24 HW / SW Tech Support and Assistance, 3 Year (966-6476)	1
Dell ProSupport. For tech support, visit http://support.dell.com/ProSupport or call 1-800-945-3355 (989-3439)	1
Remote Implementation of a Layer 2 Ethernet Switch (923-2669)	1
Non-Canada Orders only (332-1286)	1
Documentation Kit, N4000 Series Switch (340-AGNR)	1
Power Cord, 125V, 15A, 10 Feet, NEMA 5-15/C13 (450-AAFH)	1
Power Cord, 250V, 12A, 2 Meters, C13/C14, US (450-AASX)	1
QSFP+ 40GbE Module, 2-Port, Hot Swap, used for 40GbE Uplink, Stacking, or 8x 10GbE Breakout (409-BBCP)	1

*Total Purchase Price:	**$46,316.40**
Product Subtotal:	$46,316.40
Tax:	$0.00
Shipping & Handling:	$0.00
State Environmental Fee:	$0.00
Shipping Method:	LTL 5 DAY OR LESS
	(* Amount denoted in $)

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If this purchase is for your internal use only: Dell's Commercial Terms of Sale (www.dell.com/CTS), which incorporate Dell's U.S. Return Policy (www.dell.com/returnpolicy) and Warranty (www.dell.com/warrantyterms).

If this purchase is intended for resale: Dell's Reseller Terms of Sale (www.dell.com/resellerterms).

If this purchase includes services: in addition to the foregoing applicable terms, Dell's Service Terms (www.dell.com/servicecontracts/global).

If this purchase includes software: in addition to the foregoing applicable terms, your use of the software is subject to the license terms accompanying the software, and in the absence of such terms, then use of the Dell-branded application software is subject to the Dell End User License Agreement - Type A (www.dell.com/AEULA) and use of the Dell-branded system software is subject to the Dell End User License Agreement - Type S (www.dell.com/SEULA).

You acknowledge having read and agree to be bound by the foregoing applicable terms in their entirety. Any terms and conditions set forth in your purchase order or any other correspondence that are in addition to, inconsistent or in conflict with, the foregoing applicable online terms will be of no force or effect unless specifically agreed to in a writing signed by Dell that expressly references such terms.

Additional Terms for Public Customers

If you are a department, agency, division, or office of any district, state, county or municipal government within the United States ("Public Customer"), the following terms ("Public Customer Terms") apply in addition to the foregoing terms: A. If any portion of the foregoing terms and conditions (or any terms referenced therein) is prohibited by law, such portion shall not apply to you. Notwithstanding anything to the contrary, the End User License Agreements shall take precedence in all conflicts relevant to your use of any software. B. By placing your order, you confirm that (1) you are a contracting officer or other authorized representative of Public Customer with authority to bind the Public Customer to these terms and conditions, and (2) you have read and agree to be bound by these terms and conditions.

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For certain products shipped to end-users in California, a State Environmental Fee will be applied to your invoice. Dell encourages customers to dispose of electronic equipment properly.

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QUOTATION

Quote #:	676449298
Customer #:	11026148
Contract #:	70137
CustomerAgreement #:	Dell Std Terms
Quote Date:	2/25/2014
Customer Name:	NORFOLK STATE UNIV

Date: 2/26/2014

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Sales Professional Information

SALES REP:	DAVID MCCULLOUGH	**PHONE:**	1888 - 9773355
Email Address:	David_Mccullough@Dell.com	**Phone Ext:**	5139074

GROUP: 1   QUANTITY: 12   SYSTEM PRICE: $15,798.96   GROUP TOTAL: $189,587.52

Description	Quantity
PowerEdge R720xd, Intel Xeon E-26XX Processors (210-ABMY)	12
PowerEdge R720 Motherboard, TPM (591-BBBP)	12
Dell Hardware Limited Warranty Plus On Site Service Initial Year (936-0967)	12
ProSupport: Next Business Day Onsite Service After Problem Diagnosis, 2 Year Extended (936-7243)	12
ProSupport: 7x24 HW / SW Tech Support and Assistance, 3 Year (936-7263)	12
Dell Hardware Limited Warranty Plus On Site Service Extended Year (939-3398)	12
ProSupport: Next Business Day Onsite Service After Problem Diagnosis, Initial Year (989-2701)	12
Dell ProSupport. For tech support, visit http://support.dell.com/ProSupport or call 1-800-945-3355 (989-3439)	12
On-Site Installation Declined (900-9997)	12
Proactive Maintenance Service Declined (926-2979)	12
PowerEdge R720 Shipping (331-4437)	12
iDRAC7 Enterprise (421-5339)	12
Intel Ethernet X540 DP 10Gb BT + I350 1Gb BT DP Network Daughter Card (430-4448)	12
Chassis with up to 24, 2.5" Hard Drives (342-3566)	12
Bezel (318-1375)	12
Power Saving Dell Active Power Controller (330-5116)	12
RAID 0 for H710P/H710/H310 (1-24 HDDs) (331-4534)	12
PERC H710 Integrated RAID Controller, 512MB NV Cache (342-3529)	12
Heat Sink for PowerEdge R720 and R720xd (331-4508)	12

Intel Xeon E5-2695v2 2.4GHz, 30M Cache, 8.0GT/s QPI, Turbo, HT, 12C, 115W, Max Mem 1866MHz (338-BCUG)	12
DIMM Blanks for Systems with 2 Processors (317-8688)	12
Heat Sink for PowerEdge R720 and R720xd (331-4508)	12
Intel Xeon E5-2695v2 2.4GHz, 30M Cache, 8.0GT/s QPI, Turbo, HT, 12C, 115W, Max Mem 1866MHz, 2nd Proc	12
8GB RDIMM, 1600MT/s, Low Volt, Dual Rank, x4 Data Width (319-1811)	96
1600 MHz RDIMMS (331-4424)	12
Performance Optimized (331-4428)	12
1TB 7.2K RPM SATA 3Gbps 2.5in Hot-plug Hard Drive (342-1998)	288
Electronic System Documentation and OpenManage DVD Kit for R720 and R720xd (331-5914)	12
ReadyRails Sliding Rails With Cable Management Arm (331-4433)	12
Dual, Hot-plug, Redundant Power Supply (1+1), 750W (331-4605)	12
Power Cord, C13 to C14, PDU Style, 12 Amps, 2 meter, Qty 1 (330-3151)	24
No Operating System (420-6320)	12
No Media Required (421-5736)	12
Maximum Microsoft OS PartitionOverride, GPT Enabled (341-5421)	12
CLOUD COMPUTE NODE,DCS, INFO MOD,HADOOP (331-3282)	12
CLOUD COMPUTE NODE,PEC,CROWBAR (331-3310)	12

*Total Purchase Price:	**$189,587.52**
Product Subtotal:	$189,587.52
Tax:	$0.00
Shipping & Handling:	$0.00
State Environmental Fee:	$0.00
Shipping Method:	LTL 5 DAY OR LESS
	(* Amount denoted in $)

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QUOTATION

Quote #:	676449296
Customer #:	11026148
Contract #:	70137
CustomerAgreement #:	Dell Std Terms
Quote Date:	2/25/2014
Customer Name:	NORFOLK STATE UNIV

Date: 2/26/2014

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Sales Professional Information

SALES REP:	DAVID MCCULLOUGH	**PHONE:**	1888 - 9773355
Email Address:	David_Mccullough@Dell.com	**Phone Ext:**	5139074

GROUP: 1   QUANTITY: 5   SYSTEM PRICE: $12,282.77   GROUP TOTAL: $61,413.85

Description	Quantity
PowerEdge R720xd, Intel Xeon E-26XX Processors (210-ABMY)	5
PowerEdge R720 Motherboard, TPM (591-BBBP)	5
Dell Hardware Limited Warranty Plus On Site Service Initial Year (936-0967)	5
ProSupport: Next Business Day Onsite Service After Problem Diagnosis, 2 Year Extended (936-7243)	5
ProSupport: 7x24 HW / SW Tech Support and Assistance, 3 Year (936-7263)	5
Dell Hardware Limited Warranty Plus On Site Service Extended Year (939-3398)	5
ProSupport: Next Business Day Onsite Service After Problem Diagnosis, Initial Year (989-2701)	5
Dell ProSupport. For tech support, visit http://support.dell.com/ProSupport or call 1-800-945-3355 (989-3439)	5
On-Site Installation Declined (900-9997)	5
Proactive Maintenance Service Declined (926-2979)	5
PowerEdge R720 Shipping (331-4437)	5
Intel Ethernet X540 DP 10GBASE-T Server Adapter (430-4440)	5
iDRAC7 Enterprise (421-5339)	5
Intel Ethernet X540 DP 10Gb BT + I350 1Gb BT DP Network Daughter Card (430-4448)	5
Chassis with up to 24, 2.5" Hard Drives (342-3566)	5
Bezel (318-1375)	5
Power Saving Dell Active Power Controller (330-5116)	5
RAID 10 for H710P/H710/H310 (4-24 HDDs in pairs) (331-4537)	5
PERC H710 Integrated RAID Controller, 512MB NV Cache (342-3529)	5

Heat Sink for PowerEdge R720 and R720xd (331-4508)	5
Intel Xeon E5-2695v2 2.4GHz, 30M Cache, 8.0GT/s QPI, Turbo, HT, 12C, 115W, Max Mem 1866MHz (338-BCUG)	5
DIMM Blanks for Systems with 2 Processors (317-8688)	5
Heat Sink for PowerEdge R720 and R720xd (331-4508)	5
Intel Xeon E5-2695v2 2.4GHz, 30M Cache, 8.0GT/s QPI, Turbo, HT, 12C, 115W, Max Mem 1866MHz, 2nd Proc	5
8GB RDIMM, 1600MT/s, Low Volt, Dual Rank, x4 Data Width (319-1811)	80
1600 MHz RDIMMS (331-4424)	5
Performance Optimized (331-4428)	5
600GB 10K RPM SAS 6Gbps 2.5in Hot-plug Hard Drive (342-0847)	30
Electronic System Documentation and OpenManage DVD Kit for R720 and R720xd (331-5914)	5
ReadyRails Sliding Rails With Cable Management Arm (331-4433)	5
Dual, Hot-plug, Redundant Power Supply (1+1), 750W (331-4605)	5
Power Cord, C13 to C14, PDU Style, 12 Amps, 2 meter, Qty 1 (330-3151)	10
No Operating System (420-6320)	5
No Media Required (421-5736)	5
CLOUD COMPUTE NODE,DCS, INFO MOD,HADOOP (331-3282)	5
CLOUD COMPUTE NODE,PEC,CROWBAR (331-3310)	5

*Total Purchase Price:	**$61,413.85**
Product Subtotal:	$61,413.85
Tax:	$0.00
Shipping & Handling:	$0.00
State Environmental Fee:	$0.00
Shipping Method:	LTL 5 DAY OR LESS
	(* Amount denoted in $)

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QUOTATION

Quote #:	676395713
Customer #:	11026148
Contract #:	96ACL
CustomerAgreement #:	VA-100111-Dell
Quote Date:	2/25/2014
Customer Name:	NORFOLK STATE UNIV

Date: 2/26/2014

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Sales Professional Information

SALES REP:	DAVID MCCULLOUGH	**PHONE:**	1888 - 9773355
Email Address:	David_Mccullough@Dell.com	**Phone Ext:**	5139074

GROUP: 1 QUANTITY: 1 SYSTEM PRICE: $25,465.80 GROUP TOTAL: $25,465.80

Description	Quantity
PowerEdge VRTX Rack (225-4380)	1
PowerEdge VRTX Chassis Configure to Order (468-0891)	1
ProSupport: Next Business Day Onsite Service After Problem Diagnosis, 2 Year Extended (954-7460)	1
ProSupport: Next Business Day Onsite Service After Problem Diagnosis, Initial Year (954-7466)	1
ProSupport: 7x24 HW / SW Tech Support and Assistance, 3 Year (954-7471)	1
Dell Hardware Limited Warranty Plus On Site Service Extended Year (954-7528)	1
Dell Hardware Limited Warranty Plus On Site Service Initial Year (954-7531)	1
Dell ProSupport. For tech support, visit http://support.dell.com/ProSupport or call 1-800-945-3355 (989-3439)	1
Installation and Implementation of a Dell PowerEdge VRTX (973-3683)	1
Proactive Maintenance Service Declined (926-2979)	1
Declined Remote Consulting Service (973-2426)	1
PowerEdge VRTX Shipping (332-0798)	1
Shipping Materials, VRTX Rack Chassis with up to Two Half-Height Server Nodes (340-AAVZ)	1
PowerEdge VRTX 1Gb Switch Module, Internal 16 ports to External 8 ports (332-0876)	1
Intel Ethernet X540 DP 10GBASE-T Server Adapter (430-4440)	2
Intel Ethernet X540 DP 10GBASE-T Server Adapter, Low Profile (430-4439)	2
PowerEdge VRTX Rack Configuration for 2.5 inch Hard Drives (max 25) (319-2038)	1
No Bezel (313-0869)	1
Chassis Management Controller Card for PowerEdge VRTX Chassis (332-0877)	1

Description	Quantity
Chassis Management Controller Card for PowerEdge VRTX Chassis (332-0877)	1
Flex Address Plus Enabled (342-1668)	1
CMC Extended Storage Card (342-2666)	1
PowerEdge VRTX 2.5 HDD Single Expander for Single Controller (319-1975)	1
PowerEdge VRTX 2.5 HDD HotPlug Backplane with Single Controller and Expander (332-0794)	1
PERC H710P Internal RAID Controller, 1GB NVRAM, for PowerEdge VRTX (342-5756)	1
1.2TB 10K RPM SAS 6Gbps 2.5in Hot-plug Hard Drive (342-5520)	25
No Documentation (310-1972)	1
No Internal Optical Drive (318-1392)	1
PowerEdge VRTX Rack Installation Rails with Cable Managemet Arm (332-0866)	1
PowerEdge VRTX Redundant Power Supply, 4 x 1100W, (3+1) (332-0865)	1
Power Cord, C13 to C14, PDU Style, 12 Amps, 4 meter, Qty 1 (330-3152)	4
PowerEdge VRTX Enterprise Management License Upgrade, with FlexAddress for CMC (421-9814)	1

GROUP: 2	QUANTITY: 2	SYSTEM PRICE: $8,372.77	GROUP TOTAL: $16,745.54

Description	Quantity
PowerEdge M620 Server Node for VRTX Chassis, Intel Xeon E-26XX Processors (210-ABVN)	2
VRTX PCIE Pass-Through Mezzanine Adapter Qty-2 (330-BBBG)	2
PowerEdge VRTX Server Node Insertion Instruction Label for Handle (340-AFBP)	2
PowerEdge M620 Regulatory Label, DAO (389-BDFT)	2
Hard Drive Blank (400-ABHQ)	2
PowerEdge M620 Motherboard, TPM, Intel Xeon E5-26XX v2 Processors (591-BBBM)	2
VRTX Softare Drivers for Add-in Broadcom PCI NICs (750-AACQ)	2
VRTX Software Driver for Shared PERC Controller (750-AACR)	2
VRTX Softare Drivers for Add-in Intel PCI NICs (750-AACS)	2
VRTX Software Drivers for Add-In AMD GPGPU (750-AACU)	2
Dell Hardware Limited Warranty Plus On Site Service Initial Year (936-2207)	2
Dell Hardware Limited Warranty Plus On Site Service Extended Year (939-5208)	2
Dell ProSupport Plus. For tech support, visit www.dell.com/prosupport/regionalcontacts (951-2015)	2
ProSupport Plus: Next Business Day Onsite Service After Problem Diagnosis, 2 Year Extended (951-6537)	2
ProSupport Plus: Next Business Day Onsite Service After Problem Diagnosis, Initial Year (951-6545)	2
ProSupport Plus: 7x24 HW/SW Tech Support and Assistance,3 Year (951-6548)	2
On-Site Installation Declined (900-9997)	2
Proactive Maintenance Service Declined (926-2979)	2
No System Documentation, No OpenManage DVD Kit (310-5171)	2
System ordered as part of Multipack order (330-4118)	2
Intel x520-k Dual Port 10Gb KR Blade Network Daughter Card (430-4399)	2

12G iDRAC7 Enterprise for Blades (421-5357)	2
Serial-Attach SCSI Backplane for M620 (331-4358)	2
Standard Cooling (331-4951)	2
Diskless Configuration w PERC (342-5764)	2
No Controller (342-1211)	2
PE M620 Heatsink For 2 Processors,LGA,3X3.9X1.26 (331-4362)	2
Intel Xeon E5-2650v2 2.6GHz, 20M Cache, 8.0GT/s QPI, Turbo, HT, 8C, 95W, Max Mem 1866MHz (338-BDBD)	2
DIMM Blanks for Systems with 2 Processors (317-8688)	2
PE M620 Heatsink For 2 Processors,LGA,3X3.9X1.26 (331-4362)	2
Intel Xeon E5-2650v2 2.6GHz, 20M Cache, 8.0GT/s QPI, Turbo, HT, 8C, 95W, Max Mem 1866MHz,2nd Proc (338-	2
16GB RDIMM, 1866MT/s, Standard Volt, Dual Rank, x4 Data Width (370-AAWL)	32
1866MT/s RDIMMs (370-AAWM)	2
Performance Optimized (331-4428)	2
No Hard Drive (341-9160)	2
No System Documentation, No OpenManage DVD Kit (310-5171)	2
2GB SD Card For RIPS (342-1627)	2
2GB SD Card For RIPS (342-1627)	2
Enable Redundant SD Cards (468-4612)	2
No OS, No Utility Partition (421-2869)	2
No Media Required (421-5736)	2
VMware ESXi v5.1U1 Embedded Image on Flash Media (421-9385)	2

GROUP: 3	QUANTITY: 2	SYSTEM PRICE: $8,372.77	GROUP TOTAL: $16,745.54

Description	Quantity
PowerEdge M620 Server Node for VRTX Chassis, Intel Xeon E-26XX Processors (210-ABVN)	2
VRTX PCIE Pass-Through Mezzanine Adapter Qty-2 (330-BBBG)	2
PowerEdge VRTX Server Node Insertion Instruction Label for Handle (340-AFBP)	2
PowerEdge M620 Regulatory Label, DAO (389-BDFT)	2
Hard Drive Blank (400-ABHQ)	2
PowerEdge M620 Motherboard, TPM, Intel Xeon E5-26XX v2 Processors (591-BBBM)	2
VRTX Softare Drivers for Add-in Broadcom PCI NICs (750-AACQ)	2
VRTX Software Driver for Shared PERC Controller (750-AACR)	2
VRTX Softare Drivers for Add-in Intel PCI NICs (750-AACS)	2
VRTX Software Drivers for Add-In AMD GPGPU (750-AACU)	2
Dell Hardware Limited Warranty Plus On Site Service Initial Year (936-2207)	2
Dell Hardware Limited Warranty Plus On Site Service Extended Year (939-5208)	2
Dell ProSupport Plus. For tech support, visit www.dell.com/prosupport/regionalcontacts (951-2015)	2

Product	Quantity
ProSupport Plus: Next Business Day Onsite Service After Problem Diagnosis, 2 Year Extended (951-6537)	2
ProSupport Plus: Next Business Day Onsite Service After Problem Diagnosis, Initial Year (951-6545)	2
ProSupport Plus: 7x24 HW/SW Tech Support and Assistance,3 Year (951-6548)	2
On-Site Installation Declined (900-9997)	2
Proactive Maintenance Service Declined (926-2979)	2
No System Documentation, No OpenManage DVD Kit (310-5171)	2
System ordered as part of Multipack order (330-4118)	2
Intel x520-k Dual Port 10Gb KR Blade Network Daughter Card (430-4399)	2
12G iDRAC7 Enterprise for Blades (421-5357)	2
Serial-Attach SCSI Backplane for M620 (331-4358)	2
Standard Cooling (331-4951)	2
Diskless Configuration w PERC (342-5764)	2
No Controller (342-1211)	2
PE M620 Heatsink For 2 Processors,LGA,3X3.9X1.26 (331-4362)	2
Intel Xeon E5-2650v2 2.6GHz, 20M Cache, 8.0GT/s QPI, Turbo, HT, 8C, 95W, Max Mem 1866MHz (338-BDBD)	2
DIMM Blanks for Systems with 2 Processors (317-8688)	2
PE M620 Heatsink For 2 Processors,LGA,3X3.9X1.26 (331-4362)	2
Intel Xeon E5-2650v2 2.6GHz, 20M Cache, 8.0GT/s QPI, Turbo, HT, 8C, 95W, Max Mem 1866MHz,2nd Proc (338-	2
16GB RDIMM, 1866MT/s, Standard Volt, Dual Rank, x4 Data Width (370-AAWL)	32
1866MT/s RDIMMs (370-AAWM)	2
Performance Optimized (331-4428)	2
No Hard Drive (341-9160)	2
No System Documentation, No OpenManage DVD Kit (310-5171)	2
2GB SD Card For RIPS (342-1627)	2
2GB SD Card For RIPS (342-1627)	2
Enable Redundant SD Cards (468-4612)	2
No OS, No Utility Partition (421-2869)	2
No Media Required (421-5736)	2
VMware ESXi v5.1U1 Embedded Image on Flash Media (421-9385)	2

SOFTWARE & ACCESSORIES	GROUP TOTAL: $0.00		
Product	Quantity	Unit Price	Total
Dell Education Services-No PowerEdge VRTX Training Selected (973-5355)	1	$0.00	$0.00

*Total Purchase Price:	**$58,956.88**
Product Subtotal:	$58,956.88
Tax:	$0.00
Shipping & Handling:	$0.00
State Environmental Fee:	$0.00
Shipping Method:	LTL 5 DAY OR LESS

(* Amount denoted in $)

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QUOTATION

Quote #:	678032822
Customer #:	11026148
Contract #:	70137
CustomerAgreement #:	Dell Std Terms
Quote Date:	3/17/2014
Customer Name:	NORFOLK STATE UNIV

Date: 3/18/2014

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Email Address:	David_Mccullough@Dell.com	**Phone Ext:**	5139074

SOFTWARE & ACCESSORIES   GROUP TOTAL: $1,241.10

Product	Quantity	Unit Price	Total
1U 17IN LCD CONSOLE W/USB TOUCHPAD KEYB/PRE-MOUNTED AV3008 (A3376441)	1	$959.50	$959.50
10FT USB CAT5 INTEGRATED ACCESS CABLE (A7385147)	8	$35.20	$281.60

***Total Purchase Price:**	**$1,241.10**
Product Subtotal:	$1,241.10
Tax:	$0.00
Shipping & Handling:	$0.00
State Environmental Fee:	$0.00
Shipping Method:	LTL 5 DAY OR LESS
	(* Amount denoted in $)

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QUOTATION

Date: 2/26/2014

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Email Address:	David_Mccullough@Dell.com	**Phone Ext:**	5139074

SOFTWARE & ACCESSORIES — GROUP TOTAL: $21,666.19

Product	Quantity	Unit Price	Total
VLA VMWARE VCENTER SVR 5 STD VSPHERE5 INSTANCE (A5406064)	1	$2,631.75	$2,631.75
VLA VMWARE PROD SUP/SUB VCENTER SVR 5 STD VSPHERE 5 (A5406063)	1	$1,233.88	$1,233.88
VLA VMWARE VSPHERE 5 ENT 1 PROC 64GBVRAM ENTITLE PROC (A5415118)	8	$1,514.77	$12,118.16
VLA VMWARE PROD SUP/SUB VSPHERE 5 ENT 1 PROC (A5457495)	8	$710.30	$5,682.40
ELECTRONIC LICENSE CONFIRMATION elec dwnld only (A3458532)	1	$0.00	$0.00

***Total Purchase Price:**	**$21,666.19**
Product Subtotal:	$21,666.19

Tax:	$0.00
Shipping & Handling:	$0.00
State Environmental Fee:	$0.00
Shipping Method:	LTL 5 DAY OR LESS
	(Amount denoted in $)*

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QUOTATION

Quote #:	658283898
Customer #:	11026148
Contract #:	70137
CustomerAgreement #:	Dell Std Terms
Quote Date:	7/19/2013
Customer Name:	NORFOLK STATE UNIV

Date: 2/26/2014

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Email Address:	David_Mccullough@Dell.com	**Phone Ext:**	5139074

SOFTWARE & ACCESSORIES — GROUP TOTAL: $17,879.22

Product	Quantity	Unit Price	Total
Installation and Implementation of The Dell Cloud Hadoop Solution, w/ 8 Nodes (961-4669)	1	$9,550.83	$9,550.83
Installation and Implementation of The Dell Cloud Hadoop Solution, w/ up to 4 Nodes - Add-On (961-4679)	3	$2,776.13	$8,328.39

***Total Purchase Price:**	**$17,879.22**
Product Subtotal:	$17,879.22
Tax:	$0.00
Shipping & Handling:	$0.00
State Environmental Fee:	$0.00
Shipping Method:	LTL 5 DAY OR LESS
	(* Amount denoted in $)

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SALES REP:	DAVID MCCULLOUGH	**PHONE:**	1888 - 9773355
Email Address:	David_Mccullough@Dell.com	**Phone Ext:**	5139074

SOFTWARE & ACCESSORIES — GROUP TOTAL: $30,940.00

Product	Quantity	Unit Price	Total
Cloudera Community (A5385927)	1	$0.00	$0.00
Cloudera Enterprise Core 8 x 5 1 yr (A6242302)	17	$1,820.00	$30,940.00

***Total Purchase Price:**	**$30,940.00**
Product Subtotal:	$30,940.00
Tax:	$0.00
Shipping & Handling:	$0.00
State Environmental Fee:	$0.00
Shipping Method:	LTL 5 DAY OR LESS
	(* Amount denoted in $)

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ATTACHMENT B – PRESENTATION

<u>Lessons Learned: Building a Big Data Research and Education Infrastructure</u>

Lessons Learned: Building a Big Data Research & Education Infrastructure

Dr. George Hsieh

R. Sye, S. Vincent and W. Hendricks

Department of Computer Science
NORFOLK STATE UNIVERSITY
Norfolk, Virginia USA

2014 Intl Conf. on Advances in Big Data Analytics
July 2014

Purpose

- Share experiences and lessons learned in our efforts to build up a **Hadoop big data** infrastructure and knowledge base with **minimum upfront investment** (from August 2013 to May 2014).
  - DIY: planning, design, vendor/equipment selection, purchasing, installation, configuration, operation, app development, security.

- Discuss plans underway to expand the infrastructure to enterprise-grade.

- Solicit inputs and explore collaboration opportunities.

Background

- **May 2013** – Decided to start research in big data with an initial interest in cybersecurity analytics and cyber crime detection.

- **July 2013** – Submitted a grant proposal to US Department of Defense (DoD) to fund equipment purchase for "Building a Cloud Computing and Big Data Infrastructure for Cyber Security Research and Education".

- **August 2013** – Started hands-on learning and experimentation in Hadoop and its ecosystem by faculty, students, and staff using existing equipment.

- **February 2014** – Grant proposal approved by DoD for $497,725, Feb 2014 - Jan 2015. Additional equipment being purchased and installed (target standup date: **4Q2014**).

Hadoop Is Great!

- Open source and de facto standard for big data platforms.

- Very powerful and flexible framework for reliable distributed computation using clusters of commodity hardware.

- Provide horizontal scalability for many types of applications.

But …

- It is very **<u>challenging</u>** to learn, install, configure, and operate Hadoop systems especially for smaller organizations without plenty of resources and expertise.

  ◦ Complex: base platforms, tools, etc.

  ◦ New and evolving architecture, APIs, packages.

  ◦ Lots of dependencies among packages/versions.

  ◦ Code releases? (Apache, Cloudera, Hortonworks).

  ◦ Lack of adequate documentation and user experience base.

Our Team

- Dr. **George Hsieh**, Professor of Computer Science, advisor and principal investigator.

- Mr. **Raymond Sye**, M.S. in Computer Science student, conducting M.S. Thesis research in big data security analytics (nearly completed now).

- Ms. **Shontae Vincent**, M.S. in Computer Science student, conducted research for a graduate independent study course and M.S. Project (completed in May 2014).

- Mr. **Wallace Hendricks**, IT Manager for Computer Science, co-PI.

Phased Approach: Incrementally and Iteratively

1. Get started with Hadoop: using **Hortonworks Sandbox** single-node VM and tutorial.

2. Install and configure a multi-node Hadoop cluster in VMs using **Hortonworks Data Platform** (HDP) release.

3. Install and configure a multi-node Hadoop cluster on commodity hardware using HDP release.

4. Get started with Hadoop app development using **Cloudera QuickStart VM** in single-node configuration.

5. Install and configure a multi-node Hadoop cluster on commodity hardware using **Cloudera CDH** release.

6. Develop a Hadoop graph application using Cloudera CDH based multi-node Hadoop cluster and Giraph package.

1. Hortonworks Sandbox

- http://hortonworks.com/products/hortonworks-sandbox/

- A personal, portable Hadoop environment with ~12 interactive Hadoop tutorials.

- A self-contained VM for VMware, VirtualBox or Hyper-V.

- Based on Hortonworks Data Platform (HDP) Hadoop release.

- Easy to install, and easy to use integrated and iterative tutorial environment providing video, graphical and text instructions along with command execution, status information, and suggestions for corrective actions.

- User can focus on key concepts and procedures (e.g., Data Processing with Pig) through the GUI without having to learn detailed mechanics under the hood.

- Very helpful in getting a quick overview of Hadoop, especially its tools – an effective learning environment for getting started.

Hortonworks Sandbox GUI

2. Multi-Node Virtual HDP Cluster

a) Design configuration for HDP VM cluster

  ◦ 6 guest hosts: Ambari Server (cluster management tool), 2 Master Nodes, 2 Data Nodes and 1 Client Node. [On same physical host.]

  ◦ FQDNs and IP addresses for all hosts on same subnet.

b) Use **Apache Ambari** Install Wizard to install and configure six-host HDP 2.0 based virtual Hadoop cluster.

  ◦ Ambari is easy to use and automates many configuration tasks.

  ◦ User specifies high level information (e.g., hosts, roles, Hadoop services to be assigned to the hosts).

  ◦ Ambari allocates services to hosts for load balancing and reliability considerations, then downloads, installs, configures, starts and tests software automatically.

• OK on workstations with modest resources (64-bit CPU with 2 - 4 cores, 8 - 16 GB RAM).

• **Challenge**: recovery from failures (e.g., rpm database corruption as a side effect).

3. Multi-Node HDP Cluster

a) Design configuration for HDP cluster
- ◦ Four physical hosts: Ambari Server, 1 Master Node, and 2 Data Nodes.
- ◦ FQDNs and IP addresses for all hosts on same subnet (access to Internet required for downloading software).

Hosts	Hostname/ local IP	CPU	RAM	Disk
Ambari Server	HDPcs2AMBARI 199.111.112.169	Intel Xeon (4C) 3GHz	8 GB	500 GB
Master Node	HDPcs2MASTER 199.111.112.171	Intel Core 2 Duo 3GHz	4 GB	250 GB
Data Node 1	HDPcs2DN1 199.111.112.180	Intel Core 2 Duo 3GHz	4 GB	250 GB
Data Node 2	HDPcs2DN2 199.111.112.189	Intel Xeon (4C) 3.2GHz	12 GB	900 GB

b) Use **Apache Ambari** Install Wizard to install and configure four-host HDP 2.0 based Hadoop cluster.

- Monitoring and managing a large scale Hadoop cluster is non-trivial, Ambari helps users deal with complexity:
  - ◦ Collect a wide range of information and present in a dashboard.
  - ◦ Allow users to perform basic management tasks, e.g., starting & stopping services, adding hosts to cluster, updating service configuration

Hortonworks Ambari Dashboard
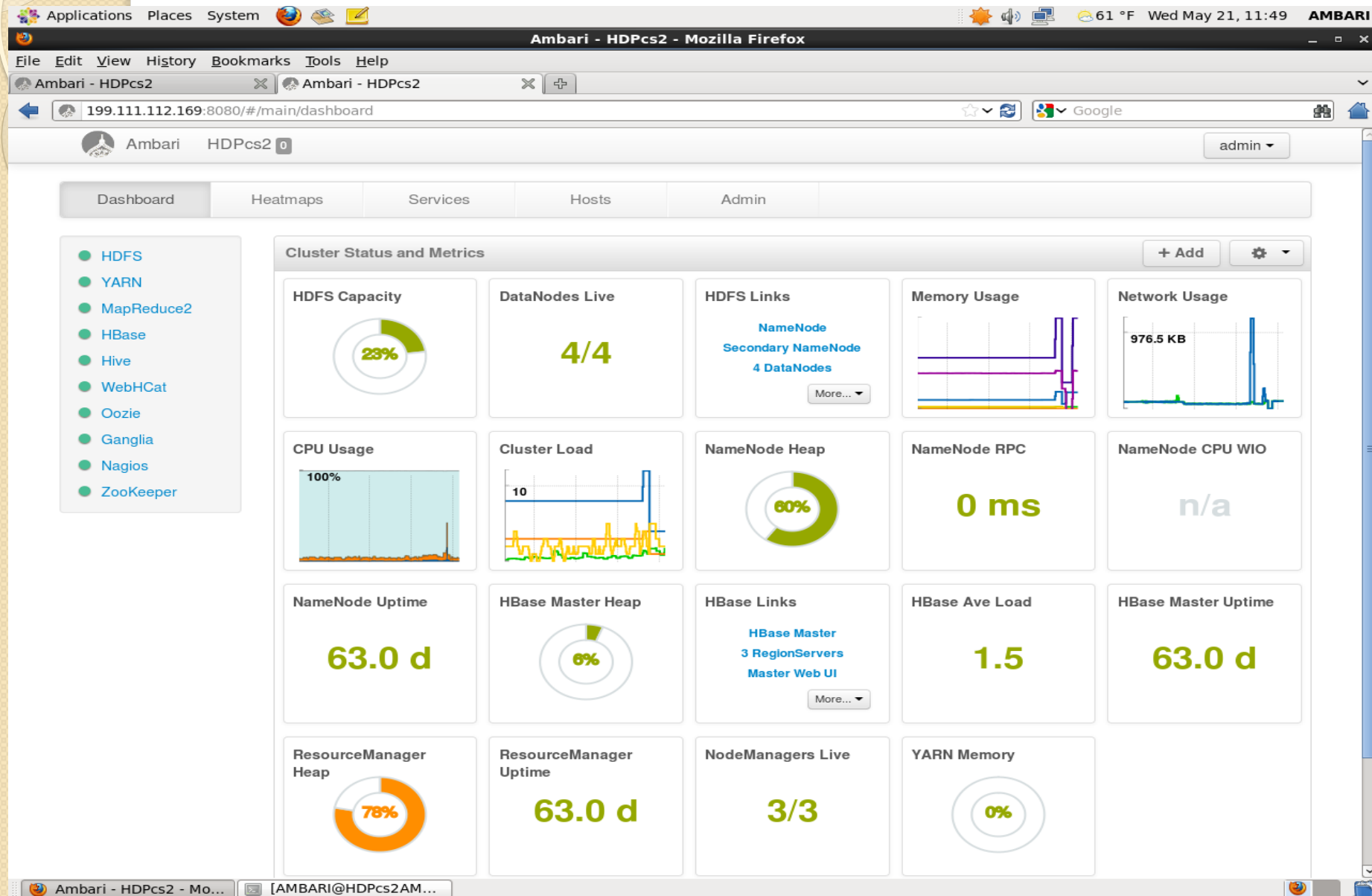
4. Cloudera QuickStart VM

- Goal – Get started with Hadoop app development.
- Need – Find a convenient software development environment.
- Select a single-node VM environment:
  - Hortonworks Sandbox did not include many required SDK.
  - Cloudera QuickStart VM had many required SDK pre-installed. [**Cloudera is viewed as market leader in Hadoop products and services.**]
a) Install CentOS Linux 6.4 with Software Development Workstation option.
b) Install Cloudera QuickStart VM CDH 4.6 release.
- http://www.cloudera.com/content/dev-center/en/home/developer-admin-resources/quickstart-vm.html

Hadoop Application Development

- Getting started can be very challenging.
- Linux proficiency in development and troubleshooting.
- Hadoop release (Apache vs. Cloudera) and installation procedure (tarballs vs. rpm/yum) can cause differences:
  - Locations of binaries, shell scripts, configuration files.
  - Default user accounts.
- Reference books used:
  - **Hadoop Beginner's Guide** by Gary Tarkington (2013).
  - **Hadoop in Practice** by Alex Holmes (2012): installing and configuring ~20 different packages manually.
- **Lessons learned**:
  - Make sure **environmental variables** (e.g., PATH) and profiles are set comprehensively and correctly.
  - Understand **symbolic links** and **dynamically generated files**, and update the appropriate files or directories without breaking links accidentally.
  - Understand **Linux alternatives system** which uses symbolic links extensively.

5. Multi-Node Cloudera CDH Cluster (1)

a) Design configuration for CDH 5.0 (Beta) cluster
  ◦ Seven physical hosts: Cloudera Manager (cluster management tool), 2 Master Nodes, and 4 Data Nodes.
  ◦ FQDNs and IP addresses for all hosts on same **private** subnet (access to Internet through Cloudera Manager host).

Internet

Cloudera Manager

Ethernet Switch

Cloudera Master1

Cloudera DataNode4

Cloudera Master2

Cloudera DataNode1

Cloudera DataNode2

Cloudera DataNode3
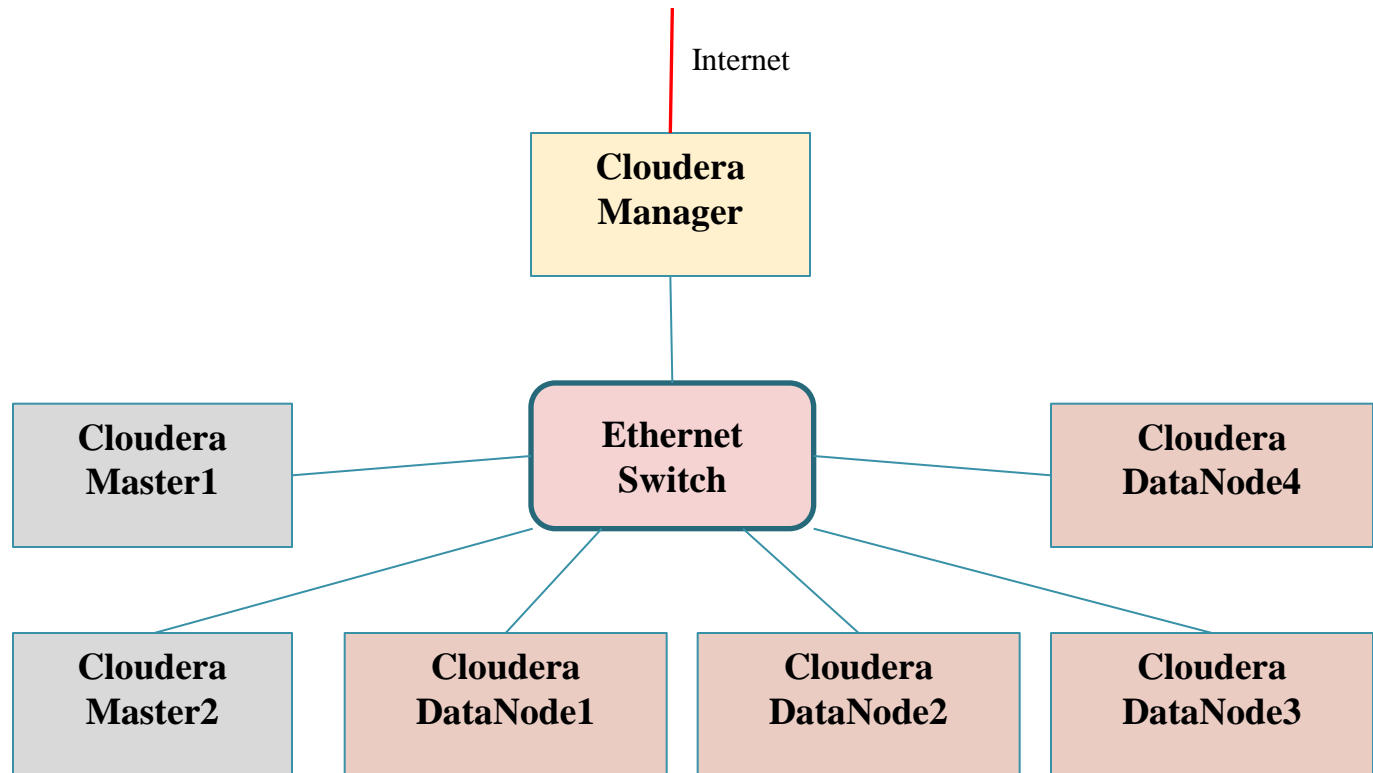
5. Multi-Node Cloudera CDH Cluster (2)

b) Use **Cloudera Manager** to install and configure seven-host CDH 5.0 (Beta) based Hadoop cluster.

- ◦ Follow Path B – Manual Installation Using Cloudera Packages.
- ◦ Manually install and configure database for Cloudera Manager Server and Hive Metastore.
- ◦ Manually install on Cloudera Manager Server host Oracle JDK and Cloudera Manager Server software.
- ◦ Use Cloudera Manager to automate installing Oracle JDK, Cloudera Manager Agent, CDH, and managed service software on cluster hosts.

Hostname	Roles
CDHcs1mgr	Cloudera Activity Monitor; Cloudera Alert Publisher; Cloudera Event Server; Cloudera Host Monitor; Cloudera Reports Manager (enterprise version); Cloudera Service Monitor. Hive Gateway; Hive Metastore. Hue Server.
CDHcs1MN1	HBase Master. HDFS Httpfs; HDFS Namenode- Active. Hive Gateway; Hive HiveServer2. Spark Master. Zookeeper Server − follower.
CDHcs1MN2	HBase Region Server. HDFS Datanode; HDFS NFSGateway; HDFS NameNode − Secondary. Solr Server. Spark Worker.
CDHcs1DN1	HBase Region Server. HDFS Datanode. HIVE Gateway. Oozie Server. YARN Job History; YARN Node Manager; YARN Resource Manager.
CDHcs1DN2	HBase Region Server. HDFS Datanode. Hive Metastore; Hive HiveServer2; Hive WebCat. YARN Node Manager.
CDHcs1DN3	Flume Agent. HBase REST server. HDFS Datanode. YARN Node Manager. Zookeeper Server − leader.
CDHcs1DN4	HBase Thrift Server. HDFS Datanode. YARN Node Manager. Zookeeper Server − follower.

Cloudera Manager Dashboard
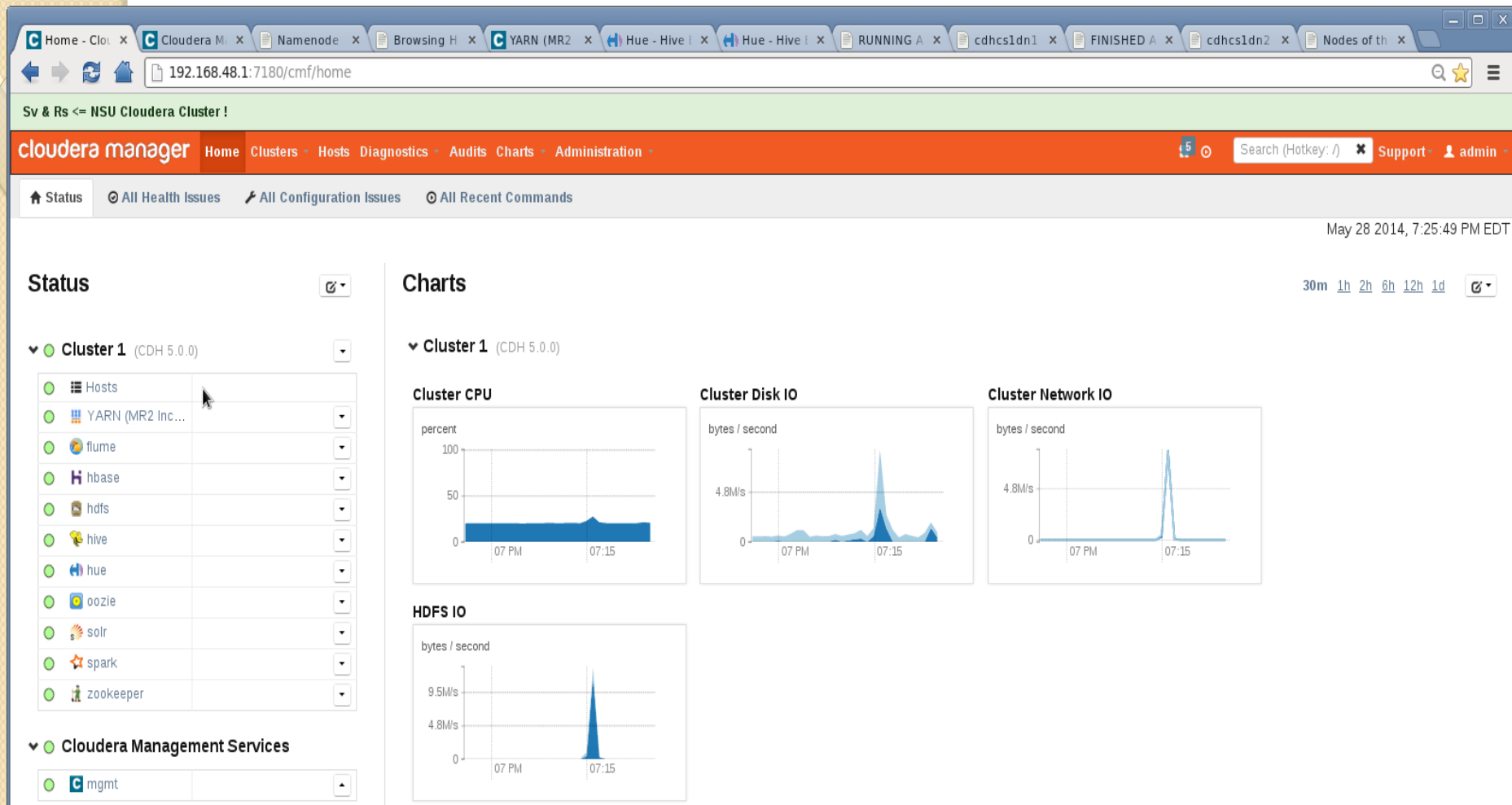
5. Multi-Node Cloudera CDH Cluster (3)

- **Lessons Learned:**
  - ◦ **Permissions**: many Hadoop packages require access to shared resources. Group permissions must be set correctly. CDH 5.0.2 documentation provides guidelines, but not beta version.
  - ◦ **User accounts and groups**: must be set up consistently.
  - ◦ **Interdependencies**: some packages need to be installed before others (e.g., Zookeeper before Hive).
  - ◦ **Performance**: better to run some services on same physical host to reduce latency and overhead.
  - ◦ **Disk storage and memory use**: need to monitor closely as log files are generated.
  - ◦ **Overwritten files**: Cloudera Manager may overwrite some files after configuration change. Make sure important files are backed up.

6. Hadoop Graph Processing (1)

- Goal – Analyze connectedness among IP addresses.
- **Apache Giraph** (v1.0.0)
  - ◦ Iterative graph processing system built for high scalability.
  - ◦ Optimized and used by Facebook to analyze social graphs (with trillions of edges).
  - ◦ http://giraph.apache.org/

a) Get started with Giraph
  - ◦ Follow **Giraph Quick Start Guide** (http://giraph.apache.org/quick_start.html).
  - ◦ Install and run Giraph on single-node Hadoop VM (Ubuntu Server 12.04.2).
  - ◦ Set up and run "SimpleShortestPathComputation" sample job – learning and verifying installation.

6. Hadoop Graph Processing (2)

b) Use Giraph on multi-node Cloudera CDH cluster

- ◦ Install Giraph on CentOS (Cloudera CDH cluster).
- ◦ Prepare and run "SimpleShortestPathComputation" sample job – verifying installation.

c) Develop Hadoop app

- ◦ Goal – Process millions of records (source IP address, destination IP address) in captured Internet trace data to find central nodes at a particular time period.
- ◦ Extract-Load-Transform source files in pcap format.
- ◦ Use Giraph for graph processing.
- ◦ Status – Completed app development and initial experimentation; now analyzing experimentation results.

Expansion Plan

- Funding support from ARO grant entitled "Building a Cloud Computing and Big Data Infrastructure for Cybersecurity Research and Education" (Feb 2014 – Jan 2015).

System	Function	#Proc	#Core	RAM (GB)	Disk (GB)	Qty	Note
Hadoop-Production	Master Node	2	24	128	3,600	5	RAID, 10Gb NIC
	Data Node	2	24	64	24,576	12	10Gb NIC
	Subtotal:	34	408	1,408	312,912		
Hadoop-Integration	M/D Node	2	24	128	3,600	5	RAID, 10Gb NIC
	Subtotal:	10	120	640	18,000		
Cloud-Production	VRTX	2	16	256	30,720	4	RAID, 10Gb NIC
	Subtotal:	8	64	1,024	30,720		Shared disks
Cloud-Integration	Compute	2	16	512	438	1	RAID, 1 Gb NIC
	Storage	0	0	0	7,200	1	RAID, 10Gb NIC
	Admin	2	12	128	2,400	2	
	Subtotal:	6	40	768	12,438		
	TOTAL:	**58**	**632**	**3,840**	**374,070**		

Summary

- Used an incremental and iterative approach to build a big data research and education infrastructure with minimum upfront investment.
  - Existing commodity hardware
  - Open source software
- The journey was very challenging, but rewarding.
  - Don't give up!
  - Keep boots on the ground!
- It will take lots of time and efforts to build up knowledge, skills and experiences before capable of doing "real" work.
- Big data and Hadoop have so much potential, it is worth the growing pain.

Acknowledgement

- Department of Computer Science
- Norfolk State University
- Army Research Office, Department of Defense
  a) "Building a Cloud Computing and Big Data Infrastructure for Cyber Security Research and Education" grant
  b) "Self-Protecting Security Framework for Assured Information Sharing" grant
- Department of Energy
  a) "Massie Chair of Excellence in Information Assurance and Cyber Security" grant
- Department of Education

QUESTIONS?

THANK YOU!

ATTACHMENT C – PRESENTATION

Big Data and Data Science @ NSU (*Tidewater Big Data Event*)

Tidewater Big Data Event 2014

Big Data and Data Science @ NSU

Dr. George Hsieh

Department of Computer Science
Norfolk State University

December 9, 2014

Overview

⌘ A new research initiative launched in summer 2013

⌘ Current efforts

⌃ Receiving funding support from three research grants

⌃ Additional funding support from education grants

⌃ Actively engaging students in research projects

⌃ Ramping up expertise and research infrastructure

⌘ Exploring new opportunities

⌃ Cybersecurity Research

⌃ Education

⌃ Collaboration

Current Funding Support

- ⌘ Research grants providing funding support
  - ⊡ **Building a Cloud Computing and Big Data Infrastructure for Cyber Security Research and Education, Army Research Office**, **$497K**, Feb 2014 - Jan 2015, for equipment purchase to implement a research and education infrastructure for cloud computing and big data
  - ⊡ **Self-Protecting Security for Assured Information Sharing, Army Research Office**, **$487K**, Feb 2012 - Feb 2015, for design and development of integrated, secure, embedded, and fine-grained security frameworks to provide self-protecting security
  - ⊡ **Massie Chair of Excellence in Information Assurance and Cyber Security**, **Department of Energy**, Sep 2009 - Mar 2015, cloud computing security and forensic analysis research subproject
- ⌘ Education program grants
  - ⊡ Title III (US Department of Education)
  - ⊡ Special Funding (Commonwealth of Virginia)
  - ⊡ NSF and DoD Cybersecurity Scholarship Grants

Research Highlights

- Previously
  - Focused on learning & small-scale application development projects
  - Published a refereed conference paper: "Lessons Learned: Building a Big Data Research and Education Infrastructure", *2014 Intl. Conf. on Big Data Analytics*, July 2014
- Currently
  - **4** faculty/staff members on research team
  - **3** undergraduate and **8** graduate students doing research
  - Investigating a broad array of Hadoop technologies & applications for cybersecurity intelligence
  - E.g., **2** graduate students completing degrees this month
    - Network Security Analysis using Hadoop Big Data Platform
    - Using Accumulo to Provide Access Control for Hadoop-Based Big Data
- Good news: no difficulty in attracting highly qualified & interested students

Research Areas

Category	Subject Area
Application Domains	Network structure analysis
	Network data analysis
	Intrusion and anomaly detection
	Event log analysis
	Data analysis and machine learning
Hadoop Tools	Graph-processing (Giraph)
	Text search (Solr)
	Log processing (Flume)
	Security - access control (Accumulo)
	Real-time processing (Storm)
	Lightning-fast cluster computing (Spark)
	Database (Mongo)
	Database (Cassandra)
	Database (HBase)
	Machine learning (R-Hadoop)

Research Infrastructure

- ⌘ Established a small-scale lab initially
  - ⌂ Using existing PC's, workstations, and servers
  - ⌂ Installed and configured 3 multi-node Hadoop clusters for learning and research (using both Cloudera and Hortonworks distributions)
- ⌘ Expanding with new equipment
  - ⌂ Hardware equipment vendor: Dell
  - ⌂ A **6-node Hadoop cluster** (integration and testing)
    - ☒ HW/SW installed by students and operational since October
    - ☒ **Cloudera CDH and CM 5.1.2 release**
  - ⌂ A **17-node Hadoop cluster** (production)
    - ☒ HW/SW installation by Dell completed on 5 Dec 2014
    - ☒ **Cloudera CDH and CM 5.2.1 release**
    - ☒ **Cloudera Enterprise – Basic Edition** subscription for one year
    - ☒ Procurement lessons learned: unexpected delay caused by service contracts/SW licenses negotiation/approval (after receiving HW)
  - ⌂ Additional cloud computing equipment being installed
  - ⌂ Adding ~650 Xeon CPU cores, 360 terabytes of hard disk storage, and 3.4 terabytes of RAM

Enhancing Research Infrastructure

System	Function	Server	#Proc	#Core	RAM (GB)	Hard Disk (GB)	Qty
Hadoop-Production	Master Node	R720xd	2	24	128	3,600	5
	Data Node	R720xd	2	24	64	24,576	12
	Subtotal:		34	408	1,408	312,912	17
Hadoop-Integration	M/D Node	R720xd	2	24	128	3,600	5
	Subtotal:			120	640	18,000	5
Cloud-Production	VRTX	M620	2	16	256	30,720	4
	Subtotal:		8	64	1,024	30,720	4
Cloud-Integration	IBM HS22	7870H5U	2	12	84	4,800	5
	Subtotal:		10	60	420	4,800	5
	TOTAL:		62	652	3,492	366,432	

Exploring Opportunities

- **K-20 Cybersecurity Workforce Pipeline Project**
  - Proposal submitted to **Department of Energy** in July 2014
  - NSU is lead institution for a consortium (PI: Dr. Sandra J. DeLoatch, Provost and VP for Academic Affairs @ NSU)
  - A **research** component included for working with Lawrence Livermore and Sandia National Labs
- **Cyber Analysis, Simulation and Experimentation Environment (CASE-V)**
  - Collaboration with **Old Dominion University/VMASC** (Dr. Jose Padilla) and Tennessee State University (Dr. Sachin Shetty)
  - Include using big data and data analysis to inform M&S operations and analyze M&S results
- **US Army Training Brain Operations Center (TBOC)**
  - Exploring student internship and joint research opportunities (Mr. Tony Cerri, Data Transformation Lead)
- **Education**
  - Courses in big data, cloud computing, data science
  - Graduate certificate programs, degree programs

Summary

❖ NSU has established a solid foundation in big data research and education

❖ NSU plans to actively expand its efforts in big data research and education

❖ NSU is eager to explore collaboration opportunities with government and private sectors on big data and data science

❖ Contact Information:

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ATTACHMENT D – PRESENTATION

<u>Big Data and Data Science @ NSU - A Briefing for US Army TBOC</u>

Big Data and Data Science @ NSU

Dr. George Hsieh

Department of Computer Science
Norfolk State University

September 2014

Overview

- ⌘ A new research initiative launched in summer 2013
- ⌘ Current efforts
  - ⌂ Receiving funding support from three research grants
  - ⌂ Additional funding support provided by NSU
  - ⌂ Actively engaging students in research projects
  - ⌂ Ramping up expertise and research infrastructure
- ⌘ Exploring new opportunities
  - ⌂ Cybersecurity
  - ⌂ Materials
  - ⌂ Collaboration

Current Funding Support

✦ Research grants providing funding support

  ◇ **Building a Cloud Computing and Big Data Infrastructure for Cyber Security Research and Education, Army Research Office, $497K**, Feb 2014 - Jan 2015, for equipment purchase to implement a research and education infrastructure for cloud computing and big data

  ◇ **Self-Protecting Security for Assured Information Sharing, Army Research Office, $487K**, Feb 2012 - Feb 2015, for design and development of integrated, secure, embedded, and fine-grained security frameworks to provide self-protecting security

  ◇ **Massie Chair of Excellence in Information Assurance and Cyber Security, Department of Energy**, Sep 2009 - Sep 2014, cloud computing security and forensic analysis research subproject

✦ Education program grants

  ◇ Title III (US Department of Education)

  ◇ OCR (Commonwealth of Virginia)

  ◇ NSF and DoD Cybersecurity Scholarship Grants

Research Highlights

- ⌘ Published a refereed conference paper titled "Lessons Learned: Building a Big Data Research and Education Infrastructure", *2014 Intl. Conf. on Big Data Analytics*, July 2014

- ⌘ **4** faculty and staff members on research team

- ⌘ **1** undergraduate and **1** graduate students completed degree-required research projects in May 2014

- ⌘ Funding **4** graduate and **1** undergraduate research assistants in Fall 2014 semester

- ⌘ **2** undergraduate and **9** graduate students doing research currently (eight are also earning credits for independent study or degree-required research courses)

  - ⊡ Investigating a broad array of technologies including machine learning, databases, real-time processing, security, text search

  - ⊡ Investigating a variety of applications for cybersecurity intelligence: network structure analysis, network data analysis, and event analysis

Research Areas

Category	Subject Area	Researcher(s)
Application Domains	Network structure analaysis	Raymond
	Network data analysis	Darryl
	Event log analysis	Kaila, Calvin
	Data analysis and machine learning	Chris, Aaron, Darius
Hadoop Tools	Graph-processing (Giraph)	Raymond
	Text search (Solr)	Kaila
	Log processing (Flume)	Calvin
	Security - access control (Accumulo)	Ramya, Darryl
	Security - encryption (Rhino)	Darryl
	Real-time processing (Storm)	Raymond, Vamshika
	Real-time processing (Spark)	Raymond, Vamshika
	Database (Mongo)	Vivek, Anuraag
	Database (Casandra)	Vivek, Anuraag
	Database (HBase)	Vivek, Anuraag
	Machine learning (R-Hadoop)	Chris, Aaron, Darius
	Machine learning (Mahout)	Chris, Aaron, Darius

Research Infrastructure

- ⌘ Established a small-scale lab in RTC-300
  - ⊡ Using existing PC's, workstations, and servers
  - ⊡ Installed and configured 3 Hadoop clusters for learning, research, and experimentation (both Cloudera and Hortonworks distributions)
- ⌘ Expanding with additional equipment & facility
  - ⊡ All new equipment will be installed in RTC-307 (CSC Server Room) or RTC-300
  - ⊡ All new equipment has been purchased and delivered by Dell
  - ⊡ Engineering and installation by Dell is delayed due to negotiation and review of service agreements
  - ⊡ Installation of equipment without Dell engineering service is proceeding in RTC-300
  - ⊡ Target completion: 4Q2014
  - ⊡ Reaching enterprise grade by adding ~650 Xeon CPU cores, 370 terabytes of disk storage, and 3.8 terabytes of RAM

Enhanced Research Infrastructure (1Q2015)

System	Function	Server	#Proc	#Core	RAM (GB)	Hard Disk (GB)	Quantity	Note
Hadoop-Production	Master Node	R720xd	2	24	128	3,600	5	RAID, 10Gb NIC
	Data Node	R720xd	2	24	64	24,576	12	10Gb NIC
	Subtotal:		**34**	**408**	**1,408**	**312,912**	**17**	
Hadoop-Integration	M/D Node	R720xd	2	24	128	3,600	5	RAID, 10Gb NIC
	Subtotal:		**10**	**120**	**640**	**18,000**		
Cloud-Production	VRTX	M620	2	16	256	30,720	4	RAID, 10Gb NIC, shared hard disks
	Subtotal:		**8**	**64**	**1,024**	**30,720**		
Cloud-Integration	IBM HS22	7870H5U	2	12	84	4,800	5	RAID, 1 Gb NIC, shared hard disks
	Subtotal:		**10**	**60**	**420**	**4,800**		
	TOTAL:		**62**	**652**	**3,492**	**366,432**		

Exploring New Opportunities (Cybersecurity)

⌘ **K-20 Cybersecurity Workforce Pipeline Proposal**

⊡ Submitted to Department of Energy in early July 2014. $5M per year for 5 years. Expecting final (favorable) decision soon.

⊡ NSU is lead institution for a consortium (PI: Dr. Sandra J. DeLoatch). Co-PI's include George Hsieh, Jonathan Graham and Aurelia Williams.

⊡ A **(faculty and student) research** component is included in proposal with a plan to work with National Labs (including Lawrence Livermore National Lab which has a strong data analytics group).

⌘ **Center of Excellence in Cyber Security Proposal**

⊡ Submitted to Department of Defense in late July 2014. $1M per year for 5 years (planned start date: 15 JAN 2015).

⊡ NSU is lead institution with two partners: Old Dominion University/ VMASC and Tennessee State University. Proposed PI: George Hsieh. Co-PI's include Jonathan Graham (NSU), Jose Padilla (VMASC), and Sachin Shetty (TSU).

⊡ Focus on developing an integrated **Cyber Analysis, Simulation and Experimentation Environment (CASE-V)**, including using big data and data analytics to improve situational awareness and decision making for cyber operations.

Exploring New Opportunities (Synergistic)

⌘ Materials Informatics

- ⊻ Purpose: Help design new materials in a way similar to using bioinformatics to help design new drugs
- ⊻ First meeting with Center for Materials Research (CMR) @ NSU, including Dr. Aswini Pradhan, in June 2014
- ⊻ NSF has a program solicitation on materials genome due January 2015. Dr. Pradhan plans to coordinate a proposal submission involving CMR and CSC (big data).

⌘ Army Training Brain Operating Center (TBOC)

- ⊻ Purpose: Leverage big data for Army training operations
- ⊻ First meeting with Data Transformation Lab of TBOC (Newport News, Virginia) in July 2014
- ⊻ Second meeting at NSU on Thursday, 18 SEP 2014

ATTACHMENT E – PRESENTATION

<u>Center for Data Analytics - An Incubator Project Concept</u>

Center for Data Analytics

An Incubator Project Concept

Dr. George Hsieh

Department of Computer Science

Norfolk State University

February 27, 2014

What Is Data Analytics (DA)?

- The science of examining raw data with the purpose of drawing conclusions about that information

- Used by many companies and organizations to make better decisions

- Also used in the sciences to verify or disprove existing models or theories

Major Industries/Users of DA

- Businesses
    - Amazon, Google, Facebook, Netflix, etc.
    - Strategic tool to gain competitive advantages and grow revenues and customer base
- Governments
    - National security (e.g., DoD, DHS, Intelligence)
    - Fraud detection (e.g., IRS, Medicare)

DA: Market Needs

- We are drowning in data, but starving for knowledge!
- IDC predicted a **$32.4B** market for big data products & services by 2017
  - **27% CAGR** – 6x overall growth rate of ICT market
- Underserved market segments
  - Small and medium businesses & non-profit organizations
  - Public sectors: local governments, education, health and human services
- Long-term talent gap in big data analytics, and thus strong need for M.S. degree or specialization programs
- Example: University of Virginia
  - Just started a professional M.S. in Data Science program
  - Just received a **$10M** endowment gift for Data Science Institute (established in 2013 and one of 15 key strategies for UVa's new strategic plan) & UVa will invest **$7M** in 6 years

Data Analytics: Challenges

- Four Vs of big data: Volume, Velocity, Variety & Variability
- Security and privacy
- Multi-disciplinary requirements
  - Domain expertise (e.g., business, social sciences, education, healthcare, security)
  - Data science/analysis
  - Machine learning and data mining
  - Statistics and mathematics
  - Computer science: software and algorithms
  - Information technology: infrastructure (compute, communication, storage)

Catalyst for CDA @ NSU

- **HEI** promoting entrepreneur culture on NSU campus: students, faculty, staff, and administration

- New research initiative on big data analytics (Hsieh)
  - Eight students working in this subject area with Dr. Hsieh
  - Small-scale research lab established in Robinson Tech Ctr
  - Still in learning phase but ramping up expertise steadily

- New equipment grant from Department of Defense
  - **Building a Cloud Computing and Big Data Infrastructure for Cybersecurity Research & Education**
  - PI: Hsieh, Co-PI: Wallace Hendricks; $497,725, 2/1/2014 – 1/31/2015; to add ~320 terabytes of storage & 300 CPU cores

Existing Plan (Computer Science)

- Facilities and personnel
  - Equipment to be installed in CS server room
  - Personnel from CS primarily
- Investment sources
  - Building a Cloud Computing and Big Data Infrastructure for Cybersecurity Research and Education, $497,725
  - **Self-Protecting Security for Assured Information Sharing**, PI: Dr. Hsieh, DoD, 2/24/2012 – 2/23/2015, $487K
  - Massie Chair grant from DoE (PI: Dr. Sandra DeLoatch)
  - Title III and OCR for MS.CSC program
- **How to maximize potential benefits to NSU?**

Mission for CDA @ NSU

- Leverage resources across NSU and from its supporters

- Develop and implement research, education and outreach programs in data analytics
  - With a goal to become a nationally known leader

- Collaborate with academic, government, and private sector partners on capacity building and service delivery in data analytics
  - Started discussion with VMASC/ODU, Virginia Tech and University of Arizona, and received positive response

- Provide data analytics **professional services** to partners in public and private sectors

Case Study: A Local Government

- Use of data analytics
  - Make better decisions for its operations (e.g., revenues, social services, health management, emergency management)
  - Provide informative data to its stakeholders (e.g., residents, businesses, economic development)
  - Provide "data analytics as a service"
- How could CDA@NSU help
  - Consultation
  - Training
  - Feasibility study and pilot projects
  - Planning, design, and implementation
  - Operation, support, and service delivery

Plan for New Equipment

- Dell to provide hardware and engineering service
- Configured as three systems
  - **Cloud Computing System (CCS)**
    - Optimized for cloud computing model
    - Large shared storage
  - **Big Data System (BDS)**
    - Optimized for big data processing model
    - Distributed storage and processing (data nodes)
    - Centralized control and management (master nodes)
  - **Big Data Integration and Testing System (BDITS)**
    - For integration and testing purposes
    - Common hardware configuration (master nodes) with service reconfiguration

Plan for Big Data System

- Hardware configurations based on Cloudera-Dell Hadoop Reference Architecture (best practices)
- Planned for balanced workloads
- Physical installation: 2 racks
  - Each rack w/ a top-of-rack switch (Force 10)
  - Each switch provides 4 x 40GbE + 48 x 10 Gb Base-T
- Data Nodes (x12): Dell PowerEdge R720xd each w/
  - 2 Intel Xeon Processors each with 6 Cores
  - 64 GB RAM; 24 TB disks
  - 10 Gb Base-T + 1 Gb Base-T
- Master Nodes (x5): Dell PowerEdge R720xd each w/
  - 2 Intel Xeon Processors each with 6 Cores
  - 128 GB RAM; 1.2 TB disks (RAID 10)
  - 10 Gb Base-T + 1 Gb Base-T

Current Lab (First Hadoop Cluster)
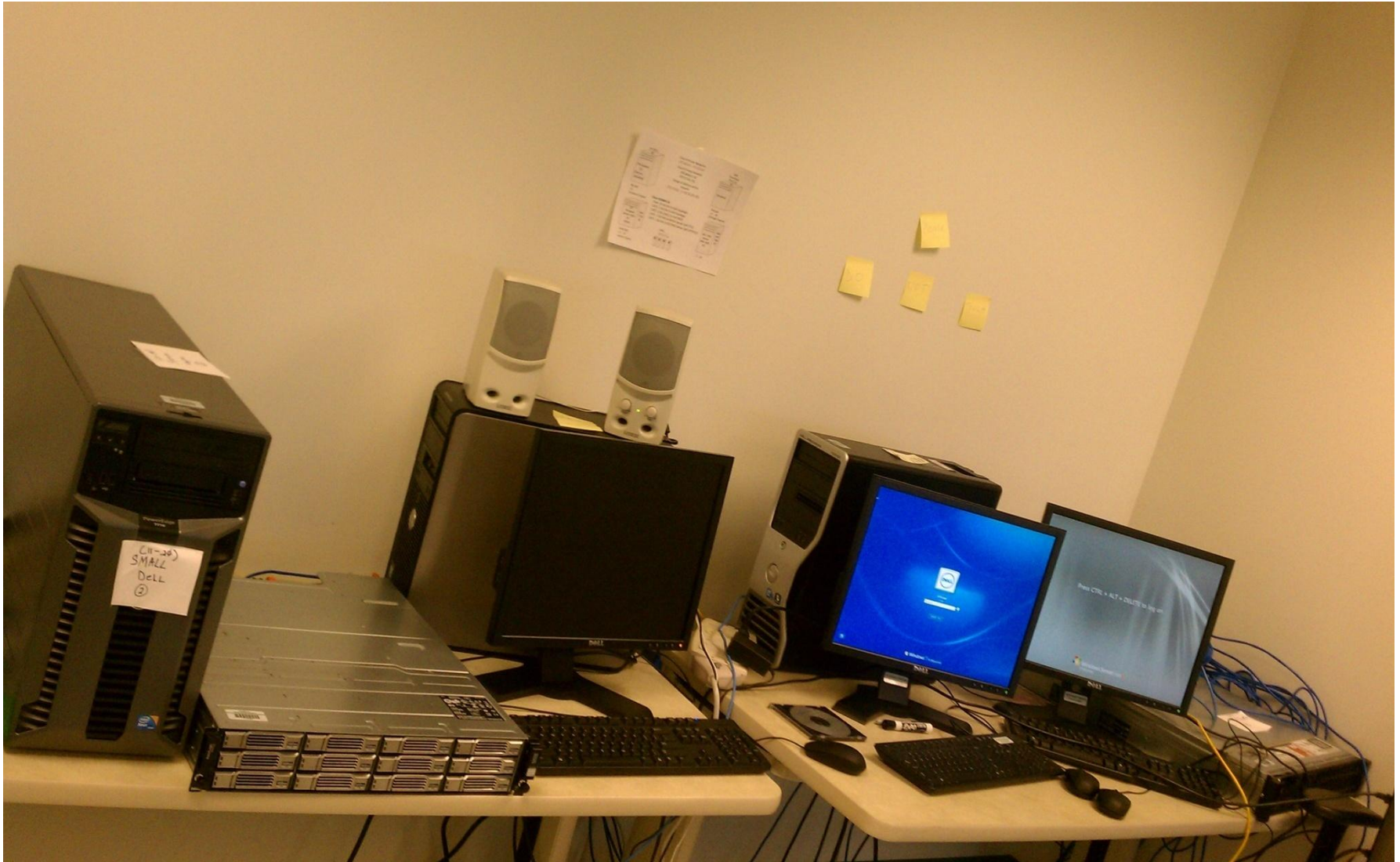
Current Lab (Second Hadoop Cluster)

Current Lab (VM/Workstations)

Current Lab (Cloud Computing System)

Incubation Plan (Assuming Minimum Investment)

- Establish a small incubation team and operate with minimal overhead
- Identify initial targeted segments and potential partners
  - Build up base capabilities for pilot projects and proposals
  - Start small
- Stand up the new cloud computing and big data infrastructure
  - Implement **long-term plan for sustaining a reliable infrastructure**
- Focus on capacity building and making real progress
  - Leverage resources appropriately and broadly
  - Minimize red tape and remove roadblocks efficiently
- **Run like a startup business!**

Incubation Team: Personnel

- Recruit capable, interested, and committed members ONLY
- Reward selected NSU employees through
    - Release/reallocation time from job duties
    - Overtime, research awards, bonus, etc.
- Encourage highly qualified NSU students to participate
    - Selected from DNIMAS/Honors College
    - Selected from capstone research courses
    - Selected from research/lab assistants

Incubation Core Team (Current Proposal)

- Computer Science
  - Dr. Hsieh (security analytics + infrastructure)
  - Mr. Wallace Hendricks, IT Manager (infrastructure)
- Mathematics: Dr. Abdinur Ali (data analysis)
- Business: Dr. Mackie Sissoko* / Dr. Jim Chen*
- Social Work: Dr. Ted Burke*
- CSET/HEI: Tonya Fields (data mining + machine learning)
- OIT*

* Tentative

Incubation Extended Team (Current Proposal)

- ## Computer Science
  - ### Dr. Aurelia T. Williams*, Chair
  - ### Students working with Dr. Hsieh
- ## OIT*

* Tentative

Incubation Angel Team (Current Proposal)

- Dr. Y. T. Shah
- Dr. Clarence D. Coleman*
- Dr. Larry Mattix*
- Dr. George Miller*
- Dr. Adebisi Oladipupo*

* Tentative

Incubation Plan (Proposed Timeline)

- Launch no later than **July 1, 2014** with
  - Official recognition by NSU as a university-wide venture
  - Designated administrative home
  - **Agreement on equipment installation (facility), operation and support plans**
  - Initial incubation teams in place
  - Agreement on additional initial investments
- Incubation period: two years
- Measure of success
  - ROI (grants, contracts, awards)
  - Collaborations and partnerships
  - Benefits to students, faculty, and academic programs

Additional Initial Investments (Minimum)

- For two-year period
- Request: $55,000 per year in personnel
    - Web master (PT): $5,000
    - Administrative assistant (PT): $2,000
    - Research awards for faculty/staff: $8,000 x 6 = $48,000

Discussion

- Questions?

- Interest?

- Feasibility?

- Suggestions

- Next steps