

Enlarged Figures and Tables from IEEE CloudCom 2011 Paper 36

K. Mills, J. Filliben and C. Dabrowski, “Comparing VM-Placement Algorithms for On-Demand Clouds”, *Proceedings of IEEE CloudCom 2011*, Nov. 29-Dec. 1, 2011

Figure 1. Schematic of Koala organization

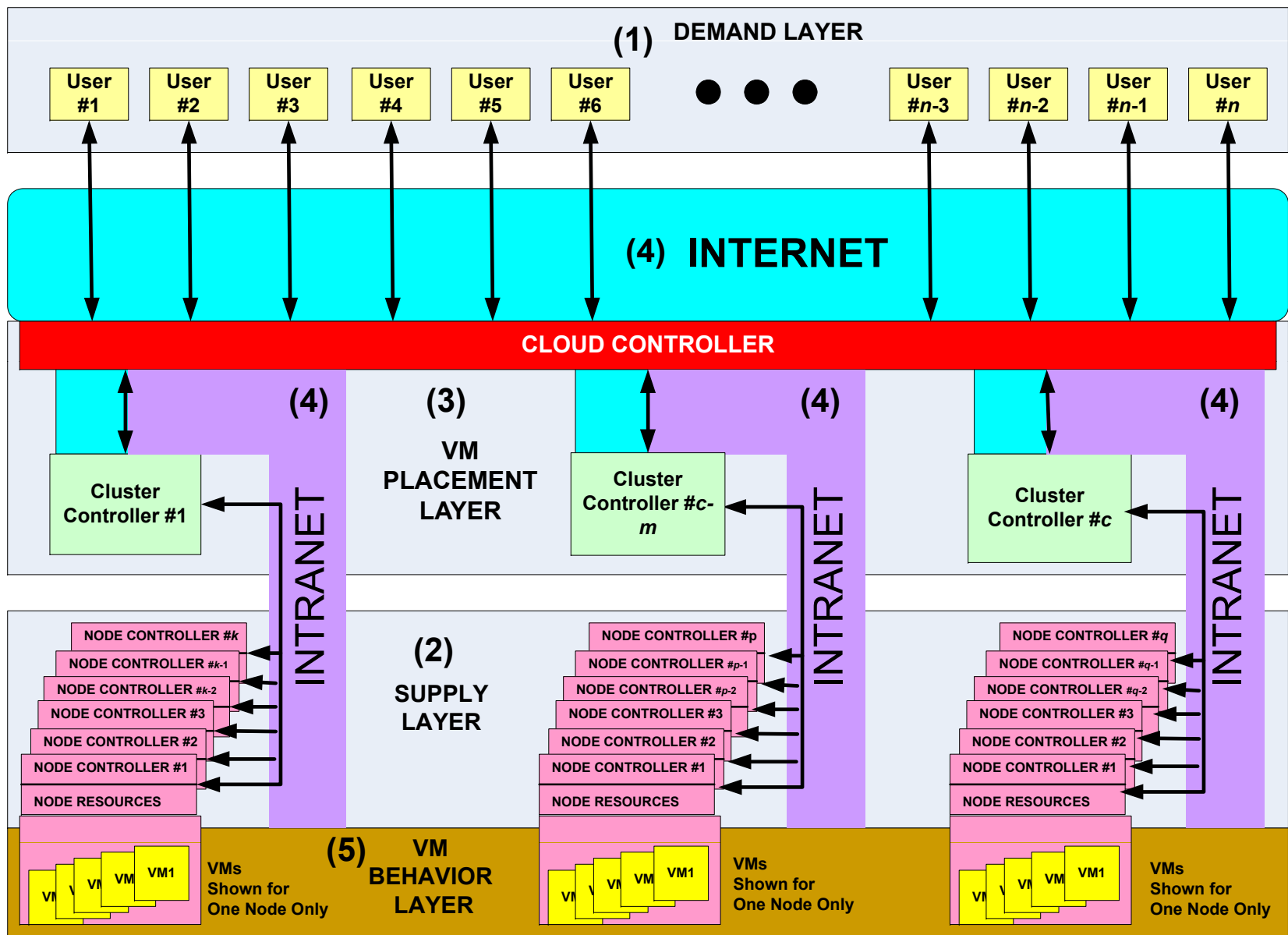


TABLE I. Description of VM types simulated in Koala

VM Type	Virtual Cores		Virtual Block Devices		# Virtual Network Interfaces	Memory (GB)	Instruct. Arch.	Price in \$/Hour
	#	Speed (GHz)	#	Size (GB) of Each				
M1 small	1	1.7	1	160	1	2	32-bit	0.12
M1 large	2	2	2	420	2	8	64-bit	0.34
M1 xlarge	4	2	4	420	2	16	64-bit	0.96
C1 medium	2	2.4	1	340	1	2	32-bit	0.17
C1 xlarge	8	2.4	4	420	2	8	64-bit	0.68
M2 xlarge	8	3	1	840	2	32	64-bit	1.00
M4 xlarge	8	3	2	850	2	64	64-bit	2.00

TABLE II. Description of selected simulated user types: processing users (PU), distributed modeling and simulation (MS) users, peer-to-peer (PS) users, Web service (WS) users, and data search (DS) users

User Type	VM Type(s)	Max-Min VMs	Max-Max VMs	User Type	VM Type(s)	Max-Min VMs	Max-Max VMs
PU1	M1 small	10	100	PS1	C1 medium	3	10
				PS2		10	50
PS3		50	100				
PU3		100	500				
PU5		500	1000	WS1	M1 large M2 xlarge C1 xlarge	1	3
PU2	M1 large	10	100	WS2	M1 large M2 xlarge C1 xlarge	3	9
PU4		100	500	WS3	M1 large M2 xlarge C1 xlarge	9	12
PU6		500	1000	DS1	M4 xlarge	10	100
MS1		M1 xlarge	10	100		DS2	100
MS3	M1 xlarge	100	500	DS3		500	1000

TABLE III. Description of selected platform types simulated in Koala

Platform Type	Physical Cores		Memory (GB)	# Physical Disks by Size				# Network Interfaces	Instruct. Arch.
	#	Speed (GHz)		250 GB	500 GB	750 GB	1000 GB		
C8	2	2.4	32	0	3	0	0	1	64-bit
C14	4	3	64	0	4	0	3	2	64-bit
C18	8	3	128	0	0	4	3	4	64-bit
C22	16	3	256	0	0	0	7	4	64-bit

TABLE IV. Alternative Criteria for Choosing Cluster and Alternative Heuristics for Choosing Nodes

Criteria for Choosing a Cluster		Heuristics for Choosing Nodes	
Identifier	Criterion Name	Identifier	Heuristic Name
LLF	Least-Full First	FF	First Fit
		LF	Least-Full First
PAL	Percent Allocated	MF	Most-Full First
		NF	Next Fit
RAN	Random	RA	Random
		TP	Tag & Pack

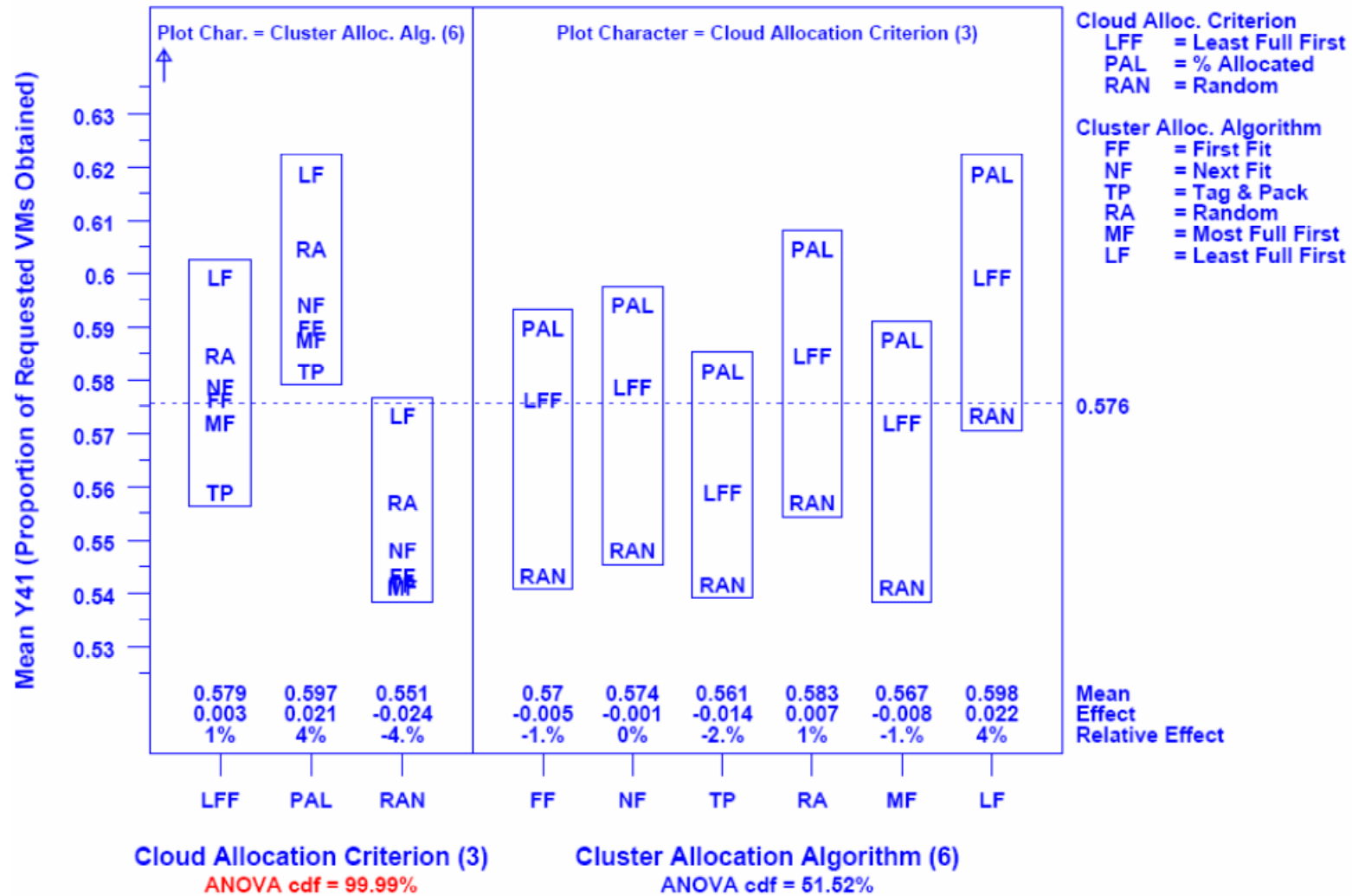
TABLE V. Two Selected Values for each Selected Koala Parameter

Layer	Parameter	Parameter Name	Plus (+) Level	Minus (-) Level
Demand Layer	$x1$	Number of users	2500	250
	$x2$	Probability of a user's type	PU1 = 0.20 PU2 = 0.20 PU3 = 0.10 PU4 = 0.10 MS1 = 0.10 MS3 = 0.01 PS1 = 0.10 PS2 = 0.01 WS1 = 0.15 WS2 = 0.07 WS3 = 0.03 DS1 = 0.10 DS2 = 0.01	PU1 = 1/6 PU2 = 1/6 MS1 = 1/6 PS1 = 1/6 WS1 = 1/6 DS1 = 1/6
	$x3$	Average (& shape) of user's holding time	8 hours (a = 1.2)	4 hours (a = 1.2)
Supply Layer	$x4$	Number of clusters	20	10
	$x5$	Number of nodes per cluster	1000	100
	$x6$	Probability of a node's platform configuration type	C22 = 1.0	C8 = 0.25 C14 = 0.25 C18 = 0.25 C22 = 0.25

Table VI. Koala Response Variables Selected for Comparison

Category	ID	Response Name	Definition
User	y1	User Request Rate	(Requests by All Users / # User Cycles)
	y2	NERA Rate	(NERAs / Requests by All Users)
	y3	Full Grant Rate	(Full Grants / (Full Grants + Partial Grants))
	y4	User Arrival Rate	(# User Cycles / Simulated Hours)
	y5	User Give-up Rate	(# Users that Gave Up / # User Cycles)
	y6	Grant Latency	Weighted Avg. Delay in Granting VMs to Users that Got VMs
	y40	User Success Rate	((Full Grants + Partial Grants)/# User Cycles)
	y41	Avg. Fraction VMs Obtained	(Allocated VMs/Requested VMs)
	y42	Avg. <i>RunInstance</i> Response Time	Weighted avg. for successful allocations
Cloud	y7	Reallocation Rate	(# Times Alternate Cluster Chosen / Requests Granted)
	y8	Full Grant Proportion	(Avg. Fraction Clusters Offering Full Grants)
	y9	NERA Proportion	(Avg. Fraction Clusters Reporting NERA)
	y10	vCore Utilization	(Avg. Fraction of Virtual Cores Used in Cloud)
	y11	Memory Utilization	(Avg. Fraction of Memory in Use in Cloud)
	y12	Disk Space Utilization	(Avg. Fraction of Disk Space in Use in Cloud)
	y13	pCore Load	(Avg. Virtual Cores Allocated / Physical Cores in Cloud)
	y14	Disk Count Load	(Avg. Virtual Disks Allocated / Physical Disks in Cloud)
Cluster	y16	vCore Utilization Variance	Avg. Variance in vCore Utilization across Clusters
	y17	Memory Utilization Variance	Avg. Variance in Memory Utilization across Clusters
	y18	Disk Space Utilization Variance	Avg. Variance in Disk Space Utilization across Clusters
	y19	pCore Load Variance	Avg. Variance in pCore Load across Clusters
	y20	Disk Count Variance	Avg. Variance in Disk Count Load across Clusters
	y21	NIC Count Variance	Avg. Variance in NIC Count Load across Clusters
	y22	Node Reallocation Rate	(# Times Alternate Node Chosen / VMs Allocated)
	y23	Cluster NERA Rate	(# NERAs / # Responses Avg. across Clusters)
	y24	Cluster Full-Grant Rate	(# Full Grants / # Responses Avg. across Clusters)
	y25	Allocation Rate	(Times Cluster chosen / Cluster offered Avg. across Clusters)
	y26	Standard Deviation-NERA	Stand. Dev. in Avg. NERA Rate across Clusters
	y27	Standard Deviation-Full-Grant	Stand. Dev. in Avg. Full-Grant Rate across Clusters
VMs	y29	Current Instances	Avg. # VM Instances Extant in Cloud
	y30	M1small Instances	Fraction of Current Instances that are M1 small VMs
	y31	M1large Instances	Fraction of Current Instances that are M1 large VMs
	y32	M1xlarge Instances	Fraction of Current Instances that are M1 xlarge VMs
	y33	C1medium Instances	Fraction of Current Instances that are C1 medium VMs
	y34	C1xlarge Instances	Fraction of Current Instances that are C1 xlarge VMs
	y35	M2xlarge Instances	Fraction of Current Instances that are M2 xlarge VMs
	y36	M4xlarge Instances	Fraction of Current Instances that are M4 xlarge VMs
Internet/ Intranet	y37	WS Message Rate	Avg. # WS Messages Send Per Simulated Hour
	y38	Intra-Site Messages	(# WS Messages Sent with Sites / # WS Messages Sent)
Revenue	y39	Aggregate Revenue in \$/Hour	Calculated from y29 through y36 & VM prices

Figure 2. Plot of ANOVA Results for Response Variable *y41*- Average Fraction of VMs Obtained (red denotes significant difference among groups)



Category	ID	Response Name	ANOVA Cdf Cloud Crit (3)	ANOVA Cdf Cluster Alg (6)
User	y1	User Request Rate	99.96	62.19
	y2	NERA Rate	100	22.33
	y3	Full Grant Rate	100	2.75
	y4	User Arrival Rate	99.87	77.15
	y5	User Give-up Rate	94.63	98.6
	y6	Grant Latency	98.01	96.11
	y40	User Success Rate	95.86	98.02
	y41	Avg. Fraction VMs Obtained	99.99	51.52
	y42	Avg. <i>RunInstance</i> Response Time	37.35	97.49
Cloud	y7	Reallocation Rate	99.99	9.5
	y8	Full Grant Proportion	100	0.02
	y9	NERA Proportion	100	0.4
	y10	vCore Utilization	67.85	99.81
	y11	Memory Utilization	98.97	91.47
	y12	Disk Space Utilization	97.29	96.27
	y13	pCore Load	67.85	99.81
	y14	Disk Count Load	96.76	97.56
	y15	NIC Count Load	99.78	79.49
Cluster	y16	vCore Utilization Variance	100	1.28
	y17	Memory Utilization Variance	100	0.09
	y18	Disk Space Utilization Variance	100	0.14
	y19	pCore Load Variance	100	1.28
	y20	Disk Count Variance	100	0.42
	y21	NIC Count Variance	100	1.02
	y22	Node Reallocation Rate	100	6.09
	y23	Cluster NERA Rate	100	0.19
	y24	Cluster Full-Grant Rate	100	0.06
	y25	Allocation Rate	99.88	77.64
	y26	Standard Deviation-NERA	63.92	61.08
y27	Standard Deviation-Full-Grant	99.73	30.95	
y28	Standard Deviation-Allocation Rate	100	0.02	
VMs	y29	Current Instances	99.98	50.54
	y30	M1small Instances	99.99	35.85
	y31	M1large Instances	60.58	99.02
	y32	M1xlarge Instances	99.83	77.1
	y33	C1medium Instances	99.97	27.57
	y34	C1xlarge Instances	82.1	99.89
	y35	M2xlarge Instances	74.62	99.97
	y36	M4xlarge Instances	99.95	66.03
Internet/ Intranet	y37	WS Message Rate	99.7	83.74
	y38	Intra-Site Messages	89	99.05
Revenue	y39	Aggregate Revenue in \$/Hour	99.99	44.51

TABLE VII. Summary of 84 ANOVA Tests: Each Row Represents One of 42 Responses; Column 4 Reports Differences Attributable to Cluster-Choice Criterion and Column 5 Reports Differences Attributable to Node-Selection Heuristic – cells highlighted in red identify significant differences

Category	ID	LLF	PAL	RAN
User	y1	7.461	8.386	7.696
	y2	0.444	0.506	0.450
	y3	0.624	0.574	0.514
	y4	37324	35878	37170
	y5	0.066	0.074	0.067
	y6	9044	10488	9526
	y40	0.925	0.915	0.923
	y41	0.579	0.597	0.551
	y42	0.278	0.277	0.278
Cloud	y7	0.000052	0.000084	0.000057
	y8	0.438	0.332	0.389
	y9	0.481	0.587	0.537
	y10	0.774	0.791	0.783
	y11	0.188	0.197	0.199
	y12	0.413	0.428	0.418
	y13	0.774	0.791	0.783
	y14	0.964	0.997	0.948
Cluster	y15	1.591	1.645	1.554
	y16	0.0017	0.019	0.0071
	y17	0.0009	0.0034	0.0015
	y18	0.0022	0.0086	0.0038
	y19	0.0017	0.019	0.0071
	y20	0.018	0.052	0.024
	y21	0.045	0.127	0.052
	y22	0.00015	0.00015	0.00008
	y23	0.507	0.606	0.562
	y24	0.421	0.323	0.375
	y25	0.19	0.232	0.232
	y26	0.01	0.01	0.011
VMs	y27	0.008	0.011	0.015
	y28	0.034	0.058	0.02
	y29	21808	22139	20365
	y30	0.355	0.354	0.333
	y31	0.308	0.311	0.307
	y32	0.138	0.142	0.151
	y33	0.057	0.053	0.052
	y34	0.025	0.022	0.025
Internet/ Intranet	y35	0.026	0.023	0.026
	y36	0.091	0.096	0.106
Revenue	y37	60867	62677	60841
	y38	0.977	0.977	0.977
	y39	11322	11706	11624

TABLE VIII. Mean for Each Response under Each of Three Cluster-Choice Criteria – cells highlighted in red per ANOVA from Table VII

Category	ID	FF	LF	MF	NF	TP	RA
User	y1	7.643	8.450	7.692	7.710	7.871	7.718
	y2	0.460	0.493	0.458	0.462	0.455	0.470
	y3	0.566	0.593	0.563	0.57	0.555	0.577
	y4	37138	35624	37188	36938	37051	36807
	y5	0.065	0.080	0.065	0.067	0.067	0.069
	y6	10130	8636	10439	9643	10420	8848
	y40	0.925	0.908	0.925	0.923	0.922	0.921
	y41	0.57	0.598	0.567	0.574	0.561	0.583
y42	0.278	0.276	0.278	0.279	0.277	0.278	
Cloud	y7	0.000063	0.000064	0.000068	0.000073	0.000055	0.000063
	y8	0.387	0.387	0.378	0.389	0.385	0.39
	y9	0.529	0.55	0.536	0.528	0.536	0.532
	y10	0.789	0.761	0.812	0.786	0.764	0.78
	y11	0.198	0.188	0.204	0.196	0.191	0.193
	y12	0.419	0.428	0.424	0.421	0.402	0.424
	y13	0.789	0.761	0.812	0.786	0.764	0.78
	y14	0.958	1.013	0.958	0.97	0.928	0.99
y15	1.58	1.639	1.597	1.592	1.542	1.631	
Cluster	y16	0.0085	0.008	0.0127	0.0097	0.008	0.008
	y17	0.0019	0.0020	0.0022	0.0019	0.0019	0.0017
	y18	0.0045	0.0054	0.0053	0.0050	0.0046	0.0045
	y19	0.0085	0.0089	0.0127	0.0097	0.0080	0.0080
	y20	0.029	0.036	0.032	0.032	0.029	0.029
	y21	0.067	0.088	0.080	0.074	0.065	0.073
	y22	0.00013	0.00012	0.00013	0.00014	0.00011	0.00012
	y23	0.555	0.569	0.562	0.552	0.558	0.553
	y24	0.373	0.375	0.364	0.376	0.373	0.378
	y25	0.228	0.192	0.237	0.216	0.232	0.201
	y26	0.011	0.009	0.013	0.010	0.010	0.009
y27	0.012	0.010	0.015	0.011	0.012	0.010	
y28	0.037	0.040	0.037	0.037	0.035	0.038	
VMs	y29	21237	22244	21020	21409	20824	21888
	y30	0.344	0.356	0.342	0.348	0.341	0.352
	y31	0.306	0.315	0.304	0.305	0.311	0.312
	y32	0.144	0.149	0.145	0.147	0.135	0.142
	y33	0.054	0.053	0.053	0.053	0.056	0.054
	y34	0.025	0.018	0.026	0.024	0.027	0.022
	y35	0.027	0.019	0.028	0.026	0.029	0.023
	y36	0.100	0.090	0.103	0.097	0.101	0.095
Internet/ Intranet	y37	61018	63016	61223	61156	60571	61785
	y38	0.977	0.977	0.977	0.977	0.976	0.977
Revenue	y39	11603	11529	11683	11587	11362	11541

TABLE IX. Mean for Each Response under Each of Six Node-Selection Heuristics – cells highlighted in red per ANOVA from Table VII