

Why is my LMS so slow?

A Case Study of D2L Performance Issues



UNIVERSITY OF
CALGARY

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- Desire-to-Learn (D2L) is the official Learning Management System (LMS) at the University of Calgary (since Spring 2014)
- Many faculty and students use D2L for their courses
- Context/Motivation:
 - Many universities use LMS (e.g., BlackBoard, D2L, Canvas, Moodle)
 - Few studies characterizing LMS usage and/or performance
 - Anecdotal reports suggest that D2L at U of C is “slow”
 - Network traffic measurement research provides a means to analyze, characterize, and understand D2L usage at U of C

- Network traffic measurement study of D2L usage (2015-2016)
- Combination of active and passive measurement approaches
- Research Questions:
 - How does D2L work?
 - How is D2L being used at the University of Calgary?
 - How can we improve the performance of D2L?

- Complex configuration of D2L setup at U of Calgary
 - Excessive HTTP redirection for session login and logout
- Long network RTT to access remotely hosted D2L content
 - Approximately 40 ms RTT to reach Kitchener, Ontario
 - No local CDN node at U of C; closest node is in Toronto
- Suboptimal configuration of TCP for D2L Web servers
 - Uploads and downloads are window-limited (64 KB per RTT)
 - D2L Web server seems very slow (IIS v7.5 on Windows 2000 R2)

- Data collection from Jan. 1, 2016 – April 30, 2016 (Winter 2016)
 - Microscopic analysis was performed for this period
- Data collection from Jan. 1, 2015 – December 31, 2016
 - Longitudinal analysis was performed for this period
- Data was processed and stored in Bro logs
 - Records connection summaries for all TCP and UDP traffic
 - Connection logs provide inbound/outbound traffic information
 - HTTP logs provide user agent information for Web browsing
 - SSL logs provide server information and encryption details
- Active and passive measurement tools were used in this research

Examples of Bro Log Records for D2L Traffic Analysis

1. Connection Logs

1 1467330654.859900	CKXf9o4AL6J22nI6z3	136.159.16.20	53484	199.30.181.42	443	tcp	ssl	155.704539	23133	97772	(empty)
RSTR T F	0 ShADadr 54	25307 144	183540	(empty)							
1 1467330654.860155	Cbw9Fm4I99LAig8qAh	136.159.16.20	53486	199.30.181.42	443	tcp	ssl	155.704494	9688	24191	(empty)
RSTR T F	0 ShADadr 23	10622 45	25999	(empty)							
1 1467330654.860159	CpIXhcl7jTGg9Z2z1	136.159.16.20	53485	199.30.181.42	443	tcp	ssl	152.229457	11067	36192	(empty)
RSTR T F	0 ShADadr 30	12281 65	38800	(empty)							
1 1467330654.860168	PCbcqU3rIeuWKE10el	136.159.16.20	53487	199.30.181.42	443	tcp	ssl	170.878203	18375	227497	(empty)
RSTR T F	0 ShADadr 55	20589 229	236665	(empty)							
1 1467330654.860185	CdsAqTGBbQz1iruPa	136.159.16.20	53488	199.30.181.42	443	tcp	ssl	150.865304	14213	375312	(empty)
RSTR T F	0 ShADadr 78	17347 335	388720	(empty)							
1 1467330654.860400	CXDLXo30KpQoXnmvld	136.159.16.20	53489	199.30.181.42	443	tcp	ssl	150.846427	8633	24990	(empty)
RSTR T F	0 ShADadr 24	9607 45	26798	(empty)							
1 1467330697.557215	CPgd5k19rfuQOP7ib9	136.159.16.20	53500	199.30.181.42	80	tcp	http	300.255577	1840	2745F	(empty)
T F 0	ShADaFf 13	2378 11	722	(empty)							
1 1467330697.557434	Cf5cxa3gDFTjMHqvj5	136.159.16.20	53501	199.30.181.42	80	tcp	http	300.255412	1850	2745F	(empty)
T F 0	ShADaFf 13	2388 11	722	(empty)							
1 1467330697.557690	CRXjUz42MLoZ3TpWb1	136.159.16.20	53502	199.30.181.42	80	tcp	-	20.042029	0	0 SF	(empty)
T F 0	ShAFaf 4 172	3 128	(empty)								
1 1467330697.557693	CnfsCzdy9UJHzkvw	136.159.16.20	53503	199.30.181.42	80	tcp	-	20.042336	0	0 SF	(empty)
T F 0	ShAFaf 4 172	3 128	(empty)								
1 1467330697.594944	CPgd5k19rfuQOP7ib9	136.159.16.20	53500	199.30.181.42	80	1	GET	d2l.ucalgary.ca			
/d2l/orgtools/style/colour.css	http://elearn.ucalgary.ca/desire2learn/log-out/	Mozilla/5.0 (Windows NT 6.3; Win64; x64) AppleWebKit/53									
7.36 (KHTML, like Gecko) Chrome/51.0.2704.103 Safari/537.36	0	0	302	Found	-	-	-	(empty) -			
1 1467330697.595288	Cf5cxa3gDFTjMHqvj5	136.159.16.20	53501	199.30.181.42	80	1	GET	d2l.ucalgary.ca			
/images/uca/lycalgo-logo.png	http://elearn.ucalgary.ca/desire2learn/log-out/	Mozilla/5.0 (Windows NT 6.3; Win64; x64) AppleWebKit/53									
7.36 (KHTML, like Gecko) Chrome/51.0.2704.103 Safari/537.36	0	0	302	Found	-	-	-	(empty) -			
1 1467330697.637188	Cf5cxa3gDFTjMHqvj5	136.159.16.20	53501	199.30.181.42	80	2	GET	d2l.ucalgary.ca			
/images/body-bg.png	http://elearn.ucalgary.ca/desire2learn/log-out/	Mozilla/5.0 (Windows NT 6.3; Win64; x64) AppleWebKit/537.36 (KH									
TML, like Gecko) Chrome/51.0.2704.103 Safari/537.36	0	0	302	Found	-	-	-	(empty) -			
1 1467330697.637257	CPgd5k19rfuQOP7ib9	136.159.16.20	53500	199.30.181.42	80	2	GET	d2l.ucalgary.ca			
/images/bg.jpg	http://elearn.ucalgary.ca/desire2learn/log-out/	Mozilla/5.0 (Windows NT 6.3; Win64; x64) AppleWebKit/537.36 (KHTML, lik									
e Gecko) Chrome/51.0.2704.103 Safari/537.36	0	0	302	Found	-	-	-	(empty) -			

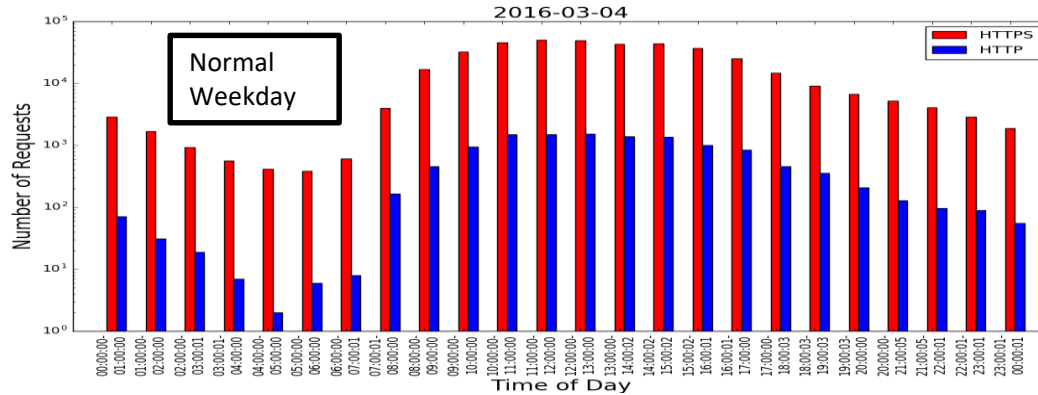
1 1467330654.897494	CKXf9o4AL6J22nI6z3	136.159.16.20	53484	199.30.181.42	443	TLsv12	TLS_ECDHE_RSA_WITH_AES_25
6_GCM_SHA384	secp256r1	d2l.ucalgary.ca F	FvrhQxo2IR8s31D5, FpjxEY3w	1083X3PRE9, FGTZf	q25kGKG71M7h	(empty)	CN=d2l.ucalgary.ca,
OU=COMODO SSL, OU=Issued through University of Calgary E-PKI Manager, OU=Domain Control Validated							CN=COMODO SSL CA, O=COMODO CA Limited
, L=Salford, ST=Greater Manchester, C=GB	-	-	-	ok			
1 1467330654.897633	CpIXhcl7jTGg9Z2z1	136.159.16.20	53485	199.30.181.42	443	TLsv12	TLS_ECDHE_RSA_WITH_AES_25
6_GCM_SHA384	secp256r1	d2l.ucalgary.ca F	FCjvHN3sXBLaKYL63, FAm10B3a	YDZsJbpD2, FTCa1kDq	FDY1YUnf	(empty)	CN=d2l.ucalgary.ca,
OU=COMODO SSL, OU=Issued through University of Calgary E-PKI Manager, OU=Domain Control Validated							CN=COMODO SSL CA, O=COMODO CA Limited
, L=Salford, ST=Greater Manchester, C=GB	-	-	-	ok			
1 1467330654.897757	CPbcqU3rIeuWKE10el	136.159.16.20	53487	199.30.181.42	443	TLsv12	TLS_ECDHE_RSA_WITH_AES_25
6_GCM_SHA384	secp256r1	d2l.ucalgary.ca F	FmxAGliev0EUXwXaQh, F0Wvsw2	yvZTRHjig, FFD05s4VBKu	USV258	(empty)	CN=d2l.ucalgary.ca,
OU=COMODO SSL, OU=Issued through University of Calgary E-PKI Manager, OU=Domain Control Validated							CN=COMODO SSL CA, O=COMODO CA Limited
, L=Salford, ST=Greater Manchester, C=GB	-	-	-	ok			
1 1467330654.897780	CXDLXo30KpQoXnmvld	136.159.16.20	53489	199.30.181.42	443	TLsv12	TLS_ECDHE_RSA_WITH_AES_25
6_GCM_SHA384	secp256r1	d2l.ucalgary.ca F	Fu2Mys4J0xVMHLDTab, FwggIT7	RAiATmr4, FDDwC2261GMO	PKG777	(empty)	CN=d2l.ucalgary.ca,
OU=COMODO SSL, OU=Issued through University of Calgary E-PKI Manager, OU=Domain Control Validated							CN=COMODO SSL CA, O=COMODO CA Limited
, L=Salford, ST=Greater Manchester, C=GB	-	-	-	ok			
1 1467330654.897816	CdsAqTGBbQz1iruPa	136.159.16.20	53488	199.30.181.42	443	TLsv12	TLS_ECDHE_RSA_WITH_AES_25
6_GCM_SHA384	secp256r1	d2l.ucalgary.ca F	FjjFmh3466aGJdJgde, FOJ9QHD	fyf9AVF7, FE2W1x3FHxKj	QqrP3	(empty)	CN=d2l.ucalgary.ca,
OU=COMODO SSL, OU=Issued through University of Calgary E-PKI Manager, OU=Domain Control Validated							CN=COMODO SSL CA, O=COMODO CA Limited
, L=Salford, ST=Greater Manchester, C=GB	-	-	-	ok			
1 1467330654.897912	Cbw9Fm4I99LAig8qAh	136.159.16.20	53486	199.30.181.42	443	TLsv12	TLS_ECDHE_RSA_WITH_AES_25
6_GCM_SHA384	secp256r1	d2l.ucalgary.ca F	FGi69G2UyCqTMKds9h, FAn1owM	CPH3c7ZcAq, FZbJs22fEzchDO	CUii	(empty)	CN=d2l.ucalgary.ca,
OU=COMODO SSL, OU=Issued through University of Calgary E-PKI Manager, OU=Domain Control Validated							CN=COMODO SSL CA, O=COMODO CA Limited
, L=Salford, ST=Greater Manchester, C=GB	-	-	-	ok			

2. SSL Logs

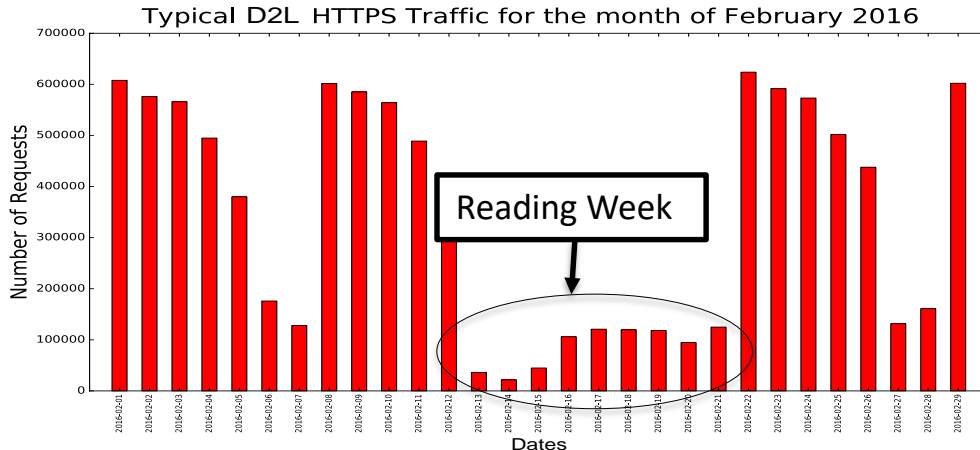
3. HTTP Logs

All D2L data
extracted using bash
and Python scripts

High-Level Characterization of D2L Usage Patterns

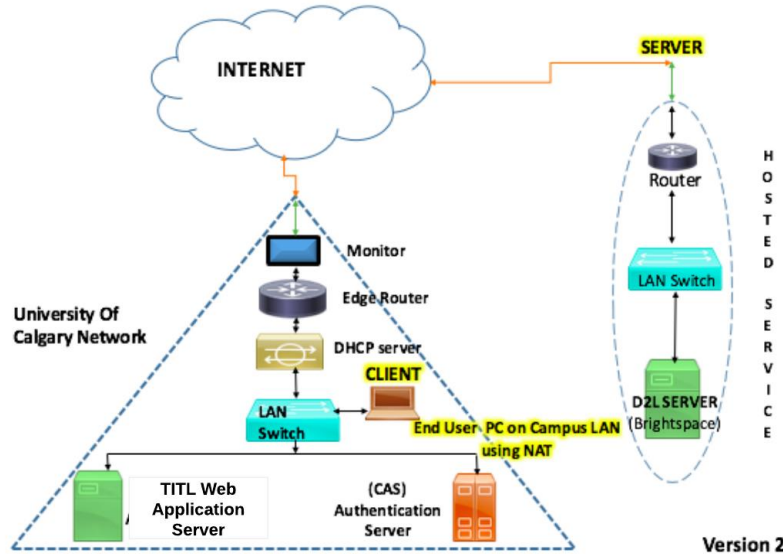


- This graph shows the number of requests made to D2L per hour over a one-day (24 hour) period
- Traffic pattern is diurnal
- Peak HTTPS traffic is 30x larger than that of HTTP traffic

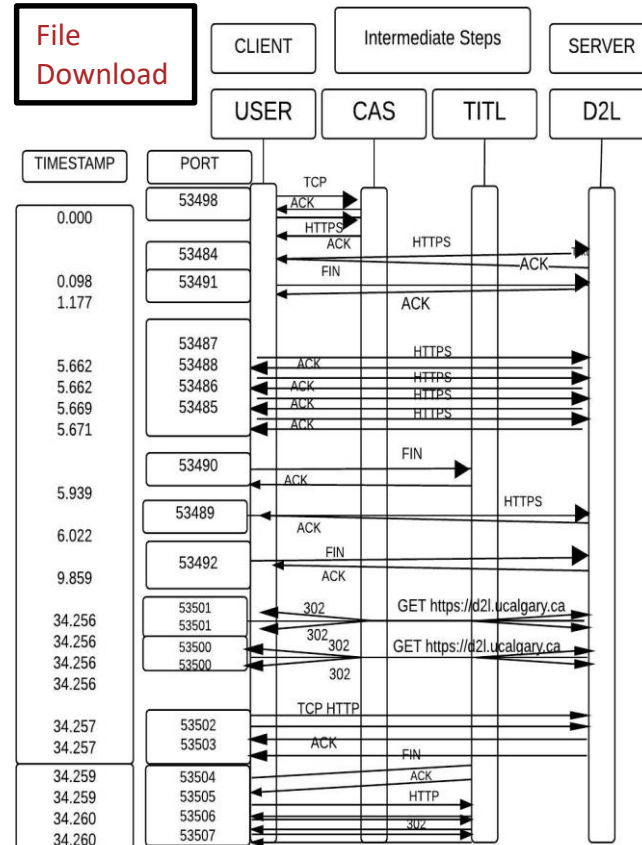


- This graph shows daily totals for D2L requests for one month
- Monday is the busiest day of the week for D2L traffic volume
- Request volume tends to decrease throughout the week
- Holidays have lower D2L traffic

D2L Configuration at U of Calgary



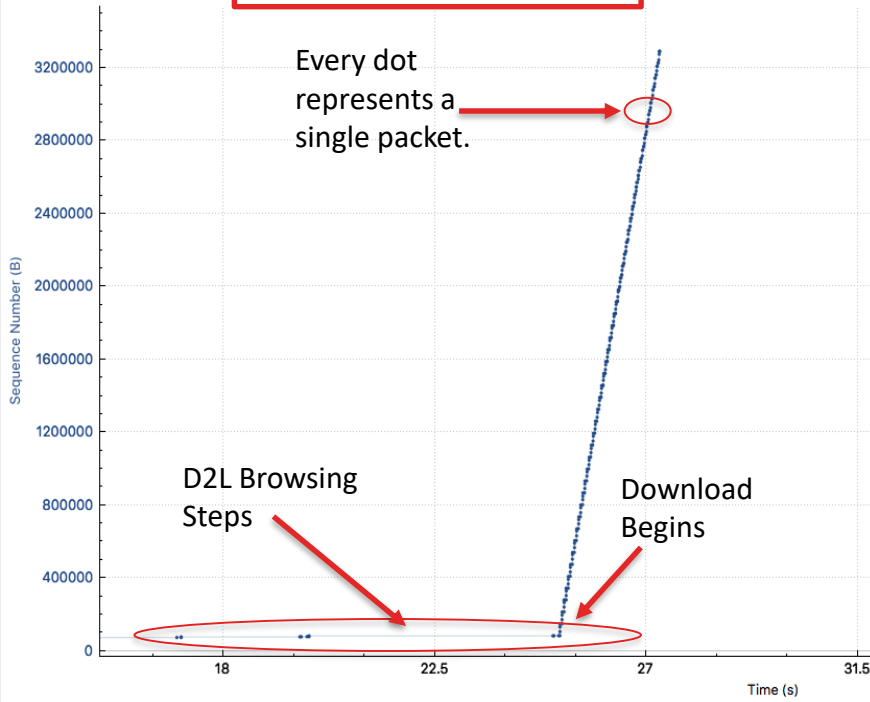
Typical Internet path for on-campus D2L users (including NAT, DHCP, wireless) spans 17 hops with 40 ms RTT



- Shows the role of intermediate servers
- Parallel connections seen when uploading or downloading files
- Persistent HTTP connections seen in D2L sessions

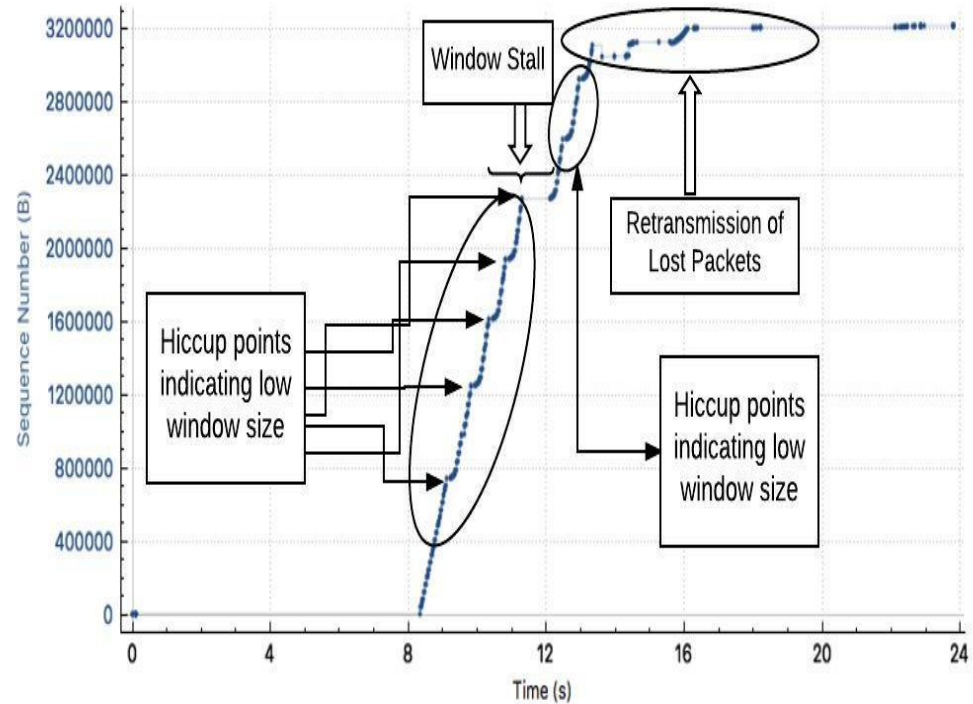
TCP Performance Issues for Downloads and Uploads

D2L File Download



TCP Throughput: 14 Mbps
RTT Latency: 45 ms

D2L File Upload



TCP Throughput: 7 Mbps

- Complex configuration of D2L setup at U of Calgary
 - Excessive HTTP redirection for session login and logout
- Long network RTT to remotely hosted D2L content
 - Approximately 40 ms RTT to reach Kitchener, Ontario
 - No local CDN node at U of C; closest node is in Toronto
- Suboptimal configuration of TCP for D2L Web servers
 - Uploads and downloads are window-limited (64 KB per RTT)
 - D2L Web server seems very slow (IIS v7.5 on Windows 2000 R2)

- Network traffic measurement can provide a better understanding of the usage of modern LMS services like D2L
- D2L at the U of C has a rather complex delivery infrastructure, and several idiosyncracies that affect its user-perceived performance
- Long network latencies make remotely hosted content painful!
- Proposed solutions:
 - Having a local CDN node could improve D2L performance
 - Improving TCP configuration (version and/or socket buffer sizes) could improve throughput for D2L users

- Questions?
- Email: carey@cpsc.ucalgary.ca

