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Private Content Delivery Network Implementation: A Case Study of MARA Network Infrastructure

[1]J. Mohd Saifullizam, [2]A. Nurulnadwan, [1]A. Azham, [1]N. Lukmanulhakim

[1]*Faculty of Computer, Media, and Technology Management, TATi University College, 24000 Kemaman, Terengganu, Malaysia.*
[2]*School of Multimedia Technology and Communication, UUM College of Arts and Sciences, University Utara Malaysia,06010 UUM Sintok, Kedah, Malaysia.*

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ABSTRACT

Recently, the advancement of web content manipulation affected to the size of content increasingly large expands and it causes to burden the content accessing on the Internet. This study reports an ongoing project regarding to validate the design of Private CDN(PCDN) by region overall and evaluate the effectiveness of PCDN. In order to achieve the stated objectives this re applied a methodology which consists of five phases: (i)problem specification (ii)solution design (iii)implementation (iv)evaluation and (v)conclusion. Generally, based on the content analysis of literatures, it was found that CDN technology was eminently practical and effective to accelerate widely delivery content around the globe which involves various ISP networks. However, previous studies indicate that applying this technique also leads to several problems occurs in organization especially those who have a lot of branches. Among the problems are, it does not guarantee to data integrity, data ownership, and security. By considering the Malaysian context, this situation leads to the case study in MARA organisation. As a result, this study found that PCDN able to accelerate the local content in Malaysian region and afford to overcome the load access consistently in peak period by distributing burden between CDN nodes. In addition, PCDN give a lot of advantages to the organization which contain a lot of branches in accelerating access by using the current resources. In conclusion, implementing PCDN means that an organization's security certificates are retained within the walls of the corporation, not given out to a vendor.

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INTRODUCTION

Over the last decade, the improvement of the web content style and presentation has always evolving. The web 2.0 improves the web in more interactive and collective intelligent present new opportunities for leveraging and engaging its users more effectively (Murugesan, 2007). However, these ongoing changes have yet to be reflected in the size of the web content that include rich element content such as streaming video and downloaded applets that interact instantly with the user. The content need to classify with different categories such personal protected, commercial, public, private and so on. In addition, these require different distributing and managing to the existing content infrastructure (Ding and Li, 2011). The main concepts of content delivery network work are replicating the content from the origin server to the closest surrogate or edge server to the user. Basically, redirect clients to different servers over short time scales can minimize client download time. There are assumptions that reducing the network with minimum hoops between client and content server can reduce the network latency and improve the response time (Vakali and Pallis, 2003). The common practice that is used by commercial CDN provider such as AKAMAI by equipping the surrogate server or CDN nodes in each ISP network in country based (Choffnes *et al.,* 2009). This technique is suitable for the content that can be accessed worldwide but due to the lack of current infrastructure, it does not increase the content delivery acceleration within region in the country because there is no surrogate server in each region in the country. Normally, the surrogate server placement is based on the ISP network which is "closer" to user. The latest technique that has been proposed by many researchers (Dias and Marinheiro, 2011) use peering CDN with peer to peer technologies because the concept of P2P can increase more resources provided by the user and it can reduce the server traffic. Contrast with hybrid CDN technique is similar with P2P CDN but it had combination with CDN infrastructure (Jiang *et al.,* 2008). While, (Mulerikkal and Khalil, 2007) has proposed the new

Corresponding Author: J. Mohd Saifullizam, Faculty of Computer, Media and Technology Management, TATi University College, 24000 Kemaman, Terengganu Malaysia.
E-mail: saifullizam@tatiuc.edu.my

architecture of distributed content delivery network (DCDN) which is uses existing resources Internet user such as internet bandwidth, storage space and connectivity to generated DCDN infrastructure.

2. Problem Statement:

All the techniques and method that has been discussed above have a big issue in term of data ownership, integrity and security because they are used and shared with the third party resources to accelerate the content delivery. For this reason, to overcome this issue, there is an urgent need for the organizations to develop their own resources as a private content delivery network (PCDN). Nevertheless, there are many costs needed to invest in developing their own CDN node in each ISP network around the world and hence, it is not a practical solution. However, the concept of PCDN is suitable for the organization that has many branches with physical network infrastructure such as internet connection, public IP and server farm in each branch. There are many organizations that do not fully utilize their current network infrastructure to increase the performance of content delivery. One of the organizations is MARA, which has many branches in each region in Malaysia where all the branches are provided with a network infrastructure. A preliminary investigation (PI) has been conducted to confirm the research problem by conducting using three types of data gathering techniques. A diagnosis tool was the major method used to evaluate the current performance; a survey for the target population and direct experience person's, interviews with IT staff were administered to confirm the problem statement. Based on the problem statement including the issues posed earlier, this study proposes to design and implement the Private CDN in Malaysian region. There are three critical parts in this study which is to ensure that the DNS server redirection will be resolved and redirect IP address to the nearby region surrogate server based on the user IP address location; the surrogate servers must always consistent to cache dynamic content with the origin web server; and to ensure the load balancing within surrogate servers on each region to cater user load during the high peak period. Finally, an experimental design was used to validate the effects of the Private CDN implementation either in term of increasing the size of bandwidth on origin web server or implementing this solution using the current resources, determining the best solution based on some factors such as response time, waiting time and user loads. The main objective to be achieved in this study is to design, implement and investigate the effects of a private CDN by region architecture in accelerating web content access. To achieve that, the following specific objectives are required to be accomplished. (1) to design and develop DNS Geo-location Malaysian region aware; (2) to validate the design of MARA Private CDN by region overall; (3) to evaluate the effectiveness of Private CDN implementation by region in Malaysia.

3. Related Works:

The particular desired quality of service associated with each type of contents but it has low delays between request and reception is good for all types of content. (Nielsen, 1999) was indicated user is most likely distracted from the current website and loses interest when the waiting more than 10 seconds. The limitation of current technology used such as border gateway protocol (BGP), transmission control protocol (TCP), and hypertext transfer protocol (HTTP) has been developed decades ago and are not ideally suited to meet performance and business requirements for today's dynamic sites application. The Border Gateway Protocol (BGP) is the core traffic routing protocol used by ISP. In article (Labovitz *et al.,* 2001) also prove that BGP has increased packet loss and latency, where the end-to-end Internet paths will experience intermittent loss of connectivity. Meanwhile, TCP protocol was built for stability is designed to negotiate communication speed between the browser and the server. Therefore, using the current technologies and integrate with content delivery network technology is the one solution to increase the performance of the web acceleration. The term content delivery network or content distribution network refers to an architecture of distributed system across the globe that content request from end-user will be routed using a network to the cache that is nearer or closer to the user and that can serve these queries in term of shorter delay, due to a smaller number of hops to be traversed (Amble *et al.,* 2011). An article (Torres *et al.,* 2011) found that YouTube CDN using new algorithms which is to determine server selection, the more popular videos are being cache to edge server co-location and unpopular videos will be stored only in YouTube origin server. In term of guarantee of speed, most of commercial CDN providers do not guarantee quality of service to the end user but CDN user will be charged based on quota transfer that has been used such as Akamai (Akamai, 2012). The elements of the CDN include DNS traffic redirection, surrogate server and load balancing within CDN nodes.

Traffic Redirection:

When implementing CDN, the most important consideration is how to redirect user request to the closest surrogate server or nearby edge server. In this case, DNS server has important role to resolve domain name and determine where the IP address of edge server that is nearby to the client. Authors(Wenting *et al.,* 2000) proposed *S3* (smart server selection) that is much better than DNS round robin because it is metric based on network hops, latency, monetary cost and both of them. While the *MyXDNS* proposed by (Alzoubi *et al.,* 2007) was achieved over 3000 resolutions/sec with sub-millisecond response on a low-end server. The advantage of this architecture is suitable for the researcher field because *MyXDNS* can request routing algorithms without worry to the internal DNS and it has its own network proximity metrics. As compared to the *GeoDNS*, it does the geographic look-up at the request time, and returns different results based on the incoming user IP address (Hawley, 2009). The *GeoDNS* will be integrated with IP dataset such as *Maxmind* Dataset by using BIND with patches or without patches (Maxmind, 2012; BIND, 2012).

Surrogate Server:

The duplicate content process in the surrogate server and the placement are the important parts to ensure all the content caching consistently and closest to the target end-user. it must to consider whether the content is highly cacheable or not, most of the static contents is cacheable, whereas dynamic content is not. In term of cache mechanism, there are many caching techniques that will help the designer to decide the most suitable one. Authors in (Mehrotra *et al.*, 2010)listed all the techniques that have pros and cons. The dynamic content is more difficult to be cached because the proxy server needs a validation time to ensure the content are always fresh and consistent between proxy cache server and the content server. In term of tackling the dynamic content that always change and scale, the Edge Side Includes or ESI is a solution that has been proved, it is a small markup language for edge level to assemble dynamic web contents (Ye and Liu, 2006). There many cache servers that support ESI language such as Varnish, Squid and Mongrel (Varnish, 2012; Squid, 2012; Mongrel, 2012). However, implementation of caching servers for CDN nodes were caches only the specific content and using the reverse proxy cache is suitable. (Ciciani *et al.*, 2003) has modeled the reverse proxy cache in term of QoS traffic among the cache nodes within CDN. The reasons of use this model because it can offload the origin web server by caching static content and distribute the load to several other web server.

Load Balancing:

Another consideration when implementing the CDN is how to balance the load within surrogate servers where there are many techniques that have been proposed to ensure the load in CDN will always balance mainly to cater the high load in certain time effectively. Author (Dahlin, 2000) proposed *Least-Loaded* algorithm, instead is a well-known dynamic strategy for load balancing. The incoming client request will be assigns to the currently least-loaded server. While (Bai *et al.*, 2009) has proposed *distributed binning strategy* which is the algorithm that will make use the best of network topological information and the historical information of file accessed, server load information so that user request can get timely response compared to existing algorithms discussed above which only emphasize even load distribution among servers. Specifically, the effectiveness of load balancing also depends on some arguments that need to configure based on the design of the load balancing.

4. Solution Design & Implementation:

Based on the comparative analysis, this study identified three component of PCDN which are DNS Malaysian region aware using BIND without patches, surrogate server using Squid Reverse proxy and load balancer using HA-Proxy. Figure 1 shows the component of Private CDN that has been designed.

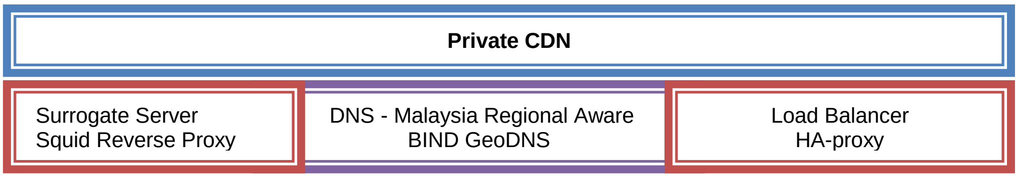

Fig. 1: Component of Private CDN.

DNS - Malaysia Regional Aware:

This part for design the DNS server to resolve the domain request and redirect to the surrogate server nearby based on user network proximity. The server will be checked the user IP, and then will resolve the domain IP that is closest to the user. Specifically, the ISP has allocated the IP range separately based on user geographical location. Therefore, the researcher has collected the IPv4 address *GeoLiteCity* block dataset in *.CSV format (Maxmind, 2012). The dataset has 2,255,499 line data for the city-block and 381,358 line data city-location include details of location Id, country, region, city, postal Code, latitude, longitude, metro Code, area Code, start IP Number, end IP Number. However, we needs the details of the IP address that has been assigned to the users based on their state or city location in Malaysia and the dataset will be extracted and sorted. This technique is the most suitable because it could automatically redirect the traffic without doing any metric comparison such as network hops, load and it can reduce process to do calculation for every request process. We decided to use BIND server package because it has been proved as a solution in commercial used and it is released under the term of open-source. Specifically, there are two types of techniques of implementing *BIND GeoDNS* which are with patches and without patches. Normally, the patching source code is entails maintenance or need to upgrade with new revision of the BIND source code when ISC releases newer versions because it has vulnerable. The method *GeoDNS* without patches is a better solution which fully controls the small database that has been extracted. Meanwhile, by concerning about the accuracy of IP geo-location, this technique allows the database to be customized and updated manually. Specifically, this method uses two fundamental things in BIND which are the “view” statement and “ACL” (access control list) clause. The MaxMind dataset file operates in IP ranges in numerical format whereas BIND ACLs operate on IP networks in dotted format.

Surrogate / Edge Server / CDN Node:

This part is a component of CDN and it will be allocated in the surrogate’s server on the selected region. The function of this server is to cache static and dynamic content with the original web server application. There are two popular applications that support for reverse cache proxy like Varnish are commonly developed based on BSD platform and Squid derived from Unix. We were decided to use Squid because it has a number of unique features that makes it the best web application accelerator in terms of performance and portability (Haproxy, 2012). Squid runs its configuration as native code giving it a spectacular performance even with configuration that span thousands of lines and it is flexible as it can implement policies such as implementing nested if-then-else statements in a structured document. Squid also support for Edge Side Includes (ESI) which is an industry standard XML-based markup language that is used together with HTML. Edge Side Includes (ESI) gives a way to do lightweight integration between different web content systems. Figure 2 shows the design of surrogate servers placement within region with the specify location and current infrastructures. The surrogate servers will be placed in five locations which are in Northern region, KL region, Southern Region and West Region. Also all the nodes will be connected using VPN MARANET with the origin web server in East Coast region. Figure 3 shows the overall design diagram for the PCDN.

Load Balancing Within CDN Nodes:

Load balancing is the important part in distributing workload across CDN node when the concurrent user are high to ensure the achievement of optimal resource utilization, avoid overload and minimize response time. Specifically, the concept is when the DNS resolves the IP and redirects to the nearby CDN node, the first thing will occur on the CDN node and it will be checked whether the current load of the server is archiving the maximum user connection that has been configured. If it has archive the maximum connection, then it will pass the traffic to the other CDN nodes. To ensure that selected CDN node is always ready to handle the client content request with optimal process, we were controlled the maximum concurrent connection for each CDN node to avoid overloading because it increases the latency although the selected CDN node was the most closest to the end-user.

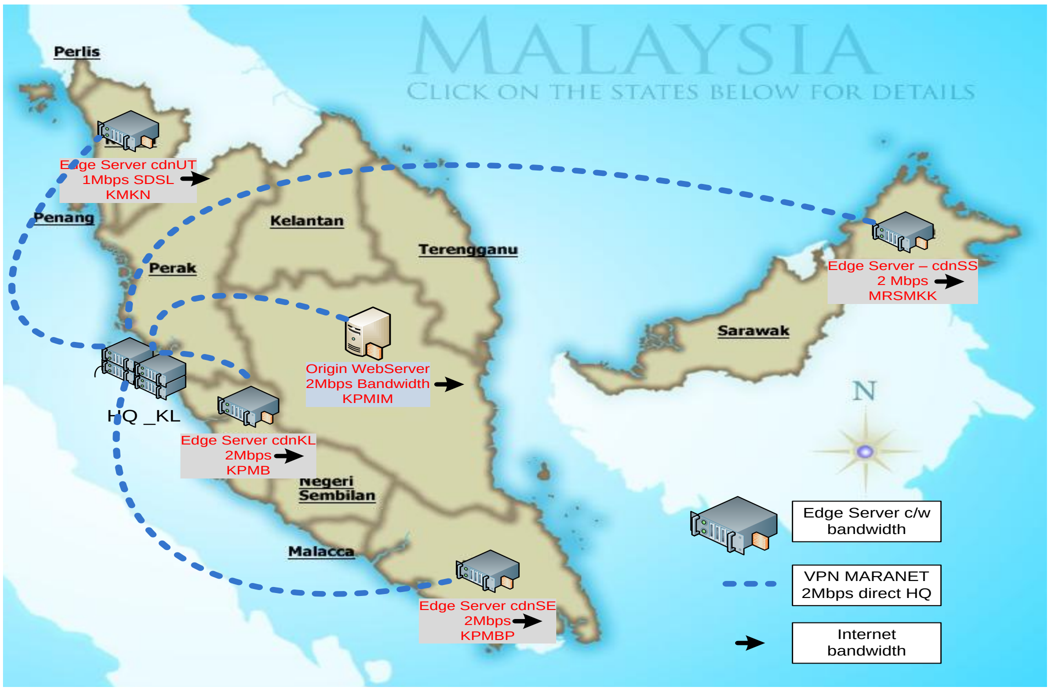

Fig. 2: Surrogate server placement within region.

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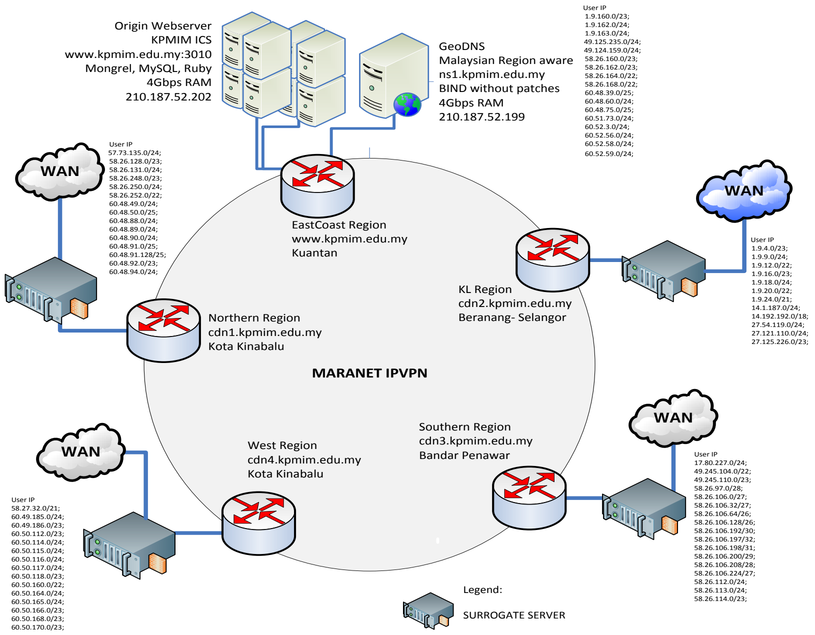


Fig. 3: Overall Private CDN Diagram.

The priority when selecting the CDN node goes to the one closest to user and the load are not over the limit and always in high availability. In this case, the researcher has chosen HA-Proxy that has unique features to support TCP and HTTP load balancing and can fill up the function that are needed. The HA-proxy has supported many load balancing algorithms and for this purpose, we configured using *source balance* algorithms (Haproxy, 2012). This algorithm is the most suitable solution to share the load within cache server. All the surrogates server will act as a front end and also function as a backend to receive incoming connections that has been forwarded. A set of listening sockets accepting client connection as a "frontend" while section is a set of servers to which the proxy will connect to forward incoming connections as a "backend". All the backend also has to be set with max connection argument to control the load of the CDN node.

5. Evaluation:

There are several types of test that has been conducted during this phase to rectify accurate results and findings. The tests that have been done with different scenarios include performance tests, load tests, stress tests and ramp tests. During the test process, we utilize several tools in different scenarios to identify, calculate and generate the accurate results. The test has been performed in different regions and several tools were used to ensure all the tests are running correctly. The tools are as follows: (1)*IPERF* – to check the current bandwidth within surrogate servers, (2)*DIG* – to identify domain resolve based on user location. (3)*TRACEROUTE* – to identify network hops, (4)*Mozilla LiveHTTP Header* – to live capture header of the pages and will shows either cache from CDN node or it redirect from origin web server, (5)*Mozilla Firebug* – to log and show where is content download in details, and (6)*Paessler Webserver Stress Tool* – as analysis tools and stress tool to evaluate the waiting time with simulate user. Moreover, this tool was the main role to analysis the result with different of scenarios and tests.

Evaluation Scenarios:

We also determine different scenario in conducting the test to ensure the result is easy to compare and evaluate. In these cases, there are two scenarios that have been identified to generate the accurate results. All the tests need to access the ICS web application through the domain ***http://www.kpmim.edu.my*** in real situations. The test is running while network are in normal condition which the bandwidth connection on CDN nodes, origin web-server and Geo DNS server are in normal rate. The researcher utilizes Iperf tool to test all the bandwidth size of node or server (Iperf, 2008). To evaluate objective one and two, we was perform two type of test to ensure the DNS Malaysian region aware was redirect the traffic to the closest surrogate server based on the region of end user using *dig* tool. The result shown that IP address in answer section has differ based on the client region location and the query time for the both only take 100-110 msec. Then, we were use a Mozilla Live HTTP tool to ensure the surrogate server had cache the web content from the origin web server and serve the client content request. The experimental result shows that most of the content such as the java-script content

of the web application has been loaded from surrogate. If the requested content are not in cache directory or the content were expired on the surrogate server, it will automatically redirect to the origin server via surrogate server by show the MISS status. We were conclude that the PCDN architecture was well functioning based on this test but to analyze their performance, two type of scenarios has been identified when simulate the tests.
Scenario I – Test with one client only access with one click
Scenario II – Test with multiple client with increasing load

Result and Finding:
Scenario I:

Table 1: Average Click Times For 1 User without PCDN.

URL No.	*Name*	*Clicks*	*Errors [%]*	*Time Spent [ms]*	*Avg. Click Time [ms]*
1	Origin_home	1	0.00	1,339	1,339

Table 2: Average Click Times for 1 User with PCDN.

URL No.	*Name*	*Clicks*	*Errors [%]*	*Time Spent [ms]*	*Avg. Click Time [ms]*
1	CDN_home	1	0.00	776	776

The result indicates that the proposed architecture was very effective to increase the performance of response time between user and contents. In addition, table 1 and 2 show in details, the result of average click time on the proposed architecture performance which has increase two times better than existing architecture whereas no errors has occur.

Scenario II:

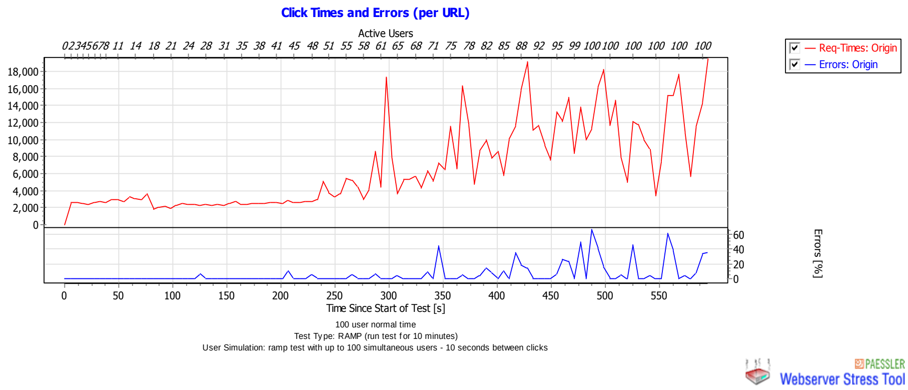
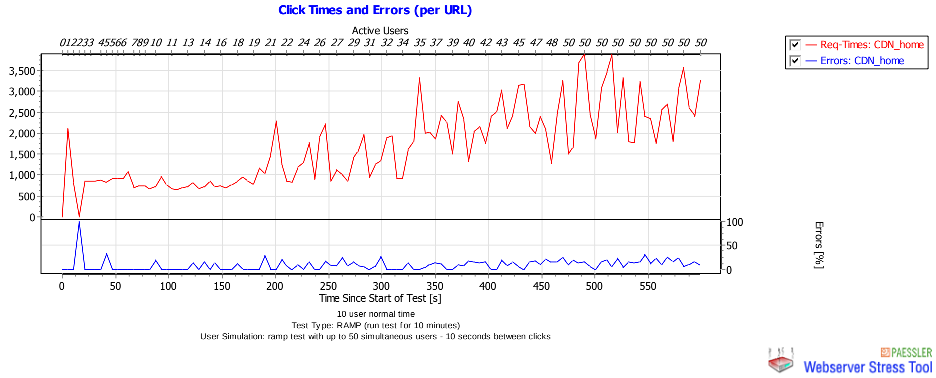
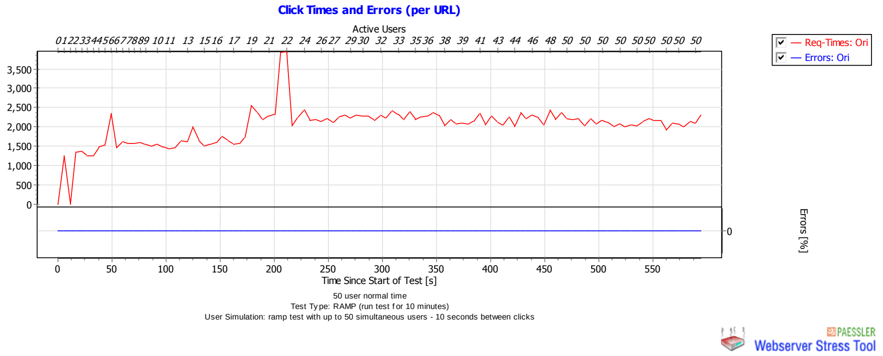


Fig. 4: Click Times and errors for 100 users without PCDN.

The graph in Figure 4 shows the result that until around 58 simultaneous users the request times for the static file were not change much at all. Then as the number of user crosses to 70, it shows that the first requests were produce errors. The graph of the percentage of errors goes up from 0% and keeps rising up and down, 40% to 60% until the end of the test. We were concluded that this web server can support about 50-60 users clicking either link every 10 seconds with an average click time below than 10 seconds. While more than 60 users the request times increase substantially. The current architecture does not support more than 90 users because with higher loads up to 50% of the request produces more errors. However, using the private CDN architecture, the server can support more user up to 100 users even it also has several errors occurs but it still give more better response time to the users below than 3.5 seconds. The graph 5(a) and (b) show that when the user access from different regions the server were distributes the load between surrogate servers. In this case, graph 5(a) has several errors when request the content from surrogate server but still below 20% of the requests produce errors. We assumes it was happen because the processing load between cache content in the surrogate server and non-cache content that redirect to the origin server were produce several redundant processes but still not over the limit 50% of errors. In contrast, compared to graph (b) there are no request errors occurs because the request directly the origin server that have all the contents. The reason is because the protocol TCP was built for stability which is designed to negotiate communication speed between the browser and the server where the process was disconnected after the server satisfies the request but if the problem occurs it will repeat the process. The server will send the request until the requester has fully receives his request but it will effect to the performance because it will repeat the same process when error occurs. The errors were occurs because the processor of the web server was over the limitation process it can cater.



(a) Traffic in CDN node in KL region



(b) Traffic in CDN node in East Coast region

Fig. 5: Click Times and errors with Private CDN 50 + 50 User access from two different regions at the same time. (a) traffic in KL region, (b) traffic in East Coast Region.

Table 3: PCDN Overall Performance Comparison.

Parameter	*Normal Load Traffic*		*High Load Traffic(based on 100 users)*	
	Without PCDN	*With PCDN*	*Without PCDN*	*With PCDN*
Avg. Click Times [ms]	1,339	776	7,896	2083
Waiting Times [ms]	2000	1000	>10000	<10000
Errors (%)	nil	nil	8.95	5.365
Max Users <10s	unlimited	unlimited	50-60	>100, more CDN node, more user support

Table 3 shows the overall performance of PCDN in normal load traffic and high load traffic using different parameter from result testing. It shows that the average click times in normal load traffic using PCDN architecture has two times better than existing architecture and their performance in high load traffic has increase three times of the current performance. Also, the user response time was still less than 10 seconds even in high load traffic. The maximum users mean the total of user accesses the web application below than 10 seconds their waiting times. It can be increased depend on more CDN nodes and more user can support The table shows that the proposed architecture was better than existing architecture and also it much better in high load traffic. The researcher concludes that the new architecture shows better performance than the existing architecture in many aspects.

Conclusion And Future Work:

This study has carried out a systematic investigation in proposing a comprehensive Private CDN implementation. All relevant elements and components in designing a Private CDN were considered and validated through testing in actual situation with different scenarios of testing. From the findings obtained in this study, there were indications that the proposed Private CDN has the following advantages which could be listed as (1) Proposed PCDN is helpful in redirect the traffic within Malaysian region, (2) Proposed PCDN is applicable using the current resources, and (3) Proposed PCDN is helpful in increasing the response time. In conclusion, it is hoped that this study was not only demonstrate the potential of private CDN implementation for the organization that has multiple branches to fully utilize their current resources but also illustrate to the network practitioner to distribute the load and reduce bandwidth consumption on the web server. Finally, implementing PCDN means that an organization's security certificates are retained within the walls of the corporation, not given out to a vendor.

Limitations of Study and Recommendations for Future Works:

There were some limitations in the study and few aspects that can be suggested for improvements. First, the Malaysian IP Regional Dataset excluded for the mobile broadband IP network because the user of mobile broadband has use and shares the same public gateway. While the IP dataset that has been generated from MaxMind dataset open source edition not much accurate and need to compare with IP dataset from all Malaysia ISP providers. Secondly, the caching technique that has been use only caches the static content and the current web application are not supported for ESI. In addition, there are several methods that been identified for future test:

1. Origin web server and surrogate server support for the ESI language.
2. Using *rsync technologies* to fully synchronize web application file system between origin web server and surrogate server.
3. Replicate the selected database to the surrogate server and support for database query cache.

Lastly, the current resources mainly for the Internet bandwidth connection at the surrogates' server are not standardized for each branches and it use from the same ISP. Thus, to ensure the load always consistent, there are some mechanisms that can be researched to check and control the max connection within surrogate servers and passed to the lowest load.

REFERENCES

Akamai, 2012. Akamai Technologies. Retrieved from http://www.akamai.com.

Alzoubi, H.A., M. Rabinovich, O. Spatscheck, 2007. MyXDNS : A Request Routing DNS Server With Decoupled Server Selection. WWW 2007/ Track: Performance and Scalability, 351-359.

Amble, M.M., P. Parag, S. Shakkottai, L. Ying, 2011. Content-aware caching and traffic management in content distribution networks. 2011 Proceedings IEEE INFOCOM, (D), 2858-2866. doi:10.1109/INFCOM.2011.5935123.

Bai, Y., B. Jia, J. Zhang, Q. Pu, 2009. An Efficient Load Balancing Technology in CDN. 2009 Sixth International Conference on Fuzzy Systems and Knowledge Discovery, 510–514. doi:10.1109/FSKD.2009.130.

Choffnes, D.R., A. Kuzmanovic, F.E. Bustamante, 2009. Drafting Behind Akamai: Inferring Network Conditions Based on CDN Redirections. IEEE/ACM Transactions on Networking, 17(6): 1752-1765. doi:10.1109/TNET.2009.2022157.

Ciciani, B., F. Quaglia, P. Romano, D. Dias, 2003. Analysis of design alternatives for reverse proxy cache providers. 11th IEEE/ACM International Symposium on Modeling, Analysis and Simulation of Computer Telecommunications Systems, 2003. MASCOTS, 316-323. doi:10.1109/MASCOT.2003.1240676.

Dahlin, M., 2000. Interpreting Stale Load Information, (June).

Dias, H., R.N. Marinheiro, 2011. Peer-to-peer collaboration in content delivery networks. The International Conference on Information Networking 2011 (ICOIN2011), 91-96. doi:10.1109/ICOIN.2011.5723140.

Ding, J., N. Li, 2011. A Distributed Adaptation Management Framework in Content Delivery Networks. 2011 7th International Conference on Wireless Communications, Networking and Mobile Computing, 1-4. doi:10.1109/wicom.2011.6040622.

HAproxy, 2012. Load balancer. Retrieved from http://haproxy.1wt.eu/.

Hawley, J., 2009. GeoDNS-Geographically-aware, protocol-agnostic load balancing at the DNS level. Linux Symposium.

Jiang, H., J. Li, Z. Li, X. Bai, 2008. Performance Evaluation of Content Distribution in Hybrid CDN-P2P Network. 2008 Second International Conference on Future Generation Communication and Networking, 188-193. doi:10.1109/FGCN.2008.63.

Labovitz, C., A. Ahuja, A. Bose, F. Jahanian, 2001. Delayed Internet Routing Convergence. IEEE/ACM Transactions on Networking, 9(3): 293-306.

Maxmind, 2012. IP Geolocation. Retrieved from http://www.maxmind.com/en/home.

Mehrotra, D., R. Nagpal, P. Bhatia, 2010. Designing metrics for caching techniques for dynamic web site. 2010 International Conference on Computer and Communication Technology (ICCCT), 589-595. doi:10.1109/ICCCT.2010.5640464.

Mongrel, 2012. Retrieved from https://github.com/mongrel/mongrel.

Mulerikkal, J.P., I. Khalil, 2007. An Architecture for Distributed Content Delivery Network. 2007 15th IEEE International Conference on Networks, 359-364. doi:10.1109/ICON.2007.4444113.

Murugesan, S., 2007. Understanding Web 2.0 IEEE Community Society, (August).

Nielsen, J., 1999. Designing Web Usability Simply the bible for website usability. New Rider Publishing.

Squid, 2012. Squid-cache. Retrieved from http://www.squid-cache.org/.

Torres, R., A. Finamore, J.R. Kim, M. Mellia, M.M. Munaf, 2011. Dissecting Video Server Selection Strategies in the YouTube CDN. International Conference on Distributed Computing Systems. doi:10.1109/ICDCS.2011.43.

Vakali, A., G. Pallis, 2003. Networks : Status and Trends, (December 2003).

Varnish, 2012. Varnish Cache. Retrieved from http://www.varnish-cache.org/.

Wenting, T., F. Ang, An, Du, Matt, *et al*., 2000. Supporting Global Replicated Services b y a Routing-Metric-Aw are DNS.

Ye, X., Q. Liu, 2006. A Study of Schemes for Caching Dynamically Generated Web Pages. The Sixth IEEE International Conference on Computer and Information Technology (CIT'06), 33-33. doi:10.1109/CIT.2006.27