Assessing the Impact of Web Caching on Resource Utilization in Low Capacity Networks

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Abstract. Caching web objects closer to hosts for reuse can improve the performance of services that rely on the Internet. However, in recent times a large portion of the Internet traffic delivery is through HTTPS where Transport Layer Security (TLS) provides end-to-end encryption ensuring data integrity, authenticity, privacy and confidentiality between the Web server and client. Encrypted traffic is not malleable to caching and reuse by the network, since each session is unique. Nonetheless, by deploying a cache system that operates over encrypted communication channels using an initial key exchange protocol and a hash function between the cache server and the clients, we implemented HTTPS Web caching configuration in an active community network environment. Results obtained from the study showed a 64.03% drop in the local loop bandwidth utilization and a reduction of the Web traffic component from 95.49% to 52.54%. In addition, there was a 44.1% decline in the local loop traffic volume. Although the LAN traffic volume is not a major area of concern due to the existence of a 1Gbps Ethernet capacity, the resulting 4.01% reduction in LAN traffic volume is a positive contribution from the study.

Keywords: Bandwidth · Proxy Caching · Encryption · Traffic Volume

1 Introduction

Web caching can improve the performance of Web-based systems by storing Web elements in locations that are closest to the host [1]. The reasoning behind this strategy is that temporal locality implies objects stored nearer to recently accessed items have a high chance of being required in the near future. Therefore, Web caching enables the possibility of fulfilling some host requests for Web objects locally resulting in improved response time. Furthermore, lowering of both network bandwidth utilization and workload on the content provider's servers occur when Web caching is adopted.

Although Web caching would be complete when local replication of Web objects occurs, the cache is limited in size. Therefore, a selection of objects to store locally is necessary. The objects requested frequently and not changed often end up being the best candidates for caching. Typically, organizational caching policies aligned to

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unique business strategies dictate which objects are selected for caching [2]. In general, the optimal cache replacement policy targets the best use of available cache capacity with the goal of improving cache hits and reducing server loads. Some of the common cache replacement policies include least recently used and least frequently used [3]. An alternative strategy is the size based web replacement policy that avoids caching of large objects.

In our previous study, a high proportion of Web traffic was evident after the optimization of DNS service [4]. In mitigation, we enabled proxy caching on the community network's gateway router. Since a majority of Web communication is through HTTPS which ensures end-to-end encryption, the implemented cache configuration operates over encrypted communication channels using an initial key exchange protocol and a hash function between the router and clients [5]. A 32GB Micro SD card stores Web objects for reuse. Adoption of the cache replacement policy shipped with the gateway routed including storage duration and Web object size is ensures efficient migration of proxy caching server within the community network environment.

2 Related Work

2.1 Benefits of Web Caching

The benefit of Web caching is in most instances improved user experience due to reduced network bandwidth utilization and improved response time [6]. Yang [7] established that Web caching improves the network latency by up to 26%. In low bandwidth network relying on modems, Cao [8] found that the average latencies experienced by clients reduces by over 23% through Web caching adoption. Work undertaken by Mahdavi [9] in the collaborative web caching environment showed that bandwidth usage per request was reduced by 1.32, 1.35, and 1.4 times for 8KB, 16KB, and 32KB cache sizes, respectively. The corresponding throughput improvement was 1.3, 1.32, and 1.35 times for 8KB, 16KB, and 32KB cache sizes. The study examined the performance of LCW, FIFO and LRU cache replacement strategies. Results showed that the Least Cache Worthiness (LCW) performs better followed by LRU and then FIFO. For a cache size of 20MB, the hit ratios were 0.23 for LCW, followed by 0.17 for LRU, and lastly 0.14 for FIFO.

In the Simultaneous Proxy Evaluation (SPE) architecture [10] where a live workload evaluation of multiple proxies is undertaken, OOPS required only 21.5% of the bandwidth of the pass through proxy. Squid used 21.0% of the bandwidth whereas Apache required 17.0% of bandwidth used when there is no web caching in place. The effectiveness of Web caching reported in the hybrid web caching architecture [11] indicates that Web caches in the local access network perform better than regional and national level ones. A different approach to Web caching adopted in the server side web caching strategy [12] showed a significant reduction in the number of cache misses which resulted in reduced bandwidth utilization and faster response time. Besides bandwidth conservation and response time improvement, the other contribution of Web caching is reduced workload on the content providers' servers [13].

Recent work on the potential of web caching has focused on networks involving Internet of Things (IoTs) [14–16] which allow many mobile based applications like smart homes, electric grids, transport, and digital health to exist. The large number of connections associated with IoTs produce massive amounts of data that require alternative caching solutions. Possible ways of addressing these challenges include the use of content identifiers rather than the host identifier where the nodes communicate through content name instead of the host address [17]. Content-based naming allows for the implementation of in-network caching feature [18] avoiding extra add-ons to the network layer. Placing replica content across the network can help improve caching efficacy in the IoT environment [19]. Requests for content need not travel across the entire network to find the content source. Instead, caching nodes along the request path provide the required resources.

2.2 Caching HTTPS Objects

A large portion of the Internet traffic delivery is through HTTPS in which the Transport Layer Security (TLS) provides end-to-end encryption to ensure data integrity, authenticity, privacy and confidentiality [5]. Encrypted traffic is typically not malleable to caching and reuse by the network, since each session is unique to the Web server and client [20]. The split-TLS Web caching strategy [5] uses an untrusted cache service deployed as a gateway for the client. To enforce cache trust by clients, a certificate is installed on the client Trusted Root Certification Authority Store. The cache server then becomes a trusted agent by the client as root Certification Authority (CA) and any certificate signed by the server is trusted and valid. The cache server forwards traffic back and forth between the client and the Web server using two separate TLS connections [5]. One connection from itself to the client and the other between itself and the Web server. The downside to the split-TLS scheme is that the cache server has full access to traffic sent between the client and the Web server.

In a cache system that operates over encrypted communication channels [21], an initial key exchange protocol and a hash function exchange between the cache server and the client occurs. The client receives the encrypted Web content from the cache server, and later gets the encrypted decryption keys from the Web service provider. Alternatively, the cache server can send the decryption key to the client alongside the Web content. The cache server manages the encrypted Web content and corresponding decryption keys. Hence guaranteeing privacy and confidentiality since the generation of keys is a process that is independent from Web content transfer and therefore the cache server has no access the Web content [21].

2.3 Web Caching Schemes

The demand for Internet content has risen in recent years. Although servers have largely improved in terms of processing power and storage capacity, network backhauls and local loops have not kept pace resulting in poor Web services [22]. For this reason, Web caching and prefetching offer effective solutions for user access latency and high network bandwidth utilization [23]. For a single user, Web caching can typically be achievement by the client Web browser. On a local area network, users obtain Web caching services from the middle layer between the client and the Web server as part of a proxy as illustrated in Fig. 1. Optimal performance proxy caches are located near the network gateway to minimize bandwidth usage across the Internet infrastructure. Proxy servers cache many objects from several servers. This enables reuse of Web objects.

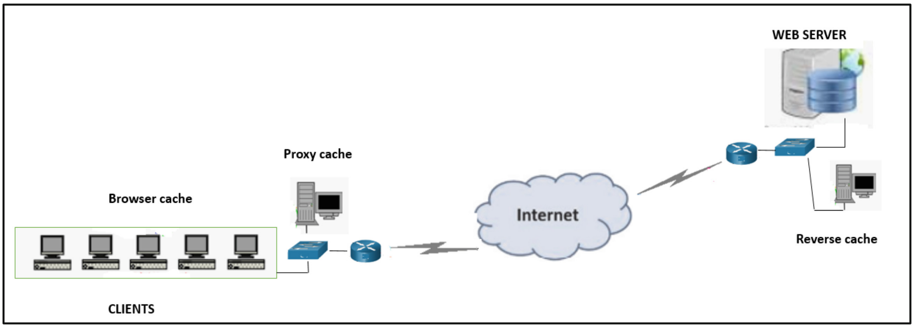

Fig. 1. Web caching service categories

When the implementation of Web caching service is next to a specific Web server instead of clients, reverse caching occurs since Web objects are stored away from clients and located closer to the Web server [24].

The proxy level caches are typically located closer to network gateway to reduce the bandwidth utilization over Internet connections and store objects from different web servers. This helps facilitate sharing of web resources. Proxy caching deployment has minimal interruption on the networking environment and is therefore the preferred configuration [25]. It achieves the economy of scale by offering services to several hosts and does not rely on the provisioning of Web servers. Consequently, end-to-end transparency during configuration change is not required since the implementation takes place within a local setting.

3 Network Environment

The implementation of proxy caching occurred on the gateway router within the community network. Figure 2 shows the topology of the community network. A 32GB Micro SD card stores Web objects for reuse. The cache system configuration adopts encrypted communication channel communication between clients and Web servers allowing the with the gateway router acting as the cache server to store and forward Web objects.

The retention of the Web object size at 500 MB and cache refresh timeout of 3 days remained in force. Enabling secure SSL channels between the gateway router and hosts on the LAN ensures security and privacy. While data collected at the router interface provides the characteristics of traffic flow to and from the Internet, the mirroring port on the LAN switch is a retrieval point for packet movement within the LAN. Packets sourced from the two capture points are dumped to disk for offline analysis.

The collection of traffic flow from both the ingress router interface and a mirroring port on the LAN switch used N-Top Deep Packet Inspection (nDPI) software [27]. To obtain exhaustive network status activity, nDPI performs traffic characterization based

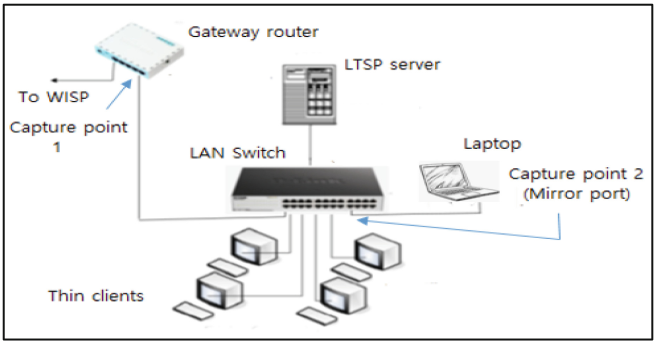

Fig. 2. Community network environment

on both MAC and IP addresses allowing recognition of IP and non-IP traffic. Additional flow information attainable from active interfaces include throughput statistics as well as Layer 4 and Layer 7 protocol activities.

4 Network Resource Utilization

4.1 Pre Web Caching

Before activating proxy caching on the gateway router, collection of control data was from both the router's ingress port and the mirroring port on the LAN switch occurred. The first instance of data collection was when the local loop capacity stood at 1 Mbps, the second occasion took place immediately after the bandwidth enhancement from to 10 Mbps [26]. A third data collection happened one month after the bandwidth upgrade to 10 Mbps [26]. The final pre-Web caching data collection took place after DNS service optimization [4]. Reported results include bandwidth utilization, traffic composition and traffic volume metrics at the four pre-Web caching measurement milestones.

Bandwidth Utilization

Table 1 shows the bandwidth utilization for the four measurement instances as 1 Mbps, 8.13 Mbps, 9.57 Mbps and 7.07 Mbps respectively. These were, before bandwidth upgrade, immediately following upgrade, one month after the upgrade and pre-DNS service optimization.

Table 1. Pre-Web Caching Bandwidth Utilization

Milestone	Before upgrade	Immediately after upgrade	One month after	After DNS service optimization
Bandwidth utilization (Mbps)	1.00	8.13	9.57	7.07

Traffic Composition and Traffic Volume

The composition of the monthly traffic collected at the router interface for the four measurement instances appears in Table 2. The highest proportion of local loop traffic is consistently web-based except one month after the bandwidth upgrade. The maximum contribution from web traffic is 95.49 and occurs after DNS optimization. The lowest proportion of 43.26% arises one month after the bandwidth upgrade.

Table 2. Percentage distribution of the top five applications

Application	Web	DNS	ICMP	NetBIOS	Unknown	Total traffic (GB)
Before upgrade	91.63	2.7	0.00	0.03	0.29	1.17
Immediately after upgrade	49.42	45.28	4.63	0.03	0.64	5.86
One month after upgrade	43.26	56.14	0.04	0.03	0.56	6.69
After DNS optimization	95.49	4.11	0.24	0.00	0.16	6.91

LAN Traffic

The analysis of data captured from the switch mirroring port immediately after the bandwidth upgrade shown in Fig. 3 indicate that SSL accounts for 48.83% of the total LAN traffic. The contribution from Google is 39.38%, Cloudflare 5.69% and Amazon 1.32%. The total LAN traffic is 25.97GB. Table 3 depicts the LAN traffic composition for the four data capture instances.

4.2 Post Web Caching

After enabling proxy caching on the gateway router, data collection takes place from both the router's ingress port and the mirroring port on the LAN switch for the duration of three months starting from 1st day of July to 30th day of September 2021. Results from the data analysis provided the updated bandwidth utilization, traffic composition and traffic volume.

Bandwidth Utilization

The weekly router interface traffic graph with proxy caching enabled is shown in Fig. 4. The maximum incoming traffic rate is 13.7 Mbps while the outgoing is 1.75 Mbps.

Traffic Composition and Traffic Volume

Figure 5 depicts the composition of local loop traffic. The highlighting of this information appears in Table 4. The highest proportion of traffic traversing the community network

Application	Duration	Sent	Received	Breakdown	Total	
Total	236:15:24	3.21 GB	22.76 GB	Sent Rcvd	25.97 GB	
Amazon	47:06:14	85.35 MB	257.49 MB	Sent Rcvd	342.84 MB	1.32 %
ApplePush	02:45:20	3.14 MB	14.59 MB	Sent Rcvd	17.73 MB	0.07 %
Cloudflare	27:34:16	152.36 KB	1.29 MB	Ser Rcvd	1.44 MB	5.69 %
DHCP	06:41:12	7.01 MB	7.01 MB	Sent Rcvd	14.02 MB	0.05 %
DNS	34:38:53	36.31 MB	61.54 MB	Sent Rcvd	97.65 MB	0.38 %
Facebook	04:15:03	13.61 MB	97.68 MB	Sen Rcvd	111.29 MB	0.43 %
Google	73:24:28	1.15 GB	9.19 GB	Ser Rcvd	10.34 GB	39.38 %
HTTP	04:15:35	17.98 MB	149.06 MB	Sen Rcvd	168.84 MB	0.65 %
ICMP	04:12:19	0 Bytes	2.61 MB	Rcvd	2.61 MB	0.01 %
IGMP	01:25:11	105.23 KB	0 Bytes	Sent	105.23 KB	0.0 %
LLMNR	04:53:23	5.22 MB	0 Bytes	Sent	5.22 MB	0.02 %
MDNS	03:46:54	5.22 MB	0 Bytes	Sent	5.22 MB	0.02 %
Microsoft	01:02:38	4.18 MB	6.26 MB	Sent Rcvd	10.44 MB	0.04 %
NetBIOS	16:36:29	26.11 MB	0 Bytes	Sent	26.11 MB	0.1 %
Office365	05:11:05	10.44 MB	41.78 MB	Sent Rcvd	52.22 MB	0.2 %
SNMP	83:07:47	54.39 MB	0 Bytes	Sent	54.39 MB	0.21 %
SSDP	42:14:25	171.41 MB	0 Bytes	Sent	171.41 MB	0.66 %
SSL	73:24:28	0.63 GB	12.05 GB	Se Rcvd	12.68 GB	48.83 %
UPnP	05:54:12	64.93 MB	0 Bytes	Sent	64.93 MB	0.25 %
Unknown	92:37:56	392.27 MB	20.15 MB	Sent Rc	412.92 MB	1.59 %
WhatsAppVoice	01:02:36	123.47 KB	0 Bytes	Sent	123.47 KB	0.0 %
WindowsUpdate	01:25:12	1.29 MB	1.29 MB	Sent Rcvd	2.58 MB	0.01 %
Yahoo	02:47:24	2.08 MB	8.31 MB	Sent Rcvd	10.39 MB	0.04 %
YouTubeUpload	00:36:39	2.34 MB	5.45 MB	Sent Rcvd	7.79 MB	0.03 %
eDonkey	00:36:38	6.23 MB	9.35 MB	Sent Rcvd	15.58 MB	0.06 %

Fig. 3. LAN traffic composition one month after bandwidth upgrade

is web-based at 52.54% followed closely by DNS with a contribution of 28.71%. The traffic volume through the router interface is 6.98 GB.

LAN Traffic

The analysis of data captured from the switch mirroring port shown in Fig. 6 and summarized in Table 5 indicate that. DNS accounts for 0.34% of the total LAN traffic. The contribution from Google is 55.58%, SSL 26.68% and Amazon 2.85%. The total LAN traffic is 18.65GB.

4.3 Comparison

The configuration of proxy caching on the gateway router was to mitigate the high proportion of the web component of the local loop traffic. To highlight the impact of web caching with respect to bandwidth utilization, traffic composition and traffic volume a comparison between pre and post Web caching is necessary.

Bandwidth Utilization

Table 6 shows the bandwidth utilization against the corresponding local loop capacity before bandwidth upgrade, immediately after bandwidth upgrade and one month

Table 3. LAN traffic composition prior to proxy caching activation

Application	SSL	Google	Apple	DNS	Microsoft	Facebook	Total traffic (GB)
Distribution (%) Before upgrade	4.76	41.52	0.01	0.65	0.83	0.0	20.18
Distribution (%) Immediately after	39.5	33.6	16.6	0.0	2.4	1.1	24.58
Distribution (%) One month after	48.83	39.38	0.07	0.36	0.04	0.43	25.97
Distribution (%) After DNS activation	11.98	32.22	0.09	0.18	42.95	0.0	19.43

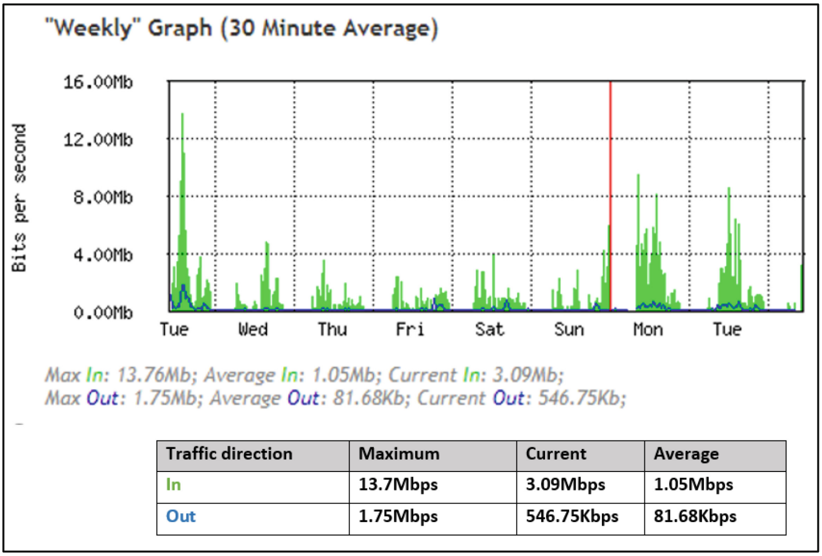

Fig. 4. Weekly Router Traffic Statistics – 10th August 2021

Direction ▾

Application	Duration	Sent	Received	Breakdown	Total	
Total	199:25:16	5.58 GB	1.48 GB	Sent Rcvd		6.98 GB
DNS	115:14:22	0.6 GB	1.41 GB	Sent Rcvd	2.01 GB	28.71 %
HTTP	6:53:15	3.48 GB	0.18 GB	Sent Rc	3.66 GB	52.54 %
ICMP	15:04:34	1.02 GB	0 MB	Sent	1.02 GB	14.69 %
Unknown	24:14:18	0.28 GB	2.9 MB	Sent	0.29 GB	4.06 %

Fig. 5. Router interface traffic composition and traffic volume - August 2021

Table 4. Tabular view of router interface traffic composition after proxy caching activation

Application	Web	DNS	ICMP	NetBIOS	Unknown	Total traffic (GB)
Distribution (%)	52.54	28.71	14.69	0.00	4.06	6.98

Application	Duration	Sent	Received	Breakdown	Total	
Total	218:25:16	1.92 GB	16.73 GB	Sen Rcvd		18.65 GB
Amazon	40:12:34	0.11 GB	0.42 GB	Sent Rcvd	0.53 GB	2.85 %
ApplePush	02:21:21	0.75 MB	1.11 MB	Sent Rcvd	1.86 MB	0.01 %
Cloudflare	25:18:07	59.00 MB	1..12 GB	Sen Rcvd	1:18 GB	6.33 %
DHCP	06:04:16	2.8 MB	2. 8 MB	Sent Rcvd	5.6 MB	0.03 %
DNS	32:18:25	1.9 MB	4.44 MB	Sent Rcvd	6.34 MB	0.34 %
Google	71:45:11	0.31 GB	10.05 GB	Se Rcvd	10.36 GB	55.58 %
GoogleServices	03:18:48	0.37 MB	7.09 MB	Sen Rcvd	7.46 MB	0.04 %
HTTP	04:03:38	12.60 MB	0.41 GB	Sei Rcvd	0.42 GB	2.3 %
ICMP	02:16:32	93.00 KB	1.77 MB	Sen Rcvd	1.86 MB	0.01 %
IGMP	01:04:19	56.00 KB	0 Bytes	Sent	56.00 KB	0.0 %
LLMNR	00:54:23	38.00 KB	0 Bytes	Sent	38.00 KB	0.0 %
MDNS	01:06:24	1.86 MB	0 Bytes	Sent	1.86 MB	0.01 %
Microsoft	18:11:23	22.38 MB	22.38 MB	Sent Rcvd	44.76 MB	0.24 %
NetBIOS	02:22:36	1.86 MB	0 Bytes	Sent	1.86 MB	0.01 %
Office365	02:26:47	13 MB	0.25 GB	Se Rcvd	0.26 GB	1.42 %
SNMP	62:03:25	24.25 MB	0 Bytes	Sent	24.25 MB	0.13 %
SSDP	58:45:37	78.15 MB	2.04 MB	Sent	80.19 MB	0.43 %
SSL	00:26:28	0.5 GB	4.48 GB	Sent Rcvd	4.98 GB	26.68 %
SSL_No_Cert	00:57:21	59 KB	0 Bytes	Sent	59 KB	0.0 %
Skype	00:58:26	0.78 MB	2.94 MB	Sent Rcvd	3.72 MB	0.02 %
UPnP	06:52:13	27.97 MB	0 Bytes	Sent	27.97 MB	0.15 %
Unknown	65:12:38	0.05 GB	0.49 GB	Sent Rcvd	0.54 GB	2.9 %
WindowsUpdate	01:52:35	2.98 MB	4.46 MB	Sent Rcvd	7.44 MB	0.04 %
Yahoo	02:03:12	2.79 MB	6.51 MB	Sent Rcvd	9.3 MB	0.05 %

Fig. 6. LAN traffic composition after proxy caching activation

Table 5. Tabular view of LAN traffic composition after proxy caching activation

Application	Google	SSL	Amazon	Office 365	DNS	Unknown	Total traffic (GB)
Distribution (%)	55.58	26.68	2.85	1.42	0.34	2.9	18.65

after upgrade bandwidth upgrade. Also indicated is the bandwidth utilization after DNS service optimization. The last data set reflects the bandwidth utilization after the activation of proxy caching. Before the upgrade, the local loop bandwidth was 1 Mbps. Subsequently, its enhancement to 10 Mbps occurred. After DNS service optimization, a second upgrade of the local loop bandwidth to 40 Mbps took place. Table 6 gives a glimpse of the relationship between bandwidth utilization and local loop capacity. A visual representation of this information appears in Fig. 7.

Table 6. Bandwidth utilization and local loop capacity

Milestone (Mbps)	Before upgrade	Immediately after upgrade	One month after upgrade	After DNS service optimization	After proxy caching
Bandwidth utilization	1.00	8.13	9.57	7.07	13.76
Local loop capacity	1.00	10	10	10	40

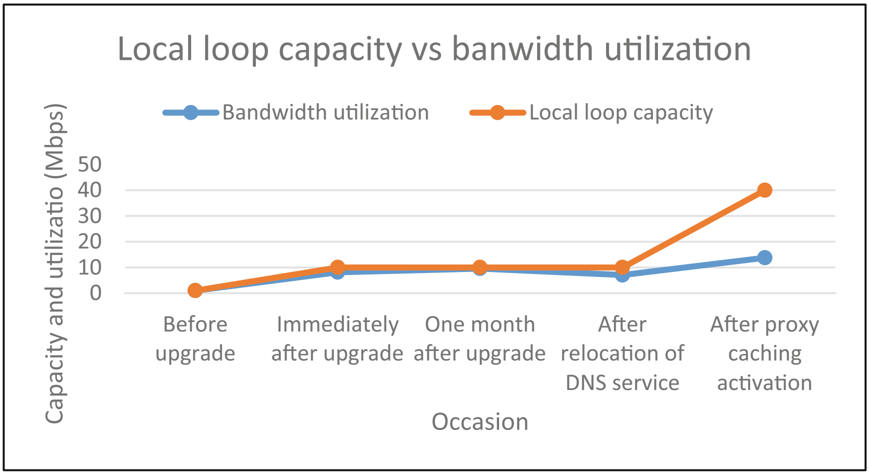

Fig. 7. Bandwidth utilization versus local loop capacity

Before the local loop capacity upgrade, the bandwidth utilization had peaked to the maximum capacity of 1 Mbps. When an upgrade to 10 Mbps occurred, bandwidth utilization increased to 8.13 Mbps. However, one month after the upgrade, bandwidth utilization rose to 9.57 Mbps. The optimization of DNS service helped reduce bandwidth utilization to 7.07 Mbps. As expected, the second bandwidth upgrade to 40 Mbps resulted in the increase of bandwidth utilization to 13.76 Mbps.

Traffic Composition

Table 7 shows the composition of local loop traffic before and after proxy cache configuration. The visual amplification of this information appears in Fig. 8.

Table 7. Router interface traffic composition after and before proxy caching activation

Application	Web	DNS	ICMP	NetBIOS	Unknown
Distribution (%) - After	52.54	28.71	14.59	0.00	4.06
Distribution (%) - Before	95.49	4.11	0.24	0.00	0.16

The deployment of a proxy cache on the gateway router resulted in a drop of the Web traffic from 95.49% to 52.54%. However, the DNS traffic component increased from 4.11% to 28.71%. Similarly, the unknown traffic flow proportion increased from 0.16% to 4.06%.

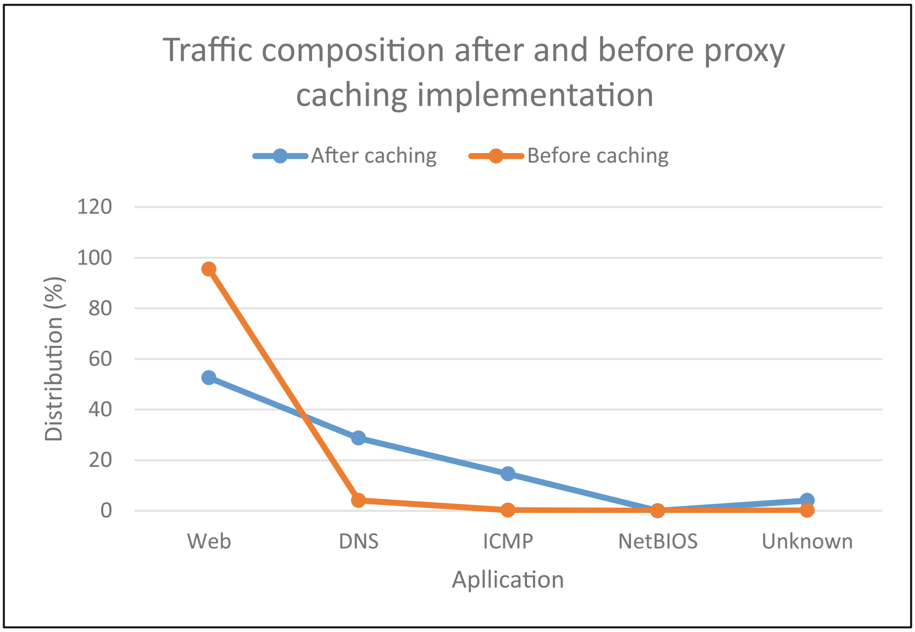

Fig. 8. Router interface traffic composition before and after proxy cache activation

The implementation of proxy caching led to an increase in the ICMP traffic portion from 0.24% to 14.59%. Only outgoing ICMP and Unknown packets from the LAN were noticeable with no evidence of incoming ICMP and Unknown packets as reflected in Fig. 6.

Traffic Volume

Table 8 shows the total local loop traffic volume as well as the LAN traffic volume before, immediately and one month after the bandwidth upgrade. Data collected after DNS service optimization and activation of proxy caching are also given.

Table 8. Local loop traffic volume and LAN traffic volume

Milestone	Before upgrade	Immediately after upgrade	One month after upgrade	After relocation of DNS service	After proxy caching
Local loop (GB)	1.17	5.86	6.69	6.91	6.98
LAN (GB)	20.18	24.56	25.97	19.43	18.65

The initial local loop and LAN total traffic were 1.17 GB and 20.18GB respectively. Both local loop and LAN traffic increased when bandwidth upgraded to 10 Mbps occurred. While the local loop traffic continued to rise one month after the bandwidth upgrade, DNS service optimization and proxy cache activation, the LAN traffic began to decline as shown in Fig. 9.

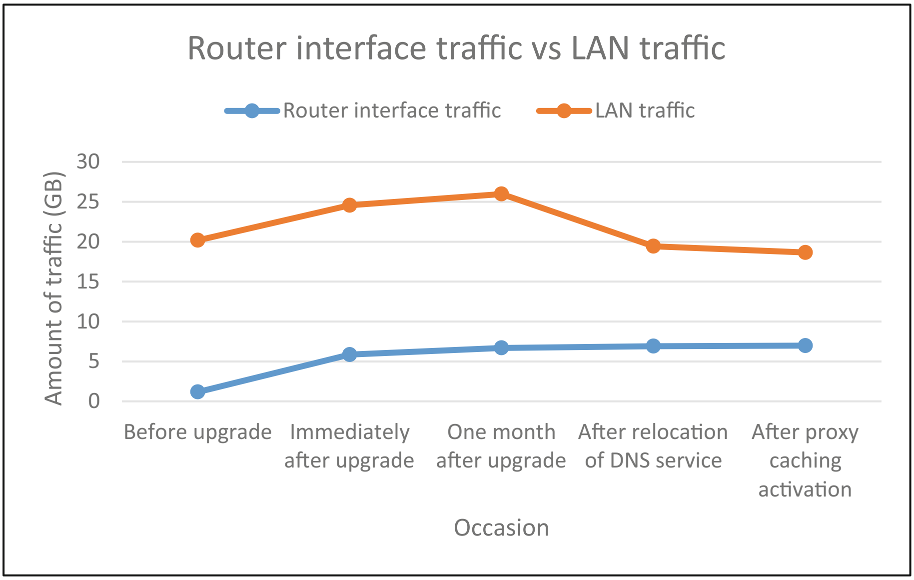

Fig. 9. Local loop traffic volume and LAN traffic volume comparison chart

The trend for the local loop traffic and LAN traffic are identical before bandwidth upgrade, immediately after upgrade and one month after the upgrade. The optimization of DNS service and activation of proxy caching resulted in a downward trend for the LAN traffic volume.

5 Discussion

Proxy caching activation on the gateway router resulted the bandwidth utilization increased from 7.07 Mbps to 13.76 Mbps represents a 94.6% surge. Prior to the implementation of proxy caching, the local loop capacity had been enhanced from 10 Mbps to 40 Mbps a 300% rise. The initial bandwidth upgrade from 1 Mbps to 10 Mbps which is a 900% escalation resulted in an increase of bandwidth utilization from 1 Mbps to 9.57 Mbps depicting a growth of 860%. Therefore, the activation of proxy caching resulted in a lower increase in bandwidth utilization. If the local loop capacity enhancement undergoes normalization to 100% through division by nine, the increase in bandwidth utilization before proxy caching activation would be 860% divide by nine resulting in 95.56%. Similarly, normalizing the second local loop upgrade to 100% through division by three gives the increase after the implementation of proxy caching to 94.6% divide by three resulting in 31.53%. This implies that the activation of proxy caching reduced the rate of increase in bandwidth utilization from 95.56% to 31.53% representing a 64.03% drop.

Before the activation of proxy caching, the Web component of the local loop traffic was 95.49%. This reduced to 52.54% after proxy caching configuration on the gateway router representing a 42.95% decrease. The main reason for implementing Web caching was to reduce the high proportion of the local loop Web traffic component. Therefore, the realization of this objective is evident.

During the initial bandwidth capacity enhancement from 1 Mbps to 10 Mbps representing an increase of 900%, the total router interface traffic grew from 1.17 GB to 5.86 GB which is a 400% rise. The subsequent bandwidth upgrade from 10 Mbps to 40 Mbps a 300% escalation led to an increase of the local loop traffic volume from 6.91 GB to 6.98 GB representing 1.01% rise. Normalizing the bandwidth capacity upgrade to 100%, the percentage increase in local loop traffic volume would be 400% divide by nine giving 44.44%. Using a similar reasoning, normalizing the subsequent local loop upgrade to 100% results in the increase in local loop traffic volume being 1.01% divided by three. This gives 0.34%. Therefore, implementing Web caching resting a drop of the local loop traffic volume from 44.44% to 0.34% representing a 44.1% reduction.

Despite the LAN traffic volume not being a major area of concern because of Ethernet capacity of 1Gbps, it is evident that the implementation of proxy caching leads to a decrease in the LAN traffic volume from 19.43 GB to 18.65 GB. This is a 4.01% reduction and occurs even though the local loop bandwidth underwent a 300% hike from 10 Mbps to 40 Mbps and therefore an increase in LAN traffic was expected.

6 Future Work

To gain better understanding of the full impact of proxy caching, it would be useful to reconfigure proxy caching on the LTSP server. This would provide data that can help establish the optimal configuration of the proxy caching within the community network environment. In addition, the implementation of reverse caching strategies in a simulated infrastructure would further assist in the investigation and quantification of the benefits of Web caching with respect to both bandwidth conservation, reduction of Web traffic and lowering of traffic volume.

7 Conclusion

Web caching is a recommended strategy for reducing bandwidth utilization and both local loop Web traffic component and traffic volume. In low capacity network environments, the main service provision constraint is the local loop. Therefore conserving local loop resource is a pleasant intervention.

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