



# Assessing the Impact of DNS Configuration on Low Bandwidth Networks

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**Abstract.** Domain name system (DNS) is an essential enabler for connecting users and services on the Internet. DNS translates human readable domain names into IP addresses and precedes client connection to a server via a domain name. DNS service is therefore expected to consume network bandwidth even though it offers no direct benefit to the user. Having observed the large component of DNS traffic on the community network local loop in our previous study, we migrated the DNS service from a server on the LAN to the gateway router and reconfigured the cache time-to-live. Results from the analysis of network traffic captured from the gateway router interface show a 26% decrease in the downlink bandwidth utilization and 46% decline in the uplink bandwidth utilization. The DNS component of the local loop traffic reduces from 45.28% to 4.11%. On the other hand, the Web component of the local loop traffic increases from 49.42% to 95.49%. Data collected from a mirroring port on the LAN switch indicate a decrease in the DNS portion of the internal traffic from 0.38% to 0.18%. Although the DNS reconfiguration helps alleviate network bandwidth constraints and reduces DNS component of the traffic, the Web portion increases. The implementation of effective, efficient and sustainable Web traffic management is therefore required.

**Keywords:** Bandwidth Utilization · Local Loop · Cache · Time-to-Live

## 1 Introduction

The common thread in low resourced community networks is limited bandwidth capacity. This necessitates careful use of the available bandwidth to avoid network throughput degradation and possible poor user experience [1]. It therefore becomes essential to deploy network bandwidth conservation techniques to counter the ever increasing user application bandwidth affinity. Since community networks operate within stringent budget constraints, it is not always feasible to enhance bandwidth in response to user requirements.

Instances of high levels of DNS traffic traversing low bandwidth community networks have been reported [2]. In this study, we attempt to reduce high proportions of

DNS traffic by relocating the DNS service from the Linux Terminal server to the gateway router. We subsequently monitor the local loop bandwidth utilization to establish the accrued impact. We also analyze the traffic composition of both the local loop and LAN to ascertain whether DNS reconfiguration results in less DNS traffic on the network. Since DNS service is a precursor to Web access, we examine the relationship between DNS reconfiguration and Web component of the network traffic.

The Linux Terminal Server Project (LTSP) helps in the booting of LAN clients from a single template installation that resides in a virtual machine image housed on the server [3]. This makes LTSP a strong candidate for deployment in a diskless client environment. Network services that can be provisioned on the LTSP server include DHCP, DNS, TFTP and SSH. For community networks, the LTSP server offers cost effectiveness, secure environment and ease of maintenance. However, a standard LTSP server installation is inefficient due to its limited ability to act as a recursive caching name server [4].

With the DNS service provisioned on the LTSP server, we analyzed the network bandwidth utilization for one month and thereafter migrated the DNS service from the LTSP server to the gateway router. We then carried out a similar evaluation for a three month period. The results show that the inbound bandwidth utilization dropped by 26% from 9.57 Mbps to 7.07 Mbps while the DNS component of the network traffic experienced a 41% decrease from 45.28% to 4.11%.

## 2 Related Work

DNS is the naming system of the Internet that translates human readable domain names into IP addresses. When a client connects to a web server a query that is resolved by the DNS server maps the server's domain name to an IP address. DNS clients often initiate requests to DNS servers over UDP but may forward requests over TCP [5]. UDP is preferred mode for DNS message transfer because setting up TCP connections require additional network utilization and necessitate the opening of TCP connections for longer durations leading to additional consumption of client and server resources. Danzig [6] established that implementation errors can cause DNS to consume 20 times extra WAN bandwidth than the norm.

According to Danzig [6], 14% of all wide-area packets were DNS in 1990, compared to 8% in 1992. As reported by Frazer [7], by 1995 the corresponding proportion of DNS traffic from the NSFNET study was 5%. From the 1997 study of the MCI backbone, the DNS portion of the WAN traffic reduced to 3% [8] indicating consistent improvement in DNS service configuration architecture. However, considering that most TCP traffic incrementally continue to consist mainly of Web traffic, which produces four connections for each successful DNS mapping [9], the reduction in DNS component of the WAN traffic is justifiable.

DNS servers can be categorized as either authoritative or recursive resolvers [10]. While authoritative name servers have the root information for a domain, recursive resolvers temporarily save the mapping results in a cache. Although each host has the capacity to run its own resolver, the practice is to host a central resolver within an organization [11]. To improve network performance, users tend to opt for recursive resolvers situated outside of their organizations [12]. A study by Muller [13] established that recursive resolvers consult all authoritative servers over time and half of recursive resolvers

prefer low latency service from authoritative servers. The preference is noticeable when there is significant latency differences in the offerings from authoritative servers. High latency results in more network bandwidth requirements.

Efficiency in DNS service requires extensive caching of responses based on the predefined time-to-live (TTL) [14]. While longer TTL values result in higher cache hit rates and less DNS traffic, lower TTL values give service providers more dynamic IP address to host name mappings and enhanced traffic flow. In mobile networking, dynamic DNS in tandem with low TTL bindings are provisioned for host mobility support [15]. Jung [16] established that when popular web sites were commissioned, the percentage of TCP connections made to DNS servers with low TTL values increased from 12% to 25% due to the increased server selection for popular sites. Results from this study suggest that caching is critical to DNS scalability since it helps reduce load on the root servers and generic top-level domain servers.

The Akamai Content Delivery Network attempts to provide media resources from nearby servers using DNS to drive clients to close proximity data centers [17]. In the Akamai setup, the first IP address received from DNS responses emanates from the closest server. This IP address has a higher likelihood of being adopted than subsequent addresses. However in standard DNS configurations, the IP address rotation performed by the recursive DNS servers distributes load across the advertised servers [18]. A study by Callahan [14] reports that 75% of the hostnames map to a single IP address while 8% have a mapping to two IP addresses. Results from the study further indicate that 11% of the hostnames associate with a minimum of five IP addresses affirming the existence of IP address replicas for specific hostnames.

## 3 Network Environment

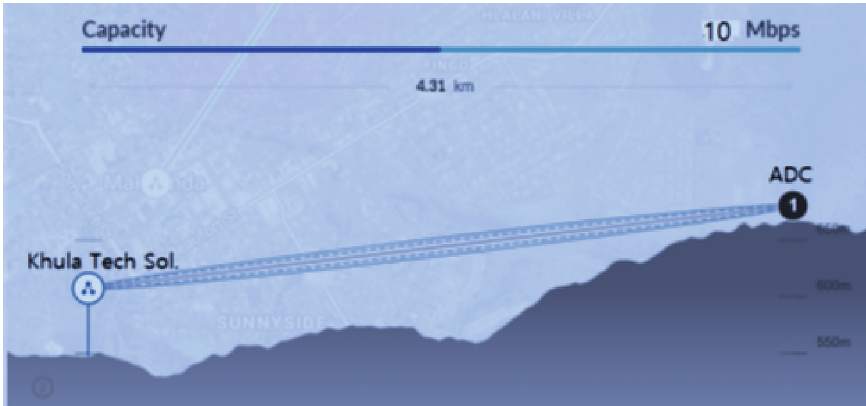
### 3.1 Local Loop

The Assumption Development Center (ADC) community network local loop consists of a unidirectional wireless system stationed at Khula Technology Solutions and an antenna deployed at the community center. The terrain view of the local loop from Khula Technology Solution to ADC is shown in Fig. 1. Khula Technology Solutions is the Wireless ISP (WISP). The aerial distance covered by the local loop is approximately 4.31 km. At the commencement of this study, the bandwidth of the local loop was 10 Mbps. However, the capacity was subsequently increased to 40 Mbps two months later.

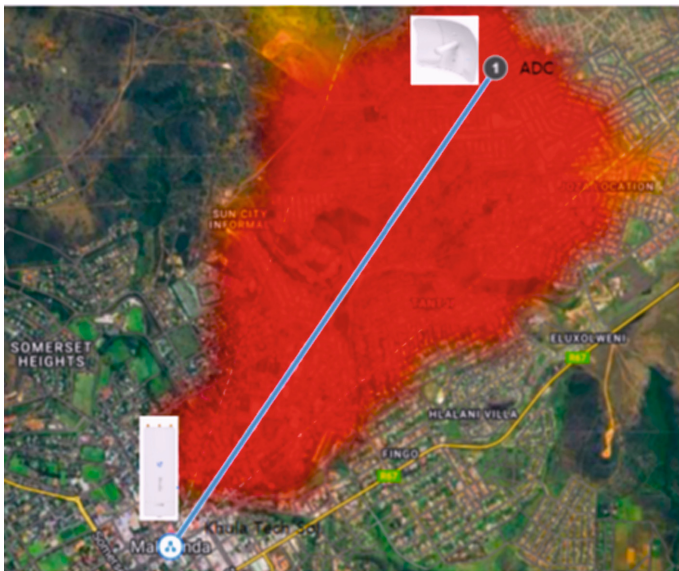
Figure 2 represents the satellite view of the local loop from the WISP to the community center. A clear line of site exists between the two locations. The signal strength shown in red shading is sufficient to cater for the requirements of the local community.

### 3.2 Local Area Network

For community networks, thin clients offer a viable and sustainable option. The deployment of thin clients is best achieved using the Linux Terminal Server Project (LTSP) architecture [19]. It is for this reason that the ADC community network uses thin clients solution. LTSP allows thin clients in a LAN to boot through the network from a single



**Fig. 1.** Terrain view of the local loop from WISP to the Community Centre (ADC)



**Fig. 2.** Satellite view of the local loop from WISP to the Community Centre

server. The communication between clients and the server is relayed through SSH-tunnels making transactions secure. In our initial LAN configuration shown in Fig. 3, the LTSP server is responsible for booting the thin clients and providing both DNS and DHCP services. We subsequently relocate the DNS service to the gateway router and analyze the traffic to establish impact on bandwidth utilization.

The community center has a computer laboratory where 10 thin clients with access to the Internet are situated. A wireless access point is available for staff and community members who prefer to use their own devices.

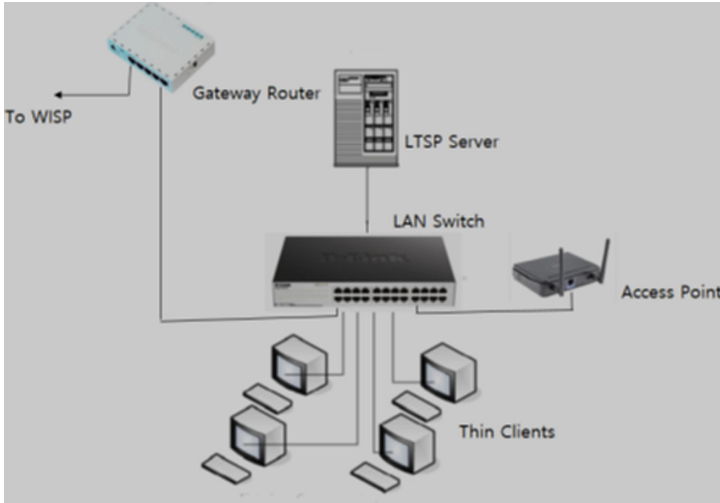


Fig. 3. Local Area Network Topology for the Community Centre

## 4 Network Usage

For this study, we collect packets from both the ingress gateway router interface and a mirroring port on the LAN switch using N-Top Deep Packet Inspection (nDPI) software [20]. While the router interface data provides traffic information to and from the Internet, the mirroring port on the switch gives an indication of the LAN traffic composition. We dump packets received from the two measurement points to disk for offline analysis. Initially, we configure DNS service on the LTSP server with the default TTL value of 24 h [21] and collect data from the 1st of March 2021 to the 31st of March 2021. We subsequently relocate the DNS service to the gateway router and collect packets from the 1st of April to the 30th of June 2021 retaining the default DNS TTL value for MikroTik RouterBoard RB750GR3 hEx of 60 s [22].

### 4.1 DNS Hosted by LTSP Server

The weekly router interface traffic graph with DNS provisioned on the LTSP server is shown in Fig. 4. The maximum incoming traffic rate is 9.57 Mbps while the outgoing is 8.01 Mbps.

The composition of the monthly traffic collected at the router interface is shown in Fig. 5 and highlighted in Table 1. The highest proportion of traffic traversing the community network is web based at 49.42% followed closely by DNS with a contribution of 45.28%.

The analysis of data captured from the switch mirroring port shown in Fig. 6 indicates that DNS component accounts for 0.38% of the total LAN traffic. The focus of the analysis is on DNS and contributions to the LAN traffic from some applications are omitted.

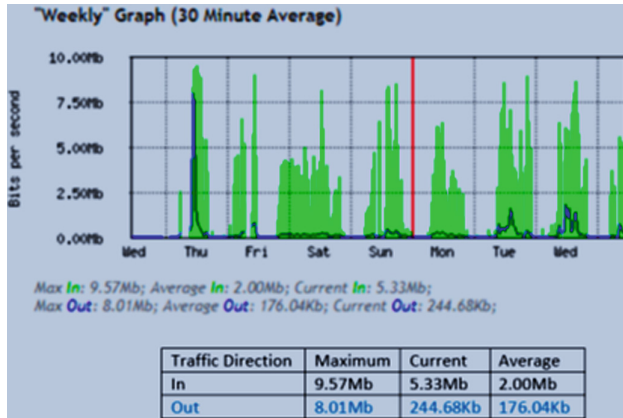


Fig. 4. Router interface weekly traffic data collected on the 26th of March 2021

Application	Duration	Sent	Received	Breakdown	Total
Total	136:20:20	521.16 MB	148.08 MB		669.24MB
DNS	120:16:30	195.91MB	107.70 MB		303.61 MB 45.28 %
HTTP	3:06:35	306.02MB	23.44 MB		329.46 MB 49.42 %
ICMP	5:09:30	15.1 MB	16.47 MB		31.57 MB 4.63 %
NetBIOS	24:40	0 MB	0.23 MB		0.23 MB 0.03 %
Unknown	6:14:55	4.13MB	0.24 MB		4.37 MB 0.64 %

Fig. 5. Monthly traffic distribution for data collected from the 1st to 31st of March 2021

Table 1. Percentage distribution of the top five applications

Application	Web	DNS	ICMP	NetBIOS	Unknown
Distribution (%)	49.42	45.28	4.63	0.03	0.64

Application	Duration	Sent	Received	Breakdown	Total
Total	236:15:24	3211.87 GB	22761.11 GB		25972.98 GB
Amazon	47:06:14	85.35 GB	257.49 GB		342.84 GB 1.32 %
ApplePush	02:45:20	3.14 GB	14.59 GB		17.73 GB 0.07 %
Cloudflare	27:34:16	152.36 MB	1.29 GB		1.44 GB 5.69 %
DHCP	06:41:12	7.01 GB	7.01 GB		14.02 GB 0.05 %
DNS	34:38:53	36.31 GB	61.54 GB		97.65 GB 0.38 %
Facebook	04:15:03	13.6 GB	97.69 GB		111.29 GB 0.43 %
Google	73:24:28	1149.11 GB	9193.05 GB		10342.16 GB 39.38 %
HTTP	04:15:35	17.98 GB	149.06 GB		168.84 GB 0.65 %

Fig. 6. Analysis of data collected from switch mirroring port – Focus is on DNS

### 4.2 DNS Hosted by Gateway Router

The weekly router interface traffic with DNS provisioned at the default gateway router is shown in Fig. 7. The maximum incoming traffic rate is 7.07 Mbps while the outgoing is 4.29 Mbps.

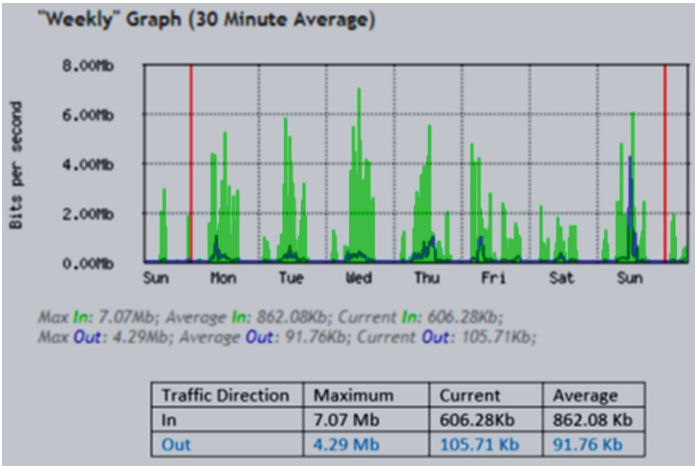


Fig. 7. Router interface weekly traffic data collected on the 13th of April 2021

The composition of the traffic collected at the router interface for a period of three months is shown in Fig. 8 and highlighted in Table 2. The highest proportion of traffic traversing the community network is web based at 95.49%. DNS portion of the traffic is 4.11%.

Application	Duration	Sent	Received	Breakdown	Total
Total	144:45:35	644.52 GB	146.68 GB	<div style="display: flex; justify-content: space-between;"> <span>Sent</span> <span>Recv</span> </div>	791.2 GB
DNS	80:05:31	20:53 GB	12.17 GB	<div style="display: flex; justify-content: space-between;"> <span>Sent</span> <span>Recv</span> </div>	32.7 GB, 4.11%
HTTP	64:35:02	621.54 GB	134.96 GB	<div style="display: flex; justify-content: space-between;"> <span>Sent</span> <span>Recv</span> </div>	756.5 GB, 95.49%
ICMP	00:48	1.1 GB	0 GB	<div style="display: flex; justify-content: space-between;"> <span>Sent</span> <span>Recv</span> </div>	1.1 GB, 0.24%
Unknown	00:04:15	655 NB	665 MB	<div style="display: flex; justify-content: space-between;"> <span>Sent</span> <span>Recv</span> </div>	1.3 GB, 0.16%

Fig. 8. Composition of traffic collected from the 1st of April to 30th of June 2021

Table 2. Percentage distribution of the top five applications immediately after network upgrade

Application	Web	DNS	ICMP	NetBIOS	Unknown
Distribution (%)	95.49	4.11	0.24	0.00	0.16

The analysis of data captured from the switch mirroring port shown in Fig. 9 indicates that DNS component accounts for 0.18% of the total LAN traffic. The focus of the

analysis is on DNS and contributions to the LAN traffic from some applications are omitted.

Application	Duration	Sent	Received	Breakdown	Total	Direction
Total	456:29:25	14359.03 GB	179959.51 GB		194318.54 GB	
Amazon	16:01:05	203.02 GB	418.80 GB	Send Received	621.82 GB	0.32%
ApplePush	05:00:20	32.07 GB	142.82 GB	Send Received	174.89 GB	0.09%
Cloudflare	15:30:01	61.15 GB	151.60 GB	Send Received	213.75 GB	0.11%
DHCP	22:01:30	62.99 GB	53.60 GB	Send Received	116.59 GB	0.06%
DNS	97:30:04	137.62 GB	212.15 GB	Send Received	349.77 GB	0.18%
Google	148:36:45	2570.16 GB	60039.27 GB	Send Received	62609.43 GB	32.22%
GoogleServices	03:20:15	36.37 GB	255.11 GB	Send Received	291.48 GB	0.15%
HTTP	84:52:21	1523.63 GB	9027.87 GB	Send Received	10551.50 GB	5.43%
ICMP	06:00:25	0.01 GB	38.85 GB	Send Received	38.86 GB	0.02%
IGMP	00:48:35	0.04 GB	0.15 GB	Send Received	0.19 GB	0.0%
LLMNR	07:10:06	19.42 GB	0.01 GB	Send Received	19.43 GB	0.01%

Fig. 9. Analysis of data collected from switch mirroring port – Focus is on DNS

### 4.3 Comparison

Migrating DNS service from the LTSP server lowers the downlink bandwidth utilization by 26% from 9.57 Mbps to 7.07 Mbps. The uplink bandwidth utilization reduces by 46% from 8.01 Mbps to 4.29 Mbps. The DNS composition of the traffic traversing the community network decreases from 45.28% to 4.11%. On the other hand, the web portion of the traffic increases significantly from 49.42% to 95.49% as indicated in Fig. 10.

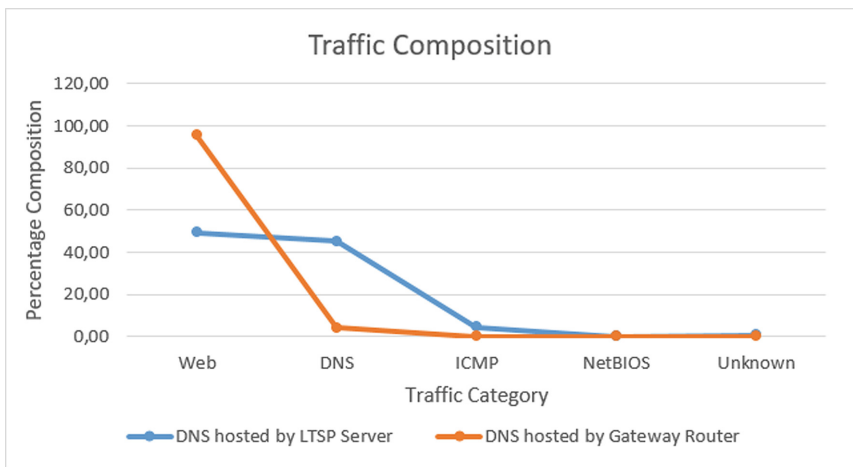


Fig. 10. Composition of traffic traversing the community network

When DNS is provisioned on the LTSP server, the DNS component of the LAN traffic is 0.38% whereas with the DNS hosted by the gateway router, the contribution of DNS to the LAN traffic is 0.18% reflecting a decrease of 52.6%.

## 5 Discussion

With DNS provisioned on the LTSP Server, the DNS component of the traffic traversing the community network is relatively high. We lower the DNS component of the traffic to the WISP by relocating DNS service to the gateway router. Incidentally this action also results in the reduction of DNS component of the LAN traffic. The advantages the gateway router has over the LTSP server are threefold. Firstly, the DNS cache TTL is 30 s instead of 24 h as is the case with the LTSP server. Secondly, the gateway router is a hop closer to the WISP than the LTSP server and therefore able to contact authoritative DNS servers faster. Lastly, the gateway router has less tasks to contend with compared to the LTSP server which takes care of DHCP services and is also responsible for booting the thin clients.

Reducing the DNS traffic component has the desirable effect of lowering the network bandwidth utilization which is our main goal. Since the majority of community network users are interested largely in Web services which requires DNS resolution beforehand, lowering DNS traffic leads to improved experience. As a result, a significant increase in Web component of the traffic traversing the community network occurs. The implication of this is that the community network is able to accommodate more users.

The composition of Web traffic observed after relocating the DNS service from the LTSP server to the gateway router is 95.49%. We intend to investigate how this can be lowered. One way of achieving this is by caching web pages at either the LTSP server or the gateway router and establishing the impact on network bandwidth utilization. Any solution that could help mitigate bandwidth consumption would be beneficial to the community and remains our number one objective.

## 6 Future Work

To ensure the community network service offering remains of acceptable quality we intend to implement Web caching capabilities so as to reduce the Web traffic. We will then establish the impact of Web caching on bandwidth utilization. Having observed that network usage is lower when the DNS service is provisioned at the gateway router, better performance may accrue from configuring Web caching on this device as well. We intend to limit the maximum inbound bandwidth utilization to 80% below the available network capacity.

## 7 Conclusion

The change in DNS configuration resulted in lower bandwidth utilization and reduced the DNS component of the traffic traversing both the network to the WISP and LAN. However, the existence of a large portion of the web component of the local loop traffic is an issue that needs to be resolved. Therefore, our next effort will be devoted to the implementation of effective, efficient and sustainable web traffic management. Our goal is to enforce prudent network bandwidth management based on the observed traffic profile so as to avoid frequent bandwidth upgrade requirements.

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