# 400G kTLS/SSL Offload & Encryption with FreeBSD

## Secure TCP/IP processing with T7 Inline kTLS/SSL Crypto Function

## Executive Summary

The Inline kTLS/SSL offload capability offered by Chelsio T7 adapters is uniquely capable of producing 370Gbps rate kTLS/SSL performance. They are designed specifically to perform computationally intensive cryptographic operations more efficiently than general purpose CPUs. Servers with system load comprising of cryptographic operations see great performance improvement by offloading crypto operations to the Chelsio T7 adapter. Thanks to an inbox driver in the FreeBSD kernel, T7-based adapters are plug-and-play solutions for secure networking.

This paper presents Chelsio 400G Inline kTLS/SSL offload performance (using T7 for networking only) with a real-world application, nginx web server running in FreeBSD. It establishes the fact that using T7 to offload the encryption, the web server consumes significantly less CPU with consistent performance.

## Chelsio T7 Inline kTLS/SSL Solution

The Terminator 7 (T7) ASIC from Chelsio Communications, Inc. is a seventh generation, high performance 1/10/25/40/50/100/200/400G unified wire engine which enables concurrent secure communication and secure storage, all for the price and power of a typical NIC. T7 supports most of the popular AES/SHA cipher suites in inline kTLS/SSL mode with **367 Gbps** (wire BW rate) and **326 Gbps** (application BW rate) bandwidth.

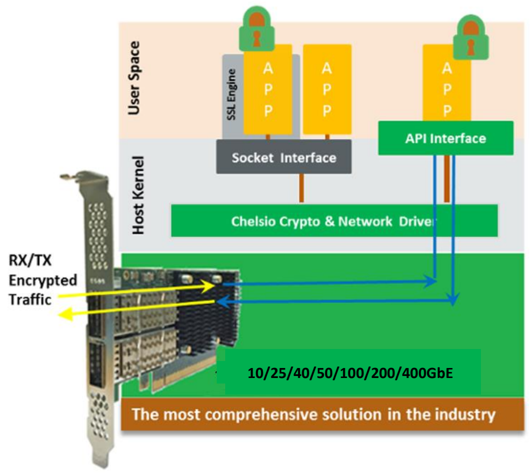

User Space
SSL Engine
APP
APP
APP
Socket Interface
API Interface
Host Kernel
Chelsio Crypto & Network Driver
RX/TX Encrypted Traffic
10/25/40/50/100/200/400GbE
The most comprehensive solution in the industry

Figure 1 - Chelsio T7 Inline kTLS/SSL

- T7 adapters offload the kTLS/SSL PDU crypto, while handshake is still performed by the host.
- OpenSSL modifies and provides hooks for data transmission, receive, and key programming.
- Third party/customized kTLS/SSL implementations are also supported.
- Supports crypto for all kTLS/SSL ports.

## Test Results

The following graph compares the throughput and CPU usage using Chelsio T7 crypto accelerator in Inline kTLS/SSL offload mode. The numbers are collected using **wrk** tool with connections ranging from 10 to 100.

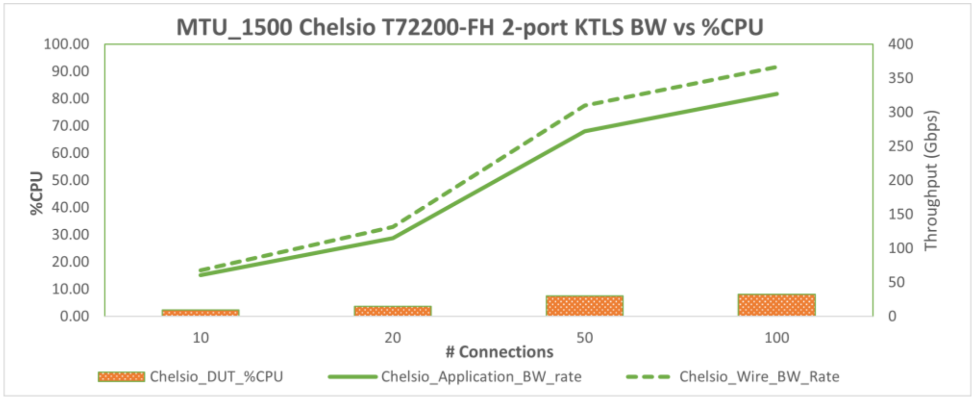
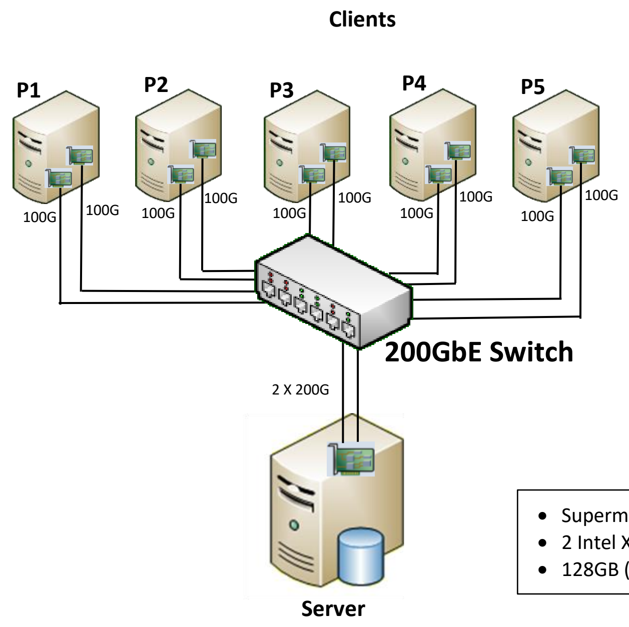


Figure 2 - Throughput and CPU Usage vs. # Connections

The above graph describes the relationship between the number of connections, CPU utilization, and throughput performance for Chelsio T7 adapters using Kernel TLS (KTLS). As the number of connections increases from 10 to 100, both application and wire bandwidth rise sharply, reaching peak throughput of approximately **367 Gbps** (wire BW rate) and **326 Gbps** (application BW rate) with moderate CPU usage.

## Test Configuration



**P1, P2**

- Dell PowerEdge R660 with 2 x T62100-CR adapters
- 2 x Intel(R) Xeon(R) Platinum 8452Y (HT disabled)
- 512GB (DDR5, 4800 MHz)
- RHEL9.6 (6.12.x kernel)

**P3**

- Dell PowerEdge R760 with 2 x T62100 adapters
- 2 x Intel(R) Xeon(R) CPU E5-1660 v4 @ 3.20GHz (HT disabled)
- 512GB (DDR5, 4800 MHz)
- RHEL9.5 (6.12.x Kernel)

**P4, P5**

- Supermicro X10DRG-Q with 2 x T62100 adapters
- 2 x Intel(R) Xeon(R) CPU E5-2687W v3 @ 3.10GHz (HT disabled)
- 12GB (DDR4, 2133 MHz)
- RHEL9.5 (6.12.x Kernel)

- Supermicro X13DEI with T72200-FH adapter
- 2 Intel Xeon CPU Gold 6530-core @ 1.90GHz (HT disabled)
- 128GB (DDR5, 4800 MHz)

Figure 3 – Test setup

The setup consists of a server connected to five clients using dual ports on each system. The server machine was configured with FreeBSD inbox drivers, and the client was configured with the latest Chelsio Unified Wire drivers for Linux. Chelsio T72200-FH adapter was installed on the Server with standard MTU of 1500B, while two Chelsio T62100-CR adapters were installed in each Client system and Port0 of each adapter configured with the standard MTU of 1500B.

## Setup Configuration

**Server**

BIOS settings:

- Disable Hyper-Threading Technology.
- Disable Sub-NUMA Clustering (SNC).
- Disable CPU Power Management Features including C-states, P-states, and Turbo Boost
- Configure System power management profile in Maximum Performance Mode.

i. Download and install **FreeBSD-16.0** from https://www.freebsd.org/ and compile latest kernel with below fix:
https://reviews.freebsd.org/D53385

ii. Add below knobs to /boot/loader.conf :

```
root@host:~ # cat /boot/loader.conf
hw.cxgbe.ntxq="32"
hw.cxgbe.nrxq="32"
hw.cxgbe.qsize_txq="2048"
hw.cxgbe.qsize_rxq="2048"
hw.cxgbe.holdoff_timer_idx="5"
hw.cxgbe.lro_mbufs="1024"
```

iii. Configure T7 interfaces with KTLS enabled:

```
root@host:~ # sysctl kern.ipc.tls.enable=1
root@host:~ # sysctl kern.ipc.tls.ifnet.permitted=1
root@host:~ # kldload if_cxgbe
root@host:~ # ifconfig che0 103.11.11.235/24 mtu 1500 up
root@host:~ # ifconfig che1 103.22.22.235/24 mtu 1500 up
root@host:~ # sysctl -w dev.chnex.0.tls.inline_keys=1
```

iv. Install nginx server and use below config file:

```
root@host:~ # cat /usr/local/etc/nginx/nginx.conf
worker_processes  auto;
events {
    worker_connections  4096;
}
http {
    include       mime.types;
    default_type  application/octet-stream;
    sendfile        on;
    keepalive_timeout  65;
    client_body_buffer_size 16k;
    proxy_buffer_size 4k;
    proxy_buffers 32 4k;
    proxy_busy_buffers_size 64k;
    server {
        listen       443 ssl;
        listen       [::]:443 ssl;
        server_name  nolin;
        ssl_certificate      cert.pem;
        ssl_certificate_key  cert.key;
        ssl_session_cache    shared:SSL:1m;
        ssl_session_timeout  5m;
        ssl_ciphers  HIGH:!aNULL:!MD5;
        ssl_protocols TLSv1.3 TLSv1.2 TLSv1.1;
        ssl_prefer_server_ciphers  on;
        ssl_conf_command Options KTLS;
        location / {
            root   /usr/local/www/nginx;
            index  index.html index.htm;
        }
    }
}
```

v. Create two files each of 2GB size for client access:

```
root@host:~ # ls /usr/local/www/nginx/P*2G
/usr/local/www/nginx/P0_2G    /usr/local/www/nginx/P1_2G
```

vi. Start nginx server:

```
root@host:~ # cpuset -l <0-31> -n ft:0 service nginx onestart
```

This configuration binds the nginx process to CPU cores 0-31, which correspond to the NUMA node local to the Chelsio T72200-FH network adapter.

**Client**

- Same as server BIOS options.
- Compile and install kernel version 6.12.28 on RHEL9.5 OS on each Peer, install the latest drivers available from Chelsio Download Center.

i. Disable virtualization, C-states technology, VT-d, Intel I/O AT, SR-IOV in system BIOS.
ii. Add the below parameters to grub kernel command line and boot into the newly installed 6.12.28 kernel.

```
[root@host~]# grubby --args="intel_idle.max_cstate=0 processor.max_cstate=0
intel_pstate=disable" --update-kernel="boot/vmlinuz-6.12.28"
```

iii. Install Chelsio Unified Wire drivers.

```
[root@host~]# cd ChelsioUwire-x.x.x.x
[root@host~]# make install
```

iv. Set the below tuned-adm profile.

```
[root@host~]# tuned-adm profile network-throughput
```

v. Load the Chelsio Network driver and bring up interfaces with IPv4 address.

```
[root@host~]# modprobe cxgb4
[root@host~]# ifconfig ethX <IPv4 address> up; ifconfig ethY <IPv4 address> up
```

ethX is a T6 interface from adapter1, ethY is a T6 interface from adapter2.

vi. CPU affinity was set.

```
[root@host~]# t4_perftune.sh -n -Q nic -c 1-16
```

vii. On each peer run below commands in parallel:

```
[root@host~]# numactl -N0 -m0 wrk -c<#conns> -t20 -d30 -v https://103.11.11.235/P0_2G &
[root@host~]# numactl -N1 -m1 wrk -c<#conns> -t20 -d30 -v https://103.22.22.235/P1_2G &
```

#conns is number of connections per client (ranging from 1 - 10).

## Conclusion

This paper describes the performance of Chelsio's T7 SSL offload solution on FreeBSD. The Chelsio T7 Inline kTLS/SSL offload achieves performance, delivering **367 Gbps wire bandwidth** and **326 Gbps application bandwidth** with **minimal CPU utilization**, significantly outperforming software-based encryption. By offloading cryptographic operations to hardware, it ensures higher efficiency, lower latency, and consistent scalability. With native FreeBSD inbox driver support, T7 provides a seamless, high-performance solution for secure and efficient data center networking.

## Related Links

Chelsio T7 NIC Performance Leadership Across Tx, Rx, and BiDi Workloads
High-Performance NIC Optimization on Linux With Chelsio T7
AI Networking Solution: Chelsio T7 DPU and S7/T6 SmartNICs
T7 Product Brief
AI Networking: The Role of DPUs
Offload Protocols with Inline IPsec demonstration on T7 Emulation Platform
iSCSI JBOF with T7
NVMe/TCP and iSCSI JBOF with T7