Fast, Flexible Packet Filtering

Lua Kernel Scripting in NetBSD

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Talk Outline

1. Background and Setup
2. Experiments
3. Performance Results
4. Conclusion

Acknowledgements

Co-investigator Sam Freed

Existing Lua scripting support in NetBSD, Marc Balmer [1]

Significant NPF Lua groundwork laid by Lourival Vieira Neto [2] [3]

Background and Setup

Lua and NetBSD

Kernel-space Lua scripting support built into NetBSD [1]

Framework to make kernel subsystems (such as NPF) scriptable

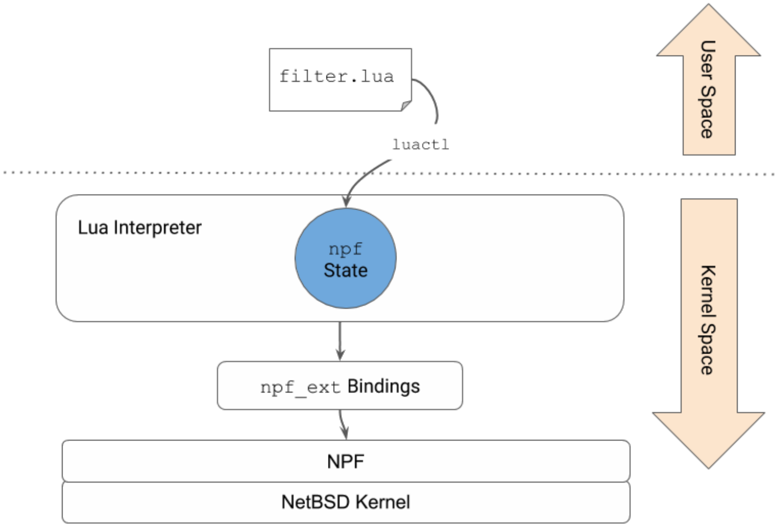
Emphasis on system integrity and performance

NetBSD Packet Filter (NPF) and Lua

`npf_ext_lua` kernel binding [2]

- Integrates directly with NPF
- Flexibility of Lua
- Supports deep packet inspection

NetBSD Packet Filter (NPF) and Lua



With the `npf_ext_lua` kernel binding, we can write packet filtering scripts in Lua.

Key Question

What is the impact on packet filtering performance when we introduce Lua?

Experiments

Setup: Test Environment

VirtualBox VMs running 64-bit NetBSD v7.0

4GB of RAM, 2 x Intel(R) Xeon(R) CPU D-1521 @ 2.40GHz

Virtual NIC speed: 1 Gbps

Setup: Kernel Module

Existing `npf_ext_lua` implementation and support code:

- `https://github.com/lneto/luadata`
- `http://netbsd.org/~lneto/pending/`
- To avoid a stack overflow error under load, add `lua_pop(L, 1);` after the line that begins with `*decision =` in the function `npf_lua()`

Setup: npf.conf

```
procedure "lua_filter" {
  # filter_function is defined in separate .lua file
  # which must be loaded into the npf state
  lua: call filter_function
}
group default {
  pass in proto tcp to $ext_if port n apply "lua_filter"
}
```

Luadata Layout: TCP Header

```
local data = require("data")
local tcphdr_layout = {
    src_port = {0, 16, 'number', 'net'},
    dst_port = {16, 16, 'number', 'net'},
    seq_num = {32, 32, 'number', 'net'},
    ack_num = {64, 32, 'number', 'net'},
    data_offset = {96, 4, 'number', 'net'},
    reserved = {100, 3, 'number', 'net'},
    control_flags = {103, 9, 'number', 'net'},
    window_size = {112, 16, 'number', 'net'},
    checksum = {128, 16, 'number', 'net'},
    urgent = {144, 16, 'number', 'net'}
}
# Layouts for other protocols take a similar form
```

Packet Filtering in Lua

```lua
-- packet_filter.lua
function filter_function(pkt)
    pkt:layout(iphdr_layout)
    tcphdr_offset = pkt.ihl * 4
    pkt = pkt:segment(tcphdr_offset)
    pkt:layout(tcphdr_layout)
    tcpdata_offset = pkt.data_offset * 4
    pkt = pkt:segment(tcpdata_offset)
    local str = tostring(pkt)

    -- packet is dropped if function returns false
    return str:find("MALICIOUS VALUE") == nil
end
```

Luactl Usage

```
# luactl load npf ./packet_filter.lua
```

This loads packet filtering code, defined in the file `packet_filter.lua`, into the `npf` Lua state.

Performance Results

Test Scenarios

(1) Simple pass-through
(2) Packet header inspection: length check
(3) Deep packet inspection: search packet body for malicious string
(4) ICMP flood

Where applicable, we compare with NPF-only approach

Traffic Generation and Measurement

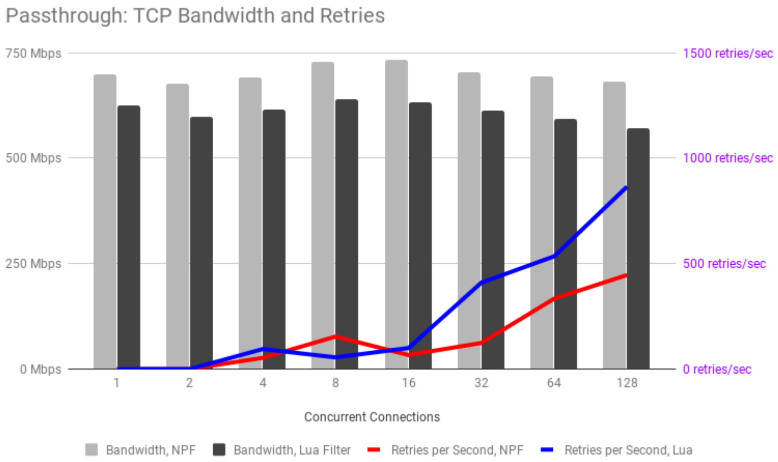
iPerf3 (`https://iperf.fr/`)

- `iperf3 -c` *`host`* `--interval 0 --bandwidth 0 --parallel` *`N`* `--file test.data`
- Measures average bandwidth (Mbps) and retry statistics

Nping (`https://nmap.org/nping/`)

- `nping --icmp --icmp-type echo-request --hide-sent --rate 100 -c 100` *`host`*
- Measures raw packets per second and RTT

Results 1 of 4: Pass-through

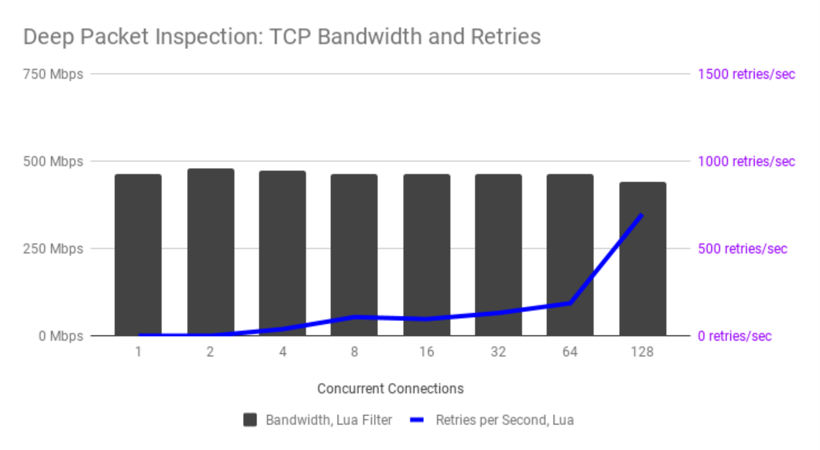


Results 2 of 4: Header Inspection

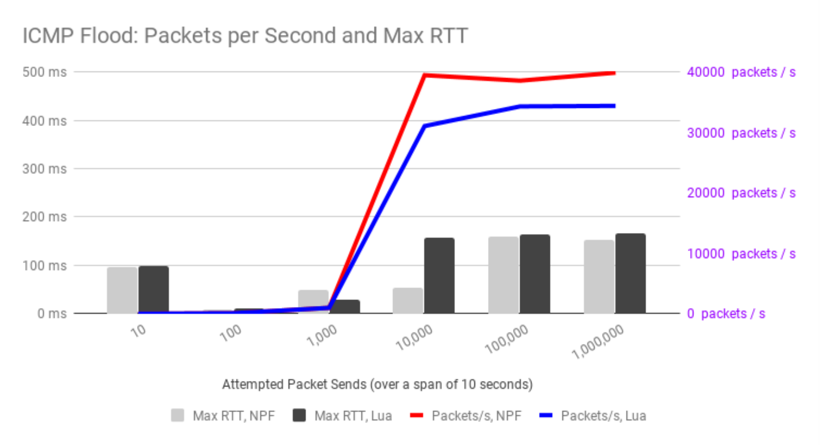
```
# npf.conf / pcap-filter
block in pcap-filter "udp and port N and greater 128"
```

```lua
-- Lua
function length_check(pkt)
    pkt:layout(iphdr_layout)
    udphdr_offset = pkt.ihl * 4
    pkt = pkt:segment(udphdr_offset)
    pkt:layout(udphdr_layout)
    return pkt.length > 128
end
```

Results 3 of 4: Deep Inspection



Results 4 of 4: ICMP Flood



Conclusion

Performance Summary

- Lua performs well, achieves good average bandwidth and high packets/second
- Adding Lua to NFP introduces an approximate 10-15% bandwidth reduction based on simple performance tests

Possibilities

- Advanced deep packet inspection logic using approachable Lua syntax
- Rapidly adapt to new packet filtering requirements
- Experiment with approaches to packet filtering: novel data structures and algorithms

Summary

- Lua can greatly extend NPF and `pcap-filter`
- Lua filtering scripts are extremely flexible and easy to maintain
- Packet filtering using the Lua scripting language, while fundamentally practicable, warrants additional investigation and profiling in areas such as:
  - CPU and memory usage
  - Impact of multi-core CPUs
  - String matching on TCP streams

Questions?

Thank you!

Further questions? **avondoll@calpoly.edu**

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