Firewall Intermediate Report

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December 5, 2014

1 Objective

I will be implementing a firewall on a Linux-based kernel that mediates access to an internal network. Given time, I will also implement a DMZ where components of the network may live outside the firewall if they need to. This project will be developed incrementally. I will first implement a stateless firewall. This means that every packet will be analyzed. I will then test the scalability of such an approach and implement a stateful approach. The implementation of the stateful approach will be discussed in the code section.

2 Firewall Language Grammar

The firewall language grammer is what tells our program which packets to block and which packets to allow through to our internal network. We need this grammar so our program parses packets correctly. The firewall language grammar will be implemented incrementally. I will primarily leverage the pcap-filer functionality to implement many of these rules. The rule syntax will generally follow the BSD syntax used in HW2. That syntax is as follows.

```
action [direction] [log] [quick] [on interface] [af] [proto protocol] \
   [from src_addr [port src_port]] [to dst_addr [port dst_port]] \
   [flags tcp_flags] [state]
```

We will not be implementing the log facility right now. This will be an extension at the end of the project cycle, because there needs to be a way to move the logged file from the firewall to the device that requested the shot. The easiest way to accomplish that is to create a HTTP server that interacts with users within the network. The second easiest way to implement the log facility is to name the log file and store it in a well known location. A user within the network can then FTP the file over with the well known details.

In the same vein, the interface of capture will be the single input interface to our firewall. This is dependent on the environment the firewall is running on, but generally there is one interface from which we are mediating access. If we want to mediate internal traffic, we will of course need to accept from multiple interfaces. This will be implemented after we implement logging.

The rest of the fields can be translated generally one-to-one to pcap filtering rules.

3 Code and Data Structures

Right now, there is a simple loop and a simple handler that grab packets off of the currently used interface. The handler for the packets captured linearly checks against a filter string. This is not extensible as there is only one rule in effect at all times.

The reason this happened was that I was basing a lot of my code from the libpcap tutorial provided by Stanford. I will be switching to a different architecture once I resolve an issue discussed in section 5.

The current architecture I have in mind is to have multithreaded pcap capture loops that grab packets that conform to their firewall rule. The $n + 1^{th}$ rule will specifically avoid packets captured by the n rule by careful use of the pcap filter expression. So, to make things easier for us, our firewall tries to match to the first rule, going top to bottom.

For a block rule, the captured packet references a special pcap handler that simply does nothing to the packet. For a pass rule, we reference a handler that injects the packet to our internal network interface port. This will give us most of the functionality that we need for our firewall. For our DMZ, we have its rules at the top of our rule set. We then have our capture loop reference a handler that forwards the packet to the DMZ interface port.

However, this will not really scale. We need a way to maintain states of connections so we do not have handle packet analysis at every packet. For large (elephant) streams, this would be very cumbersome. I am not completely sure as to how I'm going to implement state with my pre-existing code structure.

As a first step, I will maintain a hashtable of connections hashed by the source ip address within our network and the destination ip address outside our network. This hashed value will refer to a linked list that maintains all the connections between the pair. I anticipate each linked list to have average size 10. This is because many multiple connections are primarily caused by HTTP. Most browsers open 1-10 concurrent connections to a source. If this not true in practice, I will also hash by source and destination ports. This can only happen if ports exist within the connection protocol, so a special port number will be given to protocols that do not have ports.

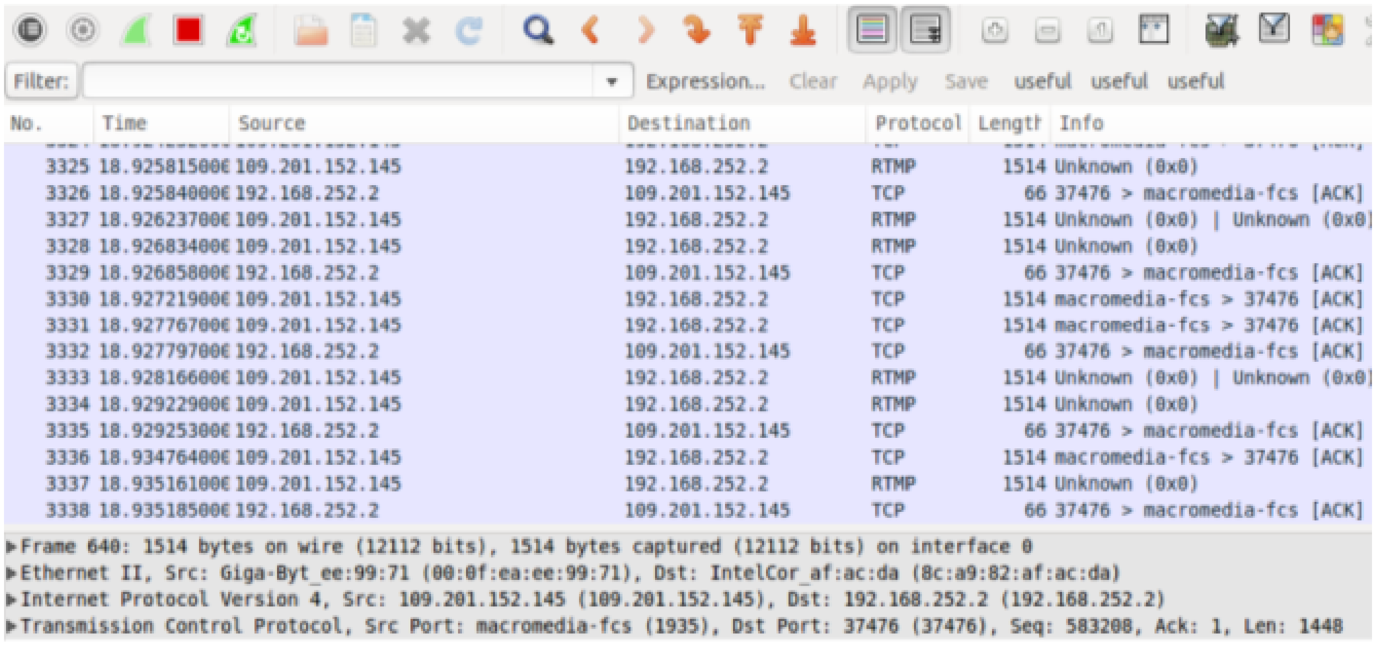
Given this somewhat constant lookup time, each loop handler will lookup whether a connection exists. If it does, we skip our updates and analyses and just forward the packet. I do not know whether I will need this state, as most of the classification is being done by our pcap filters in our capture loops. I need to investigate further.

4 Testing Strategy

The testing strategy is as follows. I will be using my HP laptop which runs Ubuntu 14.04 LTS. I will capture packets from my `wlan0` interface to feed to my firewall. Of course, to test functionality of the rules, I will capture beforehand and use libpcap's ability to read from pcap files. The `wlan0` interface will primarily test the scalability of my code. Once the packets are ingested by the program, the firewall will analyze the packets and match against rules as described in the aforementioned section. My firewall will then output the allowed packet on another interface. Usually this is described by the command line parameters; my testing instance will rely on the `eth0` interface on my laptop.

To verify our rules work, I will be using the Wireshark tool. A picture of a sample Wireshark capture all is shown in Figure 1.

I will capture the `eth0` interface. This is very useful as I can see whether my rules



```
No.    Time         Source            Destination      Protocol Length Info
  3325 18.925815006 109.201.152.145   192.168.252.2    RTMP     1514 Unknown (0x0)
  3326 18.925840006 192.168.252.2     109.201.152.145  TCP        66 37476 > macromedia-fcs [ACK]
  3327 18.926237006 109.201.152.145   192.168.252.2    RTMP     1514 Unknown (0x0) | Unknown (0x0)
  3328 18.926834006 109.201.152.145   192.168.252.2    RTMP     1514 Unknown (0x0)
  3329 18.926858006 192.168.252.2     109.201.152.145  TCP        66 37476 > macromedia-fcs [ACK]
  3330 18.927219006 109.201.152.145   192.168.252.2    TCP      1514 macromedia-fcs > 37476 [ACK]
  3331 18.927767006 109.201.152.145   192.168.252.2    TCP      1514 macromedia-fcs > 37476 [ACK]
  3332 18.927797006 192.168.252.2     109.201.152.145  TCP        66 37476 > macromedia-fcs [ACK]
  3333 18.928166006 109.201.152.145   192.168.252.2    RTMP     1514 Unknown (0x0) | Unknown (0x0)
  3334 18.929229006 109.201.152.145   192.168.252.2    RTMP     1514 Unknown (0x0)
  3335 18.929253006 192.168.252.2     109.201.152.145  TCP        66 37476 > macromedia-fcs [ACK]
  3336 18.934764006 109.201.152.145   192.168.252.2    TCP      1514 macromedia-fcs > 37476 [ACK]
  3337 18.935161006 109.201.152.145   192.168.252.2    RTMP     1514 Unknown (0x0)
  3338 18.935185006 192.168.252.2     109.201.152.145  TCP        66 37476 > macromedia-fcs [ACK]

▶Frame 640: 1514 bytes on wire (12112 bits), 1514 bytes captured (12112 bits) on interface 0
▶Ethernet II, Src: Giga-Byt_ee:99:71 (00:0f:ea:ee:99:71), Dst: IntelCor_af:ac:da (8c:a9:82:af:ac:da)
▶Internet Protocol Version 4, Src: 109.201.152.145 (109.201.152.145), Dst: 192.168.252.2 (192.168.252.2)
▶Transmission Control Protocol, Src Port: macromedia-fcs (1935), Dst Port: 37476 (37476), Seq: 583208, Ack: 1, Len: 1448
```

Figure 1: A sample Wireshark capture on our interface. You can see a streaming TCP connection in the capture.

accurately work in real time. I can then replicate my test with a dumped pcap file that Wireshark generates. The testing then also remains contained to a single machine. This way, I will not have to deal much with external network rules.

Essentially, my firewall becomes a pipe for network packets. To implement the DMZ and make the firewall more of a switch as it needs to be, I just need an interface to pipe the DMZ packets. I then just add rules to pipe packets destined to the DMZ to the appropriate interface. That will be one of the last things implemented, as it is a trivial extension if our system woks. It is just reapplying our functionality to implement a new feature.

5 Progress So Far

Currently I am able to ingest packets from the `wlan0` interface and analyze them with a generic handler. I am able to implement very simple rules that can be captured via the pcap filter. However, I can only implement one rule at a time. Of course, the block all rule works trivially.

The only problem I have with my code right now is exporting out to the `eth0` interface. I anticipate this problem will be solved within the weekend, as pcap was designed to handle exactly what I am trying to accomplish.