网络广播实验报告

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1、实验内容

（1）实现节点广播的 broadcast_packet 函数。

（2）验证广播网络能够正常运行：从一个端节点 ping 另一个端节点

（3）验证广播网络的效率：在 three_nodes_bw.py 进行 iperf 测量

（4）自己动手构建环形拓扑，验证该拓扑下节点广播会产生数据包环路。

2、实验流程

（1）实现节点广播的 broadcast_packet 函数。编译 hub 程序。

（2）修改脚本并运行，完成广播网络功能测试:

```
hub = './hub'
print(b1.cmd(hub+' &'))


print('test h1')
print(h1.cmd('ping -c 4 10.0.0.2'))
print(h1.cmd('ping -c 4 10.0.0.3'))
print('test h2')
print(h2.cmd('ping -c 4 10.0.0.1'))
print(h2.cmd('ping -c 4 10.0.0.3'))
print('test h3')
print(h3.cmd('ping -c 4 10.0.0.1'))
print(h3.cmd('ping -c 4 10.0.0.2'))
```

（3）修改脚本并运行，完成广播网络效率测试：

```
print(h1.cmd('iperf -s > out1 &'))
h2.cmd('iperf -c 10.0.0.1 -t 30 &')
h3.cmd('iperf -c 10.0.0.1 -t 30')

print('test h1 to h2 and h3:')
print(h2.cmd('iperf > out2 -s &'))
print(h3.cmd('iperf > out3 -s &'))
h1.cmd('iperf -c 10.0.0.2 -t 30 & iperf -c 10.0.0.3 -t 30')

raw_input('done.')
print('test h2 h3 to h1:')
os.system('cat out1')
```

```
print('test h1 to h2 and h3:')
os.system('cat out2')
os.system('cat out3')
```

（4）修改拓扑结构，验证环形拓扑下数据报形成环路。

拓扑结构修改如下（见 topo.py）：

```
h1 = self.addHost('h1')
h2 = self.addHost('h2')
b1 = self.addHost('b1')
b2 = self.addHost('b2')
b3 = self.addHost('b3')

self.addLink(h1, b1, bw=10)
self.addLink(h2, b2, bw=10)
self.addLink(b2, b1, bw=10)
self.addLink(b3, b1, bw=10)
self.addLink(b2, b3, bw=10)
```

3、功能实现

broadcast_packet 函数

收到每个数据包，将该包从所有其它网络端口发出去。

```
void broadcast_packet(iface_info_t *iface, const char *packet, int len)
{
    iface_info_t *iface_n = NULL;
    list_for_each_entry(iface_n, &instance->iface_list, list) {
        if (iface_n->fd != iface->fd)
            iface_send_packet(iface_n, packet, len);
    }
}
```

4、结果与讨论

（1）广播网络功能测试(ping)

结点拓扑结构如图 1。测试结果如图 2。结果显示，各 host 节点之间连接正常。

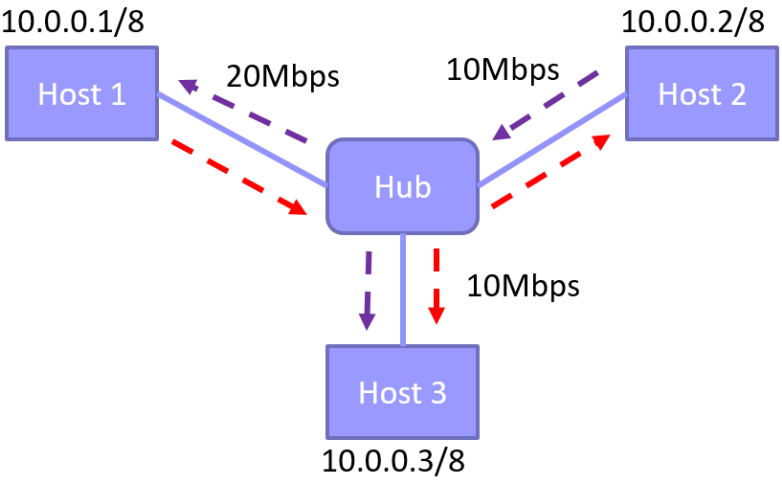

图 1

```
test h1
PING 10.0.0.2 (10.0.0.2) 56(84) bytes of data.
64 bytes from 10.0.0.2: icmp_seq=1 ttl=64 time=1020 ms
64 bytes from 10.0.0.2: icmp_seq=2 ttl=64 time=1.03 ms
64 bytes from 10.0.0.2: icmp_seq=3 ttl=64 time=0.407 ms
64 bytes from 10.0.0.2: icmp_seq=4 ttl=64 time=0.382 ms

--- 10.0.0.2 ping statistics ---
4 packets transmitted, 4 received, 0% packet loss, time 3034ms
rtt min/avg/max/mdev = 0.382/255.514/1020.231/441.509 ms, pipe 2

PING 10.0.0.3 (10.0.0.3) 56(84) bytes of data.
64 bytes from 10.0.0.3: icmp_seq=1 ttl=64 time=0.435 ms
64 bytes from 10.0.0.3: icmp_seq=2 ttl=64 time=0.366 ms
64 bytes from 10.0.0.3: icmp_seq=3 ttl=64 time=0.584 ms
64 bytes from 10.0.0.3: icmp_seq=4 ttl=64 time=0.348 ms

--- 10.0.0.3 ping statistics ---
4 packets transmitted, 4 received, 0% packet loss, time 3064ms
rtt min/avg/max/mdev = 0.348/0.433/0.584/0.094 ms
```

(a) h1 ping h2, h3

```
test h2
PING 10.0.0.1 (10.0.0.1) 56(84) bytes of data.
64 bytes from 10.0.0.1: icmp_seq=1 ttl=64 time=0.539 ms
64 bytes from 10.0.0.1: icmp_seq=2 ttl=64 time=0.379 ms
64 bytes from 10.0.0.1: icmp_seq=3 ttl=64 time=0.342 ms
64 bytes from 10.0.0.1: icmp_seq=4 ttl=64 time=0.408 ms

--- 10.0.0.1 ping statistics ---
4 packets transmitted, 4 received, 0% packet loss, time 3064ms
rtt min/avg/max/mdev = 0.342/0.417/0.539/0.074 ms

PING 10.0.0.3 (10.0.0.3) 56(84) bytes of data.
64 bytes from 10.0.0.3: icmp_seq=1 ttl=64 time=0.657 ms
64 bytes from 10.0.0.3: icmp_seq=2 ttl=64 time=0.491 ms
64 bytes from 10.0.0.3: icmp_seq=3 ttl=64 time=0.419 ms
64 bytes from 10.0.0.3: icmp_seq=4 ttl=64 time=0.439 ms

--- 10.0.0.3 ping statistics ---
4 packets transmitted, 4 received, 0% packet loss, time 3031ms
rtt min/avg/max/mdev = 0.419/0.501/0.657/0.096 ms
```

(b) h2 ping h1, h3

```
test h3
PING 10.0.0.1 (10.0.0.1) 56(84) bytes of data.
64 bytes from 10.0.0.1: icmp_seq=1 ttl=64 time=0.491 ms
64 bytes from 10.0.0.1: icmp_seq=2 ttl=64 time=0.428 ms
64 bytes from 10.0.0.1: icmp_seq=3 ttl=64 time=0.431 ms
64 bytes from 10.0.0.1: icmp_seq=4 ttl=64 time=0.443 ms

--- 10.0.0.1 ping statistics ---
4 packets transmitted, 4 received, 0% packet loss, time 3031ms
rtt min/avg/max/mdev = 0.428/0.448/0.491/0.029 ms

PING 10.0.0.2 (10.0.0.2) 56(84) bytes of data.
64 bytes from 10.0.0.2: icmp_seq=1 ttl=64 time=0.449 ms
64 bytes from 10.0.0.2: icmp_seq=2 ttl=64 time=0.352 ms
64 bytes from 10.0.0.2: icmp_seq=3 ttl=64 time=0.428 ms
64 bytes from 10.0.0.2: icmp_seq=4 ttl=64 time=4.52 ms

--- 10.0.0.2 ping statistics ---
4 packets transmitted, 4 received, 0% packet loss, time 3062ms
rtt min/avg/max/mdev = 0.352/1.438/4.524/1.782 ms
```

(c)h3 ping h1,h2

图 2

（2）广播网络效率测试(iperf)

结点拓扑结构如图 1。

① h2 和 h3 同时向 h1 测量。

```
test h2 h3 to h1:
------------------------------------------------------------
Server listening on TCP port 5001
TCP window size: 85.3 KByte (default)
------------------------------------------------------------
[  4] local 10.0.0.1 port 5001 connected with 10.0.0.2 port 36318
[  5] local 10.0.0.1 port 5001 connected with 10.0.0.3 port 48058
[ ID] Interval       Transfer     Bandwidth
[  4]  0.0-31.1 sec  32.6 MBytes  8.81 Mbits/sec
[  5]  0.0-31.9 sec  33.2 MBytes  8.73 Mbits/sec
```

图 3 h2->h1, h3->h1, h1 带宽

```
------------------------------------------------------------
Client connecting to 10.0.0.1, TCP port 5001
TCP window size: 85.3 KByte (default)
------------------------------------------------------------
[  3] local 10.0.0.3 port 48058 connected with 10.0.0.1 port 5001
[ ID] Interval       Transfer     Bandwidth
[  3]  0.0-30.5 sec  33.2 MBytes  9.15 Mbits/sec
```

图 4 h2->h1, h2 带宽

```
------------------------------------------------------------
Client connecting to 10.0.0.1, TCP port 5001
TCP window size: 85.3 KByte (default)
------------------------------------------------------------
[  3] local 10.0.0.2 port 36318 connected with 10.0.0.1 port 5001
[ ID] Interval       Transfer     Bandwidth
[  3]  0.0-30.1 sec  32.6 MBytes  9.09 Mbits/sec
```

图 5 h3->h1, h3 带宽

从图 3-图 5 看出 h1 处的吞吐量为 8.81+8.73=16.54Mbps，（单向）带宽利用率为 82.7%。h2 处的吞吐量为 9.15Mbps，利用率为 91.5%，h3 处的吞吐量为 9.09Mbps，利用率 90.9%。

② h1 同时向 h2 和 h3 测量。

```
------------------------------------------------------------
Client connecting to 10.0.0.3, TCP port 5001
TCP window size: 85.3 KByte (default)
------------------------------------------------------------
[  3] local 10.0.0.1 port 58608 connected with 10.0.0.3 port 5001
------------------------------------------------------------
Client connecting to 10.0.0.2, TCP port 5001
TCP window size: 85.3 KByte (default)
------------------------------------------------------------
[  3] local 10.0.0.1 port 51310 connected with 10.0.0.2 port 5001
[ ID] Interval       Transfer     Bandwidth
[  3]  0.0-30.1 sec  25.8 MBytes  7.19 Mbits/sec
```

图 6 h1->h2, h1->h3, h1 带宽

```
Server listening on TCP port 5001
TCP window size: 85.3 KByte (default)
------------------------------------------------------------
[  4] local 10.0.0.2 port 5001 connected with 10.0.0.1 port 51310
[ ID] Interval       Transfer     Bandwidth
[  4]  0.0-30.5 sec  7.50 MBytes  2.06 Mbits/sec
```

图 7 h1->h2, h2 带宽

```
Server listening on TCP port 5001
TCP window size: 85.3 KByte (default)
------------------------------------------------------------
[  4] local 10.0.0.3 port 5001 connected with 10.0.0.1 port 58608
[ ID] Interval       Transfer     Bandwidth
[  4]  0.0-30.4 sec  25.8 MBytes  7.10 Mbits/sec
```

图 8 h1->h3, h3 带宽

从图 3-图 5 看出 h1 处的吞吐量为 7.19Mbps，（单向）带宽利用率为 35.95%。h2 处的吞吐量为 2.06Mbps，利用率为 20.6%，h3 处的吞吐量为 7.10Mbps，利用率 71.0%。

情况②的带宽利用率较低，因为当 h1 同时向 h2 和 h3 发包时，在 b1 处包会被复制，在 b1->h2 有 h1 发往 h3 的包，在 b1->h3 有 b1 发往 h2 的包，这些冗余包占用了带宽，故总带宽利用率不到 50%。对于情况①，h2 往 b1,h1 发包时，在 b1 会被分为两份，其中一份发往 h3，但 b1->h3 的带宽和 h3->b1 的带宽是独立的，h3->b1 的包不受影响，故（单向）带宽利用率接近 100%。

由于数据链路层会把数据包额外加上一些信息，不计入带宽计算中；而且接收端返回的确认包也会占用带宽，故带宽利用率达不到 100%。

情况②中，h1->h2 的带宽显著高于 h1->h3 的带宽，若改变 h1->h2 和 h1->h3 的顺序，对结果也没有显著影响。可能是因为 b1 在处理包时，按一定的转发顺序串行处理。经测验，若将广播函数改为并发的，则这两处带宽将趋于一致。另外，若在转发包时不对接收缓冲区进行复制操作而直接转发，也能使这两处带宽将趋于一致。具体原因尚不明确。

（3）环路广播测试

搭建的环路如图 9。

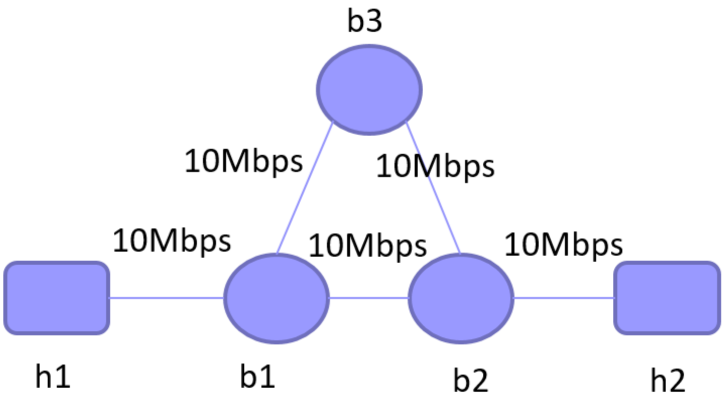

图 9

h1 向 h2 发出 ping 命令后，各个转发节点的 hub 程序输出如图 10 所示，说明环路中包被不断复制转发。

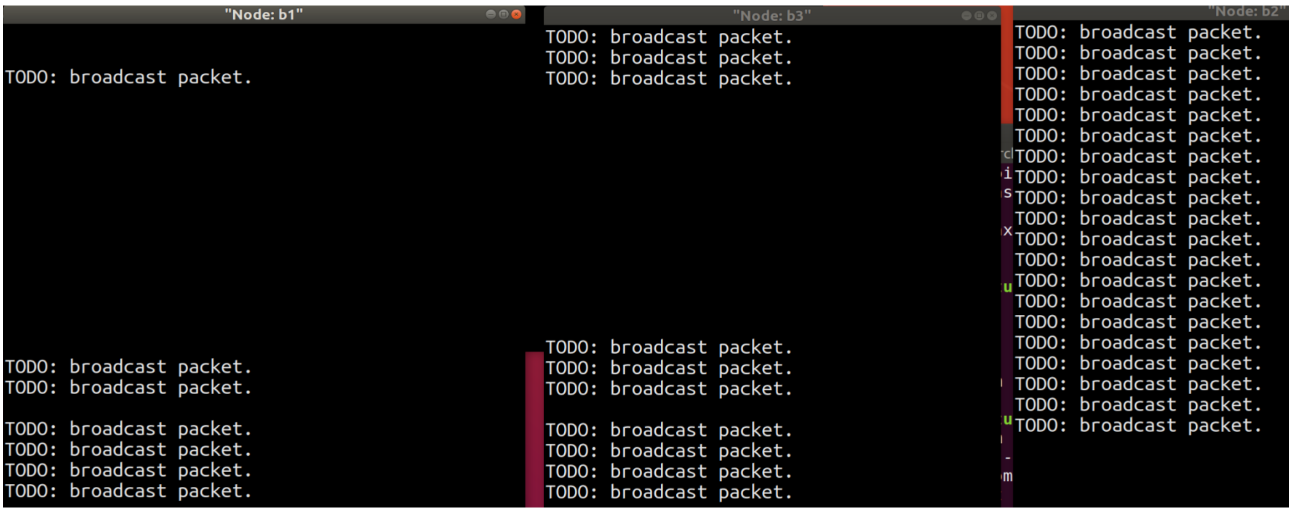

图 10

图 11 显示了 wireshark 的抓包结果，同样验证了该环形拓扑结构下形成了数据包环路。

No.	Time	Source	Destination	Protocol	Length	Info
7355	22.153673943	3a:6e:fe:26:3c:54	5e:5e:44:70:fe:fd	ARP	42	10.0.0.1 is at 3a:6e:fe:26:3c:54
7356	22.153693751	3a:6e:fe:26:3c:54	5e:5e:44:70:fe:fd	ARP	42	10.0.0.1 is at 3a:6e:fe:26:3c:54
7357	22.153715951	3a:6e:fe:26:3c:54	5e:5e:44:70:fe:fd	ARP	42	10.0.0.1 is at 3a:6e:fe:26:3c:54
7358	22.153735529	3a:6e:fe:26:3c:54	5e:5e:44:70:fe:fd	ARP	42	10.0.0.1 is at 3a:6e:fe:26:3c:54
7359	22.153757807	5e:5e:44:70:fe:fd	3a:6e:fe:26:3c:54	ARP	42	10.0.0.2 is at 5e:5e:44:70:fe:fd
7360	22.153778428	3a:6e:fe:26:3c:54	5e:5e:44:70:fe:fd	ARP	42	10.0.0.1 is at 3a:6e:fe:26:3c:54
7361	22.153800622	5e:5e:44:70:fe:fd	3a:6e:fe:26:3c:54	ARP	42	10.0.0.2 is at 5e:5e:44:70:fe:fd
7362	22.153821606	10.0.0.2	10.0.0.1	ICMP	98	Echo (ping) reply id=0xf0f3, seq=1/256, ttl=64
7363	22.153847902	5e:5e:44:70:fe:fd	3a:6e:fe:26:3c:54	ARP	42	10.0.0.2 is at 5e:5e:44:70:fe:fd
7364	22.153869144	3a:6e:fe:26:3c:54	5e:5e:44:70:fe:fd	ARP	42	10.0.0.1 is at 3a:6e:fe:26:3c:54
7365	22.153893940	3a:6e:fe:26:3c:54	5e:5e:44:70:fe:fd	ARP	42	10.0.0.1 is at 3a:6e:fe:26:3c:54
7366	22.153924732	3a:6e:fe:26:3c:54	5e:5e:44:70:fe:fd	ARP	42	10.0.0.1 is at 3a:6e:fe:26:3c:54
7367	22.153958702	10.0.0.2	10.0.0.1	ICMP	98	Echo (ping) reply id=0xf0f3, seq=1/256, ttl=64
7368	22.153995968	3a:6e:fe:26:3c:54	5e:5e:44:70:fe:fd	ARP	42	10.0.0.1 is at 3a:6e:fe:26:3c:54
7369	22.154094025	5e:5e:44:70:fe:fd	3a:6e:fe:26:3c:54	ARP	42	10.0.0.2 is at 5e:5e:44:70:fe:fd
7370	22.154156571	3a:6e:fe:26:3c:54	5e:5e:44:70:fe:fd	ARP	42	10.0.0.1 is at 3a:6e:fe:26:3c:54
7371	22.154184821	10.0.0.1	10.0.0.2	ICMP	98	Echo (ping) request id=0xf0f3, seq=1/256, ttl=64 (reply in 7373)
7372	22.154205264	3a:6e:fe:26:3c:54	5e:5e:44:70:fe:fd	ARP	42	10.0.0.1 is at 3a:6e:fe:26:3c:54
7373	22.154227974	10.0.0.2	10.0.0.1	ICMP	98	Echo (ping) reply id=0xf0f3, seq=1/256, ttl=64 (request in 7371)
7374	22.154260126	3a:6e:fe:26:3c:54	5e:5e:44:70:fe:fd	ARP	42	10.0.0.1 is at 3a:6e:fe:26:3c:54
7375	22.154283303	10.0.0.2	10.0.0.1	ICMP	98	Echo (ping) reply id=0xf0f3, seq=1/256, ttl=64
7376	22.154313622	3a:6e:fe:26:3c:54	5e:5e:44:70:fe:fd	ARP	42	10.0.0.1 is at 3a:6e:fe:26:3c:54
7377	22.154349386	10.0.0.2	10.0.0.1	ICMP	98	Echo (ping) reply id=0xf0f3, seq=1/256, ttl=64
7378	22.154388688	10.0.0.2	10.0.0.1	ICMP	98	Echo (ping) reply id=0xf0f3, seq=1/256, ttl=64
7379	22.154420890	10.0.0.2	10.0.0.1	ICMP	98	Echo (ping) reply id=0xf0f3, seq=1/256, ttl=64
7380	22.154447317	10.0.0.2	10.0.0.1	ICMP	98	Echo (ping) reply id=0xf0f3, seq=1/256, ttl=64
7381	22.154473232	10.0.0.2	10.0.0.1	ICMP	98	Echo (ping) reply id=0xf0f3, seq=1/256, ttl=64
7382	22.154498820	10.0.0.2	10.0.0.1	ICMP	98	Echo (ping) reply id=0xf0f3, seq=1/256, ttl=64
7383	22.154524350	10.0.0.2	10.0.0.1	ICMP	98	Echo (ping) reply id=0xf0f3, seq=1/256, ttl=64
7384	22.154550125	10.0.0.2	10.0.0.1	ICMP	98	Echo (ping) reply id=0xf0f3, seq=1/256, ttl=64
7385	22.154576856	10.0.0.2	10.0.0.1	ICMP	98	Echo (ping) reply id=0xf0f3, seq=1/256, ttl=64
7386	22.154602650	10.0.0.2	10.0.0.1	ICMP	98	Echo (ping) reply id=0xf0f3, seq=1/256, ttl=64
7387	22.154629040	10.0.0.2	10.0.0.1	ICMP	98	Echo (ping) reply id=0xf0f3, seq=1/256, ttl=64
7388	22.154656043	10.0.0.2	10.0.0.1	ICMP	98	Echo (ping) reply id=0xf0f3, seq=1/256, ttl=64
7389	22.154682389	10.0.0.2	10.0.0.1	ICMP	98	Echo (ping) reply id=0xf0f3, seq=1/256, ttl=64
7390	22.154722447	10.0.0.2	10.0.0.1	ICMP	98	Echo (ping) reply id=0xf0f3, seq=1/256, ttl=64
7391	23.407379825	3a:6e:fe:26:3c:54	5e:5e:44:70:fe:fd	ARP	42	10.0.0.1 is at 3a:6e:fe:26:3c:54
7392	23.407438274	10.0.0.2	10.0.0.1	ICMP	98	Echo (ping) reply id=0xf0f3, seq=1/256, ttl=64
7393	23.407508393	5e:5e:44:70:fe:fd	3a:6e:fe:26:3c:54	ARP	42	10.0.0.2 is at 5e:5e:44:70:fe:fd
7394	23.407855837	3a:6e:fe:26:3c:54	5e:5e:44:70:fe:fd	ARP	42	10.0.0.1 is at 3a:6e:fe:26:3c:54
7395	23.407901683	10.0.0.2	10.0.0.1	ICMP	98	Echo (ping) reply id=0xf0f3, seq=1/256, ttl=64
7396	23.408079873	5e:5e:44:70:fe:fd	3a:6e:fe:26:3c:54	ARP	42	10.0.0.2 is at 5e:5e:44:70:fe:fd
7397	23.408145197	5e:5e:44:70:fe:fd	3a:6e:fe:26:3c:54	ARP	42	10.0.0.2 is at 5e:5e:44:70:fe:fd
7398	23.408184139	10.0.0.2	10.0.0.1	ICMP	98	Echo (ping) reply id=0xf0f3, seq=1/256, ttl=64
7399	23.408239428	5e:5e:44:70:fe:fd	3a:6e:fe:26:3c:54	ARP	42	10.0.0.2 is at 5e:5e:44:70:fe:fd
7400	23.408277561	5e:5e:44:70:fe:fd	3a:6e:fe:26:3c:54	ARP	42	10.0.0.2 is at 5e:5e:44:70:fe:fd

图 11