延迟确认那些事

TCP 回包的磨叽姐

再聊 ACK

是不是每个数据包都对应一个 ACK 包?

是不是接收端收到数据以后必须立刻马上回复确认包?

回复一个空的 ACK 实在是太浪费了

减少网络流量的一个重要举措

接收端这个时候恰好有数据要回复客户端

ACK 搭上顺风车一块发送

期间又有客户端的数据传过来

把多次 ACK 合并成一个立刻发送出去

一段时间没有顺风车

不能让接收端等太久，一个空包也得发

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延迟确认（delayed ack）

什么时候需要回复 ACK?

```
static void __tcp_ack_snd_check(struct sock *sk, int ofo_possible)
{
  struct tcp_sock *tp = tcp_sk(sk);

      /* More than one full frame received... */
  if (((tp->rcv_nxt - tp->rcv_wup) > tp->ack.rcv_mss
       /* ... and right edge of window advances far enough.
        * (tcp_recvmsg() will send ACK otherwise). Or...
        */
       && __tcp_select_window(sk) >= tp->rcv_wnd) ||
      /* We ACK each frame or... */
      tcp_in_quickack_mode(tp) ||
      /* We have out of order data. */
      (ofo_possible &&
       skb_peek(&tp->out_of_order_queue))) {
    /* Then ack it now */
    tcp_send_ack(sk);
  } else {
    /* Else, send delayed ack. */
    tcp_send_delayed_ack(sk);
  }
}
```

1、如果接收到了大于一个frame 的报文，且需要调整窗口大小

2、处于 quickack 模式（tcp_in_quickack_mode）

3、收到乱序包（We have out of order data.）

什么时候需要回复 ACK?

```
/* Send ACKs quickly, if "quick" count is not exhausted
 * and the session is not interactive.
 */

static __inline__ int tcp_in_quickack_mode(struct tcp_sock *tp)
{
  return (tp->ack.quick && !tp->ack.pingpong);
}

/* Delayed ACK control data */
struct {
  __u8  pending;  /* ACK is pending */
  __u8  quick;    /* Scheduled number of quick acks */
  __u8  pingpong; /* The session is interactive   */
  __u8  blocked;  /* Delayed ACK was blocked by socket lock*/
  __u32 ato;    /* Predicted tick of soft clock   */
  unsigned long timeout;  /* Currently scheduled timeout    */
  __u32 lrcvtime; /* timestamp of last received data packet*/
  __u16 last_seg_size;  /* Size of last incoming segment  */
  __u16 rcv_mss;  /* MSS used for delayed ACK decisions */
} ack;
```

其中pingpong 就是判断交互连接的，只有处于非交互 TCP 连接才有可能即进入 quickack 模式。

什么是交互式和 pingpong 呢?

顾名思义，其实有来有回的双向数据传输就叫 pingpong，对于通信的某一端来说，`R-W-R-W-R-W...`（R 表示读，W 表示写）

演示

```
public class DelayAckServer {
    private static final int PORT = 8888;

    public static void main(String[] args) throws IOException {
        ServerSocket serverSocket = new ServerSocket();
        serverSocket.bind(new InetSocketAddress(PORT));
        System.out.println("Server startup at " + PORT);
        while (true) {
            Socket socket = serverSocket.accept();
            InputStream inputStream = socket.getInputStream();
            OutputStream outputStream = socket.getOutputStream();
            int i = 1;
            while (true) {
                BufferedReader reader = new BufferedReader(new InputStreamReader(inputStream));
                String line = reader.readLine();
                if (line == null) break;
                System.out.println((i++) + " : " + line);
                outputStream.write((line + "\n").getBytes());
            }
        }
    }
}
```

演示

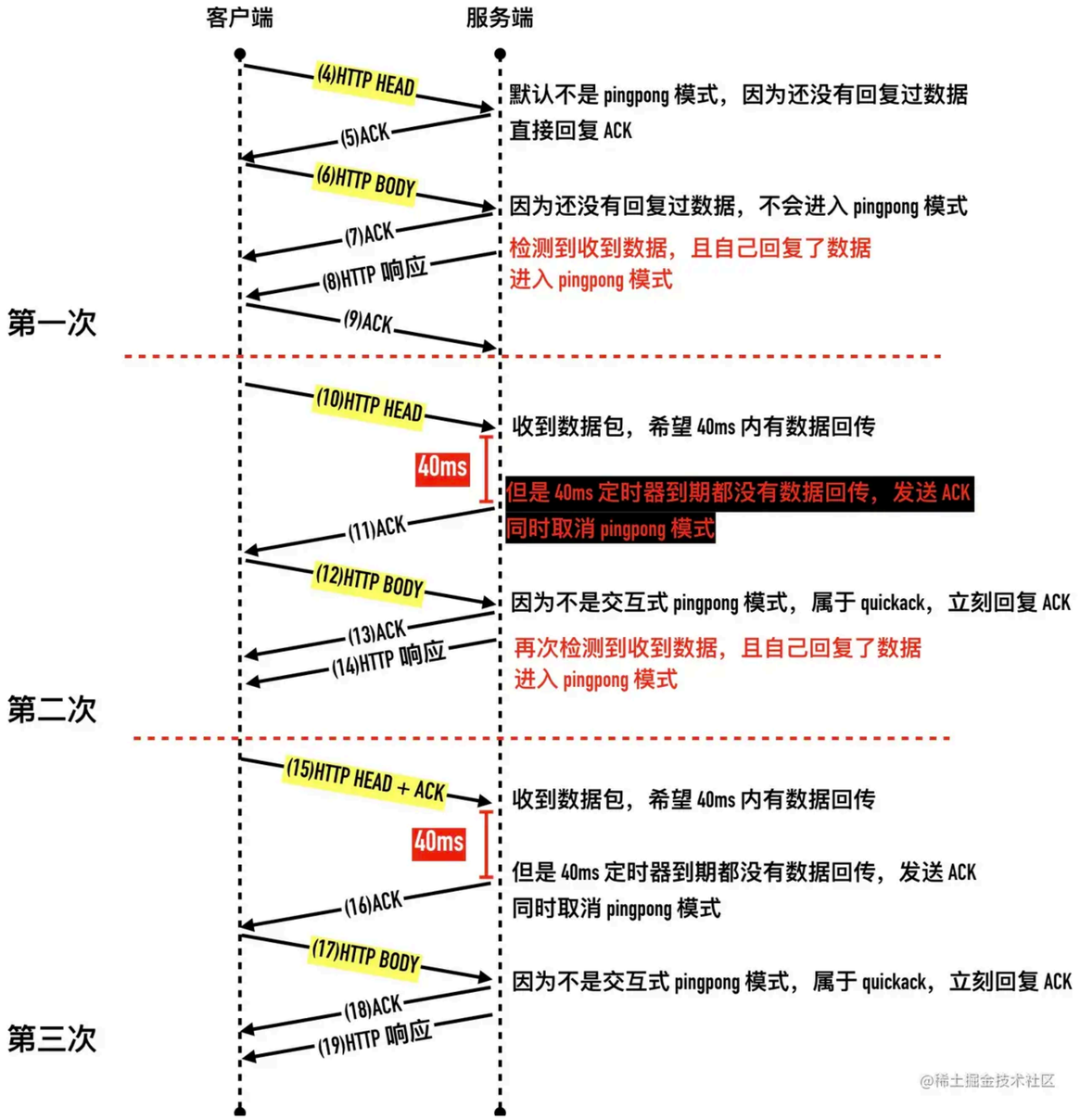
```
public class DelayAckClient {
    public static void main(String[] args) throws IOException {
        Socket socket = new Socket();
        socket.connect(new InetSocketAddress("server_ip", 8888));
        InputStream inputStream = socket.getInputStream();
        OutputStream outputStream = socket.getOutputStream();
        BufferedReader reader = new BufferedReader(new InputStreamReader(inputStream));
        String head = "hello, ";
        String body = "world\n";

        for (int i = 0; i < 10; i++) {
            long start = System.currentTimeMillis();
            outputStream.write(("#" + i + " " + head).getBytes()); // write
            outputStream.write((body).getBytes()); // write
            String line = reader.readLine(); // read
            System.out.println("RTT: " + (System.currentTimeMillis() - start) + ": " + line);
        }
        inputStream.close();
        outputStream.close();
        socket.close();
    }
}
```

包分析

No.	Time	Source	Destination	Protocol	Info
1	0.000000	10.211.55.10	10.211.55.5	TCP	58936 → 8888 [SYN] Seq=0 Win=29200 Len=0 MSS=1460 SACK_PERM=1 TSval=268816418 TSecr=0
2	0.000167	10.211.55.5	10.211.55.10	TCP	8888 → 58936 [SYN, ACK] Seq=0 Ack=1 Win=28960 Len=0 MSS=1460 SACK_PERM=1 TSval=3401616
3	0.000185	10.211.55.10	10.211.55.5	TCP	58936 → 8888 [ACK] Seq=1 Ack=1 Win=29312 Len=0 TSval=268816419 TSecr=340161632
4	0.001704	10.211.55.10	10.211.55.5	TCP	58936 → 8888 [PSH, ACK] Seq=1 Ack=1 Win=29312 Len=10 TSval=268816420 TSecr=340161632
5	0.001840	10.211.55.5	10.211.55.10	TCP	8888 → 58936 [ACK] Seq=1 Ack=11 Win=29056 Len=0 TSval=340161634 TSecr=268816420
6	0.001851	10.211.55.10	10.211.55.5	TCP	58936 → 8888 [PSH, ACK] Seq=11 Ack=1 Win=29312 Len=6 TSval=268816420 TSecr=340161634
7	0.001881	10.211.55.5	10.211.55.10	TCP	8888 → 58936 [ACK] Seq=1 Ack=17 Win=29056 Len=0 TSval=340161634 TSecr=268816420
8	0.002282	10.211.55.5	10.211.55.10	TCP	8888 → 58936 [PSH, ACK] Seq=1 Ack=17 Win=29056 Len=16 TSval=340161634 TSecr=268816420
9	0.002327	10.211.55.10	10.211.55.5	TCP	58936 → 8888 [ACK] Seq=17 Ack=17 Win=29312 Len=0 TSval=268816421 TSecr=340161634
10	0.002798	10.211.55.10	10.211.55.5	TCP	58936 → 8888 [PSH, ACK] Seq=17 Ack=17 Win=29312 Len=10 TSval=268816421 TSecr=340161634
11	0.046394	10.211.55.5	10.211.55.10	TCP	8888 → 58936 [ACK] Seq=17 Ack=27 Win=29056 Len=0 TSval=340161678 TSecr=268816421
12	0.046421	10.211.55.10	10.211.55.5	TCP	58936 → 8888 [PSH, ACK] Seq=27 Ack=17 Win=29312 Len=6 TSval=268816465 TSecr=340161678
13	0.046526	10.211.55.5	10.211.55.10	TCP	8888 → 58936 [ACK] Seq=17 Ack=33 Win=29056 Len=0 TSval=340161679 TSecr=268816465
14	0.046690	10.211.55.5	10.211.55.10	TCP	8888 → 58936 [PSH, ACK] Seq=17 Ack=33 Win=29056 Len=16 TSval=340161679 TSecr=268816465
15	0.046885	10.211.55.10	10.211.55.5	TCP	58936 → 8888 [PSH, ACK] Seq=33 Ack=33 Win=29312 Len=10 TSval=268816465 TSecr=340161679
16	0.090509	10.211.	211	TCP	8888 → 58936 [ACK] Seq=33 Ack=43 Win=29056 Len=0 TSval=340161722 TSecr=268816465
17	0.090527	10.211.55.10	10.211.55.5	TCP	58936 → 8888 [PSH, ACK] Seq=43 Ack=33 Win=29312 Len=6 TSval=268816509 TSecr=340161722
18	0.090641	10.211.55.5	10.211.55.10	TCP	8888 → 58936 [ACK] Seq=33 Ack=49 Win=29056 Len=0 TSval=340161723 TSecr=268816509
19	0.090827	10.211.55.5	10.211.55.10	TCP	8888 → 58936 [PSH, ACK] Seq=33 Ack=49 Win=29056 Len=16 TSval=340161723 TSecr=268816509
20	0.092213	10.211.55.10	10.211.55.5	TCP	58936 → 8888 [PSH, ACK] Seq=49 Ack=49 Win=29312 Len=10 TSval=268816511 TSecr=340161723
21	0.135543	10.211.55.5	10.211.55.10	TCP	8888 → 58936 [ACK] Seq=49 Ack=59 Win=29056 Len=0 TSval=340161768 TSecr=268816511
22	0.135569	10.211.55.10	10.211.55.5	TCP	58936 → 8888 [PSH, ACK] Seq=59 Ack=49 Win=29312 Len=6 TSval=268816554 TSecr=340161768
23	0.135695	10.211.55.5	10.211.55.10	TCP	8888 → 58936 [ACK] Seq=49 Ack=65 Win=29056 Len=0 TSval=340161768 TSecr=268816554
24	0.135877	10.211.55.5	10.211.55.10	TCP	8888 → 58936 [PSH, ACK] Seq=49 Ack=65 Win=29056 Len=16 TSval=340161768 TSecr=268816554
25	0.136093	10.211.55.10	10.211.55.5	TCP	58936 → 8888 [PSH, ACK] Seq=65 Ack=65 Win=29312 Len=10 TSval=268816554 TSecr=340161768

延迟确认，44ms

交互流程



packetdrill 模拟

```
--tolerance_usecs=100000
0.000 socket(..., SOCK_STREAM, IPPROTO_TCP) = 3
0.000 setsockopt(3, SOL_SOCKET, SO_REUSEADDR, [1], 4) = 0
0.000 bind(3, ..., ...) = 0
0.000 listen(3, 1) = 0

0.000 < S 0:0(0) win 32792 <mss 1000, sackOK, nop, nop, nop, wscale 7>
0.000 > S. 0:0(0) ack 1 <...>

0.000 < . 1:1(0) ack 1 win 257

0.000 accept(3, ..., ...) = 4

+ 0 setsockopt(4, SOL_TCP, TCP_NODELAY, [1], 4) = 0

// 模拟往服务端写入 HTTP 头部: POST / HTTP/1.1
+0 < P. 1:11(10) ack 1 win 257

// 模拟往服务端写入 HTTP 请求 body: {"id": 1314}
+0 < P. 11:26(15) ack 1 win 257

// 往 fd 为4 的 模拟服务器返回 HTTP response {}
+ 0 write(4, ..., 100) = 100


// 第二次模拟往服务端写入 HTTP 头部: POST / HTTP/1.1
+0 < P. 26:36(10) ack 101 win 257

// 抓包看服务器返回

+0 `sleep 1000000`
```

packetdrill 模拟

```
--tolerance_usecs=100000
0.000 socket(..., SOCK_STREAM, IPPROTO_TCP) = 3
0.000 setsockopt(3, SOL_SOCKET, SO_REUSEADDR, [1], 4) = 0
0.000 bind(3, ..., ...) = 0
0.000 listen(3, 1) = 0

0.000 < S 0:0(0) win 32792 <mss 1000, sackOK, nop, nop, nop, wscale 7>
0.000 > S. 0:0(0) ack 1 <...>

0.000 < . 1:1(0) ack 1 win 257

0.000 accept(3, ..., ...) = 4

+ 0 setsockopt(4, SOL_TCP, TCP_NODELAY, [1], 4)

// 模拟往服务端写入 HTTP 头部: POST / HTTP/1.1
+0 < P. 1:11(10) ack 1 win 257

// 模拟往服务端写入 HTTP 请求 body: {"id": 1314}
+0 < P. 11:26(15) ack 1 win 257

// 往 fd 为4 的 模拟服务器返回 HTTP response {}
+ 0 write(4, ..., 100) = 100


// 第二次模拟往服务端写入 HTTP 头部: POST / HTTP/1.1
+0 < P. 26:36(10) ack 101 win 257

// 抓包看服务器返回

+0 `sleep 1000000`
```

No.	Time	Source	Destination	Protocol	Info
1	0.000000	192.0.2.1	192.168.139.46	TCP	49604 → 8080 [SYN] Seq=0 Win=32792 Len=0 MSS=1000 SACK_PERM=
2	0.000065	192.168.139.46	192.0.2.1	TCP	8080 → 49604 [SYN, ACK] Seq=0 Ack=1 Win=29200 Len=0 MSS=146
3	0.000189	192.0.2.1	192.168.139.46	TCP	49604 → 8080 [ACK] Seq=1 Ack=1 Win=32896 Len=0
4	0.000300	192.0.2.1	192.168.139.46	TCP	49604 → 8080 [PSH, ACK] Seq=1 Ack=1 Win=32896 Len=10
5	0.000316	192.168.139.46	192.0.2.1	TCP	8080 → 49604 [ACK] Seq=1 Ack=11 Win=29312 Len=0
6	0.000339	192.0.2.1	192.168.139.46	TCP	49604 → 8080 [PSH, ACK] Seq=11 Ack=1 Win=32896 Len=15
7	0.000352	192.168.139.46	192.0.2.1	TCP	8080 → 49604 [ACK] Seq=1 Ack=26 Win=29312 Len=0
8	0.000375	192.168.139.46	192.0.2.1	TCP	8080 → 49604 [PSH, ACK] Seq=1 Ack=26 Win=29312 Len=100
9	0.000389	192.0.2.1	192.168.139.46	TCP	49604 → 8080 [PSH, ACK] Seq=26 Ack=101 Win=32896 Len=10
10	0.043645	192.168.139.46	192.0.2.1	TCP	8080 → 49604 [ACK] Seq=101 Ack=36 Win=29312 Len=0

当 Nagle 算法遇到延迟确认

Nagle 算法和延迟确认本身并没有什么问题，但一起使用就会出现很严重的性能问题了。Nagle 攒着包一次发一个，延迟确认收到包不马上回。

当 Nagle 算法遇到延迟确认

socket.setTcpNoDelay(true); // 禁用 Nagle 算法

No.	Time	Source	Destination	Protocol	Info
1	0.000000	10.211.55.10	10.211.55.5	TCP	58942 → 8888 [SYN] Seq=0 Win=29200 Len=0 MSS=1460 SACK_PERM=1 TSval=277480985 TSecr=0 WS=128
2	0.000540	10.211.55.5	10.211.55.10	TCP	8888 → 58942 [SYN, ACK] Seq=0 Ack=1 Win=28960 Len=0 MSS=1460 SACK_PERM=1 TSval=348828048 TSecr=277480985
3	0.000574	10.211.55.10	10.211.55.5	TCP	58942 → 8888 [ACK] Seq=1 Ack=1 Win=29312 Len=0 TSval=277480986 TSecr=348828048
4	0.001728	10.211.55.10	10.211.55.5	TCP	58942 → 8888 [PSH, ACK] Seq=1 Ack=1 Win=29312 Len=10 TSval=277480987 TSecr=348828048
5	0.001778	10.211.55.10	10.211.55.5	TCP	58942 → 8888 [PSH, ACK] Seq=11 Ack=1 Win=29312 Len=6 TSval=277480987 TSecr=348828048
6	0.001920	10.211.55.5	10.211.55.10	TCP	8888 → 58942 [ACK] Seq=1 Ack=11 Win=29056 Len=0 TSval=348828050 TSecr=277480987
7	0.001932	10.211.55.5	10.211.55.10	TCP	8888 → 58942 [ACK] Seq=1 Ack=17 Win=29056 Len=0 TSval=348828050 TSecr=277480987
8	0.002214	10.211.55.5	10.211.55.10	TCP	8888 → 58942 [PSH, ACK] Seq=1 Ack=17 Win=29056 Len=16 TSval=348828050 TSecr=277480987
9	0.002256	10.211.55.10	10.211.55.5	TCP	58942 → 8888 [ACK] Seq=17 Ack=17 Win=29312 Len=0 TSval=277480987 TSecr=348828050
10	0.002733	10.211.55.10	10.211.55.5	TCP	58942 → 8888 [PSH, ACK] Seq=17 Ack=17 Win=29312 Len=10 TSval=277480988 TSecr=348828050
11	0.002769	10.211.55.10	10.211.55.5	TCP	58942 → 8888 [PSH, ACK] Seq=27 Ack=17 Win=29312 Len=6 TSval=277480988 TSecr=348828050
12	0.002885	10.211.55.5	10.211.55.10	TCP	8888 → 58942 [ACK] Seq=17 Ack=33 Win=29056 Len=0 TSval=348828051 TSecr=277480988
13	0.002972	10.211.55.5	10.211.55.10	TCP	8888 → 58942 [PSH, ACK] Seq=17 Ack=33 Win=29056 Len=16 TSval=348828051 TSecr=277480988
14	0.003135	10.211.55.10	10.211.55.5	TCP	58942 → 8888 [PSH, ACK] Seq=33 Ack=33 Win=29312 Len=10 TSval=277480988 TSecr=348828051
15	0.003155	10.211.55.10	10.211.55.5	TCP	58942 → 8888 [PSH, ACK] Seq=43 Ack=33 Win=29312 Len=6 TSval=277480988 TSecr=348828051
16	0.003298	10.211.55.5	10.211.55.10	TCP	8888 → 58942 [ACK] Seq=33 Ack=49 Win=29056 Len=0 TSval=348828051 TSecr=277480988
17	0.003478	10.211.55.5	10.211.55.10	TCP	8888 → 58942 [PSH, ACK] Seq=33 Ack=49 Win=29056 Len=16 TSval=348828051 TSecr=277480988
18	0.003644	10.211.55.10	10.211.55.5	TCP	58942 → 8888 [PSH, ACK] Seq=49 Ack=49 Win=29312 Len=10 TSval=277480989 TSecr=348828051
19	0.003698	10.211.55.10	10.211.55.5	TCP	58942 → 8888 [PSH, ACK] Seq=59 Ack=49 Win=29312 Len=6 TSval=277480989 TSecr=348828051
20	0.004013	10.211.55.5	10.211.55.10	TCP	8888 → 58942 [ACK] Seq=49 Ack=65 Win=29056 Len=0 TSval=348828052 TSecr=277480989
21	0.004151	10.211.55.5	10.211.55.10	TCP	8888 → 58942 [PSH, ACK] Seq=49 Ack=65 Win=29056 Len=16 TSval=348828052 TSecr=277480989
22	0.004408	10.211.55.10	10.211.55.5	TCP	58942 → 8888 [PSH, ACK] Seq=65 Ack=65 Win=29312 Len=10 TSval=277480990 TSecr=348828052
23	0.004431	10.211.55.10	10.211.55.5	TCP	58942 → 8888 [PSH, ACK] Seq=75 Ack=65 Win=29312 Len=6 TSval=277480990 TSecr=348828052
24	0.004569	10.211.55.5	10.211.55.10	TCP	8888 → 58942 [ACK] Seq=65 Ack=81 Win=29056 Len=0 TSval=348828052 TSecr=277480990
25	0.004766	10.211.55.5	10.211.55.10	TCP	8888 → 58942 [PSH, ACK] Seq=65 Ack=81 Win=29056 Len=16 TSval=348828052 TSecr=277480990
26	0.004913	10.211.55.10	10.211.55.5	TCP	58942 → 8888 [PSH, ACK] Seq=81 Ack=81 Win=29312 Len=10 TSval=277480990 TSecr=348828052
27	0.004944	10.211.55.10	10.211.55.5	TCP	58942 → 8888 [PSH, ACK] Seq=91 Ack=81 Win=29312 Len=6 TSval=277480990 TSecr=348828052
28	0.005140	10.211.55.5	10.211.55.10	TCP	8888 → 58942 [ACK] Seq=81 Ack=97 Win=29056 Len=0 TSval=348828053 TSecr=277480990
29	0.005256	10.211.55.5	10.211.55.10	TCP	8888 → 58942 [PSH, ACK] Seq=81 Ack=97 Win=29056 Len=16 TSval=348828053 TSecr=277480990
30	0.005462	10.211.55.10	10.211.55.5	TCP	58942 → 8888 [PSH, ACK] Seq=97 Ack=97 Win=29312 Len=10 TSval=277480991 TSecr=348828053
31	0.005483	10.211.55.10	10.211.55.5	TCP	58942 → 8888 [PSH, ACK] Seq=107 Ack=97 Win=29312 Len=6 TSval=277480991 TSecr=348828053

黑色背景部分的是客户端发送给服务端的请求包