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## 《现代交换原理》实验报告

实验名称 SIP 拨打电话实验

班 级 2021211304

学 号 2021212484、2021212171、2021212492

姓 名 张梓良、杨晨、苗雨

指导教师 赵 学 达

# SIP 拨打电话实验

## 一、实验目的

结合课堂所讲的SIP信令工作流程，对软电话呼叫的信令进行抓包分析，理解VOIP呼 叫中会话信令、媒体协商信令的作用，加深对VOIP的理解。

## 二、实验内容和实验步骤

选择iptel作为SIP代理商，并注册账号。在 Windows 上配置 MicroSIP 作为 SIP 客户端，账户配置信息如下：

Account

Account Name

SIP Server

iptel.org

?

SIP Proxy

?

Username \*

ziliangzhang@iptel.org

?

Domain \*

ziliangzhang@iptel.org

?

Login

ziliangzhang

?

Password

\*\*\*\*\*

?

Display Name

zl

?

Voicemail Number

?

Dialing Prefix

?

Dial Plan

?

☐ Hide Caller ID

?

Media Encryption

Disabled

?

Transport

UDP

?

Public Address

Auto

?

Register Refresh

300

Keep-Alive

15

☐ Publish Presence

?

☐ Allow IP Rewrite

?

☐ ICE

?

☐ Disable Session Timers

?

x

Save

Cancel

## 三、抓包分析

正常打电话，接通

情形一：主叫挂机

● 主叫

27021	1893.655199	10.129.146.169	212.79.111.155	SIP/SDP	1228 Request: INVITE sip:bowing0519@iptel.org
27025	1893.957761	212.79.111.155	10.129.146.169	SIP	425 Status: 100 Trying
27026	1894.279278	212.79.111.155	10.129.146.169	SIP	690 Status: 180 Ringing
27044	1897.433390	212.79.111.155	10.129.146.169	SIP/SDP	1101 Status: 200 OK (INVITE)
27047	1897.445145	10.129.146.169	212.79.111.155	SIP	466 Request: ACK sip:6FF6720F-66598262000D58E0-688516C0@212.79.111.155;transport=udp
28079	1907.362793	10.129.146.169	212.79.111.155	SIP	495 Request: BYE sip:6FF6720F-66598262000D58E0-688516C0@212.79.111.155;transport=udp
28104	1907.864101	10.129.146.169	212.79.111.155	SIP	495 Request: BYE sip:6FF6720F-66598262000D58E0-688516C0@212.79.111.155;transport=udp
28112	1907.967820	212.79.111.155	10.129.146.169	SIP	504 Status: 200 OK (BYE)

● 被叫

12917	609.219334	212.79.111.155	10.129.25.162	SIP/SDP	1198 Request: INVITE sip:bowing0519@10.129.25.162:51978;ob
12918	609.223413	10.129.25.162	212.79.111.155	SIP	349 Status: 100 Trying
12919	609.223579	10.129.25.162	212.79.111.155	SIP	544 Status: 180 Ringing
12922	612.365625	10.129.25.162	212.79.111.155	SIP/SDP	993 Status: 200 OK (INVITE)
12948	612.866868	10.129.25.162	212.79.111.155	SIP/SDP	993 Status: 200 OK (INVITE)
12956	612.993542	212.79.111.155	10.129.25.162	SIP	594 Request: ACK sip:bowing0519@10.129.25.162:51978;ob
12973	613.168007	212.79.111.155	10.129.25.162	SIP	594 Request: ACK sip:bowing0519@10.129.25.162:51978;ob
13938	622.915129	212.79.111.155	10.129.25.162	SIP	544 Request: BYE sip:bowing0519@10.129.25.162:51978;ob
13939	622.915254	10.129.25.162	212.79.111.155	SIP	379 Status: 200 OK (BYE)

流程:

1. 主叫（10.129.146.169）向服务器（212.79.111.155）发送invite请求
2. 服务器向被叫（10.129.25.162）发送invite请求
3. 服务器向主叫发送100 Trying，尝试建立呼叫连接
4. 被叫向服务器发送100 Trying，尝试建立呼叫连接
5. 被叫向服务器发送100 Ringing，送回铃声
6. 服务器向主叫发送100 Ringing，送回铃声
7. 被叫向服务器发送200 OK（invite）通知其请求成功
8. 200 OK（invite）有一次重传
9. 服务器向主叫发送200 OK（invite）通知其请求成功
10. 主叫向服务器回复ACK
11. 服务器向被叫回复ACK
12. ACK有一次重传  
(至此呼叫连接建立)
13. 主叫向服务器发送BYE请求
14. BYE请求有一次重传
15. 服务器向被叫发送BYE请求
16. 被叫向服务器发送200 OK（BYE）通知BYE请求成功
17. 服务器向主叫发送200 OK（BYE）通知BYE请求成功  
(至此呼叫连接释放)

情形二：被叫挂机

主叫

30461	2199.591028	10.129.146.169	212.79.111.155	SIP/SDP	1227 Request: INVITE sip:bowing0519@iptel.org
30462	2199.887126	212.79.111.155	10.129.146.169	SIP	424 Status: 100 Trying
30464	2200.218058	212.79.111.155	10.129.146.169	SIP	689 Status: 180 Ringing
30470	2201.804135	212.79.111.155	10.129.146.169	SIP/SDP	1099 Status: 200 OK (INVITE)
30473	2201.805449	10.129.146.169	212.79.111.155	SIP	465 Request: ACK sip:6A38A2A2-66598394000C53B2-688516C0@212.79.111.155;transport=udp
30527	2202.292928	212.79.111.155	10.129.146.169	SIP/SDP	1099 Status: 200 OK (INVITE)
30528	2202.293044	10.129.146.169	212.79.111.155	SIP	465 Request: ACK sip:6A38A2A2-66598394000C53B2-688516C0@212.79.111.155;transport=udp
30808	2205.141195	212.79.111.155	10.129.146.169	SIP	547 Request: BYE sip:ziliangzhang@10.129.146.169:56108;ob
30809	2205.141326	10.129.146.169	212.79.111.155	SIP	377 Status: 200 OK (BYE)

被叫

14631	915.150935	212.79.111.155	10.129.25.162	SIP/SDP	1198 Request: INVITE sip:bowing0519@10.129.25.162:51978;ob
14632	915.154681	10.129.25.162	212.79.111.155	SIP	349 Status: 100 Trying
14633	915.154842	10.129.25.162	212.79.111.155	SIP	544 Status: 180 Ringing
14641	916.736981	10.129.25.162	212.79.111.155	SIP/SDP	992 Status: 200 OK (INVITE)
14669	917.237699	10.129.25.162	212.79.111.155	SIP/SDP	992 Status: 200 OK (INVITE)
14723	917.855306	212.79.111.155	10.129.25.162	SIP	594 Request: ACK sip:bowing0519@10.129.25.162:51978;ob
14944	920.084583	10.129.25.162	212.79.111.155	SIP	496 Request: BYE sip:5841559D-665983950001B021-94A316C0@212.79.111.155;transport=udp
14967	920.584748	10.129.25.162	212.79.111.155	SIP	496 Request: BYE sip:5841559D-665983950001B021-94A316C0@212.79.111.155;transport=udp
14971	920.683114	212.79.111.155	10.129.25.162	SIP	503 Status: 200 OK (BYE)
14972	920.886447	212.79.111.155	10.129.25.162	SIP	503 Status: 200 OK (BYE)

流程:

呼叫连接建立过程与之前一致)

呼叫释放过程由被叫发起，由服务器中转发到主叫，再由主叫回复释放确认：

- 1. 被叫向服务器发送BYE请求
- 2. BYE请求有一次重传
- 3. 服务器向主叫发送BYE请求
- 4. 主叫向服务器发送200 OK（BYE）通知BYE请求成功
- 5. 服务器向被叫发送200 OK（BYE）通知BYE请求成功
- 6. 200 OK（BYE）有一次重传

被叫忙拒接

主叫

48580	2571.619182	10.129.146.169	212.79.111.155	SIP/SDP	1229 Request: INVITE sip:bowing0519@iptel.org
48585	2571.910161	212.79.111.155	10.129.146.169	SIP	425 Status: 100 Trying
48586	2572.247994	212.79.111.155	10.129.146.169	SIP	690 Status: 180 Ringing
48596	2575.324469	212.79.111.155	10.129.146.169	SIP	612 Status: 486 Busy Here
48597	2575.324623	10.129.146.169	212.79.111.155	SIP	423 Request: ACK sip:bowing0519@iptel.org

被叫

15690	1287.176194	212.79.111.155	10.129.25.162	SIP/SDP	1199 Request: INVITE sip:bowing0519@10.129.25.162:51978;ob
15691	1287.180141	10.129.25.162	212.79.111.155	SIP	349 Status: 100 Trying
15692	1287.180345	10.129.25.162	212.79.111.155	SIP	544 Status: 180 Ringing
15693	1290.283003	10.129.25.162	212.79.111.155	SIP	487 Status: 486 Busy Here
15694	1290.579224	212.79.111.155	10.129.25.162	SIP	384 Request: ACK sip:bowing0519@10.129.25.162:51978;ob

流程:

1-6与正常呼叫建立流程一致

- 7. 被叫向服务器发送486 Busy Here，表示自己正忙

- 8. 服务器向主叫转发486 Busy Here，表示被叫忙
- 9. 主叫向服务器回复ACK
- 10. 服务器向被叫送ACK

久叫不答

- 主叫

9198	925.306875	212.79.111.155	10.129.146.169	SIP	696 Status: 408 Request Timeout
9199	925.307018	10.129.146.169	212.79.111.155	SIP	423 Request: ACK sip:bowing0519@iptel.org

- 被叫

241	141.178282	212.79.111.155	10.129.25.162	SIP	860 Request: CANCEL sip:bowing0519@10.129.25.162:51978;ob
242	141.178530	10.129.25.162	212.79.111.155	SIP	382 Status: 200 OK (CANCEL)
243	141.178587	10.129.25.162	212.79.111.155	SIP	496 Status: 487 Request Terminated
247	141.479465	212.79.111.155	10.129.25.162	SIP	384 Request: ACK sip:bowing0519@10.129.25.162:51978;ob

- 主叫（10.129.146.169）向服务器（212.79.111.155）发送invite请求
- 服务器向被叫（10.129.25.162）发送invite请求
- 服务器向主叫发送100 Trying，尝试建立呼叫连接
- 被叫向服务器发送100 Trying，尝试建立呼叫连接
- 服务器向被叫发送CANCEL请求
- 被叫向服务器发送200 OK，表示请求成功
- 被叫向服务器发送487 Request Terminated，表示请求已经撤销
- 服务器向主叫发送408 Request Timeout，表示请求超时
- 服务器向被叫发送ACK确认
- 主叫向服务器发送ACK确认

主叫主动取消

- 主叫

52748	2835.816779	10.129.146.169	212.79.111.155	SIP/SDP	1228 Request: INVITE sip:bowing0519@iptel.org
52749	2836.112697	212.79.111.155	10.129.146.169	SIP	425 Status: 100 Trying
52761	2836.902351	212.79.111.155	10.129.146.169	SIP	690 Status: 180 Ringing
52799	2840.974548	10.129.146.169	212.79.111.155	SIP	419 Request: CANCEL sip:bowing0519@iptel.org
52817	2841.475327	10.129.146.169	212.79.111.155	SIP	419 Request: CANCEL sip:bowing0519@iptel.org
52834	2841.770410	212.79.111.155	10.129.146.169	SIP	460 Status: 200 OK (CANCEL)
52835	2841.770410	212.79.111.155	10.129.146.169	SIP	476 Status: 487 Request terminated
52836	2841.770594	10.129.146.169	212.79.111.155	SIP	423 Request: ACK sip:bowing0519@iptel.org

- 被叫

1304...	2107.774790	212.79.111.155	10.129.25.162	SIP/SDP	1199 Request: INVITE sip:bowing0519@10.129.25.162:51978;ob
1304...	2107.779255	10.129.25.162	212.79.111.155	SIP	349 Status: 100 Trying
1304...	2107.779431	10.129.25.162	212.79.111.155	SIP	544 Status: 180 Ringing
1344...	2122.097960	212.79.111.155	10.129.25.162	SIP	860 Request: CANCEL sip:bowing0519@10.129.25.162:51978;ob
1344...	2122.098155	10.129.25.162	212.79.111.155	SIP	382 Status: 200 OK (CANCEL)
1344...	2122.098216	10.129.25.162	212.79.111.155	SIP	496 Status: 487 Request Terminated
1345...	2122.387720	212.79.111.155	10.129.25.162	SIP	384 Request: ACK sip:bowing0519@10.129.25.162:51978;ob

1-6与前面一致

- 7. 主叫向服务器发送CANCEL请求（重传一次）
- 8. 服务器向被叫发送CANCEL请求
- 9. 服务器向主叫发送200 OK，表示请求成功
- 10. 被叫向服务器发送200 OK，表示请求成功
- 11. 被叫向服务器发送487 Request Terminated，表示请求已经撤销
- 12. 服务器向主叫发送487 Request Terminated，表示请求已经撤销
- 13. 服务器向被叫发送ACK确认
- 14. 主叫向服务器发送ACK确认

## 两个电话同时拨打一个被叫

- 被叫

129 50.533056	212.79.111.155	10.129.25.162	SIP/SDP	1198 Request: INVITE sip:bowing0519@10.129.25.162:51978;ob
130 50.536728	10.129.25.162	212.79.111.155	SIP	349 Status: 100 Trying
131 50.536890	10.129.25.162	212.79.111.155	SIP	544 Status: 180 Ringing
132 54.378796	212.79.111.155	10.129.25.162	SIP/SDP	1198 Request: INVITE sip:bowing0519@10.129.25.162:51978;ob
133 54.382733	10.129.25.162	212.79.111.155	SIP	347 Status: 100 Trying
134 54.382888	10.129.25.162	212.79.111.155	SIP	542 Status: 180 Ringing

可以发现被叫能够收到两个主叫分别的拨打请求。

后续过程为

- 1. 若被叫接通一个主叫，和该主叫的通话过程为情况1:正常打电话，此时另一个主叫的请求仍然存在
- 2. 若被叫拒绝任何一个主叫，该情况为情况2：异常挂机，拒绝
- 3. 若被叫先接通一个主叫，再接通另一个主叫，那么被叫会自动向第一个主叫挂机

## 具体数据包分析

### INVITE请求

INVITE sip:bowing0519@iptel.org SIP/2.0 -- 类型

Via: SIP/2.0/UDP  
10.129.146.169:56108;rport;branch=z9hG4bKPj63adbf2589d3431691c84393cb0769d9 -- 接收发送  
请求服务器地址

From: "zl" <sip:ziliangzhang@iptel.org>;tag=150f923bb5f74b2692a93be717eac194 -- 主叫uri

To: <sip:bowing0519@iptel.org> -- 被叫uri

Contact: "zl" <sip:ziliangzhang@10.129.146.169:56108;ob> -- 响应消息发往地址

Content type: application/sdp -- 消息正文描述，音频传输，媒体呼叫

sdp: -- 主叫和被叫主要信息和能力

```

  Message Body
  Session Description Protocol
    Session Description Protocol Version (v): 0
  Owner/Creator, Session Id (o): - 3926167795 3926167795 IN IP4 10.129.146.169
    Owner Username: -
    Session ID: 3926167795
    Session Version: 3926167795
    Owner Network Type: IN
    Owner Address Type: IP4
    Owner Address: 10.129.146.169
    Session Name (s): pjmedia
  > Bandwidth Information (b): AS:84
  > Time Description, active time (t): 0 0
  > Session Attribute (a): X-nat:0
  > Media Description, name and address (m): audio 4036 RTP/AVP 8 0 101
  > Connection Information (c): IN IP4 10.129.146.169
  > Bandwidth Information (b): TIAS:64000
  > Media Attribute (a): rtcp:4037 IN IP4 10.129.146.169
    Media Attribute (a): sendrecv
  > Media Attribute (a): rtpmap:8 PCMA/8000
  > Media Attribute (a): rtpmap:0 PCMU/8000
  > Media Attribute (a): rtpmap:101 telephone-event/8000
  > Media Attribute (a): fmp:101 0-16
  > Media Attribute (a): ssrc:1497766296 cname:137c654f31af69b4
    [Generated Call-ID: 63e7dfce8ea041b3b0529d3a2b4a2aba]
```

## Busy Here

Via: SIP/2.0/UDP

10.129.146.169:56108,rport=56188;branch=z9hG4bKpje7fbe12e60794e24887c5b7ef410aef6;received-59.64.129.91

From: "zl" [sip:ziliangzhang@iptel.org](mailto:sip:ziliangzhang@iptel.org);tag=b71e0df2c7e3452f85e82d0cf888328d-- 主叫uri

To: [sip:my2021212492@iptel.org](mailto:sip:my2021212492@iptel.org);tag=4592F153-6659A5EB00BC73CD-6854E6C0-- 被叫uri

Call-ID:60043eb13fc44c328dd2592b1b3de825 --通话标识符

Generated Call-ID:60043eb13fc44c328dd2592b1b3de8257 --唯一标识符

CSeg:14413 INVITE

ALLOW: ACK, BYE, CANCEL, INFO, INVITE, MESSAGE, NOTIFY, OPTIONS, PRACK, REFER, SUBSCRIBE, UPDATE --服务器支持的SIP方法

X-Call-ID:1D5103D3-6659A5EC0001B38F-77FFF6C0

X-Call-ID:3B6BC5D2-6659A5EB000C7826-942296C0 --额外的通话标识符，用于内部追踪或日志记录

Content-Length:0



```

Session Initiation Protocol (486)
  Status-Line: SIP/2.0 486 Busy Here
    Status-Code: 486
    [Resent Packet: False]
    [Request Frame: 961]
    [Response Time (ms): 5601]
  Message Header
    > Via: SIP/2.0/UDP 10.129.146.169:56108;rport=56108;branch=z9hG4bKPje7fbe12e60794e24887c5b7ef410aef6;received=59.64.129.91
    > From: "zl" <sip:ziliangzhang@iptel.org>;tag=b71e0df2c7e3452f85e82d0cf888328d
    > To: <sip:my2021212492@iptel.org>;tag=4592F153-6659A5EB000C73CD-6854E6C0
    Call-ID: 60043eb13fc44c328dd2592b1b3de825
    [Generated Call-ID: 60043eb13fc44c328dd2592b1b3de825]
    > CSeq: 14413 INVITE
    Allow: ACK, BYE, CANCEL, INFO, INVITE, MESSAGE, NOTIFY, OPTIONS, PRACK, REFER, SUBSCRIBE, UPDATE
    > X-Call-ID: 1D5103D3-6659A5EC0001B38F-77FFF6C0
    > X-Call-ID: 3B6BC5D2-6659A5EB000C7826-942296C0
    Content-Length: 0

```

## 四、实验结果

1. 通过对SIP软电话呼叫过程的抓包分析，我们深入理解了SIP信令在VOIP通话中的作用，包括会话信令(INVITE、BYE等)和媒体协商信令(SDP)。
2. 分析了不同情况下的呼叫流程,包括正常通话、主叫/被叫挂机、被叫忙、被叫无响应、主叫主动取消，以及两个主叫同时呼叫一个被叫的情况。每种情况下SIP信令的交互过程都有所不同。
3. 通过分析具体的SIP请求报文，理解了SIP协议的各种报文头域的作用，如INVITE、BYE、ACK等，以及SDP媒体协商的内容。

## 五、实验心得

1. 本次实验让我们更加深入理解了VOIP通话的工作原理，特别是SIP信令在其中的关键作用。通过对通话过程的详细分析，对SIP信令的理解有了很大提升。
2. 对比不同情况下的呼叫流程，可以发现SIP协议具有很强的灵活性和健壮性，能够应对各种复杂的情况。这为我们设计和实现VOIP系统提供了很好的参考。
3. 从抓包分析的角度来学习SIP协议，对于理解其工作机制很有帮助。实际解析报文头域，可以加深对SIP语法和语义的理解。
4. 本次实验训练了我们的问题分析和信息提取能力，为今后在VOIP领域的工作和研究奠定了基础。