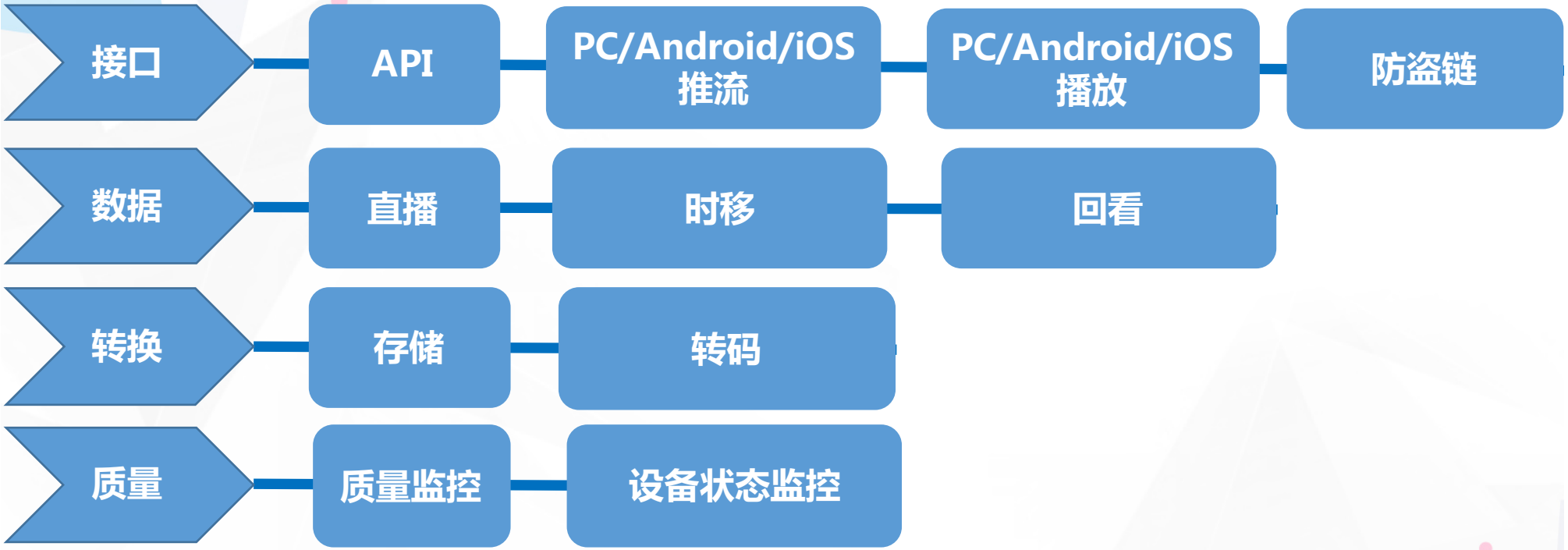
SACC 2016 第八届中国系统架构师大会
SYSTEM ARCHITECT CONFERENCE CHINA 2016
架构创新之路

CDN直播系统的优化

许开强
北京快网流媒体

业务架构



基于音视频实时数据的采集端、传输和播放端技术特性，优化延时、卡顿和首屏等重要性能指标

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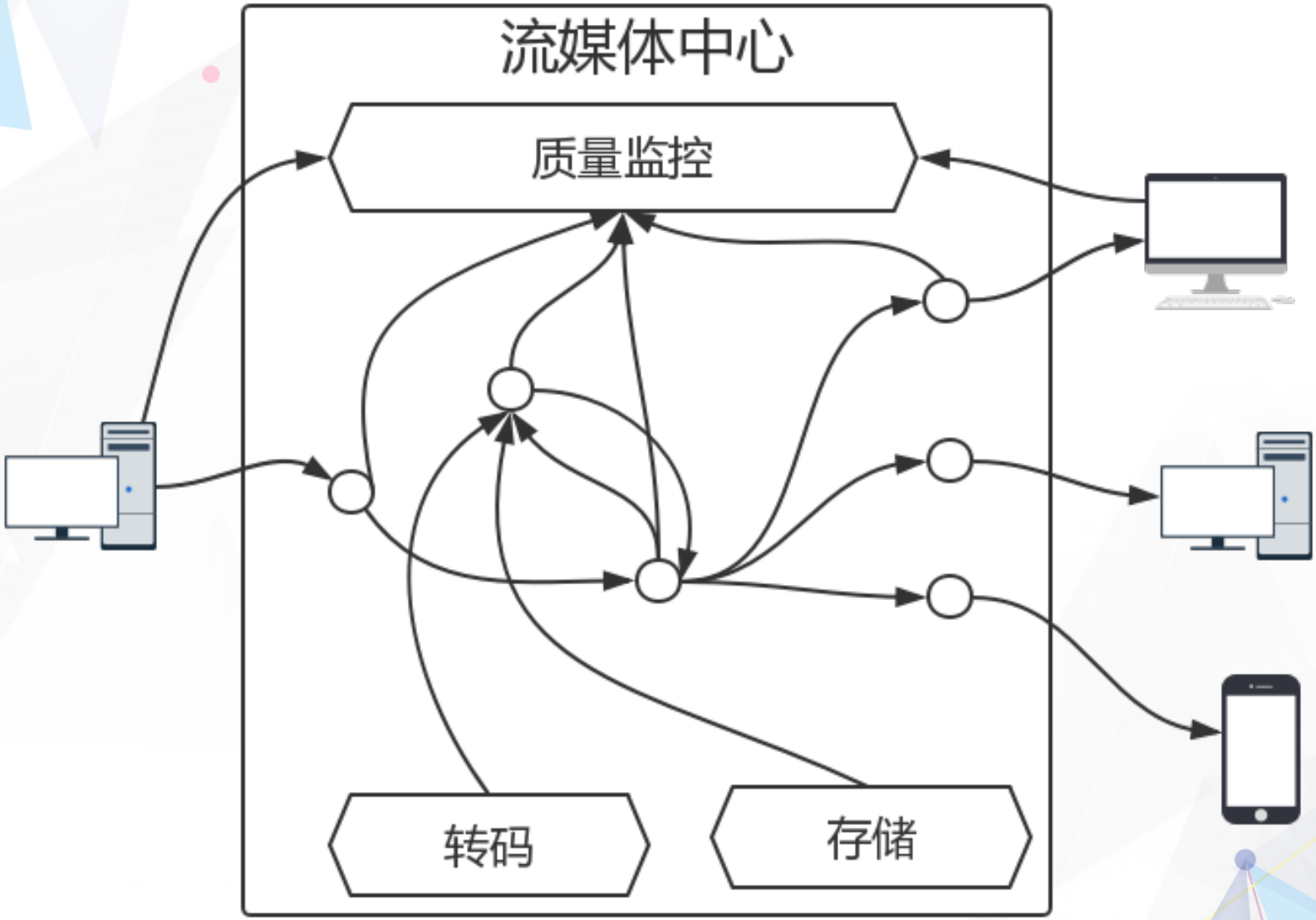
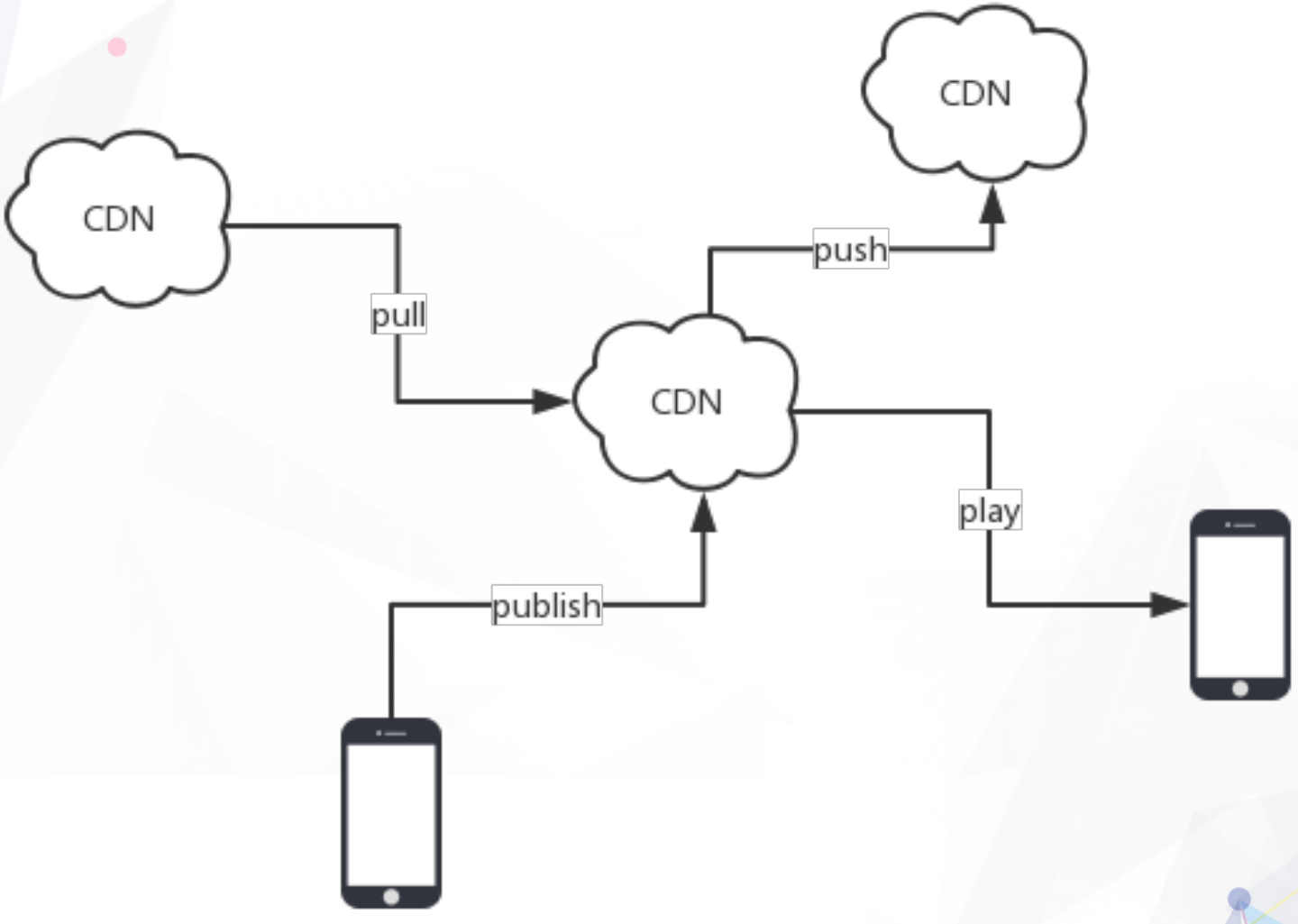
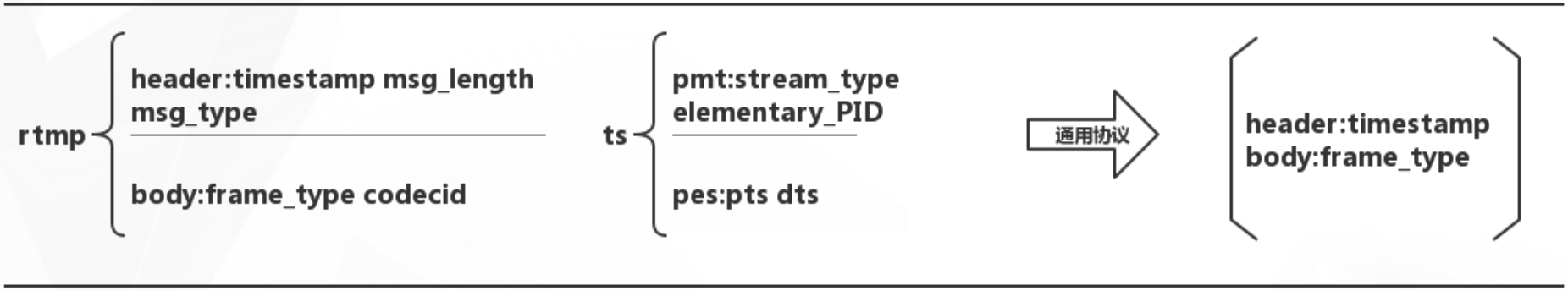
部署架构图

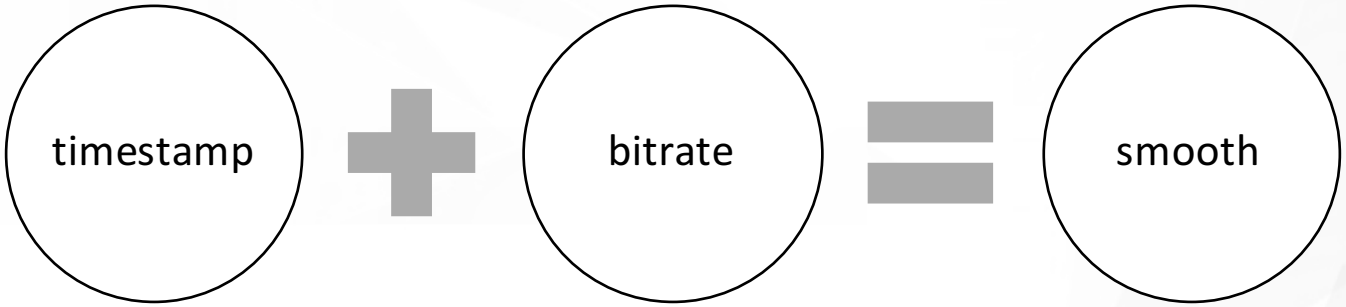


流传输



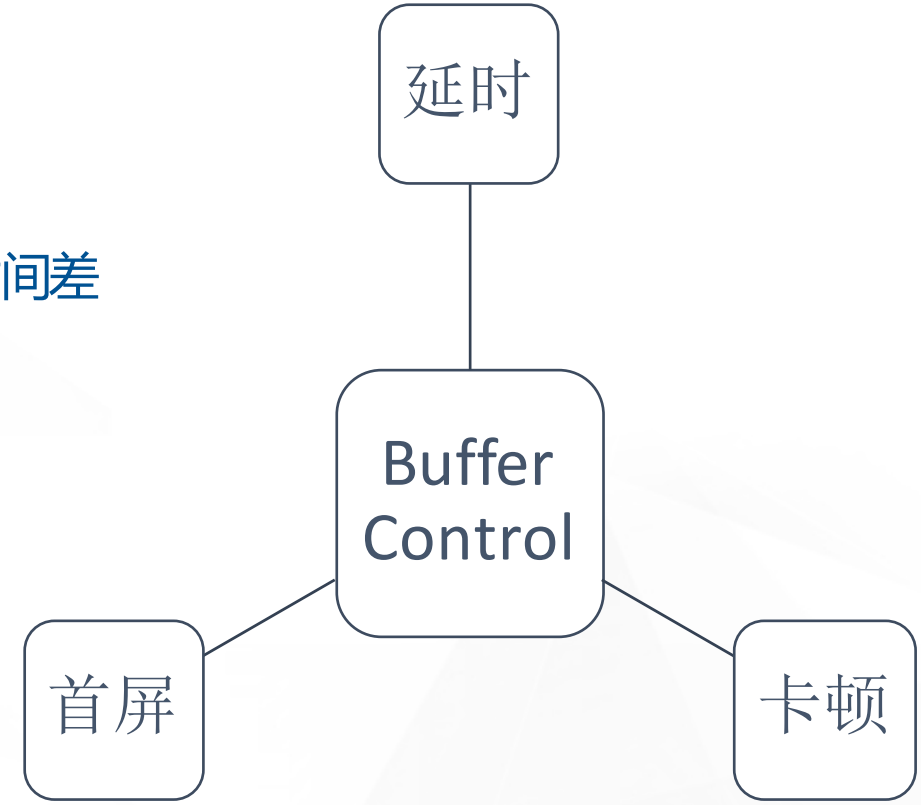
流媒体协议


rtmp
header:timestamp msg_length
msg_type
body:frame_type codecid
ts
pmt:stream_type
elementary_PID
pes:pts dts
通用协议
header:timestamp
body:frame_type

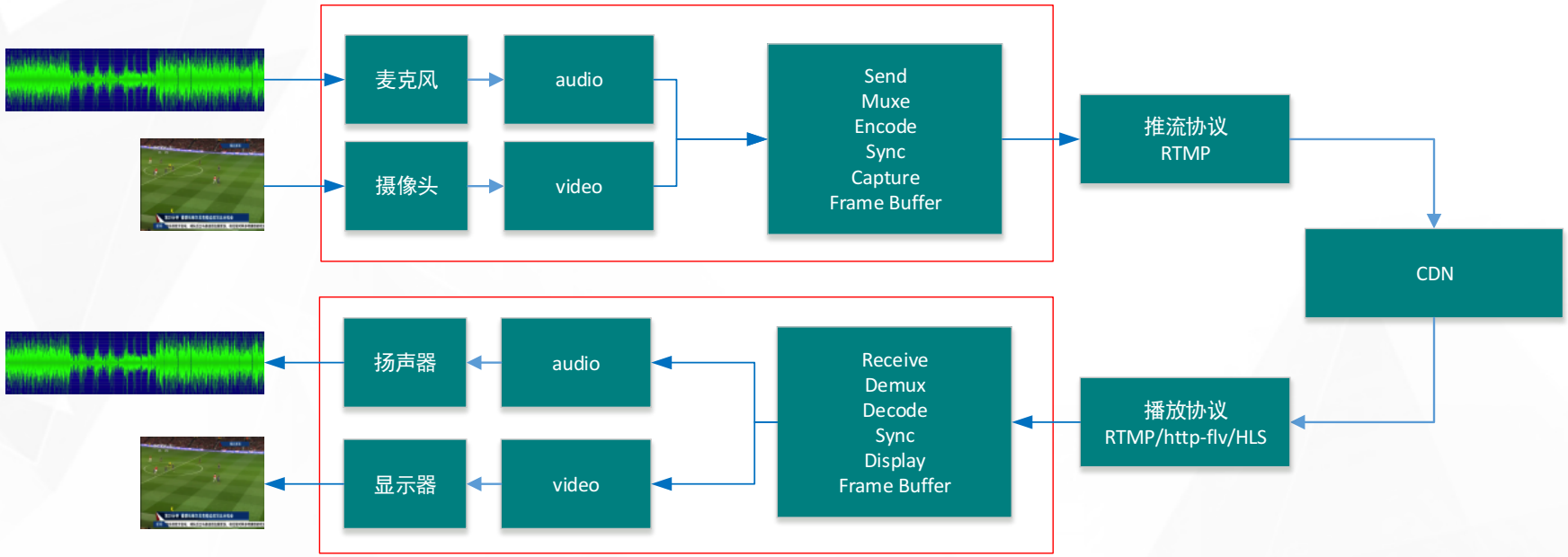

timestamp
bitrate
smooth

缓冲控制

- 延时：实时采集画面与播放展示画面的时间差
- 首屏：从点击播放到出图的时间
- 卡顿：播放过程中出现卡顿次数或时长



传输


麦克风
audio
摄像头
video
Send
Muxe
Encode
Sync
Capture
Frame Buffer
推流协议
RTMP
CDN
播放协议
RTMP/http-flv/HLS
Receive
Demux
Decode
Sync
Display
Frame Buffer
扬声器
audio
显示器
video

流媒体服务器

- 基于nginx和nginx-rtmp-module，将多进程模式改造成多线程
- 线程间消息通信，保留基于event处理逻辑
- 解决合并回源的问题
- Reload：修改Master-Worker模式
  1) worker内open和close所有fd
  2）重组connection与conf关系
- 实现rtmp/rtmp2flv/flv/hls分发
- 实现 Cache GOP、Cache Time、丢帧、时间戳修复
- 鉴权、防盗链、lua等
- 直播、时移、回看、录制、截图

时移-回看

- ■可配置时移存储时间
- ■采用小文件切片作为数据存储单元
- ■建立关键帧的索引，支持GOP级的拖动

GOP

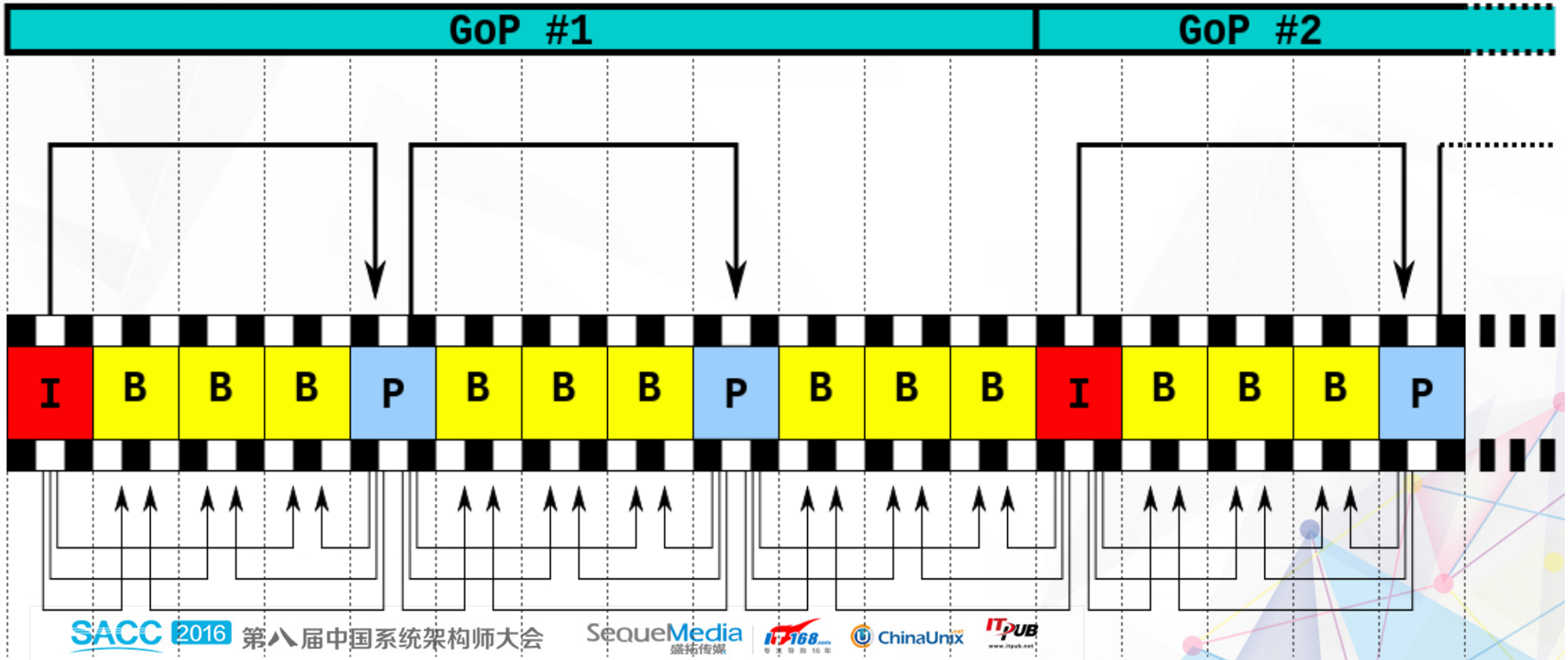
Open GOP 和 Closed GOP：

1.I帧前面的B帧是否参考该I帧

2.x264默认是Closed GOP，很多解码器不支持Open GOP

3.IDR场景切换

4. Adaptive Streaming，选择Closed GOP



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帧分析-IDR

Offset	Length	Start Code & NAL	NAL Type	Info
0x0000000000000000	27	0x0000000167	Sequence parameter set	
0x000000000000001B	10	0x0000000168	Picture parameter set	
0x0000000000000025	674	0x0000000106	SEI	
0x00000000000002C7	1109	0x0000000165	Coded slice of an IDR picture	I Slice
0x000000000000071C	237	0x0000000141	Coded slice of a non-IDR picture	P Slice
0x0000000000000809	121	0x0000000141	Coded slice of a non-IDR picture	B Slice
0x0000000000000882	72	0x0000000101	Coded slice of a non-IDR picture	B Slice
0x00000000000008CA	53	0x0000000101	Coded slice of a non-IDR picture	B Slice
0x00000000000008FF	82	0x0000000141	Coded slice of a non-IDR picture	P Slice
0x0000000000000951	115	0x0000000141	Coded slice of a non-IDR picture	B Slice
0x00000000000009C4	118	0x0000000101	Coded slice of a non-IDR picture	B Slice
0x0000000000000A3A	38	0x0000000101	Coded slice of a non-IDR picture	B Slice
0x0000000000000A60	36	0x0000000141	Coded slice of a non-IDR picture	P Slice
0x0000000000000A84	73	0x0000000141	Coded slice of a non-IDR picture	B Slice
0x0000000000000ACD	20	0x0000000101	Coded slice of a non-IDR picture	B Slice
0x0000000000000AE1	20	0x0000000101	Coded slice of a non-IDR picture	B Slice
0x0000000000000AF5	80	0x0000000141	Coded slice of a non-IDR picture	P Slice
0x0000000000000B45	75	0x0000000141	Coded slice of a non-IDR picture	B Slice
0x0000000000000B90	20	0x0000000101	Coded slice of a non-IDR picture	B Slice
0x0000000000000BA4	20	0x0000000101	Coded slice of a non-IDR picture	B Slice

```
NAL
  forbidden_zero_bit                    : 0 (1 bit)
  nal_ref_idc                           : 3 (2 bits)
  nal_unit_type                         : 5 (5 bits)
  slice_layer_without_partitioning_rbsp( )
    slice_header()
      first_mb_in_slice                 : 0 (v bits)
      slice_type                        : 7 [I Slice] (v bits)
      pic_parameter_set_id              : 0 (v bits)
      frame_num                         : 0 (v bits)
      idr_pic_id                        : 0 (v bits)
      pic_order_cnt_lsb                 : 0 (v bits)
      ref_pic_list_modification( )
    > dec_ref_pic_marking( )
      slice_qp_delta                    : -7 (v bits)
      disable_deblocking_filter_idc     : 0 (v bits)
      slice_alpha_c0_offset_div2        : 0 (v bits)
      slice_beta_offset_div2            : 0 (v bits)
  slice_data( )
  rbsp_slice_trailing_bits( )
```

帧分析- I

Offset	Length	Start Code & NAL	NAL Type	Info
0x0000000000000000	27	0x0000000167	Sequence parameter set	
0x000000000000001B	10	0x0000000168	Picture parameter set	
0x0000000000000025	674	0x0000000106	SEI	
0x00000000000002C7	1109	0x0000000165	Coded slice of an IDR picture	I Slice
0x000000000000071C	237	0x0000000141	Coded slice of a non-IDR picture	P Slice
0x0000000000000809	121	0x0000000141	Coded slice of a non-IDR picture	B Slice
0x0000000000000882	72	0x0000000101	Coded slice of a non-IDR picture	B Slice
0x00000000000008CA	53	0x0000000101	Coded slice of a non-IDR picture	B Slice
0x00000000000008FF	82	0x0000000141	Coded slice of a non-IDR picture	P Slice
0x0000000000000951	115	0x0000000141	Coded slice of a non-IDR picture	B Slice
0x00000000000009C4	118	0x0000000101	Coded slice of a non-IDR picture	B Slice
0x0000000000000A3A	38	0x0000000101	Coded slice of a non-IDR picture	B Slice
0x0000000000000A60	36	0x0000000141	Coded slice of a non-IDR picture	P Slice
0x0000000000000A84	73	0x0000000141	Coded slice of a non-IDR picture	B Slice
0x0000000000000ACD	20	0x0000000101	Coded slice of a non-IDR picture	B Slice
0x0000000000000AE1	20	0x0000000101	Coded slice of a non-IDR picture	B Slice
0x0000000000000AF5	80	0x0000000141	Coded slice of a non-IDR picture	P Slice
0x0000000000000B45	75	0x0000000141	Coded slice of a non-IDR picture	B Slice
0x0000000000000B90	20	0x0000000101	Coded slice of a non-IDR picture	B Slice
0x0000000000000BA4	20	0x0000000101	Coded slice of a non-IDR picture	B Slice
0x0000000000000BB8	36	0x0000000141	Coded slice of a non-IDR picture	P Slice
0x0000000000000BDC	74	0x0000000141	Coded slice of a non-IDR picture	B Slice
0x0000000000000C26	20	0x0000000101	Coded slice of a non-IDR picture	B Slice
0x0000000000000C3A	20	0x0000000101	Coded slice of a non-IDR picture	B Slice
0x0000000000000C4E	36	0x0000000141	Coded slice of a non-IDR picture	P Slice
0x0000000000000CBC	20	0x0000000101	Coded slice of a non-IDR picture	B Slice
0x0000000000000CD0	20	0x0000000101	Coded slice of a non-IDR picture	B Slice
0x0000000000000D08	74	0x0000000141	Coded slice of a non-IDR picture	B Slice
0x0000000000000D52	20	0x0000000101	Coded slice of a non-IDR picture	B Slice
0x0000000000000D66	20	0x0000000101	Coded slice of a non-IDR picture	B Slice
0x0000000000000D7A	27	0x0000000167	Sequence parameter set	
0x0000000000000D95	10	0x0000000168	Picture parameter set	
0x0000000000000D9F	9	0x0000000106	SEI	
0x0000000000000DA8	1161	0x0000000141	Coded slice of a non-IDR picture	I Slice
0x0000000000001231	72	0x0000000101	Coded slice of a non-IDR picture	B Slice

```
NAL
    forbidden_zero_bit                  : 0 (1 bit)
    nal_ref_idc                         : 2 (2 bits)
    nal_unit_type                       : 1 (5 bits)
  slice_layer_without_partitioning_rbsp( )
    slice_header()
      first_mb_in_slice                 : 0 (v bits)
      slice_type                        : 7 [I Slice] (v bits)
      pic_parameter_set_id              : 0 (v bits)
      frame_num                         : 15 (v bits)
      pic_order_cnt_lsb                 : 60 (v bits)
      ref_pic_list_modification( )
    > dec_ref_pic_marking( )
      slice_qp_delta                    : -10 (v bits)
      disable_deblocking_filter_idc     : 0 (v bits)
      slice_alpha_c0_offset_div2        : 0 (v bits)
      slice_beta_offset_div2            : 0 (v bits)
    slice_data( )
    rbsp_slice_trailing_bits( )
```

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帧分析- Open GOP的SEI

Offset	Length	Start Code & NAL	NAL Type	Info
0x0000000000000000	27	0x0000000167	Sequence parameter set	
0x000000000000001B	10	0x0000000168	Picture parameter set	
0x0000000000000025	674	0x0000000106	SEI	
0x00000000000002C7	1109	0x0000000165	Coded slice of an IDR picture	I Slice
0x000000000000071C	237	0x0000000141	Coded slice of a non-IDR picture	P Slice
0x0000000000000809	121	0x0000000141	Coded slice of a non-IDR picture	B Slice
0x0000000000000882	72	0x0000000101	Coded slice of a non-IDR picture	B Slice
0x00000000000008CA	53	0x0000000101	Coded slice of a non-IDR picture	B Slice
0x00000000000008FF	82	0x0000000141	Coded slice of a non-IDR picture	P Slice
0x0000000000000951	115	0x0000000141	Coded slice of a non-IDR picture	B Slice
0x00000000000009C4	118	0x0000000101	Coded slice of a non-IDR picture	B Slice
0x0000000000000A3A	38	0x0000000101	Coded slice of a non-IDR picture	B Slice
0x0000000000000A60	36	0x0000000141	Coded slice of a non-IDR picture	P Slice
0x0000000000000A84	73	0x0000000141	Coded slice of a non-IDR picture	B Slice
0x0000000000000ACD	20	0x0000000101	Coded slice of a non-IDR picture	B Slice
0x0000000000000AE1	20	0x0000000101	Coded slice of a non-IDR picture	B Slice
0x0000000000000AF5	80	0x0000000141	Coded slice of a non-IDR picture	P Slice
0x0000000000000B45	75	0x0000000141	Coded slice of a non-IDR picture	B Slice
0x0000000000000B90	20	0x0000000101	Coded slice of a non-IDR picture	B Slice
0x0000000000000BA4	20	0x0000000101	Coded slice of a non-IDR picture	B Slice
0x0000000000000BB8	36	0x0000000141	Coded slice of a non-IDR picture	P Slice
0x0000000000000BDC	74	0x0000000141	Coded slice of a non-IDR picture	B Slice
0x0000000000000C26	20	0x0000000101	Coded slice of a non-IDR picture	B Slice
0x0000000000000C3A	20	0x0000000101	Coded slice of a non-IDR picture	B Slice
0x0000000000000C4E	36	0x0000000141	Coded slice of a non-IDR picture	P Slice
0x0000000000000C72	74	0x0000000141	Coded slice of a non-IDR picture	B Slice
0x0000000000000CBC	20	0x0000000101	Coded slice of a non-IDR picture	B Slice
0x0000000000000CD0	20	0x0000000101	Coded slice of a non-IDR picture	B Slice
0x0000000000000CE4	36	0x0000000141	Coded slice of a non-IDR picture	P Slice
0x0000000000000D08	74	0x0000000141	Coded slice of a non-IDR picture	B Slice
0x0000000000000D52	20	0x0000000101	Coded slice of a non-IDR picture	B Slice
0x0000000000000D66	20	0x0000000101	Coded slice of a non-IDR picture	B Slice
0x0000000000000D7A	27	0x0000000167	Sequence parameter set	
0x0000000000000D95	10	0x0000000168	Picture parameter set	
0x0000000000000D9F	9	0x0000000106	SEI	
0x0000000000000DA8	1161	0x0000000141	Coded slice of a non-IDR picture	I Slice
0x0000000000001231	72	0x0000000101	Coded slice of a non-IDR picture	B Slice
0x0000000000001279	121	0x0000000141	Coded slice of a non-IDR picture	P Slice

```
NAL
    forbidden_zero_bit                  : 0 (1 bit)
    nal_ref_idc                         : 0 (2 bits)
    nal_unit_type                       : 6 (5 bits)
  sei_rbsp( )
    sei_message( )
      payloadType                               : 6 (v bits)
      payloadSize                               : 1 (v bits)
      sei_payload( )
        recovery_point( )
          recovery_frame_cnt                    : 0 (v bits)
          exact_match_flag                      : 1 [True] (1 bit)
          broken_link_flag                      : 0 [False] (1 bit)
          changing_slice_group_idc              : 0 (2 bits)
```

首屏

技术方面

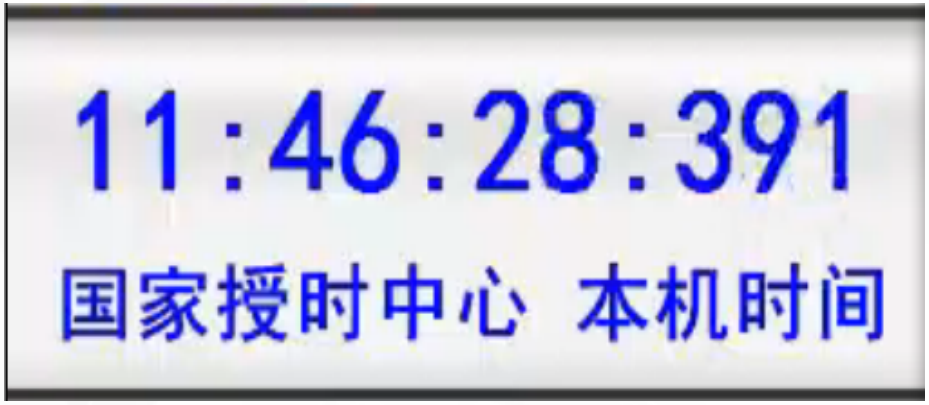
- GOP Cache：缓存当前GOP，时间戳修改
- 传输：简化协议交互， writev
- X264编码：无延时编码zerolatency，控制码率波动
- 播放：key frame解码
- 协议：http-flv

策略方面

- 预热：提前拉取热门直播
- 集群：就近共享数据

延时

播放输出

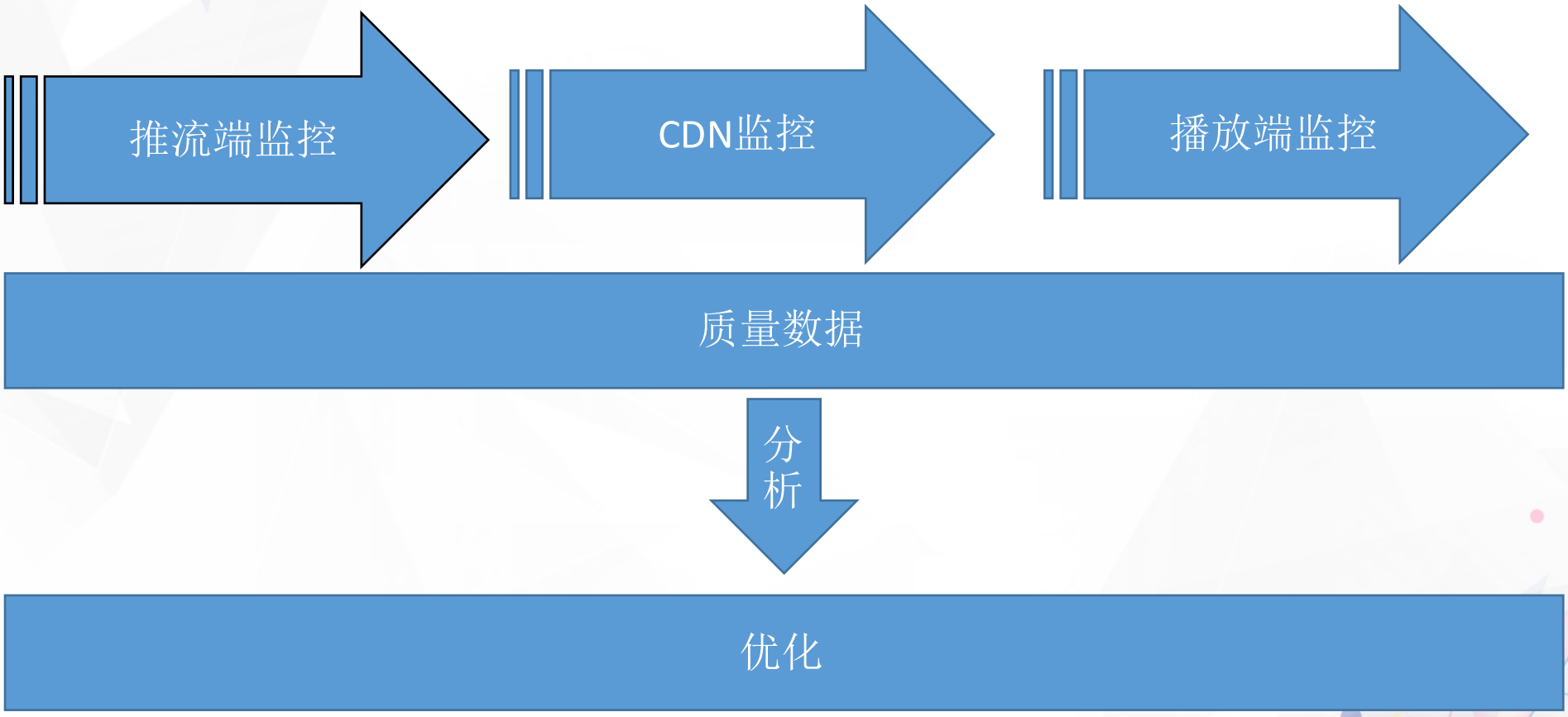


实时输入

全网延时控制

- ■延时控制：在网络拥塞严重时采用丢帧策略，保障实时播放
- ■参数更新：meta/video codec/audio codec
- ■时间戳：递增

质量监控



监控排障

链路追踪
- 从任何入口都可查找完整链路
- 所有节点的指标对比

精准度
- 区分区域、挂载点、频道
- 监控全网所有流，排查首要原因

告警
- 主动推送
- 历史回溯

播放质量

■参数：

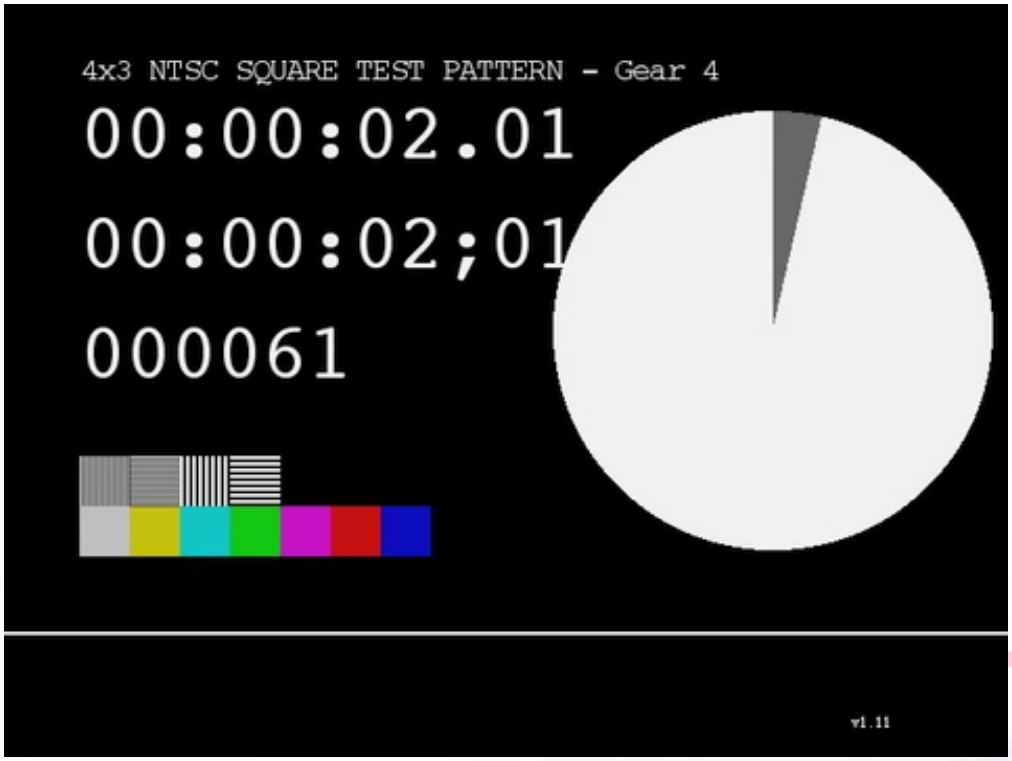
bitrate: 763 kb/s

resolution：480x360

fps：30

GOP：30

■参考指标：毫秒级、帧数、动态旋转图像



质量指标

CDN监控

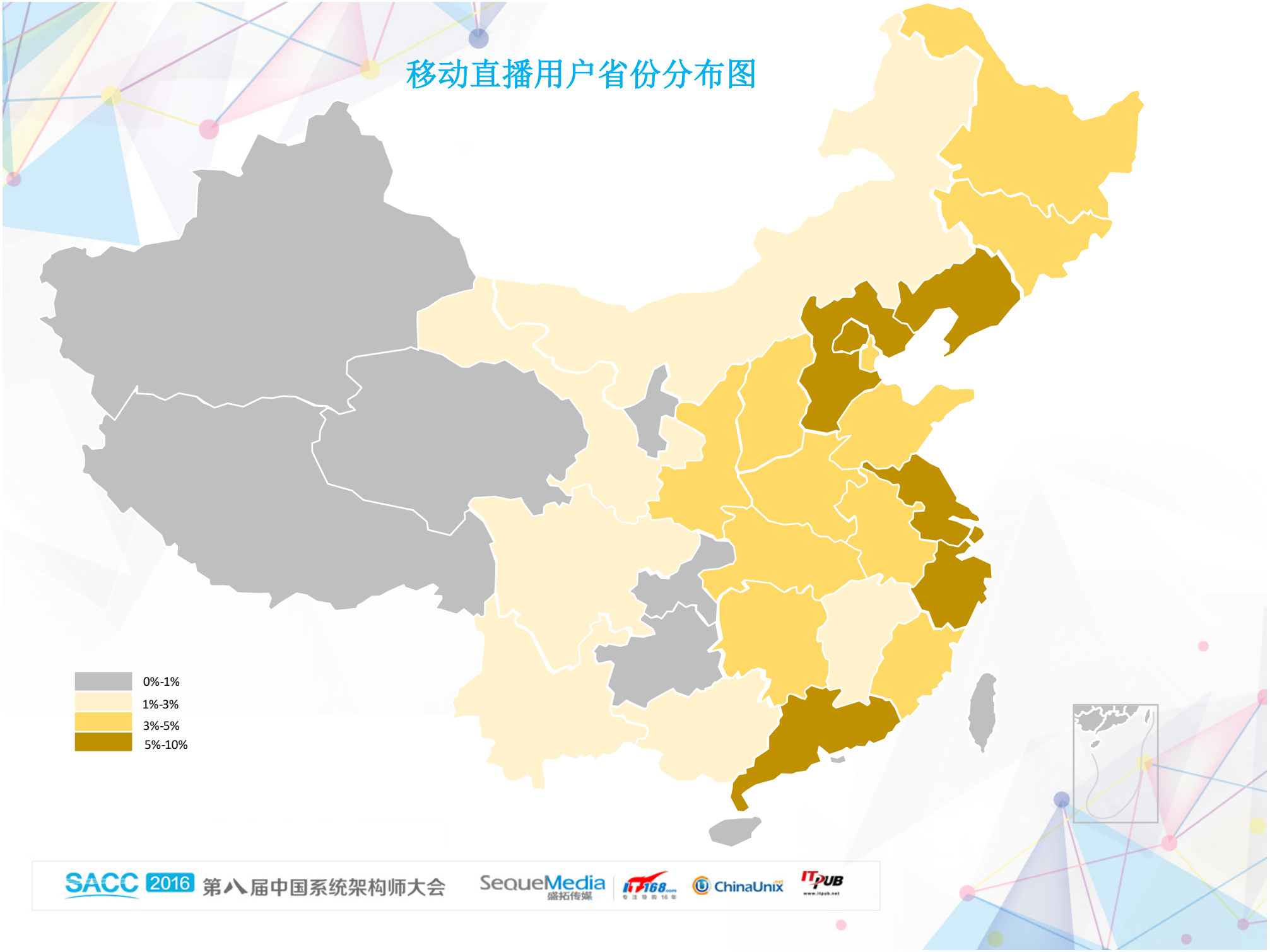
- 建连时间
- 首帧时间
- 缓存
- 帧率
- 码率
- 丢帧

端监控

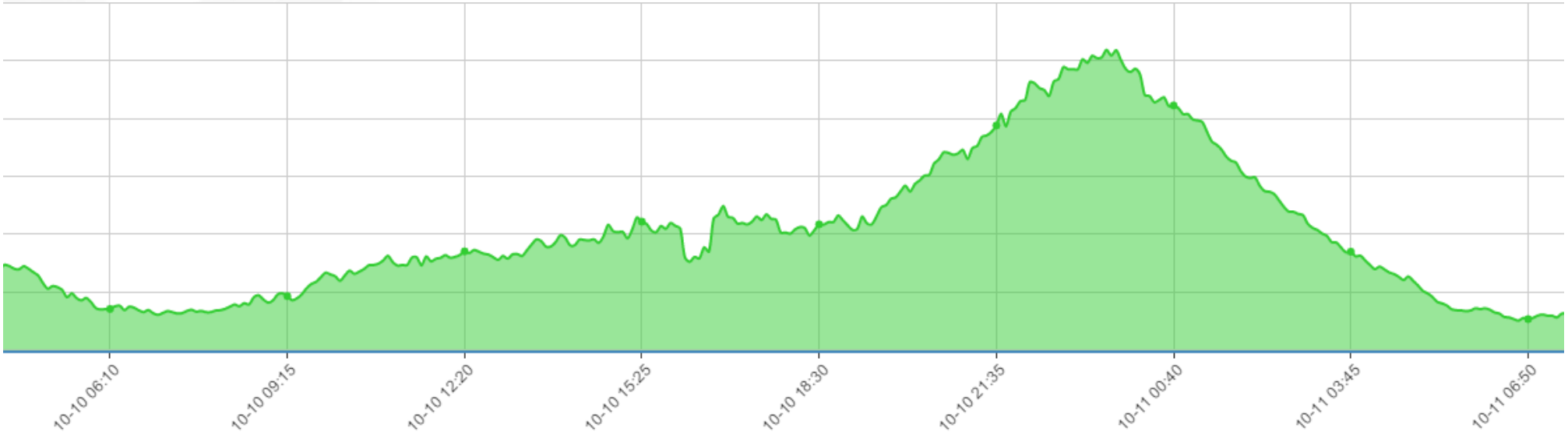
- DNS解析时间
- 建连时间
- 首帧时间
- 缓存
- 帧率
- 丢帧
- 码率
- 卡顿率
- 失败率

运营商、省份

移动直播用户省份分布图



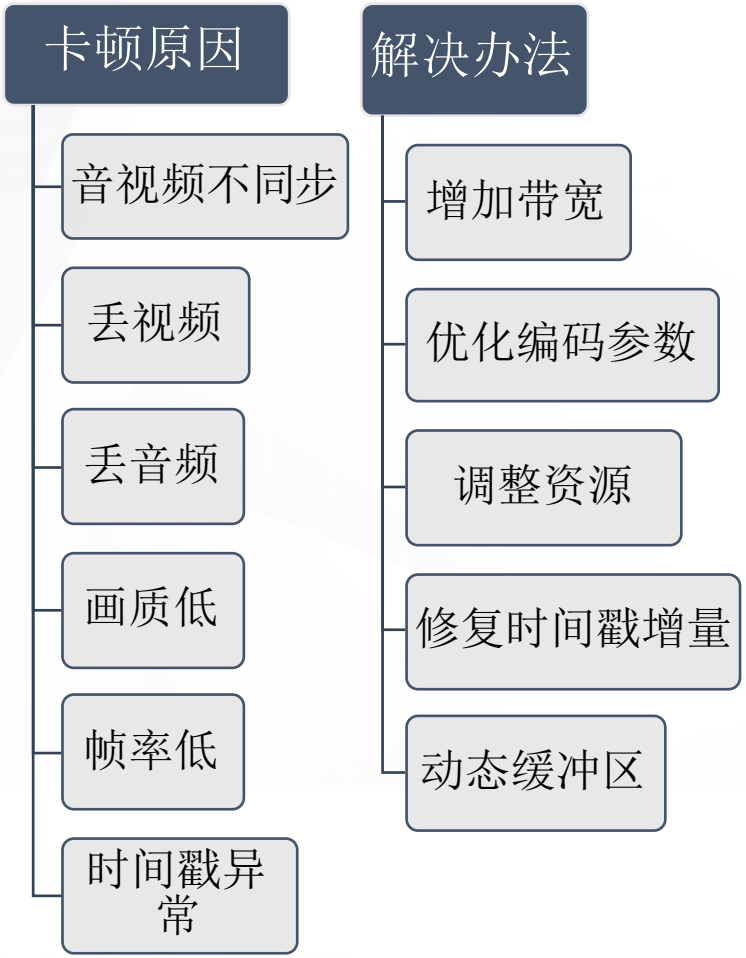
移动直播用户量时间分布图



高峰期是20点-24点，运维繁忙，质量告警

低谷期是4点-8点，更新版本，部署机器

卡顿


卡顿原因
音视频不同步
丢视频
丢音频
画质低
帧率低
时间戳异常
解决办法
增加带宽
优化编码参数
调整资源
修复时间戳增量
动态缓冲区

THANKS

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