Paper reading for CSE 5469

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Performance Characterization & Call Reliability Diagnosis Support for Voice over LTE

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Outline

- Introduction
- Background
- VoLTE performance characterization
- Call reliability study
- Stress testing and diagnosis
- Case study and root cases
- Discussion and conclusion
- Our understanding

Introduction

VoLTE: Better in most metrics such as quality

Best audio quality compared with 3G call

83% less data, 75% less energy, 40% shorter call setup time compared with OTT VoIP

Legacy call and OTT VoIP call: Better in reliability

Reasons and Methods

Reasons: Once thought: inadequate coverage

Formal methods: user feedback (unreliable and insufficient).

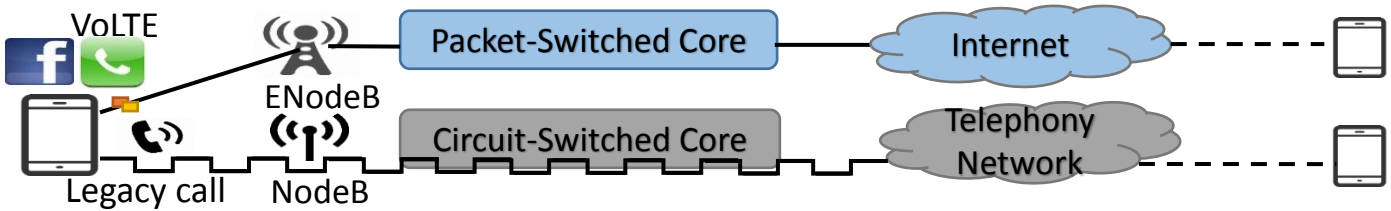
New methods: VoLTE problem detection tool & stress testing

Key Terminology

- VoLTE: Voice over LTE
- Legacy call: traditional circuit switch call
- OTT VoIP: the audio service you use over the network services such as Skype
- MOS: Mean opinion score. Used to measure human user's view of audio quality of cellular network. Range: 0-5
- CSFB: CS fallback is an alternative of VoLTE before IMS-based VoLTE architecture is deployed. It redirects a device registered on LTE network to 2G/3G network piror to starting or receiving a voice call.

PS vs CS

- 2G/3G: circuit-switched
- VoLTE: Deliver **voice** service as **data flows** within LTE network



VoLTE performance characterization

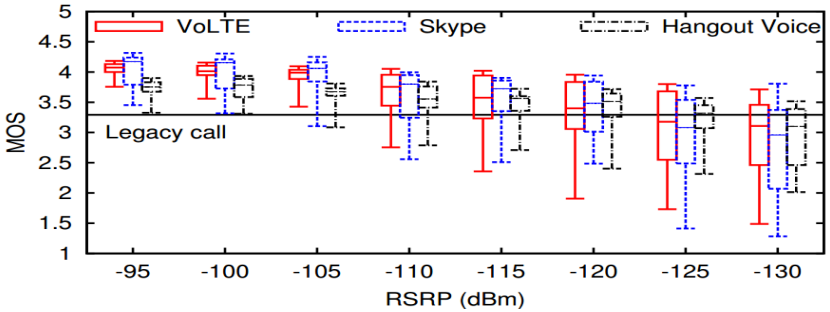
VoLTE service providers		
OP-I	OP-II	OP-III

Comparing entities		
Legacy call	Skype	Hangouts Voice

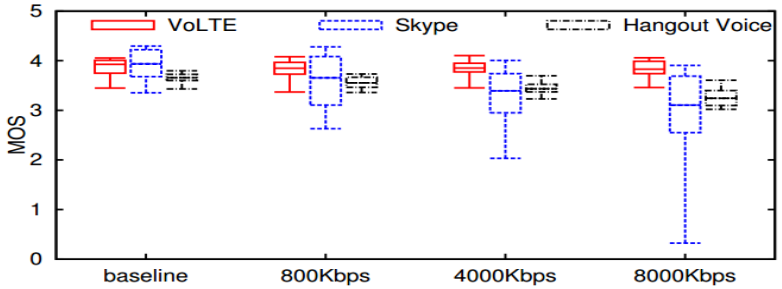
- Metrics we study
  - Smooth audio experience
    - audio quality (MOS), mouth-to-ear delay and more
  - Energy consumption
  - Bandwidth requirement
  - Reliability
    - Call setup success rate
    - Call drop rate

MOS	OP-II VoLTE	OP-II legacy call
OP-I VoLTE	3.16	3.46
OP-I legacy call	3.28	3.25

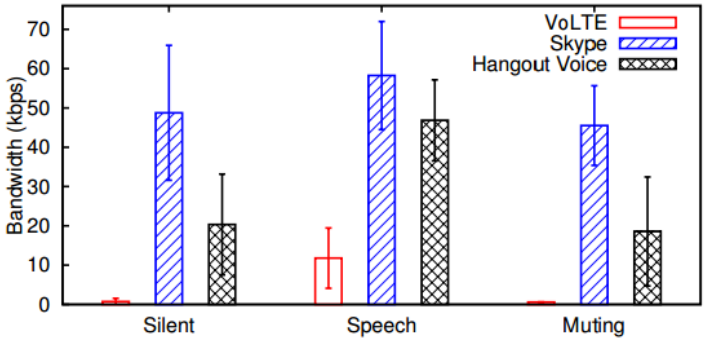
Median MOS when making calls from device indicated in row to device indicated in column.



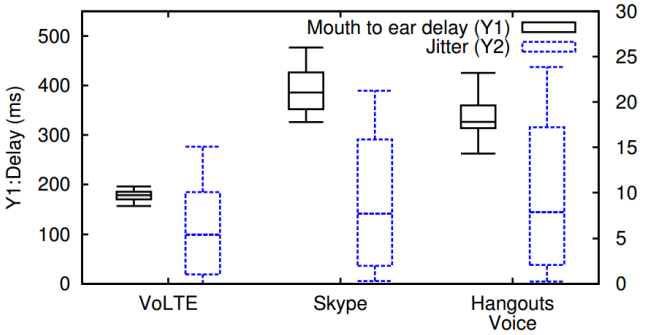
Uplink MOS under variant signal strengths. The dotted line represents the MOS a legacy call achieves in best case.



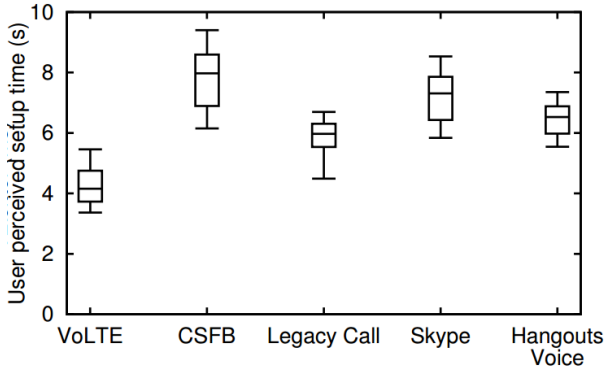
Uplink MOS under different background uploading traffic.X-axis indicates the bit rate the background application generates



RLC uplink throughput in three scenarios. Silent is when only background noise is presented and muting is when call is intentionally muted.



Jitter and mouth-to-ear delay comparison among different applications.

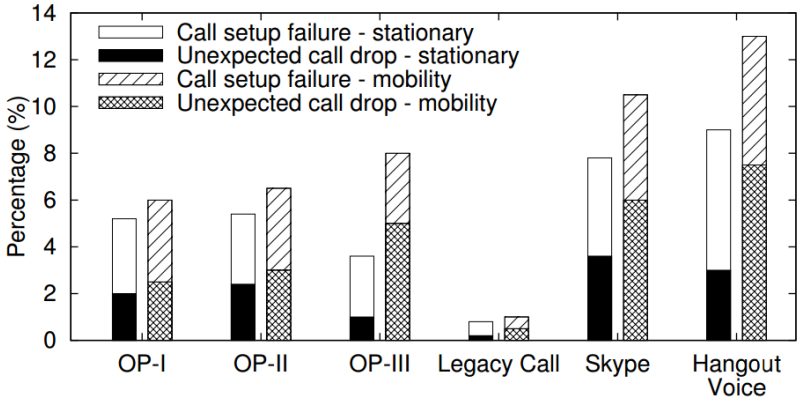


End-to-end call setup time comparison among different applications.

Description	Mean power (mW)	Std. dev.
Baseline	14.88	134.51
VoLTE	888.74	45.35
Legacy call	511.00	474.98
Skype	2027.06	495.06
Hangouts Voice	2029.53	530.58

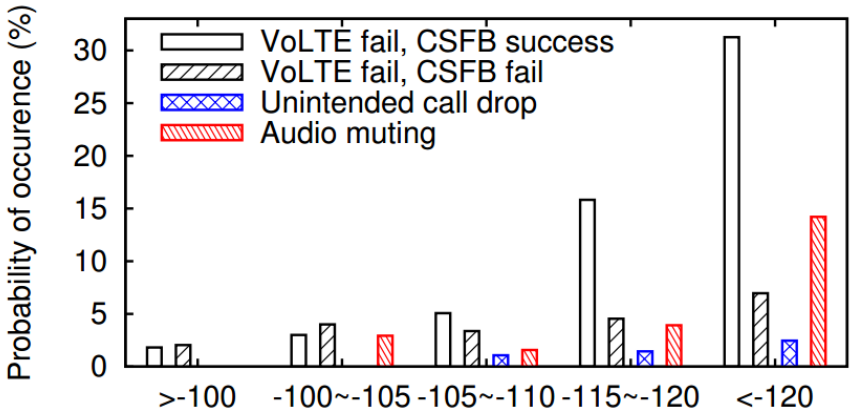
Power consumption of different applications

Call Reliability



Call reliability comparison among different applications in stationary and mobility experiments.

Audio Quality Problem



Occurrence of VoLTE problems under different signal strengths. “VoLTE fail, CSFB success” denotes VoLTE fails over to CSFB and establishes the CS call successfully. “VoLTE fail, CSFB fail” denotes the VoLTE call setup failure even with CSFB attempt.

Result overview

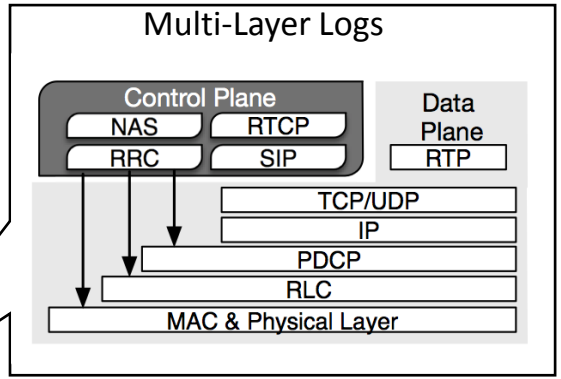
- VoLTE delivers **excellent** audio quality with
  - low bandwidth requirement
  - less user-perceived call setup time
  - low energy consumption
  - won't be affected by background traffic

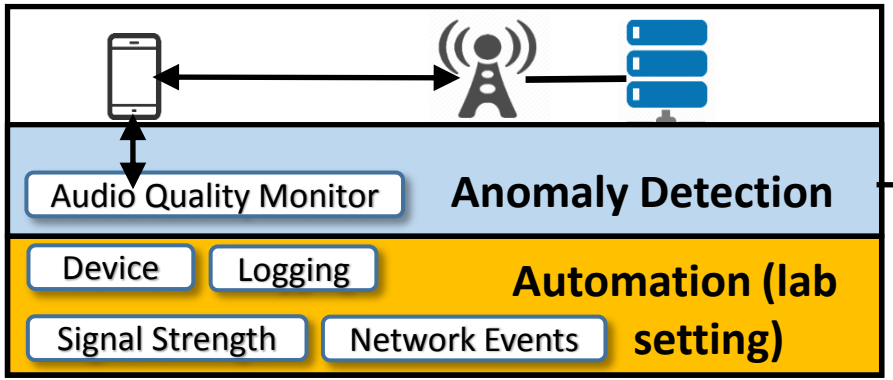
- Reliability still lags behind legacy call
  - Higher call drop rate (**5X**)
  - Higher call setup failure rate (**8X**)

Stress testing approach & diagnosis

- Why
  - Producing **more** problematic cases
  - Gathering **critical logs** in lab settings
- How
  - Tuning the network worse
- What is the challenge
  - How to control the events such as inter-cell handover and inter-RAT handover (With the help of operator, T-mobile, they can control inter-cell and inter-RAT signal strength)

Control and data plane stack for VoLTE





Basic architecture

Cross-layer Diagnosis

Potential Causes

Network Logs

QXDM

Stress testing approach & diagnosis

Basic flow

- Extract message flow
  - QXDM trace
- Control flow checker
  - Check the message flow and capture the violation information as 3GPP standard
- Connectivity checker
  - Identify which layer`s disconnection cause the problem
- Collaborative diagnosis
  - Report the problems to operator, if the problem is not caused by the device, take the network side log from BS and diagnose network-originated faults. Here is their core process!

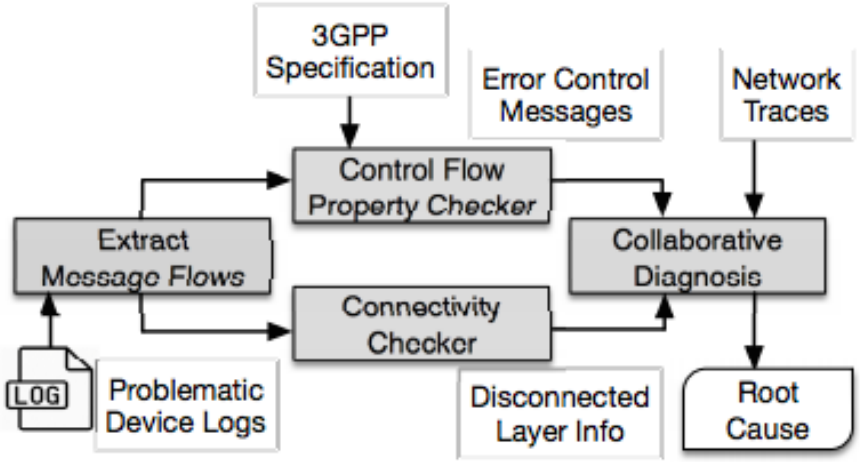


Figure 9: Cross-layer root cause diagnosis flow

Case study and root causes

Uncovered problems in VoLTE related protocol design

*These cases are concerned with system complexity and do not apply to OP-III due to its simpler design choices (e.g., no CSFB and SRVCC support). However, this simplicity leads to other reliability problems

Symptom	Impact on user experience	Carrier[1]	Potential cause
Unsuccessful call setup	Unable to make any phone call	OP-I OP-II	A lack of coordination in device-network interaction
Unintended call drop	Unable to maintain a phone call	OP-I OP-II	Incorrectly ordered inter-dependent actions
Long Audio muting	Up-to-50-second unrecoverable muting followed with call drop	OP-I OP-II	A lack of coordination in cross-layer interactions

Lacking of coordination in device-originated and network-originated events

- Problem
  - A high call setup failure rate when making VoLTE calls below certain RSRP threshold (- 110dBM, 3 out of 5 signal strength bars)
- Root cause
  - SRVCC is a network-originated events. ENodeB decide to initiate SRVCC if signal strength is bad. ENodeB sends SRVCC request .
  - CSFB is a mobile-originated event and serves as the alternative of VoLTE when LTE condition is not good enough to establish a VoLTE call. The trigger is a timer.
  - The cause of such problem is that the specifications fail to coordinate SRVCC and CSFB.
- Suggested solutions
  - Sprotocol designer to coordinate these two events, by adding logic to CSFB and SRVCC specification.

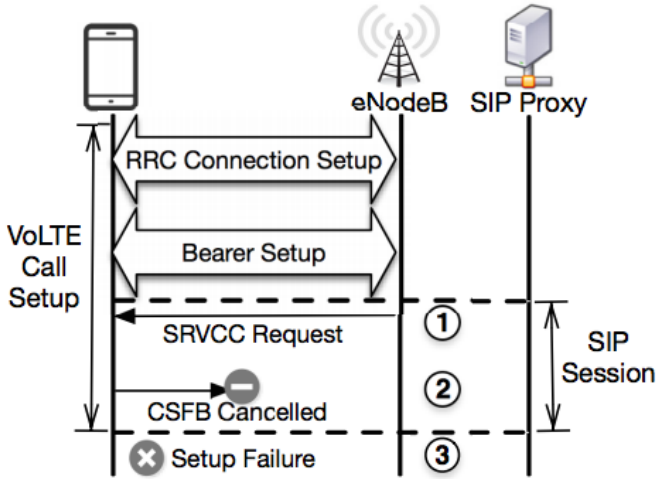
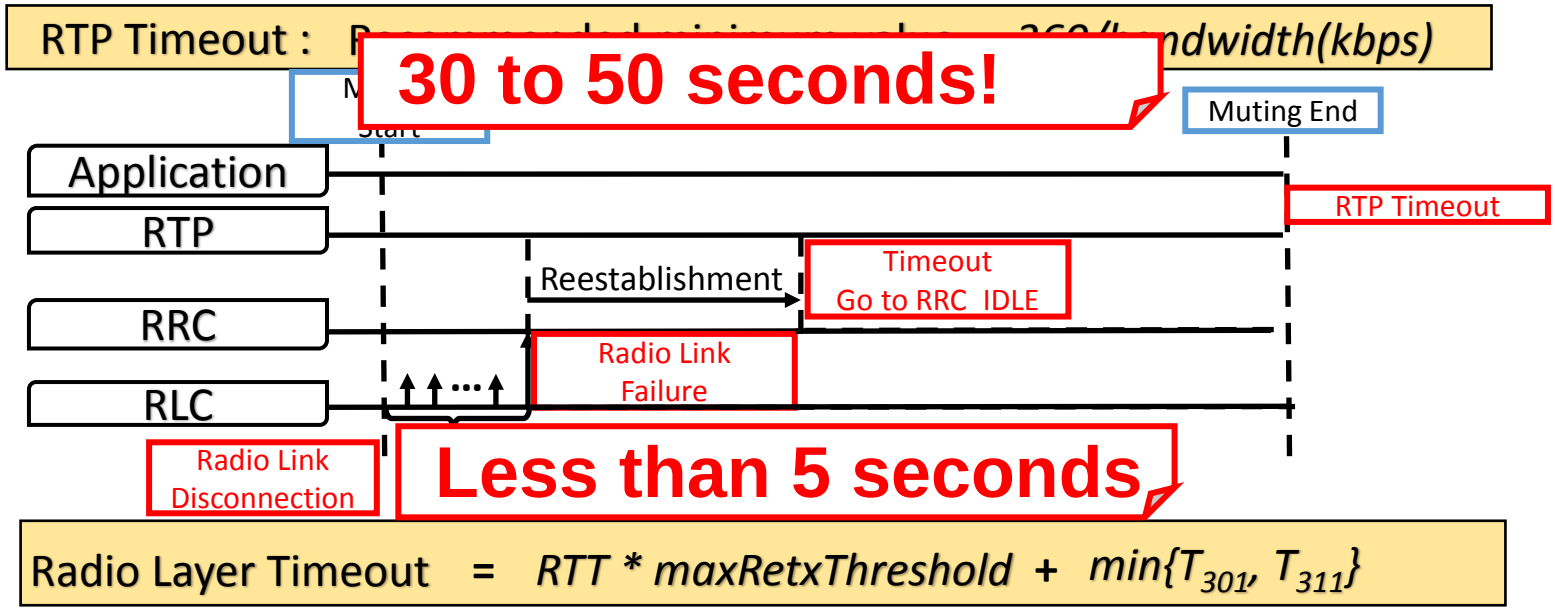


Figure 11: Call setup failure due to untimely SRVCC request.

Incorrectly ordered inter-dependent actions

- Problem
  - Unintended call drops frequently occur in our stress testing, when signal strength is tuned down to -120dBm (2 out of 5 signal strength bars)
- Root cause
  - The device handed over to the non-LTE area.
  - Inter-RAT handover occurs before SRVCC occurs. The call drop after the handover.
- Suggested solutions
  - Inter-RAT handover is actually redundant for VoLTE call, since SRVCC inherited and improved all its functionalities in VoLTE scenario. Disable inter-RAT for all dedicated bearers on ENodeB.
- Follow-up
  - OP-I has turned off the inter-RAT handover for all dedicated bearers in some markets to evaluate its effectiveness in reducing the VoLTE call drop rate. If it turns out to be effective, this change will be applied in a larger scale.

Lacking of coordination in cross-layer interactions



Lacking of coordination in cross-layer interactions

- Problem
  - RTP layer makes wrong assumption on the radio layer failure recovery
- Cause:
  - Gap between RTP (defined in RFC) and RRC/RLC (defined in 3GPP) protocol
  - Also causing similar problems in Skype and Hangouts
- Suggested solutions
    - Reporting radio link events directly to application layer

Summary

- First systematic study of VoLTE QoE in the commercial deployment
- Provide diagnosis support for VoLTE
  - Audio quality monitor to **capture** problems
  - Stress testing approach to **collect** essential information
  - Cross-layer diagnosis support to **understand** problems

Discussion

- Limitation of diagnosis support
  - Coverage
  - Not fully automated
- Follow-Up
  - Integrating OEM support for QoE problem diagnosis
  - Adding diagnosis support into protocols

Q&A

Thank you!