Resilient Baseband Processing in vRAN with Slingshot

by

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Context: Softwarization ("Virtualization") of the RAN
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vRAN offers:
• reduced vendor lock-in
• rapid feature development & upgrades
• easier maintenance

30,000 units to be deployed by Rakuten
Today’s vRANs Lack Resilience
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Video conferencing, average bitrate (kbps)

Switch

vRAN

Edge datacenter

0 100 200 300 400 500 600

0 2 4 6 8 10 12

Server failure

downtime 7 sec.

Connection recovery
Today’s vRANs Lack Resilience

Edge datacenter

Video conferencing, average bitrate (kbps)

downtime 7 sec.
Resilience with Slingshot: the Logical View

- Edge datacenter
- Switch
- vRAN

Video conferencing, average bitrate (kbps)

- Failover without Slingshot
- Failover with Slingshot

downtime 7 sec.
Focus of This Work

Edge datacenter

Switch

vRAN

vRAN

vRAN
Focus of This Work

vRAN

Layer 2
Layer 1

L2

User bits

L1 (PHY)
Baseband processing

Signal samples

Runs signal processing:
• Fourier transform
• Error correction
Existing Resilience Techniques Don't Work

#1 Real-time requirements
Hard sub-millisecond deadlines for signal processing tasks

#2 Transparency and Interoperability
Co-existence with standard vRAN infrastructure and protocols

❌ VM live migration: takes at least 100 ms

❌ Reliable state store: too much state + transparency
Challenge 1: Migration under Real Time Requirements

Insights:

(1) view baseband processing unit as a stateless functional executor

(2) treat little state inconsistency as regular wireless impairment

Performance impact of discarding PHY state ~ impact of normal wireless impairments
Challenge 2: Transparency with New Middleboxes

Issues:
- fixed mapping of cell sites
- 1-on-1 mapping of layers
Challenge 2: Transparency with New Middleboxes

Layer 1/Layer 2 middlebox:
- disaggregate MAC and PHY
- reroute MAC-to-PHY messages

Fronthaul middlebox:
- reroute connections with cell sites
- runs PHY failure detection in dataplane
Putting All Together

Layer 1/Layer 2 middlebox:
- disaggregate MAC and PHY
- reroute MAC-to-PHY messages

Fronthaul middlebox:
- reroute connections with cell sites
- runs PHY failure detection in dataplane
System Deployment: Production-Grade 5G vRAN Testbed

Hardware:
- x86 servers
- 100G NICs
- Tofino-based Arista P4 switch
- Foxconn 4x4; 100 MHz (3.3 – 3.4 GHz)

Software:
- Intel FlexRAN
- Capgemini Altran
- Metaswitch’s Fusion Core

User devices:
- Samsung A52
- OnePlus 10
- Rasberry Pi
Evaluation: PHY Failure Recovery in < 100 ms

Throughput (Mbps) vs. Milliseconds

- UDP, failover
- TCP, failover

The graph shows the throughput over time for two different protocols (UDP and TCP) and two different physical layers (PHY #1 and PHY #2). After a crash at around 300 milliseconds, the throughput recovers smoothly, demonstrating the failure recovery time is less than 100 ms.
Evaluation: PHY Live Migration with Zero Downtime

Planned update

Throughput (Mbps)

Before update

After update

Seconds

OnePlus 10
Samsung A52
Raspberry Pi
Conclusion

• vRAN is missing resilience – a must have feature of cloud applications.

• Slingshot is the first attempt to enable resilience in vRAN’s baseband processing.

• Observation: PHY’s state inconsistency ~ wireless impairment.

• Slingshot implements stateless failover to satisfy PHY’s realtime requirements.

• Slingshot works transparently through the two new vRAN middleboxes.