Dynamic Control of Real-Time Communication (RTC) using SDN:
A case study of a 5G end-to-end service

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About Nokia

Net sales 2015 by business

- 1 Nokia Networks: €11,490m (+3%)
- 2 Mobile Broadband: €6,064m (0%)
- 3 Global Services: €5,422m (+6%)
- 4 Nokia Technologies: €1,024m (+77%)

Net sales 2015 by region

- 1 Europe: €3,813m (+9%)
- 2 Middle East & Africa: €1,177m (+12%)
- 3 Greater China: €1,712m (+24%)
- 4 Asia-Pacific: €3,230m (-2%)
- 5 North America: €1,594m (+4%)
- 6 Latin America: €973m (-4%)

Average number of employees by region in 2015

- Finland: 6,042
- North America: 3,813
- Other European countries: 15,382
- China: 9,187
- Middle East & Africa: 2,321
- Asia-Pacific: 16,969
- Latin America: 2,481

After the acquisition of Alcatel Lucent in early 2016, we have approximately 120,000 employees, including more than 40,000 employees in R&D.
Mobile networks

- Faster, better connections than ever before
- Demand for bandwidth and connectivity continues to grow
  69% increase in 2014
  560% increase by 2017
- Drivers: streaming video, interactive video sessions, data center applications, tactile internet
Greatly increased range of applications and requirements
- Devices: Power-limited sensors, smart phones, tablets, virtual reality, cars, industrial applications, and others
- Data Rates: sensor data to 8K UHD video
- Latency: down to sub-millisecond
- Packet Sizes: tinygrams to jumbograms

Key Trends:
- Network performance indicators will include higher level QoE
- The network should adapt to the application, not the other way around

Flexibility and adaptability are key!
Our vision of the 5G architecture

SDN and NFV are key enablers.
SDN

- Centralized control of the network
- Separation of the Data and Control planes
Our work [1]

- Understand the interactions between the network and dynamic services
  - Dynamic services: services that demand a wide variability in network bandwidth and expectations
- Approximate a 5G network by introducing an SDN controller into a 4G/LTE testbed
- Consider an case study dynamic network service: DNE-RTC
- Identify key takeaways for the design of 5G

OTT and NE-RTC

WebRTC is an OTT service that allows real-time communications between users over the Internet

• No plugins, no apps
• Poor video quality and/or extreme latency at sub-100kbps rates
• Unfair competition: devices in similar network conditions may have rates that differ by > 2x
• Cell load changes impact random users

Network-enabled WebRTC (NE-RTC)

Network service developed by Bell Labs to provide improved, consistent video call quality

• Calculates target bitrate for video flows on base station based on SINRs and number of users
• Provides feedback to device about target bitrate
• Special radio scheduling algorithm designed for guaranteed bitrate flows
• Allocates resources across the network to provide desired bitrate
Dynamic Network-Enabled RTC (NE-RTC)

- Dynamically enable NE-RTC only when it will be useful for video calls currently in progress
  - Limiting usage of resources to only those times and calls that will benefit
  - Key character of an adaptable network, like 5G
- DNE-RTC App running on SDN Controller receives device metrics from analytics
- NE-RTC enabled/disabled based on metrics indicating its usefulness
The 4G/LTE Network

- Since no 5G testbeds exist yet, we base our proof of concept on a 4G/LTE testbed
- The 4G/LTE Network consists of a number of interacting components:
  - eNB (eNodeB) or radio base station
  - SGW (Serving Gateway) —establishes bearers for data flows
  - PGW (Packet Gateway) —policy enforcement and packet routing
  - MME (Mobility Management Entity) —key mobility control node
  - PCRF (Policy and Charging Function) —sets network policy
  - HSS (Home Subscriber Server)
Our Proof-of-Concept 5G Network

- We simulate a 5G network by introducing an SDN controller into a 4G/LTE testbed
- An OpenFlow adaptor enables SDN Controller to control the eNodeB
  - Adaptor maps between OpenFlow and the base station’s CLI commands
  - Sends device throughput info to controller and enables/disables NE-RTC
Our Proof-of-Concept 5G Network

- DNE-RTC app runs on SDN controller and uses device throughput to decide when to enable or disable NE-RTC
- App communicates with many existing components:
  - MME to map between different device identifiers
  - PCRF to setup guaranteed bitrate bearers for video flows
  - WebRTC gateway to set target bitrates
  - Device to determine when a call is occurring
DNE-RTC App

- Computes an exponentially weighted moving average of each device’s throughput
- NE-RTC is enabled when the device is in a call and its throughput drops below a low threshold
  - Enables target bitrate computation and scheduling algorithm
  - Sends target bitrate info to WebRTC gateway
  - Sets up guaranteed bitrate bearers across the network
- A second higher threshold determines when to disable NE-RTC again
  - Disables target bitrate computation and scheduling algorithm
  - Releases guaranteed bitrate bearers for this flow
Lesson 1: Horizontal SDN interactions are common

- Mobile Networks are usually separated into a number of domains: RAN, Edge, and Core
- Network services need to frequently communicate and configure components across all of these domains
  - RAN: base station throughput info and scheduling algorithm
  - Edge/Core: guaranteed bitrate bearers
  - App: target bitrate
- Thus horizontal communication between controllers in different domains MUST be efficient
Lesson 2: Identifier proliferation complicates services

- The existing 4G/LTE network components use many different identifiers for the same device
  - IMSI, S1APID, IP address, SIP URI
- Implementing the DNE-RTC service required mapping between 4 of these
  - Hardest part of the implementation
- Need to minimize the number of identifiers needed in 5G service APIs and enable easy mapping
  - The centralized information and control of SDN will help here

**IP**: 203.0.113.15

**IMSI**: 241100754492889

**S1APID**: 0x57143

**SIP**: bob@example.com
Lesson 3: Network function graphs have control plane elements

- Network function graphs provide a way to define services in terms of connected network elements
  - Being standardized by ETSI and IRTF
- Usually discussed in terms of data plane elements
  - Firewalls, load balancers, IPS, IDS, etc
- These graphs need to be able to include control plane elements in addition to data plane elements
  - The new components in DNE-RTC are control plane
Summary

• We developed a proof of concept dynamic network service by introducing an SDN controller into a 4G/LTE testbed to study the dynamics of network and service interactions
• We identified three key takeaways for future work in 5G
  - Horizontal SDN-controller interactions are common
  - Identifier proliferation complicates service development
  - Network function graphs need to be able to contain control plane elements
SDNs in Nokia Bell Labs

- Path Switching is a new data plane forwarding technology that eliminates per-flow forwarding state from intermediate routers in an SDN network while providing end-to-end per-flow routing.

- Path Switching works by replacing each packet's existing source/destination header with the packet path encoded in a sequence of labels, where each label represents the current hop's outgoing interface.

- Path Switching has been implemented in the OVS Open vSwitch softswitch in the Linux kernel.

Reference:

- Security of the SDN application plane.
- Nuage networks: SDN for Enterprises and Service Providers

http://www.nuagenetworks.com

- SDN controllers in 5G.
Questions

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