Bell Labs

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

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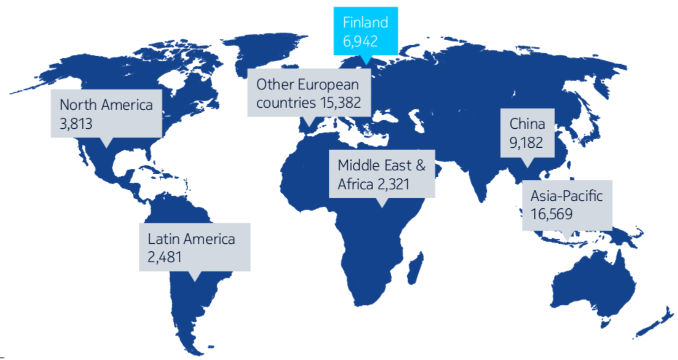
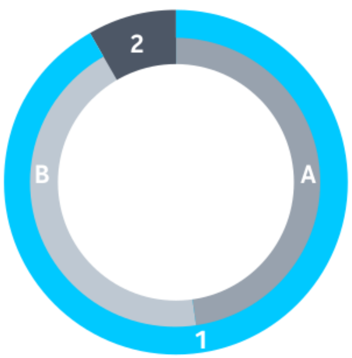
About Nokia

Average number of employees by region in 2015



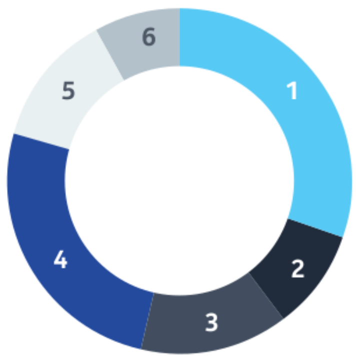
After the acquisition of Alcatel Lucent in early 2016, we have approximately 106,000 employees, including more than 40,000 employees in R&D.

Net sales 2015 by business



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

Net sales 2015 by region



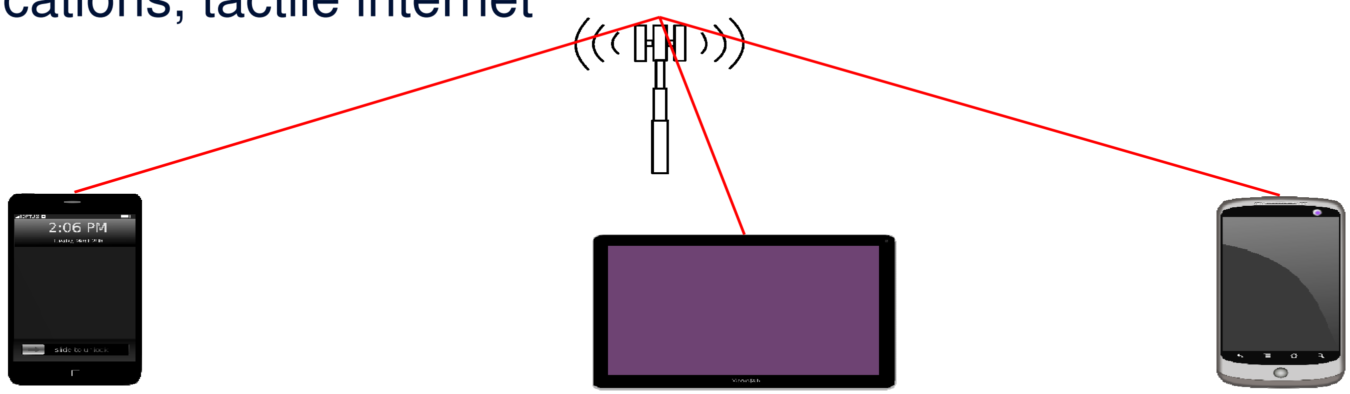
1 Europe [1]	€ 3,813m	(+9%)
2 Middle East & Africa	€ 1,177m	(+12%)
3 Greater China	€ 1,712m	(+24%)
4 Asia-Pacific	€ 3,230m	(-2%)
5 North America	€ 1,594m	(+4%)
6 Latin America	€ 973m	(-4%)

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



5G: The next generation mobile network

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!

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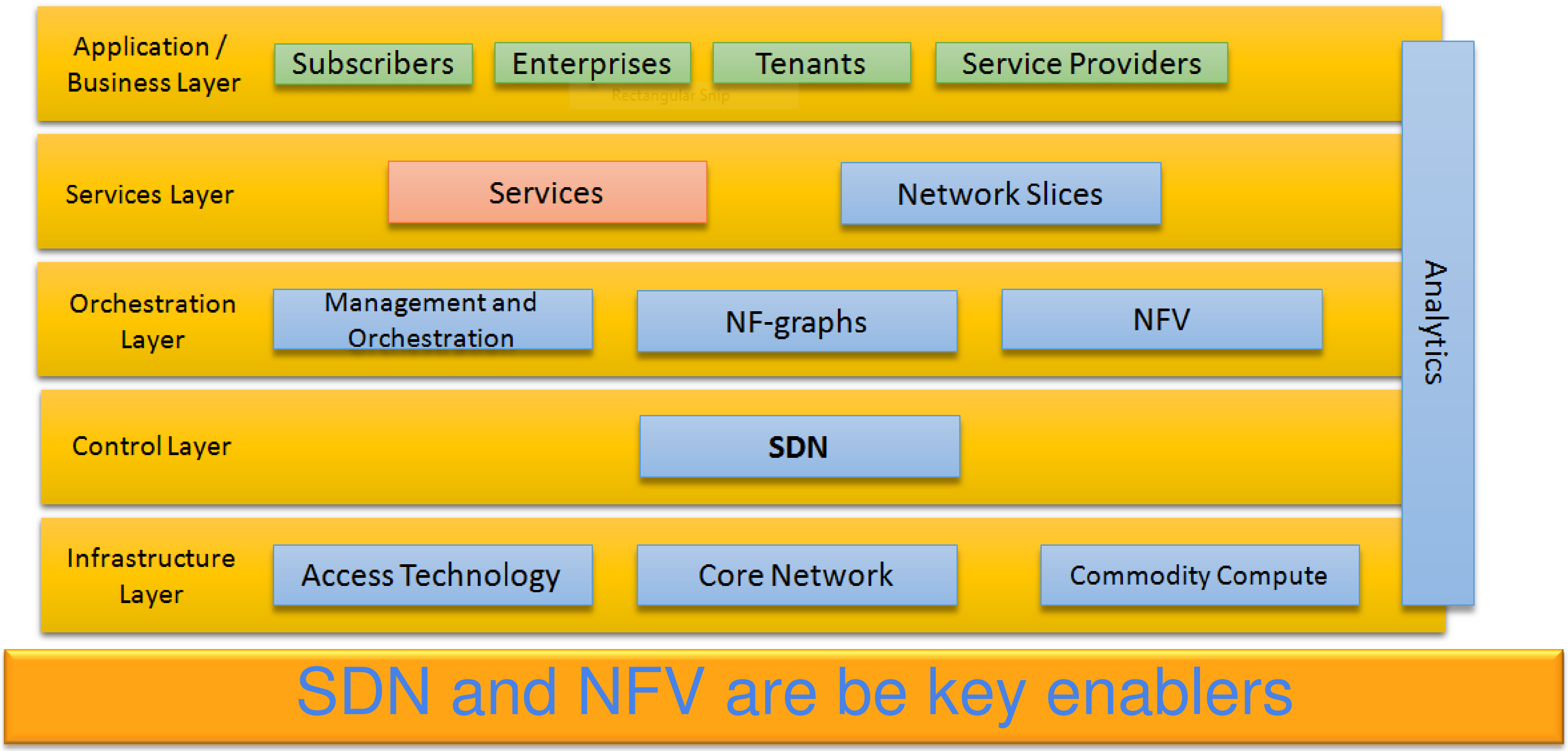
Our vision of the 5G architecture



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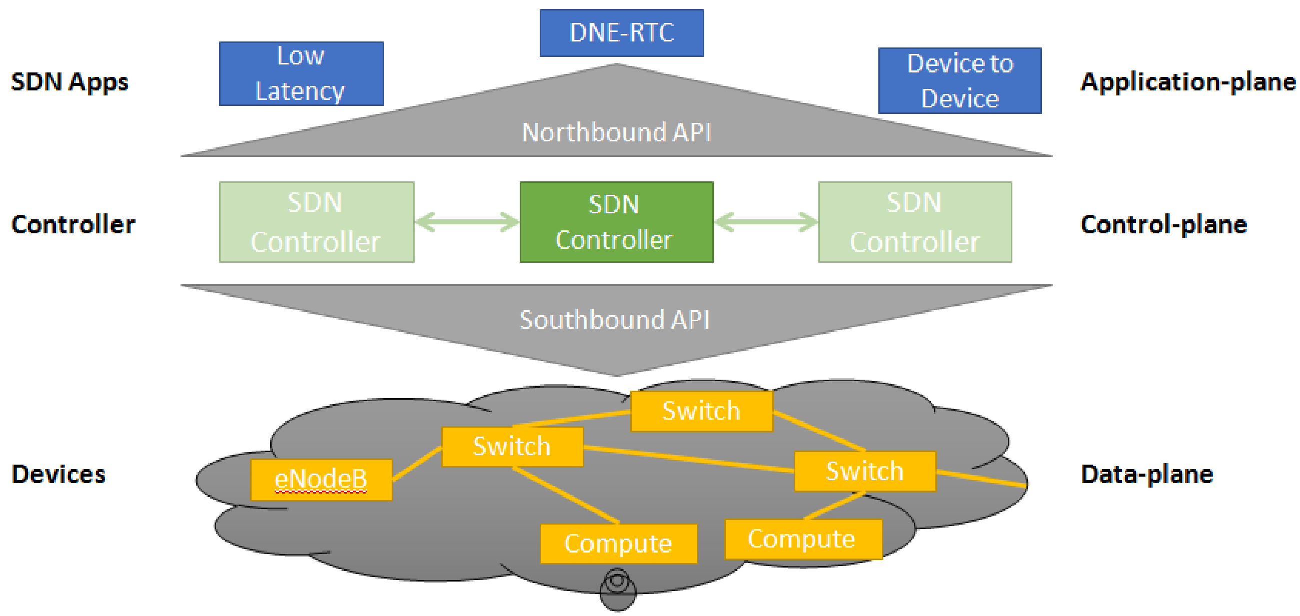
SDN

- Centralized control of the network
- Separation of the Data and Control planes



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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

[1] Dynamic control of real-time communication (RTC) using SDN: A case study of a 5G end-to-end service, Samuel Jero, Vijay K. Gurbani, Ray Miller, Bruce Cilli, Charles Payette and Sameer Sharma, to appear in Proceedings of IEEE/IFIP Network Operations and Management Symposium (NOMS), 2016.

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

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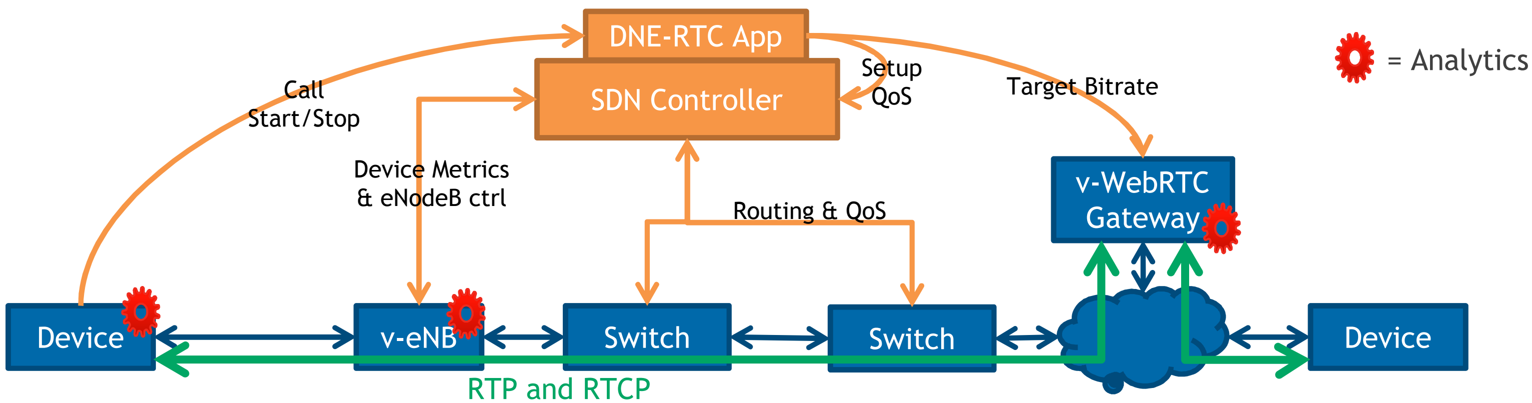
Dynamic Network-Enabled RTC (NE-RTC)

- 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



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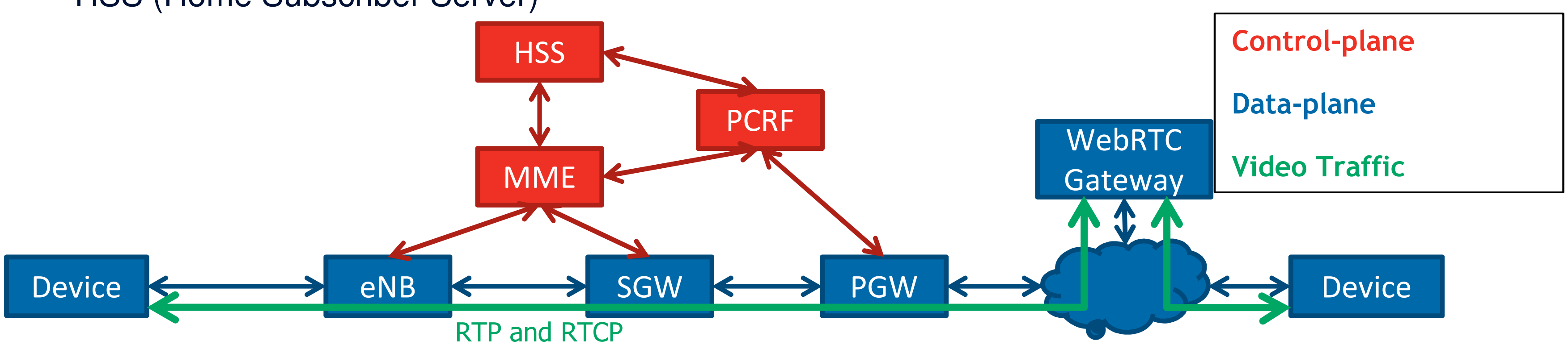
The 4G/LTE Network

- 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)



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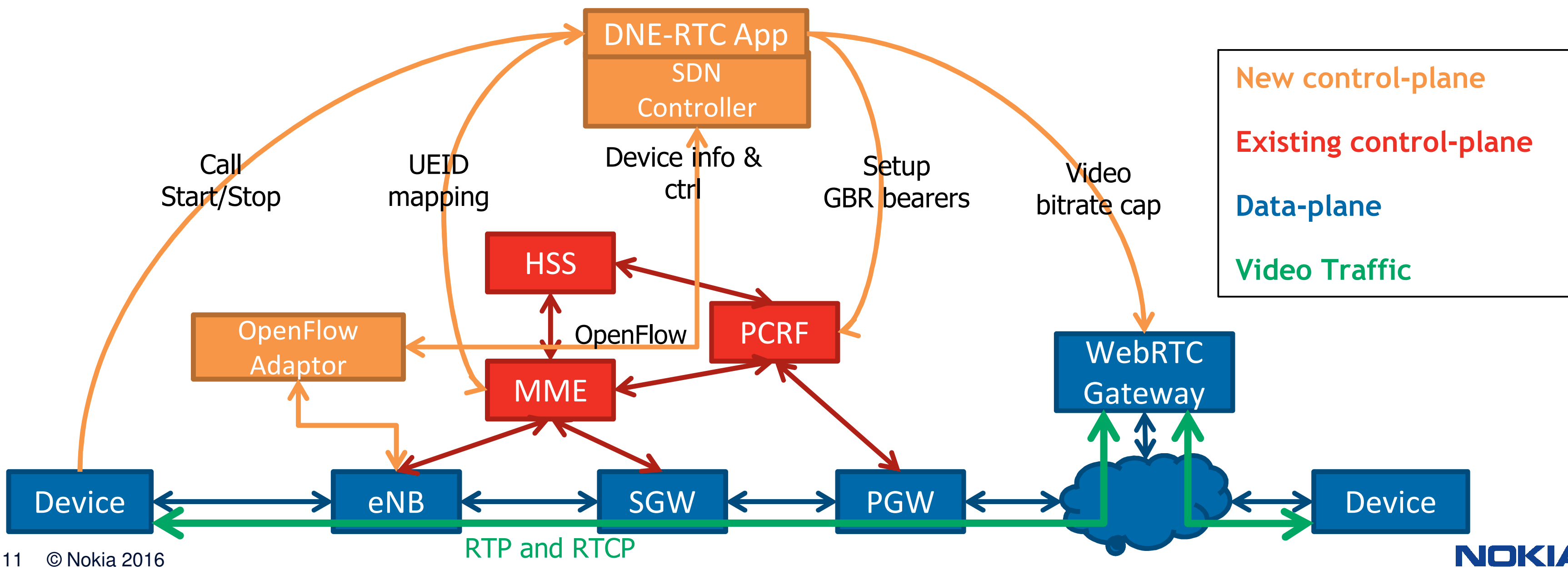
Our Proof-of-Concept 5G Network

- 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



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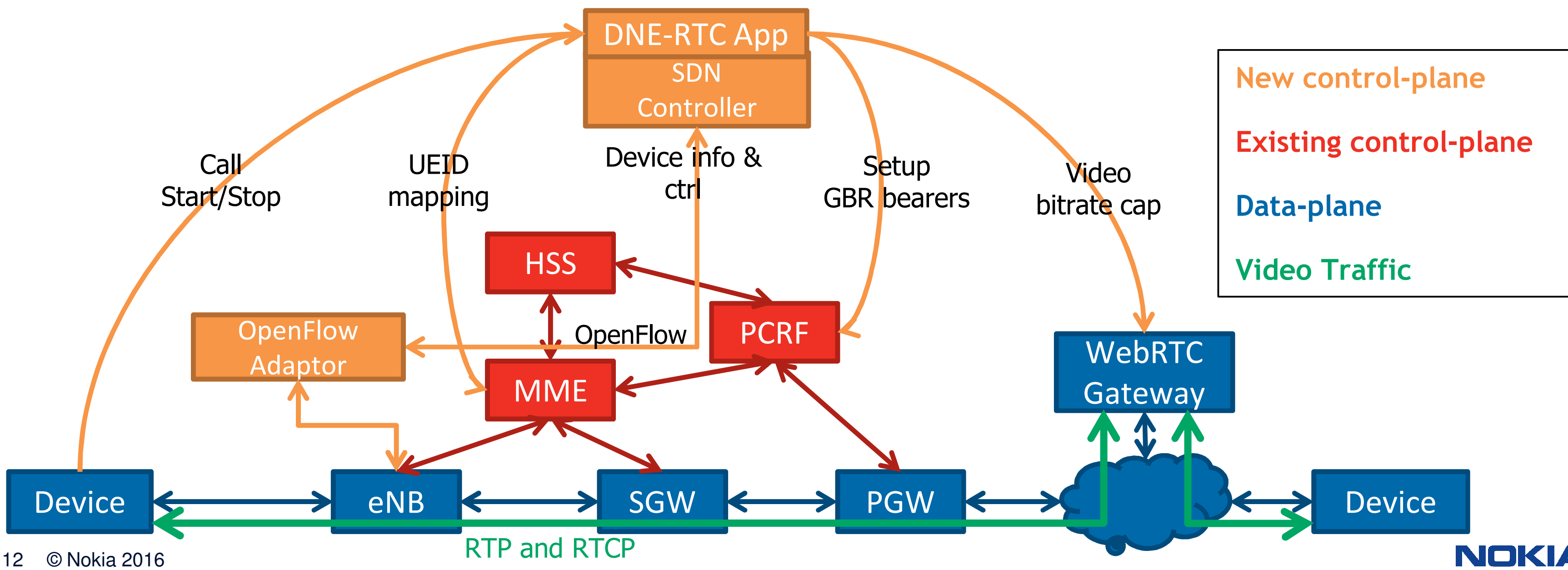
Our Proof-of-Concept 5G Network

- 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



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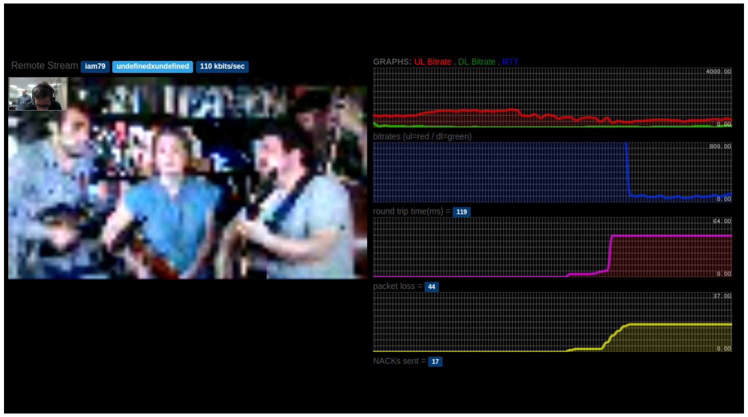
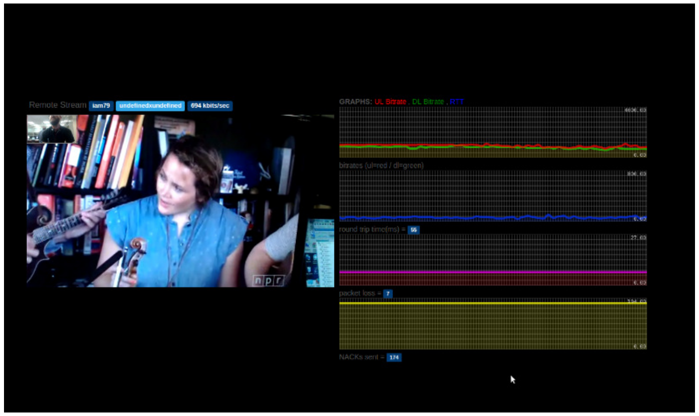
DNE-RTC App

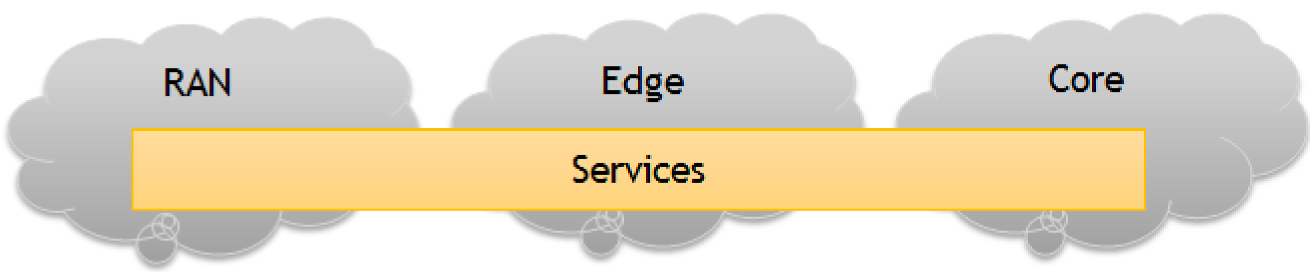
- Computes an exponentially weighted moving average of each device’s throughput
- NE-RTC is enabled when the device is in a call and its throughput drops below a low threshold
  - Enables target bitrate computation and scheduling algorithm
  - Sends target bitrate info to WebRTC gateway
  - Sets up guaranteed 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

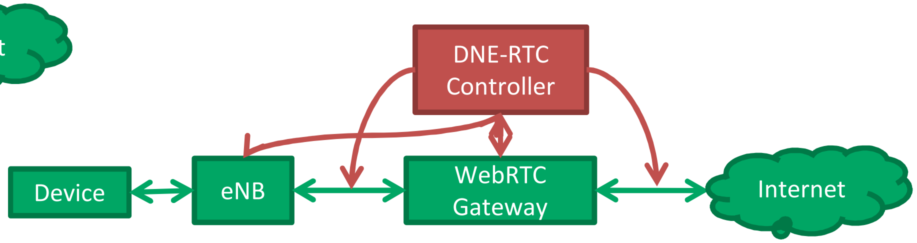
SIP: bob@example.com

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

Best Effort Network Function Graph:

DNE-RTC Network Function Graph:



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

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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 end2end 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:

Path Switching: Reduced-State Flow Handling in SDN Using Path Information, Adiseshu Hari, T.V. Lakshman and Gordon Wilfong, ACM CoNEXT 2015. DOI: http://dx.doi.org/10.1145/2716281.2836121

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

nuagenetworks
From Nokia

http://www.nuagenetworks.com

- SDN controllers in 5G.

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Questions

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