5G-UPF Flow Based QoS using VPP & DPDK

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Background: Scope of GTP tunneling in 5G

QoS Flow to DRB and GTP-U Tunnel Mapping

4G LTE:
- A one-to-one relationship for an EPS bearer between the DRB (UE to eNB), the S1-U GTP-U tunnel (eNB to S-GW) and the S5-U tunnel (S-GW to P-GW).

5GC:
- Only a single user plane network function – the UPF – for transport of data between the gNB and the core.
- one-to-many relationship between the GTP-U tunnel on N3 and the DRBs on the air interface.
- Each QoS flow on N3 is mapped to a single GTP-U tunnel.
- gNB may map individual QoS flows to one more DRBs. Thus, PDU session may contain multiple QoS flows and several DRBs but only a single N3 GTP-U tunnel.

Note: A DRB may transport one or more QoS flows.
**5G QoS Model (DRB-Flows-Tunnel)**

Data packets from applications "NAS" filters (mapping packets to QoS flows and apply marking) Data packets from applications

Mapping flows to DRBs

Application /Service Layer

"NAS" filters (mapping packets to QoS flows and apply marking)

Packet filters classify packets to SDFs

Source: 3GPP forum
### 5G vs 4G QoS & Mapping procedure

<table>
<thead>
<tr>
<th>QoS Parameter</th>
<th>5G</th>
<th>4G</th>
</tr>
</thead>
<tbody>
<tr>
<td>QoS Identifier</td>
<td>5QI / QFI field in the GTP-U extended header</td>
<td>Quality class indicator. Usually the quality is differentiated at the tunnel level – specific tunnel for a service</td>
</tr>
<tr>
<td>IP flow : UE -&gt; UPF</td>
<td>QoS flow</td>
<td>EPS Bearer</td>
</tr>
<tr>
<td>Flow identifier</td>
<td>QFI</td>
<td>Bearer ID</td>
</tr>
<tr>
<td>Reflective QoS</td>
<td>RQI</td>
<td>-</td>
</tr>
</tbody>
</table>

#### Aspects of classifying the 5G GTP-U packet stream for QoS purpose and level of classification

- Tunnel EndPoint ID along with QFI / 5QI parameters
- Mapping based on IP subnet, Source IP address, L4 port numbers, DSCP
- Identifying the service from the higher order classification (web, video, email and etc)
- DPI may not be always possible as the packets are mostly encrypted which leads to service aware planning from the deployment is required
Flow based QoS @UPF-DL, @gNB/NA & @UE

IP Flows → gNodeB

- SDAP
  - DRB1
  - DRB2
  - DRB3
  - DRB4
  - DRB5

GTP+QFI → DRB mapping

GTP-U QFI marked

QoS Flow 1, QFI=1
QoS Flow 2, QFI=2
QoS Flow 3, QFI=3
QoS Flow 4, QFI=4
QoS Flow 1, QFI=1
QoS Flow 2, QFI=2
Qos Flow 3, QFI=3
QoS Flow 1, QFI=1
QoS Flow 2, QFI=2

DSCP → 5QI / QFI

Classifier & DPDK H-QoS Engine

UPF cluster

High speed internet pipe

Voice/video service

High speed internet pipe
5G UPF QoS plugin – Goals

- DPDK H-QoS Engine integration to the VPP
- Enhancing the VPP configuration infra to support 5G QoS
- Flow classifier support (from the management plane via yang model)
- Attaching the traffic to appropriate UPF instance in a cluster (VLAN with SR-IOV, tunnel to instance)
- Metering support throughout the hierarchy
- Upstream QoS mapping verification – possible action
- Contribution to the VPP community

DPDK QoS pipeline

Port/vNIC/ SR-IOV -> UPF – instance / slice, GTP tunnel group per user -> Sub-port, GTP Tunnel(s) -> pipe, Flow -> Queue (WRR/SP)
QoS in Downstream

- GTP works on top of IP packet
- Downstream payload processing identifies the GTP tunnel ID(s)
- Tunnel is mapped to ‘pipe’ in DPDK QoS
- Group of tunnel per user maps to ‘sub-port’ (virtual port)
- DSCP (service points mapped to ‘traffic class’ – further to QFI

set dpdk interface hqos subport <interface> subport <subport_id> [rate <n>] [bktsize <n>] [tc0 <n>] [tc1 <n>] [tc2 <n>] [tc3 <n>] [period <n>]
set dpdk interface hqos pipe <interface> subport <subport_id> pipe <pipe_id> profile <profile_id>
set dpdk interface hqos placement <interface> thread <n>
set dpdk interface hqos pktfield <interface> id subport | pipe | tc offset <n> mask <hex-mask>
set dpdk interface hqos tctbl <interface> entry <map_val> tc <tc_id> queue <queue_id>
UPF – C distribution layer is like a load balance.

SMF

UPF-C 1

UPF-C 2

H-QoS enforcement points

UPF 1 (QoS management)

H-QoS

H-QoS

H-QoS

UPF – u1

UPF – u2

UPF – u1

UPF – u2

UPF – un

UPF – un

H-QoS

N3

N6

N3

N6

N6(DN)

N3(RAN)

GTP-U plane

L2-L3 stack

VPP-I0 taks (process engine)

DPDK(PKT I/O – H-QoS)

shaping and WRR

NIC-1

NIC-2

GTP QoS Plug-in

(DPDK H-QoS with GTP flow classifier support)-programable

Port -> GTP-U cluster

Sub-port to instance and queue mapping based on the classifier
5g-qos-dpdk-vpp: Code organization
Future Work / Proposal – QoS plugin Enhancement

- Possibility of Openflow enhancement to support the 5G flow classification to adapt in the SDN environment
- Pre-classification based L2 at SR-IOV / smartNIC to direct the traffic to the appropriate UPF instance + NSH header usage
- Adapting to Openstack ML2 path
- Docker based support
- Yang modeling for the GTP-U QoS
Thank You!
Backup slides
5G End to End QoS flow view

QoS flow

- the lowest level granularity within the 5G system
- the place policy and charging are enforced.
- One or more Service Data Flows (SDFs) can be transported in the same QoS flow, if they share the same policy
- All traffic within the same QoS flow receives the same treatment.
Past work with OVS adaptation with DPDK H-QoS

- Open-flow based QoS mechanism which helps the controller to manage and enforce the QoS at network level
- Reduce packet loss, latency and jitter
- Ensure deterministic performance of real time applications
- QoS Differentiated service chaining path creation to accelerate certain services while queuing some of the non-critical TCP based service
- QoS with Openstack (with ML2 initial prototyping done)

**Key use case:** For the telco cloud traffic engineering and as well on the branch office QOS characterization
QoS requirements (@UE, @AN & @UPF)

The following characteristics apply for processing of Downlink traffic:

- UPF maps User Plane traffic to QoS flows based on the SDF templates
- UPF performs Session-AMBR (Aggregate MBR) enforcement and also performs PDU counting for support of charging
- Applying Reflective QoS (based on QAI ON) – DSCP/ QFI markings

Reflective QoS: For traffic that is subject to reflective QoS, the UL packet gets the same QoS marking as the reflected DL packet.

Note: How to use QFI to be understood well while mapping to DSCP and as well as doing the shaping / scheduling function (this is the function to be done in UPF for downstream and for upstream enforcement check to be done)?

<table>
<thead>
<tr>
<th>5QI Value</th>
<th>Resource Type</th>
<th>Default Priority Level</th>
<th>Packet Delay Budget</th>
<th>Packet Error Rate</th>
<th>Default Maximum Data Burst Volume</th>
<th>Default Averaging Window</th>
<th>Example Services</th>
</tr>
</thead>
<tbody>
<tr>
<td>81</td>
<td>Delay Critical GBR</td>
<td>11</td>
<td>5 ms</td>
<td>10^{-5}</td>
<td>160 B</td>
<td>2000 ms</td>
<td>Remote control</td>
</tr>
<tr>
<td>82</td>
<td>Delay Critical GBR</td>
<td>12</td>
<td>10 ms</td>
<td>10^{-5}</td>
<td>320 B</td>
<td>2000 ms</td>
<td>Intelligent transport systems</td>
</tr>
<tr>
<td>83</td>
<td>Delay Critical GBR</td>
<td>13</td>
<td>20 ms</td>
<td>10^{-5}</td>
<td>640 B</td>
<td>2000 ms</td>
<td>Intelligent Transport Systems</td>
</tr>
<tr>
<td>84</td>
<td>Delay Critical GBR</td>
<td>19</td>
<td>10 ms</td>
<td>10^{-4}</td>
<td>255 B</td>
<td>2000 ms</td>
<td>Discrete Automation</td>
</tr>
<tr>
<td>85</td>
<td>Delay Critical GBR</td>
<td>22</td>
<td>10 ms</td>
<td>10^{-4}</td>
<td>1358 B NOTE 3</td>
<td>2000 ms</td>
<td>Discrete Automation</td>
</tr>
</tbody>
</table>

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<th>Default Avg Window</th>
<th>Example Services</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>GBR</td>
<td>20</td>
<td>100 ms</td>
<td>10^{-2}</td>
<td>2000 ms</td>
<td>Conversational Voice</td>
</tr>
<tr>
<td>2</td>
<td>GBR</td>
<td>40</td>
<td>15 ms</td>
<td>10^{-3}</td>
<td>2000 ms</td>
<td>Conversational Video (Live Streaming)</td>
</tr>
<tr>
<td>3</td>
<td></td>
<td>30</td>
<td>50 ms</td>
<td>10^{-3}</td>
<td>2000 ms</td>
<td>Real Time Gaming, V2X messages</td>
</tr>
<tr>
<td>4</td>
<td></td>
<td>50</td>
<td>300 ms</td>
<td>10^{-4}</td>
<td>2000 ms</td>
<td>Non-Conversational Video (Buffered Streaming)</td>
</tr>
<tr>
<td>65</td>
<td></td>
<td>7</td>
<td>75 ms</td>
<td>10^{-2}</td>
<td>2000 ms</td>
<td>Mission Critical user plane Push To Talk voice (e.g., MCPTT)</td>
</tr>
<tr>
<td>66</td>
<td></td>
<td>20</td>
<td>100 ms</td>
<td>10^{-2}</td>
<td>2000 ms</td>
<td>Non-Mission-Critical user plane Push To Talk voice</td>
</tr>
<tr>
<td>67</td>
<td></td>
<td>15</td>
<td>100 ms</td>
<td>10^{-3}</td>
<td>2000 ms</td>
<td>Mission Critical Video user plane</td>
</tr>
<tr>
<td>75</td>
<td></td>
<td>25</td>
<td>50 ms</td>
<td>10^{-2}</td>
<td>2000 ms</td>
<td>V2X messages</td>
</tr>
</tbody>
</table>
UL QoS requirements (@UE, @AN & @UPF)

Following processing of uplink traffic:

- UE performs the classification and marking of UL User plane traffic, i.e. the association of uplink traffic to QoS flows, based on QoS rules.
- QFI filed is populated by RAN / AN
- (R)AN performs transport level packet marking in the uplink, transport level packet marking may be based on the 5QI and ARP (bearer allocation and retention priority) of the associated QoS Flow.
- UPF verifies whether QFIs in the UL PDUs are aligned with the QoS Rules provided to the UE or implicitly derived by the UE (e.g. in case of reflective QoS)

- UPF performs Session AMBR (agg. Max bit rate) enforcement and counting of packets for charging.
- For UL Classifier PDU sessions, UL and DL Session AMBR shall be enforced in the UPF that supports the UL Classifier functionality.
- For multi-homed PDU sessions, UL and DL Session-AMBR is enforced separately per UPF that terminates the N6 interface (i.e. without requiring interaction between the UPFs)
- (R)AN shall enforce Max BitRate (UE-AMBR) limit in UL and DL per UE for non-GBR QoS flows

Ref: 3GPP recommendations

Note: Highlighted items for UPF specific
Parameters to be dealt in the QoS Plugin

QoS profile and parameters

- For each QoS flow: 5QI (5G QoS Identifier), ARP
- For GBR QoS flow only: GFBR (Guaranteed Flow Bit Rate), MFBR (Maximum Flow Bit Rate), AMBR & maximum packet loss rate for both uplink and downlink.
- For Non-GBR QoS only: Reflective QoS Attribute (RQA)
- Resource Type (GBR, delay critical GBR or non-GBR)
- Priority level
- Packet Delay Budget
- Packet Error Rate
- Averaging Window
- Maximum Data Burst Volume