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Classification and Flow Control in PGW

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Abstract— ***PDN Gateway(PGW) is one of the major module in EPC system. PGW is exit and entry point in LTE for ingress and egress data traffic packets of UE, which connects UE to external PDN.For downlink data received from Packet data networks (PDN), should be classified based on IP headers and apply classification Rules. In the downlink, ingress IP packets destined for different UEs, are classiffied by PGW and forward to respective QoS-based bearers of respective UEs.Traffic Flow Templates (TFTs) are assigned to each QoS-bearer, classification is performed based on these TFTs.Each GBR bearer is assigned with QoS parameters, PGW uses these QoS for performing flowcontrol.Irrespective of incoming rate, flow has to be controlled and sent to mobile as per the QoS rule.Here we are using token bucket algorithm for flow control.This paper reviews how Classification and Flowcontrol done in PGW.***

Keywords – **TFT, Bearer,UE,PGW,GBR,PDN.**

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I. INTRODUCTION

LTE is standardized by 3rd Generation Partnership Program(3GPP) to address the needs of growing demand for high speed connectivity for applications like mobile TV,video streaming,online gaming etc. Long Term Evolution (LTE) network architecture is designed based on IP connectivity, to provide seamless connectivity between different elements, PDN, PGW, SGW, MME, HSS, PCRF and eNodeB. MME, SGW, PGW and HSS form the EPC, Enhanced packet core, which is backbone for LTE. It supports 150 Mbps downlink and 75 Mbps uplink for the end customer. LTE supports both FDD and TDD wireless technologies. FDD required two bands one for each uplink and down link. TDD uses single frequency for uplink and downlink at different timing slots. There are different frequencies allocated to FDD and TDD. So far worldwide 32 band frequencies are allocated for FDD and 12 bands for TDD. It interops with existing wireless technologies such as GSM,GPRS and WCDMA. LTE networks are deployed worldwide to address the growing demand of mobile broadband services.

II. EPS BEARER STRUCTURE

The EPS bearers are used to deliver the traffic over LTE. EPS bearer is logical connection between the UE and PGW for every network connection. Bearer is nothing but the virtual path to deliver the traffic. Different bearers have the different QoS service.The data flows delivered on the same EPS bearer will get the same QoS service.There are two types of bearers in EPS system,they are default bearers and dedicated bearers.The default bearer is established during the initial attach procedure of UE and the default bearer does not contain the traffic flow template (TFT). The default bearer will provides the best effort service.

A dedicated bearer is established on demand[2],whenever the user wants to get sevices like internet, which need higher QoS than the default bearer,through which user is currently getting service.UE can connect with more than one PDN gateway, which has one mandatory default EPS bearer and may have zero or more dedicated bearers.The maximum number of EPS bearers which UE can have is 11.

Different applications require the different QoS requirements, To meet the requirement of different QoS services the dedicated bearers are established.We have different TFTs for uplink and downlink.The PGW contains the downlink traffic flow templates and UE contains the uplink traffic flow templates.TFT associates with the packet filters(PF).

Every packet filter associated with the traffic flow template corresponds to a particular dedicated bearer.The ingress IP data flow is classified into different SDFs based on the packet filters and send it to corresponding bearer for the transmission.

The SDFs with the same QoS can transmit in same EPS bearer,all the packet filters corresponding to the EPS bearer are included in the traffic flow template(TFT) of that bearer.Every packet filter have the unique identity to map with the corresponding bearer.Fig.1 describes the structure of EPS bearer,TFTs and SDFs.

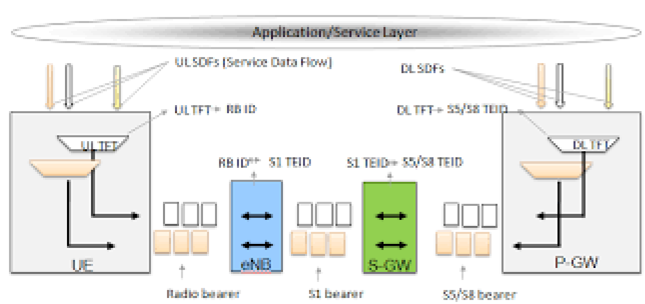

Fig.1. Mapping of Datastreams to EPS bearer

III. TRAFFIC FLOW TEMPLATE IN EPS BEARER

An operator of LTE, provides different QoS services to its end customers, i.e subscribers of LTE services. Many subscriptions levels with different QoS, are defined based on the magnitude of subscribers and their service usage for internet, voice, video conferencing etc.. Based on subscription levels, radio and network resources are assigned to each subscribers. For this purpose, LTE artchitecture provides packet filters for each ingress flow, in TFTs. The ingress traffic flow is classified into different SDFs having different QoS classes based packet filters. SDF QoS is maintained and controlled through EPS bearers in LTE network.

The ingress IP flows are matched against the packet filters i.e. SDF templates for SDFs or TFTs for EPS bearers to detect EPS bearers. The operator configurs packet filters based on PCC rules formed by policies in PCRF. An ID is assigned to each packet filter in addition to the following elements[3]:

i) Remote IP Address and Subnet Mask
ii) Protocol Number for IPv4/ Next header for IPv6
iii) Destination Port number
iv) Source Port number
v) Security Parameter Index (SPI)
vi) Type of Service for IPv4 or Traffic class for IPv6 and Mask
vii) Flow Label (IPv6).
viii) Packet Flow EPI

In LTE network, the service characteristic of each Internet Packet flows are matched with pah cket filters of SDF template. The SDFs with matched characteristics with that of TFT are mapped to an EPS bearer, which will be delivered to respective UEs. The IP packets are delivered, aggreagated to an EPS bearer with same QoS class, others are delivered to different EPS bearers.

Packet flows with EPS bearers are mapped based on PF identifiers. Each TFT associated with bearer may contain upto 16 Packet filters. A PDN context will have multiple PF filters, the matching filters with IP data packet filed information are transmitted over the bearer.

Service Data Flow

The end customers, i.e UE will run applications with different QoS requirements, for example internet applications, video conference, voice etc. Each SDF will have IP flow or aggregation of IP flows for user traffic to serve different applications with varied QoS classes. Different SDFs will have varied QoS class and thereby each application is served by one SDF., The QoS rules are applied from PCC rules. IP flows forwarded to UE are classified into different SDFs based on their service type using SDF template. Then QoS policies, like priority band width control etc., are applied to these SDFs before they are forwarded to UEs. EPS bearer provides QoS when SDFs are forwarded to UEs over LTE network, each SDF is mapped by PGW to EPS bearer, which matches with QoS parameter and delivers to UEs.

Classification using Packet Filters

Before transmitting the packet to the bearer[4],first it needs to be match with the packet filter in the TFT associated with that particular bearer.The network operators will preconfigure these TFTs based on their policy.Each packet is matched against the preconfigured TFTs.The packet may be match with the more than one packet filter for that reason the matching between the IP packet and packet filter is done based on the priority from high to low.

Sample Algorithm :

```
List of UEs -> Classifiers rules for each UE
    for (each UE)
    {
        for (each classifier of UE)
        {
            check whether in coming packet IP header
matches with classifier of the UE
            if Yes  -> Send the packet to UE
            else -> Continue classification
        }
    }

    if (no classifier matches) -> drop the packet.
```

1. In this algorithm first we need to take the list of UEs connected to the PGW.
2. Take each UE and compare the incoming packet IPheader with each classifier of the UE.
3. If the incoming packet IPheader matches with classifier send the packet to UE.
4. Otherwise continue the classification process for all the UE's.
5. If no classifier matches with the incoming packet header,then drop the packet.

IV. FLOW CONTROL

After completion of the classification the packet is send to the appropriate bearer.Before sending the packet to the bearer,we need to use the traffic shaping techniques to limit the flow or bandwidth.Each bearer is associated with the QoS.Here we are applying the traffic shaping algorithms based on the QoS.

There are two different types of bearers they are,default bearers and dedicated bearers.During the creation of the dedicated bearers only,the network resources of the particular QoS associated with it are allocated.

Dedicated bearers may be Guaranteed Bit-Rate(GBR) or Non-Guaranteed Bit-Rate(n-GBR).The packet loss related to the congestion do not occur in GBR bearers.GBR bearers are suitable for the services like voice call.The non-GBR bearers does not guarantee bit rate and the services that are using n-GBR bearers should prepare for the packet losses which are related to the congestion.Non-GBR bearers which are suitable for the services like e-mails.

Each EPS bearer is associated with the QoS class Identifier (QCI).QCI specifies the QoS treatment of user-plane data flows that are associated with the bearer.The QCI characteristics include the packet delay budget, priority, and packet error loss rate.QoS parameters include Guaranteed Bit-Rate (GBR), Maximum Bit-Rate (MBR) and ARP (Allocation and Retention Priority).If there is limited resources then that time the EPS system uses the ARP to decide whether accept or reject the new bearer establishment or modification request.

GBR stands for Guaranteed Bit-Rate,which specifies the average bit-rate that needs to be offered by the GBR bearer.Where as MBR specifies the maximum bit-rate provided by GBR bearers. In release 8, MBR is set as equal to GBR. For Non-GBR bearers also the Network operators can restrict the total amount of bit-rate consumed by a single user,using the Aggregated Maximum Bit-Rate (AMBR).

Traffic shaping controls the traffic before entering into the network.There are two types of traffic shaping algorithms.one is Leaky Bucket algorithm and another is Tocken Bucket algorithm.

Leaky Bucket Algorithm:

Let us assume that we have a bucket with small hole at the bottom,Irrespective of the rate at which water entering into the bucket,the water coming out from that small hole is constant.If any additional water is entering ,After the bucket was filled completely,then it spills and is lost.The same concept is applied here.

1. Whenever the host needs to send a packet,the packet is thrown into the bucket.
2. Always the packets are transmitted at a uniform rate.
3. Here leaky bucket converts the bursty traffic into uniform traffic.
4. The packet is discarded, whenever the bucket is full.

Thus what it essentially does is suppose the input packet generated by the source node is like this suppose it generates at the rate of 10 Mbps per 2 second and then for 2 seconds it sends at the rate of 10 Mbps so here it is bursty in nature and what the leaky bucket will do is it will smooth out and send it at the rate of 2 Mbps for 10 seconds. So, for 10 seconds it is sent in the uniform rate. So as a result as you can see the traffic is at a fixed rate throughout the 10 second period.

We can implement this algorithm easily with the finite queue.consider a finite queue and when the packet arrives,if there is available space in the queue then the packet is queued up and if there is no available space in the queue then the packet is discarded.

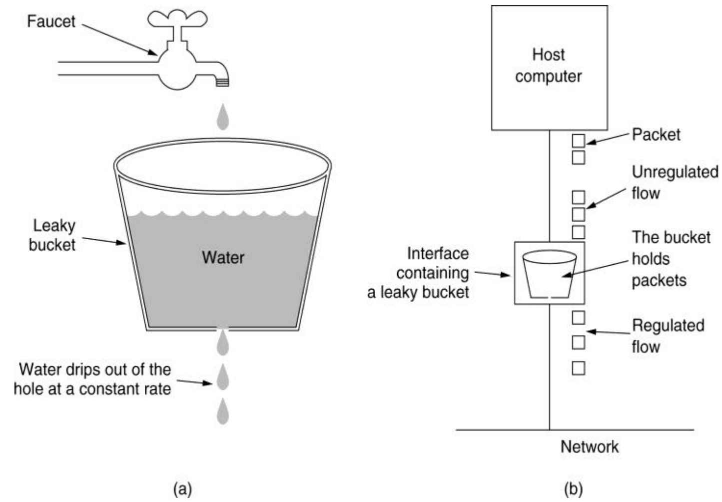

Fig.2.Leaky Bucket Scenario

Tocken Bucket Algorithm:

The main steps of the this algorithm are

1. The tockens are added into the bucket in regular intervals of time.
2. Consider the bucket with maximum capacity.
3. If the host need to send the packet,the tocken is destroyed from the bucket and send the packet.
4. The packet can't be sent,if there is no available tockens in the bucket.
5. The idle hosts can capture and store the tockens.

The leaky bucket algorithm only allows the uniform traffic,where as tocken bucket algorithm allows the bursty traffic.The tocken bucket algorithm also limits the burst by using the available number of tockens in the bucket at that particular time.we can implement the tocken bucket algorithm easily with the use of counter variable.The counter value is incremented in regular intervals of time and whenever we want to send the packet, decrement the counter and send the packet.

We can't send the packet,when the counter value is zero.

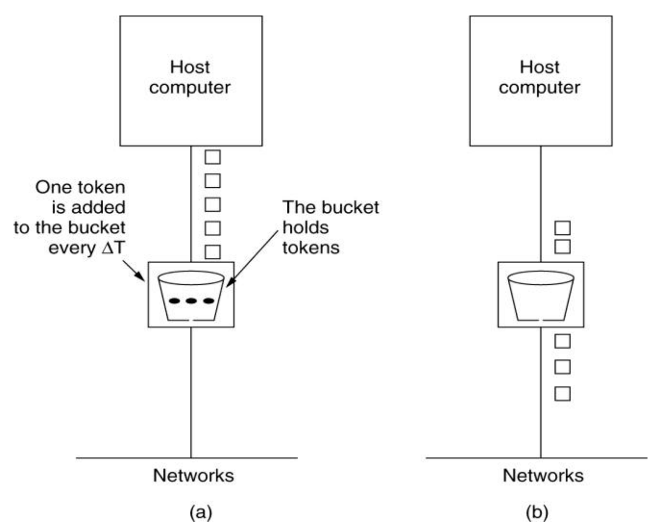

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Fig.3.Tocken Bucket Scenario

Here we are using Tocken Bucket algorithm to implement the flowcontrol in PGW.Because tocken bucket is having the advantages over leaky bucket,they are

1. In tocken bucket algorithm the idle hosts can capture and store the tockens upto maximum capacity of the bucket,where as in leaky bucket algorithm idle hosts are not allowed to save the tockens.Using the saved tockens we can send the large bursts later.
2. The tocken bucket algorithm allows the burstiness to the output stream.Consider the example that idle host saved n tockens,then it can send the n number of packets at once.
3. The tocken bucket algorithm discards the tockens whenever the bucket is full but never discards the packets,where as in the leaky bucket algorithm if the bucket is full,the packets are discarded.

While coming to the implementation of this algorithm in PGW, consider that the maximum bucket size is MBR and the tockens are added to the bucket based on the Guaranteed Bit-Rate in case of GBR bearers.Here we are taking the MBR as the maximum capacity of the bucket,that means that we are restricting to provide the services upto Maximum Bit-Rate only.Also we are adding tockens based on GBR means that,we are always providing the Guaranteed Bit-Rate.The Non-GBR bearers will have the MBR only.

Sample algorithm :

```
Get the packets after classification
  Add the tockens into the bucken in regular intervals of
    time.
     If(number of packets < = number of tockens in bucket)
       {
          1.Send the packets
           2.Reduce the tockens in the bucket by equivalent
              number of sent packets.
       }
    Else
     {
              Queued up the packets
     }
```

VI. CONCLUSION

Main functionalituies of the PGW are classification and QoS enforcement. This paper proposes and discusses algorithems on classification and QoS enforcement implemented in PGW. It is suggested and implemented token bucket algorithem for packet flow.

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