Think of transport technology to support ultra-high bandwidth and/or ultra-low latency

draft-han-6man-in-band-signaling-for-transport-qos

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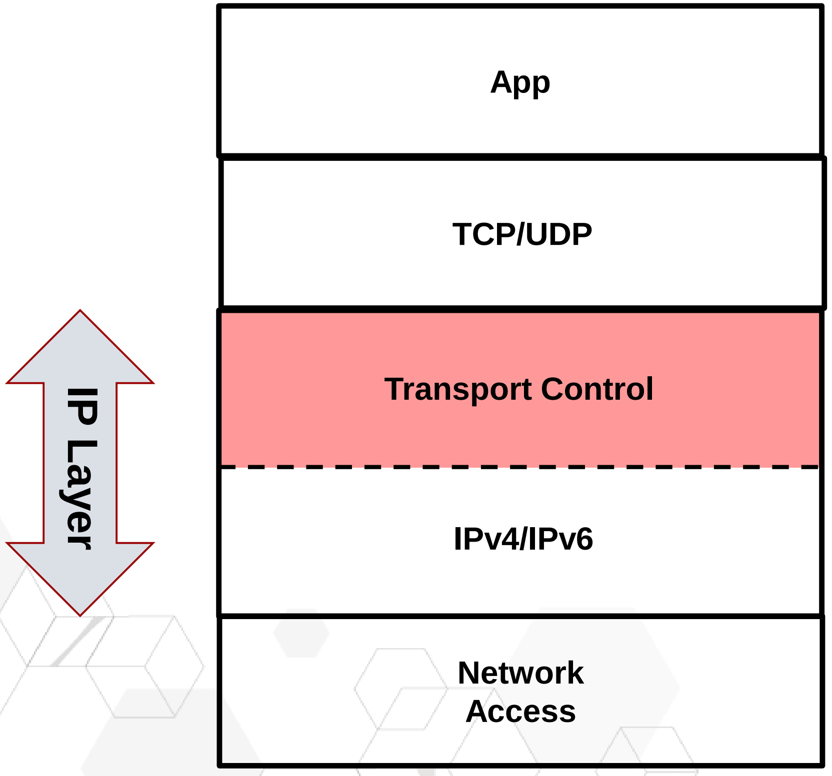
Goals of this draft

- **Motivations**
  - Transport service with on-demand resource and quality of service
  - For applications that current transport cannot provide satisfactory support
- **Ideas**
  - More involvement of Network device
  - Simpler protocols
- **Design Targets**
  - End user or application can directly use the new service
  - The new service can coexist with the current transport service and is backward compatible.
  - Application adaptive QoS
  - The service provider can manage the new service.
  - Performance and scalability targets of new service are practical for vendors to achieve.
  - The new service is transport agnostic. Both TCP, UDP and other transport protocols on top of IP can use it

Transport control sub-layer



Transport Control Functions:

- ➢ In-band Signaling
  - Signaling msg carried in the TCP packet (IP header)
  - QoS HW programming infor for device on path
  - QoS programming state returned to src
- ➢ Congestion control
  - Detect congestion state on devices on path
  - Congestion state returned to src
- ➢ IP Path OAM
  - Path property detection, static, dynamic
  - Diagnosis

Feasibility

- ➢ Network processor combines the advantages of ASIC and CPU
  - Tbl Lookup, Packet switch/fwd
  - Packet processing: QoS, ACL, DIP, Firewall, etc
  - General processing: Arithmetic, Hashing, read/write, etc

IP in-band signaling and QoS for transport

Control Plane

- **What is IP in-band signaling**
  - Signaling embedded in user's IP packet.
- **How transport control is done by IP in-band signaling**
  - Two directional messages form a closed loop control
  - Any type of data packet can be used to carry the signaling message
  - Service properties can be signaled to hardware
- **Properties**
  - Signaling message takes the same way as the user data packet
  - User controlled, data driven, transport and application agnostic
- **Congestion control**
  - New congestion control to fit to the guaranteed service and powerful OAM
- **Advantages**
  - No extra protocol needed
  - Easy to do the OAM, such as
    - congestion control
    - Fwd state detection
    - Defect diagnosis,
    - Service quality measurement

Data Plane

- What data plane is needed
  - IP forwarding with granular scheduling and shaping
- Data plane state maintenance
  - Data plane state is kept by data packet.
- Resource sharing
  - Resource are shared with current transport
- Performance
  - Minimized maintenance on line card and firmware, with minimized controller card involvement
  - Fwd with/without QoS is almost same by NPU, line rate
- Scalability
  - Thousand sessions per port
- Compatibility
  - Backward compatible
  - Coexistence with traditional transport protocols
- What happen if resource not enough on the IP path
  - Source routing can be used for non-shortest path
- What happen if rerouting/link or node failure
  - Fwd state detection can trigger the source to repair path

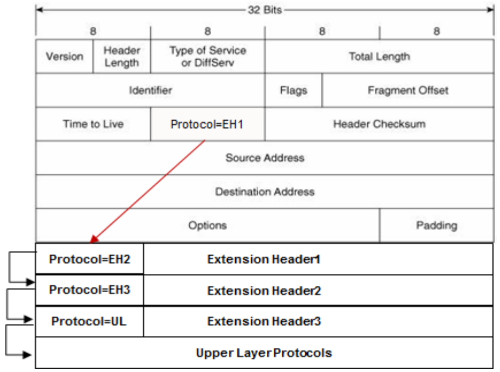
Solutions

IPv6

- **Use Hop-by-Hob Extension Hdr and Destination Extension Hdr**
- **Hop-by-Hob Extension Hdr is examined at configured devices on IP shortest path, or explicit path;**
  - QoS programming and state
  - QoS forwarding and state
  - OAM instruction and state
- **Destination Extension Hdr is examined at destination devices, for E2E infor exchanging**
  - QoS programming state report to source
  - QoS forwarding state report to source
  - OAM state report to source

IPv4

- **Current IPv4 option size is not enough**
- **New extension header for IPv4**

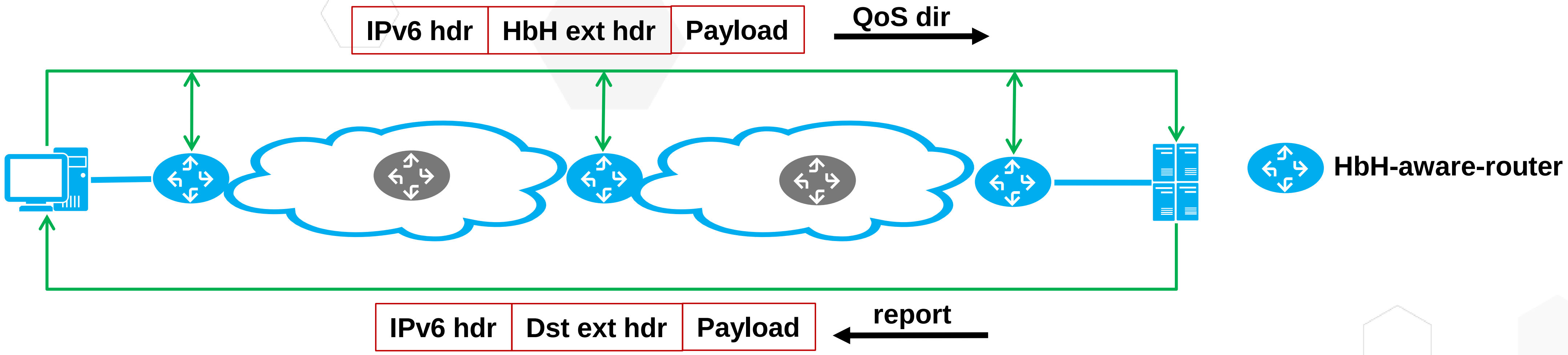


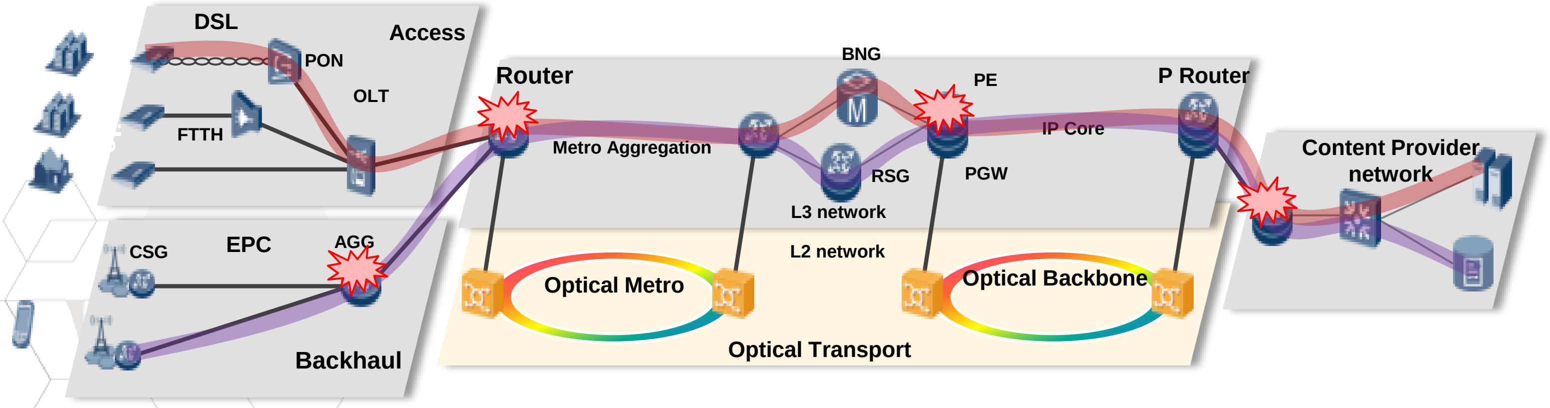
- **Use of the following protocol which is currently limited to IPv6 only:**

Protocol number	Keyword
0	HOPOPT
43	IPv6-Route
60	IPv6-Opts
135	Mobility Header

- **Same protocol number can be used for IPv4 and up to IETF approve**
- **The detailed definition of each protocol is up to IETF new RFCs.**

IPv6 in-band signaling





Scalability and Performance

- **Scalability**
  - Not targeted for applications that normal TCP works well
  - Assume 100G/NPU; 50% for new session; 100M/session -> 500 sessions
- **Performance**
  - 10ms/hop; 32 hops -> 320 ms/session

Q&A

More detailed works in
ETSI NGP (Next Generation Protocol):
https://portal.etsi.org/tb.aspx?tbid=844&SubTB=844

Experimental POC System– Based on the ATN box and NPU SD5131 with TM

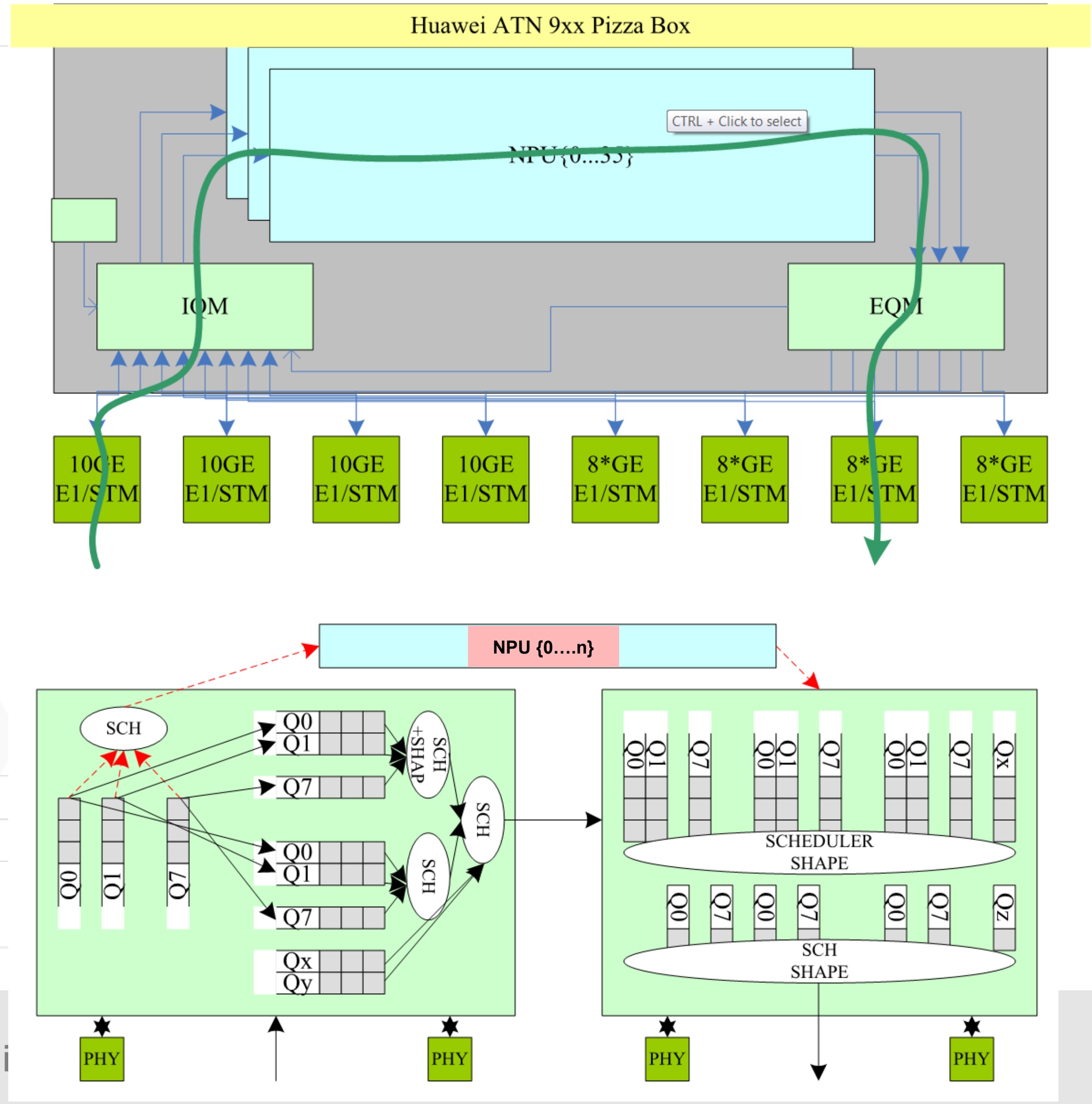
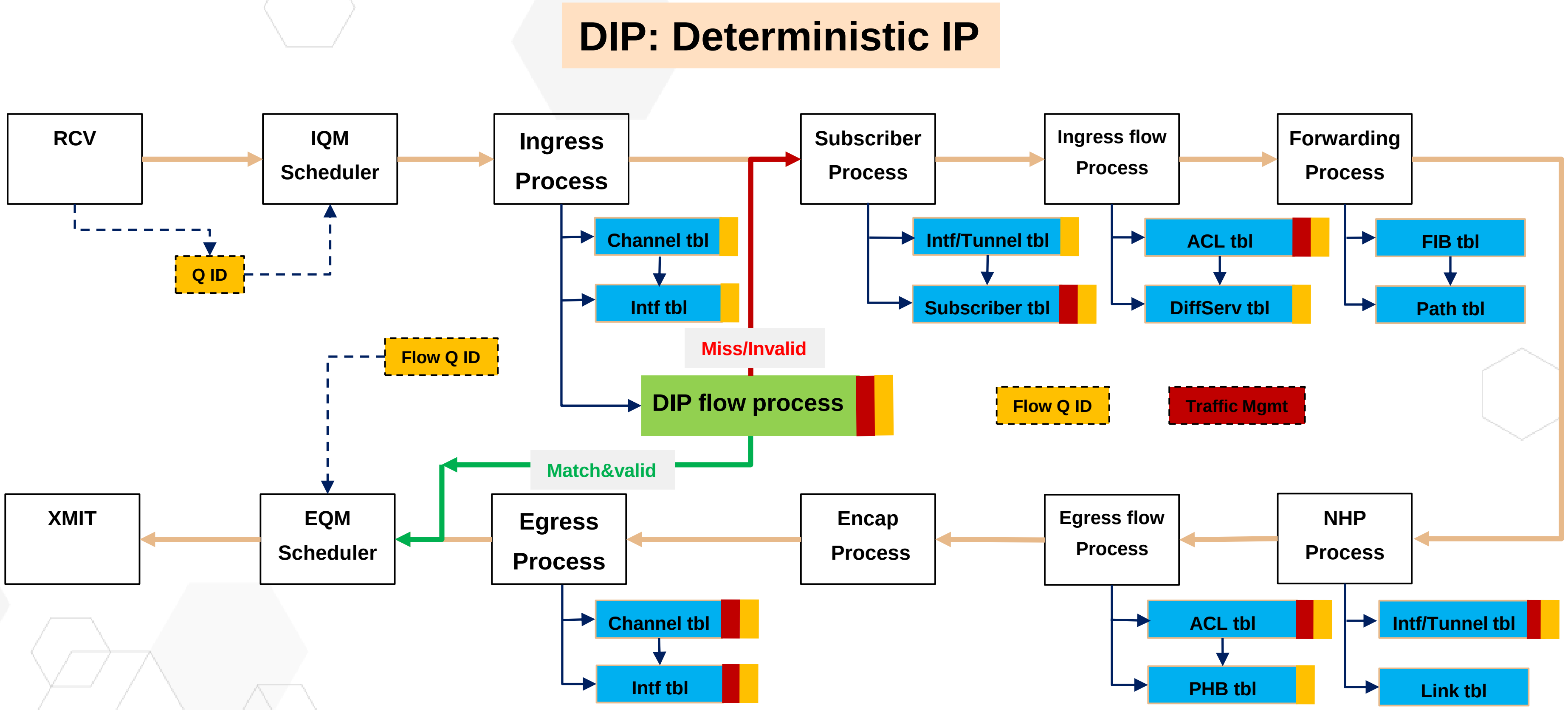
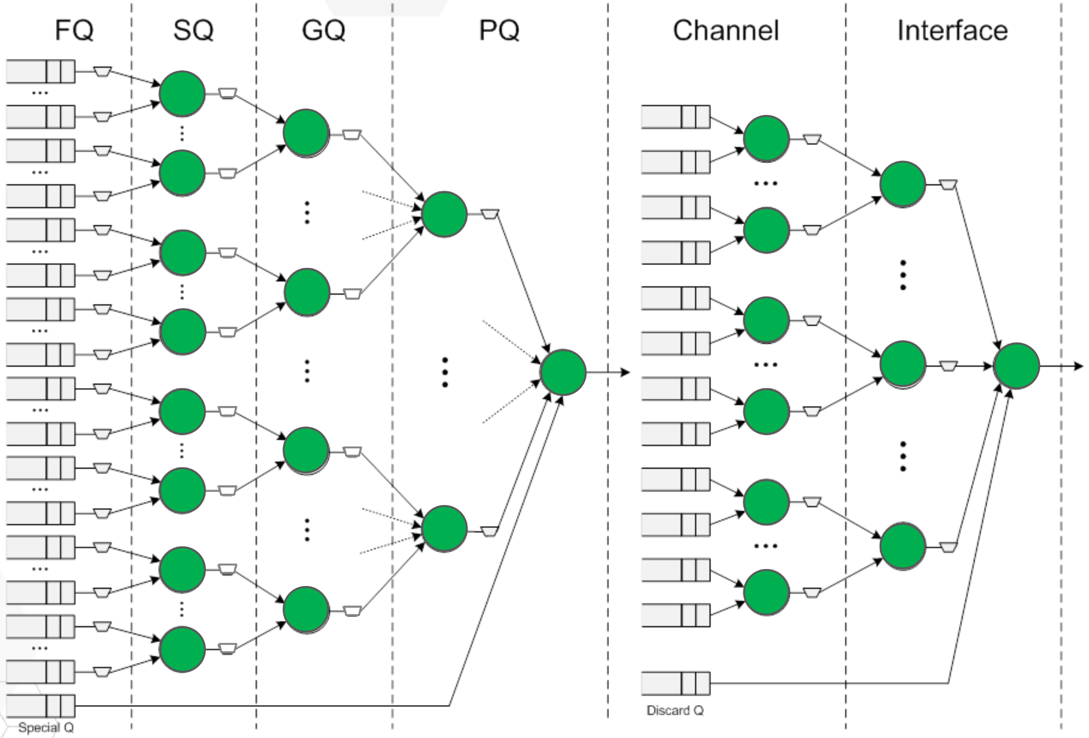


Diagram for Packet Forwarding



Hierarchy of Queuing and Scheduling



FQ: Flow Queue, 8k
SQ: Subscriber Queue, 1k
GQ: Group Queue, 1k
PQ: Port Queue, 128
64Gbps@425MHz

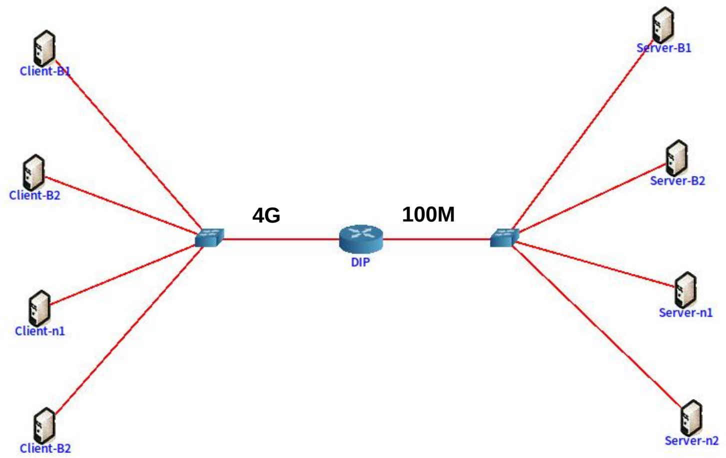

Scheduler:
SP, DWRR…

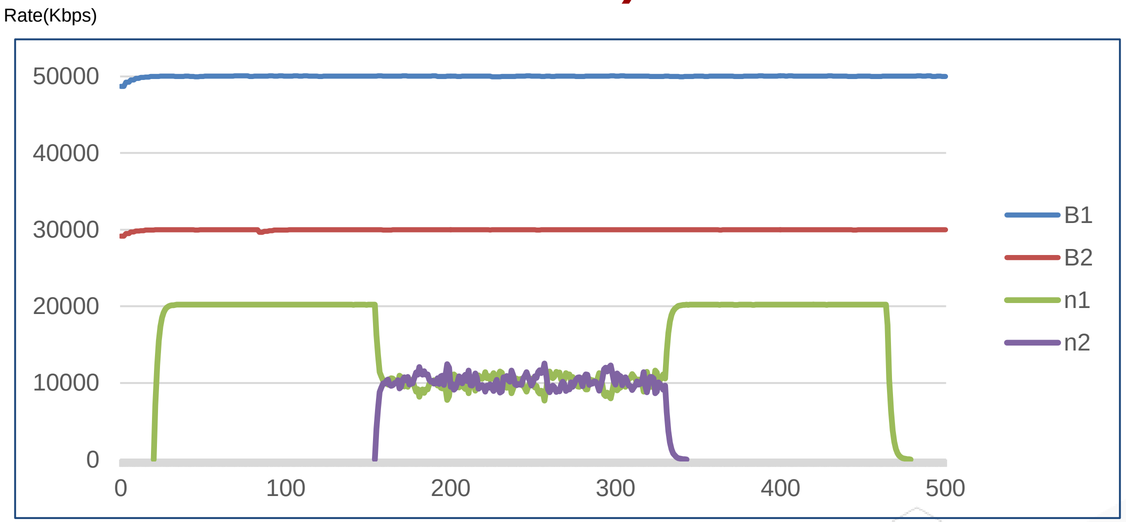

Shaper:
Dual/Single Leaky Bucket Algorithm

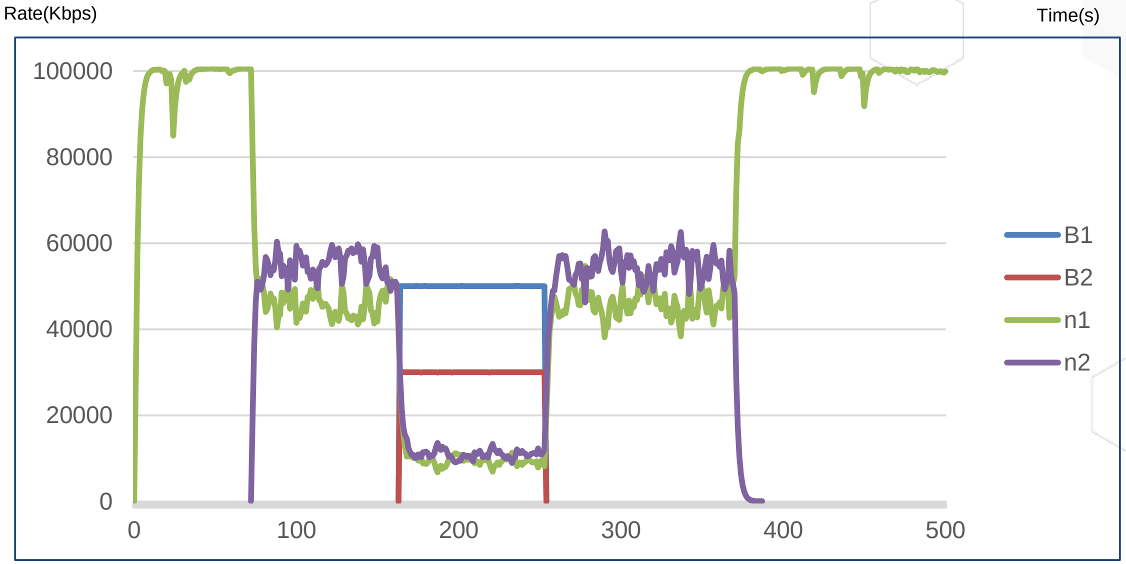
Test Results:

Guaranteed Bandwidth (CIR flows coexistence with traditional TCP)

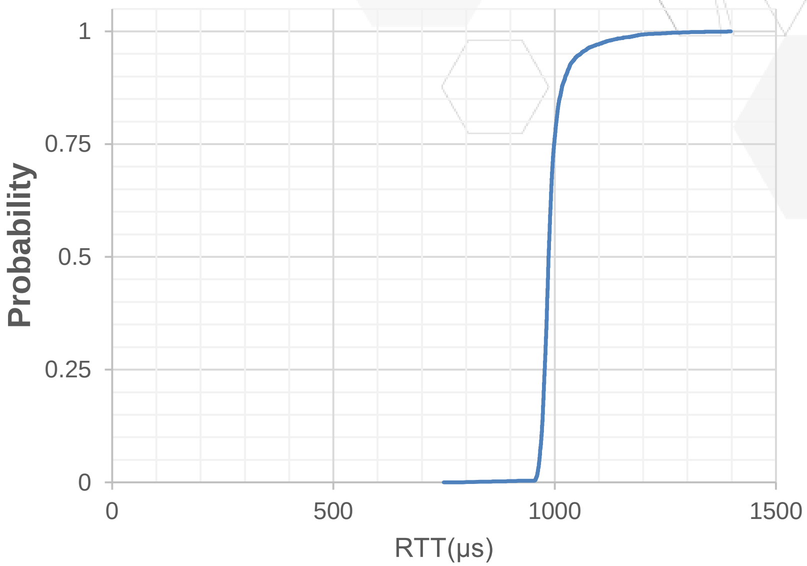
Heavily congested link

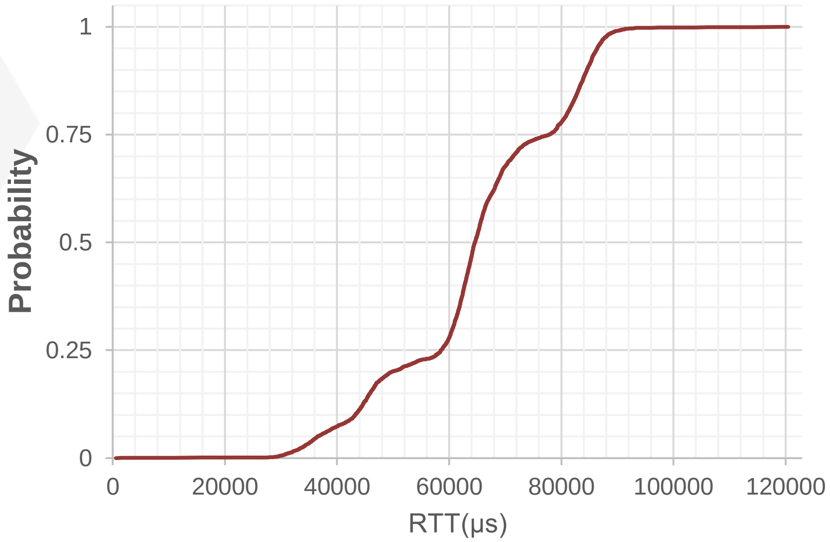


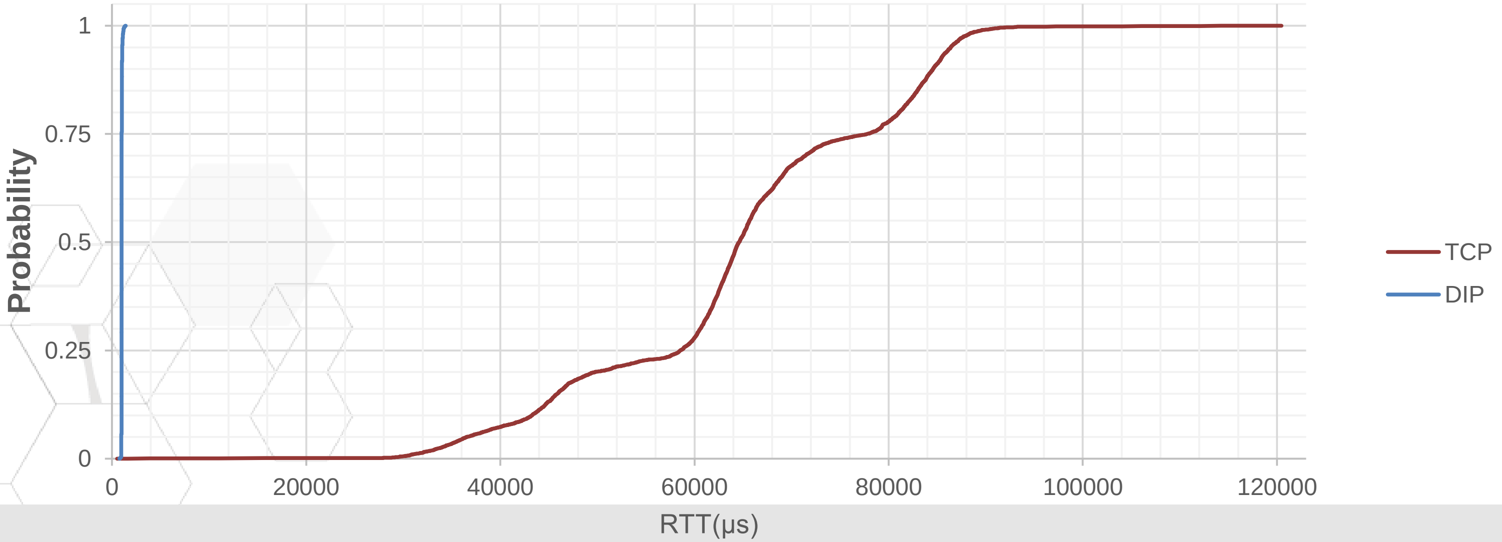




Test Results:
Guaranteed Maximum Latency (CIR flows coexistence with traditional TCP)







Congestion Control

- **With the new transport technology, the TCP congestion control is different**
- **The WND is still used, but:**
  - **Receiver** keeps AdvertisedWND = MaxRcvBuffer - (LastByteRcvd - LastByteRead), and send to Sender
  - **Sender** measure the current or average RTT, and calculate two WNDs corresponding to the MinBandwidth and MaxBandwidth
  - MinBandwidthWND = MinBandwidth *RTT ; MaxBandwidthWND = MaxBandwidth * RTT
  - MinWND = min (CongestionWND , AdvertisedWND, MinBandwidthWND);
  - MaxWND = min (CongestionWND , AdvertisedWND, MaxBandwidthWND)
  - EffectiveMinWND = MinWND – (LastByteSent– LastByteAcked); EffectiveMaxWND = MaxWND – (LastByteSent– LastByteAcked);
- **Source rate control:**
  - No slow start, the initial rate is dependent on the MinBandwdith
  - Set the EffectiveWND from the EffectiveMinWND, increase it like TCP-RENO if there is ACK, and until the WND is equal the EffectiveMaxWND, stop
  - How source send traffic
    - Option 1: Sender control the rate through the EffectiveWND
    - Option 2: Sender control the rate by pacing
- **Congestion control:**
  - Congestion and fwd state detection, Packet loss distinguishing
    - OAM detects Remained bandwidth, buffer depth and buffer RED; OAM and fwd state are reported to source by receiver
    - If packet lost after a OAM buffer RED, it is likely caused by congestion; otherwise, it is likely by random physical failure
    - If packet lost due to time out, it is likely caused by permanent physical failure
  - Congestion and failure action
    - **Congestion loss**: Source reduce the sending data size or rate, EffectiveWND = EffectiveMinWND
    - **Random physical failure loss**: Source keeps the rate
    - **Permanent physical failure loss**: Source reduce WND to 1, resend the in-band signaling to repair path.
    - **FWD failure:** Source reduce WND to 1, resend the in-band signaling to repair path

Guaranteed Bandwidth Service

- **DIP flow and TCP flow shares the same egress queue.**
- **Each DIP flow configured with**
  - Minimum Bandwidth: CIR (Committed Information Rate)
  - Maximum Bandwidth: PIR (Peak Information Rate);
- **System will guarantee each flow's CIR if** $\sum CIR < C$
- **Two scenario,**
- **Congestion: DIP Congestion (**$\sum R_{DIP}^{Ingress} > \sum CIR$**); TCP Congestion (**$\sum R_{TCP}^{Ingress} > (C - \sum R_{DIP}^{Egress})$**)**
- **No DIP and TCP congestion:**
  - All DIP flow is guaranteed to obtain its CIR, and up to PIR; exceeding PIR will be dropped.
  - All TCP flow obtain equally the rate that is excluding the bandwidth of all DIP flows: $R_{TCP}^{Egress} = (C - \sum R_{DIP}^{Egress})/N_{TCP}$
- **DIP Congestion:**
  - All DIP flow is guaranteed to obtain its CIR, may obtain the rate grater than CIR depending on the remained bandwidth
  - Two options depending on the configuration, when DIP congested ($\sum R_{DIP}^{Ingress} > \sum CIR$) :
    1. DIP flow rate grater than its CIR is proportional to its PIR ratio: $R_{extra_i}^{Egress} = \frac{w_{PIR_i}}{\sum w_{PIR}}(C - \sum CIR) - CIR_i$
    2. DIP flow rate grater than its CIR is equally distributed between DIP flows: $R_{extra_i}^{Egress} = (C - \sum CIR)/N_{DIP} - CIR_i$
  - All TCP flow obtain the rate that is excluding the bandwidth of all DIP flows: $R_{TCP}^{Egress} = (C - \sum R_{DIP}^{Egress})/N_{TCP}$
- **TCP Congestion**
  - TCP flow does not impact the DIP to obtain CIR, may reduce the DIP's rate exceeding CIR.
  - TCP flow rate has the same formula as other cases: $R_{TCP}^{Egress} = (C - \sum R_{DIP}^{Egress})/N_{TCP}$

Guaranteed Latency Service

- **All DIP flows share one or multiple high priority queue; all TCP flow share one low priority queue**
- **Maximum latency at each hop can be calculated from the queue size configured, or from the dynamic queue depth detected through OAM.**
- **No DIP and TCP congestion:**
  - DIP and TCP queue depth will be in very low level, thus very low latency
- **DIP Congestion ($\sum R_{DIP}^{Ingress} > \sum CIR$)**
  - DIP flow queue built up, its latency can be calculated by the depth of the queue that can be detected, and the maximum latency is determined by the DIP queue size
- **TCP Congestion ($\sum R_{TCP}^{Ingress} > (C - \sum R_{DIP}^{Egress})$)**
  - TCP flow does not impact the DIP queue, thus does not impact DIP latency
  - TCP latency can be calculated by the depth of the queue that can be detected, and the maximum latency is determined by the TCP queue size